Department of Defense
Report to Congress on
Use of Biofuels and Measures for Increasing Such Use in FY07–12

Section 357 of the National Defense Authorization Act (NDAA) for FY06 and the Conference Report for the John Warner NDAA for FY07

Under Secretary of Defense
(Acquisition, Technology, & Logistics)

November 2007

Contents

Figures

Tables

Executive Summary

On January 6, 2006, the National Defense Authorization Act (NDAA) for Fiscal Year (FY) 2006, was signed into law as Public Law 109-163. Section 357 of this law required the Secretary of Defense to complete a study on the "use of biodiesel and ethanol fuel by the Armed Forces and the Defense Agencies and any measures that can be taken to increase such use." The Conference Report for the John Warner NDAA for FY07 (House Report 109-702, page 701) added biofuels other than biodiesel, renewable diesel, ethanol that contains less than 85 percent ethyl alcohol, cellulosic ethanol, and synthetic hydrocarbon-based fuel to the study. This report provides the results of the Department of Defense (DoD) biofuels study, addressing the requirements of Section 357 and the Conference Report.

DoD Proposed Actions

DoD's Defense Energy Support Center tasked LMI (a not-for-profit government consulting firm) with completing an analysis to support the Congressional biofuels study. DoD has accepted LMI's analysis and has utilized its findings to complete the study's seven required elements. Based on the Congressional biofuels study analysis and results, DoD is pursuing the following measures to increase DoD's biofuel use in FY07–12:

1. **DoD will (to the maximum extent possible) ensure that biofuel-capable non-tactical vehicles (NTVs) purchase biofuel when fueling at biofuel stations**. DoD estimates that the maximum potential annual increase in biofuel use by implementing this action is 134,851 gasoline gallon equivalents (GGE)[1] of E85 and 30,893 GGE of B20.

2. **DoD will (to the maximum extent possible) divert fueling of biofuel-capable NTVs from conventional stations to nearby biofuel stations.** This action requires DoD E85 flex-fuel vehicles (FFVs) and diesel vehicles to purchase biofuels at existing commercial biofuel stations when reasonably available (i.e., within 5 miles or a 15-minute drive). DoD estimates that the maximum potential annual increase in biofuel use by implementing this action is 3,208,547 GGE of E85 and 978,983 GGE of B20.

By implementing these first two actions, DoD will ensure continued compliance with the requirements of Section 701 of the Energy Policy Act of 2005 and Executive Order 13423. These two actions will result in a maximum potential annual increase in biofuel use of 63 percent from FY06 levels.

[1] GGEs enable comparison of the usage of fuels with different energy content.

3. **DoD will consider locating new E85 FFV acquisitions near commercial E85 stations**. This action involves DoD concentrating E85 FFVs near existing commercial E85 stations through the normal acquisition replacement cycles. (As vehicles near E85 commercial stations are replaced, DoD could acquire E85 FFVs rather than gasoline vehicles.) DoD estimates that the maximum potential annual increase in E85 use by implementing this action is 2,407,587 GGE. Further analysis is required to determine the current and potential DoD E85 FFV fleet concentrations and vehicle replacement schedules at these locations before implementing this action.

4. **DoD will explore increasing the installation of new biofuel infrastructure or conversion of existing biofuel infrastructure at large-use DoD exchanges.** DoD identified 79 DoD exchanges for potential conversion or installation of E85 infrastructure and 11 DoD exchanges for potential conversion or installation of B20 infrastructure. DoD estimates that the maximum potential annual increase in biofuel use by implementing this action is 9,229,330 GGE of E85 and 1,097,233 GGE of B20. Detailed site evaluations would be necessary to confirm the identified potential increase in biofuel use, determine whether DoD policy can be met, decide whether conversion or installation of infrastructure is most appropriate, and evaluate the cost, feasibility, and advisability of the new biofuel infrastructure.

5. **DoD will investigate installing new biofuel infrastructure or convert existing biofuel infrastructure at large-use DoD installation fueling sites.** DoD identified 107 DoD installation fueling sites for potential conversion or installation of E85 infrastructure and 61 DoD installation fueling sites for potential conversion or installation of B20 infrastructure. DoD estimates that the maximum potential annual increase in biofuel use by implementing this action is 4,611,362 GGE of E85 and 4,258,244 GGE of B20. Specific and detailed site evaluations would be necessary to confirm the identified potential increase in biofuel use, determine whether DoD policy can be met, decide whether conversion or installation of infrastructure is most appropriate, and evaluate the cost, feasibility, and advisability of the new biofuel infrastructure.

INTRODUCTION

According to the Energy Information Administration, worldwide demand for petroleum is rising. Daily consumption is projected to increase from 85 million barrels in 2006 to 118 million barrels by 2030.[2] The United States is the largest consumer of petroleum: its current use of 21 million barrels per day constitutes 24 percent of the worldwide petroleum consumption.[3] U.S. petroleum demand is

[2] U.S. Department of Energy (DOE), *Petroleum—U.S. Data—Product Supplied*, Energy Information Administration, http://tonto.eia.doe.gov/dnav/pet/pet_cons_psup_dc_nus_mbbl_m.htm, July 2007.

[3] DOE, *International Energy Outlook 2007*, DOE/EIA-0484 (2007), Energy Information Administration, May 2007.

also expected to increase over the next 25 years at an annual rate of almost 1 percent per annum.

Most (roughly 65 percent) of the petroleum the United States uses is imported, much of it from unstable parts of the world. The prosperity and way of life in this country are sustained by energy use—an adequate, reliable supply of petroleum is a key ingredient of national security. The comprehensive energy strategy of the United States, as outlined in the *National Security Strategy*, consists of opening, integrating, and diversifying energy markets to ensure energy security.

As one means to help reduce our dependence on foreign petroleum, the United States is promoting the use of biofuels, such as ethanol and biodiesel.[4] The focus of increasing biofuel use is for transportation, which accounts for two-thirds of U.S. petroleum use. Ethanol blended as E85 (85 percent ethanol and 15 percent gasoline) and biodiesel blended as B20 (20 percent biodiesel and 80 percent diesel) are the primary biofuels capable of displacing gasoline and diesel, respectively.

DoD is a prime candidate for increasing biofuel use: its consumption of oil constitutes 1.2 percent of the national total. In this study we look at DoD's historical biofuel use and the potential for its increased use in FY07–12.

STUDY ELEMENTS AND RESULTS

Congress required that this study consist of seven elements. DoD's findings for each element are as follows:

1. *Historical DoD biofuel use in FY02–06*. Biofuels are any fuel produced from renewable resources, including plant biomass, vegetable oils, and treated municipal and industrial wastes. Biofuels provide many environmental advantages over petroleum-based fuels, including reducing greenhouse gas emissions. Biofuels provide a benefit by acting as a "carbon sink." Crops grown to produce biofuel feedstocks absorb carbon dioxide from the atmosphere, balancing the emissions of carbon dioxide from the combustion of the biofuel. The use of biofuels as an additive to petroleum fuels can also result in cleaner burning with less emission of carbon monoxide and particulates.

   Biofuels, however, have different chemical and physical properties than petroleum fuels and should not be considered a drop in replacement. The use of biofuels, even when blended with petroleum fuels, may be limited in some applications and environments.

   The NTV fleet accounted for almost all DoD biofuel consumption in FY02–06. DoD's use of biofuels in other applications is currently negligible and projected to remain negligible through FY12. DoD did not use other biofuels

[4] *National Security Strategy of the United States of America*, March 2006, pp. 26–29.

(biofuels other than biodiesel, renewable diesel, ethanol fuel that contains less than 85 percent ethyl alcohol, and synthetic hydrocarbon-based fuel) in FY02–06; our use of these biofuels will continue to be negligible in FY07–12. Although DoD is evaluating the use of synthetic hydrocarbon-based fuels for both ground and aviation applications, DoD projects only limited production capability (i.e., pilot plants) and availability in the U.S. through FY12.

DoD prohibits the use of biofuels in tactical vehicles due to operational and mission-readiness concerns. Other DoD applications that could potentially use biofuels include aircraft, marine vessels, and power and heat generation equipment:

- *Aircraft.* DoD does not currently use biofuels in aircraft due to the high cloud point of available biofuels (which may cause the fuel to gel and clog the engine as the aircraft climbs and temperatures decrease) and the lack of other biofuels (e.g., biobutanol and synthetic hydrocarbon-based fuel) suitable for aviation applications.

- *Marine vessels.* DoD prohibits the use of biodiesel in marine vessels due to its hydrophilic characteristics, which may result in damage to engine fuel system components, accelerate fuel storage instability, and affect the fuel's cold weather operating properties.

- *Power and heat generation equipment*. DoD does not currently use biodiesel in power and heat generation equipment due to (1) biodiesel storage instability concerns (since these equipment are used periodically, fuel typically remains in the tank over long durations) and (2) lack of standards for use of biodiesel blends as heating oil.

The concerns with using biofuels in these applications are not expected to be addressed within the time frame of this study. Therefore, the projected use of biofuels in aircraft, marine vessels, and power and heat generation equipment is expected to be negligible through FY12.

The types of NTVs that consume the primary biofuels in this study (E85 and biodiesel) are E85 FFVs and diesel vehicles. As shown in Table ES-1, DoD's use of biodiesel (blended as B20) and E85 in the NTV fleet has steadily increased over the last 5 years, from 0.96 million GGE in FY02 to 6.90 million GGEs in FY06. B20 represents the majority of DoD's biofuel consumption.

Table ES-1. DoD's Reported Use of Biofuels in NTVs, FY02–06 (Thousands of GGEs or Gallons)

Fiscal year	Biofuels in this study				Total use of biofuels	
	Biodiesel (B20)		Ethanol (E85)			
	GGE	Gallons	GGE	Gallons	GGE	Gallons
2002	960	853	—[a]	—[a]	960	853
2003	1,566	1,391	200	278	1,766	1,669
2004	5,108	4,536	250	347	5,358	4,883
2005	5,736	5,094	566	786	6,302	5,880
2006	6,060	5,382	836	1,161	6,896	6,543

[a] DoD's E85 consumption data in FY02 was greatly overstated and not included in this study.

2. *Potential requirements for increased DoD use of biofuels.* Our biofuel use has increased substantially in FY02–06. However, our use of biofuels in biofuel-capable vehicles is low. In FY06, only 4.4 percent of the fuel used in E85 FFVs was E85 (95.6 percent is gasoline) and 33 percent of the fuel used in diesel vehicles was B20.

   The primary issues currently limiting the use of biofuels in biofuel-capable vehicles include the following:

   - Fleet operator issues, such as their not knowing that the vehicle uses biofuel or not knowing where commercial biofuel stations are located.
   - Lack of biofuel infrastructure, at commercial fueling stations, DoD exchanges, and DoD installation fueling sites.
   - Incremental costs associated with buying E85 FFVs and diesel vehicles as well as purchasing biofuels for use in these vehicles.

   Addressing these limiting factors is critical to increasing our biofuel consumption in FY07–12.

3. *Forecast of DoD requirements for biofuel use in FY07–12.* We estimate that our potential demand for biofuels in FY12 will range from 1.79 million GGEs of E85 and 10.20 million GGEs of B20 (minimum regulatory requirements) to 33.96 million GGEs of E85 and 20.75 million GGEs for B20 (100 percent use in the NTV fleet). These later projections represent the amount of biofuels the DoD NTV fleet could use if there were no supply or availability issues.

   The wide range for our projections results from unknown biofuel use rates and different biofuel-capable vehicle acquisition scenarios. Our actual consumption of biofuels over this period will primarily depend on commercial biofuel availability, commercial and DoD biofuel infrastructure, and the subsequent use in DoD biofuel-capable NTVs.

4. *Current and future commercial availability of biofuels.* We project that through FY12, U.S. production of ethanol will increase 138 percent, from 4,855 to 11,556 million gallons, and production of biodiesel will increase 211 percent, from 150 to 466 million gallons. Although ethanol from cellulose offers the greatest potential for large-scale displacement of petroleum, it will not be available in quantity until at least 2012.

   Due to economic factors, almost all ethanol (99.7 percent) will be sold as an additive to gasoline (E10) rather than as E85 over this study's time frame (FY07–12). DoD potential biofuel requirements may exceed forecasted E85 retail availability at high DoD utilization rates. However, because pure ethanol is readily available in much greater quantities, high levels of DoD demand for E85 can be met through diversion of ethanol use from E10 to E85. For B20, retail availability will far exceed DoD projected demand over the next 5 fiscal years.

   The primary factors that will limit the retail availability of high blends of biodiesel (B20) and ethanol (E85) are transportation hurdles, regulatory disparities between states, efficiency issues, commercial infrastructure limitations, and demand for biofuels for use as fuel additives. Biofuels are distributed primarily through the freight rail system, which currently has limited capacity and is costly over long distances. As a result, most commercial biofuel retail fueling infrastructure will be concentrated near production facilities in the Midwest. Commercial retail fueling infrastructure may not be sufficient to cover all DoD ethanol and biodiesel requirements through FY12. DoD may need to purchase ethanol and biodiesel in bulk for distribution at DoD facilities to meet its demands.

5. *DoD future utilization of commercial infrastructure.* The primary actions DoD can take to increase biofuel use at commercial infrastructure and DoD exchanges are as follows:

   - Ensure biofuel-capable vehicles purchase biofuel when fueling at biofuel stations.
   - Divert fueling of biofuel-capable vehicles from conventional fuel stations to nearby biofuel stations.
   - Concentrate E85 FFVs near commercial E85 stations.

   By optimizing use of the existing commercial biofuel infrastructure, DoD can increase its use of E85 by 5.75 million GGE (7.99 million gallons) and B20 by 2.11 million GGE (1.87 million gallons) by FY12.

6. *DoD actions to expand public infrastructure*. The least costly alternative available (to DoD) for adding new biofuel infrastructure is to promote the expansion of new commercial biofuel stations near DoD NTV fleet locations. DoD has determined all commercial E85 and B20 stations with potential DoD

biofuel use greater than 50,000 GGEs as potential candidates for promoting the expansion of new biofuel infrastructure. Thirty-five locations met this criterion for potential commercial E85 stations. (No locations for potential commercial B20 stations were identified.)

7. *Fueling infrastructure on military installations that could be adapted or converted for biofuels.* We identified 79 DoD exchanges for potential conversion or installation of E85 infrastructure and 11 DoD exchanges for conversion or installation of B20 infrastructure. The potential increase in E85 is 9.23 million GGEs (12.8 million gallons), requiring capital investment of $14.5 million and annual costs of $11.1 million.

   To increase E85 use at military installations, we identified 56 gasoline fueling sites at DoD installations for potential conversion to E85 and 51 fueling sites for potential installation of new E85 infrastructure. The potential increase in E85 is 4.61 million GGEs (6.40 million gallons), requiring capital investment of $13.0 million and annual costs of $3.83 million.

   For B20, we identified 40 diesel fueling sites at DoD installations for potential conversion to B20 and 21 fueling sites for potential installation of new B20 infrastructure. The potential increase in B20 is 4.26 million GGEs (3.78 million gallons), requiring capital investment of $6.10 million and no change in annual operating costs.

ACTIONS TO INCREASE DOD USE OF BIOFUELS

On the basis of the issues limiting DoD biofuel use, we identified a series of actions that DoD could implement to increase its use of biofuels. These included increasing biofuel use at commercial infrastructure and expanding biofuel infrastructure at DoD exchanges and installation fueling sites. We quantified the potential increase in biofuel use and associated costs for five primary actions DoD can potentially take to increase biofuel use in FY07–12:

- Ensure biofuel-capable vehicles purchase biofuel when fueling at biofuel stations.
- Divert fueling of biofuel-capable vehicles from gasoline-only stations to nearby biofuel stations.
- Concentrate E85 FFVs near E85 stations.
- Install new biofuel infrastructure at DoD exchanges with large fuel use.
- Convert or install new biofuel infrastructure at DoD fueling sites on military bases.

Table ES-2 summarizes, for each action, DoD's potential increased use of E85 or B20 and the associated costs. The costs are provided as one-time capital investment costs, annual costs, annualized costs (annual costs plus capital costs annualized over 5 years), and cost per GGE increase in E85 or B20.

DoD could potentially increase its use of E85 by 19.6 million GGEs and its use of B20 by 6.4 million GGEs by implementing these actions fully. Our estimates reflect 100 percent utilization of biofuel infrastructure when available. Due to operational and implementation issues, actual biofuel use will likely be less than these estimates. However, even small changes in biofuel refueling behavior and limited installation of biofuel infrastructure will drastically increase biofuel use.

Table ES-2. Increased Biofuel Use and Costs

Potential DoD action	Capital investment ($)	Annual costs ($)	Total annualized costs ($)	Potential increase in biofuel use (GGE)	Cost per increase in GGE ($)
E85					
Optimize fueling of E85 FFVs at current commercial E85 stations	0	122,677	122,677	134,851	0.91
Divert fueling of E85 FFVs to nearby commercial E85 stations	422,620	8,438,375	8,522,899	3,208,547	2.66
Locate E85 FFVs near commercial E85 stations	0	3,867,302	3,867,302	2,407,587	1.61
Install new E85 infrastructure at large-use DoD exchanges and locate E85 FFVs near those stations	14,495,315	11,070,835	13,969,898	9,229,330	1.51
Convert gasoline fueling sites to E85 at DoD installations	3,672,312	2,424,056	3,158,516	2,917,133	1.08
Install new E85 infrastructure at DoD installation fueling sites when conversion is not possible	9,357,735	1,407,857	3,279,404	1,694,229	1.94
Total	27,947,982	27,331,102	32,920,696	19,591,677	1.68
B20					
Optimize fueling of diesel vehicles at current commercial B20 stations	0	0	0	30,893	0.00
Divert fueling of diesel vehicles to nearby commercial B20 stations	309,440	2,198,800	2,260,688	978,983	2.31
Install new B20 infrastructure at large-use DoD exchanges	2,243,527	301,662	750,363	1,097,233	0.68
Convert diesel fueling sites to B20 at large-use DoD installations	1,820,400	0	364,080	3,158,437	0.12
Install new B20 infrastructure at large-use DoD installation fueling sites when conversion is not possible	4,283,097	0	856,619	1,099,807	0.78
Total	8,656,464	2,500,462	4,231,750	6,365,353	0.66

The first two actions listed in Table ES-2 reflect operational changes; increases in biofuel use are from the DoD NTV fleet increasing its utilization of existing commercial biofuel stations. By also locating new E85 FFVs near commercial biofuel stations (through the standard vehicle replacement process), DoD can attain substantial further increases in E85 use at a relatively low cost.

Although the potential for increasing biofuel use at existing commercial infrastructure is substantial, the largest DoD opportunity to increase the use of biofuels is by installing biofuel infrastructure at DoD exchanges and military base fueling sites. Almost half (47 percent) of our estimated total potential increase of E85 is from installing E85 infrastructure at 79 DoD exchanges. Similarly, 50 percent of the total potential increase of B20 is from converting existing diesel fueling sites to B20.

We identified 79 DoD exchanges and 107 DoD installation fueling sites for conversion or installation of E85 infrastructure and 11 DoD exchanges and 61 DoD installation fueling sites for conversion or installation of B20 infrastructure. Specific site evaluations are necessary to confirm the identified potential increase in biofuel use, determine whether DoD policy can be met, and decide whether conversion or installation of infrastructure is most appropriate.

Even if all actions were implemented fully, our forecasted increases in E85 and B20 would not exceed the amount DoD could use in its NTV fleet under current vehicle acquisition trends. The projected E85 use would be 20.43 million GGEs, representing 95 percent utilization of the forecasted E85 FFV fleet. Similarly, the projected B20 use of 12.43 million GGEs translates to 71 percent utilization of the forecasted diesel NTV fleet. Therefore, we do not foresee that DoD would require more aggressive acquisition of E85 FFVs and diesel vehicles through FY12.

Similarly, our forecasted increases in E85 and B20 will not exceed the projected retail availability of E85 and B20. DoD would only represent 0.47 percent of the B20 market in FY12, even if it implemented all actions. Although our forecast for DoD’s potential use of E85 in FY12 represents only 0.18 percent of the forecasted ethanol market, it would constitute 69 percent of the forecasted E85 market. DoD E85 requirements would likely support the expansion of commercial infrastructure as well as additional blending of ethanol into E85.

Implementation of Potential Actions

The estimates in Table ES-2 provide the maximum potential increase in DoD biofuel use from taking each action. However, for implementation of this study, further analysis is required at the local level to determine the potential increases in biofuel use, associated costs, advisability, and feasibility of each action.

The potential increases in biofuel use and associated costs in Table ES-2 are only estimates, and based on a number of assumptions, including:

- *Maximum composition of E85 FFVs in the NTV fleet.* Estimates of the highest potential concentration of E85 FFVs in the DoD NTV fleet were based on E85 FFVs currently available and the current fleet composition. These estimates may differ based on future E85 FFV availability and fleet composition requirements at individual fleet locations.

- *Voyager Card fuel transaction coding issues.* Estimates of DoD's current fuel consumption at commercial stations were based on Voyager Card transaction data. Due to coding limitations of older generation register and computer systems, purchases of E85 and B20 at commercial stations often are coded as gasoline or diesel. Therefore, fuel transaction data were recoded based on Department of Energy lists of commercial biofuels stations and average percent use of biofuels at correctly coded stations.

- *Military fueling site tank and consumption data.* The quality and consistency of tank number and capacity data, as well as NTV consumption data at military fueling sites was limited. Therefore, a site-by-site review is required to validate the availability and suitability of specific tanks and military bases for conversion or installation of biofuel infrastructure.

Chapter 1
Introduction

This report presents an analysis of the use of biofuels by the Department of Defense (DoD) in fiscal years (FY) 2002–06 and measures that can be taken to increase such use in FY07–12. This analysis was tasked by DoD's Defense Energy Support Center (DESC), and supported by LMI, to complete the Congressional biofuels study required in the National Defense Authorization Acts (NDAAs) of FYs 2006 and 2007.

CONGRESSIONAL STUDY REQUIREMENTS

On January 6, 2006, House of Representatives (H.R.) 1815, the NDAA for FY 2006, was signed into law as Public Law 109-163. Section 357 of this law required the Secretary of Defense to complete a study on the "use of biodiesel and ethanol fuel by the Armed Forces and the Defense Agencies and any measures that can be taken to increase such use." This study includes the following elements:

- *Historical DoD biofuel use.* An evaluation of the historical utilization of biodiesel and ethanol fuel by the Armed Forces and the Defense Agencies, including the quantity of biodiesel and ethanol fuel acquired by DoD for the Armed Forces and the Defense Agencies during the 5-year period ending on the date of the report.

- *Potential DoD requirements for increased biofuel use*. A review and assessment of potential requirements for increased use of biodiesel and ethanol fuel within DoD and any research and development efforts required to meet those increased requirements.

- *Forecast of DoD biofuel requirements*. Based on this review, a forecast of the requirements of the Armed Forces and the Defense Agencies for biodiesel and ethanol fuels for each of the FYs 2007 through 2012.

- *Commercial availability.* An assessment of the current and future commercial availability of biodiesel and ethanol fuel, including facilities for the production, storage, transportation, distribution, and commercial sale of such fuel.

- *DoD utilization of commercial infrastructure.* An assessment of the utilization by DoD of the commercial infrastructure for ethanol fuel.

- *Potential DoD actions to expand public infrastructure.* A review of the actions of DoD to coordinate with State, local, and private entities to support the expansion and use of alternative fuel refueling stations that are accessible to the public.
- *Current and recommended DoD infrastructure*. An assessment of the fueling infrastructure on military installations in the United States, including storage and distribution facilities, that could be adapted or converted for the delivery of biodiesel and ethanol fuel.

The Conference Report for the John Warner NDAA for FY07 (House Report 109-702, page 701) amended the requirements of the study to include a supplementary study that would address each of these elements for the following alternative fuels: biofuels other than biodiesel, renewable diesel, ethanol that contains less than 85 percent ethyl alcohol, cellulosic ethanol, and synthetic hydrocarbon-based fuel.

Report Organization

The report is organized as follows:

- In Chapter 2, we evaluate DoD’s use of biofuels in FY02–06 (study element: *historical DoD biofuel use*).
- In Chapter 3, we discuss the current landscape for DoD’s use of biofuels (study element: *potential DoD requirements for increased biofuel use*).
- In Chapter 4, we forecast DoD’s potential demand for biofuels in FY07–12 (study element: *forecast of DoD biofuel requirements*).
- In Chapter 5, we forecast the commercial availability of ethanol and biodiesel biofuels in FY07–12 (study element: *commercial availability*).
- In Chapter 6, we present actions that DoD can take to increase its use of biofuels and our framework and approach for estimating DoD’s potential increase in biofuels from implementing these actions.
- In Chapter 7, we quantify DoD’s potential increase in biofuel use at commercial infrastructure and DoD exchanges and the associated costs (study elements: *DoD utilization of commercial infrastructure* and *potential DoD actions to expand public infrastructure*).
- In Chapter 8, we quantify DoD’s potential increase in use of biofuels by converting or installing new infrastructure at fueling sites within military bases (study element: *current and recommended DoD infrastructure*).
- In Chapter 9, we summarize the results of our analysis.

- In Chapter 10, we discuss DoD's potential use of biofuels other than ethanol and biodiesel in FY07–12 (FY07 NDAA requirements).

Chapter 2
DoD's Historical Use of Biofuels

In this chapter, we discuss DoD's use of biofuels in FY02–06. We identify the DoD biofuel users and then show the consumption of biofuels by those users over the last 5 fiscal years.

SUMMARY

The non-tactical vehicle (NTV) fleet accounts for almost all DoD biofuel consumption. DoD prohibits the use of biodiesel and E85 in tactical vehicles due to operational and mission-readiness concerns. The types of NTVs that consume the primary biofuels in this study (E85 and biodiesel) are E85 flex-fuel vehicles (FFVs) and diesel vehicles. Over the last 5 fiscal years, the Energy Policy Act of 1992 (EPAct 1992) and Executive Order (EO) 13149 requirements have driven the purchase of E85 FFVs and the use of biodiesel in DoD's NTV fleet. As a result, the percentage of gasoline vehicles in the NTV fleet has decreased from 67.1 to 52.4 percent from FY02 to FY06. Most of these vehicles have been replaced by E85 FFVs, which have increased from 8.2 to 22.4 percent of the fleet over the same period. The composition of diesel NTVs in the fleet has remained relatively constant, increasing from 20.4 to 20.7 percent.

Table 2-1 shows DoD's consumption of the primary biofuels in this study, biodiesel (blended as B20) and E85, in the NTV fleet in FY02–06. Data are reported in both gallons and gasoline gallon equivalents (GGEs), enabling comparison of the usage of fuels with different energy content. As shown in Table 2-1, DoD's consumption of biofuels has been increasing steadily over the last 5 years. B20 represents the majority of DoD's biofuel consumption.

Table 2-1. DoD's Reported Use of Biofuels in NTVs, FY02–06 (Thousands of GGEs or Gallons)

Fiscal year	Biofuels in this study				Total use of biofuels	
	Biodiesel (B20)		Ethanol (E85)			
	GGE	Gallons	GGE	Gallons	GGE	Gallons
2002	960	853	—[a]	—[a]	960	853
2003	1,566	1,391	200	278	1,766	1,669
2004	5,108	4,536	250	347	5,358	4,883
2005	5,736	5,094	566	786	6,302	5,880
2006	6,060	5,382	836	1,161	6,896	6,543

[a] DoD's E85 consumption data in FY02 is greatly overstated and not included in this analysis.

DoD Biofuel Users

NTV Fleets

According to DoD, NTVs are "any commercial motor vehicle, trailer, material handling or engineering equipment that carries passengers or cargo acquired for administrative, direct mission, or operational support of military functions." All DoD sedans, station wagons, carryalls, vans, and buses are considered "non-tactical."[1]

The types of NTVs that consume the primary biofuels in this study (E85 and biodiesel) are E85 FFVs and diesel vehicles. E85 FFVs are alternative fuel vehicles (AFVs), which are defined by EPAct 1992 as "any dedicated, flexible-fuel, or dual-fuel vehicle designed to operate on at least one alternative fuel." EPAct 1992 defines five types of AFVs: E85 flex-fuel, compressed natural gas (CNG), liquid natural gas (LNG), liquid propane gas (LPG), and electric vehicles. Diesel vehicles, although not defined as AFVs in EPAct 1992, are the only NTV type that uses blends of biodiesel (typically B20).

Therefore, our analysis focuses on the composition of E85 FFVs and diesel vehicles in the DoD NTV fleet and their consumption of biofuels.

AFV Acquisition Mandates

In FY02–06, DoD's usage of biofuels and acquisition of AFVs were driven by two regulations, EPAct 1992 (Public Law 102-486), as amended by the Energy Conservation Reauthorization Act of 1998 (ECRA, Public Law 105-388), and EO 13149, *Greening the Government through Federal Fleet and Transportation Efficiency* (65 FR 24607, April 2000). These regulations establish requirements for annual purchases of AFVs (including E85 FFVs) and provide incentives for the use of biodiesel.

EPAct 1992

EPAct 1992 established statutory requirements for the acquisition of AFVs by federal agencies to achieve the goal of reducing federal petroleum use. In FY00 and beyond, it requires AFVs to represent at least 75 percent of light-duty vehicle (LDV) acquisitions in covered fleets.[2] Vehicles heavier than 8,500 lb GVWR or not located or operated primarily in a covered MSA or CMSA are exempt from

[1] DoD, *Management, Acquisition, and Use of Motor Vehicles*, DoD 4500.36-R, March 16, 2007.

[2] LDVs have a gross vehicle weight rating (GVWR) of less than 8,500 pounds. Covered fleets include federal, state, and fuel-provider fleets of 20 or more LDVs that are centrally fueled or "capable of being centrally fueled" and primarily operated in a Metropolitan Statistical Area (MSA) or Consolidated Metropolitan Statistical Area (CMSA) having a population of 250,000 or more.

the requirements. Law enforcement, emergency, and military tactical vehicles are also exempt.[3]

Compliance with these EPAct 1992 requirements is measured by AFV acquisition credits. Agencies earn one AFV acquisition credit for each AFV acquisition. ECRA allows fleets to generate AFV acquisition credits via use of biodiesel in diesel vehicles. ECRA provides one AFV credit for every 450 gallons of pure biodiesel (B100) or 2,250 gallons of B20 used in diesel vehicles of more than 8,500 lb GVWR.

EO 13149

EO 13149, *Greening the Government through Federal Fleet and Transportation Efficiency,* directs that "each agency operating 20 or more motor vehicles within the United States shall reduce its entire vehicle fleet's annual petroleum consumption by at least 20 percent by the end of FY05, compared with FY99 petroleum consumption levels."

It reinforces EPAct 1992, modifies slightly the AFV reporting requirements, and expands the AFV acquisition credits to include each AFV acquisition, regardless of geographic placement or exemption status. "To maintain the emphasis on actual alternative fuel use, dedicated and electric vehicles will receive additional credits. Dedicated alternative fuel medium- and heavy-duty vehicles earn multiple credits because they displace more petroleum and reduce more emissions on a per mile basis compared to light-duty vehicles."[4] Table 2-2 shows how credits are earned.

Table 2-2. Credits Earned toward EPAct 1992 Compliance

Credits awarded	Situation earning credits
1	A light-duty, alternative fuel vehicle
2	A dedicated light-duty alternative fuel vehicle
3	A dedicated medium-duty, alternative fuel vehicle
4	A dedicated heavy-duty, alternative fuel vehicle

Source: EO 13149, Section 3-2.

EO 13149 requires each federal agency to develop a compliance strategy, including the following measures: (1) use of alternative fuels; (2) use of biodiesel blends; (3) acquisition of vehicles with higher fuel economy, including hybrid

[3] DOE, Office of Energy Efficiency and Renewable Energy, *About EPAct*, July 2007, http://www1.eere.energy.gov/vehiclesandfuels/epact/about/epact_afvs.html.

[4] DOE, Office of Energy Efficiency and Renewable Energy, *Executive Order 13149: Greening the Government through Federal Fleet and Transportation Efficiency, Guidance Document for Federal Agencies,* October 2000.

vehicles; (4) substitution of cars for light trucks; (5) increased vehicle load factors; (6) decreased vehicle miles traveled; and (7) decreased fleet size.[5]

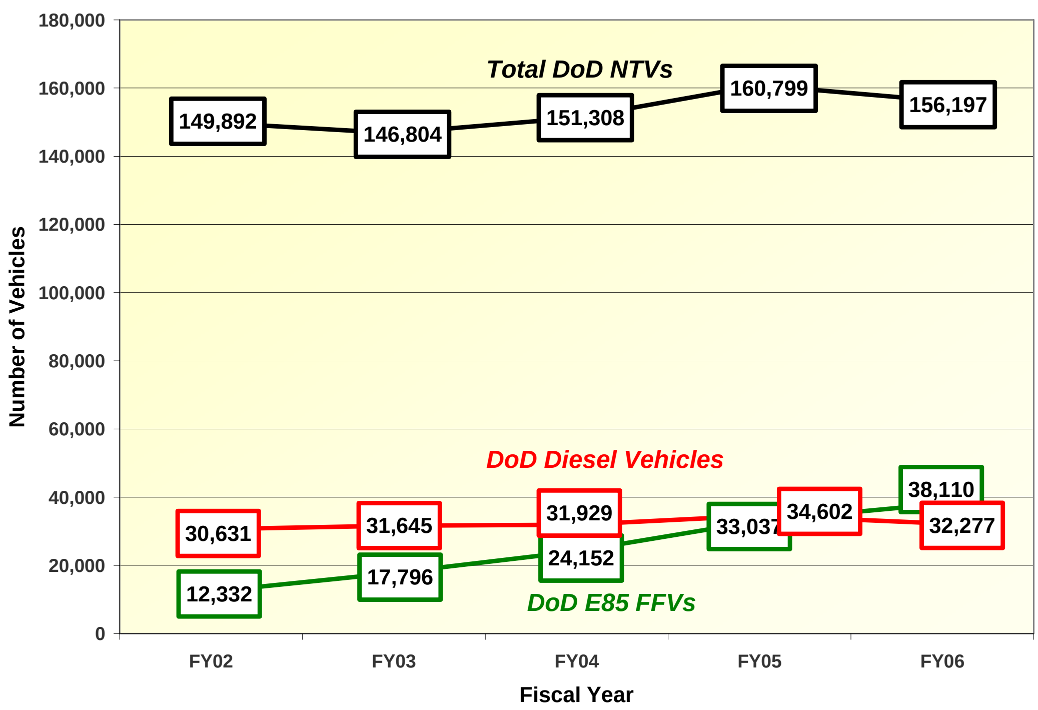
Each agency's compliance strategy was required to include the following primary approaches:

- *Use of alternative fuels in AFVs.* Agencies were required to use more than 50 percent alternative fuel in AFVs by the end of FY05.
- *Acquisition of higher fuel economy vehicles.* Agencies were required to increase (compared with FY99) the average fuel economy of acquired non-AFV passenger cars and light trucks by at least 1 mpg by the end of FY02 and at least 3 mpg by the end of FY05.

Fleet Composition

Figure 2-1 shows DoD's overall NTV fleet inventory and the inventory of E85 FFVs and diesel vehicles. In the last 5 fiscal years, the overall DoD NTV fleet has increased by 4.2 percent, fluctuating from a low of 146,804 vehicles in FY03 to a high of 160,799 vehicles in FY05.

Figure 2-1. Fleet Composition, FY02–06

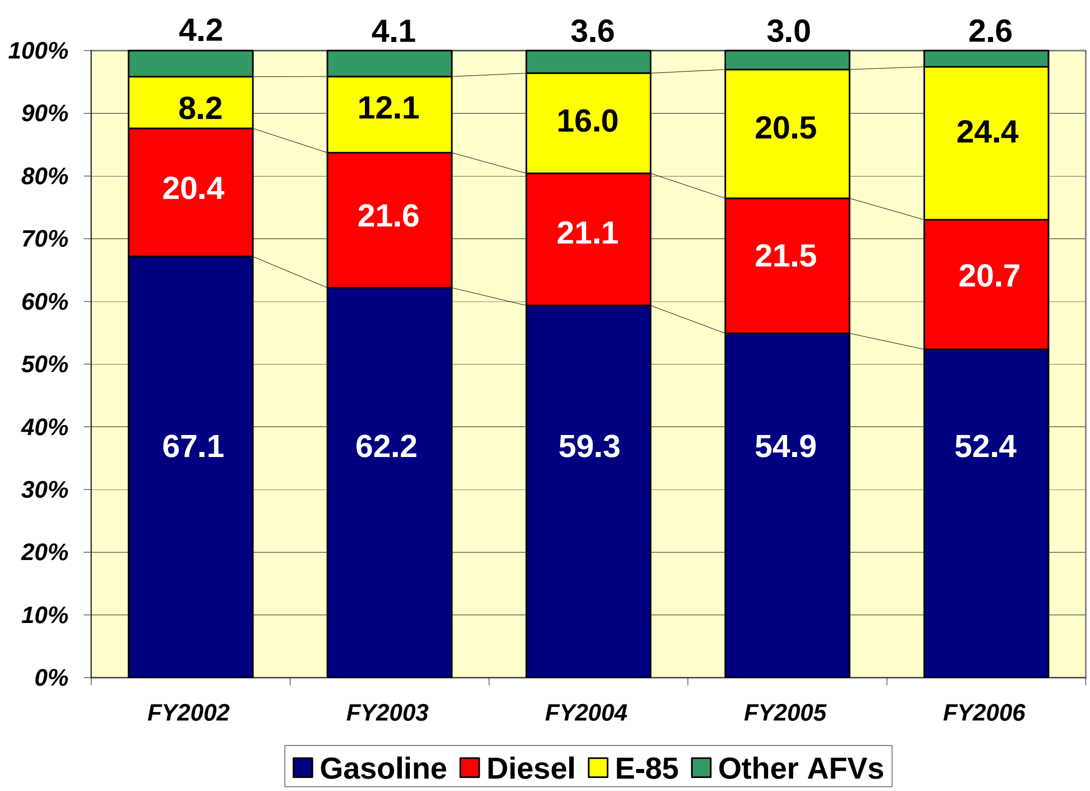


5 DOE, Office of Energy Efficiency and Renewable Energy, *Complying with EO 13149*, July 2007, http://www1.eere.energy.gov/femp/about/fleet_legislation.html.

In the same period, the inventory of vehicles that are capable of consuming biofuel has increased considerably, from 28.7 percent of the fleet (42,963 vehicles) in FY02 to 45.1 percent (70,387 vehicles) in FY06. This increase is primarily the result of E85 FFV acquisition—the number of E85 FFVs has grown more than threefold, from 12,332 vehicles in FY02 to 38,110 vehicles in FY06. Diesel vehicles, on the other hand, have only slightly increased, from 30,631 vehicles in FY02 to 32,277 vehicles in FY06.

EPAct 1992 and EO 13149 have transformed the composition of the DoD NTV fleet. As shown in Figure 2-2, the percentage of gasoline vehicles in the fleet has decreased from 67.1 to 52.4 percent in FY02–06. These vehicles have been replaced by E85 FFVs, which have increased from 8.2 to 24.4 percent in the same period. The composition of diesel NTVs in the fleet has remained virtually constant, ranging only from 20.4 to 21.6 percent (ending FY06 at 20.7 percent). Other AFVs (CNG, LNG, LPG, and electric vehicles) have decreased from 4.2 percent of the fleet in FY02 to 2.6 percent in FY06.

Figure 2-2. Overall NTV Inventory by Fuel Type, FY02–06 (%)



Tactical Vehicles and Applications

Currently, all of the DoD military services prohibit the use of biodiesel blends (including B20) and E85 in tactical vehicles and applications. DoD defines a tactical vehicle as "a motor vehicle designed to military specification or a commercial design motor vehicle modified to military specification to meet direct transportation support of combat or tactical operations, or for training of personnel for such operations. The United States Air Force (USAF) uses commercial design vehicles in tactical roles due to the on-pavement environment of their flight lines."[6]

USE OF E85

DoD has largely rejected the idea of using ethanol-based products as a tactical fuel because of its low energy content and high flammability compared with conventional gasoline.[7] "Ethanol's low energy density, high flammability, and transportation difficulties, relative to diesel and JP-8, for example, render it unsuitable as a DoD fuel."[8]

USE OF B20

All DoD services currently prohibit the use of biodiesel and biodiesel blends in tactical vehicles. The Tri-Service Petroleum, Oil, and Lubricants (POL) Users Group, comprising representatives from the Army, Navy, and Air Force, issued a position statement in March 2006 supporting the current prohibition against the use of biodiesel for tactical applications.[9] It identified the following critical issues associated with the use of biodiesel in such applications:

- *Stability*. Biodiesel is susceptible to storage instability (within a matter of days or months) that may adversely impact vehicles or vessel performance. The resulting oxidation and deterioration of the fuel may cause corrosion filter plugging and high temperature deposit formation, reducing the ability of the tactical vehicles or equipment to be stored short- (as in travel for a combat mission) or long-term. The current biodiesel commercial specification (American Society for Testing and Materials [ASTM] D 6571) also does not include methods to enable the measurement of fuel stability.

- *High temperature properties*. Biodiesel instability is accelerated by high temperatures, which may cause the fuel to degrade in days or weeks. The resulting oxidation and deterioration of the fuel may cause corrosion, filter plugging, and high temperature deposit formation, adversely impacting vehicle or vessel performance.

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[6] See Note 1, this chapter.

[7] Alex Kaplun, "Energy Policy: DoD Research Can't Drive Alternative Energy Market, Officials Say," *Environment and Energy Daily*, September 2006.

[8] JASON-The MITRE Corporation, *Reducing DoD Fossil-Fuel Dependence*, September 2006.

[9] Tri-Service POL Users Group Position Statement, *Use of Biodiesel in Tactical Vehicles and Equipment*, March 2006.

- *Low temperature properties*. Biodiesel blends in diesel or JP-8 have poor cold-weather properties, including higher cloud[10] and pour points[11]. This may adversely impact readiness for low-temperature operations.
- *Water affinity*. In the presence of water, acids are formed in biodiesel and biodiesel blends that may lead to increased corrosion and maintenance of fuel systems that contain steel. In addition, biodiesel promotes microbial growth, resulting in fuel system corrosion and fuel filter plugging.
- *Material compatibility*. Biodiesel may react adversely with certain plastics, metals, and elastomers, causing operational failure and increased maintenance requirements.
- *Solvency*. The solvency effect of biodiesel may lead to increased filter requirements.[12]

The POL Users Group concluded that these issues must be addressed before biodiesel can be used in tactical vehicles. Tactical vehicles must be capable of deployment immediately and of performing mission-critical tasks with minimal fuel-related maintenance and related risks. The use of biodiesel in tactical vehicles does not currently meet this requirement and could severely compromise operational readiness.

Other Non-Tactical Applications

Other DoD non-tactical applications that could potentially use biofuels include non-tactical aircraft, non-tactical marine vessels, and non-tactical power and heat generation equipment. DoD does not currently use biofuels in these applications due to operational and storage issues, limited biofuels availability, and DoD policy. The concerns with using biofuels in these non-tactical applications are not expected to be addressed within the time frame of this study. Therefore, the projected use of biofuels in non-tactical aircraft, marine vessels, and power and heat generation equipment is expected to be negligible through FY12.

NON-TACTICAL MARINE VESSELS

Since diesel fuel is used in non-tactical marine vessels, DoD could potentially increase biofuel use by fueling these vessels with biodiesel. However, due to the

[10] *Cloud point* is the temperature at which small solid crystals begin to form in the fuel.

[11] *Pour point* is the temperature at which the fuel in solid form begins to melt or pour. At temperatures below the pour point, the entire fuel system requires heating.

[12] See Note 9, this chapter.

hydrophilic characteristics and storage instability of biodiesel, Navy (and DoD) policy forbids the use of biodiesel in marine applications.[13]

The hydrophilic characteristics of biodiesel may lead to entrained water in the fuel, which may damage engine fuel system components, accelerate fuel storage instability, and affect the fuel's cold weather operating properties.[14] Due to operation in marine environments, most shipboard fuel storage will likely have free water located in the tank bottoms. When biodiesel contacts free water, heavy emulsion layers are formed, which can plug fuel injection nozzles, filters, and damage engine parts. Currently, there are no cleaning methods to remove these heavy emulsion layers effectively. Additionally, high water content will accelerate biodiesel storage instability concerns, which may result in corrosion filter plugging and high temperature deposit formation. Water content also may negatively impact the fuel's cold weather operating properties by increasing the pour point, cloud point, and cold filter plugging point[15].

Other biodiesel characteristics that deter its use in marine applications include lack of a marine biodiesel fuel standard, inconsistent quality, and impact on engine seals.

Due to these marine environment-specific operational and storage issues, DoD does not currently use biodiesel in marine applications. Since DoD does not expect that these concerns will be addressed within the next five years, DoD projects negligible use of biofuels in non-tactical vessels through FY12.

Non-tactical Aircraft

Only two of the biofuels included this study, biobutanol and synthetic hydrocarbon-based fuels, may be used in aircraft. No other known biofuels are currently anticipated to be suitable for aviation in the timeframe specified for this study (through FY12). The high cloud point of biodiesel would cause the fuel to gel and clog the engine as the aircraft climbs and temperatures decrease. As stated in Chapter 10 of this report, biobutanol and synthetic hydrocarbon-based fuels are not expected to be available for use until after FY12.

Non-tactical Power and Heat Generation Equipment

DoD is aware of one biofuel that may be used in power and heat generation equipment: Bioheat® fuel, a blend of pure biodiesel with conventional high or low

[13] Naval Fuels and Lubricants IPT Position Paper, *Use of Biodiesel (B100) and Biodiesel Blends (e.g. B20) Onboard U.S. Naval and MSC Vessels and in USMC Tactical Vehicles and Equipment*, October 27, 2004.

[14] U.S. Coast Guard Assistant Commandant for Engineering and Logistics (CG-4) and U.S. Coast Guard Energy Program (CG-8), *Draft Evaluation Report of A Feasibility Study for the Use of Biodiesel Type Fuels*, March 9, 2007.

[15] *Cold filter plugging point* is the temperature at which the crystallizing or gelling of a fuel will reduce or stop fuel flow through a standard filter under standard test conditions.

sulfur home heating oil.[16] However, due to storage instability issues, poor cold weather operating properties (including pour point), lack of a fuel standard and specification, inconsistent quality, and limited availability, DoD does not currently use biodiesel blends in any of its non-tactical power and heat generation equipment. Further testing is required to determine the effects and advisability of using Bioheat® fuel. DoD does not expect that these concerns will be addressed within the next five years and therefore projects negligible use of biofuels in non-tactical power and heat generation equipment through FY12.

Storage instability is the primary issue limiting DoD's use of Bioheat® fuel. Since non-tactical power and heat generation equipment are used periodically (as the backup supply when there are natural gas supply interruptions) or for emergencies, fuel typically remains in the tank over long durations. These operating conditions are not suitable for use of biodiesel and biodiesel blends, which are susceptible to storage instability. Oxidation and deterioration of the fuel may occur within a matter of days or months, ultimately leading to corrosion, filter plugging, and high temperature deposit formation.

The market for biofuel use as a substitute for conventional high or low sulfur heating oil is still in its infancy. Currently, there is no Commercial Item Description (CID) to facilitate federal purchase of Bioheat® fuel and no ASTM standard for use of biodiesel blends as a heating oil. DoD does not expect that these concerns will be solved within the next five years.

DoD Biofuel Consumption

As discussed in the previous section, NTVs account for almost all of DoD's consumption of biofuels. Table 2-3 shows fuel consumption reported by DoD agencies for their non-tactical, domestic fleet vehicles. This includes the primary biofuels in this study, B20 and E85, as well as gasoline, diesel, and other alternative fuels (CNG, electric, LPG, and LNG). The unit of measure for all the fuels is GGEs, which enables comparison of the usage of fuels with different energy content per gallon.

[16] National Biodiesel Board, *Bioheat® fuel Frequently Asked Questions*, 2007, http://www.biodiesel.org/markets/hom/faqs.asp.

