FROM BARRACKS TO THE BATTLEFIELD

CLEAN ENERGY INNOVATION AND AMERICA'S ARMED FORCES

THE PEW PROJECT ON
NATIONAL SECURITY, ENERGY AND CLIMATE

THE PEW CHARITABLE TRUSTS

The Pew Charitable Trusts applies the power of knowledge to solve today's most challenging problems. Pew employs a rigorous, analytical approach to improve public policy, inform the public and stimulate civic life. We partner with a diverse range of donors, public and private organizations and concerned citizens who share our commitment to fact-based solutions and goal-driven investments to improve society. For additional information on the Trusts, please visit www.pewtrusts.org.

THE PEW PROJECT ON NATIONAL SECURITY, ENERGY AND CLIMATE

The Pew Project on National Security, Energy and Climate, an initiative of the Trusts, works to bring together the economic, scientific and military communities to discuss the links between American energy decisions and national security. By advancing these discussions, the Pew Project hopes to formulate solutions that will make the United States more energy independent, prosperous and secure.

Joshua Reichert, managing director
Phyllis Cuttino, project director
Laura Lightbody, manager
Joseph Dooley, senior associate
Jessica Frohman Lubetsky, senior associate
Brendan Reed, associate
David Catarious, former Pew staffer
Gavin Feiger, fellow
David Harwood, consultant, Good Works Group

ACKNOWLEDGMENTS

This report benefited tremendously from the expertise and guidance of former Sen. John W. Warner, senior adviser to the Pew Project on National Security, Energy and Climate, as well as representatives from the U.S. Army, Navy, Air Force, Marine Corps and the U.S. Department of Defense.

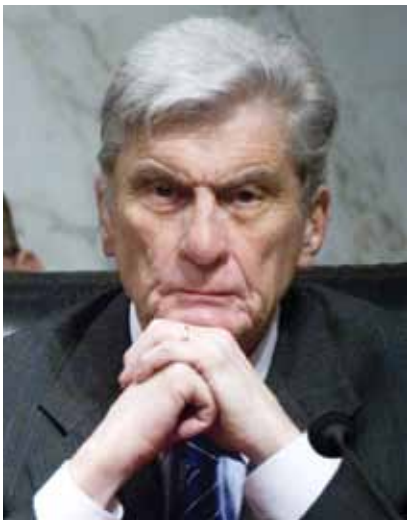
For more information, visit www.pewtrusts.org/energysecurity.

901 E St. NW, 10th Floor
Washington, D.C. 20004

2005 Market St., Suite 1700
Philadelphia, Pa. 19103

TABLE OF CONTENTS

FOREWORD
BY SEN. JOHN W. WARNER, RETIRED



For the past two years, I have had the distinct privilege of serving as senior adviser to the Pew Project on National Security, Energy and Climate, a project of The Pew Charitable Trusts.

When I retired from the U.S. Senate in 2009, I wanted to continue working on behalf of the military, as I have done throughout my long public service career. As a former Secretary of the Navy and as a former Chairman of the Senate Armed Services Committee, I have seen firsthand the ingenuity and commitment of our uniformed men and women, and their civilian Department of Defense counterparts, seeking solutions to America's toughest challenges. Their accomplishments and innovations toward lessening our nation's dependence on imported oil by finding many ways to achieve energy efficiencies, utilize renewable sources and harness advanced biofuels has placed the Department of Defense in a well-earned leadership position.

In preparation for this report, I traveled with Pew to visit military installations to observe how they are adopting clean energy technologies, improving energy efficiency and saving taxpayer dollars.

At Marine Corps Base Quantico, we witnessed a presentation of the Experimental Forward Operating Base program, which is testing and deploying renewable energy and energy efficiency initiatives in theatre in order to reduce energy consumption at forward operating locations. At the historic Portsmouth Naval Shipyard, uniformed and civilian personnel are working as a team to increase the base's energy security by constructing LEED-certified buildings, co-generating heat and power and using solar

power as backup for communications systems. At Fort Bragg, we toured the practical implementation of the initiatives that are part of an Army-wide goal to achieve "net zero" energy and water consumption and waste generation.

Such combined efforts across all branches of the military result in substantial financial savings and often encourage similar initiatives in nearby civilian communities that provide support in so many ways to military families.

The brave men and women in uniform, whether serving on U.S. bases or on forward deployments overseas, clearly understand the linkage between strong energy policies and their ability to more safely perform their missions. Under the leadership of former Secretary of Defense Robert Gates, and now Secretary Leon Panetta, the Department of Defense is exercising aggressive energy-efficiency goals to lessen our dependence and to enhance our nation's energy security.

Our nation commends the Department of Defense for being on the front lines of energy innovation, efficiency and technological advances. The Pew Project is privileged to work with them and compile their story for the public to learn more about their achievements.

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]

U.S. Navy

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

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]

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 percent[34] 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.

INTRODUCTION

Militaries that fail to innovate lose strategic advantage. Nations that fail to innovate lose economic edge. Clean energy innovation is an essential strategy for making the United States and its service men and women safer, stronger and more successful.

Time and again, military leaders have invested in new ways of harnessing energy to enhance the strength, speed, range and power of armed forces. Navies that once relied on wind power transitioned to coal, then oil and eventually nuclear power to propel fleets across the seas. Air forces harnessed jet propulsion and made superiority in the skies a central component of strategic doctrine. And on land there have been continuous improvements to tactical and non-tactical vehicles to meet the needs of ever-changing military missions.

THE MILITARY'S NEW ENERGY IMPERATIVE

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. Because of plentiful, inexpensive supplies of petroleum products and electricity, highest priority has been given, until late, to building weapons platforms that are bigger, faster and more powerful. But energy is no longer an inconsequential expense, the nature of conflict has changed and the U.S. military is responding.

The U.S. Department of Defense (DoD) has been motivated to accelerate energy innovations by a range of major developments over the past decade, most notably the conduct of wars in Iraq and Afghanistan, the rise of asymmetric threats and terrorist activities in the United States, growing concerns about the security of energy supplies, and sharp fluctuations in the price of oil.

DoD's essential energy challenges were crystallized in 2008 through the work of a distinguished panel of experts convened by the Defense Science Board. The report of the Defense Science Board Task Force on DoD Energy Strategy, "More Fight—Less Fuel," called on the department to initiate aggressive energy innovations aimed at reducing risk to soldiers and enhancing the military's long-term energy security. The task force study advises DoD to address two key challenges: reducing battlefield fuel demand and ensuring uninterrupted power supply at the nation's critical military installations.

This report details how energy innovation and clean energy are helping 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 focus is given to priority DoD initiatives in key parts of the world's burgeoning and competitive clean energy sector: vehicle efficiency, advanced biofuels, and energy efficient and renewable energy technologies for buildings.

As the largest institutional energy user in the United States, DoD is in a position to help shape the energy innovation process to its own and the nation's benefit. DoD's scale, management capacity and history of technology innovation can make a crucial difference in clean energy research and development. The department's purchasing power can help technologies make the transition from laboratories to the commercial marketplace. In the process, jobs and manufacturing opportunities can be created, along with goods and services that save money and are of value to all Americans.

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.

Just as the shift from wind to coal revolutionized naval power in the 19th century, so did the introduction of nuclear energy—on submarines and aircraft carriers—transform the global balance of power in the 20th. Our mastery of energy technology both enabled our nation to emerge as a great power and gave us a strategic edge in the Cold War.

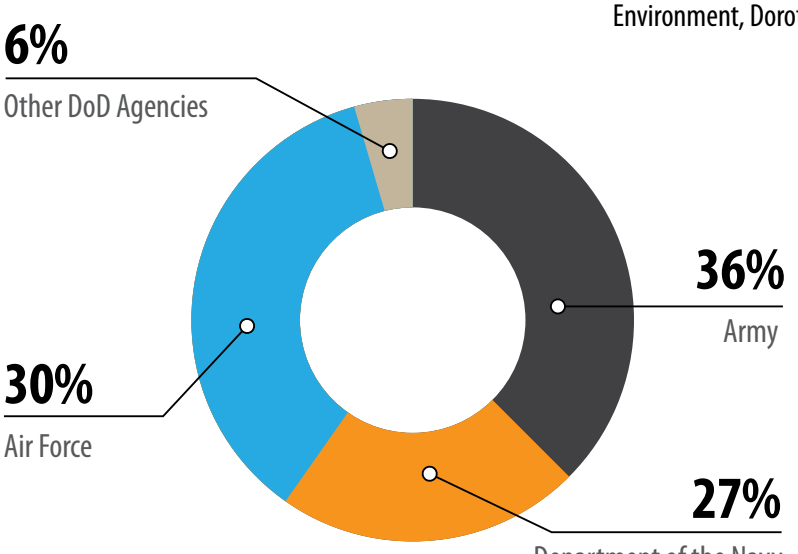
Deputy Secretary of Defense William Lynn, April 26, 2011

WHAT CLEAN ENERGY CAN DO FOR DOD

The energy risks and challenges facing DoD are evident in its energy profile. It is the single largest consumer of energy in the United States and one of the largest institutional energy users in the world, having consumed 819 trillion BTUs of energy in 2010. Oil products accounted for 80 percent of DoD's final energy consumption. In 2009, DoD used more than 375,000 barrels of oil per day, more than all but 35 countries. [39] Another 11 percent of DoD's energy is delivered in the form of electricity.

DoD's oil and electricity use are reflected in the department's emerging organizational structure for advancing energy innovation. Fuel is primarily used for operational energy requirements and is in the purview of the newly created position of Assistant Secretary of Defense for Operational Energy Plans and Programs, currently held by Sharon Burke. Operational energy has been referenced by DoD as the "energy required for training, moving, and sustaining military forces and weapons platforms for military operations."[40] Electricity is primarily needed to fulfill the energy requirements of fixed installations and bases. Installation energy management is overseen at DoD by the Deputy Undersecretary of Defense for Installations and Environment, Dorothy Robyn.

FIGURE 1: DOD ENERGY USE IN FY2010



Source: FY2010 Federal Energy Management Report

FIGURE 2: DOD ENERGY COSTS

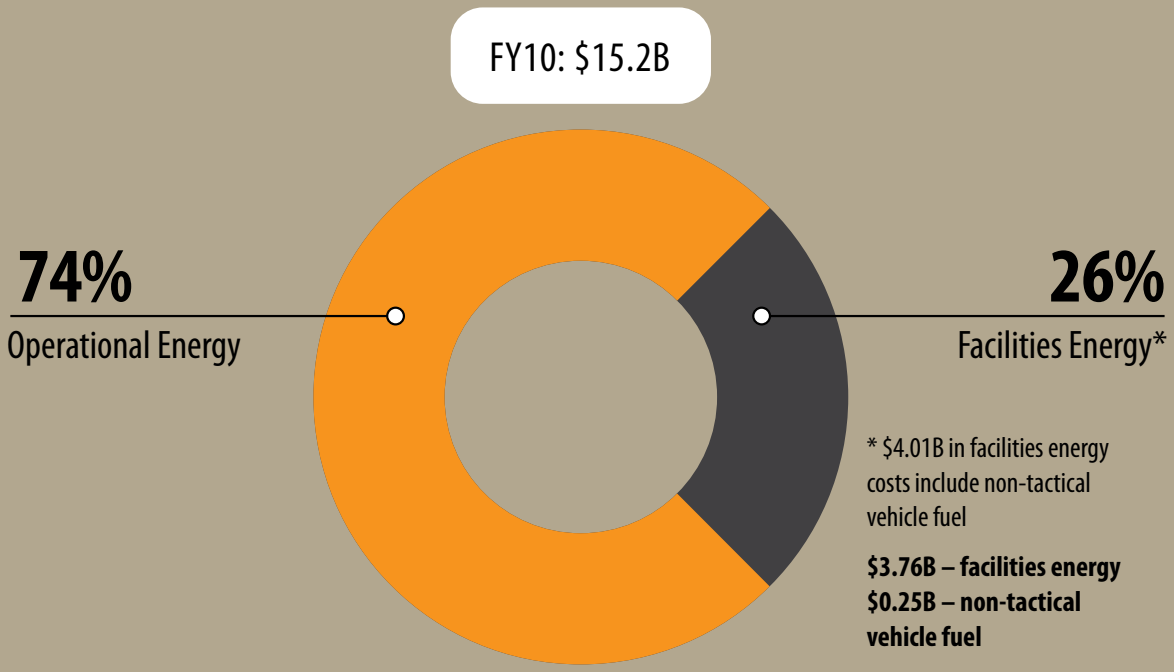
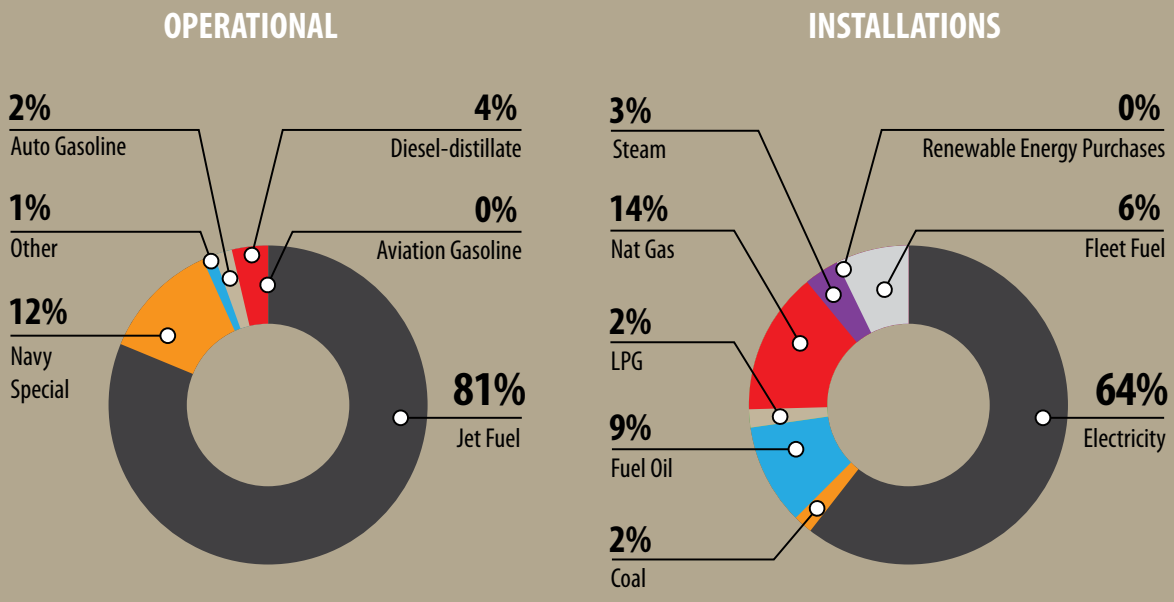


FIGURE 3: DOD ENERGY COSTS, FY2010 (ACQUISITION, TECHNOLOGY AND LOGISTICS)



Source: FY2010 Federal Energy Management Report

DOD'S MAJOR ENERGY CHALLENGES

The military's two central energy requirements—fuel for operations and electricity for installations—present five distinct challenges:

Operational Risk—Today's soldier requires 22 gallons of fuel per day on average, an increase of 175 percent since the Vietnam War.[41] In Afghanistan alone, 20 million to 50 million gallons of fuel must be delivered each month to meet these needs.[42] Eighty percent of the convoys into Iraq and Afghanistan are for fuel,[43] and it is estimated that one in 46 convoys results in a casualty.[44] From 2003 to 2007, more than 3,000 uniformed and contractor casualties were associated with the delivery of fuel. In 2010, there were 1,100 attacks on fuel convoys.[45]

Operational Effectiveness—The extensive need for fuel convoys diverts forces from combat operations and war fighting. In a memorandum to coalition forces in June 2011, Gen. David Petraeus noted that "a force that makes better use of fuel will have increased agility, improved resilience against disruption and more capacity for engaging Afghan partners, particularly at the tactical edge."

Security of Supply—DoD is concerned about two distinct energy supply issues. First, the department's operations rely upon large quantities of oil, the majority of which must be imported, often from unstable regions and/or hostile regimes. Second, installations rely on electricity transmitted over an aging and vulnerable commercial grid.

Price Volatility—The department is not immune from oil price spikes and resulting budgetary challenges. In fiscal 2005, DoD spent $8.8 billion for 130 million barrels of petroleum supplies. In fiscal 2008, 134 million barrels cost the department $17.9 billion, more than double the cost for almost the same amount of fuel purchased in 2005.[46] More recently, the price paid for gasoline by the Air Force increased in mid-2011 by $1 per gallon. Carried forward over the course of the year, this price increase could raise Air Force energy costs by $2.3 billion.[47] Across the department, operational energy costs increased from 2009 to 2010 by more than 19 percent, even though energy consumption declined by more than 9 percent.[48]

Moreover, where military operations are concerned, the pump price of gasoline does not fully account for all of the costs associated with securing, shipping and protecting fuel. Thousands of troops are put at risk, some sacrificing their lives, so that fuel can be obtained and delivered to the battlefield. These and material costs are increasingly factored into long-term military planning, and the department is exploring ways to consider what is known as the Fully Burdened Cost of Energy (FBCE), which is estimated to be as high as $40 per gallon.[49]

Compliance—DoD is required to comply with laws passed by Congress, as well as executive

U.S. Navy photo

A U.S. MARINE CORPS MV-22 OSPREY LIFTS OFF FROM NAVAL AIR STATION PATUXENT RIVER, MD., DURING A SUCCESSFUL BIOFUEL TEST FLIGHT. THE TILT-ROTOR AIRCRAFT FLEW AT ALTITUDES OF UP TO 25,000 FEET ON A 50-50 BLEND OF CAMELINA BASED BIOFUEL AND STANDARD PETROLEUM BASED JP-5 FUEL.

orders set forth by the president. A listing of legal requirements that DoD must meet related to energy can be found in the Energy Compliance Appendix.

HOW INNOVATION CAN HELP ADDRESS DOD ENERGY CHALLENGES

A marked expansion of clean energy innovations has occurred in the past decade as inventors, investors and policy leaders seek cleaner, cheaper, more secure means of meeting energy requirements. For DoD, the rapidly changing energy landscape offers promising possibilities for addressing key risks and challenges. Most importantly, the department's clean energy investments will save lives and money for many years to come.

Energy efficiency measures at forward operating bases in combat areas and across weapons platforms are reducing the need for energy in combat operations and alleviating operational risk. As part of an effort to reduce fuel use in forward operations, DoD insulated 9 million square feet of temporary structures, decreasing energy consumption by 77,000 gallons per day.[50] More broadly, the department is exploring a variety of efficiency measures at forward

DOD PHOTO BY MASTER SGT. DOUGLAS K. LINGEFELT, U.S. AIR FORCE.

U.S. AIR FORCE AIRMAN MARK HEITKAMP PULLS A FUEL SERVICE HOSE FROM AN R-11 FUEL TRUCK IN PREPARATION FOR REFUELING A KC-135 STRATOTANKER AIRCRAFT WITH JP-8 FUEL AT AN AIR BASE IN SOUTHWEST ASIA ON MAY 31, 2006.

operating bases and across weapons platforms to help ease fuel requirements and reduce risks to soldiers.

Alternative fuels and renewable energy sources can be domestically produced (and locally sourced around the world) to decrease the need for imported oil. Similarly, waste-to-energy technologies can be used to reduce logistics associated with waste management in forward operations, producing meaningful amounts of usable fuel in theater. Fixed installations, which provide critical support to combat forces, can be reliably powered by microgrids, "smart" technologies and renewable energy sources.

Energy efficiency and renewable energy will help the department avoid price shocks that have come to characterize world oil markets. Energy efficient and hybrid engine technology can reduce fuel requirements in planes, ships and ground vehicles. 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.[51]

Innovative energy technologies and applications can help enhance operational effectiveness. Energy efficiency is a force multiplier, freeing up troops from logistical support for deployment in combat operations. Lighter, longer-lasting batteries can reduce the weight soldiers must carry and extend their range, agility and endurance in the field. Portable solar energy arrays can be integrated into rucksacks to recharge batteries and power computers, communications equipment and other advanced electronic systems.

At the department's fixed installations, efficiency standards for new buildings and major retrofits can save large amounts of energy over many years. Military leaders expect base energy needs and costs to increase as overseas troops are brought home in the coming months and years, making efficiency measures even more important to maintaining the department's bottom line.[52] Alternative fuels and electric vehicles in fleets can help DoD and the nation meet their goals to reduce petroleum use and emissions. These investments in new sources of fuels and cutting-edge technologies can, in turn, improve quality of life for service members and conserve scarce budgetary resources for soldier care, morale and welfare.

Clean energy will help DoD address its key operational and installation energy challenges and make the United States and its businesses more competitive in today's rapidly emerging clean energy economy. The United States, once the world leader in attracting private clean energy investments, has fallen behind China and Germany and on a number of measures is failing to keep pace in a sector that has grown 630 percent in seven years. DoD's clean energy agenda serves the department's interest in making America's service men and women safer, stronger and more effective, and it also serves the nation's interest in creating jobs and economic opportunity in the emerging and competitive clean energy sector.

U.S. Army photo by Maj. Deanna Bague

U.S. ARMY SPC. DEAN KALOGRIS CHARGES THE INSTALLATION'S COMMAND SERGEANT MAJOR'S ELECTRIC CAR ON FORT BLISS, TEXAS, APRIL 14, 2010.THE BASE LEADERS DRIVE THE CARS, WHICH ARE MADE FROM RECYCLED PLASTIC AND CAN REACH SPEEDS OF 25 MPH, TO DEMONSTRATE THEIR COMMITMENT TO HELPING KEEP ENERGY COSTS DOWN AND PROTECTING THE ENVIRONMENT.

WHAT DOD CAN DO FOR ENERGY INNOVATION

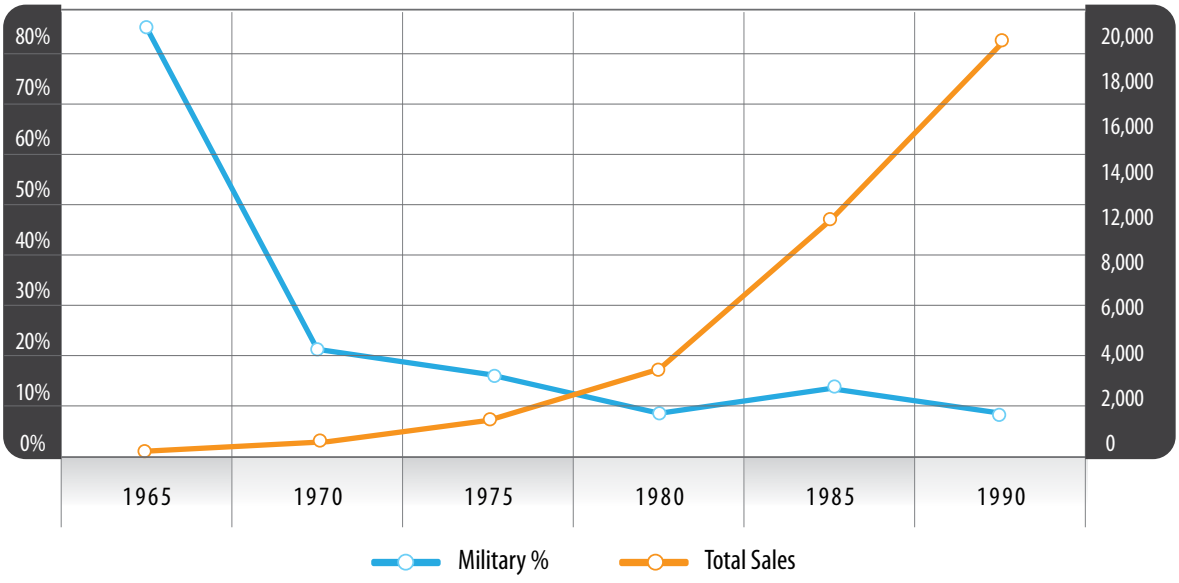
In view of the new risks and challenges that have been identified over the past decade, DoD is moving aggressively to harness new energy technologies that can reduce fuel demand and enhance long-term energy security. In all these efforts, military needs are closely aligned with national imperatives and interests.

