2007-12

Green energy for the battlefield

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NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

MBA PROFESSIONAL REPORT

Green Energy for the Battlefield

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December 2007

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REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** December 2007	**3. REPORT TYPE AND DATES COVERED** MBA Professional Report	
4. TITLE AND SUBTITLE Green Energy for the Battlefield			**5. FUNDING NUMBERS**
6. AUTHOR(S) Stephanie D. Halcrow			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited			**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200 words)

The amount of energy the United States (U.S.) consumes increases every year and this growth in energy consumption outpaces energy production. To fill this gap, the U.S. imports thirty-five percent of its energy. More importantly, the U.S. imports over 60 percent of its total oil consumption. Our country's energy production, especially our transportation sector, is highly dependent on foreign sources. Add to this, 70 percent of this energy is from non-renewable sources and this same 70 percent is petroleum-based, which produces greenhouse gas emissions.

Renewable energy sources and alternative fuels have proven to be energy efficient, cost effective and environmentally friendly. Additionally, they reduce the country's dependence on foreign sources. The military is adopting many types of renewable energy sources and alternative fuels for use and the results are impressive. However, the majority of implementation is here in the United States. These same benefits experienced at home are available for the battlefield: improved energy efficiency, cost savings and less impact on the environment. This paper discusses the available green energy sources and their potential use for the battlefield. Additionally, it offers several ways to further the use and maximize the benefits of green energy on the battlefield.

14. SUBJECT TERMS Green, Energy, Renewable Energy, Alternative Fuels, Biomass, Geothermal, Hydropower, Wind, Solar, Nuclear, Biodiesel, Ethanol, Natural Gas, Coal-Derived Liquid Fuels, Electricity, Greenhouse Gas, Emissions, Battlefield, Hybrid Vehicles			**15. NUMBER OF PAGES** 95
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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Approved for public release, distribution unlimited

GREEN ENERGY FOR THE BATTLEFIELD

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Submitted in partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
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GREEN ENERGY FOR THE BATTLEFIELD

ABSTRACT

The amount of energy the United States (U.S.) consumes increases every year and this growth in energy consumption outpaces energy production. To fill this gap, the U.S. imports 35 percent of its energy. More importantly, the U.S. imports over 60 percent of its total oil consumption. Our country's energy production, especially our transportation sector, is highly dependent on foreign sources. Add to this, 70 percent of this energy is from non-renewable sources and this same 70 percent is petroleum-based, which produces greenhouse gas emissions.

Renewable energy sources and alternative fuels have proven to be energy efficient, cost effective and environmentally friendly. Additionally, they reduce the country's dependence on foreign sources. The military is adopting many types of renewable energy sources and alternative fuels for use and the results are impressive. However, the majority of implementation is here in the United States. These same benefits experienced at home are available for the battlefield: improved energy efficiency, cost savings and less impact on the environment. This paper discusses the available green energy sources and their potential use for the battlefield. Additionally, it offers several ways to further the use and maximize the benefits of green energy on the battlefield.

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LIST OF ABBREVIATIONS AND ACRONYMS

ADAPT	Analysis of Deployable Application of Photovoltaics in Theater
AEI	Advanced Energy Initiative
AEMR	Annual Energy Management Report
AER	Annual Energy Review
ACI	American Competitiveness Initiative
AFB	Air Force Base
AFRL	Air Force Research Laboratory
ANWR	Arctic National Wildlife Refuge
ASHRAE	American Society of Heating, Refrigerating & Air-Conditioning Engineers
Btu	British Thermal Units
BBtu	Billion British Thermal Units
CAFE	Corporate Average Fuel Economy
CSP	Concentrating Solar Power
DESC	Defense Energy Support Center
DOC	Department of Commerce
DoD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
EER	Energy Efficient Ratios
EPA	Electric Power Annual
EPAct	Energy Policy Act
ESPC	Energy-Savings Performance Contract
FAR	Federal Acquisition Regulation
FEMP	Federal Energy Management Program
FFV	Fuel Flex Vehicles
F-T	Fischer Tropsch
GDP	Gross Domestic Product
GNEP	Global Nuclear Energy Partnership
GSA	General Services Administration
kW	Kilowatts
kWh	Kilowatts per Hour
LMI	Logistics Management Institute
MGal	Million Gallons

MMBtu	Million British Thermal Units
MW	Megawatts
NAS	National Academy of Sciences
NEP	National Energy Policy
PV	Photovoltaic
SUV	Sports Utility Vehicle
U.S.	United States
USDA	United States Department of Agriculture
USGS	United States Geological Service

ACKNOWLEDGMENTS

The completion of my thesis would not be possible without my advisors. I offer my sincere thanks to Lieutenant Colonel Bryan Hudgens for his invaluable perspective on life, academics and the Air Force. I also want to thank Professor Ira Lewis for his unmatched knowledge about military logistics.

I would also like to convey my appreciation to Professor John Arquilla who developed an entire seminar from scratch – just because the students expressed an interest. It was the most challenging and enjoyable course I have experienced. Additionally, I would like to thank Professor Kalev Sepp who introduced me to the book review and to Professor George Lober who helped further this interest.

Thank you all for your dedication to improving the intellect of this nation's airmen, soldier, sailors and marines.

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I. INTRODUCTION

> America's energy challenge begins with our expanding economy, growing population and rising standard of living. Our prosperity and way of life are sustained by energy use.
>
> National Energy Policy, 2001

A. ENERGY CRISIS

1. Reliance on Imports

The United States' energy consumption increases every year. This growth in energy consumption outpaces energy production. To overcome this shortfall, the U.S. must import over 35 percent of its total energy (Figure 1) as well as over 60 percent of its total oil consumption. Our country's energy consumption, especially our transportation sector, is highly dependent on foreign sources.

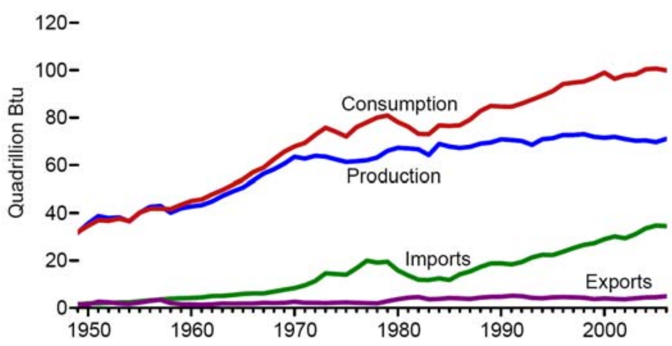

Figure 1. Energy Overview 1950-2006 (From: Annual Energy Review (AER) 2006, 2007)

2. Addicted to Oil

Within the transportation sector, the United States consumes 7.6 billion barrels each year (AER 2006, 2007). In his 2006 State of the Union address, President Bush diagnosed the United States as addicted to oil. As Figure 2 details, this addiction is getting worse; consumption is increasing while production is decreasing, with increasing imports making up the difference. In 2001, the National Energy Policy Development Group came to the same conclusion: "Our projected growing dependence on oil imports is a serious long-term challenge. U.S. economic security and that of our trading partners will remain closely tied to global oil market developments." (National Energy Policy, 2001)

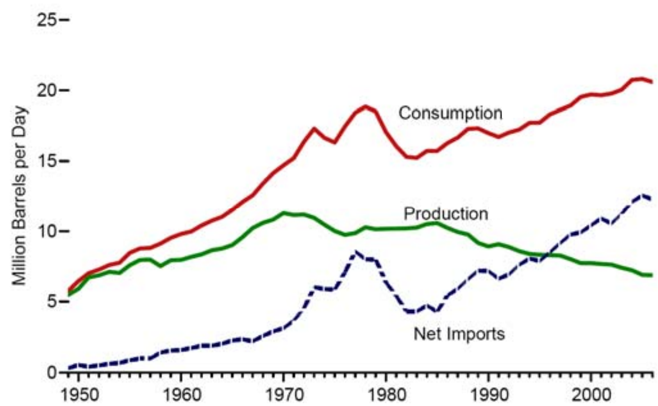

Figure 2. Petroleum Overview 1950-2006 (After: AER 2006, 2007)

3. Out of Control Costs

This addiction to oil is expensive. At 80 dollars a barrel, the U.S. spends over 608 billion dollars each year on oil. In addition to oil costs, Figure 3 illustrates the cost of producing energy from all petroleum-based sources is on the rise. In 2005, production costs increased 31.5 percent from 2004 and 114 percent from 2002 (see Figure 3). Specifically, fossil fuels (natural gas, petroleum and coal) costs increased from $2.48 per million British Thermal Units (MMBtu), a standard measurement unit, in 2004 to $3.26 per MMBtu in 2005. Petroleum was the biggest driver of increased costs and 2005 costs increased by 50.1 percent from 2004; $4.29 per MMBtu in 2004 to $6.44 per MMBtu in 2005. Natural gas production costs increased based on production disruptions in the Gulf Coast from Hurricanes Katrina, Rita and Wilma. Energy produced from natural gas increased from a record high of $5.96 per MMBtu in 2004 to a new record level of $8.21 per MMBtu – a 37.8 percent increase from 2004 and a 130.6 percent increase from 2002.

The cost of coal-produced power increased by 13.2 percent from $1.36 per MMBtu in 2004 to $1.54 per MMBtu in 2005 due to increases in extracting coal. (Electric Power Annual (EPA) 2005, 2006)

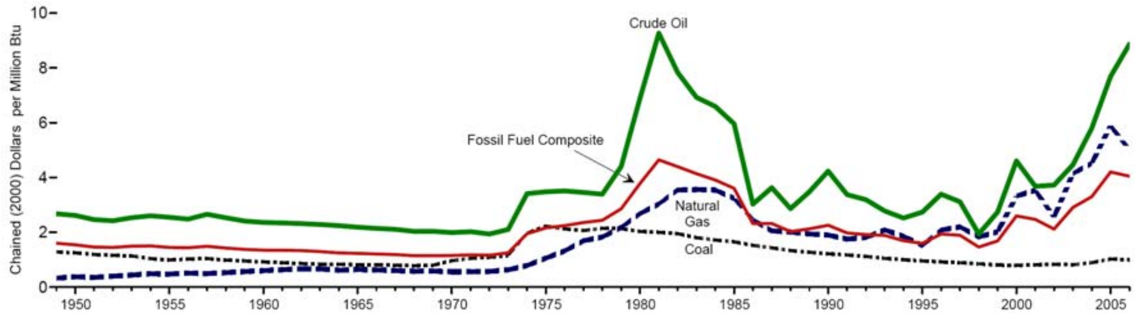

Figure 3. Fossil Fuel Costs Production Prices 1949-2006 (After: AER 2006, 2007)

Not only are the costs of producing fuel rising, but there are also hidden costs with energy consumption. Michael Copulos, president of the National Defense Council Foundation, identifies five hidden costs of foreign oil consumption in his article, *The Hidden Cost of Oil: An Update* (2007):

- The cost of oil-related defense expenditures at $137 billion annually
- The lost current economic activity due to capital outflow of $117.4 billion annually
- The loss of domestic investment of $394.2 billion annually
- The loss of government revenues of $42.9 billion annually
- The cost of periodic oil supply disruptions of $132.8 billion annually

The National Defense Council Foundation estimates the total hidden costs of foreign oil consumption to be $825.1 billion each year. Copulos continues, "To put the figure in further perspective, it is equivalent to adding $8.35 to the price of a gallon of gasoline refined from Persian Gulf oil. This would raise that figure to $10.73, making the cost of filling the gasoline tank of a sedan $214.60, and of an SUV $321.90." The costs of the U.S.'s addiction to oil are out of control.

4. Dwindling Resources

Over 70 percent of the U.S. energy consumption is from non-renewable sources: 49.7 percent from coal, 18.7 percent from natural gas and 3 percent from petroleum (Figure 4). Copulos argues in his article, *America's Untapped Depths* (2005) that the U.S. still has vast amounts of these natural resources and can be completely independent from foreign sources of energy:

- According to the U.S. Geological Survey (USGS), the United State has almost 175 billion barrels of oil reserves. These include 21.9 billion barrels of "proved oil reserve" – oil that has been discovered and can be produced right now – and more than 150 billion barrels of "undiscovered" reserves.
- The USGS estimates that the United States has 1,430.6 trillion cubic feet of natural gas reserves.
- The USGS estimate that there are 23.6 billion barrels of natural gas liquids reserves – products such as propane, butane and ethane – in U.S. resource base.
- The United States is has 496.1 billion tons of demonstrated reserves – 27 percent of the world total.
- The United States has between 500 billion and 1.1 trillion barrels of oil in the form of oil shale.
- Finally, the United States has approximately 4.85 billion pounds of uranium reserves.

The U.S. consumes 20 million barrels of petroleum a day or 7.3 billion each year. The current U.S. reserves total 175 billion barrels. If the U.S. is completely reliant on domestic resources, it will run out in 24 years. Regardless of what national resources the U.S. possess, these domestic resources are limited. Worse yet, they adversely affect the environment through emissions of greenhouse gases.

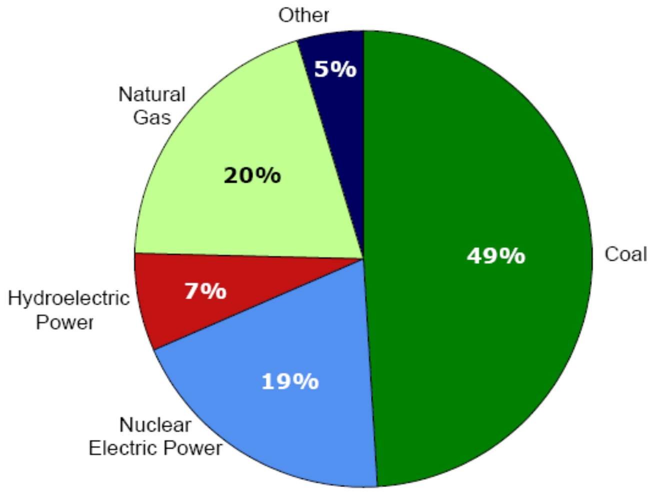

Figure 4. U.S. Electricity Generation by Source, 2006 (After: AER 2006, 2007)

5. Environmental Impacts

In 2005, energy production created 2,514 million tons of emissions – a 2.3 percent increase over 2004. Figure 5 shows the allocation of greenhouse gas emissions by each economic sector. Since industrial, residential and commercial electricity generation and the transportation sector still rely primarily on petroleum-based fuels, their hydrocarbon emissions remain on the rise.

