Assessing Biodiesel in Standby Generators for the Olympic Peninsula

Final Report

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Executive Summary

The purpose of this report is to assess the merits of renewable biodiesel fuel in standby generators for certain end-use customers of Bonneville Power Administration (BPA). The impetus for the assessment is to help meet electric transmission needs on the Olympic Peninsula in the State of Washington with distributed energy resources. A combination of energy efficiency and demand response options may be able to mitigate forecast transmission constraints in winter months.

Biodiesel is a renewable energy resource produced primarily from vegetable oils, usually soybean oil. In fact, Rudolf Diesel demonstrated his engine over 100 years ago with peanut oil. While petroleum has been the dominant fuel for diesel since then, biodiesel has grown rapidly in the last several years in transportation fleets, including BPA.

There is limited experience of fueling standby generation with B20, which is a blend of 20% biodiesel from vegetable oils and 80% from petroleum diesel. For B100 (100%), there is little experience in fleet applications and an isolated example for standby generators.

As a drop-in fuel, B20 presents relatively few problems for storage tanks, fuel lines and engines. Care needs to be taken during initial hours of operation to clean filters more often than usual, due to high solvent characteristics of biodiesel. When weather drops below freezing, care is needed to maintain cold flow characteristics, just as with #2 diesel. However, solutions exist in the form of additives, blending in #1 diesel, underground tanks, and tank heaters. Other management concerns are fuel oxidation and algae growth, though these situations also develop with diesel and may resolved similar to diesel.

The technical considerations for B20 are multiplied with B100. More precautions are worthwhile with B100 for engine parts, engine operations, and storage. It may be appropriate to replace rubber fuel hoses and seals for old engines slated for B100. Shelf life is a key consideration with B100 when fuel is stored longer than six months.

A principal benefit of biodiesel is reduced air emissions. Except for nitrogen oxides, emissions decline for B20 compared to diesel. Emissions decline even further for B100, including no sulfur emissions, half the particulate and carbon monoxide emissions, plus as much as 90% reduction in many hydrocarbons. NOx increases about 2% with B20 and about 10% with B100.

In terms of total pounds of emissions of all pollutants added together, the net reduction is significant. This is particularly the case when life cycle emissions are taken into account for biodiesel with a 78% reduction in carbon dioxide. Should a spill occur, B100 is not hazardous and degrades rapidly. An emissions permit will be needed for standby generators when changed from emergency to demand response operations.

A principal biodiesel reservation is cost. Delivery cost of B20 will be about 20-30 cents per gallon more than diesel. B100 will cost about a dollar more per gallon. However, there is anecdotal evidence of cost savings due to higher lubricity.

There is also some evidence of improved fuel efficiency even though biodiesel contains a lower heat value in BTUs per gallon. Until more experience accumulates, it is appropriate to estimate slightly more fuel consumption for B20 and about 10% more than diesel for B100.

In terms of comparative costs a typical 400 kW standby generator with a load of 300 kW, the use of B20 will cost 16% more than diesel and B100 will cost 66% more. The annual costs summarized in the table below include service costs for maintenance along with fuel costs. The table compares costs for a typical or model generator, then 16 generators cumulating 4.8 MW and the cost per megawatt hour.

Comparative Costs for One and A Fleet of Standby Generators

Fuel Type	One 400 kW Unit at 300 kW Load ($/yr)	16 Units for 4.8 MW Total Load ($/yr)	$/MWh
Diesel	$4,368	$69,888	$152
B20	$5,078	$81,242	$176
B100	$7,263	$116,205	$252

Regarding the objectives of this analysis, biodiesel can certainly be used in standby generators. Furthermore, there can be confidence that standby generators with biodiesel should reliably serve as demand response alternatives to meet transmission peak loads.

Given these findings, the following recommendations are offered for consideration by Bonneville Power Administration.

1. Proceed to use B20 in nearly any standby generator with appropriate attention to fuel management issues.

2. Proceed to use B100 in certain standby generators subject to review of engine specifications with diesel manufacturers and closer attention to fuel management issues.

3. Obtain necessary environmental permits prior to operating generators other than for emergency purposes and then manage operations for noise, visibility and emissions mitigation.

4. Operate generators as much as economically and environmentally justified for electrical transmission and distribution purposes with careful attention in the cases of B100 to consume fuel within six months of delivery.

As a result of this assessment, BPA can proceed to trials of B20 and B100 with standby generators on the Olympic Peninsula, aware of the range of costs and benefits and prepared to document the outcomes of these trials for future application to the Non-Wires Solution challenge.

Assessing Biodiesel in Standby Generators for the Olympic Peninsula

I. Introduction

Diesel generators represent a potential distributed energy resource for power reliability, particularly at remote locations in a utility service territory. They also provide an option for economy dispatch under certain spot market conditions of the electric grid. When combined with energy efficiency and other strategies, demand response arrangements with backup generators fueled by biodiesel may mitigate transmission and distribution investments for electricity supply.

Biodiesel is produced from various vegetable oils, such as soybean oil, as well as from animal fats and used cooking oil. Note the term diesel in this report will refer to petroleum diesel.

History is on the side of biodiesel. The diesel engine was developed in 1895 by Dr. Rudolf Diesel with full intention of operating on vegetable oil. When the diesel engine was exhibited at the Paris World Exhibition in 1900, it ran on peanut oil.[1] Europe leads the world in the use of biodiesel with an estimated consumption of 200-300 million gallons per year, which is about 10 times the level of consumption in the U.S.[2]

Transportation Fleet Applications. Biodiesel has been adopted in over 400 transportation fleets around the country and is expanding in use rapidly. There is growing biodiesel consumption in the Pacific Northwest for fleets of the transportation departments department of Seattle, Olympia, Ft. Lewis, McCord Air Force Base and numerous bus school systems, public transit systems, waste management companies and other firms operating diesel equipment.[3]

Bonneville Power Administration is using biodiesel in its transportation fleet. Other utility fleets using biodiesel include Alabama Power, Colorado Springs Utilities, Florida Power and Light, National Grid and Westar Energy. The fleets typically use B20, which is 20% biodiesel and 80% diesel.

Power Generation Applications. Biodiesel is starting to catch on with power generation. Several projects were undertaken in California a few years ago. It is increasingly common in generators at U.S. national parks and a recent application includes the United States Environmental Protection Agency.

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[1] Joshua Tickell, *From the Fryer to the Fuel Tank*, BookMasters, 2000, p. 23.
[2] National Biodiesel Board, Letter from Scott Hughes, State Regulatory Affairs Director to John Geesman of California Energy Commission, March 28, 2003.
[3] Tim Adams, Pacific Northwest Energy, personal communication, April 23, 2004.

In 2001, St. Mary Hospital in southern California began using biodiesel as the backup fuel for boilers and the primary fuel for standby generators. The primary fuel for the boilers is natural gas, although if prices are high enough B100 is used. B100 is the only fuel for the standby generators, since it is served from the same 15,000-gallon tank serving the boilers. B100 was tested and approved by the air quality management board for a formulation including an additive for NOx reduction. B100 has been the only fuel serving the seven standby generators totaling 1,765 kW.[4]

In 2001, Riverside Public Utilities cooperated with the University of California – Riverside in biodiesel project. A total of 6 MW from three 2 MW generators was fueled by B100, which is 100% biodiesel. B100 is also called neat biodiesel. The generators were tested weekly to help insure availability in the event of a power emergency. The units are no longer fueled with biodiesel.[5]

In 2002, Alameda Power and Telecom acquired four emergency generators of 1.5 megawatts (MW) each for a total of 6 MW. They were supplied with B20 to help keep Alameda a "clean and green community."[6] Starting in 2004, the utility discontinued the use of biodiesel and substituted a different formulation of diesel with an additive to reduce NOx.[7]

Since 2001, a blend of 2% to 5% biodiesel has been used by Blooming Prairie Public Utilities in Minnesota to operate a 2 MW and another 1.2 MW generator when needed by the Southern Minnesota Municipal Power Agency.[8] The agency is comprised of 18 municipal utilities of which 13 operate generators upon request. The units total 190 MW and typically run 300-400 hours per year for peak load and unplanned outage conditions.[9]

Scott Air Force Base in Southern Illinois operated several generators on B20. They were operated for monthly testing and then for only 10 minutes at a time. After twelve months of little use the fuel did not perform. They have discontinued use of B20 in generators but continue its use with satisfactory results in the transportation department. They recommend storing biodiesel for no longer than 6 months.[10]

Since 2001, Mt. Rainier National Park has been burning B50 in two generators. The 90 kW units provide continuous power to a remote section of the park during the summer months when that area is open to the public. Each unit runs twenty-four hours per day for about two weeks and then undergoes maintenance while the other unit runs. The park operates over 50 diesel vehicles, including snowplows, on B20 without any issues.[11]

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[4] Bill Chihak, "St. Mary Medical Center Running Clean and Green," and personal communication, June 15, 2004.
[5] National Biodiesel Board, "Biodiesel for Electrical Generation," market report, updated. www.biodiesel.org.
[6] Alameda Power and Teleom, "Alameda Power and Telecom Switches to Biodiesel for Power Generators." Press release, July 11, 2002.
[7] Jim Baak, Powel Group, personal communication, May 13, 2004.
[8] Tom Swenson, Blooming Prairie Public Utilities, personal communication, April 20, 2004.
[9] Todd Machin, Southern Minnesota Municipal Power Agency, personal communication, May 4, 2004.
[10] Sergeant Trout, Scott Air Force Base, personal communication, April 27, 2004.
[11] Joel Rodriquez, Mt. Rainier National Park, personal communication, May 11, 2004.

