Howard High School

Project Green Fleet:

Building a Sustainable Future in Howard County with Biomass

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July 2020 - April 2021

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I. Introduction

Before 1886, students around the world were without transportation (1). Thankfully, school buses provide children with reliable transportation every day. However, the same buses that help children every day are parasitic for the environment: they lack the advanced technology seen in modern vehicles. Outdated machinery, such as diesel fueled engines, contribute a large quantity of carbon emissions, causing a detriment to the environment (2). The diesel technology in these buses are unsafe and unsustainable, which is why targeting diesel school buses has great potential to decrease environmental burdens (3). Using local diesel alternatives has the potential to transform the efficiency of school buses in Howard County, Maryland. By utilizing biodiesel in school buses - who currently consume a large quantity of fossil fuels with little efficiency, leading to an increase in greenhouse gas emissions, Howard County can significantly and economically reduce greenhouse gas emissions.

II. Petroleum Diesel

In the late 19th century, Rudolph Diesel transformed the automobile industry with his relatively efficient, compression diesel engine (1). However, scientists reached a consensus that diesel is not a suitable/sustainable energy source. Standard diesel is extremely detrimental

towards the environment; Diesel contributes heavily to air pollutants, resulting in 461 million metric tons of carbon dioxide (4). This is extremely inefficient when compared to petrol cars with a catalyst: diesel engines have higher emissions of Nitrous Oxide (NOx) and much higher emissions of particulate matter (5). In addition, diesel has various ecological effects. Particulates impair visibility and adversely affect plant growth while dealing devastating damage to soil structure and property (6). These effects can drastically affect crop production and threaten many plant species due to the high NOx levels emitted from diesel; NOx's are the primary pollutants that create low level ozone (smog), acid rain, and nitrate particulates (7). Not only does diesel affect the natural world, it also harms the industrial world.

Truck Fleet managers around the country face issues surrounding diesel engines. The owners of diesel vehicles report numerous issues regarding their fuel type and engine (8). The most common of these problems are severe engine malfunctions. Diesel is more easily contaminated than other fuels because it is very viscous, resulting in glycol, dilution, soot, and water contamination of the diesel (9). Major engine disruption can occur from these contaminants if they intrude the fuel system (8). These issues can amass to the point where maintenance and repair costs are detrimental to the financial well-being of a fleet manager. Unreliable technology with outdated applications should not be entrusted to transport children every day from and to school, raising the need for alternative fuel solutions.

Fleet owners are not the sole victims of the issues facing diesel engines. Recent studies indicate that negative health effects can be directly associated with diesel interaction. Diesel may in fact be carcinogenic: it has the potential to cause cancer (10). The exhaust of diesel vehicles is an established cause of lung cancer; the IARC notes that there is evidence that

diesel may also cause bladder cancer and the OSH claims that breathing in diesel exhaust even short term can make pre-existing asthma worse(11,12). Also, studies show that very high levels can lead to asphyxiation from carbon monoxide poisoning (12). Other health complications are associated with the increased exposure to diesel fumes: irritation of the eyes, skin, or respiratory tract. Furthermore, people can experience dizziness, headache, or nausea from short-term exposure (13). Millions of children every day are exposed to these carcinogenic, harmful fumes due to the reliance on diesel school buses for transportation(14). A redirection towards more renewable fuel sources can help insure the safety of students and staff who encounter school buses on a daily basis.

III. Diesel School Buses & Solutions

School Buses carrying children to and from home rely heavily on diesel technology. Today, 94% percent of school buses in America run on diesel fuel (14). Diesel technology in school buses is outdated and lacks major innovation since its rise in the 1900s. While the world holds its breath for advanced electric vehicles and hydrogen fuel cells (both of which require great infrastructure development), innovations in biomass fuels have been occuring drastically behind the scenes as of May 2020. Utilizing biodiesel offers many advantages to standard diesel with the ability to be incorporated into existing infrastructure and technology. Biodiesel is sourced from virgin or recycled vegetable oils and animal fat residues (15). By reacting such oils or fats with alcohol and a catalyst, fatty acid methyl esters (biodiesel) are produced. Incorporation of biodiesel is very flexible, for biodiesel and petrodiesel can be blended at any rate: the most common being 20%-biodiesel 80%-petrodiesel (B20) or 5%-biodiesel

95%-petrodiesel (B5), allowing for superior versatility in a diesel fleet based on size, funding, and location (16).

