EFFECTIVENESS OF FUEL-OPERATED HEATERS IN REDUCING FUEL CONSUMPTION IN BUSES DUE TO IDLING

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By
Jamison R. Walker
Matt L. Heintz

under the faculty guidance of
Dr. Anne Henriksen, Ph.D.

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Submitted by:

Jamison Walker (Signature)

Matt Heintz (Signature)

Advised by:

Dr. Anne Henriksen (Signature)

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Introduction

Background

Idling an engine means that the engine is consuming fuel just enough to keep itself and its accessories running. Therefore, it is not producing any work or usable power. Idling is a major factor in fuel consumption and affects a vehicle's fuel efficiency. The term "idle-reduction" refers to any technology or methods used to reduce the amount of time vehicles idle their engines. Heavy-duty engines, such as those used in school buses, are referred to most in anti-idling because they contribute the majority of idle fuel consumption.

There are a variety of reasons that bus drivers idle their engines. The majority of engine idling occurs in the morning, when drivers are warming up the engines and the passenger compartments. Part of the problem with excessive idling, other than the immense amount of fuel it uses, is drivers' lack of knowledge about the fuel consumption of an idling engine. Typically, a bus driver will turn on the bus when they wake up, then proceed to get ready for the day, creating a period of excessive idling that can last up to half an hour.

The purpose of fuel-operated heaters is to eliminate this need for idling, and in turn reduce fuel consumption and costs. This technology works by using the coolant system to warm the engine, and the "thermal energy gained is then distributed through the vehicle's own heat exchanger as forced hot air. This [process] heats the interior of the vehicle via existing air vents. The engine is [also] warmed up with the residual heat in the cooling water." (1) "In general, coolant heaters burns eight times less fuel that an idling engine would, simultaneously emitting 1/20th of the emissions and producing heat significantly faster." (2)

Literature Review

Anti-idling is a field of research that has been practiced mostly by various levels of government and government agencies. A quick internet search would bring up several scientific studies on the harmful effects of diesel exhaust to human health, though, one must have to dig deeper to find field studies on previous idle reduction programs and even deeper to find another study of this specific kind. With that statement, this may be one of the first field studies done to use real-time Global Positioning System (GPS) tracked data to analyze the effects of fuel-operated heaters on idle-reduction in school buses.

The Environmental Protection Agency (EPA) and the Department of Energy (DOE) are two leaders in paving the way for idle-reduction implementation. Their respective sites offer every bit of information related to anti-idling. The DOE's Alternative Fuels and Advanced Vehicles Data Center (3), AFAVDC for short, is a one-stop domain that Clean Cities programs across the country rely on for basic and in-depth information. Its Idle-Reduction section (4) includes background information, research and development, incentives and laws, case studies, publications, related links and more and can be considered a Mecca for any research done in the field. Additionally, the EPA's National Idle-Reduction Campaign site (5), part of the Clean School Bus USA program, is an equivalent portal of information and has many ties to the

AFAVDC. Its Idle-Reduction Fuel Savings Calculator (6) is a quick estimator for annual fuel and cost savings and has produced similar numbers to what our study found.

One similar study was prepared by the Association of Central Oklahoma Governments and funded by the DOE Clean Cities program. It is the most similar study, in terms of methods and parameters used, to our study. As we did, they, too, used GPS derived data to compare idling characteristics before and after the implementation of a new idling policy. The difference was that they were quantifying the effects of an idle-reduction policy instead of implementing an actual technology. This policy was to restrict drivers from idling their engines for more than five minutes at any given time. This is the difference of reducing idling by human behavioral means versus technological means.

Mobile data tracking units were installed on fifteen buses, which used GPS tracking software to locate the buses whenever the engine was on. Similarly, these units were tied into the ignition and were on only when the ignition was turned. Though, the units used GPS technology, they did not transmit data by satellite. Instead, they transmitted the data via the bus driver's radio frequency in five minute bursts, which led to some transmittal issues due to data and voice frequencies interrupting each other. As this became bothersome, sometimes, the drivers would turn their radios off, which would disrupt data transmission back to the base computer. A field study of this nature is not flawless and can be disrupted by human and technological error, as presented in both studies. Though, it's claimed that overall data is reliable and consistent, as we claim ours is. This study compared baseline 2007 data to the new 2008 data affected by the policy change, parallel to our before and after installation data. Before the new or "after" data was taken, the drivers were trained on why the research and policy was taking place, the benefits to be expected and to be compliant with the new idling regulations, as Virginia Clean Cities, Webasto and VMACS did for the driver's preparation on using the new heaters. In the end, the Association of Central Oklahoma Governments saw an average idling duration per bus after the policy implementation of 23.746 minutes and a maximum emission decrease of 17.6% (7).

Statement of Problem

Bus drivers idle their engines to warm components before using the engine to maximize its performance and to avoid any problems that may occur from the interaction of cold parts, such as stalling. While a warmed engine is necessary to achieve maximum driving efficiency and to prevent higher maintenance costs, there are other more sustainable alternatives to idling. The problem that this project addresses is the fuel consumption due to unnecessary idling that occurs every day in fleets of school buses. Excessive idling is the root of many other problems that this project will also address, such as unnecessary emissions, excessive fuel consumption and the costs associated with each. One objective of this project is to deal with driver perception, which is the main cause of excessive idling in school buses. The other objective is to directly address the problem by implementing technology that will eliminate the need for excessive idling. The technology to be tested is called a fuel-operated heater, which is essentially an auxiliary power unit for the purpose of warm air. The heaters are installed under the hood and directly connected to the buses fuel tank. As coolant fluid flows through the heater, a flame within warms the fluid, which then circulates around the engine and creates warm air blown into the passenger compartment, therefore, preheating the engine and passenger compartment while using a fraction of the fuel.

There are no known programs in Virginia that have used this technology to limit idling and that have collected data to confirm manufacturer claims. Due to the fairly mild climate of Virginia Beach and Albemarle County, this pilot program will help capture key fuel economy, idling hours, and driver behavior data to determine how effective the coolant heater device is for idle reduction in school buses in this particular climate. (2)

Sponsors and Audiences

This project, as part of the EPA's Clean School Bus USA program, originated with a grant given by the EPA to the Mid-Atlantic Regional Air Management Authority (MARAMA) and was contracted out to Virginia Clean Cities (VCC) for the purpose of implementing an idle-reduction pilot program with fuel-operated heaters in select school systems in Virginia. The grant was divided between two school systems: Virginia Beach City Public Schools (VBCPS) and Albemarle County Public Schools (ACPS) with Virginia Clean Cities managing the project. Virginia Clean Cities "is a government-industry partnership designed to reduce petroleum consumption in the transportation sector by advancing the use of alternative fuels and vehicles, idle reduction technologies, hybrid electric vehicles, fuel blends, and fuel economy."(8) As the DOE's primary transportation sector deployment program for alternative fuels, Virginia Clean Cities receives a majority of their funding by applying for grants from the DOE and the EPA for various alternative fuel and fuel efficiency projects.