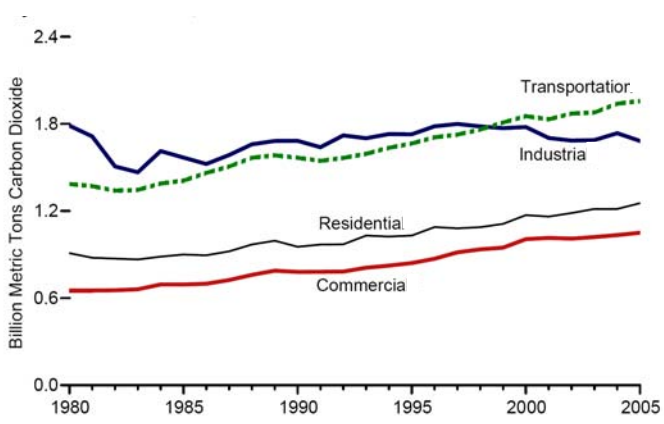

Figure 5. U.S. Greenhouse Gas Emissions (Carbon Dioxide) Allocated to Economic Sectors, 1980-2005 (After: AER 2006, 2007)

B. GREEN ENERGY SOLUTION

Green energy, defined in this paper to include renewable energy sources and alternative fuels, provides a means to reduce reliance on imports, wean the U.S. off oil and bring costs under control. Additionally, green energy is not limited in its supply and reduces negative impacts on the environment. There are several viable renewable energy sources: biomass, hydropower, geothermal, wind, solar and nuclear. In 2006, 30 percent of U.S. energy production was from renewable sources (EPA 2005, 2006) and as Figure 6 indicates, renewable energy consumption is on the rise, although, there is room for improvement. Geography limits some renewable energy sources, like hydropower while others, like nuclear power, are limited by the length of time it takes to build and certify the power plant. Nevertheless, all renewable energy sources have potential for growth.

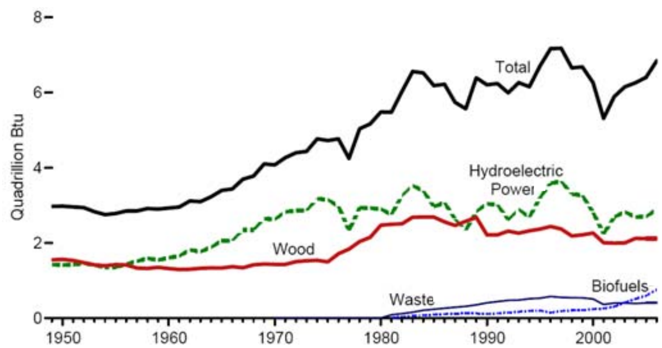

Figure 6. Renewable Energy Total Consumption and Sources, 1949-2006 (After: AER 2006, 2007)

Alternative fuels are also a key component of meeting the energy crisis. Alternative fuels include biodiesel, ethanol, natural gas, coal-derived liquid fuels, liquefied petroleum gas, methanol, hydrogen and electricity. Not all alternative fuels are renewable (natural gas, coal-derived liquid fuels) nor emissions free, but these alternative fuels offer other benefits such as reducing the dependence on foreign sources of energy. Alternative fuel use is the backbone behind a recommendation by the Southern States Energy Board, which suggests the U.S. can achieve energy security and independence through using a combination of domestic fossil fuel resources, renewable energy sources and most importantly, alternative fuels (American Energy Security, 2006).

Some critics believe the quest for energy independence is like chasing windmills. In his article, *Energy Independence* (2005), Philip Deutch argues the U.S. is more dependent on foreign sources of oil today than ever before and cannot dream of becoming energy independent. Additionally, Deutch makes the case that reducing the use of foreign oil will only drive up the costs of energy and consumers are not willing to pay more for green energy. Solar proponents Walton and Hall agree that cheap oil is affecting green energy use. However, they believe it is hampering it: relatively cheap and abundant fossil fuel-based energy supplies have greatly slowed solar energy research and usage." (Walton and Hall, 1990)

C. GREEN ENERGY AND THE MILITARY

Advocates suggest the federal government can play a vital role in solving the U.S. energy crisis. Lt Col John M. Amidon suggests in his article, *America's Strategic Imperative, a "Manhattan Project" for Energy* (2005), that the U.S. must "embark on a comprehensive plan to achieve energy independence – a type of Manhattan Project for energy – to deploy as many conservation and replacement measures as possible." This Manhattan Project approach would focus on "America's greatest strengths, those of inventor and the innovator." His argument is in line with the assessment of the U.S. Climate Action Report (2006) that the U.S. is "pursuing a comprehensive strategy to address global climate change that is science-based, fosters breakthroughs in clean energy technologies and encourages coordinated global action."

The Federal Government has taken steps to encourage and regulate green energy through various laws and initiatives. The National Energy Policy (NEP), published in 2001, provides the basis for the current legal and regulatory framework surrounding green energy. The Energy Policy Act (EPAct), passed in 2005, legislates many of the recommendations prescribed in the NEP. For example, the EPAct 2005 and subsequent legislation require the military to meet certain levels of green energy use. In compliance with this legislative mandate, the military is expanding its implementation of green energy and the results are impressive. The military meets and/or exceeds all legislative requirements. (DoD Annual Energy Management Report (AEMR), 2007) However, the vast majority of the military's use of green energy is here in the United States.

D. CONCLUSION

The U.S. addiction to oil and reliance on imports fuels today's energy crisis. The cost of this reliance is out of control and negatively affects the environment. The following chapters look at the different types of renewable energy sources and alternative fuels available and evaluate their use for the battlefield. Additionally, criteria for evaluating green energy for the battlefield as well as suggest changes to current policy and organizational structure to further the application of green energy for the battlefield.

II. THE LEGAL AND REGULATORY FRAMEWORK

A. INTRODUCTION

The National Energy Policy (NEP) provides the basis for the current legal and regulatory framework surrounding green energy. The Energy Policy Act (EPAct), passed in 2005, legislates many of the recommendations prescribed in the NEP. The American Competitiveness Initiative (ACI) supplements The EPAct of 2005 and commits to additional basic research funding in a variety of areas to include alternative fuels. Additionally, the Advanced Energy Initiative (AEI) updates funding targets for renewable energy sources and alternative fuels to EPAct 2005. Finally, Executive Order 13423, appropriately titled *Strengthening Federal Environmental, Energy and Transportation Management*, clarifies requirements for the military. These documents, along with the Federal Acquisition Regulation and Department of Defense (DoD) strategies, supply the military with a structure for implementing and advancing green energy.

B. NATIONAL ENERGY POLICY

When President Bush took office in 2001, he formed a group to develop a NEP "to help bring together business, government, local communities and citizens to promote dependable, affordable and environmentally sound energy for the future." (NEP, 2001) Unfortunately, the events of September 11, 2001 delayed implementation. Finally, in 2005, comprehensive energy legislation passed in the form of the EPAct.

The NEP outlines three challenges facing the United States beginning with the "expanding economy, growing population and rising standard of living. Our prosperity and way of life are sustained by energy use." (NEP, 2001) Next, the NEP recognizes the current U.S. energy infrastructure as being in disrepair and limited. The final challenge lies in increasing energy supplies to meet increasing energy needs while protecting the environment by tapping into renewable energy sources and alternative fuels. "Estimates indicate that over the next 20 years, U.S. oil consumption will increase by 33 percent, natural gas consumption by well over 50 percent, and demand for electricity will rise by 45 percent. If America's energy production grows at the same rate as it did in the 1990s we will face an ever-increasing gap." (NEP, 2001) This ever-increasing gap is depicted in Figure 7.

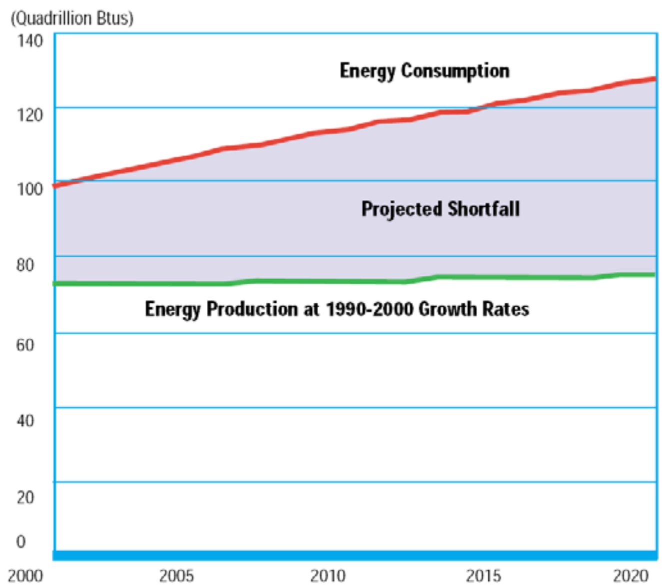

Figure 7. U.S. Energy Consumption vs. Production Shortfall (From: NEP, 2001)

The NEP advocates a long-term comprehensive approach to addressing the energy as well as looks to technology to increase the viability of alternative sources of energy. Finally, the policy seeks to increase the standard of living for the American people. To meet this vision, the NEP details five specific goals: modernize conservation, modernize the energy infrastructure, increase energy supplies, protect and improve the environment and increase energy security.[1]

Modernizing conservation includes improving energy efficiency. One measure of energy efficiency is intensity, the amount of energy it takes to produce one dollar of gross domestic product (GDP). Energy intensity in the U.S. declined from the 1970s to the 1990s. The NEP (2001) states, "half of the long-term decline in energy intensity can be

[1] The NEP recommendations are located in Appendix A.

attributed to changes in the economy, especially the shift from manufacturing to services, the other half reflects improved energy efficiency." Using a 1972 baseline, the U.S. economy improved its energy efficiency by 74 percent (see Figure 8) by adopting efficient home appliances, light bulbs and better fuel-efficient vehicles. (NEP, 2001)

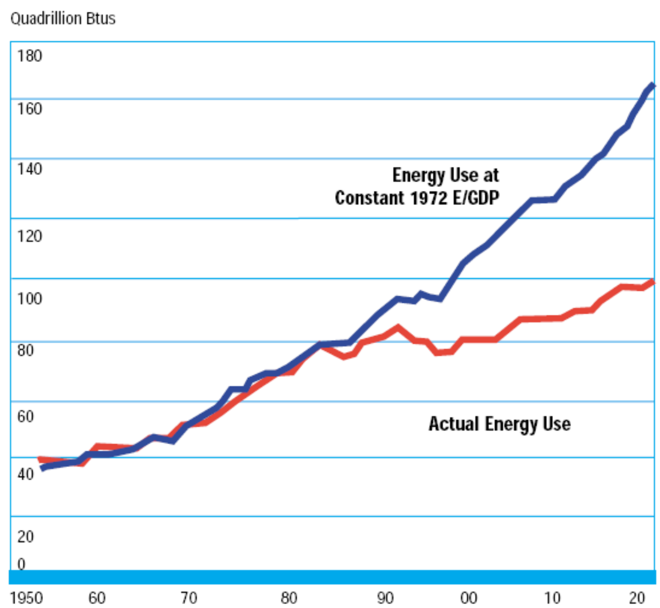

Figure 8. U.S. Economy Energy Intensity (From: NEP, 2001)

Government agencies are also becoming more energy efficient. Figure 9 shows a 30 percent reduction in government's facility energy usage in the 1990s. This reduction is due in part to the Federal Energy Management Program of the Department of Energy (DOE), which promotes energy efficiency by working "to reduce the cost and environmental impact of the Federal government by advancing energy efficiency and water conservation, promoting the use of distributed and renewable energy, and improving utility management decisions at Federal sites." (http://www1.eere.energy.gov/femp/about/index.html)

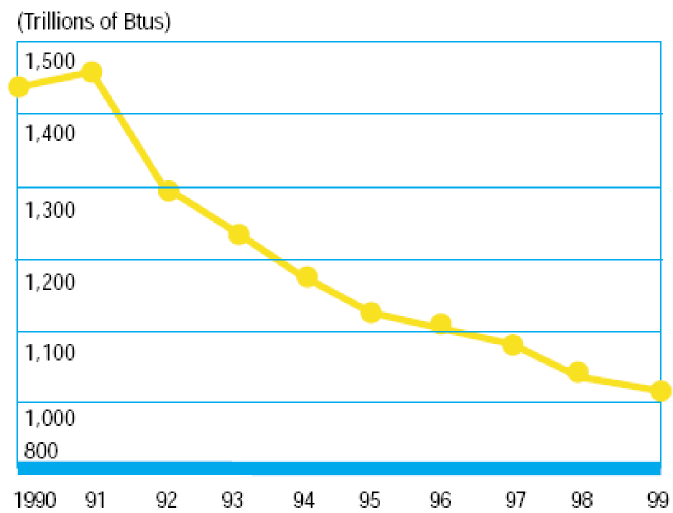

Figure 9. U.S. Government Energy Consumption (From: NEP, 2001)

Conservation and energy efficiency are not enough to significantly reduce the US dependence on foreign sources of energy. The NEP promotes enhancing domestic energy supplies. This includes increases to oil, natural gas and coal reserves yet more importantly expanding renewable sources of energy. Nuclear, hydropower and geothermal power are already proven renewable sources of energy and NEP encourages improving their utilization. Wind, solar and biomass are newer green energies that require federal support.

C. ENERGY POLICY ACT OF 2005

Based on the recommendations laid out in the NEP, the EPAct was introduced in Congress in April, passed it in July. President Bush signed the EPAct 2005 into law on August 8, 2005. President Bush commented "one day Americans will look back on this bill as a vital step toward a more secure and more prosperous nation that is less dependent on foreign sources of energy." (http://www.whitehouse.gov/news/releases/2005/08/20050808-6.html)

The EPAct requires the federal government to reduce energy usage, promotes diversification of the nation's energy supply with renewable sources and supports a new generation of energy efficient vehicles. Additionally, the legislation promotes residential efficiency, and advances efficiency of appliances and commercial products and the modernization of domestic energy infrastructure.[2] The overarching goals of this comprehensive energy strategy are (On the Road to Energy Security, 2006)

- Diversify America's energy supply by:
  - promoting alternative and renewable sources of energy
  - encouraging the expansion of nuclear energy in a safe and secure manner
  - increasing domestic production of conventional fuels
  - investing in science and technology
- Increase energy efficiency and conservation in our homes and businesses
- Improve the energy efficiency of our cars and trucks
- Modernize our electric power infrastructure
- Expand the Strategic Petroleum Reserve

There is minimal language in EPAct 2005 directed at the federal government. However, it does require the federal government to reduce its annual energy usage by 2 percent from 2006-2015.[3] Additionally, the federal government is required to increase its renewable energy usage: 3 percent or more in 2007 through 2009, 5 percent or more in 2010 through 2012 and 7.5 percent or more in 2013. (EPAct, 2005)

In addition to energy usage reduction and renewable energy use, the EPAct 2005 directs the DoD to procure alternative fuels and "develop a strategy to use fuel produced, in whole or in part, from coal, oil shale and tar sands that are extracted by either mining or in-situ methods and refined or otherwise processed in the United States." (EPAct, 2005)

[2] Highlights of EPAct 2005 can be found in Appendix B.

[3] EPAct 2005 changed the reporting baseline from 1985 to 2003.

