Department of Defense energy policy and research: A framework to support strategy⁺

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Abstract

The Department of Defense (DOD) is the major consumer of energy within the Federal government, and it has been directed to implement cost cutting measures related to energy dependence through numerous Executive Orders and Congressional legislation. As a result, the DOD released an Energy Strategy which outlines ways to reduce energy requirements in order to meet both Presidential and Congressional mandates for energy security. With this research, we provide a historical review (1973-2014) of energy policy, legislation, and research. Additionally we identify gaps between strategy and research. The results show that DOD energy research lacks a unifying structure and guiding framework. We propose a knowledge management framework to unify and guide research efforts in direct support of the DOD Energy Strategy.

Keywords: Energy strategy; knowledge management; energy security; department of defense; military operations management

1. Introduction

“Energy security for the Department [of Defense] means having assured access to reliable supplies of energy and the ability to protect and deliver sufficient energy to meet operational needs.”

—2010 Quadrennial Defense Review

1.1 Background

The United States Department of Defense (DOD) is the single largest consumer of energy in the country (Gauntlett & Adamson, 2012). This energy is consumed in the form of petroleum products, electricity, and in other forms (Energy Information Administration, 2015a). This consumption coupled with the price volatility and supply vulnerability creates budgetary and security risks for the DOD and the United States. This risk has been addressed through policy throughout the modern era, particularly since the oil embargo and price shock of the early 1970s. US energy policy has repeatedly attempted to address this risk for the past four decades. In the most recent decade, policy has aggressively addressed the risk to the DOD by focusing attention on energy strategy (Department of Defense, 2011a).

The United States and the DOD is reliant upon many sources for its supply of fuel and energy (Energy Information Administration, 2014). These sources vary from domestic producers and refiners to imported sources and alternatives as shown in table 1.4b of the December 2015 Monthly Energy Review (Energy Information Administration, 2015a). The continued dependence of the United States on imported oil and the importance of reducing this dependence is quantified in economic and national security terms (Brown & Huntington, 2015; Geller et al., 1994; Greene, 2010). The cost of the US presence in the Persian Gulf has been evaluated in terms of a national security objective as well as having been linked directly to the oil consumption of the US transportation sector (Delucchi & Murphy, 2008; Stern, 2010). Amidst the growing world demand, price volatility, and supply uncertainty, a new age of increased energy awareness in DOD policy has emerged.

Although the energy policy focus has led to a formal DOD energy strategy within the past 5 years (Department of Defense, 2011a), this strategy is in its infancy, and the means to support this strategy are not fully developed. As the DOD and each of its military services strives to make progress toward energy security, the efforts they expend are largely independent and uncoordinated, resulting in a less than optimal use of resources.

Research addresses how the DOD and the US should deal with specific aspects of fulfilling its energy security goals from different perspectives. Demand reduction is presented as a challenge-ridden objective for the DOD where a gap in policy and implementation is highlighted (Closson, 2013), and studies suggest the need for unification in efficiency efforts by the DOD (Simon, Regnier, & Whitney, 2014; Umstattd, 2009). Although there are suggested maxims to guide research (Sovacool & Brown, 2015) and the notion that DOD efforts need more coordination in this area (Closson, 2013; Simon, Regnier, & Whitney, 2014), there is no big picture in terms of what research has been done, how this research supports the DOD energy strategy, or how future research should be structured and prioritized.

In its infancy, the landscape of DOD energy awareness needs a focus and a unifying structure to assure its scarce human capital and monetary resources are used in the most effective way possible.

In this paper, we provide a first look at what DOD energy research has been done within military schools, paint a picture of common issues being addressed, and provide a state of the art in terms of issues and research. We suggest a framework based on the DOD Energy Strategy to illustrate how research supports the strategy. This serves as a guide for future research as well as a basis for unification of effort within the DOD.

Although the US no longer relies primarily on imported sources of petroleum, the DOD still uses petroleum to meet most of its energy needs. In 2014, about 27% of petroleum was imported from foreign countries (Energy Information Administration, 2015b). The DOD cost of petroleum products for fiscal year 2014 was 13.9 billion US dollars (Defense Logistics Agency –Energy, 2015). Compared to an overall DOD energy expenditure of 18.8 billion US dollars in that same year (Department of Energy, 2014), petroleum makes up about 74% of the total. The price volatility of the oil market places huge strains on the US defense budget. It has been estimated that an oil price increase of one dollar per barrel costs the DOD about 130 million dollars (Miles, 2008). And with the price of oil fluctuating between \$10.25 and \$145.31 since 2008 (WTI Cushing spot price, source: EIA), this makes budgeting for energy use difficult.

Countries like China and India have experienced rapid economic growth and along with this an increased energy demand. A 2007 report, sponsored by the US Department of Energy, found that total global demand for energy is projected to grow by 50-60 percent by 2030, driven by increasing population and the pursuit of improving living standards (Raymond, Deming, & Nichols, 2007). Although the growth of energy supply is expected to keep pace with this growth in demand for the next 25 years (Dimotakis, Grober, & Lewis, 2006), there remains significant uncertainty related to energy supply due to regional instability (Loechl et al., 2012). The advent of globalization, the war on terrorism, and the need to safeguard the earth's environment are all intertwined with US energy concerns (Wirth, Gray, & Podesta, 2003). Our economy and way of life depend on various sources of energy, the most important of which is oil (Tewksbury, 2006). These circumstances place great strain on the US government as it strives to ensure our continued economic resiliency and national security. CNA, a nonprofit research and analysis organization located in Arlington, VA, notes that US dependence on oil weakens international leverage, undermines foreign policy objectives, and entangles America with unstable or hostile regimes (CNA Military Advisory Board, 2009).

The DOD is the largest single U.S. consumer of energy, consuming 3.8 billion kilowatt hours (kWh) of electricity and over 120 million barrels of oil per year (Gauntlett & Adamson, 2012), having peaked at 145 million barrels in Fiscal Year (FY) 2003. The DOD also relies on foreign supplies of crude oil and the finished transportation fuels that are derived from it (Dimotakis et al., 2006). As a result, the DOD spends billions of dollars per year on fuel, and is pursuing numerous initiatives for reducing its fuel needs and changing the mix of energy sources that it uses (Blakely, 2012).

The DOD Operational Energy Strategy, released in 2011, sets the overall direction for operational energy security for the Office of the Secretary of Defense (OSD), Combatant Commands, Defense Agencies, and Military Departments/Services (Department of Defense, 2011a). The goal of the

DOD Operational Energy Strategy is “energy security for the warfighter” - to assure that U.S. forces have a reliable supply of energy for 21st century military missions (Department of Defense, 2011a). Furthermore, the strategy outlines three principle ways to achieve this goal. Additionally, seven targets were introduced to support the goal in the Operational Energy Strategy: Implementation Plan (Department of Defense, 2012). The categories are explained below.

Category one is: “More Fight, Less Fuel...Reduce Demand for Energy in Military Operations.” This category focuses on reducing demand and increasing efficiency to enhance combat effectiveness (Department of Defense, 2012). It includes three specific targets which are: Measure Operational Energy Consumption; Improve Energy Performance and Efficiency in Operations and Training; and Promote Operational Energy Innovation.

Category two is: “More Options, Less Risk...Expand and Secure Energy Supplies for Military Operations”. This category focuses on diversifying and protecting energy sources (Department of Defense, 2012). It includes two targets which are: Improve Operational Energy Security at Fixed Installations; and Promote the Development of Alternative Fuels.

Category three is: “More Capability, Less Cost...Build Energy Security into the Future Force.” This category focuses on integrating energy considerations into planning and policy (Department of Defense, 2012). It includes two targets which are: Incorporate Energy Security Considerations into Requirements and Acquisition; and Adapt Policy, Doctrine, Professional Military Education, and Combatant Command Activities (Change Culture).

1.2 Purpose

Although this strategy signaled a committed focus on energy management by the DOD, a unified effort and means to achieve these goals has not materialized. Policy, strategy, implementation, and research associated with these goals is fragmented and highly parochial among the military service departments. In this paper, we review US DOD energy policy since 1973, analyze the current DOD energy posture, and present a framework to organize and enable unified research to support the DOD Operational Energy Strategy and its goal.