This project required financial, technical, and logistical support from a number of organizations. The financial support came solely from the grant given to VCC under the project management of Ms. Chelsea Jenkins, Executive Director of VCC. Additional parties involved were Mr. Paul Baczewski of Webasto Products North America and Mr. Scott Faivre of Virginia Mobile Air-Conditioning Systems. Other technical and logistical support was provided by members of Argonne National Lab and VCC. Linda Gaines, of Argonne National Lab, and Dr. Christie-Joy Brodrick Hartman, who has done idling studies for Argonne National Lab and is currently at James Madison University as part of the Institute for Stewardship of the National World, are leaders in research for idle-reduction technology. Logistical support came from Dr. Anne Henriksen and other faculty of the Integrated Science and Technology department at James Madison University.

Outline of the Report

This is a full report that includes OBJECTIVES, METHODOLOGY, RESULTS, DISCUSSION, CONCLUSIONS, FUTURE WORK, UNANTICIPATED CHALLENGES, REFERENCES, ACKNOWLEDGEMENTS and APPENDIX. The literature review includes explanations of similar past projects and other various resources on the topic of idling that we used as references. The objectives provide an overview of what we expect to see in the results and how it relates to the scope of the problem. The methodology goes through how this project will be implemented including the hands-on aspects as well as the data acquisition and analysis process. The results present the compiled data as well as all graphs, figures and tables used to present the data. The discussion includes interpretations and explanations of the data analysis and an evaluation of their significance to the scope of the problem. The conclusions highlight the most important findings from the data and how they support inferences made about the heater's effectiveness in idle-reduction. The future work section includes an explanation of the potential results that could be collected if the project were ongoing. The unanticipated challenges emphasize all barriers and changes faced over the course of the project that had an impact on our objectives. The references section lists the sources we have used in this report. The acknowledgements section recognizes the key figures that assisted us over the course of this study. And finally the appendix contains the full results exported from Excel® for both school districts.

Objectives

The main objective of this study is to determine the effectiveness of fuel-operated heaters and prove that they do, in fact, reduce fuel consumption due to idling and, consequently, reduce emissions and save money. Other objectives are to produce real-world values for reductions in fuel consumption, emissions, and associated costs; to validate the claims made by the manufacturers and; as a pilot study, to act as a decision-making tool.

Methodology

Although this project dates back to 2008 via initial proposals, many actions were taken over the course of the past year and a half in order to complete this project. The type of heater, the Webasto TSL-17, was previously chosen before this project was formally begun. Also, the local distributor, through which VCC would order the heaters, was pre-selected. This distributor was VMACS; located in Chesapeake, Va. Virginia Beach was also one of the original locations in which these heaters would be implemented.

The first step was to initiate the ordering and installations of the previously determined amount of ten heaters for Virginia Beach. Virginia Beach ordered each heater on April 26, 2010 for $1,659.62 per unit plus an additional $400 in labor costs per unit. During July 2010, the fuel-operated heaters were installed on ten school buses in the Virginia Beach Public School fleet. The day of the first installation there was an idling education seminar for the bus drivers conducted by VCC and a survey was given to the bus drivers to gather information about their driving habits and knowledge. There was also a mechanics training to teach the mechanics how to maintain the heaters, which was performed by a representative of Webasto. Virginia Beach's buses were also equipped with digital timers that were then programmed to turn the heaters on when the fleet desired, which was in the morning.

The second step was to secure Gloucester County Public Schools (GCPS) as the second fleet to test heaters with the remaining funding, as GCPS was also, initially selected as a location for this pilot project. This was the first major barrier as GCPS was not fully committed to joining the project and eventually reneged on participating, leaving VCC with $30,000 in available funding.

We went about searching for another school system to replace GCPS. We sought another school fleet that utilized the same GPS units, which will be discussed in the next section, that VBCPS used. The GPS systems were pertinent to the data gathering portion of the study. By contacting the maker of the GPS, Everyday Solutions, we found other accounts in Virginia that also used the same GPS units in their bus fleet. The Transportation Director of Albemarle County Public Schools was offered this grant and immediately accepted and joined the study, becoming the second participant to use the remaining funding. On October 28, 2010, VCC ordered 14 TSL-17 heaters and by early December 2010 they had all been installed in Albemarle County by VMACS. The same Webasto representative performed a mechanic's training, and VCC issued the same driver habits survey to the prospective bus drivers. The fleet began using the heaters in mid-December 2010.

Acquiring Data

The importance of the GPS units, which are not to be confused with the fuel-operated heaters or digital timers, involves the acquisition of idling data. Since we are comparing the change in idling durations of before and after installations, we needed something that could record accurately when a target bus is idling. The GPS and its respective computer software, *Everywhere Light*®, has the ability to record idling data from each bus equipped with a GPS and export via an Idling Summary Report that can be uploaded and imported to Microsoft Excel® spreadsheets. The GPS works by analyzing what the bus is actually doing. When the key is turned in the ignition, the GPS is on and tracking. If the bus is still, then the GPS will record that time as idling and will stop once the bus begins to move. If the bus begins to move again before the excessive idling threshold is reached then that idling occurrence will be discarded. In our case, the excessive idling threshold was ten minutes. Unfortunately, the GPS will still continue to count up idling times when only the auxiliary power is on but the engine is off. Assuming that the drivers do not let their auxiliary power stay on when the engine is off, we can neglect this characteristic because, in our case, it is not measurable how often they would do this.

The Microsoft Excel® spreadsheets, which can be seen in the Appendix, show certain data including vehicle number, total excessive idle duration, excessive idle occurrences, cost of gas used during idling, and various types of emissions. The program can pull information from the GPS based on any day and time and archives a full year's worth of daily data. The compared data would include characteristics from January, February, and March of 2010 and 2011 so that we could see trends between different idling characteristics in similar temperatures of before and after installation. We would receive this data from Virginia Beach via exported Microsoft Excel® attachments in emails and from ACPS via Dropbox®, which is an online backup and file-sharing software solution. All of our data was stored and organized using Dropbox®. It's to be noted that we were entirely dependent on external sources to acquire our data.

Analyzing Data

The parameters for the data analysis were set to certain times of the year. Since the software has the ability to go back to old data, our goal was to compare data of the target buses and two other control groups; one control group was created based on similar idle durations (Idling Time Control Group) and the other was created based on similar miles driven and fuel economy (MPG Control Group).

For Virginia Beach, the selection of each particular control bus was done very carefully. One of the documents that we received from Robert Clinebell, Fleet Manager at VBCPS, contained a profile for each bus in their fleet with bus number, year, make, model, engine type, mileage, fuel quantity, and fuel economy. Both control groups were selected from the buses that had the same year, make, model, and engine type that the experimental group had. These buses were all 2004 Freightliner FS65 7.2L. The MPG Control Group was selected one-by-one by similar fuel economy. Each Experimental Group bus had a corresponding Control Group bus. For example, A1 from the Experimental Group matches up with B1 from the MPG Control Group and C1 from the Idling Time Control Group. The Idling Time Control Group was selected by compiling and averaging actual idling data from January and February 2010. Each bus was selected one-by-one by similar idling times.