Dependence on foreign oil is a concern of the military and civilian sectors alike. Power outages, which threaten the continuity of military operations, are of equal concern to America's commercial interests and homeowners. Rising energy costs are a major factor for household budgets as well as military financial planning. Inefficient legacy infrastructure is as much of a challenge across the country as it is across DoD's facilities. Further, both sectors are concerned about the environmental impact of current energy options.

DOD'S HISTORY OF TECHNOLOGY INNOVATION

While the department is focused appropriately on its priority mission of protecting the American people, it has demonstrated that it can also help advance America's

FIGURE 4: TOTAL SALES AND MILITARY SHARE OF U.S. INTEGRATED CIRCUIT SALES



Source: David Mowery, Haas School of Business, University of California Berkeley

technology development and commercial interests. The scale of its operations, its continuous need for improved technologies and its capacity for technology development and deployment have played a key role in a wide and important range of recent innovations such as semiconductors, computers, the GPS and the Internet.

In all of these efforts, DoD helped new technologies reach commercial maturity. As illustrated in Figure 4 and documented by David Mowery of the Haas School of Business at the University of California, Berkeley, "the military applications of semiconductors and computers meant that defense-related research and development funding and procurement were important to their early development. The 'R&D infrastructure' created in U.S. universities by defense-related and other federal R&D expenditures contributed to technical developments in semiconductors, computer hardware, and computer software, in addition to training a large cadre of scientists and engineers."[53]

In its pursuit of advanced technologies such as semiconductors, the basis of modern electronics including transistors, computers and telephones, DoD aligned its considerable research and development capabilities with the expertise of other federal agencies and the dynamism of the private sector. In doing so, the department reflected an understanding of the links between economic and military security. A vibrant, innovative American economy is crucial to a strong, technologically superior U.S. defense posture.

Encouragingly, DoD's energy innovation efforts are taking a similar approach. The inaugural Operational Energy Strategy, released in June 2011, notes that "the department has an interest in long-term national security and should take steps to work with other federal agencies and the private sector to diversify and secure fuel supplies."[54] The 2010 Quadrennial Defense Review (QDR) notes that the department's Environmental Security and Technology Certification Program is actively engaged in using "military installations as a test bed to demonstrate and create a market for innovative energy efficiency and renewable energy technologies coming out of the private sector and DoD and Department of Energy laboratories."[55]

In fact, the department has created a far-reaching memorandum of understanding (MOU) with the Department of Energy (DoE) to help accelerate the energy innovation process in service of the nation's energy and national security goals. DoD and DoE are working cooperatively on advanced batteries, energy efficiency, microgrids and "smart" technology.[56] Similarly, DoD has initiated an MOU with the Department of Agriculture to

> The DOE is the lead federal agency responsible for the development and deployment of advanced energy technologies, yet DOD will need to invest in many of these same energy technologies. ... Partnering with DOD provides DOE the opportunity to accelerate the deployment of its technologies and expertise toward the critical economic and energy security needs of the United States and to promote scientific and technological innovation.
>
> **DOD–DOE Memorandum of Understanding, July 22, 2010**

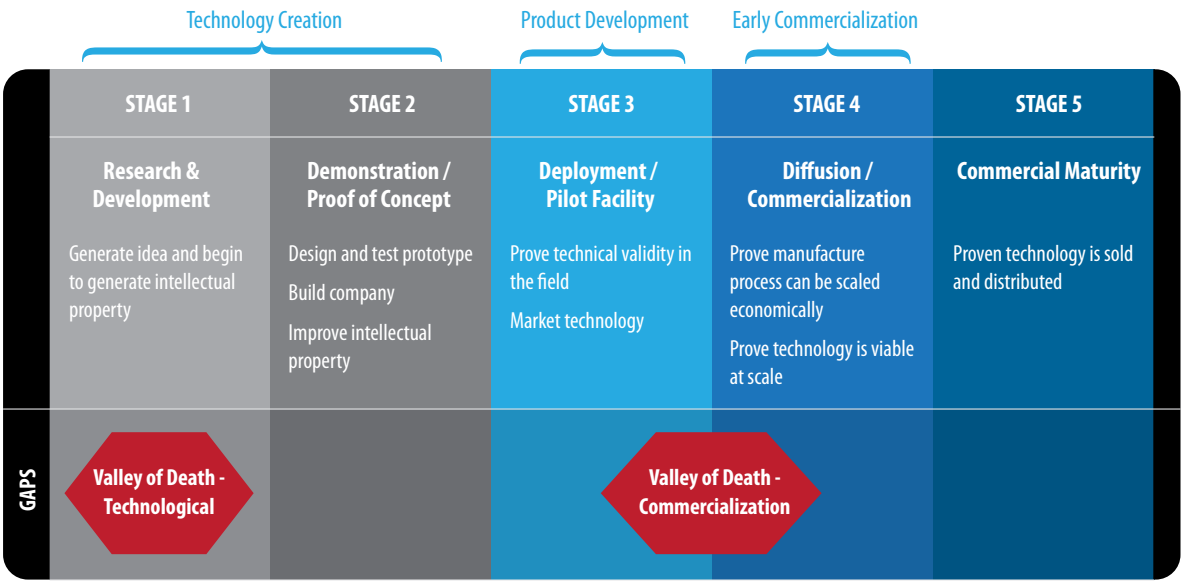
help accelerate development of advanced biofuels that can be produced in the United States at cost-competitive prices and without negatively affecting food producton.

DoD is also working cooperatively with the private sector by engaging scientists and corporations, as well as the defense industrial base. While the department is depending in large part on the private sector to provide energy technologies, it is actively engaged in preparing its infrastructure and vehicles to accept new products.

DOD'S TECHNOLOGY INNOVATION ASSETS

Whether on fixed installations or on the battlefield, DoD brings a variety of strengths to the major stages of energy innovation: research and development, proof of concept, pilot testing, diffusion, and commercial maturity.

FIGURE 5: STAGES OF TECHNOLOGY DEVELOPMENT



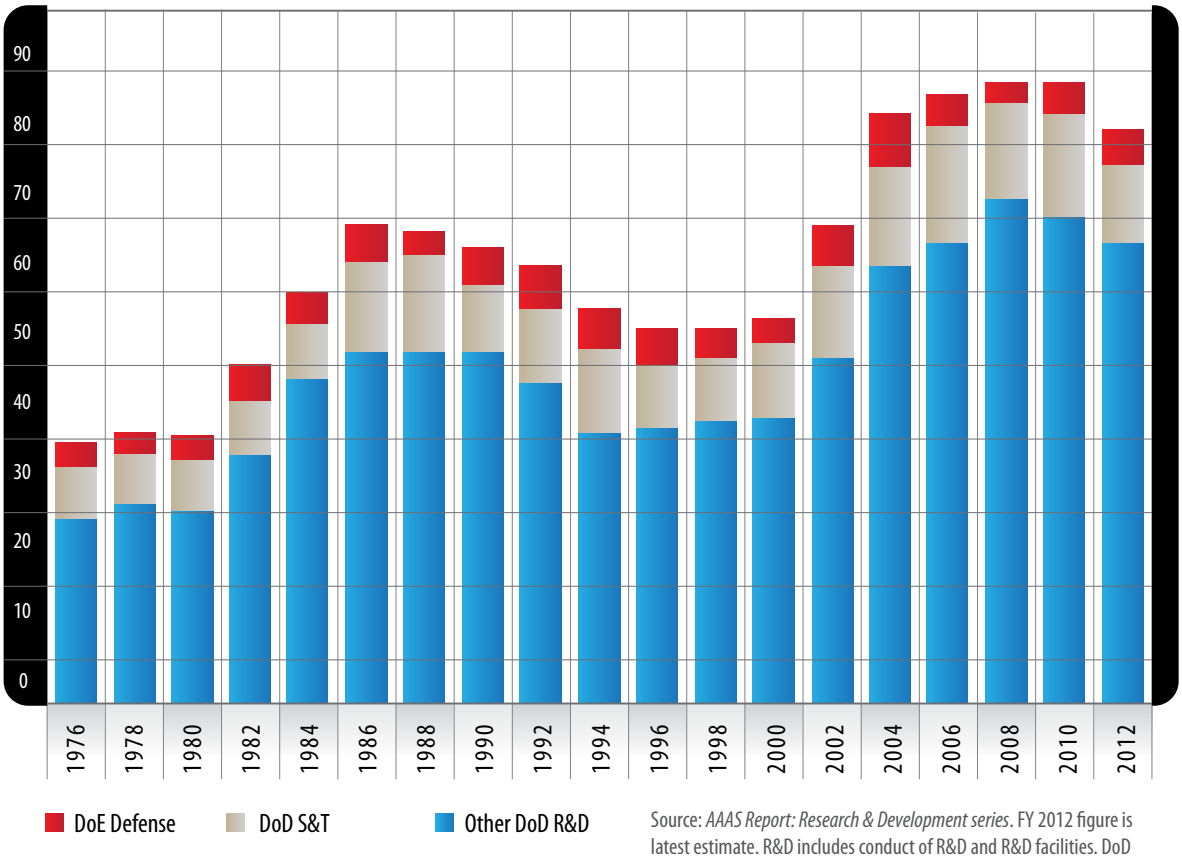
Source: Bloomberg New Energy Finance

In all of these efforts, the department brings a broad range of expertise and institutional capacity to bear, including:

An Established R&D System—DoD has a mature research and development system, giving the department an understanding and structure for managing far-reaching technology development processes, from research to procurement. For example, the Defense Advanced Research Products Agency (DARPA) has a 50-year tradition of accelerating technology development, and DoD's military construction and logistics capabilities are world renowned. DoD research and development spending, mostly on weapons and platforms, has averaged more than $80 billion annually over the past decade.[57] The department also has long-established relationships with the defense industrial base, which can aid the technology development process.

Scale—DoD conducts operations across the United States and around the world, in all regions, climates and geographic settings, making it an apt proving ground for new technologies and applications. The various branches of the military also bring a wide range of expertise

FIGURE 6: TRENDS IN DEFENSE R&D (IN BILLIONS OF CONSTANT FY 2011 DOLLARS)



Source: *AAAS Report: Research & Development series*. FY 2012 figure is latest estimate. R&D includes conduct of R&D and R&D facilities. DoD S&T figures are not comparable for all years because of changing definitions. © 2011 AAAS

and requirements to the technology development process. These capabilities and interests can help drive technological progress on ships, aircraft and ground-based vehicles.

Purchasing Power—DoD acquires $400 billion worth of goods and services each year.[58] This purchasing power can be a crucial lifeline to fledgling technologies and companies working to usher technologies across the so-called "Valley of Death" between the idea and commercial viability stages of business development. Moreover, DoD has made extensive use of innovative third-party financing arrangements, from performance contracts to power purchase agreements.*

Commitment—The department has the culture of discipline and management structure necessary to foster technology innovation. At the same time, DoD has the staying power to complete complex technology development processes, and it has the urgency needed to accelerate the process.

Trust—DoD enjoys high levels of trust among the public and policymakers alike. A Gallup poll in 2009 found overall public support for DoD at 78 percent, and broad public esteem for the military.[59] As a result, technologies that have met the rigorous requirements and certifications demanded by DoD are well regarded in the commercial sector.

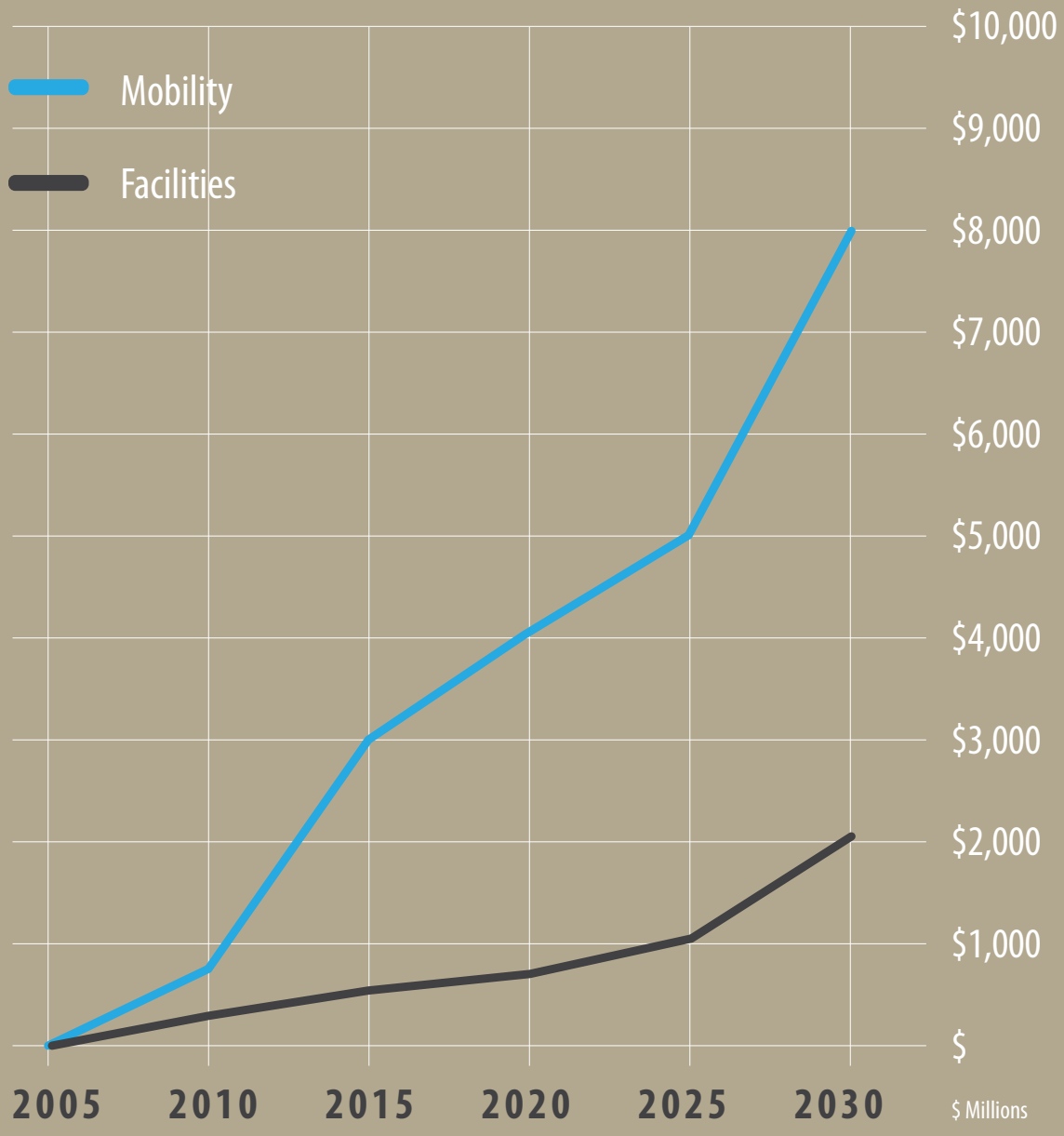
DOD'S INVESTMENTS IN CLEAN ENERGY ARE GROWING

In recent years, DoD has begun to harness these capabilities in service of energy technology innovation. Its budget for energy security initiatives has increased from $400 million to $1.2 billion over the past four years.[60] DARPA is engaged in research efforts on advanced batteries, super-efficient solar cells and new biofuels. The Installation Energy Test Bed Initiative is piloting emerging energy efficiency and renewable energy technologies with the aim of diffusing them throughout DoD facilities. The department is proving out concepts for portable solar power packs. Microgrids are being deployed at fixed installations and forward operating bases. Across the services, power purchase agreements and other innovative financing mechanisms are being used to harness commercially mature and cost-effective renewable energy and energy efficiency technologies.

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.[61] More broadly, Pike estimates that the global military marketplace for clean energy technologies will grow from $1.8 billion in 2010 to $26.8 billion by 2030.

* Energy saving performance contracts (ESPCs) are agreements between DoD and a private contractor which evaluates energy efficiency opportunities and costs, helps pay upfront costs and is remunerated through the savings that result from efficiency measures. Power purchase agreements (PPAs) are long-term contracts between DoD and electricity providers, which incur the cost of developing power supply and are remunerated at an agreed-price over the length of the agreement.

FIGURE 7: DOD'S INVESTMENTS IN CLEAN ENERGY



Source: Pike Research

TECHNOLOGY PROFILES

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 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.

DEVELOPMENT OF MORE EFFICIENT VEHICLES

THE RATIONALE FOR DOD VEHICLE EFFICIENCY

The primary energy challenge for the Department of Defense is to reduce the operational demand for liquid fuels, which now totals about 375,000 barrels of oil each day.[62] Energy efficiency constitutes the cheapest, fastest, most effective means of reducing consumption and addressing operational risk to soldiers, price volatility, supply security and mission success. That is why DoD is moving expeditiously to improve the fuel efficiency of its tactical and non-tactical vehicles and investing in electric vehicle (EV) technologies.

Liquid petroleum fuels account for approximately three-quarters of DoD's annual energy consumption and more than $11 billion of the department's annual energy bill.[63]

The scale of DoD fuel requirements creates significant transportation needs, with attendant risk and budgetary impacts. For example, in fiscal 2005, DoD spent $8.8 billion for 130 million barrels of petroleum supplies. In fiscal 2008, 134 million barrels cost the department $17.9 billion, more than double the cost for almost the same amount of fuel purchased in 2005.[64]

To avoid the significant costs—in dollars and lives—and achieve energy security, the Air Force, Army and Navy are initiating management and process improvements that save energy, developing more efficient and reliable engines and introducing electric vehicles across the DoD fleet of 11,000 aircraft and helicopters, 200 combat and support Navy vessels, and 200,000 tactical vehicles and 190,000 non-tactical vehicles.[65]

These efforts are guided by the findings of the Defense Science Board Task Force on DoD Energy Strategy, whose report, "More Fight—Less Fuel," found that combat operations "suffer from unnecessarily high, and growing battle space fuel demand which degrades capability, increases force balance problems, exposes support operations to greater risk than necessary, and increases life-cycle operations and support costs."[66] One of the report's primary recommendations was for DoD to invest in energy efficiency at a level "commensurate with their

operational and financial value."[67] The report goes on to note: "It is unlikely that energy efficiency has a higher value to any other organization in the country, possibly the world."[68]

DoD's role in the advancement of efficiency and electric vehicle technologies can have important positive effects on the growth of the clean energy sector and corollary impacts on future missions. In the United States, it is estimated that the commercial transportation sector will use more than 40 times the amount of energy consumed by the military by 2020.[69] Because the defense and commercial industrial bases are closely aligned, technological advances in military vehicles are likely to migrate to commercial civilian markets, as has occurred with a long list of key technologies. Moreover, efficiency gains and electric vehicle deployment in the private sector markets can also relieve DoD's future burdens associated with securing oil transport routes and the impacts of climate change.

Efficiency is a major priority across the commercial transportation marketplace, especially for the domestic aviation industry. The U.S. Department of Commerce recently reported that ticket prices for commercial airlines rose more than 12 percent over a six-month period beginning in October 2010, which coincided with a 22 percent rise in the price of petroleum.[70] Without strong gains in efficiency and diversification of the fuel mix, ticket price increases are likely to continue. In fact, the U.S. Energy Information Administration projects that energy prices for aircraft will rise 30 percent from 2011 to 2020.[71] DoD efforts on aviation efficiency can help overcome barriers, reduce costs and prove out technologies of commercial significance.

Boeing, which produces several types of aircraft for the department, is working aggressively to deploy efficient new fleets of commercial aircraft. The Dreamliner 787 is advertised to be 20 percent more fuel efficient than comparably sized commercial aircraft. To date, more than 800 Dreamliners valued at $162 billion have been ordered.[72]

Finally, DoD transportation efficiency efforts are consistent with key national goals and requirements. A listing of legal requirements that DoD must meet related to energy can be found in the Energy Compliance Appendix.