Starting in 2002, Glacier National Park has operated four units with B20. No cold flow additives are included, although the diesel portion is 70% of #2 oil and 30% of #1 oil. The effect of #1 is to improve the flow characteristics in winter. They have experienced no problems with the generators or with the 60 diesel engines in their fleet.[12]

Starting in January 2004, EPA began using B20 at a facility on the Olympic Peninsula. The U.S. Environmental Protection Agency uses biodiesel for heating a laboratory building and for a standby generator. The generator is a 375 kW unit that operates once a month for about 15 minutes, but not loaded. No additives are applied to the fuel. It is stored in a 10,000-gallon tank that is underground. Due to the boiler heating of the building, the tank is refilled about twice a month in the winter. Biodiesel has performed well.[13]

A. Study Purpose

Bonneville Power Administration (BPA) is interested in exploring the use of biodiesel in diesel generators. While BPA has been using B20 in part of its transportation fleet, there is no experience with power production. BPA wants to examine the advantages and disadvantages of biodiesel for remote portions of their service territory as a distributed energy alternative to transmission and distribution investments. One particular location of interest is the Olympic Peninsula in Washington State, where BPA is testing distributed generation as one of a portfolio of actions to defer a transmission construction projected forecasted to be needed in 2008 to meet one in twenty year winter peak loads. The study will examine the advantages and disadvantages of biodiesel as a potential fuel for 5 megawatts of existing diesel generators.

B. Study Scope

The study scope will focus on the BPA situation and the potential application of biodiesel fuel in existing customer owned backup generation. The analysis will be based on differences between operating backup generators with biodiesel compared to petroleum diesel. The study will consist of five parts.

1. General Background on Biodiesel
2. Technical Considerations of Biodiesel in Backup Generators
3. Environmental Implications with Biodiesel
4. Economic Costs and Savings
5. Conclusions and Recommendations

The study is based on research of biodiesel applications in diesel engines in generation applications, but also in transportation where there is much more experience and information. This is supplemented by primary research involving interviews with diesel generation manufacturers, biodiesel producers and distributors, environmental officials, facility managers, energy managers, and others.

[12] Lou Summerfield, Glacier National Park, personal communication, May 13, 2004.
[13] Robert Manor, U.S. Environmental Protection Agency, personal communication, April 27, 2004.

II. General Background

A. Standby Generator Markets

Nationally over 100,000 end-use customers have standby generators. Based on a 2001 survey of customers, the installed capacity of over 80,000 MW represents about 10% of U.S. generating capacity. About 50% of the backup generation is found in large engine sizes of over 20 MW and nearly 40% over a third in 2-20 MW as seen in the table below.[14]

Table 1
Standby Generation in the U.S.

Unit Capacity	Estimated U.S. Capacity (MW)
20,000 kW +	42,800
2,000-20,000 kW	32,100
100 – 1,999 kW	5,400
< 100 kW	200
Total	80,500

Standby generators are found predominately in large commercial and industrial facilities. These include such facilities as airports, casinos, data centers, food processing facilities, high rise buildings, hospitals, manufacturing plants, military bases, police stations, prisons, refineries, telecommunication centers, warehouses, wastewater treatment plants, water treatment plants and many other facilities.

The technical potential for standby generators to participate in demand response programs is about half the installed standby generation capacity in New York State. This represents about 5% of the installed capacity of central generation available to the New York Independent System Operator.[15]

For the Olympic Peninsula, the goal is to partner with customers that operate about 15 MW of backup generation capacity as part of a portfolio of peak load management efforts totaling about 60 MW. This is a long-term goal for partnership by 2008. The goal for 2004 is to establish partnerships with about 5 MW of capacity. It is hoped to have partnerships in place and generators participating before the end of the summer of 2004. Operations will run-up from dry runs to aggregated simultaneous dispatch by the end of the year.

Prospects for participation in 2004 have been identified. Partners are being recruited in parallel with the research efforts of this study. Table 2 summarizes some of the key

[14] Leland Keller, "Distributed Generation: Aggregation, Dispatch and Control," 3rd Annual International Symposium on Distributed Energy Resources, November 1, 2001.
[15] Based on New York ISO press release of April 8, 2004 and study by Electrotek Concepts, "Aggregation of Distributed Generation Assets in New York State," National Renewable Energy Laboratory, NREL/SR-560-34779, January 2004, p. viii.

characteristics of the prospects, while attempting to protect confidentiality. One location is new whose engine and fuel storage characteristics are yet to be determined (TBD).

Table 2
Prospective Participants

Site	Facility	Generator	Capacity (kW)	Load (kW)	Tank Capacity (gallons)	Tank Location
1	Casino hotel	Onan	1,000	750	2,000	Outside
2	Casino casino	Onan	350	125	Same tank	
3	Wastewater pump	Kohler	400	240	300	Outside
4	Hospital old	Onan	350	240	5,000	Outside
5	Hospital new	Onan	350	75	Same tank	
6	Offices	Kohler	125	65	100	Inside
7	Substation	Kohler	125	60	100	Inside
8	Offices	Generac	250	75	200	Outside
9	Casino	Planned	750	600	Planned	Planned
10	Fire dept.	Generac	175	70	200	Outside
11	Police dept.	Generac	50	35	75	Outside
12	Water pump	Detroit D	900	800	1,000	Outside
13	Offices	Onan	75	53	75	Outside
14	Civic center	Onan	125	90	100	Outside
15	Water pump	Onan	350	200	300	Outside
16	Hospital	Onan &CAT	1,375	1,375	3,000	Outside
	Totals		6,750	4,853	12,450	

The prospect list adds to 6.8 MW of rated capacity and 4.9 MW of connected load. The average generator is rated at about 400 kW with an average connected load of about 300 kW. These figures include increasing the connected load for some generators to an average of about _ of capacity.

The median generator capacity is 350 kW and the median load is 200 kW.

Tank capacities range from 5,000 gallons to 75 gallons. The average tank is 960 gallons and the median tank is 200 gallons. In several cases one large tank serves two generators.

B. Biodiesel Fuel Production

Biodiesel is produced in a simple refining process from several possible feedstocks. These include:

- Virgin oils derived from soybeans and other seed crops, such as canola seeds and mustard seeds,
- Recycling cooking or yellow grease that typically comes from soybean oil, and
- Animal fats from rendered carcasses.

Methyl Esters. The biodiesel production process is well understood and long standing. Biodiesel, or its chemical name, methyl ester, is produced through a chemical process known as transesterification. This catalytic process is characterized by low temperature (150 F), low pressure (20 psi) and a high conversion factor (98%) and minimal reaction time.

In the process, the fat or oil is reacted with an alcohol, such as methanol. The reaction takes place in the presence of a catalyst such sodium or potassium hydroxide, which has been mixed already with the methanol. There are two principal outputs. One is glycerine that can be used in soaps and other products. The main output is methyl ester, the chemical name for biodiesel. The methanol is charged in excess quantities to allow quick conversion and recovered for reuse in the process.[16]

Oilseed Feedstocks. For large quantities of biodiesel the main feed stock is vegetable oil. Biodiesel is also produced from animal products. These include lard, grease and tallow. There are some advantages in terms of low cost relative to vegetable oils. But there are disadvantages in terms of consistency, as one might imagine when considering the variety of animals in rendering facilities and types of grease from restaurants.

The principal feedstock for biodiesel is soybean oil and is the focus of this project, since it is the most readily available. A byproduct of producing soybean oil is a meal left over from the crushed beans. This product also has value, primarily as a food supplement for cattle and other farm animals.

Some recognition should be given to other vegetable oils since they may have certain advantages over soybean oils. Rapeseed is used to produce biodiesel in large quantities in Europe. Canola seed plants, which are related to rapeseed plants, produce oils that can be refined into biodiesel. Another source is mustard seed. None of these are grown extensively in the U.S. for biodiesel at this time.

However one attraction is that these other seed crops produce three times as much oil as compared to soybeans.[17] Partly for this reason, one manufacturer of biodiesel in Colorado is contracting with for the production of mustard seed and canola seed for exclusive use.[18] Similar plans are afoot in Washington and Oregon.

Of the many types of oilseed grown and harvested, soybeans are the most significant crop, by an extremely large margin, as shown in the Table 3.

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[16] "What is Biodiesel," *Biodiesel on the Road to Fueling the Future*, Hart/IRI Fuels Information Service, 2001, p. 10-11.
[17] Kim Janssen, Illinois Department of Agriculture, personal communication, March 26, 2004.
[18] Personal conversation with John Long, Blue Sun Biodiesel, March 13, 2004.

Table 3
Oilseed Crops Harvested in the United States in 2003

Crop	Acreage in 2003 (1,000 acres)[19]
Soybeans	72,321
Sunflowers	2,197
Peanuts	1,312
Canola	1,068
Mustard seed	107

Soybeans are the principal source for biodiesel as observed from the following statistics:

- 29 states produce soybeans
- 400,000 farmers produce soybeans
- 38 bushels per acre
- $5.40/bushel. [20]

It takes about 7.3 pounds of soybean oil to produce a gallon of biodiesel.[21] Another conversion average is:[22]

- 1 bushel of soybeans produces 11 pounds of soybean oil
- 11 pounds of soybean oil produces 1.5 gallons of biodiesel
- Thus 1 bushel of soybeans results in 1.5 gallons of biodiesel.

