Producing and Using Biodiesel in Afghanistan

How the U.S. can save lives, money, and challenge the opium trade

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This paper reflects the views of the authors and was not sponsored or funded by an organization. The authors have lived in New York City for many years, including on September 11, 2001.

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Preface

The inspiration for this paper was President Obama's speech at West Point on December 1, 2009, where he announced that the U.S. will be sending 30,000 additional troops to Afghanistan.

The mission of the United States in Afghanistan has two primary goals: defending the U.S. from further attack and helping Afghanistan to become a secure and productive nation. As has been widely acknowledged, these are both very difficult goals. We asked ourselves the question "What can we do to help?" More specifically, we pondered what actions could be taken that would increase the probability of U.S. and International Security Assistance Force (ISAF) success in Afghanistan. This paper, offering our recommendations, is the result.

The Authors

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John Fox is formerly Chief Executive Officer of Innovation Fuels. He has been building businesses and products for the past fifteen years, nine years of which have been in the energy industry. In 2001, Mr. Fox started a renewable energy project development company, Homeland Energy Resources Development, Inc., initiating its biodiesel division in 2005. Both businesses were then merged into Innovation Fuels. Fox led Innovation Fuels to a profitable business with $15 million in annual revenues, and the company became one of the top three biodiesel refinery and distribution companies in the United States. Prior to founding Homeland Energy, Mr. Fox led the business development of a biogas technology company, completed the financing of an independent oil and gas company, and participated in product development at a Lucent Technologies company. Since 1991, Mr. Fox has served as General Partner at Renard Properties, a Mid-Atlantic real-estate development and management company. He holds a BA from Syracuse University and an MBA from Columbia Business School and is currently a member of the National Biodiesel Board, American Council on Renewable Energy, and the Dean's Advisory Council for Syracuse University's L.C. Smith College of Engineering.

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Sources of Information

Please note that the authors use both "English" units of measure (i.e. the U.S. Customary System) and metric units (International System or SI units) in the paper, depending upon the source of data. In general, in summary sections data is presented in both forms. Also "B" is used as an abbreviation for billion and "M" as an abbreviation for million.

Wherever possible the authors have tried to use the most recent sources of information.

Executive Summary

President Obama's announcement on December 1, 2009 that 30,000 more troops will be sent to Afghanistan was the catalyst for developing the ideas expressed in this paper. The foundation of the strategy proposed rests on three insights.

Insights and Benefits

The first insight is that it is very expensive for the military to import fuel into Afghanistan. In October 2009 DOD officials reported to Congress that the average cost of importing fuel into Afghanistan, or the Fully Burdened Cost of Fuel (FBCF), approaches $400 per gallon when all direct and indirect costs are accounted for, and even sometimes exceeds $400. A 2008 Defense Science Board study, "More Fight Less Fuel," described the FBCF as "several hundred dollars per gallon." By contrast, a November 2009 Deloitte study, "Energy Security- America's Best Defense," calculated the FBCF in a war zone at $45 per gallon. More recently, in an April 2010 paper, "DOD's Energy Challenge as Strategic Opportunity," Amory Lovins, Chairman and Chief Scientist of the Rocky Mountain Institute, described the FBCF as one to two orders of magnitude higher than standard market prices. Regardless, whether the actual FBCF figure is $40 per gallon or $400, the military's cost of fuel in Afghanistan is many times higher than a typical civilian or domestic military market price.

The second insight is that modern biodiesel production technology is both proven technology and relatively inexpensive. The cost of building a medium-sized plant, even in Afghanistan, is on the order of tens of millions of dollars, not hundreds of millions or more.

The third insight is that a high percentage of U.S. casualties in Afghanistan stem from protecting convoys of fuel, water, and other military supplies. The Army calculated in a 2009 study that one fatality occurs for every 24 fuel convoys in Afghanistan.

Our central proposal is to reduce the need for fuel convoys by producing biodiesel fuel in Afghanistan for use by the U.S. military. Because the military would, at least initially, be the sole customer of the biodiesel plant, avoiding the expensive process of importing fuel, the military could afford to pay a higher price for locally produced biodiesel than the petroleum diesel price assessed Army and Marine units by the DOD's Defense Energy Support Center (DESC). The plant, in turn, could pay Afghan farmers a crop rate competitive with that of poppy. (In 2009 Afghan farmers earned three times more growing poppy than growing a food crop such as wheat). Producing and using biodiesel in Afghanistan can therefore reduce U.S. fuel convoys and thereby casualties, achieve dramatic fuel cost savings for the U.S. military, and significantly reduce opium production, hence limiting its trade. Two other important benefits can also be realized: freeing-up troops currently protecting convoys for new missions, and, over time, the creation of a new agriculture-based industry for Afghanistan.

Biodiesel and Military Equipment

Biodiesel has several advantages and disadvantages versus petroleum diesel. Biodiesel has a higher ignition temperature and thus is safer in a war zone than petroleum diesel. Biodiesel is also a better lubricant, prolonging engine life. The two most significant disadvantages for the military are (1) that biodiesel's cold weather properties are in general not as favorable as petroleum diesel, and (2) that above a biodiesel fuel percentage of 5%, most diesel engines designed to meet recent emission standards must also specifically be designed to support the use of biodiesel. Both of these problems can, however, be accommodated.

Safflower is best suited as Afghanistan's first biodiesel crop. It is native to the region and although not a major crop, safflower is already cultivated in Afghanistan. Safflower has a long tap root and is highly drought-resistant. If more safflower is planted than is needed to supply the first biodiesel plant, the oil could be sold to consumers - safflower oil is one of the healthiest vegetable oils for human consumption. (Afghanistan currently imports most of its vegetable oil.) Safflower oil's cold weather properties approach those of petroleum diesel. For subsequent biodiesel plants, crops such as camelina and pennycress should be considered; these crops are not, however, currently grown in Afghanistan.

Addressing the second point above, the biodiesel plant would be generating fuel for the Army or the Marines for use in either generators or vehicles. We recommend that the output of the first biodiesel plant be used exclusively by generators, and that the generators be capable of combusting any percentage of biodiesel from 0% (100% petroleum diesel) to 100% (B100 or 100% biodiesel). About 40% of the oil imported by the military in Afghanistan is used to generate electricity. Although many generator suppliers (and manufacturers of diesel engines for generators) support B100, including John Deere, JS Power, MAN Diesel, Mahindra, Scania, and Wärtsilä, two key U.S. military suppliers of generators, Caterpillar and Cummins, do not warrant their generators for B100. Caterpillar warrants B30 (30% biodiesel) and Cummins B20 (20% biodiesel). Thus, a recommended prerequisite for the military's use of biodiesel in Afghanistan is that Caterpillar and Cummins support B100. In 2010, Cummins begins production of the next generation of medium-sized generator (Advanced Mobile Medium Power Sources or AMMPS), replacing an older generation (Tactical Quiet Generators or TQG). If generators in Afghanistan were only able to support B20 or B30, fuel logistics would be more complex, fewer convoys would be eliminated, and thus fewer lives would be saved. DOD policy should require that all military generators support B100.

If additional biodiesel plants are built, then the military should use biodiesel in vehicles in addition to generators. There are three types of military vehicles deployed in Afghanistan: combat vehicles, tactical combat vehicles, and tactical supply vehicles (trucks). Caterpillar and Cummins and supply most of the diesel engines used in tactical combat vehicles, and Caterpillar supplies virtually all of the engines in the families of tactical supply vehicles currently being produced for the Army and Marines. Combat-related vehicles should be capable of supporting B30, Caterpillar's current standard. Tactical supply vehicles should be capable of supporting

B100. A number of leading truck manufacturers, including MAN Nutzfahrzeuge, PACCAR's European subsidiary DAF, and Scania support B100. The military should have the same flexibility to use biodiesel that exists in the commercial marketplace.

The Biodiesel Plant in Kandahar

We recommend that the military initially contract for a single medium-sized biodiesel plant capable of producing 12 million gallons per year (56.8 million liters), using private industry for both construction and on-going operations. This capacity allows the generation of electricity for a range of 4,800 – 5,600 soldiers. The plant should be located near a large U.S. or International Security Assistance Force (ISAF) base in Kandahar Province, since the southern provinces of Kandahar and Helmand account for 73% of Afghanistan's poppy cultivation. The climate in Kandahar is also very warm; the average low temperature reaches freezing levels only in December and January (-1 °C), so biodiesel would rarely be combusted under cold weather conditions. Afghan farmers would need to plant about 61,500 hectares of safflower in order to generate enough safflower oil to produce 12M gallons of biodiesel. 61,500 hectares is equivalent to about 50% of the 2009 Afghanistan poppy crop. For every 100 gallons of biodiesel produced in Afghanistan, 13.75 gallons of chemical inputs must be imported by the military: 11 gallons of methanol, 2.25 gallons of a catalyst (sodium methylate), and 0.5 gallons of acid (typically sulfuric or phosphoric).

Biodiesel production technology platforms can be modular. Roughly 75% of the biodiesel plant can be manufactured in the U.S. before shipment to Afghanistan, minimizing local construction time. Elapsed time, from start of the project to production in Afghanistan, is expected to be thirteen months.

Financial Analysis

The one-time cost of building the plant is $90M, a relatively small cost compared to other military expenditures in Afghanistan. This figure includes $31.7M in plant capital costs, $30M for the purchase of new generators capable of supporting B100, $5M for transportation of equipment from the U.S. to Afghanistan, another $5M for a U.S. program to buy safflower-based biodiesel for testing by generator suppliers, and $18.3M for working capital and miscellaneous expenditures.

Annual operating costs cover importing the chemical inputs, safflower payments to farmers, labor costs for a plant staff of twenty people, a contract for a private security team of eighteen security personnel, and electricity to run the plant. Initially nearly all of the staff and security personnel would be experienced American or ISAF professionals.

Now let's look at two scenarios, one using a FBCF of $400 per gallon, and one using a FBCF of $41 per gallon. Both scenarios assume biodiesel production of 12M gallons per year, and that the cost per gallon of chemical inputs is the same as the FBCF. Afghan farmers would be paid $5,000 per hectare of safflower, which is 40% higher than the price they were paid for poppy in

2009. When the FBCF is $400 per gallon, the military saves $3.7B the first year of operation and $3.8M per year in subsequent years. Savings are higher in subsequent years because the $90M one-time cost has already been recovered. Payback of the $90M occurs in much less than a month. When the FBCF is $41 per gallon, payback is about one year. The military saves $90M per year starting in the second year. Since the plant is fully paid for after one year, the production cost per gallon drops from $41 per gallon to $33.50 per gallon. The average farm size in Helmand Province is 6.92 hectares. Thus to realize the savings above projected for the $400 per gallon case or the $41 per gallon case about 8,900 farmers must be persuaded to switch from poppy to safflower. This objective appears to be achievable, since USAID trained more than 160,000 farmers across Afghanistan in 2009.

As long as the plant achieves 12M gallons of biodiesel production in the first year, our assumptions are very conservative. Although part of the project plan, the effect of methanol recycling technology has not been included in the financial analysis. This recycling technology could reduce costs by 25%. Also, if methanol (or ethanol which can substitute for methanol) can be procured locally then costs would decline dramatically. Two byproducts of the production process, glycerin and safflower meal, have not been valued. Glycerin can be used as a deicing agent for aircraft, a fuel, or, depending on its purity, as a food additive for humans or animals. Safflower meal is valuable as an animal feed. Over time, labor costs could decline if Afghan labor is substituted for American labor. Lastly, carbon credits could become an additional source of revenue.

Other DOD Projects to Reduce Petroleum Dependence

The DOD has made significant progress in reducing its dependence on petroleum in the U.S. but only limited progress in non-domestic military theaters. To our knowledge, the DOD is not investigating the use of biodiesel in either generators or tactical vehicles. However, producing and using biodiesel in Afghanistan would be consistent with several other projects described in the chapter "Current Efforts by the Army and Marines to Reduce Petroleum Dependence." Our research has highlighted two cases where the DOD's approach is suboptimal. First, given the critical importance of generators and generator efficiency, the military should be running projects to modernize small, medium, and large generators in parallel, not sequentially. Second, since 1998, New York City has been using hybrid diesel-electric buses, similar in weight to military supply trucks; 38% of New York City buses are now hybrids. U.S. truck manufacturers Freightliner, Navistar, and PACCAR all sell hybrid trucks in the heaviest weight classes (Class 6, Class 7, and Class 8). By contrast, the Army has been unsuccessful in deploying hybrid technology, even on a trial basis. Moreover the Army is focusing on tactical combat vehicles, rather than supply trucks. Supply trucks consume the greatest amount of fuel during wartime and are the tactical vehicles most similar to commercial vehicles. When used together, hybrid technology and biodiesel are symbiotic. Both reduce diesel fuel consumption via strategies of improved fuel efficiency and substitution of a renewable fuel for petroleum.

Two Complementary Recommendations

If the Pakistan railroad network were extended 115 km (71 miles) from Chaman, Pakistan to Kandahar the military may be able to further reduce the cost of importing fuel, lower casualties, and at the same time improve Afghanistan's infrastructure. This extension has long been desired by Pakistan, and is worthy of further analysis.

USAID should fund a study to investigate the creation of a commodities exchange in Afghanistan. A commodities exchange could both support Afghanistan's critical agricultural sector, including biodiesel crops, and create a new financial industry for Afghanistan. Two commodities exchanges in the region have recently been launched: Pakistan's National Commodities Exchange Limited (2007) and Mercantile Exchange Nepal Limited (2009).

Additional Benefits

The capacity of the initial biodiesel plant matches the fuel needs of utilities' diesel generators that supply electricity in Kandahar and Helmand Provinces. In Kabul, the 100 MW Tarakhil power plant (which uses Caterpillar equipment) could use the output of one Kandahar-sized biodiesel plant, assuming the generators combust B20, or five plants, assuming combustion of B100. The Kabul vehicle market is four times larger than the capacity of the Kandahar biodiesel plant, assuming the use of B20. In addition, an export market may be possible since neighboring countries also import large quantities of oil. However, U.S. and ISAF countries may need to offer assistance to local biodiesel producers for several years as the Afghan biodiesel market evolves from a military to a commercial market.

Russia should be very interested in biodiesel's potential to challenge the opium trade. Russia suffers from a high incidence of heroin addiction and AIDS, and 90% of the world's opium, the source of heroin, originates in Afghanistan.

Conclusion

A single medium-sized biodiesel plant in Afghanistan can achieve five benefits: casualties can be reduced by four to five soldiers a year, about 120 soldiers can be reassigned from fuel convoys to new missions, millions or billions of dollars can be saved each year, up to 50% of the poppy crop can be replaced by a biodiesel crop, and a new industry may be created that, over time, can greatly benefit the Afghan people.

Producing and using biodiesel in Afghanistan is consistent with the three pillars of American strategy in Afghanistan: improving security, improving Afghan governance, and accelerating economic development.

The Afghanistan biodiesel project spans the interest of multiple government agencies: the Department of Agriculture, Department of Defense, Department of Energy, State Department and USAID. Since many agencies are involved, we believe the project will require a champion with the support of the Administration who can motivate these disparate agencies to work together with a sense of urgency.

Introduction

Abstract

On December 1, 2009, President Obama announced to the nation that the U.S. would send 30,000 additional troops to Afghanistan as soon as possible. These additional troops would bring the U.S. total in Afghanistan to around 100,000. The additional troop commitment is part of a strategy to reverse the Taliban's recent gains and stabilize the country's government.

Afghanistan is a landlocked country; the supply lines to U.S. and ISAF (International Security Assistance Force) troops are long and difficult. The additional troops will require more convoys to supply fuel, food, and munitions, leading to increased casualties and expenditures.

We believe the U.S. should manufacture biodiesel in Afghanistan for use in electrical generators and military vehicles, replacing some of the diesel fuel that must currently be imported. Manufacturing and consuming biodiesel locally would reduce U.S. casualties, lower military fuel expenditures, substitute a valuable crop for poppies, thereby reducing the opium trade, and possibly create a new industry for Afghanistan that would contribute towards Afghanistan's future growth.

The Challenge Facing U.S. and ISAF Forces

Afghanistan has little experience with democracy, and the current government suffers from corruption. The country's infrastructure, including roads, generation of electricity, hospitals, and schools, is underdeveloped. The Afghan people are desperately poor and uneducated, and life expectancy is less than 45 years. The United States faces a stubborn insurgency that, among other advantages, benefits from a safe haven in neighboring Pakistan. Afghanistan's terrain is extremely rugged and the borders are difficult to defend. What can the U.S. do to increase the odds of success?

The addition of more U.S troops and ISAF forces should diminish the threat of the Taliban, and with luck and persistence the U.S. may be able to capture more of those responsible for the September 11 attacks. However, it is very hard to see how the U.S. can prevail militarily in the long run. The American people are unlikely to be willing to support 100,000 troops in Afghanistan for the lengthy period necessary to keep the Taliban at bay. Secretary of Defense Robert Gates, in his testimony to Congress December 2, 2009, discussed aligning civilian and military resources according to six primary objectives. These objectives call for degrading the capability of the Taliban, but do not include their military defeat. Similarly, in testimony before Congress on December 8, 2009, Ambassador Eikenberry outlined the three main pillars of the U.S. effort in Afghanistan: security, governance, and development.

The U.S. goal then should be to win the support of the Afghan people, so that, over time, they gain the motivation to either defeat the Taliban or persuade many of the Taliban forces to switch sides. The only way we foresee this result happening is through economic means – providing the Afghans who cooperate with the U.S., ISAF and the Afghan government with a higher standard of living. Our proposal to persuade Afghan farmers to grow biodiesel crops in Afghanistan so that biodiesel can be manufactured locally is in the U.S.'s own self-interest. If successful, it will reduce casualties and decrease the cost of the war.[1] But, use of biodiesel may also help with the third pillar of U.S. strategy described by Ambassador Eikenberry: creating economic development that will benefit the people of Afghanistan.

This paper outlines five principal benefits of producing and using biodiesel in Afghanistan: a reduction in American casualties, savings of millions or billions of dollars a year that otherwise would be spent importing petroleum diesel into Afghanistan, freeing up troops for new assignments who are currently needed to staff fuel convoys, a reduction of the cultivation of poppy and therefore also the opium trade, and lastly the possible creation of a local biodiesel market and thus a new industry in Afghanistan.

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[1] The Congressional Research Services estimated in September 2009 that the cumulative cost of the war in Afghanistan, from FY 2001 through FY 2010 (ending September 30, 2010) will be $300B. The FY 2010 budgetary request for Afghanistan, not including troop increases announced by President Obama on December 1, 2009, is $73B. Congressional Research Service, *The Cost of Iraq, Afghanistan, and Other Global War on Terror Operations Since 9/11* (Report RL33110), by Amy Belasco, Specialist in U.S. Defense Policy and Budget, September 28, 2009, pages 9, 13.

Agriculture in Afghanistan

Afghanistan Agriculture Today

Most Afghans are rural (75% per the CIA World Factbook), and the economy is largely based on agriculture, and will remain so for many years. The literacy rate of the overall population is only 28% (43% for men) and the country is landlocked with poor transportation, so even light manufacturing requiring semi-skilled labor is difficult. Consequently, the key to quickly improving the standard of living for the greatest number of Afghans is via agriculture. According to the U.S. Department of Agriculture (USDA), 80% of Afghanistan's population is involved in farming, herding, or both, even though just 12% of Afghanistan's total land area is arable and less than 6% is currently cultivated.

Poppy Production

The production of poppy in Afghanistan, used to produce opium and heroin, is one of the most serious problems faced by the Afghanistan Government. Cultivation increased from 225 metric tons in 1981 to 7,700 metric tons in 2008. Afghanistan is the source of 90% of the world's opium. Afghan President Hamid Karzai has described the opium economy as "the single greatest challenge to the long-term security, development, and effective governance of Afghanistan."[2] About 1.6 million people are involved in opium cultivation, or about 6.4% of the population. The estimated $700 million farm-gate value (equal to volume multiplied by the price of non-dried opium paid to farmers) of the 2007-2008 opium harvest is equivalent in value to approximately 7% of the country's licit GDP. The export value may exceed $3.4 billion, equivalent to approximately 33% of the country's licit GDP.

Recently, the amount of land dedicated to poppy cultivation has declined somewhat, from 157,000 hectares in 2008 to 123,000 hectares in 2009. The southern provinces of Kandahar and Helmand account for 73% of the production; 99% of the production occurs in the south and the west. The gross income earned by farmers per hectare of poppy was $4,662 in 2007 and $3,562 in 2007.[3] In 2009, the average farm-gate price of fresh opium was $55 per kilogram, a reduction of 34% from $86 per kilogram in 2007. These were the lowest prices recorded since 2000. Nevertheless, the 2009 opium harvest was the third largest since 1986.[4]

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[2] Congressional Research Service, *Afghanistan: Narcotics and U.S. Policy* (Report RL32686*)*, by Christopher M. Blanchard, Analyst in Middle Eastern Affairs, August 12 2009, Summary page.

[3] United Nations Office on Drugs and Crime, *Afghan Opium Survey 2009 Summary Findings*, September 2009, pages 2, 25.

[4] *Afghanistan: Narcotics and U.S. Policy*, pages 5, 7.

In spite of recent progress, the Afghan government faces a stark challenge when one considers the following table from the UNODC 2009 Afghanistan Opium Survey:

Table 1 Afghanistan Opium and Wheat Income

Year	Opium Income in US$/hectare	Wheat Income in US$/hectare	Ratio Opium/Wheat Income
2003	12,700	470	27:1
2004	4,600	390	12:1
2005	5,400	550	10:1
2006	4,600	530	9:1
2007	5,200	546	10:1
2008	4,662	1,625	3:1
2009	3,562	1,101	3:1

Afghan farmers still earn much more money planting poppy than a critical food source such as wheat.

The Bush Administration spent over $800M a year on poppy eradication. The Obama Administration has changed course, focusing on drug interdiction and assistance to farmers, rather than eradication. Ambassador Richard Holbrooke, Special Representative for Afghanistan and Pakistan, has argued that the $800M a year the U.S. was spending on counter-narcotics would be better used in supporting Afghan farmers. "All we did was alienate poppy farmers who were poor farmers, who were growing the best cash crop they could grow, in a market where they couldn't get other things to market."[5]

Other approaches have also been unsuccessful. In 2002 the U.S. paid farmers $1,750 per hectare in the eastern province of Nangarhar not to cultivate poppy, similar to U.S. programs that provide American farmers incentives to remove land from cultivation for various reasons. When farmers in the northern province of Badakhstan learned of the program, they planted poppy hoping to receive the same payments the subsequent growing season.[6]

Yet the opium trade continues to threaten the very existence of the Afghan state. The Taliban have been involved at all levels "with farmers, opium brokers, lab operators, smugglers and

[5] Stephen Kaufman, "U.S. Scraps Afghan Crop Eradication in Favor of Interdiction," *America.gov,* July 29, 2009. (http://www.america.gov/st/sca-english/2009/July/20090729184555esnamfuak0.4385187.html)

[6] Atiq Sarwari and Robert D. Crews, "Epilogue," in Robert D. Crews and Amin Tarzi, editors*, The Taliban and the Crisis of Afghanistan*, (Cambridge, MA: Harvard University Press, 2008), page 334.

major drug barons, as well as the export to international markets."[7] The Afghanistan National Security Council noted in its 2005 National Threat Assessment that the "corruption and crime associated with the drug trade will proliferate in Afghan society and the government administration."[8]

A reduction in the opium trade would be enormously beneficial. If the opium trade remains at current high levels, it seems unlikely that the Taliban can be marginalized or that the Afghan government will succeed.

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[7] Seth G. Jones, *In the Graveyard of Empires: America's War in Afghanistan*, (New York, NY: W.W. Norton & Company, Inc., 2009), page 195.

[8] *In The Graveyard of Empires: America's War in Afghanistan,* page 199.

Biodiesel

Introduction to Biodiesel

Biodiesel is an organic oil-based fuel that can be used as a blend stock or direct replacement of any middle distillate fuel including diesel, heating oil, or kerosene. In 1912, Rudolph Diesel, the inventor of the diesel engine, said "The use of vegetable oils for engine fuels may seem insignificant today, but such oils may become, in the course of time, as important as petroleum and the coal tar products of the present time."[9] When Rudolf Diesel demonstrated a diesel engine at the World Exhibition in Paris in 1900 it ran on peanut oil.

The use of biodiesel has been promoted as a means to reduce air pollution and reliance on imported petroleum products as well as to promote domestic agricultural industries. To date, the European Union (E.U.) and the United States have been the strongest biofuel proponents, although other areas of the world are showing increased interest. In many cases biodiesel can be used as a substitute for petroleum diesel with little or no modification to an engine or heating equipment. More frequently, biodiesel is blended with petroleum diesel fuel to create a fuel that is readily deployed in vehicles, power generators, construction equipment, heating oil burners, and off-road engines. The most standard blends are B5 (5% biodiesel/95% petroleum diesel) and B20 (20% biodiesel/80% petroleum diesel).

The production and consumption of biodiesel has become a large influential business in many parts of the world. In 2008 the E.U. was the largest producer of biodiesel with 1.7B gallons of production a year, followed by the U.S. with 677M, Brazil with 300M, and Argentina with 250M gallons per year.[10] There are about 170 biodiesel plants in the U.S. with a production capacity of 2.7B gallons a year. The U.S. National Renewable Fuel Standard (RFS) program, updated by the EPA in February 2010 (RFS2), specifies minimum levels of renewable fuel to be consumed as transportation fuel. For 2012, the biomass-based diesel requirement is 1B gallons per year.[11] The RFS program includes gasoline and diesel fuel intended for use in highway vehicles and engines, plus nonroad, locomotive and marine engines. The EPA stated "the increased use of renewable fuels required by the RFS2 standards is expected to reduce dependence on foreign

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[9] "National Biodiesel Day – March 18th," *National Biodiesel Board*, March 18, 2010. (http://www.biodiesel.org/biodiesel_day/)

[10] Emma Ritch, "US biodiesel drowning in surplus?" *Cleantech Group*, September 18, 2009. (http://cleantech.com/news/5029/us-biodiesel-industry-drowing-surp)

[11] Biomass-based diesel includes two types of non-petroleum diesel: biodiesel made from plant materials and biodiesel made from animal materials, such as fats and greases.

sources of crude oil and increase domestic sources of energy, while at the same time providing important reductions in greenhouse gas emissions that contribute to climate change."[12]

Biodiesel can be stored anywhere that petroleum diesel fuel is stored, although in cold climates insulation or heating of the fuel may be necessary. According to various studies, the storage life of biodiesel is less than petroleum diesel, and most biodiesel refiners recommend storage of no more than six months. The DOE's National Energy Research Laboratory (NREL) states "B100 should not be stored longer than four months unless it has been tested with synthetic additives."[13] Empirical data, however, suggests that biodiesel can be stored for longer periods with certain chemical additives, and ongoing studies are being performed to develop additives that will extend shelf-life.[14] Biodiesel is safer to handle and transport than petroleum diesel fuel because biodiesel is biodegradable and has a higher flashpoint (temperature of vaporization when fuel becomes ignitable) of greater than 130°C (266°F) compared to petroleum diesel fuel, which has a flashpoint of greater than 62°C (144°F). Biodiesel can extend the life of diesel engines because it lubricates more effectively than petroleum diesel and also serves as a detergent, flushing engine systems of built-up materials every time it is used, reducing maintenance requirements. Fuel consumption, auto ignition, power output, and engine torque are relatively unaffected by the use of biodiesel. Biodiesel is recognized as a "carbon neutral" fuel, which means that the use of biodiesel does not produce more carbon dioxide gas than the feedstock[15] source removes during its growth cycle. Carbon dioxide is recognized as a greenhouse gas and is widely thought to contribute to global warming.

Biodiesel is commonly made through a refining process whereby the molecular structure of organic oil is transformed or more precisely transesterified through the use of a chemical catalyst and an alcohol. After the chemical reaction, two co-products are generated: biodiesel, chemically known as an "ester," and glycerin, an alcohol. An alternative name for biodiesel manufactured using the transesterification process is FAME: Fatty Acid Methyl Ester. In 2001, a U.S. industry standard was created, ASTM (American Society for Testing and Materials) D6751,

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[12] EPA, *EPA Finalizes Regulations for the National Renewable Fuel Standard Program for 2010 and Beyond,* (EPA-420-F-10-007), February 2010, page 6.

[13] DOE, National Renewable Energy Laboratory, *Biodiesel Handling and Use Guide Fourth Edition*, (NREL/TP-540-43672), Revised January 2009, page 21.

[14] The current industry recommendation is that biodiesel be used within six months, or reanalyzed after six months to ensure the fuel meets ASTM standards (D-6751). A longer storage life is possible depending on the fuel consumption and the use of storage enhancing additives. See biodiesel.org for more general information.

[15] A feedstock is a base input upon which agricultural, chemical or petroleum products can be derived. For example soybean oil is considered a feedstock for biodiesel refineries.

which defines biodiesel and establishes a variety of specifications the fuel must meet in order to be used in fuel systems. Periodically, the standard is updated, and at the end of 2008, the diesel ASTM specification was amended to include important cold-flow requirements. In addition, that same year ASTM amended the diesel standard specification (ASTM D975) to allow up to 5% of biodiesel blended into the diesel product without the need for disclosure. An analogous European standard is known as EN 14214.

Biodiesel Emission Properties

On balance, the combustion of biodiesel generates significantly less pollution than combustion of petroleum-based diesel: virtually all pollutants are lower with the exception of nitrous oxide emissions, which may be up to 10% higher for B100.[16]

Table 2 Biodiesel Pollutants

Pollutant	Reduction/Increase
Carbon Monoxide (CO)	-45%
Carbon Dioxide (CO_2)	Up to -78% (lifecycle)
Nitrous Oxides (NOx)	+10%
Particulate Matter (PM)	-47%
Polycyclic Aromatic Hydrocarbons (PAH)	-80%
Nitrated-PAH	-90%
Sulfates	-100%

Some particulate matter and hydrocarbon emissions (such as PAH and n-PAH) from petroleum diesel fuel combustion are toxic or carcinogenic. Using B100 can eliminate as much as 90% of these air toxics. The positive effects of biodiesel on air toxics have been shown in numerous studies.[17]

Nitrous oxide, a greenhouse gas, has a Global Warming Potential (GWP) about 298 times more powerful than carbon dioxide.[18] One widely cited study has concluded that use of biodiesel does

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[16] The table was derived from three sources. The majority of the data is from EPA, *A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions*, (EPA 420-P-02-001), October 2002. The PAH and sulfur data is from California Resources Board, *Appendix IV, Fuels Report: Appendix to the Diesel Risk Reduction Plan*, October 2002. The carbon dioxide data is from DOE, National Renewable Energy Laboratory, *Clean Cities Fact Sheet,* (DOE/GO-102005-2029), April 2005.

[17] *Biodiesel Handling and Use Guide, Fourth Edition*, page 8.

[18] NO_x is an abbreviation for either Nitric Oxide (NO) or Nitrogen Dioxide (NO_2), also called nitrous oxide. In the presence of oxygen, NO converts into NO_2. For a list of the GWPs of greenhouse gases see EPA, Climate Change Greenhouse Gas Emissions, *2010 Introduction of Greenhouse Gas Emissions and Sinks: 1990 – 2008* (US EPA #430-12-10-006), April 2010, Introduction I-7.

not actually reduce greenhouse gas emissions.[19] However the two largest sources of nitrous oxide emissions, according to the EPA, are agriculture soil management and mobile combustion, with agriculture soil management emitting 6.9 times more nitrous oxide than mobile sources.[20] If biodiesel crops are cultivated using only modest amounts of nitrogen-based fertilizers, then substitution of biodiesel for petroleum diesel should lower greenhouse gas emissions, although more research is needed.

Purdue University and Cummins recently concluded a study regarding biodiesel fuel consumption and emissions. Gregory Shaver, an Assistant Professor at Purdue, stated “We were able to improve the fuel economy with a biodiesel blend while reducing nitrogen oxides to where they were with conventional diesel. At the same time, we were able to maintain the customary biodiesel reductions in particulate matter emissions compared to ordinary diesel fuel while not increasing noise emissions.”[21] Since the EPA biodiesel emissions data is now eight years old, the EPA should sponsor a new emissions study comparing B100 to ULSD (Ultra Low Sulfur Diesel) in a 2011 model engine.[22]

(http://epa.gov/climatechange/emissions/downloads10/US-GHG-Inventory-2010_Chapter1-Introduction.pdf)

[19] P.J. Crusen, A.R. Mosier, K.A. Smith, W. Winiwarter, “Nitrous Oxide release from agro-biofuel negates global warming production by replacing fossil fuels,” Atmospheric, Chemistry and Physics Discussions (ACPD), 7, 11191-11205, August 1, 2007. (http://www.atmos-chem-phys-discuss.net/7/11191/2007/acpd-7-11191-2007.pdf)

[20] EPA, *U.S. Nitrous Oxide Emissions by Source*, accessed April 2, 2010. (http://www.epa.gov/nitrousoxide/sources.html)

[21] Emil Venere, “Advanced engine-control system reduces biodiesel fuel consumption and emissions,” *Purdue University News Service*, January 25, 2010. (http://www.purdue.edu/newsroom/research/2010/100125ShaverBiodiesel.html)

[22] A number of clean diesel engine designs, including those from BMW, Ford, GM (later in 2010), and Mercedes Benz use urea to reduce nitrous oxide emissions in a technology called Selective Catalytic Reduction (SCR). These companies use SCR in order to comply with EPA emission requirements for heavy duty highway engines that were phased in from 2007-2009. In the SCR approach a urea solution is injected into the engine exhaust-gas stream which then releases ammonia. The ammonia converts up to 80% of the nitrous oxide into nitrogen and water by a process of reduction in the vehicle’s catalytic converter. If a diesel engine combusting B100 were also to use a urea system, it is unclear whether the reduction in nitrous oxide emissions would be proportional to the petroleum diesel case or could reach the same absolute level of emissions reduction. If the reduction were proportional then the reduction of emissions compared to the initial petroleum diesel emissions would be up to 78% rather than 80%. SCR usually competes with, or sometimes is combined with, an alternative approach called EGR (Exhaust Gas

The 2002 EPA study concluded that there is no measurable difference in carbon dioxide emissions when combusting biodiesel instead of petroleum diesel; the carbon content of the two fuels is similar. The reduction listed in Table 2 derives from the complete lifecycle of producing biodiesel since a biodiesel crop will absorb carbon dioxide when growing. The reduction in carbon dioxide emissions versus petroleum diesel will be dramatic as long as the land supporting the biodiesel crop did not previously also remove the same amount of carbon dioxide from the atmosphere.

Biodiesel can also be used in engines that must satisfy the toughest EPA emissions standards for vehicles (Tier 2) or off-road vehicles (Tier 3 and Tier 4). The EPA's Tier 4a or Tier 4 Interim is an emissions standard that goes into effect during the years 2011-2012 and Tier 4 Final goes into effect 2013-2015. A number of manufacturers have announced support for various blends of biodiesel in combination with new engine designs needed to support the tougher emissions requirements of Tier 4 Interim. For example, all of John Deere's diesel engines that support Tier 4 Interim also support B100 if the biodiesel is manufactured according to the EN 14214 standard. Also the Congressional Budget Office, U.S. Department of Defense, U.S. Department of Agriculture, and others have determined that biodiesel is a viable alternative fuel option for fleets that are required to meet requirements of the Energy Policy Act.

