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Energy Security in the United States Department of Defense: How and why the U.S. Army and Navy are reducing their reliance on fossil fuels and the electrical grid, and what it could mean for the rest of us.

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Energy Security in the United States Department of Defense:

How and why the U.S. Army and Navy are reducing their reliance on fossil fuels and the electrical grid, and what it could mean for the rest of us.

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Abstract

Reliance on petroleum-based fuels produces a two-pronged security threat to modern societies. The first is a direct economic and geopolitical vulnerability, which is experienced on a national and international scale, as well as by the U.S. military specifically. The second is the impact that the greenhouse gases emitted by petroleum-based energy have on the planet's climate. Global climate change has and will continue to contribute to global instability by causing natural disasters, and food and water scarcity. The two issues are inextricably linked, and in fact share a common solution: a shift in the energy landscape towards more diversified and renewable sources. Focusing on the Army and Navy, this thesis will explore the ways in which the U.S. Department of Defense (DoD) is impacted by issues of energy security, as well as steps it has taken to address it. Finally, I will discuss the potential role DoD could play in transitioning the civilian energy sector towards a greener and more secure future.

1. Introduction

There is little doubt, scientifically speaking, that our over-consumption and reliance on carbon-based energy has dire consequences, both for ourselves and the planet. However, in the United States, discussions of climate change, energy consumption, and fossil fuels are polarizing, and often highly politicized. This makes it difficult to meaningfully address the problem through legislation, particularly when the conversation is framed in terms of the environment vs. the economy. However, there is one branch of the federal government that has taken significant steps towards reducing their energy consumption and reliance on petroleum, and that is the Department of Defense (DoD). They are able to do so by framing climate change and energy use as a national security threat, rather than by emphasizing environmental protection.

The national security threat is two-pronged. The most well known threat is climate change; the direct result of our energy habits, rather than our energy habits themselves. Burning fossil fuels releases greenhouse gases, most commonly carbon dioxide, which contributes to the warming of the planet and causes global climate change. According to the latest International Panel on Climate Change (IPCC) report, climate change has been observed to affect the availability and quality of water supplies, and negative impacts on food production are more common than positive impacts (IPCC, 2014). Essentially, food and water scarcities will become increasingly problematic. In addition, extreme weather events and sea level rise will cause massive population relocations and create refugees, particularly in already impoverished or unstable areas. For these reasons, the Department of Defense describes climate change as a "threat amplifier," and they expect destabilization driven by climate change to increase the mission burden of the U.S. Military (Military Advisory Board, 2007).

The second aspect of the security threat is the impact of global petroleum-based energy consumption itself, particularly oil. The ensuing economic and geopolitical vulnerability is experienced on a national and international scale, as well as by DoD specifically. Internationally, demand for oil is skyrocketing as developing nations become more industrialized. This is expected to lead to increased competition over resources, and ultimately escalating conflict. Because oil and gas are such vital resources, they are thought to be key factors in many areas of global conflict, for example Sudan, the Ukraine, and of course the Middle East (Sidahmed, 2013).

Oil and energy security are immensely important to the United States, and dictate much of America's foreign and defense policies. In 1980, President Carter responded to the Soviet Union's intervention in Afghanistan by declaring that due to the region's strategic importance-- specifically its vast oil resources-- "any attempt by an outside force to gain control of the Persian Gulf region will be regarded as an assault on the vital interests of the United States of America, and such an assault will be repelled by any means necessary, including military force." Since 1980, what became known as the Carter doctrine has been expanded on by his successors, and "ensur[ing] the free flow of oil, to the U.S. and to our allies," has been a defining factor in American overseas deployments, according to the Military Advisory Board (Military Advisory Board, 2009).

There is also an issue of the value that oil brings to certain nations; oil-producing regions have disproportionate geopolitical power, as oil is such a valuable resource. Some of the largest oil producers are considered to be hostile or unstable by the US military, including Iran and Russia. Therefore, from an American perspective, oil resources and the wealth that come from them may pose national security threats, even if the nation in question is not one of the main suppliers to the US. Iran, for example, had oil export revenues of $56 billion in FY 2013/2014 (although that number is down significantly from previous years due to sanctions from the US and EU) (EIA, 2014). Oil-producing nations can also be vulnerable to what is known as the dutch disease, which is when the economy of a nation endowed with vast natural resources is overly dependent on that resource, at the expense of other sectors. If this is the case, when something goes wrong or prices fall, their economy suffers disproportionately. In an era of increasing globalization, that can have a destabilizing effect that reaches much farther than the economy of the oil-producing nation (Military Advisory Board, 2009).

As the largest consumer of oil in the world,[1] the United States has a particular vested interest in global energy security (EIA, 2014). Domestic oil production is steadily increasing, but the United States is still a net importer-- in 2013, the U.S. imported 9.9 million barrels per day, 52% of its total oil consumption. That dependency makes the US particularly susceptible to price changes, which undermines national economic stability. According to the Military Advisory Board, it also “weakens international leverage, undermines foreign policy objectives, [and] entangles America with unstable or hostile regimes” (2009).

Reliance on oil and other fossil fuels poses a unique security problem for the US Department of Defense. One reason is economic; DoD is the largest single energy user in the country, and spent an intimidating $18.9 billion on energy in financial year 2013-- mostly consisting of oil or other petroleum derivatives (Department of Defense, 2014). Consequently, they experience a similar economic vulnerability as the US in general. When prices rise, they are forced to divert resources that would allegedly be spent protecting the nation and spend them on fuel instead, which can compromise strategic missions. Furthermore, oil being such a volatile

[1] The united states consumes 18,490 thousand barrels per day. China is next, with 10,303. The next is Japan at 4,531.

commodity makes it difficult for DoD to reliably budget their energy costs, creating an uncertainty that ultimately becomes a security risk.

There is also a security risk associated with the fuel logistics themselves, particularly for more remote outposts. For example, in 2012, Operation Enduring Freedom (OEF) in Afghanistan required nearly 13 million barrels of liquid fuels to supply vehicles, aircrafts, surveillance equipment, and the bases and outposts which were run almost entirely off diesel generators (Department of Defense, 2014). Resupply convoys transporting fuel to these stations encounter numerous logistical complications, including poorly maintained roads, bad weather, and potential attacks; fuel supply lines and convoys also make for vulnerable targets, particularly as enemies acquire higher precision technology (D. Duckworth, personal communication, December 5 2014). From FY 2003-2007 in Iraq and Afghanistan, more than 3,000 army personnel were wounded or killed on fuel and water resupply convoys (Army Environmental Policy Institute, 2009). To minimize risk, some fuel supply convoys are re-routed or even delivered by air, which is ten times as expensive as a traditional supply convoy (Mcnabb, 2011)

Not only is the Department of Defense dramatically affected by issues of energy security, they are also in a unique position to address them in a way that could impact the rest of the country. It would not be the first time DoD's research resulted in technological innovations that spread to the civilian sector. The most famous example is ARPANET, a packet switching network project funded by the Defense Advanced Research Projects Agency (DARPA) in 1969, also known as the earliest precursor to the internet. GPS is another technological innovation that was created and realized by the Department of Defense. In a more relevant example, the US Navy has a long history of leading the way in fuel technology; switching from sails, to coal, to oil, and now to nuclear, well before these propulsion methods were considered the norm.

When it comes to energy, the Department of Defense can play the role of technological innovator, early adopter, test-bed, and finally consumer. They are empowered to do so by their strong, politically palatable incentive for reducing their fossil fuel use, as well as by their budget. With an annual allotment of $643 billion-- 19% of the federal budget, and roughly 24 times that of the Department of Energy-- they have an unparalleled capacity to research and invest in technologies that might not be produced by the market left to its own devices, or by any other branch of government. Their investments are long term by nature, so they are able to make investments others might shy away from. Military planners routinely consider the 30-40 year life span of major weapon systems, as compared to a politician whose priority is seeing immediate electoral results. Furthermore, because their primary motivation is ensuring the security of the nation and not generating profit, they are able to make investments that the private sector would not.

Focusing on the Army and Navy, this thesis aims to explore some of those investments-- what technologies are these branches investing in, and why? I will also discuss the potential of select investments to be applied to the civilian energy and transportation sectors, focusing specifically on the Army's initiatives on microgrids and the Navy's research on alternative fuels. Section 1 provides a general overview of the Department's energy use, as well as specific information about energy security and existing policies. In Section 2, I will analyze the energy use of the Army, and their main sources of insecurity. I will then examine their work on microgrids, explaining the function microgrids serve in improving energy security before discussing their potential role in the civilian energy sector. Section 3 addresses energy security in the Navy, focusing specifically on their efforts to deploy alternative fuel blends. Section 4 will be the conclusion, in which I discuss lessons learned from DoD's energy security initiatives, as well as their social and political implications.

Ultimately, these problems-- climate change, global fossil fuel volatility, and military energy insecurity-- are interrelated, and they share a common solution: a shift away from fossil fuels, and an energy landscape that incorporates more diverse and renewable sources. This holds true whether your chief concern is for biodiversity or national security. Of course there is no one easy fix, and as an institution that has destroyed numerous ecosystems and emits more greenhouse gases than most small countries, the Department of Defense should not be held up as the paragon of environmental stewardship. Nonetheless, their research and technological innovation has the potential to influence America's energy industry in a way that could ultimately make our country safer and more sustainable.