1. American Competiveness Initiative

To complement the EPAct 2005, President Bush introduced the American Competitiveness Initiative (ACI) to fund basic research and education beginning in 2006. Although not specifically targeted at renewable energy sources and alternative fuels, the goal of ACI (ACI, 2007) is to:

- Keep America the most innovative and competitive economy in the world by encouraging more aggressive investment by businesses through a permanent enhanced research and development tax credit ($3.2 billion in FY 2008 and $117 billion over ten years)
- Greatly increase and prioritize Federal support for vital research (a $764 million increase in FY 2008 for ACI research agencies)
- Improve math and science education for America's students (a $365 million increase in FY 2008 at the Department of Education) [sic]

ACI doubles the funding for basic research across the board, furthering research in both renewable energy sources and alternative fuels.

2. Advanced Energy Initiative

Also in 2006, President Bush announced the Advanced Energy Initiative (AEI) to advance the provisions of EPAct 2005. The plan targets additional funds for clean-energy technology research in two areas: alternative vehicle fuel and renewable domestic based energy sources. The AEI (2006) set the following goals:

1. Fueling Our Vehicles

- Develop advanced battery technologies that allow a plug-in hybrid-electric vehicle to have a 40-mile range operating solely on battery charge.
- Foster the breakthrough technologies needed to make cellulosic ethanol cost competitive with corn-based ethanol by 2012.
- Accelerate progress towards the President’s goal of enabling large numbers of Americans to choose hydrogen fuel cell vehicles by 2020.

2. Powering Our Homes and Businesses

- Complete the President’s commitment to $2 billion in clean coal technology research funding, and move the resulting innovations into the marketplace.

- Develop a new Global Nuclear Energy Partnership (GNEP) to address spent nuclear fuel, eliminate proliferation risks and expand the promise of clean, reliable and affordable nuclear energy.
- Reduce the cost of solar photovoltaic technologies so that they become cost competitive by 2015, and expand access to wind energy through technology.

The AEI forms the basis for the President's budget requests with focused efforts on vehicle fuel economy standards, clean diesel regulations and alternative fuel facilities. Each focus area indirectly benefits the federal government. The AEI raised vehicle fuel economy standards from 20.7 miles per gallon (mpg) to 22.2 mpg. Furthermore, AEI scheduled increased light trucks and SUVs fuels standards in 2008 and beyond. Regulations also reduced maximum diesel emissions by 90 percent. Finally, the AEI includes a 30 percent tax credit for building alternative fuel stations – increasing the alternative fuel infrastructure. (AEI, 2006)

The AEI goes further than the NEP and EPAct 2005 and proposes additional funding for three new future technologies. The AEI identifies additional funding for "advanced batteries" to increase the range and speed of hybrid-electric vehicles. Currently, hybrid-electric vehicles can only operate at low speeds for a very short distance; accordingly advanced battery technology is required. The second future technology is cellulosic ethanol or ethanol produced from biomass. Gasoline blended with ethanol achieves fewer emissions. Currently, corn is the main feedstock of ethanol, but trees, algae[4] and garbage dumps produce ethanol. The AEI proposes funding for research into additional sources of biomass and reducing the cost of production. Lastly, the AEI includes funding hydrogen vehicle research as another alternative fuel source.

In addition to alternative fuels, the AEI highlights renewable energy sources. Non-renewable energy sources produce over 70 percent of the energy produced in the United States and coal alone accounts for 50 percent (EPA 2005, 2006). The ACI recommends funding for clean coal technology or a "nearly emissions-free coal plant of

[4] Commander James Custer argues that algae is the best source for biomass. See James Custer, *Algae: America's Pathway to Independence*, March 30, 2007. Carlisle, PA: Army War College. Available from the Defense Technical Information Center, http://stinet.dtic.mil (Accession Number ADA469390).

the future that captures and stores the carbon dioxide it produces rather than releasing it into the atmosphere." (AEI, 2006) Nuclear power is the next focus area of the AEI. Nuclear power is a clean source of domestic produced power but the racioactive waste disposal issue still haunts its use. The AEI looks to partner with other nations to develop ways to recycle spent nuclear fuel. Solar and wind power are the final emphasis of the AEI, which identifies additional funding for advanced photovolatic materials and more energy efficient and cost effective wind turbines.

3. Executive Order 13423

President Bush signed Executive Order 13423, *Strengthening Federal Environmental, Energy and Transportation Management*, January 2007. The Executive Order strengthens and clarifies language set forth in the EPAct 2005. Among other provisions, the Executive Order requires a reduction in the federal government's energy intensity[5] annually by 3 percent through 2015 – for a total reduction of 30 percent. It also requires at least half of the renewable energy to be from "new"[6] renewable energy sources.

EPAct 2005 imposed requirements for the federal government's use of alternative vehicle fuels. Added to this, the Executive Order requires a 10 percent annual increase in non-petroleum fuel consumption and an annual 2 percent reduction in petroleum products through 2015.

D. DEPARTMENT OF DEFENSE ENERGY POLICIES

The Federal Acquisition Regulation (FAR) "is the primary regulation for use by all Federal Executive agencies in their acquisition of supplies and services with appropriated funds." (FAR Part 1.101, 2005) The Defense Federal Acquisition Regulation Supplement provides additional guidance specific to defense agencies.

[5] "Energy intensity" means energy consumption per square foot of building space, including industrial or laboratory facilities.

[6] "New" renewable sources means sources of renewable energy placed into service after January 1, 1999.

The DoD achieves the goals outlined in EPAct 2005 and Executive Order 13423 by giving the "defense components the flexibility to manage their own energy programs." (DoD Annual Energy Management Report (AEMR), 2007) Nevertheless, the DoD report lists the following strategies:

- Invest in energy efficient technologies, such as high efficiency lighting and ballasts, energy efficient motors, and packaged heating and cooling equipment with energy efficiency ratios (EER) that meet or exceed Federal criteria for retrofitting existing buildings.
- Utilize Energy Saving Performance Contracts and Utility Energy Service Contracts
- Invest [sic] in Energy Management and Conservation Systems
- Re-energize [sic] of Energy Awareness Campaigns
- Provide [sic] training to energy coordinators at both the region and installation level

Based on this general guidance, the DoD achieved impressive results in energy efficiency. As Table 1 shows, the DoD reduced its energy use by 5.5 percent, decreased its use of petroleum-based fuels for facilities by 23 percent and cut water consumption by 29.6 percent. In addition, the DoD increased its purchase of renewable energy by 194.8 percent, representing 9.5 percent of all its energy usage.

	Previous Year (2005)	**Current Year (2006)**	**Percent Change (Current vs. Base)**
Energy Efficiency	103,371.7 Btu	107,212.7 Btu	-5.5%
Petroleum-Based Fuel Use (Facilities)	27,377.5 BBtu	25,546.6 BBtu	-23.0%
Water Consumption	124,293.2 MGal	114,115.9 MGal	-29.6%
Renewable Energy	8,353.6 BBtu	9,631.3 BBtu	194.8%

Table 1. FY 06 DoD Energy Scorecard (After: DoD AEMR, 2007)

E. MILITARY DEPARTMENT ENERGY POLICIES

In general, the individual military departments do not go beyond the "green energy" laws, regulations and policies set forth by the federal government, but each service does have its own energy vision and/or strategy.

1. Air Force

The 2007 Air Force energy vision is under development, but Mr. William Anderson, Assistant Secretary of Installations, Environment and Logistics, articulated the following goals in October 2007 (http://www.af.mil/news/story.asp?id=123071452):

- Reduce demand by increasing our energy efficiency and reducing our energy consumption
- Increase supply by researching, testing and certifying new technologies
- Investigate [sic] cutting edge uses of renewable and conventional sources of energy in order to create new domestic sources of supply
- Change the culture to ensure energy is a consideration in all we do

2. Army

The U.S. Army Energy Strategy for Installations (2006) lists the following goals:

- Eliminate/Reduce energy waste in existing facilities
- Increase energy efficiency in new/renovated construction
- Reduce dependence on fossil fuels
- Conserve water resources
- Improve energy security

3. Navy

The Department of the Navy Shore Energy Business Plan (2001) contains the following mission areas:

- Life cycle cost effective utilities management
- Energy efficient construction and retrofit
- Conservation of resources
- Emerging, proven technology application
- Innovative financing and contracting methods
- Awareness and training

F. CONCLUSION

The green energy legal and regulatory framework is extensive. The NEP sets the stage for research, development and use of green energy through conservation and improving the domestic energy supply. The EPAct 2005 seeks diversify America's energy supply by promoting alternative and renewable sources of energy. Moreover, EPAct 2005 regulates energy efficiency in facilities as well as in vehicles. Both the American Competitiveness Initiative and the Advanced Energy Initiative update EPAct 2005 funding goals for green energy research, renewable energy sources and alternative fuels. Executive Order 13423 toughens requirements for federal government use of green energy.

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III. RENEWABLE ENERGY SOURCES

A. INTRODUCTION

There are several types of renewable sources of energy: biomass, hydropower, geothermal, wind, solar, and nuclear. Renewable energy is just that, renewable. Unlike fossil fuels, there is no concern about depleting reserves. Additionally, renewable energy produces fewer emissions than its petroleum based counterparts. Produced domestically, renewable energy is not reliant on imports. Finally, renewable energy is becoming more and more cost efficient making it more and more attractive to consumers.

Almost 30 percent of the current U.S. energy production is from renewable sources (EPA 2005, 2006). As Figure 10 indicates, renewable energy consumption is on the rise; nevertheless, there is room for improvement. Each renewable energy source has the potential for growth, although some are more amenable to growth than others. Availability, cost, improved efficiency are all factors in determining future use of renewable energy sources.

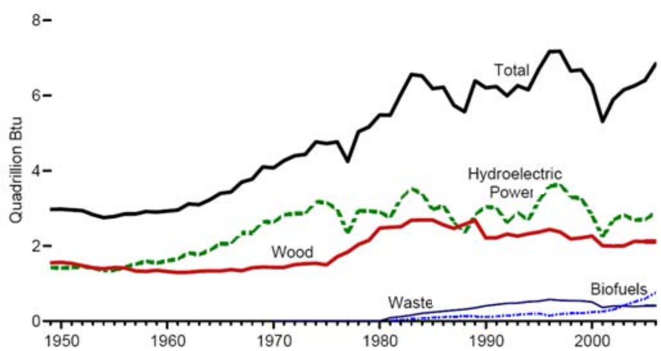

Figure 10. Renewable Energy Total Consumption and Sources, 1949-2006 (From: AER 2006, 2007)

B. TYPES OF RENEWABLE ENERGY SOURCES

1. Biomass

Biomass is man's oldest source of fuel. As soon as man learned to harness a flame, he used biomass to generate power – with wood. Today, power in generated from a variety of biomass sources. In addition to wood, biomass sources include landfill gases and energy crops such as corn and grasses. Still, 75 percent of current biomass production comes from wood. In 2005, renewable energy sources contributed seven percent of the nation's energy and biomass accounted for 48 percent of the renewable energy consumed in the U.S. (not including nuclear power). Figure 11 breaks out the renewable energy components even further, including biomass sources of wood (31 percent), biofuels such as ethanol and biodiesel (11 percent) and waste sources such as landfills and agricultural bioproducts (6 percent waste).

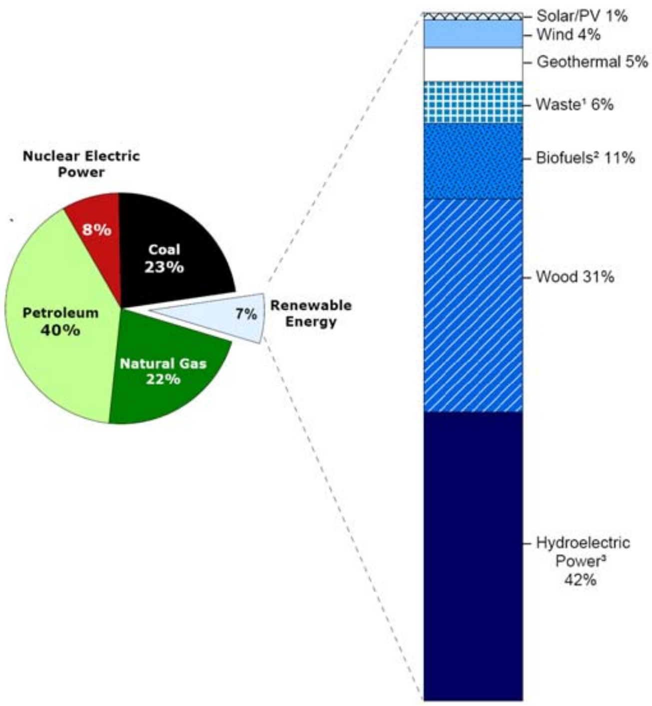

Figure 11. Renewable Energy Consumption by Major Sources, 2006 (After: AER 2006, 2007)

Biomass resources are primarily located in the eastern half of the country and on the west coast (see Figure 12). According to the Biomass Research and Development Initiative, the goal for biomass production is to supply 5 percent of the nation's power and 20 percent of transportation fuels. Together, this would replace 30 percent of the current petroleum consumption but would require one billion dry tons of biomass feedstock annually. Today, the U.S. only produces 190 million dry tons of biomass. Achieving this goal would require five times as much biomass production. A joint 2005 study by the Departments of Energy and Agriculture concluded the U.S. has the capability to produce 1.366 billion dry tons of biomass from forestlands and agriculture.[7] (Biomass as a Feedstock, 2005)

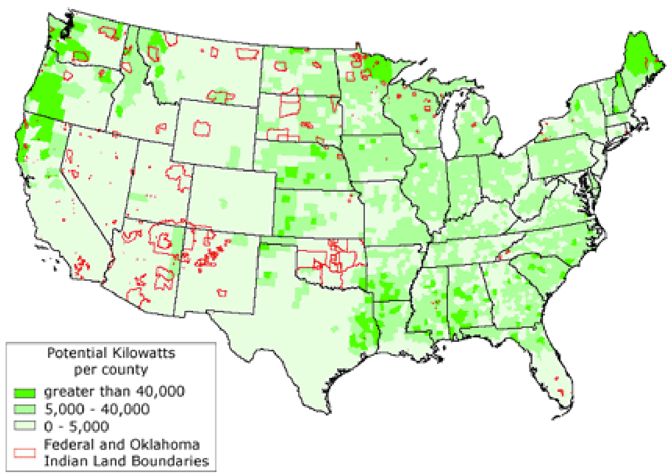

Figure 12. U.S. Biomass Resources (From: http://nationalatlas.gov/articles/people/a_energy.html#three)

The use of biomass reduces greenhouse gas emissions. According to the DOE, biomass use has the potential to reduce greenhouse emissions from between 52 to 86 percent. (http://www1.eere.energy.gov/biomass/environmental.html) An added benefit of biomass crops is they create a carbon sink. Plants require carbon dioxide to grow and

[7] The Biomass as Feedstock study made several important assumptions while coming to this conclusion, such as excluding environmentally sensitive areas and maintaining current food, feed and export demands.

the physical production of biomass crops directly reduces the amount of greenhouse gases. Energy produced from biomass is as inexpensive as six cents per kilowatt-hour and is in line with other renewable sources of energy (Table 2).

