MEASURING THE COST-EFFECTIVENESS OF IDLE REDUCTION TECHNOLOGIES IN HEAVY-DUTY TRUCKS

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LIST OF SYMBOLS AND ABBREVIATIONS

AFLEET	Alternative Fuel Life-Cycle Environmental and Economic Transportation
APU	Auxiliary Power Unit
ARRA	American Recovery and Reinvestment Act
ATC	U.S. Army's Aberdeen Test Center
ATRI	American Transportation Research Institute
ATSE	Advanced Truck Stop Electrification
BAC	Battery Air Conditioning Systems
BPAPU	Battery-powered APUs
CARB	California Air Reources Board
CMAQ	Congestion Mitigation and Air Quality
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COPD	Chronic Obstructivepulmonary Disease
CPI	Consumer Price Index
DFH	Direct-Fire Heaters
DOT	Department of Transportation
DPF	Diesel Particulate Filters
EAC	Equivalent Annual Cost
EIOLCA	Economic Input-Output Life Cycle Analysis
EPA	U.S. Environmental Protection Agency
ERC	Emissions Reduction Credits
FEC	Fuels and Emission Calculator
FMCSA	Federal Motor Carrier Safety Administration
GPS	Global Positioning System
GREET	Greenhouse Gases, Regulated Emissions & Energy use in Transportation Model
GVWR	Gross Vehicle Weight Rating

HC	Hydrocarbons
LCA	Life-cycle Assessment
MAP-21	Moving Ahead for Progress in the 21st Century Act
MOVES	Motor Vehicle Emissions Simulator
NAAQS	National Ambient Air Quality Standards
NESCAUM	Northeast States for Coordinated Air Use Management
NESHAP	National Emission Standards for Hazardous Air Pollutants
NO_2	Nitrogen Dioxide
NOx	Nitrogen Oxides
NPV	Net Present Value
NSPS	New Source Performance Standards
O_3	Ground-level ozone
Pb	Lead
PEI	Potential Environmental Impact
PM	Particulate Matter
ROVER	Realtime On-road Vehicle Emissions Reporter
RPM	Revolutions Per Minute
SCS	Shore Connection Systems
SDHT	SmartDriver for Highway Trucking
SIP	State Implementation Plans
SO_2	Sulfure Dioxide
SoCAB	South California Air Basin
TES	Thermal Storage Systems
TSE	Truck Stop Electrification
VOC	Volatile Organic Compounds

SUMMARY

The main objective of idle reduction devices is to reduce the amount of energy wasted by idling trucks, decrease exhaust emissions and save in fuel use and maintenance costs and vehicle life extension. To achieve reductions emissions from vehicle idling in heavy-duty trucks, strategies and actions have been employed through the use of various technologies, namely auxiliary power units (APUs), direct-fire heaters (DFHs), truck stop electrification (TSE) and advanced truck stop electrification (ATSE). Little quantitative data exists on the amount of emissions that are emitted by heavy-duty trucks during idling. In general, diesel engines emit less CO and hydrocarbons (HC) when compared to gasoline engines since fuel-lean mixtures tend to reduce CO and HC emissions.

The purpose of this study is to conduct a systematic review that illustrates the status of data present in literature for costs and emissions reduced for APUs, DFHs, TSEs and ATSEs. From the review process, a cost calculator was devised from the synthesis of literature data to measure cost-effectiveness of these technologies in dollars per year per ton per year of emissions reduced over a 30 year investment period. Data on capital costs, maintenance and operational costs, and fuel costs were reported in order to calculate net present values, payback periods and fuel savings from each technology. Given the relevant data available from various studies that compute the efficiency of competing technologies, TSEs were the most cost-effective for the investor and the truck owner in regards to NOx emissions reduction. Cost-effectiveness measured for investors at $1,707.57 and $1,473.27 per ton of NOx reduced, and $16,799.91, $22,261.44, and $20,583.79 per ton of NOx reduced for truck owners.

The calculator also served as a tool to illustrate insufficient data currently present in the body of literature. Limited quantitative data and unknown variability of costs as a function of time over the 30-year investment period was used to assess best practices. Thus, policymakers and other stakeholders can benefit from this review in order to

conduct future studies that would enlighten greater understanding of data points from specifications of the operating context and devise more robust models for the sake of comparing these technologies based on impact and risk.

CHAPTER 1

INTRODUCTION

Emissions and Idling of Heavy-Duty Trucks

Heavy-duty truck drivers are required by law to rest 8 hours for every 10 driving hours. As a consequence, trucks idle for long periods of time to heat or cool the cabin, keep the engine warm, run electrical appliances, and refrigerate or heat truck cargo. This idling results in gaseous and particulate emissions, wasted fuel, and is costly to the driver, to the fleet owner, and to the environment. Long-duration truck engine idling expends more than one billion gallons of diesel fuel per year and emits 11 million tons of carbon dioxide, 200,000 tons of oxides of nitrogen, and 5,000 tons of particulate matter ("NRDC: Smarten Up and Stop Idling," 2015). Most idling is preventable; creating pollution that could be avoided through idle reduction technology. Idling can also increase engine maintenance costs, shorten engine life, harm driver well-being, and elevate noise levels. However, there are many alternatives to long-duration engine idling: they range in cost from a minimal investment to several thousand dollars.

Various technologies can be used to replace truck idling, including heaters, auxiliary power units, parking space electrification, and heating and air conditioning units in the parking space. Each year, U.S. passenger vehicles, light trucks, medium-duty trucks, and heavy-duty vehicles consume more than 6 billion gallons of diesel fuel and gasoline combined—without even moving. Roughly half of that fuel is wasted by passenger vehicles (cars and light trucks); the remaining half by medium-duty and heavy-duty vehicles. In addition, idling vehicles emit particulate matter (PM), nitrogen oxides (NOx), carbon monoxide (CO), and carbon dioxide (CO_2). These emissions, along with noise from idling vehicles, have led to many local and state restrictions on idling, and research towards reduction of idling given various technologies (Laboratory).

There is very little quantitative data available to assess the emission rates and total emissions from heavy-duty truck idling. In general, diesel engines emit less CO and hydrocarbons (HC) compared to gasoline engines, because fuel-lean mixtures tend to reduce CO and HC emissions (James A. Calcagno, 2004; James A Calcagno, 2005). However, diesel engines emit more PM and NOx per unit of fuel burned compared to gasoline engines.

According to a freight analysis forecast published by the Department of Transportation (DOT), total domestic freight volume, which combines air, highway, rail and water freight, is expected to grow by more than 65 percent, increasing from 13.5 billion freight tons in 1998 to 22.5 billion freight tons in 2020. Freight trucks moved 77 percent of the total tonnage in 1998, and are expected to move at least 75 percent of the total tonnage in 2020 (Bureau of Transportation, 2015). Thus, the number of heavy-duty trucks will increase to satisfy the necessity to transport the additional freight tonnage.

National Ambient Air Quality Standards (NAAQS) have been established for the following criteria pollutants: carbon monoxide, nitrogen dioxide (NO_2), particulate PM, ground-level ozone (O_3), sulfur dioxide (SO_2) and lead (Pb). Total emissions for the six criteria air pollutants have generally declined 48% in the US between 1970 and 2002. During this same time-period, gross national product increased 164 %, VMT increased 155%, energy consumption increased 42% and population increased 38% (James A Calcagno, 2005). Overall, when assessing the effects of these factors on vehicle idling emission programs, principal effort should focus on reducing emissions in an effort to meet air quality standards, if possible.

A substantial amount of heavy-duty diesel vehicle idling can be reduced by using currently available idle control technologies. Auxiliary power units (APUs), Truck Stop Electrification (TSE), Advanced Truck Stop Electrification (ATSE) and Direct-Fire Heaters (DFH) will be the main focus of this analysis, as the leading technologies in idle reduction. Other technologies certified by the U.S. Environmental Protection Agency's (EPA) SmartWay Program include automatic stop-start systems, shore connection systems for locomotives, battery air conditioning systems (BAC), and thermal storage systems (TES). Automatic stop-start systems are mostly comprised of engine software controls that automatically stop and restart the engine as necessary to maintain the engine and cab temperatures within preset limits (Xu et al., 2013). A shore connection system (SCS) allows locomotives to plug into an electrical power source instead of using its diesel engines while at the rail yard. The SCS maintains the coolant temperature and charges all systems without the need for constant idling. A BAC system uses batteries to power an independent electric cooling system. Typically, these systems integrate a fuel-operated heaters to supply heating. EPA has evaluated BACs, but has not found these systems to reduce emissions on long-haul, Class 8 trucks compared to the truck's baseline emissions (Department of the Environment). Thermal Energy Storage is designed to keep the cab or sleeper bunk of a heavy-duty truck cool on hot nights without requiring the idling of the truck's engine or the running of an auxiliary power unit. While direct-fired heaters are light weight and use very little diesel fuel, the addition of air conditioning adds significant weight and requires much more power. The BlueCool product uses a different approach to achieve an effective cooling solution. The core technology is an innovative cold storage cell that is charged during the daytime when the truck is being driven. At night, the truck engine can be switched off, the BlueCool system turned on, with the result that cool air is circulated throughout the truck's interior (Wang et al., 2007). These technologies are recognized by EPA, but are outside of the context of this report.

The purpose of this study is to conduct a systematic review that illustrates the status of data present in literature for costs and emissions reduced for APUs, DFHs, TSEs and ATSEs. From the review process, a cost calculator spreadsheet in Excel was developed and populated with technology cost and effectiveness data derived from a synthesis of the literature to assess the cost-effectiveness of these technologies in units of dollars per year per ton per year of emissions reduced. Using the spreadsheet and relevant data available from various studies that estimate the efficiency of competing technologies, this thesis provides recommendation on specific programs that appear to be the most promising for idle reduction with respect to cost. States and local agencies involved in developing and implementing idling control programs will be able to use the information in this thesis in assessing programs and investments designed to achieve air quality and public health goals. The study will also help freight carriers assess the potential performance and effectiveness of investments in fuel savings and emission reduction technologies.Any deficit of information from this report that is necessary for assessment of future decisions should encourage greater research endeavors to form a robust set of data that would aid in the development of increased idle reduction through sound technology.

Research Approach and Objective

One of the basic goals of this research was to quantify the total emission reductions that can be expected from idle reduction programs to support future administrative decisions from standpoints of environmental planning, human health, and economic cost. To aid in this end, it is necessary to examine: (1) quantifiable data that measure the amount of emissions reductions expected per program for heavy-duty truck idling, (2) the life cycle cost of each technology in net present value, (3) the cost-effectiveness per program measured in dollars per year per ton per year of emissions reduced. The thesis also discusses future research and data collection actviities that will help policymakers better understand the impacts and identify additional solutions that can achieve cost-effective idling emissions reductions.

The first objective of this research is to conduct an extensive literature review of studies that have measured the amount of emissions reduced in idling activity given anti-idling technologies for on-road and off-road use of heavy-duty trucks in the goods movement sectoir. Identifying and acknowledging the risk of biased data, inconsistent literature findings, and the dearth of certain information in the body of literature is a second objective of this research effort. Conclusions and recommendations for further research are based on results of data analysis, and caveated with respect to uncertain elements in the reported analyses. The results of the review is a calculator that predicts the effectiveness of idling technology based on cost and emission reductions for key pollutants that have substantial environmental and health effects. Within the scope of this study, cost-effectiveness is measured for reduced emissions in HC, NOx, VOC (volatile organic compounds), PM, CO and CO_2. However, emphasis is placed on NOx and PM reductions.

Impacts of strengthening idle reduction programs also provide health and welfare benefits. Health problems related to increased emissions from idling engines include an increased risk of cardiac events, nausea, chronic bronchitis, decreased lung function, and in some cases, death. Health concerns caused by NOx in particular are wide-ranging from lung irritation and decreased resistance to respiratory infection, to the formation of acid rain, which disturbs both aquatic and terrestrial ecosystems. The contribution to pollutant haze by NO_2 and airborne nitrates is also very high (Rahman et al., 2013). Another pollutant posing great risk is ambient PM, with health effects such as ischemic heart disease, heart failure, respiratory disease, including chronic obstructivepulmonary disease (COPD) and pneumonia. Short-term elevations in ambient PM have also been associated with increased cough, lower respiratory symptoms, and decreases in lung function. Short-term variations in ambient PM have also been associated with increases in total and cardiorespiratory mortality (Agency, 2004). Additionally, diesel exhaust in general poses health risks. The EPA believes that diesel exhaust is likely carcinogenic, with the associated risk with exposure to exhaust coming from particulate and gaseous components such benzene, formaldehyde, acetaldehyde, acrolein, and 1,3–butadiene, all of which are known or suspected carcinogens (Ris, 2007) . Diesel exhaust can also pose a hazard for lung cancer and pulmonary inflammation. EPA assessed air toxic emissions and their associated risk in a 1999 study, which concluded that diesel exhaust joins the ranks of other national-scale risks to health. Reducing the amount of pollutants and exhaust substances posing health threats is an objective of considering idle reduction technologies as it impacts human welfare (Bailar III et al., 1999).

Existing tools that are used in assessing cost-effectiveness across various technologies include the EPA's Motor Vehicle Emissions Simulator (MOVES), the Argonne National Laboratory's Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) tool, the Congestion Mitigation and Air Quality (CMAQ) Improvement Program Guidance under the Moving Ahead for Progress in the 21st Century Act (MAP-21), and the Fuels and Emission Calculator (FEC), a spreadsheet-based tool developed by Georgia Institute of Technology for Oak Ridge National Laboratory and the Federal Transit Administration (ORNL and Georgia Tech, 2014). While these tools provide data on costs incurred against emissions reductions per technology, this report seeks to explain the criteria of pollutants being studied and the variability of the data currently existing in the body of literature to inform direction in future studies to the effect of calculating cost-effectiveness across various factors.

Information on program lifetimes is provided as reported by literature. Where such information was unavailable, approximate value were calculated, based on supplementary sources. Costs for each program are presented in an annualized format to facilitate comparison across technologies. Emissions reductions for all programs are presented in tons per year to facilitate ease of data review. In some cases, information gathered from the literature has been converted from kilograms or grams per day using appropriate conversion factors and a standard program effectiveness rate of 10 hours per day and 300 days per year. In most cases, reductions are presented as reported in the study; therefore the number of pollutants reported varies from program to program.

Thesis Organization

The thesis is organized as follows: Chapter 2 covers the operational characteristics of heavy-duty trucks, as well as a project overview of idle-reduction strategies being implemented at the local, state, and federal levels. Chapter 3 covers the methodology, approach to devising the cost calculator from life cycle analyses and emissions reductions measurements, and the comparison of metadata with other verifiable emissions programs for cost-effectiveness of technologies. Chapter 4 continues with fuel savings estimations and results, and the baselines scenarios for the cost profiles behavioral and infrastructure-related programs. The results from the calculator is summarized in this chapter as well. Finally, Chapter 5 will conclude with a summary of reduction and cost results, recommendations based on project effectiveness and considerations for further analysis.

CHAPTER 2

HEAVY-DUTY TRUCK OPERATIONS AND IDLE ACTIVITY

Operating Characteristics of Heavy-duty Trucks

A nationwide survey of long-haul truck drivers by researchers at the University of California, Davis, collected data on truck operations and driver behavior. Variables of interest included usage rates for accessories, duration of idling, and engine speed while idling. The study showed that long-haul truck engines idled for an average of 34% of total engine run time, which is approximately 1,700 hours per truck annually. However, approximately 10% of drivers reported idling 10% or less of engine run time, while another 100 reported idling more than 54% of engine run time, varying by season, truck ownership, truck company idling policies and driver experience. The mean annual fuel used during idle was estimated to be 1,600 gallons per year, but the standard deviation was 1,300 gallons per year. An estimated 25% of drivers consumed more than 2,300 gallons of fuel during idle, and 10% of drivers consumed more than 3,400 gallons per year (Nicholas P. Lutsey, 2004). These findings propose that grid connections and APUs have the potential to provide large energy, environmental, and possible economic benefits.

The survey results reveal that average driving and idling time differ greatly and that an average can be deceptive. Some drivers admitted to deliberately underestimating their driving. However, results indicate that an average long-haul truck driver travels about 112,000 mi annually during a 292-day period (Nicholas P. Lutsey, 2004). An average long-haul day includes about 10.4 hours driving, about 5.9 hours idling, and about 3.3 hours with the engine off, based on driver responses. Using responses for driving hours per day and idle hours per day, idling accounted for 34% of total engine run time. Relating to accessory use, the survey showed that climate control is the main motivation for idling throughout the year, with air conditioning being used more frequently than heating. Other reasons included start-up problems, drowning out other noise and reducing engine maintenance.

Engine speed, measured in revolutions per minute (RPM), has a considerable effect on fuel consumption and emissions of heavy-duty trucks at idle. Because drivers can adjust the setting for engine speed, information was requested about the idle speed (engine revolutions per minute) setting and whether and for what reason drivers change that setting. Generally, factory default settings for engines are lower than those that drivers reported, ranging from 600 to 100 rpm (Brodrick, Dwyer, Farshchi, Harris, & Jr., 2011). When respondents were asked the idle speed of their engines, the average response was about 810 rpm, with responses fairly evenly distributed from 600 to 1,200 rpm and small peaks around 650 and 1,000 rpm. On average, these trucks consume about 1,600 gallons per year for idling, though this varies widely, with about 10% of trucks annually consuming more than 3,400 gallons (Nicholas P. Lutsey, 2004).

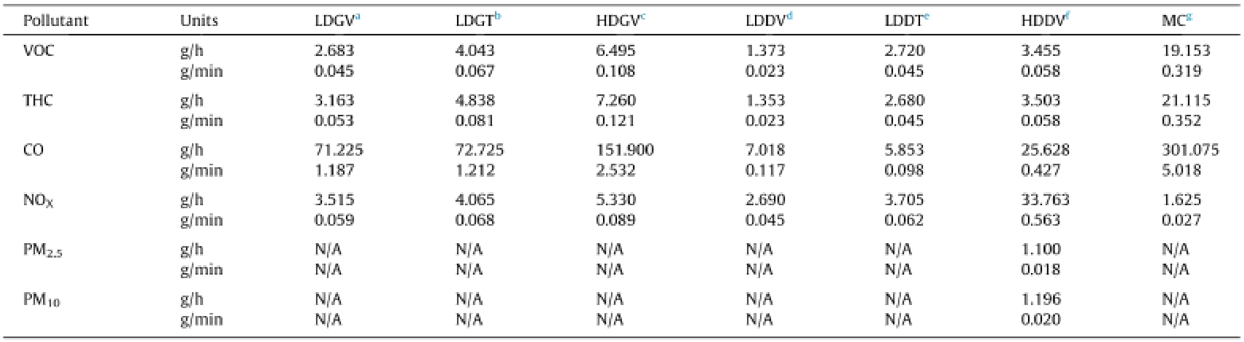
Current Idling Emissions

Diesel-powered vehicles are naturally more fuel efficient in comparison to their gasoline-powered counterparts, given their greater efficiencies in combustion processes and the higher energy density of diesel fuel. Thus, one liter of fuel for a diesel vehicle will yield more mileage than its gasoline equivalent, but will emit more CO_2 at approximately 15% more than gasoline (Shancita et al., 2014). Shutting down and starting up the engine and keeping it at an idling condition generates similar amounts of criteria air contaminant emissions. Hence, literature claims that distinguishing between diesel-powered and gasoline-powered vehicles is deemed unnecessary. In general, diesel-powered vehicles generate greater amounts of particulates and

NOx than their gasoline equivalents, and the potential solution is to turn the engine off to reduce emissions as well as fuel consumption. For each liter of gasoline usage, a vehicle exhausts approximately 2300 grams of CO_2, which is the principal greenhouse gas responsible for climate change. Reduction of CO_2 emissions from heavy-duty vehicles could be achieved by eradicating unnecessary vehicle idling. The reality is that compared with idling at more than 10 seconds, restarting an engine consumes more fuel and produces more CO_2. More practical instructions suggest that 60 seconds is the recommended interval for adjusting factors such as fuel economy, overall emissions and wear and tear of important parts inside the starter and battery. If a vehicle will be stopped for more than 60 second, turning the engine off is an option except while in traffic. A vehicle should also be properly maintained to limit unnecessary idling that wastes fuel and money and produces greenhouse gases contributing to climate change (Taylor, Eng, & Woodlawn, 2003)

On a daily basis, a long-haul truck idling accounts for approximately 13% of the NOX and 3% of the PM from the total emissions of these species (Hawelti et al., 2012). The EPA uses the most modern version of the computer model called MOBILE6.2, which estimates average in-use emissions from highway cars in different geographically distinct areas and over certain time durations. The amounts of hydrocarbons that include both THC and VOCs, CO and NOx emitted from vehicles during idling are given in the tables below.

Table 1 - Rates of idle emissions of pollutant for different vehicle types on average (source: Shancita, et al., 2014).



Pollutant	Units	LDGV[a]	LDGT[b]	HDGV[c]	LDDV[d]	LDDT[e]	HDDV[f]	MC[g]
VOC	g/h	2.683	4.043	6.495	1.373	2.720	3.455	19.153
	g/min	0.045	0.067	0.108	0.023	0.045	0.058	0.319
THC	g/h	3.163	4.838	7.260	1.353	2.680	3.503	21.115
	g/min	0.053	0.081	0.121	0.023	0.045	0.058	0.352
CO	g/h	71.225	72.725	151.900	7.018	5.853	25.628	301.075
	g/min	1.187	1.212	2.532	0.117	0.098	0.427	5.018
NO_X	g/h	3.515	4.065	5.330	2.690	3.705	33.763	1.625
	g/min	0.059	0.068	0.089	0.045	0.062	0.563	0.027
$PM_{2.5}$	g/h	N/A	N/A	N/A	N/A	N/A	1.100	N/A
	g/min	N/A	N/A	N/A	N/A	N/A	0.018	N/A
PM_{10}	g/h	N/A	N/A	N/A	N/A	N/A	1.196	N/A
	g/min	N/A	N/A	N/A	N/A	N/A	0.020	N/A

The MOBILE model also gives the emission rates of PM_{10} and $PM_{2.5}$ for heavy-duty diesel vehicles during idling, but does not include PM emissions for other classes of vehicles. Factors that impact the amount of emission include whether a vehicle is properly maintained, diesel- or gasoline-fueled, or subjected on a hot or cold day. HC and CO emissions can be higher during very hot and cold weather (Shancita et al., 2014).

CHAPTER 3

IDLE CONTROL AND INTERVENTION

Review of Relevant Literature

This section reviews of literature associated with program costs and effectiveness of idle reduction, and provides an analysis of methodologies used in these studies to assess the emisisons reductions from each technology, organized by: 1) infrastructure systems, which includes auxiliary power units, direct-fire heaters, truck stop electrification, and advanced truck stop electrification, and 2) behavioral systems, which includes driver and operator training, driver incentive programs and state and local policy as competing technologies to reduce idling in heavy-duty trucks.

Best practices in idling-reduction strategies are a result of economic analyses that compare trade-offs based of the assumptions that effect lifetime costs. This study surveys various methods used to capture emissions and cost data from these four anti-idling strategies in order to assess the most cost-effective solution.