2. Department of Defense Energy

2.1: Energy Consumption Overview

The United States Department of Defense is a colossal global force. It employs over 3 million people, approximately 450,000 of whom are overseas. The department's physical presence spans more than 5,000 locations, which added together would exceed 30 million acres--about the size of New York State (Department of Defense). Maintaining such a significant presence requires vehicles, bases, facilities, and an enormous fleet of ships and aircrafts, which require energy to function. As an example, one of the Navy's warships is the Arleigh-Burke class guided missile destroyer. Destroyers are fast and maneuverable warships, which are intended to escort and defend larger vessels. Depending on its speed and other factors, a single destroyer at sea can consume anywhere from 600-7,000 gallons of fuel per hour, equating to a weekly consumption between 100,000 and 1,000,000 gallons (Brown et al, 2007).[2] The Navy has 62 destroyers, and destroyers are but one of 51 different ships contained in their fleet. Consider that this is just one facet of the energy use of one branch, and one can begin to conceptualize the magnitude of American military energy consumption.

In total, the Department of Defense consumed 125 million barrels of oil equivalent in 2013, costing $18.9 billion (Department of Defense, 2014). That amount is typically broken down into two categories: facility energy (30% of consumption) and operational energy (70%). Facility energy refers to the energy consumed by fixed installations, which number over 500 worldwide, comprising nearly 300,000 buildings. Operational energy is defined by statute as "energy required for training, moving, and sustaining military forces and weapons platforms for military operations," and constitutes the significant majority of DoD energy consumption.

[2] For reference, the average U.S. citizen drives 13,476 miles per year. If the car gets 20 miles per gallon, that equates to an annual consumption of 673.8 gallons, and a weekly consumption of roughly **13 gallons**. (Federal Highway Administration, http://www.fhwa.dot.gov/ohim/onh00/bar8.htm)

In addition to facility vs. operational, energy use within DoD also varies by service branch. Due to the unique nature of each service branch, each has specific energy needs, as well as specific energy security vulnerabilities. The Air Force is the most energy intensive branch, accounting for 48 percent of total DoD energy consumption, and 51 percent of energy costs (U.S. Air Force, 2013). Most of that is spent on petroleum-based aviation fuel; aviation accounts for 81% of the Air Force's energy use, translating to roughly 2.5 billion gallons of fuel per year. The rest of their energy is consumed by facilities (16%) and tactical vehicles (3%).

Energy use in the Department of the Navy (DoN) is slightly more diversified, accounting for roughly one third of DoD's total energy consumption (Department of the Navy, 2010). While the majority of the DoN's energy comes from petroleum fuel (57%), they also use a significant amount of electricity and natural gas, as well as nuclear, which they have deployed to power select ships. Renewables account for a very small portion of their energy portfolio. Within the Navy, the bulk of petroleum fuel is used to power maritime and aviation fleets. The Marine Corps, by contrast, uses more energy for expeditionary purposes (i.e. ground forces). For both services, shore energy-- which is essentially the same as facility-- is very small; around 5-6%.

The Army consumes roughly 10% of total DoD energy, significantly less than the Navy/Marine Corps or Air Force (Kidd, 2013). In contrast to the other two branches, facility energy constitutes a much larger portion of the Army's consumption. Operational energy is consumed by bases, soldiers, and vehicles as opposed to ships or aircrafts. Consequently, they only account for 9% of DoD's total petroleum fuel consumption, and 40% of that goes to producing electricity.

In terms of cost, $18.9 billion is a relatively small portion of DoD's total budget-- around 3% in 2013. However, this number does not factor in the energy use of thousands of contractors that have been hired by the Department. Additionally, as it relates to security, the problem is not necessarily the total amount, but rather rising costs over the past decade and price volatility. The military's oil demand increased significantly as a result of operations in Iraq and Afghanistan, coinciding with an increase of $122 per barrel in the price of oil between 2003-2008. As a result, DoD's oil related expenditures rose by nearly 500% from 2000-2008 (Andrews, 2009). Furthermore, it is important to consider the situation in terms of opportunity cost. An increase in the price of oil by $10 per barrel increases military energy expenditures by $1.3 billion, which is equal to the entirety of the Marine Corps' 2015 proposed overseas contingency budget (Montgomery, 2007). Finally, because oil is such a volatile commodity, it creates a difficulty when planning budgets, and creates financial instability.

2.2: Energy Management & Policy

As one might imagine, managing such significant and varied energy use is extremely complicated. Consequently, there are multiple offices in charge of energy-related responsibilities, specified by the Department's 2014 Energy Policy. The Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (OUSD(AT&L)) establishes policies for logistics, maintenance, and sustainment support for all elements of the Department of Defense. This includes establishing DoD energy policy, and overseeing its implementation. There are then several offices that work under USD(AT&L) to provide guidance for the management of energy commodities, and the acquisition of the technologies that will improve energy use.

The Assistant Secretary of Defense for Operational Energy Plans & Programs (ASD(OEP&P)) serves as the principal advisory to the Secretary of Defense and USD(AT&L)

on matters of operational energy, and is responsible for oversight and guidance related to Operational Energy Strategy. Facility energy is managed by the Under Secretary of Defense for Installations & Environment (USD(I&E)). Both work with the Assistant Secretary of Defense for Research & Engineering to develop technologies that will improve energy performance and diversify their energy supply. Each service branch is then responsible for creating its own energy plan in accordance with the energy policy, as well as measuring and analyzing their own energy use and reporting back to the Office of the Secretary of Defense (OSD).

The impressive feat of procuring energy to supply the needs of each branch is the responsibility of DLA Energy. DLA Energy is a branch of the Defense Logistics Agency, which provides all branches of the military with nearly 100% of the consumable items they need to operate. That includes food, uniforms, medical supplies, and of course, fuel and energy. DLA Energy has 23 locations in North America, Europe, Africa, the Middle East, and Asia.

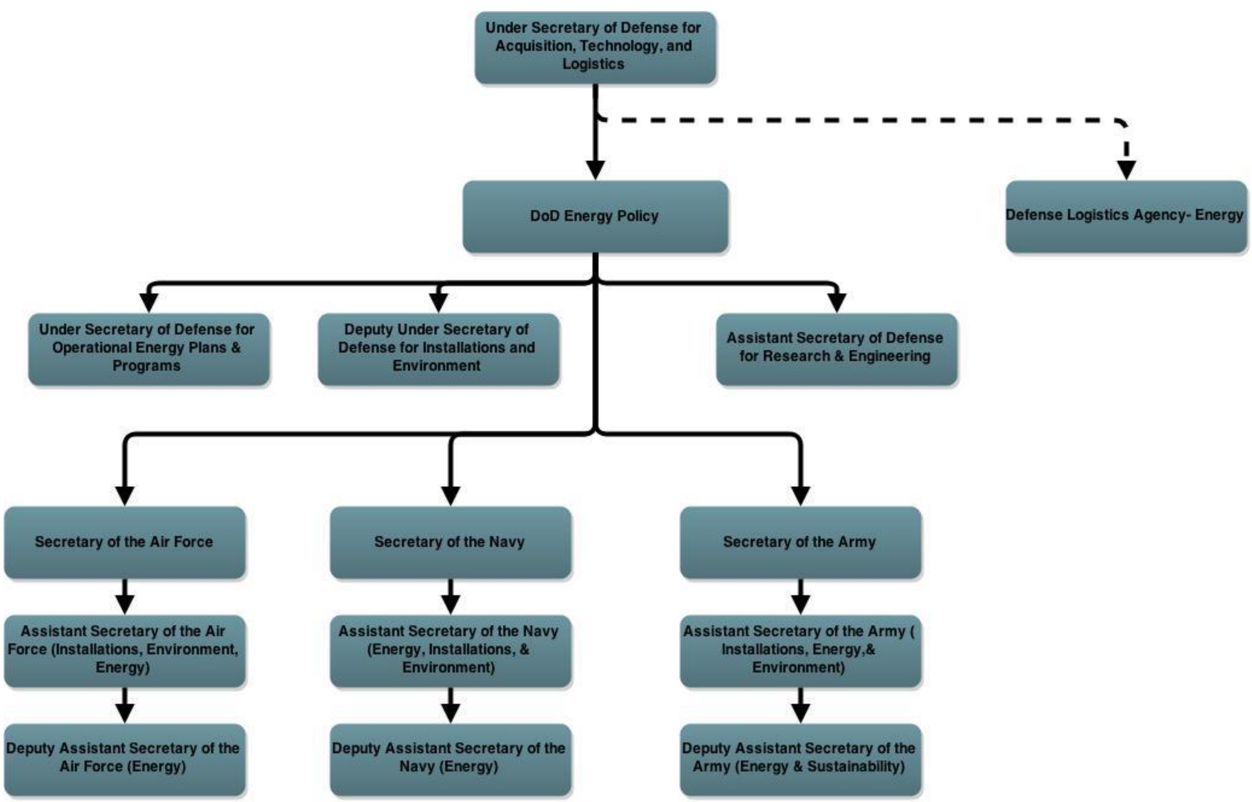

Figure 1: The governance structure is illustrated by the chart shown above. It should be noted that for the sake of readability, I have omitted several offices which deal more with logistics and procurement than energy policy and implementation, so it is somewhat simplified.

In addition to policy dictating energy management, there is also regulation that addresses concerns of energy security specifically. In response to growing awareness regarding the importance of energy security within the military, Congress and the Department of Defense have created numerous policies and initiatives to address the issue and improve energy management. In 2006, a new chapter on Energy Security was added to Title 10 of the U.S. Code, which governs the Armed Forces. Chapter 173: Energy Security requires the Secretary of Defense to submit annual energy performance goals and an energy performance plan to the congressional defense committees, focusing on cost-effectiveness and opportunities to reduce consumption, improve efficiency, and incorporate renewable sources.