DOD VEHICLE EFFICIENCY INITIATIVES

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 its fleets. Overall DoD spending to harness clean energy technologies in the air, at sea and on the ground are projected to increase to $2.25 billion annually by 2015.[73]

MORE EFFICIENT 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.[74]

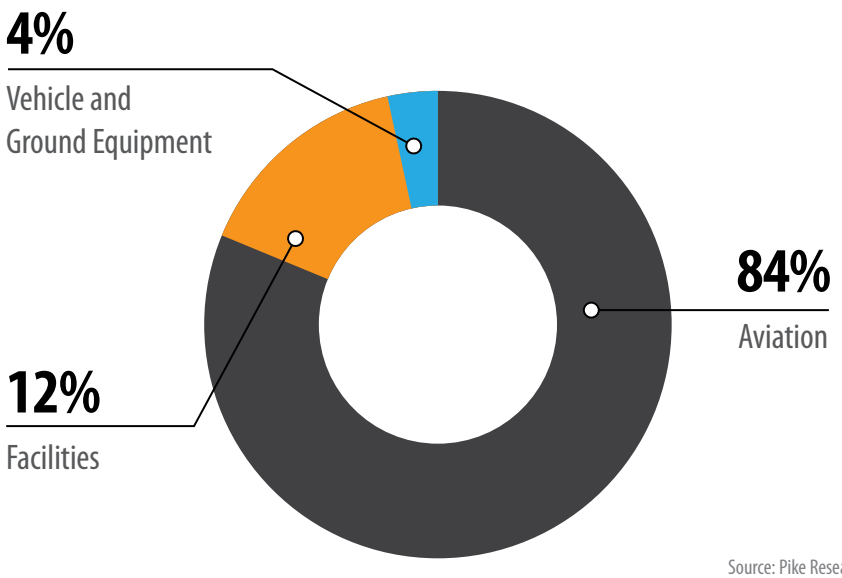
The U.S. Air Force uses 64 percent of DoD's petroleum supplies. More than 84 percent of the Air Force's petroleum use is in the form of jet fuel. As a result, the Air Force is seeking to reduce aviation fuel use by 10 percent by 2015.[75] As the first Report on Operational Energy Budget Certification notes, "increasing the energy efficiency of the current legacy fleet presents the greatest opportunity for optimizing use of operational energy" in activities that cannot be reprogrammed to simulators or other techniques.[76] 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.[77]

While the Air Force plans and budgets for retrofitting legacy systems, it is taking steps to optimize fuel consumption by implementing energy management and operational initiatives—modifying routes, improving aircraft centers of gravity, using flight simulators and adjusting aircraft crew ratios—that will result in fiscal 2012 energy savings totaling $494 million.[78]

The Air Force is investing in a Versatile Affordable Advanced Turbine Engine (VAATE) program, in which two key components seek to improve fuel consumption by 25 percent compared with a fiscal 2000 state-of-the-art engine, such as the Joint Strike Fighter.[79]

The first initiative under VAATE is the Adaptive Versatile Engine Technology program (ADVENT), in which aircraft are fitted with a "multi-design point engine" that incorporates the best characteristics of high-performance and fuel-efficient jet engines into a single engine that will perform consistently under a broad range of conditions. For example, fan and core designs of the ADVENT engine will generate thrust when needed and optimize fuel efficiency when cruising, with the goal of improving efficiency by 35 percent in subsonic performance and 14 percent in supersonic performance compared with fiscal 2000 state-of-the-art engines.[80] ADVENT can be applied operationally

FIGURE 8: U.S. AIR FORCE ENERGY UTILIZATION



Source: Pike Research

to increase supersonic range in the sixth-generation TACAIR, the Air Force and Navy fighter jets likely to be placed into service in the next 20 years.[81]

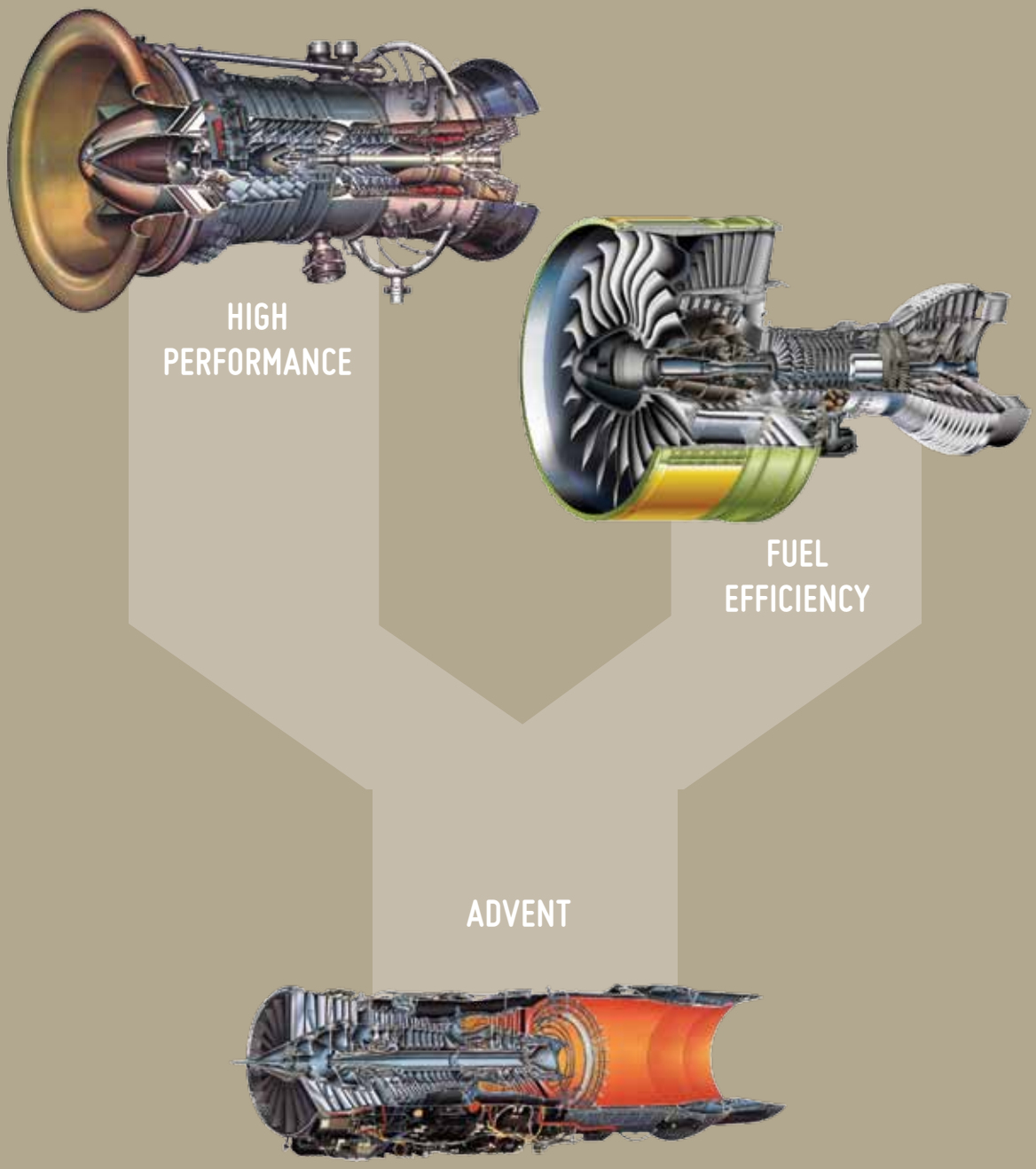
Looking beyond ADVENT, the Air Force is designing the Highly Efficient Embedded Turbine Engine (HEETE). HEETE will reduce engine weight, improve the thrust-to-weight ratio, and increase operational effectiveness.[82] HEETE will also improve fuel efficiency 10 percent beyond ADVENT while increasing payload and transport range.[83]

The Air Force is investing $94 million in the VAATE program in fiscal 2012, with more than $361 million scheduled for the next five years.

ELECTRIC VEHICLES

DoD is also advancing ground vehicle fuel efficiency and electric vehicle technologies. Although they make up a much smaller component of the department's energy use compared to aircraft, ground vehicles at military bases and installations are an important test bed for the deployment of fuel-saving 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 fossil fuel use by 2020. Of special note are DoD efforts on electric vehicle technologies. The Army is particularly focused on

FIGURE 9: ADAPTIVE VERSATILE ENGINE TECHNOLOGY (ADVENT)



HIGH EFFICIENCY CORE + ADAPTIVE ENGINE TECHNOLOGY =

SIGNIFICANT FUEL DEMAND REDUCTION

Source: Mike Aimone, Batelle Memorial Institute

the transfer of electrical power between the vehicle and grid and is investing part of its $13 million Alternative Energy Technologies budget for fiscal 2012 in these activities.[84]

DoD has also deployed thousands of non-tactical, slow-moving electric vehicles (on-base vehicles that travel at less than 25 mph) powered by batteries and is considering broader deployment of electric vehicles for medium and heavy duty trucks, particularly those used on U.S. installations where vehicles tend to drive less than 100 miles per day. Similar to corporate fleets, these vehicles have predictable usage cycles and can be fueled from a central depot, making installation of required charging infrastructure simple.

In June 2011, the department requested 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 the cost of internal combustion engine vehicles. The deployment of medium and heavy duty electric vehicles in military fleets, comprising more than 190,000 non-tactical vehicles, could be significant in just a few years, assuming that procurement can be achieved at competitive prices.

Research and testing of electric vehicle technologies are also continuing at the Army's Tank Automotive Research Development and Engineering Center (TARDEC). As tactical vehicles that are deployed on the front lines, combat vehicles cannot use technologies that limit effectiveness and will employ new efficiency and electric vehicle technologies more slowly than will non-tactical vehicles. However, TARDEC is active in research and testing of EV and efficiency technologies, often with consortia made up of manufacturers and universities, including CALSTART and the National Automotive Research Center.[85] Efforts to test technologies are proceeding, and TARDEC's new Ground System Power and Energy Facility is likely to open in late 2011. At this facility, the Army will be able to test EV and efficiency

"The Department of Defense has a large and diversified fleet with many of the same vehicles that we have in the utility industry. Their participation in the development of clean energy technologies will create the critical mass that many manufacturers need to commercialize some of their products and technologies, which ultimately will benefit commercial and utility fleets."

– Dave Meisel, Director of Transportation Services, Pacific Gas and Electric Company

technologies in extreme temperatures in a laboratory environment.[86] TARDEC is also testing the Fuel Efficiency Demonstrator Alpha (FED-Alpha), a vehicle with the same capabilities as the M1114 Humvee but that seeks to improve fuel efficiency by 70 percent.[87]

DoD is also investing in development of electric vehicle technologies through the Near Term Energy Efficient Technologies Program (NTEET). Investments in applied research and development of high-temperature silicon carbide power semiconductors will enable deployment of additional heavy-duty electric vehicles, because improvements in semiconductors can potentially allow for storage of higher energy levels. Under NTEET, the department will also invest in ground vehicles that can export electric power from onboard storage systems, allowing vehicle-to-grid and other applications that can result in reduced peak energy use on DoD installations, and mobile generator units that reduce the need to transport liquid fuel to remote locations.

MORE EFFICIENT SHIPS

With a goal of increasing efficiency and reducing fuel consumption on ships by 15 percent from 2010 to 2020, the Navy is testing and advancing new technologies in its operational vessels.[88] To achieve its fuel reduction goal, the Navy is investing $91 million in fiscal 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.[89]

U.S. ARMY

THE ARMY'S FUEL EFFICIENT GROUND VEHICLE DEMONSTRATOR (FED) WITH KOLLMORGEN'S LOW VOLTAGE POWER GENERATION PLATFORM.

CHRIS TINDAL, DIRECTOR OF OPERATIONAL ENERGY, U.S. NAVY

THE USS MAKIN ISLAND ON ITS 2009 MAIDEN VOYAGE.

Electric propulsion technologies are also making their way into Navy vessels. The Navy has plans to test and construct a hybrid electric drive system on the USS Truxtun, a guided missile destroyer, and plans to invest more than $16 million in research and development next year.[90] The Navy expects the hybrid engine to save 8,500 barrels of fuel per year.

Industry leaders have also completed a successful test of a 36.5 MW motor for use in the Navy's "Great Green Fleet" and for future use in all electric ships and submarines. This technology, a high-temperature superconductor (HTS) motor, involves replacement of copper wire that results in electricity that is conducted more than 150 times more efficiently. The Navy has already invested more than $100 million in HTS technologies. Hybrid shaft generators can also provide auxiliary power to vessel propellers and at higher levels of efficiency.[91]

Deployment of ships with hybrid electric propulsion systems began with the commission of the USS Makin Island in 2009, an amphibious assault vessel that the Navy expects to save more than $250 million in fuel costs over the life of the ship.[92]

HARNESSING ADVANCED BIOFUELS

DOD'S AMBITIOUS GOALS

Even with sustained improvements in vehicle efficiency efforts, the Department of Defense will rely for the foreseeable future on liquid fuels as its primary energy source. Today, DoD is the largest single consumer of liquid fuels in the world. With uncertainties surrounding the long-term supply and cost of fuels, DoD is complementing vehicle efficiency initiatives with prudent efforts to explore development of alternative fuels. The 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.

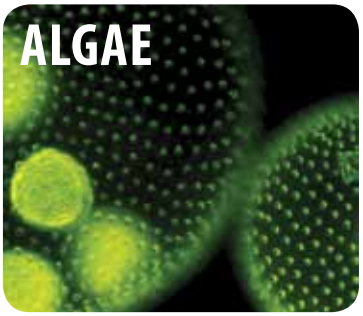
- The Navy aims to sail the Great Green Fleet and with the Marines plans to use alternative energy sources to meet 50 percent of its energy requirements across operational platforms by 2020.

- The Army seeks to harness alternative fuels to power its vehicle fleet and meet the goal set by Executive Order 13423 to increase non-petroleum fuels by 10 percent annually in non-tactical vehicles.

The biofuels being pursued by military and commercial interests include hydro-treated renewable jet fuel (HR-J) and hydro-processed renewable diesel fuel (HR-D), both of which can be made from the same materials or feedstocks. Production-level feedstocks include oil seeds such as camelina, jatropha, rapeseed, soybeans and babassu; animal fats; and plant and cellulosic materials such as crop residue, wood scraps and switchgrass. In the case of oil seeds and animal fats, oil is directly extracted from the feedstock and then refined into the final product. Grasses and crop and forest scraps contain cellulose, which must be mixed with yeast or bacteria to create a product that can be refined into the final product.

Emerging feedstocks, currently the focus of a great deal of research, development and pilot projects, include algae, seaweed and electrofuels. Although algae and seaweed produce a relatively large amount of oil per area, they rely on inefficient photosynthesis. Electrofuels are the most advanced nascent biofuel technology being pursued, with the goal of making liquid fuels using organisms that can convert carbon dioxide into fuel-like molecules without using photosynthesis.

DoD must consider a variety of factors and move forward with great care in the development and deployment of alternative fuels. The military must ensure that any alternative fuels are not harmful to legacy infrastructure and the significant investments that have created them. DoD's top priority is to achieve its core mission—protecting the interests of the American people and the brave men and women serving the armed services—but it also seeks to lessen America's dependence on foreign oil.



CRITERIA FOR ADVANCED BIOFUELS

In view of these and other considerations, DoD is working to harness biofuels that are consistent with key criteria. These include:

Cost—In the near term and consistent with its interest in the development of advanced biofuels, DoD can pay a premium for small quantities of prospective alternative fuels for testing, certification and demonstration purposes. But over the long term, the department has made clear that its interest is in alternative fuels that are less expensive than petroleum products, and that it will be able to purchase large quantities of such fuels only if they become cost competitive. The Navy, which is working with researchers at the Massachusetts Institute of Technology's Sloan School of Management, predicts that the biofuels being developed today will reach cost parity with oil by 2020.[93]

Compatibility—As previously noted, DoD's tactical weapons systems make the U.S. military the most capable fighting force in the world. The renewable fuels being pursued by the military and commercial transportation industries are "drop-in" substitutes for petroleum fuels. That is, no significant costly additional engine or systems engineering is required, because the fuels must be chemically equivalent and perform to the standards of the petroleum-based fuels they are replacing.

Versatility—Military operations occur in every region and climate in the world. Therefore, alternative fuels must meet versatile performance criteria, such as an ability to perform in very hot and cold temperatures with equal efficacy as petroleum-based fuels.

Scale—Viable advanced biofuels must be capable of being produced at scale. The department must be able to purchase and deploy large volumes of these prospective fuels. For example, to meet its strategic goals, the Navy will need 336,000 gallons of biofuels (jet fuel and diesel) in 2012, 3.36 million gallons in 2016, and 336 million gallons in 2020.[94]

Environment—The 2010 QDR recognized the important challenges that climate change poses for America's military. Accordingly, DoD is committed to ensuring that alternative fuels are not more carbon-intensive than the petroleum fuels now in use. This commitment is consistent with Section 526 of the Energy Independence and Security Act of 2007, which requires all federal agencies to purchase alternative fuels with lower life-cycle greenhouse gas emissions than are produced by conventional fuels. This mandate is supported by DoD and has never prevented the department from meeting its current mission needs.

DoD's leadership role in the development of advanced biofuels and its associated infrastructure are of acute interest and potentially enormous value to the commercial aviation, shipping and auto manufacturing industries, which are keen to learn more about the viability of advanced biofuels. For example, U.S. airline

and cargo operations use approximately 17.5 billion gallons of jet fuel a year[95] and the industry is eager to benefit from lessons learned through DoD initiatives.

DOD'S ADVANCED BIOFUELS INITIATIVES

DoD is moving forward carefully but methodically to help accelerate development of advanced biofuels. The department is engaged in a variety of efforts across the early stages of the technology development process in hopes of demonstrating compatibility and moving toward early adoption of alternative fuels that meet its well-founded performance and cost criteria.

RESEARCH

DoD is involved in a variety of research activities aimed at advancing technological progress on advanced biofuels.

DARPA is exploring a variety of biofuel technologies on behalf of the armed services. Although much of the research and results are classified, DARPA predicts that cost-competitive algal-based biofuels will be available within five years.

Early DARPA biofuel partners include Honeywell UOP and General Atomics, both of which supplied test batches of jet fuel and are on the path to commercial production. Honeywell UOP worked with General Electric Global Research and the University of North Dakota's Energy and Environmental Research Center to create a feedstock-flexible process to produce oil from non-food crops such as soy, camelina, canola, palm, coconut oils, jatropha, algae and cuphea. San Diego-based General Atomics worked with a number of academic and commercial partners to explore ways of lowering the cost of algae production, specifically by increasing per-acre yield. Both projects delivered renewable Air Force jet fuel at the end of 2008.

In July 2011, Texas-based Terrabon was awarded a $9.6 million, 18-month contract by Virginia-based Logos Technologies to design a lower-cost process to produce renewable jet fuel from a variety of feedstocks for DARPA. Terrabon will use its demonstration facility in Bryan, Texas, to design and operate a customized process for DARPA in an effort to produce 1,500 gallons of jet fuel using Terrabon's advanced biorefining technology, MixAlco.[96] The MixAlco process uses low-cost, readily available, non-food feedstocks, such as municipal waste, wood chips and waste and sweet sorghum, to produce products for biorefining. The process does not require sterilization, which significantly reduces costs. Just as DARPA programs are responsible for the Internet and GPS, the next generation of renewable fuels may well be a product of this program if current funding levels are maintained or increased.

TESTING AND CERTIFICATION

On March 25, 2010, the Air Force made history with the first flight of a biomass-powered aircraft.[97] The A-10C Thunderbolt II, taking off from Eglin Air Force Base in Florida, flew on a 50-50 blend of camelina HR-J and conventional Air Force jet fuel (JP-8). In February 2011, the Air Force announced certification of the first

aircraft platform for biofuel use: the fuel-hungry C-17 Globemaster III. [98] The C-17 was certified for unlimited HR-J-blend use, leading the way for certifications across the Air Force fleet. To date, 99 percent of the Air Force fleet is certified to fly on biofuel blends.[99] The Air Force expects to complete all flight testing by February 2012 and all certifications by December 2012. The Air Force has also extended the certification requirements to any new platform purchses.

CHRIS TINDAL, DIRECTOR OF OPERATIONAL ENERGY, U.S. NAVY

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

The Navy, too, is actively engaged in testing and certifying advanced biofuels for planes and ships. The service is continuing to certify more of its vessels on biofuels through 2011 and 2012 in preparation for a Green Strike Group demonstration in 2012.[100] In one of the first steps, on April 22, 2010 the Navy made headlines by demonstrating an F/A-18 Super Hornet, dubbed the "Green Hornet," on a 50-50 blend of traditional Navy jet fuel (JP-5) and camelina-based HR-J.[101]

In October 2010, the Navy tested the Riverine Command Boat-Experimental (RCB-X) on a biofuel derived from algae.[102] As with the Green Hornet, the riverine craft was tested using a blend of the traditional petroleum-based marine fuel with the algae-based substitute.

The test represented the first time a Navy vessel was driven at full speed with biofuels in the tank. It is noteworthy that the algae fuel was produced from a plant that was constructed with a $21.8 million grant from the Department of Energy in 2009. In fact, the fuel's entire value chain supported the United States economy. Solazyme, a California-based company with manufacturing facilities in Pennsylvania, produced and dried the algae before shipping it to Iowa, where the oil is extracted and sent to refineries in Texas to produce the final fuel, which is blended with petroleum fuel at NAS Patuxent in Maryland.[103]

Throughout 2011, to support the 2016 and 2020 alternative fuel goals, the Navy has successfully tested

HOME-GROWN FUELS

California-based Solazyme signed a 150,000-gallon contract with DoD for delivery of algal biofuel during 2011. Solazyme focuses on algae-based fuels.

Illinois-based Honeywell UOP and Seattle-based Sustainable Oils each supplied more than 500,000 gallons of HR-J from a variety of advanced feedstocks to military branches for testing and certification in 2011. Honeywell UOP benefited from DARPA funding in 2007 to develop a military-specific jet fuel (which can also be used commercially) in 2010. Sustainable Oils is focusing on camelina-based biofuels grown on marginal lands in Montana.

a number of other applications on biofuels, including: the Allison 501 K gas turbine engine,[104] the Marine Corps MV 22 Osprey[105] and the T-45 Goshawk.[106] During their annual Labor Day performance, the Navy's Blue Angels flew for the first time on a 50-50 biofuel blend.[107] In 2012, the Navy plans to run a self-defense test ship on a biofuel blend.[108]

DEMONSTRATION

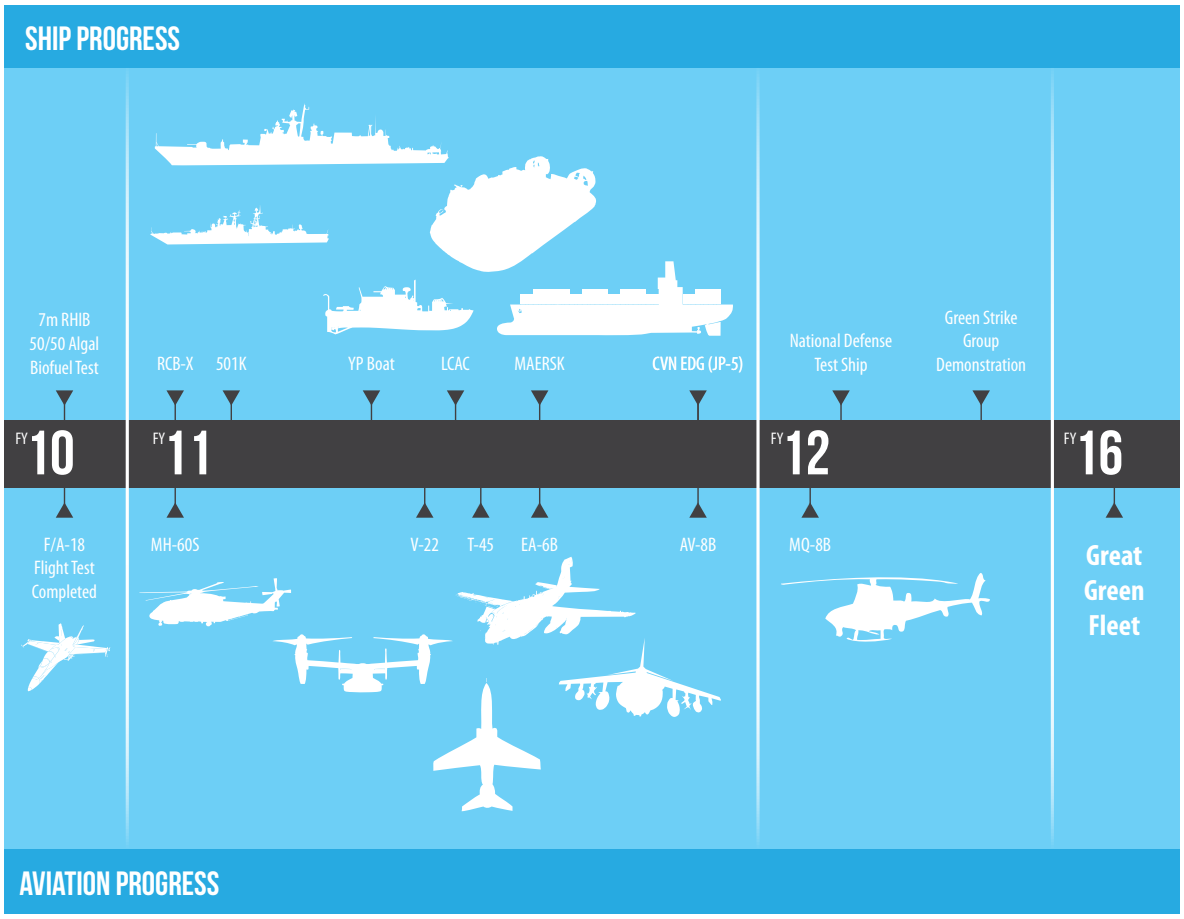
The Navy successfully flew a MH-60S Seahawk helicopter on a 50-50 blend of Solazyme's algae-derived Solajet HRJ-5 (a JP-5 drop-in substitute) in June 2011—the first military aircraft ever to fly on algal biofuel. Throughout 2011, the Seahawk is being flown on 100 percent biofuel for more extensive testing and evaluation.

