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Energy Security for Defense

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Presented at the
Western Economic Association International
83rd Annual Conference

Honolulu, HI

July, 2008

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Introduction

The Department of Defense (DoD) consumes more energy than any other organization in the world. With 250 major installations, 150,000 ground vehicles, 22,000 aircraft, and hundreds of ocean-going vehicles, the energy requirements to run the U.S. defense establishment are truly staggering. Although energy costs are at first glance relatively small as a share of total DoD costs (2.5% to 3%), there are significant additional costs of the logistics and other infrastructure required to deliver energy to the battlefield or to aircraft in flight.

The two main categories of total DoD energy use are petroleum based fossil fuel for mobility platforms (aircraft, tanks, ships, vehicles) and natural gas and electricity required to support infrastructure (buildings, facilities, airfields, etc.). Not surprisingly, over 75% of total energy cost consists of direct purchases of fuel for mobility platforms. Of the overall total, aircraft alone account for over 58%. The energy security issues relating to these two categories are quite different, require separate policy structures, and relate to different chains of management within DoD. DoD has already made significant improvements in the energy efficiency of its infrastructure, though more needs to be done. In particular, DoD facilities need better protection against interruptions in electricity supply, due either to natural disaster or an attack on the grid. However, there is probably more potential for improving energy security through improvements in efficiency and logistics for mobility platforms.

In addition to these direct energy requirements, there are sizeable indirect requirements for defense. The production of missiles, tanks, trucks and aircraft require energy, as does the production of the steel, aluminum, plastics and other materials needed to produce these defense goods. The production of electricity for DoD facilities generates indirect requirements of coal and natural gas. The total energy requirements of DoD, and their susceptibility to energy disruption, is larger than may appear from looking only at direct requirements. The interdependence of the DoD with the civilian economy implies that DoD energy issues need to be viewed in the context of national energy policy as a whole.

In this paper we will provide exploratory background material for the investigation of issues related to defense energy consumption. We compile and summarize available data on the consumption of energy by type and by end use. We develop a prototype model for calculating DoD energy consumption for buildings and tactical ("non-fleet") vehicles,

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[•] The findings and interpretations presented in this paper represent the views of the authors and do not necessarily reflect those of the Department of Defense.

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and calculating the cost of this energy consumption. We propose to do a preliminary survey of available fuel-saving technologies and alternative fuels that are feasible for DoD use, and make estimates of the possible oil import savings from these technologies and alternative fuels. This paper draws heavily on other recent studies of DoD energy consumption. We will briefly review some of those studies and their policy recommendations.

Section 1 of this paper will review the currently available data on DoD energy consumption as well as discuss some ways in which these data could be improved for the purpose of studying the impacts of efficiency improvements and uses of alternative fuels. Section 2 provides a brief review of some in depth studies of DoD energy consumption. Section 3 reviews potential policies and technologies that have been discussed for enhancing energy security, either through improving efficiency, reducing fossil fuel use, or by otherwise reducing the dependence of DoD on imported oil, as through production of synfuels or biofuels. In section 4 we develop a simplified model of DoD energy use, which also highlights some of the data constraints we face. In this section we develop a "business as usual" scenario, and compare it with a scenario that incorporates selected policy and technology assumptions. Section 5 concludes, and discusses how this modeling research could be extended.

1. DoD Energy Consumption

The supply of energy products to DoD agencies is handled by the Defense Energy Support Center (DESC), which is part of the Defense Logistics Agency. The DESC makes energy products available to its purchasers at a standard price, which is published on the DESC website. The use of this standard price helps agencies in planning for fuel costs. However, it often masks the true opportunity cost of using fuel, as it may be lower or higher than the market price. DESC publishes annually the DESC Fact Book, which includes information on sales of energy products by service, and by fuel type. In FY2007, the latest year for which data are currently available, the DESC sold about $13 billion of energy to the DoD services. The distribution of total energy by service is shown in Figure 1. (These figures are based on dollar net sales.) The Air Force is by far the largest user, at 52% of the total, followed by the Navy at 29%.

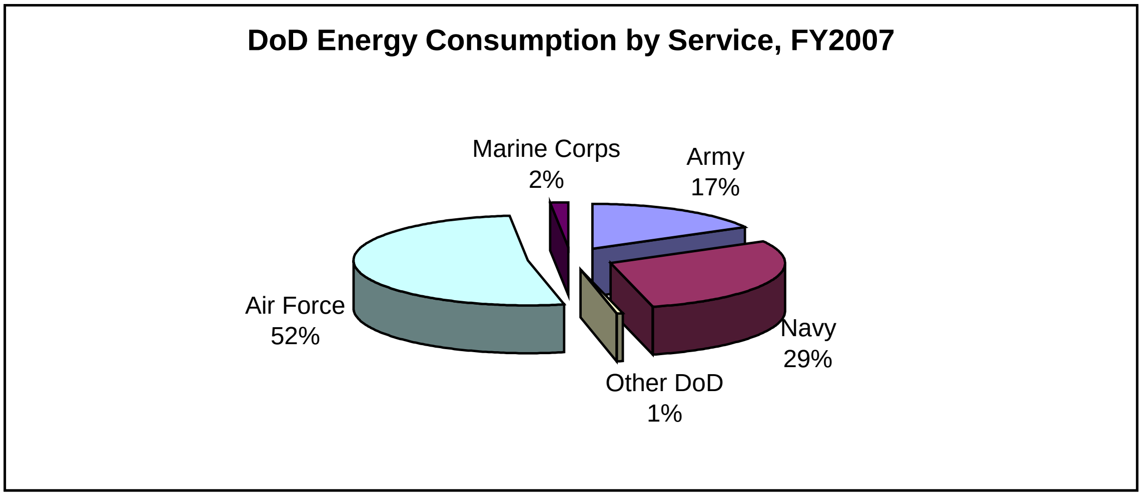

Figure 1

The DESC Fact Book also shows a table of total product cost by type of fuel. This table is reproduced at the back of this paper as Table 1. According to this table, total petroleum product purchases were about $11.5 billion in FY07, and about 73% of this total, or about $8.3 billion, was comprised of the various types of "jet" fuel.[1] Another significant component is Distillates and diesel, which made up about 17% of the total, or about $1.9 billion. The *Fact Book* also contains a lot of useful information on contract awards for intoplane fueling, bunkers, natural gas and electricity supply. However, what the *Fact Book* lacks is a comprehensive accounting of DoD fuel use, and the data in the book are only available in PDF.

Another source of data on DoD energy consumption is the *DoD Annual Energy Management Report* (AEMR), and its accompanying *Energy Management Data Report* (EMDR). Executive Order 13123 and the Energy Policy Act of 2005 (EPACT) require federal agencies to track and reduce their energy use in buildings and facilities. So, along with the other federal agencies, DoD submits energy consumption information in the AEMR. The main table from this data report is reproduced as Table 2 at the back of this paper. The EMDR has a more comprehensive accounting for energy used in buildings than the *Fact Book*. It groups buildings into EPACT Goal Subject Buildings and EPACT Goal Excluded Facilities. Total energy use of buildings in 2007 was about $3.4 billion, of which about $3.2 billion was in Goal Subject facilities. The largest component of buildings and facilities energy expenditures was electricity, at $2.2 billion, followed by natural gas, at $622 million. The other two tables contain data on "non-fleet" vehicles (which are also known as tactical vehicles) and partial data on fleet vehicles (passenger cars, buses, trucks, ambulances, etc.) Total fuel consumption by non-fleet vehicles was $9.5 billion, of which jet fuel was the largest, at $7 billion. This was followed by "Navy Special" at $1.3 billion, and Diesel-distillate at $1.0 billion. Expenditures on fuel for

[1] Although primarily for jet aircraft, these fuels also are used for many combat and other ground mobility vehicles.

fleet vehicles seem surprisingly small, at only $247 million. Total energy use by DoD for buildings, fleet vehicles and non-fleet vehicles comes to a total of $13.2 billion.

The data in the EMDR are more comprehensive than the *Fact Book.* However, a consistent time series of data is not available, as definitions for buildings changed in FY06, and this source has only summary coverage for fleet vehicles.

More detailed coverage for fleet vehicles can be found in the GSA *Federal Fleet Report*. This annual report contains data on vehicle inventory and vehicle acquisitions by type and by agency, vintage of vehicles, and fuel cost by type. Unfortunately, fuel consumption in this document is available by dollar value only, not by quantity. The total dollar figure agrees with that provided in the EMDR, $247 million for FY07. These data are reproduced as Table 3.

The Department of Energy's *Annual Report to Congress* on Federal Government Energy Management and Conservation Programs has data on energy consumption in Federal buildings, operations and vehicles. Particularly interesting is table 6, which contains data on Federal petroleum usage in Bbtus and Petajoules, broken down by DoD and civilian uses (Bbtus only), by type of fuel.