Table 2-3. DoD's Reported Use of Fuels in Domestic NTVs, FY02–06 (Thousands of GGEs and % of Total Fuel)

Year	Biofuels in this study				Petroleum fuels				Other alternative fuels		Total fuel (GGE)
	Biodiesel (B20)		Ethanol (E85)		Gasoline		Diesel				
	GGE	%	GGE	%	GGE	%	GGE	%	GGE	%	
FY02	960	1.1	1,435[a]	1.7	65,672	77.4	15,736	18.5	902	1.1	84,895
FY03	1,566	2.0	200	0.3	61,576	79.8	13,550	17.6	296	0.4	77,188
FY04	5,108	6.4	250	0.3	61,715	77.2	12,401	15.5	487	0.6	79,961
FY05	5,736	6.4	566	0.6	69,424	77.1	13,730	15.2	644	0.7	90,101
FY06	6,060	7.5	836	1.0	61,810	76.1	12,139	14.9	438	0.5	81,239

[a] E85 consumption data in FY02 is greatly overstated, reflecting early difficulties in estimating E85 usage by federal agencies.

Figures 2-3 and 2-4 show DoD's consumption of E85 and B20 in FY02–06, both total fuel consumed and percentage of total fuel used by the NTV fleet. Total biofuel (E85 and B20) consumption increased by 290 percent, from 1,766,000 to 6,896,000 GGEs in FY03–06. As a result, biofuels share of total NTV fuel usage has increased from 2.3 to 8.5 percent over this period.

Figure 2-3. DoD NTV Fleet Consumption of B20 and E85, FY02–06

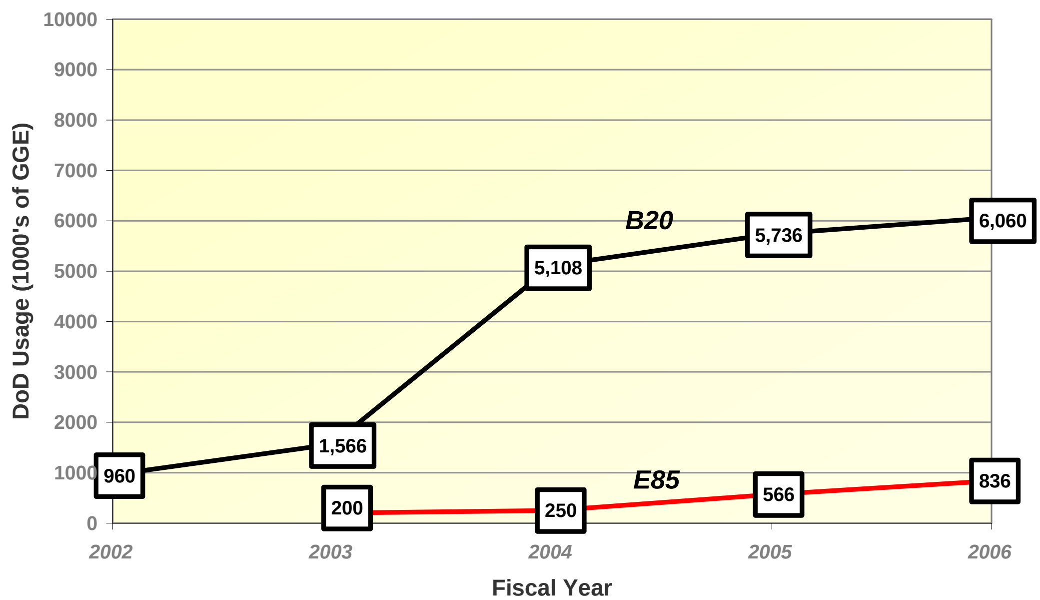
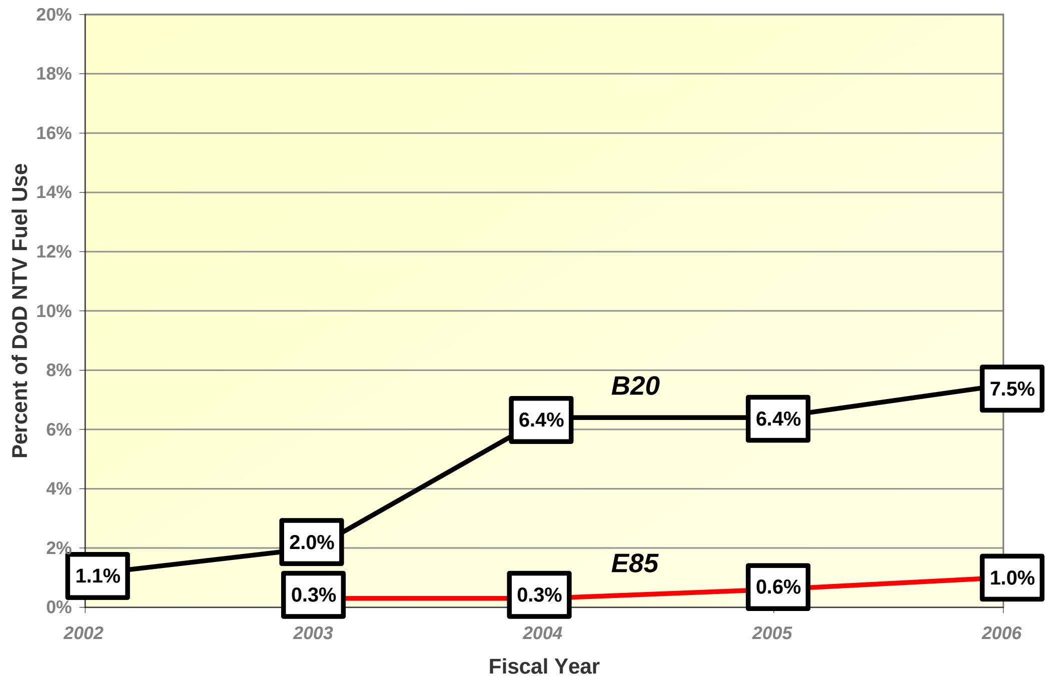


Figure 2-4. DoD Consumption of B20 and E85 as Percentage of Total Fuel Consumed by NTV Fleet, FY02–06



EPAct 1992 and EO 13149 require federal agencies to report the types and amounts of petroleum and alternative fuels used in their fleets of NTVs to Congress each year. This report also contains inventory and acquisition data by vehicle type, as well as other vehicle data. The data is input into the Federal Automotive Statistical System (FAST), and a narrative report explaining the data is submitted to Congress. FAST is the primary source of the data in this section.

Data Quality Issues

Some of the biofuel consumption data reported in FAST are of suspect quality, primarily due to fuel-coding issues for General Services Administration (GSA) and DoD Voyager card transactions at commercial stations. Due to coding limitations of older generation register and computer systems, purchases of E85 and B20 at commercial stations often are coded as gasoline or diesel.

Because DoD consumes most of its fuel at military fueling stations, the overall impact of these data quality issues is not as great as for other agencies. In FY06, roughly 16 percent of DoD's consumption of E85 and 8 percent of B20 were at commercial stations.

LMI analysis of the FY06 GSA and DoD Voyager card raw transaction data suggests that only 18 percent of E85 purchased at commercial stations is correctly coded. Most E85 is coded as gasoline (59 percent) or marine fuel (19 percent). Similarly, many stations incorrectly code gasoline or diesel sales as E85. LMI estimates that 59 percent of E85 transactions (by volume) reported to GSA by commercial stations are actually gasoline or diesel.

Although by volume most B20 transactions (94 percent) are coded correctly, only 4 percent of stations that sell B20 actually code the fuel correctly. Similarly, LMI estimates that 92 percent of commercial stations that report selling B20 do not sell the fuel.

In FY06, GSA began addressing E85 coding issues by reporting all E85 FFV transactions at commercial stations that sell E85 as E85. LMI's analysis of correctly coded fuel transactions suggests that 45 percent of transactions by E85 FFVs represent gasoline rather than E85. Therefore, LMI believes that GSA may be overestimating commercial E85 usage in FY06.

Biofuel Usage Trends

DoD's consumption of biofuels has been increasing steadily over the last 5 fiscal years. Total biofuel (E85 and B20) consumption increased by 290 percent, from 1,766,000 to 6,896,000 GGEs in FY03–06. As a result, biofuels share of total NTV fuel usage has increased from 2.3 to 8.5 percent over this period. (E85 consumption data in FY02 is greatly overstated, reflecting early difficulties in estimating E85 usage by federal agencies, so we do not include those data in this analysis.)

B20 represents a majority of DoD's biofuel usage, ranging between 88 and 95 percent of total biofuel consumption in FY03–06. However, over the last few years, E85 usage has been increasing at a faster rate than B20 consumption. DoD's E85 usage has grown from 5 percent of total biofuels consumption in FY04 to 12 percent in FY06.

DoD has a great opportunity to increase the use of biofuels in the non-tactical fleet. Biofuel use represents only a small percentage of total DoD fuel use: 91 percent of the fuel used in the NTV fleet is gasoline or diesel. In Chapter 3, we discuss use of biofuels in E85 FFVs and diesel vehicles, and current issues limiting biofuel use.

Chapter 3
DoD Biofuel Usage Issues

In this chapter, we discuss the current landscape for DoD's use of biofuels.[1] We evaluate the current composition of the DoD NTV fleet and examine the opportunities for increasing the number of biofuel-capable vehicles.

SUMMARY

Our analysis of DoD's current use of ethanol (as E85) and biodiesel (as B20) in NTVs suggests the following:

- Replacing light- and medium-duty gasoline vehicles provides a significant opportunity for DoD to increase the number of vehicles capable of using biofuel. We estimate that DoD could potentially replace up to 49,658 light-duty gasoline vehicles with E85 FFVs and up to 31,434 medium-duty gasoline vehicles with diesel vehicles.
- Currently, biofuels only represent a small percentage (8.5 percent) of total NTV fuel use.
- DoD's use of E85 in E85 FFVs is relatively low—only 4.4 percent of the fuel used in E85 FFVs is E85 (95.6 percent is gasoline).
- DoD's use of B20 in diesel vehicles (33 percent) is far greater than its use of E85 in E85 FFVs. This is due to the availability and use of B20 at DoD installations and DoD policy encouraging the use of B20 in diesel vehicles.
- Two regulations, EO 13423 and Section 701 of EPAct 2005, will drive DoD's consumption of alternative fuel in FY07–12. EO 13423 requires DoD to increase alternative fuel consumption by 10 percent compounded annually from 2005 levels. Section 701 of EPAct 2005 requires DoD to use 100 percent alternative fuel in AFVs when reasonably available (within a 15-minute drive or within 5 miles).

The primary issues currently limiting the use of biofuels in biofuel-capable vehicles include the following:

- Fleet operator issues, such as their not knowing that the vehicle uses E85, not knowing where commercial biofuel stations are located, not wanting to

[1] Our "current" figures are for FY06.

wait in lines at limited pumps for E85, and purchasing gasoline rather than E85 due to price

- Lack of biofuel infrastructure, at commercial fueling stations, DoD exchanges, and DoD installation fueling sites
- Incremental costs associated with buying E85 FFVs and diesel vehicles as well as purchasing biofuels for use in these vehicles
- Warranty issues and lack of fuel quality standards that reduce the use and availability of B20.

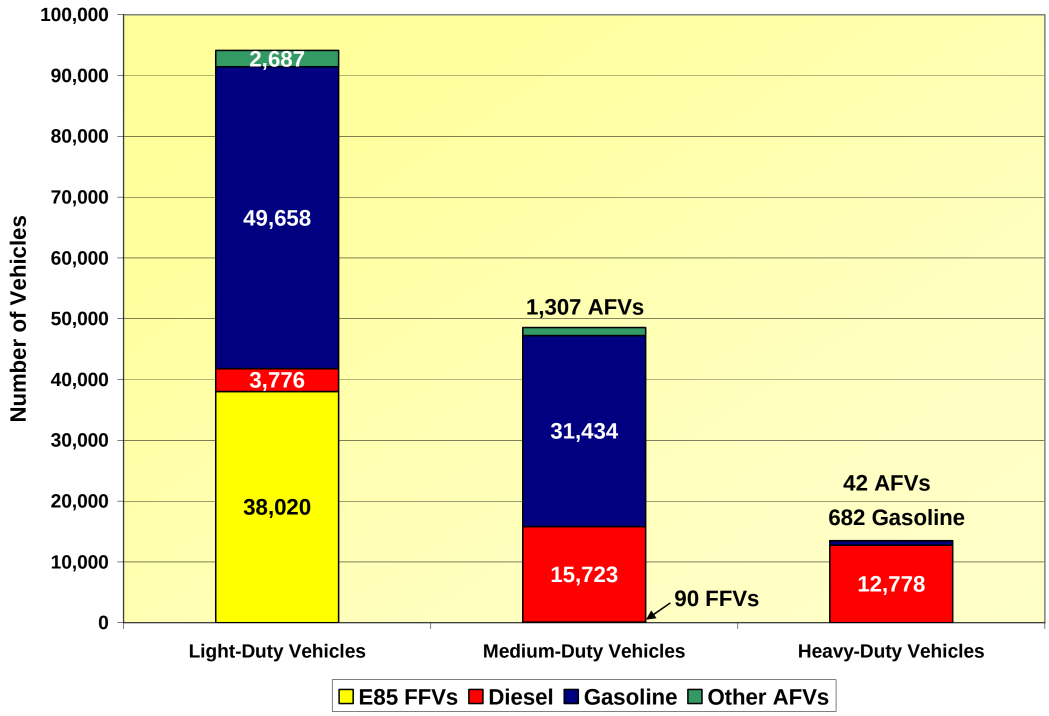
Addressing these limiting factors is critical to DoD's increasing its biofuel consumption in FY07–12.

DoD NTV Fleet Composition

As discussed in Chapter 2, almost all biofuels consumed by DoD are by the NTV fleet. The primary biofuels of this study (E85 and biodiesel) are consumed by E85 FFVs and diesel vehicles. Assuming biofuels are available, one way for DoD to increase its use of biofuels is to add more E85 FFVs and diesel vehicles to the fleet.

EPAct 1992 and EO 13149 requirements (that AFVs represent at least 75 percent of LDV acquisitions) have driven the increase of E85 FFVs in the DoD NTV fleet. As shown in Figure 3-1, the number of light-duty E85 FFVs was 38,020 in FY06, or 24.4 percent of the total fleet. However, the DoD NTV fleet includes only a handful (90) of medium-duty E85 FFVs and no heavy-duty E85 FFVs.

Figure 3-1. DoD-Reported Inventory of NTVs by Vehicle Fuel Type and Size, FY06



On the basis of FY06 data, diesel vehicles constitute 20.7 percent of the NTV fleet, a proportion that has remained relatively constant over the last 5 years: EPAct 1992 and EO 13149 provide incentives for biodiesel use but not for the acquisition of diesel vehicles. Of the 32,277 diesel vehicles in the fleet, most are medium duty (15,723) and heavy duty (12,778). Diesel vehicles represent 32.4 percent of medium-duty vehicles and 94.6 percent of heavy-duty vehicles. The 3,776 light-duty diesel vehicles constitute only 4 percent of DoD LDVs.

Replacing light- and medium-duty gasoline vehicles is an opportunity for DoD to increase the number of vehicles capable of using biofuels. DoD could replace up to 49,658 gasoline vehicles with E85 FFVs in the light-duty segment and up to 31,434 gasoline vehicles with diesel vehicles in the medium-duty segment.

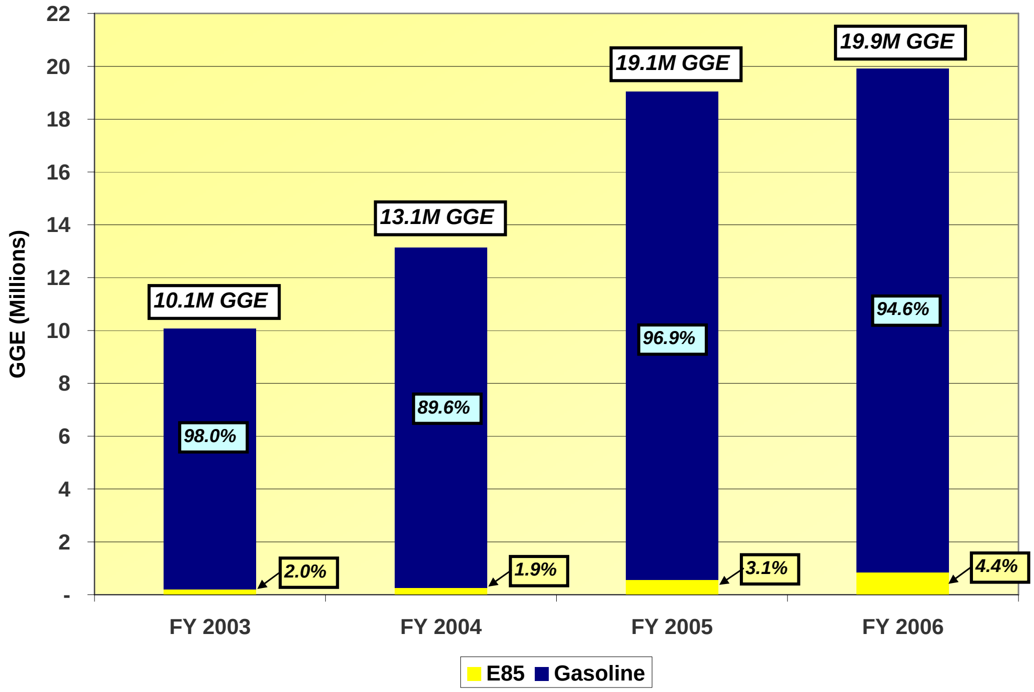
Current Use of Biofuels

In this section, we discuss use of biofuels in DoD NTVs capable of using biofuels. Our analysis focuses on the percentage of E85 and gasoline used in E85 FFVs and the percentages of B20 and diesel used in diesel vehicles in FY06.

E85 Use in E85 FFVs

In FY06, E85 constituted only 4.4 percent of all fuel used in E85 FFVs, almost all of which refuel with gasoline. Over the past 4 fiscal years, DoD's use of E85 in E85 FFVs has increased from 2.0 to 4.4 percent (Figure 3-2).

Figure 3-2. DoD's Use of E85 in E85 FFVs, FY03–06



The primary factors limiting E85 use are as follows:

- *Poor availability of an E85 fueling infrastructure.* As discussed in Chapter 5, the Department of Energy (DOE) estimates that E85 is available at only 1,053 of 168,987 publicly accessible fuel stations.[2] Most are in the Midwest and not where DoD's E85 FFVs are located. Similarly, E85 is only available at a limited number of DoD fueling stations: 1 Army and Air Force Exchange Service (AAFES) gas station, 1 Navy Exchange Service (NEX), and 24 of the 491 DoD installation fueling sites. DoD fleet personnel struggle to find locations to refuel with E85.

- *Lack of operational measures to ensure FFVs use existing E85 infrastructure.* LMI's analysis (detailed in Chapter 7) shows that most DoD E85 FFVs (1) do not use the commercial E85 infrastructure when they are near those stations, or (2) use gasoline in E85 FFVs at stations where E85 is sold. We suspect that operators do not use E85 because they (1) do not know that the vehicle uses E85, (2) do not know the locations of

[2] Energy Information Administration, *A Primer on Gasoline*, May 2007.

E85 stations, (3) do not want to wait in lines at limited pumps for E85, or (4) use gasoline rather than E85 due to price.

B20 Use in Diesel Vehicles

DoD uses B20 in diesel vehicles much more than it uses E85 in E85 FFVs. B20 represents one-third of all fuel used in diesel vehicles—almost eight times the percentage use of E85. As shown in Figure 3-3, DoD's use of B20 in diesel vehicles has increased from 5.8 to 33.3 percent over the past 5 fiscal years.

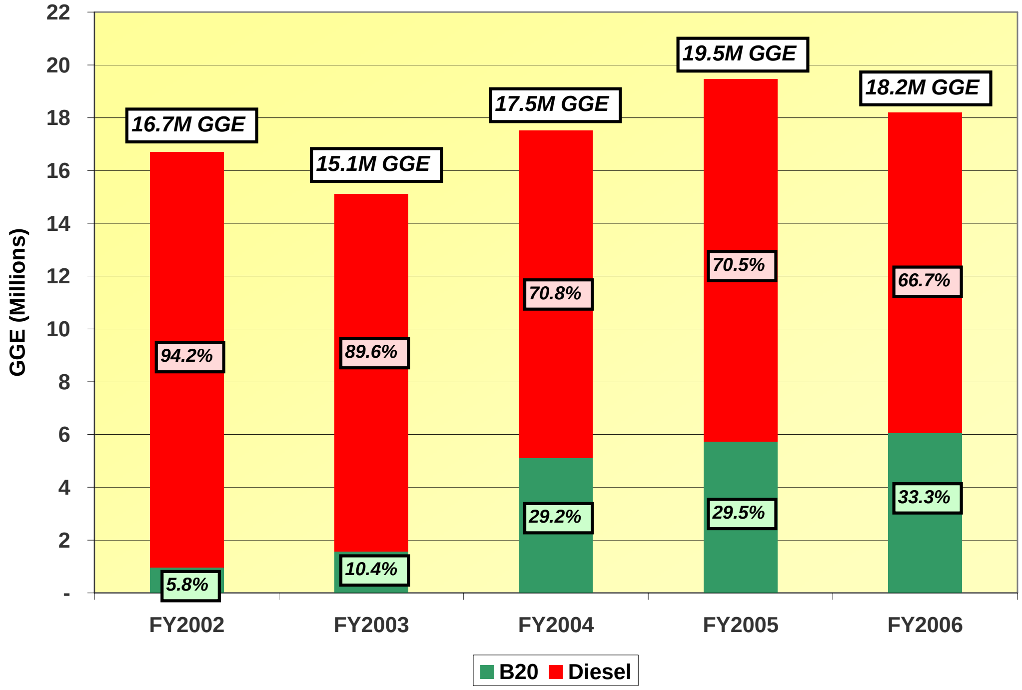
The primary factors driving the use of B20 in diesel vehicles are as follows:

- *High availability and use of B20 at DoD installations.* B20 infrastructure is available at 87 of the 491 DoD installation fueling sites and 6 NEXs. B20 constitutes 22 percent of all diesel fueling (including diesel use in tactical vehicles) at DoD installations.
- *DoD and service policy that mandate or encourage the use of B20 in diesel vehicles.* A Navy memorandum mandated that all non-tactical diesel vehicles "operate on biodiesel fuel (B20) no later than 1 June 2005 where B20 can be supplied by DESC, adequate fuel tanks are available, and the use of biodiesel fuel is allowable."[3] Similarly, a Deputy Under Secretary of Defense memorandum urged fleet managers to "evaluate the use of biodiesel as an option for meeting a portion of your AFV requirements."[4]

[3] Department of the Navy, Office of the Assistant Secretary (Installations and Environment), *Department of the Navy Environmental Policy Memorandum 05-01; Biodiesel Fuel Use in Diesel Engines*, January 18, 2005.

[4] Deputy Under Secretary of Defense (Environmental Security), *Using Biodiesel to Meet Alternative Fueled Vehicle Requirements*, December 14, 1999.

Figure 3-3. DoD Use of B20 in Diesel Vehicles, FY02–06



NTV Acquisition Regulations

In FY07–12, DoD vehicle acquisitions will be driven by three federal regulations designed to promote the purchase of AFVs and use of alternative fuels: EPAct 1992, EO 13423, and EPAct 2005. In Chapter 2, we discuss the requirements of EPAct 1992, which remain in effect. Below, we discuss the other two regulations, EO 13423 and EPAct 2005.

EO 13423

The January 2007 EO 13423, *Strengthening Federal Environmental, Energy, and Transportation Management*, requires federal agencies to take comprehensive measures to improve their environmental performance in a variety of ways, including fleet management. The EO directs every agency operating a fleet of at least 20 motor vehicles to reduce the fleet's total consumption of petroleum products by 2 percent annually through the end of FY15 and increase non-petroleum fuel consumption by 10 percent compounded annually (relative to agency baselines for FY05). The directive also encourages agencies to use "plug-in hybrid (PIH) vehicles when PIH vehicles are commercially available at a cost reasonably comparable, on the basis of life-cycle cost, to non-PIH vehicles."

EO 13423 revokes EO 13149, but continues its goal of reducing petroleum consumption and increasing the use of alternative fuels. The new EO applies to fuel usage in all domestic NTVs, except those used for law enforcement, emergency response, or strictly off-road applications. Under the EO, petroleum fuel includes the 80 percent of B20 that is diesel, but does not include the 15 percent of E85 that is gasoline.

EPAct 2005

Section 701 of EPAct 2005 (Public Law 109-58), "Use of Alternative Fuels by Dual-Fueled Vehicles," requires federal fleets to replace petroleum use with alternative fuels. Under this provision, all dual-fueled vehicles are required to use alternative fuels unless they have received a waiver from DOE. Waivers are granted on the basis of two exemption criteria: an alternative fuel is not reasonably available, or its cost is unreasonably high.

Under EPAct 2005, not reasonably available is defined as "alternative fuel that cannot be obtained within a 15-minute drive or within 5 miles (one way), whichever is greater." If, however, the nearest available alternative fuel station is outside of the "reasonably available" range but is along the normal route of the vehicle, then it is not eligible for the waiver. Unreasonably expensive is defined as "costing at least 15 percent more than gasoline on a gasoline gallon equivalent (GGE) basis."[5]

OPERATOR ISSUES

As discussed, use of biofuels in biofuel-capable vehicles is relatively low. Low usage is the result of both availability (lack of biofuels stations) as well as operator issues (operators not using biofuels when available). Operators often do not use commercial E85 infrastructure when they are near those stations and use gasoline in E85 FFVs at stations where E85 is sold. Below, we discuss many of the operator issues limiting the use of biofuels.

Four primary operator issues limit biofuel use:

- *Not knowing that the vehicle uses E85*. E85 FFVs look like regular gas vehicles; often the only difference is an FFV badge on the rear of the vehicle. Therefore, many operators are unaware that the vehicle they are driving is capable of using E85.

  To address these issues, DoD fleet managers recommend taking measures to ensure that drivers have a clear understanding which vehicles can use E85 and which cannot. Their suggested solutions include the following:

  - Installing yellow gas caps on E85 FFVs

[5] Shabnam Fardanesh, *Guidance: Documentation Requirements for Waiver Requests under EPACT 2005 Section 701*, DOE, March 2007. http://www1.eere.energy.gov/vehiclesandfuels/epact/pdfs/701_guidance.pdf.

- Putting E85 signs on the visor
- Placing E85 decals near the gas cap
- Installing window decals
- Placing information packets and dashboard brochures in E85 FFVs
- Providing yellow VILKEY or Voyager Cards
- Locking out gasoline purchases on VILKEY or Voyager Cards for E85 FFVs.

- *Not knowing where commercial biofuel stations are located.* Due to the limited number of commercial E85 and B20 stations, fleet operators often cannot find E85 or B20 stations for refueling. In addition, these stations are typically farther from current refueling stations—fleet operators often find using these stations inconvenient.

  To address these issues, DoD fleet managers could include E85 and B20 fueling station maps in the E85 FFVs and diesel vehicles. Also, DOE's Alternative Fuels Data Center offers an alternative fueling station locator and route mapper to assist fleet operators in locating nearby commercial biofuel stations (http://www.eere.energy.gov/afdc).

- *Not wanting to wait in lines at limited pumps for E85.* Typically, commercial E85 stations have only a few E85 pumps—far more gasoline pumps are available. As a result, lines often form at the E85 pumps, and fleet operators use the gasoline pumps to save time.

- *Using gasoline rather than E85 due to price.* E85 prices are typically lower than gasoline prices per gallon. However, on an energy content basis (GGE), E85 is typically 27 percent costlier than gasoline. As a result, DoD fleet operators often use gasoline instead of E85 to save the government money.

COST ISSUES

As DoD increases the use of biofuels in its NTV fleet, it incurs additional costs associated with buying E85 FFVs and diesel vehicles as well as incremental costs for using biofuels in these vehicles. However, the current pricing systems for both the acquisition of vehicles and use of biofuels tend to obscure the specific incremental costs of increasing biofuel use. GSA is currently spreading the acquisition cost of AFVs across all vehicles, and GSA fuel payment arrangements (wet leases) reflect total fuel cost rather than incremental biofuel costs. Below, we discuss the potential costs of increasing biofuel use in the NTV fleet. (We discuss costs for supplying biofuels, such as the fueling infrastructure, later in this report.)

Cost of Biofuel-Capable Vehicles

Typically, the acquisition cost of both E85 FFVs and diesel vehicles is greater than that of their gasoline equivalents. Understanding how much more it costs to buy an E85 FFV or a diesel vehicle is necessary so that adequate funding is provided for DoD to meet its EPAct requirements.

E85 Vehicles

E85 FFVs are the most common type of AFV, widely available through both GSA and commercial vehicle dealers. These vehicles are able to run on any blend of gasoline and up to 85 percent ethanol. To allow for this flexibility, the E85 FFVs are equipped with fuel sensors to determine the alcohol content of the fuel and adjust the timing of the spark plugs and fuel injectors to optimize combustion in the engine. The addition of these sensors and the smaller production runs of FFVs increase their cost to the consumer.

The majority (93 percent) of E85 FFVs in the DoD NTV fleet are leased from GSA. All agencies that lease vehicles through GSA are charged a monthly fee per vehicle, plus an additional rate based on mileage. GSA calculates that the average incremental cost per AFV over the last 3 years is $1,166.[6] EPAct 2005 required GSA to surcharge all customer agencies to recover AFV incremental costs. Agencies are charged on the basis of the cost to replace 75 percent of the agencies' acquisitions with AFVs; the cost is spread evenly across all GSA leased vehicles. In FY06, the average surcharge per vehicle was approximately $180. GSA's fleet surcharge policy hides the incremental cost to DoD—roughly $10.4 million per year—to acquire E85 FFVs.[7]

Acquiring E85 FFVs may also generate incremental costs to DoD due to limitations in E85 FFV availability. Currently, automobile manufacturers do not offer a four-cylinder E85 FFV. Therefore, federal agencies, including DoD, often purchase larger and more expensive six-cylinder E85 FFV models to meet AFV acquisition requirements.

Diesel Vehicles

Diesel engines produce more torque than gasoline, and they achieve higher fuel efficiency for medium- and heavy-duty applications, such as moving heavy loads. Diesel engines operate at higher compression ratios than gasoline and as a result are built to be more robust and durable. This means that diesel models have historically been more expensive than their gasoline counterparts, but also can remain in operation longer.

[6] General Services Administration, *FY07 AFV Surcharge Fact Sheet*, 2007.

[7] Based on LMI's analysis of actual DoD FY06 acquisition of E85 FFVs and GSA surcharges.

In 2006–07, environmental controls on diesel technology were significantly tightened. In 2006, all diesel distributors were required to switch from low sulfur diesel (LSD), which contains 500 parts per million (ppm) sulfur to ultra-low sulfur diesel (ULSD), which contains 15 ppm sulfur. In 2007, all diesel vehicles were required to have new exhaust control systems that drastically decrease the particulate exhaust from the engine. These requirements will make diesel vehicles even more expensive than their gasoline equivalents in FY07–12.

Unlike E85 FFVs, diesel vehicles are not considered AFVs by GSA, so the incremental cost of buying a diesel is not spread across all of an agency's vehicles. GSA has already warned that in 2007 the cost of leasing a diesel vehicle will increase greatly. Therefore, DoD may incur high incremental costs for increasing the composition of diesel vehicles in the NTV fleet.

Cost of Using Biofuel

In addition to the increased cost of acquiring vehicles capable of using biofuels, the cost of biofuel itself may be higher than that of gasoline or diesel. Tables 3-1 and 3-2 compare the cost per GGE of E85 and B20 to gasoline and diesel, respectively.

Table 3-1. Comparison of Current Cost per GGE of E85 to Gasoline

Category	E85	Gasoline
GGE/gallon	0.72	1.00
Retail price (per gallon)	$2.10	$2.30
Retail price (per GGE)	$2.92	$2.30

Source: DOE, EERE, *Clean Cities Alternative Fuel Price Report*, March 2007.

Table 3-2. Comparison of Current Cost per GGE of B20 to Diesel

Category	B20	Diesel
GGE/Gallon	1.126	1.147
Retail price (per Gallon)	$2.53	$2.63
Retail price (per GGE)	$2.25	$2.29

Source: DOE, EERE, *Clean Cities Alternative Fuel Price Report*, March 2007.

E85 Costs

A gallon of E85 contains 28 percent less energy than a gallon of gasoline, but the average retail price of E85 is only 9 percent less than that of gasoline. This means that every gallon of E85 purchased costs an additional $0.62. At DoD's current use of E85 (836,000 GGE in FY06), this amounts to over $510,000 in additional fuel costs. These costs will increase as DoD increases its use of E85.

B20 Costs

B20 has slightly lower energy content than traditional diesel (98.2 percent), but it also sells at a lower retail price. Overall, B20 is less expensive than diesel on a energy content basis. Increasing B20 use may reduce DoD fuel costs slightly.

B20 Issues

B20 Fuel Quality Standards

In the United States, the ASTM establishes fuel quality standards for diesel and biodiesel. In December 2001, the current specification for biodiesel (ASTM D 6751-06) was approved. This fuel standard applies to biodiesel used for blending with diesel up to 20 percent (B20 and lower). However, this ASTM standard only applies to pure biodiesel: there is no standard for the B20 already blended.

The federal government currently uses specification A-A-59693A for purchasing B20. DESC adds a requirement (not included in the base A-A-59693A specification) that the B20 be produced from "virgin vegetable oil blend stock and/or yellow grease blend stock conforming to the requirements of ASTM D 6751." Also, the No. 2-D or 1-D diesel fuel in the B20 must conform to ASTM D 975 or to specification A-A-52557. The DESC excludes B20 produced from animal fats due to instability and other issues.

The lack of an ASTM standard for B20 limits the availability of B20 that meets DoD quality requirements. Within the next few years, this issue is expected to be addressed: ASTM expects to complete a "blend" specification for B5 and B20 by the end of 2007.

Warranty Issues

Fleet operators may be concerned over the warranty impacts of using biodiesel in their diesel vehicles. Most engine and vehicle manufacturers will not cover damage caused by an external condition, such as the quality of the fuel used in the vehicle. However, the National Biodiesel Board explains, "If an engine that uses biodiesel experiences a failure unrelated to the biodiesel use, it must be covered by the Original Equipment Manufacturer's (OEM's) warranty. Federal law (The Magnuson Moss Act), prohibits the voiding of a warranty just because biodiesel was used—it has to be the cause of the failure."

Most major engine manufacturers have formally issued statements that using biodiesel blends up to 20 percent (B20) will not void warranties. Some manufacturers have also said that biodiesel blends must meet ASTM D-6751. The National

Biodiesel Board expects all diesel engine manufacturers to require biodiesel used in the engine to meet the ASTM biodiesel standard.[8]

[8] National Biodiesel Board, *Standards and Warranties*, 2007, http://www.biodiesel.org/resources/fuelfactsheets/standards_and_warranties.shtm.

Chapter 4
Projected DoD Demand for Biofuels

The potential demand for biofuels by DoD in FY07–12 depends on the number of NTVs capable of using biofuels in the fleet, the availability of biofuels at the locations of these NTVs, and the use of available biofuels by these vehicles.

We evaluated three potential scenarios to project the future composition of biofuel-capable vehicles in the DoD fleet. These scenarios include

- current acquisition trends driven by EPAct requirements,
- optimized (maximum potential) acquisition of biofuel-capable vehicles within vehicle model, and
- optimized acquisition of biofuel-capable vehicles within vehicle class.

After projecting the composition of the DoD NTV fleet for each fleet scenario, we then projected the potential consumption of biofuels in those vehicles through FY12. We show biofuel consumption estimates as a range, from a minimum regulatory required level to 100 percent biofuel use.

SUMMARY

In FY07–12, three primary mechanisms will drive increased DoD use of biofuels:

- More biofuel-capable vehicles in the DoD NTV fleet
- More biofuel available at the vehicle locations
- More use of biofuels by the vehicles.

Our projections for the composition of the DoD NTV fleet under the three acquisition scenarios are as follows:

- The percentage of the DoD fleet that is capable of using biofuels will increase from 45.1 percent in FY06 to between 46.2 and 65.1 percent by FY12.
- Under the current (minimum) vehicle acquisition trends, E85 FFV and diesel NTV acquisition have reached "steady state" equilibrium—the percentage of biofuel-capable vehicles acquired is nearly equal to the percentage already in the fleet inventory. Therefore, we do not project major fleet composition changes through FY12 if current fleet acquisition trends continue.

- With more aggressive DoD acquisition of E85 FFVs and diesel vehicles, we project E85 FFVs would increase from 24.4 percent in FY06 to between 32.2 and 41.6 percent by FY12. The composition of diesel vehicles, however, is not expected to change significantly—from the current 20.7 percent of the fleet, diesel vehicles are projected to range from 20.1 to 23.5 percent in FY12.

- We estimate that the incremental cost of acquiring biofuel-capable vehicles instead of the equivalent gasoline models will generate an incremental cost of between $12.2 million and $18.0 million per year.

From these NTV fleet projections, we estimate that DoD's potential demand for biofuels in FY12 will range from 1.79 million GGEs of E85 and 10.20 million GGEs of B20 (minimum regulatory requirements) to 33.96 million GGEs of E85 and 20.75 million GGEs for B20 (100 percent use in the NTV fleet). These projections are for DoD demand, that is, the amount of biofuels DoD could use if there were no supply or availability issues.

The wide range for our projections of DoD's potential demand for biofuels in FY07–12 results from unknown biofuel use rates and the three different vehicle acquisition scenarios. DoD's actual consumption of biofuels over this period will primarily depend on commercial biofuel availability, commercial and DoD biofuel infrastructure, and the subsequent use in DoD biofuel-capable NTVs.

Projected Fleet Composition

We projected the composition of biofuel-capable vehicles in the DoD NTV fleet in FY07–12 under three different acquisition scenarios. By varying the composition of vehicles acquired each year, our projections reflect a potential range of biofuel-capable vehicles in the NTV fleet. The three scenarios are based on DoD's current NTV acquisition characteristics (vehicle types, classes, and numbers). They differ in the percentage of E85 FFVs and diesel vehicles acquired each year, ranging from the minimum EPAct requirements to the maximum number of biofuel-capable vehicles that can be acquired within each vehicle class.

The three acquisition scenarios are as follows:

- *EPAct acquisition.* This scenario uses the composition of vehicles (including biofuel-capable vehicles) in DoD's most recent fiscal year's NTV fleet acquisition (FY06). Since current NTV acquisition policy is driven by meeting EPAct requirements, this represents the "minimum" scenario for the projection of biofuel-capable NTVs in the DoD fleet.

- *Optimized acquisition by vehicle model.* We adjusted DoD's NTV fleet acquisition in the most recent fiscal year (FY06) by replacing planned gasoline vehicle acquisitions with E85 FFVs if available for that *specific model*. In addition, we replaced gasoline vehicles within each model type with diesel vehicles, if available. Due to availability and cost of diesel engines, we conservatively limited the replacement of gasoline vehicles with diesel vehicles to 25 percent. This represents the “middle” scenario in the analysis.

- *Optimized acquisition by vehicle federal standard identification number (SIN).* We further adjusted DoD’s NTV fleet acquisition in FY06 by replacing planned gasoline vehicle acquisitions with E85 FFVs if available for that *specific vehicle class or federal SIN.*[1] In addition, we replaced 50 percent of gasoline vehicles within each model type with diesel vehicles, if available. This scenario represents the “maximum” scenario for the projection of biofuel-capable NTVs in the DoD fleet.

We used FY06 acquisition data to predict future DoD NTV acquisitions because they are driven by current purchasing policy and vehicle availability. These acquisition data also reflect DoD fleet managers’ best estimate of projections for new vehicle acquisitions. Future vehicle availability is based on GSA’s list of available alternative vehicles in FY07–08, augmented by information provided by American auto manufacturers (GM, Ford, and Chrysler).

Current Fleet

Table 4-1 shows the current (FY06) DoD inventory of NTVs by fuel type (including E85 FFVs and diesel vehicles) and vehicle size (light, medium, and heavy duty). Currently, 45.1 percent of the NTV fleet is capable of using biofuel. Most of these vehicles are light-duty E85 FFVs, which constitute 24.3 percent of the DoD NTV fleet and 40.4 percent of LDVs. Diesel vehicles constitute 20.7 percent of the NTV fleet, 32.4 percent of medium-duty vehicles, and 94.6 percent of heavy-duty vehicles. These diesel vehicles are capable of using B20 without engine modification.

[1] SINs are specific descriptions of a vehicle’s features (for example, item 10B represents a five-passenger, four-door, midsize passenger sedan with a six-cylinder, 2.7-liter engine.) For a given SIN, often only one manufacturer makes a biofuel-capable model available through GSA. For example, of the three 10B models—Dodge Charger, Ford Taurus, and Chevy Impala—only the Impala is available with an E85 compatible engine.

Table 4-1. Inventory of DoD NTVs by Fuel Type and Size, FY06

Vehicle type	Total inventory	E85 FFVs		Diesel vehicles		Biofuel-capable vehicles	
		Inventory	% of Inventory	Inventory	% of Inventory	Inventory	% of Inventory
LDVs							
Sedan, compact	30,573	19,398	63.4	75	0.2	19,473	63.6
Passenger minivan	12,826	7,167	55.9	5	0.0	7,172	55.9
LD pickup 4×2	21,264	6,175	29.0	136	0.6	6,311	29.6
LD pickup 4×4	7,991	1,347	16.9	2,626	32.9	3,973	49.7
SUV 4×4	7,663	2,080	27.1	860	11.2	2,940	38.4
Sedan, midsize	3,735	997	26.7	1	0.0	998	26.7
Passenger van	5,011	387	7.7	8	0.2	395	7.9
SUV 4×2	825	271	32.8	15	1.8	286	34.7
Cargo minivan	826	167	20.2	1	0.1	168	20.3
Cargo van	2,270	11	0.5	28	1.2	39	1.7
Other light duty	169	1	0.6	19	11.2	20	11.8
Sedan, subcompct	623	18	2.9	1	0.2	19	3.0
Sedan, large	291	1	0.3	0	0.0	1	0.3
Limousine	74	0	0.0	1	1.4	1	1.4
Subtotal	94,141	38,020	40.4	3,776	4.0	41,796	44.4
Medium-duty vehicles							
MD pickup	15,878	30	0.2	5,998	37.8	6,028	38.0
Bus	3,987	0	0.0	3,853	96.6	3,853	96.6
Cargo van	8,016	0	0.0	2,473	30.9	2,473	30.9
Other MD	10,221	35	0.3	1,966	19.2	2,001	19.6
Ambulance	791	0	0.0	771	97.5	771	97.5
MD emergency	436	0	0.0	306	70.2	306	70.2
MD SUV	1,159	24	2.1	193	16.7	217	18.7
Passenger van	8,066	1	0.0	163	2.0	164	2.0
Subtotal	48,554	90	0.2	15,723	32.4	15,813	32.6
Heavy-duty vehicles							
HD emergency	11,548	0	0.0	10,854	94.0	10,854	94.0
Other HD	1,954	0	0.0	1,924	98.5	1,924	98.5
Subtotal	13,502	0	0.0	12,778	94.6	12,778	94.6
Total	156,197	38,110	24.4	32,277	20.7	70,387	45.1

Acquisition Scenarios

Each year, DoD acquires roughly 25,000 vehicles through GSA lease, DoD lease, or ownership. Most vehicle acquisitions are to replace GSA-leased vehicles, which generally are leased for 3-year terms. Tables 4-2 and 4-3 show, for each acquisition scenario, the annual acquisition breakdown for E85 FFVs and diesel vehicles, respectively. Although almost half of the current NTV fleet is capable of using biofuel, we forecast that the percentage composition of biofuel-capable vehicles in the DoD NTV fleet will remain close to current levels or grow through FY12, regardless of acquisition scenario. This is primarily driven by the acquisition composition of E85 FFVs, which remain close to or exceed the current percentage acquisition under all scenarios.

Table 4-2. Acquisition of E85 FFVs by Acquisition Scenario, FY07–12

Vehicle type	E85 FFVs (total acquisitions)			Percentage of total acquisitions		
	Minimum (EPAct)	Middle (optimized by model)	Maximum (optimized by SIN)	Minimum (EPAct)	Middle (optimized by model)	Maximum (optimized by SIN)
LDVs						
Sedan, compact	4,743	4,743	7,561	62.7	62.7	100
Passenger minivan	1,636	1,636	2,383	67.6	67.6	98.4
LD pickup 4×2	1,196	1,814	1,895	44.8	70.3	71.0
LD pickup 4×4	575	1,277	1,420	39.7	88.7	97.9
SUV 4×4	389	450	899	35.3	40.8	81.6
Sedan, midsize	427	685	685	34.4	55.1	55.1
Passenger van	3	3	3	0.5	0.5	0.5
SUV 4×2	64	79	111	44.4	54.5	76.6
Cargo minivan	84	108	108	77.8	100	100
Cargo van	15	172	192	7.8	89.1	100
Other light duty	0	0	0	0.0	0.0	0.0
Sedan, subcompct	0	0	0	0.0	0.0	0.0
Sedan, large	0	0	0	0.0	0.0	0.0
Limousine	0	0	0	0.0	0.0	0.0
Subtotal	9,132	10,967	15,257	51.4	62.0	85.8
Medium-duty vehicles						
MD pickup	20	100	181	1.1	5.3	9.5
Bus	0	0	0	0.0	0.0	0.0
Cargo van	0	0	0	0.0	0.0	0.0
Other MD	19	523	558	1.6	43.0	45.8
Ambulance	0	0	0	0.0	0.0	0.0
MD emergency	0	8	8	0.0	44.4	44.4
MD SUV	0	0	0	0.0	0.0	0.0
Passenger van	0	0	0	0.0	0.0	0.0
Subtotal	39	631	747	0.7	10.9	12.9
Heavy-duty vehicles						
HD emergency	0	0	0	0.0	0.0	0.0
Other HD	0	0	0	0.0	0.0	0.0
Subtotal	0	0	0	0.0	0.0	0.0
Total	9,171	11,598	16,004	37.4	47.4	65.2

Table 4-3. Acquisition of Diesel NTVs by Acquisition Scenario, FY07–12

Vehicle type	Diesel NTVs (total acquisitions)			Percentage of total acquisitions		
	Minimum (EPAct)	Middle (optimized by model)	Maximum (optimized by SIN)	Minimum (EPAct)	Middle (optimized by model)	Maximum (optimized by SIN)
LDVs						
Sedan, compact	0	0	0	0.0	0.0	0.0
Passenger minivan	0	0	0	0.0	0.0	0.0
LD pickup 4×2	0	0	0	0.0	0.0	0.0
LD pickup 4×4	0	0	0	0.0	0.0	0.0
SUV 4×4	0	0	0	0.0	0.0	0.0
Sedan, midsize	0	2	274	0.0	0.2	22.0
Passenger van	0	0	0	0.0	0.0	0.0
SUV 4×2	0	0	0	0.0	0.0	0.0
Cargo minivan	0	0	0	0.0	0.0	0.0
Cargo van	0	0	0	0.0	0.0	0.0
Other light duty	6	15	15	40	100	100
Sedan, subcompct	0	0	0	0.0	0.0	0.0
Sedan, large	0	0	0	0.0	0.0	0.0
Limousine	1	6	6	1.5	9.1	9.1
Subtotal	7	23	295	0.04	0.1	1.7
Medium-duty vehicles						
MD pickup	509	509	873	26.8	26.8	45.9
Bus	312	382	382	81.7	100	100
Cargo van	63	78	213	10.0	12.3	33.6
Other MD	162	173	263	13.3	14.2	21.6
Ambulance	104	106	106	96.3	97.2	97.2
MD emergency	3	3	4	17.6	17.6	22.2
MD SUV	0	0	0	0.0	0.0	0.0
Passenger van	9	195	684	0.7	14.3	50.3
Subtotal	1,162	1,446	2,525	20.0	24.9	43.4
Heavy-duty vehicles						
HD emergency	46	46	46	97.9	97.9	97.9
Other HD	817	888	891	90.1	97.8	98.1
Subtotal	863	934	937	90.6	97.8	98.1
Total	2,032	2,403	3,757	8.3	9.8	15.3

Projections under Each Scenario

Using the three acquisition scenarios, we projected the composition of the overall DoD NTV fleet in FY07–12. The projections were developed using an iterative algorithm, each year replacing a portion of the fleet with the acquisition set. A key assumption in these projections is that the number of vehicles acquired each year will remain constant; this assumption is consistent with DoD's NTV acquisitions over the last 5 fiscal years.

Figures 4-1 through 4-4 present the projected composition of the DoD NTV for E85 FFVs, diesel vehicles, gasoline vehicles, and other AFVs, respectively. Our analysis shows that under the current acquisition scenario (EPAct), the E85 FFV and diesel NTV acquisition trends have reached steady-state equilibrium: the percentage of biofuel-capable vehicles acquired is nearly equal to the percentage in the existing fleet inventory. Therefore, under the EPAct scenario, we do not project major fleet composition changes through FY12.

