Biodiesel at Smith College:
Getting the Ball Rolling

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Abstract: The United States is responsible for a disproportionate amount of the world's petroleum consumption. Our contribution to the air-borne health and environmental risks incurred by the combustion of petroleum products is therefore unacceptably high. Smith College officially recognized the need reduce its contribution to the global issue of climate change and deteriorating environmental and human health when it signed the Clean Air- Cool Planet document, pledging to reduce greenhouse gas emissions and promote "awareness among its students, faculty and staff of the importance of responsible environmental stewardship". Using biodiesel is one way in which Smith College could significantly reduce its yearly volume of diesel emissions, both greenhouse gas and other. This soybean-based fuel is EPA certified and could be used in all 20 diesel engine vehicles used to maintain the Smith College campus. Through conducting interviews and making calculations this project compares the change in emissions volume generated by Smith Grounds Crew vehicles at three biodiesel concentrations, and assesses the cost-feasibility of such a move. The major findings were that all EPA regulated and unregulated emissions showed a reduction when compared to diesel fuel except for nitrogen oxides. Additionally, although the upfront cost of biodiesel is greater than that of petroleum diesel, the reduction in long term maintenance costs due to the high lubricity of biodiesel, as well as the opportunity to support campus sustainability could offset this price significantly enough to make it a feasible and attractive option for Smith College.

Introduction:

The United States represents 4.6% of earth's population and is responsible for 25.5% of the world's petroleum consumption (US Department of Energy, 2001, 2003). Combustion of these fossil fuels releases gasses which contribute to the serious threats posed by global warming and acid rain. The contribution that the United States makes to global environmental degradation is unacceptably high, and we must look for alternatives. Although the success of transforming an infrastructure based on petroleum consumption through legislation seems doubtful, we must not underestimate the power of the consumer. The role of small-scale consumers of petroleum products, and the decisions they make, will without question determine the direction our nation takes on this critical issue.

Smith College is one such small-scale consumer of petroleum products. For the June 2003-June 2004 year, Smith college purchased 9,200 gallons of diesel fuel, 26,000 gallons of gasoline, and 1,800,000 gallons of heating oil #6 (Bob Dombkowski- Personal Communication, 2004). This institution's contribution to national petroleum consumption is significant and demands the attention of the administration if we are to honor the commitment made on April 14, 2004 when we entered into a voluntary partnership agreement with Clean Air-Cool Planet. By signing this document, President Carol T. Christ pledged that the college would work toward reducing greenhouse gasses and promoting "awareness among its students, faculty and staff of the importance of responsible environmental stewardship" (Fenlason, 2004).

Seeking out alternative sources of fuel is one way we could honor our commitment to Clean Air- Cool Planet. One very attractive option is a soybean-derived fuel called biodiesel. Biodiesel has enjoyed a growing popularity in the past five years with 500,000 gallons sold nationwide in 1999 and 25 million sold in 2003. It is less toxic than table salt and biodegrades at the same rate as sugar. It is the safest of all fuels, with a flashpoint over 100º F. higher than that of petroleum diesel. It is registered with the EPA and its production has specific protocols under the American Society of Testing and Materials, making it safe for warrantees (National Biodiesel Board, 2004). Finally and most significantly, using biodiesel requires no modifications of the current infrastructure and could be run at similar performance rates in all of Smith College's diesel engines (McCormick, 2003).

There are currently 17 vehicles and 13 other pieces of equipment used by Smith College Ground's Crew to maintain the campus that run on petroleum diesel fuel (Dombkowski- Personal Communication, 2004). Diesel engines are more fuel efficient than gasoline engines because of the additional force provided by compression ignition, and also because diesel fuel has 15% more energy than gasoline (Academic Search Primer, 2004). The heavy usage of Smith Grounds Crew vehicles for activities, such as snow-plowing and lawn care, requires a significant amount of power. Were these vehicles to run on gasoline, they would require double the volume of fuel that they do today (Dombkowski- Personal Communication, 2004).