Finally, the DOE *Annual Energy Review* (AER) provides time series of U.S. Government energy consumption by agency (table 1.11), U.S. Government energy consumption by source (table 1.12) and U.S. Government energy consumption by agency and source (table 1.13, for two years only). These data are available in trillions of Btus only. Table 1.13 is reproduced at the back of this paper as Table 4.

Although it is useful to have these several alternative sources of data on DoD energy consumption, none of them are fully adequate for a study to determine consumption and cost impacts of energy security policies and technologies. Ideally, it would be desirable to have the detailed AER table available in quantity units (gallons, Mwh, etc.) and in dollars as well as in Btus, and to have a time series, instead of just two years of data. Furthermore, the petroleum usage data in the DESC Fact Book disagrees somewhat with the DOE data, for various reasons, so one needs to be cautious in taking quantity or dollar figures from the DESC.

2. Studies of DoD Energy Use

As fuel and other energy costs have risen in recent years, DoD has become more cognizant of the need to understand the determinants of the department's heavy requirements of fuel and other energy, and to explore ways to reduce energy use. Furthermore, a consensus has arisen that in addition to doing its part to reduce U.S. dependence on foreign oil, a more effective and economical use of fuel can lead to a more flexible and effective fighting force. Some general conclusions of these studies are:

1. DoD will continue to be heavily dependent on petroleum-derived fossil fuels, but this dependence can be mitigated by pursuing a portfolio of technology and alternative fuel options;
2. More realistic appraisal of the "fully burdened" cost of fuel is important for appropriately evaluating design and retrofitting decisions; and

3. Rethinking of organization and logistics is crucially important.

One of the earliest DoD studies on fuel use was conducted by the Defense Science Board (DSB) in 2001.[2] One of the main focuses of this study was to understand the fully burdened cost of fuel. For example, some estimates indicated that in 2001 the cost of fuel delivered to a tank on the battlefield was on the order of $400 to $600 per gallon. Fuel delivered to other battlefield vehicles and generators is also much more expensive than the cost of fuel alone. Their fuel multiplier appears to be in the neighborhood of 16 to 20 gallons used for each gallon of fuel delivered. Large multipliers are also applicable to intoplane fueling.

Here are some interesting facts: Over 70% of the tonnage required to get today's Army into battle is fuel. The Air Force spends a large part of its fuel budget on airborne tankers to deliver fuel to fighters and other final users. Some of the top fuel guzzlers in the battlefield carry fuel and supplies. Over half of the fuel transported to the battlefield is used by support vehicles. The army has 40,000 troops involved in either the distribution or movement of energy.[3]

One of the main findings of this study was that the full logistics and cost benefits of fuel efficiency are not emphasized in the DoD requirements and acquisition process.[4] Another important finding was that DoD prices fuel based on the wholesale refinery price, and does not include the cost of delivery to its customers. The third finding was that the DoD resource allocation and accounting processes do not reward fuel efficiency sufficiently. Finally, the report found that there were existing fuel efficient technologies currently available, but their adoption required accurate weighting of fuel costs in the decision process.

In 2006 the office of the Director, Defense Research and Engineering (DDR&E) asked the JASON group at the MITRE corporation to assess ways in which DoD could reduce demand for fossil fuels using advanced technology.[5] However, Air Force fuel usage was excluded from the study.

The general tone of the findings in the JASON study is less forceful about the need to improve fuel efficiency than the DSB study. The main findings were:

1. Although DoD fuel costs are high, they are only about 2.5-3% of the overall budget, and should not be a primary decision driver. Although not focusing on aircraft, they also noted that the number of DoD aircraft is expected to significantly decline in the next few years, reducing fuel use.

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[2] U.S. Department of Defense, *More Capable Warfighting Through Reduced Fuel Burden*, 2001. Interestingly, Amory Lovins of the Rocky Mountain Institute, was a member of this study team.

[3] Sohbet Karbuz, "U.S. Military Energy Consumption – Facts and Figures", at http://karbuz.blogspot.com. These are selected figures from the 2001 DSB study highlighted in his article.

[4] An example of this is provided below, in the discussion of the B-52 re-engining cost/benefit analysis.

[5] JASON, *Reducing DoD Fossil-Fuel Dependence*, September 2006.

2. The technologies that show the most near-term promise for significant fuel savings are light-weighting and modernizing diesel engines. Not much use was seen at present for hybrids, electric or fuel-cell vehicles. For light-weighting, the JASON study recommended decreasing the weight of manned vehicles and using more unmanned vehicles.
3. Since the DoD uses less than 2% of the total oil consumed in the U.S., it is not large enough to drive the market for alternative fuels. However, DoD may still play a significant role in testing, certifying and demonstrating the use of synthetic fuel. The JASON team decided that ethanol was not suitable as a DoD fuel due to its low energy density and high flammability.

The Energy Security Task Force was formed in spring 2006 to examine the issue of energy security, devise a plan for lowering DoD's fossil fuel requirements, identify alternate energy sources, and to examine past studies to explore DoD's policy options.[6] This effort was led by the DDR&E. The presentation delivered by the task force did not include a written report, and comprised three recommendations:

1. *Increase weapon platform fuel efficiency*. This should be done by: incorporating energy efficiency considerations into acquisition decisions; developing more efficient propulsion systems, power generators and machinery; and developing more lightweight vehicles.
2. *Accelerate energy efficiency initiatives for military installations*. This goal should be met by: meeting or accelerating current energy efficiency goals for military installations; improving the energy efficiency of installation-based non-tactical vehicles; and expanding Energy Conservation Investment Program (ECIP) and Energy Saving Performance Contracts (ESPCs).
3. *Establish an alternative fuels program.* –The goals are to further develop and test synthetic and alternative fuels for military weapons systems; to measure and assess DoD's progress in alternate fuel use, and to develop incentives programs for the alternative fuels industry.

In April 2007, LMI completed a study commissioned by the Office of Force Transformation and Resources, entitled *Transforming the Way DoD Looks at Energy*.[7] According to its authors, the main contributions of the study were to identify three areas of disconnect between DoD's current energy practices and the capability requirements of its strategic goals:

1. *Strategic* – Dependence on foreign suppliers of oil limits our flexibility in dealing with producer nations, who may hinder or oppose our goals.

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[6] Al Shaffer, "DoD Energy Security Task Force", May 2007.

[7] Thomas Crowley et al, *Transforming the Way DoD Looks at Energy: An Approach to Establishing an Energy Strategy*, April 2007.

2. *Operational* – DoD needs greater mobility, persistence and agility. However, fuel logistics requirements limit these capabilities.
3. *Fiscal* – DoD needs to reduce operating costs. However increased energy consumption and energy costs imply that energy-associated costs are growing.

The study also mentioned the importance of reducing DoD-related greenhouse emissions. The report concludes that DoD needs to fundamentally change how it views, values and uses energy. To implement the necessary transformation, the study suggests:

- Incorporate energy considerations into the department's key corporate processes: strategic planning, analytic agenda, joint concept and joint capability development, acquisition, and planning, programming, budgeting and execution (PPBE).
- Establish a corporate governance structure with policy and resource oversight to focus the department's energy efforts.
- Apply a structured framework to address energy efficiency.

Much of the material in this report is not new, and many of the recommendations are unclear in their specifics. For example, the study makes strong recommendations for increased use of biofuels, but does not offer specifics of how to overcome objections to those fuels already discussed in the JASON study. It also suggests that the department follow the recommendations for buildings of a 3% annual reduction in energy requirements to mobility operations, without any logical support of why this rate of increase is feasible or optimal.

This study contains a useful and informative set of appendices, including a list of legislative and executive orders relating to energy (Appendix C), a list of DoD Energy Initiatives (D), a survey of technologies (E), and an interesting and heuristic study of energy savings estimates for mobility operations (G).

In June, 2007, the Congressional Research Service delivered a report to Congress on reducing fossil-based aviation fuel.[8] This study reviewed many of the earlier studies, focusing particularly on issues relevant to jet aircraft efficiency. Table 1 in that report contains data on representative aircraft fuel consumption, provided by the Air Force. The report highlights the fact that aviation fuel should be a primary target in reducing the reliance on fossil fuels, as aviation use of fuel accounts for the largest share of use within the department. Although there exist several methods for reducing fuel use, they can generally be placed in two categories: 1) increasing the use and supply of alternative fuels; and 2) decreasing the demand for fuel overall. For the first category, some options include synthetic fuels from coal or natural gas, biofuels and fuel cells. In the second

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[8] Kristine Blackwell, *The Department of Defense: Reducing Its Reliance on Fossil-Based Aviation Fuel – Issues for Congress*, June, 2007.

category fall the various options for incrementally increasing the efficiency of aircraft, including re-engining and winglets.