For Albemarle County, the control group selection was more challenging. We did not have access to the same materials that we did for Virginia Beach, namely the fleet profile. So we could not select control groups knowing that we were selecting buses that were all the same make, model, and year. We did have access to reports from January to March 2011 taken whenever a bus refuels that logs the odometer reading and how much fuel was pumped into the bus. From this we could determine approximate fuel economy. So, in Albemarle County we selected a MPG Control Group. Before we could select an Idling Time Control Group, we needed to acquire some idling data. We ran into numerous roadblocks at this step. There were problems on the Albemarle County end related to administrative access into the *Everyday Light®* program. After numerous calls to Everyday Solutions this issue was resolved but there were still issues with exporting the data. In late March 2011, we went to the bus facility in Albemarle to collect the data personally. Due to our late start with Albemarle County, the numerous roadblocks in data acquisition, and the fact that archived data in Everyday Light only goes back one year, we were unable to obtain any data from the target period in 2010.

Assumptions

When the fleet manager of either fleet logs into *Everywhere Light®* to export the reports, they adjust one variable. This variable is the price of the fuel for the day of each particular report. The cost of fuel used for idling is a function of a pre-determined rate of fuel consumption during idling and the price of fuel for that day. The rate of fuel consumption used in this study was 1.3 gallons of diesel fuel per hour of idling. This is the default value in the software, though, we are able to adjust this and use various scenarios of heavy and light consumption values. The measure of emissions is a function of pre-determined rates of emissions per hour of idling and idle duration. Each type of emission had a unique rate. This study assumes that one hour of idling emits 41 grams of carbon monoxide (CO), 109 grams of nitrous oxides (NO_x), 8 grams of hydrocarbons (HC), 5,846 grams of carbon dioxide (CO_2), and 0.35 grams of particulate matter (PM); also, commonly published values and default values from the *Everywhere Light®* program. From this data, we were able to determine the changes due to use of the fuel-operated heaters in duration of idling, cost of fuel consumed from idling, and emissions from idling. We also assumed that any difference between the before and after data is a direct effect of heater use and not from a change in bus use between the two periods.

Another important assumption that was made for purposes of this study was the excessive idling threshold. In this study we used a threshold of ten minutes. Excessive idling thresholds are defined differently in various parts of the country and ten minutes is a conservative figure and a figure use commonly used in Virginia. As referenced in the Virginia Administrative Code, ARTICLE 41. EMISSION STANDARDS FOR MOBILE SOURCES (RULE 4-41), 9 VAC 5-40-5670, "diesel powered vehicles may idle for up to ten minutes to minimize restart problems."

It is also to be noted that the data we retrieved from each bus may not be lab-tested, but can be used as theoretical values. Each bus, though, using the same make, model and year engines, may also have different fuel consumption and emission rates. The process to actually measure each bus's consumption and emission rates would have been too complicated and time consuming for the extent of this project, though we did attempt to acquire rates directly from the manufacturers, but we were only able to find California Air Resource Board documents stating the engines met certain limitations and not the actual measurements. It is also to be noted that we did attempt to acquire consumption and emission rates from the manufacturers.

Once we had the data, we could make comparisons between the three groups of buses and expected to see a decline in idle duration, idle cost and emissions in the experimental group. The various chart comparisons can be seen in the Appendix, but a few key figures will be discussed in the results.

Results

In this section we will present a summary of the results we observed in each school district. For Virginia Beach, we will present a few tables that cover the most important findings from our study in addition to a simple economic analysis. We will also present figures that graphically summarize our most important results. For Albemarle County we will present a table summarizing the preliminary results that we were able to see.

Virginia Beach City Public Schools

On the following page, Table 1 shows the idling results that we observed in the Experimental Group. There was a decrease in both the average idling duration as well as the average idling occurrences. The average idling duration fell from 58 minutes and 28 seconds to 41 minutes and 48 seconds. This drop of 16 minutes and 40 seconds translates to a 28.5% reduction.

Table 1. Reductions in Experimental Group due to installation of fuel-operated heaters.

Average Idling Duration (MM:SS)	
Before Installation	58:28
After Installation	41:48
Reduction	16:40 (28.5%)
Average Idling Occurrences	
Before Installation	3.28
After Installation	2.42
Reduction	0.86 (26.1%)

Table 2 below details the emissions reductions that were observed in the Experimental Group. Each pollutant dropped by 28.5% over the experimental period, though the actual values vary greatly due to the varying constants on which they are based. CO_2 was the largest emission, while particulate matter was the smallest.

Table 2. Reductions in emissions in Experimental Group due to installation of fuel-operated heaters.

	CO	**NO_x**	**HC**	**CO_2**	**PM**
Before	39.9	106.2	7.79	5,695.9	0.344
After	28.6	75.9	5.57	4,072.1	0.245
Reduction	11.4	30.3	2.22	1,623.8	0.098
			(28.5%)		

The Figure 1 below graphically illustrates the reductions in average daily idling time for each group. As was stated earlier, the Experimental Group experienced the greatest decrease from the before period to the after with a 16:40 difference. The Idling Time Control Group, with a 11:15 drop, and the MPG Control Group, with a 5:49 drop, also experienced a decrease but not to the same degree. The percentage decrease for each group is shown in Figure 2 on the following page. The Experimental Group's decrease of 28.5% was much more than the decrease in the MPG Control Group of 10.3% and slightly more than the Idling Time Control Group's decrease of 23.7%.