Energy balance is most favorable for biodiesel. For every unit of fossil energy used to produce biodiesel, a total of 3.37 units of energy from biodiesel are created.[23]

Feedstock Producing States. The top producing states in declining order are Iowa, Illinois, Minnesota, Indiana and Nebraska. There is no recorded production of soybeans in the western states including the Pacific Northwest.[24]

There is interest in producing biodiesel in the states of Oregon, Washington and Idaho.[25] State agencies have been promoting the development of crushing facilities to turn bean crops into vegetable oils and a meal as a way to stimulate agricultural economies through more crop diversity.[26] There are at least three biodiesel production plants that are being considered for the

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[19] U.S. Department of Agriculture, "Crop Production," National Agricultural Statistics Service, March 10, 2004, p. 6.
[20] U.S. Department of Agriculture, *Agricultural Statistics: 2003*, U.S. Government Printing Office, 2003, III-13.
[21] U.S. Department of Energy, "Biodiesel Fuel Market," Alternative Fuels Data Center, undated, www.afdc.doe.gov.
[22] Shane Tyson, *Biodiesel Handling and Use Guidelines.* National Renewable Energy Laboratory, September 2001,
[23] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, "Biofuels for Sustainable Transportation," November 11, 2002. www.ott.doe.gov.
[24] U.S. Department of Agriculture, *Agricultural Statistics: 2003*, U.S. Government Printing Office, 2003, III-15.
[25] Larry Clark, "Biodiesel: Local Fuel from Farmers?" *Washington State Grange*, November 2002.
[26] Ty Myers, Washington State Extension Service, personal conversation, April 23, 2004.

Portland area. The potential to supply feedstock to such plants could be substantial. For canola, there are only about 5,000 acres planted annually in Oregon. Yet, canola is a good rotation crop for the million acres planted annually in wheat. Currently, much wheat acreage lies fallow in the every other year rotation common among growers. This acreage could grow canola if sufficient demand existed for biodiesel and other oilseed products.[27]

C. Production Cost

The estimated production cost has been estimated for biodiesel from soybean oil and from yellow kitchen grease. The production cost of biodiesel from soybean oil is estimated at $1.698 per gallon. The major component is the cost of soybean oil feedstock at $1.49 per gallon of biodiesel. Other costs are for capital and plant operations. The total cost for biodiesel from yellow grease is estimated at $.773 per gallon. The feedstock of yellow grease is the main cost although much less than soybean oil at $.54 per gallon. However a major drawback of yellow grease biodiesel is poor performance in cold weather.[28]

Biodiesel is not immune from market pressures. In the spring of 2004, the wholesale cost of biodiesel increased for one distributor from $1.90 per gallon to $2.90 per gallon in one part of the country. In another part of the country, B100 increased from $1.70/gallon in January to $2.10 in April.

D. Biodiesel Use

Biodiesel production is growing rapidly to an estimated 33 million gallons in 2004, as seen in the Table 4.[29]

Table 4
Production of Biodiesel Fuel

Year	Millions of Gallons
2000	3.5
2001	5.0
2002	15.0
2003	25.0
2004	33.0

Existing Capacity Grants. The Commodity Credit Corporation of the U.S. Department of Agriculture provides grants for the expansion of biodiesel production of $1.43 to $1.46 per gallon of capacity for soybean biodiesel and 88 to 90 cents per gallon of capacity for yellow

[27] Brent Searle, Oregon Department of Agriculture, personal communication, April 26, 2004.
[28] U.S. Department of Energy, "Impact of Renewable Fuels Standard MTBE Provisions of S. 1766," Energy Information Administration, SR/OILF/2002-06, March 2002, p. 11.
[29] For 2000-2003, National Biodiesel Board, personal communication, March 25, 2004. For 2004, U.S. Department of Energy, *Analyses of Selected Provisions of Proposed Energy Legislation: 2003*, Energy Information Administration, September 2003, p. 67.

grease biodiesel. The availability of the credit is a function of the level of appropriations and the demand for grants.[30]

Proposed Tax Incentives. Tax incentives have been proposed in various energy and transportation bills considered by the U.S. Congress. The tax incentives proposed in the energy bill have been incorporated into the transportation bill (S. 1072), as of April 2004. It offers a tax credit of $1 per gallon for biodiesel made from virgin oils and $.50 per gallon for biodiesel from other sources. The incentive lasts until December 31, 2005.[31]

Production Capacity. Biodiesel production capacity is estimated between 60 and 80 million gallons per year. There are at least 12 companies developing and actively marketing biodiesel. Since capacity is mostly modular, production can be double or tripled within 12 months.[32] It is estimated production could reach 2 billion gallons per year and equivalent to 8% of highway diesel consumption.[33]

Numerous production facilities are in place and many more are planned. This promises to keep biodiesel competitive, even as demand grows rapidly. As of March 2004, the capacity situation was as follows:

- 21 production plants in the U.S., most in the Midwest
- 6 existing plants in western states of which 5 are in California and 1 in Nevada
- 16 plants planned including one in Montana.[34]

Other plants are being considered in both Oregon and Washington that have been identified during the course of this project. They are not yet included in the statistics above from the National Biodiesel Board.

Transportation Applications. Biodiesel is used predominately in transportation. It is typically blended into 20% biodiesel and 80% petroleum diesel. This is referred to as B20. Pure blends of 100% biodiesel are referred to as B100 or as "neat" biodiesel.

Biodiesel use is growing rapidly in the transportation sector. About 400 fleets use biodiesel as of February 2004. In addition to commercial trucking fleets, biodiesel is consumed by fleets operated by all branches of the military, U.S. Postal Service, National Park Service, universities, school districts, and municipal transit authorities.[35] Fleet use has grown by over 50% in a little over one year.

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[30] U.S. Department of Energy, *Analyses of Selected Provisions of Proposed Energy Legislation: 2003*, Energy Information Administration, September 2003, p. 67.
[31] Tony Radich, U.S. Department of Energy, Energy Information Administration, personnel communication, April 26, 2004.
[32] National Biodiesel Board, "U.S. Biodiesel Production Capacity," undated, www.biodiesel.org.
[33] U.S. Department of Energy, "Biofuels and Agriculture: A Fact Sheet for Farmers," September 2001.
[34] National Biodiesel Board, "Current and Proposed Biodiesel Production Plants," March 2004, www.biodiesel.org.
[35] National Biodiesel Board, "Harvard Makes Smart Move to Biodiesel," press release, February 20, 2004, www.biodiesel.org.

Federal Agency Incentives. Certain government agencies benefit from biodiesel in meeting federal orders to purchase Alternative Fuel Vehicles. The Energy Policy Act of 1992 requires certain federal and state agencies to switch to alternative-fueled vehicles. The act required 75% of purchases of new vehicles to be capable of running on alternative fuels. The Energy Conservation and Reauthorization Act of 1998 gave fleet operators the option of using biodiesel credits instead of fulfilling vehicle purchase requirements. Each 450 gallons of biodiesel purchased and consumed is awarded a full vehicle credit. The fuel must contain at least 20% biodiesel.[36]

Biodiesel is available for retail use as well and is sold in most states. As of March 2003, consumers may purchase biodiesel fuel through three locations in Oregon and at least six locations in Washington, all in the Puget Sound area.[37]

Biodiesel is subject to standards to better insure quality products. The American Society of Testing and Materials (ASTM) issued Specification D 6751 for all biodiesel fuel bought and sold in the U.S. This also helps the procurement process.[38]

Standby Generator Use. Biodiesel use in standby generators is such a new consideration that there is little information about such applications. There is limited experience on which to base estimated fuel use. The generators at the University of California – Riverside consumed about 75 gallons per hour per megawatt.[39] The same consumption rate has been noted at Blooming Prairie Public Utilities.[40] Blooming Prairie is part of the Southern Minnesota Municipal Power Agency, which serves 18 utilities. The agency dispatches some 190 MW of generator capacity burning B2 to B5 fuels. Typically operations are 300 to 400 hours per year for peaking purposes. The engines are well over one megawatt in capacity and consume on an average of 62 gallons per hour per megawatt, suggesting they operate near full load.[41]

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[36] U.S. Department of Energy, *Analyses of Selected Provisions of Proposed Energy Legislation: 2003*, Energy Information Administration, September 2003, p. 64.
[37] National Biodiesel Board, "Retail Fueling Sites," as of March 16, 2004, www.biodiesel.org.
[38] National Biodiesel Board, "Safe, Cleaner Market for Government Fleets," undated, www.biodiesel.org.
[39] National Biodiesel Board, "Biodiesel for Electrical Generation," market report, updated. www.biodiesel.org.
[40] Tom Swenson, Blooming Prairie Public Utilities, personal communication, April 20, 2004.
[41] Southern Minnesota Municipal Power Agency, personal communication, May 7, 2004.

III. Biodiesel Technical Considerations

A. Engine Operations

Biodiesel fuel operates in conventional diesel engines, just as does petroleum diesel. Few, if any, modifications are required to the engine or the fuel system. Certainly no capital investments are anticipated.

Lubricity. Diesel acts to lubricate moving parts such as fuel pumps and injectors. However, refining processes that reduce sulfur also reduce lubricity. This can increase wear and tear on the engine and cause catastrophic failure on occasion. Reducing sulfur content of diesel from 500 ppm to 15 ppm will exacerbate the problem by reducing lubricity. However, biodiesel has been shown to increase lubricity substantially. Tests on 1% biodiesel show lubricity increases up to 65%.[42]

Efficiency and Effectiveness. Biodiesel provides similar horsepower, torque and mileage as diesel based on over 50 million miles of demonstrations on the road.[43] Fleet managers report no noticeable loss in fuel efficiency as a result of using biodiesel. If there is any, it is not noticeable.[44]

There are instances that biodiesel has been shown to increase fuel efficiency as measured in miles per gallon. The most likely explanation is that the solvent characteristics of biodiesel clean the engine so well that more complete combustion occurs. Biodiesel acts as a detergent and like conventional detergent additives it improves mileage.[45]

Until more evidence accumulates, it is advisable to recognize that the energy content of B100 is about 10% less than diesel No. 2 and comparable to diesel No. 1. Fuel use efficiency is comparable as well. Fuel economy, power and torque are proportional to the heating value of biodiesel or biodiesel blends. Thus B20 operates with about a 2% reduction in power, torque and fuel economy compared to diesel. Fuel properties are listed in the Table 5.[46]

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[42] Paul Nazarro, "Biodiesel Is Lubricity," *Biodiesel: On the Road to Fueling the Future*, Hart/IRI Fuels Information Service, 2001, p. 9.
[43] National Biodiesel Board, "Biodiesel Performance," undated, www.biodiesel.org.
[44] Dan Bell, Town of Breckenridge, personal communication, April 16, 2004.
[45] Steve Howell, National Biodiesel Board, personal communication, May 27, 2004.
[46] Shane Tyson, *Biodiesel Handling and Use Guidelines.* National Renewable Energy Laboratory, September 2001, pp. 1-2.