The Great Green Fleet goals begin with testing a carrier strike group composed of nuclear ships, hybrid ships, traditional ships and aircraft all powered by biofuel, with plans to demonstrate the fleet locally in 2012 and sail an extended mission in 2016. To test the Green Fleet during 2010, Solazyme delivered more than 20,000 gallons of algae-based jet fuel to the Navy. In July 2011, the Navy signed a contract for 100,000 gallons of renewable jet fuel and 350,000 gallons of biodiesel, to date the largest single order for the Navy, to test and certify ships and aircraft for alternative fuel use.

DEPLOYMENT

Executive Order 13423 of 2007 requires most federal agency fleets (non-tactical vehicles) to increase total non-petroleum fuel consumption by 10 percent, compounded annually through 2015, compared with a 2005 baseline.[109] EISA Section 246 requires modification of large fueling sites to provide alternative fuels. Of the 137 DoD sites dispensing more than 100,000 gallons per year, 63 percent were modified by 2010 and 25 percent plan to make the modifications in the near future. The Navy has an accelerated goal to cut in half the amount of fuel used in its non-tactical fleet through hybrid, electric

FIGURE 10: TESTING AND CERTIFICATION OF THE GREAT GREEN FLEET



SOURCE: CHRIS TINDAL, DIRECTOR OF OPERATIONAL ENERGY, U.S. NAVY

and flex-fuel vehicles. The Air Force has a specific goal to purchase 100 percent light-duty alternative or flex-fuel vehicles where commercially available, a goal 25 percent above federal mandates.[110] Flex-fuel vehicles are available from most major automobile companies and can run on a blend of up to 85 percent ethanol. In 2009, the most recent year with available data, DoD purchased 1,485 flex-fuel vehicles and installed 16 alternative fueling stations.[111] At the end of fiscal 2009, the Air Force had more than 7,000 flex-fuel vehicles, 25 E85 fuel pumps and 62 B20 dispensaries.[112] The Army is also purchasing flex-fuel vehicles at rates meeting or exceeding federal mandates. This is another case of the military leading the way to greater commercialization of a biofuel technology. In Virginia, for example, the Navy has the largest fleet of alternative-fuel vehicles in the state. It is installing flex-

fuel pumps for its vehicles but also making some of them available to the public.

As an example of the effort to use a single fuel for as many applications as possible, the Air Force successfully refueled a B-52 Stratofortress with biofuel, using a 72,000-pound hybrid refueling truck running on the same HR-J blend.[113]

COOPERATION WITH INDUSTRY

DoD is cognizant of the extensive commercial interest in development of advanced biofuels. The department also knows that, provided that fuels meet DoD criteria, its role as an early adopter could help create a larger industry. Not surprisingly, numerous companies are actively engaged in the effort to commercialize advanced biofuels to supply the permanent and growing military and commercial airline sectors. Beyond traditional oil companies, the standouts include Neste Oil, Honeywell UOP, Sapphire Energy, Sustainable Oils and Imperium Renewables. Additionally, a number of companies filed IPOs in 2010 and 2011, including Renewable Energy Group, Ceres, KiOR, Gevo and Solazyme.[114] Solazyme, for example, went public in May 2011, taking in $200 million with its initial public offering of more than 10 million shares, exceeding projections and representing a record IPO for advanced industrial biotech. At full commercial scale, the company plans to produce renewable crude oil at $3.44 per gallon with its current technology.[115]

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 in the next three years.[116] 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.[117] 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.

DoD's advanced biofuels efforts also have significant implications for the aviation industry. On July 1, 2011, the American Society for Testing and Materials (ASTM) approved a 50 percent biofuel blend for use in conventional commercial and military aircraft. ASTM is an international standards organization that develops and publishes technical standards for a wide range of materials, products, systems and services. Although it has no role in requiring or enforcing compliance with its standards, corporations and government bodies often make the standards mandatory.

After the official ASTM biofuel certification in July 2011, Lufthansa launched four return daily flights between Hamburg and Frankfurt. The regular flights use an Airbus A321 fueled by Finland-based Neste Oil's biofuel made from jatropha, camelina and animal fats. Airbus estimates that fuel from plant-derived sources could account for 30 percent of airlines' consumption by 2030,[118] and Boeing estimates that biofuels could reduce flight-related life cycle greenhouse-gas emissions by 60 to 80 percent.[119] Airbus and Boeing, which together manufacture about 80

percent of the world's passenger planes, plan to invest in global biofuel production and distribution.[120]

Under its emissions trading program, Europe will begin regulating greenhouse gas emissions from air carriers, including military, in 2012, and Australia plans to impose a carbon tax in 2012 and emissions trading in 2015. In response and anticipation, some commercial airlines, including Air New Zealand, Virgin Atlantic, KLM Royal Dutch Airlines, Japan Airlines and Continental, have tested biofuels in passenger-free trials. California-based Sapphire Energy supplied biofuels tested in a commercial Boeing 737 by Continental Airlines.

Looking forward, Seattle-based AltAir Fuels, affiliated with Sustainable Oils, is building two biorefineries to supply drop-in substitutes for traditional jet fuels to the Air Force, with production beginning in Bakersfield, Calif., in late 2012 and in Tacoma, Wash., in 2014.[121] Sapphire is building a production facility in New Mexico that is projected to begin operation by 2013 and produce 100 million gallons of renewable diesel and jet fuel by 2018 and 1 billion gallons by 2025. Additionally, an Australian coalition including Qantas, Virgin and Boeing plans to ensure that five percent of Australia's aviation fuel will be biofuel by 2015 and 40 percent by 2050.[122] These private-sector investments are a strong indicator of the effect that the military s having on the commercial biofuel industry.

ENERGY EFFICIENCY, RENEWABLES AND STORAGE AT BASES

THE RATIONALE FOR CLEAN ENERGY AT BASES

> "We are ready and eager to use this fuel. ...If they'll produce it, we'll buy it."
>
> —Terry Yonkers, Air Force assistant secretary for installations, environment and logistics

The Department of Defense manages a prodigious inventory of real estate: 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.[123]

In theater, DoD also manages a number of forward operating bases that require energy to power electronics, provide lighting, and heat or cool air and water. Because of increased energy requirements during wartime and rising costs, the department has placed a priority on ways to better manage its energy usage at battlefield facilities. There are currently thousands of forward operating bases deployed throughout Iraq and Afghanistan.

Across its fixed building stock and forward operating bases, DoD has ample opportunities to save energy

U.S. Marine Corps

MARINES AND SAILORS OF INDIA COMPANY, 3RD BATTALION, 5TH MARINES, AND THEIR AFGHAN NATIONAL ARMY COUNTERPARTS, POSE IN FRONT OF SOLAR PANELS AT PATROL BASE SPARKS, IN HELMAND PROVINCE. NICKNAMED "THE RAPTOR," AFTER THE TYPE OF POWER CELLS IN ITS SIX SOLAR PANELS, THE SYSTEM CAN KEEP MORE THAN 17 COMPUTERS AND 15 LIGHTING UNITS RUNNING THROUGHOUT THE NIGHT.

and deploy new alternative energy sources. Efficiency opportunities exist in improved design, operations and power management technologies as well as energy-saving "smart" products and microgrids. Many of these enhancements can be integrated with the deployment and use of new renewable energy technologies. And all of these efforts can be utilized as key strategies in the effort to reduce costs, increase security and improve the operational effectiveness of the U.S. military.

DoD has been a leader in U.S. federal energy management efforts at its installations for several decades. Since 1985, DoD has reduced its facility energy consumption by more than 30 percent.[124] Under the auspices of the Office of the Secretary of Defense, the Energy Conservation Investment Program (ECIP) is used to finance efficiency and other innovative energy projects that have maximal savings-to-investment ratios. Over the past decade, ECIP financed more than $440 million worth of energy-saving measures at installations. Defense facilities have also pursued on-site energy efficiency initiatives through the use of creative financing arrangements offered through utilities and energy service companies. For example, performance-based contracts allow large facilities and buildings to undertake efficiency improvements at little or no upfront cost. Instead, third-party contractors are paid through a portion of the savings generated as a result of energy-saving measures. From 1999 to 2007, more than $3.8 billion worth of energy efficiency improvements at DoD facilities were financed through these arrangements.[125] DoD expenditures in fiscal 2010 alone totaled $575 million for energy and water efficiency and renewable energy, and $323 million worth of energy efficiency measures were financed through performance contracts.[126] In addition, DoD spent $190 million in fiscal 2010 to install advanced energy meters, a precursor to "smart" projects and enhanced management techniques.[127]

Historically, DoD energy enhancements have been advanced by facility energy managers. More recently, senior military leaders have come to appreciate the

relationship between installation energy efficiency and management and the strategic imperatives of energy use for the safety of America's soldiers and the effectiveness of combat operations. Military brass has also recently stressed an organization-wide culture change of every warfighter being his own "power manager."

Moreover, DoD is increasingly aware of the substantial opportunities presented by energy efficiency and improved resource management at facilities and forward operating locations. DoD's Defense Science Board found in its important report, "More Fight—Less Fuel," that "it is important to DoD's energy future to aggressively increase the efficiency levels of buildings and infrastructure."[128] Furthermore, one of the two principal findings of the Defense Science Board report was that dependence of DoD's facilities on an antiquated and vulnerable electricity grid poses significant risks to the continuity and success of vital defense missions and must be addressed.

The department also understands the budgetary imperative of sound energy resource management at its facilities. In 2010, DoD's facility energy costs totaled more than $4 billion and accounted for more than 25 percent of the department's overall energy bill. Absent concerted action to save energy and reduce costs, DoD's facility energy tab is expected to increase in the coming years as troop deployments end and more of the armed forces are stationed at permanent U.S. defense facilities.[129]

Recognizing the benefits of actively managing energy use at its facilities, DoD has established three central goals for installation energy:

- Reducing energy use.
- Increasing usage of renewable energy and onsite power generation.
- Enhancing energy security.

In pursuit of these goals, DoD is working with the private sector and other government entities to accelerate the process of researching, developing, testing and deploying energy-saving and alternative energy technologies for facilities. As the largest institutional energy user in the world, DoD recognizes that a strategic approach to facility energy use can be a win-win-win proposition: enhancing DoD energy security, conserving scarce budgetary resources and fostering economic progress for private industry and American competitiveness. These mutual benefits were expressly recognized in the 2010 Quadrennial Defense Review (QDR), which found that defense installations can be used as "a test bed to demonstrate and create a market for innovative energy efficiency and renewable energy technologies coming out of the private sector and DoD and Department of Energy laboratories."[130]

The department is playing an important role across the technology development spectrum, from basic and applied research to testing and deploying emerging technologies for energy efficiency and renewable energy generation. DoD continues to demonstrate that its early adoption of important new technologies can play a critical role in accelerating product commercialization. In short, its energy efficiency and resource management efforts are simultaneously strengthening its mission and advancing U.S. interests in the emerging clean energy economy.

DOD BASE ENERGY INITIATIVES

ENERGY EFFICIENT TECHNOLOGIES AND OPERATIONS

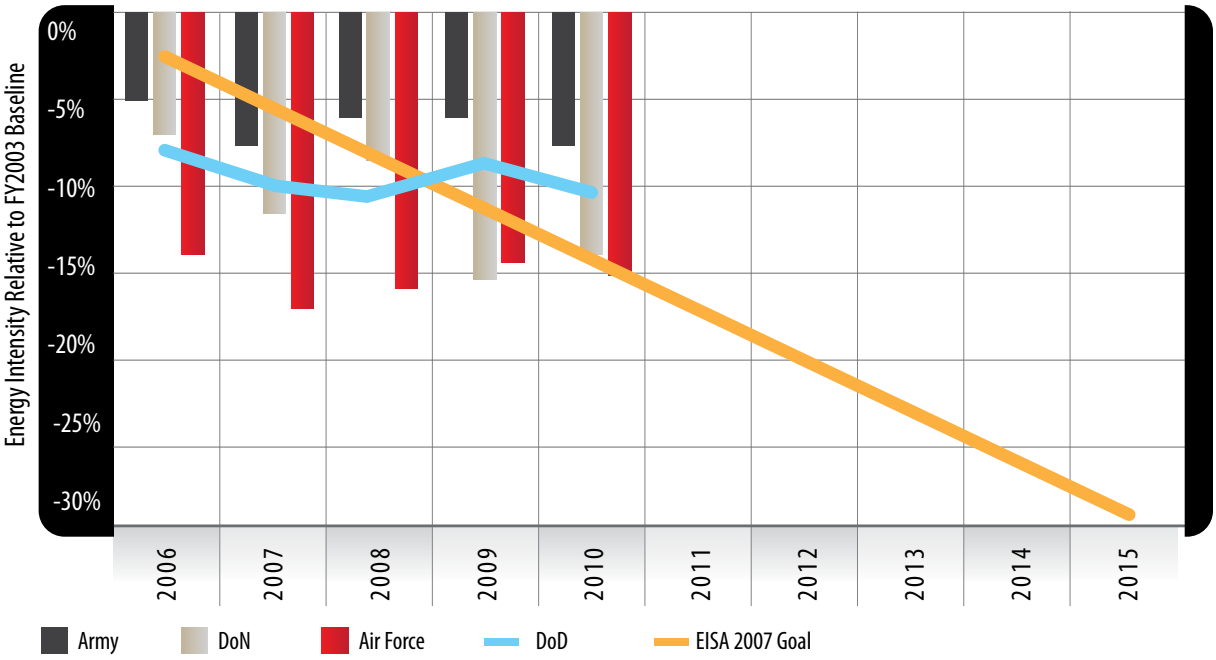
By virtue of numbers and geographic diversity, America's defense installations, both fixed and at forward operating locations, can help to demonstrate a wide range of energy efficiency and new energy technologies. And they have: From fiscal 2003 to fiscal 2010, Department of Defense installation energy initiatives reduced overall energy intensity (energy use per square foot) by 11.4 percent, short of the EISA 2007 goal.[131]

The department has initiated the Installation Energy Test Bed Program to identify key energy management strategies that can be broadly deployed in defense installations and transferred to the civilian sector as well.

Under the direction of the Environmental Security Technology Certification Program (ESTCP) and with $30 million in funding in fiscal 2010, the Installation Energy Test Bed Program works closely with the Department of Energy to identify and demonstrate innovative, cost-effective energy technologies that hold the potential for significantly altering DoD energy trends. The program is developing and testing new energy technologies and techniques in five focus areas:

- Advanced components (lighting, heating/cooling).
- Energy management and control tools.
- Smart grid and energy storage.

FIGURE 11: ENERGY INTENSITY COMPARED WITH EISA 2007 GOAL



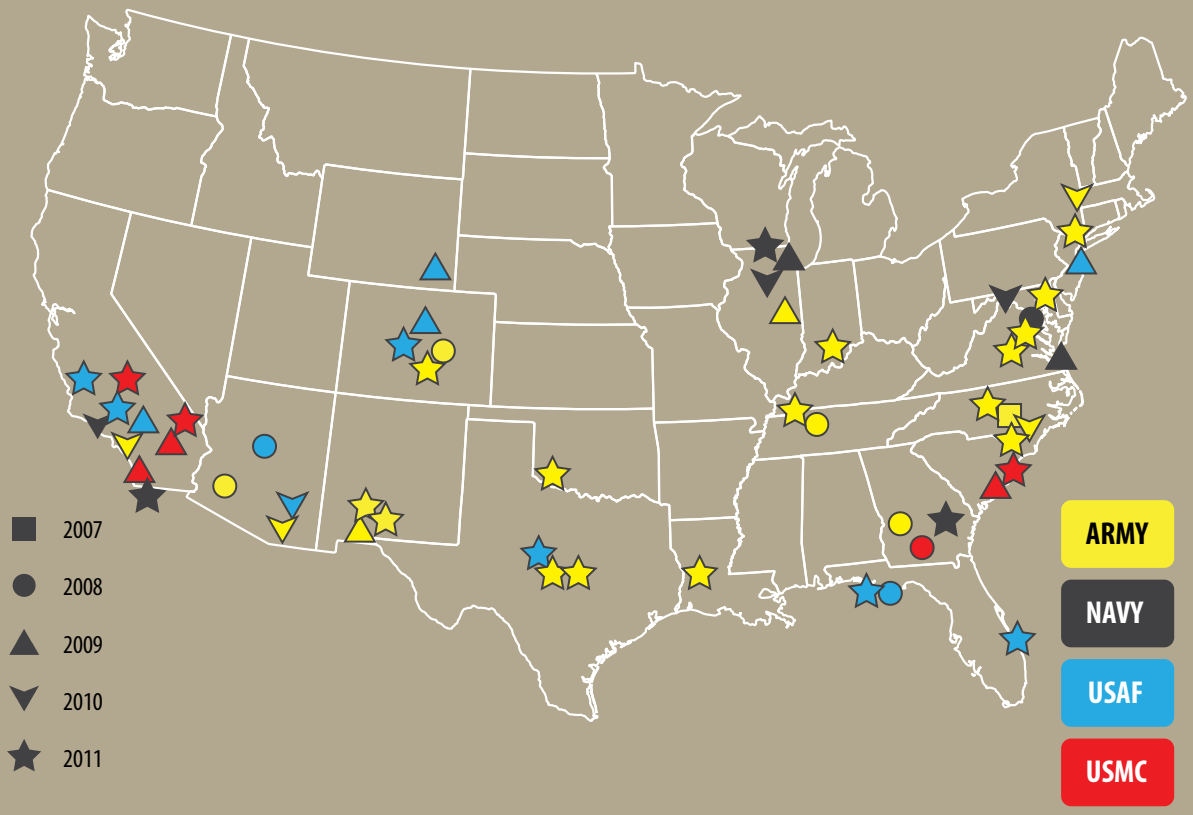
Source: FY2010 Federal Energy Management Report

- Energy assessment and design tools.
- Alternative energy generation.

The two-year-old initiative has more than 45 demonstration projects underway and is responding to a variety of recommendations that hold the potential for reducing demand by 50 percent in existing buildings and 70 percent in new construction.[132] Last year, the program received more than 300 proposals from a diverse set of private- and public-sector entities interested in demonstrating and commercializing energy saving and management technologies.

Similarly, energy efficiency initiatives hold great promise for forward locations and operating bases in theater. Portable power generators provide the electricity needed at forward operating locations, but they are expensive and hazardous. DoD has 125,000 generators deployed,[133] and, when considering the fully burdened cost of fuel, it is estimated that in wartime, the department spends

FIGURE 12: INSTALLATION ENERGY TEST BED PROJECT LOCATIONS



Source: Strategic Environmental Research and Development Program

$3.5 billion to $5 billion annually to power them.[134] More importantly, fuel convoys are required to provide the fuel necessary to power the generators, and these convoys are popular targets for insurgents; according to the Army, there is one casualty for every 46 ground resupply convoys in Afghanistan.[135]

Because of this burden, sustainable sources of power that can be produced in remote forward operating locations have become a priority for the military. In 2010, the Marines initiated the Experimental Forward Operating Base Program (ExFOB) at Marine Corps Base Quantico. The program tested energy efficiency technologies at forward operating bases[136] and allowed private industries to demonstrate operational energy technologies that included renewable energy generation, energy efficient heating and cooling systems, efficient shelters and efficient water purification.[137]

ExFOB demonstrations at Quantico and other Marine bases around the country provided critical information about how clean energy technologies could be incorporated into deployed structures. For example, the Marines have incorporated flexible solar technology into their tent structures, with 1 to 2 kilowatts of capacity built into the roof for radios, laptops and other electronic devices.[138] During a recent ExFOB demonstration at Marine Corps Air Ground Combat Center Twentynine Palms, 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.[139] Equally as important as the on-site power generation is solar power's quiet nature, which, unlike noisy generators, does not alert insurgents to Marines' whereabouts.

As a result of the demonstrations, a group of Marines from India Company, 3rd Battalion, 5th Marines

Marine Corps photo

POWERSHADES FIT OVER STANDARD MARINE CORPS TENTS AND CUT THE TEMPERATURE INSIDE BY 10-15 DEGREES. SOLAR PANELS EMBEDDED INTO THE CANVAS PROVIDE ENOUGH ENERGY TO RUN THE TENT'S LIGHTS.

was deployed to Afghanistan in the fall of 2010 to demonstrate the ExFOB program in theater.[141] Energy savings from the deployment included:[142]

- 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.

These savings have prompted the Marines to invest $25 million to provide the same capabilities to all of its units in the Helmand Province.[143] In August 2011, Marines from 2nd Battalion, 4th Marines deployed after having trained at Twentynine Palms during the next phase of ExFOB. Their equipment targets battalion level command and control systems, which are major energy consumers in the battlefield. Capabilities of the Marines' equipment include hybrid power systems and efficient air conditioning, which had demonstrated 83% savings during ExFOB.[144]

Lessons learned through the Installation Energy Test Bed Program and ExFOB Program hold the promise of helping the United States realize the large potential for energy efficiency improvements throughout the nation's building stock. A 2008 review by the Lawrence Berkeley National Laboratory estimates that energy efficiency improvements in U.S. buildings have the potential to cut the nation's energy bill by up to $170 billion annually in 2030.[145]

"As far as disadvantages, I really haven't seen any. You don't need any fuel, it's much quieter than a generator but can still power any electrical asset you need."[140]

—Sgt. Gregory Wenzel, intelligence analyst, India Company, 3rd Battalion, 5th Marines, on using the expeditionary energy system

MICROGRIDS

The Department of Defense is moving rapidly to examine the potential of self-contained "microgrids" that hold promise for addressing one of the primary challenges set forth by the Defense Science Board in "More Fight—Less Fuel" ensuring the continuity of critical DoD operations at domestic bases.