Chapter 173 has since been amended and is now much more extensive. It includes specific guidelines and requirements regarding energy efficiency, energy conservation, different types of renewable energy, and cost-effectiveness. In addition to submitting energy performance goals, the Secretary of Defense is required to develop a comprehensive master plan for achieving them. The chapter also requires the Secretary of Defense to establish a training policy for Department of Defense energy managers, and encourages collaboration between the Departments of Defense and Energy. It has resulted in a number of important initiatives, including a partnership with National Renewable Energy Lab (NREL),[3] and the publication of an Annual Energy Management Report that details DoD energy use, and their progress on meeting their energy reduction goals.

[3] More information, please visit http://www.nrel.gov/defense/

2.3: Energy Security in the Department of Defense

In the most basic sense, energy security is defined by Chapter 173 as "having assured access to reliable supplies of energy and the ability to protect and deliver sufficient energy to meet mission essential requirements." This manifests itself in different ways, depending on the service branch in question, the location, and the particular mission. For operational energy, the primary security threats are the cost of the fuel itself, as well as the high cost and physical danger associated with transporting fuel to combat outposts. By contrast, facility energy insecurity largely stems from over-reliance on an unreliable electrical grid, in addition to fuel costs. The Defense Science Board (DSB) Task Force on Energy Security was the first to explicitly highlight these challenges in 2008, when it published "More Fight, Less Fuel," a report that has since served as the guiding document surrounding energy security.

2.3.1: Operational Energy Security

Operational energy entails powering ground troops, operational bases, tactical vehicles, and ship and aircraft fleets. As a result, it consists almost entirely of liquid fuel. For the Navy and Air Force, who consume vast quantities of fuel to power their fleets, the predominant security issues are the tactical disadvantage caused by the constant need to refuel, as well as the cost volatility concerns mentioned before. Particularly for deployments in the Army and Marine Corps, the transportation of fuel is another critical issue, both in terms of safety and cost. In "More Fight, Less Fuel," the Defense Science Board (DSB) estimated that the average cost of delivering fuel to an in-flight aircraft was roughly $42 per gallon, while delivering fuel to ground forces ranges from $15 to hundreds of dollars per gallon.

This figure is known as the Fully Burdened Cost of Energy (FBCE) or Fuel (FBCF), defined by the National Defense Authorization Act of 2009 as "the commodity price for fuel plus the total cost of all personnel and assets required to move and, when necessary, protect the fuel from the point at which the fuel is received from the commercial supplier to the point of use." The calculations are very complicated, but essentially, they take the cost at point of sale, and add the cost of transporting it to the destination. For accessible Forward Operating Bases (FOBs), this is fairly straightforward, as it is just the cost to truck the fuel. However, as destinations get more remote, there are added costs. Bases or combat outposts (COPs) in areas with difficult terrain may need to be transported via helicopter or airlift. In addition, security forces must be employed to protect against possible attacks. Ultimately, the FBCF is scenario specific, depending on where a user is located, and what modes of transport are required to supply that user. Below is a simplified example to illustrate the concept (Department of Defense):

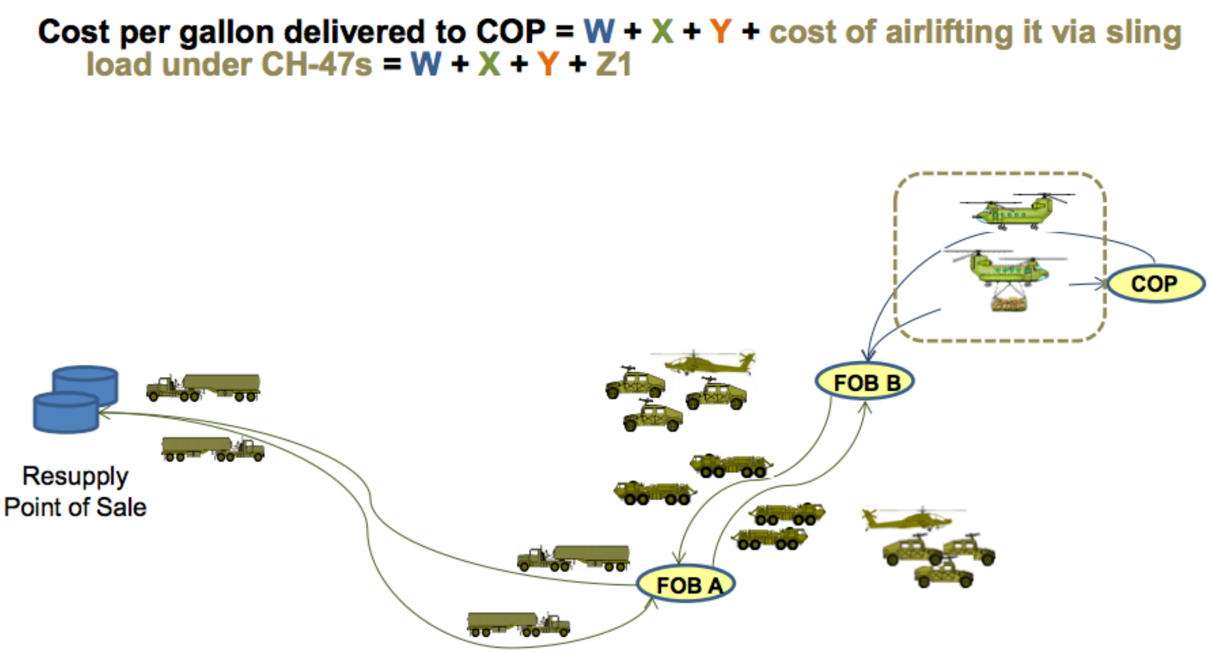

Figure 2: Diagram illustrating FBCF. W= price at point of sale, X= cost of trucking fuel to FOB A, Y= cost of transporting in HEMTTs to FOB B (tactical vehicles for terrain).

What becomes apparent is that the point-of-sale price, though influential, ultimately is not an informative indicator of fuel's true cost for remote bases and combat outposts. Therefore, even in light of the recent drop in oil prices, it is still important to invest in technologies that reduce military energy demand-- particularly in remote locations. For that reason, NDAA 2009 directed the Secretary of Defense to require life-cycle cost analyses for new capabilities to include the FBCF during the analysis and evaluation of alternatives.

The reason the FBCF can be so expensive is because fuel use and transportation are highly dangerous; fuel infrastructure and convoys make desirable and vulnerable targets for enemy forces. For example, in 2011 there were 34 attacks on fuel tankers in Pakistan, most of which were destined for NATO and US forces stationed in Afghanistan (SATP, 2015).[4] Many targeted one to three tankers and did not have casualties, but six resulted in the death of at least one person, and three resulted in the destruction of at least 15 tankers. In 2012, the Taliban planted a bomb which destroyed 22 fuel tankers carrying supplies from Uzbekistan to coalition forces in Northern Afghanistan. Consequently, military planning must provide security forces, as well as taking into account weather, terrain, and air MEDVAC support for each fuel convoy (Duckworth).

Fuel logistics also cause tactical constraints. Forces constantly have to alter their missions in order to accommodate their significant need for fuel, and have been doing so for decades. In World War II, for example, General Patton's Third Army was prevented from potentially taking Berlin due to a fuel shortage (Blumenson, 2009).[5] More recently, in 2003, highly mobile forces commanded by General James Mattis consistently outpaced their fuel supply in Baghdad, slowing down their operation. The experience prompted Mattis to demand that the DoD find a way to "unleash us from the tether of fuel" (Hudak, 2013).

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[4]Specific dates: Jan 7, Jan 14 (big one, 20 tankers), Jan 17, Jan 28, Jan 30, Feb 8, Feb 25 (15 tankers, 4 dead, 17 injured), Feb 28, March 16, April 16, April 21, April 29, May 3, May 31, June 13 (7 tankers), June 15, June 16, June 16, June 17, June 23 (two persons shot dead while carrying fuel for NATO forces), July 28, August 6 (16 tankers), August 15 (5), Sept 19, Sept 20, Oct 8, Oct 11, Oct 13, Oct 19, Nov 22,

[5] [5] Blumenson, Martin. *The Patton Papers: 1940-1945*. Da Capo Press, 2009.

The Operational Energy Strategy and Implementation Plan, which were released in 2011 and 2012, respectively, are DoD's response. The Strategy is based on a three-fold approach: 1. Reduce demand for military operations; 2. Expand and secure the supply of energy to military operations; and 3. Build energy security into future force by integrating fuel-related costs and risks into planning and force development. In addition to the energy security benefits of taking such action-- save lives now lost during fuel transport, strengthen Department's resilience to energy price and supply volatility, etc -- they also point to the positive effect it will have on contributing to national goals including cutting greenhouse gas emissions, and stimulating innovation in the civilian sector.

The first part of the strategy, reducing demand, is their main priority, and is widely considered to be the most effective way for the Department to reduce its vulnerability to the risk and cost associated with high energy dependence. The most basic impediment to reducing consumption is the lack of visibility and data on military energy consumption, because the Department needs information on how much energy is being consumed, and where, in order to improve efficiency. To that end, the first target outlined in the implementation plan is improving the measuring capability of the Department by establishing and improving energy consumption baselines. Additional targets include improving energy performance and efficiency and promoting operational energy innovation. They are also taking behavioral steps to reduce their energy consumption, such as changing flight lines to make them more efficient and reducing aircraft weight.

The second aspect of the strategy, expand and secure supply, is informed by the fact that most operations depend on a single source-- petroleum-- which has economic, strategic, and environmental drawbacks. The Assistant Secretary, along with many others, has therefore identified the need to diversify sources while improving infrastructure and protecting access to supplies. For alternative energy, there is an emphasis on energy that can be produced locally; for example, exploring solar potential in Northern Afghanistan, or waste to energy technology that can be installed on ships. Investment in research, development, testing & execution (RDT&E) must be economically and technically feasible, immediately compatible with current equipment and infrastructure, and able to support a global force. Furthermore, investments must take “upstream and downstream” effects into account; for example, using land to grow crops for biofuel may impact food prices, which would produce further destabilization. In addition, lifecycle greenhouse gas emissions must be equal or less than conventional sources.