For the other acquisition scenarios, we project E85 FFVs to increase from 24.4 percent in FY06 to between 32.2 and 41.6 percent by FY12. The composition of diesel vehicles, however, is not expected to change significantly: from the current 20.7 percent of the fleet, diesel vehicles are projected in FY12 to range from 20.1 to 23.5 percent of the DoD NTV fleet.

Currently, 45.1 percent of the DoD fleet is capable of using biofuel. We project that this percentage will increase under all three scenarios. Biofuel-capable vehicles are projected to constitute between 46.2 and 65.1 percent by FY12.

The increased percentage of E85 FFVs and diesel NTVs in the DoD fleet by FY12 will replace gasoline and other AFVs. We project gasoline vehicles to decrease from the current 52.4 percent of the fleet to between 33.6 and 52.1 percent in FY12. Similarly, other AFVs will continue trending downward to constitute between 1.2 and 1.6 percent of the fleet in FY12.

Figure 4-1. Projections of E85 FFVs by Acquisition Scenario, FY07–12

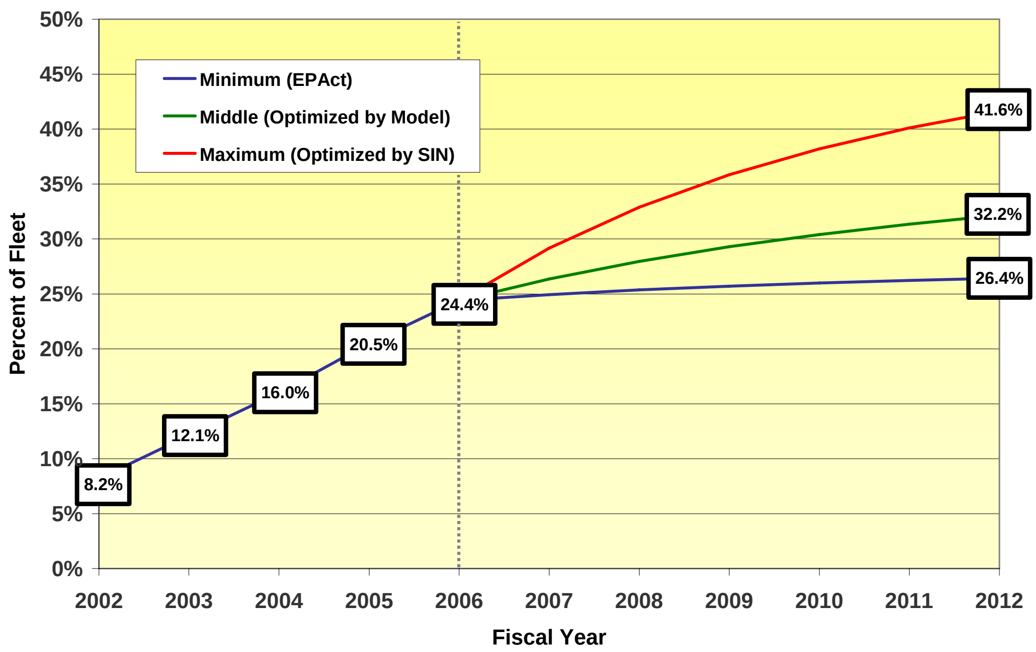


Figure 4-2. Projections of Diesel NTVs by Acquisition Scenario, FY07–12

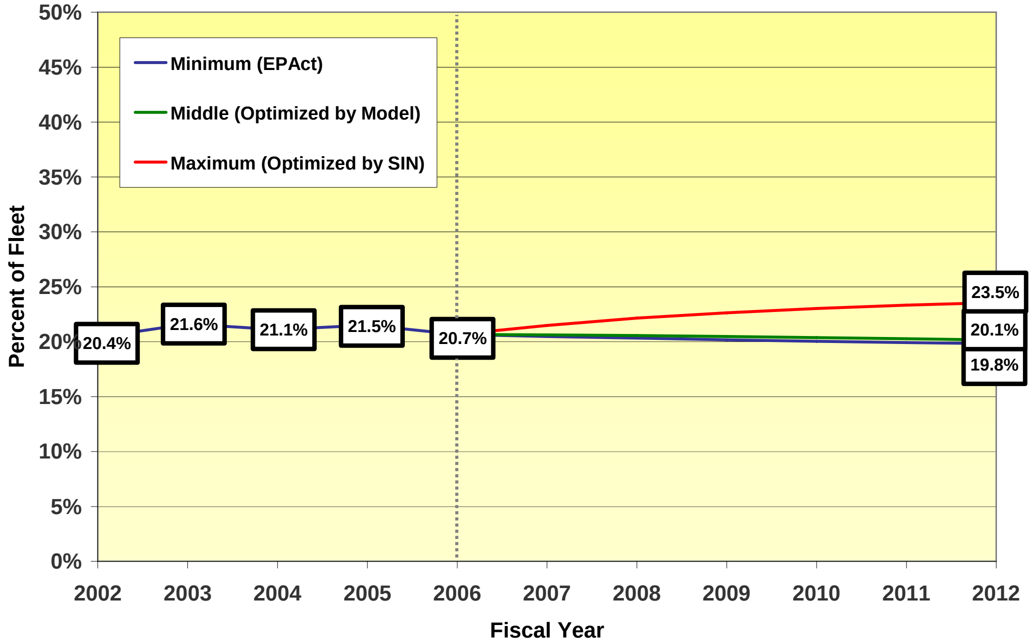


Figure 4-3. Projections of Gasoline NTVs by Acquisition Scenario, FY07–12

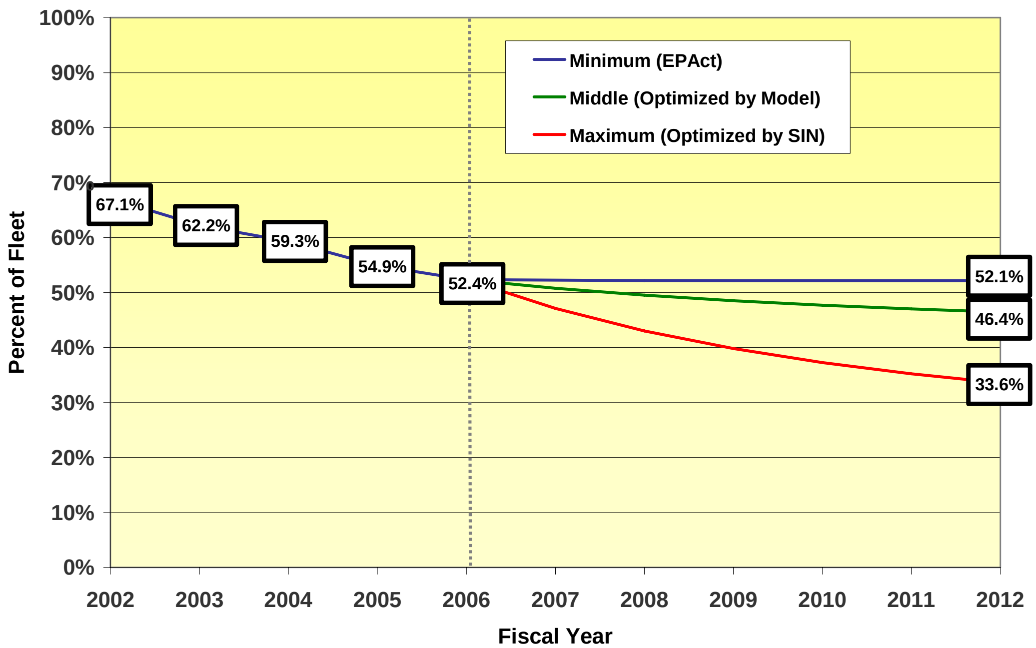
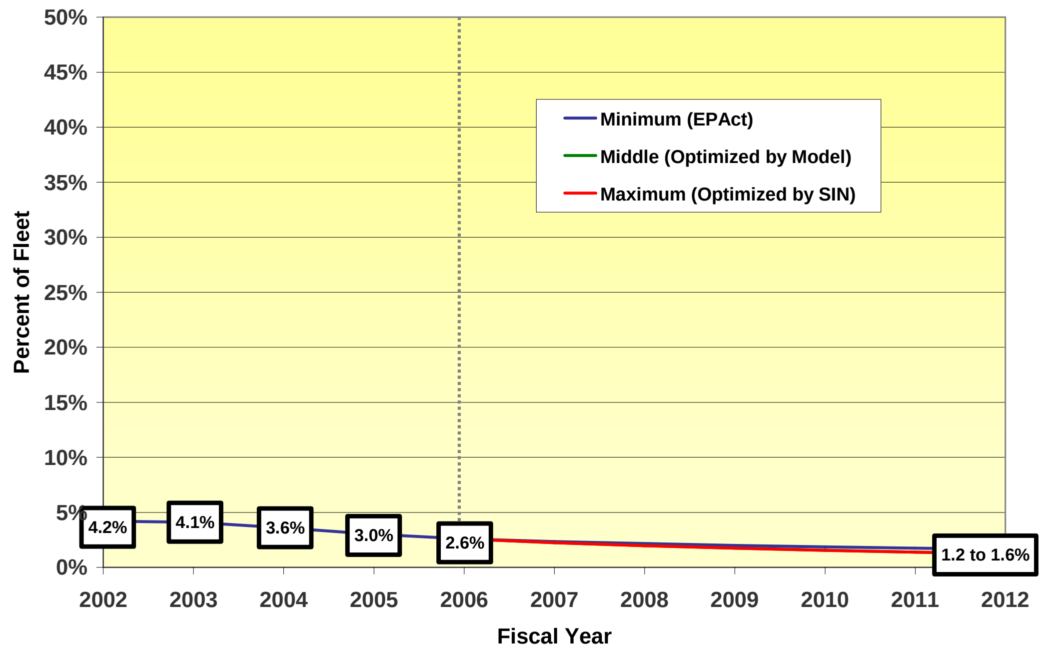


Figure 4-4. Projections of Other AFVs by Acquisition Scenario, FY07–12



SCENARIO COSTS

As explained in Chapter 3, E85 FFVs and diesel vehicles are typically more expensive to acquire than gasoline vehicles. Therefore, an increase in the percentage of biofuel-capable vehicles in the NTV fleet will generate additional costs for DoD.

As shown in Table 4-4, under the minimum scenario (current acquisition plans), we estimate that the incremental cost of acquiring biofuel-capable vehicles instead of the equivalent gasoline models will generate an incremental cost of $12,160,000 per year to DoD. The incremental vehicle acquisition cost is higher for the more aggressive acquisition scenarios. For the middle scenario, the incremental cost is $14,220,000 per year (17 percent higher than the minimum scenario), and for the maximum scenario, the incremental cost is $17,970,000 per year (48 percent higher than the minimum scenario).

Table 4-4. Annual Incremental Costs to DoD for Acquisition of Biofuel-Capable Vehicles by Acquisition Scenario, FY07–12

Scenario	Annual incremental cost ($)	Percentage increase from minimum scenario
Minimum (EPAct)	12,160,000	—
Middle (optimized by Model)	14,220,000	17
Middle (optimized by SIN)	17,970,000	48

PROJECTED DoD BIOFUEL DEMAND

In this section, we project DoD biofuel demand in FY07–12. These estimates range from a minimum regulatory-driven level (mandated under EO 13423 and EPAct) to a maximum 100 percent use of biofuels by all biofuel-capable vehicles. (These projections are for DoD demand, meaning the amount of biofuels DoD could use if supply or availability were not issues.)

Similar to the fleet projection scenarios, we used alternative fuel-use scenarios to project the range of potential demand for biofuels by DoD NTVs through FY12. From now until FY15, DoD must comply with the fuel-use requirements of EO 13423, increasing its alternative fuel use 10 percent each year compounded annually and decreasing "subject" petroleum use by 2 percent each year from 2005 baseline levels. As of August 2007, DOE established DoD's petroleum reduction baseline as 79.35 million GGEs and its alternative fuel baseline as 2.32 million GGE.

Figures 4-5 and 4-6 (and Tables 4-5 and 4-6) show DoD's projected demand for E85 and B20, respectively. To comply with EO 13423, DoD will, at a minimum, need to increase the use rate of E85 in its E85 FFVs from 4.2 percent to an estimated 7.4 to 8.3 percent (depending on acquisition scenario) by FY12. Similarly, it will need to increase B20 use from 33 to 58 percent.

Figure 4-5. Projected DoD Demand for E85 by Acquisition Scenario for Varying Use Rates, FY12

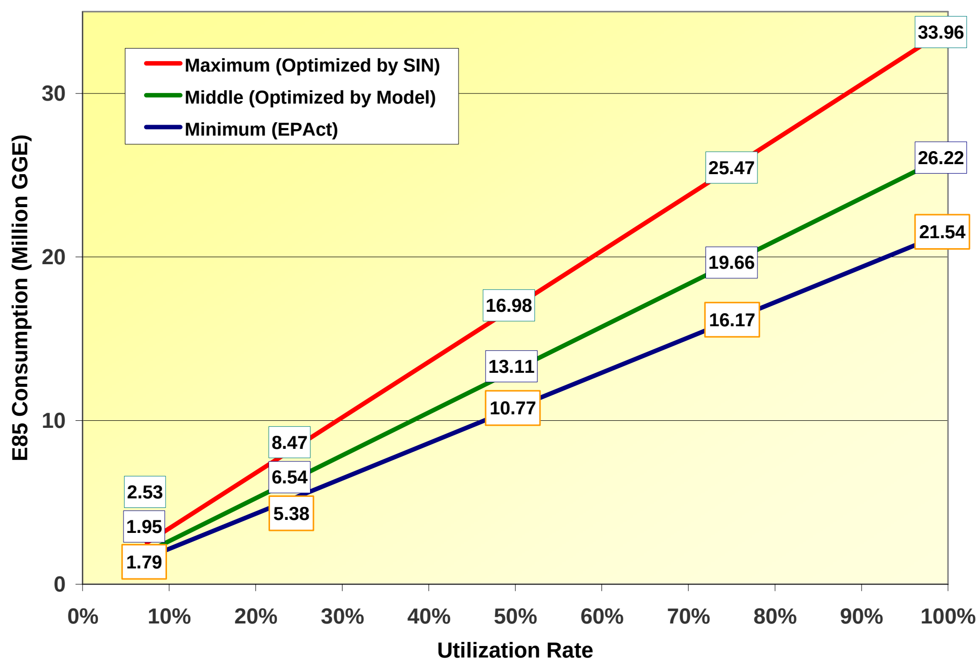


Figure 4-6. Projected DoD Demand for B20 by Acquisition Scenario for Varying Use Rates, FY12

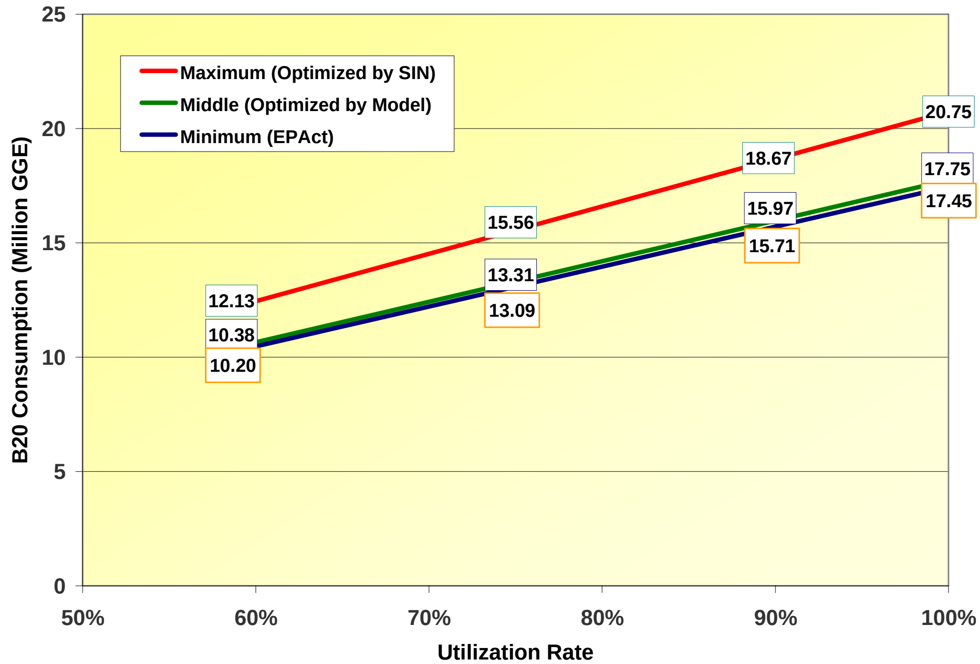


Table 4-5. Projected DoD Demand for E85 by Acquisition Scenario for Varying Use Rates, FY07–12 (Million GGEs)

FY	FY12 use rate (%)					
	7.4	8.3	25	50	75	100
Minimum acquisition scenario (EPAct)						
2007	0.96	—	1.15	1.29	1.38	1.45
2008	1.09	—	1.57	1.98	1.61	2.51
2009	1.24	—	2.15	3.04	3.72	4.34
2010	1.40	—	2.92	4.64	6.08	7.46
2011	1.58	—	3.97	7.07	9.92	12.82
2012	1.79	—	5.38	10.77	16.17	21.54
Middle acquisition scenario (optimized by Model)						
2007	—	0.99	1.21	1.36	1.46	1.53
2008	—	1.16	1.73	2.19	2.50	2.76
2009	—	1.33	2.44	3.46	4.24	4.90
2010	—	1.52	3.41	5.43	7.11	8.64
2011	—	1.73	4.74	8.45	11.85	15.13
2012	—	1.95	6.54	13.11	19.66	26.22
Maximum acquisition scenario (optimized by SIN)						
2007	—	1.10	1.34	1.51	1.61	1.69
2008	—	1.36	2.04	2.57	2.94	3.24
2009	—	1.63	2.99	4.23	5.19	6.00
2010	—	1.91	4.29	6.82	8.94	10.86
2011	—	2.21	6.06	10.82	15.17	19.35
2012	—	2.53	8.47	16.98	25.47	33.96

Table 4-6. Projected DoD Demand for B20 by Acquisition Scenario for Varying Use Rates, FY07–12 (Million GGEs)

FY	FY12 use rate (%)			
	58.5	75	90	100
Minimum acquisition scenario (EPAct)				
2007	6.55	6.83	7.04	7.17
2008	7.15	7.76	7.35	8.56
2009	7.80	8.84	9.68	10.23
2010	8.53	10.07	11.37	12.24
2011	9.33	11.47	13.36	14.64
2012	10.20	13.09	15.71	17.45
Middle acquisition scenario (optimized by Model)				
2007	6.60	6.87	7.09	7.21
2008	7.23	7.86	8.35	8.65
2009	7.92	8.97	9.83	10.36
2010	8.67	10.24	11.56	12.40
2011	9.49	11.67	13.59	14.84
2012	10.38	13.31	15.97	17.75
Maximum acquisition scenario (optimized by SIN)				
2007	6.87	7.16	7.38	7.52
2008	7.79	8.46	8.99	9.31
2009	8.76	9.92	10.87	11.46
2010	9.80	11.57	13.06	14.02
2011	10.92	13.44	15.64	17.08
2012	12.13	15.56	18.67	20.75

DoD's maximum biofuel demand (that is, 100 percent biofuel use under the maximum acquisition scenario) will be an estimated 33.96 million GGEs for E85 and 20.75 million GGEs for B20. Thus, under this scenario, DoD would consume as many as 54 million gallons of biofuels by 2012, or almost eight times what it consumes today.

Chapter 5
Ethanol and Biodiesel Availability

In this chapter, we present our assessment of the current and future commercial availability of ethanol and biodiesel. We forecast the production of ethanol and biodiesel through FY12 and identify the primary factors that will limit the commercial availability of these biofuels.

Ethanol and biodiesel are receiving widespread attention as solutions to achieve greater energy independence and energy security, and reduce climate change and economic growth concerns. The major hurdle to using these fuels (over this study's time frame) is commercial availability, which is limited and highly regionalized. In this chapter, we discuss the projected commercial availability of ethanol and biodiesel through FY12.

To forecast their commercial availability, we consider each supply chain stage. The supply chain includes feedstock production and distribution, fuel production, transportation of fuel to bulk facilities for blending with conventional fuels, and finally, transportation to a retail facility for final sale to consumers. Market conditions, costs, and bottlenecks at each of these stages of the supply chain determine the availability of biofuels.

SUMMARY

We project that in FY06–12, U.S. production of ethanol will increase 138 percent, from 4,855 to 11,556 million gallons, and production of biodiesel will increase 211 percent, from 150 to 466 million gallons (Table 5-1). However, ethanol and biodiesel production will still be low relative to total U.S. gasoline and diesel consumption levels. In 2006, ethanol production represented 3.4 percent of the gasoline and biodiesel 0.33 percent of the diesel used nationally for vehicle transportation.[1]

DoD potential demand (discussed in Chapter 4) may exceed forecasted E85 retail availability at high DoD utilization rates. However, because pure ethanol is readily available in much greater quantities, high levels of DoD demand for E85 can be met through diversion of ethanol use from E10 to E85. For B20, retail availability will far exceed DoD demand over the next 5 fiscal years.

The primary factors that will limit the retail availability of high blends of biodiesel (B20) and ethanol (E85) are transportation hurdles, regulatory

[1] Energy Information Administration, *Short-Term Energy Outlook*, July 2007.

disparities between states, efficiency issues, commercial infrastructure limitations, and demand for biofuels for use as fuel additives.

Table 5-1. Ethanol and Biodiesel Retail Availability, FY06–12

Biofuel	2006	2007	2008	2009	2010	2011	2012
	Millions of gallons						
Ethanol Total	4,855	7,002	8,856	10,383	11,130	11,357	11,556
E85	14.9	15.4	16.0	16.5	23.8	27.6	29.5
E10	4,840	6,986	8,840	10,377	11,106	11,329	11,526
Biodiesel (B100)	150	173	216	270	323	388	466
B20	750	865	1,080	1,350	1,615	1,940	2,330
Biofuel	Millions of GGEs						
Ethanol Total	3,496	5,041	6,376	7,476	8,014	8,177	8,320
E85	10.7	11.1	11.5	11.9	17.1	19.9	21.2
E10	3,485	5,030	6,365	7,471	7,996	8,157	8,299
Biodiesel (B100)	169	195	243	304	364	437	525
B20	845	974	1,216	1,520	1,818	2,184	2,624

Source: Ethanol projections are based on Energy Information Administration, Goldman Sachs, and LECG forecast data. Biodiesel projections are based on LECG forecast data.

Our analysis of the commercial availability of ethanol and biodiesel suggests the following:

- Biofuels are currently competitive with oil above $50 to $60 per barrel, but a drop in prices could undercut this competitive advantage.[2,3]
- Due to economic factors, almost all ethanol (99.7 percent) will be sold as an additive to gasoline (E10) rather than as E85 over this study's time frame (FY07–12).
- Although production capacity for biodiesel will grow to 2.5 billion gallons in the next few years, biodiesel retail sales will be limited by high feedstock costs and subsequent retail prices, its chemical properties in colder environments, inconsistent quality, and tenuous consumer acceptance.
- Ethanol will dominate the alternative fuel market: capacity and production are expected to almost double over this study's time frame.
- Commercial retail fueling infrastructure will not be sufficient to cover all DoD ethanol and biodiesel requirements through FY12. DoD will need to

[2] 25×′25 National Steering Committee, *25×′25 Action Plan: Charting America's Energy Future*, February 2007.

[3] Goldman Sachs Group, *OPIS Ethanol and Biodiesel Supply Summit: Wall Street View of Ethanol Sector*, March 1, 2007.

purchase ethanol and biodiesel in bulk for distribution at DoD facilities to meet its demands.

- Biofuels are distributed primarily through the freight rail system, which currently has limited capacity and is costly over long distances. As a result, most commercial biofuel retail fueling infrastructure will be concentrated near production facilities in the Midwest.[4]
- Ethanol from cellulose offers the greatest potential to for large-scale displacement of petroleum, but will not be available in quantity until at least 2012.

ETHANOL

We forecast that national ethanol retail sales will increase 138 percent to 11,556 million gallons by 2012 (Table 5-2). In the short-term (through 2008), the primary factor limiting ethanol availability is production capacity rather than feedstock availability. As new capacity comes online after 2008, feedstock availability, primarily corn, will be the bottleneck in ethanol production.

Table 5-2. Ethanol Forecasts for Supply Chain Stages, 2006–12 (Millions of Gallons)

Stage	Type	2006	2007	2008	2009	2010	2011	2012
Feedstock availability	Corn[a]	5,697	7,857	9,586	10,105	11,070	11,610	12,174
	Cellulose[b]	0	0	3	13	27	54	109
	Others[c]	169	218	267	316	364	>364	>364
	Total	5,866	8,075	9,856	10,434	11,461	12,028	12,647
Production capacity	Corn[c]	5,330	7,070	8,780	10,500	12,200	>12,200	>12,200
	Cellulose[b]	0	0	3	13	27	54	109
	Others[c]	169	218	267	316	364	>364	>364
	Total	5,500	7,290	9,050	10,800	12,600	>12,600	>12,700
Transport and blending		Bottleneck is geographical availability						
Retail sales	E85[d]	14.9	15.4	16.0	16.5	23.8	27.6	29.5
	E10	4,840	6,986	8,840	10,377	11,106	11,329	11,526
	Total[d,e,f]	4,855	7,002	8,856	10,383	11,130	11,357	11,556

[a] USDA, *USDA Agricultural Projections to 2016*, OCE-2007-1, February 2007.

[b] Food and Agricultural Policy Research Institute (FAPRI) at The University of Missouri, *FAPRI U.S. Baseline Briefing Book*, FAPRI-UMC Report 02-07, February 2007.

[c] Renewable Fuels Association, *Industry Statistics,* July 2007, http://www.ethanolrfa.org/industry/locations/.

[d] Energy Information Administration, *Annual Energy Outlook 2007*, February 2007.

[e] Goldman Sachs Group, *OPIS Ethanol and Biodiesel Supply Summit: Wall Street View of Ethanol Sector*, March 1, 2007.

[f] John M. Urbanchuk, *Contribution of the Ethanol Industry to the Economy of the United States,* Prepared for the Renewable Fuels Association, LECG, LLC, February 21, 2006.

[4] Government Accountability Office (GAO), *Biofuels: DOE Lacks a Strategic Approach to Coordinate Increasing Production with Infrastructure Development and Vehicle Needs*, GAO-07-713, June 2007.

The federal Renewable Fuel Standard (RFS) Program has bolstered the demand for ethanol, and its chemical properties make it a relatively good gasoline additive as an oxygenate and octane enhancer. However, high oil and gasoline prices have supported ethanol production volumes greater than the demand created by the RFS. In 2007, the RFS requires 4.7 billon gallons of ethanol, slightly more than the 4 billion gallons of ethanol used in reformulated gasoline blends (RFG), which substitute ethanol for methyl tertiary butyl ether (MTBE) as an oxygenate.[5] This is much less than the 7 billion gallons of expected demand. High oil and gasoline prices, coupled with the price support provided by subsidies, have made ethanol an economical gasoline blending component. Ethanol production volumes will continue to outpace the RFS requirements as long as oil and gasoline prices remain relatively high.

During the study time frame (FY07–12), most ethanol (99.7 percent) will be blended as E10, so retail sales of ethanol will mirror the demand for E10 until the fuel additive market is saturated in 2015. The remaining ethanol will be blended as E85, which is forecast to increase 98 percent, from the current 14.9 million gallons to 29.5 million. The lack of commercial fueling infrastructure, as well as the cost and distribution of expanding use away from production areas, limits sales of E85.

Supply Chain Overview

Ethanol, or ethyl alcohol, is produced through the fermentation and distillation of simple sugars. Ethanol can be made from a wide array of biological feedstocks that contain either substantial amounts of sugar or materials that can be converted into sugar (such as starch or cellulose). In the United States, most ethanol is produced from corn: the starch in corn is readily converted into sugar. Other potential feedstocks include grasses (cellulose) and sugars, but they are currently not commercially viable due to cost and feedstock availability.

As of July 2007, 122 ethanol refineries were operating in the United States, at a total annual production capacity of 6.4 billion gallons (4.9 billion gallons in 2006).[6] Almost all of these refineries produce ethanol from corn, so they are concentrated near the feedstock source, the “Corn Belt.” Production capacity will increase to 12.6 billion gallons per year (bgpy) in the next few years through the 81 ethanol refineries that are expanding or under construction.[7]

Denatured ethanol is transported from the refinery to either a bulk terminal or a redistribution bulk terminal (Figure 5-1). Most ethanol is transported to terminals on the freight rail system, and the remainder is transported via tanker truck or

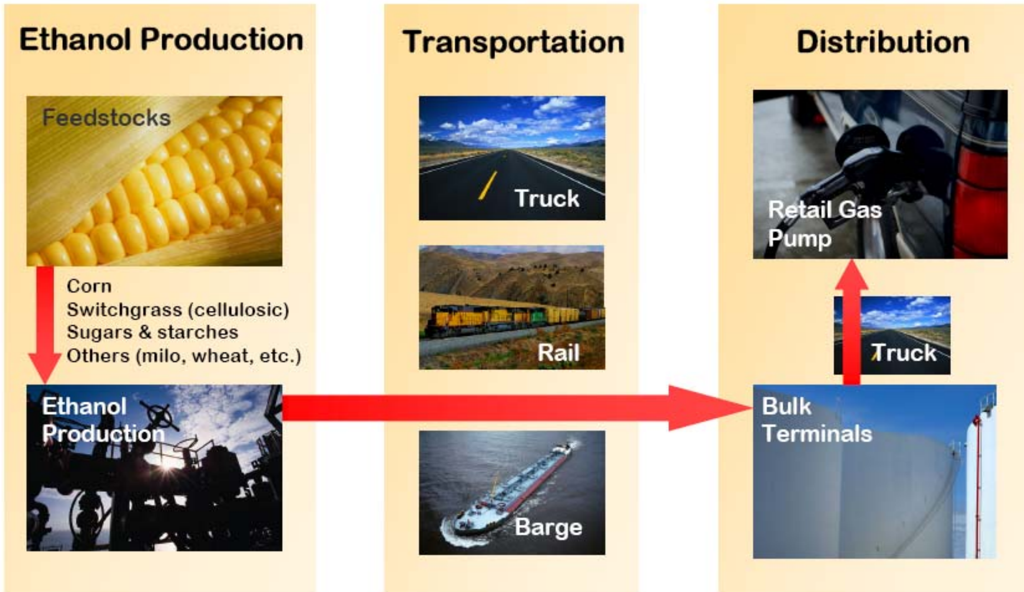
[5] Energy Policy Research Foundation, *Ethanol Part II: Is a Home-Grown Fuel Policy Undermining U.S. Energy Security?*, April 2, 2007.

[6] Renewable Fuels Association, *Industry Statistics*, July 2007, http://www.ethanolrfa.org/industry/locations/.

[7] See Note 6, this chapter.

barge.[8] From the terminals, ethanol is transported (typically after blending with gasoline) to retail locations by tanker truck for sale to end users. Most ethanol (99.7 percent) is sold as E10,[9] and the remainder is sold as E85.

Figure 5-1. Ethanol Supply Chain



Ethanol Feedstocks

As discussed above, potential feedstocks for ethanol production in the United States until 2012 are as follows:

- *Corn*. Although estimates vary, more than 98 percent of the ethanol produced in the United States comes from corn.[10] The production of ethanol from corn requires the use of enzymes to break down the corn starch into sugars, which are then fermented into ethanol.
- *Sugars and starches*. Sugar-based feedstocks include sugar beets, sugar cane, and sweet sorghum. Ethanol production using sugar-based feedstocks is more efficient because the initial enzymatic step required for corn processing is unnecessary. However, only one refinery in the United States produces ethanol from sugar, and its annual capacity is only 1.5 million gallons. Growing conditions (sugar beets must be rotated with other crops) and government tariffs are primarily responsible for limiting sugar as a feedstock in the United States.

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[8] See Note 4, this chapter.

[9] Energy Information Administration, *Annual Energy Outlook 2007*, DOE/EIA-0383(2007), February 2007.

[10] USDA, *The Economic Feasibility of Ethanol Production from Sugar in the United States*, July 2006.

- *Cellulose.* Cellulosic feedstocks include corn stover, timber wastes, and dedicated energy crops such as switchgrass. Ethanol is produced from these feedstocks by isolating sugar molecules in the plant cell walls and converting them into ethanol. Technology enabling the production of ethanol from cellulosic materials is still in its infancy, but several pilot plants are in operation, and this number is expected to grow.

- *Other Feedstocks*. Other feedstocks for ethanol production include milo, wheat, sorghum, barley, brewery waste products, and cheese whey. However, feedstock availability and policy preferences will limit their use over the time frame of this study.

SUMMARY

The forecast for feedstocks for ethanol production until at least 2012 is as follows:

- *Corn will continue as the feedstock for roughly 97 percent of ethanol produced.* Corn will remain the preferred feedstock for ethanol production due to its availability, commodity cost, and economics for ethanol production. Corn is the only feedstock that enables ethanol to compete with the cost of petroleum at the scale necessary to meet demand (billions of gallons annually).

- *Sugar will not significantly contribute to the ethanol market.* Sugar is grown in only four U.S. states and Puerto Rico, so it is not available on the scale necessary to produce significant quantities of ethanol. The availability of sugar as a feedstock for ethanol production is further limited by its importance in the food market—diverting its use to ethanol would compete with its use as a food product. In addition, although sugarcane has a higher yield than corn for ethanol production, its domestic commodity cost leads to a much higher ethanol cost per gallon than corn.

- *The cellulosic pathway will not be commercially viable before 2012*. Cellulosic biomass is considered the only ethanol feedstock capable of replacing 30 percent of U.S. petroleum use.[11] DOE projects commercial demonstration of a viable pathway by 2012 and commercially viable ethanol production from cellulosic biomass beyond that date.

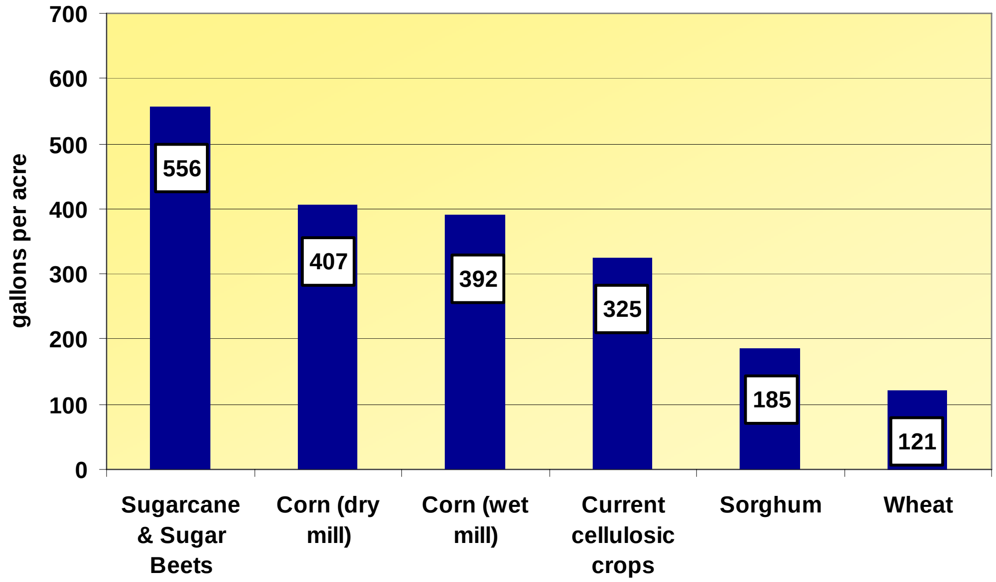
FEEDSTOCK YIELDS AND COSTS

As shown in Figure 5-2, of the ethanol feedstocks, sugarcane and sugar beets have the highest yield in gallons per acre, 37 percent higher than corn. However, due to corn's lower commodity cost and byproducts—U.S.-produced sugarcane costs $1.53 per gallon of ethanol compared with corn grain at less than $1.00 per gallon

[11] DOE, National Renewable Energy Laboratory, *From Biomass to Biofuels*, NREL/BR-510-39436, August 2006.

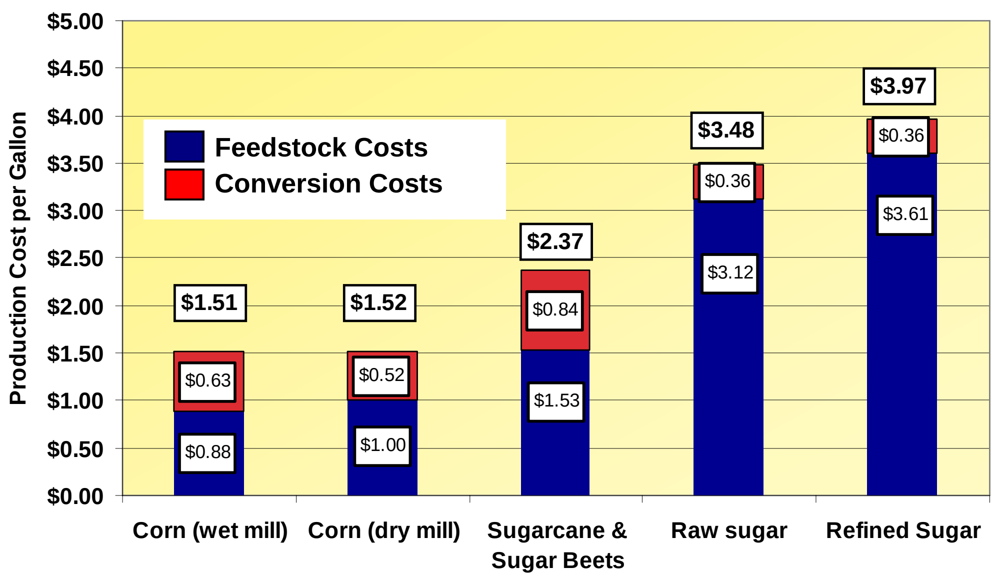
of ethanol at current commodity prices[12]—ethanol production from corn is roughly 28 percent cheaper than from sugar ($1.51 compared with $2.37 per gallon). Figure 5-3 shows ethanol production costs for each of the primary feedstocks.

Figure 5-2. Ethanol Production Yields for Primary Feedstocks (Gallons per Acre)



Source: USDA, *The Economic Feasibility of Ethanol Production from Sugar in the United States*, July 2006.

Figure 5-3. Ethanol Production Costs for Primary Feedstocks ($ per Gallon)



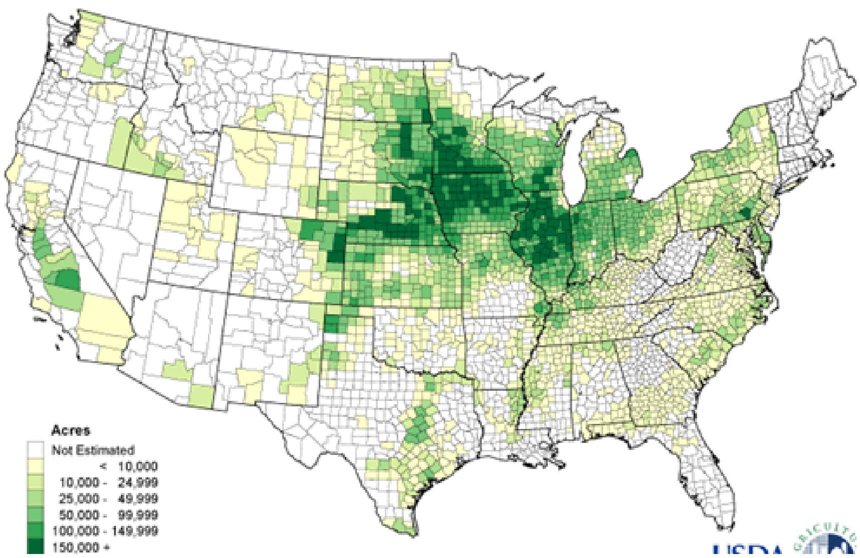
Source: USDA, *The Economic Feasibility of Ethanol Production from Sugar in the United States*, July 2006.

[12] See Note 10, this chapter (assumes corn prices of $3.50 per bushel).

CORN

The United States Department of Agriculture (USDA) reported that 78.3 million acres of corn were planted, yielding 10,535 million bushels (or 149 bushels per acre), in 2006. As shown in Figure 5-4, the majority of this acreage is located in the Midwest.

Figure 5-4. Planted Acres of Corn for Grain by County (2005)



Source: USDA, National Agricultural Statistics Service, July 2007.

Annual crop yields for corn have greatly increased over the last 10 years, from 113.5 bushels per acre in 1995 to 149.1 bushels per acre in 2006.[13] USDA projects that advances in biotechnology and plant breeding techniques will further increase yields to 162.6 bushels per acre by 2012.[14]

From the USDA and National Corn Growers Association (NCGA) data, we project that the corn available annually for ethanol production will rise sharply from 2,150 to 4,365 million bushels between 2006 and 2012. This rise reflects projected corn production above a "baseline" demand for non-ethanol uses of corn of 9.1 billion bushels.[15] From this growth in available corn—coupled with projected slight increases in the conversion rate of ethanol from corn—we project that the potential ethanol that can be produced from corn will increase 114 percent, from 5,697 to 12,174 million gallons between 2006 and 2012 (Table 5-3 and Figure 5-5).

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[13] USDA, National Agricultural Statistics Service, *Yield by Year, US*, July 2007, http://www.nass.usda.gov/.

[14] USDA, *USDA Agricultural Projections to 2016*, OCE-2007-1, February 2007.

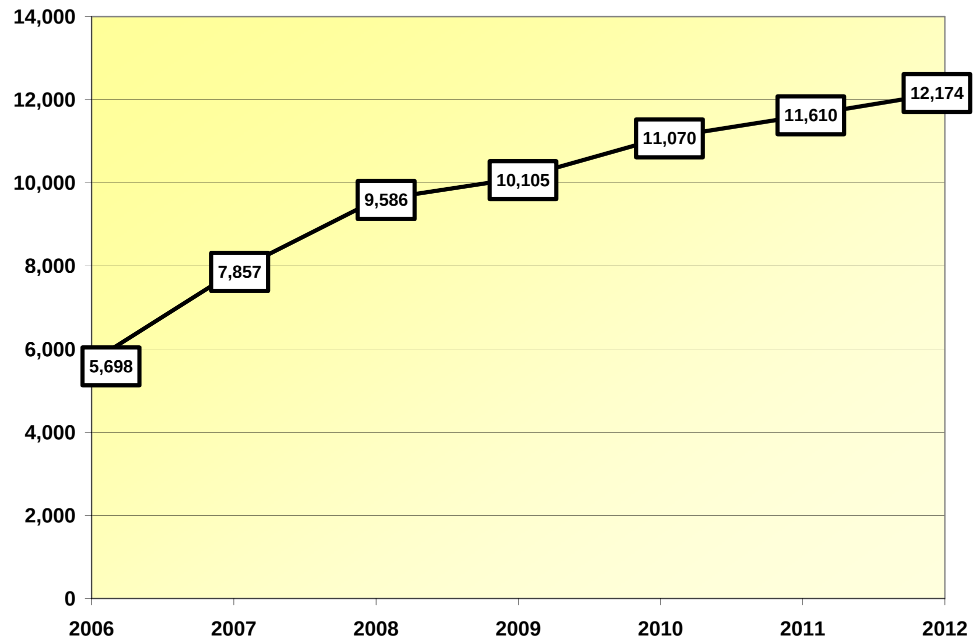
[15] NCGA, *How much ethanol can come from corn?* February 2007.

Table 5-3. Forecast of Potential Ethanol Production from Corn, 2006–12

	2006	2007	2008	2009	2010	2011	2012
Million acres planted	78.3	86	89	89	90	90	90
Yield (bushels per acre)	149.1	153.1	155	156.9	158.8	160.7	162.6
Corn produced[a]	10,535	12,065	12,680	12,835	13,150	13,305	13,465
Corn available for ethanol use[a]	2,150	2,965	3,580	3,735	4,050	4,205	4,365
Ethanol conversion rate[b]	2.65	2.65	2.68	2.71	2.73	2.76	2.79
Potential ethanol production[a]	5,697	7,857	9,586	10,105	11,070	11,610	12,174

[a] Millions of bushels.
[b] Gallons per bushel.

Figure 5-5. Forecast of Potential Ethanol Production from Corn, 2006–12



Most of the projected growth in corn production will be to meet demand from the rapid expansion of ethanol production. Supply growth will result from both increased yields and acreage planted. [16] Whether the corn supply will exceed demand for ethanol use by 2012 is unclear. Until this happens, corn stocks will be limited (for domestic corn animal feed and exports), and corn prices will remain relatively high compared with historical levels.

[16] See Note 14, this chapter.

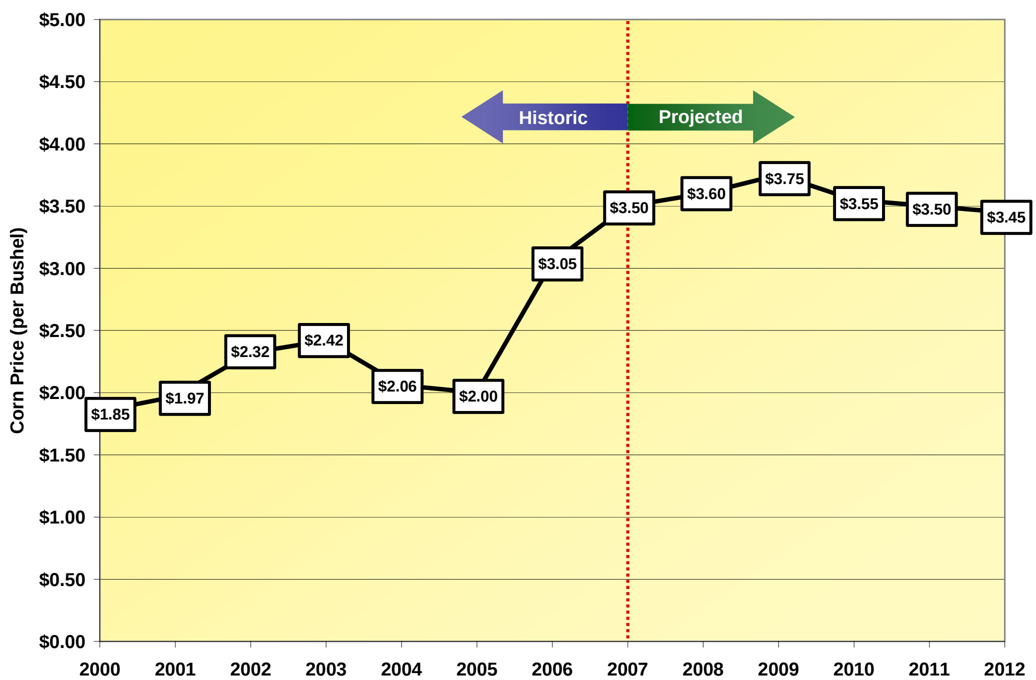
Corn Prices

One of the key factors keeping ethanol cost-competitive with gasoline is the price of corn. According to the DOE's *Annual Energy Outlook*, corn feedstock constitutes 57 percent of ethanol production costs.

The cost of corn depends on the supply and demand dynamics of the corn market. Corn is the largest crop (by acreage) in the United States. A staple in the food and agricultural feed industries, it is used for everything from tortillas to beverage sweeteners to animal feed. As the demand for corn from any of the various market sectors that depend on it increases, annual reserve stocks decrease and prices increase. These price increases affect the end prices of all products that use corn, including ethanol.

Recent increases in ethanol production have driven corn prices from $2.04 per bushel in March 2006 to $3.76 in March 2007.[17] USDA forecasts that corn production will expand to meet ethanol requirements over the next 10 years, and corn prices will stabilize near $3.50 per bushel (Figure 5-6).[18]

Figure 5-6. Forecast of Corn Prices, 2006–12



If corn prices behave as forecast, ethanol will continue to be cost-competitive with gasoline. Given current tax credits for ethanol production, Aventine

[17] USDA Economic Research Service, *Feed Situation and Outlook Yearbook*, Report FDS-2007, April 2007.

[18] See Note 14, this chapter.