The report is a useful survey of the various technologies and issues in the adoption of alternative fuel sources and method to increase efficiency. The general conclusion is that the options are limited, and not likely to have a large impact in the near-term. The paper concludes with a discussion of organizational and policy changes within DoD that could help with management of the department's energy reduction efforts. It suggests six options for Congress:

1. Mandate the establishment of a DoD Office of Energy Security. This office would put in place clearer lines of authority for the department's various energy-related initiatives.
2. Mandate fuel efficiency in aircraft. Precedent exists in the mandated requirements for buildings and facilities in the 2005 Energy Policy Act.
3. Mandate fuel efficiency as a consideration in new DoD acquisitions. Energy efficiency would be mandated as a key performance parameter (KPP) in all new DoD acquisitions.
4. Amend Title 10 to allow DoD to enter into contracts for synthetic fuel beyond five years.
5. Direct DoD to devote more funding to research and development of long-term alternative energy sources for aviation.
6. Mandate alternative fuel use.

DoD Energy Initiatives

Within the department, DoD has undertaken several initiatives to address energy security:

The OSD Assured Fuels Initiative is a multi-service/agency effort undertaken through USD (AT&L), intended to support production of clean fuels for the military by commercial industry. The key objectives of this initiative are: 1) to form partnerships with industry, academia and civil agencies to encourage development and investment in energy resources; 2) to develop a transition plan for introducing and using alternative energy DoD-side; and 3) to review the use of fuels in all tactical vehicles, aircraft and ships, and develop specifications for fuel with non-petroleum components.

The Energy Security IPT is a task force with representatives from the military services, defense agencies and U.S. Transportation Command, with the following goals: 1) to define an investment roadmap for reducing DoD's fossil fuel requirements and to develop alternative fuels; 2) present findings on the total delivered cost of fuel to DoD platforms; 3) prepare proposals to improve efficiency of DoD platforms; and 4) develop recommendations to enable the production and use of alternative fuels. One of the main overarching objectives of the IPT is to reduce dependence on foreign oil.

The Energy Conservation lecture series has been cosponsored by the USD (AT&L) and the Deputy Assistant Secretary of Defense for Forces, Transformation and Resources. The purpose of this series, started in March 2006, is to engage leaders across the government and other sectors in a dialog about energy as a national security issue. Each month, a speaker is invited to lead a conversation on an energy related topic.

The Defense Science Board Task Force on Energy Strategy is comprised of senior DoD civilians and representatives outside DoD. It was commissioned to identify opportunities to reduce fuel demand by deployed forces, and assess the effects on cost, operations and force structure; identify opportunities to deploy renewable and alternative energy sources for facilities and deployed forces; identify institutional barriers to making the transitions recommended by the Task Force; identify and recommend programs to reduce facility energy use, and identify the potential national benefits from DoD deployment of new energy technologies. It released its report this February.[9] The report identified two main energy challenges: 1) operations suffer from unnecessarily high, and growing, battlespace fuel demand; and 2) military installations are almost completely dependent on a fragile and vulnerable commercial power grid, placing critical military and Homeland defense missions at unacceptable risk of extended outage. Other key findings, listed in chapter 6, include:

- The recommendations of the 2001 DSB Task Force Report have still not been implemented.
- The Department lacks the strategy, policies, metrics, information or governance structure necessary to properly manage its energy risks.
- There are technologies now available to make DoD systems more energy efficient, but they are undervalued, slowing their implementation and resulting in inadequate investments.
- There are many opportunities to reduce energy demand by changing wasteful operational practices and procedures.
- Operational risks from fuel disruption require demand-side remedies; mission risks from electricity disruption to installations require both demand- and supply-side remedies.

The report also contains a detailed list of recommendations for installations and facilities and a list of recommended technologies to explore for increasing the efficiency of mobility platforms.

The next section reviews several of the technologies that have received considerable attention within the DoD energy security debate.

3. Technologies and Practices for Enhancing Energy Security

Installations and Buildings, Renewable Power

Currently, about 25% of the total energy requirements of DoD are used in installations and buildings. Although the department has come under criticism for focusing more resources on improving efficiency in this area than in the much larger consumption of

[9] U.S. Department of Defense, *More Fight – Less Fuel*, February 2008.

fuel for mobility platforms, installations and buildings are an important component of overall DoD energy strategy. DoD occupies about 1.95 billion square feet in over 545,000 facilities comprising more than 536 installations and spent over $3.4 billion on facility energy consumption in FY 2007.[10]

Between 1985 and 2006, DoD's total site delivered energy consumption declined more than 60%.[11] Energy consumption in buildings and installations went down, but much of this was due to closure of military bases, privatization and outsourcing. Total energy efficiency gains over that period have been on the order of closer to 30%.

The DoD has been driven to increase energy efficiency in buildings in part due to several pieces of legislation and executive orders.

- The Energy Policy Act of 1992 promulgated a comprehensive federal energy policy to reduce facility energy usage by 25% by 2000.
- Executive Order 13123 ("Greening the Government Through Efficient Energy Management", June 1999) directed consolidated energy reporting, extended energy and greenhouse reduction goals through 2010, and encouraged procurement of energy-efficient products and expanded renewable energy use. This order included a mandated energy reduction goal of 35% by 2010.
- Presidential Memorandum, "Energy Conservation at Federal Facilities" (2001) directed heads of executive departments and agencies to conserve energy use at their facilities, and identify and implement ways to reduce energy use.
- The Energy Policy Act of 2005 (EPACT05) established the latest national policy on energy and a new energy baseline (2003).
- Executive Order 13423 ("Strengthening Federal Environmental, Energy and Transportation Management", January 2007) modified the annual energy reduction requirement to 3% per year, or 30% by 2015.

There have also been several internal DoD memos and guidance on reducing energy use at facilities.

Progress on attaining the goals set forth in EPACT05 and Executive Order 13423 is described in the *DoD Annual Energy Management Report*. In addition to the goals described above, the mandates specify that the percentage of renewable energy reach a level of 7.5 percent by 2013, require increased energy efficiency of new construction to 30 percent above the current standard, and required metering electricity consumption of all facilities.

The National Defense Authorization Act of 2007 codified a 2005 DoD goal to produce or procure renewable energy equivalent to 25 percent of facility electrical consumption by 2025. The total renewable energy that the Department produced or procured in FY 2007

[10] Office of the Deputy Under Secretary of Defense, Installations and Environment, Energy Home, at www.acq.osd.mil/ie/irm/Energy/energy.shtml.

[11] DOE, *Federal Energy Management Report*

amounted to 12,054 trillion Btu and already represents 5.5 percent of the facility electrical consumption.

In the area of renewable energy generation, DoD is spearheading several new initiatives. The Air Force is the largest renewable energy power purchaser in the U.S. and the third largest in the world. With respect to solar energy, Nellis Air Force Base (NV) awarded a contract in July 2006 to build the world's largest photovoltaic array in the world. The array will have a capacity of a minimum of 15 MW and provide a third of the base's power needs. Solar power can also contribute to supporting operations in desert regions of the world and to economizing on the operation of diesel-powered generators. The two main challenges of solar power include its relatively high cost and inefficiency.

The Navy Shore Energy Office is currently working on their fourth geothermal production project. The first one, at China Lake, generates 270 MW, enough to power 180,000 homes. The U.S. Navy is also operating the largest wind/diesel hybrid plant in the world in Guantanamo Bay.

The combined effect of continued building efficiencies, higher efficiency standards for new buildings, and the use of more renewables will be a decrease in electricity purchases from the power grid, and in many cases, a more secure electricity supply.

Synthetic Fuels

Interest in synthetic fuels or Fischer-Tropsch diesel (F-T) fuels has increased in recent years because of their potential to displace imported petroleum. Synthetic fuels are created when gaseous fuels such as natural gas or biogas are converted to liquid fuels that can be refined into gasoline and diesel. Synthetic fuel is generally designed to behave much like conventional fuel, so that little or no changes are needed in the equipment that uses it or the infrastructure for storing and distributing it.

In September 2006, DoD successfully tested a 50-50 blend of synthetic fuel (made from natural gas) and conventional fuel in a B-52 bomber. Synthetic fuel blends were also tested in a C-17 Globemaster. In March of this year, synthetic fuel was tested in a B-1B Lancer which became the first USAF aircraft to fly at supersonic speed using a synfuel blend. In April, engineers began testing synthetic fuel in the Pratt & Whitney F100 engine, which is the power plant for the F-15 Eagle and F-16 fighting Falcon. Although the Air Force paid about $20 a gallon for the fuel used for these tests, it is generally agreed that costs will come down considerably as larger scale production takes place.

