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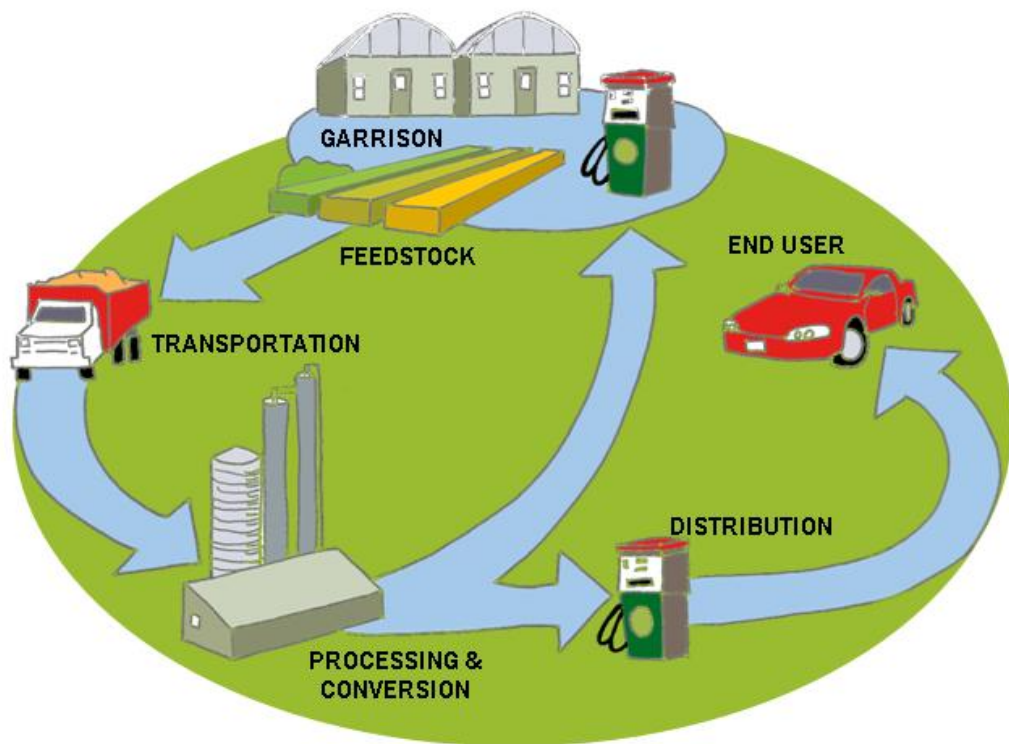
Center for the Advancement of Sustainability Innovations (CASI)

Onsite Army Biofuel Production

Opportunities, Thresholds, and Considerations

Natalie R. Myers, Heidi R. Howard, Dick L. Gebhart,
Nickolas M. Josefik, and Muhammad Sharif

September 2013



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Abstract

Energy crops are a potentially inexpensive, renewable fuel source for the Army that will also meet net-zero energy goals. Currently, there is no guidance on the production of biofuel crops within the DoD. Independent studies address other aspects of bioenergy crops, but none directly addresses the risks and tradeoffs associated with this alternative on Army lands. Portions of Army lands are viewed as compatible with oilseed and cellulosic feedstock crops, including roadside and utility rights-of-way, drop zones, storage and maintenance areas, and managed open spaces. Since conventional farming equipment and agricultural practices can be used, implementation of oilseed and cellulosic feedstock crops on these lands can be rapid (2-4 years). However, significant negative impacts often result from the conversion of marginal and/or previously uncultivated lands into cropland supporting biofuel production. Given this paradox, what has not been considered is establishing a way forward for installations to integrate bioenergy crops into the local ecosystem and Army mission. REAP and KDF modeling environments provide this opportunity, whereby site-specific geographic, environmental, installation infrastructure, business, and economic resource inputs can be used to identify constraints that might impact successful participation in regional biofuels production, transportation, processing, and distribution systems.

Executive Summary

The significant amount of petroleum fuels purchased and consumed by the US Department of Defense (DoD) has brought to the forefront a need to examine biofuels as a potential means for energy security. Examples of biomass matter from which fuel could be obtained include grass species, oilseed crops, wood waste, and animal manure.

Before considering energy crops as an inexpensive renewable fuel alternative for use at Army installations, however, proper evaluation of their “side effects” will be needed. The introduction of such crops can alter soil conditions, plant/animal species composition, and economies.

Legislative action to promote alternative energy sources has actually been ongoing for the past 30 years. The Arab nations’ oil embargo in 1974 spurred research into less dependence on foreign oil, and lawmakers have since offered tax breaks, subsidies, and more to support “green” fuels. The Energy Policy Act of 1992 accelerated research and guidance for programs to increase production of biofuels. Former President George W. Bush called for a 20% reduction in gasoline consumption in 2007. President Barack Obama has affirmed his commitment to bioenergy technology research and pursued a national policy on the use of biofuels.

The Army lacks a specific management plan to develop and produce cellulosic biofuels. Critics envision land grabs, deforestation, and increased food prices and carbon emissions. However, after consulting with numerous agencies already pursuing biofuels initiatives, the following recommendations have been made:

- Enter the biofuels arena cautiously to gain appreciation of how production will impact the installation’s daily operations.
- Accelerate commercialization of technologies to establish the biofuels industry.
- Select installations representing ample geographic and climatic diversity.

- Establish a monitoring organization that can review and track progress of biofuel projects.
- Partner with the Interagency Working Group (IWG), a biofuels group established by President Obama that has published strategies to support the biofuels industry.

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Preface

This study was performed under the Center for the Advancement of Sustainability Innovations (CASI) Program for the US Army Engineer Research and Development Center in coordination with the office of the Assistant Secretary of the Army Installations, Energy, and Environment (ASA(IE&E)) and the US Army Installation Management Command (IMCOM). The Director of the Center for Advancement of Sustainability Innovations (CASI) was William D. Goran, and the Associate Director was Michelle J. Hanson.

The work was performed by the Ecological Processes Branch (CN-N) of the Environmental Division (CN) and the Energy Branch (CF-E) of the Facilities Division (CF), US Army Engineer Research and Development Center–Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, William D. Meyer was Chief, CEERD-CN-N, and Michelle J. Hanson was Chief, CEERD-CN; Franklin H. Holcomb was Chief, CEERD-CF-E, and L. Michael Golish was Chief, CEERD-CF. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti, and the Director was Dr. Ilker Adiguzel.

COL Jeffrey R. Eckstein was the Commander of ERDC and Dr. Jeffery P. Holland was the Director.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
degrees Fahrenheit	$(F-32)/1.8$	degrees Celsius
feet	0.3048	meters
gallons (US liquid)	3.785412 E-03	cubic meters

Abbreviations

Term	Spellout
AEC	Army Environmental Command
AESI	Army Energy Security Implementation Strategy
AFPET	Air Force Petroleum Agency
ASAIEE	Assistant Secretary for Army Installations, Energy, and Environment
BCAP	Biomass Crop Assistance Program
CASI	Center for the Advancement of Sustainability Innovations
CEERD	US Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
CRS	Congressional Research Service
DLA	Defense Logistics Agency
DoD	US Department of Defense
DOE	US Department of Energy
DOT	Department of Transportation
DPW	Directorate of Public Works
EERE	Energy Efficiency and Renewable Energy
EIA	US Energy Information Administration
EISA	Energy Independence and Security Act
EITF	Army Energy Initiative Task Force
EO	Executive Order
EOP	Executive Office of the President
EPA	Environmental Protection Agency
ERDC	Engineer Research and Development Center
ESG	Strategic Energy Security Goal
ESTCP	Environmental Security Technology Certification Program
F2F	Freeway to Fuels
FAO	Food and Agriculture Organization of the United Nations
FLW	Fort Leonard Wood
FY	fiscal year
GIS	Geographic Information System
IDOT	Illinois Department of Transportation
IMCOM	Installations Management Command
ISSP	Installation Strategic Sustainability Plan
IWG	Interagency Working Group
KDF	Knowledge Discovery Framework
MATOC	Multiple-Award Task Order
MIPR	Military Interdepartmental Purchase Request

Term	Spellout
MOU	Memorandum of Understanding
NAVAIR	Naval Air Systems Command
NCDOT	North Carolina Department of Transportation
NAVFAC	US Naval Facilities Engineering Command
NCSU	North Carolina State University
NDAA	Congressional National Defense Authorization Act
NDCEE	National Defense Center for Energy and Environment
NREL	National Renewable Energy Laboratory
ODASA (E&S)	Office of Deputy Assistant Secretary of the Army for Installations, Energy and Sustainability
OPEC	Organization of the Petroleum Exporting Countries
PNNL	Pacific Northwest National Laboratory
PPA	Power Purchase Agreement
R&D	research and development
RAE	Renewable and Alternative Energy
REAP	Renewable Energy Analysis Protocol
RFP	request for proposal
RFS	Renewable Fuels Standard
SBIR	Small Business Innovation Research
SERDP	Strategic Environmental Research and Development Program
SOC	soil organic carbon
TARDEC	US Army Tank Automotive Research, Development and Engineering Center
TR	technical report
UDOT	Utah Department of Transportation
URL	Universal Resource Locator
US	United States
USACE	US Army Corps of Engineers
USAF	US Air Force
USAG-HI	US Army Garrison-Hawaii
USDA	US Department of Agriculture
USGS	United States Geological Survey
USU	Utah State University

1 Introduction

1.1 What are biofuels and why are they important to the Army?

Any fuel produced from biological materials—whether burned for heat or processed into alcohol—qualifies as a “biofuel.” However, the term is most often used to refer to liquid transportation fuels produced from some type of biomass.¹ Biomass is organic matter that can be converted into energy. Common examples of biomass include food/grain crops, crops for energy (e.g., switchgrass or other perennial grass species and oilseed crops), crop residues, wood waste and byproducts, and animal manure. Over the last few years, the concept of biomass has come to define the different biofuels programs. A distinction is made between primary, secondary, and tertiary biofuels. Primary biofuels consist of ethanol from sugar or starch crops (such as sugar cane or corn) and biodiesel from animal fats and vegetable oils derived from oilseed crops. Secondary biofuels—or cellulosic biofuels—are made from cellulose, which is available from non-food crops and waste biomass such as corn stover, corn cobs, straw, perennial grasses (e.g., switchgrass or miscanthus) and wood chips. Tertiary biofuels use algae as feedstock. Second- and third-generation biofuels, commonly called advanced biofuels, are not yet produced commercially.