Renewable Energy estimates that for ethanol to compete with gasoline at $30 per barrel of crude oil, corn prices must be less than $3.00 per bushel. At $40 per barrel of crude oil, ethanol is cost-competitive at corn prices less than $4.00.[19] If crude continues to cost well over $40 per barrel, a $4 per bushel cost of corn is probably sustainable.

Without tax credits for ethanol production, the landscape would change. Goldman Sachs estimates that if tax credits were taken away, new ethanol refinery builds would only be justified at crude oil prices above $60 per barrel (at projected long-term corn prices of $3.50 per bushel). If corn prices rise to $4.00 per bushel, ethanol production would expand only at crude oil prices above $65 per barrel. At $3.25 per bushel, such expansion would occur only at $55 per barrel and at $2.50 per bushel, expansion would occur at a crude oil cost above $45 per barrel.[20]

Corn Availability for Food

Ethanol has been taking up an increasingly large share of U.S. corn production. In 2006, 20.4 percent of the corn crop was used for the production of ethanol fuel.[21] This number increased steadily from 5 percent in 1995. The USDA estimates that by 2012, 30 percent of the corn crop will be used as feedstock for ethanol.[22] However, demand for livestock feed is flat and is not expected to rise.

Some argue that the increased percentage of corn used for ethanol raises a “food-versus-fuel” concern. However, the use of corn as a feedstock for ethanol has relatively little effect on the availability of corn for food. Non-ethanol corn use will continue to represent approximately 9.1 billion bushels per year.[23] Impacts on animal feed are also expected to be minimal due to ethanol production byproducts, distillers dry grains with solubles (DDGS). DDGS have been introduced to the market relatively recently, and advances in related technologies and infrastructure may allow them to displace up to 1 billion bushels of corn as animal feed annually, beginning in 2009.[24]

SUGARS AND STARCHES

Ethanol production from sugars and starches is limited due its high cost and limited availability relative to corn. Currently, one refinery in the United States is producing ethanol from sugars and starches, and one new refinery is planned. Combined, they represent a capacity of 3 million gallons per year of ethanol, or 0.02 percent of the current and total planned ethanol production capacity.

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[19] Aventine Renewable Energy Inc., *Presentation at OPIS Energy and Biodiesel Summit*, March 1, 2007.

[20] See Note 3, this chapter.

[21] USDA Economic Research Service, *Feed Grains Database: Custom Queries*, June 2007, http://www.ers.usda.gov/data/feedgrains/FeedGrainsQueriable.aspx.

[22] See Note 14, this chapter.

[23] See Note 15, this chapter.

[24] See Note 15, this chapter.

Sugarcane is grown in Texas, Louisiana, Hawaii, and Florida, and sugar beets are grown in several western states. In FY06, U.S. sugarcane production was 3.49 million tons and U.S. sugar beet production 5.00 million tons.[25] At this production level, total potential ethanol production using the entire harvest of domestic sugars and starches is only 184 million gallons, or roughly 3 percent of the ethanol that was produced from corn in 2006.

Even if availability were not an issue, high feedstock and processing costs limit the current commercially viability of ethanol produced from sugar. At today's domestic sugar prices, the cost of converting sugarcane to ethanol is roughly $2.40 per gallon and for sugar beets is roughly $2.35 per gallon.[26] Feedstock costs represent between 62 and 67 percent of total production costs. With current ethanol prices around $2.50 per gallon, producing ethanol from sugar is unprofitable.

CELLULOSE

Cellulosic biomass feedstocks offer the greatest potential for producing quantities of ethanol necessary to significantly displace petroleum. Cellulosic crops have a higher yield per acre planted than corn—800 gallons compared with 416. Since these feedstocks can be grown on marginal lands with low energy, water, and fertilizer requirements, cellulosic biomass may be produced at much higher quantities and lower costs than corn. DOE and USDA estimate that enough land is available to produce over 1 billion tons of cellulosic biomass, enough to generate 60 billion gallons of ethanol or roughly 40 percent of current gasoline usage.[27]

Cellulosic ethanol is created by isolating the sugar molecules in plant cell walls and converting them into ethanol. Potential cellulosic biomass feedstocks include corn stover, timber wastes, and dedicated energy crops such as switchgrass. The current technology for conversion of cellulosic biomass into ethanol is the acid hydrolysis process. Since processing costs are 50 percent higher and capital costs are almost 300 percent higher than that of ethanol production from corn, this pathway is not yet economically viable.[28]

The barrier to the commercial viability of ethanol production from cellulosic biomass is that its sugars are locked in a complex polymer composite. Overcoming this barrier involves developing new technologies based on the

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[25] USDA Economic Research Service, *Sugar and Sweeteners: Data Tables*, July 2007, http://www.ers.usda.gov/Briefing/Sugar/data.htm.

[26] See Note 10, this chapter.

[27] DOE, *Fact Sheet: A Scientific Roadmap for Making Cellulosic Ethanol: A Practical Alternative to Gasoline*, 2006.

[28] Renewable Fuels Association, *OPIS Ethanol and Biodiesel Supply Summit: Current Ethanol Policy Framework: What Is Needed—From Producers' and Growers' Perspective*, March 1, 2007.

enzymatic breakdown of cellulosic biomass to component sugars and lignin, using a combination of thermochemical and biological processes.[29]

DOE's *25×25 Action Plan* (2007) set "goals for commercial demonstration of cost-competitive cellulosic ethanol technologies by 2012, and the introduction of fully integrated commercial facilities within 15 years."[30,31,32] Therefore, cellulosic ethanol likely will not contribute to ethanol supply before 2012 and is unlikely to play a major role before 2022.

Several efforts are underway to support the advancement of cellulosic ethanol:

- USDA is expected to spend almost $400 million on six cellulosic plants to test a range of technologies.
- EPAct 2005 authorizes a loan guarantee program of up to $250 million for cellulose-based biorefineries and spending packages for cellulosic ethanol research and development centers.
- The USDA Farm Bill proposal includes $1.6 billion in renewable energy funding targeted at cellulosic ethanol production.[33]
- The American Fuels Act, proposed by Senators Barack Obama (D-IL), Dick Lugar (R-IN), and Tom Harkin (D-IA), would promote an increase in the domestic production of cellulosic biomass ethanol to 250 million gallons by 2012.

Ethanol Production

As of July 2007, 119 ethanol refineries were operating in the United States, representing a total production capacity of 6.4 bgpy (2006 production reached 4.9 billion gallons); 86 new ethanol refineries are under construction, which will increase production capacity to 12.7 bgpy over the next few years.[34] This increase in capacity will phase in over the next several years as construction projects are completed.

Currently, almost all ethanol refinery capacity uses corn as the primary feedstock—6,321 million gallons (or 98.9 percent) of the 6,389 million gallons of total capacity.[35] This will continue in the foreseeable future because almost all (98.2 percent) of the planned expansion of production capacity in the next few

[29] DOE, *Breaking the Biological Barriers to Cellulosic Ethanol: A Joint Research Agenda*, DOE/SC-0095, 2006.

[30] See Note 11, this chapter.

[31] See Note 29, this chapter.

[32] See Note 2, this chapter.

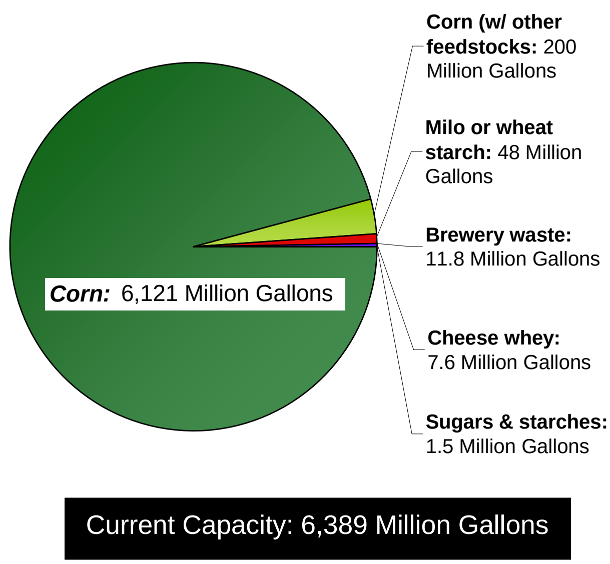
[33] See Note 28, this chapter.

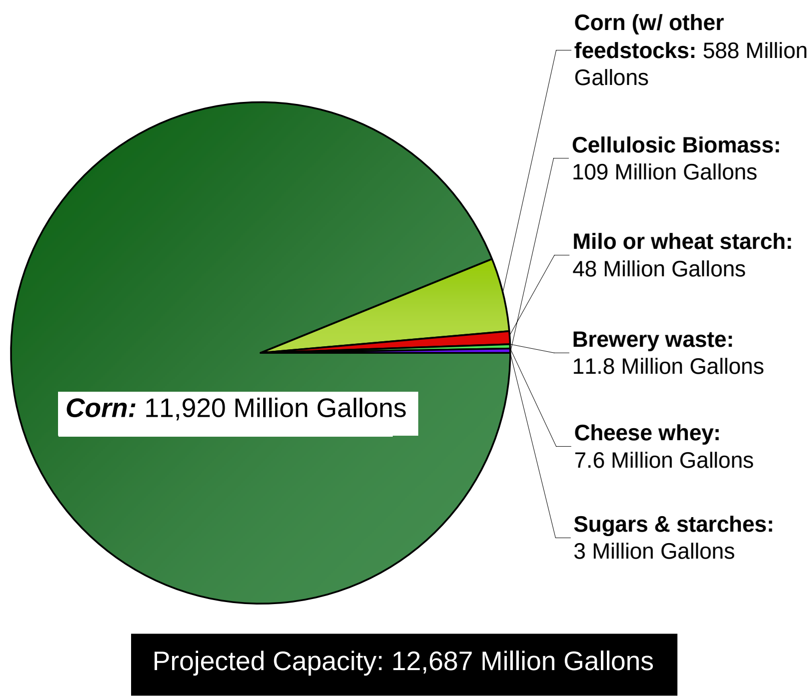
[34] See Note 6, this chapter.

[35] See Note 6, this chapter.

years will utilize corn feedstocks. As shown in Figure 5-7, after planned capacity comes online, ethanol production from corn will constitute 12,508 million gallons (or 98.6 percent) of the 12,687 million gallons of total ethanol refining capacity.

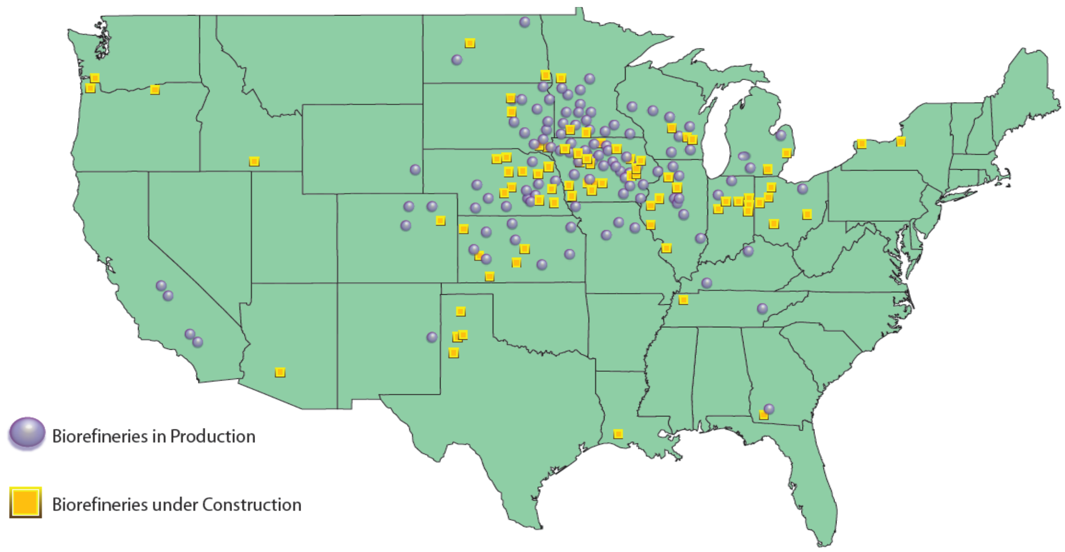
Figure 5-7. Capacity of Ethanol Refineries by Feedstock





As shown in Figure 5-8, most of the current and planned refineries are located in the Corn Belt near the feedstock source. Of the currently operating ethanol plants, 60 percent are located in Iowa, Minnesota, Nebraska, and South Dakota, which produce 44 percent of the U.S. corn crop.[36] The industry is slowly expanding beyond the Corn Belt, as new facilities are expected to come online in Oregon, New York, Texas, and other states within the next few years.

Figure 5-8. Locations of Current and Planned Ethanol Refineries



Source: Renewable Fuels Association, April 2007

As discussed earlier, cellulosic ethanol is not expected to be commercially viable until after 2012. However, pilot plants will likely be in operation before 2012 as technologies to produce ethanol from cellulosic biomass are evaluated. In addition, smaller-scale "niche" cellulosic ethanol plants may be built to capture favorable economic opportunities. For example, in July 2007, FPL Energy announced the intent to build a cellulosic ethanol plant in Florida to produce 4 million gallons of ethanol per year from citrus peel.

Production Processes

Biorefineries produce corn-based ethanol using either dry or wet milling techniques (dry milling is the most common). Current dry milling techniques can produce 2.75 gallons of ethanol per bushel of corn (roughly 400 gallons/acre), while wet milling techniques yield 2.65 gallons per bushel (390 gallons/acre). The primary difference between the two processes is the pretreatment of the incoming grain—dry milling uses hammer mills to grind the grain into a starch-containing powder, while wet milling uses a liquid solution to separate the grain into a range of constituent parts, including starch. For either process, once the initial grain pretreatment occurs, enzymes convert the starch into sugars, which are them fermented into ethanol. The final step is to denature the ethanol by adding a small amount of gasoline to render it undrinkable.

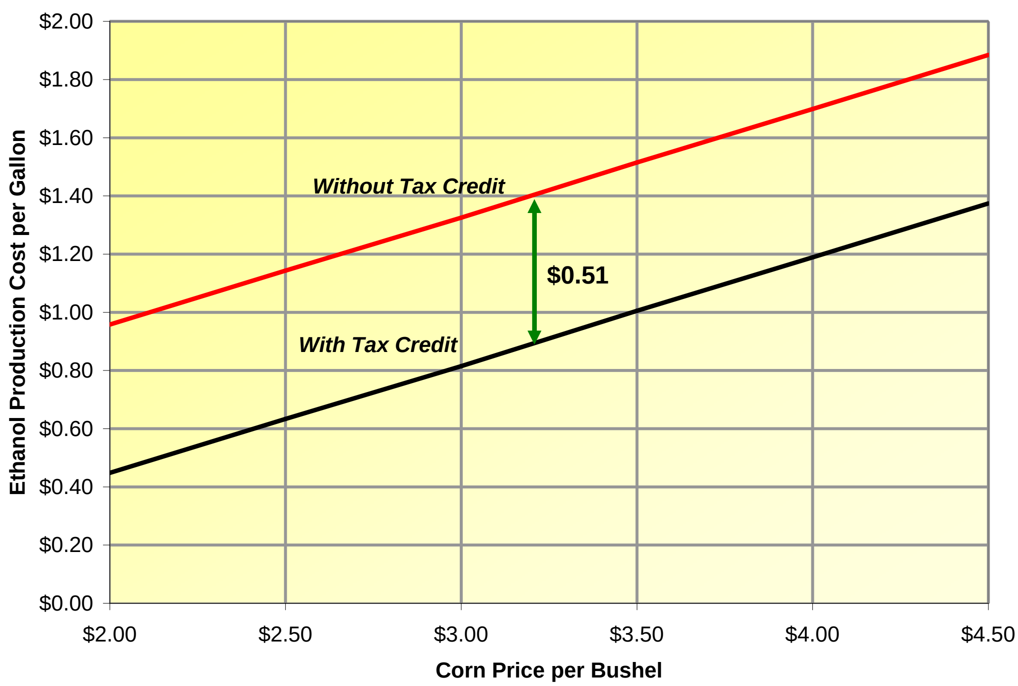
[36] USDA, National Agricultural Statistics Service, June 2007, http://www.nass.usda.gov/QuickStats/.

Ethanol production from corn also generates byproducts that result in additional revenue for the refinery. In the dry milling process, roughly 6 pounds of DDGS, sold for use in animal feed, are produced per gallon of ethanol. The byproducts of the wet milling process include roughly 4.9 pounds of corn gluten feed, 0.9 pounds of corn gluten meal, and 0.6 pounds of corn oil per gallon of ethanol.[37]

ETHANOL PRODUCTION COSTS

As shown in Figure 5-9, the production cost of ethanol rises and falls with the price of corn. At the current price of corn ($3.50 per bushel), the net production cost per gallon of ethanol is $1.01. For each gallon of ethanol produced, feedstock costs are $1.27 (dry milling) or $1.32 (wet milling), sales of byproducts are $0.28 (dry milling) or $0.44 (wet milling), processing costs are $0.52 (dry milling) or $0.63 (wet milling) per gallon, and the tax credit is $0.51 per gallon. The tax credit actually is provided directly to ethanol blenders, and it is implied in the comparison of production costs with gasoline.

Figure 5-9. Net Ethanol Production Costs and Commodity Price of Corn



The current $0.51 per gallon tax credit keeps ethanol competitive with gasoline as a fuel additive. The current implied ethanol production price of $1.01 per gallon (with tax credit) is equivalent to gasoline production with crude oil at $35 per barrel. Without the tax credit, the equivalent crude oil price jumps to $57 per barrel.

[37] See Note 10, this chapter.

Ethanol Transportation

Denatured ethanol produced at ethanol refineries is transported to bulk terminals before final distribution to retail facilities. The primary mode of transport from refineries is freight rail; other modes include tanker truck and tank barge. Almost all deliveries from bulk terminals to retail fueling facilities are by tanker trucks.

The challenge to national distribution of ethanol is lack of capacity of the freight rail system, coupled with the lack of dedicated ethanol pipelines.[38] As of the first quarter 2007, there was a backlog of 79,038 freight cars, representing approximately 1 year of rail car production.[39] We estimate that 27,500 additional freight cars will be required to handle the projected increase in ethanol production by 2010,[40] or 15 percent of all freight cars produced during this period.

Because no pipeline exists for ethanol transport, moving it to the point of sale is far more expensive per gallon than gasoline. DOE's National Renewable Energy Laboratory (NREL) estimates that the full transportation cost per gallon of ethanol (from refineries to fueling facilities) is 13 to 18 cents, depending on distance and transportation mode,[41] roughly four times the transportation cost for gasoline, an estimated 3 to 5 cents per gallon.

Pipeline

Ethanol is not currently transported through existing petroleum pipelines, although this mode is the most cost-effective for transporting fuel across significant distances. The primary reasons limiting ethanol in pipelines are (1) ethanol absorbs water and impurities in pipelines, reducing product quality; (2) most ethanol production is not located near pipelines; and (3) individual shipments of ethanol are too small to warrant shipping grade designation.[42] In the foreseeable future, a pipeline dedicated to ethanol transport is unlikely to be constructed, primarily due to high capital requirements relative to potential ethanol pipeline volume. NREL estimates that an ethanol pipeline could cost at much as $1 million per mile.[43]

Tank Barges

Tank barges, at an average cost of 0.72 cents per ton-mile, are the most cost-effective transportation mode currently available for ethanol.[44] The cost

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[38] See Note 4, this chapter.

[39] Railway Supply Institute, American Railway Car Institute Committee, *Freight Car Orders, Deliveries & Backlogs*, July 2007, http://www.rsiweb.org/committees/com_arci_stats.aspx#q.

[40] Ken Columbia, World Energy, Presentation at National Biodiesel Board Convention: Trains, Trucks, Tanks & Barges, February 6, 2007.

[41] See Note 4, this chapter.

[42] John Whims, *Pipeline Considerations for Ethanol*, August 2002.

[43] NREL report cited in Note 4, this chapter, *Biofuels Availability and Use*, June 2007.

[44] American Commercial Lines, *Presentation at OPIS Ethanol and Biodiesel Summit, Moving America 2007*, March 2007.

effectiveness stems primarily from scale—one tank barge is the equivalent of 15 rail tank cars or 80 tanker trucks. Barge infrastructure is located near the nation's major waterways, in the Midwest, Northeast, Mid-Atlantic, and Gulf Coast. Although the barge industry has sufficient capacity, ethanol transport via tank barges is limited due to lack of proximity of ethanol refineries to barge terminals and the limited scale of ethanol deliveries.

RAIL TANK CARS

At an average cost of 2.24 cents per ton-mile, transportation by rail tank car is three times more costly than via tank barge.[45] To obtain transportation efficiencies, ethanol is increasingly being transported using unit trains, dedicated freight trains with 75 to 95 tank cars of ethanol.[46] Many ethanol refineries are upgrading their rail yard facilities to handle unit trains. For example, Union Pacific Corporation required Golden Grain Energy, LLC, in Iowa to triple the size of its rail yard in 2006 when its ethanol production increased to a point where unit trains were economically feasible.

The freight rail infrastructure will be stressed by increased ethanol production and sales. *The Wall Street Journal* reports, "As ethanol producers ramp up production, they are straining railroads already taxed by burgeoning shipments of coal, containers, and grain. And they worry that the transportation crunch could make it difficult for ethanol, despite its surge of support in Washington, to compete with energy rivals."[47]

TANKER TRUCKS

Tanker truck is the most available but also the most costly ethanol transportation method: its average cost of 26.61 cents per ton-mile is almost 12 times that of rail tank cars.[48] Therefore, tank trucks are primarily used for delivery from the terminal to the retail infrastructure (short distance and lower volume requirements).

Ethanol Blending

Because it tends to separate from gasoline, ethanol is typically blended at distribution terminals, just prior to transportation to retail stations.[49] Therefore, there may be significant storage requirements for ethanol prior to blending and transporting to retail stations. Because ethanol is more corrosive than gasoline, storage tanks must meet unique specifications.

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[45] See Note 44, this chapter.

[46] Brat, Ilan, and Daniel Machalaba, "Can Ethanol Get a Ticket to Ride?" *The Wall Street Journal*, February 1, 2007.

[47] See Note 46, this chapter.

[48] See Note 44, this chapter.

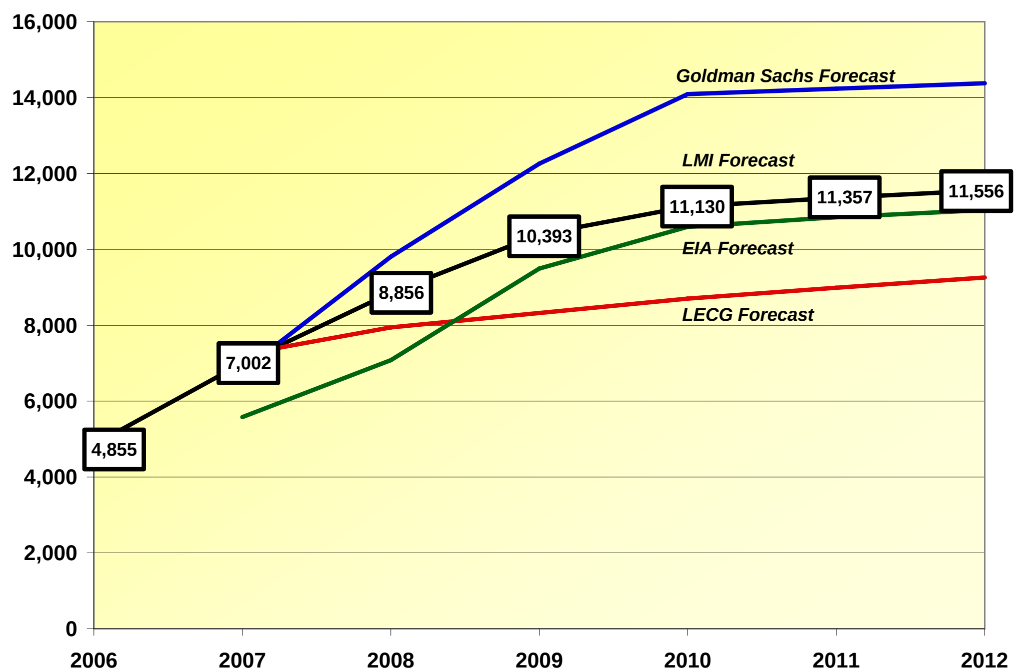
[49] Patricia Ellis, *Presentation at EPA Region 3 LUST Conference: Ethanol, Will It Drive You to Drink?* Delaware Department of Natural Resources and Environmental Control, April 2006.

Ethanol Retail Sales

The retail demand for ethanol and available production capacity drive its production. Most of the demand for ethanol in the United States is as an additive (1) to replace MTBE, a suspected carcinogen which has been implicated in the contamination of drinking water, and (2) as a relatively low-cost octane enhancer. As an additive, ethanol is blended with gasoline at 10 percent volume, referred to as E10. Ethanol blended as E10 accounts for 99.7 percent of all ethanol used in the United States and is expected to remain at this proportion past 2012. Almost all remaining ethanol production will be blended as E85.

Forecasts for retail sales of ethanol vary, yet all project significant growth over the next 5 years. Our forecast for retail ethanol sales was calculated as the average of three forecast projections: Energy Information Administration, Goldman Sachs, and LECG. As shown in Figure 5-10, we project ethanol retail sales to increase 141 percent from 2006 to 2012, from 4,855 to 11,693 million gallons.

Figure 5-10. Retail Sales of Ethanol, 2006–12 (Millions of Gallons)



Sources: Energy Information Administration, *Annual Energy Outlook 2007*, February 2007; Goldman Sachs Group, *OPIS Ethanol and Biodiesel Supply Summit: Wall Street View of Ethanol Sector*, March 1, 2007; John M. Urbanchuk, *Contribution of the Ethanol Industry to the Economy of the United States*, Prepared for the Renewable Fuels Association, LECG, LLC, February 21, 2006.

E10 Retail Sales

MTBE is banned in 25 states, and 5 more have proposed such bans.[50] In the next 5 years, the remainder are likely to ban MTBE. As shown in Table 5-4, meeting E10 demand will require most of the projected ethanol production through 2012.

Table 5-4. Forecast of E10 Demand, Production Capacity, and E10 Retail Sales, 2007–12 (Billions of Gallons)

Year	Total gasoline sales	E10 market share (%)	% of total gasoline sales	Ethanol market range[a]	Ethanol production capacity[a]	Ethanol retail sales[a]
2007	145	41–48	4.1–4.8	6.0–7.0	7.3	7.0
2008	147	55–64	5.5–6.4	8.2–9.5	9.1	9.0
2009	149	63–70	6.3–7.0	9.5–10.5	10.8	10.4
2010	150	69–79	6.9–7.9	10.5–12.0	12.6	11.3
2011	152	71–81	7.1–8.1	11.0–12.5	>12.6	11.5
2012	155	73–80	7.3–8.0	11.5–12.5	>12.7	11.7

Source: Hart Energy Consulting, *OPIS Ethanol and Biodiesel Supply Summit: Outlook & Impact for Renewables in North American Refining and Gasoline Markets*, 2006–2015, March 2, 2007.

[a] Projected.

Economics also drive the demand for ethanol blended as E10—the market value of ethanol blended as E10 is far higher than as E85. Since E85 has only 72 percent of the energy content per gallon of gasoline, ethanol blended as E85 must be discounted at the pump to account for its reduced fuel efficiency. However, since ethanol is a relatively cost-effective oxygenate or octane enhancer in gasoline, E10 is sold at the same price as gasoline. Therefore, at the current price of gasoline of $3.00 per gallon, the implied wholesale price of ethanol in E10 is $2.91 per gallons, or 54 percent higher than the implied wholesale price of ethanol in E85 of $1.89 per gallon. Table 5-5 shows the calculation of the implied wholesale prices for ethanol in E85 and E10.

Because E10 is sold through the same pump and tank systems as gasoline, it carries no infrastructure issues.

[50] W.R. Hambrecht & Co., *Ethanol Industry: E10 Yes, E85 Maybe Later*, January 4, 2007.

Table 5-5. Implied Wholesale Prices of E10 and E85 at Current Gasoline Prices

Category	Gasoline	E10	E85
Implied Cost of Ethanol at Retail Pump			
Pump price (per gallon)	$3.00	$3.00	$2.13
Taxes and margin (per gallon)	$(0.60)	$(0.60)	$(0.60)
Implied fuel cost (per gallon)	$2.40	$2.40	$1.53
Neat gasoline actual cost	$2.40		
Sub-octane gasoline actual cost		$2.16	$0.36
Ethanol implied cost		$0.24	$1.17
Implied Ethanol Wholesale Value			
Ethanol revenue per gallon of fuel sold at pump		$0.24	$1.17
Gallons of ethanol		0.10 gallon	0.85 gallon
Value of ethanol		$2.40	$1.38
Volumetric Ethanol Excise Tax Credit (VEETC)		$0.51	$0.51
Ethanol implied wholesale value/price		$2.91	$1.89

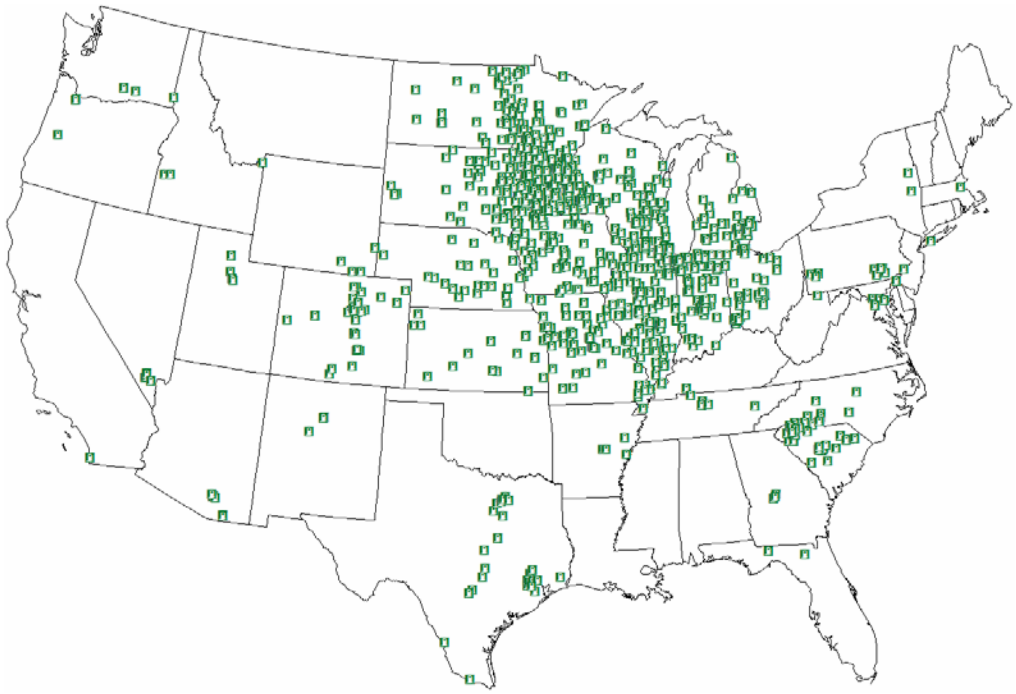
Source: Cliff Cook, Marathon Oil, *OPIS Ethanol and Biodiesel Supply Summit: Ethanol Expansion into Growth Markets*, March 2, 2007.

E85 Retail Sales

DOE estimates that E85 is currently available at only 1,053 of the 168,987 publicly accessible fuel stations.[51] An additional 107 private stations also provide E85 to their fleets. As shown in Figure 5-11, most of these stations are located near production facilities, in the Midwest.

[51] Energy Information Administration, *A Primer on Gasoline*, May 2007.

Figure 5-11. Location of Commercial E85 Stations, July 2007



The availability of E85 is limited by the following:

- *High infrastructure cost requirements*. Providing E85, as opposed to E10, requires a dedicated dispensing unit, either through retrofitting an existing unit or installing a new one, which typically requires installing an underground storage tank. Costs for installing a new unit approach $200,000.

- *Dispenser certification issues.* On October 5, 2006, Underwriters Laboratories (UL), an industrial equipment certifying organization, suspended its approval of dispensing equipment for fuels blended with more than 15 percent alcohol over concerns that E85's corrosive nature could result in leaks. UL is revising E85 certification requirements and will test fueling system components. Although some states have issued letters bypassing the certification requirements, the lack of UL certification currently limits the expansion of E85 stations.

  On August 2, 2007, UL announced that it will accept certification investigation requests for the gaskets and seals used in E85 dispensers. As a result, we expect that E85 stations may continue growing at historical rates in the near future.

- *Low concentration of FFVs.* Approximately 6 million of the roughly 191 million vehicles in the United States are E85 FFVs.[52] Although some areas have a higher concentrations of FFVs, generally only 3 percent of the vehicles passing by gas stations can use E85.

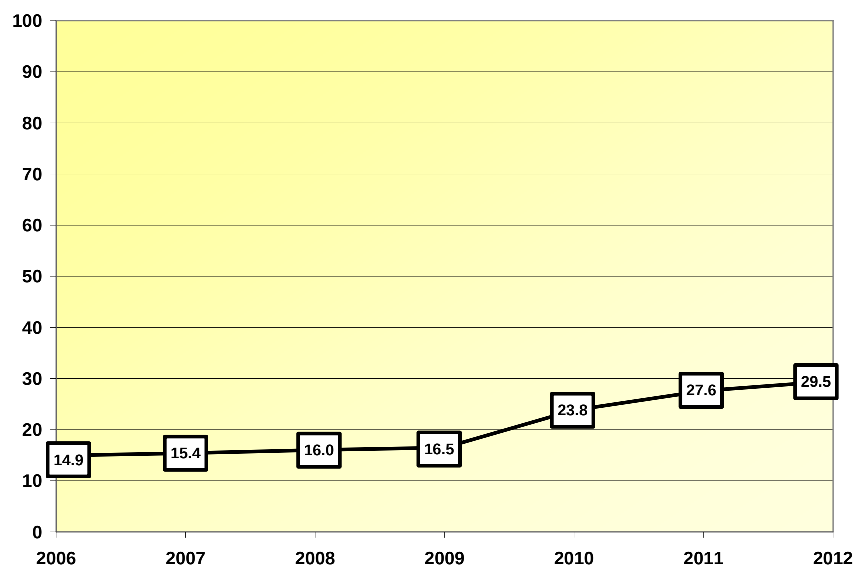
- *Price and fuel efficiency of E85 compared with gasoline*. As discussed above, because E85 gets fewer miles per gallon, it typically is sold at a discount to gasoline at the pump. Therefore, blending ethanol as E85 is less profitable than blending as E10.

- *Franchise restrictions by major oil companies*. Most major brand gas stations (Exxon Mobil, Chevron, ConocoPhillips, BP, etc.) are operated under franchise agreements with the corresponding oil company. Because none of these oil companies produce ethanol, selling E85 would reduce their sales and profitability. Therefore, oil companies include requirements in franchise agreements to prohibit the sale of E85, unless the station obtains an exemption from the oil company.

- *Transportation issues*. As discussed above, most E85 stations are located near ethanol production facilities. Transportation availability, efficiency, and cost limit the national availability of E85 fueling infrastructure.

We forecast retail sales of E85 on the basis of Energy Information Administration data. As shown in Figure 5-12, we project that E85 retail sales will increase 98 percent in 2006–12, from 14.9 to 29.5 million gallons.

Figure 5-12. Retail Sales of E85, 2006–12 (Millions of Gallons)



Source: Energy Information Administration, *Annual Energy Outlook 2007*, February 2007.

[52] Ethanol Promotion and Information Council, *E85: Your alternative fuel choice*, July 2007, http://www.drivingethanol.org/ethanol_in_vehicles/e85.aspx.

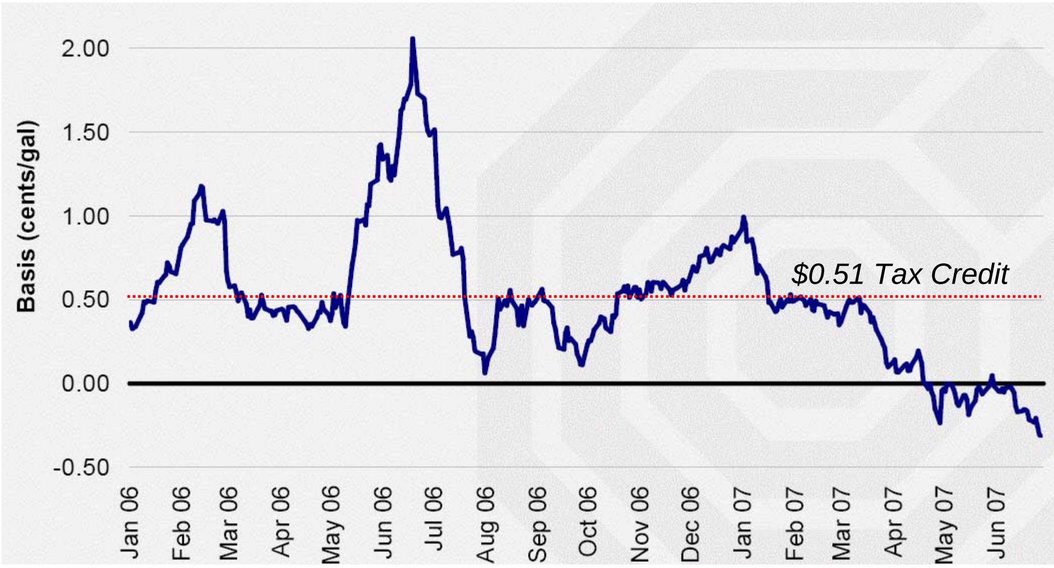
ETHANOL PRICES

Ethanol Commodity Prices

The supply of and demand for ethanol production determine the price of ethanol. When demand and production are in equilibrium, the wholesale price of ethanol is tied to the wholesale price of unleaded gasoline, maintaining a $0.51 per gallon premium based on the tax credit.[53] However, when ethanol demand and supply are unbalanced, ethanol prices begin to deviate from gasoline prices. In cases of excess demand, ethanol prices increase relative to gasoline prices, and vice-versa in cases of excess supply.

As shown in Figure 5-13, recent increases in ethanol production capacity have resulted in a temporary dip in ethanol prices below unleaded gasoline prices. As demand for ethanol in E10 catches up with production capacity, ethanol prices will return to equilibrium.

Figure 5-13. Spread between Ethanol and Unleaded Gasoline Prices



Source: Chicago Board of Trade, *CBOT® Ethanol, Key Charts & Data Updated through June 2007*, June 2007.

Retail E85 Prices

Nationally, retail prices for E85 are lower than for regular unleaded gasoline, primarily to promote E85 use and account for E85's lower energy content (and fuel efficiency). In March 2007, DOE's Clean Cities Program reported that the national average price of E85 was $0.20 (or 9 percent) lower than regular

[53] Logan Caldwell, "The Changing Ethanol Market: Implications for Stakeholders," *Energy Producer Magazine*, July 2007.

gasoline.[54] With the exception of the Central Atlantic region, E85 was cheaper than gasoline, and the largest price differential ($0.29) was on the West Coast.

Based its energy content, E85 should be priced at 72 percent of the regular gasoline price—E85 is currently priced at a premium to the consumer. Whether consumers will require a lower E85 price compared with gasoline in the future is unclear.

BIODIESEL

As shown in Table 5-6, we forecast that biodiesel use will increase 211 percent to 466 million gallons by FY12. Throughout the next 5 fiscal years, the primary factor limiting biodiesel availability is retail demand—feedstock availability may tighten closer to FY12. Production capacity is expected to far exceed retail sales of biodiesel, representing more than five times retail sales in FY12. Soybeans will be the primary feedstock in the near term, and canola oil is the other major feedstock.

Table 5-6. Biodiesel Forecasts for Each Stage of Supply Chain, 2006–12 (Millions of Gallons)

Stage	Type	2006	2007	2008	2009	2010	2011	2012
Feedstock availability	Soybeans[a]	554	587	610	635	662	684	684
	Canola[a,b]	12	20	27	35	46	60	74
	Others[a,b]	9	9	12	15	20	26	34
	Total	575	616	659	685	728	770	792
Production capacity	Soybeans[c]	746	1,181	1,616	2,052	>2,052	>2,052	>2,052
	Canola[c]	69	150	231	312	>312	>312	>312
	Others[c]	52	81	111	140	>140	>140	>140
	Total	867	1,413	1,958	2,504	>2,504	>2,504	>2,504
Commercial blending		Bottleneck is geographical availability.						
Retail sales[d]		150	173	216	270	323	388	466

[a] USDA, *USDA Agricultural Projections to 2016*, OCE-2007-1, February 2007.

[b] FAPRI at The University of Missouri, *FAPRI U.S. Baseline Briefing Book*, FAPRI-UMC Report 02-07, February 2007.

[c] National Biodiesel Board, *U.S. Biodiesel Production Capacity,* January 2007, http://www.biodiesel.org/pdf_files/fuelfactsheets/Production_Capacity.pdf.

[d] John M. Urbanchuk, *Contribution of the Ethanol Industry to the Economy of the United States,* Prepared for the Renewable Fuels Association, LECG, LLC, February 21, 2006.

Biodiesel use is limited by high production costs and retail prices, its chemical properties in colder environments, inconsistent quality, and lack of consumer acceptance. Federal regulations have created a niche market for biodiesel, but

[54] DOE, Office of Energy Efficiency and Renewable Energy, *Clean Cities Alternative Fuel Price Report*, March 2007.

until prices become consistently competitive with diesel, its demand will remain low.

Supply Chain Overview

The supply chain for biodiesel is similar to that of ethanol (Figure 5-1), except with different feedstocks. Biodiesel is produced from soybean oil, other vegetable oils, or animal fats through a process called transesterification, which separates glycerin from oil. The process generates two primary products, glycerin and biodiesel (methyl esters). In 2005, approximately 90 million gallons of biodiesel were produced in the United States, primarily from soybean oil. [55]

As of January 2007, 105 biodiesel production plants were operating at an annual capacity of 867 million gallons. Approximately 1.7 billion gallons of capacity is currently under construction, and 77 companies project completion of new construction by 2009. [56] The annual capacity to produce biodiesel will surpass an estimated 2.5 billion gallons by 2009.

Like ethanol, biodiesel cannot be transported through existing pipelines. The Energy Information Administration explains, “As a result, railroad cars and tanker trucks made from biofuel-compatible materials are needed to transport large volumes of biofuels to market.”[57]

Biodiesel is typically blended as B2 (2 percent biodiesel and 98 percent diesel), B5 (5 percent biodiesel), B20 (20 percent biodiesel), or B100 (pure biodiesel)—most biodiesel is sold as B20.

Retail sales of biodiesel have grown rapidly—in 2006, they reached 150 million gallons—and are projected to increase threefold by FY12. However, biodiesel only represents a very small fraction (0.33 percent in 2006) of U.S. diesel transportation demand.

The future growth of biodiesel depends on its acceptance by consumers and market demand for diesel. If biodiesel becomes more highly accepted by diesel fleet operators, production may increase further.

Biodiesel Feedstocks

Biodiesel can be produced from a wide array of feedstocks, including soybean and other vegetable oils, animal fats, and used or recycled vegetable oils and fats. Currently, soybean oil is the feedstock for almost all (91 percent) biodiesel

[55] See Note 9, this chapter.

[56] National Biodiesel Board, *U.S. Biodiesel Production Capacity*, January 2007, http://www.biodiesel.org/pdf_files/fuelfactsheets/Production_Capacity.pdf.

[57] See Note 9, this chapter.

production in the United States and is forecast to remain the primary feedstock through FY12.[58]

The major feedstocks that will contribute to biodiesel production over the next 5 years include the following:

- *Soybean oil*. Soybean oil is produced as a byproduct from soybean meal processing. Up to 767 million gallons of biodiesel may be produced from soybean oil by 2012.
- *Canola oil*. Canola oil is expected to provide feedstock for up to 74 million gallons of biodiesel by 2012.
- *Other fats and oils*. Other fats and oils include waste vegetable oil, animal fats, algae, and many others. These may account for up to 7 percent of feedstock used in U.S. biodiesel production by 2012.

Summary

The forecast for feedstocks for biodiesel production are as follows:

- *Soybean oil will dominate as the feedstock for biodiesel for the next 10 years.* Soybean oil will be the preferred feedstock for biodiesel in the near term due to its availability and lower production costs relative to other biodiesel feedstocks.
- *Biodiesel production capacity is unlikely to be a limiting factor in the future.* However, feedstock cost will greatly influence sales and production.

Feedstock Yields and Costs

The economics of biodiesel production primarily depend on the cost of the feedstock. Feedstocks costs are the largest component of biodiesel production costs—the Iowa State Center for Industrial Research and Service estimates that feedstock costs constitute 72 percent of total biodiesel production costs.[59] Table 5-7 and Figure 5-14 compare wholesale production costs for biodiesel produced from different feedstocks.

[58] John M. Urbanchuk, *Contribution of the Biodiesel Industry to the Economy of the United States*, Prepared for the National Biodiesel Board, LECG, LLC, June 19, 2006.

[59] Rudy Pruszko, *PowerPoint Presentation: Biodiesel Basics—How it Works & What it Costs*, Center for Industrial Research and Service, Iowa State University Extension.

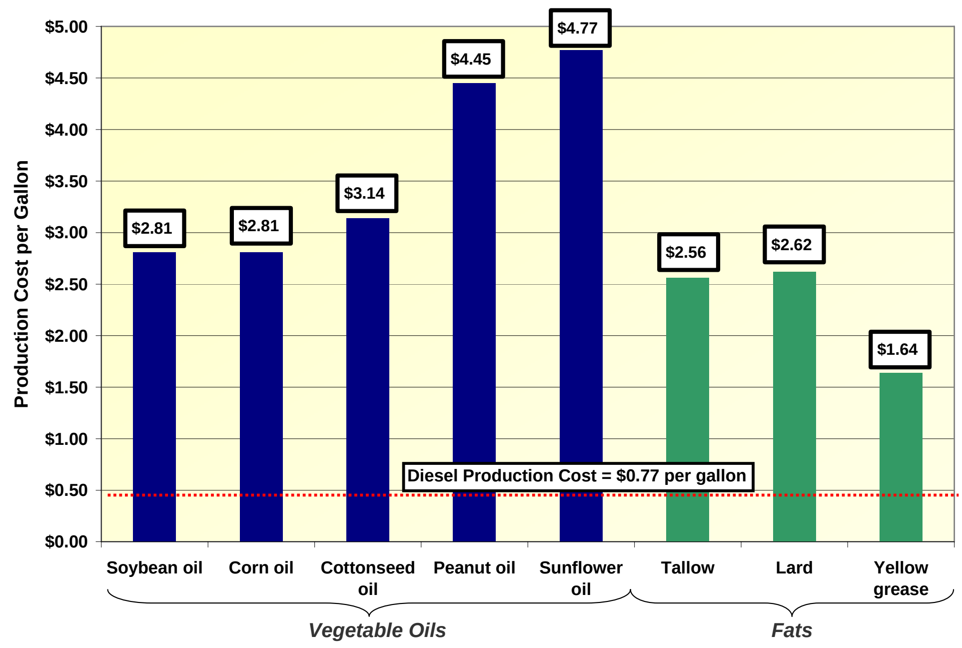
Table 5-7. Comparison of Biodiesel Production Costs by Feedstock

Feedstock	Wholesale feedstock price ($ per pound)	Wholesale feedstock price ($ per gallon of biodiesel)	Biodiesel production cost ($ per gallon)	Biodiesel wholesale cost ($ per gallon)
Soybean oil	0.3100	2.33	0.48	2.81
Corn oil	0.3100	2.33	0.48	2.81
Cottonseed oil	0.3550	2.66	0.48	3.14
Peanut oil	0.5299	3.97	0.48	4.45
Sunflower oil	0.5725	4.29	0.48	4.77
Tallow	0.2775	2.08	0.48	2.56
Lard	0.2850	2.14	0.48	2.62
Yellow grease	0.1520[a]	1.16[a]	0.48	1.64

Sources: USDA, *Oil Crops Outlook*, OCS-07g, August 13, 2007; Congressional Research Service, *Biodiesel Fuel and U.S. Agriculture*, RS21563, July 7, 2003; Anthony Radich, *Biodiesel Performance, Costs, and Use*, June 8, 2004, http://www.eia.doe.gov/oiaf/analysispaper/biodiesel/index.html; Vernon R. Eidman, "Renewable Liquid Fuels: Current Situation and Prospects," *Choices Magazine*, 1st quarter 2006.

[a] Yellow grease prices are typically 49 percent of soybean oil prices.