Table 5
Fuel Properties of Diesel and Biodiesel

Fuel Property	Diesel	Biodiesel
Heating value, Btu/gal	131,295	117,093
Specific gravity, kg/l @ 60 F	0.85	0.88
Density, lb/gal @ 15 C	7.079	7.328
Carbon, wt %	87	77
Hydrogen, wt%	13	12
Oxygen, by dif. wt %	0	11
Sulfur, wt%	0.05	0.0 – 0.0024
Flash point, C	60-80	100-170
Cloud point, C	-15 to 5	-3 to 12
Pour point, C	-35 to -15	-15 to 10
Cetane number	40-55	48-55
Stoichiometric air/fuel ratio, wt/wt	15	13.8

Sulfur. Sulfur affects engine materials. High sulfur content increases wear in injectors, piston rings, and bearings. Fuels with high sulfur content may warrant the use of additional lubricants. Sulfur also contributes to acid formation and exhaust particulates. And sulfur contaminates catalytic emission devices. Biodiesel contains virtually no sulfur and thus decreases engine wear, reduces pollution directly as well as indirectly by improving the operation of catalytic devices.

Flash Point. Biodiesel has a higher flash point compared to other fuels as seen in Table 6. Flash point is the temperature at which a fuel will ignite when exposed to a spark. It is claimed that a match can be tossed into biodiesel and it will go out.[47]

Table 6
Fuel Flash Point

Fuel	Flash Point °F
Gasoline	- 50
Jet fuel	100
Diesel	110-155
Bunker fuel	150-240
Biodiesel	300

Cloud Point. Cloud point refers to the temperature at which crystals of paraffin wax first appear. Crystals can be detected by the cloudiness of the fuel. Biodiesel starts to cloud at a few degrees higher temperatures than diesel.

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[47] Steve Howell, "Rigorous Standards Ensure Biodiesel Performance, *Biodiesel: On the Road to Fueling the Future*, Hart/IRI Fuels Information Service, 2001, p. 7.

Pour Point. Pour point is the lowest temperature at which fuel can still flow. Fuel pumps may not be able to operate with temperatures at or below the pour point. Biodiesel has a higher pour point than diesel. It is recommended that B100 be kept at temperatures about 15 degrees above the pour point or about 45 – 50 F.[48] At least one manufacturer recommends keeping fuel at 10 to 15 degrees F above the pour point.[49]

Cetane Number. The cetane number measures the starting and warm-up characteristics of the fuel. A higher cetane number is desirable, especially in areas of cold weather or infrequent usage. Biodiesel has a higher cetane number.

Solvent Affects. Biodiesel possesses excellent solvent properties and may deteriorate natural rubber or polyurethane materials. Biodiesel can impact fuel system components such as fuel hoses and fuel pump seals. The advent of lower sulfur diesel fuels has caused most diesel manufacturers to switch to components that function well with these fuels, including biodiesel.[50]

Because of its solvent properties, biodiesel when first introduced into engines fired with petroleum diesel will dissolve sediments accumulated in fuel lines, tanks and delivery systems. The solution is to simply replace filters frequently until the deposits from petroleum diesel are cleaned out.[51] With B20, the need to change filters more frequently should disappear after the first few tanks.

Stability and Oxidation. Biodiesel, as well as diesel, oxidizes in the presence of air, heat, and water. Poor stability can result in higher acidity, higher viscosity and formation of gums and sediments.[52] This can cause filter plugging, combustion chamber deposit formation, and gumming or lacquering of injection system components.[53]

Acidity and viscosity can be tested to assess stability where fuel may be standing longer than six months. It is recommended that tests be conducted at the beginning when fuel is acquired and then tested on a regular basis.[54]

Various simple solutions are available. One is to minimize contact between the fuel and air by keeping tanks full. The general practice is to add anti-oxidants to the fuel. This is usually not needed, unless the biodiesel is stored longer than 6 months.[55] The cost is a couple of cents per gallon.

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[48] Shane Tyson, *Biodiesel Handling and Use Guidelines.* National Renewable Energy Laboratory, September 2001, pp. 8.
[49] Cummins, "Service Bulletin Fuels for Cummins Engines." p. 8.
[50] National Biodiesel Board, "Biodiesel Performance," undated, www.biodiesel.org.
[51] National Biodiesel Board, "Biodiesel Usage Checklist," undated, www.biodiesel.org.
[52] Shane Tyson, *Biodiesel Handling and Use Guidelines.* National Renewable Energy Laboratory, September 2001, pp. 11.
[53] Detroit Diesel, "Lubricating Oil, Fuel, and Filters: Engine Requirements," 2001, p. 20.
[54] Shane Tyson, *Biodiesel Handling and Use Guidelines.* National Renewable Energy Laboratory, September 2001, pp. 11.
[55] Shane Tyson, *Biodiesel Handling and Use Guidelines.* National Renewable Energy Laboratory, September 2001, pp. 11.

Some manufacturers of biodiesel claim good stability beyond six months and a shelf life of 12 months. The same recommendation is made for diesel, namely plan on a shelf life of no longer than 12 months.[56]

Engine Warranty. Diesel engine manufacturers warranty their engines based on materials and workmanship. No engine warranty covers fuels. In the case of biodiesel, the manufacturer recommendations vary from manufacturer to manufacturer. Table 7 below summarizes their policies. In general, biodiesel will not void warranties.[57]

Table 7
Manufacturer Warranty Summary

Manufacturer	Statement Summary
Caterpillar	For specified engines: "Biodiesel meeting the requirements listed in Caterpillar's biodiesel specification or, meeting either ASTM 6751 or DIN 51606, are acceptable. They may also be blended in any percentage with an accepted fuel, provided the diesel meets the requirements outlined in Table 6 prior to blending." For other specified engines: "…biodiesel..may be blended..at a maximum of 5%." "The use of biodiesel fuels does not affect Caterpillar's materials and workmanship warranty."[58]
Cummins	"Cummins neither approves or disapproves of the use of bio-diesel blends. …The use of biodiesel fuel does not affect Cummins materials and workmanship warranty…It is expected that blending up to a 5 percent volume concentration should or most probably will not cause serious problems."[59]
Detroit Diesel	"…permits the use of biodiesel derived from virgin soy methyl ester and rapeseed methyl ester when blended up to 20% maximum in diesel fuel."[60]
John Deere	"…has approved the use of up to 5% concentration of soy-based biodiesel fuel…"[61]

In the case of Caterpillar, a few models are identified where no more than B5 is suggested. But for most models, the general specification holds, meaning that higher blends are acceptable within proper specifications.

It is noteworthy that even where B5 is recommended, the common practice in transportation fleets is to use B20. Engine manufacturers have yet to report problems with biodiesel even at higher concentrations.

Engine warranties are not typically based on vintage of engine. Warranties are generally good for two years on new engines. While engines after 1994 are reportedly more accepting of lower sulfur fuels, biodiesel blends can be used in all vintages according to at least one major

[56] Gary Haer, West Central Soy, personal communication, May 13, 2004.
[57] Louisa Aronow, "California's Endangered Species?" *Biodiesel Magazine*, Mar/Apr 2004, p. 27.
[58] Caterpillar, "Caterpillar On-highway Diesel Truck Engine Fluid Recommendations," July 2003, p. 21.
[59] Cummins, "Service Bulletin Fuels for Cummins Engines." p. 8.
[60] Detroit Diesel, "Lubricating Oil, Fuel, and Filters: Engine Requirements," 2001, p. 18.
[61] John Deere, "John Deere Approves Eco-Friendly Biodiesel Fuel for Its Products," press release, February 21, 2002.

manufacturer. As long as the blend is within the specifications of the manufacturer, namely up to 5%, any vintage engine should be able to accept biodiesel.

Additives. While manufacturers claim engines are designed to work without additives in most situations, the companies acknowledge additives may be useful. Additives of potential value, whether for diesel or biodiesel, include:

- pour point depressant to improve flow characteristics,
- wax crystal modifier to reduce plugging of filters,
- anti-icer to inhibit water effects in fuels,
- anti-oxidants or storage stability additives to mitigate fuel system deposits and poor storage stability, and
- biocides or fungicides to reduce contamination with bacteria or fungus.[62]

B. Maintenance and Repairs

Maintenance Schedules. Manufacturers recommend regular maintenance schedules diesel engines regardless of biodiesel usage. Cummins Engine recommends semi-annual maintenance checks as a minimum. Otherwise maintenance checks should be performed every 200 to 300 hours of operation in the case of standby generators.

Filter Maintenance. The key maintenance activity is to monitor engine filters. Because biodiesel is an excellent solvent, filters may need to be changed more often in engines converted from diesel. This could include changing filters every 15-20 hours of operation at the beginning. However, once the engine runs for significant hours with biodiesel, the normal filter replacement schedule should work.

C. Handling and Storage

Tank Types. Biodiesel does not require special storage and can be stored where petroleum diesel is stored, except concrete lined tanks. Biodiesel may be stored in aluminum, steel, fluorinated polyethylene, fluorinated polypropylene and teflon. It may deteriorate natural rubber or polyurethane materials. It is best kept in clean, dry, and dark environments.[63]

Because of its solvency characteristics, biodiesel tends to "clean-out' storage tanks and fuel systems. Diesel tends to form sediments that stick to and accumulate in storage systems. As systems grow older the deposits may grow.