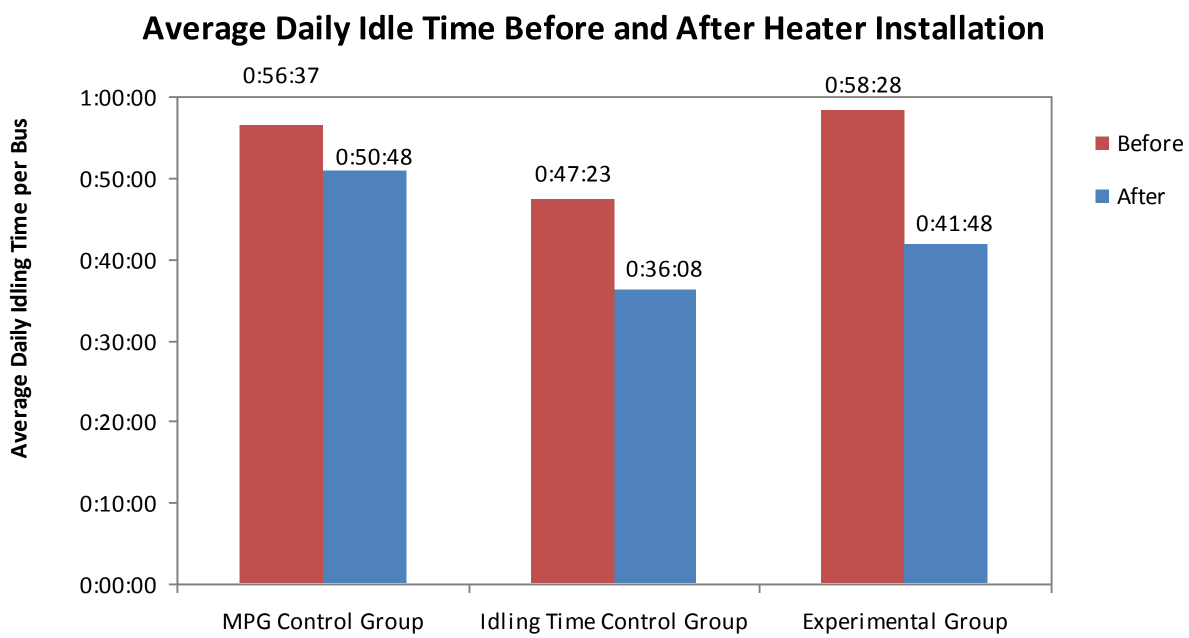

Figure 1. Comparing the idling times from before (January to March 2010) and after (January to March 2011) fuel-operated heater installation for each group.

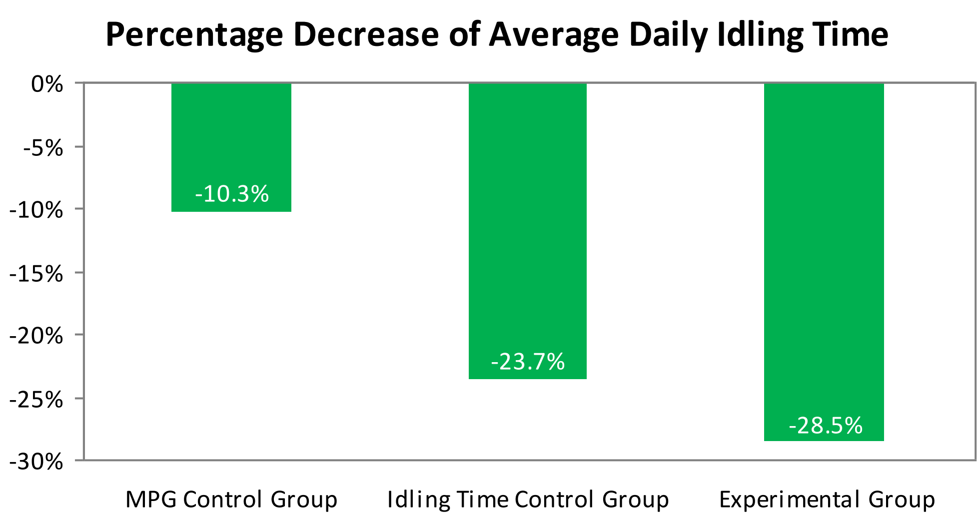

Figure 2. Percentage decrease from before to after fuel-operated heater installation in average daily idling time for each group.

The average daily emissions of the Experimental Group for each pollutant for both the before and after period are illustrated in Figure 3 below. While each pollutant decreased by different amounts, each experienced the same percentage decrease from before to after as can be seen in Figure 4. The percentage decrease of each pollutant is also shown for both of the control groups in Figure 4. The percentage decrease in emission for each group is the same as the percentage decrease in average daily idling time for each group as seen in Figure 2.

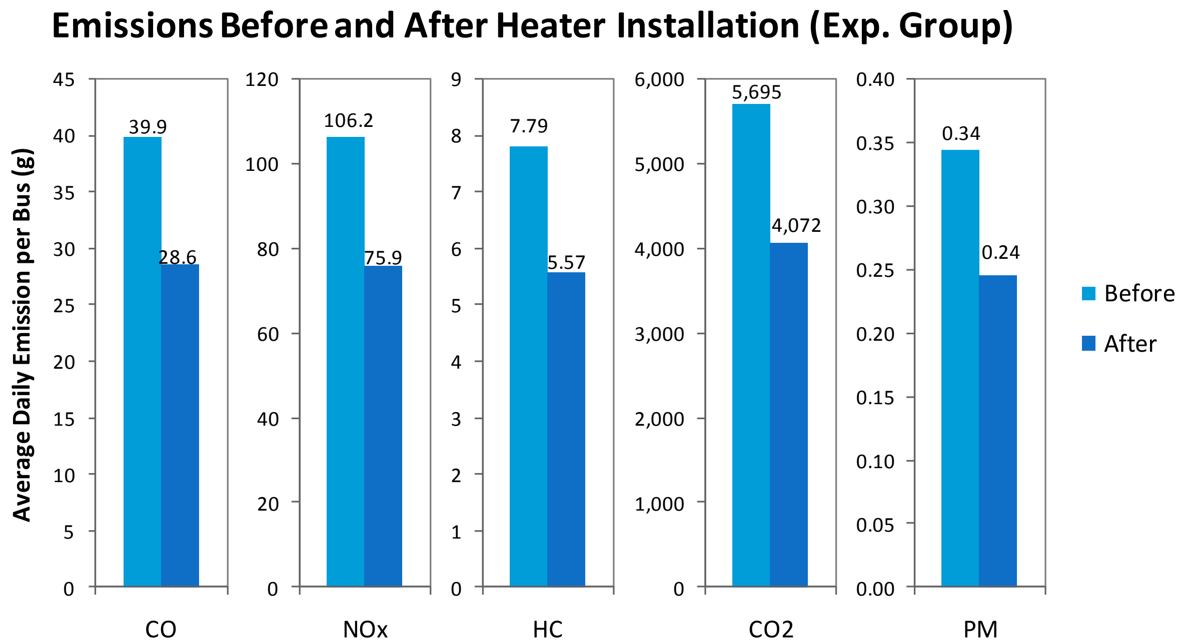

Figure 3. Reduction of average daily emission per bus from Experimental Group before and after fuel-operated heater installation.