Despite the benefits of fuel efficiency, diesel emissions are notorious for the human health and environmental problems that they cause. The South Coast Air Quality Management District found that particulate matter from diesel exhaust is responsible for 71% of airborne lung cancer risk. In addition to lung cancer risk, the Environmental Protection Agency (EPA) asserts that diesel exhaust is also associated with asthma and acute respiratory illnesses. Particularly at risk are those in low income communities and children, whose lung development may be impaired by inhalation of oxides, according to a study by the University of Southern California. In terms of environmental issues, emissions from diesel are major contributors to acid rain, global warming, and regional smog formation (Environmental and Energy Study Institute, 2004).

According to the EPA the four most destructive diesel emissions are hydrocarbons, carbon monoxide, particulate matter, and nitrogen oxides. Also harmful, but less difficult to measure and therefore unregulated are sulfates, polycyclic aromatic hydrocarbons (PAH), and nitrogenous PAH's (nPAH) (US EPA, 2002). If we are to successfully reduce the amount of emissions we must concentrate on alternative fuel sources whose combustion can produce the same amount of work while generating fewer of these seven dangerous emissions.

Biodiesel emissions show a decrease in all EPA recognized diesel emissions except for nitrogen oxide, whose increase is comparatively incremental, and thus potentially insignificant. This project seeks to calculate the volume of the change on emissions production from all of Smith's diesel engines if we were to burn biodiesel instead of petroleum diesel. A secondary goal is to establish a relationship between Smith College Physical Plant and Alliance Energy Services, a local biodiesel distributor, in the hopes of making this move a reality.

Methods:

The methods for this project consisted of personal interviews and emissions calculations. My first interview was with Bob Dombkowski the director of Smith College Grounds Crew. He was able to tell me how many diesel vehicles grounds crew uses, and how much diesel fuel they consume in a year. For my next interview I arranged a meeting between Mr. Dombkowski and Jim Brown, the sales representative for biodiesel at Alliance Energy Services in Holyoke. At this meeting I took notes on their conversation, which mostly revolved around financial feasibility of biodiesel.

To calculate EPA regulated diesel emissions of Smith Grounds Crew vehicles I contacted Christine Sansevero, an environmental engineer at the US EPA New England office. Ms. Sansevero helped me convert a spreadsheet she is using to evaluate the effectiveness of catalytic converter control technology on Boston busses. At Ms. Sansevero's suggestion, I used the maximum emissions limit enforced by the EPA for pre-1990, 1994-1998, and 1998-2002 vehicles and then averaged these three to calculate emissions produced by 9200 gallons of diesel fuel (amount used by Smith in 2003-2004 year). This method assumes that some vehicles will be below the maximum (particularly when new), while others will be at or above the maximum. It also assumes that Smith's vehicles are a mixture of older and newer vehicles.

To compare EPA regulated emissions produced in one year by Smith Grounds Crew vehicles if they used biodiesel, I calculated a percentage change based on the data in the EPA 2002 Draft Technical Report "Comprehensive Analysis of Biodiesel Impacts of Exhaust Emissions". Below is the figure on which I based the percent change in emissions production. I calculated percentage change for 100% biodiesel (B100), 20% biodiesel (B20), and 10% biodiesel (B10).