The US Energy Information Administration (EIA) has published 2012 statistics indicating biofuels accounted for 1% of total transport fuel consumption or 13.8 billion gallons (Figure 1). Additionally, ethanol accounted for 94% of all biofuel production in 2012, with the other 6% composed of biodiesel. In 2011, the United States imported approximately 45% of their petroleum requirements. In 2011, approximately 90% of US fuels were blended with ethanol or biodiesel (EIA 2012).

Given the significant amount of petroleum fuels purchased and consumed by the US. Department of Defense (DoD; Figure 2), biofuels development and production are of prime importance for assuring future energy security not only for them, but also for the United States. There are high expectations surrounding liquid biofuels as a resource that can potentially mitigate global climate change, offset current petroleum requirements,

¹ For more information, see CRS Report R40529, *Biomass: Comparison of Definitions in Legislations Through the 111th Congress*, by Kelsi Bracmort and Ross W. Gorte.

contribute to energy security, and support agricultural producers and rural development. These expectations are often cited as economic and sustainability goals that justify the implementation of government policies promoting the production and use of liquid biofuels based on agricultural commodities.²

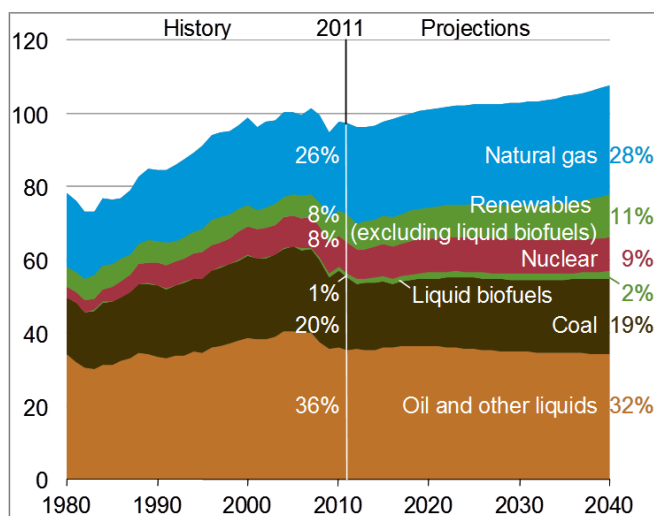


Figure 1. Primary energy consumption by fuel, 1980-2040 (EIA 2012).

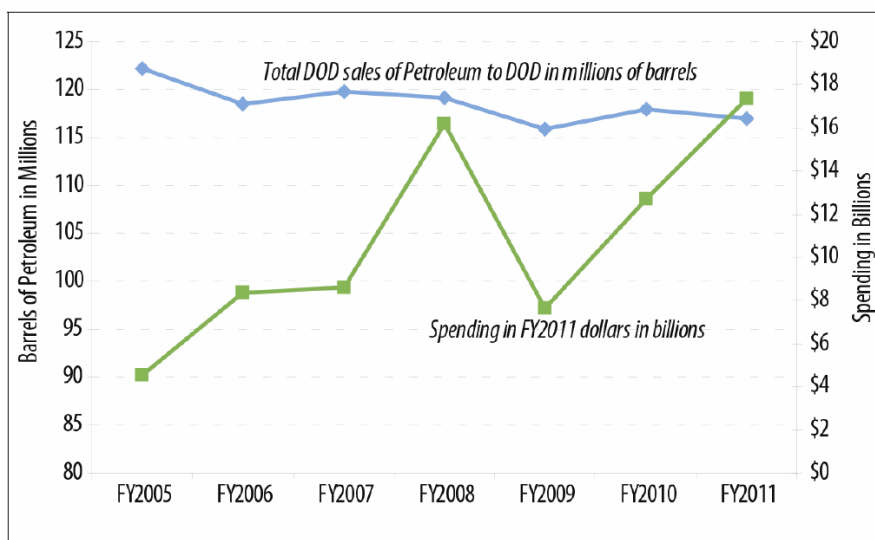


Figure 2. DoD petroleum spending and consumption (Schwartz 2012).

² For more information, see CRS Report R42558, *Department of Defense Energy Initiatives: Background and Issues for Congress*, by Moshe Schwartz, Katherine Blakeley, and Ronald O'Rourke.

1.2 Availability of biofuels

Biomass resource availability in the United States is shown in Figure 3. This map shows the geographic distribution of biomass and clearly illustrates the relationship between climate and biomass—showing greater biomass production occurs in the eastern portions of the United States, a location where higher precipitation and more favorable precipitation distribution patterns support plant communities and agricultural production systems with high biomass yield potentials.

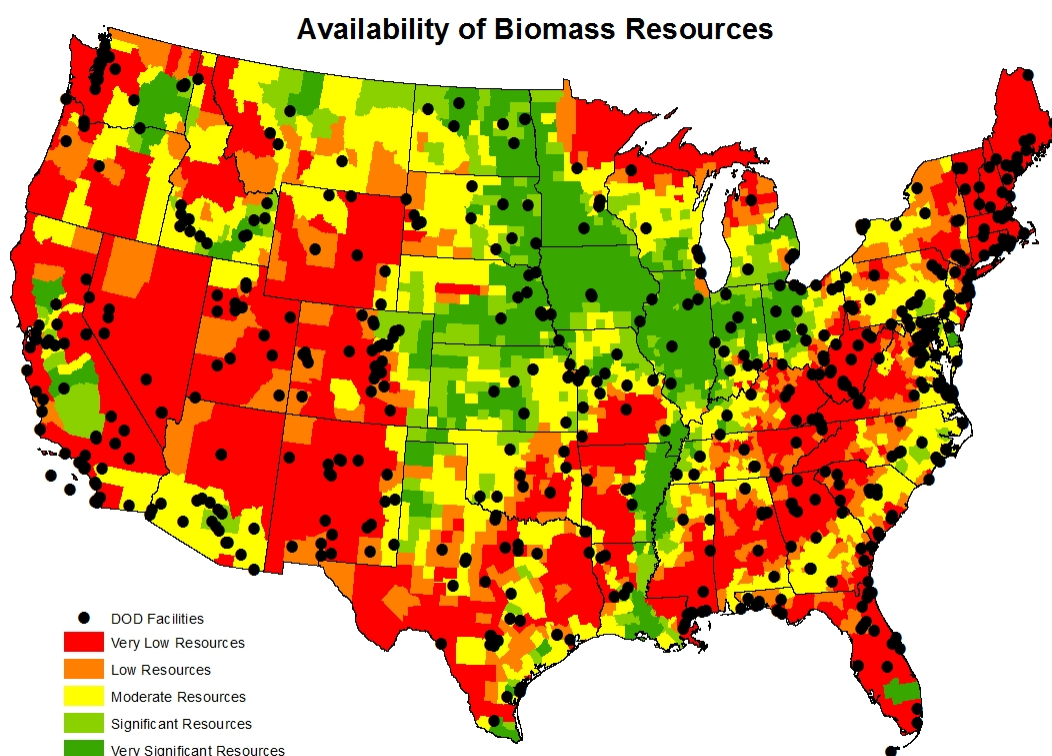


Figure 3. Total biomass resources available in the United States by county (Milbrandt 2005).

The relationship between biofuel processing plants and locations of US military installations is shown in Figure 4. For much of the eastern United States, where biofuel production would be most probable, biofuel processing plants are abundant and also within reasonable distance of major military installations, thereby minimizing transportation costs. In the western United States, distances between processing plants and military installations increase significantly, resulting in transportation costs that might preclude biofuel development and production. Under unique circumstances where either significant western biomass sources exist (e.g.,

coniferous forests, shrub-dominated systems, invasive species infestations) or can be grown because of favorable soils and water availability, the construction of small-scale processing facilities may allow utilization of these biomass sources. It should be noted, however, that given the initial capital investment, permitting regulations, and infrastructure requirements (sewer systems, wastewater treatment plants, water supply, skilled labor, and proximity of service sector suppliers) for constructing and operating biofuels processing plants, even these types of small-scale processing facilities would need to be considered in a more regional context with other local partners rather than as a stand-alone plant at a specific Army installation.