In 2007 the Air Force bought over 200 thousand gallons of synthetic fuel, derived from natural gas. The Air Force currently plans to have half of its aviation fuel come from domestically supplied alternative fuel sources by 2016, through coal-to-liquid derived synthetic fuels.

Despite their current high cost, synthetic fuels also present environmental drawbacks, due to their production process. Without carbon sequestration (which is not yet technologically ready) the coal-to-liquid process produces twice as much CO2 as petroleum-based fuel. Even when carbon sequestration is ready, it would increase production costs by 25 to 40 percent. Because of the high capital cost of producing synthetic fuels, few companies can guarantee production of the large quantities DoD will need without a long-term contract.

The effects of adopting synthetic fuels if successful will be: 1) reduced petroleum imports; 2) increased carbon emissions; and 3) increased average fuel cost to DoD, at least in the near-term.

Use of Ethanol and Other Biofuels

Ethanol has experienced a boom in the last five years. From a level of production of 2 billion gallons in 2002, production grew to 6.5 billion gallons in 2007 and is expected to reach close to 8 billion gallons in 2008. Most of this ethanol is currently produced from corn, but this feedstock will probably reach its limit at about 15 billion gallons, which is expected to occur before 2015. With advances in technology, cellulosic ethanol (produced from corn stover, switchgrass and other woody plant materials) is expected to become economical, reaching a billion gallons perhaps by 2010 or 2011. Pilot cellulosic plants are already producing small quantities of fuel.

The advantages of ethanol are that it reduces dependence on oil imports, provides oxygenates for cleaner burning (reducing toxic emissions such as carbon monoxide), and reduces overall carbon emissions. The disadvantage of ethanol, at least in high concentrations such as E85 (85% ethanol, 15% gasoline), is that it requires special storage and distribution facilities, as well as retrofits to vehicles that use it. As pointed out in the JASON study, it is unsuitable as a battlefield fuel due to its high volatility, special handling requirements, and low energy density (only 2/3 of gasoline).

Biodiesel is produced from oil crops such as soybeans and rapeseed. It is also currently being produced in small quantities from waste oil from restaurants and food processing plants. Biodiesel is most often blended with standard diesel as B20 (20% biodiesel, 80% diesel). The DESC has been the single largest purchaser of B20 biodiesel, and the U.S. Navy is the largest single user.

Neither ethanol nor biodiesel are a suitable replacement for jet fuels. Ethanol does not have enough energy density, and biodiesel solidifies at low temperatures that exist at high altitudes.

Another biofuel that may prove interesting is biobutanol. It is made in a process similar to that of ethanol, but uses a bacteria rather than yeast to produce fuel via a sugar fermentation process. Biobutanol has a higher energy content than ethanol, and is less corrosive. Biobutanol facilities are expected to be producing fuel for commercial sale by 2010. If used by DoD, it would probably be limited to nontactical vehicles.

The DARPA Biofuels Program is seeking a bio-based alternative to petroleum-based JP-8 fuel. So far, the program has issued a broad agency announcement to produce a surrogate for JP-8 from oil rich crops, which can ultimately serve as an affordable alternative to JP-8.

The total use of ethanol, biodiesel and other biofuels is likely to be relatively small. However, DoD has already made significant investments in converting fleet vehicles and certain special purpose vehicles to run on B20 or E85.

Aircraft Re-engining

In 2007, the Air Force tasked the National Research Council with examining and assessing options for improving the engine efficiency of all large nonfighter aircraft in the force. In their study, they found three key recommendations to reduce oil consumption of nonfighter aircrafts by engine modifications and re-engining.

1. The Air Force should purse re-engining the C-130H since this aircraft is one of the largest users of fuel in the Air Force inventory. Engine models between the AE2100 and PW150 appear to be acceptable on a technical and performance basis to replace the current engine, T56.
2. There exist commercial engine/airframe counterparts for many nonfighter aircrafts (KC-10/DC-10, F1-3/CF6-50, KC-135/B-707, TF33/JT3, F-108/CFM56, etc). This should be closely monitored the engine's original equipment manufacturers' and commercial operators' activities and actions relative to re-engining and engine modification as a measure of the cost/benefit for these activities.
3. For the C-17/F117 system, the Air Force should conduct an engine model derivative program study with Boeing and Pratt & Whitney to determine possible fuel savings, implementation costs, and a schedule that would give the best return on investment for the Air Force.

"Light-weighting" of Vehicles and Aircraft

Another way to increase the fuel efficiency is to use light weight composite materials on DoD platforms. Lighter vehicles can travel faster on less fuel. DoD has been striving a low-cost titanium alloy to replace the heavy steel used in many weapon systems. Titanium is valued for military applications because of its high strength-to-weight ratio and its resistance to corrosion. However, due to its high cost of $30 per pound, it is only used for select aviation and space applications. Currently, DARPA is sponsoring a program to develop an environmentally friendly production capability for a titanium alloy under $4 per pound.

Additionally, using more unmanned aerial vehicles (UAV) is another way to reduce fuel consumption. Advantages of using UAVs are not only fuel efficient but also decrease the chance of putting a service member in danger and are low-cost relative to the manned systems. However, UAVs do not offer human judgment and flexibility of on-scene human operators.

Options for Navy Ships

Although not as large an energy consumer as aircraft, fuel consumption by navy ships is still significant, with roughly 700 million gallons of fuel consumed in FY2007, at a cost of $1.3 billion. This section discusses options that have been proposed for reducing fossil fuel consumption on ships. A 2006 CRS Report identified and proposed several propulsion technologies for reducing oil use, and provided estimates of the expected fuel savings.[12] These proposed technologies are summarized below:

- *Retrofitting to reduce hotel loads* – Estimates suggest that up to 30% of the Navy's non-aviation fuel use is for generating power for hotel loads (HVAC, lighting, other electrical power). This could be reduced by retrofitting motors, pumps, fans, chillers, lights and potable water systems. This could yield overall fuel savings of 10-25 percent on a large ship.
- *Bulbous bows, stern flaps and propeller coatings* – A bulbous bow reduces a ship's wavemaking resistance, and can be expected to reduce fuel use by 4-5 percent. A stern flap is a relatively small plate that extends behind a ship's transom, reducing a ship's resistance. Preliminary tests indicated a 6-7.5 percent energy savings. Applying special propeller coatings to navy ship propellers may reduce ship fuel use by 4-5 percent.
- *Higher-Efficiency Gas Turbines* – Gas turbines with greater efficiencies than the simple-cycle turbines currently used could reduce fuel use by 25-30 percent.
- *Integrated Electric-Drive Propulsion* – An integrated propulsion system permits a ship's single combined set of turbines to be run more often at their most fuel-efficient speeds, for a savings of 15-20 percent.
- *Fuel Cells* – Fuel cell technology is very promising for naval applications, and will probably enter into acquisition in the 3-5 year time frame.
- *Nuclear Propulsion* – Submarines and carriers are already powered by nuclear propulsion. A 2005 "quick look" analysis by the Naval Nuclear Propulsion Program found that large-deck amphibious assault ships and large surface combatants could economically be converted to nuclear, at oil prices of $70 and $178 per barrel, respectively.
- *Wind Sails and Kites* – These technologies have already been adopted on a few commercial ships, with up to 50% savings in fuel consumption.

It is not clear at present what mix of these technologies the Navy will choose to adopt. With the current high oil price, many more of these technologies generate clear cost savings. The Navy has a stated goal of 30% overall energy usage reduction by 2015, but this total is for buildings and installations, ships, aircraft and other vehicles.

4. Modeling DoD Energy Consumption Savings

In this section we present a prototype defense energy consumption model for evaluating the effects of several of the energy saving technologies and practices described in the previous section. This prototype is linked to the Inforum LIFT (Long-term Interindustry Forecasting Tool) model of the U.S. economy, which is a detailed interindustry macro

[12] See Ronald O'Rourke, *Navy Ship Propulsion Technologies: Options for Reducing Oil Use – Background for Congress*, Congressional Research Service, December 2006.

model. The LIFT model forecasts output, employment, prices and many other variables for nearly 100 industries, and shows their interrelationships (i.e., who buys what from whom). The LIFT model contains fairly detailed accounting for the federal defense sector, showing which industries are impacted by 25 different categories of defense spending. The LIFT model is used already by DoD as one component of DEPPS (the Defense Employment and Purchases Projections System), along with the *Iliad* (Interindustry Large-scale Integrated And Dynamic) model which provides 360 industry detail consistent with LIFT.[13]

This prototype model works by relating energy consumption in units (gallons, Kwh, tons, etc.) to indicators of use (square feet, flying hours, number of ships, etc.), with efficiency coefficients that summarize the effects of technological efficiency or conservation achievements. The model uses LIFT price drivers to estimate the future prices of electricity, coal, gas and petroleum products, so that dollar values of spending can be calculated.