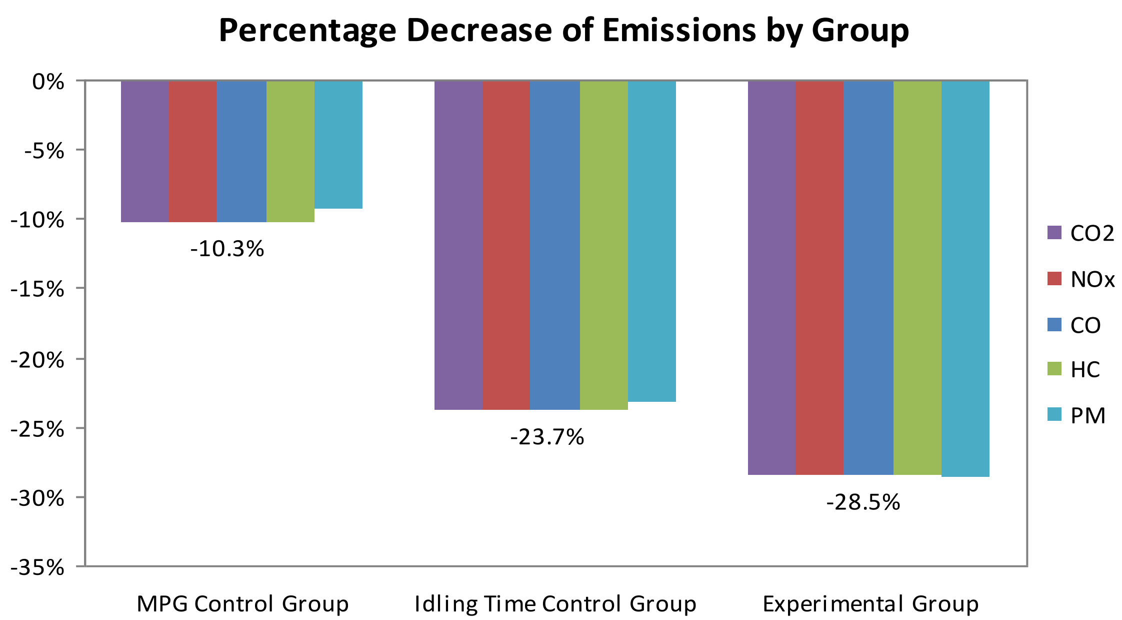

Figure 4. Percentage decrease of each emission for each group from before period to after period.

Figure 5, below, shows the average daily cost of the fuel per bus that is used on idling for each group. Values for both the before period and after period are shown. Figure 6 summarizes the percentage change in the average daily cost of fuel used on idling. Each group experienced a different change. The cost for the MPG Control Group rose by $0.49, the Idling Time Control Group's cost stayed the same, while the Experimental Group was the only group whose average daily cost of fuel decreased, by $0.13. These numbers do not take into account the increase in fuel price from 2010 to 2011.

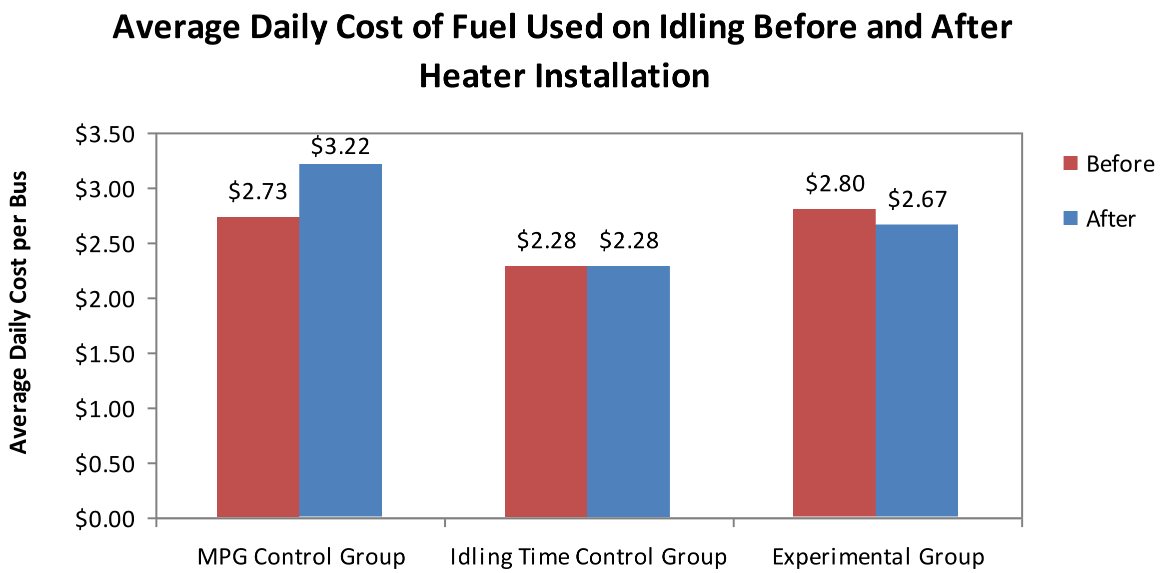

Figure 5. Average daily cost of fuel per bus used on idling before and after fuel-operated heater installation for each group.

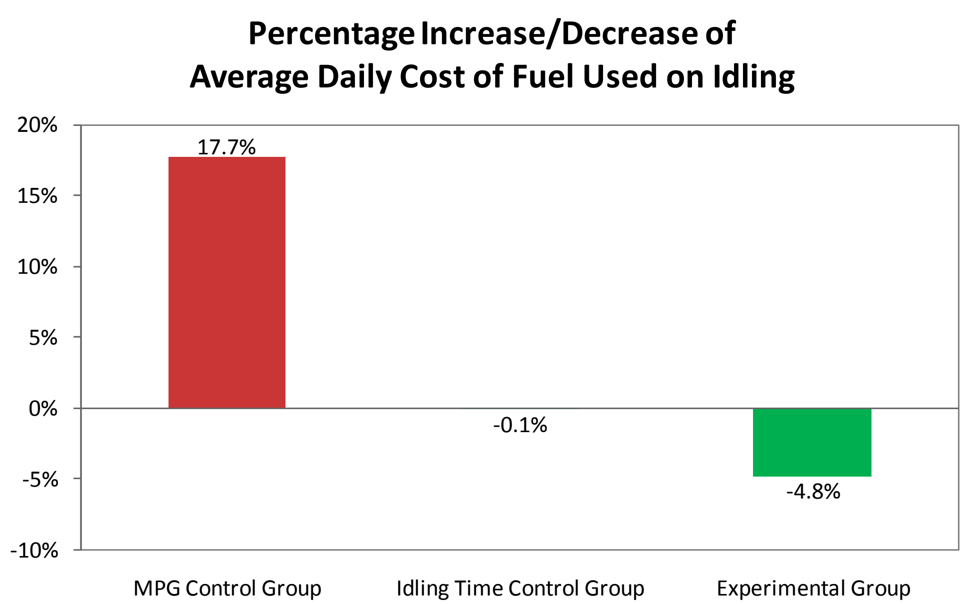

Figure 6. Percentage change in average daily cost of fuel used on idling for each group.

The average daily excessive idling occurrences per bus for each group are illustrated in Figure 7. The biggest difference was observed in the Experimental Group with a 0.86 drop from the before to the after period. The MPG Control Group's occurrences stayed about the same for both periods and the Idling Time Control Group dropped by 0.33 occurrences per day.