Biodiesel Fuel Property Summary

Functionally biodiesel:

- Runs well in most conventional, unmodified diesel engines when blended in low percentages (diesel or compression engines that are not specifically optimized for higher blends of biodiesel may over time develop problems due to biodiesel’s detergent effects);
- Can be stored anywhere that petroleum diesel fuel is stored;
- Is 11% oxygen by weight, higher than petroleum diesel, and thus burns more efficiently;
- Contains no sulfur and fuels containing sulfur are susceptible to corrosion;
- Has a much higher flash point (ignition temperature) than petroleum diesel, greater than 130 °C (266° F) versus 62°C (144° F), and thus is safer to transport and store in a war zone;
- Usually has a higher cloud point (temperature where the fuel gels) than petroleum diesel, although the cloud point varies by the type of biodiesel (this disadvantage can be addressed via blending in more petroleum diesel during colder months or via additives, see discussion below);

Recirculation) where cooled exhaust gas is reintroduced in the engine’s combustion chamber to lower the combustion temperature and thereby reduce the creation of nitrous oxide.

- Is nontoxic and biodegradable (in the case of a spill biodiesel degrades about four times faster than petroleum diesel);
- Is considered a lubricant and is more lubricating than low sulfur diesel fuels, helping to prolong engine life; and
- Does not significantly impact fuel consumption, auto ignition, power output and engine torque (although biodiesel has a higher cetane level that slightly elevates torque and power output, it contains up to 8% less energy per unit of volume (BTU per gallon) than standard diesel fuel, depending on feedstock used).

Biodiesel Energy Content and Fuel Energy Ratio

As shown below, biodiesel has a higher energy content than most other fuels used for electricity generation, heating or transportation:[23]

Table 3 Biodiesel Energy Content

Fuel	MegaJoules/ m^3	Thousand BTUs/ ft^3
Diesel fuel	39.4	1,058
Fischer-Tropsch diesel	36.9	990
Biodiesel	35.4	950
Gasoline	34.3	922
Propane (LPG)	25.4	683
Liquid Natural Gas (LNG)	23.7	635
Ethanol	22.1	594
Methanol	18.2	488
Liquid Hydrogen (H_2)	10.1	270
Compressed Natural Gas (CNG) @ 3626 psi	9.9	266
Compressed Hydrogen@3626 psi	2.5	68
Nickel-metal hydride (NiMH) battery	0.6	16

The energy density of a fuel is only part of the overall energy equation. In order to fully assess the efficacy of a fuel, one must look at the energy used to produce the fuel, the energy content of the fuel itself, and then how efficiently the fuel's energy can be converted into useful work. A Life Cycle Analysis (LCA), also called a "Well to Wheel" analysis for transportation applications, looks at this total picture.

The measure Net Energy Balance (NEB) looks at the first two steps: the amount of energy required to create a fuel of certain energy content. If the NEB is negative, then more energy is

[23] DOE, *U.S. Energy Dependence is Driven by Transportation*, (DOE/ORNL-6966), September 2001

expended in creating the fuel than is available to be consumed. Another perspective on a fuel's NEB is a measure called Fossil Energy Ratio (FER). For example producing one unit of gasoline requires 1.25 units of fossil fuel energy, so gasoline's NEB is negative and its FER is 0.8.

Biodiesel has very a good FER. According to two U.S. Government studies, the FER of biodiesel manufactured from soybean oil is 4.56[24] and the FER of ethanol made from corn is 1.36.[25] Arguably, biodiesel has a claim to being the most effective renewable fuel currently being manufactured in volume, although the FERs of biodiesel and ethanol should both further improve over time. However, a study funded by Nature Conservancy and Northwestern University has reported that soybean oil biodiesel's land intensity (land area per unit of energy) is 2.6 times higher than that of ethanol made from corn.[26]

Significant volumes of biodiesel are now being produced from non-food crops that require less fertilizer and pesticide than soybeans, and many companies are working to produce cellulosic ethanol. New biodiesel crop varieties are intended to both increase yields and reduce consumption of water, fertilizer and pesticides. (See the discussion of first, second and third generation fuels below.)

Biodiesel Byproduct – Glycerin (Glycerol)

Processing feedstock into biodiesel produces, as a by-product, about 10%-15% glycerin, depending on raw oil quality and processing techniques. Glycerin (also called glycerine or glycerol) is an alcohol that is an oily, colorless, odorless, sweet tasting viscous liquid. Glycerin is a sugar substitute and is about 60% as sweet as sucrose. It is a marketable commodity that is used in hundreds of products including cosmetics, medical products, liquid soaps, inks, and lubricants. Glycerin with low levels of contaminants can also be used as a sweetener in human food, in animal feed, and in other products that are ingested. The global supply of glycerin has recently increased significantly, in part due to increased biodiesel production, particularly in Europe.

Glycerin could be used by the military in Afghanistan several ways. Glycerin could be used to produce Mono Propylene Glycol (MPG), a non-toxic deicer component, which could replace

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[24] USDA, Office of the Chief Economist, *Energy Life-Cycle Assessment of Soybean Biodiesel*, (Agricultural Report Number 845), by J.A. Duffield, M. Haas, A. McAloon, A. Pradhan, H. Shapouri, D.S. Shrestha. W. Yee, September 2009, page iv.

[25] DOE, Argonne National Laboratory, Center for Transportation Energy Research Systems, *Energy and Greenhouse Gas Emissions Impacts of Fuel Ethanol,* by Michael Wang, August 23, 2005, slide 6.

[26] Robert I. McDonald, Joseph Fangione, Joe Kiesecker, William M. Miller, Jimmie Powell, *Energy Sprawl or Energy Efficiency: Climate Policy Impacts on Natural Habitat for the United States of America*, Nature Conservancy and Northwestern University, August 26, 2009, Figure 3. (http://www.plosone.org/article/info:doi/10.1371/journal.pone.0006802)

petroleum-based ethylene glycol and which could be used at U.S. and ISAF air bases in Afghanistan. Glycerin could be used as a fuel, augmenting steam boiler operations in the biodiesel plant proposed for Afghanistan. Or glycerin could be used as a fuel to generate electricity via fuel cells, although this application would require additional research and development. Finally, glycerin could be sold to Afghan livestock farmers or food processing companies.

Using Biodiesel in Colder Climates

Petroleum diesel fuel, due to the refining process, has less favorable cold flow properties than that of its sister, gasoline. Over the past hundred years, much research has taken place to determine how to improve the low temperature operability of petroleum diesel fuel. Typically, the main fuel parameters that are used to measure behavior in cold temperatures are cloud point (an ASTM measure) and Cold Filter Plugging Point (CFPP, an EN measure). A fuel's CFPP is lower than the cloud point and is the temperature where precipitation of wax crystals in the fuel may lead to blocking or plugging of equipment. ASTM and EN processes both test for these specifications in diesel fuel, and they are generally accurate to plus or minus 1 to 2 °C.

In order to improve the low temperature operability of standard Number 2 diesel fuel (the predominant fuel for commercial vehicles in the U.S.), petroleum refiners tend to blend in larger components of Number 1 diesel fuel (or kerosene) and other additives during the winter months to guard against fuel filter plugging of their customers' engines. Fleet owners in northern states who manage vehicles with diesel engines are aware of potential cold start problems and guard against this possibility through proper storage and blending of the fuel. The U.S. Army TARDEC Fuels and Lubricants Research Facility (at Southwest Research Institute) performed a study of diesel fuels used in U.S. military facilities. This study investigated cloud points of petroleum diesel fuel and kerosene in actual field use from 112 samples, and the cloud points varied widely from +1°C to -66.5°C.[27]

As mentioned above, biodiesel has different cold flow characteristics based on the feedstock used to make the fuel, and in general biodiesel's cold-flow properties are not as favorable as those of petroleum diesel. But it is interesting to note that some cold-flow improvers provide significantly greater benefits to the underlying fuel with the addition of biodiesel. The National Biodiesel Board issued a report which stated "An example provided by Lubrizol provided the results below with biodiesel mixtures and a cold flow additive. With the incorporation of

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[27] U.S. Army, Tank Automotive Research, Development and Engineering Center (TARDEC), *Survey of Diesel Fuels and Aviation Kerosenes From U.S. Military Installations*, by Steven R. Westbrook and Maurice E. LePera, Presented at the 6th International Conference on Stability and Handling of Liquid Fuels, October 13-17, 1997, Vancouver, B.C., Canada, Table 3: Fuel Analysis Data.

additives, the cold filter plugging point of the B20 and the B10 mixtures were both better than that of the base diesel fuel alone."[28]

Table 4 Effect of Additives on Cold Flow (CFPP) Temperatures

Fuel	Additive	Treat Rate (ppm)	CFPP (°F)	CFPP (°C)
Base Diesel	0	0	+4	-15.6
B20	LZ7670	1,000	-12	-24.4
B10	LZ7670	1,000	-22	-30.0

If cold-flow-improvers are added to biodiesel in excess, the improvers can cause problems in combustion engines. Therefore, care should be exercised in adding the recommended volumes but no more.

Renewable Energy Group, a large U.S.-based biodiesel refiner, performed a study of the characteristics of biodiesel made from 34 different feedstocks. In general, crops in the mustard seed family and crops with similar characteristics (for example rapeseed and sunflower) provide the best biodiesel cold flow performance. Please see Table 5 below.[29]

Table 5 Cold Flow Properties of Various Feedstocks

Feedstock	Cloud Point (degrees C)	Cold Flow Plug Point (degrees C)	Cold Soak Filtration (< 360 sec)
Algae 1	-5.2	-7	85
Algae 2	3.9	2	84
Babassu	4.0	10	310
Beef Tallow	16.0	14	76
Borage	-1.3	-4	74
Camelina	1.5	-1	223
Canola	-3.3	-13	113
Castor	-13.4	7	>720
Choice White	7.0	6	72

[28] "Fuel Fact Sheets," *National Biodiesel Board*, March 18, 1020, page 5. (www.biodiesel.org/pdf_files/fuelfactsheets/Cold%20Flow.pdf)

[29] Renewable Energy Group Inc., *Feedstock and Biodiesel Characteristics Report*, Shannon D. Sanford, James M. White, Parag S. Shah, Claudia Wee, Marlen A. Valverde, and Glen R. Meier, www.regfuel.com, Publication date November 17, 2009.

Grease			
Coconut	0.0	-4	49
Coffee	0.2	-4	203
Corn, Distiller's	-2.8	-3	131
Cuphea Viscosissima	N/Av	N/Av	N/Av
Evening Primrose	-7.5	-10	269
Fish	3.2	0	68
Hemp	-1.3	-6	66
Hepar, High IV	16.0	13	87
Hepar, Low IV	6.7	6	77
Jatropha	2.7	0	286
Lesquerella Fendleri	-11.6	-6	>720
Linseed	-3.8	-8	64
Moringa Oleifera	13.3	13	78
Mustard	3.2	-5	N/Av
Neem	14.4	11	>720
Palm	13.0	12	88
Perilla Seed	-8.5	-11	200
Poultry Fat	6.1	2	>720
Rice Bran	0.3	-3	111
Soy Bean (Refined)	0.9	-4	67
Stillinga	-8.5	-12	N/Av
Sunflower	3.4	-3	107
Tung	-10.0	-11	>720
Used Cooking Oil	2.4	-2	81
Yellow Grease	6.0	2	95

While not cited in Renewable Energy Group's report, pennycress has also been shown (at the laboratory level) to produce biodiesel with a CFPP value of -15 C to -25°C, which puts it in line with base diesel fuels.

We recommend the construction of the first biodiesel plant near Kandahar, in the region of the greatest amount of poppy cultivation. Kandahar has mild winters and hot summers; its weather is slightly cooler than Las Vegas, Nevada.[30] The initial crop we recommend, safflower, is a crop native to the region that is already cultivated in Afghanistan. Safflower, similar to sunflower, has cold flow properties approaching those of petroleum diesel, minimizing the need for cold-flow improvers. Safflower's cold flow properties are discussed later in the paper.

For subsequent biodiesel manufacturing plants we recommend that crops in the mustard seed family should also be considered. This recommendation is based on empirical and laboratory data collected over the past five years. The data suggests that, when coupled with additives, biodiesel made from mustard seeds results in a fuel that can stand the test of cold winters. As the petroleum industry used blending to meet poor low temperature operability challenges associated with petroleum diesel, biodiesel refiners can use similar blending techniques and additives to improve biodiesel cold-flow properties.

Properties of Various Biodiesel Crops

A variety of oils can be used as feedstock for the biodiesel production process. Most biodiesel manufacturing plants throughout the world use oils from rapeseed (canola), palm, soybean or animal fats and used cooking oils. However, significant research has gone into new and innovative crops that can produce oil at lower cost due to higher yields. In addition, in colder climates, a critical result of any biodiesel manufacturing operation is the ending cold-flow property of the fuel, which, as outlined in Table 5 above, is dependent upon the properties of the incoming feedstock. Table 6 below gives the yields of a variety of biodiesel crops. Some of these crops have been used to produce biodiesel for many years, such as canola and soybean. Others are new crop varietals, or so called "advanced biofuels," which are not food crops. Biodiesel and ethanol are often described as either first, second, or third generation fuels, depending upon the crops and technologies used in production.

A first generation biofuel is one produced from a first generation feedstock that is also a food source. Most biofuel production is first generation, since ethanol is largely produced from corn or sugarcane and biodiesel from rapeseed (canola), palm, or soybean oils. In the U.S. ethanol production is nearly entirely from corn and biodiesel production is primarily from soybean oil. Second generation fuels are produced from sources that are not primarily food sources. Cellulosic ethanol is produced from the non-edible portions of plants and second generation biodiesel feedstocks such as pennycress and camelina are not currently used as food sources, although they may be edible. Third generation biofuels (including ethanol and biodiesel) are based on algae.[31] Second and third generation biofuels are also called advanced biofuels.

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[30] Per BCC weather statistics there are only two months out of the year, December and January, when Kandahar's average low temperature is less than freezing: -1° C (30° F) in both cases. The record low is -10° C (14° F), (http://www.bbc.co.uk/weather/world/city_guides/results.shtml?tt=TT002010)

[31] There are many U.S. companies working on a variety of second and third generation biofuels, including biodiesel, ethanol, and butanol. These firms include Advanced Biofuels (DuPont & BP), Algenol Biofuels,

Biofuels, or liquid fuels derived from biomass (biological material derived from living, or recently living organisms) are a subset of renewable fuels. The EPA's Renewable Fuels Standard program promotes fuels that are not fossil fuels. Hydrogen, if produced with renewable processes, is considered a renewable fuel or energy carrier that is not a biofuel. Renewable methanol, depending on how it is manufactured, is another example.[32]

Table 6 Feedstock Crop Yield

Oil Crop	Liters per Hectare	Gallons per Acre
Palm	5,435-5,940	580-635
Coconut	2,685	287
Jatropha	1,637	175
Rapeseed (Canola)	1,029-1,356	110-145
Peanut	1,057	113
Sunflower	954	102
Safflower	776	83
Mustard	571	61
Soybean	374-449	40-48
Corn	168	18
Pennycress	702-1,122	75-120
Camelina	702-1,122	75-120

In addition, studies regarding the composition of fats and oils for biodiesel (including Figure 1 taken from a National Energy Renewable Laboratory paper) provide a roadmap for the beneficial effects of feedstocks converted into biodiesel.[33]

Amyris, Aurora Biofuels, BioFuelBox, Butamax Ceres, Cobalt Biofuels, Bluefire Ethanol, Coskata Inc, DuPont Danisco, EdeniQ, Fulcrum Bioenergy, Gevo, Honeywell UOP, Imperium Renewables, Kaiima, KiOR, KL Energy, LanzaTech, Live Fuels, LS9 Inc., Mascoma Corporation, OriginOil, PetroAlgae, POET LLC, Qteros, Range Fuels, Renewable Energy Group, Sapphire Energy, SG Biofuels, Solazyme, Solix Biofuels Sustainable Oils, Synthetic Genomics (Exxon partnership), Terrabon, Verenium Corporation, Virent Energy Systems, Zeachem Inc.

[32] Joule Biotechnologies uses genome engineering to develop organisms that use carbon dioxide as input to create renewable ethanol or diesel. Carbon Recycling International, an American-Icelandic company, is building a plant to produce renewable methanol using carbon dioxide and water as inputs. Novemer focuses on using carbon monoxide and dioxide as chemical inputs to create green feedstocks.

[33] *Biodiesel Handling and Use Guide, Fourth Edition,* page 18.

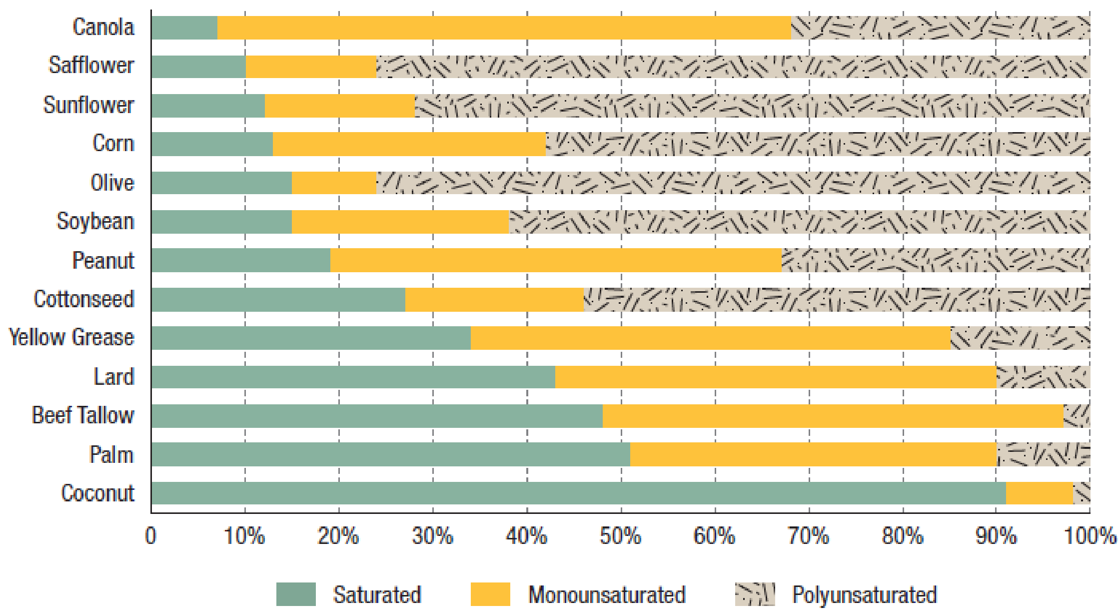

Figure 1 Composition of Feedstocks in Order of Increasing Saturated Fatty Acid Content

In Figure 1, the crops low on the y-axis, such as palm and coconut, have higher cetane values. (The Cetane Number or CN is a measurement of the combustion quality of diesel fuel during compression ignition). The crops high on the y-axis, such as safflower and canola, have the best cold flow properties.

We believe that the best suited crops for Afghanistan are varieties of the mustard seed family (*Brassicaceae)* and safflower and sunflower *(Asteraceae*). These crops grow well in the region and have both been cultivated there for thousands of years.[34] The next chapter, "Biodiesel Crops in Afghanistan," discusses the safflower and the mustard seed family of crops and their applicability to Afghanistan in more detail.

Biodiesel Production Techniques

There are a variety of processes and technologies that could be used to convert organic content into a diesel substitute, including transesterification, thermal depolymerization, pyrolysis, and Fischer-Tropsch, to name a few.[35] Most of these technologies and processes require large

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[34] The New Testament and the Koran both reference mustard seeds multiple times. For example, Luke 13:19, "It is like a grain of mustard seed, which a man took, and cast into his garden; and it grew, and waxed a great tree; and the fowls of the air lodged in the branches of it." In the Koran, 21:47, "We will establish the scales of justice on the Day of Resurrection. No soul will suffer the least injustice. Even the equivalent of a mustard seed will be accounted for. We are the most efficient reckoners."

[35] For example the Fischer-Tropsch (F-T) process converts carbon monoxide and hydrogen, called synthesis gas or syngas, into liquid hydrocarbon fuels like synthetic diesel and jet fuel. It was first commercialized in Germany in 1936.

amounts of capital and infrastructure to operate on a commercial scale. What has made transesterification so commonplace worldwide is the relatively modest amounts of capital, infrastructure, energy usage, and time needed to build the biodiesel refineries. Therefore, in order to develop a viable plant in Afghanistan in a little over a year, we recommend using a transesterification technology that is modular, skid-mounted and can be fabricated in the United States and shipped to Afghanistan.

Biodiesel Disadvantages

In summary, biodiesel has many advantages, but also four principal disadvantages. When B100 is combusted it pollutes less than petroleum diesel with one significant exception, nitrous oxide emissions (depending on feedstocks and equipment used for combustion). The Nature Conservancy concluded that biodiesel is more land-intensive than other alternative fuels. In general, biodiesel's cold temperature properties are not quite as favorable as petroleum diesel. Lastly, biodiesel's storage life is not as long as petroleum diesel.

Biodiesel Summary

Biodiesel is now being viewed by many American experts as an important future energy source. Increased availability of biodiesel will enhance U.S. energy security by lessening reliance on politically unstable nations with ties to terrorism and replacing petroleum imports with domestic feedstock used for biodiesel production. Feedstock supplies today are mainly composed of palm, soybean and rapeseed (canola) oils, the latter two being renewable resources widely available in North America. Additional oil bearing crops, many of which are not food crops, can potentially be developed economically and in relatively short periods of time to meet increased demand for feedstock. These additional feedstocks would allow the biodiesel market to continue to grow without adversely affecting the availability of food crops for the U.S. export market and especially for the developing world.

The next chapter discusses which crops are best suited for the production of biodiesel in Afghanistan.

Biodiesel Crops in Afghanistan

Recommendation for the Initial Biodiesel Plant

Safflower: native, drought resistant, and good cold weather properties

The crop we recommend for an initial biodiesel plant in Kandahar is safflower, a first generation biodiesel feedstock. Safflower is native to the region, has an oil content of up to 48% in some varieties,[36] and is already grown in Afghanistan, although not to a great extent today. The major oil crops of Afghanistan are cotton, sesame, sunflower, and flax. In 2005 world production of safflower was estimated to be approximately 815,000 hectares in 20 countries. India was then the world's largest producer of safflower, although most of the production is consumed internally, with Mexico being the second largest producer. The U.S. ranked third.[37] Iran is also a significant importer of safflower oil. In the U.S. California grows over 50% of the U.S. safflower crop, with Montana being the second leading producer. Surprisingly, in 2008, the U.S. was a net importer of safflower.[38]

There are two types of safflower oil with corresponding types of safflower varieties (subspecies): oil high in monounsaturated fatty acid (oleic) and oil high in polyunsaturated fatty acid (linoleic). Safflower can be harvested mechanically, and safflower meal is a viable livestock food additive, although protein and energy values are less than those of other oilseed meals, such as cottonseed, rapeseed (canola), soybean, and sunflower.[39] The yield from safflower and the

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[36] A study conducted by the USDA and Washington State University reported safflower yields of 40% - 45%. Ashok Alva, Rick Boydston, Harold P. Collins and Steve Fransen, An Hang, Phil Wanderschneider, *Biofuel Variety Trials Factsheet,* USDA Agricultural Research Service and Washington State University, accessed April 1, 2010. (http://www.pacificbiomass.org/documents/OilSeed/BiofuelsVarietyTrialsHalCollins.pdf)

[37] U.N., Food and Agricultural Organization, Economics and Social Department Statistics Division, Major Food and Agricultural Commodities and Producers*, Safflower Seed in 2005,* data from FAOSTAT database accessed March 2010. (http://www.fao.org/es/ess/top/commodity.html;jsessionid=5D9FEC1DB036D8A99D81F10D9418A5B1?lang=en&item=280&year=2005)

[38] Michael Boland, "Safflower," *Agricultural Marketing Research Center (AgMRC)*, Iowa State University, January 2010. (http://www.agmrc.org/commodities__products/grains__oilseeds/safflower.cfm)

[39] "Oilseed crops in Beef Cattle Rations," Julie Walker, Extension Beef Specialist, South Dakota State University College of Agricultural & Biological Sciences / USDA, 2006.

number of hectares recommended for cultivation (61,500) is consistent with the output projected for the plant: 12M gallons of biodiesel per year.[40]

Safflower oil is considered one of the best vegetable oils for human consumption, given safflower's low saturated fat content. High oleic safflower oil is lower in saturates and higher in monounsaturates than olive oil. High linoleic safflower oil includes essential fats that the body needs but cannot produce itself, such as omega-6 and omega-3, which play crucial roles in brain function and in the normal growth and development of one's body. Other vegetable oils high in polyunsaturates include corn, sunflower, and soy oil; however, high-linoleic safflower has more linoleic acid than any other vegetable oil. Both varieties of safflower oil, high oleic and high linoleic, have health benefits when used instead of oils higher in saturated fats or trans fats, and when consumed in moderation.[41]

High-oleic safflower has very good low temperature properties represented by a low Cloud Point (CP) and Pour Point (PP), or the European measure, Cold Filter Plugging Point (CFPP). High-oleic safflower has a CP of -12.2° C and a PP of -20.6° C, approaching the cold temperature characteristics of Number 2 diesel fuel (-15° C; -33.0° C).[42]

The International Center for Agricultural Research in the Dry Areas (ICARDA) states that safflower is both more drought and cold tolerant than other oilseed crops including mustard, rapeseed (canola), soybean, and sunflower. Safflower disadvantages include a lower yield potential, safflower's long (ten month) growing season if winter-sown, and its ability to sap soil

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[40] Using the USDA and Washington State University data: 1,500 safflower seed lbs/acre = 1,681 kg/hectare. 1,681 * 61,500 hectares grown * 45% (average oil content of seed) = 46,529,334 oil yield in kg = 46,529 oil yield in metric tons. Now applying industry standard yields for crushing (91%), degumming (98%), and transesterification (97%), the oil yield is 45,529 * 0.91 * 0.98 * 0.97 = 40,250 metric tons = 12.0M gallons. Similar results can be are achieved using safflower data from a 2007 North Dakota State University Study: Duane R. Berglund, Jerald Bergman, Neil Riveland, *Safflower Production* (A-870 Revised), Table 2. (http://www.ag.ndsu.edu/pubs/plantsci/crops/a870w.htm)

[41] Per the Mayo clinic "These (unsaturated) fats, if used in place of others (saturated fats or trans fats), can lower your risk of heart disease by reducing the total cholesterol and low-density lipoprotein (LDL) cholesterol levels in your blood. One type of polyunsaturated fat, omega-3 fatty acids, may be especially beneficial to your heart. Omega-3s appear to decrease the risk of coronary artery disease. They may also protect against irregular heartbeats and help lower blood pressure levels." (http://mayoclinic.com/health/fat/NU00262)

[42] DOA, National Center for Agricultural Utilization Research, Agricultural Research Service, *Biodiesel: The Use of Vegetable Oils and Their Derivatives as Alternative Diesel Fuels*, by Gerhard Knothe, Robert O. Dunn, and Marvin O. Bagby, 1997, Table III: Fuel-related properties and iodine values of various fats and oils.

moisture, leaving little for the following crop if safflower is being rotated with another crop.[43] Safflower's deep taproot system, enabling it to grow on residual moisture for the whole season, is thus both an advantage and a disadvantage.

ICARDA described safflower in its 2005 annual report as "safflower is a drought resistant oilseed crop with great potential in Afghanistan."[44] Also ICARDA stated that Afghanistan imports more than 90% (over 180,000 metric tons) of the vegetable oil its inhabitants consume each year.[45]

A comprehensive 2007 USAID study (United States Agency for International Development) regarding the Afghan edible oils market stated "safflower, canola, and soybean have been tested in Afghanistan. Of these crops safflower and canola have agricultural potential."[46] The study also recognized safflower's advantages when irrigation is limited, explaining "safflower is a drought-resistant crop and is well adapted to dry land-cropping, due to its long roots."[47]

The Afghanistan Investment Support Agency (AISA) is an Afghan governmental agency responsible for the facilitating the registration, licensing, and promotion of all investments in Afghanistan. The AISA profile for Kandahar Province promotes safflower "Intercropping (orchards) with new high value crops such as cumin, safflower, soya or sunflower, with guaranteed marketing channels and producer prices, will go a long way in assisting farmers to re-enter into high value fruit and field crop production as an alternative to poppy and wheat production."[48] The profile for Helmand Province also highlights the potential of oil crops including safflower and sunflower.

Although it is true that safflower is a food crop, in the case of producing biodiesel in Afghanistan, farmers would be displacing a non-food crop, poppy. If more safflower is produced

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[43] Naazar Ali, Ahmed A. Attary, Akhtar Beg, K. Alizadeh Dezaj, Habib Ketata, S.S. Pourdad, Abdul Rashid, "Oilseed Crops for the Highlands of Central and West Asia and North Africa (CWANA)," *ICARDA Caravan 16*, June 2002, (http://www.icarda.cgiar.org/publications1/caravan/caravan16/cara16.htm)

[44] ICARDA, 2005 Annual Report, page 75 (http://www.icarda.org/Publications/AnnualReport/2005/PDF/FullReport.pdf)

[45] Ibid.

[46] USAID, Afghanistan Small and Medium Enterprise Development (ASMED), "Edible Vegetable Oil, Final Report," Market Information – Phase 2, prepared by Altai Consulting, November, 2007, page 11. (http://www.asmed.af/userfiles/file/Edible%20Vegetable%20Oil.pdf)

[47] "Edible Vegetable Oil," page 16.

[48] Afghanistan Investment Support Agency, Regional Rural Economic Regeneration Strategies (RRERS), "Provincial profile for Kandahar Province," pages 9-10. (http://www.aisa.org.af/Downloads/ProvincialProfiles/Kandahar.pdf)

than the biodiesel plant can consume, safflower prices would decrease. Or, if farmers who did not previously grow poppy begin to grow safflower (replacing a food crop), the excess safflower would also put downward pressure on safflower prices. Fundamentally, additional local production of vegetable oil for human consumption would reduce vegetable oil imports and help address a critical need. However, if multiple biodiesel plants relied on safflower oil, then the production of biodiesel using safflower might have a negative impact on local food crop prices.

We also looked at other crops for producing biodiesel, including sesame and sunflower. Like safflower, sesame is drought resistant, and is the preferred oil for making pulau, the national rice and meat dish. Sesame oil's saturated fat content is low, but not as low as safflower oil. Either sunflower or sesame is a viable alternative to safflower, but safflower has best combination of hardiness and favorable low temperature characteristics. Safflower is a particularly appropriate choice for the provinces of southern Afghanistan which have long hot summers and where growing crops without irrigation is difficult.

Safflower versus poppy: persuading Afghan farmers

What are the arguments that could persuade an Afghan farmer in Kandahar Province or Helmand Province to replace poppy with safflower? They are:

1. The farmer will be paid more to grow safflower than poppy (at least for the foreseeable future). In the United Nations Office on Drugs and Crime (UNODC) 2009 Afghanistan Opium Survey, 508 farmers were asked why they cultivate opium. The five leading answers were: high sale price of opium (61%), poverty (11%), high demand for opium (8%), easy way to earn more money (7%), high income from little land (5%).[49]

2. Safflower requires less water than poppy. This relative advantage, even if small, could be an important factor during a drought, or if the farmer believes that he might not receive a fair allocation of irrigation water. Afghanistan has experienced a number of severe droughts over the last decade.[50]

3. Harvesting poppy is a manually intensive process, and children are often enlisted to do the harvesting.[51] If a program to replace poppy with safflower is combined with building

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[49] *Afghanistan Opium Survey 2009*, page 26.

[50] This advantage is a conjecture which should be confirmed with further research.

[51] "Since poppy pods ripen at different stages, farmers must carefully examine each one to determine if it is ready for harvesting. Farmers typically begin to harvest opium about two weeks after the petals have fallen. While still on the stem, the farmer makes vertical incisions on two or three sides of the pod. The farmer must carefully cut the pod so that the cut is not too deep. Otherwise, the milky white sap, called *sheera*, will flow too quickly and drip to the ground. So that the opium will ooze out overnight onto the

schools in villages, Afghan farmers may view safflower's lower labor requirements as an advantage.

4. The farmer can use safflower meal to feed animals. Poppy does not have a byproduct with a similar economic value. In times of scarcity, the farmer will be less likely to lose his livestock.

5. Heroin addiction is an increasingly difficult problem, with few, if any, services available to help those who become addicted. If the farmer stops growing poppy, members of his family are less likely to become heroin addicts through exposure to the manufacturing process or opium buyers.

6. Selling opium is illegal in Afghanistan and is contrary to Islamic belief; selling safflower is not.

Recommendation for Subsequent Biodiesel Plants

Two mustard seed crops: pennycress and camelina

Once an initial biodiesel plant based on safflower production is successfully launched, we recommend the possible introduction in Afghanistan of two second generation feedstocks from the mustard seed family: pennycress and camelina. These crops are not currently cultivated in Afghanistan, although, as mentioned earlier, the mustard seed family, *Brassicaceae*, has been grown in South Asia for thousands of years. The Cornell Cooperative Extension and Morrisville State College, State University of New York (SUNY) are researching mustard seeds as a source for renewable fuels, and their consensus is that mustard seeds are a viable biodiesel crop. Pennycress and camelina would grow particularly well in Afghanistan due to the agricultural characteristics of the land. An initial biodiesel manufacturing plant will require just over a year to build and one or two years to assess the degree of success. This latter period of assessment will allow time for further research into the advisability of introducing pennycress or camelina into Afghanistan.

Pennycress

Cornell and Morrisville have carefully analyzed pennycress (*thlaspi arvense*), closely related to rapeseed, canola (a type of rapeseed) and camelina. Most of the 60 varieties are Eurasian, but a few are native to North and South America, mostly in mountain areas. The properties of pennycress that make it very attractive as a feedstock for biodiesel include:

1. Grows extremely well on marginal land, and does not displace food crops or forest land;

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pod's surface, incisions are made in the afternoon. The pods will continue to secrete opium for several days." Bitter Harvest, Heroin Handbook: From Poppy to Heroin, PBS.org, accessed March 29, 2010. (http://www.pbs.org/wnet/wideangle/shows/centralasia/heroin5.html)

2. Extremely hardy plant, very robust and competitive with grasses and other plants;
3. No need of fertilizers, pesticides, or herbicides;
4. Extremely fast growth, matures in 10-15 weeks;
5. Very tolerant of variable moisture, climate, and temperature conditions;
6. Seeds are 40% oil (by weight), and over 2,466 kilograms per hectare (2,200 pounds per acre) of seed have been harvested from volunteer fields;
7. Very high quality feedstock oil, with CFPP measured at -15°C (5°F) to -25°C (-13°F); and
8. Very prolific with extremely rapid propagation cycle.

Pennycress has never been cultivated as a crop plant in North America, although there are projects underway in Illinois that are likely to lead to the commercial cultivation of pennycress as a renewable energy oilseed crop. The USDA is extending crop insurance for pennycress to achieve the objective of 20,000 acres of cultivation in 2010 and 100,000 acres in 2011.[52]

In September, 2009, Innovation Fuels began a research and development experiment to determine if a pennycress species indigenous to New York State could potentially be grown as a winter crop in combination with corn or soybeans in Upstate New York. The pennycress would be sown into the soil after corn or soybeans were harvested in the fall, and then allowed to grow to seed in the spring in order to harvest. Theoretically, if the pennycress could be sown in late autumn and harvested before June 15th of the following year, there would be enough time for producers to till the land again and follow the pennycress crop with corn or soybeans. This theory was discussed with representatives of both Cornell and Morrisville, and the collective opinion was that it warranted sufficient potential to be tested.