2. Methods

Our systematic approach included a review and analysis of US energy legislation, policy, and DOD-specific energy studies from military schools.

We review US energy policy and legislation since 1973 to frame the evolution and context of the DOD’s thought and perspective on energy security. Next, we present a qualitative analysis of the broad spectrum of US DOD energy literature to assess the current posture and issues associated with DOD energy security and provide a basis for a research framework. We confine the scope of the final literature survey and content analysis to include only objective research from military academic institutions. A broader scope is not included at this time for two reasons. First, the graduate military academic institutions provide a well-catalogued and accessible collection of studies from which to base an analysis, and second, our time and resources were not sufficient to cover the potential breadth of areas, outlets, and topics to be covered in a truly exhaustive search of energy literature. This, however, does not detract from the primary contribution of this study, which is to provide a structure and

classification schema for connecting research to strategy in the DOD. Finally, we develop a framework and present an initial categorization of the aforementioned military research.

3. Analysis

3.1 *The Inception and Evolution of US Energy Policy*

Policy makers have been wrestling with the concept of US energy security for decades. The most notable shift of attention toward US energy policy occurred in 1973 as a consequence of the Arab Oil Embargo in reaction to the US support for Israel in the Yom Kippur war (Fehner & Holl, 1994). The Arab oil embargo, sometimes referred to as “Energy Pearl Harbor Day” (Light, 1976) caused the price of oil to triple overnight, which resulted in long gas lines and large price increases at the pump.

A string of executive policy decisions have been made in every administration since this time. During this crisis, President Nixon launched “*Project Independence*,” consisting of synthetic fuel programs (Fialka, 2006) and assured, “In the last third of this century, our independence will depend on maintaining and achieving self-sufficiency in energy” (Potter, 2008). President Nixon further asserted this project would “...insure that by the end of this decade, Americans will not have to rely on any source of energy beyond our own” (Fehner & Holl, 1994). On the policy front, the *Federal Energy Administration Act of 1974*, which established the Federal Energy Administration was passed. Since Nixon, every U.S. President has made an effort to free the United States of its dependence on foreign fossil fuels.

President Ford continued this agenda by signing the *Energy Reorganization Act of 1974*, which consolidated the various departments and administrative staffs that dealt with energy under one umbrella (Black, 2009). He later moved the date for achieving American energy independence to 1985 with the signing of the *Energy Policy and Conservation Act of 1975*. It was this Act that required fuel efficiency labeling for new car and major appliances. President Jimmy Carter, in his 1979 “Crisis of Confidence Speech,” declared “Beginning this moment, this nation will never use more foreign oil than we did in 1977—never.” He proposed an energy plan of 142 billion dollars to establish energy independence by 1990 (Carter, 1979) and gave the management of energy a cabinet-level position with the establishment of the Department of Energy in 1977 (Black, 2009).

In the 1980’s, the U.S. government looked to the development of synthetic fuels and to eliminating price controls on oil and natural gas. Congress, through the passing of the *Energy Security Act of 1980*, sought to reduce dependence on foreign energy resources by producing synthetic fuel. It established a national goal of achieving a synthetic fuel production capability equivalent to at least 500,000 barrels per day of crude oil by 1987 and of at least 2,000,000 barrels per day of crude oil by 1992 from domestic sources (Energy Security Act, 1980). However, this venture never produced the expected results and was terminated in 1986 (Blumberg, 2013). Additionally, President Ronald Reagan signed Executive Order (EO) 12287 – “*Decontrol of Crude Oil and Refined Petroleum Products*” in 1981 which eliminated price controls on oil and natural gas.

In 1991, President George H. W. Bush announced a strategy aimed at “reducing our dependence on foreign oil.” He later funded the U.S. Advanced Battery Consortium with a 260 million dollar research project with the goal of developing lightweight battery systems for electric vehicles (Kraemer, 2006). Later, with the *Energy Policy Act of 1992*, we sought to account for the full cost of energy to include

accounting for the cost of production, distribution, proper disposal and ensuring access to sources of supply for imported energy resources (Energy Policy Act, 1992).

President Bill Clinton's approach to the energy problem was to propose a large tax on crude oil in order to discourage dependence on foreign sources of oil in 1992. The following year, he launched a billion dollar Partnership for New Generation Vehicles with the Big Three automakers, to produce a prototype car, three times more fuel-efficient than conventional vehicles by 2004 (Fehner & Holl, 1994). Additionally, he issued Executive Order (EO) 13123 – "*Greening the Government through Efficient Energy Management*," directing the Federal Government, as the Nation's largest energy consumer, to significantly improve its energy management to save money and reduce emissions that contribute to air pollution and global climate change (Clinton, 1999). EO 13123 was later revoked by the new and improved EO 13423 – "*Strengthening Federal Environmental, Energy, and Transportation Management*," in 2007.

President George W. Bush asserted that addressing the nation's "energy crisis" was his most important task as president prior to the terrorist attacks on the World Trade Center and the Pentagon on September 11, 2001 (Klare, 2004). During his first term in office, he declared this, via his 2003 State of the Union address, "to promote energy independence for our country" (Bush, 2003). He announced a 1.2 billion dollar FreedomCAR (Cooperative Automotive Research) proposal to develop hydrogen-fueled vehicles (Kraemer, 2006; Wirth et al., 2003). Additionally, the Bush administration modified the *Energy Policy Act of 2005* and called it the *Energy Independence and Security Act of 2007* as a way to address the country's energy security concerns (Scofield, 2009).

In early 2007, President Obama, who was then just beginning his campaign for the White House, declared that America must break free of the "tyranny of oil" (Bryce, 2009). In his 2011 "*Blueprint for a Secure Energy Future*," he continued the assault on the country's dependency on foreign oil by proposing an ambitious but achievable standard for America. He declared that by 2035, "we will generate 80 percent of our electricity from a diverse set of clean energy sources - including renewable energy sources" (White House, 2011). The Obama administration gave energy security its due share of benefits through the passing of the \$800 billion dollar *American Recovery and Reinvestment Act of 2009* (ARRA) also called the *Recovery Act of 2009*. The energy portion alone consisted of approximately \$50 billion dollars whereby the largest partition of that money (\$11B) was appropriated for development of an electric smart grid to digitize power distribution and improve the grid's efficiency (Scofield, 2009).

Additionally, the DOD is moving aggressively to integrate alternative fuels on its bases, ships, and aircraft from the \$7.1 billion in stimulus appropriations by the ARRA to, among other things, modernize DOD's energy infrastructure and conduct targeted energy efficiency research and development projects (Rosen, 2010). The Obama administration is now pushing automakers to hit a 54.5 miles per gallon fleet-wide average by 2025 as a means of increasing vehicle fuel efficiency and thus reducing the consumption of fossil fuels (Krauss & Lipton, 2012). Most recently, an Executive Order was signed on March 19, 2015 on the subject of planning for federal sustainment over the next decade. This policy focuses the government on reducing greenhouse gas emissions while continuing to meet mission requirements.

3.2 Continued Policy and Action in the Department of Defense

In an effort to align the DOD with federal energy policies, the DOD Operational Energy Strategy was released and the position of Assistant Secretary of Defense for Operational Energy Plans and Programs (ASD (OEPP)) was established in 2011 (Department of Defense, 2011a), and an accompanying Energy Strategy Implementation Plan was released in 2012 to guide the department with specific targets to achieve the overall strategic goal of the plan (Department of Defense, 2012).

All military branches have developed their own policies (United States Air Force, 2013, United States Army, 2009, United States Marine Corps, 2009, United States Navy, 2010) with respect to energy and have been actively engaged in energy reduction efforts as well as alternative energy initiatives - a process often referred to as decarbonization (Shinnar & Citro, 2008). As of 14 December 2012, the military service departments had spent approximately 48 million dollars on alternative fuels, and the Navy proposed a 170 million dollar investment in biofuel production capability. By comparison, DOD purchases of petroleum fuels totaled 18.1 billion dollars in FY2011 (Defense Logistics Agency - Energy, 2013). These figures are evidence that progress is being made by each military branch as they strive to meet both Federal and DOD mandates and policies.