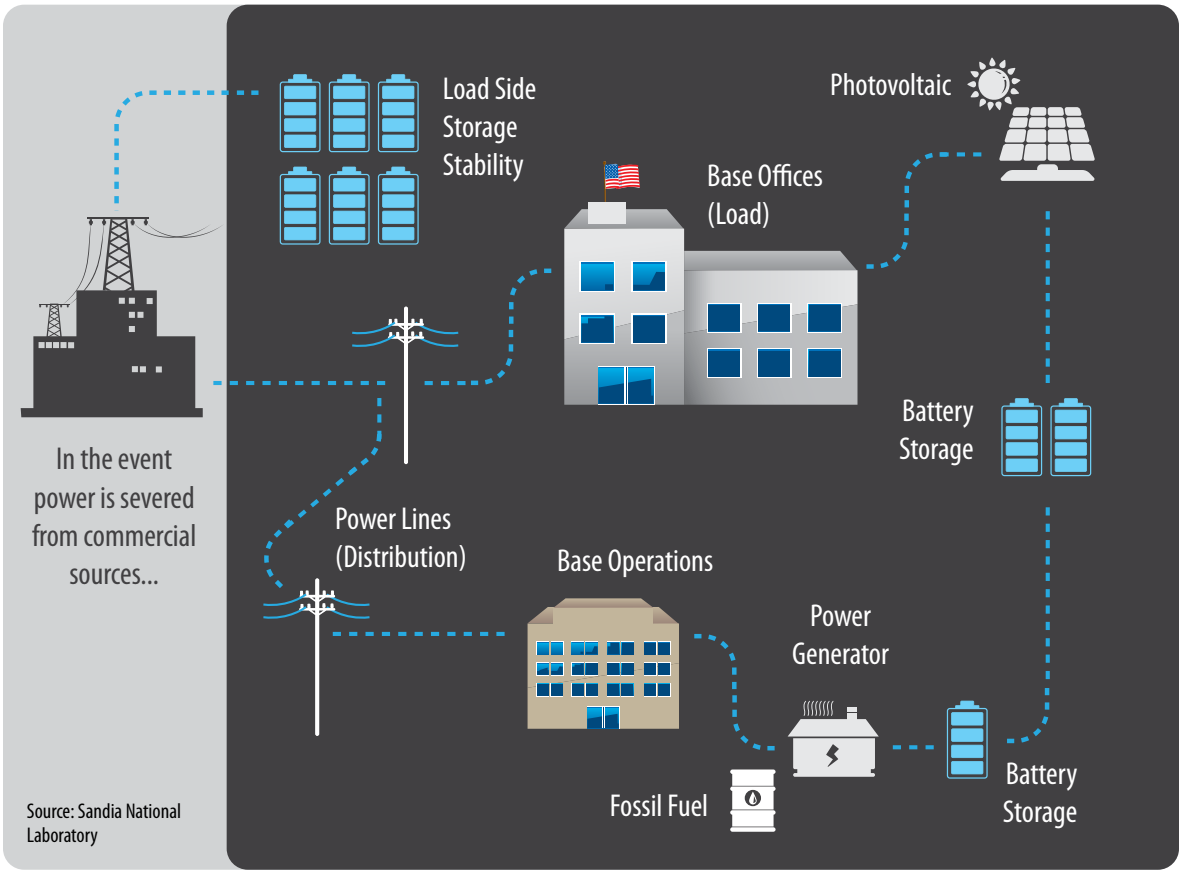
At DoD installations across the United States, large amounts of energy are required to power the lights, run the computers and operate the buildings in which key defense missions are conducted, from combat support and operation of unmanned aircraft to training and care for America's warriors. When U.S. troops and national security interests are at risk, there is no room for electric service interruptions.

It is estimated that DoD depends on civilian utility companies for 99 percent of its electricity requirements.[146] Although the U.S. electricity sector is highly reliable, the current grid is old, unsuited for new and emerging technologies, and vulnerable to natural disasters and terrorist attack.

For these reasons, DoD is playing a key role in the development of microgrid technologies. Microgrids are self-contained islands of energy generation and management capacity that may or may not be attached to the commercial grid. In most cases, the military is developing microgrids as contingency power sources to support critical operations in the event of an outage associated with utility power provision. Microgrid technology also helps facilitate integration of renewable energy sources, energy efficient and demand management technologies, and other "smart grid" components.

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.[147] Market analysts indicate that DoD will account for almost 15 percent

FIGURE 13: MILITARY SURETY MICROGRID



Source: Sandia National Laboratory

of the microgrid market in 2013 and that military implementation of microgrids will grow by 375 percent to $1.6 billion annually in 2020.[148]

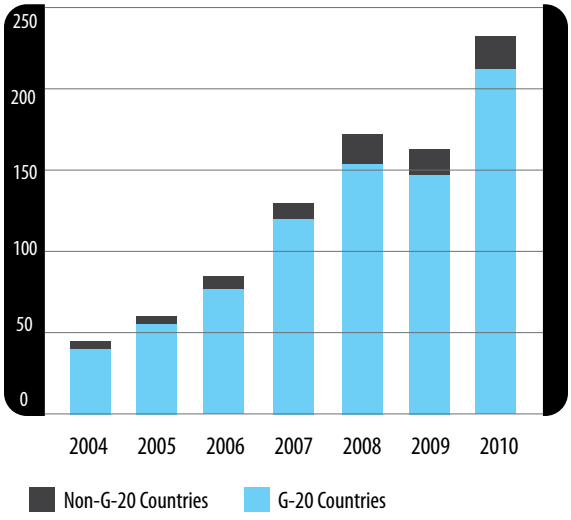
In addition, DoD's interest is drawing the expertise of major technology industries and companies. The complex but promising opportunities associated with microgrids and smart grids require the kind of integrated systems approach that the traditional defense industries can bring to bear. Encouragingly, a number of major defense industry organizations such as Lockheed-Martin, Boeing, United Technologies and General Electric are taking an interest in the emerging potential of smart grid and microgrid technologies. "DoD's push on innovation with microgrids could have major ramifications for the broader economy, replicating past successes with cutting edge technologies such as the Internet, GPS systems, computers and airplanes," says Peter Asmus of Pike Research.[149]

Among the key projects underway are deployment of microgrid control technologies at the Marine Corps' largest base, Twentynine Palms in California, and the Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS), a collaborative technology demonstration involving the U.S. Pacific and Northern Commands, DoE laboratories and local utilities in proximity to Fort Carson in Colorado and Camp Smith in Hawaii.

RENEWABLE ENERGY GENERATION TECHNOLOGY

The renewable energy sector is growing at a rapid pace all over the world. As documented in a Pew Charitable Trusts report, "Who's Winning the Clean Energy Race? 2010 Edition," worldwide investment in clean energy increased 30 percent in 2010 to a record $243 billion. Over the past six years, worldwide investments in clean energy have grown 367 percent. These encouraging numbers are

FIGURE 14: GLOBAL AND G-20 CLEAN ENERGY INVESTMENT, 2004–10 (BILLIONS OF $)

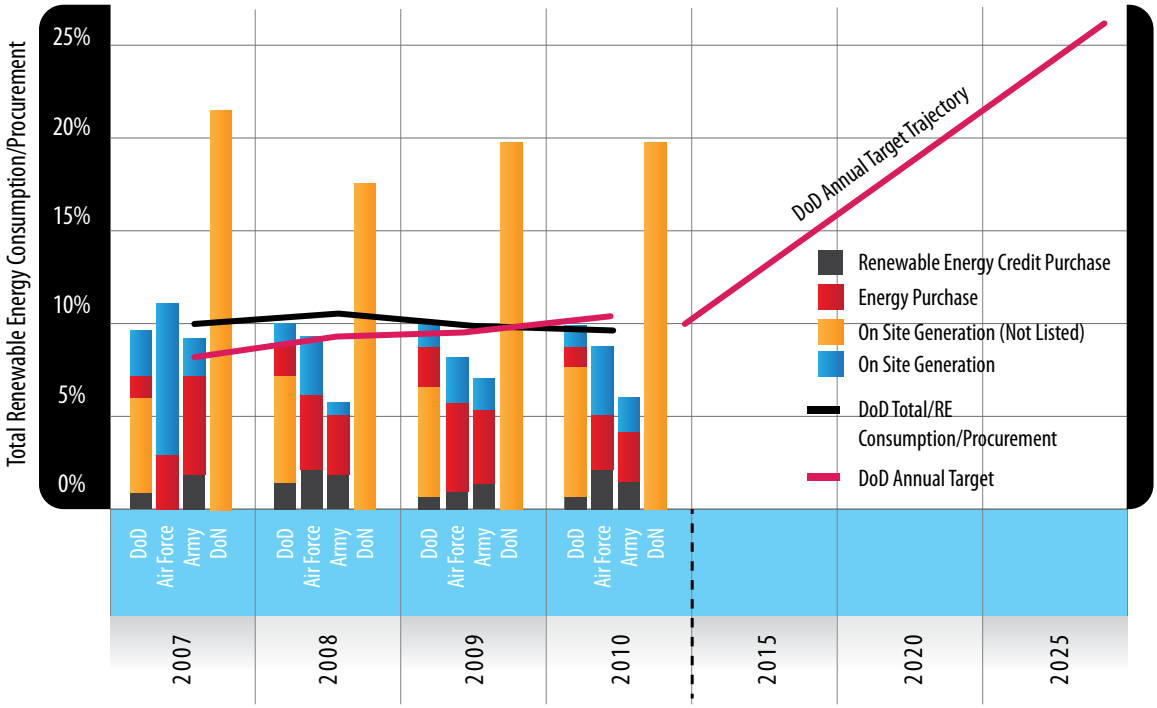


Source: The Pew Charitable Trusts

tempered in the United States by the fact that the U.S. competitive position in the clean energy marketplace has been slipping in recent years. Although many of the leading renewable energy technologies have been pioneered in the United States, manufacturing and use of renewables has shifted markedly to Europe and Asia.

The Department of Defense does not use energy on a sufficient scale to single-handedly enhance the clean energy competitiveness of the United States, but as the world's largest institutional energy user and with a

FIGURE 15: DOD RENEWABLE ENERGY TREND TOWARD 25% GOAL



Source: FY2010 Federal Energy Management Report

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.[150]

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 the next steps in product engineering and manufacturing.[151]

At the other end of the technology development spectrum, DoD is deploying commercially available renewable energy technologies that serve three organizational goals: reducing dependence on fossil fuels, saving money and improving the security and reliability of electricity supplies.

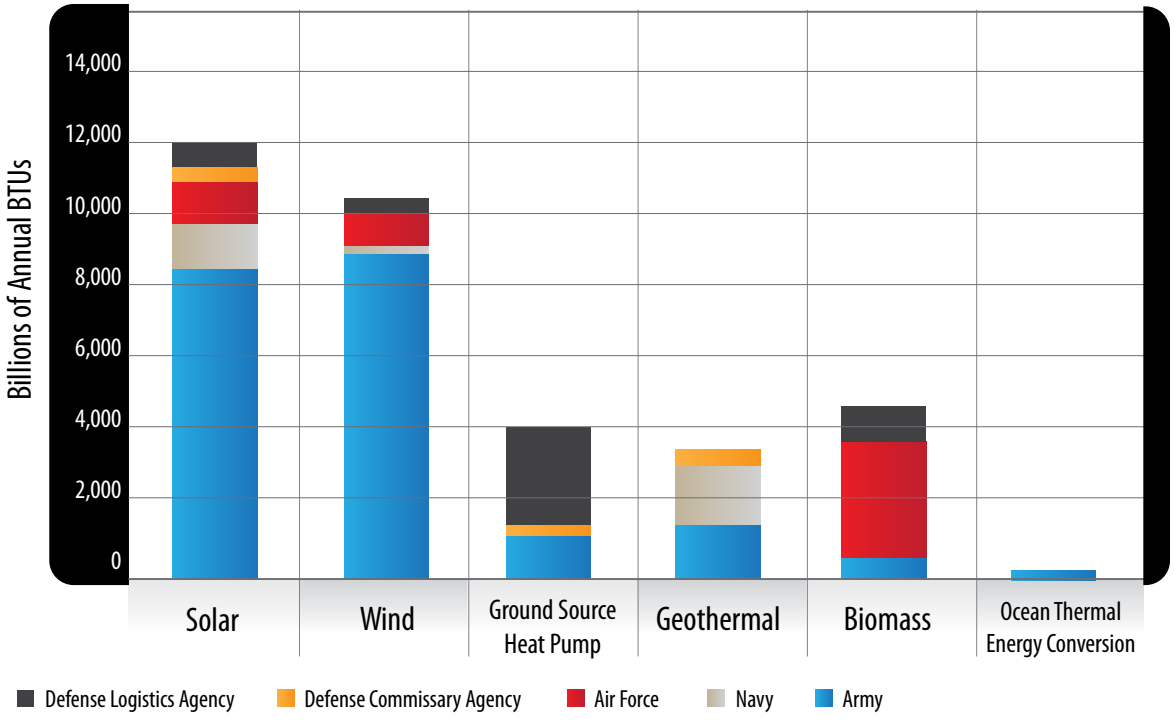
Deployment: As of mid-2010, the Department of Defense was operating more than 450 projects involving solar, wind, geothermal and biomass energy at its fixed installations.[152] More than two-thirds of these projects (311) involve solar photovoltaic or solar thermal technologies, with an additional 56 projects involving geothermal energy. The U.S. Navy accounts for 60 percent of DoD's renewable energy projects, a total of

about 250. As of mid-2010, the Army was operating 115 projects and the Air Force 70 projects. The 14 MW solar array at Nellis Air Force base 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 currently produces or procures approximately 10 trillion BTUs of renewable energy.[153] A 2009 study undertaken across the armed forces found that the department has the potential to produce on-site at its facilities three times that amount of renewable energy, an overall potential of 33 trillion BTUs, or almost five times more than is needed to reach the 2025 goal of obtaining 25 percent of its facility energy from alternative sources.[154]

Financing for DoD renewable energy projects is derived from the Energy Conservation Investment Program and innovative third-party financing mechanisms such as enhanced use leases (EULs) that allow private entities to set up renewable energy generating capacity on under-utilized installation property, and power purchase agreements (PPAs) with renewable energy companies. EULs and PPAs are attractive for major institutions because they take advantage of private sector expertise, minimize government risk and reduce upfront construction and ongoing maintenance costs. The Navy recently initiated a 40 MW solar power purchase agreement for facilities across California. In August 2011,

FIGURE 16: DOD ESTIMATE OF RENEWABLE ENERGY PRODUCTION POTENTIAL



Source: FY2010 Federal Energy Management Report

the Navy issued a $500 million multiple award contract for solar power at its installations across Hawaii.[155]

In 2007, new policies were initiated that allow for 30-year power purchase agreements where such purchases are cost-effective.[156] This policy should help reduce costs and expand opportunities for renewable energy projects for the armed services.

ENERGY STORAGE

As electronics become increasingly more important to troops on the battlefield, so, too, does energy storage. Lightweight and long-lasting power is crucial for troops who need computers, radios or night-vision goggles on extended missions. Similar to other energy sources, the military has long viewed portable electricity as a readily available resource. However, with a new emphasis on changing the culture surrounding energy consumption, DoD is increasingly stressing to its ground troops the importance of viewing themselves as managers of their own power.

Batteries: It is estimated that up to 20 percent[157] of a soldier's 70- to 90-pound pack consists solely of batteries. Army soldiers must carry seven or more pounds of batteries for each day on mission,[158] which, in the sweltering heat of Iraq or Afghanistan, can hamper mobility. DoD's Operational Energy Strategy projects that battery demands will increase and that by 2012, war fighters on a three-day foot patrol will require 50 batteries per soldier weighing a total of 18 pounds.[160] Batteries also contribute to DoD's enormous energy bill: A typical infantry battalion uses $150,000 worth of batteries during a one-year deployment.[160] Costs are also up because of the lack of common standards; the Army spends about $10 million a year on custom-made radio batteries alone.[161]

"Dow Kokam provides the Department of Defense with advanced batteries that decrease costs and provide power in smaller, lighter packages to reduce burdens on warfighters. DOD is a critical customer for advanced clean energy manufacturers that are scaling up new technologies for both defense and commercial markets."

–Ravi Shanker, President and Chief Executive Officer, Dow Kokam

Combined with equipment efficiency improvements, batteries that are more efficient, longer-lasting and lighter can significantly improve mission effectiveness and mobility. While technological research into advanced battery technologies is being pursued by

RUCKSACK ENHANCED PORTABLE POWER SYSTEM IS A LIGHTWEIGHT, PORTABLE POWER SYSTEM CAPABLE OF RECHARGING BATTERIES AND/OR ACTING AS A CONTINUOUS POWER SOURCE. IT COMBINES ANTI-GLINT SOLAR PANELS, CONNECTORS AND ADAPTORS FOR INCREASED CHARGING OPTIONS, AND CAN CHARGE MOST COMMON MILITARY BATTERY TYPES IN FIVE TO SIX HOURS.

DoD and the Department of Energy, the military is pairing rechargeable batteries with renewable energy technologies to extend soldier range and effectiveness.

The Army and Marines have developed portable power systems that include rechargeable batteries and solar-powered recharging devices. For example, the Army's 10-pound Rucksack Enhanced Portable Power System (REPPS), is a portable battery recharging kit made up of a thin 62-watt solar mat that can roll up when carried, as well as associated rechargeable batteries and fuel cell chargers.[162] REPPS can charge most military batteries in five to six hours[163] and can be linked to accommodate larger energy requirements.

US Navy

US NAVY-WATT PHOTOVOLTAIC BATTERY SYSTEM, DEVELOPED BY THE OFFICE OF NAVAL RESEARCH, CAN PROVIDE CONTINUOUS POWER TO MARINES IN THE FIELD

Wayne V. Hall, U.S. Army

THE U.S. ARMY TANK AUTOMOTIVE RESEARCH, DEVELOPMENT AND ENGINEERING CENTER UNVEILED ITS FUEL EFFICIENT GROUND VEHICLE DEMONSTRATOR ALPHA TO EMPLOYEES AT THE PENTAGON JULY 12, 2011. TARDEC SERVES AS THE LEAD PROGRAM AGENCY ON THE OFFICE OF THE SECRETARY OF DEFENSE'S FED PROGRAM TO ADDRESS FUEL CONSERVATION NEEDS ACROSS THE MILITARY. THE ALPHA REPRESENTS THE FIRST OF TWO VEHICLES BEING DEVELOPED TO COMPETE FOR A ROLE IN THE SERVICE OF THE U.S. MILITARY.

The Marines have a similar system called the Solar Portable Alternative Communication Energy System (SPACES), which is a small, flexible solar panel that can fit inside a backpack and charges smaller items such as radio batteries.[164] Additionally, deployed Marines in Afghanistan are using the Ground Renewable Expeditionary Energy System (GREENS), a larger, portable power system consisting of rechargeable batteries and solar panels that can provide 300 watts of electricity.[165]

In July 2010, a memorandum of understanding (MOU) was established between DoD and the DoE to "strengthen coordination of efforts to enhance national security, and demonstrate Federal Government leadership in transitioning America to a low carbon economy."[166] Under the MOU is work on battery research and development,[167] whereby the Advanced Research Projects Agency-Energy (ARPA-E) and DoD are jointly working to develop hybrid energy storage systems.[168] The extensive battery work being done by DoE only reinforces the notion that there are a multitude of markets that can be penetrated by DoD's adoption of better batteries.

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.[169] 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 kerosene or JP-8 powered generators, fuel cells are lighter, quieter, produce fewer emissions and are estimated to be 83 percent more efficient.[170]

Of the many different storage types of fuel cells, perhaps the two most relevant to portable power are cells in the sub-50 W and sub-250 W categories. Sub-50 W cells are small, can operate under a wide range of temperatures and are up to 70 percent lighter than conventional batteries,[171] meaning they can be worn by soldiers. The Army's Soldier Conformable Rechargeable Battery (SCRB) is thin enough to conform to soldiers' protective chest plates. Using a small 25-watt fuel cell, the SCRB can support a 72-hour mission before recharging is necessary.[172] Sub-50 W cells also have applications for unattended ground sensors (UGS), which detect information on a wide range of targets such as motion or weather patterns.[173]

Sub-250 W fuel cells are aimed at recharging larger-scale batteries used in squadron-sized charging units, unmanned vehicles and tactical satellite radios.[174] Defense contractors are targeting the military's Joint Tactical Radio System Program (JTRS) for development of satellite radios in ground vehicles and aircraft. Tactical satellite radios have significant advantages over currently deployed radios in that they can transmit JPEGs and other larger-scale data.[176] It is estimated that by switching to secondary batteries, the military can avoid purchasing 100,000 primary batteries and save $20 million a year.[176]

DoD's use of fuel cell technology can play a large role in the development of fuel cells at commercial scale. A recently announced component of the DoD-DoE MOU has been the fuel cell backup power demonstration, which will examine how DoD's use of fuel cells can improve existing commercial fuel cell technology. The partnership calls for DoD to monitor the deployment of fuel cell systems across eight military installations. In exchange, scientists from the National Renewable Energy Laboratory (NREL) will collect performance data and make it available to fuel cell developers in the commercial and government sectors that are interested in adopting the technology.[177]

In the DoD market alone, requirements for sub-50 W and sub-250 W fuel cells over the next five years would spur investments of $550 million to 650 million.[178] According to DoE, research and development in the fuel cell industry has reduced costs by up to 80 percent since 2002,[179] and as costs come down, fuel cell technology will become increasingly competitive in the vast commercial marketplace.

U.S. Army

A 300-WATT FUEL CELL USED BY THE ARMY. FUEL CELLS ARE ESTIMATED TO BE 83% MORE EFFICIENT THAN TRADITIONAL GENERATORS.

U.S. Air Force photo/Lance Cheung

CONCLUSION

The past decade has been one of great challenges and successes for the United States military. The Department of Defense has been charged with managing two wars, helping oversee establishment of more robust homeland security measures and responding to a large number of worldwide humanitarian emergencies. America's service men and women have been deployed for long stretches in difficult environments and circumstances and at great risk.

Throughout this trying decade, the military has had the foresight to look inside its operations, learn lessons and find opportunities for improvement. The energy issue, long an afterthought to the nuts and bolts of military hardware, has clearly emerged as a key strategic consideration for the future of military operations in the Middle East and around the world. Operational energy considerations have penetrated the top tier of considerations for troop safety, budget integrity and mission success.

Recognizing the strategic importance of energy security, the Department of Defense has set essential institutional frameworks and initiatives for confronting its long-term energy challenges. But as the nation knows, interest in an energy policy that makes economic, national security and environmental sense does not necessarily translate into coherent and sustained success in the needed energy transformation.

DoD has the need and institutional capacity to help lead the nation toward a more rationale long-term energy future—cleaner, stronger and more economically sound. But succeeding in this important mission will require vigilance and leadership.

The department has established ambitious and far-reaching goals that would transform military energy use, from platforms to practices. But these lofty goals are unlikely to be met unless DoD's rhetoric is matched by sustained policies and resources. Energy innovation must be a budgetary priority, a focus of cooperation between the department and Congress, and part of the reward structure and culture of the department.

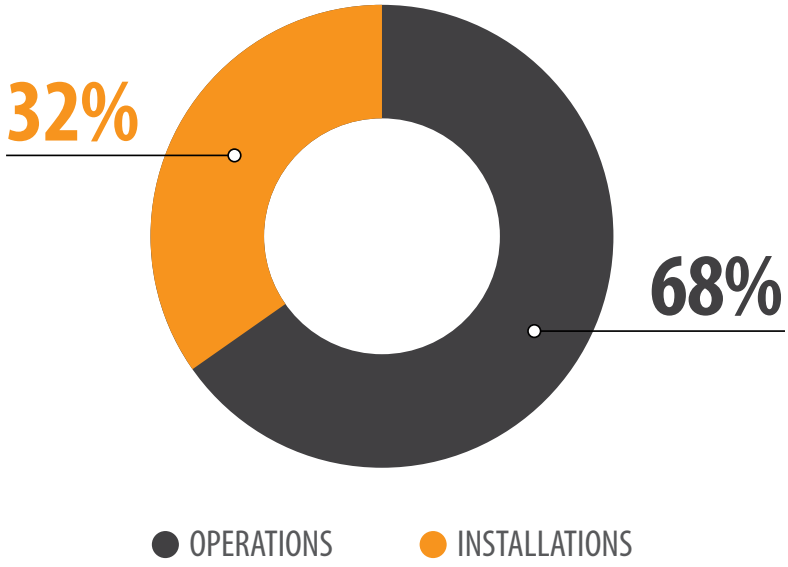
As this report documents, the rationale for DoD action on energy innovation is clear, as is the role that the department can play in accelerating the technology development process. Already, the department is engaged in encouraging initiatives on vehicle efficiency, alternative fuels, renewable energy and energy management and storage.