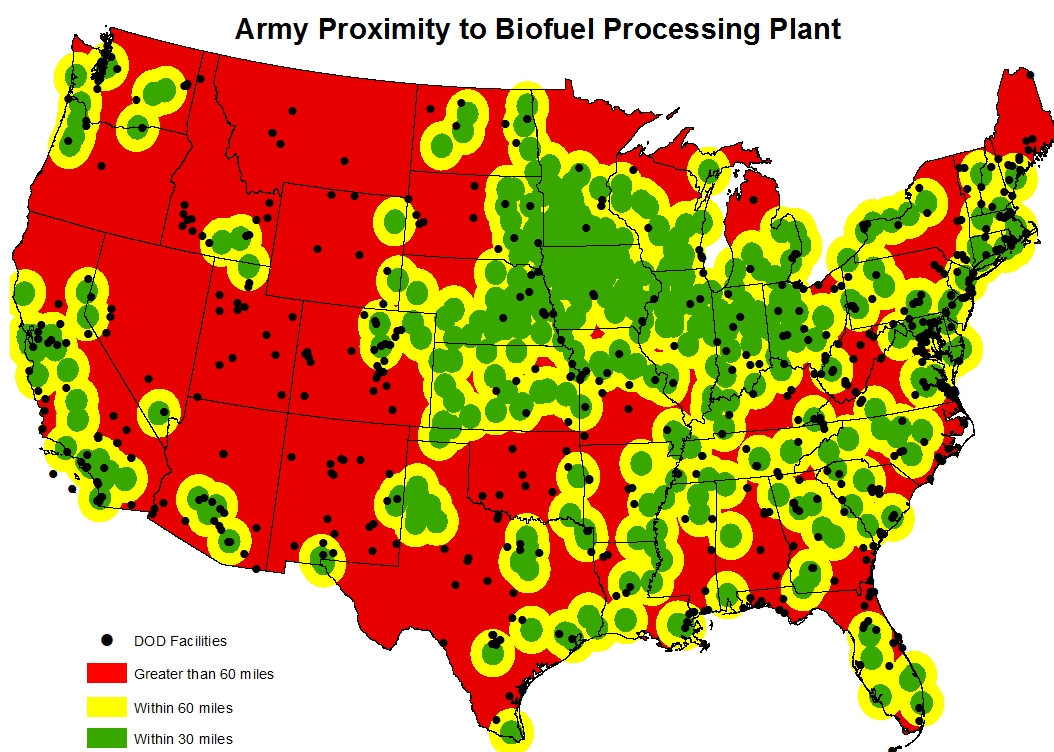


Figure 4. Locations of biofuel processing plants and major military installations (<http://www.ethanol.org> and <http://www.biodiesel.org>).

1.3 Issues and concerns

World economic, political, and environmental concerns have raised serious questions regarding future implications for food security, energy security, and environmental sustainability. With regard to biofuels, there has been a marked change in perceptions for biofuels being able to meet 100% of military fuel needs. Environmental impacts of producing cellulosic bio-

fuels from marginal or secondary agricultural resource bases have had limited research to determine their extent and ramifications. Additional studies have questioned the use of biodiesels and consequences to infrastructure and equipment. The costs of policies aimed at promoting liquid biofuels, and their possible unintended consequences, are beginning to attract scrutiny. Utilizing 100% biofuel for energy security and long-term sustainability are desirable goals, but logistics of production, refinement, and storage on military installations have not been investigated. Some common issues and concerns include:

- How do biofuels influence greenhouse gases and carbon budgets? Given the complete production process for biofuels and possible land-use changes needed to expand cellulosic feedstock, will increased production critically alter proposed greenhouse gases and carbon budget goals?
- Do biofuels threaten land, water, and biodiversity? Will biodiversity, habitat, and species of concern population goals be significantly impacted by converting natural areas into areas for agricultural production of cellulosic feedstocks?
- Can the Army develop or become integrated into an economically viable biofuel sector? Assuming a commercial role in the biofuels sector, have the logistics of production, storage, and distribution been considered within the framework of Army policy, government downsizing, or an existing regional biofuel processing industry?

1.4 Objectives

The objective of this effort is to understand how energy-crop production is being addressed by others and recommend approaches for the Army to consider, thereby ensuring a balanced and sensible approach relevant to regional, ecological, and logistical contexts.

1.5 Approach

This work was accomplished in the following steps.

1. A team (composed of ERDC-CERL agronomists, agricultural engineers, urban planners, and energy engineers) was formed to take a broad, strategic, and forward-minded look at evolving conditions and to explore approaches and investments that are most critical to address potential biofuel production on Army installations.

2. Team members reviewed a variety of ongoing biofuel efforts—leading to the presentation of key emerging issues.
3. Future challenges relevant to the Army were highlighted.
4. Finally, the team prepared a set of recommended actions for consideration.

2 Status of Policy, Projects, and Research

This report is based on review of the available literature and on discussions with a number of subject matter experts and industry practitioners.

The most authoritative and widely used guides and toolkits come from the Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE). EERE has two highly referenced publications: *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply* (US DOE 2005), which was updated in 2011 (US DOE 2011), and *A Geographic Perspective on the Current Biomass Resource Availability in the United States* (Milbrant 2005).

EERE toolkits include:

- Bioenergy Knowledge Discovery Framework (<https://bioenergykdf.net>)
- Biofuels Atlas (<http://maps.nrel.gov/biomass>)
- Alternative Fuels Data Center (<http://www.afdc.energy.gov>)
- US Energy Information Center (<http://www.eia.gov/>)

Other highly referenced reports include:

Biofuels and the Environment: The First Triennial Report to Congress (US EPA 2011)

Alternative Fuels for Military Applications (Bartis and Van Bibber 2011)

The State Of Food And Agriculture, Biofuels: Prospects, Risks and Opportunities (FAO [Food and Agriculture Organization] of the United Nation 2008)

General support and promotion of biofuels is available through the National Biodiesel Board³ and the American Coalition of Ethanol⁴—two voices of the industry providing the latest news, policy, and datasets.

Under congressional tasking, the Congressional Research Service (CRS) continues to publish a series of biofuels reports. These include:

Department of Defense Energy Initiatives: Background and Issues for Congress (Schwartz et al. 2012)

³ <http://www.biodiesel.org>

⁴ <http://www.ethanol.org>

The Navy Biofuel Initiative under the Defense Production Act (Andrews et al. 2012)

Agriculture-Based Biofuels: Overview and Emerging Issues (Schnepf 2013)

Cellulosic Biofuels: Analysis of Policy Issues for Congress (Bracmort et al. 2010) and

Biofuels incentives: A Summary of Federal Programs (Yacobucci 2008).

Less frequently cited, but of significant value to this report, are the Biofuels Interagency Working Group (IWG) established by President Obama in May of 2009 and the Army Energy Initiative Task Force (EITF) established by the Secretary of the Army in September 2011. The IWG report, *Growing America's Fuel: An Innovation Approach to Achieving the President's Biofuels Target* (IWG 2010), is the government's published strategy to support the biofuels industry. The EITF⁵ has the central role of supporting projects to meet the Army energy goals, and thus it maintains a number of resources including a renewable energy screening process and database of energy incentive programs.

2.1 Organizations consulted

For the preparation of this report, numerous organizations with ongoing biofuels initiatives, knowledge of military policy, or projects in the area of biofuel production on military lands were contacted. These organizations included:

United States Army

- Army Environmental Command (AEC)
- Defense Logistics Agency (DLA)
- Energy Initiatives Task Force (EITF)
- Office of Deputy Assistant Secretary of the Army (Energy and Sustainability) (ODASA[E&S])
- Engineering Research Development Center: Construction Engineering Research Laboratory (ERDC-CERL)
- Installation Management Command (IMCOM)
- US Army Tank Automotive Research, Development and Engineering Center (TARDEC).

Individuals at TARDEC advised that to their knowledge there are no known ongoing studies or assessments for biofuel cropping or production.

⁵ <http://www.armyeitf.com>

- Fort Leonard Wood Sustainability Coordinator
- Tooele Army Depot Biofuel Pilot Program

United States Air Force: Air Force Petroleum Agency

Individuals were only aware of the US Air Force (USAF) process for certification of alternative and alternate fuels. Individuals at USAF Petroleum Agency had no knowledge on studies or assessments for biofuel cropping or production. A chemist at USAF Fuel Certification Office advised that, to his knowledge, there have been no studies on the growth or production of biofuels on USAF lands. Currently, the issues with certified biofuels (20% biodiesel/80% diesel) have resulted in damaged vehicles, putting soldier readiness at risk. Unresolved issues that were mentioned included: alcohol production in countries that bar alcohol, destruction of equipment, no GI Coding for soldier harvest/production, non-uniformity of end-product, end-product not meeting code, and voiding of warranties on equipment.

United States Department of Agriculture (USDA), Agricultural Research Service

United States Geological Survey (USGS)

Department of Energy (DOE)

- Biomass Program, Bioenergy Knowledge Discovery Framework (KDF)
- National Renewable Energy Laboratory: (NREL), US Biomass Resource Availability
- Pacific Northwest National Laboratory (PNNL)

Departments of Transportation (DOTs)

- Illinois DOT (IDOT)

IDOT is interested in improving its sustainability profile. IDOT was contacted regarding an IDOT study with the University of Illinois to assess right-of-ways for biofuel production and cropping. This study was initiated in July 2012 and will undertake the development of an optimization tool for site selection. This feasibility study will assess IDOT rights-of-way for the production of biomass for biofuels, including crop growth and management, feedstock analysis, biomass conversion, and logistics. Year 2 of the 3-year feasibility study will start 1 July 2013. The study will investigate the growth, yield, and harvesting characteristics of five species planted

on several sites across Illinois. The optimization model will address agronomy and production rates. The Illinois Sustainability Center will assess feed stock and gross energy yield, combustion versus fermentation processes (optimization), and ash content for combustion. Logistical modeling for the site, location, area available, restrictions, best harvest method, optimal equipment, storage of biomass, and local regulations will also be addressed in the study. Additionally, the University of Illinois is currently conducting a rape seed and prairie rape seed demonstration along several highway rights-of-way.