Infrastructure Systems

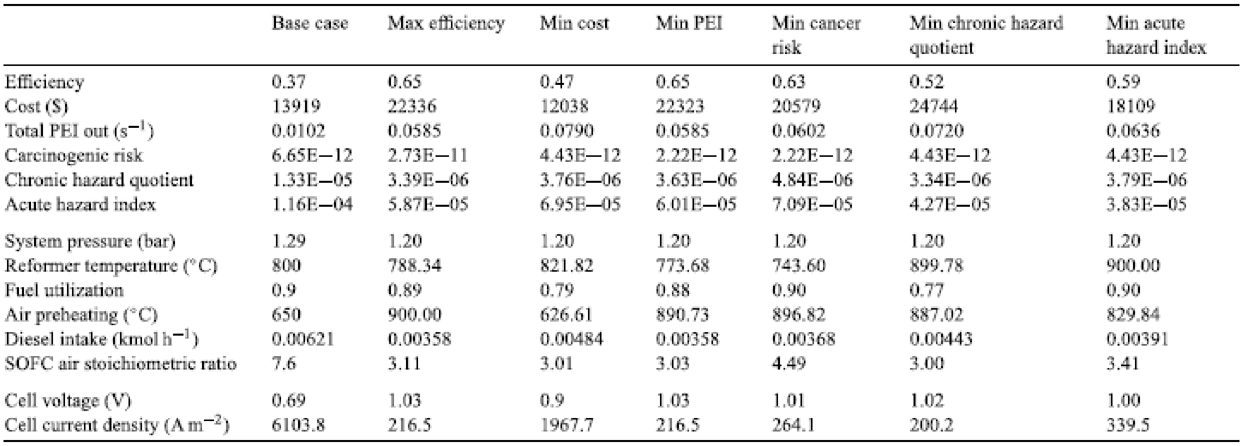
Auxiliary Power Units

Auxiliary Power Units or generator sets are small, diesel-powered engines that are installed on the truck to provide air conditioning, heating and electrical power to run components like lights, on-board equipment and appliances in the truck. APUs are portable and vehicle-mounted systems that can provide power for climate control and electrical devices without idling. These systems largely consist of a small internal combustion engine with a generator and heat-recovery system to run the electricity and heat. For air conditioning, an electrically powered air-conditioning unit is installed in the sleeper, although some systems use the truck's air-conditioning system (Argonne National Laboratory, 2014).

APUs provide all or part of the non-propulsion power for vehicles as a low-emission, low consumption and low-noise alternative that would displace the need for idling. The portable, vehicle-mounted systems can power climate control features and electrical devices in trucks without idling, using a small internal combustion engine with a generator and heat-recovery system that provides electricity and heat. In some systems, electrically powered air-conditioning units are used in lieu of the truck’s air-conditioning system ("Idle Reduction Technologies for Heavy-Duty Vehicles," 2014). Several goals must be achieved in designating and operating fuel cell-based APUs. To be economically viable, cost or profits must be competitive with existing technology. The environmental and human health impacts from the release of chemicals, according to Baratto, in the process must be low, which is a challenge that is answered by quantifying the trade-offs between different objectives (Francesco Baratto, 2005). Simulations were based in the South California Air Basin (SoCAB), an area that requires, as of 2007, the installation of non-adjustable idle reduction systems on all new on-road heavy-duty diesel engines with a gross vehicle weight rating (GVWR) greater than 14,000 pounds, which shows an interest in that region for the idling emissions problem. The study involved a multi-objective optimization of the system, including a sensitivity analysis, payoff table and optimal trade-off surface analysis. These analyses are based on a constraint method to transform the multi-objective optimization problem into a series of single-objective optimization problems with *k* objectives. These *k* single-objective optimization problems were solved using the original constraints of the multi-objective optimization problem to form the basis of the payoff table with the potential range of optimum points for each *k* objective, and the trade-off surfaces were analyzed henceforth (Francesco Baratto, 2005). The objectives in the optimization were based on total cost, efficiency, total output potential environmental impact (PEI), carcinogenic risk, chronic hazard quotient, acute hazard index, and variables of diesel intake, system pressure, reformer temperature, fuel utilization, cathode air stoichiometric ratio, and air preheating temperature (Francesco Baratto, 2005).

Baratto and Diwekar's payoff table contains the values of each of the six objectives at each of the six individual optimal solutions, which shows that designs minimizing PEI and health impacts have very high efficiency and high costs, based on a low manufacturing cost and high operating cost due to higher fuel intake. Thus, the design that minimizes cost has a trade-off in environmental and health impacts. The analysis of the trade-off surfaces shows that high efficiency above 60% can be achieved at any range of cost and with minimum environmental impact. Operating with the objective of low health impacts, whether carcinogenic, chronic or acute can be achieved at low cost but moderate environmental impact and efficiency (Francesco Baratto, 2005).

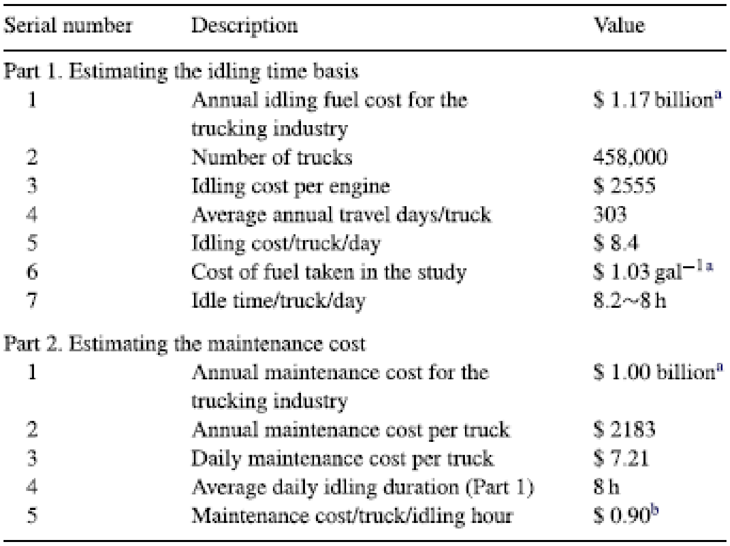
Table 2 - Payoff table (Francesco Baratto, 2005)



	Base case	Max efficiency	Min cost	Min PEI	Min cancer risk	Min chronic hazard quotient	Min acute hazard index
Efficiency	0.37	0.65	0.47	0.65	0.63	0.52	0.59
Cost ($)	13919	22336	12038	22323	20579	24744	18109
Total PEI out (s^{-1})	0.0102	0.0585	0.0790	0.0585	0.0602	0.0720	0.0636
Carcinogenic risk	6.65E−12	2.73E−11	4.43E−12	2.22E−12	2.22E−12	4.43E−12	4.43E−12
Chronic hazard quotient	1.33E−05	3.39E−06	3.76E−06	3.63E−06	4.84E−06	3.34E−06	3.79E−06
Acute hazard index	1.16E−04	5.87E−05	6.95E−05	6.01E−05	7.09E−05	4.27E−05	3.83E−05
System pressure (bar)	1.29	1.20	1.20	1.20	1.20	1.20	1.20
Reformer temperature (°C)	800	788.34	821.82	773.68	743.60	899.78	900.00
Fuel utilization	0.9	0.89	0.79	0.88	0.90	0.77	0.90
Air preheating (°C)	650	900.00	626.61	890.73	896.82	887.02	829.84
Diesel intake (kmol h^{-1})	0.00621	0.00358	0.00484	0.00358	0.00368	0.00443	0.00391
SOFC air stoichiometric ratio	7.6	3.11	3.01	3.03	4.49	3.00	3.41
Cell voltage (V)	0.69	1.03	0.9	1.03	1.01	1.02	1.00
Cell current density (A m^{-2})	6103.8	216.5	1967.7	216.5	264.1	200.2	339.5

Jain, et al. (2006) evaluate the economic viability of fuel cell APU's based on estimated and projected efficiency data, fuel consumption patterns, capital investment and operating costs of APUs to explore the break-even periods as a function of various cost profiles and idling efficiency. The idling rate, according to Argonne National Laboratory estimates, for the 458,000 long-haul trucks in the United States that travel more than 500 miles from a base each day is between 3.3 and 16.5 hours per day, and based on various studies, this idling time is observed to be between 40-50% (Stodolsky, Gaines, & Vyas, 2000). The value selected for idling efficiency is 30%, with respect to long-haul trucks of diesel. The analysis assumed maintenance cost to be linearly proportional to idling time. The table below shows the maintenance cost per truck her hour idled based on data from the Department of Energy and existing literature.

Table 3 - Estimates of maintenance cost per truck per hour idled (Jain, Chen, & Schwank, 2006)



Serial number	Description	Value
Part 1. Estimating the idling time basis		
1	Annual idling fuel cost for the trucking industry	$ 1.17 billion[a]
2	Number of trucks	458,000
3	Idling cost per engine	$ 2555
4	Average annual travel days/truck	303
5	Idling cost/truck/day	$ 8.4
6	Cost of fuel taken in the study	$ 1.03 gal^{-1}[a]
7	Idle time/truck/day	8.2~8 h
Part 2. Estimating the maintenance cost		
1	Annual maintenance cost for the trucking industry	$ 1.00 billion[a]
2	Annual maintenance cost per truck	$ 2183
3	Daily maintenance cost per truck	$ 7.21
4	Average daily idling duration (Part 1)	8 h
5	Maintenance cost/truck/idling hour	$ 0.90[b]

The overall maintenance value is $0.9 per hour given an 8 hour idling day. The economic analysis assumes that a typical APU is 5kW per unit, and that annual idling time in hours is the product of hours idled per day and the number of operation days in a year. The annual fuel consumption in gallons is fuel consumed per one hour and hours of annual idling. The total cost of idling in a diesel engine was based on the sum spent on the fuel used in idling plus the associated maintenance cost. The break-even period in years of a fuel-cell APU was the cost of engine idling when equal to the investment and running cost of a fuel cell (Jain, Chen, & Schwank, 2006). Using these formulas, the break-even period as a function of idling time per day, came to 4.31 years for a diesel-powered fuel-cell APU. To validate these findings, the fuel-cell APU was compared to results of a direct hydrogen fuel cell under identical conditions, which had a break-even period of 3.2 years. The study explored a range of parameters for investment cost, consumption rate and maintenance costs. The investment costs ranged from $100 to $3,000 per kW, diesel fuel ranged from $1.0 to $2.5 per gallon, fuel consumption rates ranged from 0.60 to 2.25 gallons per hour, and idling time was between 3.3 to 16.5 hours a day. At an investment cost of $3000 per kW, break-even is observed only at the extreme higher end of the fuel consumption and idling rates. This means that if the fuel costs $2.00 per gallon, the break-even period makes the cut-off only when fuel consumption exceeds 2.0 gal per hour and idling time is greater than 9 hours a day. On the other side of the range, if the investment rate falls to $100 per kW, all combinations make the 2-year cut-off, and the break-even is well within 1 year for almost the entire range of fuel cost, idling per day, and fuel consumption per idling hour (Jain et al., 2006). The most critical parameter in achieving lower break-even periods is the investment cost. Current investment costs are highly dependent on cost of manufacturing of fuel cells and fuel processors. The study recommends combining the APU application for fuel cells with demand from other small and medium-sized fuel cell market segments to bring down manufacturing costs. The analysis indicates that there are large ranges of operating conditions and fuel costs where APU systems would be economical (Jain et al., 2006).

Analyses on the savings related to reduced engine maintenance and increased engine life was conducted through a life cycle assessment, a “cradle-to-grave” approach to assess the major industrial activities in production, use and disposal of each system. Ginn, Toback Hearne and Marchese compared ACU’s with competing technologies by conducting this LCA included assessing all inputs and outputs of implementing each technology through a life cycle inventory and assessing associated emissions and ecological burdens (Ginn et al., 2004). The LCA methodology gathered data from the Carnegie-Mellon developed Economic Input-Output Life Cycle Analysis (EIOLCA) web software, calculated use emissions through experimental data and Argonne National Labs Greenhouse Gases, Regulated Emissions & Energy use in Transportation Model (GREET model), and estimated the end of life impact. The study compared APUs, DFHs, TSE and ATSE. The recommendation on strategies to be implemented to reduce heavy-duty truck idling was estimated by quantifying the overall ecological burdens from the manufacture and use of each technology, along with ecological impacts and an economic analysis. The assessment assumed the production phase of engine idling based on the amount of diesel fuel required for the functional unit, which was estimated by calculating the amount of fuel consumed over the functional unit at $1.50 per gallon. Based on estimates from the Argonne National Laboratory, truck idling was estimated at 8 hours per day and 300 days a year, which totals 2,400 hours each year. The life cycle assessment (LCA) included all emissions released throughout the functional unit, based on the GREET model from Argonne National Laboratory as a way to compare types of technologies were experimental data was not available (Ginn et al., 2004). The end of life portion of the LCA was assumed negligible, since the end of like of a truck would not be affected by wear of the engine due to idling.

The results from the Ginn, et al. (2004) study are summarized the table below, based on cost inputs for each individual technology. Comparing the four technologies show that APUs have less criteria pollutant emissions from the production and use portions of the LCA than DFH. APUs and ATSEs have comparable levels of CO, VOC and NOx levels, however the ATSE has a significantly higher CO_2 level. The study shows that the DFH results in the most emissions of the four alternatives to idling. This result is due to the assumption that the DFH would be in use for half of the functional unit hours, while the remaining hours would be spent idling. The majority of the SO_2 emissions are a result of the production process of each technology and the required amount of petroleum refining (Ginn et al., 2004).

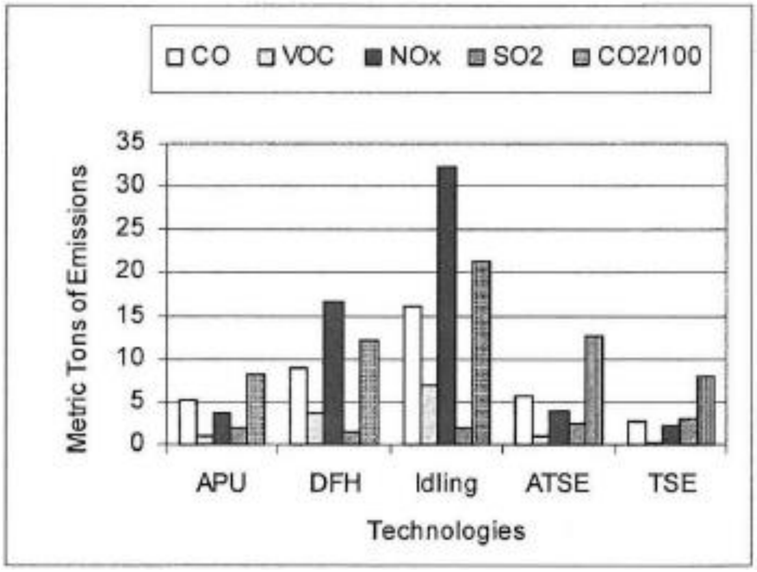


Figure 1- Total criteria pollutant emissions from the production and use portions of the LCA (Ginn et al., 2004)

Ginn, et. al. subsequently conducted economic analyses based on payback period and net present value. Using initial costs including installation, and the maintenance and wear savings associated with using each option, and the savings or profit accumulated, payback period in years was calculated. The results show that each option has a low payback period and all options will pay back the driver in approximately one year. The net present value (NPV) approach took into account the time value of money, considering an interest rate of 5% annually. The NPV was equated to the total cost divided by the 5% interest to the exponent of 3, signifying a 3 year period. Based on the NPV for thirty units versus the fuel price in dollars per gallon, the ATSE was the most economical option for the truck driver when the cost of fuel is above $1.25 per gallon. Above $1.75 per gallon, APUs are most economical. The NPV analysis does not include increases in costs per kWh because the truck owners were assumed to charge a consistent fee per hour of truck use (Ginn et al., 2004).

Based on the economic analyses, $1 .50 per gallon was used in the methodology to generate the relative emissions savings, in kilograms, per cost analysis for each option. The emissions savings were calculated by subtracting the total emissions for each technology for three years from the total emissions from truck idling. The emissions savings were then divided by the NPV for three-years for each option at a fuel cost of $1.50 per gallon (Ginn et al., 2004). The third best option based on savings per dollar would be Pony Pack, based on 30 unit retrofit and a fuel price of $1 .50 per gallon. The study shows that of the four technologies considered, The APU option showed considerable reductions in emissions and costs for the drivers. Since the APU is a more efficient diesel engine for idling, the fuel consumption rate is lower than idling the engine, and the emissions and ecological burdens are lowered as a result. Also, the APU appears to be be the second most economical option, at a fuel price of $1.50 per gallon and above, by evaluating the net present value of each technology. However, the amount of emissions lowered due to the implementation of 30 APUs for three years is less efficient than both ATSE and TSE (Ginn et al., 2004). The figure below illustrates the emissions savings and cost effectiveness of reducing emissions per technology.

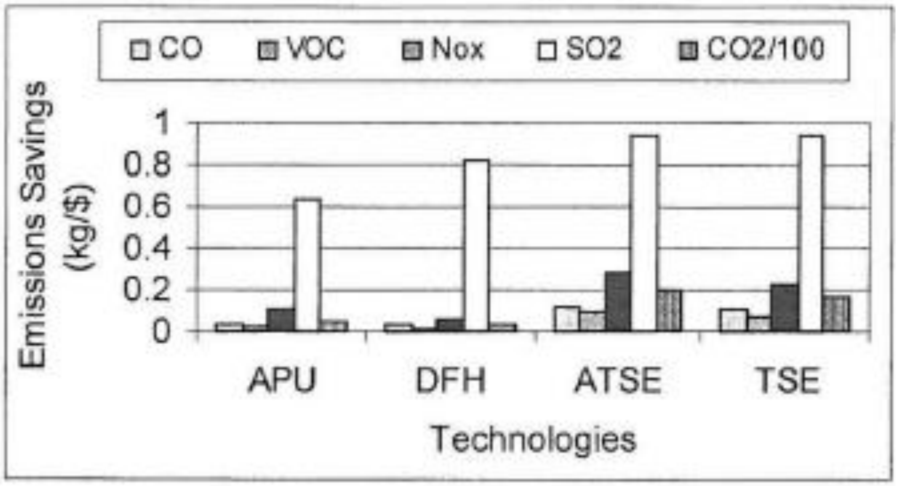


Figure 2 - Emissions savings per dollar in kg/$ based on driver costs (Ginn, Toback, Hearne, & Marchese, 2004)

A similar study was performed at the University of Maryland, in which off the shelf systems are compared in an attempt to discern which is more advantageous in terms of factors such as lifetime cost, lifetime cost per hour, and payback period (Lust, Horton, & Radermacher, 2008). The systems evaluated include TSEs, diesel-powered APUs, battery-powered APUs (BPAPUs) which include fuel-cell APUs, TSE, and fuel-fired heaters. In particular, diesel-powered APUs and BPAPUs were compared because they are the primary competing technologies in terms of complete energy systems. It is assumed that both APUs and BPAPUs are equipped with a conventional air conditioning systems and electric resistance heaters (Lust et al., 2008). A sensitivity analysis was conducted to assess the uncertainty regarding inputs of fuel costs and idling hours. Due to price projection uncertainty, the rise in fuel costs was accounted for using an escalation rate. For comparisons in which the escalation rate was fixed, a baseline of a 10% price increase per year was used based on the approximate average price per gallon increase from 2002 to 2007 (Lust et al., 2008). Annual idling hours were also varied to include the lower and upper average values. The total lifetime cost of all technologies considered was calculated by summing the annual variable costs, which include operating and maintenance costs, and weight and alternator penalties, as applicable, with the total fixed costs, which include capital and component replacement costs. Instead of applying an hourly savings to each idle-reduction technology, the costs are included as a penalty against the baseline case of main engine idling. At very low comparative operating hours, the APUs and BPAPUs have near equal payback periods. The BPAPS is shown to be the least cost option compared with the APU at both 4 and 7 years of ownership. Over the long term, however, the comparative advantage of both technologies becomes more pronounced as compared with the baseline (Lust et al., 2008).

Direct-Fire Heaters

Direct-fired heaters are small, lightweight devices usually installed in the luggage compartment. Direct-fired heaters are used to provide heat to both the cab/sleeper and engine, or just one or the other. Direct-fired heaters are small, inexpensive and consume much less diesel fuel and have a higher heating efficiency than an idling diesel engine. The drawbacks of this technology are its inability to provide cooling and its use of the truck's battery power for operation. Cost of direct-fired heaters range between $1,000 to $3,000 each. According to Argonne National Laboratory, direct-fired heaters are many times more efficient (80%) than engine idling (11-15%), typically running 20-plus hours on a single gallon of diesel, as compared to idled engines burning 1 gallon of fuel per hour (Wang et al., 2007). With only a 0.50 year simple payback period, direct-fired heaters are more economically attractive than APUs, whose simple payback time is 1.83 years. The cost per ton of NOx emission reductions is $5.07 for direct-fired 46 heaters and $9.10 for APUs. It may not be appropriate to compare the two mobile solutions equally, however, because the heaters do not provide cooling, whereas APUs offer cooling in the cab (Wang et al., 2007).

The U.S. EPA initiated a study to quantify long duration idling emissions and fuel consumption rates, based on a two year analysis performed at the U.S. Army's Aberdeen Test Center (ATC). In total, ATC performed 42 tests on nine heavy-duty trucks, two of those trucks were equipped with APUs, and one was equipped with a DFH. All tests were run in a climate controlled chamber (Lim, 2002). EPA's ROVER (Realtime On-road Vehicle Emissions Reporter) and ORNL laboratory emissions instruments were simultaneously used for measuring in-use fuel consumption rates, HC, NOx, CO, CO_2, O_2 and PM emissions directly from a truck's tailpipe. The ROVER program was set up to quantify mass emissions in real time. The results show that HC and CO data presented low level emissions that are typical of diesel engines (Lim, 2002). After about three hours of idling, the NOx emissions reach a steady state condition. Additionally, CO_2 remains at a fairly constant steady state condition throughout an idling test. The idle technologies selected impact the emissions associated with effectiveness, and their potential emission reductions when compared to baseline idling emissions from the test vehicles. The DFH produced 0.21 g/hr of NOx and the test vehicle Caterpillar engine emitted 137 to 197 g/hr, indicating that the DFH provided a 99% reduction in idle NOx emissions (Lim, 2002). Many studies have examined idling for brief periods of time, but the EPA test finally assessed the more realistic long-duration idling periods. Based on the emissions and fuel consumption data generated from the EPA study, the test data showed that on average, a heavy-duty truck could emit 144 g/hr of NOx and 8224 g/hr of CO_2, and could consume about 0.82 gal/hr of diesel fuel. The study purports that the use of idle reduction technologies can reduce fuel consumption and emissions significantly (Lim, 2002).

Similar testing at the ATC climate controlled chamber was conducted by Oak Ridge National Laboratory personnel, who measured CO, HC, NOx, CO_2, O_2, PM, aldehyde and ketone emissions from truck idle exhaust (Storey et al., 2003). Two methods of quantifying PM were employed, that being conventional filters and a Tapered Element Oscillating Microbalance. A partial flow micro-dilution tunnel was used to dilute the sampled exhaust to make the PM and aldehyde measurements. ATC performed 37 tests on five class-8 trucks (model years ranging from 1992 to 2001). One truck was equipped with an APU and another with DFH technology. However, the diesel-fired heater had significantly lower emissions and fuel consumption than the APU, providing fuel savings (and CO_2 reduction) on the order of 60-85%, 50-97% reductions in NOx, CO and HC, and PM reductions of -20% to 95% (Storey et al., 2003).

Researchers from the University of Maryland cite the advantages of using a direct-fired heater include significant increase in heating efficiency over main engine idling, a small electric draw compared with an electric resistance system, compact size, negligible weight, and perhaps most significantly, direct-fired heaters generally exceed all U.S. federal and state emissions restrictions, including California tier III emissions standards (Lust et al., 2008).