The modeling exercise we perform consists of two cases, with projections out to 2020:

1. *Base*: No change in efficiency – Efficiency for buildings, aircraft, ships and vehicles will be held at their current levels.
2. *Policy*: Policy and technology change – Policy and technology changes are implemented, as described below.

Buildings, Installations and Renewable Energy. The DOE *Annual Energy Management Report* divides buildings and installations into three categories: 1) Standard buildings; 2) Energy intensive facilities; and 3) Exempt facilities. The last year available for this report is FY05. In this year, total federal expenditures were $4.3 billion for standard buildings, with $2.5 billion spent by DoD. Total expenditures for energy intensive facilities was $927 million, of which $294 million was spent by DoD. The energy used in exempt facilities was about 2.9% of the total energy bill, or about $416 million for the total Federal government.

Standard buildings site-delivered energy is by far the largest component of total energy use. The table below shows the result of the combined effects of square feet and energy use changes between 1985 and 2005, resulting in a 28% energy efficiency improvement.

Part of the overall decline in building energy use between 1984 and 2005 has been the sheer decline in gross square feet. The average annual decline over that period was about 0.65 percent per year. In the two forecast cases, we assume that the decline in gross square feet continues, but at a slowing rate, flattening by 2013.

[13] See Meade (2001) for a description of the LIFT model, and Meade and Lile (2002) for more information on DEPPS.

DoD Site-Delivered Energy Use in Standard Buildings and Energy Intensive Facilities							
	FY1985			FY2005			%Change 1985-2005
	Gross Square Feet (thous)	Billion Btu	Btu/GSF	Gross Square Feet (thous)	Billion Btu	Btu/GSF	
Standard Buildings	2,224,527	304,190	136,744	1,953,859	191,870	98,201	-28.2
Energy Intensive Facilities	183,779	39,209	213,349	158,230	26,459	167,221	-21.6

Source: Federal Agency Annual Energy Management Data Reports

The assumptions for standard buildings for the policy case are simple: a 3% annual increase in overall efficiency in goal subject buildings until 2020. This assumption is consistent with the goals set forth in E.O. 13423. We maintain detail in the model at the level reported in the DoD *Energy Management Data Report*. We also assume that DoD reaches a target of 20% of all electricity used by military facilities to be supplied by renewables by 2020.[14]

Aircraft – To accurately model the consumption of fuel by aircraft in detail, one needs to know (or estimate) the approximate annual hours of flight time of each type of aircraft and the average gallons of fuel per hour consumed. We also need assessments of which types of aircraft are susceptible to fuel efficiency improvement, by how much, at what date, and what share of the fleet will be upgraded. Finally, we would need to know how many aircraft of each type are in the fleet inventory in future periods.

Although we have not been able to construct a full database, we put together an initial version, consisting of aircraft listed in the Active Duty Inventory of the Air Force Almanac. Table 5 shows a summary of these data for FY 2006, listing the major types of aircraft in the inventory by broad type (bomber, fighter, transport, etc.). Flying hours were adjusted to reach a total close to that reported in the Almanac. After making these adjustments, total fuel use for 2006 came to a total of about 2.6 billion gallons, which is close to the published figure.

Very rough projections of future fleet size were made using figures from the CBO study, *The Long-term Implications of Current Defense Plans.*[15]

To model efficiency changes, we first make assumptions for USAF Aircraft, that certain models of aircraft such as the C-130, B-1, B-52 undergo re-engining. Table 6 shows a list of these aircraft, and the percentage increase in fuel efficiency expected.[16] Total fuel

[14] The current share is about 12%. The Pentagon has stated that it plans to raise that share to 25% by 2025.

[15] CBO, March 2008. Unfortunately, the authors of this report have communicated that they are unable to make these data available in electronic form, or even in tables.

[16] Based on data in *Improving the Efficiency of Engines in Nonfighter Aircraft*, NAS, 2007.

savings, based on the calculation in Table 5 (for FY2006) is 181 million gallons, or about 7 percent of total fuel use. For the policy case, we assume that re-engining upgrades will have been completed on all aircraft of these types by 2015. We also assume that through the adoption of winglets on selected aircraft, there will be another 0.5 percent of fuel savings by 2015. Finally, we assume an additional constant 1% per year fuel efficiency gain applicable to the entire fleet, based on the current and expected high price of fuel, and the energy saving goals of the Pentagon. These savings are assumed to continue to accrue throughout the projection period.[17]

We have not yet been able to gather as much detailed data on Navy aircraft as for the Air Force. Therefore, we assume that the rate of fuel efficiency improvement of Navy aircraft is comparable to Air Force aircraft.

Ships – For the policy case, we assume that technologies in section 3 will be adopted at such a rate as to achieve a 30 percent increase in fuel efficiency by 2015. After 2015, we assume the efficiency increases to continue at that rate.

Tactical Vehicles – For the policy case, we assume a 3 percent annual improvement in the efficiency of tactical vehicles, due to lightweighting, adoption of hybrid electric technologies, and retrofitting to reduce hotel loads in tanks and ground combat vehicles.

Fleet Vehicles – We have not yet made assumptions about fleet vehicles at this stage of the study. While important, and generating a lot of public interest, they still comprise a relatively small share (1.9%) of total energy consumption by the DoD..

Synthetic fuels: We follow the USAF's stated policy goal of achieving 50% of CONUS consumption from a 50/50 synfuel/jet fuel mix by 2016. While not counting as fuel efficiency *per se*, the adoption of synthetic fuel reduces U.S. requirements for imports of crude oil.

Simulation Results

Model variables were calculated to be consistent with data presented in the *Energy Management Data Report (EMDR).* Table 7 shows the results for buildings and installations. In these tables, projections for goal subject buildings and goal excluded buildings are combined. The table shows annual cost (millions of $), btus (billions), consumption (quantities), and the projected energy prices by energy type for buildings. For each variable presented in the table, the first line shows the value in the base case in levels, and the value for the policy case as a difference from the base.

Total annual cost for buildings and installations is projected to be $4389.2 million in 2020, and to be $1335.1 lower in the policy simulation. This is roughly 30% lower total cost than the base case, and is simply a reflection of the assumption of 3% annual efficiency improvements relative to the base case. Note that price projections were made

[17] Note that this rate of fuel efficiency improvement in aircraft is smaller than the 3% annual increase assumed in the Appendix G of the LMI Study, *Transforming the Way DoD Looks at Energy.*

by starting with the price by energy type in the *EMDR* for 2007 and moving it forward by the growth rate of the corresponding energy price projected in the LIFT model.[18]

The percent of electricity obtained from renewables is assumed to remain constant in the base at 12%[19], but to rise to 20% by 2020 in the policy case. This results in a reduction in consumption of non-renewable (coal, natural gas) electricity of 9.4 million Mwh by 2020.

Results for non-fleet (tactical) vehicles are shown in Table 8. The first block of the table shows the assumptions used to arrive at fuel consumption by Air force aircraft. Assumed efficiency improvements show up in the line "Avg. gallons/hour". With these assumed improvements, the Air force uses about 504 million gallons less fuel in 2020, and its fuel budget declines by $1.1 billion. Consumption in the base case was a total of 2.3 billion gallons, at a cost of about $5.1 billion.

The second block of table 8 shows DoD consumption in gallons by type of fuel. Purchases of jet fuel, the largest category, are divided into Air force, other aircraft (Navy, Marines and Army), and other jet fuel. Synthetic fuel purchases by the Air force are estimated and shown on a separate line. Total jet fuel use reaches 3.2 billion gallons in the base, but is 709 million gallons lower in the policy case. The Air force is projected to buy 453 million gallons of synthetic fuel by 2020 in the policy case.

Navy consumption of fuel for ships reaches 745 million gallons by 2020 in the base case. The policy case shows a savings of 335 million gallons by 2020, or a savings of about 45%.[20]

Total requirements of petroleum based fuels reach a total of 4.4 billion gallons in the base, and are lower by 1.6 billion gallons in the policy case. This translates into 39.2 million barrels less of crude oil requirements for the U.S.

Total annual cost of fuel for tactical vehicles is projected to be $9.6 billion in the base case, and to be $2.6 billion lower in the policy case, a total savings of 26%.

5. Conclusions and Proposal for Further Work

This paper has described the state of DoD energy consumption, reviewed some of the major energy policy issues facing DoD, and discussed policy and technology options available for reducing energy use.