A total of five test plots of pennycress were planted in the fall of 2008. Overall, Innovation Fuels considers this research project to have been quite successful and this conclusion has also been supported by Cornell and the USDA.[53] Current work is investigating germ plasm enhancements and proper cultivation techniques to ensure sufficient yield. In general, test results indicate that double cropping can be accomplished and marginal lands can be used without the use of fertilizers and modern irrigation practices.

The 60% (by weight) portion of pennycress that is not oil may be used as either a fuel or organic fertilizer. Using pennycress byproducts as a fuel may be very helpful in rural Afghan villages.

Camelina

Originating from northern Europe, camelina, like pennycress, is a second generation biofuel feedstock that requires minimal water, fertilizer, and pesticide use and can be grown on

[52] Clare Howard, "Schock gets USDA aid on pennycress," *Journal Star*, January 14, 2009. (http://www.pjstar.com/news/x101110169/Schock-gets-USDA-aid-on-pennycress)

[53] Morrisville's part of the study, an investigation of the uses of pennycress meal, is still on-going.

marginal lands. Camelina is not used in significant quantities in food applications. Camelina's oil content can approach 38%, nearly as high as pennycress.

A camelina by-product, meal, offers a high-quality animal feed which further improves the economics of growing camelina. Meal contains high levels of protein and energy, as well as significant amounts of omega-3 fatty acid. These characteristics are highly valued in animal feed, and would help support Afghanistan's livestock industry. In 2009 the FDA approved the inclusion of camelina meal in cattle feed, allowing up to 10% camelina in cattle feed. In the U.S., meal is also allowed on a limited basis as chicken or swine feed, but the FDA has yet to grant broader approval for these uses.

Two American producers that specialize in camelina are Great Plains Oil & Exploration and Sustainable Oils. Great Plains has studied and optimized camelina for more than twelve years; over the last three years they have commercialized the crop for biofuel production, claiming to be the world's largest producer of camelina. On October 1, 2009, the Defense Energy Support Center (DESC) awarded Sustainable Oils a contract to supply camelina-based jet fuel for the Air Force. The contract is for 100,000 gallons of fuel beginning 2009 through 2010, and includes an option to purchase an additional 100,000 gallons between June 2010 and December 2012.

In comparing pennycress and camelina, camelina has had a more significant use in biofuel fuel production than pennycress. However, pennycress may be a better fit for Afghanistan since biodiesel made from pennycress has better cold temperature characteristics than biofuel made from camelina.

Afghanistan Biodiesel Crop Recommendation Summary

There are other crops that could be cultivated in Afghanistan for biodiesel production, including rapeseed, sunflower and safflower. However, given the data available, we recommend focusing on safflower initially, and, over time, on second generation feedstocks such as pennycress and camelina.

All of these crops are well suited to Afghanistan's climate. Pennycress is perhaps better suited for Afghanistan's colder northern climates and camelina is perhaps better suited for Afghanistan's hotter southern climates. Many different strains of pennycress and camelina exist; additional research on the properties of these various strains would be valuable. These crops do not require fertilizers or large amounts of water, an especially important consideration in the south, where water is scarce, and irrigation usually necessary. In short, these biodiesel crops should be no more difficult to grow in Afghanistan than poppy. In offering farmers an alternative to growing poppy, the Afghan government, the U.S., and ISAF can moderate the economic importance of the illegal drug industry and, hence, the influence of the Taliban.

In the next chapter we look at the demand side of the equation: the U.S. military's use of petroleum for fuel.

U.S. Military's Consumption of Fuel in Afghanistan

Three Supply Problems in Pursuing the War in Afghanistan

The U.S. military must confront three very difficult supply problems in pursuing the war in Afghanistan. First, the cost of delivering fuel in Afghanistan is very expensive. Second, the military consumes very large amounts of fuel, both diesel fuel and aviation fuel, so the need for fuel is high. Third, the supply lines are long and treacherous. The surge announced by President Obama is making these supply problems even more challenging. More troops must be supplied, and the substitution of heavily armored vehicles for lightly armored vehicles is reducing efficiency and thus further increasing fuel consumption. Consequently casualties and the cost of the war will increase.

Cost of Fuel in Afghanistan

This past autumn Pentagon officials informed the House Appropriations Defense Subcommittee that the Fully Burdened Cost of Fuel (FBCF) is about $400 per gallon ($106 per liter) by the time it arrives in the remote locations in Afghanistan where U.S. troops operate.[54] The FBCF includes the cost of transporting fuel to where it is needed. An Army official, Dr. Kevin T. Geiss, stated that in some remote locations in Afghanistan, the FBCF may be as high as $1,000 per gallon.[55] Another source, the Defense Science Board (DSB) Task Force on DOD Energy Strategy, stated in a February 2008 report that the FBCF is "several hundred dollars per gallon for combat forces and forward operating bases deep within a battlespace."[56] By contrast, a Deloitte study, using figures from the Department of Defense (DOD), calculated the FBCF as $45 per gallon.[57,58] More

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54 Roxana Tiron, "$400 per gallon gas to drive debate over cost of war in Afghanistan," *The Hill,* October 15, 2009. (http://thehill.com/homenews/administration/63407-400gallon-gas-another-cost-of-war-in-afghanistan-)

55 C. Todd Lopez, "Beans, bullets and BTU's define Army energy security," *Army.mil* (The Official Homepage of the U.S. Army), July 16, 2009. (http://www.army.mil/-news/2009/07/16/24504-beans-bullets-and-btus-define-army-energy-security).

56 DOD, Defense Science Board, *More Fight – Less Fuel*, Report of the Defense Science Board Task Force on DOD Energy Strategy, February 2008, page 30.

57 Deloitte LLP, *Energy Security – America's Best Defense*, November 9, 2009, page 19. (http://www.deloitte.com/us/aerospacedefense/energysecurity)

58 The Deloitte FBCF figure of $45 per gallon assumes that the supply route is 950 miles (roundtrip) or 475 miles (one way). However, as discussed in the section Long Supply Lines and Casualties, southern Afghanistan southern supply routes are longer. The distance from Kabul to Hairatan, the northern border town on the Uzbekistan border, is 277 miles. But adding in the segment from Kabul to Kandahar, the distance becomes 577 miles. So all supply routes to Kandahar are longer than 475 miles (one way).

recently, in an April 2010 paper, "DOD's Energy Challenge as Strategic Opportunity", Amory Lovins, Chairman and Chief Scientist of the Rocky Mountain Institute, described the FBCF as one to two orders of magnitude higher than standard market prices.[59] Regardless, whether the actual FBCF figure is $40 per gallon or $400, the military's cost of fuel in Afghanistan is many times higher than a typical civilian or domestic military market price.

Consumption of Fuel in Afghanistan

The military consumes enormous quantities of fuel, both in general and in Afghanistan. The cost of fuel as a percentage of the DOD's total budget has been increasing. In FY 2000, the cost of fuel represented 1.2% of DOD spending. By FY 2008 that percentage had increased to 3%. Approximately 72% of the DOD's fuel expenditures are for aviation fuel, and 18% for diesel fuel.[60] This paper focuses primarily on the consumption of diesel fuel by the Army and the Marines in Afghanistan, plus large generators used by the Air Force.

According to one report, the Marines alone consume 800,000 gallons a day in Afghanistan. Deloitte calculated that the U.S. military consumes 22 gallons per solder per day based on five previous U.S. military conflicts. Using this figure, once the surge is implemented, the 100,000 U.S. military forces will be consuming 2.2M gallons a day in Afghanistan, or on the order of $880M per day worth of fuel (at $400 per gallon). This figure does not take into account the additional fuel consumed by military contractors, allies, and U.S. Navy ships in the region supporting the efforts of the Army and the Marines. Contractors make up 53% of DOD's workforce in Iraq and Afghanistan.[61]

According to a 2008 Defense Science Board task force, generators become the single largest fuel consumers on the battlefield during wartime.[62] National Defense reported in December 2009 that the daily fuel requirement in Afghanistan's Helmand Province for the 2nd Marine Expeditionary Brigade is 88,000 gallons a day. About half of the fuel goes to aviators. The other

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[59] Amory Lovins, Chairman and Chief Scientist, Rocky Mountain Institute, "DOD's Energy Challenge as Strategic Opportunity," *Joint Force Quarterly Issue 57,* 2nd Quarter 2010, pages 36-26. (http://www.ndu.edu/press/lib/images/jfq-57/lovins.pdf)

[60] Congressional Research Service, *Department of Defense Fuel Spending, Supply, Acquisition and Policy*, (Report R40459), by Anthony Andrews, Specialist in Energy and Infrastructure Policy, September 22, 2009, page 2.

[61] Congressional Research Service, *Department of Defense Contractors in Iraq and Afghanistan: Background and Analysis*, (Report R40764), by Moshe Schwartz, Specialist in Defense Acquisition, December 14, 2009, Summary page.

[62] *More Flight – Less Fuel*, page 44.

half goes to ground vehicles and logistics (electricity generation).[63] (The Brigade's deployment in Afghanistan been reported to be approximately 7,000 soldiers.) The U.S. General Accountability Office (GAO) released a study in February 2009 of fuel consumption at forward-deployed military bases. The GAO looked at fuel consumption at five military bases overseas: two in Iraq, one in Kuwait, one in Djibouti, and one in Afghanistan. Fuel consumption for base support activities (i.e. generation of electricity) ranged from a high of 78% in Camp Arifjan (Kuwait) to a low of 13% at Bagram Air Field (Afghanistan). Fuel consumption for base support when the data for all five bases was combined was 35%; the average percentage for each base was 56%. At Bagram Air Field most of the fuel is used for aviation, nevertheless the absolute amount of fuel used for base support is still very large: 11M gallons per year (30,564 gallons per day). Consequently, we believe that the assertion that 40% of the fuel consumed in Afghanistan is used for the generation of electricity is a conservative assumption.[64]

Long Supply Lines and Casualties

The Afghanistan supply lines are long and treacherous. The U.S. must supply military forces with fuel, ammunition, food and other supplies but the majority of the tonnage transported into Afghanistan is fuel. According to Alan Haggerty, Deputy Under Secretary of Defense, 70% of the tonnage moved when the Army deploys is fuel.[65] The Marines' calculation is that 39% of their tonnage is fuel, and 90% is either fuel or water.[66] In 2005, roughly two thirds of the fuel imported into Pakistan was imported through Pakistan, either the route through Chaman to Kandahar in the south, or over the Khyber Pass to the Kabul region in the center of the country.

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[63] Sandra I. Irwin, "Gargantuan Thirst for Fuel Creates Logistical Nightmare for Marines," *National Defense Magazine*,
(http://www.nationaldefensemagazine.org/ARCHIVE/2009/DECEMBER/Pages/GargantuanThirstforFuelCreatesLogisticalNightmareforMarines.aspx)

[64] General Accountability Office, Defense Management: *DOD Needs to Increase Attention on Fuel Demand Management at Forward-Deployed Locations* (GAO-09-300). February, 2009, pages 40-47. The data regarding the five bases is also somewhat inconsistent because Camp Arifjan also purchased electricity from the Kuwait government, and Q-West Air base (Iraq) reported fuel for aerospace ground equipment in the base support activities category. The percentage of fuel needed for base support for the two bases without flying missions was 75%.

[65] DOD, S&*T and Maneuver Warfare: A Current Success and a Future Challenge*, by Alan E. Haggerty, Deputy Under Secretary of Defense, July 29, 2008, slide 14.

[66] U.S. Marine Corps, Installation and Logistics Department, Headquarters, *USMC Energy Efforts and Challenges*, by Carla Lucchino, Assistant Deputy Commandant, October 19, 2009, slide 3.

One third was delivered in the north via Turkmenistan or Uzbekistan.[67] These northern supply routes are up to five times longer, but are less susceptible to attack. In the last four years, the U.S. military has succeeded in shipping more supplies via the northern routes. In a July 2009 interview with Vice Admiral Alan Thompson, head of the DOD's Defense Logistics Agency, he stated that roughly 70% of the fuel that DLA provides to forces in Afghanistan comes through the northern supply routes.[68] Most of the first wave of the of extra U.S. troops announced by President Obama will be going to the south in Helmand and Kandahar Provinces, far from northern supply routes.

The southern route from the Pakistani seaports via Peshawar and the Khyber pass to Kabul extends approximately 1,250 miles (2012 km), with transit times averaging five to fourteen days. The other southern route from the same seaports to Kandahar is approximately 570 miles (917 km) long, with transit times averaging five to seven days.[69] According to Pakistani customs officials, in early 2009 about 300 trucks with ISAF force supplies normally traveled through the Khyber Pass crossing every day, compared with about 100 through the Chaman crossing.[70]

The U.S. military has not always depended so extensively on oil. Militaries largely switched to petroleum in the years leading up to WWII. Famously, First Lord of the Admiralty Winston Churchill led the British decision to change the fuel of the British Navy from coal to fuel in WWI. Since then, with the exception of nuclear-powered ships and submarines, military forces have become increasingly dependent on oil, and therefore supply lines to deliver oil to ships, planes and armies. Arguably the last campaign where a U.S. Army succeeded in at least partially living off the land, relying on local resources, was Sherman's march to the sea from Atlanta to Savannah during the Civil War. Military strategy is a complex subject, but success often depends upon a fundamental balance between being militarily aggressive in pursuing the enemy, but not exceeding the capacity of supply lines. General Patton periodically outran his supply lines during WWII, but was ultimately militarily successful because his supply lines could be quickly reestablished. Napoleon suffered the consequences of lack of supplies in his capture of Moscow. Napoleon attacked Russia on June 24, 1812 with an army of 690,000 men, finally capturing

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[67] According to Defense Logistics Agency (DLA) documentation posted then removed from the Internet, Sarah Myer, *The Pentagon and Oil*, Index Research, July 24, 2008. (http://indexresearch.blogspot.com/2008/07/index-research-pentagon-and-oil.html)

[68] James Kitfield, "Interview with DLA Director, Vice Admiral Alan Thompson," *Defense Standard*, July 24, 2009. (http://www.facebook.com/topic.php?uid=102308743822&topic=16756)

[69] Colonel Kurt J. Ryan, *Exploring Alternatives for Strategic Access to Afghanistan*, Strategy Research Project, U.S. Army War College, March 20, 2009, page 12.

[70] Robert Birsel, "Factbox: Afghan supply routes: problems and possibilities," *Reuters,* February 3, 2009. (http://www.reuters.com/article/idUSTRE5121FU20090203)

Moscow on September 14. The Russians however, had stripped Moscow of supplies. Without supplies, the French Army was forced to retreat back to Vilnius (Lithuania), arriving in December. Only 20,000 soldiers survived.

The potential Achilles heel of U.S. military strategy in Afghanistan is the cost and danger of protecting the supply lines. The Taliban know this, and increasingly have been avoiding direct battles with U.S. and ISAF forces and have instead been planting IEDs (Improvised Explosive Devices), attacking convoys, or both. They are fighting a war of attrition.

According to a September 2009 Army report, resupply casualties have been significant in Iraq and Afghanistan. Resupply convoy casualties have increased in Afghanistan from five in 2003, to seventy five in 2007. About 50% of these casualties are related to the transport of fuel.[71] Marine Corps Commandant General James T Conway has stated “Some 80% of U.S. military casualties in Afghanistan are due to improvised explosive devices (IEDS), and many of those placed in the path of supply convoys.”[72] The Chapter “Benefits of Biodiesel in Afghanistan: Lower Casualties and Fuel" discusses the reduction in casualties that can be achieved by eliminating some of the fuel convoys.

As a nation, the U.S. believes strongly in the value of advanced technology in the military, both to increase the probability of success and to reduce casualties. The U.S. has produced advanced weapons such as the M1 Abrahams tank and the Apache Attack Helicopter that give troops advantages on the battlefield. U.S. troops are using computers and other electronic devices extensively in the field, unlike in conflicts only twenty years ago. Approximately 15% - 20% of a soldier’s 70 to 90 pound (32-41 kg) pack consists of batteries.[73] These weapons and the troops that use them consume significant amounts of electricity and fuel, and the U.S. has underinvested in the unglamorous business of lessening the dependence on expensive and

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[71] Army Environmental Policy Institute, *Sustain the Mission Project: Casualty Factors for Fuel and Water Resupply Convoys*, AEPI Report (Contract Number W74V8H-04-D-0005, Task Number 0545), September 2009, page 5.

[72] Suzanne Goldenberg, U.S. environmental correspondent, “U.S. marines in Afghanistan launch first energy efficient audit in war zone,” *guardian.co.uk*, August 13, 2009. http://www.guardian.co.uk/environment/2009/aug/13/us-marines-afghanistan-fuel-efficiency)

[73] *More Fight – Less Fuel*, page 44. For readers that have not backpacked in mountainous terrain the addition of 10 pounds or more of weight unrelated to food, water, clothing, or shelter is a demanding burden.

dangerous supply lines. While the total defense outlays increased 200% over the period of FY 2000 – FY 2008 (in current dollars), fuel costs increased 497%.[74]

Why the Supply Problem Will Worsen

Increase in troops and more M-ATVs

The supply problems are intensified by the dynamic that the cost of the war, and the casualties resulting from pursuit of the war, will get worse. The planned increase in troops by 30,000 will put more soldiers at risk. In addition, these troops will require more convoys to supply fuel, providing the Taliban with additional opportunities to attack the convoys. The greater the number of convoys, the more likely the Taliban can choose times and conditions that are more favorable to attack. Lastly, the U.S. is rapidly replacing lightly armored troop transport vehicles, such as the Humvee, with the more heavily armored M-ATV. The M-ATV is significantly heavier than an armored Humvee and therefore its mileage is worse. The DOD has authorized purchase of 6,600 M-ATVs; the first delivery in Afghanistan occurred in October 2009. The M-ATVs will save lives in the battlefield, but will also cause more lives to be lost in protecting fuel convoys. If the U.S. continues on the current path, both the cost of the war and the number of casualties is likely to increase non-linearly.

A comparison of armored vehicles

Table 7 below compares the mileage of important armored vehicles used for transport or combat currently deployed by the Army and Marines. The first vehicle, M-1113, is a standard Humvee and is the only vehicle that is not armored. The M-1113 mileage is provided as a baseline.[75]

Table 7 Armored Vehicle Miles Per Gallon

Manufacturer	Vehicle	Mileage
AM General	M-113 Humvee	12.0 mpg
AM General	M-1151 Armored Humvee	4.0 mpg
BAE Systems	M2A3 Bradley Infantry Combat Vehicle	1.7 mpg
BAE Systems	Caiman MRAP	5.5 mpg
BAE Systems	RG-31 MRAP	8.6 mpg
BAE Systems	RG-33 MRAP	6.6 mpg

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[74] Congressional Research Service, *Department of Defense Fuel Spending, Supply, Acquisition and Policy*, (Report R40459), by Anthony Andrews, Specialist in Energy and Energy Infrastructure Policy, March 20, 2009, page 5.

[75] Sherri Reed, Lieutenant Colonel, US Army, ISAF Deputy PAO, provided the authors mpg figures for all vehicles except the M-1151 Armored Humvee and the M-ATV. The M-1151 mpg figure is from *More Fight Less Fuel* referenced earlier, page 41. Sherri Reed, email message to Jake Turetsky, January 5, 2010.

Force Protection Inc.	Cougar Cat I MRAP	6.0 mpg
Force Protection Inc.	Cougar Cat II MRAP	5.0 mpg
General Dynamics	Stryker	2.9 mpg
General Dynamics	M1A2 Abrams Tank	0.6 mpg
Oshkosh Truck	M-ATV MRAP	2.0 mpg[76]
Navistar	MaxxPro MRAP	5.8 mpg

The M-ATVs were designed for Afghanistan; the DOD is purchasing over 6,000. Suppose we assume all M-ATVs replace existing up-armored Humvees. This is a conservative assumption. First, because 30,000 additional troops are being sent to Afghanistan some M-ATVs will not be replacing existing vehicles. Also, some M-ATVs could be replacing standard M-ATVs with higher mpg than up-armored M-ATVs. The Congressional Budget Office (CBO) reported in 2007 that up-armored Humvees were driven about 640 miles per month in Iraq and Afghanistan, and Strykers, more similar to M-ATVs than Humvees, were driven about 1,200 miles per month.[77] Using 750 miles per month as an estimate, only about 20% higher than the Humvee figure, this amount of driving equates to 9,000 miles a year. That degree of use for 6,000 vehicles equates to an additional 13.5M gallons a year, requiring 138 more fuel convoys a year.[78] In FY 2007 there were 807 fuel convoys in Afghanistan, so an increase of 138 more fuel convoys is quite significant, increasing the number of fuel convoys needed by over 15% due to the deployment of a single type of vehicle.

In summary, the supply problems confronted by U.S. forces make pursuit of the war in Afghanistan both dangerous and expensive. The addition of more troops and the substitution of more heavily armored vehicles for lightly armored vehicles will further increase casualties and costs.

The next chapter, “Could the U.S. Military Substitute Biodiesel for Oil in Afghanistan?” explores whether it is currently feasible for the military to substitute biodiesel for petroleum in

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[76] A basic Humvee (M-1113) weighs 5,200 whereas an armored Humvee (M-1151) weighs 9,800 pounds. With a full payload the Gross Vehicle Weight (GVW) is 12,100 lbs. The M-ATV weighs 25,000 lbs with a GVW of 29,000 lbs., 2.4 times heavier. Assuming the M-ATV engine and drivetrain are more efficient than the M-1151, we have assumed that mileage is 50% lower, or 2 mpg. Off-road mileage in rough terrain is likely worse.

[77] Congressional Budget Office, *Replacing and Repairing Equipment Use in Iraq and Afghanistan: The Army’s Reset Program*, September 2007, page 9.

[78] 9,000 miles / 4mpg – 9,000 miles / 2mpg = 2,250 increase in gallons per year per vehicle. 2,250 * 6,000 vehicles = 13.5M gallons per year. 13,500,000 gallons / 98,000 gallons per convoy = 138 more convoys.

Afghanistan in volumes large enough to quickly make a difference, thereby saving lives and money.

Could the U.S. Military Substitute Biodiesel for Oil in Afghanistan?

Military use of Biodiesel in the U.S.

Military use of biofuels

The U.S. military has promoted the use of biodiesel in the U.S. Tens of military bases across the country use B20. According to a June 2008 DOD Congressional study, the DOD 's use of biofuels (ethanol and biodiesel) has increased in four years (FY 2002 – FY 2006) from only 2.3% to 8.5% of fuel consumed by non-tactical vehicles.[79] However, use of biodiesel in military theaters such as Iraq or Afghanistan is non-existent and even more general efforts to reduce energy consumption in military theaters are limited. Per the GAO the "DOD generally lacks guidance that directs forward-deployed locations to manage and reduce their fuel demand – at the department level, combatant level, and military service level."[80]

Fuel is consumed by the U.S. military in Afghanistan for three major categories of use: stationary power generation, vehicles and aircraft. Unlike Iraq, Afghanistan is both landlocked and not a producer of petroleum, so the supply logistics are more challenging in Afghanistan than Iraq.

General developments assisting engine manufacturers

Recent development of ASTM biodiesel standards (e.g. ASTM D6751) and the European B100 standard, EN 14214, have given engine manufacturers better guidelines for supporting biodiesel than previously existed. The National Biodiesel BQ-9000 accreditation program is open to any biodiesel manufacturer, marketer, or distributor of biodiesel and biodiesel blends in the United States and Canada, allowing biodiesel providers to assure customers that their fuels meet specific standards.

Agricultural Equipment

Most of the agricultural equipment manufacturers support the use of B100, and the leading manufacturers are American companies. The top three producers of agricultural equipment worldwide are John Deere, CNH, and AGCO.

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[79] DOD, LMI Consulting, *DOD Biofuels Congressional Study*, by Julian Bentley, Research Fellow, Submitted to the Committee on Armed Services of the Senate and the Committee on Armed Services of the House of Representatives, Federal Environmental Symposium East, June 3, 2008, slide 14.

[80] *Increased on Fuel Demand Management at DOD's Forward-Deployed Locations could reduce Operational Risks and Costs,* page 4. Also "Many of DOD's efforts to reduce fuel demands at forward-deployed locations are in a research and development phase, and the extent to which they will be fielded and under what time frame is uncertain." Report Highlights page.

1. John Deere: All John Deere engines can run on B100 if the biodiesel meets the EN 14214 standard and a John Deere fuel additive is also used.
2. CNH (Case New Holland): CNH's two largest brands, Case and New Holland, were originally companies founded in the U.S. In November 2007, New Holland announced that nearly 80% of New Holland-branded products with diesel engines can operate on B100. In December 2007, Case International Harvester announced that farmers can use B100 on nearly all Case IH medium- to high-horsepower tractors, combines, windrowers, and most self-propelled sprayers and cotton pickers. (The majority owner of CNH is Fiat.)
3. AGCO: AGCO, headquartered in Atlanta and founded in 1990, owns a number of well-known brands including Challenger, Fendt, Massey Ferguson and Valtra. ACGO farm equipment models that take advantage of diesel engines from AGCO's engine subsidiary, SisuDiesel, support B100.

However, unlike the agricultural equipment industry, two key U.S. generator diesel engine manufacturers, both critical military suppliers, are lagging the industry.

Electrical Power Generation

Current use of biodiesel in commercial generators

U.S. diesel engine generator manufacturers

The three U.S. suppliers of diesel engines for generator sets (gensets) that have the largest international sales, distribution and support networks are Caterpillar, Cummins, and John Deere. Detroit Diesel Power Generation is owned by Germany's Tognum Group and has been combined with Germany's MTU Friedrichshafen and rebranded MTU Onsite Energy. Kohler Power Systems, a subsidiary of Kohler Co, is also a major vendor of generators with significant international business. Caterpillar, Cummins, John Deere, and Kohler all pursue OEM business and sell their diesel engines to other manufacturers of gensets. Additional American manufacturers of diesel engines for commercial generators include Electromotive Diesel, Fairbanks Morse Engine (FME), Fisher Panda, Generac (for gensets up to 30 kW) , and Northern Lights. (FME, Fisher Panda, and Northern Lights specialize in marine applications.)

John Deere Power Systems generator diesel engines support the use of B100.[81] John Deere supplies engines for the 30kW and 60 kW generators in the TQG family of military generators.

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[81] John Deere engines can operate on biodiesel blends above B20 (up to 100% biodiesel) only if the biodiesel meets the EN 14214 specification. Engines operating on biodiesel blends above B20 may not fully comply with all applicable emissions regulations. Expect up to a 12% reduction in power and an 18% reduction in fuel economy when using 100% biodiesel. John Deere approved fuel conditioners containing detergent/dispersant additives are required. Heather Landers, Marketing Communications Specialist, John Deere Power Systems, email message to Wayne Arden, March 23, 2010.

Currently Caterpillar and Cummins do not officially support B100; however, B100 has been used in the U.S. to generate electricity using their equipment in several cases. Biofuels Power Corporation has been generating power using B100 in North Oak Ridge, Texas from biodiesel since 2007, using three Caterpillar 1.6 MW generators (Model 3516). In central Tennessee, McMinnville Electric has been operating using B100 in a 2 megawatt (MW) power generator on a Caterpillar generator (Model 3516). Minnville Electric System generates power for the Tennessee Valley Authority. And in 2001 the University of California, Riverside implemented a pilot program using B100 to generate 2 MW of electricity using three Cummins generators.

On February 1, 2007 FME approved 100% biodiesel for use in medium speed diesel engines. FME is a key contractor to the Navy, supplying diesel engines for propulsion. FME also sells large stationary generators (up to 2,000 kVA).

European and Indian generator manufacturers

United Kingdom-based JS Power Ltd. offers electrical generators for emergency, standby, and stand-alone applications fueled by B100 (or any mixture of biodiesel and petroleum diesel), up to 500 kVA. Germany's MAN Diesel (a subsidiary of MAN SE) sells electrical generators for use running B100, and has at least nineteen installations in production in Europe, ranging from 0.6 MW to 85 MW.[82] Finland's Wärtsilä is another very large European manufacturer of diesel generators that supports B100[83] as does Scania. India's Mahindra also offers B100 generators, up to 140 kVA.[84] The commercial suppliers of B100-capable electrical power generators currently span the entire range of military generator kW ratings described below.

Current family of military generators

The U.S. Military classifies Tactical Electrical Power (TEP) generators into three families: small (2-3 kW), medium (5-60 kW), and large (100-920 kW). The Army uses 82% of all military generators, followed by the Air Force at 11%, the Marines 6%, and the Navy using the remaining 1%. As of March 2009, 125,125 generators were in the field. The generators are managed by a

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[82] MAN Diesel, *Green Power, From Diesel Engines Burning Biological Oils and Recycled Fat*, 2009, page 9. (http://www.manbw.com/files/news/filesof9804/Brochure%20Green%20Power.pdf). Since this publication was written MAN has announced several new biofuel power plants. Rudolph Diesel originally licensed his engine technology to MAN SE, and MAN Diesel claims to be the world's leading provider of large-bore diesel engines for marine and power plant applications.

[83] American readers may not be familiar with MAN Diesel and Wärtsilä; they are very large companies. MAN SE's 2009 revenues were 12.0B euros ($16.2B); Wärtsilä's 2009 revenues were 5.3B euros ($7.1B).

[84] For DC power applications 1 kVA = 1 kW; for AC power applications 1 kVA = 1kW if in phase; less than 1 kW if not in phase. kVA is a measure of apparent power; kW is a measure of real power drawn by the equipment. 1000 kW (kilowatt) = 1 MW (megawatt). As discussed later in the paper, JS Power's 500 kVA generator is larger than all military generators manufactured on behalf of the Army and the Marines.

small DOD department serving all four military branches called Mobile Electric Power (MEP). In FY 2008 MEP's budget was $245M; MEP was responsible for the manufacture of 9,923 new generators. The majority of the generators deployed are medium-sized generators.[85]

The U.S. military has deployed two generations of generators and is working on deployment of a third generation. The original generation, Military Standard (MIL-STD) was introduced in the early 1970s. This generation included a variety of engine types: gasoline, diesel, and gas turbine. The second generation, TQG (Tactical Quiet Generators), was introduced in the 1990s, and standardized on diesel fuel and diesel engines. Approximately 70% of the generators in the field are of the TQG generation. Requirements for military generators are, in general, more demanding than for commercial generators, including, for example, the ability to support multiple types of fuel (in particular grades of diesel fuel and jet fuel), battlefield mobility, high reliability, the ability to handle environmental extremes (-50° F to +120° F; -45.6° C to +48.9° C), reduced noise and infrared signatures, and rated power at altitude.

Next generation family of military generators

The military is working on a third generation of generators:

1. STEP (Small Tactical Electric Power): 3 kW or less
2. AMMPS (Advanced Medium Mobile Power Sources): 5kW – 100 kW
3. LAMPS (Large Advanced Mobile Power Sources): 100 kW – 1 MW

Among the goals of this third generation of generators are leveraging commercial technologies, minimizing the number of models, use of commercially proven technologies and replacing the entire DOD generator fleet every fifteen years.[86] Of these three initiatives, only AMMPS is close to deployment. In 2010, the Army is expected to authorize production of AMMPS generators, manufactured by Cummins. These generators will be 15% - 25% more efficient than the previous generation of TQG generators. The initial phase of the next generation, RDT&E (Research, Development, Test and Evaluation), has yet to be announced for either LAMPS or STEP generators, although RDT&E for the LAMPS project is expected to begin in FY 2010, and for STEP in FY 2012.

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[85] DOD, Mobile Electric Power Systems, *Command Brief to EGSA* (Electrical Generator Systems Association), by Paul Richard, Deputy Project Manager, March 2009, slides 12, 24. (www.esga.org then ESGA-S09-Government-Relations-PM-MEP-Brief.pdf)

[86] DOD, Mobile Electric Power Systems, *Mobile Electric Power for Today and Tomorrow*, by Paul Richard, Acting DOD Project Manager, presented at Joint Service Power Expo, April 25, 2007, slides 8, 28. (http://www.dtic.mil/ndia/2007power/NDIARegency/Wed/Session5PMMEPBriefatJointServicePowerExpo25Apr07.pdf)

Air Force generators

The Air Force is responsible for a class of generator called the Deployable Power Generation and Distribution System (DPGDS). DPGDS generators may range in capacity from 765 kW to 920 kW, depending on the implementation. DPGS generators were first ordered in 1998 and deployed in 2003, replacing an older class of generators called MEP-12 rated at 750 kW. DPGDS generators are intended for Air Force Forward Operating Bases (FOB), which in Air Force terminology are called Basic Expeditionary Airfield Resources (BEAR). DPGS generators are large enough to be considered prime power generators, overlapping with smaller generators that produce tactical power and larger generators that produce commercial power. The use of a prime power approach requires the implementation of distribution networks to deliver power to users. DPGDS generators are manufactured by DRS Technologies and use Caterpillar diesel engines.

Military generator engine suppliers

The existing manufacturer of most of the range of TQG generators from 2 kW to 200 kW is DRS Industries' Fremont division. DRS also makes the DPGDS 920 kW generator. The engine suppliers are given in Table 8 below.

Table 8 Military Generator Diesel Engine Suppliers

kW	Engine Supplier
2	Yanmar
3	Yanmar
5	Cummins Onan
10	Cummins Onan
15	Isuzu
30	John Deere
60	John Deere
100	Caterpillar
200	Caterpillar
920	Caterpillar

The Marines also use a non-TQG 20 kW generator manufactured by Magnum. Current Magnum generators in that kW range use Isuzu engines.

Retrofitting generators for biodiesel

As highlighted earlier in the examples of Biofuels Power, McMinnville Electric, and the University of California, Riverside, retrofitting diesel engines in generators to support B100 is not in most cases a complex or expensive process. Retrofitting is explored in more detail below in the section "Retrofitting vehicles for biodiesel."

Fuel Cells - an alternative to generators

Fuel cells are an alternative technology vying to replace generators. Fuel cells are similar to conventional electrochemical batteries but, unlike a battery, they consume reactant from an external source, which must be replenished. Fuel cells convert the chemical energy of a fuel into electricity more efficiently than diesel generators and potentially are more reliable, since a fuel cell has no moving parts. The first commercial use of a fuel cell was in NASA's Gemini missions in the 1960s. Bloom Energy was recently profiled on CBS' 60 Minutes (February 21) prior to their public introduction of fuel cells on February 24, and there are many U.S. fuel cell companies focusing on electrical power generation markets, including for example Acumentrics, Adaptive Materials Inc., Altergy Systems, ClearEdge, FuelCell Energy, GE Power Systems, IdaTech, Plug Power, UTC Power, and Versa Power Systems. Some of these companies are suppliers to the military; Adaptive Materials was recently awarded a small contract ($3M) to provide 60-watt fuel cell systems to the Air Force.

Except in specialized applications, fuel cells have yet to compete successfully with diesel generators on a cost per kilowatt-hour basis. Several of the highest profile fuel companies, including Canada's Ballard Power Systems, FuelCell Energy and Plug Power, have never been profitable. Ballard Power Systems and Plug Power have been manufacturing and selling fuel cells for a decade.