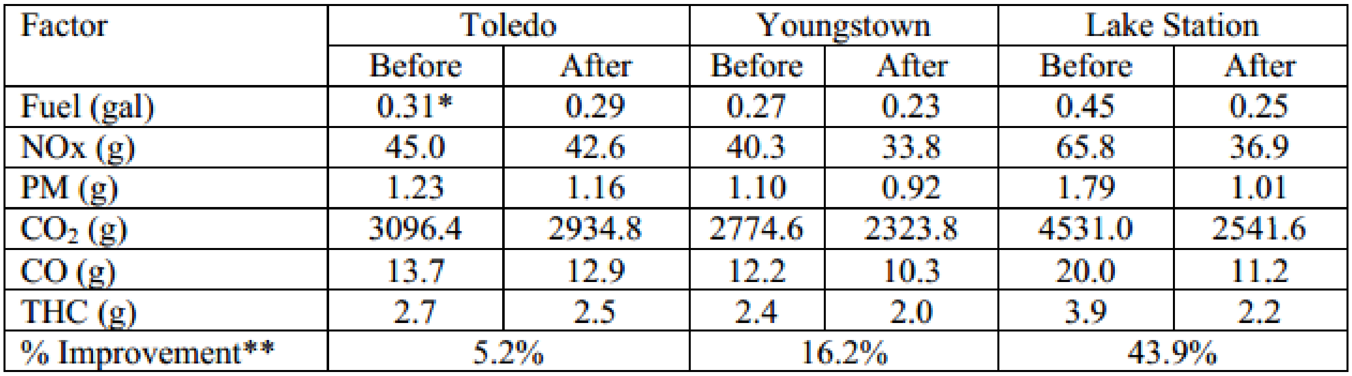
Electrification

Truck Stop Electrification

There are two components within the truck stop electrification (TSE) category of idle technology. Electrification refers to using electricity-powered components to provide the operator with climate control and auxiliary power without having to idle the main engine, which can be on-board equipment, like inverters and plugs, or off-board equipment, like electrified parking spaces or a system that directly provides heating, cooling, etc., or a combination of the two. The first, shore power, takes its name from the process used to supply electricity to mobile users at marinas and recreational vehicle parks. At a truck stop, the driver would run an outdoor extension cord from the electricity source to the truck to power any appliances without idling (Turchetta, 2014). This option requires that the truck's engine be capable of plugging in the electrical connection points (by OEM design or modification). The other option is an off-board system such as an electrified parking space. Within off-board systems, the Advanced Truck Stop Electrification (ATSE) category provides electricity from an external source, but doesn’t require the truck to be equipped with special systems. Truck parking bays are installed with equipment that offers the cab electrical power, heating, cooling, and other amenities through an external console that fits through the truck’s window (U.S. Environmental Protection Agency, 2014b). The TSE system requires no modification to the truck (Turchetta, 2014).

TSE’s qualify under stationary anti-idling technologies, which provide an interface between the truck and electric grid (Boeckenstedt, 2005). It simply provides reliable electrical power in the voltage and alternating current (AC) that household appliances and accessories normally use. Truck stop testing sites were used to gather observed data via survey analysis at the Texas Transportation Institute. The before survey (without TSE installations) was conducted in September, 2006 and the after survey (with TSE installed) in September, 2007 at three site locations (Zietsman, Farzaneh, Schneider IV, Lee, & Bubbosh, 2009). During the 72-hour periods, hourly counts were performed of the number of trucks on the lot, number of trucks idling, number of trucks with their engines off, and the number of trucks that are using the TSE facilities. The results of the TSE technology on the three sites shows a reduction in fuel consumption, greenhouse gases, and pollutant emissions. The percentage improvements range from 5.2% to almost 44%. Table 4 shows the before and after results for the three test sites based on fuel and emissions (Zietsman et al., 2009).

Table 4- Savings due to TSE for fuel consumption and emissions using observed data (Zietsman, Farzaneh, Schneider IV, Lee, & Bubbosh, 2009)



Factor	Toledo		Youngstown		Lake Station	
	Before	After	Before	After	Before	After
Fuel (gal)	0.31*	0.29	0.27	0.23	0.45	0.25
NOx (g)	45.0	42.6	40.3	33.8	65.8	36.9
PM (g)	1.23	1.16	1.10	0.92	1.79	1.01
CO_2 (g)	3096.4	2934.8	2774.6	2323.8	4531.0	2541.6
CO (g)	13.7	12.9	12.2	10.3	20.0	11.2
THC (g)	2.7	2.5	2.4	2.0	3.9	2.2
% Improvement**	5.2%		16.2%		43.9%	

A similar field data study from the University of Tennessee used portable emission monitoring equipment (James A Calcagno, 2005). Sampling data thus obtained were used to generate typical average cold-start and extended-idling emission factors and were used to estimate potential emission reductions associated from using TSEs. Cold-start and long-term duration idling emissions were measured in the field from class 8 heavy-duty diesel trucks. Instruments included gaseous analyzers, which measured exhaust gasses configured for O_2, CO, NO, NO_2 and SO_2 concentrations; particulate matter analyzer which is a portable aerosol device; an exhaust gas flow meter, and miscellaneous equipment (James A Calcagno, 2005). The study showed that large emission reduction benefits are connected to the TSE technology. However, these benefits from TSE will be slightly smaller, because the actual reduction in emissions associated with TSE is calculated by subtracting the initial benefits by the sum of the the cold-start emissions and the emissions that are associated with electricity consumption used in the TSE (James A Calcagno, 2005). Thus, cold-start emissions and emissions that are associated with the production of electricity, which is necessary to provide TSE in place of truck idling, were used to adjust the extended-idling emission factors. In general, it was found that the cold-start emissions and the emissions from electricity were moderately small in compared with the extended-idling emissions. However, with the use of TSE technology, and the shorter amount of idling time between starting the engine and moving the vehicle, the overall benefit would be greater. Otherwise, the longer idling time, the greater the cold-start emissions, which would lower the magnitude of benefit from TSEs (James A Calcagno, 2005).

Based on applying information regarding equipment costs and fuel prices, an analysis was done on the economics of idle reduction techniques based on fuel savings for truckers, for investors and for the public. For truckers, the study estimated cost savings from energy reduction by multiplying net savings and price of the reduction; estimated hourly charges accumulated by the use of stationary anti-idling technology; and calculated the initial, operating, and maintenance costs for mobile anti-idling technologies. Investors, who are responsible for purchasing, installing, operating and maintaining the technology, may secure a return on their investment by charging truckers for a certain service fee as revenue. To estimate this return, a payback period analysis was conducted. For the public, the health benefit of anti-idling technologies was estimated based on the respiratory health costs that the technologies prevent (Wang et al., 2007). The results of this study show that stationary technologies entail large initial capital investments from investors, but off-board TSE, compared with on-board TSEs, which in this study is the IdleAire ATSE system, does not require any upfront financial expenditure by drivers or fleet owners. Over a 15 year period, the payback time is 4.6 years for an on-board TSE system and 6.65 years for the off-board TSE (Wang et al., 2007). The cost-effectiveness was calculated based on dollars spent per ton of NOx emissions reduced only, due to a lack of data on PM emissions from mobile technologies available, and a lack of the economic values of CO_2

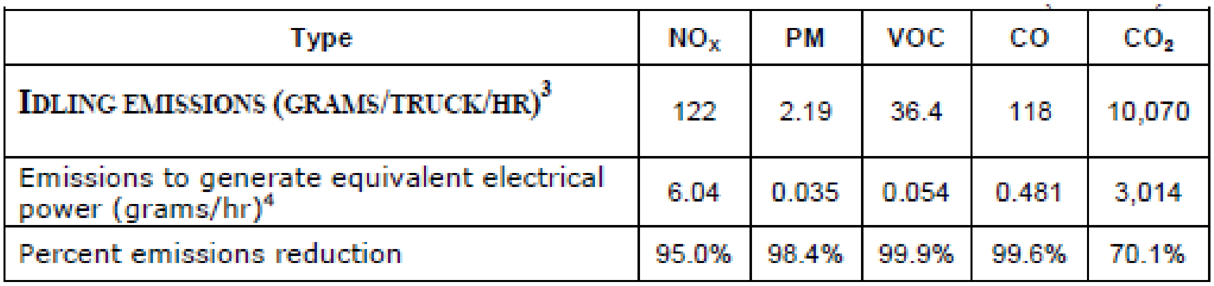
emissions, since CO_2 emissions are not a focus of the EPA's guidance. The cost-effectiveness calculations show that on-board TSE is more cost-effective than off-board TSE (Wang et al., 2007).

Advanced Truck Stop Electrification

The same result was gathered by Boeckenstadt, who conducted a similar reference to payback studies between an off-board TSE and on-board ATSE. Boeckenstadt calculated full-service and shorepower TSE paybacks, based on parking space equipment costs and truck mounted equipment as a total investment, whereas Wang, Byrne and Rickerson estimated separate simple paybacks for investors and for truckers. The full-service, off-board TSEs were based on IdleAire's model, which requires a large site to generate enough revenues to cover the labor cost of the on-site coordinators. The model also depends on the truck stop providing its parking lot for free for a percentage of the total revenue (Wang et al., 2007). The IdleAire product is a stationary structure that is installed at the rest area, which provides each parking space with an external high capacity heating and air conditioning unit. A flexible duct from the main unit connects to the truck via a window-mounted module, which also provides outlets for appliances. Outside on the module, separate electric receptacles provide external service to power refrigeration units. Other amenities, such as telephone, television and Internet access can be provided to the cab via the mounted service module (James A. Calcagno, 2004). The on-board shorepower model is based on Shurepower, a brand that provides reliable electrical power in the voltage and alternating current is common with household appliances. Once a driver plugs in, the electricity can be used to power a wide range of onboard devices, components and equipment. The system comes with a 120-volt wiring in the sleeper, a 12-to-120-volt inverter and an extension cord (Boeckenstedt, 2005). Between the IdleAire full-service TSE and the Shurepower shorepower TSE, the latter has the smaller payback period of 3.4 years, and a higher net annual savings of $2,640, which is $900 more than the IdleAire system. However, between the two TSE technologies and APUs, APUs appear to have the shortest rate of payback at 2.3 years when taking costs into consideration. Boeckenstadt claims that because APUs require a less-fixed capital requirement, they may progress toward lower costs at a faster rate (Boeckenstedt, 2005).

Furthermore, the IdleAire technology was assessed by the Northeast States for Coordinated Air Use Management (NESCAUM) in a study aimed to quantify a projected range of environmental benefits. The study used data from a 2002 analysis performed by EPA for heavy-duty diesel emissions factors at Aberdeen Proving Grounds in 2002 and data from EPA's MOBILE6 model (Goldstein, 2003). Transactional data came from web cameras monitoring in the idling location at Syracuse-DeWitt in real time, which revealed a comparative analysis of emissions from heavy-duty diesel engines that are idling with the emissions from power plants generating equivalent electrical power. Table 5 shows results from the real time analysis, which support IdleAire's premise that fossil fuels can be transformed into useable energy in a cleaner and more efficient manor by commercial power plants than by idling diesel combustion engines (Goldstein, 2003).

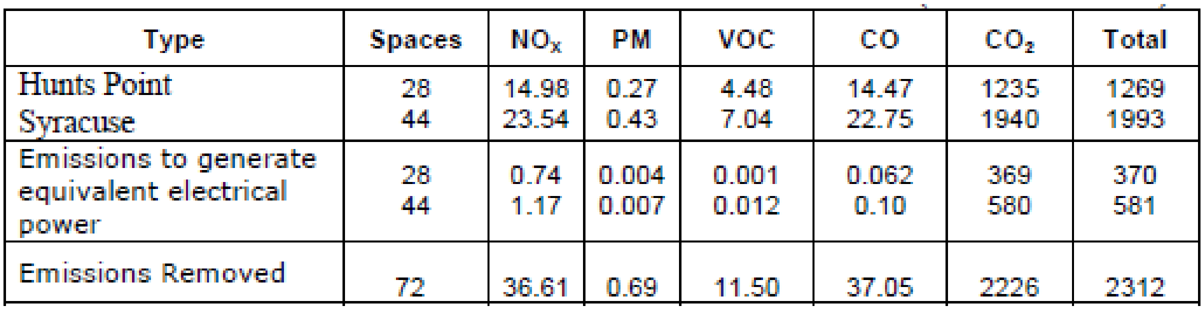
Table 5 - Emissions reductions avhievable by ATSE (Goldstein, 2003)



Type	NO_x	PM	VOC	CO	CO_2
IDLING EMISSIONS (GRAMS/TRUCK/HR)[3]	122	2.19	36.4	118	10,070
Emissions to generate equivalent electrical power (grams/hr)[4]	6.04	0.035	0.054	0.481	3,014
Percent emissions reduction	95.0%	98.4%	99.9%	99.6%	70.1%

The findings from these data are consistent with the estimation of emissions reductions theoretically obtained by the truck spaces operating in Syracuse and a second location in Hunts Point using IdleAire technology at 50% utilization annually, at 12 hours per day on average. These results are in Table 6.

Table 6 - Estimated electrification emissions reductions (metric tons per year) (Goldstein, 2003)



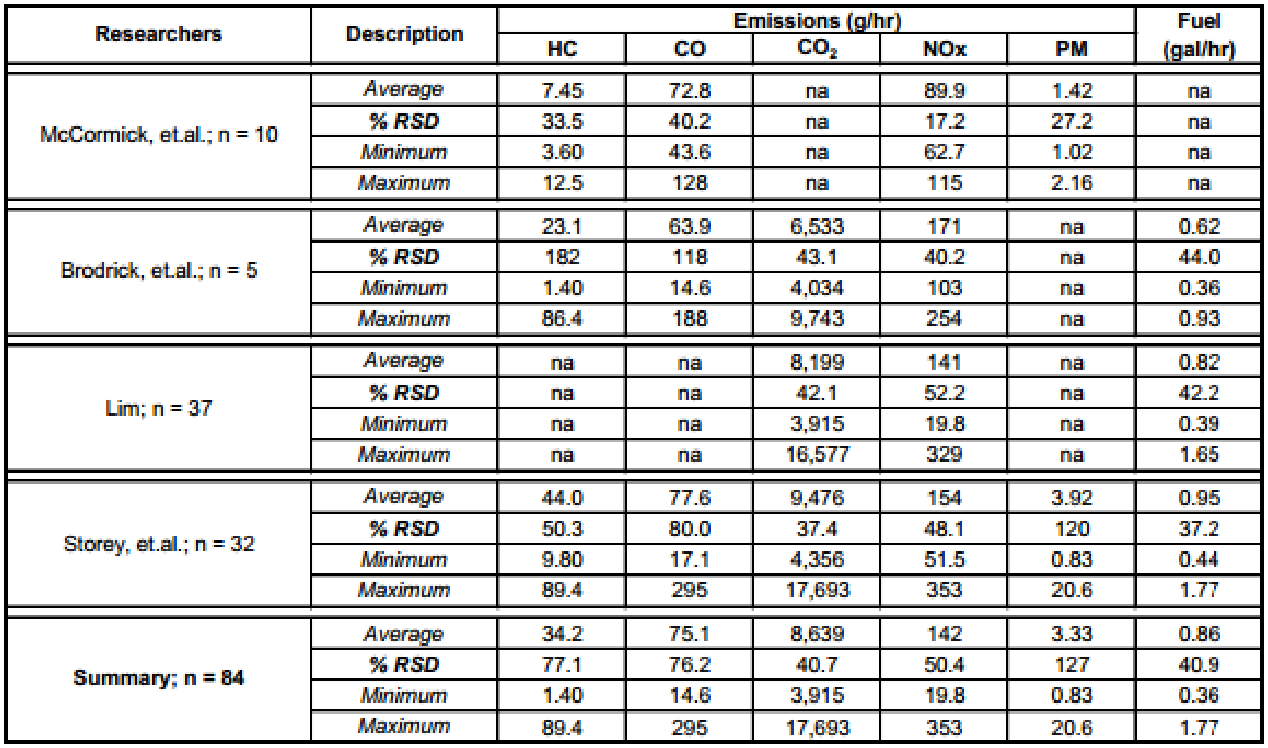
Type	Spaces	NO_x	PM	VOC	CO	CO_2	Total
Hunts Point	28	14.98	0.27	4.48	14.47	1235	1269
Syracuse	44	23.54	0.43	7.04	22.75	1940	1993
Emissions to generate equivalent electrical power	28	0.74	0.004	0.001	0.062	369	370
	44	1.17	0.007	0.012	0.10	580	581
Emissions Removed	72	36.61	0.69	11.50	37.05	2226	2312

From an environmental benefits perspective, the Syracuse and Hunts Point emissions reduction projections can be extrapolated to assess potential regional benefits, which estimated by calculating the net emissions reductions from the installation of an IdleAire system within an area of greatest truck stop cluster within an I-95 member state. These clusters were identified by NESCAUM through a mapping exercise for the I-95 corridor, to map approximately 200 truck stop locations by GPS coordinates within a legend that also identified 2000 Census population density, 1 hour and 8 hour Ozone attainment status and utility jurisdiction (Goldstein, 2003). Benefits are predicted to accrue over a 10 year lifetime, starting at a 50% system utilization rate (12 hours/day) and subsequently until full utilization is achieved in year (Goldstein, 2003).

Predictions of IdleAire's potential to reduce emissions was similar extrapolated in a report from the University of Tennessee, Knoxville, which evaluated the current literature with respect to exhaust emissions from heavy-duty diesel vehicles at low speeds, idling and cold-start engine conditions to gather an estimate for the potential benefit of IdleAire technology (James A.

Calcagno, 2004). The estimates include approximate magnitude of idling emissions for HC, CO, CO_2, NOx and PM. The diesel fuel consumption rates during idling were also estimated. The summary of results are extracted from a literature review of six sources, all of which measured idling emissions rates using instrumentation, such as a full exhaust-flow dilution tunnel, dynamometer tests, portable emissions tests, emissions measurement trailer, climate controlled chamber and the EPA ROVER (James A. Calcagno, 2004). Table 7 summarizes the literature.

Table 7 - Summary of Long-duration emissions and fuel consumption rates (Calcagno, 2004)



Researchers	**Description**	**Emissions (g/hr)**					**Fuel**
		HC	**CO**	**CO_2**	**NOx**	**PM**	**(gal/hr)**
McCormick, et.al.; n = 10	*Average*	7.45	72.8	na	89.9	1.42	na
	% RSD	33.5	40.2	na	17.2	27.2	na
	Minimum	3.60	43.6	na	62.7	1.02	na
	Maximum	12.5	128	na	115	2.16	na
Brodrick, et.al.; n = 5	*Average*	23.1	63.9	6,533	171	na	0.62
	% RSD	182	118	43.1	40.2	na	44.0
	Minimum	1.40	14.6	4,034	103	na	0.36
	Maximum	86.4	188	9,743	254	na	0.93
Lim; n = 37	*Average*	na	na	8,199	141	na	0.82
	% RSD	na	na	42.1	52.2	na	42.2
	Minimum	na	na	3,915	19.8	na	0.39
	Maximum	na	na	16,577	329	na	1.65
Storey, et.al.; n = 32	*Average*	44.0	77.6	9,476	154	3.92	0.95
	% RSD	50.3	80.0	37.4	48.1	120	37.2
	Minimum	9.80	17.1	4,356	51.5	0.83	0.44
	Maximum	89.4	295	17,693	353	20.6	1.77
Summary; n = 84	*Average*	34.2	75.1	8,639	142	3.33	0.86
	% RSD	77.1	76.2	40.7	50.4	127	40.9
	Minimum	1.40	14.6	3,915	19.8	0.83	0.36
	Maximum	89.4	295	17,693	353	20.6	1.77

The results were grouped together by vehicle testing program from these studies being characteristic of long-duration idling periods common to roadside resting areas. Values for the emissions and fuel rates were calculated from the results of these four research papers. To demonstrate the full range of emission rates that are possible at various speeds, the MOBILE6 model was used to generate emission rates at 5, 10, 20, 40, 50 and 60 mph for the heavy-duty diesel trucks using the original default scenario parameters. The results show that there may be significant differences between short-term and long-term duration idling emissions factors. The truck testing data also indicate that there is variability between individual vehicles tested at different engine rpm and accessory load conditions. Still by using alternative technologies such as ATSEs, which eliminate the need to idle the engine, it will be possible to reduce portions of regional emissions (James A. Calcagno, 2004).

Behavioral Systems

Reducing idling requires driver education, leading to behavior change, stricter enforcement of existing state and local anti-idling laws, in addition to wider adoption of technologies that reduce the need to idle. To advise behavior that is fuel efficient and safe for the driver, various initiatives to train drivers and reward efficient driving behavior. The skill with which a driver controls a vehicle, the frequency of idling and average vehicle speed all play a role in how efficiently a vehicle is operated ("The Role of Truck Drivers in Sustainability," 2014).

Research shows the impact of vehicles operating at consistent speeds to improve fuel efficiency. An analysis performed by the American Transportation Research Institute (ATRI) evaluated the potential fuel consumption and emissions impacts of operating a vehicle on two roughly parallel routes of approximately 70 miles in Maine (Tunnell, 2011) . One route was a state highway that had several signalized intersections. The second route was an Interstate highway that had no stop lights, but was approximately 5 miles longer. Despite the longer travel distance of the second route, total fuel consumption was found to be an average of 1 to 2 gallons less compared to the state highway route. These findings support the importance of maintaining a consistent speed to improve fuel efficiency. Driving in a manner to reduce fuel consumption and emissions is commonly known as "Ecodriving."

Understanding driver motives and routines is needed in developing proper training of driver behavior to reduce idling. Researchers at the Center for Energy and Environmental Policy at the University of Delaware conducted personal interviews with drivers at area truck stops and rest stops and identified some common themes that are important to consider when implementing state idle-reduction policies. The anecdotes and insights provided by the drivers in informal interviews were highly informative of the issues around and reasons for idling. Key lessons from the interview included the following (Wang et al., 2007):

- Company fleets are often installing electronic onboard computers that measure idling time, and these devices act as a disincentive for fleet drivers to idle
- Big trucking firms have incentive programs in place for drivers who do not idle. After a trip, drivers can receive a bonus based on a formula that analyzes the amount of fuel consumed to the number of miles traveled
- Many drivers insist that it takes 15 minutes for the engine to warm up in colder weather and, therefore, a five-minute maximum limit on idling is not reasonable. Start-up in cold weather is particularly damaging to the engine or its related components like turbochargers, according to drivers.
- To reduce loneliness while on the road, drivers may house pets in their truck cabs. Occasionally, fleet owners will encourage pets as a means of improving driver retention and to boost morale. Depending on the animal, pets may be more sensitive than humans to temperature and humidity conditions and may be at risk without adequate climate

control. Therefore, animal care is a vital factor in considering conditions alongside human concerns.

According to the nationwide survey conducted by the University of California at Davis, the top three reasons truck drivers idle their engines are climate control (heat and A/C), powering accessories (cooler, TV, etc) and protecting the engine during cold weather. The figure below shows the results from the survey of why drivers idle their engines. The surprising result from the UC Davis survey is that 9% of drivers said that idling their engine was useful for drowning out other noises so that they could sleep better, which indicates that “noise pollution” is an additional externality that is not commonly perceived by truckers as a problem associated with idling (Nicholas P. Lutsey, 2004).