Figure 5-14 Comparison of Biodiesel Production Costs by Feedstock



Of the vegetable oil feedstocks (soybean, corn, cottonseed, peanut, and sunflower oils), soybean and corn are the most cost competitive for biodiesel production. Because it is more cost-effective to convert corn into ethanol than biodiesel, corn oil is not a major feedstock for biodiesel.

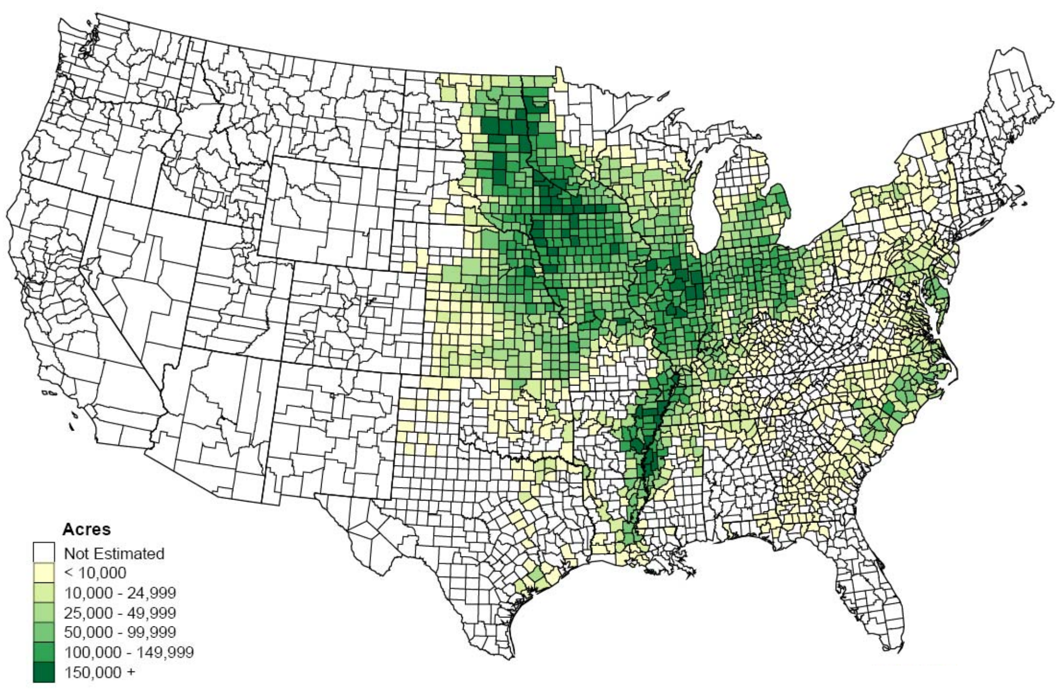
Although production costs from fats are lower than for vegetable oils, supply availability and fuel quality issues limit the potential from these feedstocks. Currently, DoD excludes the procurement of biodiesel produced from animal fats due to the poor cold weather performance (gelling) of such blends relative to that of biodiesel produced from vegetable oils.

Wholesale production costs for biodiesel ($1.64 to $4.77 per gallon) are significantly higher than production costs for diesel produced from crude oil ($0.77 per gallon). Currently, high subsidy levels enable biodiesel to remain cost competitive with diesel in retail markets.

Soybean Oil

USDA reported that in 2006, 72.0 million acres of soybeans were planted, yielding 3,063 million bushels (or 43 bushels per acre). As shown in Figure 5-15, the majority of this acreage is located in the Midwest and Mid-Atlantic states.

Figure 5-15. Planted Acres of Soybeans by County (2005)



Source: USDA, National Agricultural Statistics Service, July 2007.

From USDA and NCGA data, we project that soybean oil potentially available annually for biodiesel production will increase from 4,165 to 5,145 million pounds between 2006 and 2012. This increase is projected even though soybean acreage is expected to decline, due to demand for acreage for growing corn.[60] On the basis of a standard conversion rate of 1 gallon per 7.5 pounds, we project the

[60] See Note 14, this chapter.

potential biodiesel that can be produced from soybean oil to increase 24 percent, from 554 to 684 million gallons between 2006 and 2012 (Table 5-8).

Table 5-8. Forecast of Potential Biodiesel Production from Soybean Oil, 2006–12

Category	2006	2007	2008	2009	2010	2011	2012
Soybean oil produced (millions of pounds)	20,115	20,500	20,815	21,126	21,445	21,725	22,025
Projected use of soy for food (millions of pounds)	15,950	16,090	16,231	16,348	16,464	16,580	16,880
Soy available for biodiesel use (millions of pounds)	4,165	4,410	4,584	4,778	4,981	5,145	5,145
Potential biodiesel production from soy (millions of gallons)	554	587	610	635	662	684	684

Source: USDA, *USDA Agricultural Projections to 2016,* OCE-2007-1, February 2007.

The Energy Information Administration has explained why soybean oil dominates as a feedstock for biodiesel production:

> Soy is a versatile, nitrogen-fixing crop that yields oil and food for humans and livestock. Soybean meal is of higher market value than soy oil. Consequently, soy oil is a low-priced byproduct available in relatively large volumes. Currently, it is a cheaper virgin feedstock than other oilseeds. The processing and distribution infrastructure for soybeans is already in place, with more capacity being added as more biodiesel production facilities come online.[61]

Although the potential for biodiesel production from soybean oil was 554 million gallons in 2006, only 136 million gallons of biodiesel was produced. The production represents roughly 370 million bushels of soybeans, or 10.6 percent of all soybeans harvested in the United States.[62]

Production of biodiesel from soybeans is not expected to significantly impact the food markets. The primary feedstock for biodiesel production is surplus soybean oil, which is generated as a coproduct from soybean meal production. However, at annual biodiesel production levels between 300 and 600 million gallons, high demand for soybean oil may raise the wholesale price of soybeans.[63]

Increased biodiesel production may also affect the market for glycerin. Roughly 10 pounds of crude glycerin is generated as a coproduct for every 100 pounds of biodiesel production. The amount of glycerin generated by a 300 to 600 million gallon per year biodiesel industry could result in substantial oversupply

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[61] National Sustainable Agriculture Information Service, http://attra.ncat.org/attra-pub/PDF/biodiesel_sustainable.pdf.

[62] DOE, *Biomass Energy Data Book: Edition 1*, ORNL/TM-2006/571, Prepared by Oak Ridge National Laboratory for EERE, September 2006.

[63] See Note 9, this chapter.

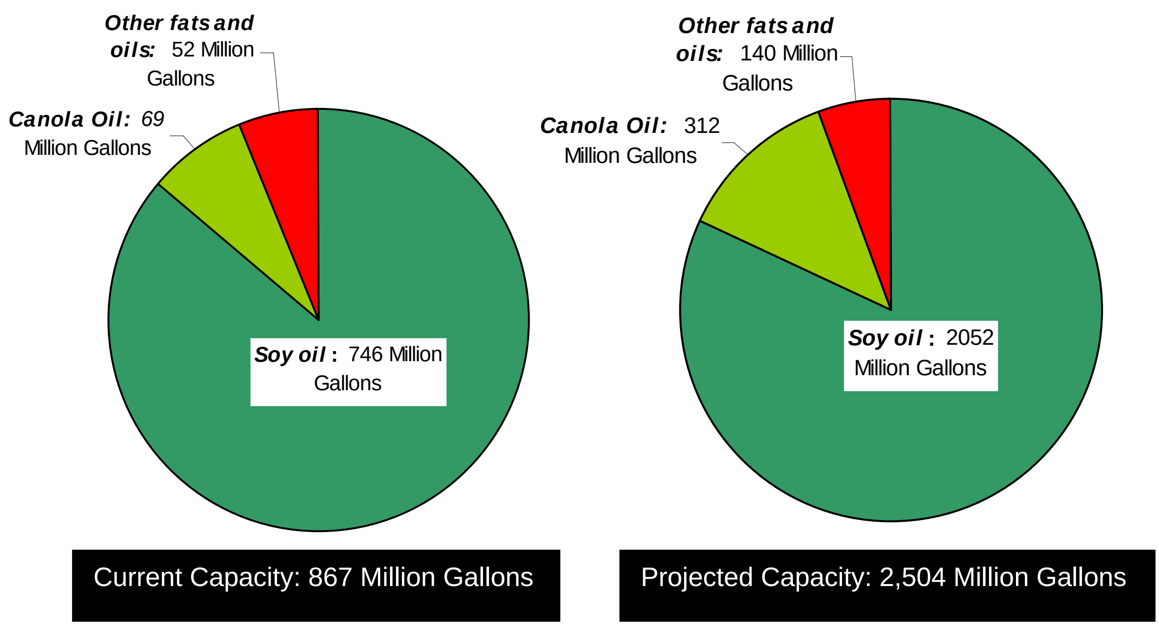
(amounting to roughly 50 percent of the current 692 million pounds of glycerin produced domestically in North America).[64]

Biodiesel Production

Biodiesel annual production capacity currently exceeds the amount of biodiesel produced.[65] The National Biodiesel Board reports that as of January 2007, the annual operational capacity of the biodiesel industry in the United States was 867 million gallons (105 plants). Approximately 1.7 billion gallons of new capacity is under construction, and 77 companies project completion of new construction by 2009.[66]

Currently, most biodiesel refinery capacity uses soybean oil as the primary feedstock—746 million gallons (or 86 percent) of the 867 million gallons of total capacity. This will continue in the foreseeable future, as most (80 percent) of the planned expansion of production capacity represents soybean oil feedstocks. As shown in Figure 5-16, after planned capacity comes online, biodiesel production from soybeans will represent 2,052 million gallons (or 82 percent) of the 2,504 million gallons of total biodiesel refining capacity.

Figure 5-16. Capacity of Current and Planned Biodiesel Refineries by Feedstock

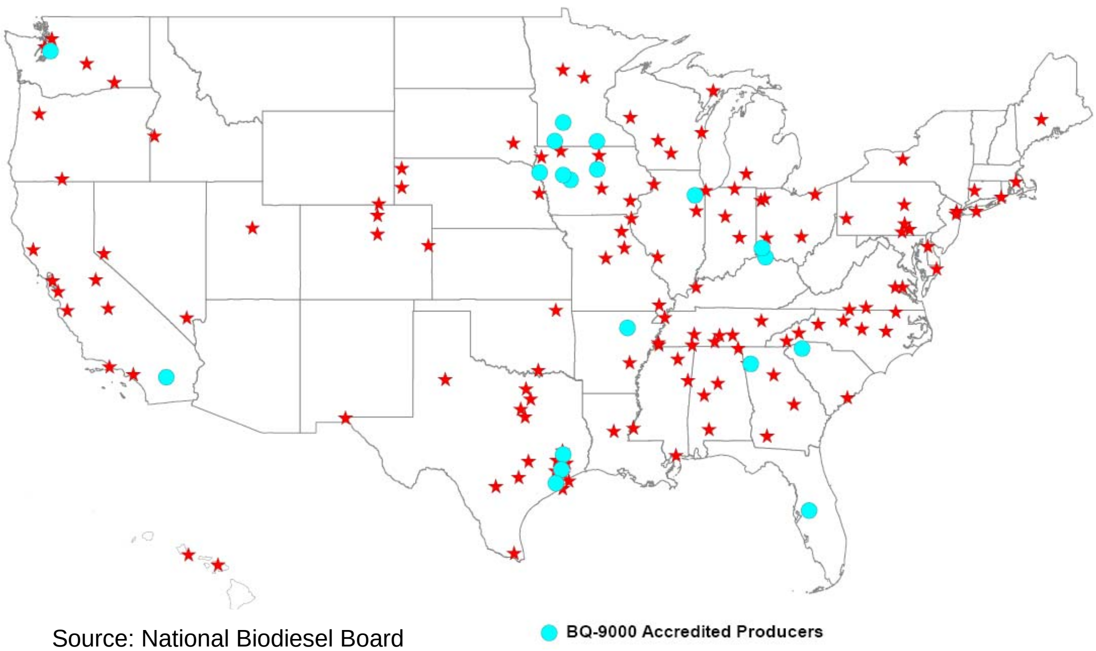


[64] See Note 9, this chapter.
[65] See Note 60, this chapter.
[66] See Note 57, this chapter.

PRODUCTION LOCATION

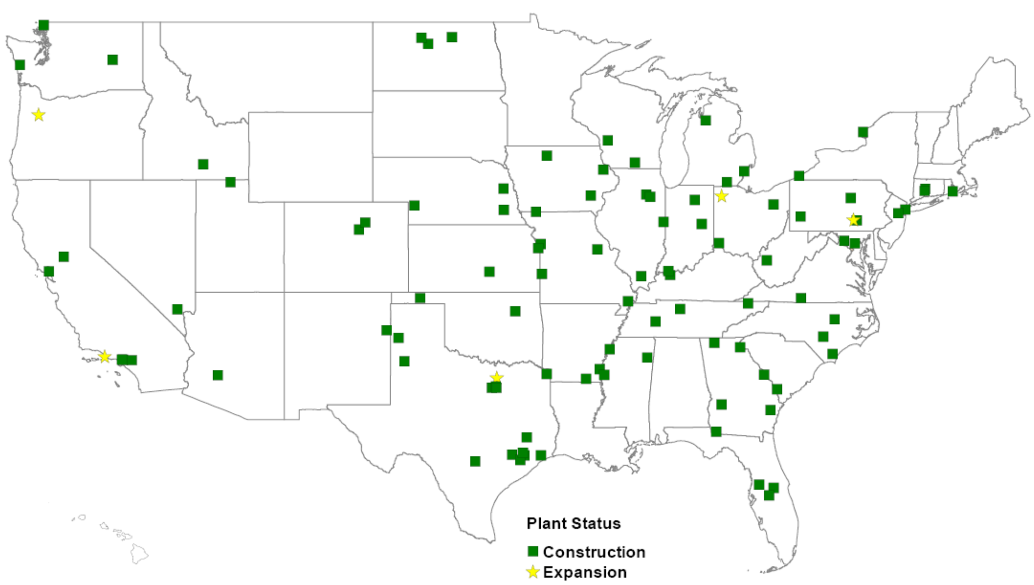
Most biodiesel refineries are located in the Midwest and Mid-Atlantic, near the primary feedstock source (Figure 5-17). There are some exceptions, as biodiesel refineries are also concentrated in areas such as California and Texas. It appears that expanded plants will be located in similar areas as well (Figure 5-18).

Figure 5-17. Locations of Current Biodiesel Production Plants (June 2007)



Source: National Biodiesel Board

Figure 5-18. Locations of Planned Biodiesel Production Plants (June 2007)

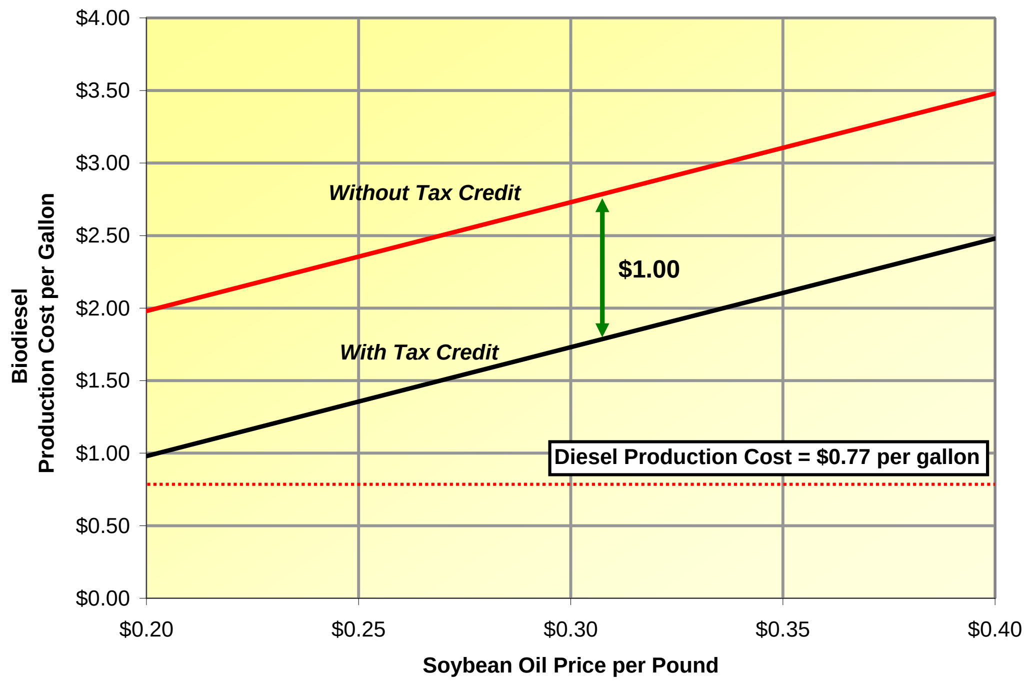


Source: National Biodiesel Board

PRODUCTION COSTS

As discussed above, feedstock costs represent most (72 percent) of the total production cost of biodiesel. As shown in Figure 5-19, the production cost of biodiesel rises and falls with the price of soybean oil. At the current price of that oil ($0.31 per pound), the net production cost of biodiesel is $2.81 per gallon.

Figure 5-19. Net Biodiesel Production Costs and Commodity Price of Soybean Oil



Section 302 of the American Jobs Creation Act of 2004 (extended by Section 1344 of EPAct 2005) established biodiesel producer tax credits of $1.00 per gallon for "agri-biodiesel" (biodiesel produced from agricultural products such as soybean oil or animal fats), or $0.50 per gallon for biodiesel produced from other sources (e.g. recycled vegetable oil). These tax credits will be in effect through December 31, 2008.

EPAct 2005 also established the Small Agri-Biodiesel Producer Credit for agri-biodiesel producers with annual production capacities less than 60 million gallons. This credit provides an income tax credit of $0.10 for each gallon of agri-biodiesel produced in a tax year.

Biodiesel Transportation

Biodiesel transportation encounters issues similar to ethanol—rail tank cars and tanker trucks have limited availability, and a pipeline transportation alternative is lacking. The lower production and distribution volumes for biodiesel compared with ethanol compound the transportation issues in that diseconomies of scale are accentuated. However, biodiesel production and point of sale are generally more dispersed than for ethanol, which could help support faster development of transportation infrastructure.

Biodiesel Blending

Biodiesel distribution is complicated by storage challenges, blending limitations, and physical state issues. Pure biodiesel (B100) is believed to degrade to below acceptable quality if stored for periods of more than 6 months.[67] Biodiesel can also dissolve accumulated sediments in storage and engine fuel tanks, so tanks must be cleaned thoroughly before biodiesel is added. These dissolved sediments could cause eventual fuel injection failure.[68] The National Biodiesel Board recommends, “B100 be shipped in a way that does not lead to contamination. The association says trucks and/or railcars should be washed out before being loaded—and the only residual that is acceptable in a tanker is petroleum diesel.”[69]

The Energy Information Administration handling guide reports,

> As demand for biodiesel increases, petroleum terminals and pipeline racks are installing biodiesel blending capability so that jobbers and distributors can receive a biodiesel blend directly at the rack and store and distribute only the blended biodiesel. This finished blend can then be sold to fleet or other applications that have some type of on-site storage. Even more recently, there are an increasing number of public pumps and key card pumps that are carrying biodiesel blends for individual users or for fleets who do not have their own on-site storage capability. As the market matures and volumes continue to increase, it is likely that the actual point of blending will occur further and further upstream in the distribution system.[70]

Biodiesel can be blended with petroleum diesel at any concentration to produce a biodiesel blend. At blends of 20 percent and lower, the fuel can be treated just like conventional diesel. Biodiesel can be blended by one of three primary methods:

- B100 (100 percent biodiesel) splash blended with diesel fuel by the end user
- Blended by a jobber or distribution company and offered for sale as a finished blend
- Blended at a petroleum terminal or rack by a pipeline or terminal company and offered as a finished blend. This product is sold directly to customers

[67] DOE, *Biodiesel Handling and Use Guidelines*, DOE/GO-1-2006-2358, EERE, September 2006.
[68] See Note 68, this chapter.
[69] Nicholas Zeman, “From the plant to the pump,” *Biodiesel Magazine*, 2007.
[70] See Note 68, this chapter.

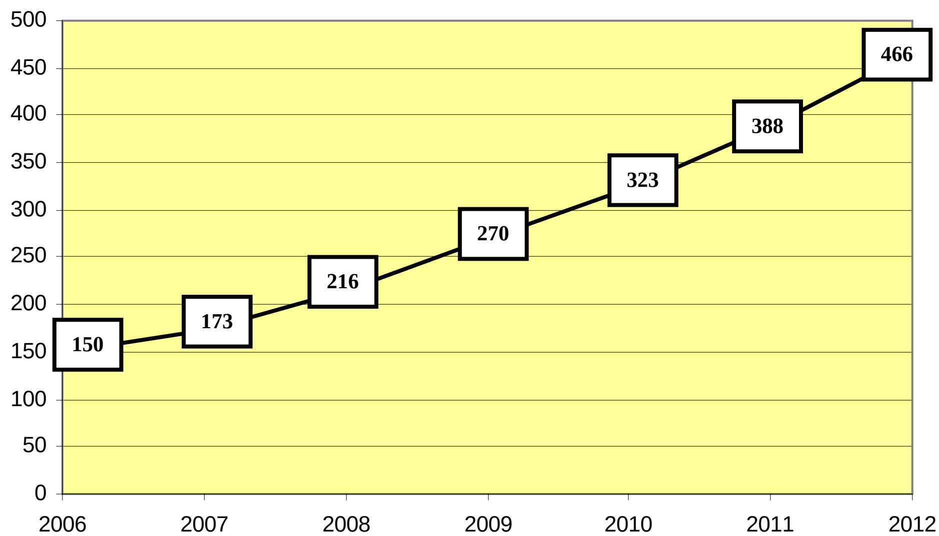
or to a petroleum jobber or distribution company for further sale to customers.[71]

Biodiesel Retail Sales

Although biodiesel retail sales have grown significantly since 2000, consumer concerns over the image of diesel as a dirty fuel, biodiesel's performance issues in cold weather, and uncertainty over biodiesel's impact on engine warranties have hindered growth. New ULSD regulations passed in October 2006 may help to combat the negative image of diesel, and biodiesel's lubricity characteristics may encourage the use of the fuel as an additive to correct ULSD's low lubricity.

We forecast retail sales of biodiesel on the basis of LECG data. As shown in Figure 5-20, we project biodiesel retail sales to increase 211 percent in 2006–12, from 150 to 466 million gallons. Most of this biodiesel will be blended and sold as B20.

Figure 5-20. Retail Sales of Biodiesel, 2006–12 (Millions of Gallons)



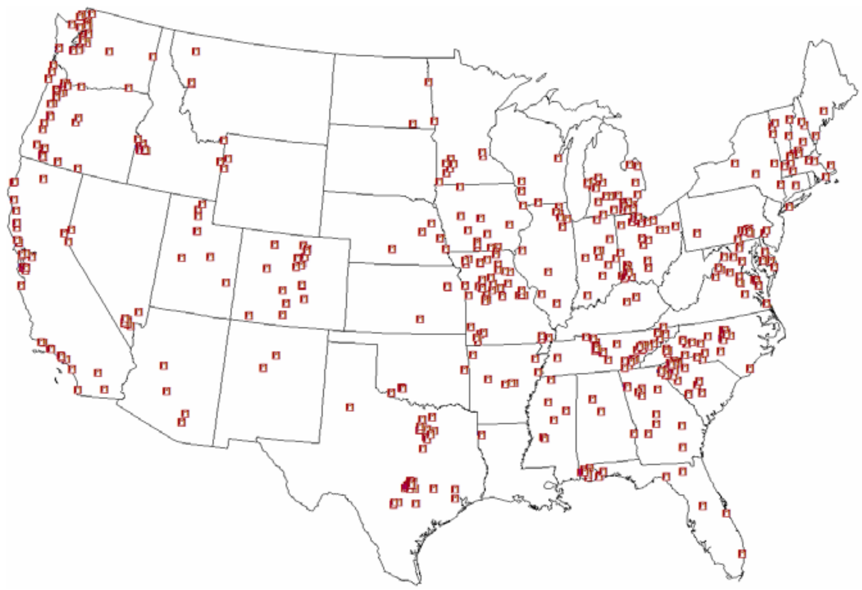
John M. Urbanchuk, *Contribution of the Biodiesel Industry to the Economy of the United States,* Prepared for the National Biodiesel Board, LECG, LLC, June 19, 2006.

DOE estimates that B20 is available today at only 638 of the 168,987 publicly accessible fuel stations.[72] An additional 165 private stations provide biodiesel to their fleets. Unlike E85 stations, which are concentrated near production facilities, B20 stations are more dispersed throughout the United States (Figure 5-21).

[71] See Note 68, this chapter.

[72] Energy Information Administration, *A Primer on Gasoline*, May 2007.

Figure 5-21. Location of Commercial B20 Stations, July 2007



BIODIESEL WARRANTY ISSUES

Some vehicle owners and operators express concern over the warranty impacts of using biodiesel in their diesel vehicles. Most engine and vehicle manufacturers will not cover damage caused by an external condition, such as the quality of fuel used in the vehicle. However, the National Biodiesel Board explains, "If an engine that uses biodiesel experiences a failure unrelated to biodiesel use, it must be covered by the OEM's warranty. Federal law (The Magnuson Moss Act), prohibits the voiding of a warranty just because biodiesel was used—it has to be the cause of the failure."

BIODIESEL RETAIL PRICES

B20 is competitively priced compared with diesel. Unlike ethanol, B20 has a comparably high energy content to diesel—98.2 percent the energy content. At current prices, the implied price of B20 at the pump is $2.58,[73] yet it is currently being sold at $2.53. Therefore, B20 is currently cheaper on an energy content basis than diesel.

FEDERAL LEGISLATION

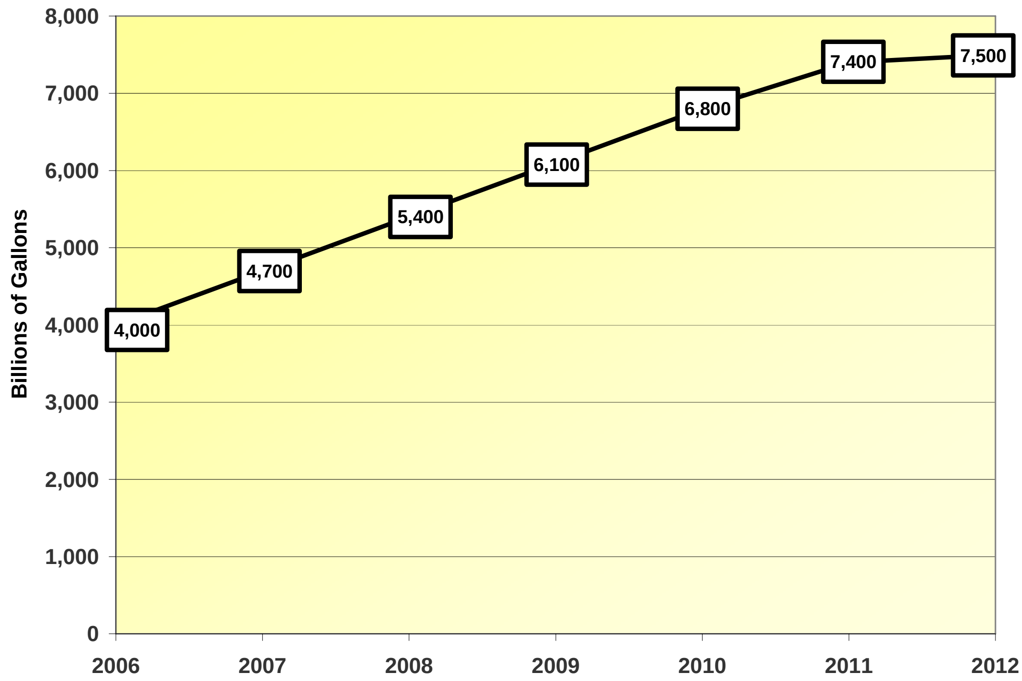
Renewable Fuels Standard

The RFS is the primary regulation driving the production of biofuels in the United States. The RFS program was established by EPAct 2005 (amending the Clean Air Act) to encourage the production of renewable fuels (including ethanol and

[73] See Note 55, this chapter.

biodiesel) for motor vehicles. The RFS program establishes volumetric requirements for the production of renewable fuels in the United States (Figure 5-22).

Figure 5-22. RFS Requirements, 2006–12



Under the RFS program, any producer or importer of gasoline within the continental United States is required to meet the RFS. The standard is calculated as a percentage of the total fuel produced (or imported), referred to as renewable volume obligations (RVOs). Companies that do not produce or import renewable fuels can trade for RFS compliance using renewable identification numbers (RINs).

Recently Passed Legislation

Two bills, H.R. 6 and H.R. 3221, have been passed (in one or both the houses of Congress), with potential to affect the composition of federal fleets and the availability of biofuels. If signed into law, these two bills will likely (1) expand biofuels infrastructure by requiring each federal agency to install one renewable pump at each federal fleet fueling center and (2) increase the number of hybrid vehicles in the federal fleet by amending EPAct to define medium and heavy duty hybrid vehicles as AFVs.

RENEWABLE FUELS, CONSUMER PROTECTION, AND ENERGY EFFICIENCY ACT OF 2007 (H.R. 6)

H.R.6 will provide expand the definition of EPAct credits to include hybrid electric vehicles (HEVs), PIH electric vehicles (PHEVs), and electric vehicles (all vehicles, whether light duty, medium duty, or heavy duty would receive credits).

The House version of this bill includes measures to change the definition of "alternative fuel vehicle" to include medium and heavy duty hybrid vehicles. The Stupak amendment to the House version requires each federal agency to install one renewable pump at each federal fleet fueling center. The Senate version of this bill would give EPAct credits (up to five) for infrastructure development or investment in alternative fuel technologies.

Status: Passed by both House and Senate. Currently in Conference to resolve House and Senate differences.

NEW DIRECTION FOR ENERGY INDEPENDENCE, NATIONAL SECURITY, AND CONSUMER PROTECTION ACT (H.R. 3221)

This bill, passed immediately before the August recess, has many measures that would affect DoD and other federal fleets if it becomes law. It would require at least one renewable fuel pump at each federal fleet fueling center in the United States. Section 6201 of the bill mandates that federal agencies shall acquire only "low greenhouse gas emitting" light duty or medium duty passenger vehicles. The bill amends EPAct to include medium and heavy duty hybrid vehicles as AFVs. EPAct credits would be expanded to cover HEVs, plug-in hybrid vehicles, fuel cell vehicles (FCVs), neighborhood electric vehicles (NEVs), and medium or heavy duty versions of any of these vehicles.

Status: Passed by the House and sent to the Senate.

Pending Legislation

Currently, there are many bills introduced in Congress that also would affect the composition of federal fleets and the availability of biofuels. While most of the projections in this report are based on current legislation, this section briefly addresses the proposed changes and some of their impacts on biodiesel and ethanol use by the DoD NTV fleet.

FEDERAL FLEETS

The following provisions affect federal fleets:

- Senate (S.) 1554.IS and S.1115 require federal fleets to achieve a 30 percent reduction in petroleum consumption between 2005 and 2016.

- S.1554.IS requires that by 2016, 30 percent of covered AFVs (under EPAct) shall be hybrid vehicles.
- S. 339 and H.R. 670 converts the E.O. 13423 petroleum reduction and alternative fuel use requirements into law.
- H.R. 2809 increases the required percentage of light duty covered fleet acquisitions from 75 percent to 100 percent by 2008.

AVAILABILITY OF BIOFUELS

The following provisions affect the commercial availability of biofuels:

- S.23.IS and H.R. 559 IH increase the RFS to 10 billion gallons in 2010, 30 billion gallons in 2020, and 60 billion gallons in 2030.
- S.133.IS and H.R. 2354 IH promote the increase of the domestic production of cellulosic biomass ethanol to reach 250 million gallons by 2012.
- H.R. 2809 requires that major oil companies install E85 pumps at 5 percent of their stations by 2008, and increase this percentage by 5 percent annually. S.23.IS and H.R. 559 IH require that 50 percent of major oil company stations install an E85 pump.
- HR 1300 IH requires DOE to identify areas where alternative fuels are “not readily available” and install infrastructure accordingly.
- S.133.IS and H.R. 2354 IH expand incentives to reduce the retail price of alternative fuels.

Chapter 6
Analysis Framework

DoD's use of biofuel is primarily limited by its utilization in biofuel-capable vehicles and availability of biofuel infrastructure. Actions available to DoD for increasing its use of biofuel in biofuel-capable NTVs through FY12, in order of priority, are as follows:

1. Increase the use of the commercial biofuel infrastructure.

2. Promote the expansion of new commercial biofuel infrastructure near DoD fleet locations.

3. Install new biofuel infrastructure at DoD exchange gas stations.

4. Install new biofuel infrastructure at DoD installation fueling locations.

This chapter presents the framework and approach for estimating DoD's potential increase in biofuels from implementing these actions.

COMMERCIAL INFRASTRUCTURE

Increasing Consumption

Increased use of commercial biofuel stations is the easiest and lowest-cost alternative for DoD to increase its consumption of biofuel. Taking this opportunity only requires that DoD establish internal processes and controls to ensure biofuel-capable vehicle operators refuel at biofuel stations when nearby. Costs include increased management oversight and vehicle relocation to concentrate biofuel-capable vehicles near the commercial biofuel stations.

DoD has four primary opportunities to increase biofuel use at commercial infrastructure:

- *Ensure purchase of biofuel when fueling at commercial biofuel stations.* We estimate that DoD is using biofuel in only 46 percent of fuel transactions by biofuel-capable vehicles at existing biofuel stations. This means that 54 percent of the time, E85 FFVs and diesel vehicles refuel with gasoline or diesel (respectively) when using commercial biofuel stations. DoD can almost double biofuel use by ensuring that operators fill their biofuel-capable vehicles with biofuel at commercial stations.

- *Divert fueling of biofuel-capable vehicles to nearby commercial biofuel stations.* EPAct 2005 requires federal fleets to use only E85 in E85 FFVs unless E85 is not reasonably available (cannot be obtained within 5 miles or a 15-minute drive). Therefore, DoD is mandated to divert FFVs to E85 stations if within 5 miles or a 15-minute drive. In keeping with the intent of EPAct 2005, DoD may also increase B20 use by diverting diesel vehicles to commercial B20 stations if within 5 miles or a 15-minute drive.

- *Locate E85 FFVs near commercial E85 stations.* In FY06, FFVs constituted roughly 38 percent of all gasoline-capable vehicle refueling transactions. The maximum concentration of E85 FFVs at a specific location is 77 percent of all gasoline vehicles (on the basis of the maximum acquisition scenario in Chapter 4). Therefore, by deploying the maximum concentration of E85 FFVs near commercial E85 stations, DoD may increase E85 consumption by 103 percent.

  Relocation of existing vehicles is cost prohibitive. Therefore, this action consists of replacing or purchasing new E85 FFVs near commercial E85 stations through the normal acquisition and replacement process.

- *Use new commercial biofuel stations when available*. Although representing less than 1 percent of all commercial stations, the number of biofuel stations has been growing rapidly over the last few years. For example, the number of E85 stations has grown from less than 200 in 2004 to more than in 1,053 in July 2007—last year, the number of E85 stations grew 48 percent.

  As new E85 and B20 stations open, DoD can increase E85 and B20 use by diverting refueling of biofuel-capable vehicles at nearby stations to the new biofuel stations. The potential locations of these stations are unknown, so the magnitude of the impact on DoD's use of biofuel is uncertain.

  Recent growth in commercial E85 stations has been limited by the October 2006 certification suspension by UL for individual parts that compose an E85 fuel dispenser. On August 2, 2007, UL announced that it will accept certification investigation requests for the gaskets and seals used in E85 dispensers. As a result, we expect that the number of E85 stations will continue to grow in the foreseeable future.

Promoting Expansion

In a perfect world, biofuel commercial infrastructure would expand to serve all DoD fleet locations, enabling full use of biofuel by biofuel-capable vehicles—all at minimal cost to the federal government. However, DoD cannot require or enter into contracts for new commercial biofuel stations to open near DoD NTV fleet locations. DoD must instead coordinate with state, local, and private entities to promote the expansion and use of publicly accessible biofuel stations.

By publicizing the locations and concentrations of its E85 FFV and diesel NTV fleets, DoD can encourage private entities to invest in nearby biofuel infrastructure. Private gas station operators understand that Section 701 will require DoD FFVs to use nearby commercial E85 stations. Coupled with information on the size and locations of the DoD NTV fleet, private entities may see a positive business case for building a commercial biofuel station near DoD fleet locations (without any contracts or guarantees from DoD).

FUNDING RESOURCES

The federal government provides funding assistance for commercial stations to install new biofuel infrastructure through tax credits. EPAct 2005, Section 1342, provides commercial stations a tax credit equal to 30 percent of the cost of E85 and B20 refueling property, up to $30,000. The credit is currently effective through December 31, 2009.

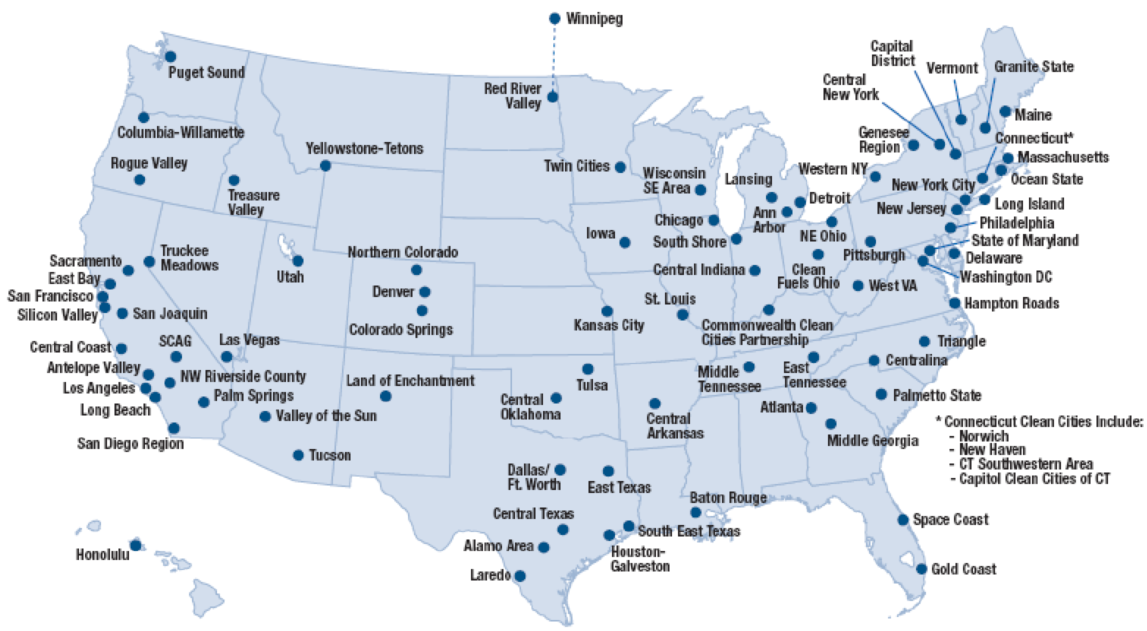
Some states also provide funding assistance for new biofuel infrastructure:

- *New York*. The New York State Energy Research and Development Authority offers reimbursement of 50 percent of the costs (up to $50,000 per site) for new installation of biofuel infrastructure.
- *Idaho*. The Rural Idaho Economic Development Biofuel Infrastructure Matching Grant Fund provides grants for up to 50 percent of new biofuel infrastructure costs.
- *Illinois.* The Illinois Clean Energy Community Foundation provides (1) up to 50 percent of the costs for converting an existing pumping system to E85 (up to $3,000 per facility), or (2) up to 30 percent of the costs for new installation of E85 infrastructure (up to $30,000 per facility).
- *Indiana.* The E85 Fueling Station Grant Program provides grants of up to $5,000 for installation of new E85 infrastructure or the conversion of existing infrastructure for E85.
- *Michigan.* The Michigan Strategic Fund provides grants for (1) up 75 percent of the costs to convert existing refueling infrastructure to E85 or B20 (up to $3,000 per facility) and (2) up to 50 percent of the costs for new installation of E85 or B20 infrastructure (up to $12,000 per facility for E85 and $4,000 per facility for B20).

DOE'S CLEAN CITIES PROGRAM

DOE's Clean Cities program is a valuable resource for promoting the expansion and use of publicly accessible biofuel stations. "Clean Cities is a government-industry partnership designed to reduce petroleum consumption in the transportation sector by advancing the use of alternative fuels and vehicles."[1] The organization, established in 1993 under EPAct 92, currently includes 85 active local coalitions, serving roughly 63 percent of the U.S. population.[2] Figure 6-1 shows the locations of these active local coalitions.

Figure 6-1. Local Clean Cities Program Coalitions



Source: DOE, *Clean Cities Fact Sheet*, EERE, March 2007.

Fort Hood Example

One example of DoD's promoting the expansion of commercial biofuel infrastructure is the opening of the "Here Everything's Better" (HEB) E85 station in Killeen, TX, near the gates of Fort Hood.

For a year and half, the U.S. Army, Central Texas Clean Cities program, National Ethanol Vehicle Coalition (NEVC), Clean Fuel USA, and HEB worked together to bring E85 fuel to the Killeen and Fort Hood area. The primary reason for pursuing E85 infrastructure was Fort Hood's air sustainability goals—increasing E85 use in FFVs helps reduce emissions from vehicles, Fort Hood's largest pollution source.

In 2006, the HEB grocery store chain decided to open E85 pumps at five of its locations along IH-35 in Texas. At the time, about 450,000 Texas drivers owned

[1] DOE, *Clean Cities Fact Sheet*, EERE, March 2007.

[2] Marcy Rood, Director Clean Cities Coalitions, U.S. DOE, *Presentation at SAE Government-Industry Meeting: Clean Cities, Program Overview*, May 14, 2007.

FFVs, but no infrastructure existed. HEB saw a profitable business opportunity in providing E85 fueling stations in Texas.

HEB chose to install E85 pumps at its Killeen location due to the concentration of E85 FFVs stationed at Fort Hood (roughly 200 vehicles) and its proximity to the post. The business case for HEB was solidified by the EPAct 2005 (Section 701) requirement mandating the use of E85 infrastructure by DoD's FFVs.

The Army's recent success in utilizing the HEB E85 stations resulted from cooperation between internal organizations responsible for fleet management. The Logistics Department, which controls the vehicle fleet, is coordinating with the Environmental Department, which supports fueling the fleet at the HEB E85 pumps.

HEB is also reaping the benefits of installing E85 pumps in Killeen. First, the E85 station has drawn business from both the DoD and private FFV owners. Second, gasoline sales have also been increasing, perhaps from support for HEB's efforts to provide a renewable fuel source.

DoD's success in promoting new commercial E85 infrastructure near Fort Hood can be replicated near other DoD installations. Success requires the following:

- Developing partnerships to promote installation of biofuel infrastructure, such as with DOE's Clean Cities Program, NEVC, and the National Biodiesel Board
- Communicating the business opportunities, including the concentration of DoD E85 FFVs, to private entities
- Promoting internal communication to ensure use of the commercial biofuel infrastructure.

DoD Exchanges

The DoD exchange organizations—AAFES, Navy Exchange Command (NEXCOM), and Marine Corps Exchange (MCX)—operate gas stations at most large DoD installations, with multiple locations at the larger installations. DoD exchange locations are preferable to DoD installation fueling locations for DoD biofuel infrastructure for the following reasons:

- *Economies of scale.* Because personal vehicles of active duty, guard, and reserve members, military retirees, and their families use DoD exchange gas stations in addition to DoD NTVs, the potential use of biofuel pumps at DoD exchanges is greater than at DoD installation locations.

- *Accessibility*. DoD exchanges are typically located close to gates, providing easier accessibility for DoD NTV fleets that at DoD installation locations.

- *Convenience*. Most DoD-leased vehicles use Voyager cards, most of which are prepaid through "wet-lease" arrangements with GSA. Since DoD exchanges accept Voyager cards and DoD installations require a separate VILKEY account, fueling at DoD exchanges is typically more convenient for DoD-leased vehicles.

DoD Installations

Most DoD NTVs that use DoD installation fueling infrastructure typically remain on base. Therefore, diverting the refueling of these vehicles to commercial biofuel stations or DoD exchanges is inconvenient and potentially costly.

DoD could increase its consumption of biofuel on DoD installations by installing new biofuel infrastructure at existing installation refueling locations. The alternatives available to DoD for developing new biofuel infrastructure on installations include the following:

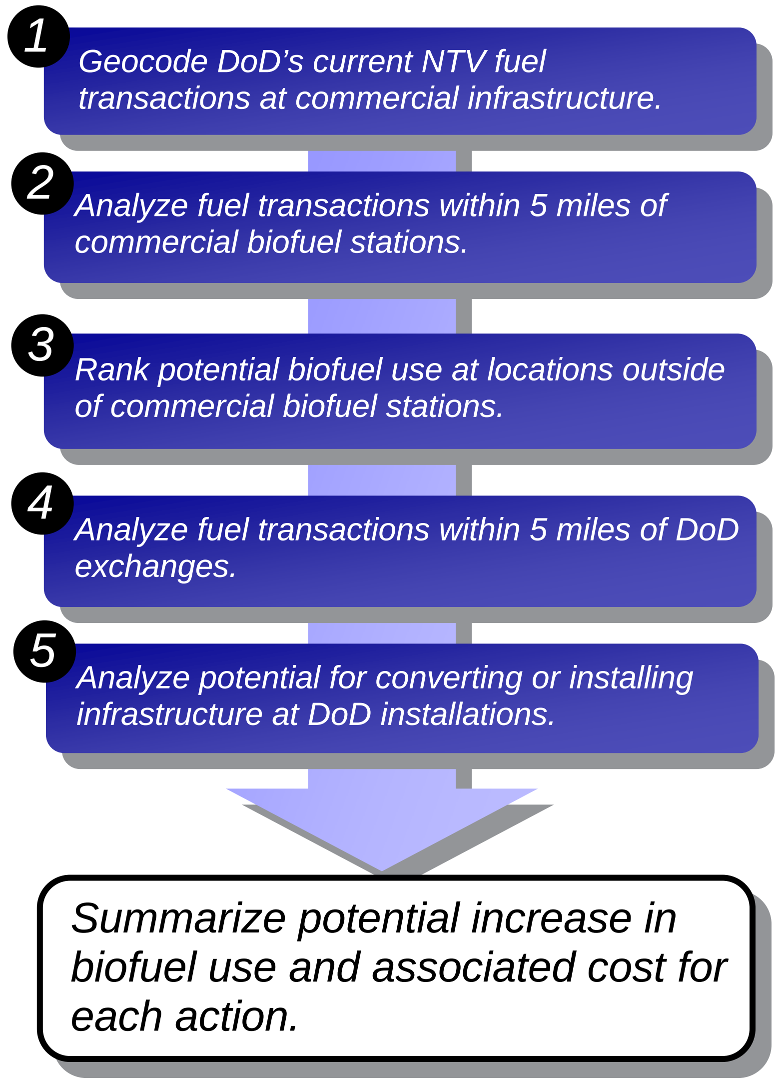
- *Convert an existing tank system to biofuel*. At refueling sites with more than one gasoline or diesel tank, DoD can convert one of the tank systems to biofuel. The costs for this alternative are typically only a fraction of the costs for installing a new tank system. Conversion of existing tank systems includes cleaning the tank and lines, ensuring fuel lines and dispenser components are compatible with biofuel, and calibration of the fuel metering system.

- *Install a new tank system*. Since installations cannot use biofuel in tactical vehicles, DoD must install a new tank system at refueling sites with only one gasoline or diesel tank. This is the most costly of the alternatives, involving installation of a new storage tank and associated equipment, as well as related excavation, concrete, and electrical work.

Analysis

Our analysis focuses on quantifying DoD's potential increase in biofuel consumption through FY12 from the actions discussed in the previous sections. Figure 6-2 summarizes our framework for quantifying the potential increase in biofuel consumption by DoD over the next 5 years, which is based on the relative attractiveness of these potential actions.

Figure 6-2. Overview of Analysis Framework



Geocoding

DATABASE DEVELOPMENT

We obtained FY06 fuel transaction data from GSA (for GSA wet-leased vehicles) and DESC's Business System Modernization (BSM) Energy system (for DoD-leased and -owned vehicles). These data represent all DoD Voyager card transactions at commercial stations, including DoD exchanges.