Each branch of the military has a specific vision and plan to achieve the goals outlined in the Operational Energy Strategy, which are relayed in full in the appendix of this chapter. Ultimately, reducing operational energy demand presents a much tougher challenge than facility energy, because it is more difficult to procure liquid fuel from alternative sources than it is to produce alternative electricity.

2.3.2: Facility Energy Security

For facility energy, the main sources of insecurity are cost and reliance on the electrical grid. The solutions, at least in terms of fuel reliance, are more straightforward, as bases and other fixed installations present one of the most readily available opportunities to cut down on petroleum consumption. Currently, fuel is used on most bases to power electric generators for communications infrastructure, living quarters, administrative areas, and eating facilities. Given the technology we have available today, this is a much easier problem to address, as there are more alternative sources that generate electricity than there are alternative fuel sources for vehicles. It is also relatively easy to reduce electricity demand with energy efficient infrastructure, which many military installations have done: each service branch has reduced facility energy intensity by at least 17% relative to a 2001 baseline, and renewable energy as a percentage of total facility energy has increased by 11.8% in the Department overall (Department of Defense, 2014).

The security threat unique to facility energy, particularly on domestic installations, is reliance on a fragile and increasingly fallible national grid. Critical missions at DoD domestic installations have expanded in the past decade or so as a result of natural disaster relief efforts, as well as an increase in new homeland defense missions. Installations with substantial Command, Control, Communications, Intelligence, Surveillance, and Reconnaissance (C4ISR) responsibilities in particular have higher mission criticality, and must operate 24/7. Consequently, they have a greater requirement for a secure supply of power, as they directly support real-time operations and must be a dependable source of command and control. Unfortunately, most of these installations are wholly reliant on the national grid to meet their electricity needs, with an insufficient supply of backup generators and spare parts in the case of a grid failure. As the DSB noted, military installations are unequipped to handle an extended power outage.

As the “More Fight Less Fuel” report details, the grid is vulnerable in numerous ways that cause it to be an unacceptably high security risk. The first is a vulnerability from overload, which is becoming increasingly problematic as demand increases without a corresponding improvement in infrastructure. Overload causes wires to heat up and sag, and potentially become entangled with other objects such as trees. This is exactly what happened in 2003, when a high-voltage line came into contact with overgrown trees, creating a blackout that spanned 9,300 square miles in the Northeast U.S. and Canada. The incident shut down 500 generating units, including 22 nuclear plants, and caused 50 million people to lose power (U.S.-Canada Power System Outage Task Force, 2014). Without meaningful action on behalf of the government to address infrastructural issues, any installations connected to the grid are vulnerable to similar disruptions in the future.

The second vulnerability is from natural disasters such as hurricanes or tornadoes, many of which are expected to increase in frequency and intensity due to global climate change. Considering that such a colossal grid failure was caused by a single tree, there is great concern over the potential impact that a natural disaster would have on the system, as it would have the additional effect of physically damaging the infrastructure. That means that unlike the situation in Ohio, which was restored with relative ease, it could take much longer to get the system up and running.

A similar threat exists from the possibility of sabotage or a terrorist attack. As the DSB reported, "the grid is a relatively easy target... it is brittle, increasingly centralized, capacity-strained, and largely unprotected from physical attack, with little stockpiling of critical hardware." While a single point of failure could be restored with relative speed, it would take much longer for the grid to recover in the event of a multi-pronged attack or failure. Furthermore, if someone were to target a critical system component with a long-lead time, such as a breaker or high-voltage transformer, that grid section could be down for months. There are limited backups available, and many of them are located in the same place as the operating equipment, meaning that they could be destroyed in the same attack. If this were the case and the component had to be newly manufactured, it could be years before the section fully recovered. In addition to physical attacks, the control systems themselves are vulnerable to cyber-attacks, so the potential exists for major outages from that angle as well.

The final risk as reported by the DSB is interruption to the power supply, which could be caused by similar factors as the grid disruptions themselves-- infrastructure failure, natural events, or attack-- as well as market forces. Coal, which is responsible for roughly 40% of electrical generation in the US, is often transported along remote routes that lack alternatives (EIA, 2015). Therefore, damage to critical rail lines or bridges could delay coal from reaching generating plants for an extended period of time, causing a shortage of supply and an increase in prices. The vulnerability of the grid compounds the risk of a supply disruption, because an electricity failure could disable pipelines used by other forms of energy (Defense Science Board, 2008).

The DSB recommended several steps DoD should take in order to address grid insecurity issues, including demand- and supply-side solutions. In terms of demand side options, improving the efficiency of lighting and heating in military installations, as well as utilizing passive efficient-building designs, could significantly reduce the amount of energy necessary to sustain operations. This means that backup power supplies could last much longer in the event of a grid failure. On the supply side, building local power sources and making grids that are able to operate self-sufficiently can reduce vulnerability to grid problems that occur outside the installation in question. I will explore both of these options in greater detail in the following chapter, with special focus on the Army's efforts to deploy microgrid technology in select bases.

Appendix: Service Energy Visions

Army

"An effective and innovative Army energy posture, which enhances and ensures mission success and quality of life for our Soldiers, Civilians and their Families through Leadership, Partnership, and Ownership, and also serves as a model for the nation."

- Reduced energy consumption
- Increased energy efficiency across platforms and facilities
- Increased use of renewable/alternative energy
- Assured access to sufficient energy supplies\
- Reduced adverse impacts on the environment

Navy

"Our Energy Vision is a Navy that values energy as a strategic resource; a Navy that understands how energy security is fundamental to executing our mission afloat and ashore; and a Navy that is resilient to any potential energy future."

- Assure Mobility and Protect Critical Infrastructure
- Lighten the Load and Expand Tactical Reach
- Green the Footprint

Air Force

"Make Energy a Consideration In All We Do. Achieving the Air Force energy vision involves establishing a clear picture of how energy impacts the Air Force's critical capabilities: Global Vigilance, Global Reach, and Global Power. Energy must be recognized as the base ingredient for Air Force missions and operations. By considering energy in every mission and organization, the Air Force can leverage energy as a combat enabler and increase its energy security posture."

- Reduce Demand
- Increase Supply
- Culture Change

Marine Corps

"To be the premier self-sufficient expeditionary force, instilled with a warrior ethos that equates the efficient use of vital resources with increased combat effectiveness."

- Instill an Ethos
- Increase Energy Efficiency in USMC Equipment and Installations
- Increase Use of Renewable and Alternative Energy

3. United States Army

3.1 U.S. Army Energy Overview

The U.S. Army has 158 installations worldwide, encompassing more than 132 square miles of infrastructure, over one billion square feet of office space, and 15 million acres of land (ASA IE&E, 2011). As a result of its expansive installations, the Army consumes considerably more facility energy than the other branches, despite being the smallest overall user. Operationally, in addition to less publicized or humanitarian missions, they are involved in consistent conflict in the Middle East, where they operate out of large base camps and smaller combat outposts. Operational energy (OE) in the Army can be broken down into three categories: soldier, vehicles, and basing. Each energy category has its own specific energy security vulnerabilities, and the Army is taking steps to address each of them, which I will discuss in this chapter. In terms of facility energy, I will focus specifically on their work with net-zero installations and microgrids, as I believe these to have the greatest potential to be applied to the civilian energy sector.

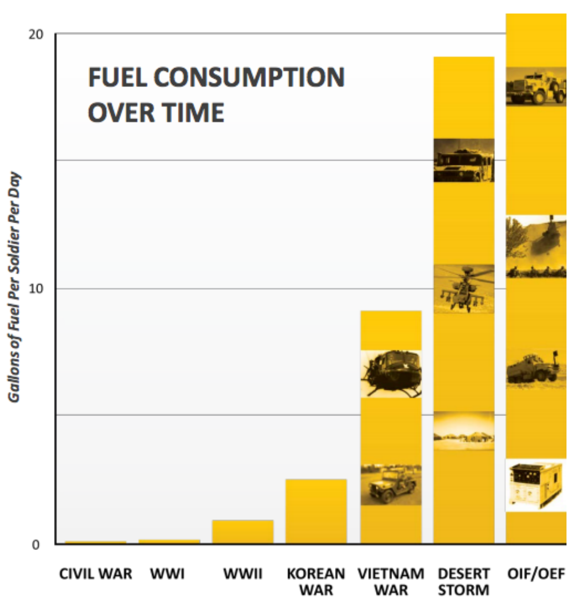

Figure 1: Army's fuel consumption over time, measured in gallons of fuel per soldier per day. "Desert Storm" refers to the Gulf War, and OIF/OEF stand for "Operation Iraqi Freedom" and "Operation Enduring Freedom," which refer to the wars in Iraq and Afghanistan, respectively.

Source: Kidd, Richard. "Army Energy and Sustainability Program."

The Army's fuel consumption has increased drastically since World War II, as demonstrated by the figure above, and now amounts to over 20 gallons of fuel per soldier per day on the battlefield. This is largely due to ever-advancing technology, as well as increased standards of living for deployed soldiers. However, the Army has successfully reduced total consumption by 16.2%, from 86.7 trillion BTU to 72.6 BTU. They have also reduced their total energy intensity (BTU per square foot) by 15.7% compared 2003 (Kidd). The reduction in energy intensity is particularly impressive, given that population on installations has increased by 20%.