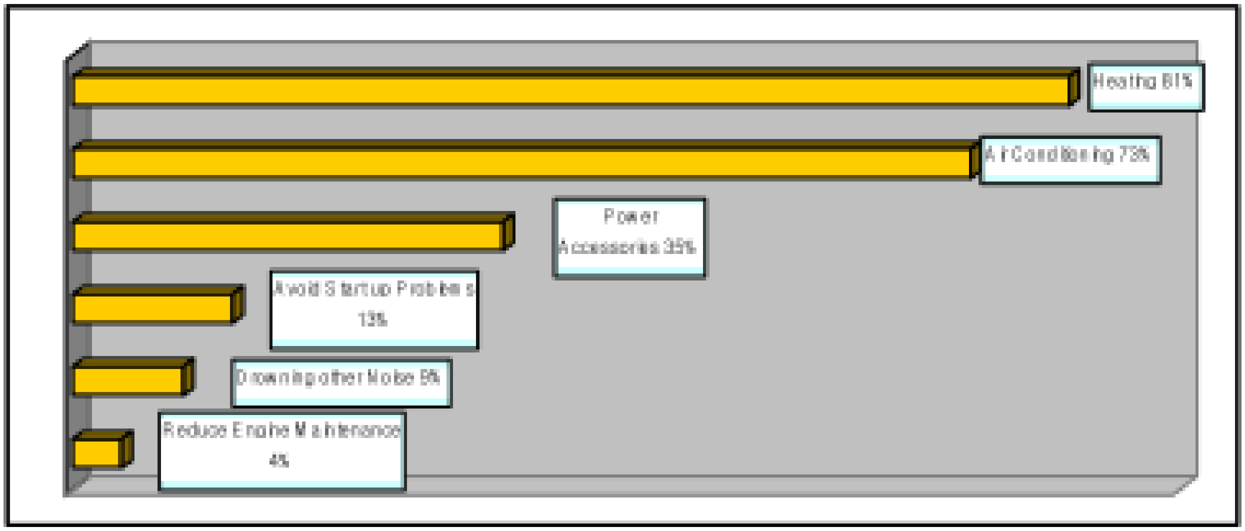
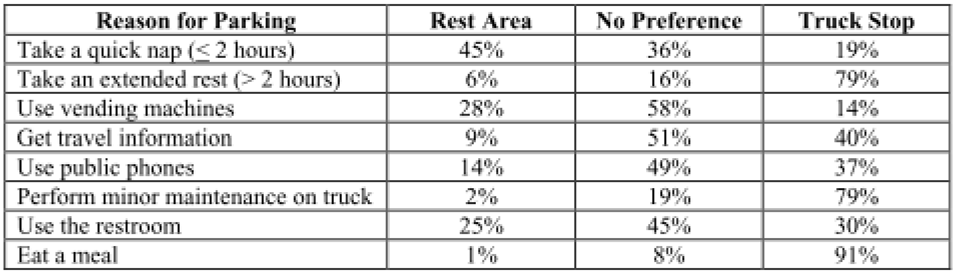


Figure 3 - Why Engines Idle according to Nationwide Survey (Source: Nicholas P. Lutsey, 2004)

Additionally, data have been gathered to indicate drivers’ preferences for choice of parking depending on objective or activity. Compared to rest areas, truck stops are preferred sites for meeting the need for most truck drivers: extended rest; travel information; public phone; minor maintenance; and meal (Fleger et al., 2002). The table below summarizes the parking facility preferences by drivers based on purpose of stop.

Table 8 - Drivers' Parking Facility Preferences by Purpose of Stop (Source: Fleger et al., 2002)



Reason for Parking	Rest Area	No Preference	Truck Stop
Take a quick nap (≤ 2 hours)	45%	36%	19%
Take an extended rest (> 2 hours)	6%	16%	79%
Use vending machines	28%	58%	14%
Get travel information	9%	51%	40%
Use public phones	14%	49%	37%
Perform minor maintenance on truck	2%	19%	79%
Use the restroom	25%	45%	30%
Eat a meal	1%	8%	91%

Results show that drivers stopping for a quick nap for two hours or less have a slight preference for parking at a public rest area, and drivers stopping for an extended rest for more than two hours strongly prefer a commercial truck stop or travel plaza to a public rest area. These preferences may help inform future policy decisions on training and incentive programs tailored to drivers.

Driver and Operator Training

Training that targets fuel efficiency can help drivers recognize and change driving habits that waste fuel. For example, driving 65 mph instead of 55 mph can use up to 20 percent more fuel due to increased wind resistance. Idling a typical heavy-duty engine burns about 0.8 to 1.0 gallons of fuel per hour, and driving with the engine rpm too high can waste several gallons of fuel each hour (U.S. Environmental Protection Agency, 2014b). Common habits that reduce fuel economy are frequent or improper shifting, too rapid acceleration, too-frequent stops and starts from failing to anticipate traffic flow, and taking circuitous routes. A few simple changes in driving techniques can produce sizable fuel savings of 5 percent or more ("The Role of Truck Drivers in Sustainability," 2014). A study for the European Commission estimates that an annual one-day driver-training course will improve truck fuel efficiency by 5 percent. To develop the skills necessary for improving vehicle fuel efficiency, fleets may opt to use a variety of training techniques including classroom, online, in-cab and/or driving simulator-based programs. For example, Schneider National conducted a study on its own fleet (12,000 drivers) and concluded that safer drivers obtain better their fuel economy ("Safer Drivers Have Better MPG," 2012). Schneider offers a variety of training options to their drivers such as online and in-cab training, driver management systems, driver monitoring and in-person coaching. For online training, Schneider National has enrolled their drivers in a fuel management course which offers training on a variety of skills and techniques such as idling, progressive shifting and situational driving.

Natural Resources Canada's program FleetSmart, launched in 1999, helps commercial and municipal fleets reduce fuel consumption and engine emissions through improved energy efficient practices and educational opportunities. FleetSmart's conducts a free professional driver training called SmartDriver for Highway Trucking (SDHT), an effective fleet energy-management training that helps drivers improve fuel efficiency by up to 35 percent ("SmartDriver Training," 2015). The course focuses on energy management factors within driver control, such as idling, start/stop techniques, progressive shifting, trip planning and maintenance. The program involves a combination of skills and attitudes, such as reading traffic conditions, avoiding traffic congestion, maintaining safe following distance, driving within the speed limit and staying calm and alert. The added benefit is that bus drivers can help prevent accidents in spite of the actions of others. The SDHT training goes beyond a one-day course to promote changing driving habits and one's physical and mental state. Those who complete the training with a score of at least 80 percent are rewarded a certificate of achievement (Jenkins, 2008). Additionally, FleetSmart provides the Fuel Management 101 one-day workshop to help fleet managers develop and implement effective fuel management plans, and a web-based training for trucking professionals to have instant access to course content on the internet. According to a telephone survey conducted across Canada with 503 FleetSmart membersand 501 non-FleetSmart members in 2007, 85 percent of participants considered the SDHT training to be useful. Although the program does not meet everyone's needs, 43 percent of participants indicate that it meets all or most of their needs. Importantly, the materials are both easy to understand and access as well as being something that members look forward to receiving as deemed by the survey (Jenkins, 2008).

Strayer and Drews studied the fuel efficiency of drivers before and after simulator training that focused on optimizing shifting practices and techniques. The researchers found that after a two-hour training course, study participants were able to increase fuel economy by an average of 2.8 percent. Using this average, if a vehicle consumes $75,000 of diesel annually under normal operating conditions, this two-hour training course could result in a $2,100 savings per year per driver (Strayer & Drews, 2003).

Research sponsored by the Federal Motor Carrier Safety Administration (FMCSA) reported that driving simulators typically cost $125,000 to $290,000, depending on the model and vehicle configuration used (Morgan et al., 2011). Based on this initial equipment price and factoring in a service life of 15 years and typical maintenance, the price of simulator training can therefore range between $3.37 and $5.07 per student per hour. It should be noted however, that there are industry vendors that offer mobile simulator classrooms, which can reduce simulator training costs. According to the EPA SmartWay program, fleets that improve fuel economy by at least 5 percent through driver training and monitoring programs can save more than $3,000 per truck each year in fuel costs and eliminate 8 metric tons of carbon dioxide emissions per truck each year. For a typical long-haul truck, the initial cost of training and the purchase of related equipment such as an electronic engine monitor and recorder could be recouped within two years from fuel cost savings. Trucking companies can realize even greater fuel and maintenance savings by training drivers to limit truck idling and highway speed (U.S. Environmental Protection Agency, 2014b).

Driver Incentive Programs

Trucking companies may offer fuel bonus programs to drivers, which incentivizes fuel conservation. Such programs typically pay drivers on a per mile basis if a certain fuel economy is reached over the course of a month. For example, Nussbaum Transportation deployed technology to measure and collect driver data metrics related to fuel efficiency, which are then used to calculate a driver fuel scorecard (Huff, 2013). They first created a driver safety scorecard and soon after added a fuel scorecard. The safety scorecard begins with a points balance for accident-free driving, accident-free working, and ticket-free driving. Drivers lose points when events occur in each category. Its fuel scorecard measures fuel-efficient driving, low idle, and fuel purchase compliance and is used to assess whether a driver has exceeded the fleet's mpg goal which then assigns a driver one point for every 0.01 mpg exceeded. Drivers are then presented with monetary awards based on the number of points they have accumulated and according to a predefined three-tier bonus system: Bronze in which drivers receive $0.50 for every point earned, Silver in which drivers receive $5.00 for every point earned, and Gold where drivers receive $8.00 for every point earned. As an alternative to the three-tier system, Nussbaum Transportation awards drivers up to $0.05 per mile for every point earned. Results have shown that drivers have raised their miles per gallon by one whole number just by lowering travel rate, which is another key factor in improving fuel efficiency (Huff, 2013).

Aside from monetary awards, public recognition opportunities may create a compelling value proposition to change behavior to adopt environmentally friendly driving practices to achieve program goals. Companies can implement green freight programs that leverage positive media coverage, which praises participants for committing to or reaching goals, logo usage to build value to the program via brand representation, and awards that serve as a platform for showcasing achievers (U.S. Environmental Protection Agency, 2014a).

Monitoring Technology

A growing number of fleets are turning to telematics such as vehicle recorders or global positioning systems (GPS) tracking units as a tool for managing vehicles more effectively, controlling fleet costs and improving productivity. Monitoring vehicles can improve driver safety by providing speeding alerts that notify real time speeding incidents, based on criteria such as speed thresholds, time of day, and type of vehicle. Remotely monitoring engine diagnostics can help cut down on unnecessary idling and lower fuel usage (Verizon Network Fleet, 2014). Verizon has targeted a 3-percent reduction in the 53 million gallons of fuel used by the company's vehicles by using a combination of GPS tracking, which was installed in about 25 percent of company trucks, and employee education efforts to curb unnecessary engine idling(Verizon Network Fleet, 2014). GPS monitoring can also help plan the smartest routes in order to decrease mileage. By making modifications to each driver’s route, you can improve fuel efficiency and overall driver performance and diminish vehicle deterioration.

Telematic monitoring devices are being implemented not only by private fleets, but also in the public sector. The state of South Carolina is spending approximately $4 million for GPS units to track the state's Department of Transportation road construction vehicles and on all state-operated school buses. Beyond tracking vehicles, these GPS units will transmit data when drivers speed, idle excessively and accelerate rapidly. The goal is to modify this driver behavior. Due to the size of the South Carolina fleet, if the GPS devices can successfully reduce fuel use by just a few gallons of gas per vehicle per day, they'll pay for themselves within a year (Antich, 2008).

The efficacy of these tools has been proven effective based on case studies. Utility subcontractor K-Line Maintenance and Construction, Ltd. utilizes a telematics program by GEOTAB. The company installed the system in 2004 and recently upgraded it. The program is used daily for vehicle positioning and dispatch. The Senior Vice President of Operations, Jim Kellet, claimed that the use of the telematics program has reduced idling with a substantial reduction in engine hours, reducing both fuel and maintenance costs (Fletcher & Lauron, 2009). Furthermore, Piedmont Landscape Contractors LLC, located in Chamblee, Ga. uses two GPS providers for its fleet aimed at reducing fuel costs and idling time. Overall monthly service charges from both average about $30 per truck. According to the fleet manager, the service is cost-effective in controlling excessive idling, as the data provides location, speed, idle time and mileage (Fletcher & Lauron, 2009).

Federal, State, and Local Policies

The extended federally regulated rest period required by drivers increases the pressure on them to park and idle with few other alternatives to comply with the law. Therefore, anti-idling policy has been established by individual states and municipalities around the country, with support coming from a variety of federal and industry sources.

The 111th session of Congress introduced two bills to promote idle reduction through financial incentives. Senate Bill S.855 establish an Energy Assistance fund to guarantee low-interest loans for idle reduction equipment and advanced insulation for heavy trucks, and the Senate Bill S.1098, the EnergySmart Transport Corridors Act of 2009, amends the EPAct 2005 to authorize appropriations through FY 2015 for the Idle Reduction and Energy Conservation Deployment Program (Gaines & Levinson, 2009b). Other financial incentives include issuing tax credits at the national level for buying equipment. The Economic Energy Improvement and Extension Act of 2008 provides for incentives to purchase idle reduction units, eliminating the 12% heavy-vehicle excise tax on the cost of qualified IR units. The EPA has taken the lead in federal anti-idling efforts through several initiatives focusing on technology, economic incentives, and outreach and education. Administered by EPA, The National Clean Diesel Emissions Reduction Program, created under Title VII, Subtitle G, Sections 791–797 of EPAct 2005, authorizes funding for projects, including idle reduction initiatives, that improve air quality and protect public health. In addition to regular appropriations, H.R.1, the American Recovery and Reinvestment Act (ARRA), provided an infusion of funds to these programs. The national program includes the SmartWay Clean Diesel Finance Program, which allows the EPA to issue competitive grants to establish low-cost loans or other financing programs that help fleet owners achieve reduced emissions. The financing reduces the costs for buyers by providing lower interest rates, longer repayment terms, greater likelihood of loan approval, or other financial incentives to use idle reduction technologies (Gaines & Levinson, 2009b). Additionally, EPA’s sulfur emissions reduction efforts may have some bearing on anti-idling equipment and technologies. Under the 2007 Heavy-Duty Highway Final Rule, trucks from 2007 onward must reduce sulfur emissions from 500 to 15 ppm, or roughly 97%. This cut in sulfur emissions is a pre-condition for the effective use of other emissions reduction technologies such as diesel particulates filters (DPF) and oxidation catalysts (U. S. Environmental Protection Agency, 2007b). The EPA's Office of Transportation and Air Quality also has a robust Voluntary Diesel Retrofit Program to this effect. This program is intended to improve air quality from the existing fleet of diesel vehicles while new fleets of vehicles and fuels with better emissions performance are phased in gradually (U. S. Environmental Protection Agency, 2006).

On the state level, 31 states restrict the amount of time that a vehicle's main engine can be idle. The American Transportation Research Institute (ATRI) has a complete list of state and local laws on truck idling (American Transportation Research, 2015). Two main approaches have been developed to address the problem of mobile source emissions include a command-and-control regulatory system and emissions credit trading. Three broad types of emissions credit trading programs have emerged: reduction credit, averaging, and cap-and-trade programs (U.S. Environmental Protection Agency Office of Public Affairs, 2015). In such programs, a central authority, such as an air pollution control district or a state air pollution control agency, sets limits or "caps" on certain pollutants. Companies or fleets of vehicles that intend to exceed these limits may buy emission reduction credits (ERCs) from entities that are able to remain below the designated limits.

To implement an emissions offset program, many states have established regulations allowing sources to register their ERCs that can be sold to companies required to offset emissions from new or modified sources. All commonly accepted ERCs in the United States must meet each of four criteria before they can be certified as an ERC. Namely, the emission reduction must be permanent over the period of credit generation, quantifiable, enforceable, and be surplus to emission reductions that are already being relied upon to comply with an existing local, state of Federal requirements (State of Ohio Environmental Protection Agency, 2009). These criteria are intended to ensure that the emission reductions are real and permanent reductions in emissions compared to what would be otherwise allowed from the new or expanding source.

Many regional air quality agencies around the United States have already begun to regulate idling by enforcing state-wide or local limits (Levinson, 2003). According to lists maintained by the EPA and the American Transportation Research Institute, 19 states plus the District of Columbia have enforced some form of anti-idling regulation at the state or municipal level. Most of these state policies require a maximum idling time between two and fifteen minutes across the state or in specific zones, and a monetary fine of less than $1,000 for first time offenders. Many of these policies also stipulate a set of exemptions for various circumstances including traffic congestion and maintenance, and specific vehicles for emergency or snow removal, for example (Wang et al., 2007). Cities including Boston and New York City have active enforcement laws. In 2009, New York City Council strengthened the current three minute idling limit law codified in the Administrative Code Section 24-163 by reducing allowable idling time to one minute adjacent to schools, with fines ranging from $220 to $2,000 with the maximum fine for third-time offenders (Burgess, Peffers, & Silverman, 2009).

California, through the California EPA's Air Resources Board (CARB or ARB), is aggressively addressing heavy-duty diesel emissions on long haul trucks through some of the most rigorous regulations in the country. CARB‘s activities are extensive and have resulted in important developments as summarized below:

- In July 2004, California adopted the Airborne Toxic Control Measure to Limit Diesel-Fueled Commercial Motor Vehicle Idling, which prohibits drivers of diesel-fueled commercial motor vehicles with gross vehicular weight ratings of greater than 10,000 pounds from idling the vehicle's primary diesel engine for more than 5 minutes anywhere in California. A year later, California included heavy- duty diesel trucks with sleeper cabs within this law. The same ruling mandated that all long haul trucks manufactured from 2008 onward have a non-programmable automatic engine shutdown system for trucks idled more than five minutes (Wang et al., 2007).

- CARB had the legislature pass a new law effective February 2005, that also prohibits the operation of external, diesel-fueled auxiliary power systems near restricted zones. The CARB will ban most diesel auxiliary generators from 2008 unless they are certified as emissions free because the rules for diesel engines will apply to auxiliary diesel generators equally (CARB 2005).

CHAPTER 4

COST EFFECTIVENESS EVALUATION

Methodology

This chapter outlines the criteria for selecting case studies from literature from which to include data points to devise the cost and emissions calculator, and the process to organize the data given to evaluate cost-effectiveness for each technology. In evaluating technologies and their effectiveness to reduce emissions from anti-idling mechanisms, data were gathered from case studies which used properly quantifiable emissions reductions as espoused by accepted ERCs. Emission reductions are considered quantifiable if the amount, rate and characteristics of the emission credit can be estimated through a reliable, reproducible method approved by the U.S. EPA. For the purpose of measuring cost-effectiveness of emissions reductions programs, only data from studies that meet the five criteria accepted for ERCs are included in the analysis.

Organization of Data and Assumptions Made

Data from the literature were organized into an initial spreadsheet [consider providing the spreadsheet name here, but without the date code] sorted by the source and technology, and captured data points for costs, including the capital (initial), maintenance, and operational costs and the owners of each, the fuel rate, cost and reported savings, and the measured emissions generated. The appendix contains the full literature review and data values employed. The additional information includes number of idling hours recorded, specifications of heating, air conditioning or other accessories used, lifetime of technology and payback periods of the initial costs. Information pertaining to base idling emission rates were collected in a separate worksheet, with specific test conditions to measure the pollutants emitted listed from each study, where applicable, to assess which rate to use as a controlled variable per pollutant in the calculator. For each study, the data associated with each technology were listed by row to facilitate comparisons. The various data points organized onto a master spreadsheet made clear the inconsistencies and lack of necessary information to compare each study side by side, which resulted in methodological limitations. For instance, due to the various goals of the individual studies, not all information regarding costs and emissions reductions were reported in each study, and information regarding method of measurement or conditions of the study and specifications of the fleet were not consistently documented.

To assess cost-effectiveness, studies must provide all costs incurred during the lifetime of the technology, the fuel consumption rate and fuel cost, and emissions emitted or reduced. In cases where not enough information was provided, the respective studies were not included in the overall cost-effectiveness comparison, and specific data points that were given for either costs or emissions were included for weighted averages of common measures.

To account for controlled variables that differed from study to study, a set of assumptions were used to create a model that combines data from published sources that synthesized idling behavior with in-field observations and reasonable estimates and control the variability of outputs in the comparison. These assumptions are found in a separate worksheet within the calculator:

- Idle time was assumed to be 10 hours per day, 300 days per year, which is consistent with the U.S. Department of Transportation mandate that long-haul truck drivers must rest 10 hours for every 11 hours of driving and studies conducted by EPA suggesting number of days per year of idling (Department of the Environment; Frey & Kuo, 2009)

- The idling fuel rate was assumed to be 1 gal per hour of idling, as per a UC-Davis study that estimated the fuel consumption rate observed for the 2000 model year Argosy Tractors at idle with no accessories running (Brodrick et al., 2001).
- Fuel costs not reported in the literature was estimated based on year according to the Energy Information Administration (Energy Information Administration, 2015).
- The operational lifetime for each technology in years is estimated to be 5 years for APUs and DFHs, and 15 years for TSEs and ATSEs, according to a study conducted by the Center for Energy and Environmental Policy at the University of Delaware that estimated these lifetimes based on field survey, interview with stakeholders, and literature review (Wang et al., 2007). The cost analyses were calculated assuming a 30-year investment for each technology use.
- The discount rate is estimated at 3% based on best practices in literature (Frey & Kuo, 2007)
- The fuel cost and electricity cost growth rate are estimated at 3% respectively based on information from EIA. (Energy Information Administration, 2015)

Once all of the data points were organized in order to provide an equivalent annual cost (EAC) per study and technology, the cost-effectiveness measure in dollars per year per ton per year of emissions reduced was calculated. The NPV and EAC calculations were separated into different worksheets per technology to see the breakdown of costs and savings cash flows assuming a 30-year investment for each. A summary of results were organized into relevant tables and charts, which consumed a separate worksheet within the calculator.