3.3 Current Posture and Issues

3.3.1 The DOD is in need of a cultural revolution (reduce demand)

Leadership must begin promoting the message that (fuel) efficiency at the tactical platform and system level is a clear strategic path to improve performance, reduce logistics burden and free resources from modernization and readiness (Defense Science Board, 2008; Closson, 2013). The CNA Military Advisory Board identified in its May 2009 report that DOD leadership must take an active role in transforming its energy posture and stated, "...leadership must demonstrate the proper focus and attention..." for development, testing, and deploying new technologies (Allen, 2012; CNA Military Advisory Board, 2009).

3.3.2 DOD energy security is threatened by the risk of price fluctuation (reduce demand and ensure supply)

If fuel costs exceed the amount budgeted for them, then they are financed by taking money from the budgets of other programs. This can severely affect other DOD programs, if not cancel them entirely (Fisher & Macheret, 2007). Both a reduction in demand as well as a focus on efforts to expand supply sources lessen this risk.

3.3.3 The DOD's petroleum use contributes to environmental concerns (reduce demand and expand supply)

The United States needs an energy security strategy the entire nation can support in order to cut our dependence on oil and our emissions of greenhouse gases (Center for a New American Security, 2008). Already, the carbon lodged in the atmosphere by the Industrial Revolution over the last 150 years has taken a toll: disappearing glaciers, a thinning Arctic icecap, dying coral reefs, and increasingly violent hurricanes (Kraemer, 2006). Although there has been added pressure for the U.S. to increase its domestic production of fossil fuels as a means of alleviating the dependency of foreign produced energy, critics of domestic oil production argue that fossil fuels are destroying the environment and play a role

in global warming by increasing the amount of carbon in the atmosphere (Weidenmier, Davis, & Aliaga-Diaz, 2008).

3.3.4 Political and Security effects (ensure supply)

Since the US still relies to some extent on foreign petroleum imports to meet demand, the potential for reliance on countries that have opposing political and national interests exists. Furthermore, the economic cost of dependence on foreign oil is staggering (Stein, 2011). The high oil prices of 2008 fueled one of the biggest wealth transfers in history (Haigh, 2009). At the time, the U.S. was importing some 60% of its oil from foreign sources resulting in prices adversely affecting our trade balance (Defense Science Board, 2008).

According to Powers (2010), the U.S. at one time had an oil trade deficit of approximately \$1 billion dollars per day (Halff, 2008), larger than our trade deficit with China, which in 2010 was approximately \$748,000,000 per day (United States Census Bureau, 2011). This outflow of capital not only weakened our national economy by increasing our trade deficit, but has the potential of enriching countries who may wish to harm us. Although our trade deficit has declined (Energy Information Administration, 2015b) any money from the United States to potentially hostile countries enables those nations to purchase the most advanced military technology and the human expertise to further develop and deploy it (Stein, 2011).

Former national security adviser Robert McFarlane and former CIA director James Woolsey once described our dependence on foreign oil as, “the well from which our enemies draw their political strength and financial power: the strategic importance of oil, which provides the wherewithal for a generational war against us” (McFarlane & Woolsey, 2011). Time and again, the U.S. military and national security leaders have warned of the substantial risk this outflow of capital poses to the security of the United States (Stein, 2011). However, due to the increasing demands of petroleum fuels from developing countries like China and India, the offending oil regimes will enrich themselves whether or not America does business with them (Nivola, 2008).

3.3.6 Cost and infrastructure favor oil (build energy into the future force)

By some accounts, the DOD is postured as an instrument of policy to shape the future energy development. The U.S. Congress has codified annual reporting on operational energy management and implementation of operational energy strategy (Duncan Hunter National Defense Authorization Act, 2009). By addressing its own fuel demand, the DOD can serve as a stimulus for new energy efficiency technologies, and mitigate national dependence on foreign oil (Defense Science Board, 2008).

The Defense Science Board, a group of civilian experts appointed to advise the DOD on technical and scientific matters, recommended that, “it is essential that the DOD support fundamental science investments that can lead to revolutionary improvements in the fuel efficiency of tomorrow’s weapon platform systems” (Defense Science Board, 2008). The DOD has the capability to explore better technology to reduce fuel consumption and make equipment more fuel efficient. By doing so, the DOD can also stimulate the economy and allow further development of systems the nation can use to reduce our dependence on foreign fuel and increase our national security (Allen, 2012).

However, there are opposing viewpoints which claim the DOD may not have the market power to effect alternative energy development. Furthering the threat to alternative energy are the strict

requirements that must be met in order to fully integrate such fuels into the military infrastructure. Each military service must first certify the use of alternative fuel blends with their tactical systems and these fuels must be able to be “dropped in” to current systems and meet standards for energy density, flash point, freezing point, thermal stability, lubricity, and viscosity (Mullen, 2011). However, the use of alternative energy sources must be synchronized with efforts to reduce consumption; otherwise there is no energy savings realized, but merely a shift from one supply source to another (United States Army, 2009). By seeking alternative energy technologies in combination with continued reliance on fossil fuels and conservation policies, the DOD will reduce foreign energy dependence (Holzman, 2006).

The primary consideration in the development and implementation of substantial alternative energy technologies is the cost of oil compared to the cost of alternative sources. Additionally, the current energy infrastructure, built over the last century, was designed to enable the reliable production and delivery of low-cost fuels to consumers (Verrastro et al., 2007). As a result, this infrastructure has been one of the major cost advantages for the continued use of traditional fossil fuel resources over alternative sources of energy (Verrastro & Ladislaw, 2007).

The high oil prices and fears of running out of oil in the 1970s and early 1980s encouraged investments in alternative energy sources, including synthetic fuels made from coal, but when oil prices fell, investments in these alternatives became uneconomical (Government Accountability Office, 2007). A 2006 report, *Reducing DOD Fossil Fuel Dependence*, asserts that an energy shortage is unlikely in the near term to hinder DOD operations and emphasizes the value of optimizing the energy efficiency of weapon systems over pursuing alternative fuel at this time (Blackwell, 2007; Dimotakis et al., 2006). At present, alternative fuels command a price premium which is expected to decline significantly as the market develops over the next decade. The DOD must send a clear market signal in order to enable the private sector to continue to develop cost-competitive alternative fuels (Parthemore & Nagl, 2010). A 2011 DOD study stated: “Despite the reduced premium, the Services’ renewable fuel goals could still impose \$2.2 billion in additional estimated annual fuel costs by 2020.” This would represent a 10 to 15 percent increase over the cost of conventional petroleum fuels (Department of Defense, 2011b). However, 10-year future fuel price predictions are subject to significant fluctuation in most cases and must be considered with a level of caution. Future price uncertainties notwithstanding, some analysts predict that petroleum will remain the primary source of operational energy for the DOD. According to Dimotakis and Grober (2006), barring externalities like subsidies, governmental and departmental directives, etc., non-fossil-derived fuels are not likely to play a significant role in the next 25 years because cost and current infrastructure (refining and distribution networks) favor petroleum.

As long as petroleum-based fuels are less expensive than other fuel or energy sources, this nation will continue to focus on the use of petroleum-based fuels (United States Army, 2009). With their high power density and relative low cost, fossil fuels will be difficult to replace (Blackwell, 2007). A 2011 RAND report found “that a domestic alternative fuel industry could yield large economic profits within the United States. However, RAND further concluded that there was no direct benefit to the DOD from using alternative fuels rather than petroleum-derived fuels (Bartis & Bibber, 2011). Absent a major increase in the relative reliance on alternative energy sources, oil and coal will continue to drive the energy train (United States Joint Force Command, 2010). In essence, oil will leave the economic system when it becomes more expensive than alternative sources or when the end uses it satisfies disappear (Watkins, 2006).

4. Results and Discussion

The issues revealed by the analysis of current DOD energy posture are closely aligned with the “ways” to achieving energy security identified in the DOD energy strategy and implementation plan described in section one. In the final stage of this project, we adapt these strategic categories to develop a framework and perform a content analysis of existing military research to establish theory to guide future research firmly grounded in published strategy and the current issues revealed by the qualitative analysis.

DOD energy research was collected from the Air Force Institute of Technology and the Naval Postgraduate School. These institutions focus on relevant operational problems for their respective services and the DOD, however, the concepts within the energy research they produce are applicable to all branches. They are unique in that they provide high quality academic research for the DOD through graduate education programs in the management sciences, engineering, and other technical fields. Figure 1 below shows the number of studies collected from each source, by year.