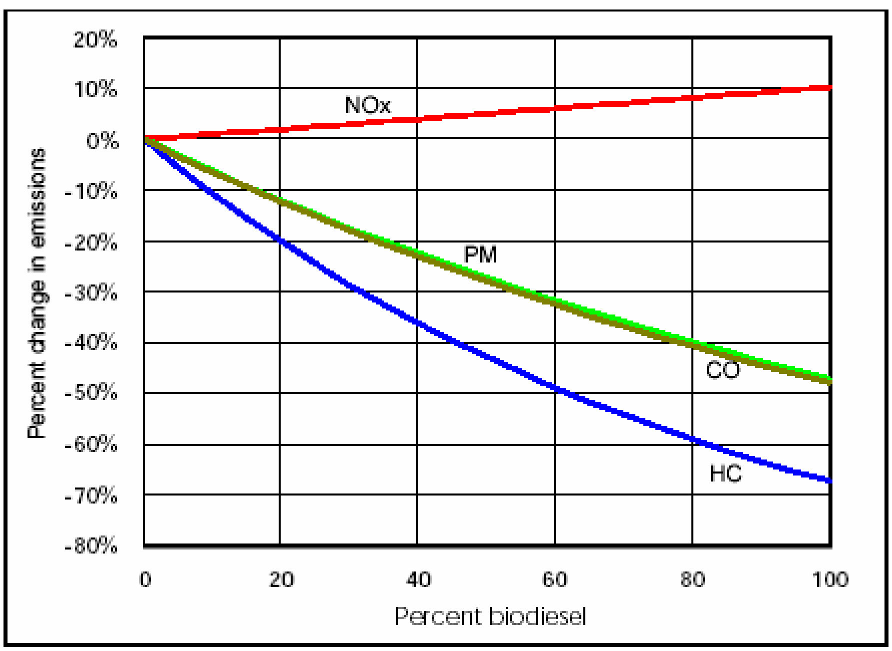


***Figure 1*. Percent change in emissions with diesel and biodiesel concentrations. (EPA, 2002)**

Results:

Emissions and Mileage- PM	Emission Rate	Conversion	Fuel Use/Year	Fuel Economy	Miles Driven	PM Emissions/ Year	PM Emissions/Year
	g/bhp-hr	g/mile	gallons	mpg	miles/year	ton/year	pounds/year
pre-1990	0.6	1.7934	9200	15	138,000	0.27	544.48
1994-1998	0.1	0.2989	9200	15	138,000	0.05	90.75
1998-2004	0.1	0.2989	9200	15	138,000	0.05	90.75
						Average	241.99

***Table 1*. Particulate matter (PM) emissions in pounds/year from Smith Ground's Crew diesel engines.**

Emissions and Mileage- HC	Emission Rate	Conversion	Fuel Use/Year	Fuel Economy	Miles Driven	PM Emissions/ Year	PM Emissions/Year
	g/bhp-hr	g/mile	gallons	mpg	miles/year	ton/year	pounds/year
pre-1990	1.3	3.8857	9200	15	138,000	0.59	1179.70
1994-1998	1.3	3.8857	9200	15	138,000	0.59	1179.70
1998-2004	1.3	3.8857	9200	15	138,000	0.59	1179.70
						Average	1179.70

***Table 2*. Hydrocarbon (HC) emissions in pounds/year from Smith Ground's Crew diesel engines.**

Emissions and Mileage- CO	Emission Rate	Conversion	Fuel Use/Year	Fuel Economy	Miles Driven	PM Emissions/ Year	PM Emissions/Year
	g/bhp-hr	g/mile	gallons	mpg	miles/year	ton/year	pounds/year
pre-1990	15.5	46.3295	9200	15	138,000	7.03	14065.64
1994-1998	15.5	46.3295	9200	15	138,000	7.03	14065.64
1998-2004	15.5	46.3295	9200	15	138,000	7.03	14065.64
						Average	14065.64

***Table 3*. Carbon Monoxide (CO) emissions in pounds/year from Smith Ground's Crew diesel engines.**[1]

Emissions and Mileage- Nox	Emission Rate	Conversion	Fuel Use/Year	Fuel Economy	Miles Driven	PM Emissions/ Year	PM Emissions/Year
	g/bhp-hr	g/mile	gallons	mpg	miles/year	ton/year	pounds/year
pre-1990	6	17.934	9200	15	138,000	2.72	5444.76
1994-1998	5	14.945	9200	15	138,000	2.27	4537.30
1998-2004	4	11.956	9200	15	138,000	1.81	3629.84
						Average	4537.30

***Table 4*. Nitrogen Oxides (NO) emissions in pounds/year from Smith Ground's Crew diesel engines.**

[1] Most vehicles do not approach 15.5 g/bhp-hr of carbon monoxide, and in-use calculations can range from 5-15.5 g/bhp-hr (Christine Sansevero- Personal Communication, 2004).

Tables 1-4 present the total volume of EPA regulated emissions from the 9200 gallons of diesel fuel used by Smith College Grounds Crew in 2003-2004 year. The highest volume is of carbon monoxide, with 14,065 pounds/year. It should be noted that in-use values for the carbon monoxide are frequently lower than the required standard. Next highest volumes are nitrogen oxides with 4527 pounds/year, hydrocarbons with 1180 pounds/year, and finally particulate matter with 242 pounds/year.