Calculations

As per the goal of this study, the measure of cost-effectiveness was derived using the annualized net present value of the technology dividied by the annual tons per year of emissions reduced by the technology. Thus, cost-effectiveness, for the purpose of this study, is defined as the cost per ton of emissions reduced. Cost-effectiveness can vary depending on a variety of influences, including the pollutant(s) for which the area is in nonattainment, precursor pollutants of concern, relative size of pollutant inventories, and the existing sources and level of control measures in place (U. S. Environmental Protection Agency, 2007a). However, the measurement of effectiveness in dollars per year per ton per year of emissions reduced for each technology may quantify the value of each investment as a viable solution tobe considered by state and local agencies given their respective local air quality characteristics. Therefore, the calculation for determining cost-effectiveness in the context of this study is given in formula below. In obtaining this value, calculations for costs and emissions used data obtained from the literature.

$$\text{Cost-Effectiveness} = \text{EAC} / \text{Tons Per Year Emissions Reduced}$$

Cost Calculations

Various calculations were required in order to organize the data around consistent measurements. This section elaborates on the calculations required for each data point. Relating to functions of cost, the maintenance and operational cost data that was presented in dollars per hours of usage was multiplied by the assumed 10 hours per day and 300 days per year of idling in order to obtain the costs in dollars per year.

$$\boxed{\frac{\text{O\&M Cost (\$)}}{\text{Hour}} * \frac{\text{10 Hours of Idling}}{\text{Day}} * \frac{\text{300 Days of Idling}}{\text{Year}} = \frac{\textbf{O\&M Cost (\$)}}{\textbf{Year}}}$$

Figure 4 - Calculation for Operation and Maintenance Costs Based On Hours of Usage

The annual fuel cost was calculated given the fuel consumption rate in gallons per hour and fuel cost in dollars per gallon reported. Where the fuel cost was not reported in literature, values were estimated based on study year and the Energy Information Administration’s per annum diesel gasoline rates. The annual fuel cost was thus measured by multiplying the fuel consumption and fuel cost with the assumed idling rate of 10 hours per day and 300 days per year, as seen in Figure 5. The annual fuel savings were taken from the difference between the annual fuel cost per technology and the annual fuel cost for base idling, which was obtained using the same formula from Figure 5 using the fuel rate of 1 gallon of per hour of idling.

$$\boxed{\frac{\text{Fuel Rate (gal)}}{\text{Hour}} * \frac{\text{Fuel Cost (\$)}}{\text{Gallon}} * \frac{\text{10 Hours of Idling}}{\text{Day}} * \frac{\text{300 Days of Idling}}{\text{Year}} = \frac{\textbf{Fuel Cost (\$)}}{\textbf{Year}}}$$

Figure 5 - Calculation for Annual Fuel Costs Given Fuel Consumption and Fuel Cost Per Gallon

The net present value calculations were derived for each technology per source given the data year, the discount rate of 3%, the fuel cost and electricity cost growth rates of 3% respectively, and the capital costs, operational and maintenance costs, fuel cost and idling fuel cost in dollars per year in 2015 dollars. To bring the yearly costs from the study data year to present value, the consumer price index (CPI) for both years was derived from the Bureau of Labor Statistics representing average change over time in the prices paid (Bureau of Labor Statistics, 2015). See Appendix for the chart of indexes used in the study. The formula used to measure the present value of these costs is below in Figure 6.

$$\boxed{\text{Data Year Cost (\$)} * \frac{\text{CPI in 2015}}{\text{CPI in Data Year}} = \textbf{2015 Cost (\$)}}$$

Figure 6 - Calculation for 2015 Value of Costs

With the 2015 value of the costs, the net present value is calculated by totalling the cash flows for each year given a 30-year investment period and the lifetime periods of 5 years for APUs and DFHs and 15 years for TSEs and ATSEs. Thus, the capital costs are renewed every 5 or 15 years given the respective lifetime periods of the technology, and the O&M cost and fuel cost are added to the total sum of cash flows. The capital costs were kept constant at 2015 values to account for the unknown variability in initial costs of the device based on technological advancements and changes in efficiency. The avoided fuel cost from idling, which is the fuel cost assumed by idling without in dollars per year, was simultaneously calculated by using the idling fuel rate and the 2015 fuel price from EIA to measure the avoided fuel cost per year for the 30-year period. With the cash flows per year and the expected discount rate established, the net present value of the investment was calculated with the formula:

$$\text{NPV} = \sum \{\text{Net Period Cash Flow}/(1+R)^T - \text{Initial Investment}$$

where R is the rate of return and T is the number of time periods

The NPV calculation was established as an Excel formula, given that the cash flows were evenly spaced over time, using the function “=NPV” with the formula “=NPV(discount rate,A1,A2,A3…A30), with A1 through A30 being the cash flows per year for the 30 year investment period. With this method, the NPV was calculated for the cost cash flows and the avoided fuel costs form idling cash flows separately. The difference between the two was taken to distinguish the cost savings of using the technology over idling without it. Additionally, the EAC cost, the cost per year of owning and operating the technology over its lifespan, was quantified by dividing the NPV by the present value of annuity factor, with ‘t’ being the number of periods, and ‘r’ being the interest rate (Investing Answers, 2015).

$$EAC = \frac{NPV}{A_{t,r}}, \text{ where } A_{t,r} = \frac{1 - \frac{1}{(1+r)^t}}{r}$$

Figure 7 - Calculation for Equivalent Annual Cost

The payback period was also calculated to assess the time required in years for the amount invested in the technology to be repaid by the net cash outflow generated by the asset. With the data established from the literature, the payback period analysis was a simple way to evaluate the risk associated with a proposed project. An investment with a shorter payback period is considered to be better, since the investor's initial outlay is at risk for a shorter period of time. This was done by dividing the initial capital cost in year 0 by the difference between the savings and total cost in year 1.

$$\text{Capital Cost}_{\text{year 0}} / (\text{Annual Fuel Cost Saved} - \text{Annual Total Cost})_{\text{year 1}}$$

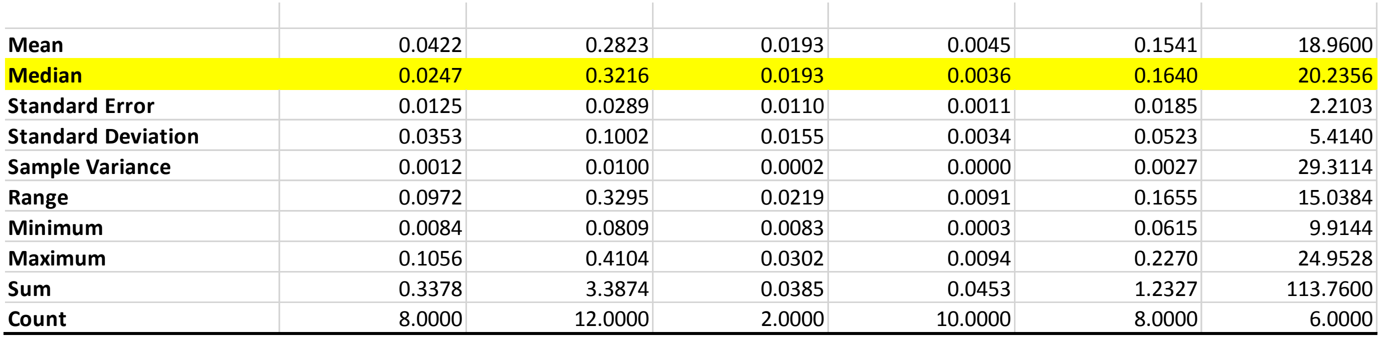
Figure 8 - Calculation for Payback Period in Years

Emissions Calculations

The emissions emitted in grams per hour as reported in the literature for technology use and base idling was converted to tons per year by using the conversion factor of 1 gram = 1e-6 metric tons, and the idling rate of 10 hours per day and 300 days per year. For base idling, various values were given for emissions generated per pollutant. This variability derived from the range of test conditions in each study which makes emissions predictions difficult to compare from study to study; there is an inherent difficulty in comparing across studies with different goals. Descriptive statistics and box plots were generated for each pollutant to better understand the variability and to help choose a valid measure of central tendency and establish a single value that would best represent the distribution of emissions reported per pollutant. The test conditions varied in ambient temperature, climate, RPM and idle time recorded, and some studies had not specified test conditions for the idling emissions rates used in their own study. Given the small number of data points between widely different sources with no reliable consistency, the median value for each set of emissions factors per pollutant was taken to represent the distribution, as to eliminate influence of outliers that are not entirely explainable and measure central tendency more conservatively with the lack of context to understand the data. The summary statistics for each pollutant is shown in the table below.

Furthermore, the emissions rates reported from using each technology in tons per year were subtracted from emissions rates for base idling in tons per year to derive the estimate for tons per year of emissions reduced per pollutant for each study. This was crucial in determind the tons per year of emissions produced per pollutant and per technology in assessing cost-effectiveness.

Table 9 - Summary Statistics For Idling Emissions Rates in Tons per Year



Mean	0.0422	0.2823	0.0193	0.0045	0.1541	18.9600
Median	0.0247	0.3216	0.0193	0.0036	0.1640	20.2356
Standard Error	0.0125	0.0289	0.0110	0.0011	0.0185	2.2103
Standard Deviation	0.0353	0.1002	0.0155	0.0034	0.0523	5.4140
Sample Variance	0.0012	0.0100	0.0002	0.0000	0.0027	29.3114
Range	0.0972	0.3295	0.0219	0.0091	0.1655	15.0384
Minimum	0.0084	0.0809	0.0083	0.0003	0.0615	9.9144
Maximum	0.1056	0.4104	0.0302	0.0094	0.2270	24.9528
Sum	0.3378	3.3874	0.0385	0.0453	1.2327	113.7600
Count	8.0000	12.0000	2.0000	10.0000	8.0000	6.0000

Evaluation of Literature With Respect to Cost-Effectiveness

Calculator Results

Based on the results of the calculator and the respective cost and emissions functions per technology and per study, TSEs are the most cost-effective for the investor and the truck owner in reducing NOx emissions. Cost-effectiveness were measured for investors at $1,707.57 and $1,473.27 per ton of NOx reduced, and $16,799.91, $22,261.44, and $20,583.79 per ton of NOx reduced for truck owners. In regards to PM reductions, TSEs also resulted in the most cost-effective solution, with $55,984.36 per ton of PM reduced for investors and $782,184.21 per ton of PM reduced for truck owners. The tables below summarize the findings of cost effectiveness of NOx, PM, and the remainining pollutants. Tables 10, 11, and 12 are represented by ownership

Table 10 - Cost-Effectiveness for the Reduction of NOx Emissions in Dollars per Tons Emissions Reduced

	Investor	Truck Owner	Unlisted Ownership
APU			
Gaines		$ 21,019.84	
Stodolsky			$ 13,809.18
Wang		$ 20,059.24	
ATSE			
Wang	$ 14,818.51	$ 22,868.55	
DFH			
Stodolsky			$ 11,659.97
Wang		$ 17,672.56	
TSE			
Gaines	$ 1,707.57	$ 16,799.91	
Ginn		$ 22,261.44	
Stodolsky			$ 8,330.62
Wang	$ 1,473.27	$ 20,583.79	

of costs, and sources without information present for a particular pollutant was not included. Thus, Table 12 only has the cost-effectiveness measure for the reduction of CO_2, as that is the only reported value filtered by investor costs for remaining pollutants.

Table 11 - Cost-Effectiveness for the Reduction of PM Emissions in Dollars Per Tons Emissions Reduced

	Investor	Truck Owner	Unlisted Ownership
APU			
Gaines			$ 2,548,566.08
Stodolsky			
Wang			
ATSE			
Wang	$ 563,103.47	$ 869,004.85	
DFH			
Stodolsky			
Wang			
TSE			
Gaines	$ (459,998.62)	$ 5,133,628.02	
Ginn		$ 2,088,588.64	
Stodolsky			$ 718,435.96
Wang	$ 55,984.36	$ 782,184.21	

Table 12 - Cost-Effectiveness For the Reduction of CO_2 Emissions in Dollars per Tons Emissions Reduced for

For Investor	Cost-Effectivess for CO2 Emissions
ATSE	
Wang	$ 278.27
TSE	
Wang	$ 32.06

Table 13 - Cost-Effectiveness for the Reduction of VOC, CO and CO_2 Emissions in Dollars per Tons Emissions Reduced for Truck Owners

	Cost-Effectiveness Per Pollutant		
For Truck Owner	**VOC**	**CO**	**CO2**
ATSE			
Wang			$ 429.44
DFH			
Wang			$ 383.58
TSE			
Gaines			
Ginn	$ 367,310.26	$ 43,164.68	$ 387.48
Wang			$ 447.99

Table 14 - Cost-Effectiveness for the Reduction of HC, VOC, CO and CO_2 in Dollars per Tons Emissions Reduced for Unlisted Owners

	Cost-Effectiveness Per Pollutant			
Unlisted Ownership	**HC**	**VOC**	**CO**	**CO2**
APU				
Stodolsky	$ 169,468.19	$ 220,983.80	$ 27,981.29	$ 270.85
DFH				
Stodolsky		$ 199,499.32	$ 22,986.76	$ 235.74
TSE				
Stodolsky		$ 132,295.98	$ 15,548.73	$ 225.86

Based on the data available, TSE's are the most cost-effective values for the investor, truck owner, and in studies where ownership was unlisted for the pollutants in question. For PM emissions reductions based on Table 11, Wang's data represents a cost-effectiveness measure of $55,984.36 per ton of PM emissions reduced for the investor, which is vastly different than the reported -$459,998.62 from Gaines, as Gaines' emissions reduction of PM in tons per year is at a deficit from the base idling rate. For the truck owner, the cost-effectiveness of a technology in reducing CO_2 emissions is similar between TSEs and DFHs, and certain studies measure TSEs and ATSEs similarly in cost-effectiveness of CO_2 emissions reduced.

Summary of Costs and Benefits

Aside from the cost-effectiveness analysis based on emissions reduction, fuel savings is a significant benefit from idle reduction. Given the variability in savings based on variability fuel costs. To give context to the technology comparison from a broader perspective, Table 15 below outlines the greater costs and benefits for each program.

Table 15 - Summary of Advantages and Disadvantages

System	Advantages	Disadvantages
Idling	No investment	High emissions, fuel use
APU	Technology can be used anywhere/anytime	High cost and weight
DFH	Negligible emissions in Nox Lightweight	Consumes large amount of electricitiy
TSE	No local emissions Pay per use Quiet, no noise Simple plug-in power	Requires equipped location Higher costs than ATSE
ATSE	Immediate HVAC without special equipment Quiet, no noise Significant fuel cost savings	Requires equipped location

Onboard devices can be used wherever and whenever the truck is stopped, but they add weight to the truck. DFHs supply warm air to the cab/sleeper, and an engine block heater can also be included. Fuel use and emissions by diesel heaters are very low, because they supply heat directly from a small combustion flame to a heat exchanger, though the electricity usage is high (Gaines & Levinson, 2009a). APUs are on-board systems that can be used anywhere, and the emissions are compliant with small engine standards, though depending on state and local policies, such as in California, heavy restrictions and additional controls may be necessary. Electrification systems add little or no weight to the truck and cause no local emissions, because no diesel fuel is consumed. However, there are upstream emissions from generating the electricity and producing and transporting the power plant fuel (Gaines & Levinson, 2009b).

The high costs of these technologies may be offset by fuel savings, and other considerations including idling time and age of trucks. For trucks that idle over 20–30 hours per week, technologies using on-board equipment, including TSEs, result in lower total cost to the truck owner over five years of operation. NOx emissions from pre-2007 trucks and CO_2 emissions can be reduced by air-conditioning via electrification, but this results in an increase in PM because of the use of coal in the grid mix in all states (Gaines & Levinson, 2009b). Policies must take into account local air quality characteristics in deciding effective solutions for emissions reductions.

Given the cost-effectiveness and fuel savings, a risk assessment should be carried to assess the accepted risk tolerated due to associated vulnerability exceeding the loss from implementing countermeasures to idling. In assessing health risks, there must be a specification about risks incurred by general exposure to pollutants and health risks for drivers. In some cases, truck pollution concentrations are significantly higher inside the cab than outside, with PM and NOx emissions exceeding NAAQS regulations (Burgess et al., 2009). Studies also show that increased occupational exposure to diesel pollution, such as truck drivers, have elevated risks for lung cancer and other health problems (Steenland, Deddens, & Stayner, 1998). More data are necessary in understanding the operating context and environment of truck idling at various stops or geographic concentrations and their imposed risk on the environment, health and truck drivers to understand the effectiveness of reducing emissions, appraise risk and establish acceptable risk criteria.

CHAPTER 5

CONCLUSIONS AND RESULTS

Idle Reduction and Cost Results

The research conducted in the preparation of this thesis resulted in the development of an Excel cost calculator spreadsheet that contains information on initial, operational, and maintenance costs, fuel cost and savings, idling rates, emissions rates and reductions, and payback periods for various heavy-duty vehicle idle control strateiges so that users can select the most cost effective technology for idle reduction in heavy-duty trucks. The calculator revealed that TSEs are the most cost-effective for the investor and the truck owner in reducing NOx emissions. Cost-effectiveness measures for investors range from $1,708 and $1,473 per ton of NOx reduced, and $16,800, $22,261.44, and $20,583.79 per ton of NOx reduced for truck owners according to the studies used. In regards to PM reductions, TSEs also resulted in the most cost-effective solution, with $55,984 per ton of PM reduced for investors and $782,184 per ton of PM reduced for truck owners. Additionally, added context confirmed that various factors control the impact of IR technologies, and the effectiveness of these options may vary with time and location.

The literature review of various studies that measured costs and emissions reductions of the idle reduction technologies provided a dataset of test conditions, assumptions and methodology of the study from which the calculator's data points were derived. The organization of data points into the calculator showed the inconsistencies and variability of cost and emissions values based on varying study assumptions. The calculator also provides a review of information present in the current body of literature and information that is deficient but necessary to provide a sound recommendation on the most cost-effective technology as a comparison of others. This comparison is achieved by analysis data on cost and emissions reductions per technology with constant test assumptions, fuel costs and fuel consumption rates for both the technology and the base idling measure. This study recommends that researchers use this tool to evaluate further studies to calibrate an accurate measure of cost-effectiveness across technologies. Additionally, data gathering by fleets, government agencies, environmental groups and research entities would expand information on idle behavior, costs incurred by truck owners and investors, and accurate idling costs for each technology. Thist study concludes that the role of research and development in providing more robust data will enable broader and more economically attractive penetration of idle-reduction technologies for wider use.

Project Effectiveness

The limitations of the study were to rely on the literature to gain a standardized set of data for all technologies surveyed in order to compare systems and costs with consistent test conditions. Various literature searched provided different scopes within the study area, and thus a compilation of relevant data and information was included within the calculator. Users are able to select from the list of four technologies and set scenarios that will reveal payback periods and cost effectiveness profiles, which was estimated using overall cost divided by percentage of NOx emissions reduced. Values for idling were used as a baseline comparison between vehicle idling and technologies to replace idling in trucks. Each row of the calculator is one dataset from literature. Some studies had emission reductions without initial costs, and some studies had the reverse. A few studies had a whole set of robust data. Studies that included all cost and emissions data were evaluated to assess effectiveness. Between all technologies, truck stop electrification and advanced truck stop electrification are the most effective, depending on cost ownership, across pollutants.

Limited quantitative data and unknown variability of costs as a function of time over the 30-year investment period was used to assess best practices. The calculator served as a tool to illustrate insufficient data currently present in the body of literature. Policymakers and other stakeholders can benefit from conducting studies that would enlighten greater understanding of data points from specifications of the operating context, and researchers could benefit from understanding specific voids in the systematic review of data to revisit their study conditions and outputs and iterate more robust models for the sake of comparing these technologies based on impact and risk. This report does not make specific recommendations about the use of strategies as best practices, because the information given is incomplete and does not enable situation-specific assessment and comparison. However, based on the costs and emissions profiles from the calculator, officials, investors and fleet owners are encouraged to make decisions based on the quantitative analysis given coupled with greater understanding of local characteristics and climate for idle reduction. Determining the effectiveness of these technologies is important, given that an unsatisfactory system performance cannot obtain a comprehensive market approval.

Future Research

To further inform decision making on the adoption of suitable best practices with respect to idle reduction, the following is recommended for future research.

1. Update information and revise cost estimates as new data become available. There is a critical need for more cost information, including cost ownership, estimates in growth

rates and initial investment costs over time. Ongoing work is recommended to develop cost estimates for best practices and update cost estimates as new data becomes available for use.

2. Evaluate key assumptions and influencing factors to inform selection of best practices. Factors such as market penetration rates, fuel prices, and costs may be assessed via sensitivity analysis, and the outlying influences such as policies and regulations, government incentives and costs and beenfits as seen by various operators in the system are necessary qualitative data to have in order to build context around the operational conditions.
3. Develop tools around new, robust data as a mechanism for decision-making. Such tools can include a decision tree involving the hierarchy of stipulations in guiding responsible and targeted solutions to appropriate situations. Decision trees can also include choice nodes and valuation (Frey & Kuo, 2007). Additionally, existing tools from federal programs can be strengthened by research in risk assessment and specified emissions environments and criteria by geography. A tool where users can input their own assumptions and data based on a framework of possibilities and multiple best practices is advised.

APPENDIX A.1 CALCULATOR ASSUMPTIONS

Idle Time	10 hours per day, 300 days per year
Idling Fuel Rate	1 gal per hour of idling
Fuel Cost (unreported)	Estimated based on year according to the EIA
Operational Lifetime	5 years for APUs and DFHs, and 15 years for TSEs and ATSEs
Discount Rate	3%
Fuel Cost Growth Rate	3%
Electricity Cost Growth Rate	3%

APPENDIX B.1 LITERATURE DATA – CAPITAL AND O&M COSTS

SCENARIO				**COSTS**		
Source	**Technology**	**Year**	**Owner**	**Capital Cost**	**Maintenance Cost ($/year)**	**Operational Cost ($/year)**
Ginn	APU	2004	Truck Owner	$ 7,000.00	$ 1,339.00	
Lust	APU	2008		$ 9,000.00	$ 125.00	
Stodolsky	APU	2000		$ 7,095.00		
Boeckenstedt	APU	2005		$ 7,840.00		$ 745.00
Gaines	APU	2009	Truck Owner	$ 8,000.00	$ 990.00	
Lim	APU	2001				
Lim	APU	2001				
Storey	APU	2003				
Storey	APU	2003				
Wang	APU	2007	Truck Owner	$ 8,000.00	$ 500.00	
Ginn	ATSE	2004	Truck Owner	$ 10.00		$ 3,750.00
Ginn	ATSE	2004	Investor	$ 10,000.00		
Boeckenstedt	ATSE	2005		$ 18,010.00		$ 2,400.00
Gaines	ATSE	2009	Investor	$ 10,000.00		
Gaines	ATSE	2009	Truck Owner	$ 10.00		$ 3,000.00
Gaines	ATSE	2009	Investor	$ 16,700.00		
Gaines	ATSE	2009	Truck Owner	$ 10.00		$ 7,350.00
Shancita	ATSE	2014		$ 10,000.00		$ 3,750.00
Wang	ATSE	2007	Investor	$ 16,000.00	$ 2,500.00	
Wang	ATSE	2007	Truck Owner	$ -		$ 5,250.00
Ginn	DFH	2004		$ 2,000.00		
Lust	DFH	2008		$ 1,200.00	$ 110.00	
Stodolsky	DFH	1996		$ 3,200.00		
Gaines	DFH	2009				
Lim	DFH	1997				
Storey	DFH	2003				
Wang	DFH	2007	Truck Owner	$ 2,000.00	$ 500.00	
Ginn	TSE	2004	Truck Owner	$ 2,500.00		$ 3,750.00
Ginn	TSE	2004	Investor	$ 2,500.00		
Lust	TSE	2008		$ 4,000.00		$ 6,000.00
Stodolsky	TSE	1999		$ 4,200.00		$ 1,032.00
Boeckenstedt	TSE	2005		$ 9,000.00		$ 1,500.00
Gaines	TSE	2009	Investor	$ 6,000.00		
Gaines	TSE	2009	Truck Owner	$ 2,500.00	$ 210.00	$ 3,000.00
Calcagno	TSE	2004				
Calcagno	TSE	2004				
Calcagno	TSE	2004				
Zietsman	TSE	2009				
Zietsman	TSE	2009				
Zietsman	TSE	2009				
Shancita	TSE	2014		$ 6,750.00		
Wang	TSE	2007	Investor	$ 6,000.00		
Wang	TSE	2007	Truck Owner	$ 4,000.00	$ 1,500.00	$ 3,000.00