Continue to invest in generators with biodiesel

The objective of this paper is to recommend specific technologies and processes to the U.S. military that will quickly save lives, money, and challenge the Afghan opium trade – while being achievable. A related objective is to minimize change to current military equipment and processes. The Armed Services are proficient in procuring, deploying, and maintaining generators in military locations throughout the world. Over the next few years, the military should continue to rely on generators, improving generator technology as much as possible. But at the same time the military should test in U.S. bases fuel cells running renewable fuel such as biodiesel, reassessing the applicability of fuel cells as a tactical power supply in several years. Acumentrics is working to add biodiesel as a supported fuel. InnovaTek, a supplier of technology to fuel cell companies, was awarded by the DOE a Phase II Small Business Innovation Research contract to develop a biomass based power plant. InnovaTek will use its proprietary catalytic reactor technology with a solid oxide fuel cell to generate distributed power in the range from 3 to 30 kW. The bio-oil that will be used in the proposed process is made from agricultural and forestry residues. In addition, the military should evaluate glycerin as a fuel for fuel cells.

A potential evolutionary path for producing electrical power at a FOB would be: 1) a biodiesel plant combined with generators to produce electricity, using methanol as a chemical input, 2) a biodiesel plant and an ethanol plant combined with generators (using ethanol as a chemical input), 3) a biodiesel plant and an ethanol plant with generators, plus fuel cells powered by the biodiesel byproduct glycerin and finally 4) a biodiesel plant and an ethanol plant, using fuel cells powered by biodiesel or glycerin.

But, over the next few years the military should prioritize funding for projects reducing petroleum dependence that can be quickly deployed in the field. These projects should include efforts to improve generators and to take advantage of biodiesel in generators and tactical vehicles.

Military Vehicles

The military divides vehicles into three general classes: combat, tactical, and non-tactical vehicles. Combat vehicles are designed for a specific fighting function and tactical vehicles are designed primarily for use by forces in the field in connection with or in support of tactical operations. Combat vehicles generally move on tracks versus wheels and include the Abrams tank, the Bradley Fighting vehicle, and the Paladin self-propelled howitzer. Tactical vehicles generally move on wheels and include the High Mobility Multi-purpose Wheeled Vehicle (HMMWV, or Humvee), Mine Resistant Ambush Protected (MRAP) vehicles, and families of trucks and trailers. Tactical vehicles are then further divided into two broad categories: combat tactical vehicles and support tactical vehicles. Support tactical vehicles are designed to transport materials such as fuel, water, food, ammunition, and equipment. Non-tactical vehicles (passenger cars, vans, SUVs, trucks, buses, ambulances, etc.) are intended for normal use away from the battlefield. Tactical vehicles differ from commercial vehicles in that they may have specialized requirements for ruggedness, for operation in harsh conditions, or the need to use multiple fuel types.

The military's drive over the last ten years to increase the use of vehicular biofuel (in particular ethanol and biodiesel) has been focused nearly entirely on non-tactical vehicles. The vast majority of non-tactical vehicles used by the military are situated in the U.S.

A number of the leading diesel engine manufactures who sell their engines for both commercial and military uses, such as Cummins and Caterpillar, warrant their engines for B20 or higher. Cummins supports B20 in many highway and off-highway engines manufactured in 2002 or later. All Cummins 2010 highway engines designed for North America support B20. Caterpillar supports B30 for most engines medium-sized and larger, including the C series of engines starting at C7 (7.2 liters) and larger.[87]

General manufacturers of commercial vehicles, such as Chrysler (2006) and Ford (in 2010), and GM (in 2010) support B20 in their trucks. (Cummins supplies diesel engines to Chrysler). In Europe, Ford's diesel engines support B30 in a variety of models, including the Ford Fiesta, Focus, S-Max, and Mondeo.

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[87] Caterpillar, Marketing and Product Support Division, *Biodiesel Validation in Caterpillar Engines*, Hind Abi-Akar, presented at 2008 National Biodiesel Conference & Expo, Orlando Florida, February 5, 2008, slides 14-19. (http://www.biodieselconference.org/2008/post/secure/_xlI10oO/29_User%20Abi-Akar.pdf).

Since so many Army and Marine military vehicles take advantage of Caterpillar or Cummins engines, military vehicles in Afghanistan have the potential to use at least B20 or B30; however, many large European vehicle manufacturers support B100.

Manufacturers such as PACCAR/DAF in their CF75/85 and XF95 vehicles,[88] MAN Nutzfahrzeuge (MAN's truck division),[89] Mercedes, and Scania have all approved certain models and engine types to use with B100. In Germany B100 is sold at 1,900 outlets (as of 2005), equivalent to one in every ten public gas stations, and is used by commercial vehicle and bus operators. Ullrich GmbH, Germany's largest independent truck load carrier, has more than 1,000 trucks and uses B100 exclusively. In January 2010, PACCAR announced that the MX engine, developed in Europe by DAF, will be installed in Kenworth and Peterbilt trucks beginning this summer.[90] The MX engine supports B100. Kenworth and Peterbilt trucks are thus the first American large commercial trucks with the potential to use B100.

Important combat vehicles and combat tactical vehicles

Table 9 lists the engine manufacturers and potential biodiesel support of the most numerous Army and Marine (self-propelled) combat-related vehicles. Engine biodiesel support refers to the current biodiesel support of engine manufacturers.

Table 9 Diesel Engine Manufacturers of Combat Vehicles and Combat Tactical Vehicles

Manufacturer	Vehicle	Approx. Number in Service or Ordered	Engine	Engine Biodiesel Support
AM General	Humvees	160,000	AM General	none[91]
BAE Systems	AAV-7A1 Amphibious Assault Vehicle[92]	1,320	Cummins	unclear, no longer in

[88] DAF, *Sales Engineering Information: Fuel Specification for DAF diesel engines,* Modification date May 2, 2008. (http://www.zero.no/transport/biodrivstoff/biler/daf-2008.pdf)

[89] MAN Group, MAN Nutzfahrzeuge, Service Information, *Adding up to 7 Vol.% FAME to diesel fuel,* SI 2nd Supplement No. 180911b, April 2, 2009 plus *Operations of MAN engines/vehicles with FAME*, SI No. 180911b, June 20, 2007. (http://www.biofuel-express.com/6storage/877/4/180911en_man04042009uk.pdf)

[90] "PACCAR launches PACCAR MX Engine for Kenworth and Peterbilt Trucks," PACCAR, Bellevue Washington, January 25, 2010.

[91] Dan Collins at AM General's engine division (General Engine Products) warranty and service department confirmed that no blend of biodiesel is factory approved or under warranty. Conversation with Jake Turetsky January 14, 2010.

				production
BAE Systems	Caiman MRAP	2,800	Caterpillar C7	B30
BAE Systems	M2/M3 & other Bradley Fighting Vehicles	6,700	Cummins V903	B20
BAE Systems	M9 Armored Combat Earthmover (ACE)	500	Cummins V903	B20
BAE Systems	M88 Hercules Tank Recovery Vehicle	675	General Dynamics	unclear
BAE Systems	M109 Paladin Howitzer	950	Cummins 600hp	B20
BAE Systems	M113 Armored Personnel Carrier	10,000	Detroit Diesel	B5
BAE Systems	RG-31 and RG-33 MRAPs	1,400	Cummins 6.7L QSG & 400 I6	B20
Force Protection Inc.	Cougars I & II MRAPs	3,500	Caterpillar C7	B30
Force Protection Inc.	Buffalo Mine Clearer	200	Mack	unclear
General Dynamics	Abrams Tank[93]	7,850	Honeywell turbine	untested
General Dynamics	Stryker	2,575	Caterpillar C7	B30
General Dynamics	Growler Internally Transportable Vehicle (ITV)	150	GMC	B20 (2010)
Navistar International	MaxxPro MRAP	5,250	Navistar	B5
Oshkosh	M-ATV MRAP	6,600	Caterpillar C7	B30

[92] The Marines' projected replacement of the AAV is called the Expeditionary Fighting Vehicle (EFV). The Marines will be evaluating prototypes in 2010. Earlier EFV prototypes suffered from reliability problems.

[93] There are also a number of engineering combat vehicles that were developed in limited numbers using the M1 Abrams platform: the M104 Wolverine Heavy Assault Bridge (45), the M1 Assault Breaching Vehicle (33), the M1 Panther Remote Controlled Mine Clearing Vehicle (10), and the M1 Grizzly Combat Mobility Vehicle (a handful).

Truck				
Textron Systems	M1117 Armored Security Vehicle	2,060	Cummins 6CTA8.3	B20

The Caterpillar C7 engine is currently used in more than 18,000 vehicles (combat and support) in Iraq and Afghanistan. Caterpillar engines are also used by European allies. British combat engineering vehicles, tank transporters, and military trucks use Caterpillar engines; British Army's Challenger tanks use an engine designed by Caterpillar's U.K. subsidiary, Perkins. The CV90 family of Infantry Fighting Vehicles, used by Denmark, Finland, the Netherlands, Norway, Sweden, and Switzerland also incorporates a Caterpillar engine.

Note that the General Dynamics M1A2 Abrams tank is equipped with a Honeywell AGT 1500 turbine engine, rather than a reciprocating engine. The tank can be fueled with diesel fuel, kerosene, any grade of motor gasoline, JP-4 jet fuel, or JP-8 jet fuel; the U.S. Army uses JP-8 jet fuel in order to simplify logistics. The Royal Australian Armoured Corps, another Abrams customer, uses diesel fuel. In general, turbines are flexible and can handle many different kinds of fuel. GE has successfully tested turbines with biodiesel.[94]

Combat-related vehicle summary

Most of the engines in combat-related vehicles already support B20 or higher, with two critical exceptions: Humvees manufactured by AM General and M113 Armored Personnel Carriers manufactured by BAE Systems. Per a GAO September 28, 2009 report, the Army will buy 21,209 Expanded Capability Vehicles (Humvees) from 2009 through 2010 for $3.2B.[95] The DOD should mandate that the AM General diesel engine support a minimum of B30, or that AM General replace their internally-developed engine with one that is widely deployed in military vehicles and currently supports B30, for example, one from a manufacturer such as Caterpillar.

The Army, Marines, and Special Operations Command are jointly sponsoring an effort to replace the Humvee with a new generation of vehicle, called the Joint Light Tactical Vehicle (JLTV). In October 2008 the DOD announced that three vendors remained in the running to build the JLTV: Lockheed Martin, General Tactical Vehicles and BAE Systems/Navistar. (General Tactical Vehicles is a joint venture between AM General and General Dynamics Land Systems.) Each team received contracts worth between $35.9M and $45M to begin the second phase of the program, which could ultimately be worth $20B or more. According to the Congressional Research Service, the Army has a need for nearly 141,000 JLTVs. If the project stays on schedule, the

[94] See www.gepower.com/prod_serv/products/tech_docs/en/downloads/GER4601.pdf

[95] General Accountability Office, Acquisition and Sourcing Management, *Study of DOD Tactical Wheeled Vehicle Strategy,* (GAO-09-968R), by Michael J. Sullivan, Director, Acquisition and Sourcing Management, September 28, 2009, page 9.

winner will be announced January 2012. The DOD should mandate that JLTV diesel engines be capable of supporting B100.

Important support tactical vehicles

The U.S Army has two families of support tactical vehicles: FHTV (Family Heavy Tactical Vehicles) and FMTV (Family Medium Tactical Vehicles). The Marines also deploy two vehicle families: the LVSR (Logistics Vehicle System Replacement) series of heavy trucks and the MTVR (Medium Tactical Vehicle Replacement) series of medium-sized trucks.

Army FHTV

FHTV: Oshkosh Truck Corporation is the manufacturer of all eleven FHTV vehicles. Oshkosh has delivered more than 30,000 FHTV vehicles to the Army.

Of these, the largest number deployed are a family of trucks called Heavy Expanded Mobility Tactical Trucks (HEMTT) There are three generations of HEMTT under consideration:

- HEMTT A2. These are the trucks that are currently deployed, using Detroit Diesel engines. They are no longer being manufactured, but can be upgraded to A4s.
- HEMTT A3. The HEMTT A3 is equipped with the Oshkosh proprietary ProPulse diesel electric hybrid system, a technology developed by Oshkosh but never ordered in volume by the military. The A3 truck features a 9L Cummins ISL diesel engine. (See discussion of hybrid technology later in Chapter "Current Efforts by the Army and Marines to Reduce Oil Dependence."
- HEMTT A4: These trucks use a Caterpillar C15 500 hp engine and replace the A2s. Oshkosh received its initial HEMTT A4 production contract in October 2007.

Other FHTV vehicles include:

- The PLS: The Palletized Load System is used to transport containers. The new PLS is a cousin of the HEMTT A4 and also uses Caterpillar C15 engines.
- The Heavy Equipment Transporter (HET) M1070 A1. These trucks use Caterpillar C18 engines.

Army FMTV

FMTV is a series of fourteen vehicles based on a common chassis, which vary by payload and mission requirements. The Light Medium Tactical Vehicle (LMTV) has a 2.5-ton capacity (cargo and van models) and the Medium Tactical Vehicle (MTV) has a 5-ton capacity. The contract was originally awarded to Stewart & Stevenson, which was acquired by BAE Systems in 2007. The military currently has about 48,000 FMTV trucks in inventory.[96] All of these vehicles use

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[96] "USA Looks to Bridge FMTV Truck Orders Until 2011," *Defense Industry Daily*, August 27, 2009. (http://www.defenseindustrydaily.com/USA-Looks-to-Bridge-FMTV-Truck-Orders-Until-2009-2010-04924/)

Caterpillar C6.6 or C7 engines. The vehicles include cargo trucks, vans, dump trucks, fuel tenders, wreckers and long wheel base trucks.[97]

Marines LVSR

Oshkosh manufactures the LVSRs. The LVSRs replace the older LVS family of trucks that was put into service in 1985 which were also manufactured by Oshkosh. The trucks deployed by the Marines are of a different design than the Army trucks and have less in common with commercial trucks. The LVSR trucks, for example, have 10 by 10 all-wheel drive and can ford five feet of water. The LVSR family of trucks uses the Caterpillar C15 engine. The first LVSR was delivered to Afghanistan in September 2009, and 100 were expected by the end of 2009. The Marines have ordered 1,600 vehicles.

Marines MTVR

Oshkosh also manufactures the Marines' MTVR family of trucks, six-wheel drive all-terrain vehicles that replace the old M939 tactical trucks. They were first fielded in 1998. There are nine variations of the 7-ton MTVR. The MTVR trucks use the Caterpillar C12 engine and entered production in 2005; the Marines have ordered approximately 500.

Other older supply vehicles

- The LAV (Light Amphibious Vehicle) Family of vehicles is no longer in production but is still used by the Marines. They were originally deployed in 1983 and consist of the LAV-25, an eight wheeled amphibious vehicle, and other variants, including the LAV-C2, LAV-M, and LAV-R. The LAVs were manufactured by General Dynamics Land Systems of Canada and use Detroit Diesel engines. About 645 are in service.
- The M-35 family of 2.5 ton trucks, originally deployed in 1951, has been replaced by LMTVs (of the FMTV family). The M35 series was still used by the U.S. in Iraq during Operation Iraqi Freedom.
- The M915 Series of Heavy trucks date from the early 1980s and are still in use, intended for transport of bulk supplies from ocean ports to division support areas within a theater of operation. AM General produced M915-series variants M915 and M915A1, then Freightliner produced the M915A2 through M915A5, based upon Freightliner's commercial FLD120 tractors. Some of the engines were supplied by Cummins, some by Detroit Diesel.
- The M939 series is a family of Army logistical transportation 5.0 ton trucks which was deployed in the late 1980s and is still in service. About 32,000 M939 series trucks are in service today. The M939 series is an improved version of the older M809 series of trucks. Larger models use a Cummins 250 hp diesel engine; smaller models use the Cummins 6CTA8.3 engine producing 240 hp.

[97] Commercial Utility Cargo Vehicles (CUCV) was an attempt by the Marines to deploy a family of six Light Utility Vehicles based on commercial vehicles from Chrysler and GM. The program was phased out in the late 1990s.

Support tactical vehicle summary

Table 10 summarizes support tactical vehicles and their engines. Engine biodiesel support refers to the current biodiesel support of engine manufacturers.

Table 10 Diesel Engine Manufacturers of Supply Trucks Currently in Production

Manufacturer	Family	Type	Engine	Engine Biodiesel Support
BAE Systems	FMTV	LMTV	Caterpillar C6.6	B20
BAE Systems	FMTV	MTV	Caterpillar C7	B30
Oshkosh Truck	FHTV	HEMTT A4	Caterpillar C15	B30
Oshkosh Truck	FHTV	PLS	Caterpillar C15	B30
Oshkosh Truck	FHTV	HET	Caterpillar C18	B30
Oshkosh Truck	LVSR	Marines	Caterpillar C15	B30
Oshkosh Truck	MTVR	Marines & Navy	Caterpillar C12	B30

Table 11 Diesel Engine Manufacturers of Supply Trucks no Longer in Production

Manufacturer	Family	Type	Engine	Biodiesel
AM General & others	M35	2.5 ton trucks	Various	No
AM General	M915	Heavy Trucks	Detroit Diesel then Cummins	Some B5?
Oshkosh Trucks	FHTV	HEMTT A2	Detroit Diesel	No
Stewart & Stevenson	M939/M809	5 ton trucks	Cummins	B5?

In summary, all of the supply trucks in production use Caterpillar engines. If manufactured recently, all engines should be capable of using B30 except LMTV trucks whose engines could use B20. If MAN Nutzfahrzeuge, PACCAR's DAF, Scania, and other vehicle manufacturers in Europe can successfully build and warrant diesel engines for vehicles that run on B100, there is no reason why Caterpillar, Cummins and other U.S. diesel engine and truck manufacturers cannot do the same.

Tactical vehicle fuel consumption

In general, the classes of tactical vehicles that consume the greatest amount of petroleum are support vehicles. According to a 2005 Naval Research Advisory Committee (NRAC) report, the vehicles in the Marines that consume the greatest amount of fuel are 5-ton trucks (58% of the total), and LVSRs, formerly called LVSs (18.8%). Humvees consumed 11.7%. By contrast, heavy combat vehicles such as assault vehicles consumed 4.8% and tanks 4.5%.[98]

A 2001 Defense Science Board report looked at the first Gulf War's top ten battlefield fuel users. Only two were combat platforms capable of firing weapons: the M1A1 Abrahams tank (#5) and the AH-64D Apache Attack Helicopter (#10). Three of the top four fuel users were trucks: #1 Truck Tractor M915 (heavy truck for transporting bulk supplies), #3 Truck Tractor MTV W/E (medium 5-ton truck), #4 Truck Tractor Heavy Equipment Transporter (HET; for carrying tanks, etc.). Humvees (for troop transport) ranked #8. The table below gives the full list.

Table 12 First Gulf War's Top 10 Battlefield Fuel Users

Rank	Equipment
#1	Truck Tractor M915
#2	Helicopter Utility UH-60L
#3	Truck Tractor MTV
#4	Truck Tractor HET
#5	Tank M1A2
#6	Helicopter Transport CH-47D
#7	Decontaminating Apparatus
#8	Truck Utility: Humvee
#9	Water Heaters
#10	Helicopter Attack AH-64D

In order to reduce the logistics vulnerabilities of supplying fuel during wartime the Army and the Marines should thus focus much of their effort on improving the efficiency of supply trucks.

Retrofitting vehicles for biodiesel

The EPA sponsors a program for retrofitting existing diesel vehicles to reduce pollution. Manufacturers with verified retrofit programs include Johnson Matthey, Donaldson, Caterpillar, Cummins, ECS (Engine Control Systems) and Cleaire.[99] Retrofitting an engine to meet EPA emission standards such as Tier 4 is a different process than retrofitting an engine to support B100. The EPA or the DOE have not conducted studies about the costs of upgrading a diesel engine to support B100. Consequently, in order to discuss such costs, we have used data from practitioners.

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[98] U.S. Navy, Office of Naval Research, Naval Research Advisory Committee, *Future Fuels*, Office of Naval Research, Flag Officers & Senior Executive Service, the Pentagon Auditorium, October 4, 2005, slide 10. (http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA444374&Location=U2&doc=GetTRDoc.pdf)

[99] EPA, *Diesel Retrofit Technology Verification*. (http://www.epa.gov/oms/retrofit/verif-list.htm)

Retrofit Example 1

The University of California, Irvine (UCI) retrofitted a fleet of campus buses to run on B100; the first of the ten retrofitted buses was placed into service in March 2007. UCI reported a retrofit cost of $1,500 per bus.[100]

Retrofit Example 2

Kurt Baker, co-owner of LA City Biodiesel, states that the cost of retrofitting an engine to support B100 is modest as long as the engine does not use a post-injection technique for regeneration (cleaning) of its particulate filter. In general, post-injection is used by smaller diesel engines in cars, and is less common in larger diesel engines used in larger trucks, off-road equipment or electrical generators.[101]

In half an hour increments, the labor required to upgrade a diesel engine to support B100 are:

1. Purge the fuel system of petroleum diesel and clean the fuel tank. This step includes removing the fuel tank, cleaning it (possibly with a pressure wash), drying and reinstalling it. This step could take three to five hours depending on size of tank and whether the tank is internal or external to the vehicle's frame. Some tanks would not need to be removed depending on the cleaning method used.
2. Replace the fuel lines with a fuel lines made from a synthetic material. If needed this step would require one half hour.
3. Install a new filter. This step should require no more than one half hour.

Biodiesel acts as a solvent and, when first used, will clean the engine and fuel system of petroleum diesel impurities. So when the vehicle or generator first uses biodiesel, up to three filters could be consumed fairly quickly. A filter for a large vehicle can cost up to $200. Commercial labor rates to perform the work above range from an estimate of $39 per hour in Georgia to $109 per hour in California. A rate of $100 per hour is assumed. Baker estimates that

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[100] University California Irvine, Administrative and Business Services, *The B100 Retrofit Process*, 2007, Introduction to Selective Catalytic Reduction Technology (page 3). ((http://www.abs.uci.edu/b100retrofitprocess.pdf)

[101] Modern fuel injection systems are highly precise, and fuel is injected into a cylinder multiple times before and during combustion. A diesel engine using post-injection for regeneration of the particulate filter periodically adds a bit of fuel after combustion. The fuel vapor is heated in the cylinder and this hot gas then cleans the particulate filter. Biodiesel has a higher ignition temperature than petroleum diesel and over time could leave residue in the cylinders.

the cost of retrofitting a diesel engine in a generator or vehicle to support B100 should be no more than $1,200 per engine.[102]

This estimate is high if multiple vehicles are converted at once or if filters are purchased in bulk; in these cases the cost per vehicle could be considerably reduced. The cost of maintenance for vehicles using B100 versus vehicles using petroleum diesel will be lower since catalytic converters will last longer.

Retrofit Example 3

Barry Carr, Coordinator of the U.S. DOE Clean Cities Coalition for Central New York, agrees with Kurt Baker but would allocate two hours to replace the fuel lines, rather than half an hour. Carr's estimate to retrofit an engine to support B100 is therefore $1,350 per engine.[103]

Retrofit Example 4

Mathew George, General Manager of Commercial Engine Service for Peterson Power Systems, responded that if a customer asked Peterson to retrofit a Caterpillar engine in a generator or vehicle for B100 he would explain that Caterpillar does not warrant B100. However the retrofitting process is not expensive for recently manufactured engines. The engine and fuel tank would need to be cleaned. The fuel system components (more specifically the elastomers) are made of synthetic materials which already support B100. A new filter would be needed. Depending on local labor rates, the labor and filters needed to retrofit a medium-sized Caterpillar engine, such as a C7, would cost about $1,500. The biodiesel should be purchased from an accredited supplier, and the fuel carefully monitored.[104]

Retrofit cost estimate

In later calculations in section "Retrofitting all 250,000 tactical vehicles" we have used the highest estimate: $1,500 per engine.

Engine designs for Tier 4

Caterpillar ACERT diesel engine technology has been applied to on-road vehicles, off-road vehicles and diesel generators. ACERT engines do not employ post-injection techniques. In order to satisfy the Tier 3 standards in 2007 Caterpillar added a system downstream from the engine called the Cat Regeneration System (CRS) which contains an auxiliary heater. The heater periodically injects fuel, ignites it, and raises the temperature of the exhaust gases so that the

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[102] Assume step 1 takes an average of 4 hours. Total costs then are 5*100 (steps 1-3) + 3*$200 (for filters) + 1*100 (an hour of labor to install two extra filters) = $1,200. Kurt Baker, email messages to Wayne Arden, March 22, 2010 and March 26, 2010.

[103] Barry Carr, email message to Wayne Arden, March 24, 2010. CCNY's website is www.cc-cny.com.

[104] Mathew George, email message to Wayne Arden, March 29, 2010.

soot in the particulate filter is oxidized (burned).[105] The more recent Caterpillar ACERT engines announced in 2009 and 2010 for Tier 4 Interim standards contain a Clean Emissions Module (CEM). The CEM also applies the CRS methodology to minimize particulate emissions. ACERT engines meeting the Tier 4 standard have been announced in nearly all of the engine sizes currently used in U.S. military vehicles, including the C6.6, C7, C13 (slightly larger than C12), C15 and C18 engine sizes.

By contrast, in certain circumstances new Cummins engines do employ post-injection techniques to meet EPA Tier 4 emission standards, a process Cummins terms “active regeneration by fuel injection.”[106] Cummins' choice of emissions technology should not deter the use of B100 by Cummins generators in Afghanistan for the following reasons:

1. The AMMPS program spans generators from 5kW – 100kW. Cummins engines that are 37 kW or smaller do not need exhaust after-treatment (e.g. active regeneration) to meet the particulate matter specifications of the Tier 4 standard.[107] The majority of diesel generators used in the field by the Army and Marines are 30 kW and smaller.

2. Tier 4 Interim requirements for engines from 37kW to less than 56kW will phase in during 2012, with Tier 4 Final for these engines beginning January 2013. Tier 4 Interim requirements for engines from 56 kW to less than 130 kW will phase-in during the period 2012 through 2014, with Tier 4 Final for these engines beginning January 2015. So, for most engines in the range of 37 kW – 100 kW, engineers have several years to determine how to support B100 in the Cummins Tier 4-compliant design.

3. Cummins has not confirmed to the authors what generator design they have selected for the AMMPS generators. Cummins may not have selected a Tier 4-compliant design, given other higher priority military requirements. In this case, support of B100 should be fairly straightforward.

4. Afghanistan has not implemented U.S. Tier 4 (off-road) emission standards or similar European Stage IV or Japanese Tier 4 standards. The potential obstacle that could inhibit the rapid use of B100 in Cummins generators is one of engineering complexity and cost.

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[105] Caterpillar Inc., *Caterpillar C7 with ACERT Technology*, Charlie Martin, presentation at Florida Association Pupil Transport Conference, June 25-30, 2006, pages 10-12. (http://faptflorida.org/Conference06/Caterpillar%20FAPT%20Presentation.pdf)

[106] Cummins Inc., *Mobile Off-Highway Emissions Technology*, Bulletin 4087130, December 2009, pages 21-22. (http://www.cumminspower.com/www/literature/technicalpapers/gdrive-mobileOffHighway-1209-en.pdf)

[107] *Mobile Off-Highway Emissions Technology*, page 8.

If Cummins has selected a Tier IV compliant design for the AMMPS generators could Cummins support B100 in generators in the sizes 38kW – 100 kW at reasonable cost? The answer should be yes: the modified Cummins engine would omit the post-injection addition of fuel and therefore should be able to support B100, although in this case it would no longer be capable of meeting all Tier 4 emission standards.

Retrofitting all 250,000 tactical vehicles

Retrofitting support tactical vehicles to support B100, and combat tactical vehicles to support B30, would consequently be relatively inexpensive. The Army and the Marines have about 250,000 tactical vehicles (the CBO reported 234,400 at the end of 2006). As of 2006, 23% of these vehicles were old (for example the M-35 family of trucks), and it may or may not be advisable to retrofit older vehicles to support biodiesel. But assuming an average cost of $1,500 per each vehicle, as determined in section "Retrofit cost estimate," retrofitting 250,000 tactical vehicles would cost approximately $375M, a fraction of what the DOD is spending to deploy just one type of MRAP vehicle, the M-ATV. (The military would either retrofit vehicles directly at a labor rate much lower than the commercial rate of $100 per hour used to derive the $1,500 retrofit cost, or subcontract retrofitting via a competitive bid process to a commercial firm.)

But only a small percentage of all these vehicles are being used in Afghanistan, and only support tactical vehicles would be retrofitted to support B100. The AEPI study referenced earlier reported 5,133 fuel convoys and 3,287 water convoys in Iraq in 2006, or a subtotal of 8,420 convoys. This figure is approximately 70% of the total number of convoys, which is 12,029 convoys.[108] Since the DOD is sending more troops to Afghanistan to bring the U.S. total to 100,000, let's use the Iraq 2006 data which should be conservative (i.e. high). Throughout 2006, troop levels in Iraq were significantly greater than 100,000. Using the Army's figure of an average of 20 trucks per convoy (sixteen supply and four gun trucks), and a round trip once every four weeks, only 18,506 trucks are needed.[109] But some trucks are certainly needed continuously in Afghanistan, one must plan for the longest convoys, not just the average-length convoys, some trucks will be unavailable due to maintenance, and the above costs are for retrofitting in the U.S., not in Pakistan or Afghanistan. So let's assume twice as many trucks are needed. The costs of retrofitting 37,000 supply trucks for B100 would still only be about $55.5M.

Aircraft

In November 2008, Boeing's Darrin Morgan, responsible for Boeing's Sustainable Biofuels Program, made an optimistic prediction, stating that authorities will certify a bio-fuel blend for

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[108] *Sustain the Mission Project: Casualty Factors for Fuel and Water Resupply Convoys,* Pages 3, 5.

[109] 12,029 convoys * 20 trucks = 240,580 truck-trips per year. 240,580 * (4/52) = 18,506 trucks per year. Doubling this figure = 37,012; 37,000 trucks * $1,500 retrofit per truck = $55.5M.

commercial use in three to five years.[110] We hope that he is correct, but we recognize that the military will be cautious in implementing biofuel for aviation. Nevertheless, commercial aviation is making significant progress. The Sustainable Aviation Fuel Users Group (SAFUG) is a consortium of fifteen air carriers who have pledged to accelerate the development, certification, and commercial use of environmentally and socially acceptable aviation fuel. SAFUG has tested an aviation fuel comprised of 50% biofuel on Boeing airplanes using several different turbine manufacturers.

On December 15, 2009, a Seattle-based biofuel start-up, AltAir Fuels, announced a Memorandum of Understanding (MOU) with fourteen airlines from North American and Germany to purchase up to 750M gallons of renewable jet fuel and diesel produced by AltAir Fuels. AltAir's facility will have a capacity of about 100M gallons per year and it is expected to begin production in late 2012. MOUs are rarely binding agreements, but the AltAir agreement is another sign of increasing acceptance of biofuel in commercial aviation.[111]

The U.S. military primarily uses two aviation fuels: JP-8 (Jet Propulsion), and the Navy's JP-5. (An older standard, JP-4, is also still in use). These fuels have properties that are significantly different than normal biodiesel. DARPA has initiated several programs whose objectives are to find biofuel replacements for JP-8 and JP-5. These programs seem unlikely to succeed so quickly that aviation biofuel could be deployed in Afghanistan within the next five years; consequently we have not analyzed this possibility further. Given that aviation fuel specifications are more difficult than fuel specifications for electrical power generation or vehicles, generating biodiesel locally in Afghanistan for these latter two uses would be an important step towards achieving DARPA's objective of satisfying energy needs in situ. DARPA's Douglas Dr. Douglas Kirkpatrick expressed the military's desire to reduce energy dependence "We're talking complete self-sufficiency. The ability to satisfy our energy needs in situ. That's our end-state vision."[112]

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[110] "Boeing: Jet biofuel in three years," *Climate Progress*, November 7, 2008. (http://climateprogress.org/2008/11/07/boeing-jet-biofuel-in-three-years/)

[111] The 14 airlines include most of the big U.S. commercial airlines plus the leading cargo carriers: American Airlines, Air Canada, Alaska Airlines, Atlas Air, Delta Air Lines, FedEx Express, Hawaiian Airlines, Jet Blue Airways, Lufthansa German Airlines, Mexicana Airlines, Polar Air Cargo, United Airlines, UPS Airlines, and US Airways. The plant capacity is equivalent to about 10% of the fuel consumed each year at the Seattle-Tacoma airport (SEA). SEA was the 17th busiest U.S. airport in 2008 by number of passengers.

[112] DOD, DARPA, Strategic Technology Office, *Energy as a Tactical Asset*, speech by Dr. Douglas Kirkpatrick, Program Manager, Strategic Technology Office, August 9, 2007, at DARPATech, DARPA's 25th Systems & Technology Symposium, Anaheim California. (http://www.darpa.mil/darpatech2007/proceedings/dt07-sto-w-kirkpatrick-energy.pdf)

In 2009 the Navy conducted its first test of biofuel in a jet engine. The Navy tested a blend of camelina-based JP-5 blended with petroleum-based JP-5 and the initial results indicated that "the engine performed as expected with petroleum-based JP-5."[113]

Stationary turbines can be engineered to combust a wide variety of fuels. Perhaps the Army and Marines should investigate whether existing turbines in aircraft such as the AH-64 Apache (GE turbine), V-22 Osprey (Allison turbine), UH-60 Blackhawk (GE turbine), and other tactical low-flying aircraft could run on biodiesel, even if on a temporary basis. Such logistical flexibility, if not excessively expensive to implement, could be valuable when operating in a military theater.

Yes, the Military Could Use Biodiesel in Afghanistan

Concluding discussion

At the start of the war in Afghanistan in 2001, it probably would not have been feasible for the military to use significant quantities of biodiesel. During the past eight years, biodiesel acceptance and use has increased significantly. Leading manufacturers of diesel engines used in military vehicles, including Caterpillar and Cummins, warrant the use of B20 or B30. General manufacturers of commercial vehicles, such as Chrysler, Ford, and GM support B20 in trucks. All leading vendors of farm equipment warrant the use of B100 across most of their product line. A number of diesel engine manufacturers, including John Deere, directly support the use of B100 for power generation. Caterpillar and Cummins have supported B100 for specific projects on a limited basis. Many European truck manufacturers support B100, including PACCAR's DAF subsidiary. Thus appropriate biodiesel technology is substantially available today to be deployed in Afghanistan. With additional commercialization of existing technology, military use of biodiesel could be even more extensive.

The DOD should act quickly to improve efficiency and accelerate the use of biodiesel in generators deployed in Afghanistan. At a minimum all MIL-STD generators in Afghanistan should be replaced and when maintenance is needed existing TQG generators should be retrofitted to support B100. Given the critical impact of electricity generation in Afghanistan, the military should investigate replacing all generators in Afghanistan with the most efficient models possible, requiring of course support for B100. The entire budget of the DOD MEP department in FY 2008 was only $245M, and the department procured nearly 10,000 generators. Furthermore, all next generation generators should be capable of supporting B100 and the AMMPS and LAMPS programs should be dramatically accelerated.