We have developed a small prototype model of DoD energy consumption, based on the aggregate data in the *Energy Management Data Report*. We have adopted assumptions

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[18] This simulation of LIFT was calibrated to the March, 2008 version of the DOE/EIA 2007 *Annual Energy Outlook.*

[19] DoD has already significantly increased the share of renewable energy, and this trend is expected to continue. However, our modeling strategy is to compare a "base case", with no change in energy efficiency, renewables, or synthetic fuel use with a "policy case" that has fairly optimistic projections for these variables. For this reason, the renewables share is kept constant in the base case.

[20] We assumed a 30% savings by 2015, and extended the savings linearly to 2020.

that we feel are reasonable summaries of technology and policy decisions that DoD is considering within the period to 2020, and shown how this prototype model can be used to generate quantitative impacts of those decisions.

In this section, we would like to propose how this approach could be refined and extended, assuming that the relevant data are available, and that there is sufficient interest within DoD to provide support for this work.

The *Energy Data Management Report* available to us was for all of DoD. Apparently, separate reports are generated for the Air Force, Navy and Army, but are not available to the public. It seems that such a three-fold division of the *EMDR* accounting would be the appropriate aggregates for modeling DoD Energy Consumption. If these reports by service could be made available for publication, that would improve the potential to model energy use by service immensely. It would also be helpful to have consumption of jet fuel broken out by fuel actually consumed by jets, and jet fuel consumed by ground vehicles.

A database of the inventory of vehicles, ships and aircraft similar to the aircraft listing we compiled in Table 5 would be extremely useful. These data exist, and CBO makes projections for a subset of types[21]. However, as mentioned above, CBO only publishes the inventories in graphical form, which makes analysis difficult. For each type of vehicle, aircraft or ship, it is necessary to get data or make assumptions as to how that unit is used in an average year, and what is its efficiency. For example: "an M-1 Abrams tank gets 2 gallons per mile, and drives on average 1000 miles per year". The data presented in Table 5, if even close to correct, could be used to considerably refine the fuel use projections of air force aircraft, if informed projections of future inventories of aircraft could be obtained.

Finally, a more realistic model would incorporate the relationships embodied in the concept of the "fully burdened" cost of fuel. Much of the fuel expended by DoD is needed to deliver fuel (tanker planes and tanker trucks). This amount needs to be quantified, and fuel cost for tankers needs to be related to the final consumption of battlefield vehicles or aircraft. This point was one of the main findings of the 2001 Defense Science Board study, but the anecdotal estimates of this burden vary by a large magnitude. Arguably this fully burdened cost should be the measure used to evaluate cost/benefit of such decisions such as re-engining, winglets and lightweight ground combat vehicles. Having a model that can calculate the aggregate effects of these decisions and their implications for fully burdened fuel cost should be extremely useful to DoD.

The simple prototype model we have constructed for this study can already be put to useful work analyzing the energy savings generated in several alternative policy

[21] CBO, *The Long-Term Implications of Current Defense Plans*, March 2008.

scenarios, incorporating different rates of technology adoption, and different oil price assumptions.[22]

Several of the studies reviewed in section 2 called for a re-organization and centralization of decision making functions relating to energy within DoD. (The CRS study discussed above proposed the establishment of an "Office of Energy Security".) Two functions of such an office might be to organize a comprehensive and detailed set of DoD energy accounts, and to model DoD energy requirements under different assumptions. A more refined version of the simple model presented here would certainly be a logical tool develop for such an organization.

[22] The oil price projection used in these scenarios may seem optimistic to some. It is based on the 2007 *Annual Energy Outlook,* which projects oil prices to fall from 2011 to 2015 before rising again. A steadily rising price forecast, say to $200/bbl by 2015, would find much larger dollar savings than shown here.

Table 1. Product Cost: Petroleum, Natural Gas & Aerospace Energy

	FY2005	FY2006	FY2007
AVGAS	2.8	2.6	5.1
Distillates & Diesel	1,393.9	1,821.9	1,916.5
Gasohol	1.9	4.4	4.8
JP-4, JAB, JAA & JA1	518.2	1,122.5	1,322.1
JP-5	863.9	1,240.1	1,146.3
JP-8, JPTS	4,965.4	6,162.3	5,869.8
Lube Oils	3.9	5.0	4.7
MOGAS (Leaded & Unleaded)	149.1	176.1	181.7
Residuals	37.6	40.8	22.5
Intoplane	354.7	396.1	462.0
Bunkers	376.4	330.8	334.5
Local Purchase	175.2	201.5	194.8
Total Petroleum	**8,843.0**	**11,504.1**	**11,464.8**
Natural Gas	128.2	130.2	153.2
Aerospace Energy	25.1	27.2	24.9

Source: Defense Energy Support Center Factbook, FY 2007

Table 2. FY2007 Energy Management Data Report

EPACT/E.O. Goal Subject Buildings

Energy Type	Units	Annual Consumption	Annual Cost (thous. $)	Unit Cost ($)	
Electricity	MWH	26,998,532.6	$1,979,699.40	$0.07	/kWh
Fuel Oil	Thous. Gal.	157,936.2	$317,135.00	$2.01	/gallon
Natural Gas	Thous. Cubic Ft.	65,109,519.0	$601,955.10	$9.25	/Thou Cu Ft
LPG/Propane	Thous. Gal.	13,929.3	$20,800.00	$1.49	/gallon
Coal	Short Ton	620,122.7	$53,656.50	$86.53	/S. Ton
Purch. Steam	BBtu	6,895.9	$179,655.50	$26.05	/MMBtu
Other	Bbtu	499.1	$3,009.10	$6.03	/MMBtu
			$3,155,910.50		

EPACT/E.O. Goal Excluded Facilities

Energy Type	Units	Annual Consumption	Annual Cost (thous. $)	Unit Cost ($)	
Electricity	MWH	2,657,570.50	$204,042.10	$0.08	/kWh
Fuel Oil	Thou. Gal.	6,106.90	$10,965.80	$1.80	/gallon
Natural Gas	Thou. Cubic Ft.	2,281,863.20	$20,132.10	$8.82	/Thou Cu Ft
LPG/Propane	Thou. Gal.	147	$250.90	$1.71	/gallon
Coal	S. Ton	6,222.50	$559.80	$89.97	/S. Ton
Purch. Steam	BBtu	481.1	$24,262.10	$50.43	/MMBtu
Other	BBtu	26.4	$573.00	$21.71	/MMBtu
		Total Costs:	**$260,786.00**		

Non fleet vehicles and other equipment

Energy Type	Units	Annual Consumption	Annual Cost (thous. $)	Unit Cost ($)		Btu (Billion)
Auto Gasoline	Thou. Gal.	67,342.10	$155,560.30	$2.31	/gallon	8,417.80
Diesel-Distillate	Thou. Gal.	518,328.90	$1,047,024.30	$2.02	/gallon	71,892.20
LPG/Propane	Thou. Gal.	0	$0.00		/gallon	0
Aviation Gasoline	Thou. Gal.	839.6	$3,921.00	$4.67	/gallon	105
Jet Fuel	Thou. Gal.	3,504,548.20	$7,009,096.40	$2.00	/gallon	455,591.30
Navy Special	Thou. Gal.	698,935.50	$1,293,030.60	$1.85	/gallon	96,942.30
Other	BBtu	875.1	$3,832.80	$4.38	/MMBtu	875.1
		Total Costs:	**$9,512,465.40**		633,823.60	

Fleet vehicle consumption and cost captured by the FAST system

Description	Consumption Units	Annual Consumption	Annual Cost (Actual $)	Btu (Billion)
Biodiesel	GEG	5,145,315.00	$10,534,262	643.2
Diesel	GEG	19,824,553.00	$42,099,460	2,478.10
Electric	GEG	2,259.00	$6,777	0.3
E-85	GEG	1,122,457.00	$3,605,260	140.3
Gasoline	GEG	75,156,215.00	$189,918,319	9,394.50
Hydrogen	GEG			0
M-85	GEG	98	$473	0
LPG	GEG	3,924.00	$9,616	0.5
NG	GEG	484,775.00	$714,896	60.6
Other	GEG			0
TOTAL	GEG	101,739,596.00	**$246,889,063**	12,717.40

Table 3. Federal DoD Fleet, Fuel Cost by Type

Thousands of Dollars

	Gasoline	Diesel	Biodiesel (B20)	Biodiesel (B100)	CNG	Electric	Ethanol (E85)	LPG	Total
Corps of Engineers, Civil Works	8,519.2	712.1	0.2	-	0.1	-	101.2	0.0	9,332.8
Defense Agencies	3,720.9	852.5	90.9	-	0.8	-	82.3	-	4,747.4
Department of the Air Force	34,941.1	12,300.1	6,177.7	-	103.4	6.8	1,333.0	0.1	54,862.3
Department of the Army	94,573.2	21,174.1	631.2	-	2.9	-	1,246.6	8.9	117,636.9
Department of the Navy	32,800.5	5,034.7	1,136.7	0.0	332.7	-	663.2	0.4	39,968.2
United States Marine Corps	15,363.4	2,025.9	2,497.6	-	275.1	-	179.4	0.2	20,341.6
Total	189,918.3	42,099.5	10,534.2	0.0	714.9	6.8	3,605.7	9.6	**246,889.1**