APPENDIX B.2 LITERATURE DATA – FUEL COSTS AND SAVINGS

SCENARIO				**COSTS**				
Source	**Technology**	**Year**	**Owner**	**Fuel Rate (gal/hr)**	**Fuel Cost ($/gal)**	**Annual Fuel Cost ($/year)**	**Annual Idling Fuel Cost ($)**	**Fuel Savings ($)**
Ginn	APU	2004	Truck Owner	0.215	$ 1.50	$ 967.50	$ 4,500.00	$ 3,532.50
Lust	APU	2008		0.85	$ 3.45	$ 8,797.50	$ 10,350.00	$ 1,552.50
Stodolsky	APU	2000		0.18	$ 1.75	$ 945.00	$ 5,250.00	$ 4,305.00
Boeckenstedt	APU	2005		0.178	$ 2.07	$ 1,105.38	$ 6,210.00	$ 5,104.62
Gaines	APU	2009	Truck Owner	0.23	$ 2.47	$ 1,702.23	$ 7,401.00	$ 5,698.77
Lim	APU	2001		0.2				
Lim	APU	2001		0.23				
Storey	APU	2003						
Storey	APU	2003						
Wang	APU	2007	Truck Owner	0.2	$ 2.89	$ 1,731.00	$ 8,655.00	$ 6,924.00
Ginn	ATSE	2004	Truck Owner		$ 1.50			
Ginn	ATSE	2004	Investor		$ 1.50			
Boeckenstedt	ATSE	2005						$ 4,140.00
Gaines	ATSE	2009	Investor					
Gaines	ATSE	2009	Truck Owner					
Gaines	ATSE	2009	Investor					
Gaines	ATSE	2009	Truck Owner					
Shancita	ATSE	2014						
Wang	ATSE	2007	Investor					
Wang	ATSE	2007	Truck Owner					
Ginn	DFH	2004		0.04	$ 1.50	$ 180.00	$ 4,500.00	$ 4,320.00
Lust	DFH	2008		0.85	$ 3.45	$ 8,797.50	$ 10,350.00	$ 1,552.50
Stodolsky	DFH	1996		0.2	$ 1.75	$ 1,050.00	$ 5,250.00	$ 4,200.00
Gaines	DFH	2009		0.055				
Lim	DFH	1997		0.04				
Storey	DFH	2003		0.037				
Wang	DFH	2007	Truck Owner	0.3	$ 2.89	$ 2,596.50	$ 8,655.00	$ 6,058.50
Ginn	TSE	2004	Truck Owner		$ 1.50			
Ginn	TSE	2004	Investor		$ 1.50			
Lust	TSE	2008		0.85	$ 3.45	$ 8,797.50	$ 10,350.00	$ 1,552.50
Stodolsky	TSE	1999			$ 1.75			
Boeckenstedt	TSE	2005						$ 4,140.00
Gaines	TSE	2009	Investor					
Gaines	TSE	2009	Truck Owner					
Calcagno	TSE	2004						
Calcagno	TSE	2004						
Calcagno	TSE	2004						
Zietsman	TSE	2009		0.29				$ 4,512.00
Zietsman	TSE	2009		0.23				
Zietsman	TSE	2009		0.25				
Shancita	TSE	2014						
Wang	TSE	2007	Investor					
Wang	TSE	2007	Truck Owner					

APPENDIX B.3 LITERATURE DATA – LIFETIME AND PAYBACK

SCENARIO				LIFETIME AND PAYBACK			
Source	**Technology**	**Year**	**Owner**	**Lifetime (Years)**	**Payback Period Reported (Years)**	**Payback Period Estimated (Years)**	**EQUIVALENT ANNUAL COST ($)**
Ginn	APU	2004	Truck Owner	5	2.13	3.19	$ 6,058.12
Lust	APU	2008		7	2.7	6.30	$ 16,327.85
Stodolsky	APU	2000		5		2.11	$ 3,960.47
Boeckenstedt	APU	2005		5	2.3	2.41	$ 5,275.07
Gaines	APU	2009	Truck Owner	5		1.70	$ 6,186.14
Lim	APU	2001		5			
Lim	APU	2001		5			
Storey	APU	2003		5			
Storey	APU	2003		5			
Wang	APU	2007	Truck Owner	5		1.25	$ 5,638.65
Ginn	ATSE	2004	Truck Owner	15	0.83	0.00	$ 6,812.82
Ginn	ATSE	2004	Investor	15	3.66	1.72	$ 1,023.96
Boeckenstedt	ATSE	2005		15	10.4	4.97	$ 6,000.40
Gaines	ATSE	2009	Investor	15		1.51	$ 901.60
Gaines	ATSE	2009	Truck Owner	15		0.00	$ 0.90
Gaines	ATSE	2009	Investor	15		(0.01)	$ 11,756.57
Gaines	ATSE	2009	Truck Owner	15		2.52	$ 1,505.67
Shancita	ATSE	2014		15		3.78	$ 7,140.25
Wang	ATSE	2007	Investor	15	6.65	4.11	$ 5,631.03
Wang	ATSE	2007	Truck Owner	15		-	$ 8,690.05
Ginn	DFH	2004		5	3.02	0.46	$ 860.80
Lust	DFH	2008		7		0.83	$ 14,477.29
Stodolsky	DFH	1996		5		0.76	$ 3,740.61
Gaines	DFH	2009		5			
Lim	DFH	1997		5			
Storey	DFH	2003		5			
Wang	DFH	2007	Truck Owner	5		0.36	$ 5,611.92
Ginn	TSE	2004	Truck Owner	15	1.53	1.20	$ 7,067.78
Ginn	TSE	2004	Investor	15	1.16	0.43	$ 255.99
Lust	TSE	2008		7	1.4	(0.76)	$ 25,279.18
Stodolsky	TSE	1999		15		0.98	$ 2,528.18
Boeckenstedt	TSE	2005		15	3.4	1.99	$ 3,526.79
Gaines	TSE	2009	Investor	15		0.91	$ 540.96
Gaines	TSE	2009	Truck Owner	15		0.73	$ 5,359.51
Calcagno	TSE	2004		15			
Calcagno	TSE	2004		15			
Calcagno	TSE	2004		15			
Zietsman	TSE	2009		15			
Zietsman	TSE	2009		15			
Zietsman	TSE	2009		15			
Shancita	TSE	2014		15		0.63	$ 373.23
Wang	TSE	2007	Investor	15	4.6	0.94	$ 559.84
Wang	TSE	2007	Truck Owner	15	0.95	2.11	$ 7,821.84

APPENDIX C.1 EMISSIONS DATA REPORTED IN LITERATURE

SCENARIO				**EMISSIONS REPORTED (grams/hour)**						**EMISSIONS ESTIMATED (tons/year)**					
Source	**Technology**	**Year**	**Owner**	**HC**	**NOx**	**VOC**	**PM**	**CO**	**CO2**	**HC**	**NOx**	**VOC**	**PM**	**CO**	**CO2**
Ginn	APU	2004	Truck Owner												
Lust	APU	2008													
Stodolsky	APU	2000		0.45	11.6	0.45	0.69	7.5	1871	0.0014	0.0348	0.0014	0.0021	0.0225	5.613
Boeckenstedt	APU	2005													
Gaines	APU	2009	Truck Owner		9.1		0.72		2800		0.0273		0.0022		8.4
Lim	APU	2001			7.3				2053		0.0219				6.159
Lim	APU	2001			10				2353		0.03				7.059
Storey	APU	2003													
Storey	APU	2003													
Wang	APU	2007	Truck Owner		13.5						0.0405				
Ginn	ATSE	2004	Truck Owner												
Ginn	ATSE	2004	Investor												
Boeckenstedt	ATSE	2005													
Gaines	ATSE	2009	Investor												
Gaines	ATSE	2009	Truck Owner												
Gaines	ATSE	2009	Investor												
Gaines	ATSE	2009	Truck Owner												
Shancita	ATSE	2014													
Wang	ATSE	2007	Investor												
Wang	ATSE	2007	Truck Owner												
Ginn	DFH	2004													
Lust	DFH	2008													
Stodolsky	DFH	1996			0.26	0.17		0.44	1456		0.0008	0.0005		0.0013	4.368
Gaines	DFH	2009			0.2		0.06				0.0006		0.0002		
Lim	DFH	1997			0.21				402		0.0006				1.206
Storey	DFH	2003			0.2		0.06	0.1	445		0.0006		0.0002	0.0003	1.335
Wang	DFH	2007	Truck Owner		1.35				1868.40		0.0041				5.6052
Ginn	TSE	2004	Truck Owner		1.37	0.01	0.08	0.1	665		0.0041	3E-05	0.0002	0.0003	1.995
Ginn	TSE	2004	Investor												
Lust	TSE	2008													
Stodolsky	TSE	1999			6.04	0.05	0.04	0.48	3014		0.0181	0.0002	0.0001	0.0014	9.042
Boeckenstedt	TSE	2005													
Gaines	TSE	2009	Investor		1.6		1.6				0.0048		0.0048		
Gaines	TSE	2009	Truck Owner		0.86		0.86				0.0026		0.0026		
Calcagno	TSE	2004			5.84			0.19			0.0175			0.0006	
Calcagno	TSE	2004			5.84			0.19			0.0175			0.0006	
Calcagno	TSE	2004			5.84			0.19			0.0175			0.0006	
Zietsman	TSE	2009			42.6		1.16	12.9			0.1278		0.0035	0.0387	
Zietsman	TSE	2009			33.8		0.92	10.3			0.1014		0.0028	0.0309	
Zietsman	TSE	2009			36.9		1.01	11.2			0.1107		0.003	0.0336	
Shancita	TSE	2014													
Wang	TSE	2007	Investor												
Wang	TSE	2007	Truck Owner												

APPENDIX C.2 EMISSIONS REDUCED IN TONS/YEAR

SCENARIO				**EMISSIONS REDUCED (tons/year)**					
Source	**Technology**	**Year**	**Owner**	**HC**	**NOx**	**VOC**	**PM**	**CO**	**CO2**
Ginn	APU	2004	Truck Owner						
Lust	APU	2008							
Stodolsky	APU	2000		0.023	0.2868	0.018	0.00155	0.1415	14.623
Boeckenstedt	APU	2005							
Gaines	APU	2009	Truck Owner		0.2943		0.00146		11.836
Lim	APU	2001			0.2997				14.077
Lim	APU	2001			0.2916				13.177
Storey	APU	2003							
Storey	APU	2003							
Wang	APU	2007	Truck Owner		0.2811				
Ginn	ATSE	2004	Truck Owner						
Ginn	ATSE	2004	Investor						
Boeckenstedt	ATSE	2005							
Gaines	ATSE	2009	Investor						
Gaines	ATSE	2009	Truck Owner						
Gaines	ATSE	2009	Investor						
Gaines	ATSE	2009	Truck Owner						
Shancita	ATSE	2014							
Wang	ATSE	2007	Investor		0.38		0.01		20.236
Wang	ATSE	2007	Truck Owner		0.38		0.01		20.236
Ginn	DFH	2004							
Lust	DFH	2008							
Stodolsky	DFH	1996			0.3208	0.019		0.1627	15.868
Gaines	DFH	2009			0.321		0.00344		
Lim	DFH	1997			0.321				19.03
Storey	DFH	2003					0.00346	0.1637	18.901
Wang	DFH	2007	Truck Owner		0.3176				14.63
Ginn	TSE	2004	Truck Owner		0.3175	0.019	0.00338	0.1637	18.241
Ginn	TSE	2004	Investor						
Lust	TSE	2008							
Stodolsky	TSE	1999			0.3035	0.019	0.00352	0.1626	11.194
Boeckenstedt	TSE	2005							
Gaines	TSE	2009	Investor		0.3168		-0.0012		
Gaines	TSE	2009	Truck Owner		0.319		0.00104		
Calcagno	TSE	2004			0.3041			0.1635	
Calcagno	TSE	2004			0.3041			0.1635	
Calcagno	TSE	2004			0.3041			0.1635	
Zietsman	TSE	2009					0.00014	0.1253	
Zietsman	TSE	2009					0.00086	0.1331	
Zietsman	TSE	2009					0.00059	0.1304	
Shancita	TSE	2014							
Wang	TSE	2007	Investor		0.38		0.01		17.46
Wang	TSE	2007	Truck Owner		0.38		0.01		17.46

APPENDIX C.3 EMISSIONS FROM IDLING BASED ON LITERATURE

			EMISSIONS PER TRUCK (grams/hour)						EMISSIONS PER TRUCK (tons/year)					
Source	**Test Conditions**	**Fuel Consumption (gal/h)**	**HC**	**NOx**	**VOC**	**PM**	**CO**	**CO2**	**HC**	**NOx**	**VOC**	**PM**	**CO**	**CO2**
Stodolsky	N/A		12.60	56.70	12.60	2.57	94.60	10397.00	0.0302	0.1361	0.0302	0.0062	0.2270	24.9528
Shancita	N/A		7.90	84.10		1.60	63.00	4131.00	0.0190	0.2018		0.0038	0.1512	9.9144
EPA 2008	• Ambient temperatures: 72 to 92 °F day time range • Nominal gasoline volatility: 9.0 psi Reid vapor pressure (RVP) • Weathered fuel volatility: 8.6 psi RVP • Gasoline sulfur content: 30 ppm • Diesel sulfur content: 330 ppm • Inspection/maintenance program: No • Reformulated gasoline: No		3.50	33.70	3.46	1.20	25.63		0.0084	0.0809	0.0083	0.0029	0.0615	
Gaines	• Idling 2007 Truck • Heating	0.53		133.00		0.14				0.3192		0.0003		
Gaines	• Idling 2007 Truck • Cooling	0.72		133.00		0.14				0.3192		0.0003		
Brodrick	N/A	0.62	23.10	171.00			63.90	6533.00	0.0554	0.4104			0.1534	15.6792
Lim	• Tests run in a climate controlled chamber, where the trucks idled at high and low RPMs in the following environments: - 90 degrees Fahrenheit with A/C on - 0 degrees Fahrenheit with heater on - 65 degrees Fahrenheit with no accessories on • Target cab temperature was 70 degrees Fahrenheit • Each idling test was run approximately 3 hours • Average taken	0.82		144.00				8224.00		0.3456				19.7376
Storey	600 RPM	0.95	44.00	154.00		3.92	77.60	9476.00	0.1056	0.3696		0.0094	0.1862	22.7424
EPA Guidance	N/A			135.00		0.89				0.3240		0.0021		
EPA Guidance	N/A			135.00		3.68				0.3240		0.0088		
Sierra Club, Maine Chapter	N/A		8.00				41.00		0.0192				0.0984	
Lutsey	N/A													
McCormick	N/A		7.45	89.90		1.42	72.80		0.0179	0.2158		0.0034	0.1747	
Calcagno	N/A	0.86	34.20	142.00		3.33	75.10	8639.00	0.0821	0.3408		0.0080	0.1802	20.7336

APPENDIX D.1 COST-EFFECTIVENESS MEASURED FOR EACH STUDY

SCENARIO				COST-EFFECTIVENESS ($/year per ton/year)					
Source	**Technology**	**Year**	**Owner**	**HC**	**NOx**	**VOC**	**PM**	**CO**	**CO2**
Ginn	APU	2004	Truck Owner						
Lust	APU	2008							
Stodolsky	APU	2000		$ 169,468.19	$ 13,809.18	$ 220,983.80	$2,548,566.08	$ 27,981.29	$ 270.85
Boeckenstedt	APU	2005							
Gaines	APU	2009	Truck Owner		$ 21,019.84		$4,225,504.34		$ 522.67
Lim	APU	2001							
Lim	APU	2001							
Storey	APU	2003							
Storey	APU	2003							
Wang	APU	2007	Truck Owner		$ 20,059.24				
Ginn	ATSE	2004	Truck Owner						
Ginn	ATSE	2004	Investor						
Boeckenstedt	ATSE	2005							
Gaines	ATSE	2009	Investor						
Gaines	ATSE	2009	Truck Owner						
Gaines	ATSE	2009	Investor						
Gaines	ATSE	2009	Truck Owner						
Shancita	ATSE	2014							
Wang	ATSE	2007	Investor		$ 14,818.51		$ 563,103.47		$ 278.27
Wang	ATSE	2007	Truck Owner		$ 22,868.55		$ 869,004.85		$ 429.44
Ginn	DFH	2004							
Lust	DFH	2008							
Stodolsky	DFH	1996			$ 11,659.97	$ 199,499.32		$ 22,986.76	$ 235.74
Gaines	DFH	2009							
Lim	DFH	1997							
Storey	DFH	2003							
Wang	DFH	2007	Truck Owner		$ 17,672.56				$ 383.58
Ginn	TSE	2004	Truck Owner		$ 22,261.44	$ 367,310.26	$2,088,588.64	$ 43,164.68	$ 387.48
Ginn	TSE	2004	Investor						
Lust	TSE	2008							
Stodolsky	TSE	1999			$ 8,330.62	$ 132,295.98	$ 718,435.96	$ 15,548.73	$ 225.86
Boeckenstedt	TSE	2005							
Gaines	TSE	2009	Investor		$ 1,707.57		$ (459,998.62)		
Gaines	TSE	2009	Truck Owner		$ 16,799.91		$5,133,628.02		
Calcagno	TSE	2004							
Calcagno	TSE	2004							
Calcagno	TSE	2004							
Zietsman	TSE	2009							
Zietsman	TSE	2009							
Zietsman	TSE	2009							
Shancita	TSE	2014							
Wang	TSE	2007	Investor		$ 1,473.27		$ 55,984.36		$ 32.06
Wang	TSE	2007	Truck Owner		$ 20,583.79		$ 782,184.21		$ 447.99

APPENDIX E.1 NET PRESENT VALUE CALCULATIONS FOR APUS BY SOURCE

GINN					
Data Year	2004				
Capital Cost in 2015	$ 8,813.48				
O&M/Year in 2015	$ 1,685.89				
Fuel Cost/Year in 2015	$ 1,218.15				
Idling Fuel Cost/Year in 2015	$ 5,665.81				
Discount Rate	3.00%				
Fuel Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 8,813.48			$ 8,813.48	
1		$ 1,218.15	$ 1,685.89	$ 2,904.04	$ 5,665.81
2		$ 1,254.69	$ 1,736.47	$ 2,991.16	$ 5,835.78
3		$ 1,292.33	$ 1,788.56	$ 3,080.90	$ 6,010.85
4		$ 1,331.10	$ 1,842.22	$ 3,173.32	$ 6,191.18
5	$ 8,813.48	$ 1,371.04	$ 1,897.49	$ 12,082.00	$ 6,376.92
6		$ 1,412.17	$ 1,954.41	$ 3,366.58	$ 6,568.22
7		$ 1,454.53	$ 2,013.04	$ 3,467.58	$ 6,765.27
8		$ 1,498.17	$ 2,073.44	$ 3,571.60	$ 6,968.23
9		$ 1,543.11	$ 2,135.64	$ 3,678.75	$ 7,177.28
10	$ 8,813.48	$ 1,589.41	$ 2,199.71	$ 12,602.59	$ 7,392.59
11		$ 1,637.09	$ 2,265.70	$ 3,902.79	$ 7,614.37
12		$ 1,686.20	$ 2,333.67	$ 4,019.87	$ 7,842.80
13		$ 1,736.79	$ 2,403.68	$ 4,140.47	$ 8,078.09
14		$ 1,788.89	$ 2,475.79	$ 4,264.68	$ 8,320.43
15	$ 8,813.48	$ 1,842.56	$ 2,550.06	$ 13,206.10	$ 8,570.04
16		$ 1,897.84	$ 2,626.57	$ 4,524.40	$ 8,827.14
17		$ 1,954.77	$ 2,705.36	$ 4,660.13	$ 9,091.96
18		$ 2,013.41	$ 2,786.52	$ 4,799.94	$ 9,364.72
19		$ 2,073.82	$ 2,870.12	$ 4,943.94	$ 9,645.66
20	$ 8,813.48	$ 2,136.03	$ 2,956.22	$ 13,905.73	$ 9,935.03
21		$ 2,200.11	$ 3,044.91	$ 5,245.02	$ 10,233.08
22		$ 2,266.12	$ 3,136.26	$ 5,402.37	$ 10,540.07
23		$ 2,334.10	$ 3,230.34	$ 5,564.44	$ 10,856.27
24		$ 2,404.12	$ 3,327.25	$ 5,731.38	$ 11,181.96
25	$ 8,813.48	$ 2,476.25	$ 3,427.07	$ 14,716.80	$ 11,517.42
26		$ 2,550.53	$ 3,529.88	$ 6,080.42	$ 11,862.94
27		$ 2,627.05	$ 3,635.78	$ 6,262.83	$ 12,218.83
28		$ 2,705.86	$ 3,744.85	$ 6,450.71	$ 12,585.40
29		$ 2,787.04	$ 3,857.20	$ 6,644.24	$ 12,962.96
30		$ 2,870.65	$ 3,972.92	$ 6,843.56	$ 13,351.85
SUM OF CASH FLOWS				**$ 191,041.83**	**$ 269,553.14**
NET PRESENT VALUE				**$ 118,741.79**	**$165,023.51**
DIFFERENCE OF COST				$ (46,281.72)	
EQUIVALENT ANNUAL COST				**$ 6,058.12**	
PAYBACK PERIOD				**3.19**	

LUST					
Data Year	2008				
Capital Cost in 2015	$ 9,942.14				
O&M/Year in 2015	$ 138.09				
Fuel Cost/Year in 2015	$ 9,718.44				
Idling Fuel Cost/Year in 2015	$ 11,433.46				
Discount Rate	3.00%				
Fuel Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 9,942.14			$ 9,942.14	
1		$ 9,718.44	$ 138.09	$ 9,856.52	$ 11,433.46
2		$ 10,009.99	$ 142.23	$ 10,152.22	$ 11,776.46
3		$ 10,310.29	$ 146.49	$ 10,456.79	$ 12,129.75
4		$ 10,619.60	$ 150.89	$ 10,770.49	$ 12,493.65
5	$ 9,942.14	$ 10,938.19	$ 155.42	$ 21,035.74	$ 12,868.46
6		$ 11,266.33	$ 160.08	$ 11,426.41	$ 13,254.51
7		$ 11,604.32	$ 164.88	$ 11,769.20	$ 13,652.15
8		$ 11,952.45	$ 169.83	$ 12,122.28	$ 14,061.71
9		$ 12,311.03	$ 174.92	$ 12,485.95	$ 14,483.56
10	$ 9,942.14	$ 12,680.36	$ 180.17	$ 22,802.66	$ 14,918.07
11		$ 13,060.77	$ 185.58	$ 13,246.34	$ 15,365.61
12		$ 13,452.59	$ 191.14	$ 13,643.73	$ 15,826.58
13		$ 13,856.17	$ 196.88	$ 14,053.05	$ 16,301.38
14		$ 14,271.85	$ 202.78	$ 14,474.64	$ 16,790.42
15	$ 9,942.14	$ 14,700.01	$ 208.87	$ 24,851.01	$ 17,294.13
16		$ 15,141.01	$ 215.13	$ 15,356.14	$ 17,812.95
17		$ 15,595.24	$ 221.59	$ 15,816.83	$ 18,347.34
18		$ 16,063.10	$ 228.23	$ 16,291.33	$ 18,897.76
19		$ 16,544.99	$ 235.08	$ 16,780.07	$ 19,464.70
20	$ 9,942.14	$ 17,041.34	$ 242.13	$ 27,225.61	$ 20,048.64
21		$ 17,552.58	$ 249.40	$ 17,801.98	$ 20,650.10
22		$ 18,079.16	$ 256.88	$ 18,336.04	$ 21,269.60
23		$ 18,621.53	$ 264.59	$ 18,886.12	$ 21,907.69
24		$ 19,180.18	$ 272.52	$ 19,452.70	$ 22,564.92
25	$ 9,942.14	$ 19,755.58	$ 280.70	$ 29,978.42	$ 23,241.86
26		$ 20,348.25	$ 289.12	$ 20,637.37	$ 23,939.12
27		$ 20,958.70	$ 297.79	$ 21,256.49	$ 24,657.29
28		$ 21,587.46	$ 306.73	$ 21,894.19	$ 25,397.01
29		$ 22,235.08	$ 315.93	$ 22,551.01	$ 26,158.92
30		$ 22,902.14	$ 325.41	$ 23,227.54	$ 26,943.69
SUM OF CASH FLOWS				**$ 528,581.03**	**$ 543,951.47**
NET PRESENT VALUE				**$320,033.04**	**$333,013.31**
DIFFERENCE OF COST				($12,980.27)	
EQUIVALENT ANNUAL COST				**$ 16,327.85**	
PAYBACK PERIOD				**6.30**	