With sustained effort and initiative, the department can realize the multiple benefits of a new energy future: increasing military effectiveness, saving money and lives, and advancing the economic and national security interests of the United States.

ARMY

The U.S. Army's wide-ranging war-fighting responsibilities require large amounts of energy at fixed and forward facilities. The service manages about 150,000 buildings worldwide, more square footage than Wal-Mart Stores Inc. With its significant fuel and electricity needs, the Army is an excellent proving ground for alternative power sources that enhance energy security, save money and lower the risk to the service members and civilians who protect vulnerable supply lines. The Army is combating its reliance on an aging domestic electricity grid, its long tail of fuel convoys and its unpredictable fuel costs by pursuing renewable energy and initiating efficiency and conservation measures. In 2010, the Army had 126 active renewable thermal and electric energy projects operating. Forty percent of the Army's 80,000 non-tactical vehicles are alternative fuel or hybrid. The Army's "net zero" program will result in eight installations that generate as much energy on-site as they consume by 2020.

ARMY ENERGY USE 2010 (PERCENT OF TOTAL ENERGY COST)



The information presented in the service profile is derived from official data provided for this report by the armed services or in the Department of Defense Fiscal Year 2010 Annual Energy Management Report; the Department of Defense Operational Energy Budget Certification Report for Fiscal Year 2012; the U.S. Armed Forces Energy Strategy documents; and presentations by representatives of the armed forces at a July 7, 2011, forum hosted by The Pew Charitable Trusts.

ENERGY USE AND COST (FISCAL 2010)

Total Energy Use	**= 295 trillion BTU**
Total Energy Cost	**= $4 billion**
Operational Energy Cost	**= $2.7 billion**
Installation Energy Cost	**= $1.2 billion**

CLEAN ENERGY GOALS

Renewable:
Increase the amount of renewable energy to 25 percent of total energy consumed by 2025.

Vehicles:
4,000 electric vehicles by 2012.

Net-Zero Installations:
Six installations producing as much as they consume in energy, six in water and six in waste by 2020. Additionally, two other installations will become net zero in all three.

CLEAN ENERGY PROGRESS (FISCAL 2010)

Total Renewable Energy Produced/Procured:
5.6 percent of electricity consumption.

Energy Intensity Reduction:
8.7 percent relative to 2003 baseline.

Electric Metering:
100 percent of facilities required to have electric meters by 2012.

BUDGET AND INITIATIVES (FISCAL 2012)

Operational Energy Budget:
$212 million requested in fiscal 2012 for operational energy initiatives.

Major Initiatives:

1. Research, develop and procure Advanced Mobile Medium Power Sources—new generators that are quiet, easy to operate and repair, and more fuel efficient.
2. Increase energy efficiency of existing ground and air vehicles.
3. Hybrid vehicles with energy storage systems that reduce fuel demand and can provide energy to forward-operating bases.
4. Investigate and develop advanced power sources and storage to enhance soldier mobility and sustainability.

KEY CLEAN ENERGY PROJECTS

NAME OF FACILITY/PROJECT	MW OR OTHER MEASURE OF QUANTITY
Tooele Army Depot, Utah	Tooele has the Army's first wind turbine. The 1.5-MW turbine is expected to save more than $200,000 a year. Additionally, the post installed passive solar heating walls on 11 buildings, saving another $100,000 annually in heating costs. The facility even installed solar-powered warning sirens.
Fort Benning, Ga.	Fort Benning is using landfill gas to generate 250-kilowatts of electricity, enough to power about 250 homes. Looking forward, the fort is testing two advanced wind turbines that take advantage of air flowing from chillers that normally is vented into the atmosphere.
Fort Irwin, Calif.	In 2009, the Army Corps of Engineers signed an agreement with Energy Security Partners to construct a 500-MW solar energy complex by 2024. The partnership will take advantage of 2,400 underused acres and provide enough energy to meet the post's entire demand. The project is planned to expand to 1 gigawatt.
Fort Carson, Colo.	Fort Carson is one of the Army's net-zero bases, with plans to achieve net-zero status for energy, waste and water by 2020. The post started in December 2007 when a 2-MW solar array was completed. The solar panels were installed on 12 acres, half of which is a former landfill, and will fill more than 2 percent of the electricity demand. The panels were built under a partnership agreement with the local utility, which ensures a fixed price for the electricity for 20 years, protecting the facility from price volatility.

Secretary of the Army John McHugh
GovEnergy Conference
Cincinnati, OH
August 10, 2011

We have 1.1 million Soldiers in our ranks. We have more than 400,000 civilian and contracted employees. If the Army were a city, we would represent the fourth largest city in America. We have 158 installations worldwide and own more than 15 million acres of land across the United States. If the Army was a state, we'd be the 42nd largest.

We have more people than the city of Philadelphia and more territory than the state of Maryland. What I'm trying to say is, we're pretty darn big. But like those cities, those states, and the people who live in them, we have an obligation to manage and conserve. I'm pleased to tell you that we have already begun.

Last fiscal year, the Army had 126 renewable energy projects, with nearly all the energy produced from them on-site, for Army installations. We've launched a "net zero" initiative, identifying installations that will produce as much energy on-site as they use in a year. And we've replaced "point generation" power production with several minigrid/power plants supporting U.S. forces in Afghanistan with plans to incorporate 20 more in the near future.

In World War II, the average daily fuel consumption for an allied Soldier was about one gallon a day. Today, it's between 15 and 22 gallons per Soldier a day. In Iraq and Afghanistan, fuel and water comprise about 70 to 80 percent of ground resupply weight. In Afghanistan, we suffer one casualty for every 46 resupply convoys. Less energy use means fewer convoys, and fewer convoys mean fewer casualties.

So our commitment to Energy Security, and certainly mine as Secretary of the Army, is about much more than pinching pennies and the budget. Addressing our energy security needs is operationally necessary, fiscally prudent and vital to mission accomplishment.

ENERGY ORGANIZATION CHART

SECRETARY OF THE ARMY / CSA

SENIOR ENERGY COUNCIL
ASA / 3 - AND 4-STAR EQUIVALENTS
CO-CHAIRS: VCSA / ASA (I&E)
EXECUTIVE SECRETARY: DASA (E&P)

SEC ADVISORY BOARD
DASA / 2-STAR EQUIVALENTS

CHAIR: DASA (E&P)

SEC WORKING GROUPS
O-6 LEVEL

CHAIR: ODAS (E&P) STAFF

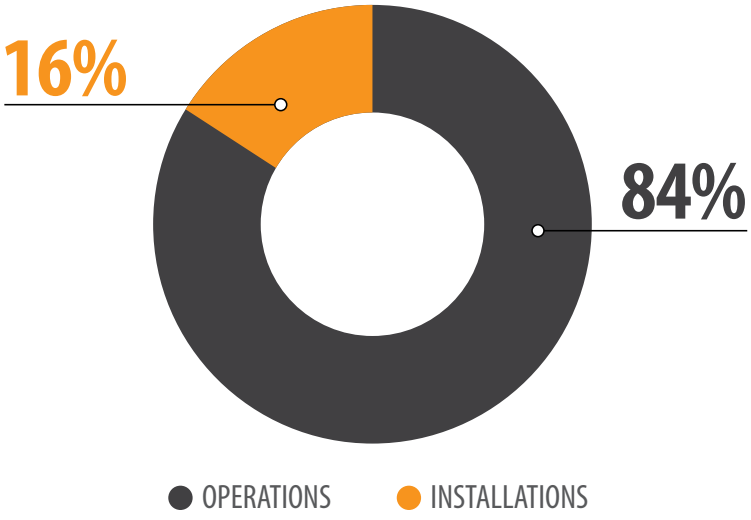
OFFICES OF PRIMARY RESPONSIBILITY

U.S.ARMY

AIR FORCE

With its large appetite for energy, the Air Force is ideally situated to make great strides in increasing energy security while reducing government spending and driving investment in the commercial sector. Research, development and purchasing provide the spark needed to commercialize renewable fuels, clean and efficient vehicles and energy efficiency technologies. To date, the service has met or exceeded every energy efficiency goal it has confronted. The Air Force is well on its way to meeting the newest aggressive goals of generating 25 percent of facility energy with renewable sources by 2025 and obtaining 50 percent of aviation fuels from alternative blends by 2016. The service has approximately 80 renewable energy projects on 43 installations around the world, and 99 percent of its aviation fleetis certified to fly on a 50-50 alternative blend. With its on-site electricity generation, renewable power purchasing, efficiency upgrades, biofuel certification and procurement and conservation measures, the Air Force will continue to set the bar high for the Department of Defense, the U.S. government and the rest of the country.

AIR FORCE ENERGY USE 2010 (PERCENT OF TOTAL ENERGY COST)



The information presented in the service profile is derived from official data provided for this report by the armed services or in the Department of Defense Fiscal Year 2010 Annual Energy Management Report; the Department of Defense Operational Energy Budget Certification Report for Fiscal Year 2012; the U.S. Armed Forces Energy Strategy documents; and presentations by representatives of the armed forces at a July 7, 2011, forum hosted by The Pew Charitable Trusts.

ENERGY USE AND COST (FISCAL 2010)

Total Energy Use	**= 246 trillion BTU**
Total Energy Cost	**= $8.17 billion**
Operational Energy Cost	**= $6.83 billion**
Installation Energy Cost	**= $1.34 billion**

CLEAN ENERGY GOALS

Renewable: Increase renewable energy use at installations 7.5 percent by 2013 and 25 percent by 2025 (Department of Defense goal).

Alternative Aviation Fuels: Acquire 50 percent of aviation fuels with alternative blends by 2016.

Energy Efficiency: Reduce installation energy intensity from 2005 levels by 3 percent a year or 30 percent by 2015.

Reduce fuel burn in existing aircraft by 5 percent in 2016, 10 percent in 2020 and 20 percent in 2030.

Increase lift-to-drag ratio 20 percent by 2016.

CLEAN ENERGY PROGRESS

Total Renewable Energy Produced/Procured: 8.1 percent of electricity consumption.
Approximately 80 renewable energy projects.

Energy Intensity Reduction: 14.9 percent relative to 2003 baseline.

Electric Metering: 87 percent of facilities required to have electric meters toward 2012 requirement of 100 percent.

Other: 75 percent of new vehicle purchases have been alternative-fuel capable over the past seven years.
99 percent of aviation fleet certified to fly on 50-50 alternative blends.

BUDGET AND INITIATIVES

Operational Energy Budget: $261 million in fiscal 2012 requested for operational energy initiatives.

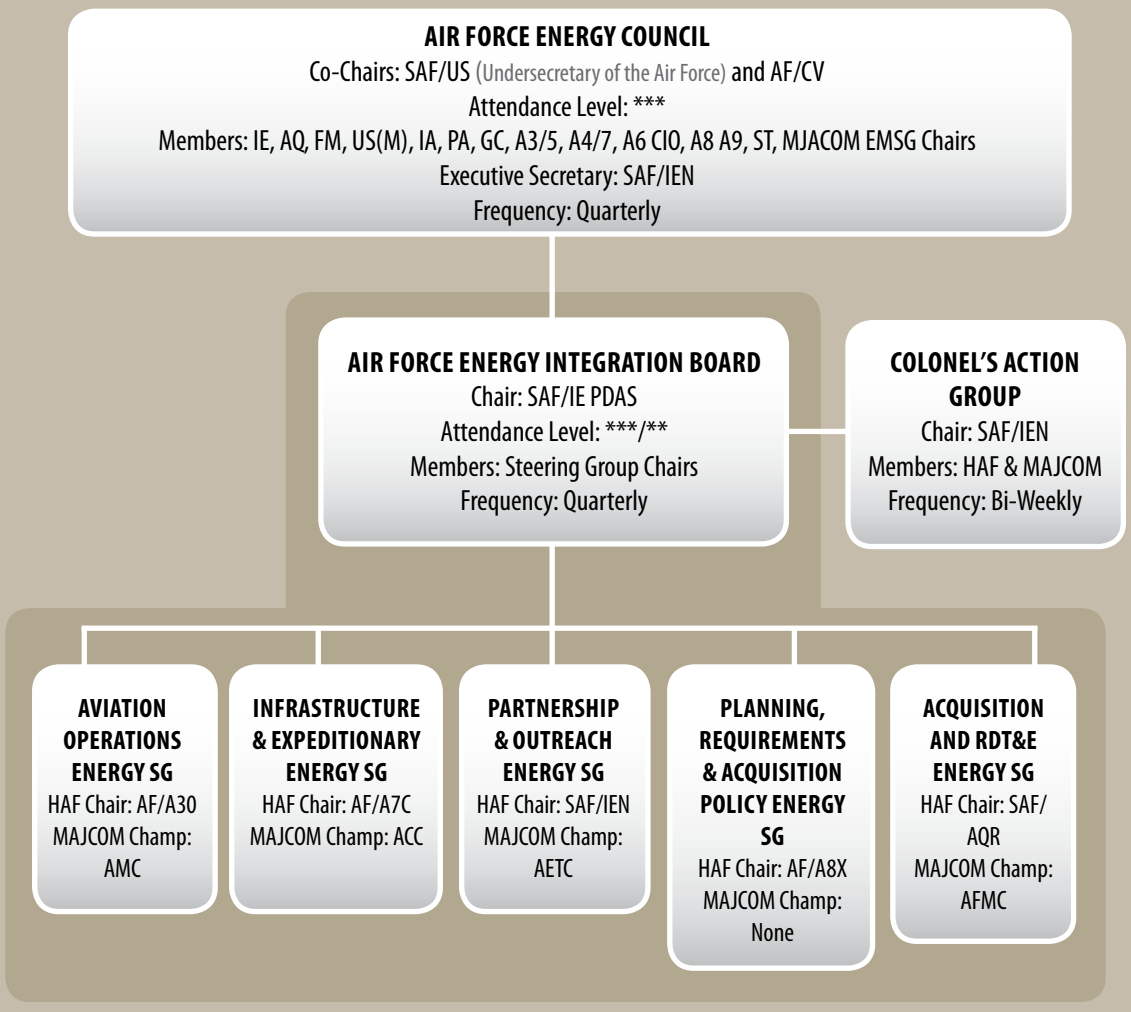
Major Initiatives *(and estimated fiscal 2012 savings):*

1. Certify all aircraft and systems for a 50-50 biofuel blend.
2. Increase use of flight simulators ($368 million).
3. Research and development of the Highly Efficient Embedded Turbine Engine (HEETE) and the Adaptive Versatile Engine Technology program (ADVENT).
4. Other materiel initiatives such as optimizing aircraft centers of gravity, efficient routing, aircraft crew ratios and aircraft over fueling ($59 million).

KEY CLEAN ENERGY PROJECTS

NAME OF FACILITY/PROJECT	MW OR OTHER MEASURE OF QUANTITY
Davis-Monthan AFB, Ariz.	14.5-MW solar on underused land and 6-MW at new Soaring Heights Community (displacing coal). Saving more than $500,000 a year.
Edwards AFB, Calif.	Received 2010 Air Force Energy Conservation Award. All of the base's electricity is from renewable sources. Has contracted for a 3,288-acre, 440-MW photovoltaic solar facility through an enhanced use lease. This will be one of the largest solar arrays in the world, capable of powering 89,000 homes.
Air Force Academy, Colo.	The Academy has a "net zero" initiative, which sets a goal of generating all the electricity it needs via on-base renewable energy sources by 2015. In June, the Academy took a large step toward that goal by dedicating a 6-MW solar array on 30 underused acres. The array will supply 11 percent of the Academy's electricity needs and save up to $1 million a year.
Luke AFB, Ariz.	Luke plans to build a 15-MW solar array on 100 underused acres on base. The array is projected to meet half of the base's energy needs and save up to $10 million on utility bills over 25 years.

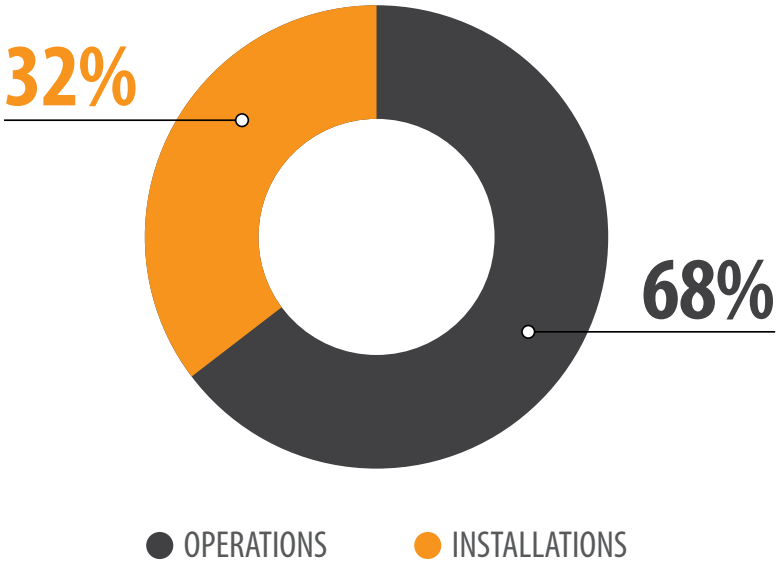
ENERGY ORGANIZATION CHART



MARINE CORPS

Under the leadership of Secretary Ray Mabus, the Department of the Navy has set some of the most ambitious clean energy goals in the nation. In recent years, equipment improvements have enhanced the Marine Corps' war-fighting capability but have also made it heavier, less-agile and more dependent on energy. To address this trend, Marine Corps leaders have made energy innovation a top priority. They aim to increase operational energy efficiency 50 percent and to reduce the amount of energy consumed per Marine by a similar amount. To achieve these goals, the service is targeting energy efficiency at fixed and forward-deployed structures, creating power-management strategies that can reduce generator requirements by two-thirds, and using renewable energy to power the increased need for batteries, computers and radios. A 2010 assessment of energy requirements in Afghanistan found that fuel consumption could be reduced 60 percent through enhanced management of generators and more-efficient structures. In the same year, the Marine Corps launched an Expeditionary Energy Strategy that highlights key goals, initiatives and expectations for Marines individually and the Corps overall.

MARINE CORPS ENERGY USE 2010 (PERCENT OF TOTAL ENERGY COST)



The information presented in the service profile is derived from official data provided for this report by the armed services or in the Department of Defense Fiscal Year 2010 Annual Energy Management Report; the Department of Defense Operational Energy Budget Certification Report for Fiscal Year 2012; the U.S. Armed Forces Energy Strategy documents; and presentations by representatives of the armed forces at a July 7, 2011, forum hosted by The Pew Charitable Trusts.

ENERGY USE AND COST (FISCAL 2010)

Total Energy Use	**= 221 trillion BTU***
Total Energy Cost	**= $651 million**
Operational Energy Cost	**= $440 million**
Installation Energy Cost	**= $211 million**

CLEAN ENERGY GOALS

Renewable: 50 percent of energy consumption at installations from alternative sources by 2020.
50 percent of facilities "net zero" by 2020.

Energy Efficiency: Reduce battlefield fuel demand 25 percent by 2015 and 50 percent by 2025.
Reduce installation energy intensity from 2005 levels by 3 percent a year or 30 percent by 2015.

Vehicles: 50 percent reduction in petroleum use in non-tactical vehicles by 2015.

CLEAN ENERGY PROGRESS

Total Renewable Energy Produced/Procured*: 18.5 percent of electricity consumption

Energy Intensity Reduction*: 16 percent. Department of the Navy requires a 30 percent reduction by 2015.

Electric Metering*: 22,000 advanced meters will be installed by 2016, exceeding goal of metering 95 percent of all electricity.

Other: Rapid deployment of clean energy technologies in Afghanistan through India Company, 3rd Battalion, 5th Marines

BUDGET AND INITIATIVES

Operational Energy Budget: $42 million in fiscal 2012 for operational energy initiatives.

Major Initiatives:

1. Expeditionary energy initiatives—evaluating and deploying battlefield energy efficiency and renewable energy technologies.

2. Energy efficient equipment—procurement of advanced environmental control units and energy efficient shelters.

3. Research and development—advanced batteries for mobile forces; advanced power distribution/generation technology and lightweight power systems.

*Numbers reflect the Department of the Navy (Navy and Marine Corps)

KEY CLEAN ENERGY PROJECTS

NAME OF FACILITY/PROJECT	SIZE
Marine Corps Air Ground Task Force Training Command, Twentynine Palms, Calif.	1.1-MW solar
Marine Corps Base Camp Pendleton, Calif.	1.5-MW solar
Marine Corps Logistics Base Barstow, Calif.	1.5-MW wind
Marine Corps Logistics Base Albany, Ga.	1.9-MW combined heat and power generator run with landfill gas
Marine Corps Base Hawaii	First grid-connected wave-energy project
Marine Corps Air Station Miramar, Calif.	3.2-MW landfill-gas project

Secretary of the Navy Ray Mabus
National Clean Energy Summit 4.0
Las Vegas, NV
August 30, 2011

Why the interest in alternative energy? The answer is pretty straightforward: We buy too much fossil fuel from potentially or actually volatile places on earth. We buy our energy from people who may not be our friends. We would never let the countries that we buy energy from build our ships or our aircraft or our ground vehicles, but we give them a say on whether those ships sail, whether those aircraft fly, whether those ground vehicles operate because we buy their energy.

There are great strategic reasons for moving away from fossil fuels. It's costly. Every time the cost of a barrel of oil goes up a dollar, it costs the United States Navy $31 million in extra fuel costs. But it's costly in more ways than just money. For every 50 convoys of gasoline we bring in, we lose a Marine. We lose a Marine, killed or wounded. That is too high a price to pay for fuel.