B-100			
Emission	Percent Change	Pounds/Year Change	Pounds/Year Emitted
PM	-47	-113.74	128.25
HC	-67	-790.40	389.30
CO	-48	-6751.51	7314.13
Nox	10	453.73	4991.03

***Table 5*. Change in pound/year of regulated EPA emissions using 100% biodiesel in the Smith Grounds Crew diesel engines.**

B-20			
Emission	Percent Change	Pounds/Year Change	Pounds/Year Emitted
PM	-11	-26.62	215.37
HC	-20	-235.94	943.76
CO	-11	-1547.22	12518.42
Nox	2	90.75	4628.05

***Table 6*. Change in pound/year of regulated EPA emissions using 20% biodiesel in the Smith Grounds Crew diesel engines.**

B-10			
Emission	Percent Change	Pounds/Year Change	Pounds/Year Emitted
PM	-5	-12.10	254.09
HC	-10	-117.97	1297.67
CO	-5	-703.28	14768.92
Nox	1	45.37	4582.68

***Table 7*. Change in pound/year of regulated EPA emissions using 10% biodiesel in the Smith Grounds Crew diesel engines.**

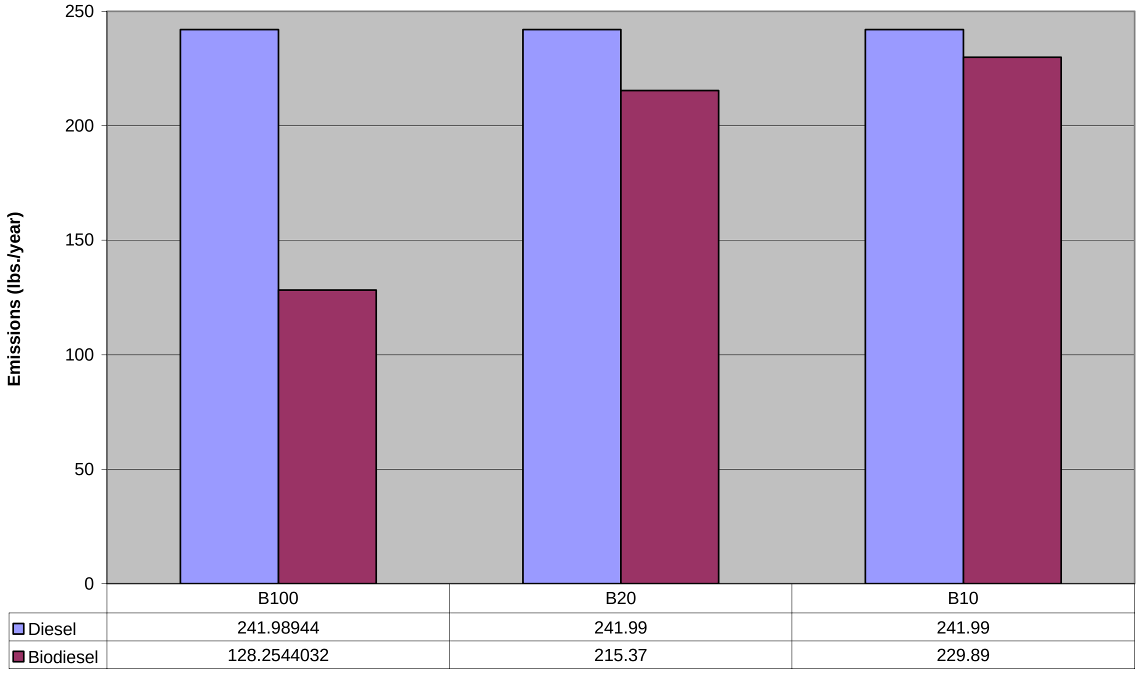


***Figure 2*. Comparison of particulate matter emissions between petroleum diesel and B100, B20, and B10 biodiesel blends in the Smith Grounds Crew diesel engines.**