STODOLSKY					
Data Year	2000				
Capital Cost in 2015	$ 9,799.42				
O&M/Year in 2015	$ -				
Fuel Cost/Year in 2015	$ 1,305.21				
Idling Fuel Cost/Year in 2015	$ 5,945.95				
Discount Rate	3.00%				
Fuel Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 9,799.42			$ 9,799.42	
1		$ 1,305.21	$ -	$ 1,305.21	$ 5,945.95
2		$ 1,344.36	$ -	$ 1,344.36	$ 6,124.33
3		$ 1,384.70	$ -	$ 1,384.70	$ 6,308.06
4		$ 1,426.24	$ -	$ 1,426.24	$ 6,497.30
5	$ 9,799.42	$ 1,469.02	$ -	$ 11,268.45	$ 6,692.22
6		$ 1,513.09	$ -	$ 1,513.09	$ 6,892.99
7		$ 1,558.49	$ -	$ 1,558.49	$ 7,099.78
8		$ 1,605.24	$ -	$ 1,605.24	$ 7,312.77
9		$ 1,653.40	$ -	$ 1,653.40	$ 7,532.15
10	$ 9,799.42	$ 1,703.00	$ -	$ 11,502.42	$ 7,758.12
11		$ 1,754.09	$ -	$ 1,754.09	$ 7,990.86
12		$ 1,806.71	$ -	$ 1,806.71	$ 8,230.59
13		$ 1,860.92	$ -	$ 1,860.92	$ 8,477.50
14		$ 1,916.74	$ -	$ 1,916.74	$ 8,731.83
15	$ 9,799.42	$ 1,974.25	$ -	$ 11,773.67	$ 8,993.78
16		$ 2,033.47	$ -	$ 2,033.47	$ 9,263.60
17		$ 2,094.48	$ -	$ 2,094.48	$ 9,541.50
18		$ 2,157.31	$ -	$ 2,157.31	$ 9,827.75
19		$ 2,222.03	$ -	$ 2,222.03	$ 10,122.58
20	$ 9,799.42	$ 2,288.69	$ -	$ 12,088.11	$ 10,426.26
21		$ 2,357.35	$ -	$ 2,357.35	$ 10,739.05
22		$ 2,428.07	$ -	$ 2,428.07	$ 11,061.22
23		$ 2,500.91	$ -	$ 2,500.91	$ 11,393.06
24		$ 2,575.94	$ -	$ 2,575.94	$ 11,734.85
25	$ 9,799.42	$ 2,653.22	$ -	$ 12,452.64	$ 12,086.89
26		$ 2,732.82	$ -	$ 2,732.82	$ 12,449.50
27		$ 2,814.80	$ -	$ 2,814.80	$ 12,822.98
28		$ 2,899.25	$ -	$ 2,899.25	$ 13,207.67
29		$ 2,986.22	$ -	$ 2,986.22	$ 13,603.90
30		$ 3,075.81	$ -	$ 3,075.81	$ 14,012.02
SUM OF CASH FLOWS				**$ 120,892.38**	**$ 282,881.04**
NET PRESENT VALUE				**$77,626.99**	**$173,183.01**
DIFFERENCE OF COST				($95,556.02)	
EQUIVALENT ANNUAL COST				**$ 3,960.47**	
PAYBACK PERIOD				**2.11**	

BOECKENSTEDT					
Data Year	2005				
Capital Cost in 2015	$ 9,547.62				
O&M/Year in 2015	$ 907.27				
Fuel Cost/Year in 2015	$ 1,346.14				
Idling Fuel Cost/Year in 2	$ 6,216.45				
Discount Rate	3.00%				
Fuel Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 9,547.62			$ 9,547.62	
1		$ 1,346.14	$ 907.27	$ 2,253.41	$ 6,216.45
2		$ 1,386.53	$ 934.49	$ 2,321.01	$ 6,402.94
3		$ 1,428.12	$ 962.52	$ 2,390.64	$ 6,595.03
4		$ 1,470.96	$ 991.40	$ 2,462.36	$ 6,792.88
5	$ 9,547.62	$ 1,515.09	$ 1,021.14	$ 12,083.85	$ 6,996.67
6		$ 1,560.55	$ 1,051.77	$ 2,612.32	$ 7,206.57
7		$ 1,607.36	$ 1,083.32	$ 2,690.69	$ 7,422.77
8		$ 1,655.58	$ 1,115.82	$ 2,771.41	$ 7,645.45
9		$ 1,705.25	$ 1,149.30	$ 2,854.55	$ 7,874.81
10	$ 9,547.62	$ 1,756.41	$ 1,183.78	$ 12,487.81	$ 8,111.06
11		$ 1,809.10	$ 1,219.29	$ 3,028.39	$ 8,354.39
12		$ 1,863.37	$ 1,255.87	$ 3,119.24	$ 8,605.02
13		$ 1,919.28	$ 1,293.55	$ 3,212.82	$ 8,863.17
14		$ 1,976.85	$ 1,332.35	$ 3,309.21	$ 9,129.07
15	$ 9,547.62	$ 2,036.16	$ 1,372.32	$ 12,956.10	$ 9,402.94
16		$ 2,097.24	$ 1,413.49	$ 3,510.74	$ 9,685.03
17		$ 2,160.16	$ 1,455.90	$ 3,616.06	$ 9,975.58
18		$ 2,224.97	$ 1,499.57	$ 3,724.54	$ 10,274.84
19		$ 2,291.72	$ 1,544.56	$ 3,836.28	$ 10,583.09
20	$ 9,547.62	$ 2,360.47	$ 1,590.90	$ 13,498.98	$ 10,900.58
21		$ 2,431.28	$ 1,638.63	$ 4,069.91	$ 11,227.60
22		$ 2,504.22	$ 1,687.78	$ 4,192.00	$ 11,564.43
23		$ 2,579.35	$ 1,738.42	$ 4,317.76	$ 11,911.36
24		$ 2,656.73	$ 1,790.57	$ 4,447.30	$ 12,268.70
25	$ 9,547.62	$ 2,736.43	$ 1,844.29	$ 14,128.33	$ 12,636.76
26		$ 2,818.52	$ 1,899.62	$ 4,718.14	$ 13,015.87
27		$ 2,903.08	$ 1,956.60	$ 4,859.68	$ 13,406.34
28		$ 2,990.17	$ 2,015.30	$ 5,005.47	$ 13,808.53
29		$ 3,079.87	$ 2,075.76	$ 5,155.64	$ 14,222.79
30		$ 3,172.27	$ 2,138.03	$ 5,310.30	$ 14,649.47
SUM OF CASH FLOWS				**$ 164,492.56**	**$ 295,750.18**
NET PRESENT VALUE				**$103,393.78**	**$181,061.64**
DIFFERENCE OF COST				($77,667.86)	
EQUIVALENT ANNUAL COST				**$ 5,275.07**	
PAYBACK PERIOD				**2.41**	

GAINES					
Data Year	2009				
Capital Cost in 2015	$ 8,868.89				
O&M/Year in 2015	$ 1,097.52				
Fuel Cost/Year in 2015	$ 1,887.11				
Idling Fuel Cost/Year in 2015	$ 8,204.83				
Discount Rate	3.00%				
Fuel Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 8,868.89			$ 8,868.89	
1		$ 1,887.11	$ 1,097.52	$ 2,984.63	$ 8,204.83
2		$ 1,943.72	$ 1,130.45	$ 3,074.17	$ 8,450.97
3		$ 2,002.04	$ 1,164.36	$ 3,166.40	$ 8,704.50
4		$ 2,062.10	$ 1,199.29	$ 3,261.39	$ 8,965.64
5	$ 8,868.89	$ 2,123.96	$ 1,235.27	$ 12,228.12	$ 9,234.61
6		$ 2,187.68	$ 1,272.33	$ 3,460.01	$ 9,511.64
7		$ 2,253.31	$ 1,310.50	$ 3,563.81	$ 9,796.99
8		$ 2,320.91	$ 1,349.82	$ 3,670.72	$ 10,090.90
9		$ 2,390.53	$ 1,390.31	$ 3,780.85	$ 10,393.63
10	$ 8,868.89	$ 2,462.25	$ 1,432.02	$ 12,763.16	$ 10,705.44
11		$ 2,536.12	$ 1,474.98	$ 4,011.10	$ 11,026.60
12		$ 2,612.20	$ 1,519.23	$ 4,131.43	$ 11,357.40
13		$ 2,690.57	$ 1,564.81	$ 4,255.38	$ 11,698.12
14		$ 2,771.29	$ 1,611.75	$ 4,383.04	$ 12,049.07
15	$ 8,868.89	$ 2,854.42	$ 1,660.10	$ 13,383.41	$ 12,410.54
16		$ 2,940.06	$ 1,709.91	$ 4,649.96	$ 12,782.85
17		$ 3,028.26	$ 1,761.20	$ 4,789.46	$ 13,166.34
18		$ 3,119.11	$ 1,814.04	$ 4,933.15	$ 13,561.33
19		$ 3,212.68	$ 1,868.46	$ 5,081.14	$ 13,968.17
20	$ 8,868.89	$ 3,309.06	$ 1,924.52	$ 14,102.46	$ 14,387.21
21		$ 3,408.33	$ 1,982.25	$ 5,390.58	$ 14,818.83
22		$ 3,510.58	$ 2,041.72	$ 5,552.30	$ 15,263.40
23		$ 3,615.90	$ 2,102.97	$ 5,718.87	$ 15,721.30
24		$ 3,724.38	$ 2,166.06	$ 5,890.44	$ 16,192.94
25	$ 8,868.89	$ 3,836.11	$ 2,231.04	$ 14,936.03	$ 16,678.72
26		$ 3,951.19	$ 2,297.97	$ 6,249.16	$ 17,179.09
27		$ 4,069.73	$ 2,366.91	$ 6,436.64	$ 17,694.46
28		$ 4,191.82	$ 2,437.92	$ 6,629.74	$ 18,225.29
29		$ 4,317.57	$ 2,511.06	$ 6,828.63	$ 18,772.05
30		$ 4,447.10	$ 2,586.39	$ 7,033.49	$ 19,335.21
SUM OF CASH FLOWS				**$ 195,208.55**	**$ 390,348.07**
NET PRESENT VALUE				**$121,251.04**	**$238,975.55**
DIFFERENCE OF COST				($117,724.51)	
EQUIVALENT ANNUAL COST				**$ 6,186.14**	
PAYBACK PERIOD				**1.70**	

WANG					
Data Year	2007				
Capital Cost in 2015	$ 9,178.50				
O&M/Year in 2015	$ 573.66				
Fuel Cost/Year in 2015	$ 1,986.00				
Idling Fuel Cost/Year in 2015	$ 9,929.99				
Discount Rate	3.00%				
Fuel Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 9,178.50			$ 9,178.50	
1		$ 1,986.00	$ 573.66	$ 2,559.66	$ 9,929.99
2		$ 2,045.58	$ 590.87	$ 2,636.45	$ 10,227.89
3		$ 2,106.95	$ 608.59	$ 2,715.54	$ 10,534.73
4		$ 2,170.15	$ 626.85	$ 2,797.00	$ 10,850.77
5	$ 9,178.50	$ 2,235.26	$ 645.66	$ 12,059.42	$ 11,176.30
6		$ 2,302.32	$ 665.03	$ 2,967.34	$ 11,511.59
7		$ 2,371.39	$ 684.98	$ 3,056.36	$ 11,856.93
8		$ 2,442.53	$ 705.53	$ 3,148.05	$ 12,212.64
9		$ 2,515.80	$ 726.69	$ 3,242.49	$ 12,579.02
10	$ 9,178.50	$ 2,591.28	$ 748.49	$ 12,518.27	$ 12,956.39
11		$ 2,669.02	$ 770.95	$ 3,439.96	$ 13,345.08
12		$ 2,749.09	$ 794.07	$ 3,543.16	$ 13,745.43
13		$ 2,831.56	$ 817.90	$ 3,649.46	$ 14,157.80
14		$ 2,916.51	$ 842.43	$ 3,758.94	$ 14,582.53
15	$ 9,178.50	$ 3,004.00	$ 867.71	$ 13,050.21	$ 15,020.01
16		$ 3,094.12	$ 893.74	$ 3,987.86	$ 15,470.61
17		$ 3,186.95	$ 920.55	$ 4,107.50	$ 15,934.73
18		$ 3,282.55	$ 948.17	$ 4,230.72	$ 16,412.77
19		$ 3,381.03	$ 976.61	$ 4,357.64	$ 16,905.15
20	$ 9,178.50	$ 3,482.46	$ 1,005.91	$ 13,666.88	$ 17,412.31
21		$ 3,586.93	$ 1,036.09	$ 4,623.02	$ 17,934.67
22		$ 3,694.54	$ 1,067.17	$ 4,761.71	$ 18,472.72
23		$ 3,805.38	$ 1,099.19	$ 4,904.56	$ 19,026.90
24		$ 3,919.54	$ 1,132.16	$ 5,051.70	$ 19,597.70
25	$ 9,178.50	$ 4,037.13	$ 1,166.13	$ 14,381.76	$ 20,185.63
26		$ 4,158.24	$ 1,201.11	$ 5,359.35	$ 20,791.20
27		$ 4,282.99	$ 1,237.14	$ 5,520.13	$ 21,414.94
28		$ 4,411.48	$ 1,274.26	$ 5,685.73	$ 22,057.39
29		$ 4,543.82	$ 1,312.48	$ 5,856.31	$ 22,719.11
30		$ 4,680.14	$ 1,351.86	$ 6,032.00	$ 23,400.68
SUM OF CASH FLOWS				**$ 176,847.70**	**$ 472,423.62**
NET PRESENT VALUE				**$110,520.06**	**$289,223.15**
DIFFERENCE OF COST				($178,703.09)	
EQUIVALENT ANNUAL COST				**$ 5,638.65**	
PAYBACK PERIOD				**1.25**	

APPENDIX D.2 NET PRESENT VALUE CALCULATIONS FOR DFHS BY SOURCE

GINN					
Data Year	2004				
Capital Cost in 2015	$ 2,518.14				
O&M/Year in 2015	$ -				
Fuel Cost/Year in 2015	$ 226.63				
Idling Fuel Cost/Year in 2015	$ 5,665.81				
Discount Rate	3.00%				
Fuel Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 2,518.14			$ 2,518.14	
1		$ 226.63	$ -	$ 226.63	$ 5,665.81
2		$ 233.43	$ -	$ 233.43	$ 5,835.78
3		$ 240.43	$ -	$ 240.43	$ 6,010.85
4		$ 247.65	$ -	$ 247.65	$ 6,191.18
5	$ 2,518.14	$ 255.08	$ -	$ 2,773.21	$ 6,376.92
6		$ 262.73	$ -	$ 262.73	$ 6,568.22
7		$ 270.61	$ -	$ 270.61	$ 6,765.27
8		$ 278.73	$ -	$ 278.73	$ 6,968.23
9		$ 287.09	$ -	$ 287.09	$ 7,177.28
10	$ 2,518.14	$ 295.70	$ -	$ 2,813.84	$ 7,392.59
11		$ 304.57	$ -	$ 304.57	$ 7,614.37
12		$ 313.71	$ -	$ 313.71	$ 7,842.80
13		$ 323.12	$ -	$ 323.12	$ 8,078.09
14		$ 332.82	$ -	$ 332.82	$ 8,320.43
15	$ 2,518.14	$ 342.80	$ -	$ 2,860.94	$ 8,570.04
16		$ 353.09	$ -	$ 353.09	$ 8,827.14
17		$ 363.68	$ -	$ 363.68	$ 9,091.96
18		$ 374.59	$ -	$ 374.59	$ 9,364.72
19		$ 385.83	$ -	$ 385.83	$ 9,645.66
20	$ 2,518.14	$ 397.40	$ -	$ 2,915.54	$ 9,935.03
21		$ 409.32	$ -	$ 409.32	$ 10,233.08
22		$ 421.60	$ -	$ 421.60	$ 10,540.07
23		$ 434.25	$ -	$ 434.25	$ 10,856.27
24		$ 447.28	$ -	$ 447.28	$ 11,181.96
25	$ 2,518.14	$ 460.70	$ -	$ 2,978.83	$ 11,517.42
26		$ 474.52	$ -	$ 474.52	$ 11,862.94
27		$ 488.75	$ -	$ 488.75	$ 12,218.83
28		$ 503.42	$ -	$ 503.42	$ 12,585.40
29		$ 518.52	$ -	$ 518.52	$ 12,962.96
30		$ 534.07	$ -	$ 534.07	$ 13,351.85
SUM OF CASH FLOWS				**$ 25,890.94**	**$ 269,553.14**
NET PRESENT VALUE				**$16,872.02**	**$165,023.51**
DIFFERENCE OF COST				($148,151.50)	
EQUIVALENT ANNUAL COST				**$ 860.80**	
PAYBACK PERIOD				**0.46**	

LUST					
Data Year	2008				
Capital Cost in 2015	$ 1,325.62				
O&M/Year in 2015	$ 121.52				
Fuel Cost/Year in 2015	$ 9,718.44				
Idling Fuel Cost/Year in 2015	$ 11,433.46				
Discount Rate	3.00%				
Fuel Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 1,325.62			$ 1,325.62	
1		$ 9,718.44	$ 121.52	$ 9,839.95	$ 11,433.46
2		$ 10,009.99	$ 125.16	$ 10,135.15	$ 11,776.46
3		$ 10,310.29	$ 128.92	$ 10,439.21	$ 12,129.75
4		$ 10,619.60	$ 132.78	$ 10,752.38	$ 12,493.65
5	$ 1,325.62	$ 10,938.19	$ 136.77	$ 12,400.57	$ 12,868.46
6		$ 11,266.33	$ 140.87	$ 11,407.20	$ 13,254.51
7		$ 11,604.32	$ 145.10	$ 11,749.42	$ 13,652.15
8		$ 11,952.45	$ 149.45	$ 12,101.90	$ 14,061.71
9		$ 12,311.03	$ 153.93	$ 12,464.96	$ 14,483.56
10	$ 1,325.62	$ 12,680.36	$ 158.55	$ 14,164.53	$ 14,918.07
11		$ 13,060.77	$ 163.31	$ 13,224.07	$ 15,365.61
12		$ 13,452.59	$ 168.21	$ 13,620.80	$ 15,826.58
13		$ 13,856.17	$ 173.25	$ 14,029.42	$ 16,301.38
14		$ 14,271.85	$ 178.45	$ 14,450.30	$ 16,790.42
15	$ 1,325.62	$ 14,700.01	$ 183.80	$ 16,209.43	$ 17,294.13
16		$ 15,141.01	$ 189.32	$ 15,330.33	$ 17,812.95
17		$ 15,595.24	$ 195.00	$ 15,790.24	$ 18,347.34
18		$ 16,063.10	$ 200.85	$ 16,263.94	$ 18,897.76
19		$ 16,544.99	$ 206.87	$ 16,751.86	$ 19,464.70
20	$ 1,325.62	$ 17,041.34	$ 213.08	$ 18,580.04	$ 20,048.64
21		$ 17,552.58	$ 219.47	$ 17,772.05	$ 20,650.10
22		$ 18,079.16	$ 226.05	$ 18,305.21	$ 21,269.60
23		$ 18,621.53	$ 232.84	$ 18,854.37	$ 21,907.69
24		$ 19,180.18	$ 239.82	$ 19,420.00	$ 22,564.92
25	$ 1,325.62	$ 19,755.58	$ 247.01	$ 21,328.22	$ 23,241.86
26		$ 20,348.25	$ 254.43	$ 20,602.68	$ 23,939.12
27		$ 20,958.70	$ 262.06	$ 21,220.76	$ 24,657.29
28		$ 21,587.46	$ 269.92	$ 21,857.38	$ 25,397.01
29		$ 22,235.08	$ 278.02	$ 22,513.10	$ 26,158.92
30		$ 22,902.14	$ 286.36	$ 23,188.49	$ 26,943.69
SUM OF CASH FLOWS				**$ 476,093.59**	**$ 543,951.47**
NET PRESENT VALUE				**$283,761.19**	**$333,013.31**
DIFFERENCE OF COST				($49,252.12)	
EQUIVALENT ANNUAL COST				**$ 14,477.29**	
PAYBACK PERIOD				**0.83**	

STODOLSKY					
Data Year	2000				
Capital Cost in 2015	$ 4,419.75				
O&M/Year in 2015	$ -				
Fuel Cost/Year in 2015	$ 1,450.23				
Idling Fuel Cost/Year in 2015	$ 7,251.16				
Discount Rate	3.00%				
Fuel Cost Growth Rate	5%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 4,419.75			$ 4,419.75	
1		$ 1,450.23	$ -	$ 1,450.23	$ 7,251.16
2		$ 1,522.74	$ -	$ 1,522.74	$ 7,613.72
3		$ 1,598.88	$ -	$ 1,598.88	$ 7,994.40
4		$ 1,678.82	$ -	$ 1,678.82	$ 8,394.12
5	$ 4,419.75	$ 1,762.77	$ -	$ 6,182.52	$ 8,813.83
6		$ 1,850.90	$ -	$ 1,850.90	$ 9,254.52
7		$ 1,943.45	$ -	$ 1,943.45	$ 9,717.25
8		$ 2,040.62	$ -	$ 2,040.62	$ 10,203.11
9		$ 2,142.65	$ -	$ 2,142.65	$ 10,713.26
10	$ 4,419.75	$ 2,249.79	$ -	$ 6,669.54	$ 11,248.93
11		$ 2,362.27	$ -	$ 2,362.27	$ 11,811.37
12		$ 2,480.39	$ -	$ 2,480.39	$ 12,401.94
13		$ 2,604.41	$ -	$ 2,604.41	$ 13,022.04
14		$ 2,734.63	$ -	$ 2,734.63	$ 13,673.14
15	$ 4,419.75	$ 2,871.36	$ -	$ 7,291.11	$ 14,356.80
16		$ 3,014.93	$ -	$ 3,014.93	$ 15,074.64
17		$ 3,165.67	$ -	$ 3,165.67	$ 15,828.37
18		$ 3,323.96	$ -	$ 3,323.96	$ 16,619.79
19		$ 3,490.16	$ -	$ 3,490.16	$ 17,450.78
20	$ 4,419.75	$ 3,664.66	$ -	$ 8,084.42	$ 18,323.32
21		$ 3,847.90	$ -	$ 3,847.90	$ 19,239.48
22		$ 4,040.29	$ -	$ 4,040.29	$ 20,201.46
23		$ 4,242.31	$ -	$ 4,242.31	$ 21,211.53
24		$ 4,454.42	$ -	$ 4,454.42	$ 22,272.11
25	$ 4,419.75	$ 4,677.14	$ -	$ 9,096.90	$ 23,385.71
26		$ 4,911.00	$ -	$ 4,911.00	$ 24,555.00
27		$ 5,156.55	$ -	$ 5,156.55	$ 25,782.75
28		$ 5,414.38	$ -	$ 5,414.38	$ 27,071.88
29		$ 5,685.10	$ -	$ 5,685.10	$ 28,425.48
30		$ 5,969.35	$ -	$ 5,969.35	$ 29,846.75
SUM OF CASH FLOWS				**$ 122,870.25**	**$ 481,758.62**
NET PRESENT VALUE				**$73,317.65**	**$283,006.57**
DIFFERENCE OF COST				($209,688.92)	
EQUIVALENT ANNUAL COST				**$ 3,740.61**	
PAYBACK PERIOD				**0.76**	