Insert Fig. 1 here

Fig. 1. Number of studies by source, per year

The analysis revealed that there has been an increase in energy research at these schools in the last decade, but there is no single coordinating structure behind the research.

In total, 350 studies were reviewed, catalogued and classified from AFIT and NPS, as listed in Appendix 1. This research is where the most fruitful and detailed results have been harvested. For example, the result of a single aircraft refueling logistics study has yielded the Air Force and the DOD \$111 million per year in savings via cost reduction (Air Force Institute of Technology, 2012). This type of research is where the DOD should place its largest investment. In addition to using the human capital resource available to conduct valuable research toward strategic goals, the research at these military schools also serves as an enabler for educating the force and driving culture change, a part of building energy into the future force. The students and faculty conducting this research receive educational benefit from conducting the research, and then return to the operational force with an enhanced understanding of energy matters and analytical tools to be agents of change. So, the second and third order benefits accrue to the DOD through investing in this type of research. However, the lack of a guiding framework or institutional coordination for this research means that this valuable resource is not being fully utilized.

4.1 Conceptual Development

Although the DOD has established a clear strategy, goals, and implementation plan, the research is guided only by DOD and service department mandates, sponsor encouragement, and individually established researcher and student interest. This is not to say that these are unimportant factors, but to

suggest the need for a structure such as a single research center to categorize and prioritize what the combined efforts should be focused on, and to enable long-term projects in pursuit of a single body of knowledge. Additionally, other than this project, there is no consolidation and categorization of the research to date.

4.2 A knowledge management framework

Knowledge has been viewed as a resource in strategic decision making and discussed in the context of achieving the performance-oriented goals of an organization (Holsapple & Singh, 2001; Hoopes & Postrel, 1999; Yang, 2010). In the context of energy security, knowledge management is a way of converting knowledge gathered through existing and ongoing research into a strategic asset – something the DOD has not taken advantage of to this point. One way to do this is through information technology, however, this is not always the necessary or sufficient ingredient for transforming existing knowledge into a strategic asset (Teece, 2000).

Foundationally, knowledge management resides in underlying structures used to gather, store and disseminate knowledge throughout an organization, and involves not only content but context (Teece, 2000). Knowledge management may enable organizational elements such as structure, culture, and strategy to positively influence organizational effectiveness (Zheng, Yang, & McLean, 2010). Knowledge transfer in and of itself may require a particular strategy to exploit the creation and transfer of new and existing knowledge (Von Krogh, Nonaka, & Aben, 2001).

A framework consisting of elements to not only assemble, but to contextualize DOD energy research will have a better chance of translating existing knowledge (research) into a strategic asset for the DOD as well as guide knowledge creation (future research) toward the attainment of the overall goal of energy security for the warfighter, which is our goal for the framework presented here.

Energy is fungible, therefore, the structure must recognize that all energy research is a joint endeavor. There is no “color” for energy. The Air Force, Army, and Navy all use the same energy from the same sources. Uncoordinated parochial efforts to improve energy efficiency, supply management, and culture are sub-optimal. Not all such efforts will overlap, however, there is ample opportunity for complementary efforts within a unifying schema which establishes coordinated priorities and allows for knowledge transfer and resource-sharing, which does not exist. A joint DOD center for energy research would enable the strategic exploitation of knowledge creation and transfer amongst the military services.

Previous taxonomies are sparse and either address the categorization of energy research without respect to the specific concerns of the DOD or focus on only one particular focus area of research. For example, a general set of maxims was introduced by Sovacool and Brown (2015) to guide energy researchers. The maxims presented are information, inclusivity, symmetry, reflexivity, prudence, and technological agnosticism. These maxims when taken as a whole point to the importance of having the “big picture” when conducting research. The framework presented herein theoretically organizes these general doctrinal ideals for DOD energy research. A very specific set of categories for improving energy efficiency within the DOD is presented by Umstattd (2009). These categories suggest that efficiency efforts need focus and can be grouped into three solution categories: develop renewable sources, reduce and conserve, and improve efficiency. These categories are very specific to the implementation of overall efficiency improvements in the DOD and are too narrow to capture the breadth of research topics currently being researched. Finally, Simon, Regnier, and Whitney (2014)

rightfully point out that a “lack of precision and consistency in DOD guidance limits practical usefulness” of policy in analyzing decisions. They present a value focused thinking approach to identify common objectives of semi-overlapping policy. The results include a comprehensive set of common objectives taken from current policy. These objectives include the ideas of demand reduction, supply assurance, and maximizing motivation to improve the DOD energy profile.

Since the goal of all DOD energy research is ensuring energy security, the research to support such a goal should fit within the strategy which aims to achieve the goal. The DOD Operational Energy Strategy addresses energy security through three ways: Reducing demand, expanding and securing supply, and building energy into the future force. Our framework translates the ways into research categories. These three ways form the foundational categories of our framework. A common categorization of research will enable knowledge transfer and coordination between services and within the DOD energy research community, while a joint energy research center will practically drive the strategy.

A total of 350 studies are included in these categories. The three framework categories are adapted from the three principle ways outlined in the DOD Operational Energy Strategy. Using these categories as a basis for the framework connects and focuses past and future research efforts on the overarching goal of energy security for the warfighter. The categories are broad enough to encompass the spectrum of research being conducted to support the goal, but focused enough to allow researchers and consumers of research to identify the knowledge base that exists for a particular topic. Additionally, we found that the categories need not be limited to operational energy topics. The scope of the categories allows for inclusion of installation energy topics as well as operational topics, as the goal of energy security for the warfighter certainly encompasses both realms. The categories are described next.

The first category is “reduce demand.” This category includes research that contributes to measuring consumption, improving performance and efficiency, elimination of non-value-added activities, and promoting energy innovation. This is the most straightforward of the categories as it deals primarily with energy efficiency studies and the immediate temporal benefits that accrue from energy savings. Interest in this category has been lower than the other two areas. This can be due to the focus on supply assurance and alternative energy sources found in policy since the 1970’s. The psychological link between demand reduction and energy security must be strengthened, as it is just as important a factor as supply expansion and assurance.

The second category is “expand and secure supply.” This includes research that contributes to improved energy security at installations. This category covers both current and future temporal bounds, which include the development and use of alternative fuels, physical security, grid security, broadening supplier base, etc. It may also include the development of technology or operations management techniques for the use of alternative fuels. Our analysis shows that the interest in this category has been greater than the other categories, partly because of the policy focus on alternative energy and the linkage between energy security and supply assurance.

The third category is “build energy into the future force.” This category has an exclusive forward looking temporal focus and includes literature that encompasses strategic decision making, planning, policy development, legislation, the role of geopolitics in energy strategy, and the incorporation of energy security into requirements and acquisitions. More broadly, this category includes research that

promotes overall culture change in the DOD with regard to energy. This is a particularly broad category in that it encompasses more than the typical supply chain management considerations of supply and demand. It includes factors that typically fall into the realms of public policy, political science, strategic policy, and acquisitions and requirements. A breakout of these categories and examples of topics within each is found in table 1 below.

Table 1

Categories and topics of DOD energy research

Insert Table. 1 here

Although the scope of this review does not include the general category of independent peer-reviewed research, more strategically-focused DOD sponsorship of civilian research, guided by a singular structure would benefit the DOD as well as all energy consumers.

Finally, the framework categories inherently include classification of research by either a near or long term focus. For example, many conflicting views exist on the importance of alternative energy research and application. Some believe the DOD will be a driver to the rest of society and a change agent for this type of energy implementation and research (Defense Science Board, 2008). However, some believe that the DOD simply does not constitute a large enough demand on the system to be such an agent of change (Dimotakis et al., 2006). In short, the use of alternative energy sources such as biofuels (a chief implementation goal for the DOD) is too expensive to be economically viable while the price of fossil fuels remains relatively low. It is important to deconflict these views by recognizing the temporal element in each category. For example, a given alternative energy source may become a source of security and economically feasible in the long-term, so while research in this area is extremely important to the long-term strategic outlook of our energy security future, immediate implementation may be short-sighted and extremely costly. Therefore, it should be classified as such and recommendations should not hinge on immediate implementation given the economic consequences. The three categories fall along a temporal continuum. Reducing demand encompasses current implementation, whereas building energy into the future force looks to future considerations. Assurance of supply takes both a current and long-term outlook.