B20 may be introduced with little risk. The most likely result is plugged filters for a period of time and the recommended solution is to change the filters until the accumulations abate.

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[62] Cummins, "Service Bulletin Fuels for Cummins Engines." p. 13.
[63] National Biodiesel Board, "Safer, Cleaner Market for Government Fleets," undated, www.biodiesel.org.

B100 presents greater risk. In addition to plugged filters, there is a risk of fuel injector failure. It is recommended that storage tanks be cleaned to remove water and sediment before introducing higher blends like B100.[64]

Tank Locations. Below ground tanks are acceptable for storing biodiesel, including B100. Above ground tanks may be suitable for B20, depending local conditions.[65]

At Breckenridge, the town has used biodiesel for over three years. It has been stored in both above and below ground tanks. The tanks are not heated. Instead the Town of Breckenridge specifies biodiesel with pour properties down to minus thirty degrees Fahrenheit (-30 F). Additives allow the biodiesel to pour well. It has been learned that liquid additives should be mixed in with the biodiesel when the transportation tanker truck is being loaded. If added at the beginning of the loading the additive may gel or sink and not perform well. If added later in the filling process it mixes better. The petroleum dealer has also found it helpful to keep the biodiesel stored in a warm place of 50 F or more prior to shipping.[66]

Splash Blending. When blended it is recommended that biodiesel be added on top of diesel. Biodiesel is slightly heavier with a specific gravity of 0.88 compared to 0.85 for diesel.[67] If diesel is splash blended into biodiesel, further mixing can be accomplished with agitators. Or the mixture can be pumped into another tank to increase mixing. It is also good to splash blend when the fuel temperatures are above 50 F. Once blended with diesel, biodiesel does not stratify.[68]

Weather Affects. Cold weather affects the performance of petroleum diesel and biodiesel. In most cases this has not been a problem with 20% blends since the other 80% of the blend is diesel with a more favorable pour point.

B20 has been used without problems in many cold weather areas including upper Wisconsin, upper Minnesota and Breckenridge Ski area.[69] It has also been used in other cold winter areas such as Aspen, Telluride, Spokane, Glacier, and Mt. Rainier. B100 has been used at Yellowstone National Park where the vehicles are equipped with winterization packages.[70]

Many of the solutions for #2 petroleum diesel work for biodiesel including:

- blending in #1 diesel,
- moderating temperatures with fuel heaters,

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[64] Shane Tyson, *Biodiesel Handling and Use Guidelines.* National Renewable Energy Laboratory, September 2001, pp. 12.
[65] Shane Tyson, *Biodiesel Handling and Use Guidelines.* National Renewable Energy Laboratory, September 2001, pp. 9.
[66] Dan Bell, Town of Breckenridge, personal communication, April 16, 2004
[67] Shane Tyson, *Biodiesel Handling and Use Guidelines.* National Renewable Energy Laboratory, September 2001, pp. 1.
[68] Shane Tyson, *Biodiesel Handling and Use Guidelines.* National Renewable Energy Laboratory, September 2001, pp. 8.
[69] National Biodiesel Board, "Biodiesel Usage Checklist," undated, www.biodiesel.org.
[70] Shane Tyson, *Biodiesel Handling and Use Guidelines.* National Renewable Energy Laboratory, September 2001, pp. 9.

- storing in protected areas, and
- mixing in additives designed to improve flow during cold conditions.[71]

Storage in protected areas is particularly effective. For the Olympic Peninsula where temperatures seldom fall below freezing, underground storage tanks are considered suitable for B100.

For above ground tanks, the use of heaters is not considered necessary for B20, but may be advisable for B100 in the Olympic Peninsula according to a major fuels distributor. The tank heaters are thermostatically controlled to operate only when fuel temperatures fall below some setpoint, such as 40 F. For one tank, the heater cost was $6,000.[72]

To the extent that fuel gels at low temperatures, it can be restored without affecting the performance of the biodiesel. The simple addition of heat bringing the temperature above 30 F has been sufficient. The practice of bringing a vehicle into a warmer area has been effective in vehicles and tanker trucks. It has been demonstrated also when 25,000-gallon railroad tank cars deliver B100 after weeks in transit at below freezing conditions.[73]

For B100, additives can reduce pour point by 10 to 15 degrees. This can take the pour point down to 15-20 F. [74] The additive should not be needed at all if the tank is underground in cold regions.

Water Accumulation. A principal concern is water in the fuel. Water vapor condenses in partially filled tanks due to tank breathing caused by temperature changes. As long as water does not accumulate to significant levels as determined by regular testing, diesel may last for extended periods. When water does accumulate, precipitates can be added so the water stratifies at the bottom to allow it to be pumped out readily. The higher the concentration of biodiesel in diesel, the greater the opportunity for water absorption.

Microbial Growth. Another concern is growth of bacteria resulting in algae growths. If so, a biocide or algaecide can be added to correct the situation.[75] No particular patterns have been observed to help predict when or where algae growths may be more likely in the Olympic Peninsula. There are two common treatment practices.

- Treat with the biocide only after testing and results suggest the need for the additive.
- Add the algaecide annually as a preventive measure.

The costs are considered modest at the rate of a couple of cents per gallon for one treatment.

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[71] National Biodiesel Board, "Biodiesel Performance," undated, www.biodiesel.org.
[72] Tim Adams, Pacific Northwest Energy, personal communication, April 23, 2004.
[73] Tim Adams, Pacific Northwest Energy, personal communication, April 23, 2004.
[74] Gary Haer, West Central Soy, personal communication, May 13, 2004.
[75] Shane Tyson, *Biodiesel Handling and Use Guidelines.* National Renewable Energy Laboratory, September 2001, pp. 11.

IV. Environmental Implications with Biodiesel

A. Emissions Benefits of Biodiesel

Biodiesel is the first alternative fuel to have a complete evaluation of potential emissions-related health effects. The evaluation was submitted to the U.S. Environmental Protection Agency (EPA) using the most stringent emission testing protocols ever required for certification of fuels or fuel additives in the nation.[76]

EPA Findings. A major benefit of biodiesel comes from reduced emissions compared to diesel engines as may be seen from data compiled by the EPA[77] and summarized by the National Biodiesel Board.[78] Table 8 indicates the percent changes in emissions for B100 and B20 compared to diesel. Reductions for the use of B20 are in most cases proportional to those for B100.

Table 8
Emission Changes with Biodiesel versus Diesel

Emission Type	**B100**	**B20**
Sulfates	-100%	-20%
Nitrated polycyclic aromatic hydrocarbons (nPAH)	-90%	-50%
Polycyclic aromatic hydrocarbons (PAH)	-80%	-13%
Total unburned hydrocarbons	-67%	-20%
Ozone potential of speciated HC	-50%	-10%
Carbon monoxide	-48%	-12%
Particulate matter	-47%	-12%
Nitrogen oxides	+10%	+2%

The measurements are for tailpipe emission changes from heavy duty and medium duty engines. While specific data for biodiesel in standby generation is not available, the emissions data provide a general picture of expected emission reductions.[79]

Hydrocarbons. Polycyclic aromatic hydrocarbons (PAH) and nitrited PAH compounds have been identified as potential cancer causing compounds. Both unburned hydrocarbons and nitrogen oxide are ozone or smog forming precursors.

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[76] "Biodiesel: So We Can All Breathe Easier," *Biodiesel on the Road to Fueling the Future*, Hart/IRI Fuels Information Service, 2001, p. 6.
[77] EPA, "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions: Draft Technical Report," EPA 420-P-02-001, October 2002, p. ii.
[78] National Biodiesel Board, Letter from Scott Hughes, State Regulatory Affairs Director to John Geesman of California Energy Commission, March 28, 2003.
[79] National Biodiesel Board, Letter from Scott Hughes, State Regulatory Affairs Director to John Geesman of California Energy Commission, March 28, 2003.

Carbon Dioxide. Another factor in terms of mitigating global warming is that biodiesel reduces lifecycle or net CO2 emission by 78% compared with petroleum diesel. In addition biodiesel provides modest reductions in another greenhouse gas, methane. Lifecycle refers to the sequence of steps in making and using the fuel from extraction of all materials from the environment to the final end-use. The analysis is from a 1998 study by the U.S. Department of Energy and the U.S. Department of Agriculture tracing the life cycle of biodiesel use including carbon recycling by growing plants.[80]

In addition, the biodegradability of biodiesel is four to five times greater than for diesel. B100 degrades 64% to 91% after 14 to 28 days. Diesel degrades only 15% to 18% over the same time period. Even B20 blends degrade twice as fast as diesel.[81]

In summary, biodiesel has multiple environmental benefits. It is made from renewable resources, has lower emissions than diesel, is less harmful than table salt and degrades as fast as sugar.[82]

Nitrogen oxides. One consideration is that nitrogen oxides increase according to most studies. However, this is not always the case. In fact, emissions of NOx decrease about 10% of the time according to EPA.[83]

Accepting that NOx emissions may increase, there is in total a net reduction in emissions when considering reductions in other pollutants. As seen in the Table 9, compiled from EPA studies, the overall reduction is 1,170 pounds, or 77%, of emissions per megawatt hour.