Energy concerns first became a serious priority for the Army when operations were drawing down in Iraq (Rush, 2015). An audit was published in 2010 that uncovered significant inefficiencies in contingency base planning, which triggered concern regarding the Army's energy consumption (U.S. Army Audit Agency, 2010). Prior to this event, no one besides DLA devoted much thought to energy concerns; fuel would essentially appear when they needed it (Rush, 2015). As a result, the Army only recently began keeping measurements of its fuel and electricity consumption, so it is difficult to get an accurate idea of their operational energy usage (N.Cornell, personal communication, 2015). The lack of data also makes it harder to find effective solutions to improve security. They recently began a metering project, beginning with their largest buildings (>29k square ft). That phase is almost complete, but there is still a long ways to go. Most if not all Army vehicles lack fuel meters, which would be an effective way to make soldiers aware of their energy use as well as provide helpful data for decision-makers.

However, since the "More Fight, Less Fuel," report was published in 2008, the entirety of DoD has experienced a shift in the way they value energy, and the Army is no exception. "Developing effective energy solutions" is listed in the Secretary of the Army's top priorities for

FY 2014, along with preventing sexual assault, strengthening information assurance and cyber security, and bolstering activities in the Asia-Pacific region, among others.

3.2 Energy Management & Policy

By General Order 2012-01, the Assistant Secretary of the Army for Installations, Energy and the Environment (ASA(IE&E)) supervises policies, plans and programs for energy security and operational energy, as well as water security, contingency bases and environmental initiatives. Within the office of ASA(IE&E) there is an Assistant Secretary for Energy and Sustainability who is specifically responsible for energy-related matters. A Senior Energy and Security Council (SESC) was established in 2011 to "provide strategic direction to integrate energy and sustainability into Army plans, programs, policies and regulations to meet the Army's missions and objectives." Army G-4 handles logistics, and they have an operational energy team as well..

To make this litany of official titles more accessible, the way energy in the Army works is that on the top level, ASA(IE&E) develops strategy and policy, and G-4 figures out the logistics. There is also an Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASA(AT&L)), and their office handles specific numbers. Then there is the matter of the procurement and on-the-ground consumption and logistics. To use the Middle East as an example, CENTCOM[6] will request an amount of fuel, which is validated by G4. DLA-Energy is then in charge of procuring and delivering the fuel, which the Army (or the service branch in question) purchases from them. In Afghanistan, they used to bring fuel in through supply routes

[6] Taken from centcom.mil: U.S.Central Command (CENTCOM) is one of nine unified commands in the United States military. Six of these commands, including CENTCOM, have an area of responsibility (AOR), which is a specific geographic region of the world where the combatant commanders may plan and conduct operations as defined under the Unified Command Plan.

in Pakistan, until the routes were closed due to a border conflict in 2011. Subsequently, they had to use oil that is transported through Kazakhstan, which costs $6/gallon (Rush, 2015). In order to address the geographic variation in oil prices, DLA-Energy uses a Standard Price of Oil, which is currently $3.85 for a gallon of JP-8.[7]

3.3 Operational Energy Security

For contingency operations, the key to improving energy security is reducing the required amount of resupply convoys. 70-80% of resupply weight in the theater consists of fuel and water, and by reducing that, the Army can reduce logistical burdens, save lives, and expand capability. As mentioned in the introduction, resupply convoys are highly vulnerable to deliberate attack, and difficult terrain or extreme weather makes them all the more dangerous. In order to reduce the required amount of convoys, the Army is taking steps to incorporate more efficient and renewable technologies onto bases, make their tactical and non-tactical vehicles (TV, NTV) more efficient, and institute a behavioral shift at all levels to encourage personnel to use energy in a smarter way. They have also started to standardize batteries and deploy wearable power systems in order to reduce the burden on soldiers, who previously were carrying up to 15 lbs worth of batteries.

When discussing the Army's operational energy and developing effective solutions to improve security, it is important to consider it in the uncertain context in which decision-makers must operate. At the onset of a conflict, they do not know how long they will be in a given country, which presents a challenge in establishing contingency bases.[8] They are still assessing

[7] JP-8 is a petroleum-based jet fuel. It is the most commonly used jet fuel across all service branches.
[8] Under 10 United States Code 101[a](13), a contingency operation is a military operation that: a. is designated by the Secretary of Defense as an operation in which members of the Armed Forces are or may become involved in military actions, operations, or hostilities against an enemy of the United States

the mission, so it’s difficult to know how to design bases; they don’t know how many people will be staying there, or for how long. Therefore, they are largely unable to anticipate exactly what their energy needs will be, which is a problem when investing in energy security enhancing technologies. This is a serious issue, because their budget and expenditures rely on the approval of Congress. For example, they have developed a new engine for the Apache and Blackhawk helicopters that results in fuel savings of 18-25%. However, Congress wants to know how quickly they can expect a return on investment, and since they don’t know how many Apaches they’ll need to use in the future, it’s impossible for them to really say.

This leads to a question that frequently arises when discussing energy security, in the Army and elsewhere, which is how to measure the benefits of investing in energy security. In gallons of fuel saved? In dollars and return on investment, which is what Congress is often interested in? In lives saved? Or in indirect the operational benefits of energy security? For example, soldiers who used to be needed to protect fuel resupply convoys can now be put to a more effective use. In the context of a shrinking budget and (for now) a cheap price of oil, the importance of some of these can be difficult to convey to certain members of the House Armed Services Committee.

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or against an opposing force; or b. is created by definition of law. A contingency base is a base camp that supports such operations.

3.3.1 Basing Power

Bases today are much more energy-intensive than they were a few decades ago, which contributes to the drastic increase in consumption illustrated by Figure 1. They are more reliant on electronics and sophisticated machinery; for example, everyone carries their own radio, and every base has onboard radio, optical sites, and jammers. When Col. Rush fought in the Gulf War, soldiers lived in tents with a some lights, a few radios, vehicles, and that was about it. In contrast, deployed soldiers today are used to having all the comforts of home, so bases will have lighting, dining, laundry, heating, and heated showers, most of which are running off JP-8. Indeed, 40% of the Army's fuel goes to produce electricity, 30-60% of which could be saved by implementing existing technologies and know how according to ASA(IE&E) estimates (Kidd, 2013).

Traditionally, bases have used spot generation to produce electricity. That means that they have numerous 5-10 kW generators powering a few tents at 30-40% capacity, running 100% of the time. Because these generators are inefficient and running constantly, regardless of demand, this system wasted a lot of energy. Today, they have smart grids running on 60 kW Advanced Medium Mobile Power Source (AMMP) generators. The smart grids measure demand, so generators are only running if their power is actually necessary. This has drastically improved the efficiency of contingency bases, significantly reducing their fuel demand.

Where it is possible, the Army is also installing some solar, wind, and battery backups on bases to provide power and charge batteries. For example, Army recently launched the Kuwait Energy Efficiency Project (KEEP) at Camp Buehring, Kuwait. KEEP is essentially a demonstration of existing proven technologies and best practices that have been adopted order to improve energy efficiency and reduce fuel consumption. The Army has integrated insulating liners and shading systems to reduce cooling and heating requirements, and installed a 60 kW Tactical Quiet Generator microgrid that matches power production to system loads, as mentioned before. These improvements are estimated to reduce OE and fuel requirements by 30 percent, and they expect a return on investment in year one (G-4 Public Affairs, 2012).

They have also deployed microgrids in Monrovia (ebola-related missions) and on existing facilities in Iraq. I will explain microgrids in greater detail when I discuss facility energy, but essentially, they are smaller-scale grids that incorporate distributed generation--power that is generated at the point of consumption, rather than in a centralized power source. They are also capable of functioning without being connected to a larger grid. In this context, the Army's use of microgrids demonstrates the technology's potential to provide stable and often cleaner energy in remote locations, which would be particularly valuable in developing countries where some communities lack electricity.[9] Microgrids could allow communities to have more control over their own electricity, and promote electrification in areas that would otherwise be too expensive to connect to the national grid. For example, microgrids are considered to have the potential to positively impact the rural electrification process in India, where only 31% of rural households were estimated to have reliable electricity as of 2012 (Bhoyar & Bharaktar, 2012).[10]

[9] Select contingency bases are also employing extremely interesting technology related to water and waste management, which could also potentially be helpful for rural communities. For example, they have developed a shower water re-use system that removes bacteria from grey water, allowing them to use it again for non-drinking purposes and saving 75-80% of water.

[10] However, the Army is still reliant on regular fuel shipments, which might not be possible for rural villages. Solar, which does not require additional input and little O&M cost, would be better suited, but is intermittent on its own. Another thesis could be written on what energy sources would be the most feasible and appropriate for rural microgrids.

3.3.2 Vehicle Power

When I discuss vehicle power, I am including helicopters and other aerial vehicles, tanks and fighting vehicles, support vehicles, and non-tactical vehicles. Most of the Army's initiatives involving vehicle energy are focused on making them more efficient, either with improved engines or by lightweighting (to the extent that it is possible for something like a tank). For non-tactical vehicles, they have also introduced some low speed electric vehicles, as well as hybrid electric vehicles. The Army saw a 28.5% fuel use reduction in their non-tactical vehicle fleet since FY05, and in FY12 they reduced petroleum usage in non-tactical vehicle fleet by 20% over FY11 (Kidd, 2013).

In terms of tactical vehicles, the Apache engine discussed earlier is one example of an improved efficiency engine, in this case for aircrafts. Replacement engines for Apaches and Blackhawks were developed under the Improved Turbine Engine Program (ITEP), leading to a 35% reduction in production and maintenance costs, 65% increased horsepower to weight, and 20% longer engine life, in addition to the fuel savings mentioned at the beginning of the chapter (Kidd, 2013). The improved horsepower to weight ratio allows for a heavier payload; for example, the aircraft can carry more soldiers, or a heavier slingload on a resupply convoy. It also enables extended range during attacks, and the aircraft is able to loiter and stay on site longer during operations.