Figure 2 below depicts such a framework which support the main goal of energy security for the warfighter.

Insert Fig. 2 here

Fig. 2. A framework for research to support DOD energy strategy

A preliminary classification of existing research in the categories of this framework is represented in figure 3 below.

Insert Fig. 3 here

Fig. 3. Initial categorization of DOD research by framework categories (2000-2015).

This initial classification should be refined and maintained to reflect the state of the art in the field of DOD energy research. Although it is beyond the scope and resources of this study, the classification should be expanded to include non-DOD sources of research. Further detail should be added to classify and refine the research within each broad category.

5. Conclusions and Policy Implications

The number of DOD energy studies shows a spike in interest in the most recent decade. As a result of the DOD's thrust to attain energy security, this is no real surprise. The result of this study is that most research produced is based only on a single, short-term topical research question. Additionally, much of the work done outside the DOD is of a very high level policy-oriented nature. In the DOD, policy must precede efforts to attain specific goals, however, it is important to bring more balance to the policy efforts with actionable research.

The absence of a unifying construct for DOD energy research is partially to blame for the lack of focus on specific goals and topics. Although we see a fairly wide spread of topical coverage in the research reviewed, the motivations are often driven solely by researcher interest, sponsor guidance, or parochial budgetary reasons. There is no central mechanism in-place to ensure that research efforts are directly supporting strategic goals and that efforts are not duplicated. The proposed framework will serve as a theoretical focal point and enabling mechanism for guiding energy research. The ideals of such a framework should be put into practice by a research center operating as a single unifying structure within the DOD. This will provide coordination, guidance, focus, and knowledge management functions which ultimately support the goal of the DOD energy strategy, and do not currently exist. A unifying effort is needed to maximize the research potential – particularly from the most abundant source of thought leadership available to the DOD – its military schools, students, and faculty. Such a

unifying effort will ensure that research supports strategy. Additionally, research by traditional academic institutions should be encouraged and sponsored by the DOD when possible.

Next, we have to realize that education, research, and culture change go hand in hand. The research being conducted by faculty and students at military schools fuels education efforts. This happens through direct learning of those involved in the research, the secondary benefits of taking the research findings into the classroom, and finally the third order effect of having well-informed energy change agents reintegrated into the operational environment. In short, education will spur culture change and the ability to build energy into a future force.

These observations drive three recommendations. First, a formal, joint, and permanent structure is needed to ensure the unified effort. In order to unify the research and education efforts of the DOD, a joint center or academic group is needed. This structure will ensure multi-way communication between policy makers, operational customers, and academic institutions. Next, education and research must be integrated with strategic goals of the DOD. Although the services currently have some educational opportunities in energy management, they focus almost entirely on specific jobs or career paths. With the exception of the Navy, no formal plan for energy education exists (United States Navy, 2015). Fostering an energy aware culture should have intentional education built into multiple career paths and professional military education in order to reach the widest audience and permeate the organizational culture to educate the total force. Finally, the terms, definitions, and goals of an energy aware culture must be standardized. A common language, established by a guiding framework, will enable clear communication to occur across service boundaries and within the DOD.

5.1 Limitations and Future Research

Although the content analysis presented in this paper provides the first summary of DOD energy research to date, it is not all-inclusive. The broad nature of this survey provides the “big picture” of where we are with respect to DOD energy research, however, its breadth and our limited resources prevent a deep exploration of topics by specific category at this time. Additionally, there is some overlap in the categories presented. No one set of categories will be able to capture the richness or complexity of the subject of energy security. This does provide, however, a unifying direction for future research.

What is the next step in DOD energy research? Suggestions for future research include the revising of topical categories within the framework as research evolves and technological advances are made in the areas of alternative fuel sources. Additionally, the changing budgetary posture of the DOD and the highly volatile price of oil will no doubt continue to shift focus and interest in terms of economic feasibility.

As with any large organization, culture change within the DOD is difficult and slow. Such a rigid and segmented structure changes only as senior leadership guides and codifies expected changes in policy. Communication is key to cultural shifts, and so a steady stream of information and education is needed to initiate real change. Finally, culture change and the priority placed on it will only be as effective as the budget and resources allocated to the topic. As more research is conducted and education and training programs are developed, the “spend” will reveal what the true priorities are.

Where does environmental research fit into the energy picture? More research is needed to align the complementary priorities of environmental sustainment and energy efficiency. Although the

two go hand in hand, the DOD has not yet captured how to integrate the topics, and it is outside the intended scope of the framework presented in this paper.

Are there other categories to be considered? Although the DOD primarily divides its energy use by whether it supports a fixed installation or an operational force, the two are not mutually exclusive, nor are they all encompassing. A combined effort with more detailed breakouts of energy use may be helpful in guiding and focusing future research efforts.

Finally, the mission of the DOD is to focus on effectiveness. Although efficiency is part of overall effectiveness, in the end, the DOD has a charge to provide security of a nation, which comes at a high cost. In short, we have to win wars. In the end, efficiency takes second place to meeting mission requirements.

Energy security is an overwhelmingly broad topic. Without a guiding framework to focus the future efforts and a unifying structure to make the best use of resources available for research, the time and effort needed to cover this topic will be enormous. In order to keep pace with the economic and budgetary pressures being exerted by changing technology, environmental concerns, and the ever volatile price of oil, the DOD must move forward with a combined and unified focus to address its goal of energy security.

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Number of Documents by Year

Table 1

Categories and topics of DOD energy research

Category 1	Category 2	Category 3
Reduce Demand	Expand and Secure Supply	Build Energy into the Future Force
Measure consumption Improve performance and efficiency Promote innovation	Improve energy security at installations Develop and use alternative fuels Physical security Grid security Broaden supplier base Develop technology or operations management techniques for the use of alternative fuels	Strategic decision making Planning Policy development Legislation Geopolitics Incorporation of energy security into requirements and acquisitions Culture change Education and Training

Appendix 1: List of military school studies included in content analysis

AFIT studies may be accessed via Defense Technical Information Center at <http://www.dtic.mil/dtic/>

NPS studies may be accessed via Calhoun: The NPS Institutional Archive at <http://calhoun.nps.edu/>