Table 9
Net Reduction with B100 in Pounds Per Megawatt hour for Key Emissions

Emission Type	Diesel (lbs/MWh)[84]	B100 Change %	B100 Change (lbs/MWh)	B100 (lbs/MWh)
Carbon dioxide	1,500	- 78%	-1,170	330
Nitrogen oxides	26	+ 10%	+3	29
Sulfur oxides	3	-100 %	-3	0
Total	1,529		-1,170	359

A 10% increase in nitrogen oxides for B100 translates into three pounds per megawatt hour. The reduction in sulfur oxides alone offsets the nitrogen oxide increase for no net increase in pounds of emissions between these two pollutants. When carbon dioxide is factored in with a

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[80] U.S. Department of Agriculture and U.S. Department of Energy, *Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus*," May 1998, p. v.
[81] "Summary of Results from NBB/USEPA Tier 1 Health and Environment Effects Testing for Biodiesel Under the Requirements for USEPA Registration of Fuels and Fuel Additives (40 CFR Part 79, Sec. 21, 1, (b)(2) and 21, 1, (e)): Final Report," March 1998.
[82] National Biodiesel Board, Letter from Scott Hughes, State Regulatory Affairs Director to John Geesman of California Energy Commission, March 28, 2003.
[83] EPA, "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions: Draft Technical Report," EPA 420-P-02-001, October 2002, p. 41.
[84] EPA, "Environmental Issues in Electricity Demand Response," presented at New England Demand Response Initiative, July 17, 2002.

net lifecycle savings of 78%, there is a total net reduction of 1,170 pounds of emissions. Even if one calculates a more conservative reduction of 48% in carbon monoxide by not accounting for lifecycle effects, the net emissions reduction is 720 pounds per megawatt hour.

Toxics. It is noteworthy that not only are hydrocarbons reduced in general, hazardous or toxic pollutants are reduced in particular as seen in Table 10 for B100. Reductions range from 9% to 61% for six toxic pollutants where data is available and show consistent trends. While other toxics show reductions, the data are not as conclusive.[85]

Table 10
Change in Toxics

Toxic pollutant	Average Change
Acetaldehyde	-14.4%
Acrolein	-8.5%
Ethylbenzene	-61.0%
Formaldehyde	-15.1%
Naphthalene	-26.8%
Xylene	-39.5%

Alternative Biodiesel Formulations and Emissions. Biodiesel produced from other feedstocks exhibit favorable emissions reductions. Animal based biodiesel shows the smallest increase NOx at about one fifth of the increase associated with soybean emissions. Rapeseed and canola seed are about four fifths of the increase associated with soybean emission for NOx from B100. In the case of particulates and carbon monoxide emissions, animal based biodiesel demonstrates greater reduction in emissions compared to the reductions from the other formulations.[86]

However, the energy content of alternative formulations is lower in Btu/gallon than diesel. Animal-based biodiesel from lard, grease and tallow has about an 11% reduction compared to diesel. These are based on EPA calculations of energy content from 19 comparisons and summarized in Table 11.[87]

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[85] EPA, "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions: Draft Technical Report," EPA 420-P-02-001, October 2002, p. 93.
[86] EPA, "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions: Draft Technical Report," EPA 420-P-02-001, October 2002, p. 52-55.
[87] EPA, "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions: Draft Technical Report," EPA 420-P-02-001, October 2002, p. 42.

Table 11
Comparison of Average Net Energy Content of B100

Fuel Type	Average net Btu/gal
Diesel	129,500
All biodiesels	118,296
Animal	115,720
Rapeseed/canola	119,208
Soybean	119,224

B. Further Mitigation Options

NOx may be subject to mitigation by several options. One is through engine modifications; a second is the use of an additive, and third as investment in a catalyst.

Engine Modification. The timing on engines may be reduced with beneficial impacts on NOx emissions. A one-degree reduction in timing will result in no increase in NOx. A five-degree reduction in timing will reduce NOx by 25%. This is for B20. There is some change in particulate emissions. Specifically, particulate emissions still decline, but not quite as much with the timing adjustments as without the adjustments.

Additives. Additives may also reduce NOx emissions. The National Renewable Energy Laboratory has documented two additives that reduce NOx emissions. Using di-tert-butyl peroxide (DTBP) at 1% volumes with B20 reduces NOx emissions at a cost of about $.16 per gallon. Using ethyl-hexyl-nitrate (EHN) at 0.5% volumes also reduces NOx at a lower cost of $.05 per gallon. These are both known as cetane enhancers where higher levels indicate improved performance in starting in cold weather.

It is noteworthy that many factors affect NOx production including cetane levels, additives, aromatic content of the fuel, and percentage of short chain fatty acid esthers in the fuel. Furthermore, it is not completely understood how each of the various factors affect each other and the formation of NOx in diesel fuels.[88]

Clean Diesel Technologies, Inc. reports a 5% reduction in NOx with its patented additive in B20 along with No. 1 diesel.[89]

Air Emission Tests. To gain a permit to use B100, a hospital served a test site on its boilers in Southern California. In the most stringent test, the boiler operated at high fire or full load with an additive to reduce nitrogen oxide emissions. The emission results for nitrogen

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[88] R.L. McCormick, J.R. Alvarez, and M.S. Graboski, *NOx Solutions for Biodiesel."* National Renewable Energy Laboratory, NREL/SR-510-31465, February 2003, p. ii, 1.
[89] "Clean Diesel reduces NOx in Biodiesel," *Biodiesel Magazine*, Mar/Apr 2004, p. 10.

oxide and carbon monoxide were well below limits set by the South Coast Air Quality Management District as seen in Table 12.[90]

Table 12
Hospital Boiler Emissions from B100 with Additive to Reduce Nitrogen Oxide

Emission Type	Emission Results	Allowable Emissions
Nitrogen oxide	32.68 ppm	40.00 ppm
Carbon monoxide	46.25 ppm	400.00 ppm

Catalysts. Catalysts are not generally applicable in diesel or diesel mixtures because of the presence of sulfur. Due to the absence of sulfur in B100 biodiesel, catalysts could be applied for NOx reduction.[91]

Investments in selective catalytic reduction (SCR) have been made on backup generators that are permitted to run 24 hours per day by Grays Harbor Public Utility District. The generators run on petroleum diesel. The SCR installations on 2 MW generators have exceeded the 85% reduction specified for NOx with as much as 93% reduction. However, performance of the SCR equipment has not been as reliable as anticipated. The SCR units cost $665,000 for five generators.[92] This translated to $133,000 per unit or $66.50/kW.

A range of capital costs has been developed by the U.S. Environmental Protection Agency. According to EPA literature surveys, SCR capital costs range from $55-140/kW.[93] While the range is broad and is based on large utility boilers, the Grays Harbor investment for smaller units fits within the lower end of the range.

The typical standby generator in the Olympic Peninsula is about 400 kW. Using a SCR capital cost of $70/kW, the investment would calculate to $28,000. If one large generator out of a fleet of units was targeted to obtain 90% reduction in NOx in significant quantities, a 1, 000 kW unit might require an investment of $70,000.

C. Health and Safety Benefits

Biodiesel should be handled with the same safety precautions as petroleum diesel. However, there are fewer risks with biodiesel.

B100 is not considered a hazardous material by the key federal agencies including OSHA and EPA. It may be discarded as a non-hazardous material. It is important to store away from oxidizing agents, excessive heat and ignition sources. Spills may be cleaned up with paper

[90] Bill Chihak, "St. Mary Medical Center Running Clean and Green," and personal communication, June 15, 2004.
[91] "Summary of Results from NBB/USEPA Tier 1 Health and Environment Effects Testing for Biodiesel Under the Requirements for USEPA Registration of Fuels and Fuel Additives (40 CFR Part 79, Sec. 21, 1, (b)(2) and 21, 1, (e)): Final Report," March 1998.
[92] Russ Duvall, Grays Harbor PUD, personal communication, May 13,2004.
[93] Wojciech Jozewicz, "Project Summary: Cost of Selective Catalytic Reduction (SCR) Application for NOx Control on Coal-Fired Boilers, U.S. Environmental Protection Agency, EPA/600/SR-01/087, January 2002.

towels, dirt and sand if small enough. Large spills should be collected for disposal and surfaces washed with a safety solvent or detergent to remove remaining oil film. Oil soaked rags should be washed and dried to reduce risks of spontaneous combustion. Safety glasses are recommended to protect eyes from mist or splashing. PVC gloves are recommended to prevent skin contact. In the event of fire, firefighters should use self-contained breathing apparatus.[94]

D. Environmental Regulations

For the Olympic Peninsula, performance standards are established under state and federal regulations with enforcement by the regional authority, which is the Olympic Region Clean Air Agency.[95]

Permits are required for generators over 50 horsepower of output, except emergency generators. Emergency generators are not required to have permits if under 500 hp. The agency has no rules or limits on hours of operation per year.

Emergency generators may be considered new sources if operated for reasons other than emergencies, such as peak load management. Thus emergency generator under 500 hp that are otherwise exempt from permits, may need a permit when operating under other conditions. Such a change in operations would be designated as a modification under new source review requirements of Article 7 of ORCAA regulations. This is because it may be considered a "modification to any existing stationary source." (7.01.a.2)

To get a permit under the "notice of construction" some five conditions will need to be satisfied. This assumes there is an increase in emissions. First, the best available control technology (BACT) should be applied. The use of biodiesel may be considered BACT. Second, permitted emissions will not violate any ambient air quality standard. This would include generators with exhaust emissions near occupied areas. Since generators are often at ground level and emissions may be close to ground level, it will be necessary to confirm the relationship to occupied areas.

Third, requirements for hazardous pollutants or air toxics must be met. The fact that biodiesel reduces air toxics is positive.

Fourth, the change in operations of the emission source must create no offensive odors or nuisances. In the case of generators, this could include noise as well as emissions. B20 is touted for improving odors due both to its biodiesel constituents and by eliminating odors normally associated with diesel.

Fifth, the modification does not qualify for consideration as a major source of emissions. Generators under one megawatt are not likely to be considered a major source. Larger units would also not be a concern if emissions were less than 100 tons/year of any criteria pollutant, 10

[94] National Biodiesel Board, "Sample Material Safety Data Sheet," undated, www.biodiesel.org.
[95] Based on personal communication with Mark Goodin, Olympic Region Clean Air Agency, May 12, 2004 and Article 7 of ORCAA Regulation 1.

tons/year of any hazardous pollutant, and 25 tons/year of any combination of hazardous with criteria pollutants.