As an automotive fuel, biodiesel offers many advantages. First, biodiesel can be incorporated for diesel fuel in all modern diesel vehicles without any alteration to the vehicle. Although, utilizing pure biodiesel (B100) can require some minor modifications to improve reliability (17). Furthermore, to the dismay of contrary belief, performance is *not* compromised in biodiesel systems. A three and a half year study conducted by the U.S. The Department of Energy in 1998 revealed that using low blends of canola based biodiesel causes a minimal fluctuation in fuel economy (16,18). Moreover, numerous studies indicate that biodiesel offers the same torque, horsepower, and haulage as standard petroleum diesel (18). However, the most notable advantage to biodiesel is lubricity,the ability to reduce engine wear caused by friction, and biodiesel usage results in a great increase in lubricity (19). Engine knocking is also reduced due to the higher cetane rating of biodiesel (20). Therefore, biodiesel is beneficial to the health of the vehicle, allowing it to decrease future maintenance costs.

While biodiesel still produces some direct carbon dioxide emissions, biodiesel is nevertheless a carbon neutral option. The U.S. government considers biodiesel to be carbon-neutral because the plants,used as feedstocks for making biodiesel, absorb carbon dioxide (CO2) as they grow (19). The absorption of CO2 by these plants offsets the CO2 that forms while making and burning biodiesel, thus making the use of biodiesel an effective mediator in reducing CO2 emissions. This is exceptional for it is an unrealistic goal to switch from 100% fossil fuel dependent to 0% fossil fuel dependent school buses (Electric) due to the costs associated with 0% fossil fuel dependent. Why not, during this time of situating finances, attempt

to gradually transition into zero emission vehicles? Biodiesel allows for that. The proper fuel source varies from fleet to fleet. Biodiesel may work better in some regions versus others. An analysis was conducted to determine the effectiveness of biodiesel in Howard County, Maryland. The experiment analyzes fuel consumption of randomly selected high school buses in Howard County, Maryland. The study concludes that incorporating B100 blends can reduce carbon dioxide emissions by approximately 76.32% in one year. In the study displayed in figure 1.0 , the 2019-2020 Howard County Bus Trip Summary (21) was referenced to calculate the daily path of four buses in Howard County. The total miles traveled in a year was obtained by mapping the miles traveled throughout all of the stops while assuming the shortest routes, multiplying it by two (assuming the same trip was followed in the afternoon), and then multiplying by 180 to yield an approximation of the miles traveled for a traditional school year. School buses fare an average fuel economy of approximately 4-8 miles per gallon (MPG) (22). Assuming the majority of school buses face highway and suburban driving conditions, an estimated 6 MPG is assumed for determining the gallons of fuel needed per year. By dividing the estimated distance driven in a year by six , the estimated gallons of fuels used per year by each particular bus on standard diesel can be attained. According to the National Renewable Energy Laboratory, the usage of pure biodiesel results in a minor loss of fuel economy (18). The offset is roughly 1.1 gallons of B100 needed for every 1 gallon of petrodiesel (23). By multiplying the original gallons needed for standard diesel by 1.1, an estimate for how much fuel would be needed whilst using B100 can be attained. The U.S. Department of Energy claims that burning one gallon of petroleum diesel will emit 12,360 grams of CO_2 while burning one gallon of pure biodiesel will emit 2661 grams of CO_2 (23). Therefore, by multiplying each of the buses estimated yearly petroleum diesel fuel consumption by 12,360 and multiplying the estimated yearly biodiesel fuel consumption by

2,661, the pounds of CO2 emitted can be approximated once converting from grams CO2 to pounds CO2; all while considering the slight loss in fuel economy. A decrease of approximately 76.32% of carbon dioxide emissions was estimated for each school bus in one year. But what about other options, options that allow for a reduction of 100% carbon dioxide emissions?