Author(s)	Year	Title	Source
Akinlemibola, Bolanle	2009	The Systems Engineering Design of an Energy Prediction Tool	AFIT
Amack, Daniel C.	2014	Waste-to-Energy Decision Support Method for Forward Deployed Forces	AFIT
Andrews, Sean T.	2012	An Analysis of Department of Energy Office of Environmental Management Project Cost Performance Using Logistic Regression	AFIT
Archambault-Miliner, Ryan R.	2010	An Evaluation of Compressed Work Schedules and Their Impact on Electricity Use	AFIT
Azghandi, Seif	2014	An Empirical Model for Smart Meters Using Data Security	AFIT
Badiru, Adedeji B.	2011	Advancements in Energy Technology: Implications for UAV Design and Development	AFIT
Badiru, Adedeji B.	2008	New Power Generation: Energy Requirements Planning Must Drive Future Product Development	AFIT
Barnes, Matt	IP	WTE testing procedures w/ emphasis on Air Emissions	AFIT
Borowski, John	2011	Reputation-Based Trust for a Cooperative Agent-Based Backup Protection Scheme	AFIT
Borowski, John	2010	Reputation-Based Trust for a Cooperative, Agent-Based Backup Protection Scheme for Power Networks	AFIT
Braziel, Carlos	2004	Using Value-Focused Thinking to Evaluate the Effectiveness of Air Force Utility Privatization	AFIT
Brost, Gavin D.	2013	Successfully Implementing Net-Zero Energy Policy through the Air Force Military Construction Program	AFIT
Brown, David S.	2009	An Evaluation of Solar Air Heating at United States Air Force Installations	AFIT
Brown, L.M., J.P. McComb, M.D. Vangness, L.L. Bowen, S.S. Mueller, L.M. Balster, C.A. Bleckmann	2010	Community dynamics and phylogenetics of bacteria fouling Jet A and JP-8 aviation fuel	AFIT
Burgess, James E.	2009	Fuel Savings of Removing the C-130 External Tanks	AFIT
Burton, Mark L., Michael J. Hicks, Cal Kent, and Chris Riche	2005	Regional Markets for FutureGen Products	AFIT
Cahoon, Troy L.	2011	Airborne Wind Energy: Implementation and Design for the U.S. Air Force	AFIT
Calvo, Jay	IP	Reduced Energy Consumption to Existing Facilities Through Building Envelope and Project Prioritization Improvements	AFIT
Cansick, Perry; Dietrich, Art	2015	Advanced Metering Feasibility Study at Wright Patterson Air Force Base	AFIT
Capper, Cpt. Justin R.	2014	Tanker Fuel Efficiency: Saving Through Receiver Fuel Planning	AFIT
Carlos Gonzalez, Juan	2009	An Efficient and Effective Implementation of the Trust System for Power Grid Compartmentalization	AFIT
Carlos Gonzalez, Juan	2011	Optimization of Trust System Placement for Power Grid Security and Compartmentalization	AFIT
Chinery, Mark B.	2014	Using Sensor-based Demand Controlled Ventilation to Realize Energy Savings in Laboratories	AFIT
Chun, Woo-Suk	2011	Life Cycle Assessment of LEED vs. Conventionally Built Residential Units	AFIT
Clark, Michael	2013	Towards an Understanding of the Tradeoffs in Adversary Models of Smart Grid Privacy Protocols	AFIT
Clark, Michael	2014	Transferable Multiparty Computation with Applications to the Smart Grid	AFIT
Coates, Gregory	2010	A Trust System Architecture for SCADA Network Security	AFIT
Coates, Gregory	2007	Collaborative, Trust-Based Security Mechanisms for a National Utility Intranet	AFIT
Coates, Gregory	2008	Collaborative, Trust-Based Security Mechanisms for a Regional Utility Intranet	AFIT
Coerbell, Marlon	2011	Creating a Network Model for the Integration of a Dynamic and Static Supervisory Control and Data Acquisition (SCADA) Test Environment	AFIT
Colon, Carlos J.	2010	Assessing the Economic and Environmental Impacts Associated with Current Street Lighting Technologies	AFIT
Crutchfield, Abram	IP	Decision Matrix for Logistics Planners to use WTE system	AFIT
D'Agostino, Cpt. Justin P.	2015	Forecasting Fuels Support Equipment Requisition	AFIT
Dailey, Ericka M.	2002	The Management of Energy Savings Performance Contracts (ESPCs)	AFIT
Diaz, Daniel, Jr.	2007	Diffusion of Innovation: Factors Promoting Interest in Solar Photovoltaic Generation Systems within Air Force Installations	AFIT
Dirosario, Joseph P.	2012	Asset Management: Roof Maintenance and Facility Energy Retrofits	AFIT
Drenth, Aaron C.	2009	LASER-INDUCED FLUORESCENCE AND SYNTHETIC JET FUEL ANALYSIS IN THE ULTRA COMPACT COMBUSTOR	AFIT

Author(s)	Year	Title	Source
Duke, James S.	2004	Decision Analysis Using Value-Focused Thinking to Select Renewable Energy Sources	AFIT
Duncan, Justin H.	2004	The Application of Value Focused Thinking to Utilities Privatization Source Selection	AFIT
Ehmen, Maj. Joshua	2015	Altering Flight Schedules for Increased Fuel Efficiency	AFIT
Fadul, Jose	2014	A Trust Management Toolkit for Smart Grid Protection Systems	AFIT
Fadul, Jose	2010	SCADA Trust Management System	AFIT
Fadul, Jose	2010	Simple Trust Protocol for Wired and Wireless SCADA Networks	AFIT
Fadul, Jose	2011	Trust Management and Security in the Future Communication-Based “Smart” Electric Power Grid	AFIT
Fadul, Jose	2011	Using Reputation-Based Trust to Overcome Malfunctions and Malicious Failures in Electric Power Systems	AFIT
Fett, Maj. Garrret D.	2014	Aircraft Route Optimization Using the A-Star Algorithm	AFIT
Fredin, Paul W.	2009	Ground Source Heat Pumps vs. Conventional HVAC: A Comparison of Economic and Environmental Costs	AFIT
Gaber, Harvey S.	2009	Waste Vegetable Oil as an Alternative Fuel for Diesel Vehicles	AFIT
Getzelman, Ellen M.	2011	An Analysis of Optimal Fuel Tankering in the C-17 Globemaster III to Address Differential Fuel Prices	AFIT
Gibson, William T.	2009	Jet Fuel Hedging Strategies for the Department of Defense Through Use of Financial Derivatives	AFIT
Gohn, Maj. Russell D.	2014	Changing the Culture of Fuel Efficiency: A change in Attitude	AFIT
Goltz, Dr. Mark N.	2011	Unintended Consequences, Potential Downsides of the Air Force's Conversion to Biofuels	AFIT
Greve, Gabriel	2010	Network Security Toolkit Including Heuristics Solutions for Trust System Placement and Network Obfuscation	AFIT
Griffin, J.S., A.E. Thal, Jr., and S.E. Leach	2014	Enhancing Asset Management Through a Better Understanding of Energy Consumption	AFIT
Griffin, James S.	2008	Impacts of Weather Variations on Energy Consumption Efforts at U.S. Air Force Installations	AFIT
Guler, Caglarutku	2009	Ohio River Denial as a Transportation Corridor and Its Economic Impacts on the Energy Industry	AFIT
Halvorson, Elias J.	2011	A Century Long Pursuit Of Alternative Fuels and Feedstocks: A Content Analysis	AFIT
Hargy, David F.	2003	Sustainable Development Guide for Facility and Infrastructure Projects	AFIT
Havlicek, Jeffrey D. and James T. Moore	2005	Theater Aerial Refueling Vehicle Routing Models	AFIT
Hayden, Jeffrey D. and Scott A. Vaughn	2007	United States Air Force Fuels Program: An Analysis of Automatic Data Collection Initial Investments	AFIT
Heath, Eric J.	2005	Air Force JP-8 Fuel Distribution System: A Statistical Analysis to Determine Where and When to Sample	AFIT
Heseltine, Jr., Bruce P.	2007	KC-135R Fuel Savings	AFIT
Hines, Michael S.	2007	Fuel Estimation Using Dynamic Response	AFIT
Hiserote, Ryan M.	2010	Analysis of Hybrid-Electric Propulsion Systems for Small Unmanned Aircraft Systems	AFIT
Homan, Haley A.	2014	Comparison of Ensemble Mean and Deterministic Forecasts for Long-Range Airlift Fuel Planning	AFIT
Hopkinson, Kenneth	2006	A Primary and Backup Cooperative Protection System Based on Wide Area Agents	AFIT
Hopkinson, Kenneth	2004	A Primary and Backup Cooperative Protection System Based on Wide Area Agents	AFIT
Hopkinson, Kenneth	2006	A Simulation Study of a Substation Automation Communication System Based on Ethernet Technology	AFIT
Hopkinson, Kenneth	2000	Agent Technology Applied to Adaptive Relay Setting for Multi-Terminal Lines	AFIT
Hopkinson, Kenneth	2004	Agent Technology Applied to the Protection of Power Systems	AFIT
Hopkinson, Kenneth	2002	An Agent Based Current Differential Relay for use with a Utility Intranet	AFIT
Hopkinson, Kenneth	2002	Developing an Agent-based Backup Protection System for Transmission Networks	AFIT
Hopkinson, Kenneth	2006	EPOCHS: A Platform for Agent-based Electric Power and Communication Simulation Built from Commercial Off-The-Shelf Components	AFIT
Hopkinson, Kenneth	2003	EPOCHS: Integrated Commercial Off-The-Shelf Software for Agent-based Electric Power and Communication Simulation	AFIT
Hopkinson, Kenneth	2004	Improving Local and Backup Protection Using Wide Area Agents	AFIT
Hopkinson, Kenneth	2001	Improving the Protection of EHV Teed Feeders Using Local Agents	AFIT
Hopkinson, Kenneth	2010	IP-Based Communication Systems for Wide-Area Frequency Stability Predictive Control	AFIT