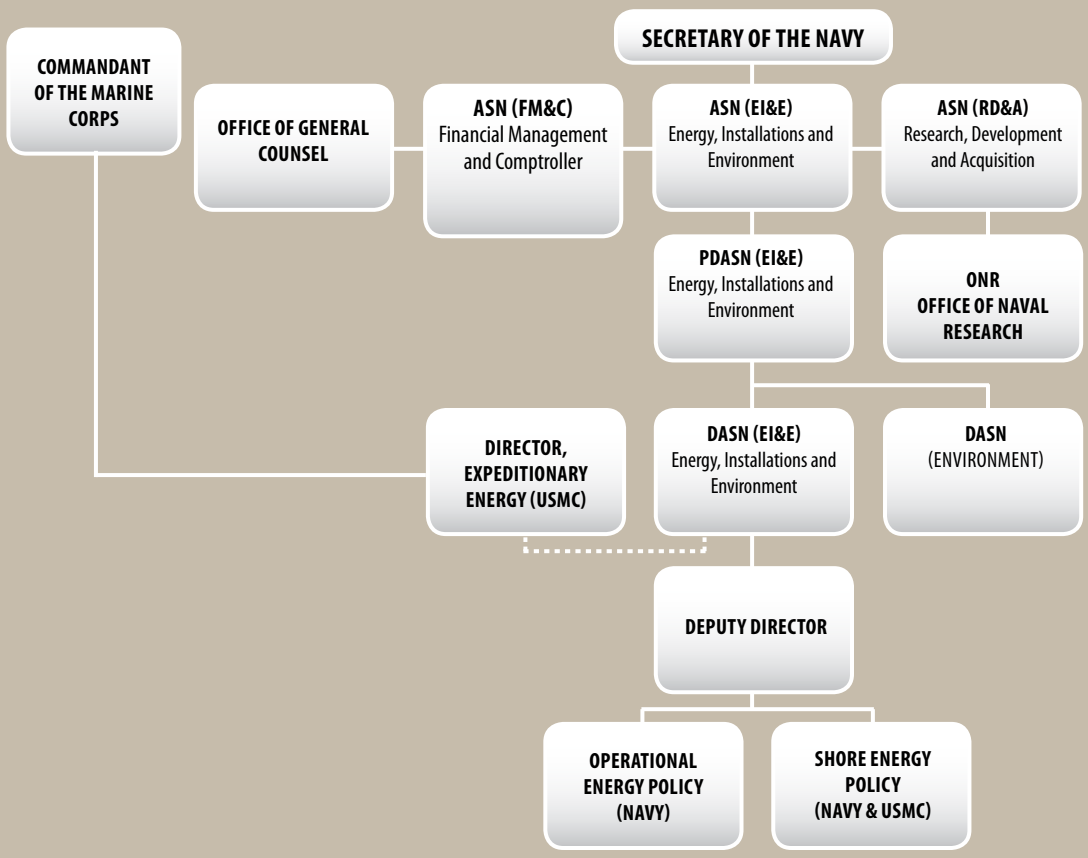
One of our most glaring vulnerabilities is how we get and how we use energy, and it's a vulnerability we have to address. Over the last two years, we've made a lot of progress. Over Labor Day weekend, the Navy's Blue Angels, for the first time ever, are going to fly on biofuels. By the end of the fall, we will have certified every single aircraft that the Navy and Marine Corps fly to run on biofuels.

On the ground, our Marines are using alternative energy devices in Afghanistan so they can do what they were

sent there to do – fight, engage and rebuild. Not to guard fuel convoys or replenishment convoys. They're using portable solar panels to power their batteries or radios or GPSs. In the mid-90s, a Marine company carried 14 radios; today, that same Marine company carries more than 120. But by relying on these portable solar mats, the Marines are saving almost 700 pounds of batteries per day that they don't have to carry.

By using alternative energy, by changing the way we use and produce energy, we're going to continue to be the most formidable expeditionary fighting force the world has ever known, and we're going to continue to do what the Navy and the Marine Corps have always done: innovate, adapt and come out on the other side victorious.

ENERGY ORGANIZATION CHART

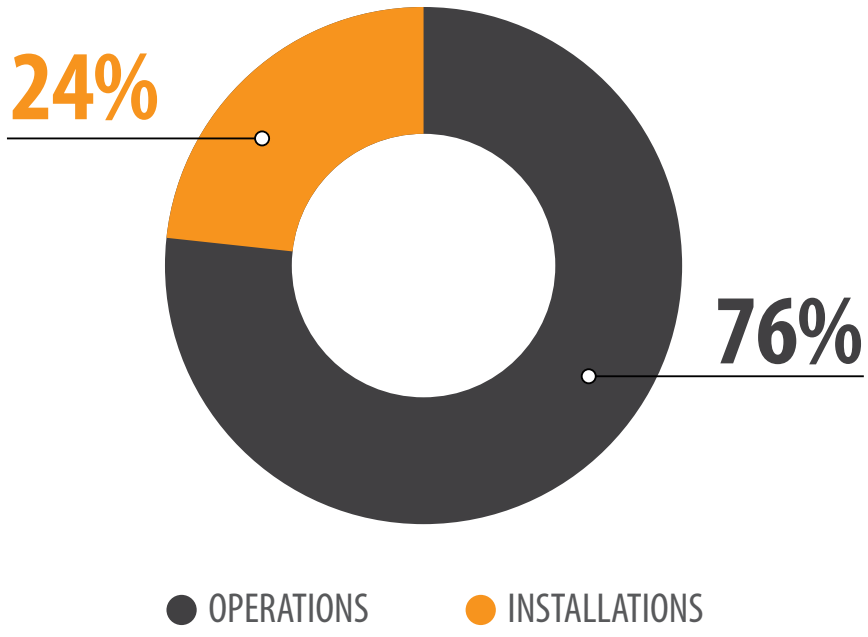


Source: 2010 Navy Energy Vision for the 21st Century

NAVY

Under the leadership of Secretary Ray Mabus, the U.S. Navy has set some of the most ambitious clean energy goals in the nation. In service of energy security and independence, the secretary has called for major energy transformations at sea and ashore through use of alternative fuels, renewable power and efficiency. The Navy has tested the F/A-18 "Green Hornet" strike fighter jet, the first aircraft to use advanced biofuels at supersonic speed (greater than 750 mph); sailed the amphibious assault ship Makin Island at a savings of $2 million on its inaugural voyage; and through the Office of Naval Research is playing an important role in developing and deploying advanced fuel cell technology. The Naval Air Weapons Station at China Lake, Calif., is home to a 270-MW geothermal energy facility, almost 10 percent of total U.S. geothermal capacity in 2010. Additionally, the Navy recently announced a $500 million contract for solar energy at its installations in the Southwest and Hawaii. The result should be almost 45 MW of new solar capacity.

NAVY ENERGY USE 2010 (PERCENT OF TOTAL ENERGY COST)



The information presented in the service profile is derived from official data provided for this report by the armed services or in the Department of Defense Fiscal Year 2010 Annual Energy Management Report; the Department of Defense Operational Energy Budget Certification Report for Fiscal Year 2012; the U.S. Armed Forces Energy Strategy documents; and presentations by representatives of the armed forces at a July 7, 2011, forum hosted by The Pew Charitable Trusts.

ENERGY USE AND COST (FISCAL 2010)

Total Energy Use	**= 221 trillion BTU***
Total Energy Cost	**= $3.17 billion**
Operational Energy Cost	**= $2.42 billion**
Installation Energy Cost	**= $751 million**

CLEAN ENERGY GOALS

Renewable: 50 percent of energy consumption from alternative sources by 2020.
50 percent of facilities "net zero" by 2020.

Biofuels: Demonstrate "Great Green Fleet" by 2016.

Energy Efficiency: Reduce installation energy intensity from 2005 levels by 3 percent a year or 30 percent by 2015.

Vehicles: 50 percent reduction in petroleum use in non-tactical vehicles by 2015.

CLEAN ENERGY PROGRESS

Total Renewable Energy Produced/Procured*: 18.5 percent of electricity consumption
Approximately 180 renewable energy projects at installations worldwide

Energy Intensity Reduction*: 16 percent. Department of the Navy requires a 30 percent reduction by 2015.

Electric Metering*: 22,000 advanced meters will be installed by 2016, exceeding goal of metering 95 percent of all electricity.

Other: Certification of 50/50 biofuels blend for Green Hornet.
Operates more than 10,000 alternative fuel vehicles

BUDGET AND INITIATIVES

Operational Energy Budget: $389 million requested in FY2012 for operational energy initiatives

Major Initiatives *[and estimated FY2012 savings]*

#1 Increase Alternatives Afloat to advance development/certification/testing of advanced biofuels.

#2 Sail the Great Green Fleet through procurement of alternative jet & maritime fuels

#3 Increase Efficiency Afloat through ship and air energy conservation training, power management systems and development of advanced efficiency technologies for ships and aircraft.

*Numbers reflect the Department of the Navy (Navy and Marine Corps)

KEY CLEAN ENERGY PROJECTS

NAME OF FACILITY/PROJECT	SIZE
China Lake, Calif.	270-MW geothermal energy project
Naval Base Guantanamo Bay	3.8-MW wind facility
San Clemente Island, Calif.	675-kW wind facility
Naval Base Coronado, Calif.	500-kW building integrated photovoltaics

Secretary of the Navy Ray Mabus
National Clean Energy Summit 4.0
Las Vegas, NV
August 30, 2011

Why the interest in alternative energy? The answer is pretty straightforward: We buy too much fossil fuel from potentially or actually volatile places on earth. We buy our energy from people who may not be our friends. We would never let the countries that we buy energy from build our ships or our aircraft or our ground vehicles, but we give them a say on whether those ships sail, whether those aircraft fly, whether those ground vehicles operate because we buy their energy.

There are great strategic reasons for moving away from fossil fuels. It's costly. Every time the cost of a barrel of oil goes up a dollar, it costs the United States Navy $31 million in extra fuel costs. But it's costly in more ways than just money. For every 50 convoys of gasoline we bring in, we lose a Marine. We lose a Marine, killed or wounded. That is too high a price to pay for fuel.

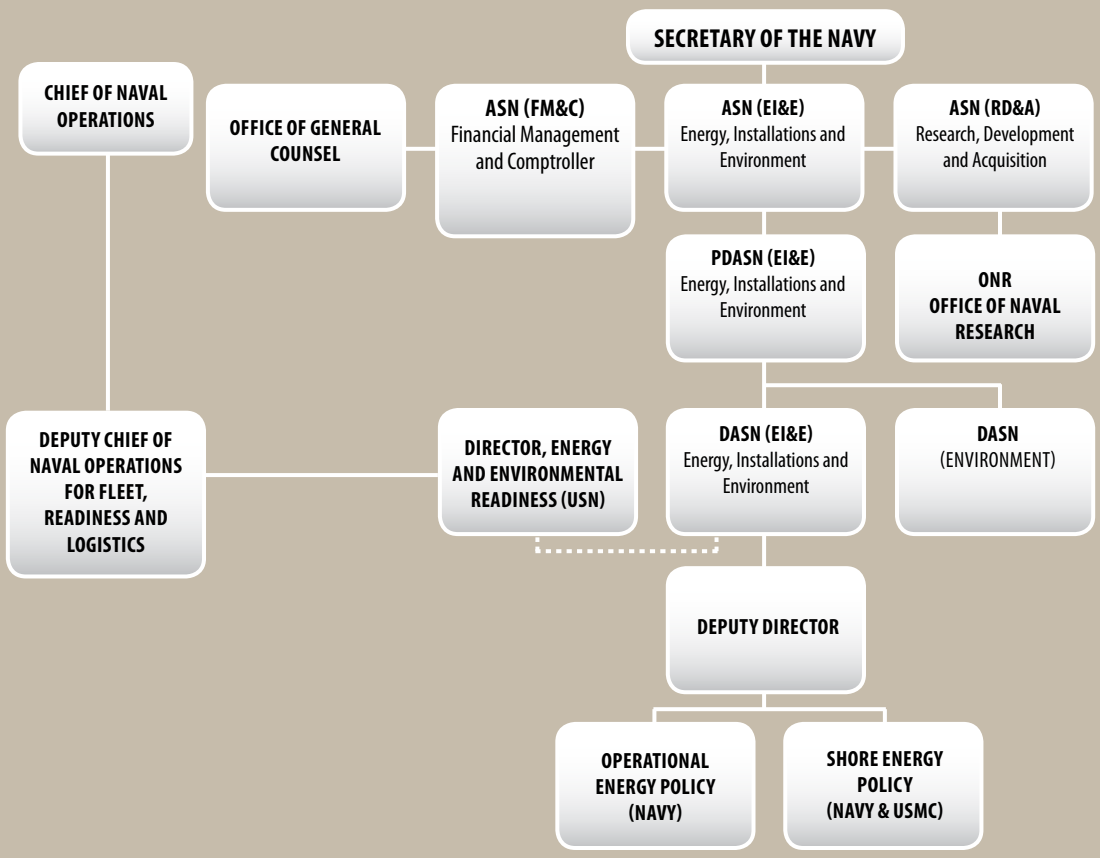
One of our most glaring vulnerabilities is how we get and how we use energy, and it's a vulnerability we have to address. Over the last two years, we've made a lot of progress. Over Labor Day weekend, the Navy's Blue Angels, for the first time ever, are going to fly on biofuels. By the end of the fall, we will have certified every single aircraft that the Navy and Marine Corps fly to run on biofuels.

On the ground, our Marines are using alternative energy devices in Afghanistan so they can do what they were sent there to do – fight, engage and rebuild. Not to guard fuel convoys or replenishment convoys. They're using portable solar panels to power their batteries or radios or GPSs. In the mid-90s, a Marine company carried 14 radios; today, that same Marine company carries more than 120. But by relying on these portable solar mats, the

Marines are saving almost 700 pounds of batteries per day that they don't have to carry.

By using alternative energy, by changing the way we use and produce energy, we're going to continue to be the most formidable expeditionary fighting force the world has ever known, and we're going to continue to do what the Navy and the Marine Corps have always done: innovate, adapt and come out on the other side victorious.

ENERGY ORGANIZATION CHART



Source: 2010 Navy Energy Vision for the 21st Century

ENERGY COMPLIANCE APPENDIX

REQUIREMENTS OF EO 13514 AND OTHER RECENT FEDERAL REQUIREMENTS RELATING TO SUSTAINABILITY

AREA	EO 13514	EO 13423	EISA	EPAct, Farm Bill
ENERGY USE	§2(a)(i): Reducing energy intensity in agency buildings should be considered. §2(g)(i): All new buildings entering planning in 2020 or later designed to achieve zero-net-energy use by 2030. §2(g)(ii),(iii): At least 15% of existing agency buildings (including leased) meet the Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings by FY15, as well as all new construction, major renovation and repair. Annual progress will be made towards 100% compliance for the building inventory. §2(g)(iv): Pursue cost-effective, innovative strategies, such as highly reflective and vegetated roofs, to minimize consumption of energy, water, and materials. §2(g)(v): Manage existing building systems to reduce consumption of energy, water, and materials, and identifying alternatives to renovation that reduce existing assets' deferred maintenance costs. §2(g)(vi): When adding assets to the agency's real property inventory, identifying opportunities to consolidate and dispose of existing assets, optimize the performance of the agency's real property portfolio, and reduce associated environmental impacts. §2(g)(vii): Ensuring that rehabilitation of federally owned historic buildings utilizes best practices and technologies in retrofitting to promote long-term viability.	§2(a) "improve energy efficiency and reduce greenhouse gas emissions of the agency, through reduction of energy intensity by (i) 3% annually through the end of fiscal year 2015, or (ii) 30% by the end of fiscal year 2015, relative to" FY03. §2(f): Ensure that (i) new construction and major renovation comply with the Guiding Principles, and (ii) 15% of the existing Federal capital asset building inventory of the agency as of the end of FY15 incorporates the sustainable practices in the Guiding Principles.	§431 (existing federal buildings): 3% reduction per year in fossil fuel use from 2008 through 2015, or 30% total by 2015, relative to FY03. §433 (new or majorly renovated buildings): fossil fuel use halved by 2030 relative to FY03, and sustainable design principles applied to their siting, design, and construction. DOE Secretary to establish a federal green certification program. In addition to water conservation required by this section, "water conservation technologies shall be applied to the extent that the technologies are life-cycle cost-effective". §434 (large capital energy investments such as HVAC): must employ "the most energy efficient designs, systems, equipment, and controls that are life-cycle cost effective". Natural gas and steam must be metered. §434 (leasing): as of 3 years after signing, all leases must be for Energy Star buildings.	EPAct §102: Agencies can keep savings from energy and water reductions. EPAct §103: Bldgs must be metered for electricity. EPAct §701: Vehicles with dual fuel capabilities shall be operated on alternative fuels.

AREA	EO 13514	EO 13423	EISA	EPAct, Farm Bill
RENEWABLE ENERGY	§2(a)(ii): Consider increasing agency use of renewable energy and implementing renewable energy generation projects on agency property. (Note, however, that U.S.C. 10 §2911(e) requires DoD to produce or procure not less than 25% of the total energy consumed within its facilities from renewable sources during FY 2025.)	§2(b): Ensure that (i) at least half of the statutorily required renewable energy consumed by the agency in a FY comes from new renewable sources, and (ii) to the extent feasible, implement renewable energy generation projects on agency property for agency use.	§523: If lifecycle cost-effective, as compared to other reasonably available technologies, not less than 30% of the hot water demand for each new Federal building or Federal building undergoing a major renovation be met through the installation and use of solar hot water heaters.	EPAct §203: Renewable energy ≥3% in FY07-09; 5% in FY10-12; 7.5% in FY13 and beyond (compared to total electricity consumption).
VEHICLE FLEETS	§2(a)(iii): (A) Use low greenhouse gas emitting vehicles including alternative fuel vehicles; (B) Optimize the number of vehicles in the agency fleet; (C): If the agency operates a fleet of at least 20 motor vehicles, reduce the agency fleet's total consumption of petroleum products by a minimum of 2% annually through the end of FY20 relative to FY05.	§2(g): (i) Reduce the "fleet's total consumption of petroleum products by 2% annually through the end of fiscal year 2015" relative to FY05 (if at least 20 motor vehicles); (ii) 10% increase in non-petroleum fuel annually relative to FY05; (iii) plug-in hybrids once economically viable.	§141: Purchase only low GHG-emitting vehicles. §142: 20% reduction in vehicle petroleum use, 10% increase in non-petroleum fuel use, annually by FY15 relative to FY05. §246: a renewable fuel pump for every fleet by 1/1/10. §526: alternative fuels cannot be used if lifecycle GHG emissions are greater than from petroleum sources.	
SCOPE 3 GHG EMISSIONS	§2(b): in setting the Scope 3 target, consider: (i) Supply Chain - opportunities with vendors and contractors to address and incorporate incentives to reduce GHG emissions. (ii) Employee Travel - implementing strategies for transit, travel, training, and conferencing that actively support lower-carbon commuting and travel by agency staff. (iii) GHG emission reductions associated with pursuing other relevant goals in this section. (iv) Developing and implementing innovative policies and practices to address scope 3 emissions unique to agency operations.			

END NOTES

1 Department of Defense. 2010. Strategic Sustainability Performance Plan. www.acq.osd.mil/ie/download/green_energy/dod_sustainability/DoD%20SSPP-PUBLIC-26Aug10.pdf.

2 Kenny, C. 2011. Foreign Policy: Let the Little Light Shine. www.npr.org/2011/07/12/137786684/foreign-policy-let-the-little-light-shine.

3 Department of Defense. 2010. Strategic Sustainability Performance Plan.

4 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency. p. 8. Pike Research.

5 This figure does not take into account the fully burdened cost of fuel, which includes logistics and assets required to deliver fuel in addition to the market price paid.

6 Lovins, A.B. 2010. DoD's Energy Challenge as Strategic Opportunity. *National Defense University Press.* (57): 37. www.ndu.edu/press/lib/images/jfq-57/lovins.pdf.

7 Burke, S. 2011. Fiscal Year 2012 Operational Energy Budget Certification Report. p. 24. Department of Defense. http://energy.defense.gov/FY12_Operational_Energy_Budget_Certification_Report_FINAL%208%20JUN.pdf.

8 Burke, S. 2011. Fiscal Year 2012 Operational Energy Budget Certification Report. p. 24. Department of Defense.

9 Cobb, J. 2011. Worldwide Military Spending for Renewable Energy to Multiply 15 Times by 2030. www.hybridcars.com/news/spending-military-renewable-energy-multiply-15-times-18-years-30205.html.

10 Department of the Navy. 2010. A Navy Energy Vision for the 21st Century. p. 8. http://greenfleet.dodlive.mil/files/2010/10/Navy-Energy-Vision-Oct-2010.pdf.

11 Burke, S. 2011. Fiscal Year 2012 Operational Energy Budget Certification Report. p. 17. Department of Defense. http://energy.defense.gov/FY12_Operational_Energy_Budget_Certification_Report_FINAL%208%20JUN.pdf.

12 U.S. Navy. 2009. Navy Stern Flap Installations Project to Save Millions in Fuel Costs. www.navy.mil/search/display.asp?story_id=44891.

13 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency. p. 2.

14 Conversation with Kate Brandt. Office of the Secretary of the Navy. September 9, 2011.

15 Yonkers, T. 2011. Leading by Example: How Energy Innovation is Strengthening America's Military. Briefing at Pew Charitable Trusts.

16 Lowe, S. 2010. Navy biofuels demonstration made possible by DLA support. Defense Logistics Agency News. www.dla.mil/dlapublic/dla_media_center/TopStories.aspx?ID=848.

17 Office of the Press Secretary. 2011. President Obama Announces Major Initiative to Spur Biofuels Industry and Enhance America's Energy Security. The White House. www.whitehouse.gov/the-press-office/2011/08/16/president-obama-announces-major-initiative-spur-biofuels-industry-and-en.

18 U.S. Navy. 2011. Navy, USDA, DOE Seek Input from Industry to Advance Biofuels for Military and Commercial Transportation. www.navy.mil/search/display.asp?story_id=62476.

19 Robyn D. 2011. DoD Installations, Energy, and the Environment: An Update. Department of Defense. Presentation at E2S2 Symposium. http://e2s2.ndia.org/speakers/Documents/Robyn.pdf.

20 Department of Defense. 2011. Annual Energy Management Report Fiscal Year 2010. www.acq.osd.mil/ie/energy/DoD_AEMR_FY2010__July_2011%5B1%5D%5B1%5D.pdf.

21 Andrews, A. 2009. Department of Defense Facilities Energy Conservation Policies and Spending. pp. 12-13. Congressional Research Service.

22 Department of Defense. 2011. Annual Energy Management Report Fiscal Year 2010. pp. 44-45. www.acq.osd.mil/ie/energy/DoD_AEMR_FY2010__July_2011%5B1%5D%5B1%5D.pdf.

23 Department of Defense. 2011. Annual Energy Management Report Fiscal Year 2010. p. 18.

24 Strategic Environmental Research and Development Program. 2011. White House Energy Security Blueprint References ESTCP. www.serdp.org/News-and-Events/In-the-Spotlight/White-House-Energy-Security-Blueprint-References-ESTCP.

25 Strategic Environmental Research and Development Program. 2011. White House Energy Security Blueprint References ESTCP.

26 U.S. Marine Corps. 2011. Experimental Forward Operating Base (Fact Sheet). http://marines.mil/community/Documents/ExFOB%20pdf.pdf.

27 U.S. Marine Corps. 2011. Experimental Forward Operating Base (Fact Sheet).

28 Hulme, G. V. 2011. Despite years of talk, utilities remain compromised, vulnerable. www.csoonline.com/article/684287/despite-years-of-talk-utilities-remain-compromised-vulnerable.

29 SBI Energy. 2011. Expanding Military Interest in Microgrid Technology Fuels $4 Billion Industry. www.sbireports.com/about/release.asp?id=1856.

30 SBI Energy. 2011. Expanding Military Interest in Microgrid Technology Fuels $4 Billion Industry.

31 Department of Defense. 2011. Annual Energy Management Report Fiscal Year 2010. p. 25. www.acq.osd.mil/ie/energy/DoD_AEMR_FY2010__July_2011%5B1%5D%5B1%5D.pdf.

32 University of Delaware. 2007. UD-led team sets solar cell record, joins DuPont on $100 million project. www.udel.edu/PR/UDaily/2008/jul/solar072307.html.

33 Government Accountability Office. 2010. Defense Infrastructure: Department of Defense's Renewable Energy Initiatives. p. 10. www.gao.gov/new.items/d10681r.pdf.

34 Defense Science Board Task Force. 2008. More Fight—Less Fuel. Office of the Under Secretary of Defense for Acquisition, Technology and Logistics. www.acq.osd.mil/dsb/reports/ADA477619.pdf.