Figure 1.0: Carbon Dioxide Emissions Standard vs Biodiesel

Bus	Distance Traveled In A Year (Miles)	Estimated Yearly Petrodiesel Fuel Consumption (gallons)	Estimated Yearly Biodiesel Fuel Consumption (gallons)	Carbon Dioxide Emissions Using Diesel Fuel (lbs)	Carbon dioxide Emissions Using Biodiesel (B100) Fuel (lbs)	
ATHOLTON HS BUS 54 AM	3564	594	653.4	16,185.99	3,833.17	
HOWARD HS BUS 726	2844	474	521.4	12,916.09	3,058.79	
MT HEBRON HS BUS 129	3096	516	567.6	14,060.55	3,329.83	
MARRIOTTS RIDGE HS BUS 105	3420	570	627	15,532.00	3,678.29	
% change						-76.32%

Electric vehicles have zero dependence on fossil fuels, and thus emit nothing. Electric

vehicles have increased in popularity at an incredible rate, with Bloomberg estimating that by 2040 electric vehicles will account for 35% of new car sales (see figure 2.0). Although electric vehicles are an excellent alternative to traditional gasoline and diesel, many drawbacks exist which prove that electric school buses are not an ideal fit for the Howard County Public School System at this time.

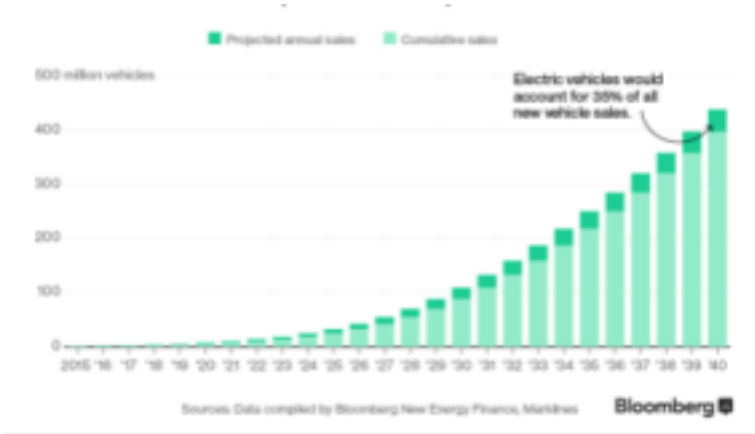

Figure 2.0 Electric Vehicle Market Boom

The first major issue with electric school buses has been a problem surrounding all electric vehicles since their debut: cost. An electric school bus can cost as much as $400,000, costing at least two to three times as much as standard diesel buses. These massive costs take a toll on a school district's ability to fund entire fleets (24). Furthemore, costs electric vehicles are projected to decrease over the next decade as the infrastructure matures, so purchasing an electric vehicle now would provide a lower carbon reduction than using the same amount of money to convert roughly 30 school buses to B100 until the cost decreases and other complications are addressed. This demonstrates that biodiesel buses can be more effective than a small quantity of electric vehicles.

In addition to the high costs of electric vehicles, battery material supply cannot keep up with the demand. While the market for electric vehicles expands, so does the battery market: the lithium ion battery market is also expected to rise at 21.7% annually (25). The primary materials that

make up EV's batteries are Nickel, Manganese, Cobalt, and Aluminum . Cobalt is the most expensive of these raw materials: at $27,000 per ton (26). Due to high prices and scarcity of these metals, analysts predict that a natural resource limiting factor for the EV industry will arise. Desjardins, an author for Business Insider, writes on how Cobalt poses the greatest difficulty: 65% of all cobalt production comes from the Democratic Republic of Congo (DRC), who are in a politically corrupt situation (26). Battery demand is rising fast, production is cut from the DRC, and a supply deficit is becoming more evident. The market for electric vehicles has potential to become much more volatile, and it may not be a best option for the future.

Furthermore, a problem with electric vehicles lies within the roots of all lithium ion batteries. Electric car (EV) batteries are made up of thousands and smaller batteries that together hold enough energy to push a vehicle at high speeds for a long range (27). However, all rechargeable batteries degrade over time and a list of regulations decreases the capabilities of the battery (28). Eventually, when the battery dies, there are few EV battery recycling systems in the United States. However, it is possible that in the future EV batteries become a closed loop in which the production of the batteries is made with high quality material for the intention of reusing the battery material after it is replaced; which typically occurs when the battery is 30% degraded(26,28).

Figure 3.0

Finally, it is a common misnomer for electric vehicles to display "zero emission" (*figure 3.0)*. However, this term is very misleading. Although electric vehicles may have no direct carbon dioxide emissions, there are more to emissions than directly what comes out of the tailpipe (29).