Author(s)	Year	Title	Source
Hopkinson, Kenneth	2005	Novel Backup Protection Systems for the Electric Power Grid Using Agents	AFIT
Hopkinson, Kenneth	2005	Overcoming Communications Challenges in Software for Monitoring and Controlling Power Systems	AFIT
Hopkinson, Kenneth	2009	The Modeling and Verification of Peer-to-Peer Negotiating Multi-Agent Colored Petri Nets for Wide-Area Backup Protection	AFIT
Hopkinson, Kenneth	2013	The Study of a Regional Decentralized Peer-to-Peer Negotiation-Based Wide-Area Backup Protection Multi-Agent System	AFIT
Hrad, Paul M.	2010	Conceptual Design Tool For Fuel-Cell Powered Micro Air Vehicles	AFIT
Hu, M., Weir, J. D., Wu, T.	2011	Decentralized Operation Strategies for an Integrated Building Energy System using a Memetic Algorithm	AFIT
Jeoun, James	2005	Using Value-Focused Thinking to Evaluate the Practicality of Ground-Source Heat Pumps at Military Installations	AFIT
Jordt, G. J., Baldwin, R. O., Raquet, J. F., and Mullins, B. E.	2008	Energy Cost and Error Performance of Range-Aware, Anchor-Free Localization Algorithms	AFIT
Kale, William H.	2001	Weapon System Environmental Life Cycle Cost Methodologies and Models	AFIT
Kannon, Cpt. Tanya E.	2014	Improving the Air Mobility Commands's Air Refueler Route Building Capabilities	AFIT
Kasperek, Andrew	2012	Enhancing Trust in the Smart Grid by Applying a Modified Exponentially Weighted Moving Averages Algorithm	AFIT
Kellner, Mostyn	2006	A Decision Model for Choosing Among Photovoltaic Technologies to Generate Electricity at Grid-Connected Air Force Facilities: A Value-Focused Approach	AFIT
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Poulton, Joshua M.	2010	A Study of the Relationship Between Proenvironmental Product Use and Environmental Concern	AFIT
Pratt, David M.	2006	Selecting Energy Efficient Building Envelope Retrofits to Existing Department of Defense Building Using Value Focused Thinking	AFIT
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Ross, Keith	2013	Using a Distributed Agent-Based Communication Enabled Special Protection System to Enhance Smart Grid Security	AFIT
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Shipman, Crystal	2012	An Application of Con-Resistant Trust to Improve the Reliability of Special Protection Systems within the Smart Grid	AFIT
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Sponseller, Maj. Hugh	2014	Over the Pole: A Fuel Efficiency Analysis of Employing Joint Base Elmendorf-Richardson for Polar Route Utilization	AFIT
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Stumme, Luke D.	2008	Optimal Adoption of Green Roofs: Hydrology and Public Finance Applications	AFIT
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Wolfe, Austin	IP	Cost-Benefit Analysis for using WTE system	AFIT
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Aladaili, Aabdulaziz A.	2013	Technological advancements in EW: a way forward for Royal Saudi Naval Force	NPS
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Alexandre, Kevin L.	2014	Evaluation of system architectures for the Army Aviation Ground Power Unit	NPS
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Al-Saadi, Sabri Zire	2012	New Economic Model for Iraq Future Vision and Market-Oriented State Corporations Foster Liberalization of Oil-Rentier Economies	NPS
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Apte, Aruna; Simon, Jay; Nussbaum, Daniel; Regnier, Eva; Khawam, John	2013	Fully-Burdened Cost of Supply in Self-Sustaining Logistics Networks	NPS
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Armstrong, Lincoln; Kelly, Mary; Nester, Amie; Schindler, Theodore; Young, Michael; Colon, John; King, Joseph; Parr, Jennifer; Small, Kenneth; Finch, Chad; McCreary, James; Rodecap, Nathan; Sunshine, Nicholas	2010	A study of alternative fuel impacts to navy fueling infrastructure	NPS
Atkinson, Thomas A.	2014	Marine Corps Expeditionary Rifle Platoon Energy Burden	NPS
Bailey, Troy D.	2014	Modeling and implementing a digitally embedded maximum power point tracking algorithm and a series-loaded resonant DC-DC converter to integrate a photovoltaic array with a micro-grid	NPS
Barma, Naazneen	2014	Mixed blessings, Naazneen H Barma surveys the various resource curses plaguing Asia and the Pacific	NPS
Battaglia, Corsin; Xu, Jingsan; Zheng, Maxwell; Yin, Xingtian; Hettick, Mark; Chen, Kevin; Haegel, Nancy; Javey, Ali	2014	Enhanced Near-Bandgap Response in InP Nanopillar Solar Cells	NPS
Beach, Joseph N.	2012	Integration of an Acoustic Modem onto a Wave Glider Unmanned Surface Vehicle	NPS
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Blais, Curtis	2010	Setting a Course for the Human Social Culture Behavior (HSCB) Modeling Standards Study Group	NPS
Blumberg, G. (2013)	2013	The Origin of the Department of the Navy's Biofuel Initiative and the Volatility Problem for Defense Energy	NPS
Boonyobhas, Rex A.	2014	Control strategy: wind energy powered variable chiller with thermal ice storage	NPS
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Brown, Gerald Gerard; Kline, Jeffrey Eugene; Rosenthal, Richard Edwin; Menconi, Pascale; Washburn, Alan R.	2011	Mixed-Mode Fuel Minimization	NPS
Burgess, Marion	2010	The proposed Fissile Material Cutoff Treaty (FMCT) and its potential impact on U.S. Navy nuclear propulsion programs	NPS
Burnett, K.O.; Crooker, P.P.; Haegel, N.M.; Yoshioka, Y.; MacKenzie, D.	2011	Temperature-dependent kinetics of printed polymer light-emitting electrochemical cells	NPS
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Cabiling, Alan P.	2013	Ultra Low-Voltage Energy Harvesting	NPS
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Carey, Seamus B.	2014	Increasing the endurance and payload capacity of unmanned aerial vehicles with thin-film photovoltaics	NPS
Carr, M. Aaron	2012	he Comparison of Hydrotreated Vegetable Oils With respect to Petroleum Derived Fuels and the Effects of Transient Plasma Ignition in a Compression-Ignition Engine	NPS
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Chisom, Christopher M.; Templeton, Jack C., II	2013	Analysis of Marine Corps Renewable Energy Planning to Meet Installation Energy Security Requirements	NPS
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Columbus, Douglas A.	2014	Design and optimization of Copper Indium Gallium Selenide solar cells for lightweight battlefield application	NPS
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Cowden, Daniel R.	2013	Policy in conflict: The struggle between environmental policy and homeland security goals	NPS
Craparo, Emily; Singham, Dashi	2014	Hybrid Microgrids Containing Renewable Energy Sources	NPS
Crawford, Dustin K.	2014	Alternative practices to improve surface fleet fuel efficiency	NPS
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DeDeaux, Cedric N.	2010	Energy Capture Module (ECM) for use in Unmanned Mobile Vehicles (UMVS) with a specific study of the Draganflyer X6 UAV	NPS
Demersseman, Earl J.; Mack, Andrew D.; Witherill, Michael A.	2014	An operational utility assessment: measuring the effectiveness of the experimental forward operating base program	NPS
Dickenson, Michael R.	2014	Solving operational models of interdependent infrastructure systems	NPS
Dillard, Chase H.	2014	Energy-efficient underwater surveillance by means of hybrid aquacopters	NPS
DiMaggio, Dominic	2014	The role and variability of ocean heat content in the Arctic Ocean: 1948-2009	NPS
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Dubbs, Sean R.	2011	Estimating the fully burdened cost of fuel using an input-output model - a micro-level analysis	NPS
Ewachiw, Mark A. Jr.	2014	Design of an Autonomous Underwater Vehicle (AUV) Charging System for Underway, Underwater Recharging	NPS
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Fotis, Konstantinos	2012	Modeling and simulation of a dual-junction CIGS solar cell using Silvaco ATLAS	NPS
Gable, Adam V.	2014	Study of Naval Air Station operations to reduce fuel consumption	NPS
Garfrerick, Adam R.	2012	Modeling Heterogeneous Carbon Nanotube Networks for Photovoltaic Applications Using Silvaco Atlas Software	NPS
Geiser, Matthew T.	2012	Improving Aircraft Refueling Procedures at Naval Air Station Oceana	NPS
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Grachev, Andrey A.; Andreas, Edgar L.; Fairall, Christopher W.; Guest, Peter S.; Persson, P. Ola G.	2012	The Critical Richardson Number and Limits of Applicability of Local Similarity Theory in the Stable Boundary	NPS
Grbovic, Dragoslav; Osswald, Sebastian	2013	Bimaterial Microelectromechanical System (MEMS) Solar Power Generator	NPS
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Hall, Stacey L.	2012	Effect of the Environment and Environmental Uncertainty on Ship Routes	NPS
Hanthorn, David G.	2010	Vulnerability analysis of an all-electric warship	NPS
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Hebner, Robert E.; Gattozzi, Angelo L.; Cohn, Keith R.; Colson, William B.	2010	Analysis of the Power Quality Impact of Multiple Directed Energy Loads on an Electric Ship Power System	NPS
Helker, Joseph K.	2014	NPS Solar Cell Array Tester CubeSat flight testing and integration	NPS
Henne, Austin L.	2014	Solar photovoltaic and liquid natural gas opportunities for Command Naval Region Hawaii	NPS
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Hill, Adam L.	2012	NPS-SCAT CONOPS and Radiation Environment	NPS
Hills, Allison	2012	Life Cycle Cost Estimate of LSD(X)	NPS
Hines, Jonathan T.	2012	Emulation of Wind Power with a DC Machine to Provide Input to a Doubly-Fed Induction Machine	NPS
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Householder, Timothy J.	2014	MEMS-based waste vibration and acoustic energy harvesters	NPS
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Jaffer, Navin	2014	Cyber security vulnerabilities during long term evolution power-saving discontinuous reception protocol	NPS
Jaskoski, Maiah	2012	Resource Conflicts: Emerging Struggles over Strategic Commodities in Latin America	NPS
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Jenkins, Robert D.	2010	NPS-SCAT : Systems Engineering and payload subsystem design, integration, and testing of NPS' first CubeSat	NPS
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Karakas, Huseyin; Tilki, Timur	2012	An Analysis of Effect of Water Resources Constraint on Energy Production in Turkey	NPS
Kiletico, Micah J.	2014	Integrating Recycled Glass Cullet in Asphalt Roof Shingles to Mitigate Heat Island Effect	NPS
Kirar, Carl V.	2011	Cost analysis of LEED certified United States navy buildings	NPS
Kirkpatrick, Justin P.	2013	An investigation of the effectiveness of solar power on Navy surface combatants	NPS
Koletsios, Evangelos	2012	GaAs/InAs multi quantum well solar cell	NPS
Kroll, Douglas M.	2010	Using polymer electrolyte membrane fuel cells in a hybrid surface ship propulsion plant to increase fuel efficiency	NPS
Lamprou, Spyridon Theofilos	2012	A Technical Feasibility Study of a Green Area	NPS
Law, Derek J.; Tyley, Scott M.	2012	Development and Application of an Approach to Optimize Renewable Energy Systems in Afghanistan	NPS
Lebel, Richard B.	2011	Modeling and analysis of a constant power series-loaded resonant converter	NPS
Lee, Deok-Jin; Andersson, Klas	2011	Hybrid control of long-endurance aerial robotic vehicles for wireless sensor networks	NPS
Leewright, Corey K.	2012	A Cost-Benefit Analysis of Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS)	NPS
Long, James A.	2011	Optimizing logistical planning factors for fuel rate consumption within the FIFTH FLEET area of responsibility	NPS
Luhrs, Claudia C.	2014	Tailored Nanomaterial Electrodes for Energy Storage Applications	NPS
MacKenzie, Cameron A.; Barker, Kash	2013	Empirical data and regression analysis for estimation of infrastructure resilience, with application to electric power outages	NPS
Mangasarian, Seth	2010	Energy consumption evaluation of United States Navy LEED certified buildings for fiscal year 2009	NPS
Marquis, Fernand D.S.	2011	Carbon Nanotube Nanostructured Hybrid Materials Systems for Renewable Energy Applications	NPS
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Martin, Kevin M.	2014	A geographic and functional network flow analysis tool	NPS
McClellan, Mark R.; Kiper, Troy O.; Hughley, Anthony E.	2010	Batteries on the battlefield: Developing a methodology to estimate the fully burdened cost of batteries in the Department of Defense	NPS
McCown, Eddie E.	2014	Systems engineering technology readiness assessment of hybrid-electric technologies for tactical wheeled vehicles	NPS
McFaul, Jon P.; Rojas, Paulina S.	2012	Comparative cost-benefit analysis of renewable energy resource trade offs for military installations	NPS
Metlen, Tate	2014	LEED Construction and Performance Standards Mission Accomplishment	NPS
Miller, Scott E.	2012	Smart Voyage Planning Model Sensitivity Analysis Using Ocean and Atmospheric Models Including Ensemble Methods	NPS
Millsaps, Knox T.	2010	Integrated Electric Gas Turbine	NPS
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Mock, Philip J.	2012	Measuring Combat Logistics Force (CLF) Adequacy in Supporting Naval Operations	NPS
Monahan, Joseph	2013	Life-cycle cost modeling to determine whether vehicle-to-grid (V2G) integration and ancillary service revenue can generate a viable case for plug-in electric drive vehicles	NPS
Moreno, Matthew S.	2012	Modeling and assessment of alternative cooling methods of the Combat Operation Center	NPS
Morse, Matthew M.	2014	Assessing the operational robustness of the HOMER model for Marine Corps use in expeditionary environments	NPS
Newell, Brandon H.	2010	The evaluation of HOMER as a Marine Corps expeditionary energy pre-deployment tool	NPS
Nguyen, Vinh N.; Eddy, Daniel J.; Greenwald, Jonathan B.	2013	Use of Energy-efficient technologies: U.S. Marine Corps perceptions to adoption	NPS