	Biomass	Hydropower	Geothermal	Wind	Solar	Nuclear
Annual Generation (Trillion Btus)	3,277	2,889	349	258	70	2,686
Cost (cents/kWh)	6-20	2-6	5-8	4-6	20	3

Table 2. Electricity Generated by Renewable Sources, 1999 (After: AER 2006, 2007 and NEP, 2001)

2. Hydropower

While biomass is the oldest form of renewable energy, hydropower is the most successful (NEP, 2001). Unfortunately, limited growth is the most significant drawback to hydropower; dams are already located in most of the desirable locations.

Hydropower uses water to create electricity, usually through a dam. Water flow, regulated by the dam, turns turbines (see Figure 13), which turn generators and create electricity. With a dam, water flow is available and controlled producing a large amount, consistent flow of electricity. As an example, the Hoover Dam produces on average 4.4 billion kilowatt hours per year - enough to serve 1.3 million people (http://www.usbr.gov/lc/hooverdam/faqs/powerfaq.html).

Overall, hydropower produces 42 percent of the nation’s renewable energy and is the second leading producer – recently surpassed by biomass. Hydropower produces energy for as little as two cents per kilowatt, yet the capital investment in building a dam is obviously high.

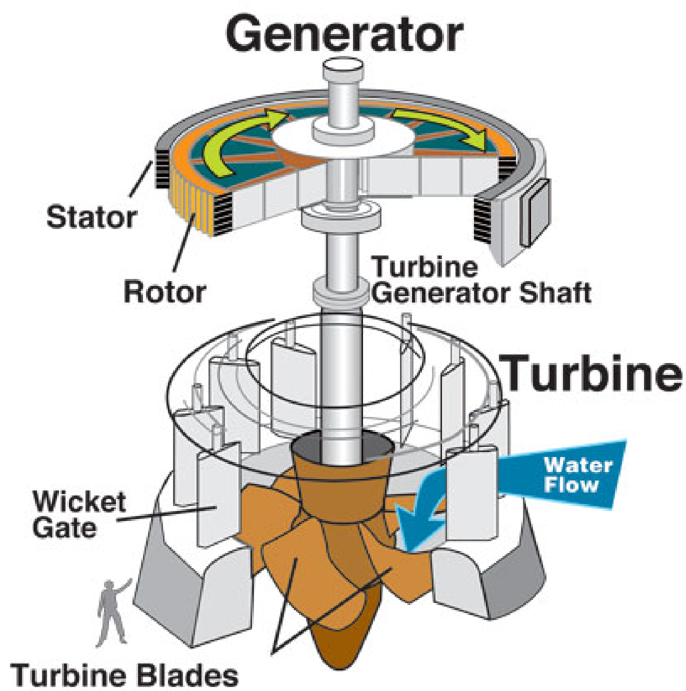

Figure 13. Water Turbine (From: http://en.wikipedia.org/wiki/Image:Water_turbine.jpg)

Hydropower dams are beneficial in ways unrelated to renewable energy. In fact, the Army Corps of Engineers quantifies power generation as the least important purpose of dams.[8] (Hydropower, 2003) Dams provide a reliable water source for downstream agricultural business and drinking water. Engineers regulate water for flood control and ensure farmers have enough water to irrigate their crops. Dams also provide water recreational areas for boaters and anglers.

3. Geothermal

Geothermal technologies use steam and hot water generated from the earth to produce power. Geothermal power plants work very similarly to hydropower. Steam or hot water extracted from the ground turns a turbine linked to a generator that produces

[8] The Army Corp of Engineers list the primary purpose or benefits of dams as: recreation – 35 percent, stock/farm ponds – 18 percent, flood control – 15 percent, public water supply – 12 percent, irrigation – 11 percent, other – 7 percent and hydroelectric power – 2 percent.

electricity (see Figure 14). Geothermal power plants produce energy efficiently for 5 cents per kilowatt-hour and are almost emission free. (http://www1.eere.energy.gov/geothermal/powerplants.html#drysteam).

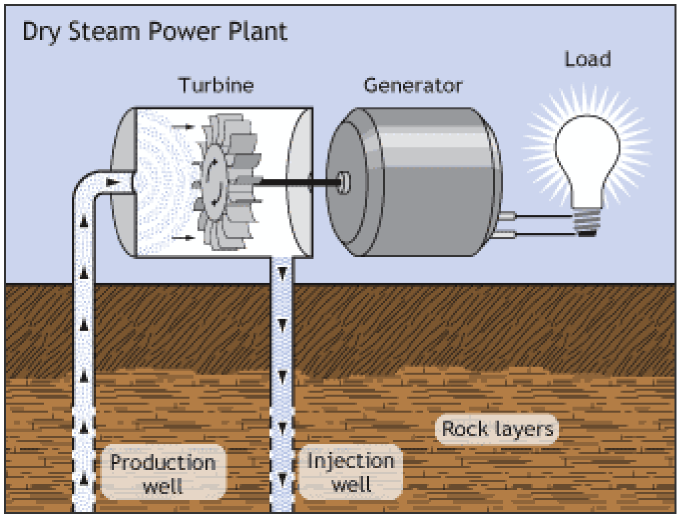

Figure 14. Geothermal Turbine (From: http://www1.eere.energy.gov/geothermal/powerplants.html#drysteam)

Seventeen percent of renewable energy electricity generation is from geothermal activities and Figure 15 indicates the potential U.S. resources. The DOE considers geothermal resources above 200˚ Celsius (red on the map below) as excellent sites while those with 150˚ Celsius (orange) as having good potential.

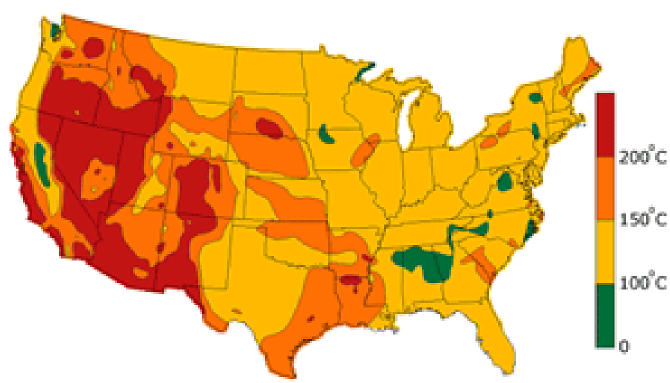

Figure 15. U.S. Geothermal Resources (From: http://nationalatlas.gov/articles/people/a_energy.html#three)

4. Wind

Wind power is a growing source of alternative energy. In 2005, the United States installed more new wind farms than any other country in the world (AEI, 2006). Wind power is renewable, creates no emissions and requires no sources of oil, foreign or domestic. Wind generated energy is also extremely inexpensive and ranks as a low-priced renewable energy costing between four and six cents per kilowatt-hour (NEP, 2001). Today, the US generates over 11,600 megawatts from wind farms – enough electricity to power over 2.3 million households.

Wind power is actually a form of solar energy, since the sun creates wind. The wind generates electricity by turning a blade that connects to a shaft that turns a generator (see Figure 16). This size of the windmill determines the potential power generation which can range anywhere from 100 kilowatts to several megawatts. Multiply a single windmill output by the number of windmills in a wind farm and the power generation is significant.

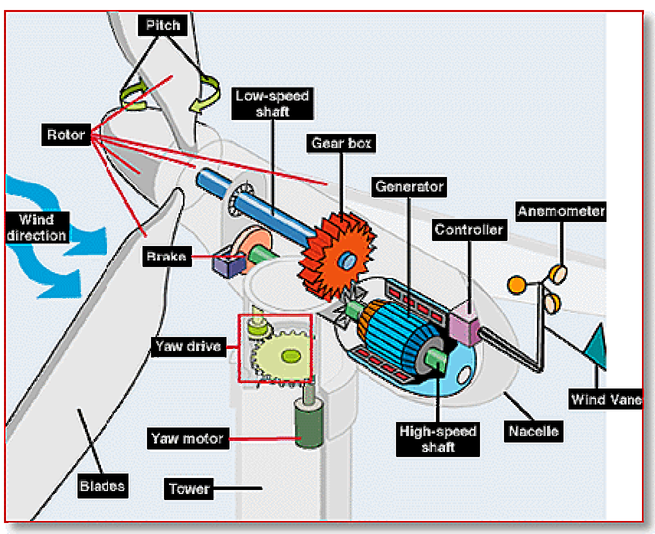

Figure 16. Wind Turbine (From: http://www1.eere.energy.gov/windandhydro/wind_how.html)

The potential of wind energy is almost unlimited. Good wind areas cover six percent of the United States and these areas can supply one and a half times the nation's current electrical needs. The DOE categorizes wind power into seven classes and Figure 17 shows the location and strength of wind throughout the country. Power class 4 and greater is suitable for current wind power generation.

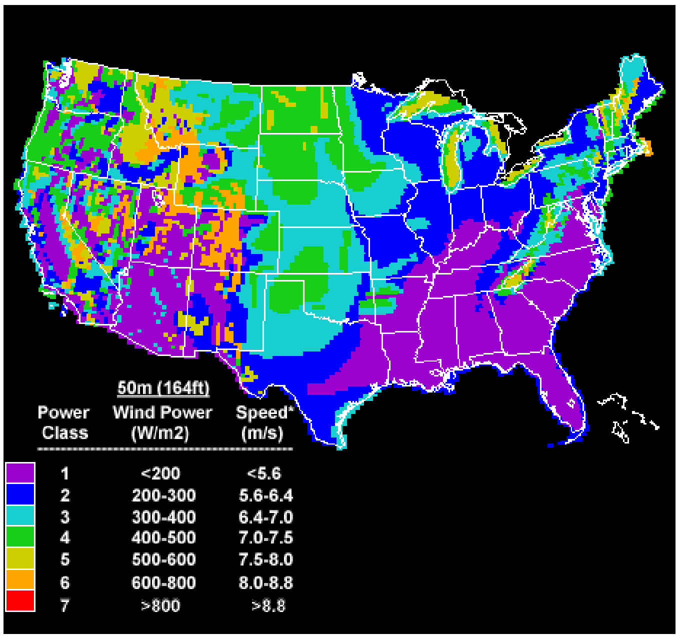

Figure 17. U.S. Wind Resources (From: http://www1.eere.energy.gov/windandhydro/wind_potential.html)

While wind power is can be produced for as little as four cents per kilowatt-hour, it requires an initial capital investment. However, this investment is usually less than non-renewable energy systems. The estimated cost of a wind-diesel hybrid system is $450,000 – much less than the $870,000 diesel only option (Technology Focus, 1998).

Because the wind must blow to generate power, creating a stable supply of electricity is a challenge for wind power. Batteries can store the energy generated or a complementary source of power can augment the system. The U.S. Forest Service uses wind power for communication sites and incorporates diesel generators to augment the wind power. On a larger scale, the DOE is researching how to integrate wind and hydropower. By tying wind power to a hydropower distribution network, the dam only needs to create electricity when the wind does not blow. This creates a stable supply of electricity as well as takes advantage of existing distribution networks.

5. Solar

The sun provides renewable energy in several manners. The two most mature and common forms of solar power include photovoltaics, a semiconductor material that converts sunlight directly to electricity and solar heating, where the sun's energy directly heats water or building interiors. Two areas of ongoing solar research include concentrating solar power (CSP) and solar lighting. CSP is the process where the sun's heat energy is concentrated through mirrors and drives a generator that produces electricity. Solar power illuminates buildings by collecting sunlight in fiber optic systems (www1.eere.energy.gov/solar).

Photovoltaics are a very common form of solar power. Calculators, watches and even emergency roadside telephones use photovoltaics. Photovoltaics are made of a silicon substance that releases ions when excited by sunlight. These ions are collected and generate electricity. There are three ways to organize photovoltaics: cells, modules or arrays (see Figure 18). A few individual cells can power a watch but commercial level power generation requires a series of arrays. To maximize energy produced, arrays positioned on tilt plates follow the sun as it moves throughout the day.

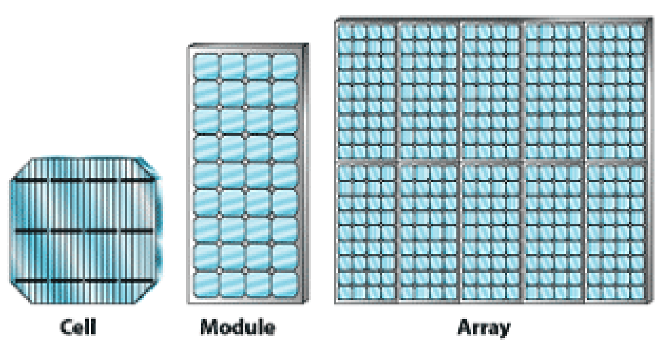

Figure 18. Photovoltaic cell, module and array (From: http://www1.eere.energy.gov/solar/pv_systems.html)

Solar heating provides heat to both water and space. For water heating, the sun heats water or a heat transferring liquid. The water is then stored in a collection tank (or the heat transferring liquid heats the water). Conventional heating systems provide any additional heat. For heat or air conditioning, the air routes through a solar collector and the collector adds or removes heat depending on the season.

Opponents of solar power point out that the sun only shines for one-half of the day. Even then, there are clouds and bad weather that interfere with collection. Insolation is the measure of the average amount of sun light available at a place for collection. Figure 19 shows that the best areas for solar energy are located in the southwestern part of the country.

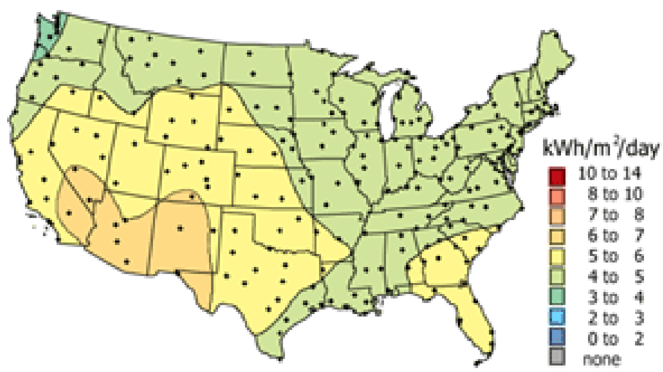

Figure 19. U.S. Solar Resources (From: http://nationalatlas.gov/articles/people/a_energy.html#three)

6. Nuclear

Nuclear power is another alternative energy source. It is renewable and domestically produced. In a nuclear power plant, the reactor core heats the water and produces steam, which turns a turbine generator and produces electricity. This process is extremely effective and efficient; nuclear reactors currently generate about 8 percent of the United States electricity usage.