We consolidated these raw transaction data for each commercial station, by fuel and vehicle type. As discussed in Chapter 2, we are aware of issues in the coding of biofuel in Voyager transaction data. Due to coding limitations of older generation register and computer systems, purchases of E85 and B20 at commercial stations often are coded as gasoline or diesel.

We corrected the fuel coding issues as follows:

- *Identified commercial E85 and B20 stations in the database*. We used the DOE's Alternative Fuels Data Center's (AFDC) alternative fuel station locator (http://afdcmap2.nrel.gov/locator) to identify commercial E85 and B20 stations. We augmented the AFDC list of B20 stations with the National Biodiesel Board's list of B20 stations (http://www.biodiesel.org/buyingbiodiesel/retailfuelingsites).
- *Recoded E85 and B20 transactions at stations not identified as selling those fuels.* Of the 533 stations that reported selling E85 in the Voyager transaction database, only 159 were identified by AFDC as actually selling E85. Similarly, of the 98 stations that reported selling B20, only 8 were identified as actually selling biodiesel by AFDC or the National Biodiesel Board. We recoded the E85 and B20 transactions at the stations not identified as biofuel stations as gasoline or diesel on the basis of vehicle type corresponding to the transactions.
- *Reviewed coding of fuel at E85 and B20 stations to determine whether correctly coded.* We identified 491 commercial E85 stations where DoD E85 FFVs purchased fuel but no E85 sales were reported in the Voyager transaction database. At these stations, FFV fuel transactions were coded as gasoline (460 stations), diesel (15 stations), CNG (5 stations), marine (1 station), aviation (3 stations), kerosene (4 stations), or LPG (3 stations). We also identified 133 commercial B20 stations were DoD diesel NTVs purchased fuel, but no B20 was reported. At these stations, biodiesel was coded as diesel (117 stations), gasoline (15 stations), and aviation fuel (1 station).
- *Recoded all fuel transactions by biofuel-capable vehicles at commercial biofuel stations where no biofuel sales were reported.* A portion of the E85 FFVs and diesel NTV transactions at these commercial biofuel stations where no biofuel sales were reported was likely E85 or B20. On the basis of data from the 159 commercial E85 stations, 55 percent of the total fuel quantity (in gallons) purchased by E85 FFVs at E85 stations is E85; the remaining 45 percent is gasoline. This ratio was applied to all E85 FFV transactions at commercial E85 stations where no E85 sales were reported in the Voyager transaction database. Due to limitations in B20 data, the same ratio was applied to all diesel NTV transactions at commercial B20 stations where no B20 sales were reported.
- *Recoded all fuel transactions on the basis of vehicle type.* Since our confidence in vehicle type coding is much greater than in fuel coding, we recoded all transactions by gasoline vehicles as gasoline and all transactions by diesel vehicles as diesel.

After recoding the Voyager fuel transaction database, we created two summary databases, one for E85 and gasoline transaction data and the other for B20 and diesel transaction data. These databases, which contain the total quantity (in GGEs) purchased by DoD at each commercial station in FY06, by fuel and vehicle type, are the source data for the geocoding analysis.

GEOCODING TRANSACTION DATA

We used the Environmental Systems Research Institute's (ESRI's) ArcGIS Version 9.2 desktop geographic information system (GIS) suite to assign geographic locations to Voyager transaction data. After the geocoding process, all fuel transactions at commercial stations in the Voyager transaction data were assigned a specific geographic coordinate, expressed as latitude and longitude.

We geocoded each Voyager transaction database as follows:

- *Performed automated ArcGIS geocoding at default levels*. We uploaded each Voyager transaction database in ArcGIS and assigned the *U.S. Streets with Zone* as the address locator file for as the geocoding service. This file matches geographic locations to data primarily on the basis of street address and Zip Code. At the default spelling sensitivity, candidate score, and matching scores, approximately 65 percent of the commercial stations were geocoded.

- *Performed automated ArcGIS geocoding at less sensitive levels*. On the basis of ESRI support, we reduced the spelling sensitivity from 80 to 70 and the matching score level from 80 to 60. An additional 15 percent of the databases were geocoded at these settings.

- *Manually geocoded all large volume transactions*. We manually matched all locations greater than 5,000 GGEs for E85 and gasoline transaction data and 2,000 GGEs for B20 and diesel transaction data. Addresses were also mapped in GoogleMaps and MapQuest to assist in the manual geocoding.

- *Geocode remaining locations at Zip Code centroid points*. For all remaining nongeocoded fuel transaction data, we mapped the data to the centroid point of the location Zip Code.

Transactions within 5 Miles of Commercial Biofuel Stations

DATABASE GEOCODING AND DEVELOPMENT

We developed databases containing the locations of commercial E85 and B20 stations (not including DoD exchange locations). These databases were based on AFDC's alternative fuel station locator and the list of B20 stations on the National Biodiesel Board's website. These databases were geocoded using the same method as for fuel transaction data, except all locations not automatically geocoded were manually geocoded.

Using ArcGIS, we overlaid the commercial E85 and B20 station databases on the E85 and gasoline transaction as well as B20 and diesel transaction databases, respectively. Using queries in ArcGIS, we created databases of all fuel transaction data within 5 miles of each commercial E85 and B20 station—if a fuel transaction data point was within more than one biofuel station it was assigned to the closest station. For each commercial biofuel station, the query results included the nearby commercial station, distance to the commercial biofuel station, and fuel use in GGEs (E85 consumption, E85 and gasoline consumption by E85 FFVs, and E85 and gasoline consumption by all vehicles).

The ArcGIS query results include all fuel transactions within 5 miles, point-to-point, of commercial biofuel stations. The actual driving distances for some of these stations may be greater than 5 miles. Therefore, we analyzed the driving distances (using GoogleMaps and MapQuest) for all fuel transaction volumes greater than 2,500 GGEs for E85 and gasoline transaction data and 1,500 GGEs for B20 and diesel transaction data, and removed all data greater than 5 miles from commercial biofuel stations.

Data Analysis

We quantified each of the three primary opportunities for DoD to increase biofuel use at existing commercial infrastructure as follows:

- *Ensure purchase of biofuel when fueling at commercial biofuel stations.* We compared the current consumption of E85 and B20 at existing commercial biofuel stations to the total fuel consumption by E85 FFVs and diesel vehicles at those stations. The difference reflects the potential to increase biofuel use by changing fueling behavior when using commercial biofuel stations.
- *Divert fueling of biofuel-capable vehicles to nearby commercial biofuel stations.* We summed the total fuel consumption by E85 FFVs and diesel vehicles within 5 miles of each existing commercial biofuel station. The data were analyzed in bands of 1 through 5 miles from the commercial biofuel station. The sum reflects the potential to increase biofuel use by diverting fueling of biofuel-capable vehicles from conventional stations to nearby commercial biofuel stations.
- *Locate E85 FFVs near commercial E85 stations.* We summed the total gasoline fuel consumption within 5 miles of each existing commercial biofuel station. All data were multiplied by 77 percent (the maximum concentration of E85 FFVs at a specific location) and summed to quantify the potential to increase biofuel use by also locating E85 FFVs near commercial E85 stations.

Ranking Potential Biofuel Use Outside of Commercial Biofuel Station Locations

Using ArcGIS version 9.2, we queried the commercial E85 and B20 station databases for all fuel transaction locations more than 10 miles outside the commercial biofuel stations. Next, we summed the all fuel transactions within 5 miles of each fuel transaction location. We then summed the total fuel consumption by E85 FFVs, gasoline-capable vehicles, and diesel vehicles to determine the potential for biofuel use if that station installed biofuel infrastructure. Finally, we ranked these locations to determine the best locations to promote expansion of new commercial biofuel infrastructure.

Transactions within 5 Miles of DoD Exchanges

We completed this analysis in ArcGIS using the same method as for the analysis of fuel transactions within 5 miles of commercial biofuel stations, except a database of DoD exchanges was used. From these results, we selected all DoD exchanges with potential biofuel use greater than 50,000 GGEs as candidate locations for biofuel infrastructure.[3] Since E85 is not available in Alaska and Hawaii and B20 is not available in Alaska, candidate locations in these states were removed from the analysis.

Potential for New Biofuel Infrastructure at DoD Installations

EXISTING INFRASTRUCTURE AND FUEL TRANSACTIONS

Identification of Sites

We reviewed several databases provided by the Defense Logistics Agency (DLA), DESC, and the military services to identify existing DoD conventional fuel and biofuel infrastructure. We determined that the most complete database was the DESC Contract Information System, which maintains historical records of all ground fuel requirements for which the military services request DESC to establish direct-to-tank delivery of conventional and biofuel. The records include the purchasing command, its location, product type, and detailed tank data. DESC provided detailed tank information for the 50 states and District of Columbia for all tanks, including those that may be converted to biofuel. This information was keyed to the DoD Activity Address Code (DODAAC), which allowed these data to be linked to DESC's billing data.

We then manually reviewed the data obtained from the Contract Information System to eliminate duplicate information. The duplicate information exists because the same existing fuel tanks have accommodated changes in fuels

[3] 50,000 GGEs is sufficient scale to ensure cost effectiveness.

historically as sulfur limits have been reduced and because fuel grades change seasonally to meet performance requirements across the country.

Query of Transaction Data

DESC's FY06 billing records provided the amount of fuel consumption at most military sites. In the case of Defense Fuel Support Points (DFSPs), sales data were available showing the amount of product sold in retail quantities by site. For other military service fuel sites, the sales data showed bulk deliveries by tank truck. Queries selected all relevant transactions for all grades of diesel, gasoline, B20, and E85. These data were linked by DODAAC to infrastructure information gathered from the Contract Information System.

Estimate of Potential Use

The conversion or building of biofuel infrastructure does not result in the use of more fuel. Rather, the type of fuel used shifts from one product to the other. Therefore, current total fuel consumption is a good estimate of the future total fuel consumption. We analyzed data for those sites reporting consumption of biofuel and conventional fuel. Sites using both diesel and biodiesel converted an average of 69.86 percent of their diesel consumption to the use of B20. Sites using both gasoline and E85 had converted on average 22.75 percent of their gasoline consumption to the use of E85.

DEVELOP CRITERIA TO IDENTIFY POTENTIAL SITES

Conversion

We established the following minimum criteria to identify sites for potential *conversion* from conventional fuel to biofuel. Each identified site had to meet all of the following criteria:

- *Cannot already have E85 or B20 infrastructure*.
- *Must have two or more tanks in gasoline or diesel service.* Many uses remain for conventional petroleum fuels and therefore complete conversion to biofuel is often impractical at a specific site. This is especially true for E85, which is only used in FFVs (which are not readily available in medium- or heavy-duty vehicles). Therefore, at least two diesel tanks must be available to convert one to B20 and at least two gasoline tanks to convert one to E85.
- *Total available tank capacity must exceed 10,000 gallons*. The tanks proposed for conversion must have sufficient capacity, either singly or as a group, to permit the tank truck delivery of 7,500 gallons of fuel at a single time to minimize transportation costs. This is especially true for E85, where production facilities and terminal stocks are often distant from military sites. The minimum size tank or tank group with the capability to

receive 7,500 gallons in a single delivery and still have operating stocks available is approximately 10,000 gallons.

- *Average available tank capacity must exceed 3,000 gallons*. Many of the sites identified had large numbers of individual small tanks—some as small as 280 gallons. Delivery of biofuel into a large number of small tanks, even if they aggregate to greater than 10,000 gallons, is not cost-effective. Therefore, we considered facilities with an average available tank capacity less than 3,000 gallons as not suitable for conversion to biofuel.
- *Projected sales must exceed 15,000 gallons annually.* Stocks of B20 and E85 must be consumed within 6 months of delivery to accommodate seasonal fuel blend adjustments and maintain product quality. Sites without the potential of using 15,000 gallons of biofuel each year—the equivalent of two tank truck deliveries of 7,500 gallons each—are not appropriate for conversion or installation of biofuel infrastructure.
- *Conversion to B20 and E85 was not considered for Alaska because they are not available in that state*.
- *Conversion to E85 was not considered in Hawaii because it is not available in that state*.

Installation

We established the following minimum criteria to identify sites for potential *installation* of biofuel infrastructure. Each identified site had to meet all of the following criteria:

- *Cannot already have E85 or B20 infrastructure.*
- *Projected sales must exceed 15,000 gallons annually.* Stocks of B20 and E85 must be consumed within 6 months of delivery to accommodate seasonal fuel blend adjustments and maintain product quality. Sites without the potential of using 15,000 gallons of biofuel each year—the equivalent of two tank truck deliveries of 7,500 gallons each—are not appropriate for conversion or installation of biofuel infrastructure.
- *Installation of B20 and E85 tanks was not considered for Alaska because they are not available in that state.*
- *Installation of E85 tanks was not considered in Hawaii because it is not available in that state.*
- *Removed sites identified for potential conversion.* A site identified for potential *conversion* was not counted a second time as a potential site for *installation* of biofuel infrastructure even though installation might be determined to be the better choice after all options are examined in detail.

Chapter 7
Potential for Increased Use of Biofuel at Commercial Infrastructure and DoD Exchanges

In this chapter, we quantify DoD's potential increase in biofuel use at commercial infrastructure and DoD exchanges and the associated costs. We show DoD's current fuel consumption behavior, primary actions DoD can take to increase biofuel use, potential increases in biofuel use, and costs for each action.

SUMMARY

The primary actions DoD can take to increase biofuel use at commercial infrastructure and DoD exchanges are as follows:

- Ensure purchase of biofuel when fueling at biofuel stations.
- Divert fueling of biofuel-capable vehicles from gasoline-only stations to nearby biofuel stations.
- Concentrate E85 FFVs near E85 stations.
- Install new biofuel infrastructure at DoD exchanges with large fuel use.

Table 7-1 summarizes, for each action, DoD's potential increased use of E85 or B20 and the associated costs. The costs are provided as one-time capital investment costs, annual costs, annualized costs (annual costs plus capital costs annualized over 5 years), and cost per GGE increase in E85 or B20.

DoD can further increase biofuel use by promoting the expansion of commercial biofuel infrastructure where potential DoD consumption of biofuel is relatively large. The candidate commercial stations would be outside of current or planned E85 stations or DoD exchanges where new infrastructure will be installed. Because DoD cannot require commercial stations to install biofuel pumps, quantifying the potential increase in use and associated costs for this action is difficult.

Our estimates of potential increased biofuel use reflect full use of commercial biofuel infrastructure where reasonably available. Operational and implementation issues will likely limit 100 percent utilization of biofuel infrastructure, but even small changes in biofuel refueling behavior and limited installation of biofuel infrastructure will drastically increase biofuel use.

Table 7-1. Increased Biofuel Use and Costs

Potential DoD action	Capital investment ($)	Annual costs ($)	Total annualized costs ($)	Potential increase in biofuel use (GGE)	Cost per increase in GGE ($)
E85					
Optimize fueling of E85 FFVs at current commercial E85 stations	0	122,677	122,677	134,851	0.91
Divert fueling of E85 FFVs to nearby commercial E85 stations	422,620	8,438,375	8,522,899	3,208,547	2.66
Locate E85 FFVs near commercial E85 stations	0	3,867,302	3,867,302	2,407,587	1.61
Install new E85 infrastructure at large-use DoD exchanges and locate E85 FFVs near those stations	14,495,315	11,070,835	13,969,898	9,229,330	1.51
Total	14,917,935	23,499,189	26,482,776	14,980,315	1.77
B20					
Optimize fueling of diesel vehicles at current commercial B20 stations	0	0	0	30,893	0.00
Divert fueling of diesel vehicles to nearby commercial B20 stations	309,440	2,198,800	2,260,688	978,983	2.31
Install new B20 infrastructure at large-use DoD exchanges	2,243,527	301,662	750,363	1,097,233	0.68
Total	2,552,967	2,500,462	3,011,051	2,107,109	1.43

The cost estimates in Table 7-1 are based on a number of conservative assumptions and may be reduced by the following:

- *Reduction in the price premium for E85 compared with gasoline per GGE*. The DOE Clean Cities Program's most recent alternative price report suggests that E85 price premium is remaining at $0.62 per GGE.[1] If E85 prices equate to gasoline prices per GGE, the implementation costs for E85 actions will be reduced by $0.62 per GGE.
- *Lower vehicle use and labor costs to divert vehicles to biofuel stations*. If diverting vehicles to commercial biofuel stations for fueling is more convenient than estimated, implementation costs will be lower.
- *DoD exchanges converting existing infrastructure to biofuel rather than installing new tank systems.* The cost for installing new infrastructure is roughly three times the cost of converting existing tank systems.

[1] DOE, *Clean Cities Alternative Fuel Price Report*, EERE, July 2007.

DoD Geographic Fuel Consumption

As discussed in Chapter 6, we used FY06 Voyager card transaction data (provided by GSA and DoD) to geocode current DoD NTV fleet fuel consumption. We first adjusted the data to correct fuel coding problems and then geocoded the data using ArcGIS 9.2.

Gasoline and E85

Figure 7-1 shows the geographic concentration of DoD gasoline vehicle (gasoline and E85 FFV) fuel consumption in the continental United States at commercial stations. As expected, the densest fuel usage is near major cities and DoD installations as well as along major interstates. DoD fuel use is concentrated near the coasts; little fuel is used in the West outside of the West Coast.

Figure 7-1. DoD FY06 Fuel Consumption by Gasoline Vehicles and E85 FFVs

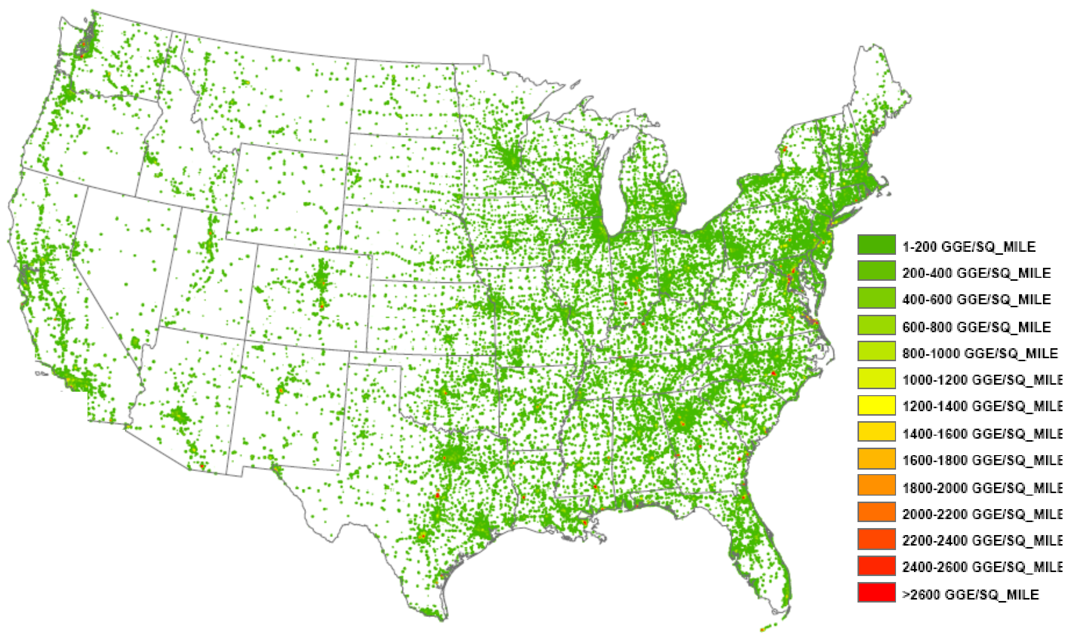
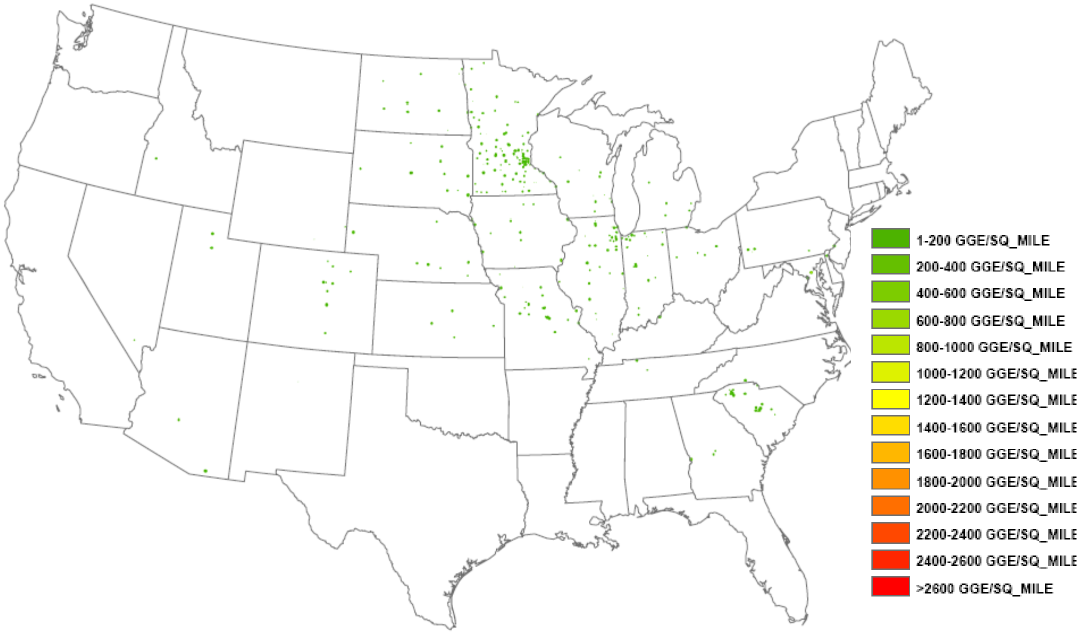


Figure 7-2 shows current DoD consumption of E85 at commercial E85 stations. Current E85 consumption represents 117,166 GGEs (or 0.24 percent) of DoD's total gasoline vehicle and E85 FFV usage at commercial stations of 48.5 million GGEs. As a result, the geographic concentration of E85 consumption is far less than shown in Figure 7-1 for gasoline vehicles.

Most of DoD's E85 consumption is near the primary locations of commercial E85 infrastructure, the Midwest. DoD also uses the relatively high concentration of E85 stations in South Carolina.

Figure 7-2. DoD's FY06 Consumption of E85



Diesel and B20

Figure 7-3 shows the geographic concentration of diesel NTV fuel consumption in the continental United States at commercial stations. DoD consumption of diesel and B20 at commercial stations is lower than for gasoline vehicles and E85 FFVs. Similar to gasoline and E85, diesel and B20 fuel use at commercial stations is concentrated near major cities, DoD installations, and along major interstates, with little fuel use in the West outside of the West Coast.

Figure 7-3. DoD FY06 Fuel Consumption by Diesel NTVs

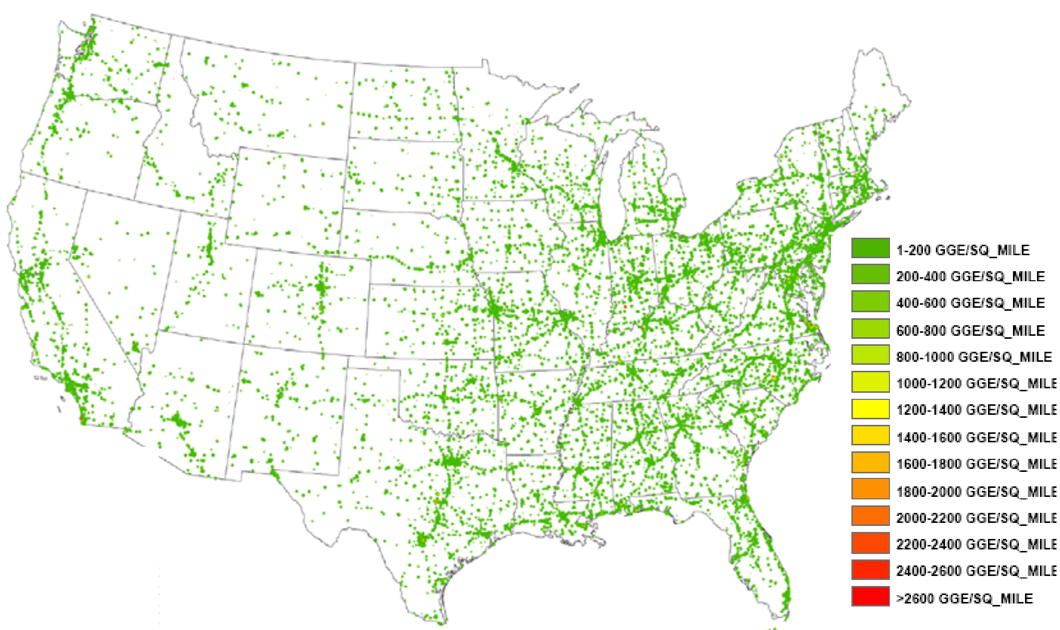
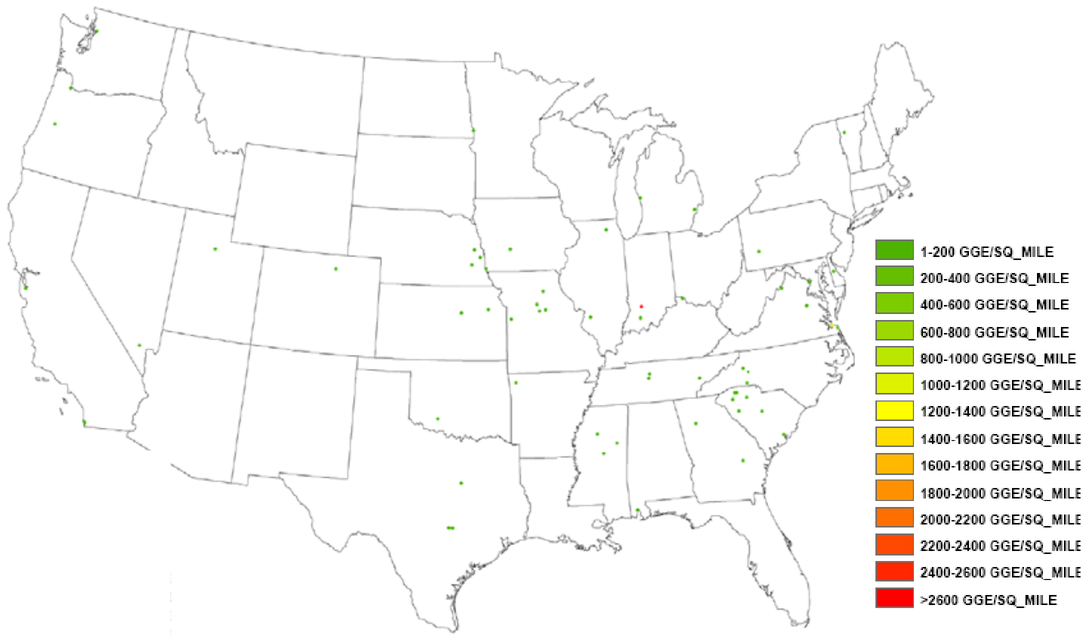


Figure 7-4 shows DoD current consumption of B20 at commercial B20 stations. Current B20 consumption represents 26,126 GGEs (or 0.27 percent) of DoD's total diesel vehicle consumption at commercial stations of 9.8 million GGEs. As a result, the geographic concentration of B20 consumption is far less than shown in Figure 7-3 for diesel vehicles.

Figure 7-4. DoD FY06 Consumption of B20



PURCHASING BIOFUEL AT COMMERCIAL BIOFUEL STATIONS

Potential Increase in E85 Use

From FY06 data, DoD purchases 117,166 GGEs (162,731 gallons) of E85 annually at 648 commercial E85 stations. As shown in Table 7-2, most (65,588 GGEs, or 56 percent) of DoD's commercial E85 consumption occurs at only 10 of these commercial E85 stations.

We estimate that DoD is using biofuel in only 46 percent of fuel transactions by biofuel-capable vehicles at commercial biofuel stations. This estimate is based on analysis of DoD's FY06 biofuel transactions at biofuel stations. As shown in Table 7-3, ensuring that DoD uses E85 in the other 54 percent of E85 FFV fueling transactions will enable it to increase E85 consumption by 134,851 GGEs (or 187,293 gallons). This represents a 115 percent increase over DoD's E85 consumption at commercial E85 stations and a 16 percent increase over DoD's total E85 consumption in FY06.

Table 7-2. Current DoD E85 Consumption at Top 10 Commercial E85 Stations

Station name	City and state	DoD E85 consumption (GGEs)	% of DoD commercial E85 consumption
Chevron Service Center	Laurel, MD	29,346	25.0
Highway 34 Truckstop—Texaco	West Burlington, IA	14,871	12.7
Draper Chevron	Draper, UT	3,951	3.4
JP's American Car Care	Clearfield, UT	3,777	3.2
SuperAmerica	Des Plaines, IL	3,242	2.8
The Corner Pantry	Columbia, SC	2,998	2.6
Phillips—Apollo Mart	Bartonville, IL	2,725	2.3
Conoco Convenient Mart	Jefferson City, MO	1,736	1.5
Acorn	Colorado Springs, CO	1,512	1.3
Pitt Stop Convenience Store	Columbia, SC	1,430	1.2
DoD E85 consumption at top 10 E85 stations		65,588	56.0
All 638 other E85 stations		51,578	44.0

Table 7-3. Potential DoD E85 Consumption by Optimizing Fueling of E85 FFVs at Current Commercial E85 Stations (GGEs)

Station name	City and state	Current E85 consumption	Potential E85 consumption if all FFVs used E85	Potential increase in E85 consumption
Chevron Service Center	Laurel, MD	29,346	39,157	9,811
Highway 34 Truckstop—Texaco	West Burlington, IA	14,871	31,752	16,881
Draper Chevron	Draper, UT	3,951	8,442	4,491
JP's American Car Care	Clearfield, UT	3,777	8,065	4,288
SuperAmerica	Des Plaines, IL	3,242	6,938	3,696
The Corner Pantry	Columbia, SC	2,998	6,606	3,608
Phillips—Apollo Mart	Bartonville, IL	2,725	5,895	3,170
Conoco Convenient Mart	Jefferson City, MO	1,736	3,720	1,984
Acorn	Colorado Springs, CO	1,512	2,324	812
Pitt Stop Convenience Store	Columbia, SC	1,430	3,061	1,631
DoD E85 consumption at top 10 E85 stations		65,588	115,960	50,372
All 638 other E85 stations		51,578	136,057	84,479
Total		117,166	252,017	134,851

Potential Increase in B20 Use

FY06 data show that DoD purchases 26,126 GGEs (23,202 gallons) of B20 annually at 135 commercial B20 stations. Similar to E85 commercial stations, most (14,382 GGEs, or 55 percent) of DoD's commercial B20 consumption occurs at only 10 of these commercial B20 stations (Table 7-4).

Table 7-4. Current DoD B20 Consumption at Top 10 Commercial B20 Stations

Station name	City and state	DoD current B20 consumption (GGEs)	Percentage of DoD commercial B20 consumption
Sapp Bros—Omaha	Omaha, NE	3,790	14.2
Cubbard Express	Lenior, NC	1,706	6.4
Cardwell Distributing	Midvale, UT	1,610	6.0
Merritt Oil	Mobile, AL	1,199	4.5
SA White Oil Company	Marrietta, GA	1,140	4.3
Rotten Robbie	Mountain View, CA	1,098	4.1
SeQuential Biofuel	Portland, OR	1,039	3.9
Export Fuel Company	Export, PA	982	3.7
Carmel Church Pit Stop—Exxon	Ruther Glen, VA	942	3.5
Rackley Oil Fuel Center	Starkville, MS	876	3.3
DoD B20 consumption at top 10 B20 stations		14,382	55.0
All 125 other B20 stations		11,744	45.0

We estimate that DoD is using B20 in only 46 percent of diesel vehicle fuel transactions at commercial B20 stations. As shown in Table 7-5, ensuring that DoD uses B20 in the other 54 percent of diesel NTV fueling transactions will enable DoD to increase B20 consumption by 30,893 GGEs (or 27,436 gallons). This represents a 118 percent increase over DoD's B20 consumption at commercial B20 stations, but only a 0.5 percent increase over DoD's total B20 consumption in FY06.

Table 7-5. Potential DoD B20 Consumption by Optimizing Fueling of Diesel NTVs at Current Commercial B20 Stations (GGEs)

Station name	City and state	DoD current B20 consumption	Potential B20 consumption if all diesel NTVs used B20	Potential increase in B20 consumption
Sapp Bros—Omaha	Omaha, NE	3,790	7,715	3,925
Cubbard Express	Lenior, NC	1,706	3,395	1,689
Cardwell Distributing	Midvale, UT	1,610	3,204	1,594
Merritt Oil	Mobile, AL	1,199	2,386	1,187
SA White Oil Company	Marrietta, GA	1,140	2,268	1,128
Rotten Robbie	Mountain View, CA	1,098	2,185	1,087
SeQuential Biofuel	Portland, OR	1,039	2,068	1,029
Export Fuel Company	Export, PA	982	1,954	972
Carmel Church Pit Stop—Exxon	Ruther Glen, VA	942	1,875	933
Rackley Oil Fuel Center	Starkville, MS	876	1,743	867
DoD B20 consumption at top 10 B20 stations		14,382	28,793	14,411
All 125 other B20 stations		11,744	28,226	16,482
Total		26,126	57,019	30,893

Estimated Costs

DoD will incur incremental costs for purchasing only biofuel when using commercial biofuel stations:

- *E85 fuel incremental cost*. As discussed in Chapter 3, at current prices, E85 costs $0.62 more than gasoline per GGE.

- *More frequent refueling of E85 FFVs*. Due to the lower energy content of E85 (72 percent of gasoline), E85 FFVs, on average, will require 39 percent more refuelings when using E85 instead of gasoline. This assumes that fleet operators refuel when vehicles are nearly empty, rather than daily or otherwise frequently. In this latter case, costs would not rise to the same extent. We used an average fill-up of 12 gallons per transaction. The additional 134,851 GGEs of E85 represents 4,370 more transactions per year than using gasoline.

  Costs associated with more frequent refueling of E85 FFVs include the vehicle use costs associated with additional trips to the station (estimated at 5 miles at $0.485 per mile) and the labor costs associated with refueling (estimated at 15 minutes at $26.05 per hour).[2]

- *Training of fleet operators and materials*. To take this action, DoD needs to train fleet operators and management to ensure that (1) E85 FFVs refuel with E85 rather than gasoline, and (2) diesel NTVs use B20 rather than diesel. However, the training and materials would primarily support the action to divert fueling of biofuel-capable vehicles to nearby commercial biofuel stations rather than increasing the purchase of biofuel when using current stations. Therefore, they are included in cost estimates for diverting fueling below.

As shown in Table 7-6, we estimate that the total annual cost for taking this action is $122,677 for E85 and no cost for B20. This represents an incremental cost to DoD of $0.91 per GGE for increasing the use of E85 in this manner.

Table 7-6. Estimated Incremental Cost to Purchase Only Biofuel When Using Commercial Biofuel Stations

Cost category	Annual transactions	Cost per transaction ($)	Total annual cost ($)
E85 incremental costs			
E85 fuel cost	134,851 GGEs	0.62	83,608
Vehicle use costs (extra refuelings)	4,370	2.43	10,620
Labor for refueling (extra refuelings)	4,370	6.51	28,449
Total			122,677
Increase in E85 consumption (GGEs)			134,851
Cost per GGE increase in E85 consumption			0.91
B20 incremental costs			
Total			0

[2] We estimated base hourly labor rates ($19.09) using Office of Personnel Management hourly rates for Grade 8, Step 5 (http://www.opm.gov/oca/07tables/pdf/gs_h.pdf). The rates were adjusted using a full fringe benefit cost factor of 36.45 percent, from an October 2006 memorandum from Rob Portman, Director, Office of Management and Budget, subject: “Update to Civilian Position Full Fringe Benefit Cost Factor, Federal Pay Raise Assumptions, Inflation Factors, and Tax Rates used in OMB Circular No. A-76, Performance of Commercial Activities.”

DIVERTING BIOFUEL-CAPABLE VEHICLES TO NEARBY COMMERCIAL BIOFUELS STATIONS

Potential Increase in E85 Use

As discussed in Chapter 6, EPAct 2005 mandates that federal fleets refuel E85 FFVs with E85 unless it is not reasonably available (cannot be obtained within 5 miles or a 15-minute drive). Therefore, through FY12, DoD is mandated to divert E85 FFVs to E85 stations if within 5 miles or a 15-minute drive (one way).

Table 7-7 shows potential DoD consumption of E85 if all fuel use within 5 miles or 15 minutes of existing or currently planned (as of July 2007) commercial E85 stations was diverted to those stations. Results are presented in radii of 1 through 5 miles from the commercial E85 stations.

Table 7-7. Potential DoD E85 Consumption by Diverting Fueling (GGEs)

Distance to E85 station (miles)	Current E85 consumption	Potential E85 consumption if all FFVs used E85	Potential increase in E85 consumption
At E85 station[a]	117,166	252,017	134,851
Within 1 mile	117,166	697,928	580,762
Within 2 miles	117,166	1,462,727	1,345,561
Within 3 miles	117,166	2,148,743	2,031,577
Within 4 miles	117,166	2,780,745	2,663,579
Within 5 miles	117,166	3,325,713	3,208,547

[a] These data reflect our earlier results for purchasing only E85 when using commercial E85 stations.

We estimate that the potential increase in DoD E85 consumption from meeting EPAct Section 701 requirements is very large, as much as 3.21 million GGEs (or 4.46 million gallons) annually. This represents more than 27 times DoD's current consumption at commercial E85 stations, and a 283 percent increase over DoD's total E85 consumption in FY06.

DoD can achieve most of the potential increase in E85 consumption by focusing on the strongest opportunities. The top 20 commercial E85 stations represent roughly a quarter (23.3 percent) and the top 100 represent more than a half (52.8 percent) of the potential increase in E85 consumption. Table 7-8 shows the top 20 commercial E85 stations, potential increase in E85 consumption, and nearby DoD installation (if any).

Table 7-8. Top 20 Locations for DoD to Increase E85 Consumption by Diverting Fueling of E85 FFVs to Nearby Commercial E85 Stations (within 5 miles)

Station name	City and state	Potential increase in E85 consumption (GGEs)	Nearest DoD installation[a]
Chevron Service Center	Laurel, MD	156,748	Fort George G. Meade
CleanFuel USA	San Antonio, TX	91,719	Fort Sam Houston
RTC Fuel Depot—Pearson Ford	San Diego, CA	45,498	Miramar Marine Corps Air Station
JP's American Car Care	Clearfield, UT	35,435	Hill Air Force Base (AFB)
GasAmerica #51	Indianapolis, IN	34,341	
H-E-B	Killeen, TX	33,403	Fort Hood
Gas City	Sierra Vista, AZ	32,850	Fort Huachuca
Western Convenience Store	Aurora, CO	32,428	Buckley AFB
Fillers #21 Shell	Warner Robins, GA	31,436	Robins AFB
Georgetown Chevron	Washington, DC	31,209	Fort Myer
Meijer Gas #237	Warren, MI	26,365	Detroit Arsenal Tank Plant
Ever-Ready Oil Company	Albuquerque, NM	26,119	Kirtland AFB
Sinclair	Cheyenne, WY	25,047	FE Warren AFB
Kroger	Columbus, OH	23,929	Defense Supply Center Columbus
Pitt Stop Convenience Store	Columbia, SC	22,474	Fort Jackson
Center City Shell—S&B Auto	Philadelphia, PA	21,862	Defense Supply Center
Western Convenience Store	Colorado Springs, CO	19,949	Peterson AFB and Fort Carson
Kean Oil Company	Chicago, IL	19,417	
Sheetz Store #353	Pittsburgh, PA	19,346	
Formula Marathon	Mount Prospect, IL	19,071	
Total		748,646	

[a] At some locations not near major DoD installations, DoD fuel transactions may still be relatively large.

Potential Increase in B20 Use

EPAct 2005 does not require diesel vehicles to refuel with B20, even if reasonably available. However, by implementing the intent of EPAct 2005 for B20 and diverting diesel vehicles to B20 stations if within 5 miles or a 15-minute drive (one way), DoD can significantly increase the consumption of B20.

Table 7-9 shows DoD's potential consumption of B20 if all fuel use within 5 miles or a 15 minute drive of existing or currently planned (as of July 2007) commercial B20 stations was diverted to those stations. Results are presented in radii of 1 through 5 miles from the commercial B20 stations.

We estimate that diverting diesel NTV refueling to nearby commercial B20 stations has the potential to increase DoD's B20 consumption by 978,983 GGEs (or 869,434 gallons) annually. This represents more than 37 times DoD's current consumption at commercial B20 stations, and a 16 percent increase over DoD's total B20 consumption in FY06.

Table 7-9. DoD's Potential B20 Consumption by Diverting Fueling of Diesel NTVs to Nearby Commercial B20 Stations (GGEs)

Distance to B20 station (miles)	Current B20 consumption	Potential B20 consumption if all diesel NTVs used B20	Potential increase in B20 consumption
At B20 station[a]	26,126	57,019	30,893
Within 1 mile	26,126	225,695	199,569
Within 2 miles	26,126	484,456	458,330
Within 3 miles	26,126	627,834	601,708
Within 4 miles	26,126	791,019	764,893
Within 5 miles	26,126	1,005,109	978,983

[a] These data reflect the earlier results for purchasing only B20 when using commercial B20 stations.

Similar to the analysis for E85, DoD can achieve most of the potential increase in B20 consumption by focusing on the largest opportunities. The top 20 commercial B20 stations represent almost one-half (43.1 percent) and the top 100 represent more than one three-quarters (76.7 percent) of the potential increase in B20 consumption. Table 7-10 shows the top 20 commercial B20 stations, potential increase in B20 consumption, and nearby DoD installation (if any).

Table 7-10. Top 20 Locations for DoD to Increase B20 Consumption by Diverting Fueling of Diesel NTVs to Nearby Commercial B20 Stations (within 5 miles)

Station name	City and state	Potential increase in B20 consumption (GGEs)	Nearest DoD installation
Merritt Oil	Mobile, AL	51,375	
Quality Parade	Pensacola, FL	34,861	Naval Air Station Pensacola
Carl's Junior 76 Station	Honolulu, HI	32,515	Fort Shafter
PAPCO Oil Company	Virginia Beach, VA	29,881	Oceana Naval Air Station, Little Creek Amphibious Base
Carmel Church Pit Stop—Exxon	Ruther Glen, VA	25,414	
Phillips 66	Lawton, OK	24,094	Fort Sill
Pettit Oil	Tacoma, WA	22,365	Fort Lewis, McChord AFB
Chief Petroleum	Colorado Springs, CO	21,221	Fort Carson, Air Force Academy
Aliance Mart	Monterey, CA	20,765	Presidio of Monterey, Navy Postgraduate School
Associated Petroleum Products	Tacoma, WA	18,137	
MFA Oil Petro-Card 24	Boonville, MO	17,275	
RTC Fuel Depot—Pearson Ford	San Diego, CA	17,126	Miramar Marine Corps Air Station
Acorn Petroleum	Colorado Springs, CO	16,905	Fort Carson, Air Force Academy
Go Green Biofuel	Little Rock, AR	16,861	Camp Robinson
Chief Petroleum	Colorado Springs, CO	14,702	Fort Carson, Air Force Academy
Pacific Pride	Astoria, OR	14,365	Camp Rilea
MFA Oil Petro-Card 24	Columbia, MO	12,457	
Flower Power Biodiesel Cooperative	Salem, OR	10,891	McNary Field
Capitol City Oil Inc.	Topeka, KS	10,526	Forbes Field
Hone Oil	Ogden, UT	10,434	Hill AFB
Total		422,170	

Estimated Costs

We estimate that DoD is likely to incur the following incremental costs for diverting fueling of biofuel-capable vehicles to nearby commercial biofuel stations:

- *E85 fuel incremental cost*. At current prices, E85 costs $0.62 more than gasoline per GGE.
- *More frequent refueling of E85 FFVs*. As discussed earlier in this chapter, the lower energy content of E85 will require FFVs to refuel 39 percent more when using E85 rather than gasoline. Costs associated with more frequent refueling of E85 FFVs include the vehicle-use costs associated

with additional trips to a station and the labor costs associated with refueling.

- *Extra driving distance and time per refueling*. Since this action calls on fleet operators to divert refueling to nearby commercial stations, DoD will incur incremental costs associated with vehicle use and labor. Extra driving requirements apply only to fuel transactions not currently at the commercial biofuel stations (92.4 percent of E85 and 94.3 percent of B20 fuel use). We estimate that additional driving requirements are 2.5 miles each way (at $0.485 per mile) and the total additional driving time is 15 minutes roundtrip (at labor costs estimated at $26.05 per hour). We used an average fill-up of 12 gallons per transaction for E85 FFVs and 26 gallons for diesel vehicles.

- *Training fleet operators and materials*. To take this action, DoD will need to train both fleet operators and management. We estimate the training requirement at 1 hour per year per biofuel-capable vehicle operator (at $26.05 per hour). Costs for materials, including yellow gas caps, E85 signs and decals, and information packets are expected to cost roughly $10 per vehicle. These costs were annualized over the 5-year time frame of this study.

- *Management oversight (performance metrics).* To ensure compliance with this action (and EPAct Section 701), DoD will need to review (using monthly GSA data) the fueling behavior of the NTV fleet. Specifically, DoD fleet managers will need to analyze the purchase of fuel by biofuel-capable vehicles within 5 miles of biofuel stations. The results of this analysis will identify locations where use of commercial biofuel stations can be improved. We estimate that the annual cost of this effort will be $500,000.

- *Enforcement.* DoD fleet managers will need to evaluate the performance of fleet operators to ensure compliance with this action. We estimate this will require 1 hour per biofuel-capable vehicle operator per year (at $26.05 per hour).

As shown in Table 7-11, we estimate that the total annualized costs for taking this action is $8,522,899 for E85 and $2,260,688 for B20. The capital investment costs included in these annualized costs are $422,620 for E85 and $309,440 for B20. By taking this action, DoD will incur estimated incremental costs of $2.66 per GGE for increasing the use of E85 and $2.31 per GGE for B20.

Table 7-11. Annual Incremental Costs for Diverting to Nearby Commercial Biofuel Stations (within 5 miles)

Cost category	Annual transactions	Cost per transaction ($)	Total annualized cost ($)
E85 Incremental Costs			
E85 fuel cost (GGE)	3,208,547	0.62	1,989,299
Vehicle use costs (extra refuelings)	103,981	2.43	252,674
Labor for refueling (extra refuelings)	103,981	6.51	676,916
Vehicle use costs (extra driving distance)	343,136	2.43	833,820
Extra driving time labor	343,136	6.51	2,233,815
Training of fleet operators and managers	42,262	26.05	1,100,925
Vehicle materials	42,262	2[a]	84,524
Management oversight	1	250,000	250,000
Enforcement	42,262	26.05	1,100,925
Total E85 annualized cost			8,522,899
Increase in E85 consumption (GGEs)			3,208,547
Cost per GGE increase in E85 consumption			2.66
B20 Incremental Costs			
Vehicle use costs (extra driving distance)	37,653	2.43	91,497
Extra driving time labor	37,653	6.51	245,121
Training of fleet operators and managers	30,944	26.05	806,091
Vehicle materials	30,944	2[a]	61,888
Management oversight	1	250,000	250,000
Enforcement	30,944	26.05	806,091
Total B20 Cost			2,260,688
Increase in B20 consumption (GGEs)			978,983
Cost per GGE increase in B20 consumption			2.31

[a] The total capital investment of $10 per vehicle is annualized over 5 years.

LOCATING E85 FFVS NEAR STATIONS

As discussed in Chapter 6, DoD can further increase its consumption of E85 by locating E85 FFVs near the E85 commercial fueling infrastructure. In FY06, E85 FFVs constituted roughly 38 percent of all gasoline-capable vehicles refueling transactions. From our analysis in Chapter 4, the maximum concentration of E85 FFVs at a specific location is 77 percent of all gasoline vehicles. This represents the maximum number of E85 FFVs given the required composition (in terms of vehicle specifications) of the DoD NTV fleet.

Deploying the maximum concentration of E85 FFVs near commercial E85 stations further increases DoD's potential increase of E85 consumption. This action is complementary to purchasing only E85 when using commercial biofuel stations and diverting fueling of E85 FFVs to nearby commercial E85 stations.