A very important concept when evaluating the sustainability of electric vehicles is the carbon cycle, which explains the transfer of energy and carbon throughout the geosphere. Figure 4.0 demonstrates that 72.01% of electricity in the United States comes from a fossil fuel source, with 49.61% alone coming from coal. This means that every time an electric bus is being charged in Howard County, the electricity will come from fossil fuels, and thus emit carbon dioxide indirectly. Some electric vehicle companies like Tesla, however, utilize only renewable energy at charging stations (30). This is an excellent idea but until the infrastructure is in place where Howard County can attain electricity through renewable sources for a low price, the technology remains immature when evaluating electric school buses and their flaws holistically.

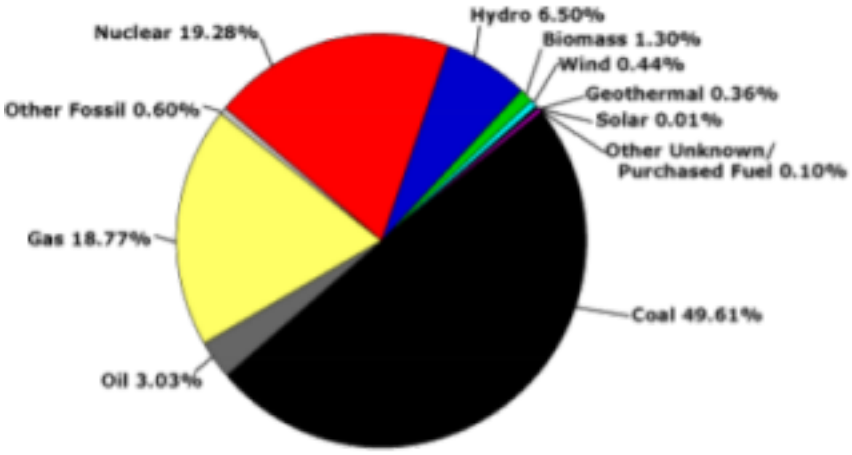

Figure 4.0: Sources of Electricity in the United States

IV. Funding & Strategy

In terms of biodiesel blend possibilities, the two most probable ratios are B20 and B100. B20 requires no conversion in a standard school bus and they can run year round (16). If higher blend usage is favorable, it is possible to utilize B100 blends without the fear of biodiesel gel building up during wintertime. This is possible due to the technology created by Optimus Technology, a biodiesel conversion company located in Pennsylvania. The Chief Executive Officer (CEO) of Optimus Technology, Colin Huwyler, explained the technology that allows

B100 to be utilized without gel production or any harmful effects. The conversion is called the vector system, it replaces the standard fuel tank with a split tank, and the vehicle runs on diesel until the engine warms up. Then, the engine draws the fuel out of the component of the fuel tank that contains the B100, so it is warmed and will not gel (17).

Hypothetically, the vector system sounds remarkable--however, pricing is one of the most important factors when evaluating practicality of an alternative fuel source (31). Huwyler claims that the average cost per conversion is around $12,000 to $15,000. Although it seems like a hefty sum, it is rather minuscule when compared to the potential $400,000 vehicle price per electric school bus (24). The Thomas Experiment was conducted in which a scenario is presented where the Howard County Public School System is granted $1.2 million to begin the development of alternative fuel school buses. The experiment does not put into account tax credits, electric bills, or fuel transportation costs, for these are addressed later. The experiment assumes an average diesel bus in Howard County emits 14,000 lbs CO2 (see figure 1.0) --Figure 5.0 demonstrates the results. The number available to purchase is obtained by dividing the **raw** cost of each type of bus by the allotted money ($1.2 million). The average price of a standard diesel bus of $50,000 was used, the maximum price of Optimus Technology B100 conversion at $15,000 was applied, and the cost of $400,000 per electric bus was assumed. Emission reductions indicates the difference between the amount of CO2 emitted by standard diesel versus the experimental fuel. B100 value was obtained through the calculation: (14,000*.7632)-14000, where .7632 was derived from figure 1.0. Because the source of electricity is not put into account, the electric bus reduces CO2 emissions by 100%, and thus the difference is 14,000 lbs CO2. These values are then multiplied by the number available to purchase, and it is evident that purchasing a greater quantity of less effective biodiesel school buses has a greater impact on reducing emissions than

purchasing fewer, more expensive, electric buses.