The greatest challenge of nuclear power is the disposal of radioactive waste. The United States plans to use Yucca Mountain, Nevada as the storage location. However, this plan has met with state and local resistance and Yucca Mountain will not be open any sooner than 2017. Currently, spent nuclear rods are stored in holding tanks at the nuclear power plants and most of these tanks are overcrowded. Until this issue is resolved, building more nuclear power plants is not an attractive undertaking.

Rigorous regulations are another challenge to nuclear energy. In response to the 1979 Three Mile Island incident, nuclear regulations became more stringent. So stringent in fact, that since 1978, investors cancelled over 100 orders and no one ordered any new nuclear reactors until recently. The Tennessee Valley Authority's Watts Bar 1, ordered in 1970, was the last reactor to come on line in 1996 (Nuclear Energy Policy, 2007).

The NEP, EPAct of 2005 and the AEI provide incentives for rejuvenating the nuclear power industry and revamping the licensing procedures. As a result, the Nuclear Regulatory Commission expects to receive, for the first time in 30 years, application for licenses for new nuclear power plants (Atomic Renaissance: Nuclear Power, 2007). One of the ways the NEP recommends increasing the generation capacity of existing nuclear plants is to increase their operating time from 90 percent to 92 percent. This would increase nuclear power output by 2,000 MW. Additionally, nuclear plants can generate 12,000 MW more electricity by being uprated, using new technologies to produce more power while operating safely.

C. CURRENT DOD RESEARCH AND APPLICATIONS

The DoD increased its total renewable energy usage in 2006 to 9.5 percent or 9.361 trillion Btus as well as increased its energy efficiency in facilities by 5.5 percent. As Table 3 shows, the DoD reduced its energy use by 5.5 percent, decreased its use of petroleum-based fuels for facilities by 23 percent and cut water consumption by 29.6 percent.

The DoD also increased its renewable energy consumption by 194.8 percent. The DoD accomplished this by acquiring power directly from a renewable power source, as is the case with the Nellis Air Force Base (AFB) Solar Power System, as well as purchasing renewable energy certificates. By purchasing renewable energy certificates, a military installation may or may not be actually getting their energy from a renewable source. The installation purchases the energy at the “green” price and in this way supports renewable energy infrastructure. (http://www1.eere.energy.gov/femp/renewable_energy/renewable_purchasepower.html)

To achieve these results, the DoD maintains an aggressive plan for identifying and adopting energy efficient practices as well as seeking out opportunities to generate and purchase renewable energy. Hundreds of efforts exist at bases throughout the United States; a few of the more successful and recent projects are listed below.

1. Biomass – Hill Air Force Base Biomass Power Plant

Hill AFB, Utah collaborated with the Davis County Landfill (as well as local utilities) to install a connecting pipeline and a biomass power plant. The off-base landfill produces methane gas, which a pipeline transports to a biomass power plant on Hill AFB. This biomass power plant produces 5,318 Megawatt hours annually, corresponding to a savings of $400,000. Additionally, use of the biomass power plant reduces annual production of greenhouse gases by 5,000 tons. (Abbuehl, 2005)

2. Geothermal – Coso Geothermal Project

In Coso Hot Springs, CA, the Navy has four geothermal power plants. Operated in conjunction with the DOE, the Coso Geothermal Project serves as a test site for new geothermal technology applications. The Coso Geothermal Project currently produces 280 Megawatt hours of energy. (Geothermal Technologies Program, 2004)

3. Wind – Ascension Island

In 1995, the Air Force installed four wind turbines at Ascension Island, a British territory in the South Atlantic Ocean where a U.S. satellite tracking station is located. These four wind turbines, paired with a diesel power plant, produce 2.7 Megawatt hours or 25 percent of the islands electricity needs. At the time, the wind turbines eliminated the need for 250,000 gallons of diesel fuel. This wind power not only saves fuel directly, but also the fuel needed to transport to the remote island In 2002, a second set of wind turbines tripled the power generation to 9,500 Megawatt hours per year. Now, the wind farm saves 700,000 gallons of fuel per year and 1 million dollars as well as reducing greenhouse gases by 198,000 pounds. (Clinchard et al., 2004)

4. Solar – Nellis Air Force Base Solar Power System

The Nellis AFB Solar Power System is an example of a current alternative energy application. Nellis AFB collaborated with local government agencies and commercial firms to build and operate the largest solar farm in the United States. This farm will have 70,000 solar panels and 140 acres of photovoltaic sensors. When completed, the solar farm will generate 15 megawatts of power, providing 30 percent of the power for Nellis AFB. The solar farm completion is scheduled for early 2008.

The Nellis Air Force Base Solar Power Systems provides one of the best examples of collaborating with commercial and government entities to employ renewable energy sources. Many military bases are located in areas with high insolation as well as on large tracts of land. Some of this land is reserved for training and other areas are simply buffer zones. Because of this two attributes, military bases are prime locations for solar farms. (Nellis AFB Solar Power System Fact Sheet, 2007).

D. CONCLUSION

There is no one solution to providing a cost effective, renewable, domestically produced alternative energy source to meet the entire country's energy needs. Nor are all renewable energy sources available in all parts of the country. Many sources, like hydropower and wind, are geographically specific. Nevertheless, together there are more than enough resources to fulfill the country's energy needs. Moreover, the combination of all renewable energy sources has the potential to supplement traditional sources of energy, notably fossil fuels, in providing a cost effective, energy efficient means of improving the environment and national security.

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IV. ALTERNATIVE FUELS

A. INTRODUCTION

The EPAct of 1992 states that alternative fuels must meet three criteria: be substantially nonpetroleum, yield substantial energy security benefits and offer substantial environmental benefits. Based on these criteria, the EPAct lists the following as alternative fuels: biodiesel (B100), ethanol, natural gas, coal-derived liquid fuels, liquefied petroleum gas (propane), methanol, hydrogen, electricity. Alternative fuels that meet these criteria qualify for funding and are subject to regulation.

B. TYPES OF ALTERNATIVE FUELS

1. Biodiesel

Biodiesel is considered an alternative fuel only if it 100 percent pure (B100). Biodiesel is a product of biomass (vegetable oils and animal fats) sources; most often blended with petroleum diesel. These blends (B20 and B2-5) are more common and popular because of their versatility. According to the DOE Alternative Fuels Data Center[9], current diesel engines can use blends of up to 20 percent biodiesel (B20). Higher blends would most likely require engine modifications. Regardless, B100 or any blend reduces the amount of hydrocarbons emissions with significant environmental benefits.

While B100 is more expensive than petroleum diesel, B20 is cheaper. In July 2007, the nationwide price for diesel was $2.96 per gallon and biodiesel (B20) was $2.84 per gallon (Clean Cities Alternative Fuel Price Report, July 2007). Critics point out that the prices of alternative fuels are misleading and simply capture the selling price of the fuel. Alternative fuels are generally less efficient than their diesel or gasoline counterpart and require more fuel to achieve the same amount of energy. For example, a truck using

[9] The DOE Alternative Fuels Data Center is a good source for current research and application for alternative fuels.

B20 would require more fuel to travel the same distance as using regular diesel. Table 3 lists the price for alternate fuels in July 2007 as well as the normalized price for energy equivalents. When normalized for energy equivalency, the price of B20 is $3.02 per gallon, more than for regular diesel. Even so, the DOE records "consumer interest in alternative fuels increases as the price differential per gallon increases, even if that differential does not directly translate to savings on an energy-equivalent basis."

	National Average (July 2007)	**Gasoline/Diesel Gallon Equivalents**
Gasoline	$3.03	$3.04
Diesel	$2.96	$2.96
CNG	$2.09	$2.10
Ethanol	$2.63	$3.72
Biodiesel (B20)	$2.84	$3.02
Biodiesel (B99-B100)	$3.27	$3.59

Table 3. Alternative Fuel Price Comparisons (After: Clean Cities Alternative Fuel Report, July 2007)

2. Ethanol

A more familiar alternative fuel is ethanol, also produced from biomass. Ethanol is the additive used to oxygenate fuels to a certain octane level. Blends of at least 85 percent (E85) power flex fuel vehicles (FFV) which produce fewer emissions and are more efficient than gasoline-only vehicles. E85 is also cheaper than regular gasoline: $3.03 per gallon versus $2.63 per gallon, although when normalized for energy equivalency, the price of E85 jumps to $3.72 per gallon (Clean Cities Alternative Fuel Price Report, July 2007).

3. Natural Gas

Another familiar alternative fuel is natural gas. Natural gas accounts for 20 percent of the fuel used in the U.S., but the majority generates electricity. Oil companies extract natural gas directly from natural reserves, but it is also a byproduct of oil production and gas wells. Large amounts are available for import. However, the U.S. domestically produces 85 percent of its natural gas consumption (AER 2006, 2007).

4. Coal-Derived Liquid Fuels

A fuel converted from coal is another alternative fuel called Fischer Tropsch (F-T). The F-T process liquefies coal or natural gas into a fuel. The obvious drawback to coal-derived liquid fuels is they are not renewable sources of fuel, although they are cheaper to produce, manufactured domestically and generate fewer emissions. Fortunately, the United States possesses vast coal reserves estimated to last for the next two centuries. These deposits reside in a variety of states including Illinois, Kentucky, West Virginia, Montana, Wyoming, Texas, North Dakota, Ohio and Pennsylvania (Annual Coal Report, 2005). The DOE's Energy Information Administration estimates that over 275 billion short tons of coal are recoverable from across the U.S. This quantity equates to over 200 years of U.S. consumption at current rates. (http://www.eia.doe.gov/neic/infosheets/coalreserves.html). So, while not renewable, the coal supplies necessary for F-T production are not at risk of depletion.

The Germans designed the F-T process in the 1920s and used it extensively for fuel production during World War II. Since Germany had no petroleum reserves, their war making capability was "fueled" by their domestic production of liquid fuel. At its peak in 1944, German fuel production topped 124,000 barrels per day (http://www.fe.doe.gov/aboutus/history/syntheticfuels_history.html). Over the years, producing fuel from the F-T process has fallen by the wayside—mainly because of the abundance of petroleum sources and stable international trade. An exception is South Africa, which uses 100 percent of Fischer Tropsch fuel – relying on this domestic source of fuel since placed under Apartheid economic sanctions in the 1980s. With the rising petroleum prices and unrest in crude oil producing nations, F-T fuel has become more attractive.

Fischer Tropsch fuel is cheaper to produce gasoline and the Great Plains Synfuels Plant in central North Dakota produces F-T gas at half the cost of the current market of

1.74 dollars per gallon (Technical Options for Improved Air Vehicle Fuel Efficiency, 2006). This 50 percent reduction in cost would result in a savings of 100 million dollars a year.

5. Electricity

Electricity from a battery, as used in an electric-hybrid vehicle, produces no emissions and is significantly less expensive than gasoline. A current electric-hybrid vehicle would cost $.03 per mile to operate while a gasoline-powered car would cost $0.12 per mile (when the vehicle gets 25 miles per gallon and gasoline costs $3.00 per gallon) (http://www.eere.energy.gov/afdc/vehicles/electric_what_is.html). Electric only vehicles have limited battery life, but advanced battery technology will increase electric vehicle speed and range capabilities. However, all batteries contain chemicals whose manufacture has environmental repercussions.

C. CURRENT DOD RESEARCH AND APPLICATIONS

1. Coal-Derived Liquid Fuels – Assured Fuels Initiative

The majority of the DoD's fuel used for is aviation: 6.1 billion dollars a year are spent on JP-8 (the primary aviation fuel) alone. The Assured Fuels Initiative (AFI) is studying and researching a variety of more cost efficient and domestic sources of fuel. The most promising source is the gas to liquid fuel Fischer Tropsch.

In 2006, Congress recognized the importance of finding a domestic source of fuel and the need for a less expensive aviation fuel option. Congressional support in the Fiscal Year 2006 budget gave the Air Force the ability to begin Alternative Aviation Fuels testing. Congressional funding of 4.8 million dollars kicked off this effort.

Based on this additional funding provided by Congress, Air Force Research Laboratory (AFRL) began testing TF-33 engines with a fuel blend of 50 percent Fischer Tropsch and 50 percent JP-8. Several aircraft in the Air Force inventory uses the TF-33 engine in several aircraft in the Air Force inventory, to including the B-52 Stratofortress bomber. The 50/50 fuel blend has shown a "20 percent-40 percent decrease in particle concentration and smoke number and a 30 percent-60 percent reduction in particulate mass." (http://www.wpafb.af.mil/news/story_print.asp?storyID=123040425) In addition, AFRL found that F-T has "excellent low temperature properties, which can help improve capacity for flying at higher altitudes, and have increased fuel thermal stability, which allows development of more fuel efficient propulsion systems." (http://www.wpafb.af.mil/news/story.asp?id=123034176) F-T burns cleaner for the environment and is more fuel efficient, performing better in the operational setting.

The Air Force followed up these ground tests of the TF-33 with in-flight tests on the B-52. In October, the B-52 began flying routine operational missions with the 50/50 fuel blend. The Air Force has also ordered 281,000 gallons of the 50/50 fuels for testing on the B-1 Lancer bomber and the C-17 Globemaster III transport aircraft. The Air Force plans to complete certification of the fuel for all its aircraft and ground-support equipment as well as increasing the ratio of 50/50 fuel blend. The goal is for the entire Air Force fleet to run on a synthetic blend by 2011. (AIR FORCE Magazine, 2007)

2. Electricity – Luke Air Force Base Electric Vehicle Program

Currently, Luke AFB, AZ utilizes over 450 electric vehicles in its daily operations. The electric vehicle program reduces greenhouse gas emissions by 79 tons annually. (http://www.luke.af.mil/news/story.asp?id=123058135) Electric vehicles are emission-free and can be cheaper to purchase, operate and maintain, depending how they are used and in what environment.

D. CONCLUSION

Alternative fuels offer an environmentally friendly technology with great potential for military application. Fischer-Tropsch and biodiesel fuel show immediate promise for home station (on-base use) with no known adverse affect on deployed operations at this point. Cost and performance are still the evaluation criteria for F-T, biodiesel and other alternative fuels. However, cost evaluations should include the impact on the environment and national security. Incentivizing alternative fuel use for both the DoD components and contractors could facilitate their adoption. Further research into potential application of alternative fuel offers the promise of cost savings, environmental benefits and increased national security.

V. GREEN ENERGY FOR THE BATTLEFIELD

A. INTRODUCTION

Green energy for the battlefield has the potential to reduce the U.S. dependence on foreign sources of oil, keep costs under control and improve environmental emissions. However, green energy for the battlefield also has the potential to reduce the logistics tail and improve mission effectiveness. For example, if an application of green energy reduces the logistics fuel requirement by 30 percent, then there will be a 30 percent reduction in the need for convoys. There will be a 30 percent reduction in the need for personnel on the convoys and this could translate into 30 percent less casualties. The following section looks at the viable renewable energy sources and alternative fuels for use on the battlefield.