The process of obtaining a permit may take 30 to 90 days. It takes 30-60 days to obtain a notice of construction permit. If public notice is required, another 30 days may be added.

V. Economic Costs and Benefits

The purpose of this section is to pull together the various factors influencing costs and develop a comparative analysis of biodiesel to diesel. There are multiple factors that influence costs. For any cost variable there can be multiple estimates. This section identified the key factors and ranges for costs.

For purposes of comparison, judgments are made about how to balance the cost factors. And judgments are made about what estimates to use for each factor. Where assumptions are needed, these will be indicated.

A. Fuel Costs

One rule of thumb is that biodiesel costs about one cent more per percentage point increase in concentration. Under this formula, B20 would cost twenty cents more per gallon compared to diesel and B100 would cost $1.00 per gallon more. However, with higher blends there is some economy that allows a little savings in some cases. Thus: "A 2 percent blend currently sells for about 2 cents per gallon more than diesel; a 20 percent blend sells for about 18 cents per gallon more than diesel."[96]

Cold Flow Additives. To improve cold flow properties, additives can be used. One source quotes $75/gallon for cold flow additive. Normally about one gallon of additive per 1,500 gallons of B20 should be sufficient according to the source. This translates into an extra five cents per gallon for winter usage. In other seasons, cold flow additives should not be needed.

Manufacturers may include cold flow additives routinely in the fall for biodiesel being shipped to colder regions. This is then factored into their free on board (FOB) price from the plant. Several purchasers claim to have been able to obtain B20 biodiesel at 16 cents per gallon premium. And this was with additives for cold flow conditions.

Another option is to blend in #1 diesel to improve cold flow properties. This is probably sufficient for many chilly climates. For a five to ten percent mix with #1 diesel, the cost is considered about the same or a little more than cold flow additives.

Price Fluctuations. There can be significant fluctuations. In the spring of 2004, one distributor in a region without production capacity faced an increase of nearly a dollar a gallon for B100 from $1.95 to $2.95. However, distributors in other regions did not report such short-term spot prices increases.

Distributors for the Pacific Northwest indicate prices for biodiesel will be somewhat higher than national averages given the long distances from production regions in the Midwest

[96] U.S. Department of Energy, *Analyses of Selected Provisions of Proposed Energy Legislation: 2003*, Energy Information Administration, September 2003, p. 65.

and no local processing facility. Prices also depend on fluctuations in the price of petroleum, the price of soybean oil, the demand for biodiesel, the location of the facilities and the method of transport. Regarding local transportation methods, tractor and trailer tanks of 7,000 gallons or more can be more economical than deliveries in tank wagons of 4,000 gallons or less.[97]

A factor mitigating price increases over the long term is production capacity. Significant increases in biodiesel production capacity can be made in a relatively short time from existing resources, if the demand materializes and crop production levels grow. Furthermore, many production facilities are in various stages of planning and construction for biodiesel. Finally, there are plans in some regions to produce canola and mustard seed as a feedstock for biodiesel.

Recent Prices. According to one distributor, prices as of April 2004 for B20 are about 16 cents per gallon and for B100 80 cents per gallon higher than petroleum. In May, the price of B20 was 30 cents higher and B100 was 90 cents higher than diesel at $1.50 per gallon, according to another large distributor in the Pacific Northwest.

Taxes. For transportation uses, diesel and biodiesel are subject to highway gasoline taxes. Fuels used for non-highway applications are exempt. This avoids US and Washington state taxes of $.537/gallon for diesel fuels.

B. Other Operating and Maintenance Costs and Savings

As a drop-in fuel to existing tanks and engines, biodiesel has negligible additional operating and maintenance costs. The one small cost may be more frequent change of engine filters. Because biodiesel is a solvent, accumulated deposits in tanks and engines may be loosed and flushed out. This may necessitate more frequent changing of filters until the materials are flushed out. Afterwards, even less maintenance may be needed with associated savings.

Savings have recently been documented by St. John Public Schools in Michigan. After a million miles of school bus use of B20 starting in 2002, the district officials report:

- Oil changes have been extended because B20 burns cleaner and does not dirty the oil as quickly. Oil changes normally made after 8,000 to 10,000 miles have been extended 10% more miles with a goal of 20-30% extension as experience develops.
- Oil filters and oil conditioners have been reduced.
- Fuel pump life has been extended. They have not had to change a fuel pump since 2002. Normally one of the 31 buses needed a change each year.
- Mileage has increased about 9%. Prior to April 2002, mileage was 8.1 miles per gallon, but has subsequently increased to 8.8 miles per gallon.
- Net financial savings are positive. Even though B20 has been costing about 15 cents per gallon more, the savings are greater in reduced oil changes, reduced oil

[97] Tim Adams, Pacific Northwest Energy, personal communication, April 23, 2004.

filter changes, reduced use of oil conditioners, extended fuel pump life, and better mileage.[98]

Equipment should be serviced on regular intervals. Backup generators are typically serviced twice a year when deployed as emergency units. It is assumed that service calls will increase under this program both for diesel and biodiesel applications, especially for the first year. It may be after the first year, the engines can return to a normal cycle of semi-annual service calls.

- Diesel fuel: 3 service calls per year.
- B20: 3 service calls per year per year
- B100: 4 service calls per year.

The service costs are estimated at $400 per service call. This is based on current industry experience.[99]

D. Comparative Resource Costs

Comparative resource costs are now developed for biodiesel. The analysis develops cost estimates for service costs and fuel costs. The service costs include such maintenance costs as filter changes. The fuel costs include additives for cold flow protection in the winter months.

No costs are estimated to upgrade engines to operate under a demand management program as this is treated elsewhere. No capital costs are estimated for biodiesel applications in keeping with the characteristics of biodiesel as a drop-in fuel. Neither are additional costs imposed for NOx mitigation.

For purposes of clarity in comparing alternatives, it is assumed that all units are fired under one of three fuel scenarios:

1. Diesel fuel
2. B20
3. B100

Naturally, various combinations may be adopted, so that some generators may be selected to run on diesel only, some on B20 and some on B100. Other combinations could include running generators on B100 for part of the year, such as the summer, and B20 for the remainder of the year, such as the winter.

This analysis proceeds in two steps. First, costs are estimated for one average site based on assumed generator conditions and hours of operation. Second, costs are estimated for a fleet of generators.

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[98] "St. Johns School Buses Rolling 1 Million Miles on Biodiesel," Michigan Soybean Promotion Committee, April 27, 2004. www.biodiesel.org.
[99] Dennis Quinn, Celerity Energy, Inc., personal communication, May 24, 2004

Model Generator. Key assumptions are shown in Table 12 for generator operations and loading. The typical or model generator is assumed to be 400 kW in capacity with 300 kW of connected load and is in keeping with current prospective participants in the program. In particular, the generator is expected to operate about 96 hours per year including 72 hours in the winter months when needs are more likely to be higher.

Table 12

Standby Generator Hours of Operation

Winter	Hours	Summer	Hours
Nov	4	May	0
Dec	16	Jun	4
Jan	16	Jul	8
Feb	16	Aug	8
Mar	16	Sep	4
Apr	4	Oct	0
Total	72		24
Annual Total			96

Costs for fuel and service calls are based on the situation as of May 2004 and summarized in Table 13. Prices of biodiesel have been rising during the course of 2004 and may remain at elevated levels according to some sources.

A higher price fuel price for biodiesel has been assumed for the winter relative to the summer. This is to cover modest costs for cold flow additives. Such as premium for winter additives is a conservative assumption that may prove unnecessary upon implementation for two reasons. First, the cold flow additive may already be reflected in the base price for biodiesel when quoted by distributors. Second, some diesel is shipped for winter use with additives as well resulting in an elevated cost for diesel in the winter.

On the other hand, no extra costs have been included for biocide, water draining and oxidation treatments, as these are usually pennies per gallon. Such extra expenses should not be required in normal circumstances and, if so, on an occasional tankful, not every tankload.

Maintenance service costs are based on three calls per year for diesel and B20 and four service calls per year for B100. Again, in practice, these may be more aggressive than needed, especially after the first year.

Table 13

Assumptions for Fuel Cost and Service

Item	Metric	Diesel	B20	B100
Fuel summer	$/gallon	$1.50	$1.80	$2.40
Fuel winter	$/gallon	$1.50	$1.80	$2.45
Service calls	No./yr.	3	3	4
Service costs	$400	$1,200	$1,200	$1,600

Fuel usage calculations start with the amount of fuel burned per hour per engine. Diesel fuel will be consumed at the rate of 22 gallons per hour for the typical generator of 400 kW capacity operating at _ load or 300 kW.[100] Biodiesel fuel consumption could be higher based on the lower energy content of 117,000 Btu/hour compared to 131,000 for diesel. Thus B100 would require about 10% more fuel and B20 about 2% more fuel to satisfy the load requirements. Yet, there is some experience that efficiency increases as has been reported with a school bus fleet in Michigan. It is not clear whether the B20 used by the fleet was higher in heat content, benefited from higher cetane levels and improve lubricity, or other factors. For purposes of this analysis, it is assumed fuel requirements for biodiesel for will increase when compared to diesel by 2% for B20 and 10% for B100. These assumptions and calculations are shown in Table 14.

Table 14
Fuel Use Per Year Per Generator

Fuel use per hour		**Diesel**	**B20**	**B100**
Fuel multiplier		1	1.02	1.10
Fuel use (gallons/hr)		22	22.44	24.20

Fuel use gallons/season

Summer hours	24	528.00	538.56	580.80
Winter hours	72	1,584.00	1,615.68	1,742.40
Total per year	96	2,112.00	2,154.24	2,323.20

Costs may now be calculated based on the fuel prices, fuel quantities and service costs. These are summarized in Table 15. The summer costs and winter costs differ due both to the number of hours and prices of fuel. The annual fuel cost for the model generator is $3,168 for diesel. B20 is 22% higher. B 100 is 79% higher per year. When service costs are included, the annual cost increases for B20 by 16% and for B100 by 66%.