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Orfanos-Pepainas, Stamatios	2011	Adaptive control and parameter identification of a doubly-fed induction generator for wind power	NPS
Oriti, Giovanna; Julian, Alexander L.; Zulaica, Dan	2011	Doubly fed induction machine drive distance learning laboratory for wind power and electric ship propulsion applications	NPS
Paradis, Jason D.	2014	An Assessment of Hydrogen as a Means to Implement the United States Navy's Renewable Energy Initiative	NPS
Pate, Chad P.	2010	Easing the Arctic tension an economic solution	NPS
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Pierce, Seth J.	2013	Reducing stator current harmonics for a doubly-fed induction generator connected to a distorted grid	NPS
Pifer, Ryan J.	2010	Modeling of the electric ship	NPS
Ponder, Jason K.	2012	Development and Analysis of a Bi-Directional Tidal Turbine	NPS
Porter, Wayne	2014	Looking Beyond Policy and Tactics: The Strategic Implications of Energy	NPS
Prato, Michael V.	2014	Reactive power compensation using an energy management system	NPS
Psallidas, Konstantinos; Whitcomb, Clifford A.; Hootman, John C.	2010	Design of a conventional submarines with advanced air independent propulsion systems and determination of corresponding theater-level impacts	NPS
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Reed, Matthew B.; McIntyre, Donald M.; Gatchalian, Nomer I.	2014	The use of social media to maximize energy performance in the United States Marine Corps	NPS
Regnier, Eva; Simon, Jay; Nussbaum, Daniel A.; Whitney, Laura K.; Regnier, Eva; Simon, Jay; Nussbaum, Daniel A.; Whitney, Laura K.	2013	The Fuel Multiplier in Multi-Stage Supply Chains	NPS
Robbin, Daryl	2011	Arctic Defense Concerns Reorganizing U.S. Defense Structure to Meet Threats in the Changing Arctic	NPS
Roth, George J	2012	Stability Analysis of a Constant Power Load Serviced by a Buck Converter as the Source Impedance Varies	NPS
Rydalch, Andrew J.	2014	Ignition delay properties of alternative fuels with Navy-relevant diesel injectors	NPS
Sachinski, Jeffrey M.; Cook, Rudolph W.; Matteson, Beth M.	2014	Budget savings through the responsible use of energy in Navy privatized housing communities	NPS
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