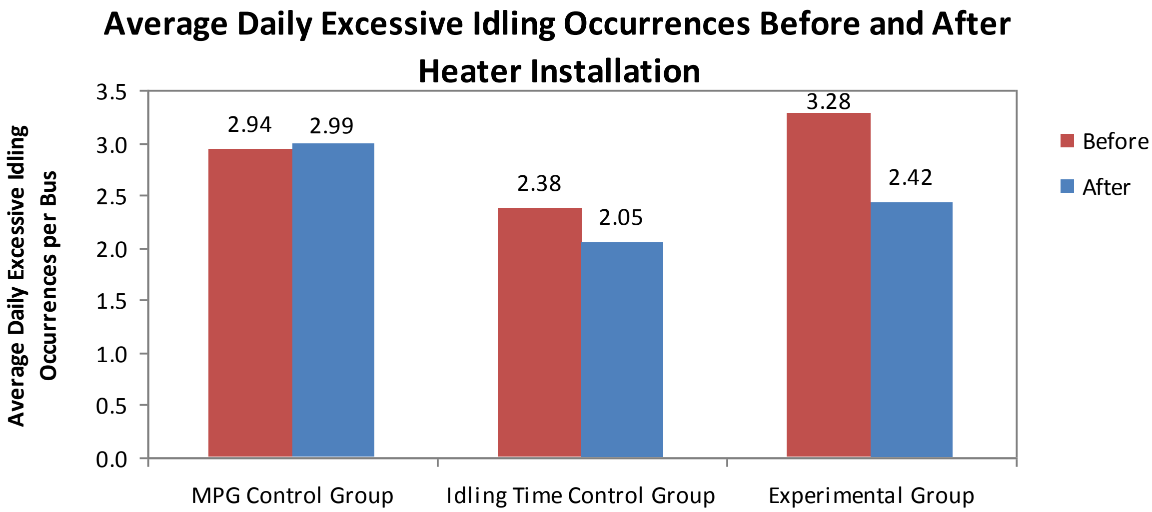

Figure 7. Average daily excessive idling occurrences per bus before and after fuel-operated heater installation for each group.

The values presented in Table 3 illustrate the avoided costs associated with our results. The average cost per day fell by $0.13 from before to after installation of the heaters even though the average fuel price per gallon increased by $0.73 over the same period.

Table 3. Avoided costs in Experimental Group due to installation of fuel-operated heaters.

Before Costs – Experimental Group	
Total Cost of Fuel Used for Idling	$545.20
Total Idling Duration (HHH:MM:SS)	189:33:22
Cost/Hour of Idling	$2.88
Average Fuel Price/Gallon (based on 1.3 gal/hr)	$2.21
After Costs – Experimental Group	
Total Cost of Fuel Used for Idling	$512.73
Total Idling Duration (HHH:MM:SS)	134:17:27
Cost/Hour of Idling	$3.82
Average Fuel Price/Gallon (based on 1.3 gal/hr)	$2.94
Difference in Average Fuel Price/Gallon	$0.73
Average Measured Cost/Day (Before)	$2.80
Average Measured Cost/Day (After)	$2.67
Difference in Cost/Day	$0.13

Table 4 details a simple payback calculation based on the price of fuel and the observed savings per bus. These savings are then projected for five months of use per year. Based on the initial investment of $20,000 for the ten heaters and the current cost of fuel, the payback period derived from our observed results would be 25 years.

Table 4. Calculations for simple payback period for the ten fuel-operated heaters installed in Virginia Beach.

If average fuel price stayed at $2.21 for After, the After Cost/Day would be:	$2.00
Savings per bus per day:	$0.80
Savings per day for ten buses:	$8.00
Savings for five months of use (five days/wk)(four wks/mo):	$800.00
Simple Payback Period ($20,000 initial investment):	25 years

Albemarle County Public Schools

The following Table 5 shows the average idling duration and average idling occurrences for both the Experimental Group and the MPG Control Group in Albemarle County. The average idling duration was roughly the same for both groups, but the Experimental Group had slightly fewer average occurrences.

Table 5. Average idling results in Albemarle County for each group.

Average Idling Duration (MM:SS)	
Experimental Group	39:58
MPG Control Group	39:34
Average Idling Occurrences	
Experimental Group	2.03
MPG Control Group	2.16

Discussion

It is important to acknowledge that our results are conservative based on our assumed idling fuel consumption rate of 1.3 gallons per hour. But because our results are linearly proportional to the idling fuel consumption rate it is easy make adjustments our results had we assumed a lower value. Argonne National Lab uses a value of 0.64 gallons per hour, so to adjust our results based on this rate we would simply divide our results in half. It is also important to recognize that setting the threshold for excessive idling to ten minutes does not account for any idling occurrence less than ten minutes. Depending on the type of route and driver behavior, there could have been several accumulated shorter idling occurrences that would not have been accounted for. These occurrences were not measured, but may act to balance the conservative fuel consumption rate.

Virginia Beach City Public Schools

We found that the heaters essentially eliminated 0.86 morning idle occurrences each day, accounting for 16 minutes and 40 seconds each time. This supports our theory that bus drivers may idle their engines anywhere between 15 and 30 minutes during morning pre-route. This 0.86 less occurrences each day is a 26.1% decline in idle occurrences, but accounts for a 28.5% decline in total idle duration, which can be seen in Table 1. Since the emissions are directly proportional to the fuel consumption, the 28.5% figure also describes the reductions in emissions, as seen in Table 2. Note that CO_2 comprises 97.4% of overall emissions. The environmental benefits seen in the use of these heaters are significant and normally seen from conservation in fuel use and not from the effects of increased efficiency, which is disproved by this heater.

The financial benefits of the heaters add to the environmental benefits. Actual costs associated with the time period that we tested from are not important, and were only used in our calculations to determine potential savings the heaters could have in a longer period and/or lifetime. By dividing the total cost of idling for the period and dividing by the total number of hours we could determine the cost per hour of idling. By diving this by 1.3, we retrieved the average cost per gallon for the period. We did this for both periods and found that the average cost for fuel was $2.21 before and $2.94 after, a $0.73 rise in average fuel cost. Even with this rise in fuel price, we still saw a decrease in cost of fuel consumed by idling per day of $0.13 as seen in Table 3. This is because the significant reduction of 28.5% in fuel consumed outweighed the increase in fuel cost. For an even better comparison, we calculated what savings would have been had the price in fuel stayed constant between the periods. By multiplying the average fuel price of the before period ($2.21) by the average duration of idling for the after period (0:41:48 = 0.697 hours) by 1.3 gallons of fuel used on idling per hour we determined the cost of fuel due to idling per day would have been $2.00. This is a $0.80 reduction from the average cost of idling per day per bus in the before period as seen in Table 4. This number can be manipulated into numerous savings depending on how often throughout the year a school decides to use the heaters.

Albemarle County Public Schools

Due to the various challenges that hindered our data acquisition with Albemarle County, we could not observe the same results nor draw the same conclusions as we did with Virginia Beach. We did not collect sufficient data. However, from the data that we could retrieve, we did observe idling times for the Experimental Group that were very similar to the idling times observed in Virginia Beach after the fuel-operated heaters were installed. There has also been a very positive response from the drivers of the buses with the heaters in Albemarle County. Christine Martinez, Fleet Manager at ACPS, reported that the drivers could not say enough about the heaters' ease of use and effectiveness. She said that they “absolutely love” being able to go out to a warm bus in the mornings. (9)

Conclusions

While the heaters do reduce fuel consumption due to idling and emissions significantly, based on their initial costs we did not find them to be cost effective in the short term with a simple payback period of 25 years. This is assuming that a school would use the heaters during five cold months, four weeks a month, and five days a week. Though, the payback period will decrease the more the heaters are used. For example, if they were to be used year-round in Flint, Michigan then we could see double the savings and therefore half the payback period. Also, as the price of fuel goes up, the heaters become more cost effective because they save more money per unit of fuel. For a ten-year payback, the fuel price would need to be $5.53 per gallon. For a five-year payback, fuel would need to cost $11.05 per gallon. This application may be most economically feasible somewhere with more extreme temperatures and higher fuel prices unlike the temperate climate of Virginia, where fuel price is below the national average. We estimate that if this heater were used ten months out of the year in a colder climate like Michigan and fuel was higher, one could see a payback in as little as a few years. Although savings in this scenario proved to be ineffective economically, if the environmental effects cover the remaining costs then it could be worth it, but that is dependent on the parameters of the user.