- North Carolina DOT (NCDOT)

Environmental Protection Agency (EPA)

Universities:

- North Carolina State University (NCSU)
NCSU⁶ was contacted regarding a study to assess lands for biofuel production and cropping. Dr. Matthew Veal has developed an optimization GIS tool for site selection and conducted small-scale studies along NCDOT right-of-ways for biocropping.
- University of North Dakota, Energy and Environmental Research Center, Quantification of Biomass Resources in the United States
- University of Illinois, Agricultural and Biological Engineering Department
- Utah State University, Center for Agronomic and Woody Biomass F2F (Freeway to Fuels)

Pacific Biodiesel

Ethical Markets, Green Transition Scoreboard

2.2 US biofuel goals and efforts

2.2.1 Federal legislation

It was the Arab nations' 1974 oil embargo that provided an urgent impetus for Congress to realize that reliance on foreign oil was dangerously detrimental to national security. Prompted by such concerns, lawmakers took

⁶ <http://www.bae.ncsu.edu/topic/biofuels>

the first of many legislative steps to look for alternative energy sources, including ethanol made from grains as an alternative fuel. A series of tax breaks, grants, and subsidies were provided to support this home-grown “green” fuel as a means for lessening America’s dependence on foreign oil.(Meyer and Thompson 2012).

The US Congress has been using legislative measures and directives to promote alternative energy sources including ethanol and advanced cellulosic biofuels over the last 30 years. Nevertheless, the real boom began in 2005 and continues to the present. As a result of expanding legislative support, biofuel production (primarily corn-based ethanol and biodiesel) has grown over 600% since early 2000s (Schnepf and Yacobucci 2013).

The following list presents a brief review of legislative actions on energy security and the development, production, promotion, and use of biofuels.

- **Energy Policy Act of 1992:** One of the earlier legislative actions that directed accelerated research and development (R&D) on biofuels and provided guidance for programs to increase production of biofuels, particularly corn-based ethanol.
- **Energy Policy Act of 2005 (EPAct 2005):** Created the Renewable Fuels Standards (RFS) program and established the first renewable fuel volume mandate of 7.5 billion gallons of ethanol to be blended into gasoline by 2012.
- **Energy Independence and Security Act of 2007 (EISA):** Enacted the RFS goal of 36 billion gallons of biofuel supply by 2022, of which 21 billion gallons must come from “advanced fuels” produced from non-edible cellulosic feedstocks. The Act also set an upper limit of 15 billion gallons from corn-based ethanol, not to be exceeded after 2015.
- **Food, Energy, and Conservation Act of 2008 (Farm Bill 2008):** Created USDA Biomass Crop Assistance Program (see below)
- **American Recovery and Reinvestment Act of 2009 (The Recovery Act):** Creates provision to provide \$786.5M to accelerate advanced fuels R&D and expanded commercialization of biofuels and bioindustry.
- **Biofuel Market Expansion Act of 2011:** Set goals to provide and expand markets for the production and use of biofuels by ensuring the availability of dual-fueled automobiles. The Act set minimum production requirements such that automobiles and light duty trucks must be

dual-fueled and meet market shares not less than 50% by model year 2015, increasing to a minimum of 90% for model year 2016.

- **Renewable Fuels Standards:** One of the many legislative policy tools used to promote biofuels and stimulate bioindustry is a minimum renewable fuel usage requirement known as Renewable Fuels Standard (RFS). The RFS requires a minimum volume of biofuels to be mixed in the national gasoline fuel supply each year. The main purpose of RFS enactment is to guarantee a market for biofuels irrespective of their production cost. Schnepf and Yacobucci (2013) describe the general nature of the RFS mandate, implementation specifics, and issues related to the continued growth of biofuel production needed to fulfill the expanding RFS mandate as well as the emergence of potential unintended consequences of this rapid expansion.

Congress delegated EPA the responsibility for developing and implementing regulations to ensure compliance with RFS requirements as intended by law. For example, the 2007 EISA mandates that biofuels make up at least 22% of gasoline mix by the year 2022. This translates to 36 billion gallons of ethanol, composed of 15 billion gallons of corn-based and 21 billion gallons of cellulosic ethanol.

Additionally, the law (Energy Policy Act of 2005; EISA 2007-Section 204) also requires EPA to assess and report to Congress every three years on the current and potential future environmental and resource conservation impacts associated with increased biofuel production and use.

- **USDA Biomass Crop Assistance Program (BCAP):** Besides 15 billion gallons of corn-based ethanol, the EISA 2007 mandated 21 billion gallons of cellulosic biofuels to be added in the national fuel supply by 2022. The EISA 2007 further mandated that these new types of cellulosic biomass come from non-starch-based feedstocks. The 2008 Farm Bill created BCAP to help meet this requirement. The BCAP program provides incentives to farmers, ranchers, and forest landowners to establish, cultivate, and harvest biomass for bio-based products and biofuels. Another goal of the program guaranteed protection of investments by producers who volunteer to grow unconventional crops in support of the emerging biofuel industry.

2.2.1.1 Presidential actions

The generation and use of biofuels inside the fences helps military agencies achieve the Executive Order (EO) 13423 (Bush 2007) goals of reducing greenhouse gas emissions by 3% annually through 2015, or 30% by 2015

(Sec. 2 [a]), along with ensuring that the renewable energy generation projects are on agency property for agency use (Sec. 2 [b]). In his 2007 State of the Union Address, President Bush announced the “20 in 10” plan that called for a 20% reduction in the consumption of gasoline within 10 years (2007–2017). This plan also set an annual RFS goal of 35 billion gallons of ethanol production by 2017.⁷

President Obama has pursued a comprehensive national policy on both the production and use of biofuels as well as in support of emerging bioindustry, emphasizing government-private sector partnership. Some examples of President Obama’s bioenergy support are given below.

- In July 2012, an Executive Memorandum (Science and Technology Priorities for FY2012) was issued requiring a priority for federal agencies to “support research to establish the foundations for a 21st century bio-economy” (EOP 2012).
- In January 2011, the State of the Union address affirmed the administration’s commitment to bioenergy technology R&D as an “investment that will strengthen our security, protect our planet (environmental sustainability), and create countless new (green) jobs for our people” (Obama 2011).
- In March 2011, issued “*Blueprint for a Secure Energy Future*” (The White House 2012) directive and then announced in August 2011 that Department of Navy, DOE, and USDA invest \$510M through 2013 to produce advanced drop-in aviation and marine biofuels to “power military and commercial transportation.”
- In a 2011 speech at Georgetown University on energy security, a 2020 goal was announced for cutting foreign oil imports by 33% (Georgetown 2011).

2.2.1.2 Department of Defense and biofuels

The DoD has been a strong leader in facilitating, supporting, and promoting the development of renewable energy, particularly advanced biofuels. The National Defense Authorization Act (NDAA) of 2007⁸ states DoD’s

⁷ Transcript of speech available at <http://www.washingtonpost.com/wp-dyn/content/article/2007/01/23/AR2007012301075.html>.

⁸ 10 U.S.C. 2533b. 2007. National Defense Authorization Act for Fiscal Year 2007.

voluntary goal—that 25% of all energy consumed by 2025 should come from biofuels—but does not include any interim targets.

During the spring of 2011, the Secretaries of Energy, Agriculture, and the Navy entered into a Memorandum of Understanding (MOU) to “assist the development and support of a sustainable commercial biofuels industry.”⁹

Major legislation in 2012 allowed the DoD to develop and purchase biofuels for use throughout its operations. Biofuels used in vehicles will help meet the requirement of a 10% annual increase of non-petroleum-fueled vehicle usage. In November, Congress passed legislation that the President signed into law on 2 Jan 2013, enabling NDAA’s ability to continue developing and investing in the construction of biofuel refineries. The legislation also authorized DoD to purchase biofuels even if they cost more than conventional petroleum-based fuels. Nevertheless, the DoD has adopted a policy that the feedstock used in all of their biofuel projects must come from non-food, sustainable (cellulosic) feedstocks and that the military’s biofuels must be “drop-in” substitutes, with comparable energy and performance as conventional petroleum products (Erwin 2012).

The use of biomass on installations supports at least one strategic Energy Security Goal (ESG) in the Army Energy Security Implementation Strategy (ODASA [E&S] 2009). Supporting ESG #3, “Increased Use of Renewable/Alternative Energy,” helps facilities increase the share of renewable/alternative energy for power and fuel use, decreasing the dependence on fossil fuels and increasing the independence of facilities and bases.

The Net Zero Installations Initiative is broken into three parts: Net Zero Energy, Net Zero Water, and Net Zero Waste. For the Net Zero Energy initiative, an installation has to produce as much energy onsite as it uses over the course of a year. The repurposing of “waste” fields to grow biomass for the use of energy as fuel, electricity, or thermal energy will help installations achieve this goal.