Source: GSA *Federal Fleet Report FY 2007* , Table 5-2

Table 4. U.S. Government Energy Consumption by Agency and Source, Fiscal Years 1996 and 2006

(Trillion Btu)

Agency	Coal	Natural Gas	Petroleum: Aviation Gasoline	Petroleum: Distillate and Residual Fuel Oil	Petroleum: Jet Fuel	Petroleum: Motor Gasoline	Petroleum: LPG and Other	Petroleum: Total	Electricity	Purchased Steam and Other	Total
Total, 1996	**23.3**	**147.4**	**0.2**	**170.6**	**513**	**27.6**	**21.7**	**733.2**	**184.5**	**20.1**	**1,108.50**
Defense	18.1	91.7	0	155.9	504.8	3.3	13.6	677.7	104	13	904.5
Energy	5	16.7	0	1.7	0.3	1	0.3	3.4	17.7	1.9	44.6
Postal Service	0	5.9	0	2.5	0	12.3	0	14.8	15.1	0.6	36.4
Veterans Affairs	0.1	13.8	0	2.2	0	0.6	0	2.8	8.9	1.2	26.8
Transportation	0	1.2	0	0.8	4.8	0.5	6.9	13.1	5.3	0.1	19.6
General Services Administration	0	3.4	0	0.3	0	0.1	0	0.4	9	1.6	14.5
Justice	0.1	4.3	0.1	0.5	0.9	2.7	0	4	3.5	0.3	12.1
NASA	0	2.7	0	0.7	1.2	0.2	0	2.2	6.3	0.2	11.5
Agriculture	0	1.6	0.1	0.5	0	4.3	0.2	5	2	0.4	9.1
Health and Human Services	0	2.4	0	1.6	0	0	0.1	1.7	2.5	0	6.6
Interior	0	0.4	0	1	0.1	0.9	0.4	2.5	1.3	0.1	4.3
Other	0	3.5	0.1	2.9	0.9	1.6	0.1	5.6	8.8	0.6	18.5
Total, 2006 [P]	**24.2**	**129.8**	**0.6**	**207.9**	**442.7**	**47.8**	**4.7**	**703.8**	**191.2**	**17.4**	**1,066.50**
Defense	17	68.6	0.1	191.3	436.3	17.3	2.2	647.2	101.7	9.2	843.7
Postal Service	0	6.2	0	2.5	0	13.4	0.2	16.1	16.8	0.6	39.7
Energy	7	7.4	0	1.9	0.1	0.8	0.2	3.1	21	1.3	39.7
Veterans Affairs	0.2	15.1	0	1.2	0	0.8	0	2	10.4	1.6	29.3
Justice	0	10.7	0.1	1	0.1	4.7	0.1	5.9	6.1	0.8	23.5
General Services Administration	0	6.4	0	0.1	0	0	0	0.2	9.9	1.7	18.1
NASA	0	3	0	0.4	0.8	0.2	0.1	1.4	5.5	0.3	10.3
Health and Human Services	0	5.1	0	0.4	0	0.3	0.1	0.8	2.9	0.4	9.3
Interior	0	1.3	0	1.2	0.1	2.1	1	4.4	2.3	0.1	8.1
Agriculture	0	1.7	0	0.4	0	2.2	0.2	2.9	2	0.3	6.8
Transportation	0	0.7	0	0.2	0.5	0.4	0	1.2	2.7	0.1	4.6
Other	0	3.8	0.4	7.2	4.8	5.6	0.5	18.5	10	1	33.3

Source: *Annual Energy Review* ,
Table 1.13

Table 5. USAF Aircraft Characteristics, Flight Hours and Fuel Consumption

Type	Quantity (TAI) 9/30/06	Aircraft Type	Fuel Consumption Rate	Avg. Age	Avg. Hours/Year Flown	Total Flying Hours, Thousands	Avg Gal./Year, Millions
Bomber							
	51	B-1	3874	19	275	14	54
	20	B-2	2181	12	275	6	12
	85	B-52	3524	45	325	28	97
Fighter/Attack							
	128	A-10	603	25	300	38	23
	75	OA-10	600		400	30	18
	567	F-15	1800	20	500	284	510
	724	F-16	800	15	500	362	290
	73	F-22A	2000	2	400	29	58
	52	F117	2000	21	400	21	42
Helicopter							
	68	HH-60	500	16	400	27	14
	92	UH-1	300	35	400	37	11
Reconnaissance							
	32	E-3	2105	27	550	18	37
	22	RC-135	2650		500	11	29
	34	U-2	700	23	300	10	7
Special Ops							
	23	AC-130	800		300	7	6
	44	MC-130	800		300	13	11
	32	MH-53	500		300	10	5
Tanker							
	19	HC-130	800		400	8	6
	59	KC-10	2070	21	400	24	49
	200	KC-135	2650	44	750	150	398
Trainer							
	179	T-1	450	12	500	90	40
	110	T-3	200	12	500	55	11
	272	T-6	350	3	400	109	38
	171	T-37	400	42	500	86	34
	489	T-38	395	40	500	245	97
Transport							
	52	C-5	3400	22	375	20	66
	28	C-12	400	26	400	11	4
	141	C-17	2780	6	1100	155	431
	74	C-21	181	22	400	30	5
	205	C-130	742		800	164	122
	32	C-135	1700	45	550	18	30
	4153	**Sum**				2105	2555
	129	**Others**	1000		400	52	52
	4282	**Estimate**				2157	2607
	4282	**Control Total**				2164	2600

Sources:

Quantities from USAF Almanac, 2007, Equipment Chapter

Fuel Consumption Rates from Black (2007), others estimated

Annual flight times from *Improving the Efficiency of Engines for Large Nonfighter Aircraft* , others estimated

Table 6. Fuel Savings from Re-engining for Selected Aircraft

Aircraft Type	Avg Gal./Year, Millions	Re-engining Efficiency Improvement	Expected Fuel Savings
B-1	54	20	11
B-52	97	25	24
E-3	37	15	6
AC-130	6	20	1
MC-130	11	20	2
HC-130	6	20	1
KC-135	398	18	72
C-17	431	8	34
C-130	122	20	24
C-135	30	18	5
Total			**181**

Table 7. Buildings and Installations: Effect of Policy and Technology Changes

Line 1: DoDBase - No change in efficiency.
Line 2: DoDPolicy - Policy and technology changes - difference from base
(Alternatives are shown in deviations from base values)

	2007	2010	2015	2020
Annual Cost (Millions of $)				
Electricity	2183.7	2402.5	2607.9	2931.3
	0.0	-187.5	-504.0	-853.6
Fuel oil	328.1	354.0	321.9	350.6
	0.0	-43.2	-84.8	-144.7
Natural gas	622.1	679.2	670.3	769.0
	0.0	-56.6	-138.4	-239.9
LPG/propane	21.1	22.7	20.7	22.5
	0.0	-1.9	-4.4	-7.2
Coal	54.2	57.8	56.0	59.4
	0.0	-4.9	-11.8	-19.0
Purchased steam	203.9	222.6	219.7	252.1
	0.0	-16.9	-41.3	-71.2
Other	3.6	3.9	3.9	4.4
	0.0	0.1	0.3	0.5
Total	**3416.7**	**3742.7**	**3900.3**	**4389.2**
	0.0	**-310.8**	**-784.3**	**-1335.1**
Site Delivered Btus (billions)				
Electricity	101187	99680	98904	98555
	0	-7811	-19196	-28829
Fuel oil	22753	22414	22239	22161
	0	-1857	-4567	-6877
Natural gas	69481	68446	67913	67673
	0	-5692	-13996	-21077
LPG/propane	1344	1324	1314	1309
	0	-113	-277	-418
Coal	15396	15166	15048	14995
	0	-1292	-3179	-4792
Purchased steam	7377	7267	7211	7185
	0	-585	-1437	-2161
Other	526	518	514	512
	0	15	41	68
Total	**202667**	**199649**	**198094**	**197396**
	0	**-16042**	**-39434**	**-59294**

Table 7 (continued). Buildings and Installations: Effect of Policy and Technology Changes

Line 1: DoDBase - No change in efficiency.
Line 2: DoDPolicy - Policy and technology changes - difference from base
(Alternatives are shown in deviations from base values)