Future Work

One of our goals for this analysis was for it to be used as a decision-making tool for future school systems. There are not any other current or past full-cycle analyses on this technology here in Virginia and very few known in other states, which were done by other Clean Cities coalitions. Hopefully, a fleet manager or director of transportation can use this guide to aid his/her judgment, whether it is based off fuel savings, emissions reductions or both.

Unanticipated Challenges

This anti-idling project was one part of a Clean School Bus grant that involved a few other projects focused on reducing diesel consumption in school buses in Virginia. There was not an official project management plan or corrective action plan so the administrative role followed more of a “case by case” action plan. Instances of past barriers were presented in previous sections of the narrative that described the early problem with GCPS and finding another participant to finish out the grant, which required deadline extensions on the time frame of our reporting. These were problems VCC overcame to initiate the experimental portion, which had unintended consequences of its own.

The experimental portion was our main responsibility to carry out. Acquiring our data had the most roadblocks since it was dependant on external sources and in doing so, coordination was key. We started retrieving data from Mr. Robert Clinebell, until he was replaced by Mr. Curtis Barger. The switch delayed our data collection a few months as Mr. Barger had to settle into the role. In Albemarle we ended up having to retrieve the data in person because Ms. Christine Martinez’s account was not setup as having administrative access to the bus information. We resolved this by working with an Everyday Solutions' IT staffer to give her account access. Because this wasn't resolved until March 2011, we went to Albemarle and collected the data ourselves in the interest of time. Analyzing the data required problem solving, as well. We found that when we exported the reports from *Everywhere Light®* into Microsoft Excel® each sheet had to be completely reformatted to allow us to feed the information into our structure. This was a very time and effort intensive part of our project.

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Appendix

Full Results for Virginia Beach City Public Schools

Averages for Experimental Group After Installation (Jan. 21 - Mar. 21, 2011)

ID	Vehicle	Avg Excessive Idle Duration	Excessive Idle Occurrences	Cost	Emissions (g)				
					CO	NO_x	HC	CO_2	PM
A1	27	0:30:57	1.8	$1.94	21.15	56.23	4.12	3,016.10	0.19
A2	54	0:51:51	2.8	$3.27	35.43	94.18	6.91	5,051.23	0.30
A3	123	0:51:56	3.3	$3.53	35.49	94.36	6.91	5,060.77	0.30
A4	136	0:23:08	1.5	$1.44	15.81	42.03	3.09	2,254.43	0.15
A5	148	0:53:52	3.6	$3.29	36.84	97.86	7.18	5,247.74	0.30
A6	161	0:17:32	1.2	$1.10	11.97	31.84	2.35	1,707.71	0.12
A7	320	0:35:28	1.8	$2.26	24.24	64.43	4.73	3,455.37	0.21
A8	354	0:59:15	3.6	$3.79	40.49	107.64	7.90	5,772.69	0.35
A9	358	0:45:21	2.0	$2.96	30.99	82.39	6.04	4,418.94	0.28
A10	697	0:48:37	2.6	$3.09	33.21	88.32	6.48	4,736.22	0.27
	Average	0:41:48	2.42	$2.67	28.56	75.93	5.57	4,072.12	0.245

Averages for Experimental Group Before Installation (Jan. 22 - Mar. 19, 2010)

ID	Vehicle	Avg Excessive Idle Duration	Excessive Idle Occurrences	Cost	Emissions (g)				
					CO	NO_x	HC	CO_2	PM
A1	27	1:12:44	3.8	$3.48	49.70	132.14	9.70	7,086.95	0.42
A2	54	1:55:30	6.0	$5.52	78.91	209.81	15.38	11,253.04	0.67
A3	123	0:50:26	3.2	$2.44	34.47	91.62	6.71	4,913.59	0.30
A4	136	0:21:10	1.4	$1.03	14.46	38.47	2.82	2,063.03	0.14
A5	148	1:20:01	5.1	$3.85	54.69	145.37	10.66	7,796.84	0.47
A6	161	0:40:48	1.8	$1.98	27.87	74.14	5.43	3,975.92	0.25
A7	320	0:57:27	2.9	$2.75	39.26	104.37	7.66	5,597.55	0.33
A8	354	1:24:46	4.9	$3.99	57.90	153.97	11.30	8,258.37	0.49
A9	358	0:33:51	1.8	$1.61	23.13	61.49	4.51	3,297.76	0.20
A10	697	0:27:53	1.9	$1.33	19.05	50.64	3.72	2,715.96	0.17
	Average	0:58:28	3.28	$2.80	39.94	106.20	7.79	5,695.90	0.344

Averages for MPG Control Group After Installation (Jan. 21 - Mar. 21, 2011)

ID	Vehicle	Avg Excessive Idle Duration	Excessive Idle Occurrences	Cost	Emissions (g)				
					CO	NO_x	HC	CO_2	PM
B1	475	0:53:11	2.2	$3.18	36.31	96.59	7.10	5,181.66	0.30
B2	184	0:34:47	2.6	$2.20	23.76	63.18	4.63	3,388.28	0.21
B3	353	0:45:56	2.3	$2.94	31.38	83.43	6.12	4,475.06	0.27
B4	333	1:18:22	4.3	$4.99	53.55	142.37	10.44	7,635.45	0.47
B5	65	0:21:09	1.1	$1.34	14.44	38.43	2.83	2,061.40	0.14
B6	361	0:52:42	3.3	$3.30	36.02	95.74	7.03	5,134.60	0.31
B7	362	0:57:16	2.7	$3.62	39.12	104.02	7.64	5,578.88	0.33
B8	336	1:22:38	5.0	$5.28	56.46	150.11	11.02	8,050.80	0.49
B9	137	0:24:37	1.7	$1.55	16.83	44.72	3.28	2,398.42	0.15
B10	332	1:06:24	4.2	$4.23	45.37	120.63	8.86	6,469.68	0.39
	Average	0:50:48	2.99	$3.22	34.71	92.27	6.77	4,948.96	0.302

Averages for MPG Control Group Before Installation (Jan. 22 - Mar. 19, 2010)