The DoD is mandated to produce or procure from renewable resources at least 25% of its electricity consumption by 2025. Also, the Net Zero Energy initiative challenges installations to produce more energy on the installation than they consume, with emphasis on the use of renewable energy and alternative fuels. The Army seeks to meet these renewable energy

⁹ www.rurdev.usda.gov

mandates through the use of large-scale renewable and alternative energy (RAE) projects and the attainment of net zero energy status by its installations.

2.2.2 Army initiatives

In response to stricter federal mandates and rising energy security challenges, the ODASA (E&S) was tagged in 2011 as the central managing office for the development of large-scale Army renewable energy projects. By August, the Army EITF was formed. The EITF's mission is to streamline Army acquisition processes and leverage industry for the execution of large-scale renewable and alternative energy projects on Army installations. The EITF works to fill expertise gaps and provide resources focused on working with the private sector to execute large-scale energy projects. The expectation is increased interest by project developers and improved financial options of the Army. The Army recognized that installations are pursuing renewable energy infrastructure, but lacking the needed expertise in design and implementation.

For biofuels, EITF is engaging the Hawaiian Electric Company to develop a 50 Mw biofuels power plant on Schofield Barracks. More recently, in December 2012, EITF released a Request for Proposal (RFP) for electrical power (not to exceed 28 Mw) from a biomass generation facility located at Fort Drum, New York. The EITF solicits installations and businesses for project ideas. When they identify interest and potential, they conduct aggressive outreach efforts to attract and engage private industry to foster strategic and financial collaboration in support of the Army's installation energy needs.

Hawaiian installations have been particularly interested in biofuels for several reasons: (1) as islands, securing continuous fuel supplies is problematic; (2) local fuel sources are highly desirable; and (3) the local economy (e.g., farmers) could gain economically from biofuels versus alternative energy sources such as solar photovoltaic projects. As a result, IMCOM-Pacific developed a decision support tool to assist installations in evaluating potential alternative energy sources and associated cost/benefits. The intent was to develop and demonstrate a tool for US Army Garrison-Hawaii (USAG-HI) and then transfer it across the Army. This tool is the Renewable Energy Analysis Protocol (REAP) model, released in September 2009.

REAP was developed for assessing, prioritizing, and optimizing site selection for oil crop production and other alternative energy methods. REAP inputs include energy requirements; GIS data for topography, aspect, climate, and soil; and location characteristics such as accessibility, distance to agricultural biofuels sites, and renewable energy infrastructure. Prioritization algorithms within REAP calculate sustainability indices for each renewable biofuel energy crop to determine energy yield. These user inputs then optimize a blend of local renewable resources that meet energy demands and then prioritize which land areas are suitable for solar, wind, ethanol, and biodiesel production. The total sustainability index provided by REAP, however, does not provide information regarding detailed environmental (land, air, water) impacts/tradeoffs. REAP currently has no capability for life-cycle cost analysis and does not address regulatory consequences of alternative energy sources selected. Further, REAP can not quantify greenhouse gas production, carbon sequestration, or potential for natural resource impacts related to alternative energy production.

REAP model analysis indicated that USAG-HI received strong optimizations toward biofuels. ERDC-CERL initiated a Small Business Innovation Research (SBIR) project in fiscal year 2012 (FY12) to evaluate the productivity of biocropping several plant species in Hawaii. The effort, set for completion in FY14, works with the local agricultural industry to develop appropriate techniques for growing biofuel crops on agricultural lands and building capacity in the agricultural industry, to handle harvesting and conversion of biofuel crops to biodiesel.

OACSIM, under the Installation Technology Transition Program, sought in FY11 to quantify the economical and environmental potential of biofuel feedstock production on Army lands. Here, a team of agronomists focused on identifying land uses common to most Army installations that could be considered for crop production and did not interfere with training and testing activities. At Forts Bragg, Polk, Hood, Leonard Wood, and Knox and Iowa Army Ammunition Plant, test locations were established for evaluating growth, yield, and processing costs of biofuel feedstocks. The report concluded that across installations, the Army could produce a substantial portion of its fuel demand at reasonable economic costs with a recommendation to begin pilot project at each installation (The Louis Berger Group et al. 2012).

Fort Leonard Wood's (FLW) Installation Strategic Sustainability Plan (ISSP) indicates that biofuels have displaced more than 205,000 gallons of petroleum. In March 2003, FLW's Directorate of Logistics Transportation Division installed onsite E85 and B20 infrastructure in an effort to meet the petroleum reduction goal of EO13149.¹⁰ One major goal of the FLW ISSP is to optimize alternative energy sources and supplies; however, it does recognize significant uncertainty in quantifying impacts to land, water, and air.

At Tooele Army Depot, a demonstration utilizing 5,000 acres to grow oilseed crops that would be harvested and used to create biofuels has been proposed. The project would be phased in over a 3-year period, beginning with the planting of 500 acres of oilseed crops accomplished in 2013. The final outcome of what the fuel would be used for has yet to be determined, but officials at Tooele Army Depot would like to see the biofuels used to offset their fuel costs for vehicles and other equipment.

2.2.3 Navy and Air Force initiatives

The US Navy's Naval Facilities Engineering Command (NAVFAC) has been a research and development leader in biofuel utilization to offset EO13514 alternative energy requirements. The USAF has collaborated extensively with the Navy to determine the feasibility of converting fleet/tactical vehicles and aircraft over to blended fuels. Efforts for both are ongoing.

NAVFAC and the US Air Force Petroleum Agency (AFPET) collaborated on Environmental Security Technology Certification Program (ESTCP) Project WP-200728, "Demonstration of Biodiesel in Ground Tactical Vehicles and Equipment," which was designed to assess the use of B20 fuel in tactical vehicles. The study, at five military facilities across the United States, analyzed and compared fuel samples and oil samples from vehicles using biofuels, specifically a B20 blend, against vehicles using standard petroleum diesel or JP-8 fuels. Results from this study indicated that fuel stability was compromised under high-temperature properties and water affinity; however, low-temperature properties were satisfactory for fuel stability beyond the 6-month storage limit for B20. Sludge and accumulation of oxidative stability breakdown products from the biodiesel occurred in at least one vehicle while being tested under conditions of high tem-

¹⁰ EO 13149 (2000) Greening the Government Through Federal Fleet and Transportation Efficiency

perature and humidity. Additionally, the study highlighted potential voiding of engine warranties from use of fuels containing more than 5% biofuel (Chavez 2007).

In another ESTCP biofuel demonstration and evaluation project, “Effect of Biodiesel on Diesel Engine Nitrogen Oxide and Other Regulated Emissions” (WP-0308), the Navy assessed air emissions of carbon monoxide, hydrocarbons, nitrogen oxides, and particulate matter. Using EPA test standards, they conducted field and laboratory assessments of 10 types of DoD operated diesel engines operating with 5 fuel types (soy-based biodiesel, baseline petroleum-based ultra-low-sulfur diesel, JP-8, and 2 yellow grease-based biodiesels). Biodiesel fuels were mixed at 20%, 50%, 70%, and 100% concentration levels. Final results indicated no significant difference in air emission pollutants of concern between the ultra-low-sulfur diesels. The study did find that B20 is the most cost-effective method for DoD fleets to meet their alternative vehicle requirements, with an additional average cost of \$0.14 per gallon (Holden et al. 2006).

2.3 R&D production and utilization efforts

2.3.1 Department of Defense

The DoD is pursuing research to support the development and implementation of cost-effective biomass technologies. Efforts are focusing on the areas outlined below.

2.3.1.1 Biodiesel production and use

TARDEC is leading research investigating commercial biodiesel production and use. A market survey has been conducted to identify the commercial manufacturers and suppliers of biodiesel and to investigate whether virgin feedstock or recycled feedstock was used for production in generating the biodiesel. Additional topics covered were types of biodiesel product lines, including fuel blends provided, and volume per year produced of each product line. TARDEC has published the findings in a technical report titled “Biodiesel Suppliers Survey” (Alfaro 2001). TARDEC also received samples of the available biodiesel to perform analytical analysis on the samples.

National Defense Center for Energy and Environment (NDCEE), funded by the ESTCP and in cooperation with Naval Air Systems Command

(NAVAIR), AFPET, and TARDEC, is demonstrating biodiesel in tactical vehicles. These demonstrations are designed to investigate the stability of the fuel, deterioration in high-temperature environments, fuel properties and their performance in low-temperature environments, and microbial degradation. The research goals include providing guidelines on operational parameters for the armed services and determining if existing DoD infrastructure can accommodate the use of biodiesel while meeting the mission and customer requirements.

The DLA has actively been purchasing biofuels for use in the DoD. In 2011, DLA purchased 450,000 gallons of biofuel from Dynamic Fuels and Solazyme for use throughout the DoD, including the Navy. This purchase supports the Navy's plans to implement a "Great Green Fleet" by 2016 that is entirely powered by alternative fuels.

2.3.1.2 Electrical and thermal generation devices utilizing biomass, syngas, biodiesel, and ethanol

ESTCP has funded a number of research projects over the years to investigate the applicability and viability of the gasifier technology. One funded project titled "Modular Biopower System Providing Combined Heat and Power for DoD Installations EW-200940" (Browne 2009) is being performed to demonstrate a modular, renewable, distributed-energy generation gasifier technology utilizing onsite conversion of biomass to replace conventional heat and power generation in DoD buildings.