In a 2007 study, Air Force Major Randy L. Boswell described in detail the energy requirements of a 1,100 person Air Force FOB. He concluded that the FOB would require 3,878 peak kW. The FOB

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[113] U.S. Navy, *Navy Task Force Energy*, by Rear Admiral Philip H. Cullom, Director of Fleet Readiness, October 19, 2009, slide 18. (http://energyconversation.org/sites/default/files/CULLOM%20SLIDES.pdf)

used a large 750 kW generator and a number of smaller generators ranging in size from 100kW to 30kW.[114] There are also many smaller military bases in Afghanistan, such as Combat Outposts (COBs) and Patrol Bases (PBs) that would use smaller generators that suffer from declining economies of scale and are more expensive per kW. Assuming an average generator size of 15 kW and generator prices from another Army Corps of Engineers report,[115] we can estimate that procuring new generators for the existing 68,000 troops in Afghanistan would cost on the order of $300M in acquisition costs,[116] not including the cost of delivering and installing the generators on-site. $300M is a large number, but still only a fraction of the money the U.S. is spending to deploy M-ATVs. If we assume a total project cost of $600M, an average of only 12% efficiency gain versus older models, and fuel costs of $400 per gallon, the military would achieve payback in supplying new generators for 68,000 troops in Afghanistan in less than two months. There are a little more than 100 FOBs in Afghanistan, so an implementation budget of $300M equates to $3M per FOB for delivery and installation of a new generator. Of course, this calculation is a rough estimate and the potential resources to replace all generators are limited, so we are not necessarily recommending that all generators already deployed should be replaced. But it certainly makes sense to replace older models and retrofit others if the first biodiesel plant is a success.[117]

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[114] Major Randy L. Boswell, *The Impact of Renewable Energy Sources on Forward Operating Bases,* (AU/ACSC/3149/AY07), Air Command and Staff College, Air University, Maxwell Air Force Base, Alabama, April 2007, page 5.

[115] U.S. Army, U.S. Army Corp of Engineers, *Military Requirements for JP-8 Reformers and Solid Oxide Fuel Cell Power Systems*, (ERDC/CERL TR-05-36), by Jeffery D. Stangl, Robert O. Wertz, Franklin H. Holcomb, December 2005, pages 8, 24, 33-34. The 15kW assumption and associated price of $1,284 per kW is consistent with the statement in the GAO's 2009 study *DOD Needs to Increase Attention on Fuel Demand Management at Forward Deployed Locations* that the average cost of the new generation of AMMPS generators is $18,000 per generator.

[116] 68,000 soldiers * 3.525 peak kW per soldier * $1,284 per kW = $308M.

[117] Assumptions: Military fuel consumption in Afghanistan is 1,000,000 gallons/day, cost of fuel is $400/gallon, 40% of fuel is used by generators, peak kW per soldier 3.525 (from *The Impact of Renewable Energy Sources on Forward Operating Bases)*, price per kW $1,284 (from *Military Requirements for JP-8 Reformers and Solid Oxide Fuel Cell Power Systems),* efficiency gains going from MIL-STD generators to TQG generators is 16%, from TQG generators to AMMPS generators 20% (from DOD Mobile Electric Power data in material referenced earlier), and therefore from MIL-STD to AMMPS 33%. The percent of MIL-STD generators in the field in Afghanistan is 15%, and the percent of generators in the field in the kW ranges that can be upgraded to AMMPS is 50%. Improvement = 33%*(15%) + 20%*(35%) + 0%*(50%) = 12%. Baseline = 1M gallons per day * $400 per gallon * 40% = $160M per day. Savings = 12%*$160M = $19.2M per day. Payback = $600M / $19.2M = 31 days.

We estimate that the time required to build the initial biodiesel plant in Kandahar is just over a year. If this venture is successful, we recommend the construction of additional plants elsewhere in Afghanistan. During this time the DOD should encourage more generator manufacturers to formally support B100 for military stationary power generation applications.

Additionally all military tactical support vehicles should be capable of running any diesel fuel mixture up to B100, and combat and tactical combat vehicles up to B30. (Caterpillar C7 engines and larger currently support B30).

The vast majority of diesel engines in existing and planned U.S. military combat and supply vehicles are supplied by only two suppliers, Caterpillar and Cummins, and in addition military vehicles rely on a small number of engine models (e.g. the Caterpillar C7). These same two companies are also leaders in providing stationary electrical generators. By working closely with Caterpillar and Cummins on engine requirements for retrofits and newly manufactured vehicles already under contract, the Army and Marines could rapidly increase their ability to use biodiesel in Afghanistan. Similarly, the majority of tactical vehicles are being supplied or maintained by only two defense contractors, Oshkosh Trucks and BAE Systems.

Disadvantages of military use of biodiesel

Using biodiesel in Afghanistan will complicate logistics, which is an inconvenience we believe is well worth the benefits that can be achieved. The Army and Marines will be required to generate biodiesel in Afghanistan and mix it with diesel fuel. They will need to manage the distribution of three fuel types: diesel fuel, biodiesel, and jet fuel (JP-8) rather than only two. Various families of combat and support vehicles may have different maximum percentages of biodiesel. And biodiesel requires increased monitoring due to its somewhat shorter storage life than petroleum diesel. Finally, the military must import the chemical inputs required by the plant, but that challenge is not substantially different than importing diesel fuel, water, or other materials. The military's logistical arm, the Defense Logistics Agency (DLA) would determine the optimum methods for procurement and delivery of these inputs.

But as discussed in the next chapter, the potential economic and political benefits of a local biodiesel program outweigh the inconveniences of managing three rather than two types of fuel. If local biodiesel production were disrupted, the military could revert back to the normal approach of managing only diesel fuel and JP-8.

Recommendation summary for military use of biodiesel

The DOD should implement the following policies and programs, working especially closely with two engine manufacturers, Caterpillar and Cummins, and two defense contractors, Oshkosh Truck and BAE Systems:

1. Generators: Mandate that all new military generators be able to operate using B100. All generators in the field in Afghanistan should be retrofitted or replaced to support B100.

TQG generators in the field with engines made by John Deere, depending on when they were manufactured, already support B100. The programs to replace small generators (STEP) and large generators (LAMPS) should be accelerated and run in parallel with the AMMPS program to replace medium-sized generators.

2. Support Tactical Vehicles: Mandate that all new support tactical vehicles be capable of using B100. Over time, once the initial biodiesel plant in Afghanistan is a success, all support tactical vehicles in the field in Afghanistan should be retrofitted to support B100.

3. Combat-related vehicles: Mandate that all new combat and combat tactical vehicles be capable of using B30. Over time, once the initial biodiesel plant is successful in supplying fuel for generators, the DOD should implement a program to retrofit all combat-related vehicles in Afghanistan to support B30. The DOD should require of AM General that Humvee diesel engines be capable of supporting B30.

On January 11, 2010, the DOE awarded Cummins $53.8M for two separate projects: one to increase the efficiency of long-haul (Class 8) freight trucks, and a second to increase the fuel economy of passenger vehicle engines and power train systems. Of the eight companies granted funding, Cummins' amount was the largest: 29% of the $187M awarded by the DOE. We assume that if the DOD were to ask Cummins to support B100 as soon as possible in the new generation of AMMPS generators, that Cummins would be eager to do so.

The U.S. military should have the same flexibility to use biodiesel that exists in the commercial marketplace: B100 for generators, B100 for medium and large trucks and B30 for all other vehicles.

In summary, our research shows that the military could quickly be capable of using large quantities of biodiesel in Afghanistan.

The next questions to be considered are as follows: Could biodiesel be produced in Afghanistan at a cost that is lower than the $400 per gallon on average that the U.S. military is spending to import fuel into Afghanistan? Would this production allow the U.S. to pay a rate per hectare than is competitive with poppy farming? Could production volumes be large enough to both reduce U.S. casualties and fuel expenditures plus materially reduce poppy farming?

In other words, three principal variables must be optimized: reducing the cost of military fuel, paying the Afghan farmer a rate for a biodiesel crop that is competitive with poppy, and achieving sufficiently high production volumes to significantly reduce both casualties and costs.

Building a Biodiesel Plant in Afghanistan

Where to Build

Often, when building a plant, there is a marked trade-off between the size of the plant and distribution costs. Distribution costs may be a large factor because the substance being produced decays with time, or because the transportation infrastructure is poor, and thus expensive. Afghanistan suffers from the second problem. Afghanistan does not have a railroad, either for freight or passenger traffic. The roads remain primitive, although the U.S. and ISAF have worked hard to improve them.

Consequently, we believe that over time the production of biodiesel in Afghanistan should be decentralized, with production in or near major cities that are in regions suitable for biodiesel crops, and that are also served by the largest roads. These cities include Kunduz and Mazar-e Sharif in the north, Kabul in the middle, and Kandahar in the south.

Per the U.N. September 2009 Afghanistan Opium Survey, the region including Kandahar Province and Helmand Province accounts for 73% of Afghanistan's poppy production. Adding two more neighboring southern provinces, Farah and Uruzgan, brings the total to 90%. Therefore the first biodiesel plant should be built near Kandahar. The plant would likely be a target of the Taliban, so in order to safeguard the plant, it should be built near a U.S. or ISAF military base. Alternately, the plant could be built adjacent to a military base in Helmand Province, near one of the provincial towns. There are currently ISAF bases in or near Gereshk, Lashkar Gah, and Sangin. Helmand Province produces more poppy than any other province, 60% of the total. Building a plant in Helmand Province would minimize the distance from the majority of existing poppy tracts to the plant, but also lengthen supply lines for chemical inputs which at least initially must be imported. Most critically, building in Helmand Province would increase security challenges.

The plant could instead be built near Kabul or a northern Afghan city such as Mazar-e Sharif or Kunduz where the security challenges would be less severe. But the plant would then not have nearly the same impact on the opium trade.

Biodiesel Plant Background

A biodiesel plant requires the following inputs and produces the following outputs:

Biodiesel plant inputs

A biodiesel plant requires:

- Fuel crops such as safflower, pennycress, or camelina which can be grown and then crushed into oil and meal. The oil is the base feedstock for a biodiesel plant operation.

- An alcohol, usually methanol but sometimes another alcohol such as ethanol, as a component of the production process. Initially, methanol will have to be imported but methanol can also be manufactured from natural gas or coal, both of which are found in Afghanistan. For each 100 gallons of biodiesel produced, about 11 gallons of methanol are required, unless methanol recovery technology is used, which can further reduce the amount of methanol required. According to some accounts, if ethanol is used, the low temperature operability of the resulting biodiesel is improved as compared to biodiesel made using methanol, and further improvements are possible if an even more complex alcohol is used such as isopropyl (propanol) or butyl (butanol).[118] Over time a small ethanol plant could also be constructed, adjacent to the biodiesel plant, to supply the biodiesel plant. Nearly all biodiesel plants in the U.S. use methanol, largely because methanol is less expensive than ethanol.

- A catalyst, usually sodium methylate (a powerful base), is used to generate the chemical reaction. Typically, a solution of sodium methylate is used in the transesterification reaction. Transesterification is a chemical reaction where vegetable oil molecules are broken down and the glycerin is removed, resulting in methyl/ethyl esters which can be used to form biodiesel. Heat and a catalyst (an acid or base) are used to accelerate the reaction. The amount of catalyst used is usually around 2.25% of the total biodiesel volume produced. Sodium methylate is used as a catalyst in about 70% of the North American biodiesel plants. Alternatives include potassium hydroxide.

- Acids (sulfuric or phosphoric typically) are used to degum the base oil and remove any high free-fatty acids. The amount of acids needed is dependent on the incoming base oil; however, only a small amount (compared to alcohol and the catalyst) is used in the biodiesel process. Typically, the amount is less than 0.5% of the total biodiesel volume produced.

- Steam and heat are the primary utility components of biodiesel processing. A plant capable of producing 15M gallons per year will likely require a high pressure boiler operation of no more than 800 horsepower (7.85M watts).

- Electricity to run the plant. The proposed 15M capacity plant will require a 1 MW electric motor running at 80% utilization. We are assuming that the initial plant in Kandahar can take advantage of electricity generated by the nearby hydroelectric power

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[118] S. Kent Hoekman, Alan Gertler, Amber Broch, Curt Robbins, *Investigation of Biodistillates as Potential Blendstocks for Transportation Fuels*, Desert Research Institute, funded by Coordinating Research Council (CRC), CRC Report No. AVFL-17, June 2009, page 84. (http://www.crcao.com/reports/recentstudies2009/AVFL-17/CRC%20Report%20No%20AVFL-17%20June%202009_f.pdf)

plant. Alternately the plant can be powered by generators running biodiesel. In this second scenario the capacity of the plant is reduced by about 10%.

- Older biodiesel plants require a water wash of the biodiesel to remove impurities but modern designs replace this approach with a waterless chemical exchange medium to absorb impurities. Using a waterless process will be necessary in Afghanistan.

Biodiesel plant outputs

As discussed earlier, there are two outputs: biodiesel and glycerin. The proposed plant will generate about 1.5 M gallons (5.7M liters) of glycerin per year.

Import into Afghanistan of chemical inputs

In summary, the military will need to import an alcohol (methanol or ethanol), the catalyst (sodium methylate) and acids. For every 100 gallons of biodiesel output the military will be required to import 13.75 gallons of that amount or 13.75% by volume.

Methanol can be sourced from one of many countries in the region, some of which are members of ISAF, including Australia, Azerbaijan (plant under construction), Brunei, China, India, New Zealand, Oman, Russia, Saudi Arabia and Uzbekistan. Iran is also a major supplier of methanol. Major producers of sodium methylate include BASF and DuPont.

The Plant Building Process

Modular continuous flow construction

There are several methods of building a biodiesel plant, depending upon the size and location of the plant. Larger plants may be constructed using a highly customized approach. For the military we recommend a modular system of construction where much of the work can be done in the U.S. and final assembly can be completed in Afghanistan. Three skid mounted biodiesel production facilities could be manufactured in the U.S. and exported to Afghanistan for installation. Each unit would utilize a continuous flow process. One such skid-mounted system consists of four skids plus a boiler and is available as a 5M or 10M gallon per year modular system. The modular nature and skid-mounting of these units allows for ease in increasing the size of the plant in 5M or 10M gallon increments. Using this modular approach, approximately 75% of the plant could be manufactured in the U.S., with final assembly occurring in Afghanistan.

Another feature of the continuous flow technology is process intensification. Process intensification involves accelerating the rate of a chemical process in order to reduce processing time while also reducing energy and material requirements and increasing product quality. Process intensification often produces additional advantages such as reduced volumes of waste product, manufacturing flexibility, and scalability. The reactors are multi-functional, smaller, inherently safer and more energy efficient than traditional process equipment. The compact nature of this system is a significant advantage in space-constrained areas.

Leading manufacturers of biodiesel plant technology include:

- Biodiesel Industries
- Biofuel Canada Ltd.
- Cavitation Technologies
- Cenergy (owned by Germany's 2G Bio-Energietechnik AG)
- Desmet Ballestra (Belgium)
- EuroFuelTech (U.K.)
- JatroDiesel

Construction timetable

The timetable in Table 13 below outlines the major steps to develop the 15M gallon capacity plant. The time estimates listed are for each specific task. Some tasks are dependent upon earlier milestones being completed, and others are not. Elapsed time, from start of the project, to production in Afghanistan, is expected to be thirteen months.

Table 13 Biodiesel Plant Construction Timetable

Milestone	United States Completion Estimates (months)	Afghanistan Completion Estimates (months)
Request for Proposal process; General Contractor selection	3	2
Site control (negotiate and obtain lease from military)	6	1
Lease and Growing Contracts with Farmers	4	9
Off-take Agreement with U.S. Military	6	1
Selection of General Contractor	1	1
Close on Financing from U.S. Military	6	1
Permits to Build	9	1
Processing Unit and Balance of Plant Design	2	2
Processing Unit Fabrication	4	4
Installation of Processing Equipment and Balance of Plant	2	4
Commissioning of Equipment	1	1
Start of Commercial Operations from Beginning	26	13

Note that the timetable includes a competitive bid process.

Permits

In the United States (depending on state and local governments), permits are required to build industrial refineries. Depending on the commitments made by the U.S. Government in collaboration with the Afghanistan Government, we believe that a few months should provide enough time to gain the necessary permits in view of the expedited nature of the project. Typically, the following permits are required in the U.S. for construction and operation of a biodiesel plant:

Table 14 U.S. Biodiesel Plant Permit Timetable

Permit/Agency	Time to Obtain
Air Permit	6 months if a full permit application is required
Chemical Bulk Storage Permit	6 months
Building Permit	6 months
Approval to Discharge Wastewater	2 months

Crushing, refinery and Balance of Plant (BOP) design and engineering

We recommend that a U.S. or ISAF-based engineering company, funded by the U.S. military or USAID, provide engineering and design services for the biodiesel project. Construction will include design and installation of the skids into a completed system with the appropriate tankage, piping, utility connections, office and laboratory space, and other appurtenant items. The engineering firm will be responsible for plant compliance with applicable construction permits, codes and regulations, as well as final dimensional drawings. Engineering companies that may be appropriate for this design and construction work include:

- Crown Iron Works
- Desmet Ballestra (Belgium)
- The Dupps Company
- French Oil
- Insta-Pro International

General Contractor

In order to build a facility of the quality needed, a general contractor must be selected. The general contractor would purchase biodiesel refining and oilseed crushing equipment that is skid mounted and manufactured in the U.S. and oversee all installation and commissioning of systems. A general contractor would contract with biodiesel installation companies that have experience in installation and balance of plant construction. Potential contracting and engineering firms with experience building chemical plants overseas include:

- Air Liquide/Lurgi (France/Germany)
- Bechtel
- Fluor
- Jacobs Engineering
- KBR

Equipment delivery to Afghanistan

Much of the plant equipment could be delivered by air, if desirable. For example JatroDiesel's modular 5M gallons per year units can be shipped in three 40-foot containers for all process equipment and two additional ones for all ancillary equipment including power generation. The dimensions of the each container are 40 feet (length), 8 feet (height), and 10 feet (width). Each JatroDiesel container weighs 21 tons (42,000 pounds). A C-17 Globemaster cargo plane should be able to transport two containers and a C-5 Galaxy four containers. Thus, if using a C-5 the complete plant could be shipped in four trips.[119] Fuel tanks are also needed but these could be shipped by sea, constructed locally or possibly standard military fuel bladders could be used instead.[120]

Operations and Maintenance (O&M)

The Project will operate at an output level of 15M gallons per year rated production capacity, running at 80% uptime. The project will produce biodiesel that conforms to ASTM Biodiesel Standard D6751-08 and EN 14214 specifications. The U.S. military or USAID would contract with an O&M company to supply a scope of services covering complete operation and maintenance of the biodiesel plant. Such services will include: administrative, financial, accounting, production, maintenance, environmental, and health and safety functions. Under this scenario, the operator will provide all training of personnel in biodiesel production technology, quality assurance, programs for asset management and maintenance, human resources, and plant health and safety, etc. U.S. and ISAF O&M firms that may be appropriate to operate and maintain the biodiesel plant include:

- Air Liquide/Lurgi (France/Germany)
- Frazier Barnes & Associates/Biodiesel Services Group
- Greenergy (U.K.)
- Innovation Fuels[121]
- Renewable Energy Group

Biodiesel Plant Financial Analysis

Key assumptions

Although we fully understand the costs associated with building plants in the United States, we have made some assumptions regarding the construction of biodiesel plants in Afghanistan.

On August 5, 2009, President Hamid Karzai opened the first 35 megawatt block of a 100 MW diesel power plant in Tarakhil, near Kabul, funded by USAID. On the face of it, this project appears to be a good idea, but in reality it does not make sense, because all of the diesel fuel must be imported. The Afghan government cannot afford to run the plant. The cost per unit of

[119] The dimensions of the C-5's cargo hold are 121 feet (length), 13.5 feet (height) and 19 feet (width) and the C-5 has a payload capacity of 291,000 pounds. A C-5 requires a runway of at least 5,000 feet and the C-17 at least 3,000 feet. The Kandahar airport runway is over 10,000 feet.

[120] Most tanks designed to store diesel fuel will store B100 with no problem. Acceptable storage tank materials include aluminum, steel, fluorinated polyethylene, fluorinated polypropylene, Teflon, and most types of fiberglass. *Biodiesel Handling and Use Guide Fourth Edition*, page 22.

[121] Although John Fox is no longer employed by Innovation Fuels he retains a minority ownership interest.

electricity generated by Tarakhil using diesel fuel has been estimated by USAID to be 22 cents per kilowatt hour, versus 6 cents per kilowatt hour from recently completed power lines connecting Kabul to sources of power in Tajikistan and Uzbekistan.

Although the U.S. funded construction of the plant and gave it to the Afghan government, the U.S. overpaid. The U.S. spent $300M on a 100 MW plant, or $3M per MW. In the U.S. a typical cost for a smaller fossil fuel power plant would be in the neighborhood of $1M per MW to $1.5M per MW. Special Inspector General for Afghanistan Reconstruction (SIGAR) is investigating why the contractor, Black & Veatch, charged the U.S. so much money. According to Bikash Pal, an engineering expert from Imperial College in London, who has been involved with similar projects in India and Iraq, the rough price for building a 100 MW plant in Afghanistan should be $100M.[122] Nevertheless we are using the ratio 3:1 to calculate the higher construction costs anticipated in Afghanistan versus the U.S., and more generally to uplift certain costs when compared to their equivalent in the U.S.

Another assumption pertains to security. Clearly a biodiesel plant in Kandahar would require increased levels of security versus a similar plant in the United States. From the perspective of the U.S. military, we have assumed that no net increase in security resources occurs; in fact we have calculated that troops will be freed up for other duties (see discussion in the next chapter). Constructing the plant near a military base will minimize the military resources required to protect the plant. Our financial model does assume significant additional civilian staffing for security.

One-time costs

New generators

We have also included in the capital expenditures the cost of replacing all generators that will be served by the plant. We estimate this cost to be $30M, which also includes some additional funding for B100 testing by the generator manufacturer and added assistance to the military. If additional biodiesel plants are constructed in Afghanistan we recommend that the military consider retrofitting newer generators already in the field as an alternative to replacing all existing generators with new models. The estimate of $30M is conservative, because in reality this amount is incremental to expenditures the military is already incurring to procure generators for use Afghanistan, either to replace malfunctioning generators, to replace older inefficient units, or to add generators in support of the increase in troop strength. The generators being replaced may still have years of use remaining elsewhere (a residual value).

[122] Pratap Chatterjee, "Black & Veatch's Black Elephant in Kabul," *e-Ariana*, November 19, 2009. (http://www.e-ariana.com/ariana/eariana.nsf/allArticles/A0B3F3448BC2AD3F8725767300510E71?OpenDocument)

The biodiesel plant should be able to support the electricity needs of around 1,123 generators for 4,800 to 5,600 soldiers.[123] If existing generators in the Kandahar region were retrofitted to support B100, rather than replaced, then the cost would only be (1,123 generators) times ($1,500 retrofitting cost) equaling approximately $1.7M, rather than $30M. In order to maximize the probability of success we recommend that the first biodiesel plant implementation in Afghanistan also include new generators – generators that have already been designed for B100 and tested using safflower-based B100 in the U.S. prior to installation and operation in Afghanistan.

We assume that the generators will be the new generation of medium-sized generators, AMMPS, being developed by Cummins. These generators begin production in 2010. If Cummins is unable to support B100 then we recommend that new gensets with John Deere engines should be used instead of Cummins generators. As noted earlier, John Deere engines already support B100.

Transportation to Afghanistan

The one-time costs also include the cost of transporting the plant equipment from the U.S. to Afghanistan. Transportation costs are low if the plant and generators are delivered by ship, but given that the plant and new generators can be delivered in a number of C-5 or C-17 flights, accelerating the construction schedule and also avoiding a convoy, we recommend delivery by air. We have assumed $5M for transportation. In the case of the generators, this transportation cost is incremental to expenditures the military is already incurring when shipping generators to Afghanistan.

U.S. safflower biodiesel program

In parallel with the construction of the biodiesel plant intended for Afghanistan, we recommend that the USDA, on behalf of the DOD, sponsor a U.S. safflower biodiesel program. The USDA would contract with a U.S. biodiesel firm to make biodiesel from safflower. This program would have two primary objectives:

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[123] The following calculations use data from *Military Requirements for JP-8 Reformers and Solid Oxide Fuel Cell Power Systems.* The average size generator in the Army, by kW capacity, is between a 15kW and 30kW sized generator. The paper lists the purchase cost of a 15 kW generator in the years FY 2008 – FY 2018 to be $19,264 per generator. A 15 kW generator consumes 1.22 gallons of fuel per hour or 10,687 gallons year. Thus a biodiesel plant with capacity of 12M gallons a year could support 1,123 generators costing a total of $21.6M. 30 kW generators cost $27,025 and consume 2.07 gallons/hour. In this case the biodiesel plant could support 662 30kW generators costing $17.9M. Using the figure of 3.525 peak kW per soldier from *The Impact of Renewable Energy Sources on Forward Operating Bases,* the 15 kW generators support (approximately) 4,778 soldiers and the 30 kW generators support (approximately) 5,632 soldiers. Larger generators, if they are run near 100% utilization, gain from economies of scale and thus can support more soldiers.

1. To supply B100 made from safflower to generator manufacturers, in particular Caterpillar, Cummins, and possibly John Deere. The generator manufacturers would use the safflower biodiesel for testing.
2. To anticipate and address any potential problems in the U.S. in advance of the plant in Afghanistan going into production.

We have allocated $5M for this program.

Line- by- line biodiesel plant capital expenditures

Table 15 below gives a line-by-line estimate of the capital expenditures required to build a vertically integrated biodiesel crush/refinery in Afghanistan. These expenditures include a margin for a general contractor. The rows are ordered by process flows, starting with the equipment needed early in the production process. We have been conservative in our estimates and believe that, with focused project management, the costs could be further reduced, consistent with our experience in building and managing biodiesel plants.

Table 15 Biodiesel Plant Capital Equipment (15M gallons per year nameplate capacity)

Item	U.S. CapEx	AFG CapEx	Total
Seed off-loading system	225,000	0	225,000
Seed storage silo	350,000	0	350,000
Seed cleaner	75,000	0	75,000
Seed dryer	200,000	0	200,000
Seed warmer	85,000	0	85,000
Mechanical crush equipment (450 tpd)	3,75,0000	0	3,750,000
Wet press (450 tpd)	1,350,000	0	1,350,000
Meal storage	1,500,000	0	1,50,0000
Meal pelletizing system	225,000	0	225,000
Pellet storage and loading system	525,000	0	525,000
Installation of crush facility	1,100,000	960,000	2,060,000
Crude feedstock oil storage	1,500,000	0	1,500,000
Alcohol storage	150,000	0	150,000
Catalyst storage	75,000	0	75,000
Acid storage	112,500	0	112,500
Additive storage	75,000	0	75,000
Other chemical storage	112,500	0	112,500
Pretreatment system	400,000	0	400,000
Transesterification system (skid mounted)	4,200,000	0	4,200,000
Biodiesel storage	1,500,000	0	1,500,000
Chemical recovery storage	112,500	0	112,500
Glycerin storage	300,000	0	300,000
Loading facilities	300,000	0	300,000
Process control systems	450,000	0	450,000
Boiler operation (B100)	900,000	0	900,000

Power generation (1 MW using B100)	2,200,000	0	2,200,000
Installation of biodiesel systems	0	960,000	960,000
PLC installation	225,000	72,000	297,000
Electrical wiring and conduit	275,000	0	275,000
Piping	720,000	0	720,000
Heat tracing	150,000	0	150,000
Piping and tank insulation	900,000	0	900,000
Electrical installation	0	432,000	432,000
Pipefitting	0	960,000	960,000
Insulation installation	0	432,000	432,000
Building construction	500,000	0	500,000
Installation of building	0	576,000	576,000
Crane	600,000	0	600,000
Lull	150,000	0	150,000
Forklift	50,000	0	50,000
Contingency working in Afghanistan	0	2,000,000	2,000,000
Total ($)	25,342,500	6,392,000	31,734,500

Working Capital

Sufficient working capital gives a biodiesel business flexibility in managing revenue and cost cash flows, lengthening the time interval between when money is received and suppliers must be paid. With a larger amount of working capital, a biodiesel firm can buy crops, feedstocks (seeds) and chemical inputs more selectively when conditions are favorable, rather than continuously. A general rule of thumb is that a biodiesel business's working capital should be 15 cents to 20 cents per each million gallons of output. By this rule the working capital should be $2.4M. Given that the plant will be owned and operated under contract to the U.S. military, allocating working capital may not be as relevant as when a biodiesel plant is owned by a private company and partially funded by commercial debt. Nevertheless, we have allocated $15M, to allow greater flexibility in dealing with Afghan farmers. Due to the lengthy nature of farm contracts, the $15M will provide funds for initial payments to farmers to begin growing safflower. Allocating sufficient upfront working capital also lowers the probability that plant management would have to ask the U.S. Government for additional working capital.

One-time cost summary

Table 16 Biodiesel Plant One-time Cost Summary

Item	Amount (millions of $)
Plant Capital Expenditures	31.7
New generators	30.0
Transportation of plant & generators to Afghanistan	5.0
U.S. safflower biodiesel program	5.0

Working Capital	15.0
Miscellaneous	3.3
Total	90.0

Annual operating costs

General operating cost discussion

In the first year, plant operations are expected to cost approximately $994M, and the major component, by far, is that of importing input chemicals at the military's fully-burdened cost of fuel (66% of costs). If the military can procure methanol and catalysts locally and at prices close to normal market prices, the cost of operations will decline dramatically.

We have been conservative and have not modeled the financial impact of using methanol recovery technology although we recommend that methanol recovery technology should be applied. The use of methanol recovery technology would reduce methanol demand by nearly half, depending upon the supplier.

Operating costs will be considerably higher in a war zone than in the U.S. The U.S. should deploy skilled experts who can manage the plant but also, over time, train Afghanistan employees on biodiesel processing and plant equipment. We have assumed that labor operating costs in will be three times higher than in a standard plant in the U.S., and that initially all functions other than feedstock procurement are filled only by Americans. Eventually most of the plant employees would be Afghan nationals and the labor costs of operating the plant should decline. As security conditions improve, the number of American security officers could be reduced, or at least some replaced with Afghan nationals.

There are two additional improvements that we have not modeled financially because they are not necessary initially but over time could strengthen the efficacy of the plant. We have not valued the plant's principal byproduct, glycerin, which has a variety of uses. We recommend that the military implement a pilot program to test using glycerin in fuel cells to generate additional electricity. As mentioned earlier, hundreds of millions of dollars can be saved annually if methanol can be procured locally rather than imported. However, since methanol is not currently manufactured in Afghanistan, a more clever solution would be to use ethanol, rather than methanol, and to produce the ethanol locally. This approach may be less expensive than importing methanol from countries in the region and it would also create additional business for Afghan farmers.

Cost of chemical inputs

Once the plant is operational, we assume that the chemical inputs must be imported at the same rate as oil (the equivalent of $400 per gallon). The chemical inputs include an alcohol (typically methanol or ethanol), a catalyst (usually sodium methylate), and small amounts of acid compounds (such as phosphoric or sulfuric). These chemicals would be imported and a total of 1.65 million gallons of inputs would be needed to operate a 12M gallons per year facility on an annual basis, and we estimate that these chemicals would cost the same amount as importing diesel fuel into Afghanistan. For each 100 gallons of biodiesel produced, 11 gallons (11%) of methanol are needed and approximately 2.25 gallons (2.25%) of sodium methylate and 0.5 gallons (0.5%) of acid compounds are needed. Over time, if the chemical inputs could be procured in Afghanistan or from neighboring countries, reducing import transportation costs, then operating costs would significantly decline. For example, methanol currently costs approximately $1.50 – $2.00 per gallon ($0.40 to $0.53 per liter) and sodium methylate costs $3.50 – $4.00 per gallon ($0.92 to $1.06 per liter).

Cost of electricity

We are assuming that the initial plant in Kandahar can take advantage of electricity generated by the nearby hydroelectric power plant or other external facility. This approach will benefit the region, creating work and employment. We have not included a cost for connecting the plant to the local electrical distribution network; however, the plant should also be configured to use biodiesel to generate electricity if external electricity is unavailable. As described in section "Biodiesel plant inputs," using biodiesel to power the plant would reduce the amount of biodiesel available to the military by about 10%, reducing output from 12M gallons per year to 10.8M gallons per year.

In the U.S., the electricity to run the plant would cost in most locations no more than $30,000 per month. Uplifting this figure three times, we have assumed that the cost of electricity in Afghanistan will be $1.1M per year.

Cost of feedstock

Plant personnel will include at least two Afghan employees whose focus will be to work with existing USDA experts and USDA contractors to persuade Afghan farmers to grow biodiesel crops. Depending upon the qualifications of these employees, it may be appropriate for them to visit U.S. universities that have been assisting the USDA, such as the University of California Davis and Purdue University.[124] We have assumed paying Afghan farmers a rate of $5,000 per hectare for safflower. Note that $5,000 per hectare is approximately 40% higher than the current prices being paid to Afghan farmers for their poppy crops.

Cost of security

Security costs are negligible in the U.S., but of course very significant in Afghanistan. Per an August 2008 Congressional Research Service report regarding contractors in Iraq, the billing rate for U.S. security firms such as Blackwater (renamed Xe Services) and Dyncorp to provide security services to the DOD and DOS was $445,000 per year.[125] Allowing for inflation we have assumed

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[124] Both the University of California Davis and Purdue University have offices in Kabul.

[125] Congressional Budget Office, *Contractors' Support of U.S. Operations in Iraq*, (Publication Number 3053), August 2008, page 14.

$600,000 per year per security officer. The plant will occupy an area of approximately two acres (0.8 hectares). We have assumed a total staff of eighteen security personnel, or six per eight-hour shift, to protect the plant, resulting in an operating cost of $10.8M per year for security. Over time, as Afghanistan becomes more secure, this degree of security should become excessive. Biodiesel plants constructed near Kabul or in northern Afghanistan may not require this much security. Table 17 summarizes the base case operating cost for the initial plant and Table 18 summarizes the savings that can be achieved by substituting biodiesel for petroleum diesel.

Base Case assumptions

Key Assumptions:

- Afghan farmers are paid $5,000 per hectare for safflower;
- Cost of importing oil is $400 per gallon;
- Cost of importing chemical inputs is also $400 per gallon;
- Production is 12,000,000 gallons of biodiesel per year.

Base Case annual operating cost summary

Table 17 Biodiesel Plant Base Case Operating Cost Summary

Item	Amount (millions of $)
Payments to Afghan farmers	307.5
Import of methanol	528.0
Import of other chemical inputs	132.0
Plant Operations & Maintenance labor	15.0
Security Personnel	10.8
Electricity	1.1
Total	994.4

Base Case financial projections

Table 18 Biodiesel Plant Base Case Financial Projections

Category	Year 1 (millions of $)	Year 2 (millions of $)
Normal cost of importing oil	4,800	4,800
Biodiesel plant one-time costs	90	0
Biodiesel operating costs	994	994
Total biodiesel costs	1,084	994
Biodiesel savings	3,716	3,806
In dollars:		
Cost per gallon	90.37/gallon	82.87/gallon
Savings per gallon	309.63/gallon	317.13/gallon

Financial summary

Table 18 above summarizes the base case financial projections for the initial plant.

Our conclusions are:

1. A crushing operation and biodiesel plant with a nameplate capacity of 15M gallons running 80% of the time produces 12M gallons per year. The crushing operation and biodiesel plant would cost approximately $90M (including generators and working capital) to build in Afghanistan. Operating costs would be approximately $994M per year (including payments to farmers).

2. The savings per gallon will be $310 per gallon in the first year, increasing to $317 per gallon in subsequent years.

3. The payback, or time to recover the initial investment of $90M, is much less than one month using the $400 per gallon (FBCF) figure currently assumed by the DOD.

4. Even in the first year (burdened with the fully-loaded construction costs), this single 15M gallon capacity plant would save $3.7B, an extraordinary savings. The savings increases to $3.8B per year in subsequent years.