ID	Vehicle	Avg Excessive Idle Duration	Excessive Idle Occurrences	Cost	Emissions (g)				
					CO	NO_x	HC	CO_2	PM
B1	475	1:00:21	3.0	$2.90	41.25	109.65	8.04	5,880.24	0.35
B2	184	0:26:13	2.0	$1.26	17.91	47.62	3.49	2,553.64	0.15
B3	353	0:28:34	2.1	$1.37	19.52	51.87	3.80	2,782.55	0.17
B4	333	1:08:33	3.4	$3.30	46.85	124.55	9.12	6,679.77	0.40
B5	65	0:39:14	2.3	$1.89	26.81	71.28	5.23	3,822.70	0.23
B6	361	1:05:39	3.6	$3.18	44.86	119.26	8.76	6,396.11	0.40
B7	362	1:11:06	3.0	$3.46	48.59	129.16	9.48	6,927.50	0.42
B8	336	1:03:56	3.9	$3.07	43.70	116.15	8.53	6,229.88	0.37
B9	137	0:50:39	1.6	$2.44	34.60	92.00	6.75	4,934.18	0.31
B10	332	0:49:09	3.2	$2.35	33.59	89.29	6.55	4,788.85	0.28
	Average	0:56:37	2.94	$2.73	38.69	102.86	7.55	5,516.54	0.333

Averages for Idling Time Control Group After Installation (Jan. 21 - Mar. 21, 2011)

ID	Vehicle	Avg Excessive Idle Duration	Excessive Idle Occurrences	Cost	Emissions (g)				
					CO	NO_x	HC	CO_2	PM
C1	137	0:24:37	1.7	$1.55	16.83	44.72	3.28	2,398.42	0.15
C2	118	1:04:39	3.2	$4.15	44.18	117.47	8.62	6,299.69	0.39
C3	65	0:21:09	1.1	$1.34	14.44	38.43	2.83	2,061.40	0.14
C4	701	0:23:34	1.7	$1.46	16.11	42.80	3.13	2,295.53	0.14
C5	349	0:59:58	2.3	$3.81	40.98	108.95	7.99	5,843.39	0.36
C6	130	0:24:49	2.0	$1.61	16.96	45.09	3.31	2,418.52	0.14
C7	362	0:57:16	2.7	$3.62	39.12	104.02	7.64	5,578.88	0.33
C8	122	0:37:39	2.1	$2.33	25.74	68.41	5.02	3,668.86	0.23
C9	328	0:29:54	1.9	$1.88	20.44	54.31	3.98	2,912.87	0.17
C10	184	0:34:47	2.6	$2.20	23.76	63.18	4.63	3,388.28	0.21
	Average	0:36:08	2.05	$2.28	24.69	65.65	4.82	3,520.96	0.214

Averages for Idling Time Control Group Before Installation (Jan. 22 - Mar. 19, 2010)

ID	Vehicle	Avg Excessive Idle Duration	Excessive Idle Occurrences	Cost	Emissions (g)				
					CO	NO_x	HC	CO_2	PM
C1	137	0:50:39	1.6	$2.44	34.60	92.00	6.75	4,934.18	0.31
C2	118	1:09:59	3.0	$3.36	47.82	127.14	9.34	6,819.03	0.41
C3	65	0:39:14	2.3	$1.89	26.81	71.28	5.23	3,822.70	0.23
C4	701	0:22:27	1.3	$1.10	15.33	40.77	2.98	2,187.05	0.15
C5	349	1:12:15	2.5	$3.43	49.37	131.25	9.65	7,039.56	0.43
C6	130	0:37:35	2.4	$1.82	25.67	68.26	5.00	3,661.11	0.22
C7	362	1:11:06	3.0	$3.46	48.59	129.16	9.48	6,927.50	0.42
C8	122	1:08:20	3.4	$3.28	46.70	124.16	9.12	6,658.65	0.39
C9	328	0:41:53	2.1	$2.01	28.61	76.08	5.58	4,080.18	0.25
C10	184	0:26:13	2.0	$1.26	17.91	47.62	3.49	2,553.64	0.15
	Average	0:47:23	2.38	$2.28	32.38	86.07	6.32	4,616.30	0.279

Full Results for Albemarle County Public Schools

Averages for Experimental Group After Installation (Jan. 3 - Mar. 21, 2011)

ID	Vehicle	Avg Excessive Idle Duration	Excessive Idle Occurrences	Cost	Emissions (g)				
					CO	NO_x	HC	CO_2	PM
A1	60	1:00:26	3.4	$3.83	41.29	109.80	8.06	5,888.76	0.37
A2	72	0:49:39	2.5	$3.37	33.92	90.19	6.61	4,837.32	0.29
A3	88	0:27:34	1.7	$1.71	18.83	50.07	3.67	2,685.47	0.17
A4	143	0:32:47	1.1	$2.01	22.39	59.54	4.37	3,193.47	0.20
A5	146	0:28:35	1.5	$1.75	19.53	51.92	3.80	2,784.85	0.16
A6	154	0:19:13	1.2	$1.17	13.13	34.91	2.56	1,872.34	0.13
A7	164	0:46:16	2.6	$2.80	31.61	84.04	6.17	4,507.22	0.27
A8	178	0:45:49	2.3	$2.86	31.31	83.22	6.11	4,463.63	0.27
A9	181	1:01:13	3.4	$3.77	41.83	111.21	8.17	5,964.87	0.36
A10	191	0:29:19	1.4	$1.79	20.04	53.26	3.91	2,856.41	0.16
A11	194	0:38:53	1.2	$2.42	26.56	70.63	5.18	3,788.18	0.23
	Average	0:39:58	2.03	$2.50	27.31	72.62	5.33	3,894.78	0.237

Averages for MPG Control Group After Installation (Jan. 3 - Mar. 21, 2011)

ID	Vehicle	Avg Excessive Idle Duration	Excessive Idle Occurrences	Cost	Emissions (g)				
					CO	NO_x	HC	CO_2	PM
B1	177	0:18:11	1.2	$1.09	12.42	33.03	2.43	1,771.34	0.12
B2	163	0:52:56	3.1	$3.26	36.18	96.18	7.06	5,158.17	0.31
B3	153	0:49:00	2.3	$2.99	33.48	89.03	6.53	4,774.58	0.28
B4	89	1:19:52	4.2	$5.00	54.56	145.07	10.65	7,780.91	0.46
B5	156	0:42:47	2.7	$2.62	29.23	77.71	5.71	4,167.74	0.25
B6	182	0:56:03	3.6	$3.50	38.30	101.81	7.47	5,460.74	0.33
B7	75	0:30:45	1.7	$1.85	21.01	55.84	4.10	2,995.36	0.18
B8	144	0:32:20	1.7	$1.99	22.10	58.74	4.31	3,150.06	0.18
B9	167	0:31:56	2.1	$1.98	21.82	58.01	4.25	3,111.10	0.19
B10	71	0:52:58	3.0	$3.23	36.20	96.20	7.06	5,160.11	0.31
B11	168	0:41:03	1.7	$2.54	28.05	74.56	5.48	3,999.20	0.25
	Average	0:39:34	2.16	$2.44	27.04	71.88	5.27	3,855.12	0.235