B. POTENTIAL APPLICATION

1. Renewable Energy Sources

Several renewable energy sources immediately rule themselves out for potential use on the battlefield. These sources require very large fixed structures, long lead times to build and often use hazardous materials. Hydropower requires the battlefield be close to a large water source and the conflict to last long enough (several years) in order to build a dam and energy distribution system. Geothermal sources also require time to drill and place pipes into the earth. Wind power is extremely location specific. Nuclear power requires even more time to build the plant, not to mention the energy source is inherently dangerous, especially so in a war zones. On the other hand, one shining potential candidate for battlefield use is solar power. Biomass also shows potential.

a. Solar Power

Solar power is extremely flexible. It is easy to vary its size and power generation capability as well as easy to transport and setup. Several commercial companies offer solar panel chargers to power cell phones, iPods and other small electronics. The outdoor enthusiast is the target of these commercial marketing efforts. However, the military could design these devices for soldiers' personal use. The soldiers would always need batteries but solar power use would significantly reduce the weight of the soldier's gear and reduce the logistics tail of supplying as many batteries for radios, light sources and other electronic equipment.

Solar power is also a candidate for rebuilding conflict areas. Users can tailor solar power to the surrounding power needs and minimize power distribution challenges as well as it is fast and easy to install. Naval Postgraduate School students, Austin, Borja and Philips, conclude in their analysis, *Operation Solar Eagle: A Study Examining Photovoltaic (PV) Solar Power as an Alternative for the Rebuilding of the Iraqi Electrical Power Generation Infrastructure* (2005), that solar power is a viable candidate for rebuilding the Iraqi energy infrastructure. Solar power is not only attractive for U.S. use but also for our allies.

b. Biodesign Solar Panels

Another example of current alternative energy use is a low cost solar panel. A small English charity organization, Biodesign, developed a low cost solar panel for use in rural Africa to power radios. These solar panels connect to exactly the same place in radios as normal batteries – so no modification is necessary. These same solar panels can power a cell phone or a light source. The manufacturers designed the solar panels to last for 20 years and they will completely replace the need for batteries. The design and implementation is so easy, Biodesign calls their product DIY or Do It Yourself. (http://biodesign.webeden.co.uk/)

c. Air Force Basic Expeditionary Airfield Resources

The Air Force Basic Expeditionary Airfield Resources is another example of potential solar power application. The Base Power Systems Branch is researching ways to use solar power to provide electricity to deployed forces. This Tyndall AFB team is researching how to integrate photovoltaic (PV) cells into the material of the Bare

Base shelters. Bare Base shelters are the tents that deployed units use to work and live. This effort will make deployed bases more self-sufficient and sustainable and reduce the logistics tail of providing fuel for generating electricity. When fully deployable, the system would provide 4,856.16 kW of energy.[10] (Applied Research Associates Inc, 2005)

d. *Hybrid Transportable Power*

The U.S. Army is evaluating hybrid transportable power systems to reduce logistics requirements, noise generation and environmental emissions. The Analysis of Deployable Application of Photovoltaics in Theater (ADAPT) report compares conventional diesel systems and solar/diesel hybrid systems. The hybrid systems only generate 5 kW, which does not meet all the Army's power needs, but 68 percent of the generators in the 82nd Airborne and 4th Mechanized Divisions are 5 kW or less. Table 4 details the ADAPT findings but in general, the study found the solar/diesel hybrid systems met, and in some cases improved, operational requirements. (Transportable and Hybrid Transportable AC Systems, 2005)

	Security	Ops Friendly	Durability	Reliability
Diesel only	• Lower visibility • Greater heat signature • Noisier	• Greater maintenance requirements • More labor intensive	• Ruggedized • 10-20 year life cycles	• Average reliability
Solar (80%) – Diesel (20%)	• Greater trailer height visibility • Less heat signatures (solar) • Less noise (solar)	• Lower maintenance requirements • Less overall labor	• Modules ruggedized • Durable lead acid batteries • 20+ year life cycle	• PV systems has no moving parts • Reliable electronics

Table 4. ADAPT Comparison of Diesel and Solar/Diesel Hybrid System (After: Transportable and Hybrid Transportable AC Systems, 2005)

[10] This is a peak power production assuming the PV cells operate at 20 percent efficiency and the base is 6 acres. 1000W/m^2*4046.8 m/acre*6 acre* 20 percent = 4,856,160 W *0.001W/kW= 4,856.16 kW.

e. Mobile Power System

In 2007, the Army purchased a Mobile Power System from SkyBuilt Power. The system is completely transportable in one standard shipping container and is capable of generating 5 kW of power from any number of power sources: solar, wind, and diesel. It also contains batteries to store any energy created by solar or wind power. Units can easily transport the system to the front lines and set it up in minimal time. The biggest advantage of the system is that it minimizes the use of diesel, which in turns minimizes the logistics tail to support a unit. This reduces costs, but it also removes soldiers from dangerous convoys which ultimately could save lives. The system is currently undergoing test at Fort Belvoir with hopes of deploying to the battlefield soon. (Wagner, 2007)

f. Tactical Biorefinery

The Army awarded a contract to a Virginia based firm, Defense Life Sciences, to upgrade its Tactical Biorefinery and build a second prototype for testing and deployment. The Tactical Biorefinery is about the size of a moving van and can generate up to 60 kW of energy, enough energy to support a large mess tent. According to Defense Life Sciences founder Jerry Warner, each soldier generates up to four pounds of trash a day and the Tactical Biorefinery "gets rid of trash and conserves fuel at the same time" (Junk In, Power Out, 2007).

2. Alternative Fuels

Although alternative fuels are a key component of green energy, many are not from renewable sources. Domestic production is the biggest advantage offered by coal-derived liquid fuels and natural gas. Implementing domestically produced alternative fuels on the battlefield is another issue. Of course, if the alternative fuel is available in the theater, using the alternative fuel is a benefit and better for the environment. However, if the alternative fuel is not available in theater, it does not make sense to transport it to the theater. This effort consumes fuel and because most alternative fuels are not as energy efficient as regular diesel, the combination of transporting the alternative fuel and using it in theater will ultimately require more fuel.

a. Biodiesel

Biodiesel presents the military with low hanging fruit. As discussed in the alternative fuels section, the biodiesel blend B2 is cheaper than regular diesel although when normalized for energy equivalency, it is approximately the same cost. The benefits of biodiesel are that it is renewable, domestically produced and reduces emissions. Biodiesel blends are compatible with current petroleum diesel engines, storage areas and distribution systems. By sourcing only B2, it would seem the U.S. military would save 18.5 million dollars given 2006 fuel prices. However, when taking into consideration the normalized cost of biodiesel, there is no true dollar savings. The true benefit is the reduction in emissions and reducing the dependence in foreign sources of oil. Additionally, it might result in trucking companies becoming more familiar with biodiesel products and potentially adopting it for all their trucking. However, if biodiesel is not available in the theater, it makes no sense to transport it to the battlefield for use.

b. Hybrid Vehicles

Electric only vehicles may be excellent options for home station, but they present considerable logistics concerns while deployed. Hybrid vehicle were considered as an alternative in the MITRE study, *Reducing DoD Fossil-Fuel Dependence* (2006). In general, hybrid vehicles are more energy efficient, produce less emissions and reduce the logistics tail. Nevertheless, the study concluded hybrid vehicles are not beneficial on the battlefield. The energy efficiency of a hybrid vehicle is dependent on usage. Hybrid vehicles get the best fuel mileage while in urban, stop and go areas. Many military tactical vehicles operate in this environment, but often these urban environments also have "off-road" conditions. A hybrid vehicle gains no fuel efficiency in an off-road environment. Hybrid vehicle also aweigh more than their conventional counterparts do.

This extra weight actually increases the logistics needed to deploy the asset. Additionally, since there will not be any fuel efficiencies realized, the extra weight decreases the vehicles fuel efficiency.

C. EVALUATING GREEN ENERGY FOR THE BATTLEFIELD

The military operates in two distinct situations – home and deployed. When considering green energy for military uses, it is important to understand the difference. While a military unit is at its home base, the unit is primarily engaged in training operations. Although since 9/11, many units engage in combat operations while stationed at home. Additionally, the military can acquire energy and fuel from a stable source and from a stable supply chain. Units typically engage in combat operations while deployed. In a deployed environment, the military cannot rely on stable energy source or a stable energy distribution network. The military's use of fuel may be different in these two different environments and evaluations of green energy's viability must be sensitive to this difference.

There are several criteria to consider when evaluating a potential green energy application for the battlefield. The first is the green energy application must meet, or even exceed, mission requirements. Next, the green energy application must improve the environment. Not all green energy applications do this and sometimes the rush to use green energy actually has detrimental effects. For instance, this happens when the distribution of alternative fuels creates more emissions than are saved in using the alternative fuels. The transport of alternative fuels is usually done with traditional fuels. So the benefit of alternative fuel is lost by the transportation. Meeting regulatory compliance is also a factor when researching and developing green energy applications. Finally, the cost of a green energy application has to be weighed against the benefits to mission requirements, the environment, and national security.

1. Mission Requirements

Regardless of the other criteria, all green energy must meet minimum mission performance requirements. Renewable energy sources must provide the same amount and duration of power as its counterparts and must not put the soldier in more danger or require additional logistics support. Alternative fuels also require no degradation in performance. The vehicles and aircraft must be able to have the same range and power. COL Gordon Kuntz advocates in his paper, *Use of Renewable Energy in Contingency Operations* (2007), the focus of green energy should change from simply improving the environment to enhancing the mission capabilities of the war fighter. Green energy offers significant benefits to the logistical aspects of the battlefield. Any technology that can reduce the footprint of deployed forces is beneficial. Additionally, if green energy reduces the logistical supply chain, that is also a benefit.

2. Environmental Benefits

Deploying green energy on the battlefield should also reduce emissions. Several alternative fuels are classified green energy, generating fewer emissions and produced from domestic resources. Nevertheless, these same alternative fuels, namely coal-derived liquid fuels and natural gas, are still limited resources. Deployment and logistical supply of these fuels on the battlefield would not improve conditions for the environment. The use of additional fuel in the distribution negates any potential benefits.

3. Regulatory Compliance

Regulations drive a portion of green energy use. Currently there are no regulations that specifically address developing green energy for the battlefield. However, when such legislation is enacted, then regulatory compliance will become a factor in evaluating green energy applications.

4. Costs

The benefits of improved mission requirements, reduction in emissions, improved national security and regulatory compliance must balance any additional costs associated with green energy. In their paper, *Solar Power* (1990), A.L. Walton and Darwin C. Hall, suggest a utility-specific comparison method to evaluate a particular utility for a specific project for a specific utility supply plan. Utility specific comparisons include both the cost to produce the energy as well as the construction costs of the project.

Reducing DoD Fossil-Fuel Dependence (2006) found that fuel costs represent a large fraction of a weapon systems life cycle. Some green energy is actually cheaper, like coal-derived liquid fuels, than its counterparts. Additionally, as the cost of imported crude oil continues the rise, green energy becomes more and more economically attractive.

D. DEVELOPING GREEN ENERGY FOR THE BATTLEFIELD

1. Organizational Structure

In order to provide a focused effort for green energy implementation, the proper organizational structure is required. Currently, the services are pursuing green energy applications within their individual departments. They focus on complying with current regulations of renewable energy use and energy efficiency, but there is minimal coordinated effort. Kuntz (2007) came to a similar conclusion that there is no single champion to “propagate the need for and importance of renewable energy systems.” A centralized office to provide direction and oversight will maximize the benefits of green energy. A subset of this organization would focus on battlefield applications.

Lt Col Michael Hornitschek agrees transformation of the current military energy environment requires a change in the organizational structure. He recommends in his article, *War Without Oil, Catalyst for Transformation* (2006), important changes to the current organizational structure, vision and strategy. First, he recommends creating an Office of Assured Energy under the Secretary of Defense to integrate the efforts of the DOE and DoD. He argues the DOE focuses primarily on research and development (R&D) but the Office of Assured Energy would bridge the gap between R&D and military implementation.

Hornitschek bases this approach on a model for organizational change developed by John P. Kotter and popularized in his book, *Leading Change* (1996). Kotter's model includes eight steps for organizational change:

- Establish a sense of urgency
- Create a guiding coalition
- Develop a vision and strategy
- Communicate the change vision
- Empower employees for broad-based action
- Generate short-term wins
- Consolidate gains and produce more change
- Anchor new approaches

Through the application of these steps, Hornitschek's next recommendation is to create an assured energy vision and strategy for the DoD. His vision would include petroleum independence by 2050. His recommended strategy includes a three-stage approach (Hornitschek, 2006):

- A near-term (2006-2020) focus on proper strategic leadership, energy efficiency, conservation, acquisition reform, bridge energy sources and research and development
- A mid-term focus (2020-2035) on infrastructure and technology transition
- A far-term focus (2035-2050) on employing a new energy

2. Policies and Funding

Encouragement, incentives and mandates are all means to implement policy change. Encouraging green energy is a tactic that permits a certain course of action but wields no influence. Administrations use this tactic when they wish to allow a certain course of action but do not want to worry about enforcement. Often times, administrations use encouragement when it does not want to make a decision. The opposite of encouraging is mandating. Mandating requires an administration to provide decisive direction but it also requires enforcement which can be time consuming and costly. Mandates must be clear otherwise they are challenged. Incentivizing captures the best of both encouraging and mandating. It provides direction, but does not require enforcement.

Incentives are for both internal organizations and external. Internally, the military usually focuses on cost and performance. However, this is often not enough. Incentives would help internal organization realize the potential benefit to the environment and national security. The military could target external incentives at vendors providing the military with transportation services. For example, DESC could incentivize trucking companies to use biodiesel fuel. As discussed before, by incentivizing trucking companies to use biodiesel the transportation sector would produce fewer emissions and improve national security.

A study performed by LMI, Transforming the Way DoD Looks at Energy (2007), for the Under Secretary of Defense for Policy recommends several policy changes to the current military outlook on energy use. First, the study recommends expanding the energy related requirements of Executive Order 13423 to all deployed forces. This would require the military to start to incorporate energy efficient applications to the battlefield. Additionally, the study recommends incorporating "energy logistics" into all corporate processes. This would include operational plans as well as capability based planning and budgeting efforts. Finally, the study proposes incorporating energy considerations into the acquisition process.

Organizational structure and policies drive proper funding to conduct relevant research, development and acquisition. To further green energy development and deployment to the battlefield, targeted funding is required. The LMI study proposed several changes to the funding of energy efforts. The study recommends making energy a R&D priority at the same time offering incentives for investment in energy efficient applications.