	2007	2010	2015	2020
Annual Consumption				
Electricity (Mwh)	29656102	29214578	28986908	28884784
	0	-2289138	-5626158	-8449240
From Renewables	3558732	3505749	3478429	3466174
	0	308688	674593	904761
Nonrenewable	26097370	25708828	25508480	25418610
	0	-2597826	-6300752	-9354000
Fuel oil (gal)	164043	161601	160341	159777
	0	-13391	-32928	-49579
Natural gas (tcf)	67391384	66388052	65870688	65638620
	0	-5520468	-13575132	-20442896
LPG/propane (gal)	14076	13867	13759	13710
	0	-1181	-2905	-4379
Coal (tons)	626345	617020	612212	610055
	0	-52579	-129320	-194955
Purchased steam (BBtu)	7377	7267	7211	7185
	0	-585	-1437	-2161
Other (BBtu)	526	518	514	512
	0	15	41	68
Addenda:				
Percent of electricity from renewables	12.0	12.0	12.0	12.0
	0.0	2.2	5.8	9.4
Prices				
Electricity ($/Mwh)	0.073	0.082	0.090	0.101
Fuel oil ($/gal)	2.01	2.20	2.02	2.20
Natural gas ($/tcf)	9.25	10.25	10.19	11.73
LPG/propane ($/gal)	1.49	1.64	1.50	1.64
Coal ($/ton)	86.53	93.69	91.39	97.27
Purchased steam ($/BBtu)	26.05	28.87	28.72	33.06

Table 8. Non-Fleet Vehicles and Other Equipment: Effect of Policy and Technology Changes

Line 1: DoDBase - No change in efficiency.
Line 2: DoDPolicy - Policy and technology changes - difference from base
(Alternatives are shown in deviations from base values.)

	2007	2010	2015	2020
USAF Aircraft				
Number of aircraft	4250	4056	3837	3789
	0	0	0	0
Average hours/plane	506	506	506	506
	0	0	0	0
Total flight hours	2150	2052	1941	1917
	0	0	0	0
Avg. gallons/hour	1209	1209	1209	1209
	0	-69	-176	-263
Gallons of fuel	2600001	2481528	2347045	2317693
	0	-140951	-342176	-504377
Total Cost	**5200001**	**5435487**	**4712311**	**5085469**
	0	**-308736**	**-687008**	**-1106700**
Annual Consumption (thous. gal)				
Auto gasoline	67342	58065	53908	52963
	0	-4998	-11502	-17104
Diesel & distillate	518329	446926	414928	407655
	0	-38466	-88534	-131650
Aviation gasoline	840	827	830	861
	0	-71	-177	-278
Jet fuel	3504549	3360988	3224486	3224132
	0	-193187	-474992	-709129
USAF	2600001	2481528	2347045	2317693
	0	-140951	-342176	-504377
Synthetic fuels	0	0	0	0
	0	70217	427705	453329
Other aircraft	814093	801466	805031	835298
	0	-45523	-117366	-181778
Other jet fuel	90455	77994	72410	71141
	0	-6713	-15450	-22974
Navy special	698936	710584	728890	745531
	0	-79941	-218667	-335489
Other (btus)	875	883	896	910
	0	-5	-14	-23
Annual Cost (thous. $)				
Auto gasoline	155560	146899	125011	134224
	0	-12643	-26674	-43347
Diesel & distillate	1047024	988728	841407	903419
	0	-85099	-179533	-291753
Aviation gasoline	3921	4228	3892	4414
	0	-364	-831	-1425
Jet Fuel	7009098	7361839	6474006	7074372
	0	-423153	-953671	-1555966
Navy special	1293031	1439715	1353680	1513152
	0	-161968	-406104	-680918
Other	3833	4236	3941	4372
	0	-25	-63	-112
Total	**9512466**	**9945644**	**8801938**	**9633953**
	0	**-683251**	**-1566875**	**-2573521**

Table 8 (continued). Non-Fleet Vehicles and Other Equipment: Effect of Policy and Technology Changes

Line 1: DoDBase - No change in efficiency.
Line 2: DoDPolicy - Policy and technology changes - difference from base
(Alternatives are shown in deviations from base values.)

	2007	2010	2015	2020
Btus (billion)				
Auto gasoline	8418	7258	6739	6620
	0	-625	-1438	-2138
Diesel & distillate	71892	61989	57550	56542
	0	-5335	-12280	-18260
Aviation gasoline	105	103	104	108
	0	-9	-22	-35
Jet Fuel	455591	436928	419183	419137
	0	-25114	-61749	-92187
Navy special	96942	98558	101097	103405
	0	-11088	-30329	-46532
Other	875	883	896	910
	0	-5	-14	-23
Total	**633824**	**605720**	**585569**	**586722**
	0	**-42176**	**-105832**	**-159175**
Fuel Prices				
Auto gasoline	2.31	2.53	2.32	2.53
Diesel & distillate	2.02	2.21	2.03	2.22
Aviation gasoline	4.67	5.11	4.69	5.12
Jet Fuel	2.00	2.19	2.01	2.19
Navy special	1.85	2.03	1.86	2.03
Other	4.38	4.80	4.40	4.81

References

Air Force Scientific Advisory Board Quick Look, *Technology Options for Improved Air Vehicle Fuel Efficiency*, May 2006.

Air Force Studies Board, *Improving the Efficiency of Engines for Large Nonfighter Aircraft*, 2007.

Blackwell, Kristine E., "The Department of Defense: Reducing its Reliance on Fossil-Based Aviation Fuel – Issues for Congress", Congressional Research Service Report for Congress, June 2007.

Clayton, Jodi A., *An Evaluation of U.S. Air Force Aviation Fuel Consumption Factors to Accurately Predict Aviation Fuel Costs by Aircraft Mission, Design, and Series*, Master's Thesis, Air Force Institute of Technology, Wright-Patterson Air Force Base, September 1996.

Congressional Budget Office, *The Long-term Implications of Current Defense Plans: Detailed Update for Fiscal Year 2008*, March 2008.

Crowley, Thomas, et.al., *Transforming the Way DoD Looks at Energy, An Approach to Establishing an Energy Strategy*, McLean, Va.: LMI Government Consulting, April 2007.

Danigole, Mark S. *Biofuels: An Alternative to U.S. Air Force Petroleum*, Air War College Maxwell Air Force Base, Center for Strategy and Technology, December 2007.

DiPetto, Chris, "Energy Efficiency for Tactical Systems", Presentation to 2006 PEO/SYSCOM Commanders' Conference, November 8, 2006.

General Services Administration, *Federal Fleet Report FY 2007*.

Harrison, William, "The Drivers for Alternative Aviation Fuels", Presentation, 2005.

JASON, *Reducing DoD Fossil Fuel Dependence*, McLean, Va.: The MITRE Corporation, September 2006.

Lengyel, Gregory J., "Department of Defense Energy Strategy: Teaching an Old Dog New Tricks", 21st Century Defense Initiative, Foreign Policy Studies, The Brookings Institution, August 2007.

Meade, Douglas, "The LIFT Model", Inforum Working Paper, June 2001, at http://www.inforum.umd.edu/papers/wp/wp/2001/wp01002.pdf.

_______, and Ronald Lile, "Economic Implications of Future Years' Defense Purchases: An Illustration of DEPPS", Inforum Working Paper, April 2002, at http://www.inforum.umd.edu/papers/wp/wp/2002/wp02005.pdf.

Naval Research Advisory Committee, "Future Fuels", Presentation, October 4, 2005.

O'Rourke, Ronald, "Navy Ship Propulsion Technologies: Options for Reducing Oil Use Issues for Congress", Congressional Research Service Report for Congress, December 2006.

Shaffer, Al, “DoD Energy Security Task Force”, Presentation, May 22, 2007.

Stucker, James P., John F. Schank, Bonnie Dombey-Moore, “Assessment of DoD Fuel Standardization Policies”, National Defense Research Institute, Rand, 1994.

U.S. Department of Defense, *More Capable Warfighting Through Reduced Fuel Burden*, The Defense Science Board Task Force on Improving Fuel Efficiency of Weapons Platforms, Washington, D.C.: Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, January 2001.

U.S. Department of Defense, *More Fight – Less Fuel*, Report of the Defense Science Board Task Force on DoD Energy Strategy, Washington, D.C.: Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, February 2008.

U.S. Department of Defense, *Annual Energy Management Report*, Fiscal Year 2007, January 2008.

U.S. Department of Defense, Defense Energy Support Center, *Fact Book 2007*, January 2008.

U.S. Department of Energy, Assistant Secretary, Energy Efficiency and Renewable Energy Federal Energy Management Program, *Annual Report to Congress on Federal Government Energy Management and Conservation Programs, Fiscal Year 2005*, September 26, 2006.