For ground vehicles, one tactical innovation is the Auxiliar Power unit, which fits into an M1 Abrams Main Battle Tank. With this technology, users don't have to turn on a turbine engine unless they are actually driving the vehicle, so it only consumes 13-18 gallons when idle. This is an efficiency gain of 83%, which is a significant improvement (Rush, 2015). Another OE improvement relating to vehicles is a recent ability to serve as charging stations. This enables soldiers to recharge batteries, and reduces reliance on mobile power generation.

The Army is also in the process of certifying their vehicles so they can operate on alternative fuel blends, but they are not nearly as proactive in this effort as the Navy, so I will leave that discussion for the next chapter.

3.3.3 Soldier Power

The Army's attention to the soldier experience sets the Army's OE vision apart from other service branches (besides perhaps the marines), who are mainly focusing on macro-level technology. When it comes to soldier power, efforts to improve energy security are focused on reducing the physical burden of individual soldiers more so than saving fuel, although the two may overlap. Currently, soldiers on a 3-day patrol can carry as many as 70 batteries, weighing up to 16 pounds (Hammack, 2012). This constitutes a mental as well as physical burden, as soldiers are required to remember what goes where and keep track of charge levels in various pieces of equipment.

One technological response is the Soldier Worn Integrated Power Enhanced System, or SWIPES. SWIPES is a tactical vest with a central power source, which has pockets that correspond to specific devices. The pockets contain an associated power cord that connects the device to a central power source, which simplifies the process of powering electronics. As a result, soldiers don't have to carry as many batteries, nor do they have to worry about how often to charge batteries, or which batteries go where. The central power source is a conforming battery, which is typically around 2 lbs. It is flatter, lighter, and more flexible than its predecessors, which were around 3 lbs and brick shaped. For a team leader, SWIPES reduces the energy-weight for a three-day patrol by 30%, from 14 to 9.8 lbs (Armed with Science, 2014). Another innovation is the Rucksack Enhanced Portable Power System, or REPPS. REPPS is 10 lbs, portable, and uses a flexible 62W anti-glint solar panel to charge most common military batteries in five to six hours. For devices with a higher power need, REPPS can be daisy-chained in order to provide more electricity.

.In addition to introducing new technologies, the Army has an emphasis on behavioral change, and shifting the way personnel at all levels think about energy. To that end, the Army launched “The Power is in Your Hands” in 2012, a campaign to make sure soldiers are well-informed about energy, and use it in a smarter way on the battlefield. The operational energy material they distribute to soldiers appeals to their personal relationship with energy, for example carrying heavy batteries, or participating in fuel resupply convoys. They stress the improved safety and operational capabilities as the main benefit of improved energy security, again appealing directly to the interest of the soldiers (or commanders) themselves. In a joint call to action, the Sergeant Major of the Army, Chief of Staff, and Secretary of the Army stated that “when soldiers start thinking: how can I use energy smarter?, we know we are on our way.”

As of now, proper valuation of energy across all levels is still a goal, and not a reality. However, the officials I spoke to are optimistic that it will be obtained. According to Col. Rush, when the soldiers know what the right thing to do is, they will do it; it’s primarily a matter of getting them to understand the importance of operational energy, since up to this point they’ve been used to having fuel appear whenever they need it.

3.4 Facility Energy Security

The energy security issues associated with most permanent or domestic installations are very different than those of contingency operations. While the main vulnerabilities for contingency bases stem from fuel resupply convoys and excessive weight, on fixed installations they are more related to reliance on the national grid infrastructure, and general cost of fuel. In the following section, I will discuss the Army's Net-Zero initiative, domestic microgrids, and how these relate to their efforts to install smart and green energy.

Net Zero Installations are, in my opinion, perhaps the Army's most impressive feat of sustainability. According to ASA-IE&E, a net-zero installation is one that "applies an integrated approach to management of energy, water, and waste to capture and commercialize the resource value and/or enhance the ecological productivity of land, water, and air." There are three net-zero categories: energy, water, and waste. The descriptions below are taken from the ASA IE&E website:

3. Energy: A net-zero energy site is an installation that produces as much energy on-site as it uses annually;
4. Water: An installation that limits the consumption of freshwater resources and returns water back to the same watershed, so as not to deplete the groundwater and surface water resources of that region in quantity or quality over the course of a year;
5. Waste: An installation that reduces, reuses, and recovers waste streams, and converts them to resource values with zero solid waste to landfills.

Clearly, these are all very impressive and important goals, however in the interest of coherence I will focus on energy.

The first step to accomplishing net-zero energy is reducing demand, which is accomplished in a number of ways. The first is through human action and conservation measures. Next, installations must perform an energy efficiency assessment and ensure that they are using the most efficient technologies where possible. Another method is re-purposing wasted energy; for example, using co-generation to recover heat from electricity generation processes. Boiler stack exhaust and other thermal streams can all be utilized for secondary purposes. When the demand load has been reduced, it becomes feasible for the remaining demand to be produced via onsite renewable energy projects.

Because net-zero is accounted for based on production and consumption over the year, the systems may be linked to the local grid in order to “bank” energy. For example, a solar installation may produce excess energy during the day, which is then fed back into the local grid. At night, when the solar system is no longer generating power, the installation pulls energy from the grid, effectively resulting in an even trade (Booth et al., 2010). In some cases, larger renewable production facilities may end up earning additional income for the base once they have paid off the initial investment.

The map below depicts existing net-zero pilot sites, which identify themselves for participation. While most focus on achieving net-zero in one or two areas, there are two installations that have committed to all three. As it relates to the civilian world, the net-zero

initiative shows the potential for modern settlements to minimize their impact on their surrounding environment, using technology to become genuinely sustainable. In terms of energy, they highlight the fact that if a community sufficiently reduces demand, it can be met using locally produced, mostly renewable sources. However, while net-zero projects generate substantial savings in the long run, the upfront cost for both energy efficiency technologies and renewable energy infrastructure are steep. Thus, it is difficult to say how feasible widespread adoption would be in the immediate future.

In addition to net-zero, the Army established a partnership with the Department of Energy (DOE) and Department of Homeland Security (DHS) in order to develop domestic microgrid technology. Microgrids are low voltage systems that incorporate distributed energy resources, for example solar panels or small-scale, onsite thermal generators, and storage devices. What sets microgrids apart is that they are capable of operating autonomously in “island mode," but are normally connected to the larger electrical grid. In most cases, microgrids operate as part of a smart grid, which is an electricity network that can intelligently integrate the actions of all users connected to it in order to more efficiently deliver electricity supplies.

The Army's microgrid program is a joint capabilities technology demonstration from FY 2011-2015 called SPIDERS: Smart Power Infrastructure Demonstration for Energy Reliability and Security. SPIDERS has resulted in the first DoD installation to completely integrate smart grid technologies, distributed and renewable generation, energy storage, cyber defenses w/ ability to operate in an "islanded" mode for extended periods of time. It was a response to the high risk that arises from reliance on an electric grid. Microgrids are an ideal solution to this problem, because the smart energy management system is able to identify which loads are the most critical to Army missions that are actively taking place. In the event of a larger grid failure, the microgrid is able to operate in island mode and ensure that those loads continue to receive power until the grid failure is repaired. The enhanced cyber security also offers an important advantage in today's context, where cyber security is of extreme concern.

The principle objectives of SPIDERS are as follows:

1. "Protect task critical assets from loss of power due to **cyber attack**
2. **Integrate renewables**, other distributed energy generation to power task critical assets in times of emergency
3. Sustain critical operations during prolonged power outages
4. Manage installation electrical power and consumption **efficiency**, to reduce petroleum demand, carbon "bootprint," cost

Phase I, in Pearl Harbor, HI and the Idaho National Lab, was successfully demonstrated in December 2012. This system integrated solar power and backup diesel generators with a smart energy management system, and implemented validated cyber security architecture. The results were a 39-fold increase in power reliability, 30.4% diesel fuel savings, and 90% renewable energy penetration (Waugaman). Phase 2 occurred at Fort Carson, CO, and utilized a multiple circuit, multi-critical load smart microgrid. It integrated PV with electric vehicle-to-energy storage, diesel generators, and energy management with cyber secure architecture protecting missions critical assets. Demonstrations were successfully completed in Fall 2013. Phase 3, Camp H.M. Smith in Hawaii, is the first complete DoD installation with a smart, islandable, cyber-secure microgrid. Phase 3 integrates cyber security architecture, advanced meters, demand-side management, islanding hard and software, renewable energy, energy management, and battery storage.

Due to their locality and ability to measure specific load requirements, micro- and smartgrids have a unique ability to facilitate access to distributed generation, especially based on renewable energy. Incorporating local microsource generation avoids the instability of relying on centralized power sources and grid control, and results in technical, economic, environmental, and social benefits, in both military and civilian energy sectors (Hatziargyrious, 2007). Microgrids present the best opportunity for excess energy generated by solar panels, for example, to be incorporated into the larger electricity system.

Because they readily enable the incorporation of renewable energy generation, both SPIDERS and the net-zero initiatives offer opportunities to help the Army reach its goal to deploy 1 GW of renewable energy projects by 2025. If applied to the civilian energy sector, these technologies could make in enormous impact in the feasibility of achieving higher renewable energy goals. Additionally, the successful demonstration of an electric vehicle-to-grid relationship at Fort Carson has positive implications for the civilian sector. As electric vehicles become more widely used, many believe they have the potential to add greater stability to the electrical grid. Vehicles could be charged either at night, when demand is lowest, or whenever renewable sources are producing excess amounts of energy. They could then serve as a mini power source during times of low production or high demand. Such is the hope of San Diego Gas & Electric, who recently proposed a ten-year pilot program (Wood, 2015).