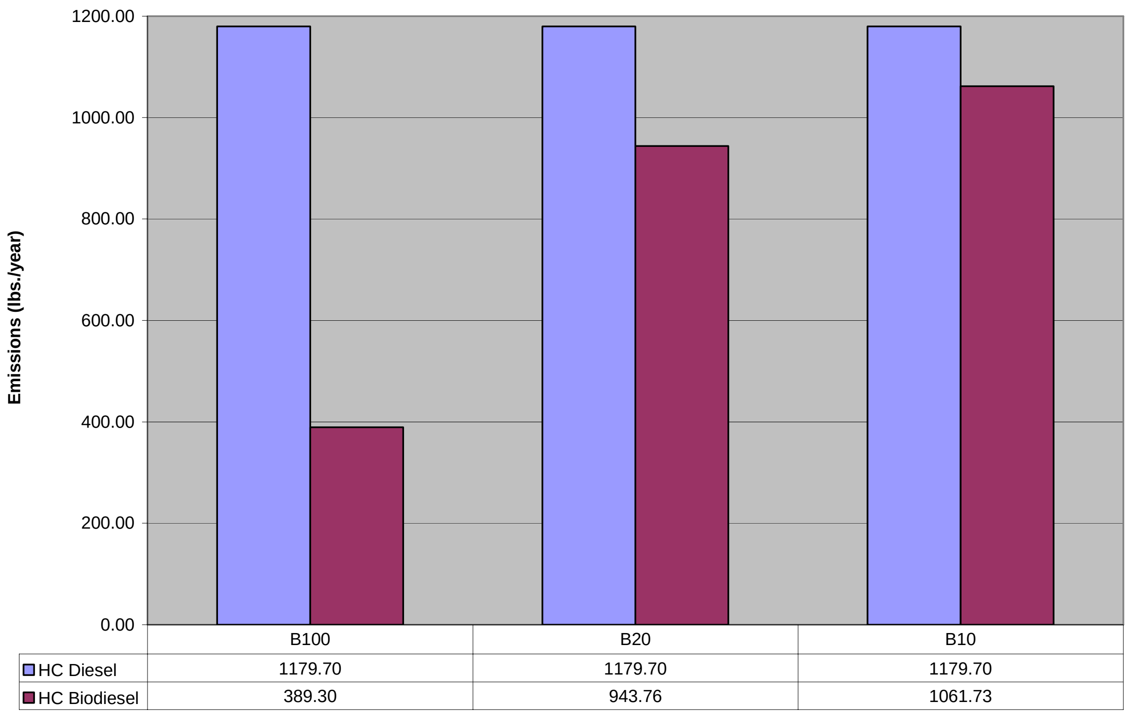
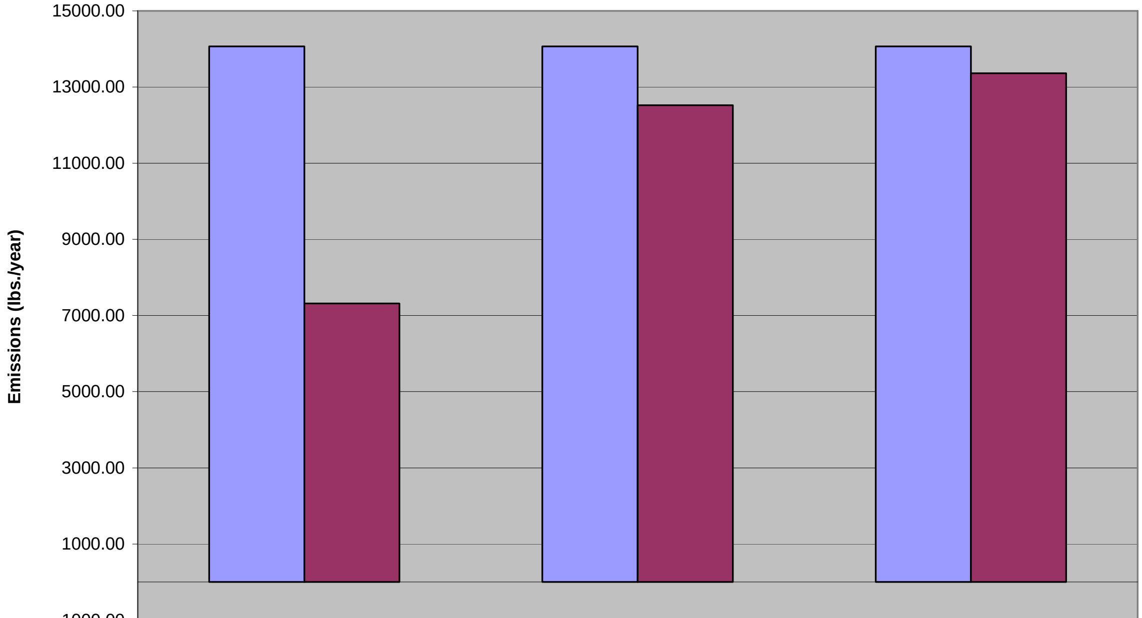