Table 15
Total Cost Per Fuel Type Per Year Per Generator

Fuel Cost Per Season		**Diesel**	**B20**	**B100**
	Summer	$792	$969	$1,394
	Winter	$2,376	$2,908	$4,269
Annual Fuel Cost		$3,168	$3,878	$5,663
Service Cost		$1,200	$1,200	$1,600
Total Annual Cost		$4,368	$5,078	$7,263

The generator costs may be compared more readily in terms of energy costs. The annual energy production will be 96 hours per year times 300 kW per hour of operation, which translates into 28.80 megawatt-hours per year. The cost per MWh is shown in Table 16 for each fuel type.

[100] Cummins Power Generation, "Diesel Fuel Consumption Rate Calculator."

Table 16

Total Cost Per Fuel Type ($/MWh)

	Diesel	B20	B100
Fuel	$110.00	$134.64	$196.63
Service	$41.67	$41.67	$55.56
Total	$151.67	$176.31	$252.18

All Generators. These estimates per generator may be multiplied to obtain estimates for a fleet of generators. To obtain nearly 5 MW of load, some 16 generators would need to be called upon at 300 kW per unit. This would yield 4.8 MW. Table 17 below summarizes the total fuel use, total energy production and total cost for 4.8 MW of generator operation.

Summary for Sixteen Generators

Generators	Number	1	16
Load	kW	300	4,800
Production	MWh/yr.	28.8	461
Fuel Use	Gallons/yr		
	Diesel	2,112	33,792
	B20	2,154	34,468
	B100	2,323	37,171
Total Cost	$/yr.		
	Diesel	$4,368	$69,888
	B20	$5,078	$81,242
	B100	$7,263	$116,205

For 16 generators operating with B20, the annual cost is about $81,000 compared to about $70,000 for diesel. If B100 is universally deployed in all 16 generators to meet the objectives of BPA for emergency generation and peak load management as an alternative to transmission upgrades the generator operating cost would be an estimated $116,000 per year.

Discussion. Several caveats may be offered for this financial analysis. Perhaps the single largest variable is the price of fuel. Given fluctuations in the worldwide petroleum market and vagaries of the agricultural sector, fuel prices for diesel and biodiesel may vary widely. Mitigating these factors are prospects for increased production capacity of biodiesel and tax incentives attached to federal legislation.

A second significant variable is burn rates of the fuel. It may be that significantly more fuel is required if engines are inefficient. On the other hand, fuel efficiency may prove higher than expected in generators just as it has in some fleet applications.

A third factor is overall engine performance. More hours of operation may compromise engine reliability. And this could be aggravated by biodiesel fuels. Conversely, engines may run smoother and more reliably requiring less service and maintenance.

A fourth factor is that generators may have to run more often as biodiesel fuel approaches its recommended maximum shelf life. However, this appears unlikely. The average tank size was 960 gallons and the medium tank size was 200 gallons. Using the average tank size of 960 gallons and an average fuel use of 24 gallons per hour for B100, the average tank should serve for 40 hours of generator operation. Assuming 96 hours of operation a year, the average tank would need to be refilled every five months. In the case of 200-gallon tanks, refills would need to occur about every 8 hours or about 12 times a year. Thus, the prospect of having to run generators to burn off biodiesel fuel is slim for B100. For B20 with 80% petroleum diesel, it is most unlikely that generators would be operated simply to reduce fuel inventory approaching its recommended shelf life, while participating in a demand response program.

VI. Conclusions and Recommendations

There is limited experience with biodiesel in standby generation. Most of the experience is with B20 in a few generators for pilot projects of a few months and with a several small generators serving national park facilities in recent years. Only one location can be documented to have used B100 in its standby generators since 2001.

Virtually all the experience with biodiesel is in the transportation industry operating as a B20 blend of 20% biodiesel and 80% petroleum or #2 diesel. There is little experience with B100, also known as neat biodiesel, in transportation fleets. Thus most of the information about biodiesel in diesel engines is based on experience with fleets of buses and other diesel vehicles.

As a drop-in fuel, biodiesel presents relatively few problems for storage tanks, fuel lines and engines. Care needs to be taken during initial hours of use to clean filters more often than usual due to high solvent characteristics of biodiesel. When weather drops below freezing, care is needed to maintain cold flow characteristics, just as with #2 diesel. However, solutions exist in the form of additives, blending in #1 diesel, underground tanks, and tank heaters. Other management concerns are fuel oxidation and algae growth, again just as can happen with diesel with available solutions.

These technical considerations for B20 are multiplied with B100. More precautions are worthwhile with B100 for engine parts, engine operations, and storage. It may be appropriate to replace rubber hoses and other parts for old engines slated for B100. Shelf life is a key consideration with B100 when fuel is stored longer than six months. Otherwise, B100 should perform just fine.

A principal benefit of biodiesel is with reduced air emissions. Except for nitrogen oxides, emissions decline for B20 compared to diesel. Emissions decline even further for B100, including no sulfur emissions, half the emission for particulate and carbon monoxide, plus as much as 90% reduction in many hydrocarbons. NOx increases about 2% with B20 and about 10% with B100.

In terms of total pounds of emissions, the reduction is significant. This is particularly the case when life cycle emissions are taken into account for biodiesel with a 78% reduction in carbon dioxide. Biodiesel is not hazardous and is biodegradable. An emissions permit will be needed for standby generators when changed from emergency to demand response operations.

A principal reservation with biodiesel is cost. Delivery cost of B20 will be about 20-30 cents per gallon more than diesel. B100 will cost about a dollar more per gallon. However, there is anecdotal evidence of cost savings in engine maintenance due to higher lubricity.

There is also some evidence of improved fuel efficiency. However, biodiesel contains a lower heat value in BTUs per gallon. Therefore, it is appropriate to estimate slightly more fuel consumption for B20 and about 10% more fuel consumption than diesel for B100.

Biodiesel can claim to be a renewable energy based on its source from agricultural and animal feedstocks. As a renewable energy, biodiesel in standby generators offers the prospect of a dispatchable resource to balance more intermittent renewable resources.

In terms of the objectives of this analysis, biodiesel can certainly be used in standby generators. Furthermore, there can be confidence that standby generators with biodiesel should reliably serve as a demand response alternative to meet peak loads and relieve transmission congestion.

Given these conclusions, the following recommendations are made for consideration by Bonneville Power Administration.

1. Proceed to use B20 in most any standby generator with appropriate attention to fuel management issues.

2. Proceed to use B100 in certain standby generators subject to review of engine specifications with diesel manufacturers and closer attention to fuel management issues.

3. Document performance such as fuel use, additives, maintenance actions, and costs.

4. Obtain necessary environmental permits prior to operating generators other than for emergency purposes and then manage operations for noise, visibility and emissions mitigation.

5. Operate generators as much as economically and environmentally justified for electrical transmission and distribution purposes with careful attention in the cases of B100 to consume fuel within six months of delivery.

As a result of this assessment, BPA can proceed to trials of B20 and B100 with standby generators on the Olympic Peninsula, aware of the range of costs and benefits and prepared to document the outcomes of these trials for future application to the Non-Wires Solution challenge.

Appendix A: Biodiesel Suppliers Contacted

Agriculture Environment Products, Lenasa, KS: Mr. Steve Nogel, 402-492-3316.

Albina Fuels, Portland, OR: Mr. Steve Corah, 503-281-1161.

Biodiesel Industries, Santa Barbara, CA: Mr. Tuss Teall, 805-683-8103.

Blue Sun Biodiesel, Fort Collins, CO: Mr. John Long, 970-221-0500.

Pacific Northwest Energy, Tacoma, WA: Mr. Tim Adams, 253-396-6888.

SHOCO Oil, Denver, CO: Mr. Scott Hohnstein, 303-289-1677.

Sustainable Systems, LLC, Missoula, MT: Mr. Paul Miller, 406-549-2893.

West Central Soy, Ralston, IA: 913-484-8521.

Western Petroleum, Glenwood Springs, CO: Mr. Doug Myers, 970-379-2384.

World Energy Alternatives, Nevada City, CA: Mr. Graham Noyes, 530-478-9196.

Note: Many other biodiesel suppliers are listed on the website of the National Biodiesel Board, www.biodiesel.org.

Appendix B: Fuel Consumption Rates

Diesel Fuel Consumption Rate Calculator
No. 2 Diesel in US gallons per hour

Generator Rating	Load On Generator			
	1/4	**1/2**	**3/4**	**Full**
50	1.30	2.10	2.90	3.90
60	1.90	2.80	3.70	4.70
70	2.01	3.06	4.20	5.34
80	2.30	3.50	4.80	6.10
100	2.60	4.10	5.80	7.50
125	3.30	5.40	7.50	9.90
150	3.70	5.90	8.40	11.30
175	3.90	6.60	9.60	13.20
200	4.60	7.80	11.10	14.50
230	5.20	8.70	12.10	15.60
250	5.50	9.30	13.20	17.30
275	5.80	10.20	14.20	19.40
300	6.20	10.90	15.50	21.40
350	8.60	13.90	19.20	24.60
400	9.80	15.80	21.20	27.10
450	10.60	17.10	23.20	30.00
500	11.20	18.50	25.40	34.80
600	14.70	24.30	34.10	44.20
750	16.00	26.20	40.50	54.70
800	16.00	28.20	43.00	57.80
900	17.00	30.50	44.90	60.20
1000	19.30	38.00	52.60	69.30
1100	27.30	43.70	59.80	77.20
1250	28.60	46.00	65.90	87.30
1500	32.80	55.80	79.40	103.50
2000	43.00	71.00	103.00	135.00

Source: Cummins Power Generation