During the course of the project (a DoD-focused biomass resource assessment), a host DoD installation will be identified that has an acceptable supply of biomass. The selected location will be chosen to maximize the use of both the electricity and heat generated from the system. A biomass assessment will be performed to identify the types and quantities of biomass available across the DoD at the various locations.

2.3.1.3 Power purchase agreements for biofuel power generation

The US Army Corps of Engineers (USACE), through its Engineering and Support Center, Huntsville, has issued a Multiple-Award Task Order (MATOC) request for proposal (RFP) to utilize power purchase agreements (PPA) to procure locally generated, renewable, and alternative energy. Biomass power production is one of the approved categories for in-

clusion in the RFP. The MATOC has a \$7 billion capacity with a 30-year maximum timeline.

2.3.2 Department of Energy

The DOE EERE Bioenergy Technologies Office¹¹ is currently leading the DOE's research for the conversion of cost-effective biomass technologies into viable biofuels and biopower. This DOE office is focusing on the areas listed below.

2.3.2.1 Feedstocks and logistics

The Bioenergy Technologies Office works in partnership with the USDA, national laboratories, universities, industry, and other key stakeholders to identify and develop economically, environmentally, and socially sustainable feedstocks for the production of energy, including transportation fuels, electrical power and heat, and other bioproducts. Efforts in this area will ultimately support the development of technologies that can provide a large and sustainable cellulosic biomass feedstock supply of acceptable quality and at a reasonable cost for use by the developing US advanced biofuel industry. One of the major efforts is to create a uniform feedstock supply system by reducing the inherent variability in biomass to produce consistent products. The research involves developing a system of distributed biomass preprocessing positioned near the biomass production locations. The proposed strategy integrates all aspects of collection, storage, and delivery to create a uniform product to be used by the biorefineries.

2.3.2.2 Processing and conversion

A large effort is being taken to convert biomass feedstocks into commercially viable liquid transportation fuels. Because of the variance in biomass, different conversion technologies must be created to optimize the process for the differing chemical and physical properties. The office is pursuing both biochemical conversion and thermochemical conversion with the hope of creating a hybrid conversion process that incorporates both. Gasification Research Center at the Gas Technology Institute is actively leading the effort to evaluate cleanup and treatment technologies of syngas created from various biomass gasification processes with the goals

¹¹ <http://www1.eere.energy.gov/biomass/>

of optimizing the integration of technologies and improving the economics.

2.3.2.3 Biorefineries

The DOE has created an interactive map detailing the DOE-funded biorefinery projects.¹² The map includes information on the primary feedstock, conversion technology, primary product, capacity, and scale.

2.3.2.4 Infrastructure

The Biofuels Distribution Infrastructure and End Use technology area focuses on the end use infrastructure and delivery of biofuels to the customer market.

2.3.2.5 Sustainability

The DOE office is also working to reduce negative impacts across the supply chain so that these impacts will not be detrimental to the environment; these impacts include water quantity and quality, soil health and agronomics, climate change and air quality, land use, and biodiversity. The DOE is accomplishing this research through a variety of partnerships and efforts as listed below.

- Bioenergy KDF, a geospatial analysis tool that is a national decision-support framework to foster a sustainable and robust bioenergy industry (Figure 5).
- Maintaining the Regional Biomass Energy Feedstock Partnership with USDA, the Sun Grant Initiative Universities, and other regional partners to improve understanding of geographic variations in climatic conditions and soil type and their impact on nutrient cycling, water quality, GHG emissions, and land use that is associated with feedstock production.
- Participating in multi-stakeholder groups developing criteria and indicators for sustainability, such as the Council on Sustainable Biomass Production, along with international efforts, such as the Roundtable on Sustainable Biofuels, the Global Bioenergy Partnership's Sustainability Task Force, and the International Standards Organization working group on bioenergy sustainability.

¹² http://www1.eere.energy.gov/biomass/integrated_biorefineries.html



Figure 5. Screenshot of the Bioenergy Knowledge Discovery Framework (<https://bioenergykdf.net>).

2.3.2.6 Analysis

The DOE has compiled a vast library of reports and data based on research and market studies that are available for viewing and cover topics such as process design of systems, state of the technology reports, greenhouse gas emissions, feedstock, and infrastructure. Biomass feedstock data are typically analyzed both statistically and graphically using geographic information systems (GIS). GIS is used to visualize relationships, patterns, or trends, answering questions such as where the resources are and how much is available. For example, the DOE's National Renewable Energy Laboratory published a report (US DOE 2005) in which they identified climate, vegetation, animals, and land use as factors determining the distribution of biomass. This report mapped a variety of indicators encompassed by the factors and ultimately combined the series of maps to generate a total biomass resource availability per person in the United States by county.

2.3.3 Department of Interior

The USGS developed a modis model, using satellite imagery to identify potentially suitable areas for cellulosic feedstock (Gu et al. 2011; Figure 6). This model was in response to growing concerns that corn-based ethanol development is limited because of its potential to indirectly cause world food shortages, livestock and food price increases, and negative environ-

mental effects (water quality impairment due to greater use of pesticide and fertilizer, more demand for water for irrigation, and soil erosion). As a result, increased interest in cellulosic biofuels produced from perennial grasses, forest woody biomass, and agricultural and municipal wastes has been noted. USGS has long provided satellite imagery in support of ecosystem performance modeling used for land management decision making. Satellite remote sensing has become an essential tool for measuring and monitoring ecosystems over large areas because of its wide coverage and high spatial and temporal resolutions. Previous studies have shown strong relationships between satellite vegetation indices and biomass productivity. Using these relationships, the USGS model can predict areas suitable for cellulosic biomass production based on the assumption that areas identified as highly productive likely lack a history of destructive land uses and can provide a sustainable supply of cellulosic feedstock. It is important to note that these models only serve to identify areas suitable for cellulosic biofuel production and do not address other issues such as harvesting, transportation, processing, or economic viability.

2.3.4 Department of Transportation

Freeways to Fuel (F2F) is a national alliance designed to investigate the use of non-traditional lands such as roadside rights-of-way, military bases, and airports for the establishment and production of biofuel feedstock crops across the country. The F2F program, which began in 2007 as a cooperative program between the Utah Department of Transportation (UDOT) and Utah State University (USU), seeks to increase the production of biofuel without affecting food, fiber, feed, or flower production by targeting lands that are not currently in production.¹³ The alliance has now grown to include other DOTs and land grant universities. As participants in the F2F program, these universities and DOTs collectively contribute to the research on whether uses of non-traditional lands are economically and environmentally feasible for the production of biofuel feedstocks. To date, the F2F national alliance has tested safflower, canola, and flax oilseed crops.

¹³ <http://freewaystofuel.org>

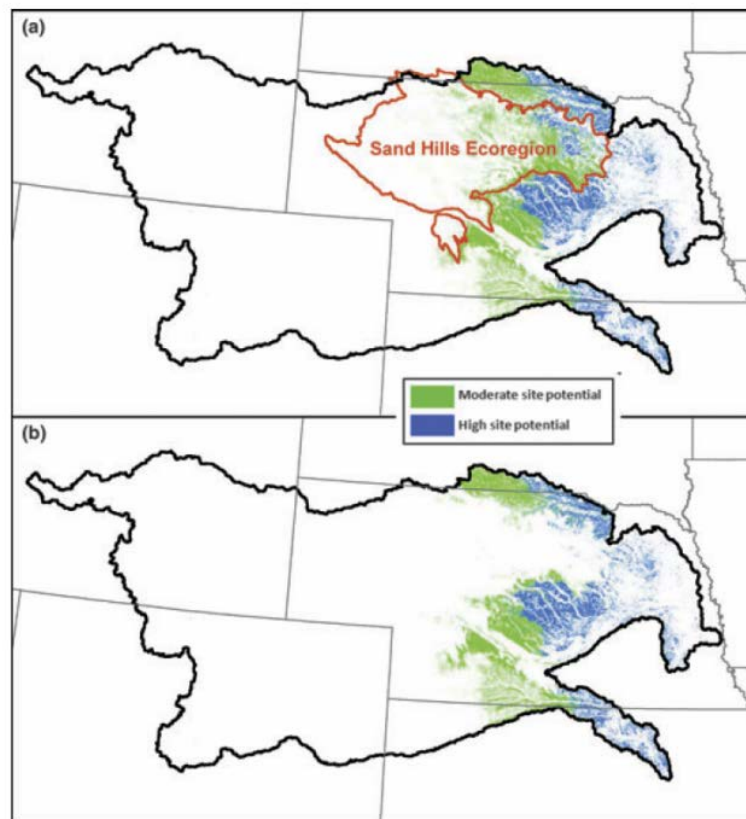


Figure 6. Using satellite imagery, maps delineating potential suitable areas (green and blue) for cellulosic feedstock development (Gu et al. 2011).

2.3.4.1 Utah case study

In 2006, the USU research team partnered with UDOT in pilot studies to plant crops in highway rights-of-way. This effort marked the first time that any group had attempted to grow biocrops for the purpose of creating a biofuel source in highway rights-of-way. While the production of biofuel was a key part of the Utah F2F pilot program, it was not the element that attracted UDOT; rather it was the potential cost savings for the department that provided the greatest interest and support.