3. Research and Development

The LMI study (2007) also looked at the role of research and development of green energy. The study suggests the following (Transforming the Way DoD Looks at Energy, 2007):

- Research is diverse and not well focused
- DoD research investment is demand-side focused
- Multiple solutions will likely be required to significantly reduce traditional energy dependence.
- Technologies with a multiplier effect may significantly reduce logistics and other support costs.
  - Unmanned vehicles offer significant opportunities
  - Better information management could be as significant as energy directed technologies

Based on these findings, the study also offers three ways to organize research and development activities: greatest use challenge, greatest difficulty challenge, greatest impact challenge. Aviation fuel is the DoD's greatest use of non-renewable energy. Efforts focused on this greatest use would find ways to reduce the consumption of petroleum based aviation fuel. This influences both home station and battlefield energy use. The greatest difficulty challenge for the DoD is supplying troops on the battlefield. Logistics supply lines are often long and the longer they are the more vulnerable they are to attack. The difficulty includes not only the supply resources, but also the potential impact on operations of interrupted logistics supply lines. By decreasing the amount of resupply required through green energy applications, units on the battlefield are more effective.

The greatest impact challenge is improving the effectiveness of the soldier. The amount of weight an individual soldier must carry into battle is ever increasing. Currently, 15 to 20 percent of the weight burden is from batteries (Transforming the Way DoD Looks at Energy, 2007). R&D in green energy solutions to minimize this weight would increase the soldier's effectiveness. According to the Committee of Soldier Power / Energy Systems (2004), "a 10 percent savings in power could be expected to reduce the number of batteries required by a comparable amount. This would have reduced the logistics cost of delivering batteries in Operation Iraqi Freedom, saving an estimated $50 million."

E. CONCLUSION

Policies that are more aggressive and centralizing the green energy efforts will go a long way to further green energy for the battlefield. The result of this will be more targeted research and development focused on applying green energy not only at home station but in the deployed situation. Benefits to the environment, improving national security and reducing costs are all criteria for evaluating green energy. However, ensuring mission requirements are met is the primary criteria. Ultimately, there is potential for green energy to not only meet mission requirements but also enhance them.

VI. CONCLUSIONS, RECOMMENDATIONS, AND AREAS FOR FURTHER ACTION AND RESEARCH

A. INTRODUCTION

The U.S. is experiencing an energy crisis and green energy offers a viable solution. As discussed previously, green energy is being implemented by the military at installations and the DoD and the nation would benefit from application to the battlefield. To further its military use and application, it is important to have criteria to evaluate the green energy. Additionally, consolidation of the organizational structure could provide better focus on the issue as well as advocate targeted policies and funding. To date, there is no true alternative fuel. Future research and development should focus on the closing the alternative fuels gap as well as developing more energy efficient vehicles.

B. CONCLUSIONS

The following conclusions are based on the previous analysis of the current energy situation.

- The U.S. is experiencing an energy crisis
- Green energy offers a viable solution
- Green energy is being implemented by the military at installations and the DoD and the nation would benefit from application to the battlefield

1. Energy Crisis

The U.S. is experiencing an energy crisis. Production is not keeping up with consumption, which results in imports: 35 percent of energy and 60 percent of oil are currently imported. This reliance on imports adversely affects national security. Additionally, the costs of many traditional energy sources, such as oil, are currently rising rapidly. Non-renewable sources (fossil fuels) produce the majority of energy, and may become increasingly difficult or expensive to exploit, and fossil fuels produce undesirable levels of greenhouse gases, which damage the environment.

2. The Green Energy Solution

Green energy (renewable energy sources and alternative fuels) provide a means to reduce reliance on imports (notably oil and gas) and reduce energy costs. Additionally, green energy is generally not as limited in supply and its exploitation can have a significantly lower impact on the environment. There are several viable renewable energy sources: biomass, hydropower, geothermal, wind, solar and nuclear. Renewable energy is just that, renewable. Additionally, renewable energy produces fewer emissions than its petroleum based counterparts, although the use of any form of renewable energy has environmental impacts. Domestically produced energy reduces reliance on imports. Finally, many forms of renewable energy are becoming more and more cost efficient, which may lower producer and consumer costs.

Alternative fuels are also a key component of meeting the energy crisis. Alternative fuels include biodiesel, ethanol, natural gas, coal-derived liquid fuels, liquefied petroleum gas, methanol, hydrogen and electricity. Not all alternative fuels are renewable (e.g., natural gas and coal-derived liquid fuels) nor emission-free, but these alternative fuels offer other benefits such as reducing the dependence on foreign sources of energy in certain cases. Green energy, as well as alternative fuels and renewable energy sources, may offer a potential solution for the current energy crisis. However, other approaches, such as conservation or increasing the energy efficiency of existing equipment, are also approaches worthy of consideration.

3. Green Energy and the Military

Green energy can suit the military well. The military is implementing green energy and in certain cases meeting or exceeding regulatory standards. Up to this point, the vast majority of green energy use is here in the U.S. However, there is potential green energy application for the battlefield. Solar power and tactical biorefineries are two current available examples.

C. RECOMMENDATIONS

Recommendations for advancing green energy for the battlefield include:

- Establishing criteria for green energy for the battlefield
- Developing an organization focused on green energy for the battlefield
- Advocating policies and funding supporting green energy for the battlefield

1. Criteria for Green Energy for the Battlefield

Green energy has great potential to benefit the soldier on the battlefield. Up to this point, the acquisition and application of this technology has been haphazard. One way to improve this situation is to codify the criteria to evaluate green energy. The criteria must include meeting (and improving) mission requirements, improving the environment and complying with regulations. Cost is only a consideration balanced by these other factors.

2. Focused Organizational Structure

Another reason the acquisition and application of green energy is haphazard is the lack of a focused organizational structure. Currently the military is using a variety of teams and initiatives to further green energy. The installation management of all three services oversees the individual military departments' energy plans. Consequently, the implementation of green energy centers on infrastructure energy. A separate effort is looking at alternative fuels - the leading contender being coal-derived liquid fuels. Neither of these efforts focuses on the benefits of green energy for the battlefield. A focused organizational structure, responsible for military energy use, would solve this problem.

3. Targeted Policies and Funding

Once clearly defined criteria for evaluating green energy and an organizational structure is in place to direct its implementation, target policies and funding is required. Targeted policies need to exist in order to align activities of research, development, acquisition and deployment. Funding is required to carry out these policies.

D. AREAS FOR FURTHER ACTION AND RESEARCH

Further action and research should focused on:

- The alternative fuels gap
- Energy efficient vehicles

1. Alternative Fuels Gap

The focus of further action and research must center on solving the alternative fuel gap. Green energy includes both renewable energy sources and alternative fuels. Several renewable energy applications are available for the military both at home station and for the battlefield.

Viable renewable energy sources are readily available. They are also currently in use by military and available for battlefield use. However, alternative fuels are not at the same point in development as renewable energy sources. Natural gas and coal-derived liquid fuels are alternatives to oil and they reduce the reliance on imports. Nevertheless, they are not renewable nor do they significantly reduce emissions. Even biodiesel is still comprised mainly of oil.

Research and development in coal-derived fuels is filling the current alternative fuels gap (even though the U.S. currently sources its coal-derived liquid fuels from foreign sources). Nevertheless, this is only an interim solution until the military can find a truly viable alternative fuel – one that is renewable, reduces emission and reduces reliance on imports. The final criterion for a true alternative fuel for the military is to improve the mission performance on the battlefield.

2. Energy Efficient Vehicles

Since there is no current alternative fuels silver bullet, energy efficient vehicles potentially offer the most promising answer to address the energy crisis and improve fuel mission effectiveness. Fuel-efficient vehicles will be able to reduce the logistics tail. As presented before, a 30 percent reduction in fuel potentially leads to 30 percent less casualties. However, fuel-efficient vehicles also reduce emissions and the reliance on foreign sources of oil. They also lessen the drain on non-renewable sources of energy and potentially are more cost effective. A key component of *Reducing the DoD Fossil-Fuel Dependence* (2006) is energy efficient vehicles. The Defense Science Board Task Force on Improving Fuel Efficiency of Weapon Platforms (2001) also advocates energy efficient vehicles as a way improve weapon system performance and reduce logistics costs.

E. CONCLUSION

Green energy is viable for the battlefield and in some instances, the technology already exists and is being applied. Green energy offers a solution to the energy crisis, improving national security, reducing emissions and controlling costs. Furthermore, green energy for the battlefield potentially improves the effectiveness of the individual soldier and the U.S. military as a whole.

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APPENDIX A. SUMMARY OF NATIONAL ENERGY POLICY RECOMMENDATIONS

The NEP builds on our nation's successful track record and will promote further improvements in the productive and efficient use of energy. This report includes recommendations to:

• Direct federal agencies to take appropriate actions to responsibly conserve energy use at their facilities, especially during periods of peak demand in regions where electricity shortages are possible, and to report to the President on actions taken.

• Increase funding for renewable energy and energy efficiency research and development programs that are performance-based and cost-shared.

• Create an income tax credit for the purchase of hybrid and fuel cell vehicles to promote fuel-efficient vehicles.

• Extend the Department of Energy's "Energy Star" efficiency program to include schools, retail buildings, health care facilities and homes and extend the "Energy Star" labeling program to additional products and appliances.

• Fund the federal government's Intelligent Transportation Systems program, the fuel cell powered transit bus program, and the Clean Buses program.

• Provide a tax incentive and streamline permitting to accelerate the development of clean Combined Heat and Power technology.

• Direct the Secretary of Transportation to review and provide recommendations on establishing Corporate Average Fuel Economy (CAFE) standards with due consideration to the National Academy of Sciences study of CAFE standards to be released in July 2001.

The NEP will modernize and expand our energy infrastructure in order to ensure that energy supplies can be safely, reliably, and affordably transported to homes and businesses. This report includes recommendations to:

• Direct agencies to improve pipeline safety and expedite pipeline permitting.

• Issue an Executive Order directing federal agencies to expedite permits and coordinate federal, state, and local actions necessary for energy-related project approvals on a national basis in an environmentally sound manner, and establish an interagency task force chaired by the Council on Environmental Quality. The task force will ensure that federal agencies set up appropriate mechanisms to coordinate federal, state and local permitting activity in particular regions where increased activity is expected.

• Grant authority to obtain rights-of way for electricity transmission lines with the goal of creating a reliable national transmission grid. Similar authority already exists for natural gas pipelines and highways.

• Enact comprehensive electricity legislation that promotes competition, encourages new generation, protects consumers, enhances reliability and promotes renewable energy.

• Implement administrative and regulatory changes to improve the reliability of the interstate transmission system and enact legislation to provide for enforcement of electricity reliability standards.

• Expand the Energy Department’s research and development on transmission reliability and superconductivity.

Our policy will increase and diversify our nation’s sources of traditional and alternative fuels in order to furnish families and businesses with reliable and affordable energy, to enhance national security, and to improve the environment. This report includes recommendations to:

• Issue an Executive Order directing all federal agencies to include in any regulatory action that could significantly and adversely affect energy supplies a detailed statement on the energy impact of the proposed action.

• Open a small fraction of the Arctic National Wildlife Refuge to environmentally regulated exploration and production using leading-edge technology. Examine the potential for the regulated increase in oil and natural gas development on other federal lands.

• Earmark $1.2 billion of bid bonuses from the environmentally responsible leasing of ANWR to fund research into alternative and renewable energy resources – including wind, solar, biomass, and geothermal.

• Enact legislation to expand existing alternative fuels tax incentives to include landfills that capture methane gas emissions for electricity generation and to electricity produced from wind and biomass. Extend the number of eligible biomass sources to include forest-related sources, agricultural sources, and certain urban sources.

• Provide $2 billion over 10 years to fund clean coal technology research and a new credit for electricity produced from biomass co-fired with coal.

• Direct federal agencies to streamline the hydropower relicensing process with proper regard given to environmental factors.

• Provide for the safe expansion of nuclear energy by establishing a national repository for nuclear waste, and by streamlining the licensing of nuclear power plants.

The NEP will build upon our nation's successful track record and will promote further improvements in the productive and efficient use of energy. This report includes recommendations to:

• Enact "multi-pollutant" legislation to establish a flexible, market-based program to significantly reduce and cap emissions of sulfur dioxide, nitrogen oxides and mercury from electric power generators.

• Increase exports of environmentally friendly, market-ready U.S. technologies that generate a clean environment and increase energy efficiency.

• Establish a new "Royalties Conservation Fund" and earmark royalties from new, clean oil and gas exploration in ANWR to fund land conservation efforts.

• Implement new guidelines to reduce truck idling emissions at truck stops.

To ensure energy security for our nation and its families, our report includes these recommendations:

• Dedicate new funds to the Low Income Home Energy Assistance Program by funneling a portion of oil and gas royalty payments to LIHEAP when oil and natural gas prices exceed a certain amount.

• Double funding for the Department of Energy's Weatherization Assistance Program, increasing funding by $1.4 billion over 10 years.

• Direct the Federal Emergency Management Administration to prepare for potential energy-related emergencies.

• Support a North American Energy Framework to expand and accelerate cross-border energy investment, oil and gas pipelines, and electricity grid connections by streamlining and expediting permitting procedures with Mexico and Canada. Direct federal agencies to expedite necessary permits for a gas pipeline route from Alaska to the lower 48 states.