Sensitivity analysis

Given that we have not constructed or operated a biodiesel plant in Afghanistan, we have had to make some assumptions about certain parameters, for example, the cost of construction and added security. The cost of importing oil into Afghanistan is, however, so high, and the cost of building and operating a biodiesel plant in Afghanistan so relatively inexpensive, that our conclusions hold true even when assumptions are dramatically changed. For example:

1. Let's assume that the cost of building the plant is much higher than anticipated and the plant capital costs are $270M, three times higher than our projection of $90M. The payback is still less than a month.

2. Let's assume that the cost of security is three times higher than what we have projected. Total capital expenditures remain the same but yearly savings are modestly lower. Payback is still much less than one month.

3. Suppose the price of heroin increases dramatically and Afghan farmers therefore must be paid $12,700 per hectare, the largest amount that the U.N. reported paid to Afghan farmers (in 2003). Total capital expenditures remain the same but yearly savings is lower, declining to $3.2B in the first year and $3.3B in subsequent years. Payback is virtually unaffected, still much less than one month.

4. Even if the military can import fuel (and therefore also biodiesel chemical inputs) for only $41.00 per gallon rather than $400 per gallon, the payback is approximately one

year. Thus the U.S. could build a plant, use it for one year, and then dispose of it while still saving lives and maintaining fuel costs constant. (Please see Table 19 and Table 20 below.) If farmers are paid the 2009 going-rate for poppy, $3,562 per hectare, then the one-year breakeven value is $33 per gallon.

5. Let's suppose that plant employees and USDA experts don't persuade as many farmers as anticipated to switch to safflower from poppy. If the plant only produces 1.23M gallons per year, or 10.25% of the 12M annual target, the plant will still break even in about a year. That production volume is equivalent to persuading farmers to plant about 6,300 hectares (15,570 acres). Richard Scott, a Helmand Province specialist who has worked for USAID, reports that the average farm size in Helmand Province is 6.92 hectares. Consequently the minimum number of farmers that must be persuaded to switch from poppy to safflower is 911, an achievable goal. (According to a recent report there are 125,000 farmers in Helmand Province.)[126] Clearly the optimal strategy in the first year or two would be to focus on the farmers owning larger farms. In the southern part of Helmand Province, populated by Baluch, the average land holding is 38.3 hectares. In this case only 165 farmers would have to be persuaded.[127] USAID reported than in FY 2009, USAID trained more than 160,000 farmers across Afghanistan.[128]

6. Now let's look at the $41 per gallon case and the situation where experts do not persuade as many farmers as anticipated to switch to safflower from poppy. If farmers are paid the 2009 going-rate for poppy, $3,562 per hectare, then payback in one year is achieved when production is 9,500,000 gallons of biodiesel a year, 79% (21% less) than the 12M annual target. This production volume is equivalent to persuading farmers to plant about 48,700 hectares (120,310 acres). The minimum number of farmers that must be persuaded to switch from poppy to safflower is 7,036 farmers. However, if the safflower payment to farmers remains $5,000 per hectare, then all 12M gallons of production are needed to achieve a one-year payback and 8,887 farmers must be persuaded, still an achievable goal. Assuming 38.3 hectares per farm then only 1,606 farmers would have to be persuaded.

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[126] Thomas L. Day, "U.S. turns to Afghan farmers to uproot insurgency," *McClatchy Newspapers*, January 12, 2010. (http://www.mcclatchydc.com/2010/01/12/82165/us-turns-to-afghan-farmers-to.html)

[127] Richard B. Scott, *Reconstruction and Opium Poppy Cultivation in Central Helmand; The Need for an Integrated Program*, Conference of Afghanistan Reconstruction: The Future, University of Nebraska at Omaha, October 3, 2008, page 3 (not including Abstract and Preface). Richard Scott first worked for USAID in Afghanistan 1971-1978; most recently he worked for USAID on Helmand Province-related projects 2002 – 2005.

[128] USAID, Afghanistan, Agriculture, *Program Description.* (http://afghanistan.usaid.gov/en/Program.19a.aspx)

$41 per gallon Case assumptions

Key Assumptions:

- Afghan farmers are paid $5,000 per hectare for safflower;
- Cost of importing oil is $41.00 per gallon;
- Cost of importing chemical inputs is also $41.00 per gallon;
- Production is 12,000,000 gallons of biodiesel per year.

$41 per gallon Case annual operating cost summary

Table 19 Biodiesel Plant $41 per gallon Case Operating Cost Summary

Item	Amount (millions of $)
Payments to Afghan farmers	307.5
Import of methanol	54.1
Import of other chemical inputs	13.5
Plant Operations & Maintenance labor	15.0
Security Personnel	10.8
Electricity	1.1
Total	402.1

$41 per gallon Case financial projections

Table 20 Biodiesel Plant $41 per gallon Case Financial Projections

Category	Year 1 (millions of $)	Year 2 (millions of $)
Normal cost of importing oil	492	492
Biodiesel plant one-time costs	90	0
Biodiesel operating costs	402	402
Total biodiesel costs	492	402
Biodiesel savings	0	90
In dollars:		
Cost per gallon	41.00/gallon	33.50/gallon
Savings per gallon	0.00/gallon	7.50/gallon

In summary, the financial case to build a biodiesel plant in Afghanistan is very strong. The production and use of biodiesel in Afghanistan will save billions of dollars a year. The project has a very strong benefit-cost ratio (BCR) since the initial investment of $90M is small compared to savings. The BCR after one year of operation, using Base Case assumptions, is 41:1. The savings in the first year of $3.7B is equivalent to 5% of the $72.9B budget for the war in Afghanistan for

FY 2010.[129] Even when the FBCF is only $41 per gallon the biodiesel plant generates significant savings after the first year of production, $90M per year.

An Additional Potential Revenue Source: Carbon Credits

Kyoto Protocol

The Kyoto Protocol is a protocol to the United Nations Framework Convention on Climate Change (UNFCCC or FCCC) aimed at combating global warming. The Protocol was first adopted on December 11, 1997 in Kyoto and went into effect on February 16, 2005. Projects that substitute biodiesel for petroleum diesel may qualify for approval per Kyoto Protocol rules. The treaty expires at the end of 2012.

Biodiesel is an important means to reduce local pollution and emissions that cause climate change. Burning petroleum diesel produces high levels of carbon dioxide (CO_2), a greenhouse gas that contributes to global warming, and other harmful pollutants. By contrast, biodiesel produces lower overall emissions because energy crops capture carbon dioxide as they grow. In addition, as detailed in the earlier section “Biodiesel Emission Properties,” biodiesel reduces other pollutants which are not considered greenhouse gases but which may be traded on financial markets. Biodiesel is virtually free of the sulfur that contributes to acid rain, and sulfur dioxide is traded in the U.S. according to the EPA’s Acid Rain Program.[130]

It is possible to capitalize on emerging carbon markets by gaining compensation in the form of carbon credits for reductions in Green House Gas (GHG) emissions. Carbon credits represent an additional stream of capital that could be treated as an element in project finance structuring. Emission Reduction Units (ERUs) can be generated through Joint Implementation (JI) projects in so-called Annex 1 nations (covering the former Soviet Union, Eastern Europe, and potentially Western Europe, Japan and Canada). Certified Emission Reductions (CERs) can be generated through Clean Development Mechanism (CDM) projects in non-Annex 1 nations (including China, South America, India, and many other developing world nations). Collectively, these carbon offsets or carbon credits help businesses and countries to meet greenhouse gas emissions reduction targets in Europe and other parts of the world. Figure 2 below illustrates the Kyoto Protocol compliance structure.

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[129] *The Cost of Iraq, Afghanistan, and Other Global War on Terror Operations Since 9/11,* page 13.

[130] The EPA Acid Rain Program also regulates nitrous oxide, and combusting B100 increases nitrous oxide emissions somewhat versus petroleum diesel. But the reduction in sulfur dioxide emissions would most likely more than offset the increase in nitrous oxide emissions.

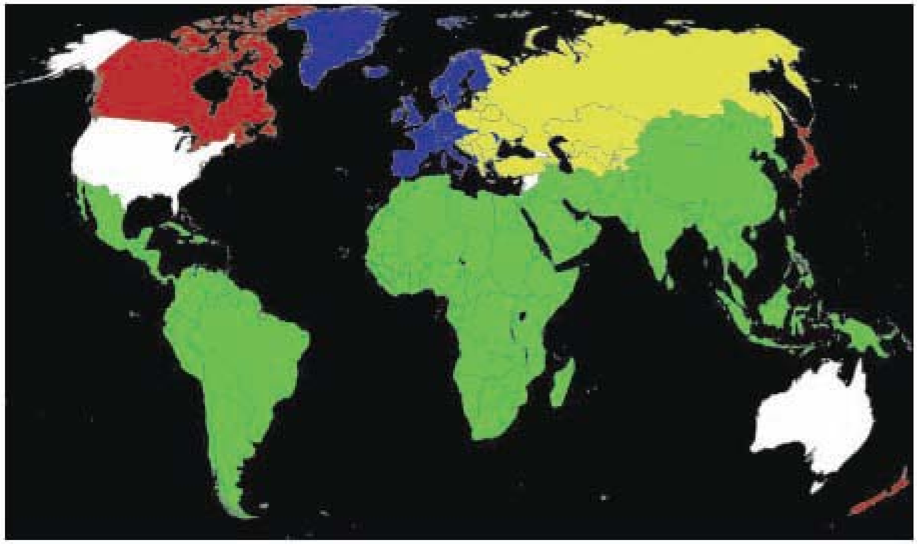

Figure 2 Kyoto Protocol Compliance Map

Courtesy of PointCarbon.com

Legend

Blue:	The European Union
Yellow:	Annex I countries with economies in transition
White:	Annex I countries that have not ratified the Kyoto Protocol
Red:	Annex II countries outside of the European Union
Green:	Non-Annex I countries. Potential CDM host countries

The number of new projects being proposed to the U.N. committee responsible for assessing Kyoto projects, the Clean Development Mechanism (CDM) Executive Board, has been declining, as less than three years remains until the treaty expires. And, nations attending the Copenhagen Climate Conference in December 2009 failed to agree upon a successor treaty. If a new treaty is ultimately realized, projects involving the production of biodiesel in Afghanistan where biodiesel is being substituted for petroleum diesel would be likely to be approved by the CDM Executive Board or its successor. In addition to the Kyoto Protocol there are several regional systems for carbon trading, including Europe's European Trading Scheme (ETS), the Western Climate Initiative (WCI), a cap and trade program involving seven states and four Canadian provinces, and the Regional Greenhouse Gas Initiative (RGGI), a cooperative effort by ten Northeast and Mid-Atlantic States to limit greenhouse gas emissions.

U.S. carbon trading expertise

Although the U.S. is not a signatory to the Kyoto Protocol, U.S. exchanges are leaders in carbon trading. The Chicago Climate Exchange (CCX) and CCX's subsidiary, the European Climate

Exchange (ECX) are the North American and European market leaders for carbon trading. In the U.S. the Chicago Mercantile Exchange (CME) has launched a competing exchange, the Green Exchange. Pending formal approval by the CFTC as an independent exchange, the Green Exchange will trade futures and options on futures contracts for a variety of pollutants. In Europe, NASDAQ OMX Commodities competes with ECX, as does BlueNext; NYSE Euronext has a 60% ownership stake in BlueNext.

Later in the Chapter "A Commodities Exchange in Afghanistan" we recommend that USAID fund a study to evaluate the viability of a commodities exchange in Afghanistan. Failing the adoption of a successor to the Kyoto Protocol, perhaps Afghanistan should consider implementing a program where carbon credits would be one of the financial instruments traded on the Afghan commodities exchange.

The subsequent chapter summarizes the benefits of producing and using biodiesel in Afghanistan.

Benefits of Biodiesel in Afghanistan: Lower Casualties and Fuel Costs

Projected Benefits

Despite increased costs of construction and operation relative to the U.S., the benefits provided by an Afghanistan-based biodiesel plant are very substantial.

1. We've analyzed a biodiesel plant consisting of three units of 5M gallons per year, for a total of 15M gallons per year nameplate capacity (56.8M liters per year). Assuming an 80% utilization rate, effective production would be around 12M gallons per year (45.4 M liters per year), equivalent to 50% of Afghanistan's poppy production (per the UNODC 2009 Afghanistan Opium Survey equivalent to about 50% of the 2009 production of 123,000 hectares or 39% of 2008 production).

2. We have assumed a low yield per hectare consistent with the arid growing conditions in southern Afghanistan, typical of a crop like safflower. Using 750 per liters per hectare (80 gallons per acre) and 61,500 hectares, we estimate that production should achieve the 12M gallons a year plant capacity. All of that production can be consumed by the U.S. military in the Kandahar region. The fuel generated by the biodiesel plant will support the needs of about 4,800 to 5,600 soldiers. Thus, biodiesel production equivalent to 50% of the poppy production could satisfy 100% of the fuel needed to generate electricity for a Marine brigade, a nontrivial amount.

3. The savings in lives would be considerable. Per the September 2009 Army report, there was one casualty for every 24 fuel resupply convoys in Afghanistan, and 897 convoys per year in FY 2007, resulting in 38 casualties.[131] In FY 2007 there were 20,000 soldiers in Afghanistan. The average capacity of a 16 supply truck convoy is 97,818 gallons. We need to look at the net reduction in imports: 12M gallons of biodiesel less 1.65M gallons of chemical inputs equals 10.35M gallons (39.2M liters) saved each year. This number of saved gallons eliminates the need for 106 convoys, and could therefore reduce casualties by four to five a year, saving lives.[132] Of course, if biodiesel capacity were expanded further or implemented in other regions of Afghanistan, more lives would be saved. President Obama's addition of 30,000 more troops will increase the number of convoys by at least another 897 convoys a year and the deployment of M-ATVs will demand even more convoys. As the number of

[131] *Sustain the Mission Project: Casualty Factors for Fuel and Water Resupply Convoys,* page 5.

[132] 106 fuel convoys saved per year / 24 casualties per fuel convoy in Afghanistan = 4.4 casualties saved per year.

convoys increases, the probability of successful attack also increases, as the Taliban benefit from more opportunities to target convoys under favorable conditions.

4. By producing biodiesel and reducing the number of convoys, the military can devote scarce resources towards defending each convoy better, thereby further reducing casualties. The Army has estimated that each convoy requires 120 soldiers for fuel trucks, protection, and other support.[133] We know however that air protection is not needed for the entire duration of a convoy, and contractors may be used on some segments of a supply route, so let's be conservative and estimate that on average 60 soldiers are needed. Eliminating 106 convoys a year therefore frees up 6,360 soldiers for the duration of a convoy. Assuming a week for each convoy,[134] that reduction in convoys equates to about 122 additional troops.[135] No doubt some of these troops would be assigned to better protect the remaining convoys and some would be needed to protect the biodiesel plant in Kandahar. But it is likely that the majority could be assigned to other duties to improve the effectiveness of the U.S. military campaign in Afghanistan.

5. By producing biodiesel in Afghanistan the potential exists to reduce casualties even more significantly. There were 24,615 U.S. troops in Afghanistan in October 20, 2007 just after the conclusion of FY 2007.[136] As stated above, there were 38 casualties protecting fuel convoys in Afghanistan in FY 2007. With the surge to 100,000 troops, and a linear increase in casualties, we can project future casualties of at least 154 casualties a year protecting fuel convoys. As discussed in Chapter "U.S. Military's Consumption of Fuel in Afghanistan" in the section "Why the Supply Problem Will Worsen," without the implementation of significant fuel conservation measures, casualties will rise at more than a linear increase. In Chapter "Building a Biodiesel Plant in Afghanistan" we modeled the impact of constructing a single

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[133] U.S. Army, Office of the Assistant Secretary of the Army, Installations and Environment, *Army Energy Security*, by Dr. Kevin T. Geiss, Program Director Energy Security, October 19, 2009, slide 10. (http://energyconversation.org/sites/default/files/GEISS%20SLIDES_0.pdf)

[134] This is a conservative assumption, consistent with the discussion in Chapter "U.S. Military's Consumption of Fuel in Afghanistan" section "Long Supply Lines and Casualties." It is unlikely that on average a convoy does a roundtrip within a week to supply U.S. forces in Afghanistan using either northern or southern supply routes.

[135] See earlier discussion in the Supply Lines and Casualties chapter. The average fuel convoy is 20 trucks: 16 for fuel and 4 for protection. Let's assume each protection truck has one driver and one gunner, so the absolute minimum number of troops required is 24.

[136] Congressional Research Service, Knowledge Services Group, *U.S. Forces in Afghanistan,* (Report RS22633), by JoAnne O'Bryant and Michael Waterhouse, Information Research Specialists, CRS Report for Congress, July 15, 2008, page 5.

biodiesel plant in Kandahar. If the U.S. military were to build enough biodiesel plants to satisfy the demand for electricity generation for all troops, which is at least 40% of fuel consumption, then 40% of 154, or 62 casualties a year could be avoided.

6. Assuming that the farmers are paid $5,000 per hectare, and feedstocks are imported at the DOD's Fully Burdened Cost of Fuel (FBCF) of $400 per gallon ($106 per liter), the resultant cost of biodiesel per gallon is $90 per gallon ($23.8 per liter) in the first year, $83 per gallon ($21.9 per liter) in subsequent years. (Note that $5,000 per hectare is approximately 40% higher than the current prices being paid to Afghan farmers for their poppy crops.) The direct cost savings to the U.S. military are also considerable. Using the figure of $400 per gallon for the cost of importing diesel fuel or biodiesel chemical inputs, the military would save $3.7B per year in the first year, and $3.8B per year in subsequent years from the construction of a single biodiesel plant.

7. Even using Deloitte's much lower figure of $45 per gallon as the FBCF and the cost of chemical inputs, the payback is less than nine months with savings of $41M in the first year and $131M in subsequent years. At $41 per gallon ($10.83 per liter) the plant has a payback of one year, and savings of $90M per year starting in the second year. Since the plant is fully paid for after one year, the production cost per gallon drops from $41 to $33.50 per gallon in the second year. Also note that these figures are only direct savings, and do not include indirect savings, such as the value of trucks and fuel destroyed in attacks on convoys.

8. The U.S. is spending millions of dollars each year to refurbish or replace supply trucks that are either destroyed or damaged in attacks, or worn out. For example, the military announced a five-year contract with Oshkosh Trucks in August to replace just one family of trucks, the Army's FMTV series. The contract covers 23,000 vehicles and is worth up to $2.6B. The DOD reported that, in June 2008 alone, the military lost 44 trucks and 220,000 gallons of fuel in Iraq and Afghanistan.[137] Using $50 per gallon as the FBCF rather than $400 (since the fuel was not successfully delivered to the military) results in a loss of $11M. The new FMTV vehicles cost about $385,000 per vehicle, totaling $16.94M. Thus the military suffered approximately $28M in losses in June 2008 due to convoy equipment and fuel that was destroyed.

Biodiesel Plant Business Model

Building biodiesel plants in Afghanistan is, of course, a risky proposition; few American companies would be willing to accept this degree of risk.

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[137] *DOD Needs to Increase Attention on Fuel Demand Management at Forward-Deployed Locations,* page 8.

Consequently we recommend that the U.S. Government own the plants and subcontract construction and operations of the plants to U.S. or ISAF firms via service contracts. The U.S. companies should be encouraged to use Afghan labor wherever feasible; this would be an excellent opportunity to train promising Afghans in agriculture and engineering.

Sadly, there are many examples in Iraq and Afghanistan of contractors who have performed poorly or overcharged the government, including construction of the Tarakhil power plant mentioned earlier in Chapter "Building a Biodiesel Plant in Afghanistan," section "Biodiesel Plant Financial Analysis." If a cost-plus business model is used rather than a fixed price model to fund construction of biodiesel plants, we recommend that two mechanisms be included in the contract. First, a substantial balloon payment should be awarded at the end of the project, when the plant first begins producing biodiesel. Second, the government should pay the contractor a declining rate once the contractor exceeds the accepted bid. For example, the contract might state that the plant should cost a specific amount and the contractor is paid cost plus 20% to achieve that result. If 10% over budget, the contractor is paid cost plus 17.5% for all future remaining expenditures, if 20% over budget, the contractor is paid cost plus 15% for all future remaining expenditures, and so on. The contractor is still paid to complete the project, but does not earn much money on the portion that is over budget.

At some point, when the biodiesel plant is operating successfully, the government should sell the plant to a private company.

Next we take a look at current military programs to reduce petroleum dependency, and to what extent producing and using biodiesel in Afghanistan is consistent with these programs.

Current Efforts by the Army and Marines to Reduce Petroleum Dependence

Overview

We have argued that it is feasible for the U.S. Army and Marines to both produce and use biodiesel in Afghanistan. But perhaps other efforts, currently in progress, will significantly reduce the dependence of the Army and Marines on petroleum, either through substitution of renewable resources or increased efficiency.

A review of the projects in progress is both encouraging and discouraging. There is now broad recognition throughout the U.S. military, including the Army and Marines, that the U.S. dependence on fossil fuel in general and petroleum more specifically is both a military and economic weakness. The DOD uses 0.8% of the country's total energy consumption, 78% of the energy consumed by the Federal Government, and consumes more energy each day than 100 other countries.[138] In recognition of this weakness, the DOD has formed a task force, the DOD Energy Security Task Force, to coordinate activities across all service branches.[139]

The DOD is making significant progress in promoting the use of renewable energy in the U.S. The scope of the Air Force programs is particularly impressive. The Air Force is the Federal government's largest purchaser of (off-base) green power, and the Air Force has thirty renewable energy projects in operation or development: eleven biomass or wind, twelve solar, and seven geothermal projects.[140] The Army is implementing a particularly large facility at Fort Irwin in California: a 500 MW solar thermal energy plant. As noted earlier in the beginning of the Chapter "Could the U.S. Military Substitute Biodiesel for Oil in Afghanistan?" all of the service branches have instituted programs to use biofuel in non-tactical vehicles in the U.S. Yet when looking at the sum of the efforts to date of the Army, Air Force, Coast Guard, Marines, and the Navy, the reduction in petroleum consumption is a small percentage of the total military energy consumption.

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[138] Jerry Warner, P.W. Singer, *Fueling the 'Balance' – A Defense Energy Primer,* Foreign Policy at Brookings, The Brookings Institution, August 2009, pages 1, 2. (http://www.brookings.edu/papers/2009/08_defense_strategy_singer.aspx)

[139] DOD, "DOD Security Task Force Update," (LLNL-PRES-408745), by Chris DiPetto, OSD/AT&L, September 18, 2008, for general background.

[140] U.S. Air Force, Headquarters, *U.S. Air Force Energy Program*, by Mike McGhee, Acting SAF/IEE, October 19, 2009, slide 16. (http://energyconversation.org/sites/default/files/MCGHEE%20SLIDES_0.pdf)

The Army and the Marines are also working on a number of programs that will reduce energy consumption, but only a few of these efforts are likely to have a significant impact on the campaign in Afghanistan within the next five years.

Let's take a look at some of the major initiatives in progress.

Common-Sense Short-Term Solutions

The Army and Marines are working on several initiatives that are being deployed or can be widely deployed within the next several years to reduce electricity demand at FOBs.

Foam-insulated tents

The Army and Marines initiated a project in 2008-2009 to insulate tents in FOBs. As of May, 2009 the military had insulated 1,200 tents in Iraq and signed an agreement to insulate 500-600 tents and temporary structures in Afghanistan.[141] According to the manufacturer, in most cases, the foam increases efficiency by about 25% - 33%, but in the high heat of Iraq the Marine Corps has reported savings of 50% - 70% with the investment breaking even within 75 days.[142]

Spot power versus primary power

Until recently, not much thought has been given to maximizing the efficiency of power generation at a FOB by optimizing the demand for power with the capacities of the base's electrical generators. Often generators were dedicated to individual applications within a FOB, but this spot power approach leads to inefficiencies. Using a 10 MW generator to produce electricity for a 5 MW load is inefficient. The ideal is where each generator runs at 100% capacity, and the remaining generator that does not run at 100% capacity is the smallest generator, minimizing inefficiency. This approach, where some generators are nearly always running to supply "primary power," requires "ganging" the generators, or connecting them in series. Another concept is called "central power," where the loads of smaller independent generators are consolidated into one or several large generators; however, multiple islands of central power may exist at a medium-sized or large military base. Dan Nolan, an energy consultant and former U.S. Army officer who participated in the Marines MEAT (Marines Energy Assessment Team), reports that military procedure in Afghanistan often limits or delays the implementation of a primary power approach.[143] Nolan's comments are consistent with the

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[141] Kris Osborn, "Foam to cut fuel costs, regulate weather," *ArmyTimes*, May 2, 2009. (http://www.armytimes.com/news/2009/05/army_foam_050209w/)

[142] U.S. Marine Corps, Installations and Logistics Department, Headquarters, *USMC Energy Efforts and Challenges*, by Carla Lucchino, Assistant Deputy Commandant, October 19, 2009, slide 6. (http://energyconversation.org/sites/default/files/LUCCHINO%20SLIDES_0.pdf)

[143] Dan Nolan, "Another Serving of Marine Energy MEAT for you," energyconversation.org, http://www.energyconversation.org/external-feed/feed-item/another-serving-marine-energy-meat-you

GAO report “DOD Needs to Increase Attention on Fuel Management at Forward-Deployed Locations” of February 2009.

New generation of Mobile Electric Power (MEP) generators

As described in the Chapter “Could the U.S. Military Substitute Biodiesel for Oil in Afghanistan?” in the section “Electrical Power Generation,” the new generation of AMMPS generators will begin production in 2010, and these generators are 15% - 25% more efficient than the previous generation of TQG generators. The TQG generators are 10% more efficient than the even older MIL-STD generators. Neither the large LAMPS generators nor the small STEP generators have begun the military’s Research Development Test & Evaluation phase. Without higher prioritization they are unlikely to be approved for production, manufactured, and deployed in volume in Afghanistan within the next five years.

Longer-Term Solutions

Military hybrid-electric vehicles

Overview

Hybrid vehicles have more than one source of power. One source is an internal combustion engine, such as a diesel engine, gasoline engine, or turbine. The second source of power is usually an electric motor, but could be another source such as a hydraulic system.

Hybrid-electric technology is now standard commercial technology in both cars and buses and increasingly in many classes of trucks. The Toyota Prius was first sold in the U.S. in 2000 as a 2001 model. Ford introduced the hybrid gasoline engine-electric motor Escape in 2004. In 2009 hybrids accounted for 2.8% of the light-duty U.S. vehicle market. In 2009, the Prius hybrid was the most popular car model in Japan.

In New York City, 25% of the over 13,200 taxis are now hybrid gasoline-electric cars. In 1998, New York City started deploying diesel-electric hybrid buses on a limited basis. Based on successful trials over a three-year period, New York began purchasing in volume in 2003. By June 2010, 1,675 of New York City’s nearly 4,400 buses, or about 38%, will be diesel-electric hybrid buses.[144] According to a DOE study, New York City's newer hybrid-powered buses cost 40% less to maintain and 24% less to operate than earlier-generation hybrids.[145] New York City purchased the hybrid diesel buses from Orion, owned by Daimler. The Orion buses use BAE

[144] Bill Sweet, “New York City Leads World in Hybrid Bus Adoption,” IEEE Spectrum, April 14, 2010. (http://spectrum.ieee.org/energywise/green-tech/advanced-cars/new-york-city-leads-world-in-hybrid-bus-adoption)

[145] “Newer NYC Buses with BAE Systems’ Hybrid Propulsion cost less to own and operate, U.S. Government says,” BAE Systems press release, Rockville, Maryland, February 6, 2008.

Systems' HybriDrive diesel-electric propulsion system with diesel engines from Cummins. New York is testing four different designs of diesel-electric hybrid garbage trucks, which are expected to reduce fuel consumption by 30% over the existing fleet. The city is also testing garbage trucks that weigh 36 tons, in the same weight class as heavy military trucks (HEMTT class).

U.S. companies such as PACCAR (which owns the Kenworth and Peterbilt brands) and Navistar (the International brand) have been selling hybrid diesel-electric commercial trucks for several years. Freightliner, a division of Daimler Trucks North America, also sells diesel-electric hybrid trucks. As of early 2010, Freightliner, Navistar, and PACCAR all sell hybrid trucks in the heaviest vehicle classes, Class 6, Class 7, and Class 8.[146] These companies often partner with two leading producers of hybrid-electric drive trains, the Eaton Corporation and Azure Dynamics.

Allison Transmission has been selling hybrid electric systems since 2000 and claims to be the world's largest heavy duty producer with 4,000 hybrid systems either delivered or awarded. Transit agencies from major American cities including Chicago, Houston, Minneapolis, Philadelphia, Seattle, and Washington D.C. use buses with Allison hybrid systems. Allison's hybrid systems use diesel engines manufactured by Cummins. Another manufacturer of hybrid drives systems for heavy-duty buses and trucks is the ISE Corporation.

Increasingly package delivery companies are using hybrid vehicles. As of December 2009, FedEx, Purolator, and UPS had each deployed several hundred hybrid-electric vehicles with more on order.

In December 2009 Caterpillar announced availability of a diesel-electric hybrid bulldozer using series hybrid technology, the D7E, an upper midsize range bulldozer. The bulldozer's C9.3 diesel engine powers a generator which in turn supplies electricity to electric motors that propel the bulldozer, and also to accessory systems such as the air conditioner, water pump and battery charger. The D7E costs 20% more than a standard model, the D7R, but is 25% more efficient. Reliability will be higher and maintenance costs lower because the D7R has 60% fewer moving parts than the D7R. The D7R weighs 47,619 pounds, in the same range as the MTVR 7-ton standard cargo trucks manufactured by Oshkosh Truck (which also use Caterpillar engines). MK23 – MK25 Standard Cargo Trucks weigh 27,900 pounds (curb weight) and 62,200 pounds (fully loaded with cargo).

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[146] Classes 1 and 2 are considered light duty trucks, 3-6 medium duty trucks, and 7-8 heavy duty trucks. Class 6 has a maximum Gross Vehicle Weight (GVW) Rating of 26,000 pounds, Class 7 33,000 pounds, and Class 8 33,001 pounds and higher. Classes 6-8 correspond to the Army's FMTV and FHTV families of vehicles. For example, a small medium duty truck, a M1079 A1 2.5 ton van, has a GVW of 24,601 pounds. Peterbilt's hybrid Model 386, with GVWR of 80,000 pounds (including the tractor and payload), is similar in class to BAE Systems FMTV M1088 5.0 Ton Tractor, which can tow up to 63,000 pounds.

Some cities are beginning to fuel diesel-electric hybrid buses with biodiesel; Minneapolis and Ann Arbor (Michigan) are examples. All buses in Minneapolis use B10; MetroTransit is testing B20. The Minnesota Department of Agriculture announced May 1, 2009 that the state has increased the amount of biodiesel required for blending into regular diesel from 2% to 5%. Minnesota will require 20% biodiesel to be blended into petroleum diesel (B20) by 2015.[147]

Diesel-electric hybrid technology and biodiesel

In applications for automobiles, competing hybrid technologies are vying in the market. Ford's Fusion and Toyota's Prius use a parallel hybrid approach, where the electric motor and gasoline engine can work independently, or together, to propel the car. In a parallel hybrid system, the conventional vehicle powertrain is supplemented by the addition of the hybrid components. The addition of the electric motor reduces the required size of the combustion engine.

GM's Volt (anticipated in late 2010) and Fisker Automotive's Karma (2012) employ a series hybrid approach, where the gasoline engine powers a generator that is not connected to the wheels of the car. In a series hybrid system, the conventional vehicle powertrain is replaced by the hybrid power system. A series hybrid greatly reduces the size of the internal combustion engine since in this design the internal combustion engine must only provide the average power required by the vehicle rather than the peak power. These latter two vehicles are also considered plug-in vehicles, because they can run in an all-electric mode for limited distances and the batteries can be recharged from an external outlet.

In the U.S. commercial vehicle segment, both approaches are also being used. City hybrid buses tend to use series hybrid technology, and longer distance Class 7 or Class 8 trucks parallel hybrid technology. The series design is particularly well suited to using B100 as a fuel, since the engine requirements are less demanding. The diesel engine in a series hybrid mostly runs at a constant speed, powering the generator to create electricity, just like a standalone generator.

The average speed of military convoys in Iraq is 35 miles per hour.[148] In Afghanistan, due to mountainous terrain and poorer roads, the average is almost certainly lower. Thus the duty cycle of military convoys is not the same as Class 8 commercial tractor-trailers that primarily operate on interstate highways in the U.S. The duty cycle of military truck convoys is more likely to resemble a mixture of urban and highway driving. The fuel efficiency benefits of adopting of hybrid technology are currently greater when the duty cycle includes urban driving.

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[147] Louisiana, New Mexico, Massachusetts, New Mexico, Oregon, Pennsylvania, and Washington have also passed biodiesel requirements.

[148] *Sustain the Mission Project: Casualty Factors for Fuel and Water Resupply Convoys,* pages A-1, A-2.

As hybrid and battery technologies continue to improve, the series hybrid design is likely to become the predominant technology for most commercial vehicle applications because greater efficiencies are possible.[149]

The Army and Marines have not made significant progress

In spite of rapid progress in the commercial sector, efforts to deploy diesel-electric hybrid technology for vehicles in the Army or Marines are moving slowly. The Army's Tank Automotive Research, Development, and Engineering Center (TARDEC) is sponsoring a number of hybrid electric prototypes, including the XM1124 Hybrid Electric Humvee, a series hybrid that can also generate electricity. But TARDEC only started working with suppliers beginning in December 2009 to test four prototypes over the next eighteen months, so it is unlikely that a production version could be deployed in volume in Afghanistan within five years.[150] Hybrid Humvee prototypes were first delivered to the Army as far back as 2002, yet the Army has failed to deploy production models or test prototypes in either Iraq or Afghanistan. TARDEC is also working on another hybrid vehicle, the Clandestine Extended Range Vehicle (CERV), but that is a small low-volume vehicle designed for U.S. Special Forces.

Oshkosh Truck developed a proof-of-concept diesel electric HEMTT in 2003 and a production-ready vehicle in 2005. Per Dan Binder, technical director for Oshkosh (in 2005) "We have a truck that is diesel-electric hybrid powered and it does virtually everything its conventional counterpart vehicle does today. It meets the grade climbing requirements, speed requirements, it's able to carry the payload and meet the temperature requirements and high expectations for cooling capability." Furthermore, the hybrid HEMTT was 3,000 pounds lighter than the second generation HEMTT then in production.[151] But the Army did not proceed. BAE Systems, the other major supplier of Army support vehicles, also developed prototype military hybrid vehicles, such as a hybrid howitzer. This project also did not advance to production.

The Army's lack of progress in deploying commercially proven hybrid technology is troubling. Diesel-electric hybrid technology for Class 6 and Class 7 medium and heavy-duty vehicles is now commercially available in significant manufacturing volumes, offered by a variety of truck

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[149] Series hybrid technology has been used in diesel-electric locomotives since the 1920s, before the term "series hybrid" was coined. Hybrid locomotives, such as GE's Evolution Hybrid locomotive, add modern batteries and electronics, in GE's case a sodium-based battery. The battery allows the locomotive to capture and store energy normally dissipated in braking for later use to increase power.

[150] "EnerDel wins U.S. Army contract to developed batteries for 'Hybrid Humvee," EnerDel press release, (EnerDel is a subsidiary of Ener1), Indianapolis Indiana, November 5, 2009.