4. United States Navy

4.1: Energy Overview

In the U.S. Navy, energy is categorized as either shore energy, which refers to permanent installations, or operational energy.[11] Shore energy, which for all intents and purposes is the same as facility energy, accounts for an extremely small portion of Navy energy use-- around 6%. The rest is operational. Whereas the Army's operational energy is consumed by bases, soldiers, and vehicles, the Navy's goes almost exclusively towards fueling their vast fleets of maritime ships (51%) and aircrafts (42%). Expeditionary energy, which would include bases, soldiers, and vehicles, is only 1% of their total consumption (Department of the Navy, 2010).

Many of the Army and Navy's OE efforts, such as behavioral change and improved energy efficiency, overlap. The two branches also share similar approaches to facility energy: reducing demand through conservation and efficiency measures, and utilizing renewable sources where possible to meet it.[12] In order to avoid repeating concepts from the previous chapter, I will not include such efforts in my analysis, but the reader should keep in mind that the Navy is equally active in these areas. What sets the Navy apart is its focus on alternative fuel options, which is what I will focus on in this chapter.[13]

[11] The U.S. Marines are also included under the Department of the Navy, but their energy security requirements are similar to those of the army, so I do not focus on them in this thesis.

[12] In 2013, the Navy produced or procured 26.6% of their total facility energy consumption quantity from renewable sources, surpassing the federally mandated goal of 25% by 2025. The 2013 Annual Energy Management report attributes this largely to their deployment of large-scale renewable projects.

[13] The Navy also has slightly different rhetoric regarding energy security, particularly as it relate to climate change. Because so many of the Navy's installations are located on coastlines, they are more vulnerable to sea level rise than other branches. Additionally, the Navy is highly aware of the strategic implications of a melting arctic ocean. While the Army does have rhetoric surrounding sustainability and minimizing the environmental impact of their installations, the Navy is more willing to acknowledge the link between operational energy use and climate change. This is an extremely interesting topic in and of itself, which I am regrettably unable to explore further. For anyone who is interested I recommend reading the Navy's Climate Change Roadmap as a start, as well as the DSB's report, "Trends and Implications

According to the officials I interviewed at the Pentagon, the Navy is considered to be the most proactive service branch in terms of energy. This is largely due to the fact that Ray Mabus, the current Secretary, made it a personal priority. Maybus was appointed as Secretary of the Navy by President Obama in 2009, and has continually stressed the importance of reducing fossil fuel reliance as a means of improving warfighting capacity. To achieve a Navy that is as energy secure as possible, Mabus has outlined six ambitious goals:

1. **Alternative Energy Afloat**: By 2020, half of the Navy's total energy consumption afloat will come from alternative sources.
2. **Great Green Fleet**: By 2016, the Navy will sail the Great Green Fleet, a carrier strike group composed of nuclear ships, hybrid electric ships running biofuel, and aircraft flying on biofuel
3. **Alternative energy ashore**: By 2020, half of the Navy's total energy consumption ashore will come from alternative sources; the Navy will make half its installations net-zero energy consumers, using solar, wind, ocean, and geothermal power generated on base
4. **Critical Infrastructure**: By 2020, all of the Navy's critical infrastructure will have reliable backup power systems and redundant power systems where viable
5. **Petroleum in Non-Tactical Vehicles**: By 2015, the Navy will cut in half the amount of petroleum used in its commercial vehicle fleet through phased adoption of hybrid, electric, and flex fuel vehicles.
6. **Efficiency and Conservation Afloat**: By 2020, the Navy will increase efficiency and reduce overall fuel consumption afloat by 15 percent

Mabus set these goals in October 2009, four months after being appointed. According to Chris Tindall, the Navy's Director for Operational Energy, the Navy is on track to meet them (Tindall, 2015). While all the goals are extremely laudable and important, I will focus on #1, Alternative energy afloat, and #2, Great green fleet. This is primarily because these are the most novel, and to focus on others might risk repeating many of the technologies described by the Army chapter. However, I encourage anyone who would like to learn more about the other goals to look at "A Navy Energy Vision for the 21st Century."[14]

In the remainder of this chapter, I will delve into what exactly is required to meet the Navy's alternative fuel goals, what the desired benefits are in terms of energy security, and what steps they are taking to get there. Finally, I will analyze broader efforts to incorporate biofuels into the civilian transportation industry, and how the Navy's work could impact it.

4.2: Alternative Fuels

In order to attain a fleet comprised of 50% alternative ships, including nuclear-powered vessels, the Navy would need 8 million barrels of alternative fuel, or 336 million gallons (Tindall, 2015). The Navy is taking several steps to make this happen. Immediately, they are working to certify all their ships to run on a 50/50 fuel blend of oil and biofuel, which requires a blend that can be used as substitute for JP-5 (aviation fuel) and F-76 (marine diesel), the Navy-specific jet fuels.

There are several key restrictions on their investments in research, development, testing and execution (RDT&E) as they relate to alternative fuels. First, they must be economically and technically feasible, and the alternative fuel must be cost-competitive with oil in order for them to use it. In addition, the new fuels must be 1. "drop in," meaning they are immediately compatible with current equipment and infrastructure; 2. able to support a global force; 3. take "upstream and downstream" effects into account, for example higher food prices as a result of growing crops for biofuel; and 4. Lifecycle GHG emissions must be equal to or less than

[14] Available at http://greenfleet.dodlive.mil/files/2010/10/Navy-Energy-Vision-Oct-2010.pdf

conventional sources. Furthermore, with biofuels as with all other energy investments, the energy impact is always secondary to capability. In other words, no service branch will make something more energy-effective if it means hindering its capacity in combat.

The Fischer-Tropsch conversion process is the Navy's most technically viable method of producing alternative fuels. It can use multiple sources, including coal, natural gas, or biomass, to produce fuels that are suitable substitutes for petroleum-based civilian and military fuels. That includes JP-8, the most common high-grade military fuel, as well as JP-5 and naval distillate. According to a 2011 RAND Corporation report on the subject, biomass and coal are both viable options for the military, as resources abound in the United States (Bartis & Van Bibber, 2011). However, because the military's alternative fuel efforts must be consistent with national climate change and GHG emissions goals, coal-based Fischer-Tropes fuel will not a plausible option unless carbon capture and sequestration technology becomes economically available. The Navy is also able to use Hydrotreated Esters and Fatty Acids (HEFA) as a drop-in fuel replacement, which are produced by processing vegetable oils or animal fats with hydrogen. Both advanced drop-in fuels have been found to function indistinguishably from conventional fuels, and the Navy will begin integrating them into the supply chain in mid-2015 (Tindall, US Department of Defense Alternative Fuels and Great Green Fleet 2016, 2015).

The performance of drop-in replacement biofuel blends were first successfully evaluated at a Great Green Fleet demonstration in Hawaii in 2012. The ships in this demonstration were running on 50-50 mixtures of biofuel from used cooking oil and algae, and standard JP-5 or F-76. In addition to alternative fuels, ships in the Great Green fleet include state-of-the-art energy efficiency technologies. To be included in the Great Green Fleet of 2016, maritime ships must contain three or more energy conservation measures, or use alternative energy for propulsion (for example alternative fuel or nuclear). Aircrafts must contain 2 or more energy conservation measures, or use alternative energy for propulsion (Tindall, U.S. Department of the Navy Advanced Biofuel Efforts, 2015).

The technical viability of alternative fuel blends has been clearly demonstrated in RDT&E. However, economic viability remains an issue. Indeed, the Great Green Fleet demonstration of 2012 was extremely expensive (alternative fuels for the demonstration cost $26 per gallon), and the Navy came under a good deal of scrutiny for it (Maclay, 2015). Republicans in Congress, for example, pointed out that the alternative fuels were nearly seven times more expensive than conventional sources, and some questioned whether Ray Mabus had provided congress with a full cost analysis (FoxNews.com, 2012). However, proponents of alternative fuel point out that while their expenditures on RDT&E may seem expensive, in reality they only amount to .03% of the total fuel budget (Tindall, Pentagon Interview, 2015). Nonetheless, the fact remains that the Navy is not allowed to widely adopt alternative fuels until they are cost competitive with their conventional counterparts.

In order to kickstart the industry, the Navy has issued a demand signal in order to increase the market's production of biofuels. In December 2013, the Navy and the Department of Agriculture (USDA) announced the"Farm to Fleet" program, a joint venture that seeks to incorporate biofuel bends into regular DoN fuel solicitations. In addition, DLA-Energy released a solicitation seeking biofuels on a large scale for operational use in June 2014 (Lowe, 2014). The idea is to drive up the market supply, which will cause the price of biofuels to decrease. Chris Tindall believes that the price will be cost-competitive before 2020.

Another issue with biofuels is that most of the Navy's fleets are non-domestic, and there isn't much point in certifying a ship in the Pacific to run off 50/50 blends if there are no 50/50 blends in the region. For that reason, DoN is attempting to persuade other navies to work towards adopting biofuels themselves. At this point, Australia has a testing and certification program, as does Italy, which opened a refinery last April. India, Singapore, and the Netherlands are also considering it (Tindall, Pentagon Interview, 2015). The fact that the U.S. Navy is doing it first is helpful, and DoN leadership expects more widespread production and adoption in the next few years.

The final controversy surrounding biofuels is whether they actually enhance military capability and operational energy security. Intuitively, it's an easy thing to question. Ships running off biofuels are still hindered by the need to refuel, so it wouldn't seem to solve that problem. However, the alternative fuel blends have a slightly higher energy content per gallon than petroleum-based jet fuel or marine diesel, and therefore allow ships to travel a greater distance before refueling (Department of Energy, 2014). Another problem is that even if the biofuels are produced domestically, they are subject to price volatility just as much if not more so than oil, because agricultural products are susceptible to natural factors such as drought (Strogen, 2015). Thus, at first glance, it wouldn't seem to provide a more stable alternative.