USU planted several test plots along the I-15 corridor, selecting 20 x 8 ft plots with eight replicates at four different locations. The team used a common drill seeder to plant biocrops and seeded at least 15 ft off the pavement on roadway shoulders. Initially, the crops did not produce a significant yield due to soil compaction issues immediately adjacent to the highway. In response, USU devised new planting techniques that loosened the roadside soil without impacting the stability of the roadway and also developed an aerator tool that could be attached to existing drill seeders.

2.3.4.2 North Carolina case study

The North Carolina F2F project, a cooperative effort between the North Carolina Department of Transportation's (NCDOT) and North Carolina State University (NCSU), started in 2009 and is now largely regarded as one of the most successful programs in the F2F alliance. North Carolina's humid climate, fertile soils, and support from the state legislature have made their biocrop growing efforts a national model (Figure 7).

As a first step in the project, NCDOT needed to identify areas in the highway rights-of-way that were suitable and amenable to biocrop production. NCSU used GIS tools to quantify slope, right-of way width, and highway shoulder width to determine the amount of acreage and mileage available for the biocrops program.



Figure 7. North Carolina Freeways to Fuels canola test crop site, 2010 (photo by Dallas Hanks, Utah State University College of Agriculture and Applied Science).

NCDOT, in collaboration with NCSU, selected four one-acre plots to plant canola and sunflower oilseed crops. Each plot was located at least 10 ft from the highway with a grass buffer strip separating the plots from the highway shoulder. Canola is typically planted in the fall and harvested in June, while sunflower is planted in July and harvested in October. By working with seasonally rotated crops on the same plot, NCDOT has been able to significantly increase biofuel yield over models where only one crop was planted. Other seasonal crops were ruled out based on their anticipated poorer growth performance in harsh right-of-way conditions (as compared to conditions on a farm, for example). NCDOT has used its own

equipment to manage the plantings, but also uses personnel from NCSU to supplement its own staff. To date, canola yields have either met or exceeded national standards. The sunflower crop harvest, while robust, was not as strong as the canola harvest. Drought was one issue that impacted sunflower yield, and future sunflower harvests along the highway are expected to vary with levels of precipitation.

In designing and implementing its biocrop projects, the NCDOT and NCSU are addressing the issues listed below.

- **Tilling:** The North Carolina project studied several appropriate tillage methods to maximize yield including no till, medium till, and maximum till. Weed control in new seedlings with herbicide application and a single tillage event was contemplated; however, testing indicated that the no-till method may be the most effective and most economical approach.
- **Safety:** Growing crops in the highway rights-of-way creates similar safety issues as any roadside revegetation or mowing program. Biocrop production has not lead to any new safety issues for the Department. In addition, by planting the crops more than 10 ft from the road, NCDOT does not have to set up a mobile operation when working at the biocrops sites.
- **Compaction:** Soil compaction is a significant issue in both biocrop production and general production agriculture. In North Carolina, vehicles and equipment have been traditionally stored on rights-of-way now used for biocrop growth, which has increased the compaction level. NCSU and NCDOT are presently exploring methods to best deal with soil compaction issues at their project sites.

In addition to the Utah and North Carolina F2F programs, several other states are researching the effectiveness and efficiency of planning biocrops on highway rights-of-way. These include efforts involving Tennessee DOT; Michigan DOT; Willamette University in Salem, Oregon, with the Oregon and Washington DOT; Texas DOT; Virginia DOT; Arkansas DOT; and the University of Illinois with IDOT.

Because more than 70% of biofuel feedstock transportation costs are associated with the fixed cost of trucking, transportation engineering studies are often conducted to locate processing plants that will minimize transportation distances. The optimal location of a processing facility is an ab-

solute necessity if a biomass system is to be economically feasible and/or competitive. Transportation engineering techniques have been used on actual road networks to estimate trucking costs from field to processing plant. These techniques allow cost contours to be generated based on mileage and travel times, thereby optimizing the biofuel production/biofuel processing combination. Figure 8 exemplifies this form of transportation modeling.

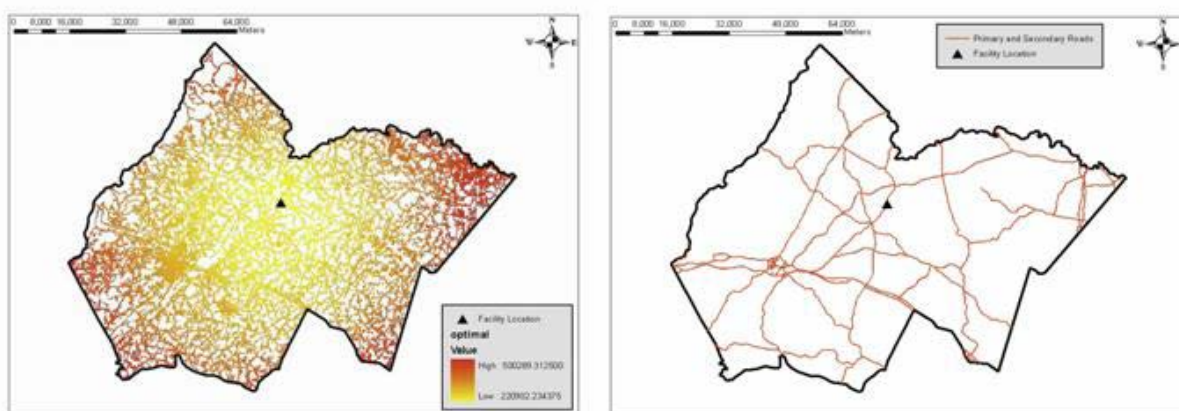


Figure 8. Maps delineating optimal biofuel processing plant location based on transportation cost curves (Ravula et al. 2005).

2.4 Land/environmental impacts

Significant research effort has been directed towards the use of annual crop species, such as corn, wheat, oats, and soybeans, for producing biofuels (grain-based ethanol). Guidelines for maximizing production of these biofuel feedstocks and efficiently harvesting, transporting, storing, processing, and refining these agricultural crops into ethanol are well developed, as evidenced by the production of nearly 9 billion gal of ethanol from 3.2 billion bushels of grain in 2008 (RFA 2009). The environmental impacts of producing grains are also well understood and conservation practices that minimize negative impacts associated with grain production such as soil erosion, water pollution, nitrogen and phosphorus runoff/leaching, and pest control are commonplace. The 2007 EISA, however, has set goals for RFS that include the production of 36 billion gallons of biofuels by 2022, with at least 21 billion gallons derived from non-edible cellulosic feedstocks.

Increased demand for grain-based ethanol/biofuels has raised concerns about rising food prices and, ultimately, food and fuel security. Interest-

ingly, ethanol derived from grain crops created commodity market inflation in 2008, further re-emphasizing the EISA policy towards increased cellulosic feedstock production as a means to avoid these types of unintended consequences from relying so heavily on grain crops as the principal feedstock for biofuels (Schnepf 2013). As such, it is widely believed that 2007 EISA goals can be met by deliberately shifting away from the use of annual grain crops for biofuel feedstock towards other sources of biomass that do not compete with traditional food crops. This biofuels production paradigm shift, however, requires that marginal lands be brought into production in order to meet cellulosic feedstock goals and requirements as farmers tend to keep highly productive cropland in cultivation regardless of changing economic conditions (Lubowski et al. 2006). Frequently, these types of land-use changes driven by favorable economic conditions can affect environmental quality, particularly when these marginal lands are ecologically sensitive in terms of critical species habitat, water quality, provision of ecosystem services, or in the case of the US Army, lands utilized for diverse testing and training activities.

Conversion of marginal lands and abandoned cropland/pasture into sources for cellulosic biomass feedstock production does not come without some risk of negative environmental impact, namely in terms of soil resources, water quality, biodiversity, and ecosystem services (Gollany et al. 2011). It is important to note that not all marginal lands can be reasonably expected to economically produce cellulosic feedstock and for the purposes of this discussion, only lands east of the 100th meridian should be considered (Mitchell et al. 2010). The reason for the distinction is because this region is considered to have both adequate precipitation and generally fertile soils necessary to produce cellulosic biofuels from perennial grasses, short rotation woody crops, or oilseed crops (Blanco-Canqui 2010). From an Army perspective, there are certainly very specific circumstances and land uses where this distinction may not apply, such as forested, shrub-dominated, or invasive species-dominated sites where specialized cellulosic biofuel feedstock harvesting is possible; however, these sites would be rare and should be considered on a case-by-case basis. It is also important to note that there is no single feedstock type or land-use management practice that will work for every potential cellulosic biofuel location, and further, the choice of an ideal cellulosic biofuel crop system will always be location- and market-specific (Dale et al. 2010).

The conversion of grasslands and forests to cropland that occurred during and after European settlement resulted in significant declines in soil organic carbon (SOC). The loss of SOC (>50%) and concomitant release of plant nutrients after the first 50 years of cultivation is well documented in the literature (Huggins et al. 1998; Paustian et al. 1997; Liebig et al. 2005). If previously uncultivated lands are brought into cellulosic biofuel production, significant releases of greenhouse gases can be expected, thereby creating a biofuel carbon debt and effectively offsetting any benefits derived from replacement of petroleum-derived fuels by cellulosic biofuels (Fargione et al. 2008). However, this biofuel production carbon debt from using previously cultivated marginal lands and abandoned croplands/pasture to produce cellulosic biofuels is significantly diminished when compared to using previously uncultivated lands (Dale et al. 2010), suggesting that most previously uncultivated lands should not be considered for cellulosic biofuel production.