Concentrating FFVs and Purchasing E85 at Biofuel Station

As shown in Table 7-12, we estimate that DoD can increase E85 consumption by 121,487 GGEs (168,732 gallons) by maximizing the concentration of E85 FFVs to 77 percent near commercial E85 stations and continuing to ensure 100 percent use of E85 when refueling at those stations. DoD's potential E85 consumption at existing E85 commercial stations would be 373,504 GGEs (518,756 gallons).

Table 7-12. DoD's Potential E85 Consumption by Locating E85 FFVs Near Commercial Stations and Maximizing Fueling

Station name	City and state	DoD current E85 consumption (GGEs)	Consumption if all FFVs used E85 (GGEs)	Consumption by concentrating E85 FFVs (GGEs)	Increase in E85 consumption by concentrating FFVs
Highway 34 Truckstop—Texaco	West Burlington, IA	14,871	31,752	53,824	22,072
Conoco Convenient Mart	Jefferson City, MO	1,736	3,720	7,729	4,009
Kum & Go #62	Johnston, IA	0	1,735	5,363	3,628
Gas City	Sierra Vista, AZ	604	1,346	4,747	3,401
Break Time Convenience Store	Jefferson City, MO	1,168	2,572	5,602	3,030
Highland Travel Plaza	Mitchell, SD	868	2,254	5,041	2,787
The Corner Pantry	Columbia, SC	2,998	6,606	9,282	2,676
Georgetown Chevron	Washington, DC	0	333	3,001	2,668
Mobil on the Run	Rolla, MO	789	1,704	4,052	2,348
Phillips 66	Sergeant Bluff, IA	640	2,465	4,362	1,897
DoD E85 Consumption at Top 10 E85 Stations		23,674	54,487	103,004	48,517
All 640 Other E85 Stations		93,492	197,530	270,500	72,970
Total		117,166	252,017	373,504	121,487

The potential opportunity from concentrating E85 FFVs and having them fill only with that fuel when refueling at commercial E85 stations represents a 104 percent increase over current E85 consumption. Also, this action would enable DoD to further increase total E85 consumption by 31 percent from FY06 levels.

Concentrating FFVs and Diverting Fueling

Earlier in this chapter, we show that DoD can potentially increase its E85 consumption by 3.21 million GGEs (or 4.46 million gallons) annually by meeting EPAct Section 701 requirements. DoD can increase E85 use even further by (1) locating E85 FFVs near commercial E85 stations (at the maximum concentration of 77 percent) and (2) diverting all E85 FFV fuel use to commercial E85 stations within 5 miles or a 15 minute drive (one way).

As shown in Table 7-13, we estimate that DoD can increase E85 consumption by an additional 2,407,587 GGEs (3,343,871 gallons) with this action. DoD's resulting E85 consumption at existing E85 commercial stations would be 5,733,300 GGEs (7,962,917 gallons). Table 7-13 presents DoD's potential consumption of E85 if DoD concentrated E85 FFVS near commercial E85 stations, and all fuel use within 5 miles or a 15 minute drive was diverted to those stations. Results are presented in radii of 1 through 5 miles from the commercial E85 stations.

Table 7-13. DoD's Potential E85 Consumption by Locating E85 FFVs Near Current Commercial Stations and Diverting Fueling (GGEs)

Distance to E85 station (miles)	Current E85 consumption	Consumption if all FFVs used E85	Consumption by concentrating E85 FFVs	Increase in consumption by concentrating FFVs
At E85 station[a]	117,166	252,017	373,504	121,487
Within 1 mile	117,166	697,928	1,133,505	435,577
Within 2 miles	117,166	1,462,727	2,436,168	973,441
Within 3 miles	117,166	2,148,743	3,761,619	1,612,876
Within 4 miles	117,166	2,780,745	4,829,019	2,048,274
Within 5 miles	117,166	3,325,713	5,733,300	2,407,587

[a] These data reflect earlier results for purchasing only E85 at commercial E85 stations.

The potential opportunity from concentrating E85 FFVs is very large, representing an additional 21 fold increase over current E85 consumption levels at commercial E85 stations. Similarly, this action enables DoD to increase total E85 consumption to almost seven times FY06 levels (increase of 585 percent).

As with our earlier analysis, DoD can achieve most of the potential increase in E85 consumption by focusing on the largest opportunities. The top 20 commercial E85 stations represent more than a third (38.6 percent) and the top 100 represent almost two-thirds (66.1 percent) of the potential increase in E85 consumption. Table 7-14 presents the top 20 commercial E85 stations, the potential increase in E85 consumption, and the nearby DoD installation (if any).

Table 7-14. Top 20 Locations for DoD to Increase E85 Consumption by Locating E85 FFVs Near Commercial E85 Stations and Diverting Fueling (within 5 miles)

Station name	City and state	Increase in E85 consumption (GGEs)[a]	Nearest DoD installation
CleanFuel USA	San Antonio, TX	127,474	Fort Sam Houston
Gas City	Sierra Vista, AZ	122,211	Fort Huachuca
Fillers #21 Shell	Warner Robins, GA	104,562	Robins AFB
JP's American Car Care	Clearfield, UT	61,517	Hill AFB
RTC Fuel Depot—Pearson Ford	San Diego, CA	57,767	Miramar USMC Air Station
Chevron Service Center	Laurel, MD	56,129	Fort George G. Meade
Georgetown Chevron	Washington, DC	53,396	Fort Myer
Western Convenience Store	Aurora, CO	44,418	Buckley AFB
Citgo	Annapolis, MD	43,689	U.S. Naval Academy
HEB	Killeen, TX	37,199	Fort Hood
Ever-Ready Oil Company	Albuquerque, NM	29,104	Kirtland AFB
Sinclair	Cheyenne, WY	26,715	FE Warren AFB
GasAmerica #51	Indianapolis, IN	25,470	
Highway 34 Truckstop—Texaco	West Burlington, IA	23,820	Iowa Army Ammunition Plant
C&T Oil Company #2	Tucson, AZ	21,186	Davis-Monthan AFB
Kroger Fuel Center #754	Dayton, OH	20,326	Wright-Patterson AFB
Western Convenience Store	Colorado Springs, CO	20,289	Peterson AFB
Arizona Petroleum Products	Tucson, AZ	18,837	Davis-Monthan AFB
Sheetz Store #353	Pittsburgh, PA	18,224	
Kum & Go #62	Johnston, IA	17,772	Camp Dodge
Total		748,646	

[a] Increase in E85 consumption specifically from concentrating E85 FFVs.

Estimated Costs

We estimate that DoD will incur the following incremental costs by concentrating E85 FFVs near current commercial E85 stations and diverting fueling of E85 FFVs to those stations:

- *E85 fuel incremental cost*. At current prices, E85 costs $0.62 more than gasoline per GGE.
- *More frequent refueling of the additional E85 FFVs*. As discussed earlier, lower energy content will require E85 FFVs to refuel 39 percent more when using E85 instead of gasoline, creating costs for vehicle use associated with additional trips to stations and the labor associated with refueling.

- *Extra driving distance and time per refueling*. Since this action calls on fleet operators to divert refueling to nearby commercial stations, DoD will incur incremental costs associated with vehicle use and labor. Extra driving requirements only apply to fuel transactions not currently at the commercial E85 stations (93.5 percent of fuel use). We estimate that additional driving requirements are 2.5 miles each way (at $0.485 per mile), and the total additional driving time is 15 minutes roundtrip (at labor costs estimated at $26.05 per hour). We used an average fill-up of 12 gallons per transaction.

Because this action involves locating E85 vehicles near stations rather than adding vehicles, we do not expect any additional costs for training of fleet operators and materials, management oversight, or enforcement. Similarly, we do not expect additional costs for relocating FFVs. Since vehicle leases are typically for only 3 years, DoD can take this action within a short time through normal acquisition rather than moving the existing fleet.

As shown in Table 7-15, we estimate that the total annual costs for taking this action are $3,867,302, an incremental cost to DoD of $1.61 per GGE for increasing the use of E85.

Table 7-15. Estimated Annual Incremental Costs for Locating E85 FFVs Near Current Commercial E85 Stations and Diverting Fueling to Those Stations (within 5 miles)

Cost category	Annual transactions	Cost per transaction ($)	Total annual cost ($)
E85 fuel cost (GGEs)	2,407,587	0.62	1,492,704
Vehicle use costs (extra refuelings)	78,024	2.43	189,598
Labor for refueling (extra refuelings)	78,024	6.51	507,936
Vehicle use costs (extra driving distance)	187,591	2.43	455,846
Extra driving time labor	187,591	6.51	1,221,217
Total E85 cost			3,867,302
Increase in E85 consumption (GGEs)			2,407,587
Cost per GGE increase in E85 consumption			1.61

Promoting Commercial Infrastructure Expansion

The least costly alternative available to DoD for adding new biofuel commercial infrastructure is to promote the expansion of new commercial biofuel stations near DoD NTV fleet locations. To encourage private entities to take this action, DoD must coordinate with state, local, and private entities and publicize the locations and concentrations of its E85 FFV and diesel NTV fleet locations and concentrations.

We first identified all commercial E85 and B20 stations used by DoD located more than 10 miles from commercial biofuel stations (including DoD exchanges). We then summed the potential consumption of biofuel at these stations if all fuel used by biofuel-capable vehicles within 5 miles or a 15 minute drive (one way) was diverted to those stations (at maximum biofuel-capable vehicle concentrations). Finally, we selected all commercial E85 and B20 stations with potential biofuel use greater than 50,000 GGEs as potential candidates for promoting the expansion of new biofuel infrastructure.

Table 7-16 lists the 35 locations that meet this criterion (no commercial B20 stations were identified). The locations are ranked by the potential E85 consumption if DoD concentrated E85 FFVs and diverted fueling of E85 FFVs to the locations.

Table 7-16. Potential Locations for Promoting Expansion of Commercial E85 Infrastructure

City and state	Zip Code	Potential E85 consumption if all FFVs used E85 (GGEs)	Potential E85 consumption by concentrating E85 FFVs (GGEs)
Los Angeles, CA	90016	50,000–75,000	100,000–150,000
Edinburgh, IN	46124	50,000–75,000	100,000–150,000
Bronx, NY	10468	75,000–100,000	100,000–150,000
El Segundo, CA	90245	50,000–75,000	100,000–150,000
Phoenix, AZ	85008	50,000–75,000	75,000–100,000
Sacramento, CA	95834	25,000–50,000	75,000–100,000
Baltimore, MD	21230	50,000–75,000	75,000–100,000
Vicksburg, MS	39180	<25,000	75,000–100,000
King George, VA	22485	25,000–50,000	75,000–100,000
Miami, FL	33172	50,000–75,000	75,000–100,000
Marietta, GA	30060	25,000–50,000	75,000–100,000
Smyrna, GA	30080	25,000–50,000	75,000–100,000
Horsham, PA	19044	25,000–50,000	75,000–100,000
Memphis, TN	38109	25,000–50,000	50,000–75,000
Orlando, FL	32812	25,000–50,000	50,000–75,000
Dallas, TX	75211	50,000–75,000	50,000–75,000
Garden City, NY	11530	25,000–50,000	50,000–75,000
Lakehurst, NJ	08733	25,000–50,000	50,000–75,000
Raleigh, NC	27604	25,000–50,000	50,000–75,000
Pineville, LA	71360	25,000–50,000	50,000–75,000
Ayer, MA	01432	25,000–50,000	50,000–75,000
Highwood, IL	60040	25,000–50,000	50,000–75,000
Chantilly, VA	20151	25,000–50,000	50,000–75,000
Blackstone, VA	23824	<25,000	50,000–75,000
Birmingham, AL	35210	25,000–50,000	50,000–75,000

Table 7-16. Potential Locations for Promoting Expansion of Commercial E85 Infrastructure

City and state	Zip Code	Potential E85 consumption if all FFVs used E85 (GGEs)	Potential E85 consumption by concentrating E85 FFVs (GGEs)
Mount Laurel, NJ	08054	25,000–50,000	50,000–75,000
Palmdale, CA	93550	<25,000	50,000–75,000
Moreno Valley, CA	92553	<25,000	50,000–75,000
Mesa, AZ	85204	25,000–50,000	50,000–75,000
Fresno, CA	93727	25,000–50,000	50,000–75,000
Anniston, AL	36201	<25,000	50,000–75,000
Tuscaloosa, AL	35401	<25,000	50,000–75,000
Upland, CA	91786	25,000–50,000	50,000–75,000
Temple, TX	76502	25,000–50,000	50,000–75,000
Tulsa, OK	74129	25,000–50,000	50,000–75,000

INSTALLING INFRASTRUCTURE AT DOD EXCHANGES

As discussed in Chapter 6, DoD exchange organizations, which operate gas stations at most large DoD installations, are preferable to DoD installation fueling locations for DoD biofuel infrastructure. Below, we present the potential increase in biofuel consumption from installing new infrastructure at DoD exchanges at the current fleet composition and by altering vehicle locations to concentrate E85 FFVs near DoD exchanges with E85 pumps.

In selecting DoD exchanges to install new infrastructure, DoD must quantify the potential use of biofuel by biofuel-capable vehicles at those stations. Due to high costs, installation of biofuel infrastructure is only cost-effective at locations with large potential fuel use.

We first evaluated the potential consumption of biofuel at DoD exchanges if all fuel use by biofuel-capable vehicles within 5 miles or a 15 minute drive (one way) was diverted to those stations. We then selected all DoD exchange stations with potential biofuel use greater than 50,000 GGEs as potential candidates for new biofuel infrastructure. Because E85 is not available in Alaska and Hawaii, candidate locations in these states were removed from the analysis.

Installing E85 Infrastructure

Table 7-17 presents DoD’s total potential consumption of E85 by installing E85 infrastructure at DoD exchanges with 50,000 GGEs or more potential E85 consumption. We have identified 79 DoD exchanges that meet this criterion. Potential E85 consumption represents all fuel use within 5 miles or a 15 minute drive (one way) of DoD exchanges. Results are presented in radii of 1 through 5 miles from the DoD exchange stations. Currently, two operating DoD exchanges have E85 pumps, AAFES at Fort Benning and the NEX at the Pentagon, where DoD can increase E85 consumption.

Table 7-17. DoD's Potential Increase in E85 Consumption by Installing E85 Infrastructure at DoD Exchanges (Current Fleet Locations)

Distance to DoD exchange (miles)	Current E85 consumption (GGEs)	Potential E85 consumption if all FFVs used E85 (GGEs)	Potential increase in E85 consumption (GGEs)
At DoD exchange	22,750	1,889,417	1,866,667
Within 1 mile	22,750	2,114,742	2,091,992
Within 2 miles	22,750	2,468,323	2,445,573
Within 3 miles	22,750	2,847,567	2,824,817
Within 4 miles	22,750	3,140,856	3,118,106
Within 5 miles	22,750	3,417,135	3,394,385

DoD use of the exchanges is relatively large, so the potential to increase E85 consumption by installing E85 infrastructure at DoD exchanges is also very large. The potential to increase DoD's E85 consumption by this action is 3.39 million GGEs (or 4.71 million gallons) annually. This represents roughly 150 times DoD's current consumption of E85 at DoD exchanges.

We have identified the following 79 DoD exchanges for potential installation of new E85 infrastructure:

Arizona

- Yuma Marine Corps Air Station (MCAS)

California

- Camp Pendleton
- Fort Rosecrans
- Coronado Naval Air Station (NAS)
- San Diego Naval Station
- Miramar MCAS
- Lemoore NAS

Colorado

- Fort Carson

District of Columbia

- Bolling AFB
- Fort McNair

Florida

- Mayport Naval Station
- Pensacola NAS
- Key West NAS
- Meridian NAS
- Jacksonville NAS

Georgia

- Fort Gillem
- Fort McPherson
- Fort Stewart–2 locations
- Hunter AFB
- Kings Bay Naval Sub Support Base
- Fort Benning–2 locations

Indiana

- Crane Naval Surface Warfare Center

Kentucky

- Fort Knox–2 locations
- Fort Campbell–2 locations

Louisiana

- Barksdale AFB
- Fort Polk

Maine

- Brunswick NAS
- Portsmouth Naval Base

Maryland

- Andrews AFB
- Walter Reed
- Aberdeen Proving Ground
- Patuxent River NAS
- Fort Detrick

Mississippi

- Gulfport Naval Construction Battalion Center

Montana

- Malmstrom AFB

New Jersey

- Fort Dix

New York

- Fort Hamilton
- Fort Drum

North Carolina

- Fort Bragg–3 locations
- Pope AFB
- Camp Lejuene

Oklahoma

- Tinker AFB–2 locations

Pennsylvania

- Fort Indiantown Gap

Rhode Island

- Newport Naval Station

Tennessee

- Mid-South Naval Support Activity

Texas

- Fort Worth NAS Joint Reserve Base
- Fort Hood–4 locations
- Ingleside Naval Station
- Corpus Christi NAS
- Kingsville NAS

Virginia

- Little Creek Amphibious Base
- Fort Belvoir
- Fort Eustis
- Oceana NAS–2 locations
- Yorktown Naval Weapons Station
- Norfolk Naval Station–3 locations
- Norfolk Naval Shipyard (Scott Center Annex)
- Fort Lee
- Quantico Marine Corps Base

Washington

- Jackson Park Naval Reservation
- Bangor Naval Submarine Base
- Fort Lewis–4 locations
- Everett Naval Station

Increasing E85 Use by Concentrating FFVs

As shown in Table 7-18, we estimate that DoD can increase E85 consumption by an additional 5,834,945 GGEs (8,104,090 gallons) by installing new E85 infrastructure at DoD exchanges and maximizing the concentration of E85 FFVs (at 77 percent) near those exchanges. With this action, DoD’s potential E85 consumption at DoD exchanges would be 9,252,080 GGEs (12,850,111 gallons).

Table 7-18. DoD's Potential E85 Consumption by Concentrating E85 FFVs Near DoD Exchanges and Diverting Fueling of E85 FFVs to Those Stations (GGEs)

Distance to DoD exchange (miles)	Current E85 consumption	Potential E85 consumption if all FFVs used E85	Potential E85 consumption by concentrating E85 FFVs	Potential Increase in E85 consumption by concentrating FFVs
At DoD exchange	22,750	1,889,417	5,657,438	3,768,021
Within 1 mile	22,750	2,114,742	6,209,654	4,094,911
Within 2 miles	22,750	2,468,323	7,136,915	4,668,592
Within 3 miles	22,750	2,847,567	7,995,848	5,148,281
Within 4 miles	22,750	3,140,856	8,654,101	5,513,245
Within 5 miles	22,750	3,417,135	9,252,080	5,834,945

As with analyses earlier in this chapter, DoD can achieve most of the potential increase in E85 consumption by focusing on the largest opportunities. The top 20 DoD exchanges represent almost half (43.3 percent) of the potential increase in E85 consumption. Table 7-19 presents the top 20 DoD exchanges and the potential increase in E85 consumption from placing infrastructure there.

Table 7-19. Top 20 Locations for DoD to Increase E85 Consumption by Installing E85 Infrastructure or Increasing Use of Existing E85 Infrastructure at DoD Exchanges

DoD exchange	Address	Potential increase in E85 consumption (GGEs)[a]
Pentagon NEX, VA[b]	801 S Joyce Street	311,208
Fort Knox, KY	708 Spearhead Division Avenue	270,800
Pensacola Naval Air Station, FL	5600 Highway 98 West	242,930
Little Creek Amphibious Base, VA	1240 Gator Boulevard	234,998
Crane Naval Surface Warfare Center, IN	300 Highway 361	227,068
Norfolk Naval Station, VA	400 Bellinger Boulevard	215,437
Jacksonville Naval Air Station, FL		214,069
Camp Pendleton, CA		202,681
Fort Hood, TX	100 Hood Rd	196,901
Scott Center Annex, VA		193,700
Fort Eustis, VA		191,413
Norfolk Naval Station, VA	B Avenue and Second St	187,251
Oceana Naval Air Station, VA	889 E Avenue	174,363
San Diego Naval Station, CA	32nd Street	172,843
Fort Bragg, NC	5050 Butner Road	167,370
Fort Stewart, GA	939 Utility Rd	164,018
Fort Bragg, NC	1302 Gruber Road	162,213

Table 7-19. Top 20 Locations for DoD to Increase E85 Consumption by Installing E85 Infrastructure or Increasing Use of Existing E85 Infrastructure at DoD Exchanges

DoD exchange	Address	Potential increase in E85 consumption (GGEs)[a]
Fort Lewis, WA	9503 Ranier Ave	158,223
Norfolk Naval Station, VA	1560 Mall Drive	156,519
Fort Benning, GA	6500 Marchant Avenue	149,802
Total		3,993,807

[a] Potential increase by diverting fueling of E85 FFVs to nearby DoD exchanges and concentrating E85 FFVs near those exchanges.

[b] DoD exchange currently has E85 infrastructure.

Estimated Costs

We estimate that DoD will likely incur the following incremental costs by installing E85 infrastructure at DoD exchanges, concentrating E85 FFVs near current DoD exchanges, and diverting fueling of E85 FFVs to those stations:

- *Infrastructure installation costs.* We estimate that installing new E85 infrastructure will cost $183,485 per station. This data, presented in Chapter 8, is based on historical DESC E85 infrastructure installation costs. These costs were annualized over the 5 year time frame of this study.

- *E85 fuel incremental cost*. At current prices, E85 costs $0.62 more than gasoline per GGE.

- *More frequent refueling of the additional E85 FFVs*. As discussed earlier in this chapter, the lower energy content of will require E85 FFVs to refuel 39 percent more when using E85 rather than gasoline, creating costs for vehicle use associated with additional trips to station and the labor associated with refueling.

- *Extra driving distance and time per refueling*. For 38.9 percent of the fuel transactions, this action calls on fleet operators to divert refueling to nearby commercial stations. DoD will incur incremental costs associated with vehicle use and labor costs. We estimate that additional driving requirements are 2.5 miles each way (at $0.485 per mile) and the total additional driving time is 15 minutes roundtrip (at labor costs estimated at $26.05 per hour).

We do not attribute any additional costs for training of fleet operators and materials, management oversight, or enforcement. Also, we do not attribute additional costs for relocating FFVs.

As shown in Table 7-20, we estimate that the total annualized costs (including installation costs) for taking this action is $13,969,898. The capital investment costs for installing E85 infrastructure are $14,495,315—these costs were annualized over 5 years. By taking this action, we estimate that DoD will incur incremental costs of $1.51 per GGE for increasing the use of E85 at DoD exchanges.

Table 7-20. Estimated Annual Incremental Costs for Installing E85 Infrastructure at DoD Exchanges

Cost category	Annual transactions	Cost per transaction ($)	Total annualized cost ($)
E85 infrastructure costs	79	36,697[a]	2,899,063
E85 fuel cost (GGEs)	9,229,330	0.62	5,722,185
Vehicle use costs (extra refuelings)	299,099	2.43	726,811
Labor for refueling (extra refuelings)	299,099	6.51	1,947,134
Vehicle use costs (extra driving distance)	299,184	2.43	727,017
Extra driving time labor	299,184	6.51	1,947,688
Total E85 cost			13,969,898
Increase in E85 consumption (GGEs)			9,229,330
Cost per GGE increase in E85 consumption			1.51

[a] The total capital investment of $183,485 is annualized over 5 years.

Installing B20 Infrastructure

Table 7-21 presents DoD’s total potential consumption of B20 by installing B20 infrastructure at DoD exchanges with 50,000 GGE or more of potential B20 consumption. We have identified 11 DoD exchanges that meet this criterion. Potential B20 consumption represents all fuel use within 5 miles or a 15 minute drive (one way) of DoD exchanges. Results are presented in radii of 1 through 5 miles from the DoD exchange stations. Additionally, there are currently six operating DoD exchanges with B20 pumps where DoD can increase B20 consumption.

Table 7-21. DoD’s Potential Increase in B20 Consumption by Installing B20 Infrastructure at DoD Exchanges (GGEs)

Distance to DoD exchange (miles)	Current B20 consumption	Potential B20 consumption if all diesel NTVs Used B20	Potential increase in B20 consumption
At DoD exchange	454,030	673,942	219,912
Within 1 mile	454,030	788,855	334,825
Within 2 miles	454,030	1,263,891	809,861
Within 3 miles	454,030	1,423,938	969,908
Within 4 miles	454,030	1,439,387	985,357
Within 5 miles	454,030	1,551,263	1,097,233

The potential increase in DoD's B20 consumption by this action is 1.10 million GGEs (or 1.24 million gallons) annually, a 142 percent increase over DoD's current consumption of B20 at DoD exchanges and an 18 percent increase over DoD's total B20 consumption in FY06.

We identified the following 11 DoD exchanges for potential installation of new B20 infrastructure:

California
- Miramar Marine Corps Air Station

Hawaii
- Schofield Barracks

Kentucky
- Fort Knox

Maryland
- Walter Reed

New York
- Fort Drum

North Carolina
- Pope AFB

Texas
- Fort Sam Houston
- Fort Hood

Virginia
- Little Creek Amphibious Base
- Fort Lee

Washington
- Jackson Park Naval Reservation

Table 7-22 presents the 17 DoD exchanges either with existing B20 infrastructure or recommended new infrastructure and the potential increase in B20 consumption.

Table 7-22. Locations for DoD to Increase B20 Consumption by Installing B20 Infrastructure or Increasing Use of Existing B20 Infrastructure at DoD Exchanges (GGEs)

DoD exchange	DoD current B20 consumption	Potential B20 consumption	Potential increase in B20 consumption
Crane Naval Surface Warfare Center, IN	289,690	292,921	3,231
Norfolk Naval Station, VA	107,854	193,887	86,033
Miramar Marine Corps Air Station, CA	—	144,673	144,673
Pope AFB, NC	—	118,607	118,607
Fort Knox, KY	—	98,716	98,716
Schofield Barracks, HI	—	94,653	94,653
Fort Sam Houston, TX	—	88,180	88,180
Fort Lee, VA	—	84,207	84,207
Fort Hood, TX	—	67,790	67,790
Pentagon, VA	560	62,843	62,283
Little Creek Amphibious Base, VA	—	60,759	60,759
Jackson Park Naval Reservation, WA	—	57,857	57,857

Table 7-22. Locations for DoD to Increase B20 Consumption by Installing B20 Infrastructure or Increasing Use of Existing B20 Infrastructure at DoD Exchanges (GGEs)

DoD exchange	DoD current B20 consumption	Potential B20 consumption	Potential increase in B20 consumption
Walter Reed, MD	—	55,756	55,756
Fort Drum, NY	—	53,049	53,049
Oceana Naval Air Station, VA	28,979	43,958	14,979
Naval Weapons Station Charleston, SC	21,942	28,365	6,423
Imperial Beach Naval Air Station, CA	5,005	5,042	37
Total	454,030	1,551,263	1,097,233

Estimated Costs

We estimate that DoD will likely incur the following incremental costs by installing B20 infrastructure at DoD exchanges and diverting fueling of diesel vehicles to those stations:

- *Infrastructure installation costs.* We estimate that installing new B20 infrastructure will cost $203,957 per station. This data, presented in Chapter 8, is based on historical DESC B20 infrastructure installation costs. These costs were annualized over the 5 year time frame of this study.

- *Extra driving distance and time per refueling*. For 80.0 percent of the fuel transactions, this action calls on fleet operators to divert refueling to nearby DoD exchanges. DoD will incur incremental costs associated with vehicle use and labor costs. We estimate that additional driving requirements are 2.5 miles each way (at $0.485 per mile) and the total additional driving time is 15 minutes roundtrip (at labor costs estimated at $26.05 per hour).

We do not expect any additional costs for training of fleet operators and materials, management oversight, or enforcement. As shown in Table 7-23, we estimate that the total annualized costs (including installation costs) for taking this action is $750,363. The capital investment costs for installing B20 infrastructure are $2,243,527—these costs were annualized over 5 years. By taking this action, we estimate that DoD will incur incremental costs of $0.68 per GGE for increasing the use of B20 at DoD exchanges.

Table 7-23. Estimated Annual Incremental Costs for Installing B20 Infrastructure at DoD Exchanges

Cost category	Annual transactions	Cost per transaction ($)	Total annualized cost ($)
B20 infrastructure costs	11	40,791[a]	448,701
Vehicle use costs (extra distance)	33,743	2.43	81,995
Extra driving time labor	33,743	6.51	219,667
Total B20 annual cost			750,363
Increase in B20 consumption (GGEs)			1,097,233
Cost per GGE increase in B20 consumption			0.68

[a] The total capital investment of $203,957 is annualized over 5 years.

Chapter 8
Potential for Increased Use of Biofuel at DoD Installation Fueling Sites

In Chapter 7, we evaluated opportunities for DoD to increase biofuel use at commercial infrastructure and DoD exchanges. This chapter focuses on the potential increase in use of biofuel by converting or installing new infrastructure at fueling sites within military bases. We discuss the current biofuel infrastructure at DoD installation fueling sites, candidate locations for converting or installing new infrastructure, potential increase in biofuel use, and associated costs.

SUMMARY

The primary opportunities (or actions) for DoD to increase biofuel use at installation fueling sites are as follows:

- Convert fueling sites from conventional fuel to biofuel.
- Install new biofuel infrastructure when conversion is not possible.

Table 8-1 summarizes DoD's potential increased use of E85 or B20 for converting existing or installing new biofuel infrastructure, along with the associated costs. Costs are provided as one-time capital investment costs, annual costs, annualized costs (annual costs plus capital costs annualized over 5 years), and cost per GGE increase in E85 or B20.

DoD can potentially increase its annual consumption of biofuel at fueling sites on military bases by 10.75 million GGEs as follows:

- *Converting 56 gasoline fueling sites to E85 and installing new E85 infrastructure at 51 DoD installation fueling sites.* The potential increase in E85 is 4.61 million GGEs (6.40 million gallons), requiring capital investment of $13.0 million and annual costs of $3.83 million.
- *Converting 40 diesel fueling sites to B20 and installing new B20 infrastructure at 21 DoD installation fueling sites.* The potential increase in B20 is 4.26 million GGEs (3.78 million gallons), requiring capital investment of $6.10 million and no change in annual operating costs.

Table 8-1. Potential Increased Use of E85 and B20 at DoD Installation Fueling Sites and Associated Costs

Potential DoD action	Capital investment ($)	Annual costs ($)	Total annualized costs ($)	Potential increase in biofuel Use (GGE)	Cost per increase in GGE ($)
E85					
Convert gasoline fueling sites to E85	3,672,312	2,424,056	3,158,516	2,917,133	1.08
Install new E85 infrastructure when conversion is not possible	9,357,735	1,407,857	3,279,404	1,694,229	1.94
Total	13,030,047	3,831,911	6,437,921	4,611,362	1.40
B20					
Convert diesel fueling sites to B20	1,820,400	0	364,080	3,158,437	0.12
Install new B20 infrastructure when conversion is not possible	4,283,097	0	856,619	1,099,807	0.78
Total	6,103,497	0	1,220,699	4,258,244	0.29

Our analysis of the potential for converting existing or installing new biofuel infrastructure at DoD installation fueling sites suggests the following:

- Sites without the potential of using 15,000 gallons of biofuel each year—the equivalent of two tank truck deliveries of 7,500 gallons each—are not appropriate for conversion or installation of biofuel infrastructure.
- Many DoD sites that use ground fuels do not meet minimum conditions for conversion or installation of biofuel infrastructure. DoD should remain selective in deciding which bases warrant an investment in biofuel infrastructure.
- Sites with the potential of using between 15,000 and 50,000 gallons of B20 or E85 annually should be considered for conversion or installation of infrastructure only on a limited basis.
- DESC is not receiving sufficient reasonable and responsive offers from commercial biofuel suppliers on long-term contracting opportunities for the supply of biofuel to military bases. Approximately 50 percent of these requirements remain pending without contract award.
- DoD has been very successful in the conversion of diesel fuels to B20 but has had only limited success in the conversion of gasoline requirements to E85 use.

- DESC working with the Services, should conduct site specific analysis and preliminary engineering design work in order to complete prioritizing sites for conversion or new construction funding.

The method used in this chapter provides a rough order of magnitude estimate of potential consumption and costs to convert or install biofuel infrastructure at selected military bases. It was limited by the quality and consistency of the databases used, so this report cannot take the place of a site-by-site review to validate the availability and suitability of specific tanks and military bases for conversion or installation of biofuel infrastructure.

CURRENT FUEL USE AT MILITARY BASES

DESC is the primary agency for the procurement and inventory management of DoD worldwide fuel requirements. DESC's total purchase and resale of fuel and energy products were $12.4 billion in FY06.[1] It purchases a full range of petroleum fuels for DoD, from commercial heating fuels to military specification jet fuels. In FY06, DoD purchased approximately 5.5 billion gallons of petroleum fuels worldwide. DoD's consumption of all petroleum products in the United States is about 2.9 billion gallons,[2] about 1.05 percent of the 282.5 billion gallons of fuel consumed in the United States.[3]

The majority of this fuel—approximately 95 percent—is military specification fuel intended for use in tactical vehicles, ships, and aircraft.[4] These fuels do not currently have a suitable biofuel substitute, so we do not evaluate these military specification fuels and associated infrastructure for conversion to biofuel. The remaining 5 percent of DESC fuel purchases in the United States are ground fuels that the military services do not typically use in tactical vehicles (Figure 8-1). These fuels include 21 grades of diesel fuel, 6 grades of gasoline, E85, and B20. DoD cannot convert all uses of diesel or gasoline to biofuel because of equipment, use, climatic, or availability issues.

The use of E85 and B20 at DoD installation fueling sites has increased dramatically over the last 5 years (Figure 8-1). The growth in biofuel use is primarily due to the large increase in the number of biofuel fueling sites on military bases.

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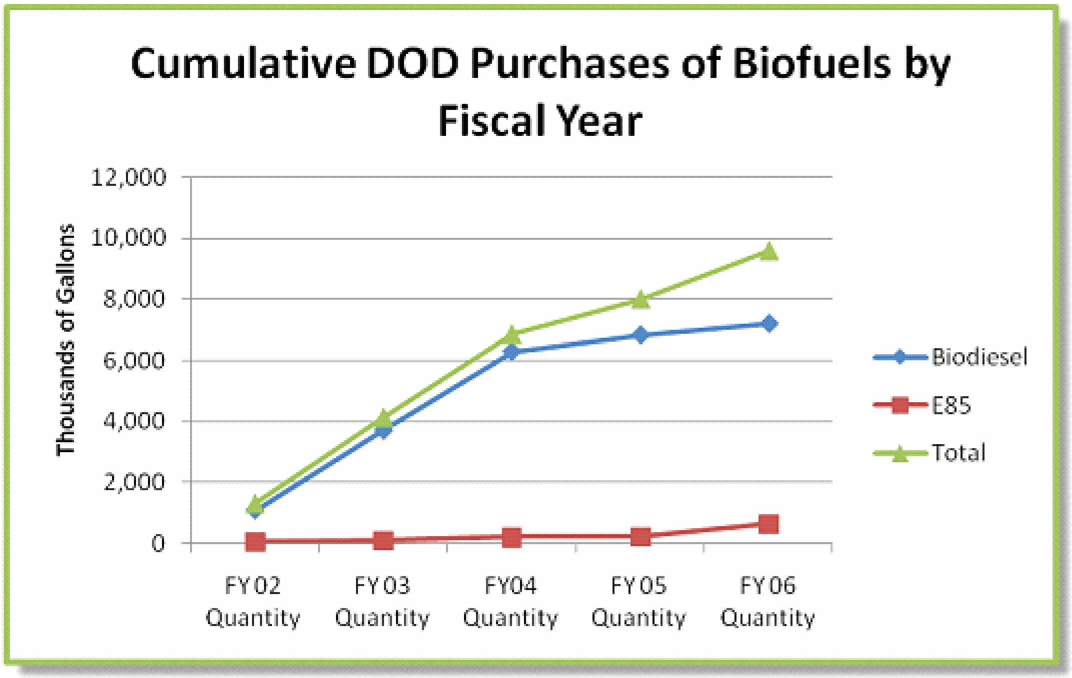
[1] DESC, *DESC Fact Book FY2006*, 2007, p. 18, http://www.desc.dla.mil/DCM/Files/FactBook_FY06.pdf.

[2] *United States* includes the 50 states and District of Columbia, not U.S. territories.

[3] Energy Information Administration, *U.S. Finished Motor Gasoline Product Supplied (Thousand Barrels)*, http://tonto.eia.doe.gov/dnav/pet/hist/mgfupus1m.htm.

[4] DESC FY06 sales database.

Figure 8-1. Growth in DoD Contract Purchases of Biofuel, FY02–06



B20 represented most of the increase in biofuel consumption at military bases from FY02–06. Factors driving DoD's increased B20 consumption on military bases included the following:

- The ease and low cost at which military facilities could convert fueling sites to B20.
- The ability of diesel vehicles to use B20 without expensive modification.
- The ability to receive significant AFV credits for use of B20.
- The low cost of AFV credits earned by the purchase of 450 gallons of neat biodiesel (B100) or 2,250 gallons of B20 (20 percent biodiesel and 80 percent petroleum diesel) compared with the cost of new AFVs.

The use of E85 in DoD has lagged behind that of B20. DoD has cited a number of reasons for E85's slow growth:

- The costs and complexity of converting existing tanks or installing new tanks for E85 are significantly greater than for B20. Most sites require the installation of new tanks, involving long-term planning and budget justification.
- Planning and budgeting for new E85 tanks has been delayed by military, local, and state fire marshals because of ongoing controversy over the

acceptability of some aboveground tank designs and the lack of UL certification of E85 dispensing systems.

EXISTING DOD FUELING INFRASTRUCTURE

The military services and DLA, through DESC, operate 491 bases, installations, or facilities in the 50 states and District of Columbia that store and issue fuels to end-use customers. DoD designs and operates these sites primarily to support the distribution, storage, and subsequent issue of military specification aviation, ground, and marine fuels to aircraft, tactical vehicles, and ships. Most of these sites also stock a variety of ground fuels for issue to end-use customers. These ground fuels include B20, E85, gasoline, and diesel fuels.

DoD uses ground fuels at a variety of individual sites and for an assortment of purposes—including tactical vehicles—within the military base boundaries. The number, sizes, and locations of storage tanks are diverse. For example, one military base has 414 individual tanks for diesel fuel and another has 26 individual tanks for gasoline.[5] Individual tank capacities range from 280 to 1.3 million gallons.[6] Diesel tanks are installed to support specific facilities and uses such as small craft refueling, emergency generation, building heating, or power plants. Gasoline tanks are similarly dedicated to specific uses. Many smaller tanks do not have the capability for subsequent redistribution of fuel.

Many existing tanks will not be suitable for conversion to biofuel because tank sizes are potentially too small or too large for proper product management. The primary product management concerns are having sufficient storage to obtain economical deliveries and sufficient consumption to ensure a minimum of two stock turns per year to maintain product quality.

The military services and DLA have converted or installed many biofuel fueling sites at installations over the past several years. These projects have needed to compete for project funds with pressing domestic and overseas operational requirements. Under DoD's policies for the integrated materiel management of petroleum, DESC has funding responsibility for DoD's worldwide fuel infrastructure where two or more customers are supplied. These sites are called capitalized sites, or DFSPs. The military services retain responsibility where fuel is supplied to a single customer. These sites are referred to as non-capitalized sites. Consistent with this responsibility and DoD policy on alternative fuels,

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[5] Active line items in DESC's Contracts Information System, https://ports2.desc.dla.mil/cis.htm.

[6] See Note 5, this chapter.

DESC has issued guidance on the conversion or installation of biofuel:

> When requesting DESC infrastructure support, activities shall optimize the distribution of alternative fuels by consolidating vehicles and dispensing facilities where possible and economical. Activities shall ensure that existing infrastructure is converted to the extent possible and economical, and that new tanks are only considered as a last alternative. If additional tanks are required, construction project requests submitted to DESC must contain detailed justification and must show that all existing tanks are fully used and unavailable for conversion. The availability of public and nonpublic alternative fuels, the capacity of existing storage tanks in relation to the economic resupply quantity/minimum delivery quantities, and seasonal change requirements shall be included in the documentation and justification for project requests.[7]

Conversion of existing tanks from diesel fuel to B20 is relatively simple and inexpensive. The most significant costs associated with conversion to B20 are tank cleaning and the potential need to install additional dispensers and control equipment. The first introduction of B20 may also require more frequent fuel filter changes on the using equipment. The military services and DLA have installed B20 infrastructure at 87 fueling sites (Table 8-2). Figure 8-2 shows the geographic distribution of these B20 sites.

Table 8-2. Military Fueling Sites with B20 or E85 Storage

Military service	All sites	Sites with B20 tanks	Sites with E85 tanks
Air Force	152	54	13
Army	213	4	2
DoD Agencies	19	3	3
Marine Corps	15	7	1
Navy	92	19	5
Total	491	87	24

Conversions of existing tanks from gasoline to E85 tend to be more complicated than B20, requiring potential change-out of parts in the existing gasoline system that are not compatible with E85. As with B20, new dispensing and control systems may be required to support E85. The military services and DLA have installed E85 infrastructure at 24 fueling sites (Table 8-2). Figure 8-3 shows the geographic distribution of these E85 sites.

[7] DLA, *Department of Defense (DoD) Bio-Fuels Program (Biodiesel (B20) and Fuel Ethanol (E85)*, Policy Number: DESC-P-9, September 21, 2005, http://www.desc.dla.mil/DCM/Files/DESC-P-9.doc.

Figure 8-2. Distribution of Existing DoD B20 Fueling Sites

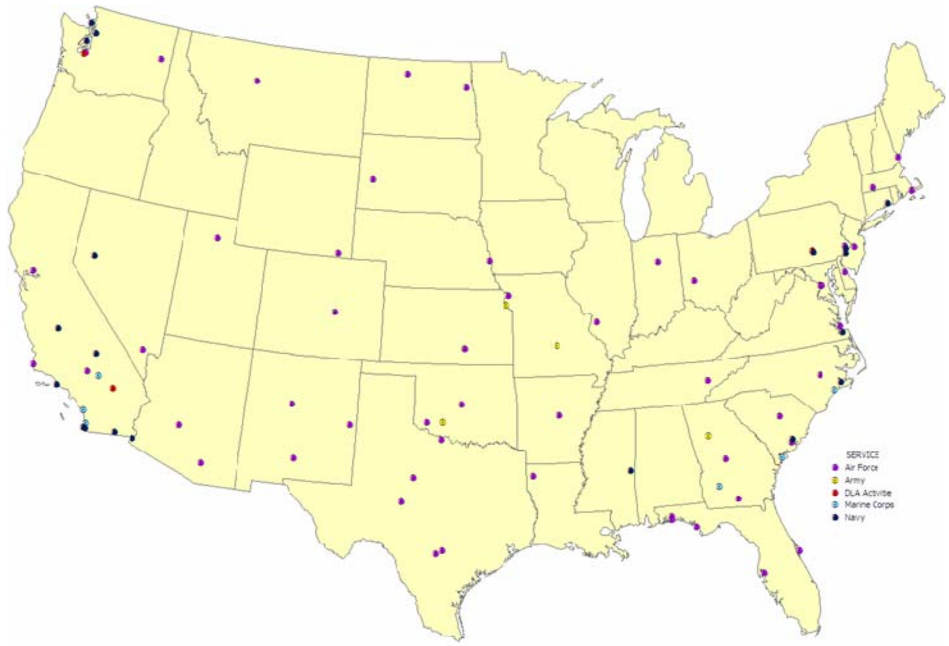
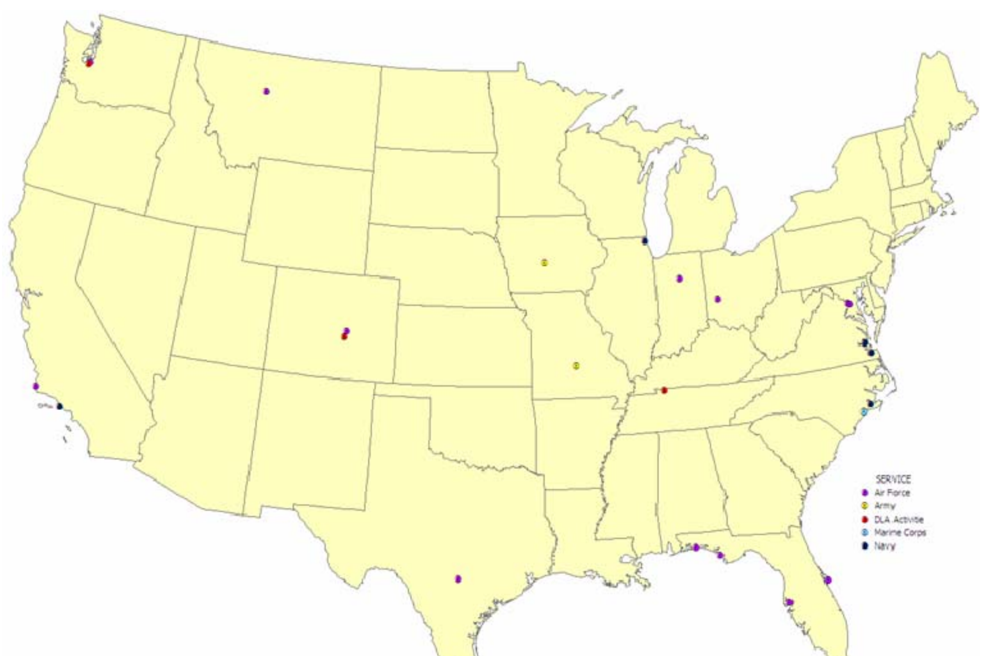


Figure 8-3. Distribution of Existing DoD E85 Fueling Sites



A site-by-site review would be required to validate the additional availability and suitability of specific tanks for conversion to biofuel. Although this type of review was beyond the scope of this analysis, we did gather sufficient data to make reasonable estimates of the locations where conversion or installation of infrastructure to increase biofuel use is most practical.

BIOFUEL SUPPLY ISSUES AT MILITARY BASES

In addition to DESC's infrastructure funding responsibilities, the agency is also the mandatory supply source for the military's petroleum and biofuel requirements. DESC contracts with local suppliers and brokers to purchase ground fuels for direct-to-tank delivery of commercial specification fuel. End-use customers receive fuel in tank truck delivery quantities approximating 7,500 gallons (typical capacity of tank truck). DESC's contracts are typically issued for 5 years, and supplemental solicitations are issued to cover emergent needs. Since December 2003, DESC has sought to establish biofuel contract coverage 346 times for specific military sites. Of these biofuel solicitations, DESC has made 158 contract awards, leaving 154 requirements without contracted supply sources (34 were cancelled or terminated). Thus, DESC has been able to successfully award supply contracts for biofuel only 50.3 percent of the time (Table 8-3).

Table 8-3. Status of Biofuel Contract Requirements December 2003 to Present

Biofuel	Status of requirement	Capitalized sites (DFSP)	Non-capitalized sites	Total
B20	Awarded	113	16	129
	Cancelled[a]	22	3	25
	Pending[b]	104	24	128
	Contracts terminated for convenience	1	1	2
	Total requirements	240	44	284
E85	Awarded	21	8	29
	Cancelled	6	1	7
	Pending	20	6	26
	Contracts terminated for convenience	0	0	0
	Total requirements	47	15	62

[a] Cancelled means that the military service withdrew the requirement for contract coverage.

[b] Pending means that the military service has a continuing requirement that is not covered by a contract.

DESC's inability to get greater contract coverage for DoD biofuel requirements suggests that biofuel suppliers are not always available or willing to participate in DoD fuel contracts. Table 8-4 lists the number of requirements without contract awards by state. In some cases, such as in California, regulatory restrictions have limited DoD's ability to obtain biofuel. In other cases, the large distances between production facilities and DoD's sites dramatically increase transportation costs, resulting in DESC being unable to obtain fair and reasonable prices. The cost of transportation is a large factor in the overall delivered cost of E85 because many proposed military E85 sites are not near the E85 production in the Midwest.

Table 8-4. Number of Pending Biofuel Requirements by State

State	B20	E85	State	B20	E85
AL	3		NE	1	
AZ	5		NH	1	
CA	28	1	NJ	6	
CO	2	1	NM	4	
CT	1		NV	3	
FL	11	5	NY	2	2
GA	1	1	OK	3	
HI	8		PA	6	2
IA	1	1	SC	1	2
IL	2	2	SD	1	
IN	1	1	TN	1	
KS	4		TX	9	7
MA	3		UT	1	
ME	1		VA	7	
MO	1		VT	1	
MS	2		WY	2	1
ND	5				

INCREASING USE BY CONVERTING OR BUILDING INFRASTRUCTURE ON BASES

DESC has published policy to implement the *Department of Defense (DoD) Bio-Fuels Program,*[8] providing guidance on the required steps to obtain DESC funding for conversion or installation of biofuel infrastructure. Consistent with federal policies, DoD policy encourages the use of commercial infrastructure near military bases and military service collaboration with other federal and non-federal fleets to promote the development of commercial infrastructure. However, additional costs may be associated with requiring vehicles to refuel off base at commercial stations. These include the loss of work time by employees and the impact of losing quarterly Federal Highway Trust Fund excise tax exemptions for vehicles that do not leave the military base.