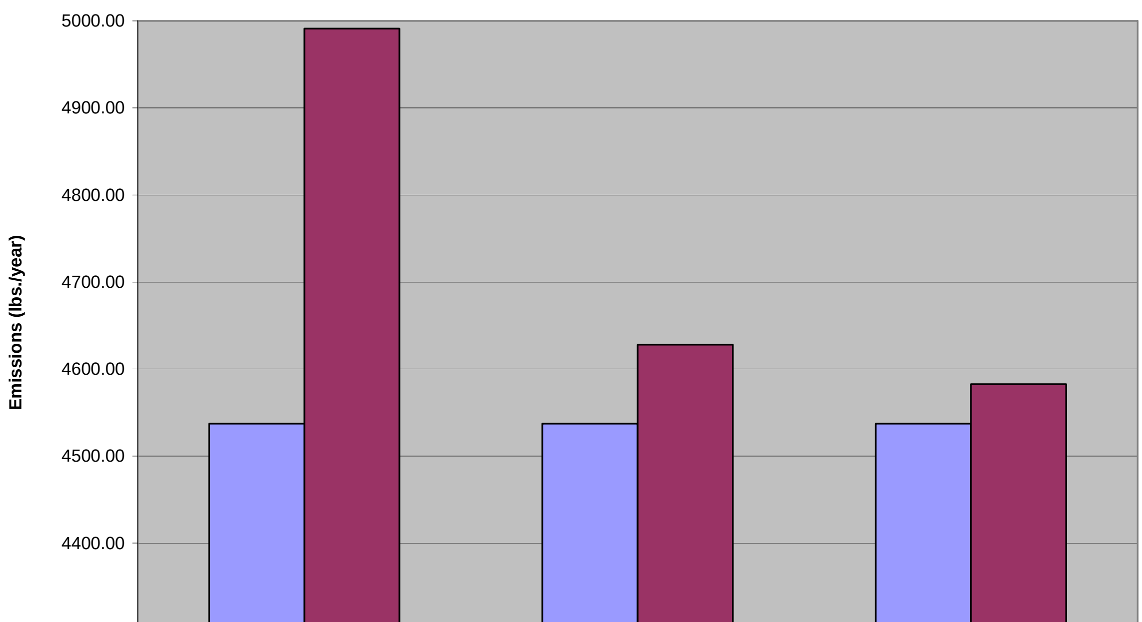