In addition to losses of SOC and leaching of newly mobilized nitrogen and phosphorus resulting from cultivation, soil erosion and accelerated sediment production from these sites usually increase as well (McLaughlin and Walsh 1998). Many of these environmental impacts may be exacerbated when marginal lands and abandoned cropland/pasture are converted into cellulosic biofuel production (Schwarz et al. 2003), because these sites have inherent factors such as poor drainage, poor soil structure and texture, and steep slopes that limit productivity, crop suitability, and equipment access necessary for efficient agricultural production.

Negative environmental impacts resulting from conversion of marginal lands into cellulosic biofuel production, however, can be minimized with adequate planning, proper site identification, selection of appropriate plant species, and implementation of conservation practices that assure sustainable establishment, maintenance, production, and harvesting protocols for the biofuel crop. For the Army, this suggests that some type of a production system employing warm season grasses, as opposed to oilseed crops, offers the greatest and most sustainable capability for cellulosic biofuel production on Army lands, the most well-known and researched species being switchgrass (*Panicum virgatum*), indiangrass (*Sorghastrum nutans*), big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and miscanthus (*Miscanthus* spp.; Mitchell et al. 2010). Figure 9 depicts miscanthus and switchgrass plant species.



Figure 9. Miscanthus and switchgrass test plots (University of Illinois Extension Office <http://agronomyday.cropsci.illinois.edu/2006/tent/biofuels.htm>).

When compared to other types of cellulosic or oilseed-based biofuels, warm season grass production systems have several characteristics that make them ideal for military training and testing lands. Foremost, they are compatible with military training and testing activities. Utilization of existing agricultural out-leasing programs with minor adjustments could provide a mechanism for planting and harvesting of biofuel crops. Conversely, if accessibility is an issue, tractors and agricultural implements for site preparation and seeding are readily available, often from DPW, Environmental, or Range Operations. Irrigation is not required, and fertilization and harvesting regimes can be customized to accommodate training schedules and habitat/nesting/brooding requirements for birds and other at-risk species. Warm season grass systems are generally tolerant of significant yearly climatic variation and, unlike annual crop species used for ethanol production, these grass are relatively resistant to pests and invasive species encroachment and will seldom “fail” as a result of extended drought or flooding.

The opportunities for incorporating warm season grass systems on Army lands are nearly endless and include (1) planting buffer strips around water sources to minimize sediment and nutrient transport into surface waters (Blanco-Canqui et al. 2004); (2) planting along road, trail, and utility rights of way; (3) developing production management plans or adjusting agricultural out-leasing programs to accommodate training areas at installations such as Fort Riley, Fort McCoy, and Fort Campbell where large training areas are already composed of warm season grass communities; and (4) developing land rehabilitation and maintenance plans that incorporate the use of warm-season grasses to the greatest extent possible. Planting monocultures of a specific species is more efficient and less ex-

pensive, and it also provides a homogenous substrate for cellulosic ethanol production, although this homogeneity comes with increased risks for insect and disease pressures as well as drastically reduced biodiversity (Blanco-Canqui 2010; Dale et al. 2010). Conversely, planting polycultures of warm season grasses confers better disease and pest resistance and provides diverse above- and below-ground structure and habitat conducive to enhanced levels of biodiversity (Lubowski et al. 2006; Dale et al. 2010).

Given that Army lands tend to support a disproportionate number of threatened and endangered species when compared to other federal- and state-managed lands (Warren et al. 2007), carefully planned warm season grass production systems may well result in a host of environmental benefits above and beyond those currently provided by non-managed lands. Among these benefits are (1) potential carbon sequestration (Tilman et al. 2006; Anderson-Teixeira et al. 2009; Blanco-Canqui and Lal 2009); (2) improved soil physical properties such as bulk density (Rachman et al. 2004), porosity (ibid.), hydraulic conductivity (Udawatta et al. 2008), infiltration (Katsvairo et al. 2007), percolation (Udawatta et al. 2008), and water holding capacity (Blanco-Canqui 2010); (3) improved soil biological properties such as microbial and macro-invertebrate biomass (Katsvairo et al. 2007); (4) improved water quality and reduced runoff and sediment yields (Eghball et al. 2000); and (5) improved contaminant capture and retention (Belden and Coats 2004; Krutz et al. 2005). Establishing warm-season grass systems for the production of cellulosic biofuels on Army lands can outweigh the negative environmental impacts, if the production is properly planned and implemented.

3 Conclusions and Recommendations

The trade-offs between benefits to energy security and reductions in greenhouse gas emissions, as opposed to large federal budget costs and the potential for unintended consequences, have led to emergence of both proponents and critics of biofuels production within the DoD. Proponents envision fields of fuel crops, powered by the sun, delivering clean, renewable energy year after year. In contrast, critics argue a whole host of problems following the push to exploit biofuels, from land grabs and deforestation to increased food prices and carbon emissions. Yet, one thing both sides agree on is that we are not on a trajectory to reach the Congressional goal of producing 36 billion gal per year by 2022.¹⁴ Some potential reasons for this shortfall include:

- Large-scale production of cellulosic biofuels requires large land areas, so current generation biofuels can only replace fossil fuels to a very limited extent. At the same time, advanced generation biofuels still need development, refinement, and cost-effective solutions.
- Challenges still exist in matching current generation biofuels and the existing petroleum fuel distribution infrastructure. Pilot demonstrations indicate difficulty in using E15 and E20 in military vehicles and unique requirements in storage, transportation, and distribution infrastructure. In other words, significant gaps in the supply chain still exist.
- Many biofuel-related projects are currently funded, but the Army still lacks an explicit management plan to achieve targets. The Army established the EITF to develop strategic partnerships among private sector, academic institutions, and state and local government to facilitate rapid adoption of research and technology. The EITF does not monitor progress toward Congressional goals or oversee the coordination of Army-wide efforts. Installation staff advise they do not have a clearly defined role with regard to development, management, and production of cellulosic biofuels.

Given the above circumstances and based on the information reviewed and discussed in this report, the following recommendations are provided

¹⁴ EIA Projections; DOE Billion-ton Report; Interagency Working Group report; CRS 2012 report all illustrate this struggle to meet goals.

as a basis for further consideration as the Army expands efforts related to biofuel production and usage.

Recommendation: Begin entry into the biofuels arena very slowly, cautiously, and at relatively small scales in order to gain an appreciation of how the addition of biofuels production will impact the installation's daily operations cycle. Due to the significant potential for negative environmental impacts associated with the conversion of marginal or previously uncultivated lands into croplands supporting oilseed and other intensively managed agricultural biofuel crops, the use of warm season grass systems is recommended as these require less management, fewer fertilizer, pesticide, and nutrient inputs, no specialized harvesting equipment, and have fewer negative environmental impacts. With the exception of very specialized circumstances (excessive forest fuels, woody/shrubby ecosystems, infestations of non-native invasive plant species), biofuel production west of the 100th meridian is not recommended due to lower, highly variable precipitation levels and generally poorer soils that result in biomass yields that are unpredictable.

Recommendation: Continue to support the existing biofuels industry and accelerate the creation and rapid commercialization of new technologies to establish an advanced biofuels industry. This requires continued funding for research and demonstration projects. It is also important to develop information from models to demonstrate which technologies and strategies have the greatest opportunities for success. The REAP and KDF models can be calibrated for different regions of the United States, allowing local managers to input resource variables (geographic, environmental, infrastructure, business, workforce) in order to identify potential constraints that may impact successful participation in regionally focused biofuels business arenas. Enhance these models as comprehensive analyses and planning tools that can specifically simulate and predict feasibility and long-term sustainability of current and future biofuel technologies. This will provide a framework for investing, developing, operating, and maintaining sustainable biofuel production initiatives at the local (installation) level.

Recommendation: As an example, conduct biofuel production suitability assessments across all Army installations and down-select several installations representing ample geographic and climatic diversity. Collect site-specific data for each down-selected installation for input into REAP and KDF models to predict positive and negative consequences of biofuel pro-

duction in terms of changes in installation logistics, biofuel harvesting and transport to regional processing facilities, and time, labor, and specialized equipment requirements. This process would enable the Army to develop plans for conducting small-scale demonstrations to more fully understand how the addition of biofuels production would alter daily operations at the installation level.

Recommendation: Establish an Army (or DOD) organization to regularly monitor and review progress related to biofuel goals and on-going biofuel projects. This organization should also establish interim milestones that are widely shared and can accommodate mid-course changes as needed. Address supply chain gaps. Assign leadership for each segment of the supply chain. Provide clear roles down the chain. Maintain case study repository, discussion boards, and provide regular and timely updates.

Recommendation: Have an Army/DoD partnership with the IWG. IWG monitors and tracks national progress towards biofuels goals. They promote local agencies to take a strong role in local management. The IWG, made up of the DOE, USDA, and EPA, has the leading biofuels research and development resources at their fingertips. They want to find ways to funnel this information to end-users so that biofuel efforts are integrated and non-duplicative across agencies. This is especially important given the extensive regulatory and infrastructure requirements associated with siting, permitting, constructing, operating, maintaining, and potentially expanding biofuels processing facilities capable of servicing a relatively large geographic area. Partnerships such as these would bring many benefits to the Army—new jobs and greater economic vitality, increased energy independence, reduced economic vulnerability to volatile oil prices and uncertain supplies, technological and industrial leadership in renewable biofuels, and reduced global warming pollution. In short, the Army will be in firmer control of its energy future as an integrated player in the emerging biofuels industry.

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