The response to this concern is that they are not trying to create a more stable single alternative; they are trying to increase the stability of the entire market. Expanding the market supply is intended to dampen the price volatility for crude oil in general. Additionally, having the capability to use alternative sources as drop-in fuels allows for greater flexibility in the Navy, because they are not entirely dependent on a single source. However, institutions such as the RAND corporation-- as well as many members of Congress-- still view the Navy's investment in biofuels as an inferior use of funding compared to improving energy efficiency, or investing in more combat-related technologies (Bartis & Van Bibber, 2011). Again, officials in the Navy are optimistic. The real incorporation of biofuels is expected to kick off in 2016, so until then one can only speculate.

If alternative fuels are successfully manufactured on a large enough scale, the security benefits of a more stable crude oil market would be realized globally, not just by the Navy. Furthermore, a viable alternative liquid fuel could have a significant impact on climate change mitigation, as the transportation sector accounts for 27% of U.S. greenhouse gas emissions. Virtually every good we consume requires liquid fuel in order to be shipped to its destination, not to mention modes of human transportation. Without a substitute for oil, those emissions will be very hard to reduce. The adoption of a less carbon-intensive fuel source for the airline or trucking industry, for example, would reduce global emissions in an extremely meaningful way. The Navy's marine diesel and aviation fuel are different than those used by these industries, but the fact that they have demonstrated the technical feasibility of creating biofuel blends that function indistinguishably from high quality jet fuel is still significant.

However, there are risks associated with biofuels. They are addressed in the Navy's policy, but must still be considered at all times, particularly if biofuels are to be adopted by commercial industries. First, in order to truly have a positive impact, biofuels must be produced in a way that ensures their lifetime emissions will be less than those of conventional sources. Land use is another factor-- as climate change is already expected to disrupt food supply chains, it is important to question whether land being used to produce biofuel is displacing crops that might otherwise supply food. Food crop concerns aside, it is still unclear whether the U.S. could even grow enough biofuel crops to support a large-scale adoption by commercial industries. Finally, the cost and economic viability are still uncertain, despite the Navy's optimism. There is still a good deal of criticism that it would be an inefficient allocation of resources, and that the

Navy would be better off investing in more energy efficiency technologies. It's possible that the commercial sector, too, would reduce short-term emissions more effectively by decreasing their consumption, rather than using biofuel.[15]

[15] Unfortunately, more in-depth research into the commercial viability of biofuels is beyond the scope of this thesis, so for now we will just have to wait and see.

5. Conclusion: Social and Political Implications

The technological implications of DoD's energy security initiatives are relatively straightforward. Generally, both the Army and Navy demonstrate an effective method of significantly decreasing fuel use: reducing demand through conservation and efficiency measures, and producing renewable energy to meet remaining demand where possible. In the right circumstances, these practices can create a wholly sustainable energy system, as the net-zero initiative highlights. This basic lesson can be applied in countless situations; the technology is readily available, if expensive, and most states have incentive policies to encourage energy-saving and renewable energy practices.

In terms of more specific technology, Microgrids can be used by communities to localize control, improve stability and efficiency, and incorporate more renewable energy sources. As the Army's deployment of microgrids in remote bases suggests, they could be particularly valuable in rural areas that have historically been difficult to electrify. Biofuels, while more controversial, could be adopted by civilian transportation industries to significantly lower global greenhouse gas emissions, in addition to stabilizing the crude oil market. There are already programs in place to accelerate the development of both technologies in the civilian sphere.[16]However, the story does not stop at the technologies themselves. There are social and political implications, as well as additional lessons to be learned from the military's situation.

For example, one of the most interesting aspects of the military's efforts to improve energy security is their focus on a behavioral shift. What would it take to instill a culture of energy-awareness in broader society, as the military is attempting to do within their ranks? Would it be a widespread, grass-roots education-based effort? Could it be legislated? Or might it

[16] See the Department of Energy's Renewable and Distributed Systems Integration (RDSI) program for microgrids, or the Commercial Aviation Alternative Fuels Initiative (CAAFI) for biofuels

stem from large companies in the private sector changing their behavior in a way that could ultimately influence others? Perhaps some combination? I discussed this question with multiple interviewees at the Pentagon and Department of Energy, and received varying responses.

One lesson learned from the military's example is that visibility and measurements are fundamental to the possibility for a behavioral energy change; installing meters and keeping data was frequently mentioned as a prerequisite for smarter energy use. Thus, making it easier for people to actually see how much energy they use and waste could be a first step. Installing SmartMeters in homes is one example of this. Perhaps there could be a mobile phone app that informs users when they are using or wasting an excess amount of energy.[17]

Another fascinating question is that of motivation. The Military is attempting to accomplish shifts in behavior by emphasizing the fact that smarter energy use leads to increased military capability. Is there any equivalent incentive for civilian society? This is a difficult question. The consequences of catastrophic drought, natural disasters, food shortages, and sea level rise as a result of climate change seem too distant, or are flat out rejected by many Americans. Energy security, social pressure, and a desire to care for the environment may motivate some people to be mindful of their energy use, but in reality economics and higher pricing are likely the only factors that will make people change their consumption behavior. Thus, changing the way we socially value energy may ultimately entail changing the way we value it economically.

In applying lessons learned from DoD's energy security efforts to the rest of the country, it is also important to keep to the Department's structure in mind. DoD is an immensely hierarchical institution, which enables Ray Mabus (for example) to state ambitious energy goals,

[17] A similar idea recently won a contest in Boston on ideas to make people care about energy and water waste. The winners designed this app, but with water use.

and other people have to make it a reality. For the general public, this is not the case. However, DoD is also very bureaucratic, and beholden to Congress, and that inevitably slows things down. Therefore, a slightly more optimistic comparison, rather than to the general public, is to the private sector. For example, Walmart decided that they were going to work towards 100% renewable energy. They are currently 32% of the way to accomplishing production or procurement of 7,000 GWh of renewable energy globally by December 31st, 2020 (WalMart).

From a Science and Technology Studies perspective, the top-down and of course militaristic nature of the Department of Defense also carries social and political implications. Many people, President Evo Morales, Naomi Klein, and individuals who ascribe to ecosocialism, believe that climate change is caused by our heavily consumptionist, capitalist society. Thus, the solution lies not in a technological fix, but by changing our entire system and way of life. Many ecosocialists view climate change as an opportunity to strive towards a more egalitarian society. In direct contrast, the Department of Defense's approach to energy security, and consequently any response to climate change based off DoD, represents model in which the aim is to innovate new technologies that allow for the maintenance, or even strenghtening of, the status quo. Thus, while the two may seem like they desire the same goal (avoiding a future where the Earth is uninhabitable to human beings), the means of achieving it differ drastically.

Biofuels may be an example where the two might clash. Biofuels represent a technology that allows for the business-as-usual transportation of goods and people to continue uninterrupted, while ecosocialists might advocate instead for more locally procured goods and slower travel. Additionally, large-scale biofuels would likely result in further monocropping and industrial agriculture at the expense of food. However, in the case of microgrids, the two may find common ground, as microgrids enable enhanced local control, and are thus an inherently democratic and community-based technology.

Whether one is a military general or an ecosocialist, the reality is that our society's colossal consumption of fossil fuels has dire consequences. The Department of Defense represents an organization that has acknowledged this reality and is working to address it. Select resulting technologies have the potential to meaningfully reduce greenhouse gas emissions, stabilize volatile markets, and improve energy security (or provide energy, period, in the case of microgrids) for communities of all sizes—from rural villages to nations.Whether, and how, these technologies will be adopted is the question.

List of Acronyms

AMMP: Advanced Medium Mobile Power Source
ASA(AT&L): Assistant Secretary of the Army for Acquisition, Logistics and Technology
ASA(IE&E): Assistant Secretary of the Army for Installations, Energy, and the Environment
ASD(OEP&P): Assistant Secretary of Defense for Operational Energy Plans & Programs
BTU: British Thermal Units
COP: Combat Outposts
C4ISR: Command, Control, Communications, Intelligence, Surveillance, and Reconnaissance
CENTCOM: U.S. Central Command
DARPA: Defense Advanced Research Projects Agency
DHS: Department of Homeland Security
DLA: Defense Logistics Agency
DoD: Department of Defense
DOE: Department of Energy
DoN: Department of the Navy
DSB: Defense Science Board
FBCF: Fully Burdened Cost of Fuel
FOB: Forward Operating Bases
FY: Financial Year
KEEP: Kuwait Energy Efficiency Project
HEMTT: Heavy Expanded Mobility Tactical Truck
IPCC: International Panel on Climate Change
ITEP: Improved Turbine Engine Program
MEDVAC: Medical Evacuation
NDAA: National Defense Authorization Act
NTV: Non-tactical Vehicle
NREL: National Renewable Energy Lab
OE: Operational Energy
OEF: Operation Enduring Freedom
OSD: Office of the Secretary of Defense
OUSD(AT&L): Office of the Undersecretary for Acquisition, Technology & Logistics
PV: Photovoltaic
RDT&E: Research, Development, Technology & Execution
REPPS: Rucksack Enhanced Portable Power System
SECNAV: Secretary of the Navy
SESC: Senior Energy and Security Council
SOF: Special Operations Forces
SPIDERS: Smart Power Infrastructure Demonstration for Energy Reliability and Security
SWIPES: Soldier Worn Integrated Power Enhanced System
TV: Tactical Vehicle
USD(I&E): Under Secretary of Defense for Installations and Environment

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