APPENDIX B. SUMMARY OF ENERGY POLICY ACT OF 2005 - PROVISIONS AFFECTING FEDERAL ENERGY MANAGERS

Section	**Lead Agency**	**Provisions**
102. Energy management goals	DOE	• Annual energy reduction goal of 2 percent from FY 2006 – FY 2015 • Reporting baseline changed from 1985 to 2003 • In 180 days, DOE issues guidelines • Retention of energy and water savings by agencies • DOE reports annually on progress to the President and Congress • DOE recommends new requirements for FY 2016 – FY 2025 by 2014
103. Energy use measurement and accounting	DOE	• Electric metering required in federal buildings by 2012 • In 180 days, DOE consults and issues guidelines • Agencies report to DOE 6 months after guidelines issued
104. Procurement of Energy Efficient Products	DOE	• Energy Star and FEMP-recommended products procurement requirement • Exception when not cost-effective or meets agency functional requirements • Energy efficient specs required in procurement bids and evaluations • Requires premium efficient products: electric motors, air conditioning, and refrigeration equipment procurements • In 180 days, DOE issues guidelines
104(c). Energy efficient products in Federal catalogs	GSA, DoD	• Requires listing of Energy Star and FEMP-recommended products by GSA and Defense Logistics Agency
105. ESPCs	DOE	• Reauthorizes ESPCs through September 30, 2016
109. Federal Building Performance Standards	DOE	• Buildings to be designed to 30 percent below ASHRAE standard or International Energy Code if life-cycle cost-effective • Application of sustainable design principles • Agencies must identify new buildings in their budget request and identify those that meet or exceed the standard • DOE must include the agency budget information above in the annual report • DOE must determine cost-effectiveness of subsequent standard revisions within one year

Section	Lead Agency	Provisions
111. Enhancing efficiency in management of Federal lands	DOI, DOC, and USDA	• Energy efficiency technologies in public and administrative buildings to the extent practical
203. Federal purchase requirement (renewables)	DOE	• Renewable electricity consumption by the Federal government cannot be less than: 3 percent in FY 2007 – FY 2009, 5 percent in FY 2010 – FY 2012, 7.5 percent in 2013 and thereafter • Defines several types of renewables • Double credit for renewables (1) produced on the site or on Federal lands and used at a Federal facility or (2) produced on Native American lands • Biannual DOE progress reporting beginning no later than April 15, 2007
204. Use of photovoltaic energy in public buildings	GSA	• Establishes a photovoltaic energy commercialization program in Federal buildings • Issue rules, develop strategies and reports annually to Congress • Install 20,000 solar energy systems in Federal buildings by 2010 • Requires an evaluation 60-days after passage • Authorizes funds for the program
207. Installation of a photoelectric system	GSA	• Authorized funds for a solar wall at DOE's Forrestal Building
1331. Energy Efficient Commercial Buildings Deduction	Treasury	• Tax deduction of $1.80 per square foot on new construction after Dec. 31, 2005 if annual energy and power costs of interior lighting systems, heating, cooling, ventilation, and hot water systems are 50 percent or more below ASHRAE Standard 90.1-2001 •Subsystems may qualify for a $.60 per square foot deduction •Treasury will issue regulations to allocate the deduction to the primary designer of a Federal, State, or local government commercial property
1802. Study of Energy Efficiency Standards	NAS	•Study on energy efficiency standards at the site compared to the source of energy production
1833. Renewable Energy on Federal Land	NAS	•Study on the potential of developing wind, solar, and ocean energy on Federal lands

APPENDIX C. FEDERAL ACQUISITION REGULATION

1. Subpart 23.2 – Energy and Water Efficiency and Renewable Energy

23.200 Scope.

(a) This subpart prescribes policies and procedures for—

(1) Acquiring energy- and water-efficient products and services, and products that use renewable energy technology; and

(2) Using an energy-savings performance contract to obtain energy-efficient technologies at Government facilities without Government capital expense.

(b) This subpart applies to acquisitions in the United States and its outlying areas. Agencies conducting acquisitions outside of these areas must use their best efforts to comply with this subpart.

23.201 Authorities.

(a) Energy Policy and Conservation Act (42 U.S.C. 6361(a)(1)) and Resource Conservation and Recovery Act of 1976 (42 U.S.C. 6901, *et seq*.).

(b) National Energy Conservation Policy Act (42 U.S.C. 8253, 8262g, and 8287).

(c) Executive Order 11912 of April 13, 1976, Delegations of Authority under the Energy Policy and Conservation Act.

(d) Executive Order 13123 of June 3, 1999, Greening the Government through Efficient Energy Management.

(e) Executive Order 13221 of July 31, 2001, Energy-Efficient Standby Power Devices.

23.202 Policy.

The Government's policy is to acquire supplies and services that promote energy and water efficiency, advance the use of renewable energy products, and help foster markets for emerging technologies. This policy extends to all acquisitions, including those below the simplified acquisition threshold.

23.203 Energy-efficient products.

(a) If life-cycle cost-effective and available—

(1) When acquiring energy-using products—

(i) Agencies shall purchase ENERGY STAR® or other energy-efficient items listed on the Department of Energy's Federal Energy Management Program (FEMP) Product Energy Efficiency Recommendations product list; and

(ii) For products that consume power in a standby mode and are listed on FEMP's Standby Power Devices product listing, agencies shall—

(A) Purchase items which meet FEMP's standby power wattage recommendation or document the reason for not purchasing such items; or

(B) If FEMP has listed a product without a corresponding wattage recommendation, purchase items which use no more than one watt in their standby power consuming mode. When it is impracticable to meet the one watt requirement, agencies shall purchase items with the lowest standby wattage practicable; and

(2) When contracting for services that will include the provision of energy-using products, including contracts for design, construction, renovation, or maintenance of a public building, the specifications shall incorporate the applicable requirements in paragraph (a)(1) of this section.

(b) The requirements in paragraph (a) of this section only apply when the relevant product's utility and performance meet the agency's need.

(c) Information is available via the Internet about—

(1) ENERGY STAR® at http://www.energystar.gov/; and

(2) FEMP at http://www.eere.energy.gov/femp/procurement.

23.204 Energy-savings performance contracts.

(a) Section 403 of Executive Order 13123 of June 3, 1999, Greening the Government through Efficient Energy Management, requires an agency to make maximum use of the authority provided in the National Energy Conservation Policy Act (42 U.S.C. 8287) to use an energy-savings performance contract (ESPC), when life-cycle cost-effective, to reduce energy use and cost in the agency's facilities and operations.

(b)

(1) Under an ESPC, an agency can contract with an energy service company for a period not to exceed 25 years to improve energy efficiency in one or more agency facilities at no direct capital cost to the United States Treasury. The energy service company finances the capital costs of implementing energy conservation measures and receives, in return, a contractually determined share of the cost savings that result.

(2) Except as provided in 10 CFR 436.34, ESPC's are subject to Subpart 17.1.

(c) To solicit and award an ESPC, the contracting officer—

(1) Must use the procedures, selection method, and terms and conditions provided in 10 CFR Part 436, Subpart B; at http://www.eren.doe.gov/femp/resources/legislation.html; and

(2) May use the "Qualified List" of energy service companies established by the Department of Energy and other agencies.

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LIST OF REFERENCES

Abbuehl, C. (2005). *Hill AFB, Utah 1st DOE biomass super ESPC project*, PowerPoint Presentation. 8th Annual LMOP Conference.

AFRL Leads Way to Test, Certify Synthetic Fuels. Retrieved 11/4/2007, from http://www.wpafb.af.mil/news/story.asp?id=123034176.

Air Force Recognizes 2006 Environmental Award Winners. Retrieved 11/21/2007, from http://www.luke.af.mil/news/story.asp?id=123058135.

Air War College Maxwell AFB Center for Strategy and Technology, Hornitschek, M. J. (2006). *War without Oil: A Catalyst for True Transformation*.

Alternative Fuels and Advanced Vehicles Data Center: What is an Electric Vehicle? Retrieved 11/5/2007, 2007, from http://www.eere.energy.gov/afdc/vehicles/electric_what_is.html.

Alternative Jet Fuel Reduces Aircraft Engine Emissions. Retrieved 11/4/2007, from http://www.wpafb.af.mil/news/story_print.asp?storyID=123040425.

Amidon, J. M. (2005). America's Strategic Imperative - A "Manhattan Project" for Energy. *Joint Force Quarterly*, (39), 68. Retrieved 11/4/2007, from http://www.dtic.mil/doctrine/jel/jfq_pubs/1339.pdf.

Applied Research Associates Inc Tyndall AFB, FL, & Keith, M. (2005). *BEAR base solar power system*.

Army Energy Program. Retrieved 11/5/2007, from http://army-energy.hqda.pentagon.mil/.

Army War College Carlisle Barracks, PA, Custer, J. (2007). *Algae: America's Pathway to Independence*.

B-52s cleared for new gas (2007), *AIR FORCE Magazine*, October 18.

Behar, M. (2007). Junk In, Power Out. *Popular Science, 270*(5), 44.

Biomass Program: Environmental Benefits. Retrieved 11/5/2007, 2007, from http://www1.eere.energy.gov/biomass/environmental.html.

Bureau of Reclamation: Lower Colorado Region - Hoover Dam Power FAQs. Retrieved 11/5/2007, from http://www.usbr.gov/lc/hooverdam/faqs/powerfaq.html.

Clinchard, C. H., Sefiert, G., Miller, C., & West, S. (2004), Ascension Island Wind Farm. *Air Force Civil Engineer, 12*(2) 12.

Commentary - Air Force Continues Success in Reducing Energy Impact. Retrieved 11/5/2007, from http://www.af.mil/news/story.asp?id=123071452.

Committee of Soldier Power/Energy Systems, National Research Council. (2004). *Meeting the Energy Needs of Future Warriors* Retrieved 11/4/2007, from http://www.nap.edu/catalog.php?record_id=11065.

Copulos, M. (2005). The Role of Renewable Energy and Energy Efficiency in National Security.

Copulos, M. (2006), America's untapped depths. [Electronic version]. *American Legion Magazine*, Retrieved 11/26/2007, from http://www.ndcf.org/.

Department of Energy - Nuclear. Retrieved 11/4/2007, from http://www.doe.gov/energysources/nuclear.htm.

Department of Energy - Renewables. Retrieved 11/4/2007, from http://www.doe.gov/energysources/renewables.htm.

Deutch, P. J. (2005). Energy Independence. *Foreign Policy*, (151), 20.

DOE – Fossil Energy: Auto Created. Retrieved 11/4/2007, from http://www.fe.doe.gov/aboutus/history/syntheticfuels_history.html.

EERE: Alternative Fuels and Advanced Vehicles Data Center Program Home Page. Retrieved 11/4/2007, from http://www.eere.energy.gov/afdc/.

EERE: Geothermal Technologies Program Home Page. Retrieved 11/4/2007, from http://www1.eere.energy.gov/geothermal/.

EERE: Solar Energy Technologies Program Home Page. Retrieved 11/4/2007, from http://www1.eere.energy.gov/solar/.

EERE: Wind and Hydropower Technologies Program Home Page. Retrieved 11/4/2007, from http://www1.eere.energy.gov/windandhydro/.

EIA - Energy Information Sheets Index: Coal Reserves. Retrieved 11/4/2007, from http://www.eia.doe.gov/neic/infosheets/coalreserves.html.

Energy Information Administration. (2006). *Electric Power Annual 2005* (EIA Publication No. DOE/EIA-0348 (2005)). Washington, DC: Retrieved 11/4/2007, from http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html.

Energy Information Administration. (2007). *Annual Energy Review* No. DOE/EIA-0384(2006).

Executive Office of the President Washington, Bush, G. W. (2001). *National Energy Policy: Report of the National Energy Policy Development Group*.

Energy Policy Act of 2005, 109-58U.S.C. (2005).

Federal Acquisition Regulation (FAR) Part 1.101. Retrieved 11/21/2007, from http://www.arnet.gov/far/.

Federal Energy Management Program: Overview. Retrieved 11/5/2007, from http://www1.eere.energy.gov/femp/about/index.html.

FEMP Renewable Energy: Purchasing Renewable Power. Retrieved 11/5/2007, from http://www1.eere.energy.gov/femp/renewable_energy/renewable_purchasepower.html.

Geothermal Technologies Program: Geothermal Power Plants. Retrieved 11/5/2007, from http://www1.eere.energy.gov/geothermal/powerplants.html#drysteam.

Global Solar Energy Inc. Tucson AZ, Albright, S. P. (2005). *Transportable and Hybrid Transportable AC Systems*.

The Defense Science Board Task Force on Improving Fuel Efficiency of Weapons Platforms. (2001). More Capable Warfighting through Reduced Fuel Burden, Office of the Under Secretary of Defense.

Keane, J. (2005). Solar Energy Turns on Radios in Africa. *Appropriate Technology, 32*(1), 62.

Kuntz, Gordon D. COL. (2007). *Use of Renewable Energy in Contingency Operations* (Research Paper.) Arlington, VA: Army Environmental Policy Institute. Retrieved 11/4/2007, from http://www.aepi.army.mil/internet/use-of-renew-en-conting-ops.pdf.

Library of Congress Washington DC Congressional Research Service , Holt, M. (2007). *Nuclear Energy Policy*.

Library of Congress Washington DC Congressional Research Service, Parker, L., & Holt, M. (2007). *Nuclear Power: Outlook for New U.S. Reactors*.

Logistics Management Institute (LMI) McLean VA, Crowley, T. D., Corrie, T. D., Diamond, D. B., Funk, S. D., Hansen, W. A., et al. (2007). *Transforming the Way DoD Looks at Energy. An Approach to Establishing an Energy Strategy*.

MITRE Corporation McLean VA JASON Program Office, Dimotakis, P., Grober, R., & Lewis, N. (2006). *Reducing DoD Fossil-Fuel Dependence*.

Nellis Air Force Base Solar Power System Fact Sheet (2007).

Oak Ridge National Laboratory TN, Perlack, R. D., Wright, L. L., Turhollow, A. F., Graham, R. L., Stokes, B. J., et al. (2005). *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*.

Office of Science and Technology Policy Washington DC. (2006). *American Competitiveness Initiative: Leading the World in Innovation*.

President signs Energy Policy Act. Retrieved 11/5/2007, from http://www.whitehouse.gov/news/releases/2005/08/20050808-6.html.

Renewable energy sources in the United States. Retrieved 11/5/2007, from http://nationalatlas.gov/articles/people/a_energy.html#three.

Schmidt, C. W. (2007). BIODIESEL Cultivating Alternative Fuels. *Environmental Health Perspectives, 115*(2), A86.

Scientific Advisory Board (Air Force) Washington DC, , Karagozian, A., Dahm, W., Glasgow, E., Howe, R., Kroo, I., et al. (2006). *Technology Options for Improved Air Vehicle Fuel Efficiency: Executive Summary and Annotated Brief*.

Solar Energy Technologies Program: PV Systems. Retrieved 11/5/2007, from http://www1.eere.energy.gov/solar/pv_systems.html.

Stein, S. (2006). Breaking the Oil Habit. *Policy Review,* (138), 53.

Technology Focus - New Wind Energy Technologies are Cost-Effective in Federal Applications(1998). No. DOE/GO-10098-583) U.S. Department of Energy.

The Southern States Energy Board. (2006). *American Energy Security: Building a Bridge to Energy Independence and to a Sustainable Energy Future* Retrieved 11/4/2007.

The White House National Economic Council. (2006). *Advance Energy Initiative*.

U.S. Climate Action Report (2006). Retrieved 11/4/2007.

U.S. Department of Energy. (2007). *Clean Cities Alternative Fuel Price Report* Retrieved 11/4/2007, from http://www.eere.energy.gov/afdc/pdfs/afpr_mar_07.pdf.

USD (AT&L). (2007). *Department of Defense Annual Energy Management Report*.

Vedenov, D. V., Duffield, J. A., & Wetzstein, M. E. (2006). Entry of Alternative Fuels in a Volatile U.S. Gasoline Market. *Journal of Agricultural and Resource Economics, 31*(1), 1.

Wagner, B. (2007). Battlefield Energy. *National Defense, 91*(641), 32.

Walton, A. L., & Hall, D. C. (1990). Solar Power. *Contemporary Policy Issues*, *8*(3), 240.

Wikipedia contributors. *Image: Water turbine.jpg.* Retrieved 11/5/2007, from http://en.wikipedia.org/wiki/image:water_turbine.jpg.

Wind and Hydropower Technologies Program: How Wind Turbines Work. Retrieved 11/5/2007, from http://www1.eere.energy.gov/windandhydro/wind_how.html.

Wind and Hydropower Technologies Program: Wind Energy Resource Potential. Retrieved 11/5/2007, from http://www1.eere.energy.gov/windandhydro/wind_potential.html.

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