35 U.S. Army. 2011. U.S. Army Energy Security and Sustainability: Vital to National Defense. www.ausa.org/publications/torchbearercampaign/tnsr/Documents/TB_Energy_web.pdf.

36 Erwin, S.I. 2011. Army, Marines Face Uphill Battle to Lighten Troops Battery Load. National Defense Magazine. www.nationaldefensemagazine.org/archive/2011/May/Pages/ArmyMarinesFaceUphillBattleToLightenTroops%E2%80%99BatteryLoad.aspx.

37 Defense Advanced Research Projects Agency. 2011. Defense Sciences Office – Robust Portable Power Sources. www.darpa.mil/Our_Work/DSO/Programs/Robust_Portable_Power.aspx.

38 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

39 Karbuz, S. 2010. DoD Energy Use in 2009. http://karbuz.blogspot.com/2010/07/dod-energy-use-in-2009.html.

40 Department of Defense. 2011. Energy For the Warfighter: Operational Energy Strategy. http://energy.defense.gov/OES_report_to_congress.pdf.

41 Deloitte. 2009. Energy Security: America's Best Defense. www.deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/Documents/AD/us_ad_EnergySecurity052010.pdf.

42 Burke, S. 2011. Leading by Example: How Energy Innovation is Strengthening America's Military. Briefing at Pew Charitable Trusts.

43 Petraeus, D.H. 2011. Supporting the Mission with Operational Energy. Memorandum for the Soldiers, Sailors, Airmen, Marines and Civilians of US Forces-Afghanistan. http://energy.defense.gov/OperationalEnergy-SpttoMission.pdf.

44 Conversation with Tarak Shah, Special Assistant to Sharon Burke, Office of Operational Energy, OSD. September 6, 2011.

45 Burke, S. 2011. Leading by Example: How Energy Innovation is Strengthening America's Military. Briefing at Pew Charitable Trusts.

46 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

47 Yonkers, T. 2011. Leading by Example: How Energy Innovation is Strengthening America's Military. Briefing at Pew Charitable Trusts.

48 Robyn, D. 2011. DoD Installations, Energy and the Environment: An Update. http://e2s2.ndia.org/speakers/Documents/Robyn.pdf.

49 Conversation with Tarak Shah, Special Assistant to Sharon Burke, Office of Operational Energy, OSD. September 6, 2011.

50 Department of Defense. 2010. Strategic Sustainability Performance Plan.

51 Kenny, C. 2011. Foreign Policy: Let the Little Light Shine. www.npr.org/2011/07/12/137786684/foreign-policy-let-the-little-light-shine.

52 Hammack, K. 2011. Leading by Example: How Energy Innovation is Strengthening America's Military. Briefing at Pew Charitable Trusts.

53 Mowery, D. 2009. Federal policy and the development of semiconductors, computer hardware, and computer software: A policy model for climate change *R&D? U.C. Berkeley Haas School of Business.*

54 Department of Defense. 2011. Energy For the Warfighter: Operational Energy Strategy. http://energy.defense.gov/OES_report_to_congress.pdf.

55 Department of Defense. 2010. Quadrennial Defense Review. www.defense.gov/qdr/qdr%20as%20of%2029jan10%201600.PDF.

56 Department of Defense and Department of Energy. 2010. Memorandum of Understanding Between U.S. Department of Energy and U.S. Department of Defense Concerning Cooperation in a Strategic Partnership to Enhance Energy Security. www.energy.gov/news/documents/Enhance-Energy-Security-MOU.pdf.

57 American Psychological Association. 2010. Advocating for Fiscal Year 2011 Psychological Research at DoD. www.apa.org/about/gr/science/spin/2010/03/psych-research.aspx.

58 Miles, D. 2011. Budget cuts demand more DOD buying power. U.S. Air Force. www.af.mil/news/story.asp?id=123252585.

59 Donna Miles, "Budget cuts demand more DOD buying power," AF.mil, April 20, 2011, http://www.af.mil/news/story.asp?id=123252585.

60 Department of Defense. 2010. Strategic Sustainability Performance Plan. www.acq.osd.mil/ie/download/green_energy/dod_sustainability/DoD%20SSPP-PUBLIC-26Aug10.pdf.

61 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

62 Karbuz, S. 2010. DoD Energy Use in 2009. http://karbuz.blogspot.com/2010/07/dod-energy-use-in-2009.html.

63 This figure does not take into account the fully burdened cost of fuel, which includes logistics and assets required to deliver fuel in addition to the market price paid.

64 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

65 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

66 Defense Science Board Task Force. 2008. More Fight—Less Fuel. Office of the Under Secretary of Defense for Acquisition, Technology and Logistics. www.acq.osd.mil/dsb/reports/ADA477619.pdf.

67 Defense Science Board Task Force. 2008. More Fight—Less Fuel. Office of the Under Secretary of Defense for Acquisition, Technology and Logistics.

68 Defense Science Board Task Force. 2008. More Fight—Less Fuel. Office of the Under Secretary of Defense for Acquisition, Technology and Logistics.

69 U.S. Energy Information Administration. 2011. Annual Energy Outlook 2011 with Projections to 2035. http://www.eia.gov/forecasts/aeo/pdf/0383%282011%29.pdf.

70 Department of Commerce. 2011. Reasons to Break America's Addiction to Foreign Oil: A Play in Three Cool Charts. Economics & Statistics Administration. www.esa.doc.gov/Blog/2011/05/18/three-more-reasons-if-we-needed-more-break-americas-addiction-foreign-oil.

71 U.S. Energy Information Administration. 2011. Annual Energy Outlook 2011 with Projections to 2035. http://www.eia.gov/forecasts/aeo/pdf/0383%282011%29.pdf.

72 110th Congress. 2007. Energy Independence and Security Act of 2007. www.govtrack.us/congress/billtext.xpd?bill=h110-6.

73 Cobb, J. 2011. Worldwide Military Spending for Renewable Energy to Multiply 15 Times by 2030. www.hybridcars.com/news/spending-military-renewable-energy-multiply-15-times-18-years-30205.html.

74 Lovins, A.B. 2010. DoD's Energy Challenge as Strategic Opportunity. National Defense University Press. (57): 37. www.ndu.edu/press/lib/images/jfq-57/lovins.pdf.

75 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

76 Burke, S. 2011. Fiscal Year 2012 Operational Energy Budget Certification Report. Department of Defense. http://energy.defense.gov/FY12_Operational_Energy_Budget_Certification_Report_FINAL%208%20JUN.pdf.

77 Burke, S. 2011. Fiscal Year 2012 Operational Energy Budget Certification Report. Department of Defense.

78 Burke, S. 2011. Fiscal Year 2012 Operational Energy Budget Certification Report. Department of Defense.

79 Defense Science Board Task Force. 2008. More Fight—Less Fuel. Office of the Under Secretary of Defense for Acquisition, Technology and Logistics. www.acq.osd.mil/dsb/reports/ADA477619.pdf.

80 Defense Science Board Task Force. 2008. More Fight—Less Fuel. Office of the Under Secretary of Defense for Acquisition, Technology and Logistics.

81 Burke, S. 2011. Fiscal Year 2012 Operational Energy Budget Certification Report. Department of Defense. http://energy.defense.gov/FY12_Operational_Energy_Budget_Certification_Report_FINAL%208%20JUN.pdf.

82 Burke, S. 2011. Fiscal Year 2012 Operational Energy Budget Certification Report. Department of Defense.

83 Burke, S. 2011. Fiscal Year 2012 Operational Energy Budget Certification Report. Department of Defense.

84 Burke, S. 2011. Fiscal Year 2012 Operational Energy Budget Certification Report. Department of Defense.

85 Conversation with Dr. David Gorsich. TARDEC. July 2011.

86 Conversation with Dr. David Gorsich, TARDEC, July 2011.

87 Burke, S. 2011. National Security and Fuels of the Future: The Importance of Sec. 526. *The White House Blog.* www.whitehouse.gov/blog/2011/07/15/national-security-and-fuels-future-importance-sec-526.

88 Department of the Navy. 2010. A Navy Energy Vision for the 21st Century. p. 8. http://greenfleet.dodlive.mil/files/2010/10/Navy-Energy-Vision-Oct-2010.pdf.

89 Burke, S. 2011. Fiscal Year 2012 Operational Energy Budget Certification Report. Department of Defense. http://energy.defense.gov/FY12_Operational_Energy_Budget_Certification_Report_FINAL%208%20JUN.pdf.

90 Burke, S. 2011. Fiscal Year 2012 Operational Energy Budget Certification Report. Department of Defense.

91 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

92 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

93 Jean, G. 2011. Navy Energy Officials Predict Biofuels Will Be Cost-Competitive by 2020. *National Defense Magazine.* www.nationaldefensemagazine.org/blog/Lists/Posts/Post.aspx?ID=372.

94 Tindal, C. 2010. Department of Navy's Biofuel Demand. Power point presentation. www.farmfoundation.org/news/articlefiles/1731-Tindal%20TO%20POST_v01_2010-11-15.pdf.

95 Air Transport Association. 2010. Airline Energy Q&A. www.airlines.org/Energy/Fuels101/Pages/AirlineEnergyQA.aspx.

96 LeCronier, M. 2011. Terrabon Inc. Awarded $9.6 Million by Logos Technologies to Produce 6,000 Liters of Renewable Jet Fuel for the Defense Advanced Research Projects Agency (DARPA). www.terrabon.com/terrabon_press_release_20110725.pdf.

97 Lowe, S. 2010. DLA supports Air Force goal of cleaner fuel, energy independence. *Defense Logistics Agency News.* www.dla.mil/DLAPublic/DLA_Media_Center/TopStories.aspx?ID=632.

98 Dowdell, R. 2011. Officials certify first aircraft for biofuel usage. *U.S. Air Force.* www.af.mil/news/story.asp?id=123242117.

99 Yonkers, T. 2011. Leading by Example: How Energy Innovation is Strengthening America's Military. Briefing at Pew Charitable Trusts.

100 Tindal, C. 2010. Department of Navy's Biofuel Demand. Power point presentation. www.farmfoundation.org/news/articlefiles/1731-Tindal%20TO%20POST_v01_2010-11-15.pdf.

101 Wright, L. 2010. Navy Tests Biofuel-Powered 'Green Hornet.' *U.S. Navy.* www.navy.mil/search/display.asp?story_id=52768.

102 Lowe, S. 2010. Navy biofuels demonstration made possible by DLA support. Defense Logistics Agency News. www.dla.mil/dlapublic/dla_media_center/TopStories.aspx?ID=848.

103 Tegler, E. 2010. Down River - The Navy's 'flex-fuel fleet' starts with RCB-X. *Defense Media Network*. www.defensemedianetwork.com/stories/down-river/.

104 Roughead, G. 2011. Testimony before the House Armed Services Committee on FY 2012 Department of Navy Posture. www.navy.mil/navydata/people/cno/Roughead/Testimony/CNO%20Roughead_Testimony_030111.pdf.

105 U.S. Navy. 2011. A U.S. Marine Corps MV-22 Osprey lifts off from Naval Air Station Patuxent River during a successful biofuel test flight. www.navy.mil/view_single.asp?id=105862.

106 U.S. Navy. 2011. First Navy Trainer Completes Biofuel Flight at Patuxent River. www.navy.mil/search/display.asp?story_id=62384.

107 Defense Logistics Agency. 2011. DLA Energy provides biofuel for Navy's Blue Angels. www.dla.mil/dla_media_center/Pages/newsarticle201109081200.aspx.

108 Tegler, E. 2010. Down River - The Navy's 'flex-fuel fleet' starts with RCB-X. Defense Media Network.

109 Office of the President. 2007. Executive Order 13423—Strengthening Federal Environmental, Energy, and Transportation Management. http://edocket.access.gpo.gov/2007/pdf/07-374.pdf.

110 U.S. Air Force. 2010. Air Force Infrastructure Energy Plan - 2010. www.dm.af.mil/shared/media/document/AFD-101202-064.pdf.

111 Department of Defense. 2010. Annual Energy Management Report Fiscal Year 2009. www.acq.osd.mil/ie/energy/library/aemr_fy_09_may_2010.pdf.

112 Department of Defense. 2010. Annual Energy Management Report Fiscal Year 2009.

113 U.S. Air Force. 2010. Air Force Acquisition & Technology Energy Plan - 2010. www.safie.hq.af.mil/shared/media/document/AFD-091208-028.pdf.

114 Korosec, K. 2011. The Year of the Biofuel IPO: The Good, Bad and Ugly. *BNET*. www.bnet.com/blog/clean-energy/the-year-of-the-biofuel-ipo-the-good-bad-and-ugly/5930.

115 Baldwin, C. and P. Henderson. 2011. Biofuel maker Solazyme shares rise in Nasdaq debut. Reuters. http://uk.reuters.com/article/2011/05/27/uk-solazyme-ipo-idUKTRE74Q70N20110527.

116 Office of the Press Secretary. 2011. President Obama Announces Major Initiative to Spur Biofuels Industry and Enhance America's Energy Security. The White House. www.whitehouse.gov/the-press-office/2011/08/16/president-obama-announces-major-initiative-spur-biofuels-industry-and-en.

117 U.S. Navy. 2011. Navy, USDA, DOE Seek Input from Industry to Advance Biofuels for Military and Commercial Transportation. www.navy.mil/search/display.asp?story_id=62476.

120 Downing, L. 2011. Airlines Win Approval to Use Plant-Based Biofuels on Commercial Flights. *Bloomberg*. www.bloomberg.com/news/2011-07-01/airlines-win-approval-to-use-plant-based-biofuels-on-commercial-flights.html.

121 Gonzalez, A. 2007. To go green in jet fuel, Boeing looks at algae. *Seattle Times.* http://seattletimes.nwsource.com/html/boeingaerospace/2003858756_boeingenergy30.html.

122 Downing, L. 2011. Airlines Win Approval to Use Plant-Based Biofuels on Commercial Flights. *Bloomberg*. www.bloomberg.com/news/2011-07-01/airlines-win-approval-to-use-plant-based-biofuels-on-commercial-flights.html.

123 Abbott, C. 2011. U.S. assists two crop-for-aviation-fuel projects. Reuters. www.reuters.com/article/2011/07/26/usa-biofuels-idUSN1E76P1C320110726.

124 Cauchi, S. 2011. Planes tap into flower power. *Sydney Morning Herald.* www.smh.com.au/environment/energy-smart/planes-tap-into-flower-power-20110709-1h7mv.html#ixzz1RIRvgco3.

125 Robyn D. 2011. DoD Installations, Energy, and the Environment: An Update. Department of Defense. Presentation at E2S2 Symposium. http://e2s2.ndia.org/speakers/Documents/Robyn.pdf.

124 Department of Defense. 2010. Annual Energy Management Report Fiscal Year 2009. www.acq.osd.mil/ie/energy/library/aemr_fy_09_may_2010.pdf.

125 Andrews, A. 2009. Department of Defense Facilities Energy Conservation Policies and Spending. pp. 12-13. *Congressional Research Service*.

126 Department of Defense. 2011. Annual Energy Management Report Fiscal Year 2010. pp. 44-45. www.acq.osd.mil/ie/energy/DoD_AEMR_FY2010__July_2011%5B1%5D%5B1%5D.pdf.

127 Department of Defense. 2011. Annual Energy Management Report Fiscal Year 2010. pp. 53-54. www.acq.osd.mil/ie/energy/DoD_AEMR_FY2010__July_2011%5B1%5D%5B1%5D.pdf.

128 Defense Science Board Task Force. 2008. More Fight—Less Fuel. Office of the Under Secretary of Defense for Acquisition, Technology and Logistics. www.acq.osd.mil/dsb/reports/ADA477619.pdf.

129 Hammack, K. 2011. Leading by Example: How Energy Innovation is Strengthening America's Military. Briefing at Pew Charitable Trusts.

130 Department of Defense. 2010. Quadrennial Defense Review. www.defense.gov/qdr/qdr%20as%20of%2029jan10%201600.PDF.

131 Department of Defense. 2011. Annual Energy Management Report Fiscal Year 2010. p. 18. www.acq.osd.mil/ie/energy/DoD_AEMR_FY2010__July_2011%5B1%5D%5B1%5D.pdf.

132 Strategic Environmental Research and Development Program. 2011. White House Energy Security Blueprint References ESTCP. www.serdp.org/News-and-Events/In-the-Spotlight/White-House-Energy-Security-Blueprint-References-ESTCP.

133 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

134 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

135 Conversation with Tarak Shah, Special Assistant to Sharon Burke, Office of Operational Energy, OSD. September 6, 2011.

136 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

137 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

138 U.S. Marine Corps. 2010. Solar powered Devil Dogs. Marine Corps Air Ground Combat Center Twentynine Palms. www.marines.mil/unit/29palms/Pages/SolarpoweredDevilDogs.aspx.

139 U.S. Marine Corps. 2010. Solar powered Devil Dogs. Marine Corps Air Ground Combat Center Twentynine Palms.

140 U.S. Marine Corps. 2010. Solar powered Devil Dogs. Marine Corps Air Ground Combat Center Twentynine Palms.

141 U.S. Marine Corps. 2011. Experimental Forward Operating Base (Fact Sheet). http://marines.mil/community/Documents/ExFOB%20pdf.pdf.

142 U.S. Marine Corps. 2011. Experimental Forward Operating Base (Fact Sheet).

143 Conversation with Bob Charette. Director of Expeditionary Energy, USMC. September 9, 2011.

144 Conversation with Bob Charette. Director of Expeditionary Energy, USMC. September 9, 2011.

145 Brown, R. *et al.* 2008. U.S. Building-Sector Energy Efficiency Potential. University of California Berkeley. http://enduse.lbl.gov/info/LBNL-1096E.pdf.

146 Hulme, G. V. 2011. Despite years of talk, utilities remain compromised, vulnerable. www.csoonline.com/article/684287/despite-years-of-talk-utilities-remain-compromised-vulnerable.

147 SBI Energy. 2011. Expanding Military Interest in Microgrid Technology Fuels $4 Billion Industry. www.sbireports.com/about/release.asp?id=1856.

148 SBI Energy. 2011. Expanding Military Interest in Microgrid Technology Fuels $4 Billion Industry.

149 Asmus, P. 2011. Which States Represent the Best Markets for Small Wind? *Pike Research Blog*. http://www.pikeresearch.com/blog/articles/which-states-represent-the-best-markets-for-small-wind.

150 Department of Defense. 2011. Annual Energy Management Report Fiscal Year 2010. p. 25. www.acq.osd.mil/ie/energy/DoD_AEMR_FY2010___July_2011[1][1].pdf.

151 University of Delaware. 2007. UD-led team sets solar cell record, joins DuPont on $100 million project. www.udel.edu/PR/UDaily/2008/jul/solar072307.html.

152 Government Accountability Office. 2010. Defense Infrastructure: Department of Defense's Renewable Energy Initiatives. p. 10. www.gao.gov/new.items/d10681r.pdf.

153 Department of Defense. 2011. Annual Energy Management Report Fiscal Year 2010. p. 28. www.acq.osd.mil/ie/energy/DoD_AEMR_FY2010___July_2011[1][1].pdf.

154 Department of Defense. 2011. Annual Energy Management Report Fiscal Year 2010. p. 31. www.acq.osd.mil/ie/energy/DoD_AEMR_FY2010___July_2011[1][1].pdf.

155 U.S. Navy. 2011. Navy Awards $500 Million Contract for Solar Energy. www.navy.mil/search/display.asp?story_id=62316.

156 U.S. Government Printing Office. 2006. 10 U.S.C.2922A – Contracts for Energy or Fuel for Military Applications. www.gpo.gov/fdsys/search/pagedetails.action?collectionCode=USCODE&searchPath=Title+10%2FSubtitle+B&granuleId=USCODE-2006-title10-subtitleA-partIV-chap173-subchapII-sec2922a&packageId=USCODE-2006-title10&oldPath=Title+10%2FSubtitle+A%2FPart+IV%2FChapter+173%2FSubchapter+II%2FSec.+2922a&fromPageDetails=true&collapse=true&bread=true.

157 Defense Science Board Task Force. 2008. More Fight—Less Fuel. Office of the Under Secretary of Defense for Acquisition, Technology and Logistics. www.acq.osd.mil/dsb/reports/ADA477619.pdf.

158 U.S. Army. 2011. U.S. Army Energy Security and Sustainability: Vital to National Defense. www.ausa.org/publications/torchbearercampaign/tnsr/Documents/TB_Energy_web.pdf.

161 Department of Defense. 2011. Energy For the Warfighter: Operational Energy Strategy. p. 4. http://energy.defense.gov/OES_report_to_congress.pdf.

162 Erwin, S.I. 2011. Army, Marines Face Uphill Battle to Lighten Troops Battery Load. *National Defense Magazine*. www.nationaldefensemagazine.org/archive/2011/May/Pages/ArmyMarinesFaceUphillBattleToLightenTroops%E2%80%99BatteryLoad.aspx.

163 Erwin, S.I. 2011. Army, Marines Face Uphill Battle to Lighten Troops Battery Load. *National Defense Magazine*.

164 Erwin, S.I. 2011. Army, Marines Face Uphill Battle to Lighten Troops Battery Load. *National Defense Magazine.*

165 Bathmann, D. 2010. Army deploys innovative battery-recharging kit. U.S. Army. www.army.mil/-news/2010/08/02/43176-army-deploys-innovative-battery-recharging-kit/.

166 Price, W. 2011. Renewable energy vital to Marines' success in Afghanistan, future. www.quantico.usmc.mil/Sentry/StoryView.aspx?SID=4874.

167 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

168 Department of Defense and Department of Energy. 2010. Memorandum of Understanding Between U.S. Department of Energy and U.S. Department of Defense Concerning Cooperation in a Strategic Partnership to Enhance Energy Security. www.energy.gov/news/documents/Enhance-Energy-Security-MOU.pdf.

169 Department of Energy. 2011. Energy and Defense Departments Announce New Steps to Enhance Cooperation on Clean Energy and Energy Security. www.energy.gov/news/10156.htm.

170 Department of Energy. 2011. Energy and Defense Departments Announce New Steps to Enhance Cooperation on Clean Energy and Energy Security.

171 Defense Advanced Research Projects Agency. 2011. Defense Sciences Office – Robust Portable Power Sources. www.darpa.mil/Our_Work/DSO/Programs/Robust_Portable_Power.aspx.

172 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

173 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

174 Soldiers Magazine. 2011. Army developing Soldier-wearable battery. http://usarmy.vo.llnwd.net/e1/soldiers/archives/pdfs/jan11all.pdf.

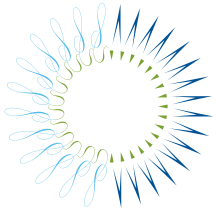
175 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

176 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

177 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

178 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.

179 Proebstel, D., and C. Wheelock. 2010. Renewable Energy for Military Applications: Solar, Wind, Biomass, Geothermal, Hydrokinetic Energy, Biofuels and Synfuels, Fuel Cells, Microgrids, Smart Meters, and Energy Efficiency.



THE
PEW
CHARITABLE TRUSTS

Philadelphia, Pa. 19103
Tel. 215-575-2000

Washington, D.C. 20004
Tel. 202-552-2000

www.PewTrusts.org/EnergySecurity