[151] Dawn M. Geske, "Making the HEMTT a hybrid: Oshkosh Truck develops a diesel-electric version of the workhorse Heavy Expanded Mobility Tactical Truck," *Diesel Progress North American Edition*, June 1, 2005. (http://www.allbusiness.com/transportation/motor-vehicle-manufacturing/457926-1.html)

suppliers. For example, Coca-Cola has purchased 305 Class 7 T370 hybrid trucks from PACCAR's Kenworth division. Truck manufacturers offer hybrids for a wide variety of applications, including refuse trucks, shuttle buses, parcel delivery, beverage trucks, utility trucks, medium and long distance delivery, dump trucks, crane trucks, and cement mixers.

If hybrid vehicles were deployed in Iraq or Afghanistan their increased efficiency would reduce fuel consumption and hence fuel convoys, thereby saving lives and billions of dollars in fuel expenses a year. The more proven the technology is, the more rapidly it can be deployed. Most critically the Army's prioritization of projects seems confused. The Army should focus more resources on the equipment in the field that both consume the greatest amount of fuel and that can be improved the most rapidly. Recall that three out of the four top users of fuel during the first Gulf war were tactical transport trucks, not tactical combat vehicles such as the Humvee (Table 12). The NRAC study mentioned earlier bears repeating: 5-ton supply trucks consume 58% of the all of the fuel consumed by the Marines combat and tactical vehicles, versus 11.7% for Humvees.[152] The requirements for military transport trucks are clearly more rigorous than those of commercial trucks but still less rigorous than combat vehicles. The Army and Marines should move to implement diesel-electric hybrid technology in transport trucks (where the diesel engine is capable of supporting B100) as soon as possible, even if only on an experimental basis. The Army or Marines should already have a test program for supply vehicles in progress in Iraq. The conditions in Iraq are hot and dusty, but less demanding than Afghanistan, and not so different from the American Southwest. However, based on the past track record, it is hard to believe that the military will succeed in deploying hybrid-electric technology in volume in Afghanistan within five years.

TARDEC and GSPEL

The Army's TARDEC has built a new laboratory in Warren, Michigan called the Ground System Power and Energy Laboratory (GSPEL), dedicated to the development of more sustainable military vehicles. With increased focus on reducing fuel consumption and using renewable resources, TARDEC can play a critical role in deploying new technologies in the Army and in coordinating or consolidating previously uncoordinated efforts.

Army HI-POWER for tactical power grids

This project is an effort to deploy an intelligent power grid in the field - a more sophisticated approach than merely connecting generators in series. The intelligent power grid is also designed to address the problem that, at larger bases with many generators, the generators are often inefficiently implemented in separate, unconnected islands. This power management architecture will include small and medium sized tactical versions for mobile forces and larger transportable systems appropriate for forward operating bases. Initial models estimate fuel savings of up to 40%, reduced maintenance and personnel requirements, and fewer power

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[152] *Future Fuels*, slide 10.

interruptions. It is unclear whether this program can be implemented in volume within five years.[153] (Another technical term that the military uses to describe projects of this nature when applied to a smaller base is a smart microgrid.)

Tactical Garbage to Energy Refinery (TIGR)

TIGR was co-developed by the Army with Purdue University; it is a biorefinery that is designed to provide energy to power the generators and stoves that account for about half of the fuel consumption at most forward operating bases. TIGR generates 55kW of output and is able to power a 60 kW generator. TGER works by turning solid trash into a synthetic gas composed of simple hydrocarbons, resembling low-grade propane. TGER also transforms liquid and food waste into a hydrous ethanol which is blended with the syngas to create usable energy. It takes TGER just six hours to fully power up, during which time the amount of diesel fed into the machine slowly drops, until the generator is powered by less than one gallon of fuel per hour, as compared to five per hour without TGER.[154] Two prototypes were tested in Iraq in 2008. If these prototypes are converted fairly quickly into production models, they could be deployed within five years.

Transportable Electric Power Source (THEPS)

Skybuilt Power of Arlington, Virginia is providing the military a mobile power station. THEPS uses several different power sources, including a wind turbine, solar panels, a diesel generator and storage batteries. The system's renewable sources minimize the fuel required by the diesel generator. The Army Rapid Equipping Force purchased four power stations in 2008 at the five-kilowatt level in 2008. The technology completed testing at Aberdeen Proving Ground in Maryland and has been installed at Fort Irwin, California for more rigorous testing.

Net-Zero Energy (NZE) projects

NZE, or NZEI (NZE Installations), are a joint effort of the DOD and DOE. A definition of NZEI is "a military installation that produces as much energy, focusing on renewable energy, on or near the installation, as it consumes in its buildings and facilities."[155] The goal of the Armed Services is

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[153] DOD, "DOD Energy Security Task Force," September, 2008, page 9. (http://www.dod.mil/ddre/doc/DoD_Energy_Security_Task_Force.pdf)

[154] Lindy Kyzer, "Army Turns Trash into Energy," *Army.mil* (The Official Homepage of the U.S. Army), June 19, 2008 (http://www.army.mil/-news/2008/06/19/10194-army-turning-trash-into-energy-in-iraq/) and Don Kennedy, "Energy-Generating TGER tested Successfully in Iraq," *U.S. Army Acquisition Support Center* (ASCC), October 2008. (Goggle cache: http://www.usaasc.info/alt_online/default.cfm?hdst=artl&iID=0811&aID=03&hsrc=artl081114)

[155] DOE, National Renewable Energy Laboratory, *DOD-DOE Initiative – Net Zero Energy Installations: Systems Approach to Energy Security*, by Bob Westby, Charting a Course to Energy Independence Conference, Providence Rhode Island, August 11, 2009, slide 7. (robert_westby@nrel.gov). This

that entire military bases, both in the U.S. and overseas, become NZE installations. An even more ambitious goal is NZE Plus, where the installation is able to sell excess green energy to the local electrical power company.

A number of military bases in the U.S. are working on NZE-related projects, including the Marines' Air Station Miramar, California and the Army's Fort Carson, Colorado. The Army's Fort Irwin in California is attempting to become an NZE-Plus installation. The Army use Fort Irwin and the Marines use Quantico in Virginia to test the applicability of NZE technologies to the demanding requirements of bases in Iraq and Afghanistan.

It is unlikely that bases in Afghanistan will achieve NZE status within five years; the efforts of the DOE and DOE are in their early stages. But the NZE initiative has the promise, over time, of significantly reducing the energy requirements of U.S. troops in the U.S. and overseas.

Military Energy-Reduction Technology Summary

A program to produce and use biodiesel in Afghanistan does not currently exist, but if the DOD were to implement such a program it would complement and enhance the effectiveness of existing projects, including hybrid vehicle efforts and the many projects designed to reduce energy consumption at military bases. Producing and using biodiesel in Afghanistan is consistent with the objectives of the Net Zero initiative.

But perhaps even more critically, biodiesel technology is proven. There are about 170 biodiesel plants in the U.S. with a production capacity of 2.7B gallons a year. Consequently production of biodiesel can be implemented to scale in Afghanistan within two years, making an enormous difference quickly. The most difficult challenge is not a technical one; rather it is one of persuasion – persuading Afghan farmers to substitute biodiesel crops for poppy. However, if the military and Department of Agriculture specialists can work together, this challenge can be met.

During WWII, many technologies that were immature at the start of the war were rapidly improved and implemented on a massive scale, including sonar, radar, synthetic rubber, and synthetic fuel manufactured from natural gas or coal. The U.S. should focus on two strategies with the same sense of purpose that was evident in the 1940s: reduction of the demand for fuel in general and the substitution of biodiesel for petroleum diesel. It is instructive to look at the efforts the U.S. military made in the early 1940s to very rapidly deploy an improved tank in the battlefield. The military worked on an interim solution, the M3 General Lee, and a significantly improved version, the M4 Sherman, nearly simultaneously:[156]

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presentation is similar to *DOD-DOE Initiative: Net Zero Energy Installation Overview*, Bob Westby, May 4, 2009, slide 6. (http://e2s2.ndia.org/pastmeetings/2009/tracks/Documents/7767.pdf)

[156] The British named American tanks after Civil war generals. The original M3 was dubbed General Lee, later variants General Grant, and the M4 was called General Sherman. The nicknames stuck. The M4 used

Table 21 U.S. Military Develops M3 and M4 Tanks within Two Years

Date	Event
June, 1940	War Department contacts Chrysler to design M3 tank
July, 1940	Chrysler provides M3 design
May, 1941	First M3 shipped to the Army
September, 1941	Army approves M4A1 for production
February, 1942	Army accepts M4A1 for volume production
October, 1942	M4 used in the second battle of El Alamein in Africa

Today, in 2010, a project to replace old MIL-STD generators or retrofit TQG generators to support B100 should be highly prioritized. The program to develop and manufacture a new generation of generators should be accelerated by the DOD. The M-ATV program is a modern example where the Army and Marines succeeded in moving quickly. From inception in 2008 to full production in late 2009 the program to specify, select a manufacturer, and deploy a mobile MRAP, optimized for the conditions in Afghanistan, took only two years.

In the opinion of the authors, we Americans sometimes seem to suffer from a national weakness regarding technology. We look to the future in the hopes of perfecting an ideal solution rather than implementing existing technology in the present that can substantially, but perhaps not entirely, address a problem. Of course, there are tradeoffs in adopting existing versus future technology. But such tradeoffs do not exist with respect to biodiesel. Biodiesel manufacturing technology is proven and can be implemented immediately. With some added work, all electrical generators and tactical transport vehicles can support B100 and tactical combat vehicles can support B30. Here, success is a question of will.

The next two chapters describe two complementary recommendations that would further improve the probability of U.S. and ISAF success in Afghanistan and benefit the Afghan people.

engines designed by five manufacturers: Caterpillar (diesel), Chrysler (gasoline), Continental (gasoline), GM (diesel), and Ford (gasoline). Ten different companies manufactured the M4.

Transportation in Afghanistan

The Current Situation

Afghanistan is a fairly large country, slightly smaller than Texas, with an oval shape oriented northeast by southwest. The Hindu Kush mountain range divides the country, extending from its highest peaks in the northeast gradually diminishing to the west and southwest. The major population centers are connected by a 2,227 km (1,384 mile) ring road. The distance from Kabul southwest to Kandahar is 482 kilometers (300 miles). From Kandahar northwest to Herat, less than 80 km (50 miles) from the Iranian border is 595 km (370 miles). There is no major east-west road connecting Herat with Kabul. From Herat the road travels northeast 733 km (455 miles) to Mazar-e Sharif. And then from Mazar-e Sharif the road goes 417 km (259 miles) southeast, through the Salang tunnel in the Hindu Kush Mountains to Kabul. The Afghanistan Ministry of Public Works stated in June, 2009 that the road is 90% complete, and will be finished in eighteen months. Most of the remaining work is in the section between Herat and Mazar-e Sharif.

Of Afghanistan's fourteen largest cities, eleven are located on the road or with good access to the road. Furthermore, even though most of Afghanistan's population is rural, it is estimated that two-thirds of Afghanis live within 50 km (31 miles) of the road. USAID is funding a project to construct a 101 km (63 mile) road connecting Afghanistan's ninth largest city, Khost, with Gardez, on the ring road south of Kabul. Khost is not far from Pakistan's tribal region of North Waziristan. The rationale for completing the ring road and enhancing the secondary roads that connect to the ring road is two-fold. With better roads, U.S. and ISAF forces will be able to move supplies more effectively and react more quickly to Taliban initiatives. But equally as important, a better road structure will stimulate commerce. USAID believes that the road improvements will allow surplus crops to be sent from Khost to others parts of Afghanistan suffering from food shortages, and over time, to international markets.

Afghanistan Railroads

Currently Afghanistan does not have a railroad, but projects are proposed or funded to extend rail lines to Afghan border towns from neighboring countries: Pakistan (proposed), Turkmenistan (exists), Uzbekistan (funded), Tajikistan (funded). Iran is also working on extend its railroad to the border near Herat and then would like to extend further to Mazar-e Sharif.

Pakistan

The Pakistan railroad currently extends to from the port city of Karachi to Chaman. It is another 15 km to the Afghan border town of Spin Baldak and then another 100 km to Kandahar for a total of 115 km (71.5 miles). Pakistan Railways has completed a feasibility study of the Chaman-

Kandahar section and, in a May 19, 2009 press release, stated that "preliminary work has been started on Chaman-Qandhar section and Peshawar-Jalalabad section."[157]

Uzbekistan

According to a September 30, 2009 press release by the Asian Development Bank, the ADB is funding 97% of a $170 million project to build a 75 kilometer (47 mile) single line railway between Hairatan, a northern town at the border with Uzbekistan that is the gateway for almost half of Afghanistan's imports and much of its humanitarian relief goods, and Mazar-e Sharif. The Afghanistan Government will be entering into direct contracts with Uzbekistan Railways Company, both for the engineering, procurement, and construction of the new facilities, and for their operation and maintenance. The project is expected to complete June 30, 2011.[158]

Tajikistan

On March 19, 2009 Radio Free Europe reported that Tajikistan has started building a railroad to connect its capital Dushanbe to a bridge on the Afghan border, a key link in the projected ISAF supply route through the former Soviet Union. The cost of building the 146-kilometer link is estimated at $131 million.[159] The Afghan Shir Khan Bandar border area is 70 km (44 miles) from Kunduz, and Kunduz is north of the ring road but accessible, about 300 km (186 miles) from Kabul.

Turkmenistan

Turkmenistan has a railroad connection to the border town of Towraghondi in the northwest of Afghanistan. This town is about 110 km (68 miles) north of Herat. Although near Herat, this access point is far from most other Afghan cities and U.S. troop locations. Once the ring road is completed, this access point to Afghanistan will become more useful.

China

In 2007 China Metallurgical Group Corporation, a state-owned company, bid $3.4B for the rights to mine copper near the village of Aynak, about 20 km (12 miles) southeast of Kabul. The Chinese offer beat out bids by four other finalists: Strikeforce, part of Russia's Basic Element Group, the London-based Kazakhmys Consortium, Hunter Dickinson of Canada, and the U.S. copper-mining firm Phelps Dodge. China is interested in building a railroad over the Khyber Pass

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[157] Government of Pakistan, Press Information Department, "Ukrainian minister calls on minister for railways," PR No. 206, Islamabad, May 19, 2009.

[158] Asian Development Bank, Media Center, "ADB-Funded Railway to Help Afghanistan Improve Regional Links, Boost Growth," Manila Philippines, September 30, 2009.

[159] "Tajikistan Starts Building Railroad to Afghan Border," *Radio Free Europe/Radio Liberty*, March 19, 2009.
(http://www.rferl.org/content/Tajikistan_Starts_Building_Railroad_To_Afghan_Border/1513160.html)

between the Pakistan border town of Landhi and Jalalabad in Afghanistan, connecting Afghanistan to the Pakistan Railways network. China and Pakistan are also exploring the feasibility of connecting Havelian in Pakistan with Kashgar in China. This project would be very ambitious, extending for 1,100 km (684 miles) and crossing the Khunjerab pass, the highest paved border crossing in the world at 4,693 m (15,397 ft.). A better option for Afghanistan would be construction of a link from Jalalabad to China via northern Afghanistan and Tajikistan. This route is not easy either: a second Salang tunnel north of Kabul would have to be constructed to accommodate rail traffic. The present Salang tunnel is 2.6 km (1.6 miles) long.

Benefits of Extending the Railroad to Kandahar

Extending the railroad from Chaman, Pakistan to Kandahar would be a complementary project to producing biodiesel in Kandahar. The Chaman border crossing is the second largest route for ISAF supplies into Afghanistan. Supplies travel from the port in Karachi, through Quetta and the Chaman crossing, to the final destination in Kandahar. There are several reasons why extension of the railroad would be beneficial.

First, railroads are much more efficient than trucks. According to the Federal Railroad Administration, railroads are 1.9 to 5.5 times more fuel-efficient than trucks, depending on the commodity carried and length of the haul. When the rail equipment is a tank car, a railroad can transport a liquid such as fuel at 370 ton-miles per gallon, versus 70 to 132 ton-miles per gallon by truck.[160] Rail's efficiency advantage in carrying fuel of approximately 3.7 times is probably even more pronounced in Afghanistan. Military transport vehicles are heavier than equivalent commercial vehicles and are not optimized for maximum fuel efficiency.

Second, extending the railroad would lower the cost of importing biodiesel feedstocks and diesel fuel, and would provide a new less expensive outlet for exporting Afghan agricultural products, including biodiesel. If Afghanistan authorities carefully inspect each train leaving Kandahar then legitimate crops, including biodiesel, would gain a competitive edge versus poppy.

Third, shipping diesel fuel by rail, rather than by truck convoy, would save lives. A railroad tank car often has a capacity of 30,000 gallons.[161] A typical fuel supply convoy consists of 16 fuel

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[160] U.S. Department of Transportation, Federal Railroad Administration (FRA), Office of Policy and Communications *Comparative Evaluation of Rail and Truck Fuel Efficiency on Competitive Corridors*, Final Report, November 19, 2009, prepared by ICF International, pages 73-74. (http://www.fra.dot.gov/Downloads/Comparative_Evaluation_Rail_Truck_Fuel_Efficiency.pdf)

[161] For example a DOT Class 111A100W1 tank car. But note than Pakistan uses a wider gauge (see below), so a tank car designed for the Pakistan railroad would hold more fuel.

trucks and carries 97,818 gallons of fuel.[162] By contrast, a 16 tank-car rail convoy could carry 480,000 gallons or nearly five times as much as a truck convoy. Depending on the track gradient and desired maximum speed, a modern 4,440 hp locomotive can pull 16 fully loaded tank cars. But by using two or more locomotives, even more fuel could be transported per rail convoy. Reducing the number of truck fuel convoys needed from Karachi to Kandahar by a minimum of 80% would reduce casualties for several reasons. Decreasing the travel time from Karachi to Kandahar also reduces the window of opportunity for the Taliban to attack the convoys, and the U.S. military would be able to devote more resources to protection of rail convoys. Finally the reduction of the number of convoys when transporting water by rail instead of by truck is even more dramatic; a 16-truck water convoy carries on average only 35,200 gallons of water.

Costs and Challenges of Extending the Railroad to Kandahar

In theory, extending the railroad would be a relatively inexpensive large infrastructure project. Mercer Consulting did a study of railroad extensions in 2005 and concluded that the average cost of extending a railroad in the U.S. is $2.5M per mile, assuming that the railroad owns the right of way.[163] That rate equates to $179M. Using the ADB rate from the Uzbekistan project, the cost would be $261M. Pakistan has long wished for this project, having completed several feasibility studies. If funded by the U.S., the best approach would be to subcontract nearly all of the work to a company in the region, logically Pakistan Railways, a nationally owned company. Using Pakistan Railways would create jobs in the region, and would perhaps improve America's troubled reputation in Pakistan. If we use the DOD's FBCF rate of $400 per gallon for fuel imported into Afghanistan, the project would pay for itself in about ten years, looking only at the narrow criteria of diesel fuel saved by rail transportation from Chaman to Kandahar. (Please see calculations at the end of this chapter.)

Of course it is not that easy. Chaman is in the Pakistani region of Baluchistan. According to the Long Journal[164] and Ahmed Rashid's book "Descent into Chaos,"[165] the Taliban maintain a strong presence in Chaman. The Taliban's shadow government for Kandahar Province is run out of Chaman. Clearly the Taliban would try to disrupt the construction of the railroad extension and the U.S. and ISAF would have to devote extra resources to protect the construction workers.

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[162] *Sustain the Mission Project: Casualty Factors for Fuel and Water Resupply Convoys,* page 3.

[163] Mercer Management Consulting, *So You want to Finance a Railroad Project?* August 30, 2005, slide 8. *(*freight.transportation.org/doc/rail/Idaho/BillHarsh.ppt)

[164] Bill Rogio, "Chaman border crossing closed to NATO traffic," *The Long War Journal*, September 9, 2009. (http://www.longwarjournal.org/archives/2009/09/chaman_border_crossi.php)

[165] Ahmed Rashid, *Descent into Chaos*, (New York, NY: Penguin Books 2009 edition), page 370.

More broadly, Baluchistan has been a major sanctuary of the Taliban. Recently on December 7, 2009, the Pakistan Prime Minister told U.S. Joint Chiefs of Staff Chairman Admiral Michael Mullen "Drone attacks in Balochistan will be highly counterproductive and will affect Pakistan's efforts to confront the challenge of terrorism."[166] If the U.S. cannot attack the Taliban in Baluchistan by air or pursue them directly in coordination with the Pakistani authorities, the odds that the U.S. surge will succeed appear to be low. The Taliban will retain their sanctuary. Although the situation seems grim, Pakistan's evident interest in the railroad presents the U.S. with an opportunity. The U.S. should push Pakistan hard for increased cooperation in Baluchistan in exchange for building the railroad.

Track Gauge

Afghanistan suffers from the unfortunate problem that its neighbors use incompatible track gauges: Pakistan and India use a wide gauge, called the broad gauge (1,767 mm), Iran and China use the standard gauge, which is considerably narrower (1,435 mm), and the Central Asian Republics of Turkmenistan, Uzbekistan and Tajikistan all use a gauge that is in between (1,520 mm). It would terribly ineffective for Afghanistan if the rail lines connecting major cities used different gauges.

The best solution seems to be to standardize on the broad gauge. Most of Afghanistan's goods will be exported the least expensive way, by sea via Pakistan. So the connection to Pakistan should be prioritized. This choice is also best for the U.S. military; the military would not want the added expense and time of a change of gauge station at Chaman or on the Afghanistan-Pakistan border.

Broad gauge should be used then to connect Chaman to Kandahar, and one day Kandahar to Kabul, Kabul to Mazar-e Sharif, Mazar-e Sharif to Herat and finally Herat to Kandahar.

Change of gauge stations then would be located in cities near the borders: at Herat changing from broad to standard (for connections to Iran) and at Mazar-e-Sharif from broad to Central Asian (for connections to Uzbekistan), and at Kunduz from broad to Central Asian (for connections to Tajikistan).

Railroad Extension Financial Analysis

Distance from Chaman to Spin Baldak

Chaman to Spin Baldak: 15 km
Spin Baldak to Kandahar: 100 km
Total Distance: 115 km (71.4 miles)

[166] "Drone Attacks in Balochistan will be counterproductive: PM," *Daily Times*, (Lahore, Pakistan), December 17, 2009. (http://www.dailytimes.com.pk/default.asp?page=2009\12\17\story_17-12-2009_pg7_14). Note that Baluchistan is also spelled Balochistan.

Rail versus truck savings per ton-mile (one-way trip)
Distance one gallon moves by rail: 370 miles per ton (FRA Report)
Chaman to Kandahar, per rail-ton: 0.193 gallons
Rail Efficiency over trucks: 3.7 times more efficient (FRA Report)
Chaman to Kandahar, per truck-ton: 0.714
Rail versus truck savings Chaman to Kandahar, per ton: 0.521 gallons

Number of tons of fuel imported via Chaman to Afghanistan (assuming 20,000 soldiers)
Fuel transported in Afghanistan Theater (FY 2007): 87,731, 302 gallons (Army Report)
Weight of one gallon of diesel fuel: 7.3 pounds per gallon
Weight of diesel fuel transported: 640,438,505 pounds
Weight of diesel fuel transported: 320,219 tons
Water transported in Afghanistan Theater (FY 2007): 15,427,528 gallons (Army Report)
Weight of one gallon of water: 8.35 pounds
Weight of water transported: 128,819,859 pounds
Weight of water transported: 64,410 tons
Weight of diesel fuel and water transported: 384,629 tons
Percent supplied via Chaman, Pakistan: 40% (conservative assumption)
Fuel and water transported via Chaman: 153,852 tons per year

Savings per year if moved by rail
Savings per year in gallons if moved by rail: 80,193 gallons (153,852 tons * 0.521 gallons per ton)
FBCF per gallon: $400 per gallon (DOD)
Savings per year if moved by rail: $32,077,183

Payback
Cost of railroad extension, per mile: $3,730,000 (Asian Development Bank rate)
Cost of railroad extension: $266,428,571
U.S. Overhead: 20% for USAID, general contractor
Total cost: $319,714,286
Payback: $319,714,286 cost / $32,077,183 savings per year = 10 years

Discussion
This analysis above looks at one-way trips from Chaman to Kandahar. It does not include the additional fact that trains on the return trip are also more efficient than trucks. Trains would also be more effective than trucks in exporting goods from Kandahar, either biodiesel or agricultural goods. This analysis assumes that the only savings are realized from Chaman to Kandahar but, in fact, the U.S. military appears not to use trains when transporting fuel or water at any point in the journey from Pakistan ports to Kandahar. Military resources to protect the construction workers have not been included in the analysis, and the cost of the railroad equipment has also not been included. The FY 2007 Afghanistan convoy data was for 20,000 U.S. troops, many fewer soldiers than are currently are deployed in Afghanistan. However, planning and construction of the railroad extension would require several years, and several years from now troop levels may be lower.

In conclusion, we believe that the idea of extending the railroad from Chaman to Kandahar is promising enough to deserve further study.

A Commodities Exchange in Afghanistan

The Iraq Stock Exchange

During the one of the bleakest periods of the Iraq war, in June 2006, OMX (now NASDAQ OMX) was selected to supply a turnkey stock exchange system to Iraq. OMX subcontracted through United Services, a U.S. general contracting firm with experience doing business in Iraq. The project was delayed, but electronic trading began in April 2009 and this past autumn Iraqi exchange management visited New York. By March 2010, the stocks of 36 companies were trading electronically on the exchange supported by 45 member firms. Today the exchange is a symbol of hope. In time the exchange should play a valuable role in helping Iraqi companies raise money and in providing investment opportunities for Iraqi and international investors. Sometimes, improbable projects do indeed succeed.

Possible Afghanistan Commodities Exchange

If the U.S. decides to proceed with the production of biodiesel in Afghanistan, it may make sense to implement a commodities exchange. Given the importance of agriculture in the economy of Afghanistan, a commodities exchange is more likely to make a strong contribution to the economy than a stock exchange.

A commodities exchange could bring added visibility to Afghan agricultural products, helping Afghanistan export more in the region. These products may include biodiesel crops some day in the future, but currently include wheat, barley, cotton, fruits (melon, watermelon, onion, potato, and tomato), vegetables (grapes, almond, apricot, pomegranate), livestock (cattle, sheep, camel, goats), and wool, but could also include non-agricultural products such as copper.

Introduction to commodities exchanges

The firms that trade on a commodities exchange are either exchange members, or participants. Participants are customers of the exchange members but not direct customers of the exchange. Furthermore firms that trade on an exchange can act as intermediaries or natural traders. The intermediaries are often banks that have no intrinsic interest in the commodities that they trade: they trade to make money, taking advantage of market trends or inefficiencies. The bank traders are thus speculators. Nevertheless the intermediaries add liquidity (trading volume) to the exchange and help make the exchange more efficient. The natural traders represent a business that uses the commodity being traded, and thus the natural traders are normally trying to hedge business risk. The natural traders vary by the type of commodity. General Mills and Kellogg’s may be natural traders for wheat futures contracts but would not be interested in trading copper futures contracts.

Commodities exchanges generally fulfill four or five economic functions. They offer a mechanism for price discovery, allowing the forces of supply and demand to find a market price for a commodities contract. They provide a mechanism for transparency, where members and participants can see the best offers to buy or sell. They lower transaction costs, by concentrating buyers and seller in one centralized marketplace and by using modern technology for marketplaces to reach large numbers of exchange members and participants, including technologies such as automated order routing, electronic trading, and distribution of market data. If futures contracts are traded (which is normally the case), commodities exchanges offer a risk transfer mechanism where participants can potentially hedge business risk by agreeing to buy or sell a commodity in the future at a specified price. Lastly, if the executed trade is subsequently cleared in a clearinghouse (also the norm), the members and participants gain an additional benefit. The firm executing the trade gains protection against counterparty risk, the risk that the other party in the futures contract could default. The firm instead depends on the creditworthiness of the clearinghouse, which is a much better bet, since clearinghouses rarely default.

Commodities exchanges generally trade spot contracts (contracts for immediate or near-immediate delivery), futures contracts, or options on futures contracts. Some of the futures contracts may settle in cash (no product is delivered but the parties settle the contract monetarily) or physically (the product is delivered to one party).

The prerequisites for a successful commodities exchange are:

1. The commodity must be in sufficient demand in the region or the world.

2. There must be enough buyers and sellers in the commodity to provide liquidity. Without liquidity, i.e. sufficient numbers of participants buying and selling, a commodities exchange does not add much value versus a bilateral agreement between buyer and seller.

3. There must be a reliable scheme for delivery, which often in turn depends upon reliable transportation. For example some U.S. wheat futures contracts that settle physically do so when delivery is made to a grain silo on the banks of the Mississippi. (Thus improvements to Afghanistan's transportation system will increase the probability of success of a commodities exchange.)

4. The commodity must be standardized in some way. In coffee contracts for example, coffee is traded based on various categories of quality.

Commodities exchanges in the region

A recent example that appears to be succeeding is ECX, the Ethiopian Commodities Exchange. In comments this past autumn the CEO of the exchange, Gabre-Maghin, stated "We started trading in April 2008 and, to date, we have 450 private members of the exchange. We have been trading in five commodities: maize, wheat, beans, sesame and coffee." Additionally, she explained that a national payment system has been set up in partnership with seven commercial banks, handling some 150,000 tons of commodities in fourteen warehouses around the country. Thousands of trades have been executed, equivalent in value to up to $5M a day.[167] Vietnam established a coffee exchange in December 2008, the Buon Ma Thuot Coffee Exchange Center (BCEC). BCEC's mission is to create new derivatives products to contribute to the sustainable and stable development for Vietnamese coffee and other agricultural products.

Other examples in the region include the National Commodities Exchange Limited (NCEL) of Pakistan, located in Karachi, which started trading on May 11, 2007, and the Mercantile Exchange Nepal Limited (MEX) which started trading January 5, 2009. NECL supports trading in palm, gold, silver, crude oil, and rice contracts, and recently added an index contract. MEX trades commodities in various categories including food grains (wheat), oil seed (soybean), vegetable oil and fat (crude soybean oil), fiber crops (cotton), other (coffee), energy (crude oil, mini-crude oil, natural gas, heating oil), precious metals (gold, mini-gold, silver), and industrial metals (copper).

Establishing a commodities exchange in Afghanistan

A technological advance that has evolved over the last nearly twenty years has greatly lowered the cost of connecting to exchanges. In 1992 Fidelity Investments and Salomon Brothers developed a protocol to automate the equity trading between the two firms. That protocol, FIX (Financial Information eXchange), has expanded to support nearly all financial instruments, and has become the prevailing standard for connectivity to exchanges, including commodities exchanges. The protocol is governed by FIX Protocol Limited (FPL), a non-profit industry association. Consequently, using FIX exchange, members and participants could connect to the Afghanistan commodities exchange from various U.S. and ISAF trading centers around the world. Much of the liquidity initially needed to make the exchange successful could therefore come from outside Afghanistan. Gradually, as the exchange gained traction, the international business would be complemented by trading from Afghan member firms and participants.[168]

The cost of implementing modern systems for the electronic trading and clearing of commodities has declined significantly over the last ten years. Technology suppliers such as Cinnober, GFI-Group Trayport, NASDAQ OMX, and Patsystems offer commodity exchange solutions, often with the option of including services to operate the technology on behalf of the

[167] Charles W. Corey, "Ethiopia Commodities Exchange Returns Value to Farmers; ECX shows commodity markets can succeed in Africa," *America.gov,* October 7, 2009. (http://www.america.gov/st/africa-english/2009/October/20091007134321WCyeroC0.4070856.html)

[168] Kabul and Kandahar are normally 3.5 hours ahead of London and 8.5 hours ahead of New York. Initially then the exchange's trading session should start in the afternoon and extend into the early evening to facilitate international trading.

exchange. In addition, much of the exchange software could be implemented outside of Afghanistan. Alternately, a secondary system, which is an exact copy of the primary system, could be implemented outside of Afghanistan, lessening the vulnerability of the exchange to disruptions in Afghanistan.

It may make sense for the exchange to outsource the clearing function to a larger clearinghouse. For example Agora-X, a new U.S. commodities Alternative Trading System (ATS) launched in late 2008, uses the CME Group's CME Clearinghouse for clearing.

A technology contract to implement and run a small commodities exchange over a five year period should be in the neighborhood of $25M, not including the cost of the exchange personnel. A small commodities exchange will initially require 20-25 permanent staff.[169]

Contango Markets Ltd. is a specialized consulting firm with expertise in derivatives and commodities exchanges. Per the founder, Clive Furness "We have reviewed the proposals for the establishment of a commodity exchange in Afghanistan in some detail and despite the obvious difficulties are fully supportive of the initiative. It is our belief that the development of a trading infrastructure within Afghanistan covering both food and biofuel-feedstock commodities will encourage a market-based economy that can be supported and developed by international trading partners at a country and private company level. The exchange does not require many products or much volume to gain traction – four to six products and a very modest volume of 150 to 250 lots a day per contract is enough to get things started. What the exchange does require is the support of international partners to deliver education and access for the farming community in Afghanistan."[170]

A viable strategy for an Afghanistan commodities exchange could be to specialize in the niche of oil crops, such as cotton, flax, rapeseed (canola), safflower, sesame, and sunflower.

Consequently, we recommend that, perhaps in partnership with Canada's International Development Agency or the U.K.'s Department for International Development, USAID hire a consulting firm to assess the viability of a commodities exchange in Afghanistan.

In the next chapter we describe additional benefits to producing and using biodiesel in Afghanistan. Some of these benefits are qualitative and some would emerge several years in the future after the success of the first biodiesel plant in Afghanistan is demonstrated.

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[169] Estimate per Wayne Arden.

[170] Clive Furness, email message to Wayne Arden, March 23, 2010.

Additional Benefits

So far we have primarily focused on three benefits of producing biodiesel in Afghanistan: reducing U.S. and ISAF casualties, reducing the cost of the war, and replacing the poppy crop with more benign crops. There are additional benefits if biodiesel is produced in scale. According to a 2004 opinion poll conducted by the Asia Foundation, Afghans responded that the two biggest problems in their local areas were the lack of jobs and the lack of electricity.[171] The production and use of biodiesel in Afghanistan has the potential to address both these issues.

The Afghanistan Biodiesel Market

We suspect that the U.S. and ISAF will have a significant presence in Afghanistan for many years. But suppose the U.S. makes a major commitment to the production of biodiesel in Afghanistan and then begins to withdraw troops, leaving many fewer troops than 100,000. Would the market for biodiesel in Afghanistan collapse, causing farmers to plant poppy again?

In a word, no. First, even if the U.S. aggressively reduces its commitment, the appetite of the U.S. military for fuel is voracious. Assuming that all electrical generators can combust B100, there will be more than enough demand for many years to come. The presence of 25,000 soldiers would result in the consumption of 550,000 gallons of fuel a day, using the Deloitte figure of 22 gallons per soldier per day. About 40%, or 220,000 gallons a day, would be needed to run generators, equivalent to 80.3M gallons a year. The initial plant we have proposed for construction in Kandahar has a capacity of 12M gallons a year, or only 15% of this amount. U.S. troop strength would have to decline to about four or five thousand soldiers for the Kandahar plant capacity to be sufficient to supply all the fuel needed for electricity generation. We have not factored in the additional possibility of using B100 in tactical support vehicles or B30 in tactical combat vehicles.