***Figure 3*. Comparison of hydrocarbon emissions between petroleum diesel and B100, B20, and B10 biodiesel blends in the Smith Grounds Crew diesel engines.**



	B100	B20	B10
CO Diesel	14065.64	14065.64	14065.64
CO Biodiesel	7314.13	12518.42	13362.35

***Figure 4*. Comparison of carbon monoxide emissions between petroleum diesel and B100, B20, and B10 biodiesel blends in the Smith Grounds Crew diesel engines.**



	B100	B20	B10
NO Diesel	4537.30	4537.30	4537.30
NO Biodiesel	4991.03	4628.05	4582.68

***Figure 5*. Comparison of carbon monoxide emissions between petroleum diesel and B100, B20, and B10 biodiesel blends in the Smith Grounds Crew diesel engines.**

Tables 5-7 show that in all regulated emissions with the exception of nitrogen oxides the volume of emissions decreases as concentration of biodiesel increases. They also reveal that the volume of the increase of emissions in pounds/year of nitrogen oxides is far lower than that of the decrease for particulate matter, hydrocarbons, and carbon monoxide.

Figures 1-4 show that the difference between diesel and biodiesel emissions volume decreases with decreasing biodiesel concentration. Figures 1-3 reveal that the volume of particulate matter, hydrocarbon and carbon monoxide emissions in pounds/year increases with decreasing biodiesel concentration. Figure 4 shows that nitrogen oxide emissions in pounds/year decrease with decreasing biodiesel concentration.

Discussion:

Three of the EPA regulated emissions clearly show a decrease in yearly output when using biodiesel and biodiesel blends, while nitrogen oxides show an increase. Although this may initially seem problematic, the decreased need for hydrocarbon and particulate matter control technologies allows for the economical introduction of efficient nitrogen oxide control technology. One such product is called Platinum Plus, a fuel-borne catalyst manufactured by Clean Diesel Technologies. A study by the Southwest Research Institute evaluating effectiveness of Platinum Plus in a B20 blend of biodiesel found that nitrogen oxide emissions were 5% lower than diesel fuel (HPI Innovations, 2004).

Although exact output changes for the four main diesel emissions not regulated by the EPA are impossible to calculate, they deserve mention because all of them show significant reductions. When comparing EPA unregulated diesel emissions with those of B100, sulfur shows a 100% reduction, PAH’s and nPAH’s 80-90% reduction, and carbon dioxide shows a net life cycle reduction of 78% (EPA, 2004). The sulfur reduction is due to the fact that sulfur additives are necessary in diesel engines to provide lubricity. Low lubricity results in high wearing and decreased component life. However, biodiesel provides its own lubricity, and sulfur additives are therefore not necessary. The Stanadyne Automotive Corporation states that a 2% blend of biodiesel is enough to produce desired lubricity in No. 1 diesel, the type used in cold weather climates (NBB, 2004).

The blend of biodiesel recommended by Jim Brown of Alliance Energy for Smith College Grounds Crew vehicles is B10. This would provide more than the desired lubricity and therefore prolong the life of diesel engine components. Since maintenance and replacement of diesel vehicles would be less necessary Smith could save a significant amount of money by using biodiesel. The reason that no blend higher than B10 is recommended to start with is because biodiesel acts as a solvent. A higher blend would dissolve particulates from petroleum diesel combustion very rapidly and potentially clog the fuel lines.

The solvent properties of biodiesel may make it an attractive option in another area of Smith College's petroleum consumption: the boiler plant. In the 2003-2004 year Smith College burned 1,800,000 gallons of #6 oil to heat the campus. The poor quality of #6 oil has caused serious problems in the boiler plant with a buildup of soot in the machinery. In response to this a new multi-million dollar plant has been proposed that can support the electricity and heating needs of Smith College. One potentially less expensive solution is to use a low blend of biodiesel instead of #oil. Biodiesel is not only compatible with heating systems, it burns cleaner, would not produce the same soot problem, and could remove some of the particulate buildup that is causing problems in the boiler plant in the first place.

Clearly biodiesel has a number of advantages in reducing air-borne risks to human health and environmental degradation. The question remains as to whether or not purchasing biodiesel is cost-effective. According to Jim Brown at Alliance Energy Services, their estimate for a B10 biodiesel blend is higher than what they could offer for petroleum diesel fuel. However, the money saved through less maintenance and perhaps even avoiding the need to build a new boiler plant could make this investment worthwhile. In addition to economics, biodiesel is a feasible and uncomplicated way that Smith College could fulfill its goal of providing an education that stresses the importance of environmental stewardship. Let's continue this institution's tradition of being on the foreground of change, and raise the bar for campus sustainability across the nation by switching to biodiesel.

Below is a list of suggestions as to how Smith College should proceed in this move to biodiesel.

Suggestions:

- Continue establishing a relationship with Alliance Energy Services (AES) in Holyoke, MA.
- Purchase all fuels directly from AES, even if we are not buying biodiesel from them. When biodiesel becomes a commitment Smith College would like to make, or the price becomes more reasonable, we would already have a reliable established relationship with a distributor.
- Use a B10 blend of biodiesel in all 20 Grounds Crew vehicles initially, and then work up to B20.
- Consider using some blend of biodiesel in the boiler plant instead of building a multi-million dollar co-generation plant as has been proposed.
- Publicize the use of biodiesel as an example of our commitment to Clean Air-Cool Planet, in hopes that other institutions follow suit.

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