Figure 5.0: The Thomas Experiment

Type of vehicle	Number available to purchase with $1.2 million	Emission reductions from standard diesel per bus	Total emission reduction
Standard Diesel Bus		0 lbs CO2	0 lbs CO2
B100 Conversion		3,315.2 lbs CO2	265,216 lbs CO2
Electric Bus		14,000 lbs CO2	42,000 lbs CO2

While the Thomas Experiment is based on a spending barrier of $1.2 million, it is highly unlikely that this magnitude of funding is attainable during this time in Howard County. However, there are many ways to fund such a program at a smaller degree.

Jill Hamilton, the president of Sustainable Energy Strategies Inc., provides several outlooks proving that funding the Optimus Technology B100 conversion is possible. The best possible option is a partnership with the Renewable Energy Group (REG). Jon Scharingson from REG will be contacted once bus companies approve the project and preliminary information is obtained. Renewable energy group works with numerous Maryland distributors and other distributors of biodiesel, and they would incentivize creating a biodiesel fueling station within reasonable distance of all of the biodiesel buses. They have previously completely funded demonstration programs, so a state demonstration would occur with Ryan Frazier of DC Public Works. Furthermore, because of the estimated $1 per gallon tax credit of biodiesel, it may need to be negotiated between the biodiesel supplier, renewable energy group, and the bus contractor.

An important factor in determining eligible bus fleets with REG is the contract of each bus. It will be best to convert buses that have the longest time remaining on the contract, or buses with the longest remaining lifetime. Based on REG's agreement, it may be needed to extend existing contracts or await for near future new diesel school bus purchases to convert those with a long lifetime ahead.

In the event that REG is unable to fund the project, obtaining a plethora of funding from state and national grants is possible. Reimbursement grants allow for the possibility for a B100 grant to pay for up to 20% of the costs of the vehicle conversion. Furthermore, Maryland had about 323,000 allocations in 2019. A diesel retrofit project grant can further help offset the costs and provide funding to implement and expand biodiesel stations throughout Howard County. Another source of funding from the state is from the Maryland soybean board. They would most likely be a reimbursement option and funding would be applied for around late February to early March of next year . The tax credits and funding capabilities are expected to increase over the next few years, so consistent funding could serve to build towards self sufficient biodiesel usage in Howard County. Specificities and intricacies can be discussed with the bus companies and then relayed back to REG where reports of updates and approvals will be relayed between myself and Howard County bus companies.

The reductions of carbon emissions, realistic costs, and improved health environments for children create many groups of consumers benefiting from the transition to renewable fuels. However, one of the greatest benefits will be imposed upon the bus company/companies that commit to utilizing renewable diesel fuel. The bus company will have the ability to improve company image astronomically, showing determination and passion for adapting and overcoming

modern changes by implementing innovative solutions. Each GreenFleet “BioBus” can be painted green, and receive sponsorships from the local companies and organizations tackling climate change. By doing so, the bus will not only carry healthy fuel, but a healthy image for the company as a whole. By investing now, the future of the bus company can be transformed into a well known initiator of a much needed change.

Biodiesel is an all around fantastic contender for renewable energy in Howard County. It is an excellent introduction to self sufficient renewable energy, and experts believe that this project can be expanded to integrate more and more buses and expand into local government buildings through anaerobic digestion and photo/dark fermentation applications. Dr. May discussed the future possibility of producing biodiesel in Howard County from waste biomass to generate revenue and supply school buses with fuel. This renewable vision is highly unheard of in typical media reports dominated by applications of electric, solar, and wind energy. However, Howard County bus companies can inspire and spread the knowledge and application of energy derived from biomass. Project GreenFleet builds upon the original genius of Rudolph Diesel and allows Howard County to serve as the staple of renewable energy in not only Maryland, but the United States as a whole.

V. COVID-19 UPDATE

Due to the COVID-19 pandemic, the state of school operation for the 2020-2021 school was determined to be virtual. However, this does not mean that the Green Fleet project is unattainable. The COVID-19 pandemic has once again portrayed the need for a switch to renewable energy. The oil and gas market has now experienced the third price crash in 12 years.

However, unlike the first two times, the industry is not likely to recover in such a manner after COVID-19. This age highlights itself as a perfect opportunity to combat increasing gas/diesel prices and uncertainty behind availability.

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