Afghanistan electrical power generation market

In the Kandahar region

Nevertheless, there is a good non-military market in Afghanistan as well. In the Kandahar region, electricity is generated from two sources, hydroelectric and diesel generators. USAID has funded the renovation of the Kajakai power plant. On October 4, 2009, Kajakai's refurbished Unit 3 went online, generating electricity. Combined with Unit 1, that USAID completed in September 2005, the total power generation capacity of the Kajakai hydro power plant is now approximately 33 MW, of which 12 MW are being transmitted to Kandahar City. The USAID plan is to install a new unit having an 18.5 MW capacity (Unit 2) in the future. The project is currently

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[171] *In The Graveyard of Empires: America's War in Afghanistan,* page 184.

on hold as a subcontractor withdrew from the project. The Kajakai Dam was originally built in 1953 using U.S. Government funds to provide irrigation in the Helmand River Valley. During the mid-1970s, USAID funded construction of the hydro power plant with two 16.5 MW turbine generators, dubbed Unit 1 and Unit 3. The rest of the power in the Kandahar region is supplied by generators. Kandahar has two diesel power plants, one 9 MW and one 14 MW. These two power stations will help to meet increased demands for electricity in the city of Kandahar. The city's long-term power source will be the Kajakai hydro power plant. USAID is also funding the operation and maintenance of diesel power plants in the southern communities of Lashkar Gah, Qalat, Tirin Kot, and Musa Qala, and the World Bank has provided a generator to Ayabak.[172] If these generators were modified to combust B100, there would be a significant long-term market for biodiesel in the Kandahar region, as outlined in Table 20.

Table 22 Power Plant Diesel Generators in Southern Afghanistan

Location	Units	Generator Capacity in MW	Site Capacity in MW	Gallons per hour per generator at full load[173]	Approx total gallons per hour
Ayabak	1	1.10	1.10	78.0	78.0
Kandahar	5	2.20	9.00	159.6	798.0
Kandahar	14	0.85	10.00	60.5	847.0
Lashkar Gah	3	1.25	3.75	88.8	266.4
Musa Qala	1	0.85	0.85	60.5	60.5
Qalat	4	0.88	3.50	64.0	256.0
Tirin Kat	1	0.88	0.88	64.0	64.0
Totals	29		29.08		2,369.9

Assuming operations 24 hours per day and 50 weeks a year, these generators could, in theory, consume about 19.9M gallons per year of B100. But demand during the night is almost always less than during the day, and some units may require more maintenance than two weeks a year.

[172] USAID, Afghan Energy Information Center (AEIC), *Afghanistan's Power Generation and Imports* (www.afghaneic.org/PowePlants.html). Also USAID, South Asia Regional Initiative for Energy, Afghanistan Energy Sector Overview, *Generation of Electricity*.(www.sari-energy.org/PageFiles/Countries/Afghanistan_Energy_detail.asp#generation)

[173] Diesel Service & Supply Inc., *Approximate Fuel Consumption Chart*. (www.dieselserviceandsupply.com/Diesel_Fuel_Consumption.aspx)

However, even 60% of this figure is 11.9M gallons per year, very similar to the capacity of the plant we have proposed to build. Thus ISAF forces could leave the Kandahar region and the local power plant diesel generators could generate enough demand to fulfill the capacity of the plant, assuming the generators are retrofitted to support B100.

In the Kabul region

Kabul has two diesel-fueled power plants: the 100 MW Tarakhil plant, described earlier, and a second, recently refurbished but inefficient plant near Kabul that has been in operation for 25 years. Even if the older plant is shut down and Tarakhil is used only for providing stand-by or peak power, it will be very expensive to run. Using locally produced biodiesel as fuel would be more advantageous than importing oil. The Tarakhil plant consists of 18 Caterpillar 6.3 MW diesel generators. If the Tarakhil plant is run at capacity throughout the year, the plant would consume nearly 60 million gallons of fuel a year. If the plant were to operate using B20, rather than B100, that demand still equates to a biodiesel opportunity of 12M gallons a year.

In Kabul alone, there are about 174,000 diesel (99%) and gasoline (1%) power generators. Almost all of these generators (99.5%) are used by households. During power shortages these generators are a major source of air pollution in Kabul. Over time, the supply of electricity in Kabul will become more reliable, and perhaps the market for household generators will slowly decline. This transition will take many years.[174]

Afghanistan transportation market

Afghanistan produces virtually no petroleum, and has a large number of commercial and diesel vehicles. The total number of vehicles registered in Afghanistan as of 2004 was 402,422, about an 18% increase from 2003 and 129% from 2002.[175] Illegal importation of vehicles is also common and it is estimated that there are about 300,000 of these vehicles in Kabul. If Afghanistan mandates that all commercial vehicles be capable of running B100, and private vehicles B20, then a significant domestic market for biodiesel will gradually be created. Based on registered vehicles, assuming only B20, that market would be at least 56M gallons (213M liters) per year.[176] This market potential is over four times greater than the capacity of the initial plant

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[174] Asian Development Bank, Country Synthesis, Report on Urban Air Quality Management, *Afghanistan*, Discussion Draft, Asian Development Bank and the Clean Air Initiative for Asian Cities Center, December 2006, page 4. (http://www.adb.org/Documents/Reports/Urban-Air-Quality-Management/afghanistan.pdf)

[175] Ibid. Registered vehicles include 83,400 trucks, 40,600 buses, and 197,500 passenger cars, including taxis.

[176] Calculations assume 50% of passenger cars run on diesel, similar to Europe. Buses and trucks achieve 10 mpg and are driven 20,000 miles/year; cars and taxis achieve 30 mpg and are driven 10,000 miles/year. Per a 2007 GE Capital Study medium-duty trucks are driven 20,000 – 25,000 miles/year in the U.S. 123,964 trucks and buses * (20,000 miles per year / 10 miles per gallon) * 20% = 49.6M gallons/year.

we have proposed for Kandahar. Assuming B100 for trucks and buses the market size increases to 255M gallons (963M liters) per year.

Exporting Biodiesel from Afghanistan to Neighboring Countries

There is also a promising biodiesel export market that improved transportation would facilitate. A number of Afghanistan's immediate neighbors must import large quantities of oil, including China, India, Pakistan, and Uzbekistan. Even if Pakistan begins to grow large quantities of biodiesel itself, there will still be a large opportunity for producers in Afghanistan. Pakistan has a population of 176 million, versus Afghanistan's 28 million, and consumes much more diesel fuel.

A number of developed countries in Asia and Oceana import the majority of petroleum they consume: Australia, Japan, Korea, New Zealand, Singapore, and Taiwan. Thailand and Indonesia also import significant quantities of petroleum, and Cambodia has no production. Many of these countries contribute troops to ISAF, including Australia, New Zealand, and Singapore. In December 2009, Korea submitted an application to contribute soldiers to protect civilian aid workers. ISAF countries have an extra incentive to help Afghanistan export biodiesel: if the economy grows and helps stabilize the country, fewer ISAF troops may be needed in Afghanistan.

Transitioning Biodiesel from a Military to a Commercial Market

One of the challenges of our recommendation is that we advocate paying farmers a rate for biodiesel crops that is competitive with poppy. In some number of years, the U.S. military commitment will diminish and the non-military market will become increasingly important. Would Afghan biodiesel producers be able to pay competitive rates to farmers, or to sell successfully to the non-military market? To be successful, would biodiesel producers have to reduce the crop prices offered to farmers?

This problem, if it occurs, would be welcome, since production of biodiesel for military use would have been successful. It is very hard to project the cost of importing petroleum diesel versus producing biodiesel locally ten years in the future in the U.S., let alone in Afghanistan. We believe that the U.S. and ISAF allies would be willing to subsidize sales of biodiesel if these subsidies contributed to the success of the country. The subsidies then could gradually be eliminated over time as biodiesel prices reach market levels. A way to address this potential problem is to now pay "just enough and no more" to persuade a critical mass of Afghan farmers to switch from growing poppy to biodiesel crops. This strategy may lessen the probability of success in the present; it should be fairly obvious to the Afghan farmer that his standard of living will improve in the near future if he switches to biodiesel crops.

197,449 cars * (50% use diesel) * (10,000 miles per year / 30 miles per gallon) * 20% = 6.6M gallons/year. B20 market = 49.6M + 6.6M = 56.2 M gallons/year.

If the plant is staffed by Afghans, security requirements diminish and are not burdensome, methanol recycling technology is used, and chemical inputs are acquired locally then in time the biodiesel sold may be competitive with imported petroleum diesel without international subsidy assistance.

The Afghanistan Energy Policy

Our advocacy of the production of biodiesel leads to the more general question of what energy policy should Afghanistan pursue? The most expedient approach is to buy electricity from neighbors that have electricity to sell. Over time, as the electrical distribution network is expanded and made more redundant, Afghanistan will be able to better hedge the risk of buying a high percentage of electricity from one country. But when much of Afghanistan does not have electricity or only has electricity intermittently, worrying about energy supplier country risk is a luxury.

As a matter of policy, Afghanistan should steadily develop local sources of electricity to supplement or replace its purchase. Afghanistan has untapped reserves of natural gas and regions with potential for hydroelectric power. USAID funded the installation of a 60kW micro-hydropower plant in Dodarak village, Nangarhar Province. The micro-power plant generates enough electricity to supply 1,600 residents plus local business.[177] No comprehensive formal study has been done of Afghanistan's potential for wind power, but in certain parts of the country the extreme changes in temperature create strong seasonal winds. In 2008 a New Zealand firm, Empower, installed American-made wind turbines in the Panjshir valley. The installation is a 17kW, 10-turbine wind farm. An Afghan company formed by Empower and staffed by fifteen engineers, mostly Afghan, will maintain the turbines. Afghanistan should never again build a large centralized power plant such as Tarakhil that relies on imported oil. Large power plants should use natural gas or be hydroelectric. Away from the grid, Afghanistan should try as much as possible to rely on local fuels, including biodiesel, wind and possibly solar. In contrast to these approaches, the power plant for the Chinese copper mine in Aynak will be fueled by coal.

U.S. Diplomatic Advantages if Biodiesel is Produced in Afghanistan

Producing biodiesel in Afghanistan would also create diplomatic advantages, or at least openings, for the U.S.

The production of biodiesel would help the U.S. demonstrate to the Afghan people that the U.S. is doing the utmost to improve Afghanistan, in spite of the inevitable destruction that

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[177] USAID/Afghanistan, "Micro-Hydropower Plant Brings Electricity and Economic Growth to Dodarak Village," *Program Highlights*, May 1- May 15, 2009, page 2. (afghanistan.usaid.gov/proxy/Document.236.aspx)

accompanies war. Also the war in Afghanistan is especially unpopular in many allied countries that have not experienced a direct terrorist attack. In December former U.S. ambassador to ISAF and RAND adviser Robert Hunter told the Council of Foreign Relations (CFR) "In terms of motivation, very few European countries believe that winning in Afghanistan -- that is, dismantling, defeating, and destroying Al-Qaeda and Taliban -- is necessary for their own security."[178]

As stated earlier, we believe that an offer to fund the extension of the Pakistan railroad from Chaman to Kandahar would be well received by Pakistan, and could lead to increased cooperation in pursuing the Taliban in Baluchistan.

In recent years, Russia has increasingly found common ground with the U.S. regarding Afghanistan. In April 2008 Russia signed an agreement allowing transport of non-lethal supplies for U.S. and ISAF troops through its territory. In July 2009 Russia expanded the policy further, allowing the U.S. to ship weapons as well as non-lethal supplies. Russia now holds a great deal of leverage over both U.S. diplomatic policy in the region and U.S. military tactics. Production of biodiesel in Afghanistan would present the U.S. with an opportunity to mitigate a severe Russian problem and bring the intersecting interests of Russia and the U.S. more in balance.

The Russian population suffers from two extraordinarily difficult health problems: a high rate of heroin addiction and AIDS (often contracted from the reuse of dirty needles). Nearly all of the opium consumed in Russia originates in Afghanistan. According to a CNN report there are between one and a half and six million heroin addicts in Russia.[179] A recent Georgetown University report explained that Russian leaders view the drug trade as a primary threat to national security, comparable to more traditional security threats.[180] Russian diplomats have pushed the U.S. very hard to do more in Afghanistan to eliminate the production of poppy. Viktor Ivanov, the Director of Russia's Federal Drug Control, visited Washington D.C. in December 2009 and urged the U.S. to use the troop surge to focus on the elimination of poppy cultivation as heroin addiction in Russia reaches epidemic levels.

Russia would like the U.S. to use tough eradication methods, similar to the approach used in Colombia where coca fields were sprayed aerially with the herbicide glyphosate. The Obama

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[178] Bernard Gwertzman, "U.S. – NATO: Looking for Common Ground in Afghanistan," *Council on Foreign Relations*, December 9, 2009. (http://www.cfr.org/publication/20938/natos_afghan_deployment.html)

[179] Paul Armstrong, "Russia seeks U.S. Help in fight against heroin epidemic," *CNN*, December 9, 2009 (http://www.cnn.com/2009/WORLD/europe/12/08/russia.afghan.heroin/index.html)

[180] Ekaterina Stepanova, *Does Russia Want the West to Succeed in Afghanistan*, PONARS Eurasia Policy Memo No. 61, Institute of World Economy and International Relations, Georgetown University, September 2009.

Administration has argued that this method is counterproductive, destroying the livelihood of Afghan farmers and motivating them to cooperate further with the Taliban.

Growing biodiesel crops in Afghanistan is an approach that both Russia and the United States could agree upon.

Lastly, it is usually best to lead by example. If the U.S. military adopts an aggressive policy to use biodiesel in the field, that stance may assist U.S. diplomats in difficult discussions with China and India regarding climate change.

Helping Afghan Women

Groups such as the Afghan Women's Business Council (sponsored by the United Nations Development Fund for Women) and Afghan Women's Business Federation (started with support of the Afghanistan Ministry of Commerce and USAID) can attest there is a growing participation of Afghan women in agricultural businesses. The promotion of biodiesel and related crop developments in Afghanistan will encourage the growth of women-owned businesses and provide an opportunity for all Afghans to participate in the economic success of biodiesel business.

Conclusion

Biodiesel will Save Lives, Money and Challenge the Opium Trade

Producing and using biodiesel in Afghanistan has the potential to achieve five objectives, any one of which would be very beneficial: reduce casualties, free up troops currently needed for fuel convoys for other assignments, save billions of dollars a year, challenge the opium trade by persuading Afghan farmers to grow biodiesel crops rather than poppy, and, over time, create a new industry for Afghanistan.

Recommendations

Our recommendations are as follows:

1. USDA experts, working closely with the staff of the biodiesel plant, should persuade Afghan farmers to grow safflower, a crop native to the region that is already cultivated in Afghanistan. Safflower is highly drought resistant, and its oil has superior cold temperature characteristics. Safflower oil is one of the best vegetable oils for human consumption, and 90% of the vegetable oils used by Afghans are currently imported. Neighboring countries, in particular India and Iran, are major consumers of safflower oil so an export market may also be possible. Over time, especially if additional biodiesel plants are built, experts should consider introducing one or two second generation biodiesel crops in the mustard family, camelina or pennycress. These crops are suitable for the Afghan climate and require low amounts of water and fertilizer.

2. The first biodiesel plant should be located in or near Kandahar, the largest city in southern Afghanistan, near an ISAF military base. Kandahar Province and adjacent Helmand Province to the west account for 73% of the poppy grown in Afghanistan. Adding two more neighboring southern provinces, Farah and Uruzgan, brings the total to 90%.

3. The plant should have a total nameplate capacity of 15 million gallons per year (56.8M liters), capable of producing approximately 12M gallons (45.4M liters) per year. The yield from safflower and the number of hectares recommended for cultivation (61,500) is consistent with the plant's output. 61,500 hectares is about 39% of the number of hectares devoted to poppy in 2008, and 50% in 2009. Biodiesel production of 12M gallons per year is large enough to achieve three objectives: reduce casualties by a non-trivial amount, provide fuel for electrical generators that support a significant number of troops, and cause a major disruption of the opium trade.

4. The DOD should implement the following policies and programs, working especially closely with two diesel engine and generator manufacturers, Caterpillar and Cummins, and two manufacturers of military vehicles, BAE Systems and Oshkosh Truck:

a. Generators: The DOD should mandate that all new military generators be able to operate using B100. Over time all generators in the field in Afghanistan should be retrofitted or replaced to support B100 (100% biodiesel). Cummins is responsible for a new generation of medium-sized generators, AMMPS (5kW – 100kW) that will begin production later in 2010. Caterpillar supplies the diesel engine and generator used in a large military generator, the DPGDS (902 kW). These generators should support the use of B100 as soon as possible. Existing TQG generators in the field with engines made by John Deere (30 kW and 60 kW), depending on when they were manufactured, already support B100.

b. Future Generators: The DOD should greatly accelerate programs to replace older generations of smaller generators (STEPS) and large generators (LAMPS). Currently these programs are only in the planning stages. The STEPS and LAMPS programs should be run in parallel with the AMMPS program.

c. Support Tactical Vehicles: The DOD should mandate that all new support tactical vehicles be capable of using B100. Once the initial biodiesel plant in Afghanistan is successful and additional plants are built then all support tactical vehicles in the field in Afghanistan should be retrofitted to support B100. This mandate would cover supply trucks in the FHTV, FMTV, LVSR, and MTVR families manufactured by BAE Systems or Oshkosh Truck. All of these trucks use Caterpillar diesel engines; Caterpillar currently supports B30 (30% biodiesel/70% petroleum diesel) in engines C7 (7.2 liters) and larger. Even if not implemented in Afghanistan, the capability of support tactical vehicles to use B100 is likely to be useful elsewhere, including the U.S., helping the military reduce its dependence on petroleum.

d. Combat-related vehicles: The DOD should mandate that all new combat and combat tactical vehicles be capable of using B30, the level of biodiesel that Caterpillar supports currently. Most combat and combat tactical vehicles with diesel engines use engines manufactured by either Caterpillar or Cummins. Cummins currently supports B20. Once the initial biodiesel plant is successful in supplying fuel for generators, the DOD should implement a program to retrofit all combat-related vehicles in Afghanistan to support B30. The DOD should require of AM General that Humvee diesel engines be capable of supporting B30.

The focus of the first biodiesel plant will be using biodiesel in generators. Generators consume 40% or more of the fuel imported into Afghanistan. The Army has determined that during wartime generators become the largest single fuel consumers on the battlefield, more than combat aircraft, tactical vehicles and combat vehicles. But if successful, additional biodiesel plants should be constructed in central and northern Afghanistan. In this case the scope of the program should be expanded beyond generators to using biodiesel in support tactical vehicles and combat-related vehicles.

The U.S. military should have the same flexibility to use biodiesel that exists in the commercial marketplace: B100 for generators, B100 for medium and large trucks and B30 for all other vehicles.

Benefits of producing and using biodiesel in Afghanistan

There are five primary benefits:

1. Reduce casualties. The initial biodiesel plant reduces the number of fuel convoys needed to supply troops in Kandahar reducing casualties by four to five soldiers a year and avoiding 22 casualties over a five year period. The plant will supply the electricity needs of approximately 4,800 to 5,600 soldiers, so even if the U.S. and ISAF draw down forces in the Kandahar region in several years, the plant is still likely to be useful to the military. Biodiesel's potential for saving additional lives in Afghanistan is significant: if the electricity needs of all 100,000 U.S. troops were satisfied through the production and use of biodiesel in generators in Afghanistan then on the order of 62 casualties a year could be avoided, or 310 soldiers over a five year period.

2. Free up troops for other assignments. A side effect of the reduction in convoys is that troops formerly required to protect convoys would be freed up for other more critical assignments. U.S. military resources are finite and the U.S. would likely be reluctant to increase the U.S. commitment beyond the current deployment of 100,000 troops. We have estimated that the biodiesel plant will free up the equivalent of about 120 soldiers each year. Some of these soldiers would be reassigned to protect the biodiesel plant or better protect remaining fuel convoys but the majority could be assigned to other critical missions.

3. Save millions or billions of dollars. The one-time costs required to build the first biodiesel plant total $90M, including the cost of replacing all of the electrical generators that will be supplied by the plant. Because the military pays so much to import a gallon of diesel fuel in Afghanistan, an average of $400 per gallon ($106 per liter) according to the DOD, and the cost of the plant is relatively low, the payback on the initial capital investment is extremely fast. Assuming $400 per gallon to import into Afghanistan either diesel fuel or biodiesel chemical inputs, we project a payback of much less than one month. The plant will save $3.7B in the first year, and $3.8B every year in operation thereafter. If one assumes that the cost of importing diesel fuel is only $41 per gallon ($13 per liter), the payback is still very good, about one year. The U.S. military could build the plant, use it only for a year, throw it away, and the project would still make financial sense: fuel costs would remain constant while saving lives. Under this scenario the plant would save $90M per year starting in the second year of operation, and the cost of fuel would decline from $41 to $33.50 per gallon.

   By contrast, the DOD has awarded Oshkosh $3.9B for the production of 6,619 M-ATVs (Mine Resistant Ambush Protected All-Terrain Vehicle), designed specifically for the conditions in Afghanistan. The M-ATV is designed to lower casualties by offering soldiers a better protected vehicle then Humvees or up-armored Humvees. But the M-ATV is heavier than the vehicles it replaces, increasing the number of fuel convoys required, thus partially offsetting the reduction in casualties. The biodiesel capital expenditures of $90M are only 2.3% of the M-ATV procurement costs.

The avoidance of fuel convoys will save additional money. During one month, June 2008, the military lost in Iraq and Afghanistan 44 trucks and 220,000 gallons of fuel, a $28M loss.

Lastly in the $400 per gallon scenario, even if plant production is only 1.23M gallons (5.7M liters) a year, nearly 90% less than the target of 12M, the plant still achieves payback in about a year. In this case only 911 farmers would have to switch from poppy to safflower. In the $41 per gallon scenario, about 8,900 farmers must be persuaded to achieve payback in about a year, still an achievable goal, since USAID trained more than 160,000 farmers across Afghanistan in FY 2009. Fewer farmers would have to be persuaded if those with larger than average land holdings switch.

4. <u>Challenge the opium trade.</u> The initial plant has the potential to reduce the cultivation of poppy up to 50%. Opium has been a source of revenue for the Taliban and has stimulated government corruption and organized crime. The opium trade has a pernicious effect on the Afghan agricultural and business community. Reducing the influence of the opium trade is one of the most difficult challenges facing the Afghan government, ISAF, and the U.N. Afghanistan produces 90% of the world's opium. The biodiesel plant will complement U.S. policy, which is focused on interdiction and persuasion – persuading Afghan farmers to substitute other crops for poppy.

5. <u>Create a new industry, production and use of biodiesel, for Afghanistan.</u> Of the five benefits, this one is perhaps the least certain, but no less important. If ISAF forces were to withdraw from southern Afghanistan, the biodiesel plant is appropriately sized to supply fuel to diesel generators in the region. But other local markets exist, including power plants in Kabul and other parts of the country, the many thousands of small generators used by families and small businesses, plus the vehicle market of cars, trucks and buses. Afghanistan has significant sources of coal and natural gas, but not oil. Importing expensive petroleum from outside the country is a drain on Afghanistan's fragile economy. In addition there is a potential export market, since a number of Afghanistan's neighboring countries, China, India, Pakistan, and Uzbekistan, must import large quantities of oil.

Timeframe

The plant can be built and placed into operation in thirteen months, assuming the U.S. and Afghanistan governments act with a sense of urgency and prioritize resources for the project.

Disadvantages

We recognize a significant trade-off: production and use of biodiesel will require the military to manage logistics for three fuels types (diesel fuel, aviation fuel, and biodiesel) rather than only two. Various families of combat and support vehicles may stipulate different maximum percentages of biodiesel. Biodiesel requires increased monitoring due to its somewhat shorter storage life than petroleum diesel. The military must import the chemical inputs required by the plant, but that challenge is not substantially different than importing diesel fuel, water, or other materials. The military's logistical arm, the Defense Logistics Agency (DLA) would need to determine the optimum methods for procurement and delivery of these inputs.

Note that the initial step is easier, since we have recommended that electrical generators be capable of running any mixture of biodiesel, from none to B100. Overall we believe the advantages summarized above far outweigh the disadvantages. If local biodiesel production were disrupted, the military could revert back to the normal approach of managing only diesel and aviation fuel. In other words, use of biodiesel in Afghanistan is not an irreversible decision.

Why the case to build a biodiesel plant can further improve

The strongest improvements to the business case relate to chemical inputs. Hundreds of millions of dollars a year can be saved if chemical inputs in general, and methanol in particular, are procured locally rather than imported. In addition the use of methanol recycling technology can reduce the amount of methanol needed by about half.

Also, labor costs can lowered if over time the American plant staff and the eighteen security officers are replaced with competent Afghans, or if fewer security officers are needed. We have not valued the plant's principal byproduct, glycerin, which has a variety of uses. We recommend that the military implement a pilot program to test using glycerin in fuel cells to generate additional electricity. Since methanol is not manufactured in Afghanistan a clever alternative would be to use ethanol, rather than methanol, and to produce the ethanol in a small plant adjacent to the biodiesel plant. This approach would create additional business for Afghan farmers. Another potential revenue source is carbon credits, if the Kyoto Protocol is extended or if Afghanistan implements or participates in a regional emissions trading program. Finally, if additional plants are built elsewhere in Afghanistan it should be possible to retrofit generator diesel engines to run on B100, rather than buying new ones.

Biodiesel, Hybrids, and other DOD Efforts to Reduce Petroleum Dependency

The DOD has made significant progress in the U.S. in reducing dependency on oil but very limited progress outside the U.S.

The Army and Marines' lack of progress in deploying hybrid technology in military vehicles is especially troubling. New York City first started testing hybrid buses in 1998 and now 38% of the New York City bus fleet consists of diesel hybrid-electric buses. PACCAR (the Kenworth and Peterbilt brands), Navistar (International), and Daimler Freightliner sell medium and heavy hybrid trucks in the three largest truck classes: Class 6, Class 7, and Class 8. Class 6 and Class 7 hybrid trucks are now being manufactured in volume. In spite of rapid progress in the commercial sector, efforts to deploy diesel-electric hybrid technology for vehicles in the Army or Marines are moving slowly, even though both BAE Systems and Oshkosh Truck have proposed hybrid trucks to the military. If hybrid vehicles were in the field now in Iraq or Afghanistan they would be saving lives and billions of dollars in fuel expenses a year. Much of Iraq is hot, dusty, and flat, not that different from the American southwest, where hybrid trucks are on the road today.

The military's slow progress in deploying new generations of more efficient generators is also troubling. More efficient generators will reduce fuel consumption and save lives.

The Army's prioritization of projects seems confused. The Army's efforts to take advantage of hybrid technology are primarily focused on the development of a hybrid electric Humvee, yet the Army seems to have forgotten the lessons of the First Gulf War. Three out of the four top users of fuel during the First Gulf War were tactical transport trucks, not tactical combat vehicles such as the Humvee.

We do not understand the Army's lack of both urgency and success in deploying proven technology such as hybrid technology and more efficient generators. By contrast, over several years at the start of WWII, the military developed and deployed not one but two tank models, the M3 "General Lee" and the M4 "Sherman" by leveraging existing technologies and manufacturing processes. There is one modern case where the Army and Marines did succeed in moving quickly. From inception in 2008 to full production in late 2009 the program to specify, select a manufacturer and deploy the M-ATV, optimized for the conditions in Afghanistan, occurred within two years.

Biodiesel and hybrid technology are symbiotic technologies. They are also fairly mature technologies, having steadily been improved over the last decade. There are approximately 170 American biodiesel companies collectively producing hundreds of millions of gallons, and thousands of diesel-electric hybrid trucks and buses are in use. When used together, hybrid technology and biodiesel offer a double benefit, reducing oil consumption via the dual strategies of improved efficiency and substitution of a renewable fuel for petroleum.

More generally the production and use of biodiesel in Afghanistan is consistent with other military efforts in progress to reduce oil consumption, including Net Zero Energy (NZE) projects, which are a joint effort of the DOD and DOE.

Two Complementary Efforts: Commodities Exchange and Railroad Extension

We have also recommended that the Administration consider two additional complementary projects.

1. Afghanistan does not have a rail network. The U.S. should consider a joint project with Pakistan to extend the Pakistan rail system 115 km (71.5 miles) from its current terminus in

Chaman, Pakistan to Kandahar. This extension has long been desired by Pakistan, and would lower the cost and time of transporting military supplies from Pakistan ports to Kandahar and points north. It would also most likely lower American casualties, since higher capacity freight trains could be used to transport supplies rather than truck convoys. Chaman is located in the Baluchistan region of Pakistan, a sanctuary of the Taliban. The U.S. has been frustrated by Pakistan's lack of interest in seriously pursuing the Taliban in Baluchistan. But, a project to extend the railroad could present the U.S. with an opportunity, where the U.S. asks Pakistan for increased cooperation in Baluchistan in exchange for working with Pakistan to build the railroad.

2. USAID should fund a study to investigate the creation of a commodities exchange in Afghanistan. A commodities exchange could bring added visibility to Afghan agricultural products, including biodiesel crops and biodiesel itself. In the last several years, new commodities exchanges have been successfully launched in two countries in the region, Nepal, and Pakistan. Ethiopia, which, like Afghanistan, is a Least Developed Country (LDC), has also launched a commodities exchange.

Additional Benefits

As we've attempted to show, there are many direct economic, political, and personnel benefits to building a biodiesel plant in Afghanistan. There are other indirect potential benefits.

We have proposed that the U.S. firm responsible for operations and maintenance of the plant hire increasing numbers of Afghanistan employees over time. A byproduct of harvesting oil, safflower meal, is a viable livestock food additive and useful to Afghan farmers. The growth of a biodiesel economy should create new opportunities in general, including opportunities for Afghan women. Production and use of biodiesel in Afghanistan will contribute towards a logical energy policy for the country.

Russia has millions of heroin addicts, and considers the opium trade a threat to the national security of the country. Russia has urged the United States to do more to reduce the cultivation of poppy in Afghanistan. A biodiesel project is likely to be well received by Russia. U.S. and ISAF success in Afghanistan is partially dependent upon Russia, since Russia permits ISAF forces to ship supplies across Russian territory.

Lastly, if influential American diesel generator and engine manufacturers such as Caterpillar and Cummins support B100, their improved support of biodiesel will accelerate the adoption of renewable fuels in general and biodiesel in particular in the U.S. Support by Caterpillar, Cummins and other diesel engine manufactures of B100 may also create additional jobs. We strongly believe that national policy aside, it is in the best business interests of Caterpillar and Cummins to support B100. They currently suffer a competitive disadvantage in competing with other large companies that support B100, especially in Europe. Other successful American companies that manufacture diesel engines including AGCO, CNH's American subsidiaries IH

Case and New Holland, FME, John Deere, and PACCAR's DAF subsidiary support B100 in most models. On January 11, 2010, the DOE awarded Cummins $53.8M for two separate projects: one to increase the efficiency of long-haul (Class 8) freight trucks, and a second to increase the fuel economy of passenger vehicle engines and power train systems. Of the eight companies granted funding, Cummins' amount was the largest: 29% of the $187M awarded by the DOE. Given U.S. Government support of Cummins, Cummins should be eager to support B100.

How the Afghanistan Biodiesel Project Could Fail

There a variety of reasons why our recommendations could fail.

- USDA experts, working with the staff of the biodiesel plant, may fail to persuade enough Afghan farmers to switch from poppy to biodiesel crops.
- U.S. and ISAF forces may fail to defend the plant against attack by the Taliban, leading to delays or interruption of production. In order for the plant to succeed, ISAF and the U.S. military must be able to defend the Kandahar plant and the region must be secure enough to allow the conduct of commerce in many parts of Kandahar Province and Helmand Province.
- U.S. and ISAF forces could withdraw before success can be demonstrated. A Taliban detainee told his American interrogators "You have the watches but we have the time."[181]
- The U.S. military may be reluctant to change established logistical procedures, hindering the spread of biodiesel in Afghanistan.
- Lack of teamwork among Washington agencies could delay implementation, reducing the probability of success.

There are two fundamental difficulties that are not under U.S. or ISAF control that could lead to failure.

First, the biodiesel plant may be perceived by Afghans living in Kandahar and Helmand Provinces as an effort of the Karzai government, and the Karzai government may fail to win the confidence of the Pashtuns. The Afghan government has struggled to provide services outside of Kabul and could fail to persuade a critical mass of Pashtun farmers, villages, and tribes to work productively with the plant management. Abdulkader Sinno has stated "If history is any guide, whoever mobilizes the Pashtuns rules Afghanistan and Afghanistan cannot be ruled without

[181] *In The Graveyard of Empires: America's War in Afghanistan,* page 325.

their consent."[182] Although the Pashtuns are a majority in Kandahar and Helmand Provinces they are a minority overall – Afghanistan is comprised of a variety of ethnic groups of varying religious, regional and political affiliations speaking different languages, including Pashtun, Uzbek, Tajik and Hazar, Aimak, Baluch, Turkmen and others.[183] The creation of a stable multi-ethnic nation state, Afghanistan, may not be possible while the government is fighting an insurgency. The Pashtun Taliban are determined to expel the U.S. and ISAF, even if their exit from Afghanistan reduces the standard of living for many Pashtun and leads to a chaotic state. On March 27, 2010, the New York Times reported that the security in Kandahar city is at its worst since 2001. Shahabuddin Akhunzada, a tribal elder from Kandahar city, said "The Americans, the international community, all the military forces have lost the people's trust."[184]

Although there are recent signs that Pakistan has become a more reliable ally to the U.S. and ISAF in the Afghanistan war, it is still unclear whether Pakistan's intelligence service, the Directorate for Inter-Services Intelligence (ISI), continues to support the Taliban, providing the Taliban and by extension Al Qaeda sanctuary in Pakistan. Ahmed Rashid in his book "Descent into Chaos" describes Pakistan's approach in dealing with the U.S. during the period Musharraf was in power as "First say yes and later say but."[185] If the Pakistan military continues to view the Taliban as their proxy in Afghanistan and continues to support or fail to confront religious extremism within Pakistan, then success will be elusive.

We believe that if the Afghanistan Government collapses it is unlikely that the U.S. will be secure. For now there is no turning back.

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[182] Abdulkader Sinno, "Explaining the Taliban's Ability to Mobilize the Pashtuns," in Robert D. Crews and Amin Tarzi editors, *The Taliban and the Crisis of Afghanistan* (Cambridge, MA: Harvard University Press, 2008), page 59.

[183] The affiliations of Afghans are complex. The two major languages are Pashto and Dari, a dialect of Persian, but some Pashtuns speak only Dari and some Tajiks only Pashto. Most Afghans are Sunni Muslims but the Hazaras are mostly Shia. One can hope that over time, with improved communications and transportation infrastructure, the overlapping complexity of these affiliations will lead to a stronger national identity.

[184] Carlotta Gall, "Kandahar, a Battlefield Even Before U.S. Offensive," *The New York Times*, March 27, 2010. (http://www.nytimes.com/2010/03/27/world/asia/27kandahar.html)

[185] *Descent into Chaos*, page 28.

Final Thoughts

Although the $90M investment needed to fund a biodiesel plant in Afghanistan is small compared to other war expenditures, and the potential benefits are dramatic, success is not guaranteed. This project is riskier than a conventional business project. Consequently, we have recommended that the U.S. Government fund and own the biodiesel plant, with the objective of selling to a private company when the plant is successful. The only customer of the first plant will be the U.S. military.

The Afghanistan biodiesel project spans the interests of multiple governmental agencies: the Department of Agriculture, Department of Defense, Department of Energy, Department of State, and USAID. Since many agencies are involved, we believe the project will require a champion with the support of the Administration who can motivate these disparate agencies to work together with a sense of urgency.

It may require several growing seasons to fully influence farmers currently growing poppy. The U.S. challenge in Afghanistan is extraordinarily difficult. Producing and using biodiesel in Afghanistan will increase the probability of success.