[8] See Note 7, this chapter.

However, few biofuel retailers are close enough to military light-duty vehicle fleets—they may be miles from the front gate—to justify routine rotation of vehicles off base to refuel. Partnerships with other federal and commercial fleets and potential biofuel retailers are difficult to establish because federal, commercial, and military fleets are widely dispersed and retailers are reluctant to make the significant investment in biofuel infrastructure without a guarantee of increased fuel use to provide a return on their investment. For these reasons, and others in a post-9/11 era, the conversion or installation of new infrastructure on military bases offers significant opportunities for the increased use of biofuel by vehicles garaged on military bases.

Our analysis identified 491 fueling sites on military bases in the United States that store conventional petroleum. Of these sites, 87 have identified storage tanks for B20 and 24 have identified storage tanks for E85. The potential for expanding biofuel infrastructure at DoD sites seems to be tremendous, but not all sites are suitable for the use of biofuel due to storage limitations, transportation costs, construction costs, or inadequate product use that would adversely impact product quality. We detail our method for identifying potential DoD fueling sites for converting existing or installing new biofuel infrastructure in the subsections that follow.

Data Used in Analysis

Recent Biofuel Infrastructure Costs

DESC provided estimated costs from proposed biofuel conversion and installation projects in FY06 and FY07.[9] We used the average costs of recent conversions and installations as the basis of estimated costs for future conversions and installations in current FY07 dollars (Table 8-5).

Table 8-5. Costs to Convert or Install New Alternative Fuel Tanks ($)

Range	Convert tanks to E85	Install New E85 infrastructure	Convert tanks to B20	Install new B20 infrastructure
Average	65,577	183,485	45,510	203,957
Minimum	6,000	49,268	1,000	24,571
Maximum	130,063	406,518	260,000	494,381
Median	59,438	164,610	17,441	157,692

Existing Tanks and Capacities

DESC provided existing tank number and capacity data queried from the Requirements Manager database. Duplicate tank data, associated with the storage of multiple product grades during the calendar year, were removed. We evaluated

[9] "DESC Alternative Fuels Infrastructure Projects Supported By MR&E And PMO Funding As Of May 9, 2007." Excel spreadsheet provided by DESC-F.

the number and capacity of existing tanks at each fueling site to determine the potential to convert conventional petroleum infrastructure to biofuel. The sizes and types of tank at each DoD fueling site were analyzed on the basis of the following requirements for biofuel infrastructure:

- *Minimum tank size*. Tanks proposed for conversion must have sufficient capacity, either singly or as a group, to permit tank truck delivery of 7,500 gallons of fuel at a single time. Establishing a minimum tank size helps ensure cost-effectiveness by minimizing transportation costs. The minimum-sized tank or tank group with the capability to receive 7,500 gallons in a single delivery and still have operating stocks available is approximately 10,000 gallons.

  The delivery of biofuel into a large number of small tanks, even if they aggregate to greater than 10,000 gallons, is not cost-effective. Therefore, we only considered sites with average tank capacities greater than 3,000 gallons.

- *Number of available tanks.* Conventional petroleum fuels will still be required after conversion of infrastructure for biofuel. For example, E85 can only be used in E85 FFVs, which are not readily available in medium- and heavy-duty vehicles. Therefore, at least two diesel tanks must be available to convert one to B20 and at least two gasoline tanks to convert one to E85. In addition, the tanks proposed for conversion must have sufficient capacity, either singly or as a group, to permit the tank truck delivery of 7,500 gallons of fuel at a single time. This minimizes transportation costs. This is especially true for E85, where production facilities and terminal stocks are often distant from military sites.

CURRENT FUEL CONSUMPTION

DESC provided FY06 billing records of fuel consumption at most military sites. In the case of DFSPs, sales data were available showing the amount of product sold in retail quantities by site. For military service fuel, sales data represented bulk deliveries by tank truck.

FY06 consumption data were used to estimate the potential consumption of biofuel at each site. Stocks of B20 and E85 must be consumed within 6 months of delivery to accommodate seasonal fuel blend adjustments and maintain product quality. Therefore, sites with potential biofuel consumption less than 15,000 gallons per year—the equivalent of two tank truck deliveries of 7,500 gallons each—are not appropriate for conversion or installation of biofuel infrastructure.

FUEL ESTIMATION CRITERIA

The conversion of existing or installation of new biofuel infrastructure does not require use of more fuel (on a GGE basis), but the type of fuel used shifts from one product to the other. Therefore, current consumption is a good estimate of the sum of the future consumption of the conventional fuel and biofuel. We analyzed consumption data at sites that currently use both biofuel and conventional fuel to project use of biofuel at potential future sites, as follows:

- *Biodiesel.* We identified 78 fueling sites that use over 15,000 gallons of B20 annually. B20 consumption at these sites ranged from 4.92 percent to 100 percent of total diesel and B20 fuel consumption combined. On average, these sites had converted 69.86 percent of their diesel consumption to the use of B20. The standard deviation was 0.3073. To include a wider range of potential sites, we selected one standard deviation below the mean as a reasonable ratio between the current use of diesel fuel and the potential use of B20. Thus, we looked for potential consumption to meet or exceed 39.31 percent of current diesel fuel consumption to define a reasonable lower limit of potential consumption. Sites with an estimated B20 potential of less than 15,000 gallons are not considered viable for conversion (or installation if conversion was not possible).

Table 8-6. B20 Percentage of Total Diesel and B20 Use at 78 DoD Sites

Range	Percentage
Minimum	4.92
Average	69.86
Maximum	100.00
Median	83.20
Mode	100.00
Standard Deviation	0.3073

- *E85.* We identified 15 fueling sites that use over 15,000 gallons of E85 annually. E85 consumption at these 15 sites ranged from a low of 6.58 percent to a high of 70.44 percent of total gasoline and E85 consumption combined. On average, these sites had converted 22.75 percent of their gasoline consumption to the use of E85. Due to the small sample size, we used this average to determine the potential consumption of E85 at DoD fueling sites. Sites with an estimated E85 potential of less than 15,000 gallons are not considered viable for conversion (or installation if conversion was not possible).

Criteria Used to Identify Candidate Sites

We used the following minimum criteria to identify DoD fueling sites for potential *conversion* from conventional fuel to biofuel:

- Cannot already have E85 or B20 infrastructure.

- Must have two or more tanks in gasoline or diesel service.
- Total tank capacity must exceed 10,000 gallons.
- Average tank capacity must exceed 3,000 gallons.
- Projected biofuel consumption must exceed 15,000 gallons annually. Projected consumption is calculated as 22.75 percent of existing gasoline sales for E85 and 39.31 percent of existing diesel sales for B20.
- Conversion to B20 and E85 will not be considered for sites in Alaska because these biofuels are not available.
- Conversion to E85 will not be considered in Hawaii because E85 is not available.

We used the following minimum criteria to identify DoD fueling sites for potential *installation* of biofuel infrastructure:

- Cannot already have E85 or B20 infrastructure.
- Projected consumption must exceed 15,000 gallons annually.
- Installation of B20 and E85 tanks will not be considered for Alaska because these biofuels are not available.
- Installation of E85 tanks will not be considered in Hawaii because E85 is not available.
- Sites already identified for potential conversion are not considered for potential new installation of biofuel infrastructure.

DoD Sites for Potential E85 Infrastructure

We estimate that DoD can increase E85 consumption by up to 4.61 million GGEs (6.40 million gallons) annually by converting existing or installing new E85 infrastructure at DoD fueling sites on military bases (Table 8-7). This includes the potential conversion of E85 infrastructure at 56 sites and the installation of new infrastructure at 51 sites. These sites met all the criteria outlined previously for the initial screening of potential conversion and installation of E85. Specific site evaluations are necessary to confirm the identified potential, determine whether DoD policy can be met, and decide whether conversion or installation of infrastructure is most appropriate.

Table 8-7. DoD's Potential Increase in E85 Consumption at DoD Infrastructure Fueling Sites and Associated Capital Costs

	Fueling sites	Potential E85 consumption (GGE)	Potential E85 consumption (volumetric gallons)	Capital investment (infrastructure) costs ($)
Conversion	56	2,917,133	4,051,573	3,672,312
New installation	51	1,694,229	2,353,096	9,357,735
Total	107	4,611,362	6,404,669	13,030,047

Table 8-8 summarizes our analysis of the potential for installing biofuel infrastructure at the 491 fueling sites. E85 tanks were listed at 24 of 491 sites. For 56 of the 491 fueling sites, no consumption or use data were available. Therefore, the potential for consumption of E85 at these sites could not be calculated. Of the remaining sites, we determined that 395 are not suitable for conversion or installation of E85 infrastructure.

Table 8-8. Analysis of DoD Fuel Sites for Potential Conversion or Installation of E85 Infrastructure

Military service	Sites	Sites with E85 tanks	Military sites without conversion opportunity and reason not suitable						Insufficient data	Sites meeting conversion criteria	Sites meeting installation criteria only
			Only one tank	Storage capacity <10,000	Average tank capacity <3,000	Sales inadequate	Alaska or Hawaii	Total			
Air Force	152	13	74	27	1	6	1	109	2	28	15
Army	213	2	174	13	1	4	1	193	3	15	21
DoD agencies	19	3	7	4		1		12	3	1	6
Marine Corps	15	1	8	2				10	1	3	3
Navy	92	5	53	14		3	1	71	7	9	6
Total	491	24	316	60	2	14	3	395	16	56	51

Conversions of existing infrastructure, where feasible, provide the most economical approach to increasing E85 use. Table 8-9 shows the estimated costs of tank conversion and tank installation throughout DoD per gallon for three projected consumption ranges.

Table 8-9. Costs of Tank Conversion or Installation for E85 Infrastructure

Potential E85 consumption range	Site count	Projected E85 consumption (volumetric gallons)	Capital investment (infrastructure) costs ($)
Conversions to E85			
> 100,000	14	2,132,185	918,078
> 50,000 and < 99,999	18	1,241,613	1,180,386
>15,000 and < 49,999	24	677,775	1,573,848
New infrastructure for E85			
> 100,000	6	738,348	1,100,910
> 50,000 and < 99,999	8	589,972	1,467,880
>15,000 and < 49,999	37	1,024,776	6,788,945

We identified the following 107 DoD fuel sites for potential conversion or installation of E85 infrastructure:

Alabama

- Fort Rucker (Installation)
- USAG Redstone (Conversion)
- Anniston Army Depot Building 513 (Conversion)
- Maxwell AFB (Conversion)

Arizona

- Luke AFB (Conversion)
- Marine Corps Air Station Yuma (Installation)

Arkansas

- Pine Bluff Arsenal (Conversion)
- Little Rock AFB (Installation)

California

- Naval Air Station North Island (Conversion)
- Navy Public Works Center (Conversion)
- Fort Irwin (Conversion)
- Edwards AFB (Conversion)
- MCAS Miramar (Conversion)
- Marine Corps Air Ground Combat Center (Installation)
- Travis AFB (Conversion)
- Fort Hunter Liggett (Installation)

California (Continued)

- Beale AFB (Conversion)
- March ARB (Conversion)
- MCLB Barstow (Installation)
- Sierra Army Depot (Installation)
- Naval Air Station Lemoore (Conversion)
- MCMWTC Bridgeport (Installation)

Colorado

- USAF Academy (Installation)
- Pueblo Chemical Depot (Conversion)

Delaware

- Dover AFB (Installation)

Florida

- Eglin AFB (Conversion)
- Naval Air Station Whiting Field (Installation)
- Naval Support Activity Panama City (Installation)
- Naval Air Station Pensacola (Conversion)

Georgia

- Fort Gordon (Installation)
- Naval Submarine Base Kings Bay (Conversion)
- Fort Benning (Conversion)
- MCLB Albany (Conversion)
- Robins AFB (Conversion)
- Fort Stewart (Installation)
- Moody AFB (Conversion)

Idaho

- Mountain Home AFB (Conversion)

Illinois

- Scott AFB (Installation)

Indiana

- Camp Atterbury (Installation)

Kansas

- Fort Riley (Conversion)
- Fort Leavenworth (Installation)
- McConnell AFB (Conversion)
- Blue Grass Army Depot (Installation)

Louisiana

- Fort Polk (Installation)

Massachusetts

- Hanscom AFB (Installation)

Maryland

- Aberdeen Proving Ground (Conversion)
- Fort Meade (Installation)
- Naval Air Warfare Center Air Div (Conversion)

Mississippi

- Camp Shelby (Installation)
- Keesler AFB (Installation)
- Columbus AFB (Conversion)

Missouri

- Whiteman AFB (Conversion)

Nebraska

- Offutt AFB (Conversion)

Nevada

- Indian Springs AFAF (Conversion)
- Nellis AFB (Conversion)
- Naval Air Station AOM (Conversion)

New Jersey

- Fort Dix (Conversion)
- Fort Monmouth (Installation)
- Picatinny Arsenal (Installation)
- McGuire AFB (Conversion)
- Naval Air Engineering Station (Installation)

New Mexico

- White Sands Missile Range (Conversion)
- Kirtland AFB (Conversion)
- Holloman AFB (Conversion)
- Cannon AFB (Installation)

New York

- Military Academy West Point (Installation)
- Fort Drum (Conversion)

North Carolina

- Pope AFB (Installation)
- MCAS New River (Installation)
- Seymour Johnson AFB (Installation)
- Fort Bragg (Installation)

North Dakota

- Minot AFB (Conversion)
- *Grand* Forks AFB (Conversion)

Oklahoma

- Fort Sill (Installation)
- McAlester Army Ammo Plant (Installation)
- Tinker AFB (Conversion)
- Vance AFB (Installation)
- Altus AFB (Installation)

Oregon

- Umatilla Chemical Depot (Installation)

Pennsylvania

- Letterkenny Army Depot (Installation)
- Defense Distribution Depot Susquehanna (Installation)

South Carolina

- Fort Jackson (Installation)
- Charleston AFB (Conversion)

South Carolina (Continued)

- MCRD Parris Island (Installation)
- Shaw AFB (Conversion)
- Marine Corps Air Station Beaufort (Conversion)

Tennessee

- Arnold AFB (Conversion)

Texas

- Fort Bliss (Conversion)
- Fort Hood (Installation)
- Red River Depot (Conversion)
- Lackland AFB (Conversion)
- Sheppard AFB (Installation)
- Laughlin AFB (Installation)
- Dyess AFB (Conversion)
- Lackland AFB (Installation)

Utah

- USA Garrison Dugway (Conversion)
- Tooele Army Depot (Conversion)
- Hill AFB (Conversion)

Virginia

- Marine Corps Base Quantico (Conversion)
- Fort Belvoir (Installation)
- Fort Myer (Installation)
- USAG Fort AP Hill (Installation)
- NAVPHIBASE (Installation)

Washington

- Naval Base Kitsap (Conversion)

Wisconsin

- Fort McCoy (Installation)

Wyoming

- F E Warren AFB (Installation)

ESTIMATED COSTS FOR INCREASING E85 USE AT DOD FUELING SITES

We estimate that DoD is likely to incur the following incremental costs by converting existing infrastructure to E85 or installing new E85 infrastructure at DoD fueling sites:

- *Infrastructure conversion costs.* We estimate that converting infrastructure from gasoline to E85 will cost $65,577 per fueling site. These costs were annualized over 5 years (FY08–12).
- *Infrastructure installation costs.* We estimate that installing new E85 infrastructure will cost $183,485 per fueling site. These costs were annualized over 5 years (FY08–12).
- *E85 fuel incremental cost.* At current (2007) prices, E85 costs $0.62 more than gasoline per GGE.
- *More frequent refueling of E85 FFVs*. As discussed in Chapter 7, the lower energy content of E85 will require E85 FFVs to refuel 39 percent more when using E85 instead of gasoline, creating additional costs for the labor associated with refueling (15 minutes at labor costs estimated at $26.05 per hour).

As shown in Table 8-10, we estimate that the total annualized costs (including installation costs) for implementing this action are $6,437,921. The capital investment costs for installing E85 infrastructure are $13,030,047—these costs were annualized over 5 years. By implementing this action, we estimate that DoD will incur incremental costs of $1.40 per GGE for increasing the use of E85 at DoD fueling sites.

Table 8-10. Estimated Annual Incremental Costs for Installing or Converting E85 Infrastructure at DoD Fueling Sites

Cost category	Annual transactions	Cost per transaction ($)	Total annualized cost ($)
E85 infrastructure conversion costs	56	13,115	734,440
E85 infrastructure installation costs	51	36,697	1,871,547
E85 fuel cost (GGEs)	4,611,362	0.62	2,859,044
Labor for refueling (increased frequency)	149,442	6.51	972,867
Total E85 cost			6,437,921
Increase in E85 consumption (GGEs)			4,611,362
Cost per GGE increase in E85 consumption			1.40

[a] The total capital investments are annualized over 5 years.

DoD Sites for Potential B20 Infrastructure

We estimate that DoD can increase B20 consumption by up to 4.26 million GGEs (3.78 million gallons) annually by converting existing or installing new B20 infrastructure at DoD fueling sites on military bases (Table 8-11). This includes the potential conversion of B20 infrastructure at 40 sites and the installation of new infrastructure at 21 sites. These sites met all the criteria outlined previously for the initial screening of potential conversion and installation of B20. Specific site evaluations are necessary to confirm the identified potential, determine whether DoD policy can be met, and decide whether conversion or installation of infrastructure is most appropriate.

Table 8-11. DoD's Potential Increase in B20 Consumption at DoD Infrastructure Fueling Sites and Associated Capital Costs

Action	Fueling sites	Potential B20 consumption (GGE)	Potential B20 consumption (volumetric gallons)	Capital investment (infrastructure) costs ($)
Conversion	40	3,158,437	2,805,006	1,820,400
New installation	21	1,099,807	976,738	4,283,097
Total	61	4,258,244	3,781,744	6,103,497

Table 8-12 summarizes our analysis of the potential for installing biofuel infrastructure at the 491 fueling sites. B20 tanks were listed at 87 of 491 sites. For 72 of the 491 fueling sites, no consumption or use data were available. Therefore, the potential for consumption of B20 at these sites could not be calculated. Of the remaining sites, we determined that 292 are not suitable for conversion or installation of B20 infrastructure.

Table 8-12. Analysis of DoD Fuel Sites for Potential Conversion or Installation of B20 Infrastructure

			Military sites without conversion opportunity and reason not suitable								
Military service	Sites	Sites with B20 tanks	Only one tank	Storage capacity <10,000	Average tank capacity <3,000	Sales inadequate	Alaska	Total	Insufficient data	Sites meeting conversion criteria	Sites meeting installation criteria only
Air Force	152	54	46	3	8	18	3	78	8	12	5
Army	213	4	114	22	15	6	1	158	33	18	11
DoD agencies	19	3	6					6	7	3	
Marine Corps	15	7	6					6	1	1	
Navy	92	19	32	1	9	1	1	44	23	6	5
Total	491	87	204	26	32	25	5	292	72	40	21

Conversions of existing infrastructure, where feasible, provide the most economical approach to increasing B20 use. Table 8-13 shows the estimated costs of tank conversion and tank installation throughout DoD per gallon for three projected consumption ranges.

Table 8-13. Costs of Tank Conversion or Installation for B20 Infrastructure

Potential consumption range (gallons)	Site count	Projected consumption (gallons)	Capital investment (infrastructure) costs ($)
Conversions to B20			
> 100,000	10	1,515,491	455,100
> 50,000 and < 99,999	5	339,759	227,550
>15,000 and < 49,999	25	949,756	1,137,750
New infrastructure for B20			
> 100,000	1	159,186	203,957
> 50,000 and < 99,999	6	388,816	1,223,742
>15,000 and < 49,999	14	428,736	2,855,398

We identified the following 61 DoD fuel sites for potential conversion or installation of B20 infrastructure:

Alabama

- Anniston Depot (Conversion)

Arizona

- USA Yuma Proving Ground (Conversion)

California

- Beale AFB (Conversion)
- US Army Depot Sierra (Conversion)
- USAG Fort Irwin (Installation)
- Fort Hunter Liggett (Installation)

Colorado

- Buckley ANG (Conversion)
- DFSP Fort Carson (Conversion)
- USAF Academy (Installation)
- Fort Carson (Installation)

Florida

- Naval Support Activity Panama City (Conversion)
- Naval Air Station Whiting Field (Installation)

Georgia

- Naval Submarine Base Kings Bay (Conversion)

Hawaii

- Navy Public Works Center (Conversion)
- Pacific Missile Range Facility (Conversion)
- Marine Corps Air Station (Installation)

Idaho

- Mountain Home AFB (Conversion)

Iowa

- Iowa ANG (Conversion)

Kansas

- Fort Riley (Conversion)

Kentucky

- DFSP Fort Campbell (Conversion)
- Fort Knox (Installation)
- Blue Grass Army Depot (Installation)
- Kentucky ARNG (Installation)

Louisiana

- NAS JRB New Orleans (Installation)

Maryland

- Aberdeen Proving Ground (Conversion)

Maryland (Continued)

Fort Meade (Conversion)

Naval Air Warfare Center Air Div (Installation)

Massachusetts

Hansom AFB (Conversion)

Westover AFB (Installation)

Michigan

Selfridge ANGB (Conversion)

Alpena Combat Readiness Training Center (Conversion)

Maneuver Training Site (Installation)

Minnesota

Minneapolis-St. Paul Joint Air Reserve Station (Conversion)

Mississippi

Construction Battalion Center (Installation)

Nevada

Indian Springs AFAF (Conversion)

New Jersey

USAR Garrison Fort Dix (Conversion)

New Mexico

White Sands Missile Range (Conversion)

New York

USAG Fort Drum (Conversion)

West Point (Conversion)

North Dakota

North Dakota Air National Guard (Installation)

Oklahoma

McAlester Army Ammo Plant (Conversion)

Vance AFB (Installation)

Pennsylvania

Letterkenny Army Depot (Installation)

PA ARNG TNG Site DET (Installation)

Texas

Laughlin AFB (Conversion)

Naval Air Station Joint Reserve Base Fort Worth (Conversion)

Red River Depot (Conversion)

DFSP Fort Hood TX (Conversion)

Lackland AFB (Installation)

Utah

Tooele Army Depot (Conversion)

USA Garrison Dugway (Conversion)

Virginia

VA ARNG (Conversion)

Fort AP Hill (Conversion)

Fort Lee (Conversion)

Marine Corps Base Quantico (Conversion)

NAVPHIBASE (Conversion)

USAG Fort Belvoir (Installation)

Fort Myer (Installation)

Washington

Naval Base Kitsap (Conversion)

Wisconsin

Volk Field (Conversion)

Fort McCoy (Conversion)

ESTIMATED COSTS FOR INCREASING B20 USE AT DOD FUELING SITES

We estimate that DoD is likely to incur no additional annual costs by converting existing infrastructure to B20 or installing new B20 infrastructure at DoD fueling sites. The only incremental costs by taking this action are the capital investment costs of $6,103,497, which when annualized over 5 years represents $0.29 per GGE increase in B20.

Chapter 9
Results

In Chapters 2 through 4, we discussed DoD's use of biofuels in FY02–06, the current landscape for DoD's use of biofuels, our projections for the composition of biofuel-capable vehicles in the DoD fleet, and DoD's potential demand for biofuels in these vehicles in FY07–12. We concluded that the primary factors limiting DoD's use of biofuels in FY07–12 will be the availability of biofuels and the use of available biofuels in the vehicles.

Chapters 5 through 8 present our analysis of measures DoD can take to address these limiting factors and increase its use of biofuels. We projected the future commercial availability of biofuels and identified a series of actions that DoD could implement to increase its use of biofuels. These included increasing biofuel use at commercial infrastructure, and expanding biofuel infrastructure at DoD exchanges and installation fueling sites. For each action, we quantified DoD's potential increase in biofuel use and associated capital investment and annual costs.

In this chapter, we summarize the results of our analysis. We compare our estimates of the potential increases in DoD's biofuels use from implementing our recommended actions to our projections of DoD's potential demand for biofuels and biofuels commercial availability through FY12.

Potential Increased Use of Biofuels

We quantified the potential increases from five primary actions DoD can take to increase biofuel use through FY12:

- Ensure purchase of biofuel when fueling at biofuel stations.
- Divert fueling of biofuel-capable vehicles from gasoline-only stations to nearby biofuel stations.
- Concentrate E85 FFVs near E85 stations.
- Install new biofuel infrastructure at DoD exchanges with large fuel use.
- Convert or install new biofuel infrastructure at DoD fueling sites on military bases.

Table 9-1 summarizes, for each action, DoD's potential increased use of E85 or B20 and the associated costs. The costs are provided as one-time capital investment costs, annual costs, annualized costs (annual costs plus capital costs annualized over 5 years), and cost per GGE increase in E85 or B20.

Table 9-1. Increased Biofuel Use and Costs

Potential DoD action	Capital investment ($)	Annual costs ($)	Total annualized costs ($)	Potential increase in biofuel use (GGE)	Cost per increase in GGE ($)
E85					
Optimize fueling of E85 FFVs at current commercial E85 stations	0	122,677	122,677	134,851	0.91
Divert fueling of E85 FFVs to nearby commercial E85 stations	422,620	8,438,375	8,522,899	3,208,547	2.66
Locate E85 FFVs near commercial E85 stations	0	3,867,302	3,867,302	2,407,587	1.61
Install new E85 infrastructure at large-use DoD exchanges and locate E85 FFVs near those stations	14,495,315	11,070,835	13,969,898	9,229,330	1.51
Convert gasoline fueling sites to E85 at DoD installations	3,672,312	2,424,056	3,158,516	2,917,133	1.08
Install new E85 infrastructure at DoD installation fueling sites when conversion is not possible	9,357,735	1,407,857	3,279,404	1,694,229	1.94
Total	27,947,982	27,331,102	32,920,696	19,591,677	1.68
B20					
Optimize fueling of diesel vehicles at current commercial B20 stations	0	0	0	30,893	0.00
Divert fueling of diesel vehicles to nearby commercial B20 stations	309,440	2,198,800	2,260,688	978,983	2.31
Install new B20 infrastructure at large-use DoD exchanges	2,243,527	301,662	750,363	1,097,233	0.68
Convert diesel fueling sites to B20 at large-use DoD installations	1,820,400	0	364,080	3,158,437	0.12
Install new B20 infrastructure at large-use DoD installation fueling sites when conversion is not possible	4,283,097	0	856,619	1,099,807	0.78
Total	8,656,464	2,500,462	4,231,750	6,365,353	0.66

We estimate that DoD could potentially increase its use of E85 by 19.6 million GGEs and its use of B20 by 6.4 million GGEs by implementing these actions fully. Our estimates reflect 100 percent utilization of biofuel infrastructure when available. Due to operational and implementation issues, actual biofuel use will likely be less than these estimates. However, even small changes in biofuel refueling behavior and limited installation of biofuel infrastructure will drastically increase biofuel use.

The first two actions listed in Table 9-1 for both E85 and B20 implement the requirements of Section 701 of EPAct 2005 which mandate federal fleets to use alternative fuels when reasonably available. By also locating E85 FFVs near commercial biofuel stations, DoD can attain substantial further increases in E85 use at a relatively low cost.

Although the potential for increasing biofuel use at commercial infrastructure is substantial, the largest opportunities for DoD to increase its use of biofuels is by installing biofuel infrastructure at DoD exchanges and military base fueling sites. Almost half (47 percent) of our estimated total potential increase of E85 is from installing E85 infrastructure at 79 DoD exchanges. Similarly, 50 percent of the total potential increase of B20 is from converting existing diesel fueling sites to B20.

We identified 79 DoD exchanges and 107 DoD installation fueling sites for conversion or installation of E85 infrastructure, and 11 DoD exchanges and 61 DoD installation fueling sites for conversion or installation of B20 infrastructure. Specific site evaluations are necessary to confirm the identified potential increase in biofuel use, determine if DoD policy can be met, and decide if conversion or installation of infrastructure is most appropriate.

COMPARISON TO PROJECTED DOD BIOFUELS DEMAND

In Chapter 4, we estimated DoD’s potential demand for biofuels through FY12. Without changing vehicle acquisition trends, DoD’s projected demand for E85 will range from 1.79 million GGEs (minimum regulatory requirements) to 21.54 million GGEs (100 percent use in the NTV fleet). We project DoD’s demand for B20 will range from 10.20 million GGEs to 17.45 million GGEs.

Even if DoD implemented all recommended actions fully, our forecasted increases in E85 and B20 would not exceed projected DoD demand under all vehicle acquisition scenarios. The projected E85 use would be 20.43 million GGE, representing 95 percent utilization of the forecasted E85 FFV fleet. Similarly, the project B20 use of 12.43 million GGE translates to 71 percent utilization of the forecasted diesel NTV fleet. Therefore, we do not foresee DoD requiring more aggressive acquisition of E85 FFVs and diesel vehicles through FY12.

COMPARISON TO COMMERCIAL AVAILABILITY

In Chapter 5, we forecasted that in FY12, the retail availability of E85 will be 29.5 million GGE and of B20 will be 2,624 million GGE. DoD would only represent 0.47 percent of the B20 market in FY12, even if DoD implemented all actions in this report. Although our forecast for DoD’s potential use of E85 in FY12 represents only 0.18 percent of the forecasted ethanol market, it would comprise 69 percent of the forecasted E85 market. DoD’s large demand for E85 would likely support the expansion of commercial infrastructure as well as additional blending of ethanol into E85.

Chapter 10
Analysis of Other Biofuels

In this chapter, we discuss DoD's potential use of biofuels other than ethanol (as E85) and biodiesel (as B20) in FY07–12. These biofuels include biobutanol, methanol, renewable diesel, and synthetic hydrocarbon-based fuels. Due to the lack of commercial availability and feasibility with the existing DoD fleet, we project that DoD's consumption of these fuels will be negligible in FY07–12.

BIOBUTANOL

Biobutanol is still in its infancy as a transportation biofuel and is unlikely to be commercially available before FY12. A partnership between BP and DuPont represents the primary effort toward commercial production of biobutanol. Research and development is still required to ensure biobutanol is cost-effective, determine its long-term effects on automobiles, and determine whether existing infrastructure will support its transport.

Butanol can be made from either fossil fuels or biomass. Butanol made from biomass is referred to as biobutanol, although both compounds have the same chemical make-up and properties. Biobutanol is produced through a fermentation process similar to that of ethanol using the same feedstocks (corn, sugar beets, wheat, sorghum, cassava, and sugarcane),[1] but the enzyme used in the process differs. Finding the correct enzyme to produce biobutanol is the main obstacle to the cost-effectiveness of its production.[2]

Biobutanol has many benefits over ethanol as a biofuel:

- *Higher energy content.* Biobutanol's energy content is 92 percent of gasoline, compared with between 65 and 70 percent for ethanol.
- *No water absorption*. Fuel testing has demonstrated that biobutanol blends do not phase separate in the presence of water.[3] Therefore, biobutanol can be added to gasoline at the refiner and shipped through the existing pipeline system.

Despite its potential, though, biobutanol has a long way to go in terms of engine testing, market introduction, and ensuring cost-effective large-scale production.

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[1] BP, *Biobutanol Fact Sheet*, June 2006.

[2] CNN, *Biobutanol: Better than Ethanol?* April 2, 2007, http://money.cnn.com/2007/04/02/news/economy/biobutanol/index.htm.

[3] Dupont, *Biobutanol Performance Similar to Unleaded Gasoline, According to New Fuel Testing*, April 19, 2007.

The partnership between BP and DuPont is still in its infancy, announcing in June 2007 that it intends to construct a biobutanol demonstration facility in the United Kingdom, which the companies are calling "the first of its kind."[4] The facility, which will not be operational before 2009, is intended to further advance commercial deployment of biobutanol. Therefore, it will likely be several years before biobutanol is introduced commercially.

BP and Dupont do not intend to introduce biobutanol into U.S. markets until they have developed their new "Gen-2" biocatalyst, which will significantly boost conversion of feedstocks to fuel. However, they believe that the earliest this will be achieved is 2010.[5] According to DuPont Biofuels Vice President and General Manager John Ranieri, biobutanol will be extended to the global markets "as technology advances and market conditions dictate."[6]

METHANOL

Methanol is an alternative fuel used in FFVs that run on M85 (a blend of 85 percent methanol and 15 percent gasoline). However, current methanol use as a transportation fuel is very small (257,000 GGEs in 2004),[7] primarily due to its low energy content compared with E85 and relative toxicity. Automobile manufacturers no longer produce M85 FFVs and are instead focusing on E85 FFVs. Between 1997 and 2004, the number of M85 FFVs in the United States decreased from 21,040 to 4,592 vehicles,[8] so we do not project the demand and use of methanol by DoD over this study's time frame.

For economic reasons, methanol is most commonly produced from natural gas, but it can also be made from any other carbon-based source, such as coal, landfill gas, seaweed, and wood waste. Methanol can also be produced from biomass by way of a process that results in lower CO_2 emissions. This process is significantly less cost-effective than producing methanol from natural gas.[9]

Currently, 10 U.S. methanol plants produce about 3.7 million metric tons annually, and the annual U.S. demand is about 8 million metric tons.[10] Thus, more than half of the methanol consumed in the United States annually is imported from other countries. Methanol is used primarily as a component in

[4] Inside Greentech*, DuPont and BP building Biobutanol Facility in U.K.*, June 27, 2007, http://insidegreentech.com/node/1383.

[5] Chemical & Engineering News, *BP and Dupont Plan 'Biobutanol'*, June 26, 2006.

[6] Earthtimes.org, *Dupont Biofuels Leader Provides Business Update at Alternative Energy Symposium*, February 21, 2007.

[7] Energy Information Administration, *Estimated Consumption of Alternative Transportation Fuels in the United States, by Fuel and Vehicle Weight, 2000, 2002, and 2004,* February 2004, http://www.eia.doe.gov/cneaf/alternate/archive/datatables/afvtable12_03.xls.

[8] See Note 7, this chapter.

[9] Brian Vermillion, *Feasibility Study of Methanol as Transportation Fuel*, March 18, 2001.

[10] Methanol Institute, *Frequently Asked Questions*, http://www.methanol.org/pdfFrame.cfm?pdf=faqs.pdf.

numerous chemical products, such as plastics, paints, construction materials, and windshield washer fluid. It is also an essential component for numerous organic chemicals, including formaldehyde, acetic acid, and MTBE.[11] Some racing organizations use methanol to fuel automobiles, but little methanol fuel, if any, is used as an alternative fuel for the public.

Neat methanol (M100) has a higher octane rating than gasoline, which allows internal combustion engines to run more efficiently and results in lower emissions. However, disadvantages include problems with cold starting (due to its boiling point of 65°C), corrosiveness to certain metals included in automobiles, and risk of explosion because saturated methanol-air mixtures are explosive at ambient temperatures.[12] Environmental Protection Agency (EPA) studies have shown that vehicle-related fires are infrequent when methanol or methanol blends are used instead of gasoline.[13] DOE notes that methanol produces a high amount of formaldehyde in its emissions.[14]

Automobiles need to undergo extensive modifications to run on neat methanol. Methanol's heat of combustion is half that of gasoline, and it needs a fuel tank approximately twice the size of that for a gasoline engine as well as more heat in the intake system to make up for this decreased energy content.[15] Cars must be outfitted with special equipment such as stainless steel fuel tanks and fuel lines and methanol-compatible elastomers.[16] Larger fuel injectors must be used to make up for the fact that methanol's energy content is approximately half that of gasoline.

Methanol blends, such as M85, still increase octane rating while helping to solve the cold starting issues associated with neat methanol. Hydrocarbon emissions from such blends are much lower than gasoline (but formaldehyde emissions increase as methanol content increases). However, as indicated previously, current automobiles cannot run on M85 fuel unless they are M85 FFVs (which are no longer in production). Also, mixtures of gasoline and methanol result in high vapor pressure, which can result in evaporation in the fuel lines, causing vapor lock.

Fueling stations for neat methanol and high methanol blends (such as M85) also need to be outfitted with special materials. Special methanol-compatible storage

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[11] See Note 10, this chapter.

[12] See Note 9, this chapter.

[13] American Methanol Institute, *Methanol Fact Sheets*, http://www.eere.energy.gov/afdc/pdfs/2475.pdf.

[14] DOE, *Methanol Benefits*, EERE Alternative Fuels Data Center.

[15] J. C. Ingamells and R. H. Lindquist, *Methanol as a Motor Fuel or a Gasoline Blending Component, Alcohols as Fuels*, Society of Automotive Engineers, 1980.

[16] American Methanol Institute, *Methanol Transportation Fuels: A Look Back and a Look Forward.*

facilities, pumps, hoses, tanks, and parts are needed due to the fuel's corrosiveness to rubber and certain metals and plastics.[17]

Support has clearly shifted away from methanol as a fuel source for automobiles and toward ethanol. The push to develop methanol as a fuel occurred in the 1980s and 1990s. California established 10-year leases with several oil companies to install methanol pumps at 60 stations. However, methanol FFVs never caught on, and after the leases terminated, any methanol pumps quickly reverted to pumping gasoline.[18] Little has been done in the past 5 years to pursue methanol as a transportation fuel.[19] Even the Indy Racing League (IRL), which used methanol exclusively for 40 years, shifted completely to ethanol in the 2007 racing season.[20]

RENEWABLE DIESEL

E-diesel (also known as renewable diesel or oxydiesel) is a blend of diesel and ethanol (between 7 .7 and 15.0 percent), with up to 5 percent additives to prevent separation of the blends. It is an experimental fuel in development by multiple companies.[21] Today, off-road applications are its only current legal use—the U.S. EPA must grant special permission for E-diesel for use in on-road applications.[22]

Over the next 5 years, the commercial use of E-diesel will be driven by its ability to reduce particulate matter and other emissions compared with regular No. 2 diesel, but due to the percentage of biofuels in the blend, B20 is preferred to E-diesel for DoD's increasing use of biofuels in the NTV fleet.

E-diesel will likely serve as another source of demand for ethanol. It offers several potential benefits over regular diesel fuel. Because ethanol is oxygenated, it reduces particulate emissions associated with diesel engines.[23] Several studies show reductions in particulate matter emissions of soot and black smoke.[24] E-diesel also reduces carbon monoxide and nitrogen oxides emissions.[25]

Several studies show that ethanol blends of up to 15 percent can be used in vehicles without engine modifications. Two on-road studies involving freight

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[17] California Energy Commission, *Resource Guide: Infrastructure for Alternative Fuel Vehicles*, June 1995, http://www.energy.ca.gov/reports/afvguide.html#500.

[18] See Note 16, this chapter.

[19] California Energy Commission, *Methanol as a Transportation Fuel*, http://www.energy.ca.gov/afvs/vehicle_fact_sheets/methanol.html.

[20] IndyCar.com, *Ethanol will Fuel the IndyCar Series*, March 3, 2005.

[21] DOE, *Renewable Diesel Fuel*, EERE, http://www1.eere.energy.gov/biomass/renewable_diesel.html.

[22] Ethanol Information, "E diesel," http://www.ethanol-information.com/ediesel.php.

[23] A. Hanson, Q. Zhang, and P. Lyne, "Ethanol-diesel fuel blend: A Review," *Bio-Resource Technology*, March 30, 2004, pp. 277–285.

[24] See Note 23, this chapter.

[25] See Note 21, this chapter.

trucks and transit buses demonstrated that no abnormal maintenance or fuel-related issues were encountered when ethanol was blended with diesel for normal operations. However, laboratory-based tests by Hanson and others did result in slight problems with the fuel injection system after 500 hours of operation. Additional tests are required to evaluate the effect of E-diesel blends on engine wear.[26] If E-diesel is found to require engine modifications to account for adverse effects, its market penetration will be hampered.

Three other factors may limit the use of E-diesel:

- *Energy content*. The energy content of diesel decreases by approximately 2 percent for every 5 percent of ethanol added to diesel.[27] This results in slightly higher operating costs when using E-diesel due to a reduction in fuel efficiency.[28]
- *Fuel specifications*. Ethanol lowers the fuel viscosity and lubricity of diesel. Minimum specifications for these characteristics are required so that the durability of the fuel injection system is not compromised and that engines are able to start reliably when hot.[29]
- *Safety*. Ethanol is more flammable than diesel (but less flammable than gasoline). The addition of ethanol to diesel would change the National Fire Protection Agency classification from Class II to Class I. Thus, E-diesel would garner more stringent requirements than regular diesel. Adjustments will need to be made for storage and handling of the fuel. For instance, a greater distance between storage tanks and property lines, buildings, and other tanks will be needed. In addition, fuel tanks may need to be outfitted with flame arresters.[30]

SYNTHETIC HYDROCARBON-BASED FUELS

Synthetic hydrocarbon-based fuels (or synfuels) are liquid fuels, such as diesel or jet fuel, manufactured from coal, natural gas, or biomass rather than oil. Unlike other alternative fuels, synfuels provide a “drop-in” replacement to traditional petroleum-based fuels, requiring no (or limited) modification to current vehicles and fuel-distribution infrastructure. Although DoD is evaluating the use of synfuels for both ground and aviation applications, DoD projects only limited production capability (i.e., pilot plants) and availability in the U.S. through FY12.

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[26] See Note 23, this chapter.

[27] University of Illinois at Urbana-Champaign, *Biennial Report: Ethanol and Diesel Blends: E-diesel Shows Promise in Tests*, http://www.aces.uiuc.edu/ACES_Research/biennial_report/abe_ediesel.shtml.

[28] See Note 21, this chapter.

[29] See Note 23, this chapter.

[30] See Note 23, this chapter.

The use of synfuels for DoD applications is still in the testing phase and likely will not in wide-scale use before FY12.

Synfuels Production Processes

Synfuels are manufactured using the Fischer-Tropsch process, referred to as Coal-To-Liquids (CTL), Gas-To-Liquids (GTL), or Biomass-To-Liquids (BTL), depending on the initial feedstock. The Fischer-Tropsch process was developed in 1923 by Franz Fischer and Hans Tropsch and consists of three major steps: (1) syngas formation from the source hydrocarbon and oxygen; (2) the Fischer-Tropsch reaction, where syngas is converted into the new hydrocarbon and water; and, (3) refining of the new hydrocarbon into synfuels. Catalysts are key to the efficiency of each step of the process. Typical catalysts used are based on iron and cobalt, but research is focusing on identifying more efficient catalysts.

Current and Future Availability of Synfuels

Currently, the only commercial-scale synfuel production facilities are operated outside the United States. Sasol’s facility in Secunda, South Africa utilizes the CTL process to produce 124,000 barrels per day of synfuels and other petrochemicals, including ethylene, propylene, ammonia and solvents.[31] In January 2007, Sasol opened a GTL facility, with Qatar Petroleum, to produce 34,000 barrels per day of synfuels. Other GTL production facilities in South Africa (Petro SA) and Malaysia (Shell Bintulu) provide an additional 36,500 barrels per day of synfuels production capacity.[32]

Currently, there are no commercial-scale synfuel production facilities in the United States. DoD is only aware of one demonstration-scale facility, operated by Syntroleum in Port of Catoosa, Oklahoma, which is capable of producing up to 70 barrels per day of synfuel. Syntroleum is currently evaluating opportunities to expand synfuels production, including entering into a joint venture formed with Tyson Foods to produce synfuels from vegetable oils, fats, and greases. However, no commercial-scale synfuel production facilities are expected to be operational in the U.S. before FY12.

Use of Synfuels in DoD Applications

The U.S. Air Force, through its Synthetic Fuel Initiative, is currently evaluating Fischer-Tropsch synthetic jet fuels for use in military aircraft. On August 8, 2007, the Air Force completed certification of a 50/50 blend Fischer-Tropsch fuel with miltary jet fuel (JP-8) in the B-52H Stratofortress. The Air Force is testing and planning to certify every airframe to fly on a domestically produced synthetic fuel blend (50/50). DoD does not anticipate synfuels for wide-scale use until after FY12.

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[31] Sasol Company, *Sasol facts*, 2007, http://www.sasol.com/sasol_internet/downloads/sasolfacts_2007_1180093894888.pdf.

[32] Oil and Gas Journal, *Special Report: GTL Prospects*, March 14, 2005.

Appendix A
Abbreviations

AFB	Air Force Base
AFDC	Alternative Fuels Data Center
AAFES	Army and Air Force Exchange Service
AFV	alternative fuel vehicle
ASTM	American Society for Testing and Materials
bgpy	billion gallons per year
BSM	Business System Modernization
CMSA	Consolidated Metropolitan Statistical Area
CNG	compressed natural gas
DDGS	distillers dry grains with solubles
DESC	Defense Energy Support Center
DFSP	Defense Fuel Support Point
DLA	Defense Logistics Agency
DoD	Department of Defense
DODAAC	Department of Defense Activity Address Code
DOE	Department of Energy
ECRA	Energy Conservation Reauthorization Act
EO	Executive Order
EPA	Environmental Protection Agency
EPAct	Energy Policy Act
ESRI	Environmental Systems Research Institute
FAPRI	Food and Agricultural Policy Research Institute
FAST	Federal Automotive Statistical System
FCV	fuel cell vehicle
FFV	flex-fuel vehicle
FY	fiscal year
GAO	Government Accountability Office
GGE	gallon gasoline equivalent

GIS	geographic information system
GSA	General Services Administration
GVWR	gross vehicle weight rating
HEB	“Here Everything’s Better”
HEV	hybrid electric vehicle
H.R.	House of Representatives
IRL	Indy Racing League
LDV	light-duty vehicle
LNG	liquid natural gas
LPG	liquid propane gas
LSD	low sulfur diesel
MCX	Marine Corps Exchange
MSA	Metropolitan Statistical Area
MTBE	methyl tertiary butyl ether
NCGA	National Corn Growers Association
NDAA	National Defense Authorization Act
NEV	neighborhood electric vehicle
NEVC	National Ethanol Vehicle Coalition
NEX	Navy Exchange Service
NEXCOM	Navy Exchange Command
NREL	National Renewable Energy Laboratory
NTV	non-tactical vehicle
OEM	Original Equipment Manufacturer
PHEV	plug-in hybrid electric vehicles
PIH	plug-in hybrid
POL	Petroleum, Oil, and Lubricants
ppm	parts per million
RFG	reformulated gasoline blends
RFS	Renewable Fuel Standard
RIN	renewable identification number
RVO	renewable volume obligation
S.	Senate

SIN	standard identification number
UL	Underwriters Laboratories
ULSD	ultra-low sulfur diesel
USAF	United States Air Force
USDA	United States Department of Agriculture
VEETC	Volumetric Ethanol Excise Tax Credit

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(MM-YYYY)*
11-2007

2. REPORT TYPE
Final

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
DoD Report to Congress on Use of Biofuels

Section 357 of NDAA for Fiscal Year 2006

5a. CONTRACT NUMBER
SP0600-04-F-5440; DO 1003

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Bentley, Julian A; Author
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

LMI
2000 Corporate Ridge
McLean, VA 22102-7805

8. PERFORMING ORGANIZATION REPORT NUMBER
LMI-DES61C1

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Andrew Pittman (DESC-DDE)
Defense Energy Support Center
8725 John J. Kingman Road
Fort Belvior, Virginia 22060

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
A Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Section 357 of Public Law 109-163 (NDAA for FY06) and Public Law 109-364 (NDAA for FY07) required the Secretary of Defense to complete a study on DoD's use of biodiesel, ethanol, and other biofuels and any measures that can be taken to increase such use. This report comprises the results of the DoD biofuels study. The seven elements of the report include: (1) historical DoD biofuel use in FY02–06; (2) potential requirements for increased DoD use of biofuels; (3) forecast of DoD requirements for biofuel use in FY07–12; (4) current and future commercial availability of biofuels; (5) DoD future utilization of commercial infrastructure; (6) DoD actions to expand public infrastructure; and (7) fueling infrastructure on military installations that could be adapted or converted for biofuels. Based on the Congressional biofuels study analysis, the report outlines the five measures DoD is pursuing to increase its biofuel use in FY07–12.

15. SUBJECT TERMS
biodiesel; ethanol; DoD; biofuel; non-tactical vehicles; E85; B20

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	Unclassified Unlimited	180	Nancy E. Handy
					19b. TELEPHONE NUMBER *(include area code)* 703-917-7249

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

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