WANG					
Data Year	2007				
Capital Cost in 2015	$ 2,294.63				
O&M/Year in 2015	$ 573.66				
Fuel Cost/Year in 2015	$ 2,979.00				
Idling Fuel Cost/Year in 2015	$ 9,929.99				
Discount Rate	3.00%				
Fuel Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 2,294.63			$ 2,294.63	
1		$ 2,979.00	$ 573.66	$ 3,552.65	$ 9,929.99
2		$ 3,068.37	$ 590.87	$ 3,659.23	$ 10,227.89
3		$ 3,160.42	$ 608.59	$ 3,769.01	$ 10,534.73
4		$ 3,255.23	$ 626.85	$ 3,882.08	$ 10,850.77
5	$ 2,294.63	$ 3,352.89	$ 645.66	$ 6,293.17	$ 11,176.30
6		$ 3,453.48	$ 665.03	$ 4,118.50	$ 11,511.59
7		$ 3,557.08	$ 684.98	$ 4,242.06	$ 11,856.93
8		$ 3,663.79	$ 705.53	$ 4,369.32	$ 12,212.64
9		$ 3,773.71	$ 726.69	$ 4,500.40	$ 12,579.02
10	$ 2,294.63	$ 3,886.92	$ 748.49	$ 6,930.04	$ 12,956.39
11		$ 4,003.52	$ 770.95	$ 4,774.47	$ 13,345.08
12		$ 4,123.63	$ 794.07	$ 4,917.71	$ 13,745.43
13		$ 4,247.34	$ 817.90	$ 5,065.24	$ 14,157.80
14		$ 4,374.76	$ 842.43	$ 5,217.19	$ 14,582.53
15	$ 2,294.63	$ 4,506.00	$ 867.71	$ 7,668.34	$ 15,020.01
16		$ 4,641.18	$ 893.74	$ 5,534.92	$ 15,470.61
17		$ 4,780.42	$ 920.55	$ 5,700.97	$ 15,934.73
18		$ 4,923.83	$ 948.17	$ 5,872.00	$ 16,412.77
19		$ 5,071.55	$ 976.61	$ 6,048.16	$ 16,905.15
20	$ 2,294.63	$ 5,223.69	$ 1,005.91	$ 8,524.23	$ 17,412.31
21		$ 5,380.40	$ 1,036.09	$ 6,416.49	$ 17,934.67
22		$ 5,541.81	$ 1,067.17	$ 6,608.98	$ 18,472.72
23		$ 5,708.07	$ 1,099.19	$ 6,807.25	$ 19,026.90
24		$ 5,879.31	$ 1,132.16	$ 7,011.47	$ 19,597.70
25	$ 2,294.63	$ 6,055.69	$ 1,166.13	$ 9,516.44	$ 20,185.63
26		$ 6,237.36	$ 1,201.11	$ 7,438.47	$ 20,791.20
27		$ 6,424.48	$ 1,237.14	$ 7,661.62	$ 21,414.94
28		$ 6,617.22	$ 1,274.26	$ 7,891.47	$ 22,057.39
29		$ 6,815.73	$ 1,312.48	$ 8,128.22	$ 22,719.11
30		$ 7,020.20	$ 1,351.86	$ 8,372.06	$ 23,400.68
SUM OF CASH FLOWS				**$ 182,786.79**	**$ 472,423.62**
NET PRESENT VALUE				**$109,996.15**	**$289,223.15**
DIFFERENCE OF COST				($179,227.00)	
EQUIVALENT ANNUAL COST				**$ 5,611.92**	
PAYBACK PERIOD				**0.36**	

APPENDIX D.3 NET PRESENT VALUE CALCULATIONS FOR TSES BY SOURCE

GINN - Truck Owner Costs					
Data Year	2004				
Capital Cost in 2015	$ 3,147.67				
O&M/Year in 2015	$ 4,721.51				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 3,147.67			$ 3,147.67	
1		$ -	$ 4,721.51	$ 4,721.51	$ 7,335.00
2		$ -	$ 4,863.15	$ 4,863.15	$ 7,555.05
3		$ -	$ 5,009.05	$ 5,009.05	$ 7,781.70
4		$ -	$ 5,159.32	$ 5,159.32	$ 8,015.15
5		$ -	$ 5,314.10	$ 5,314.10	$ 8,255.61
6		$ -	$ 5,473.52	$ 5,473.52	$ 8,503.28
7		$ -	$ 5,637.73	$ 5,637.73	$ 8,758.37
8		$ -	$ 5,806.86	$ 5,806.86	$ 9,021.12
9		$ -	$ 5,981.06	$ 5,981.06	$ 9,291.76
10		$ -	$ 6,160.49	$ 6,160.49	$ 9,570.51
11		$ -	$ 6,345.31	$ 6,345.31	$ 9,857.63
12		$ -	$ 6,535.67	$ 6,535.67	$ 10,153.36
13		$ -	$ 6,731.74	$ 6,731.74	$ 10,457.96
14		$ -	$ 6,933.69	$ 6,933.69	$ 10,771.69
15	$ 3,147.67	$ -	$ 7,141.70	$ 10,289.37	$ 11,094.85
16		$ -	$ 7,355.95	$ 7,355.95	$ 11,427.69
17		$ -	$ 7,576.63	$ 7,576.63	$ 11,770.52
18		$ -	$ 7,803.93	$ 7,803.93	$ 12,123.64
19		$ -	$ 8,038.05	$ 8,038.05	$ 12,487.35
20		$ -	$ 8,279.19	$ 8,279.19	$ 12,861.97
21		$ -	$ 8,527.57	$ 8,527.57	$ 13,247.83
22		$ -	$ 8,783.39	$ 8,783.39	$ 13,645.26
23		$ -	$ 9,046.89	$ 9,046.89	$ 14,054.62
24		$ -	$ 9,318.30	$ 9,318.30	$ 14,476.26
25		$ -	$ 9,597.85	$ 9,597.85	$ 14,910.54
26		$ -	$ 9,885.79	$ 9,885.79	$ 15,357.86
27		$ -	$ 10,182.36	$ 10,182.36	$ 15,818.60
28		$ -	$ 10,487.83	$ 10,487.83	$ 16,293.15
29		$ -	$ 10,802.46	$ 10,802.46	$ 16,781.95
30		$ -	$ 11,126.54	$ 11,126.54	$ 17,285.41
SUM OF CASH FLOWS				**$ 230,922.96**	**$ 348,965.67**
NET PRESENT VALUE				**$138,531.69**	**$213,640.78**
DIFFERENCE OF COST				($75,109.09)	
EQUIVALENT ANNUAL COST				**$ 7,067.78**	
PAYBACK PERIOD				**1.20**	

GINN - Investor Costs					
Data Year	2004				
Capital Cost in 2015	$ 3,147.67				
O&M/Year in 2015	$ -				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 3,147.67			$ 3,147.67	
1		$ -	$ -	$ -	$ 7,335.00
2		$ -	$ -	$ -	$ 7,555.05
3		$ -	$ -	$ -	$ 7,781.70
4		$ -	$ -	$ -	$ 8,015.15
5		$ -	$ -	$ -	$ 8,255.61
6		$ -	$ -	$ -	$ 8,503.28
7		$ -	$ -	$ -	$ 8,758.37
8		$ -	$ -	$ -	$ 9,021.12
9		$ -	$ -	$ -	$ 9,291.76
10		$ -	$ -	$ -	$ 9,570.51
11		$ -	$ -	$ -	$ 9,857.63
12		$ -	$ -	$ -	$ 10,153.36
13		$ -	$ -	$ -	$ 10,457.96
14		$ -	$ -	$ -	$ 10,771.69
15	$ 3,147.67	$ -	$ -	$ 3,147.67	$ 11,094.85
16		$ -	$ -	$ -	$ 11,427.69
17		$ -	$ -	$ -	$ 11,770.52
18		$ -	$ -	$ -	$ 12,123.64
19		$ -	$ -	$ -	$ 12,487.35
20		$ -	$ -	$ -	$ 12,861.97
21		$ -	$ -	$ -	$ 13,247.83
22		$ -	$ -	$ -	$ 13,645.26
23		$ -	$ -	$ -	$ 14,054.62
24		$ -	$ -	$ -	$ 14,476.26
25		$ -	$ -	$ -	$ 14,910.54
26		$ -	$ -	$ -	$ 15,357.86
27		$ -	$ -	$ -	$ 15,818.60
28		$ -	$ -	$ -	$ 16,293.15
29		$ -	$ -	$ -	$ 16,781.95
30		$ -	$ -	$ -	$ 17,285.41
SUM OF CASH FLOWS				**$ 6,295.34**	**$ 348,965.67**
NET PRESENT VALUE				**$5,017.52**	**$213,640.78**
DIFFERENCE OF COST				($208,623.26)	
EQUIVALENT ANNUAL COST				**$ 255.99**	
PAYBACK PERIOD				**0.43**	

LUST					
Data Year	2008				
Capital Cost in 2015	$ 4,418.73				
O&M/Year in 2015	$ 7,554.41				
Fuel Cost/Year in 2015	$ 9,718.44				
Idling Fuel Cost/Year in 2015	$ 11,433.46				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 4,418.73			$ 4,418.73	
1		$ 9,718.44	$ 7,554.41	$ 17,272.85	$ 11,433.46
2		$ 10,009.99	$ 7,781.04	$ 17,791.03	$ 11,776.46
3		$ 10,310.29	$ 8,014.47	$ 18,324.76	$ 12,129.75
4		$ 10,619.60	$ 8,254.91	$ 18,874.51	$ 12,493.65
5		$ 10,938.19	$ 8,502.55	$ 19,440.74	$ 12,868.46
6		$ 11,266.33	$ 8,757.63	$ 20,023.97	$ 13,254.51
7		$ 11,604.32	$ 9,020.36	$ 20,624.68	$ 13,652.15
8		$ 11,952.45	$ 9,290.97	$ 21,243.42	$ 14,061.71
9		$ 12,311.03	$ 9,569.70	$ 21,880.73	$ 14,483.56
10		$ 12,680.36	$ 9,856.79	$ 22,537.15	$ 14,918.07
11		$ 13,060.77	$ 10,152.49	$ 23,213.26	$ 15,365.61
12		$ 13,452.59	$ 10,457.07	$ 23,909.66	$ 15,826.58
13		$ 13,856.17	$ 10,770.78	$ 24,626.95	$ 16,301.38
14		$ 14,271.85	$ 11,093.91	$ 25,365.76	$ 16,790.42
15	$ 4,418.73	$ 14,700.01	$ 11,426.72	$ 30,545.46	$ 17,294.13
16		$ 15,141.01	$ 11,769.52	$ 26,910.53	$ 17,812.95
17		$ 15,595.24	$ 12,122.61	$ 27,717.85	$ 18,347.34
18		$ 16,063.10	$ 12,486.29	$ 28,549.39	$ 18,897.76
19		$ 16,544.99	$ 12,860.88	$ 29,405.87	$ 19,464.70
20		$ 17,041.34	$ 13,246.70	$ 30,288.04	$ 20,048.64
21		$ 17,552.58	$ 13,644.10	$ 31,196.69	$ 20,650.10
22		$ 18,079.16	$ 14,053.43	$ 32,132.59	$ 21,269.60
23		$ 18,621.53	$ 14,475.03	$ 33,096.56	$ 21,907.69
24		$ 19,180.18	$ 14,909.28	$ 34,089.46	$ 22,564.92
25		$ 19,755.58	$ 15,356.56	$ 35,112.14	$ 23,241.86
26		$ 20,348.25	$ 15,817.26	$ 36,165.51	$ 23,939.12
27		$ 20,958.70	$ 16,291.77	$ 37,250.47	$ 24,657.29
28		$ 21,587.46	$ 16,780.53	$ 38,367.99	$ 25,397.01
29		$ 22,235.08	$ 17,283.94	$ 39,519.03	$ 26,158.92
30		$ 22,902.14	$ 17,802.46	$ 40,704.60	$ 26,943.69
SUM OF CASH FLOWS				**$ 830,600.39**	**$ 543,951.47**
NET PRESENT VALUE				**$495,483.11**	**$333,013.31**
DIFFERENCE OF COST				$162,469.80	
EQUIVALENT ANNUAL COST				**$ 25,279.18**	
PAYBACK PERIOD				**-0.76**	

STODOLSKY					
Data Year	2000				
Capital Cost in 2015	$ 5,800.93				
O&M/Year in 2015	$ 1,425.37				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 5,800.93			$ 5,800.93	
1		$ -	$ 1,425.37	$ 1,425.37	$ 7,335.00
2		$ -	$ 1,468.13	$ 1,468.13	$ 7,555.05
3		$ -	$ 1,512.18	$ 1,512.18	$ 7,781.70
4		$ -	$ 1,557.54	$ 1,557.54	$ 8,015.15
5		$ -	$ 1,604.27	$ 1,604.27	$ 8,255.61
6		$ -	$ 1,652.40	$ 1,652.40	$ 8,503.28
7		$ -	$ 1,701.97	$ 1,701.97	$ 8,758.37
8		$ -	$ 1,753.03	$ 1,753.03	$ 9,021.12
9		$ -	$ 1,805.62	$ 1,805.62	$ 9,291.76
10		$ -	$ 1,859.79	$ 1,859.79	$ 9,570.51
11		$ -	$ 1,915.58	$ 1,915.58	$ 9,857.63
12		$ -	$ 1,973.05	$ 1,973.05	$ 10,153.36
13		$ -	$ 2,032.24	$ 2,032.24	$ 10,457.96
14		$ -	$ 2,093.20	$ 2,093.20	$ 10,771.69
15	$ 5,800.93	$ -	$ 2,156.00	$ 7,956.93	$ 11,094.85
16		$ -	$ 2,220.68	$ 2,220.68	$ 11,427.69
17		$ -	$ 2,287.30	$ 2,287.30	$ 11,770.52
18		$ -	$ 2,355.92	$ 2,355.92	$ 12,123.64
19		$ -	$ 2,426.60	$ 2,426.60	$ 12,487.35
20		$ -	$ 2,499.40	$ 2,499.40	$ 12,861.97
21		$ -	$ 2,574.38	$ 2,574.38	$ 13,247.83
22		$ -	$ 2,651.61	$ 2,651.61	$ 13,645.26
23		$ -	$ 2,731.16	$ 2,731.16	$ 14,054.62
24		$ -	$ 2,813.09	$ 2,813.09	$ 14,476.26
25		$ -	$ 2,897.48	$ 2,897.48	$ 14,910.54
26		$ -	$ 2,984.41	$ 2,984.41	$ 15,357.86
27		$ -	$ 3,073.94	$ 3,073.94	$ 15,818.60
28		$ -	$ 3,166.16	$ 3,166.16	$ 16,293.15
29		$ -	$ 3,261.14	$ 3,261.14	$ 16,781.95
30		$ -	$ 3,358.98	$ 3,358.98	$ 17,285.41
SUM OF CASH FLOWS				**$ 79,414.45**	**$ 348,965.67**
NET PRESENT VALUE				**$49,553.37**	**$213,640.78**
DIFFERENCE OF COST				($164,087.41)	
EQUIVALENT ANNUAL COST				**$ 2,528.18**	
PAYBACK PERIOD				**0.98**	

BOECKENSTADT					
Data Year	2005				
Capital Cost in 2015	$ 10,960.28				
O&M/Year in 2015	$ 1,826.71				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 10,960.28			$ 10,960.28	
1		$ -	$ 1,826.71	$ 1,826.71	$ 7,335.00
2		$ -	$ 1,881.51	$ 1,881.51	$ 7,555.05
3		$ -	$ 1,937.96	$ 1,937.96	$ 7,781.70
4		$ -	$ 1,996.10	$ 1,996.10	$ 8,015.15
5		$ -	$ 2,055.98	$ 2,055.98	$ 8,255.61
6		$ -	$ 2,117.66	$ 2,117.66	$ 8,503.28
7		$ -	$ 2,181.19	$ 2,181.19	$ 8,758.37
8		$ -	$ 2,246.63	$ 2,246.63	$ 9,021.12
9		$ -	$ 2,314.03	$ 2,314.03	$ 9,291.76
10		$ -	$ 2,383.45	$ 2,383.45	$ 9,570.51
11		$ -	$ 2,454.95	$ 2,454.95	$ 9,857.63
12		$ -	$ 2,528.60	$ 2,528.60	$ 10,153.36
13		$ -	$ 2,604.46	$ 2,604.46	$ 10,457.96
14		$ -	$ 2,682.59	$ 2,682.59	$ 10,771.69
15	$ 10,960.28	$ -	$ 2,763.07	$ 13,723.34	$ 11,094.85
16		$ -	$ 2,845.96	$ 2,845.96	$ 11,427.69
17		$ -	$ 2,931.34	$ 2,931.34	$ 11,770.52
18		$ -	$ 3,019.28	$ 3,019.28	$ 12,123.64
19		$ -	$ 3,109.86	$ 3,109.86	$ 12,487.35
20		$ -	$ 3,203.15	$ 3,203.15	$ 12,861.97
21		$ -	$ 3,299.25	$ 3,299.25	$ 13,247.83
22		$ -	$ 3,398.22	$ 3,398.22	$ 13,645.26
23		$ -	$ 3,500.17	$ 3,500.17	$ 14,054.62
24		$ -	$ 3,605.18	$ 3,605.18	$ 14,476.26
25		$ -	$ 3,713.33	$ 3,713.33	$ 14,910.54
26		$ -	$ 3,824.73	$ 3,824.73	$ 15,357.86
27		$ -	$ 3,939.47	$ 3,939.47	$ 15,818.60
28		$ -	$ 4,057.66	$ 4,057.66	$ 16,293.15
29		$ -	$ 4,179.39	$ 4,179.39	$ 16,781.95
30		$ -	$ 4,304.77	$ 4,304.77	$ 17,285.41
SUM OF CASH FLOWS				**$ 108,827.17**	**$ 348,965.67**
NET PRESENT VALUE				**$ 69,126.69**	**$ 213,640.78**
DIFFERENCE OF COST				$ (144,514.09)	
EQUIVALENT ANNUAL COST				**$ 3,526.79**	
PAYBACK PERIOD				**1.99**	

GAINES - Truck Owner Costs					
Data Year	2009				
Capital Cost in 2015	$ 2,771.53				
O&M/Year in 2015	$ 3,558.64				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 2,771.53			$ 2,771.53	
1		$ -	$ 3,558.64	$ 3,558.64	$ 7,335.00
2		$ -	$ 3,665.40	$ 3,665.40	$ 7,555.05
3		$ -	$ 3,775.36	$ 3,775.36	$ 7,781.70
4		$ -	$ 3,888.62	$ 3,888.62	$ 8,015.15
5		$ -	$ 4,005.28	$ 4,005.28	$ 8,255.61
6		$ -	$ 4,125.44	$ 4,125.44	$ 8,503.28
7		$ -	$ 4,249.20	$ 4,249.20	$ 8,758.37
8		$ -	$ 4,376.68	$ 4,376.68	$ 9,021.12
9		$ -	$ 4,507.98	$ 4,507.98	$ 9,291.76
10		$ -	$ 4,643.22	$ 4,643.22	$ 9,570.51
11		$ -	$ 4,782.51	$ 4,782.51	$ 9,857.63
12		$ -	$ 4,925.99	$ 4,925.99	$ 10,153.36
13		$ -	$ 5,073.77	$ 5,073.77	$ 10,457.96
14		$ -	$ 5,225.98	$ 5,225.98	$ 10,771.69
15	$ 2,771.53	$ -	$ 5,382.76	$ 8,154.29	$ 11,094.85
16		$ -	$ 5,544.25	$ 5,544.25	$ 11,427.69
17		$ -	$ 5,710.57	$ 5,710.57	$ 11,770.52
18		$ -	$ 5,881.89	$ 5,881.89	$ 12,123.64
19		$ -	$ 6,058.35	$ 6,058.35	$ 12,487.35
20		$ -	$ 6,240.10	$ 6,240.10	$ 12,861.97
21		$ -	$ 6,427.30	$ 6,427.30	$ 13,247.83
22		$ -	$ 6,620.12	$ 6,620.12	$ 13,645.26
23		$ -	$ 6,818.72	$ 6,818.72	$ 14,054.62
24		$ -	$ 7,023.28	$ 7,023.28	$ 14,476.26
25		$ -	$ 7,233.98	$ 7,233.98	$ 14,910.54
26		$ -	$ 7,451.00	$ 7,451.00	$ 15,357.86
27		$ -	$ 7,674.53	$ 7,674.53	$ 15,818.60
28		$ -	$ 7,904.77	$ 7,904.77	$ 16,293.15
29		$ -	$ 8,141.91	$ 8,141.91	$ 16,781.95
30		$ -	$ 8,386.17	$ 8,386.17	$ 17,285.41
SUM OF CASH FLOWS				**$ 174,846.84**	**$ 348,965.67**
NET PRESENT VALUE				**$ 105,048.72**	**$ 213,640.78**
DIFFERENCE OF COST				($108,592.06)	
EQUIVALENT ANNUAL COST				**$ 5,359.51**	
PAYBACK PERIOD				**0.73**	

GAINES - Investor Costs					
Data Year	2009				
Capital Cost in 2015	$ 6,651.66				
O&M/Year in 2015	$ -				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 6,651.66			$ 6,651.66	
1		$ -	$ -	$ -	$ 7,335.00
2		$ -	$ -	$ -	$ 7,555.05
3		$ -	$ -	$ -	$ 7,781.70
4		$ -	$ -	$ -	$ 8,015.15
5		$ -	$ -	$ -	$ 8,255.61
6		$ -	$ -	$ -	$ 8,503.28
7		$ -	$ -	$ -	$ 8,758.37
8		$ -	$ -	$ -	$ 9,021.12
9		$ -	$ -	$ -	$ 9,291.76
10		$ -	$ -	$ -	$ 9,570.51
11		$ -	$ -	$ -	$ 9,857.63
12		$ -	$ -	$ -	$ 10,153.36
13		$ -	$ -	$ -	$ 10,457.96
14		$ -	$ -	$ -	$ 10,771.69
15	$ 6,651.66	$ -	$ -	$ 6,651.66	$ 11,094.85
16		$ -	$ -	$ -	$ 11,427.69
17		$ -	$ -	$ -	$ 11,770.52
18		$ -	$ -	$ -	$ 12,123.64
19		$ -	$ -	$ -	$ 12,487.35
20		$ -	$ -	$ -	$ 12,861.97
21		$ -	$ -	$ -	$ 13,247.83
22		$ -	$ -	$ -	$ 13,645.26
23		$ -	$ -	$ -	$ 14,054.62
24		$ -	$ -	$ -	$ 14,476.26
25		$ -	$ -	$ -	$ 14,910.54
26		$ -	$ -	$ -	$ 15,357.86
27		$ -	$ -	$ -	$ 15,818.60
28		$ -	$ -	$ -	$ 16,293.15
29		$ -	$ -	$ -	$ 16,781.95
30		$ -	$ -	$ -	$ 17,285.41
SUM OF CASH FLOWS				**$ 13,303.33**	**$ 348,965.67**
NET PRESENT VALUE				**$ 10,603.02**	**$ 213,640.78**
DIFFERENCE OF COST				($203,037.75)	
EQUIVALENT ANNUAL COST				**$ 540.96**	
PAYBACK PERIOD				**0.91**	

SHANCITA					
Data Year	2007				
Capital Cost in 2015	$ 7,744.36				
O&M/Year in 2015	$ -				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 4,589.25			$ 4,589.25	
1		$ -	$ -	$ -	$ 7,335.00
2		$ -	$ -	$ -	$ 7,555.05
3		$ -	$ -	$ -	$ 7,781.70
4		$ -	$ -	$ -	$ 8,015.15
5		$ -	$ -	$ -	$ 8,255.61
6		$ -	$ -	$ -	$ 8,503.28
7		$ -	$ -	$ -	$ 8,758.37
8		$ -	$ -	$ -	$ 9,021.12
9		$ -	$ -	$ -	$ 9,291.76
10		$ -	$ -	$ -	$ 9,570.51
11		$ -	$ -	$ -	$ 9,857.63
12		$ -	$ -	$ -	$ 10,153.36
13		$ -	$ -	$ -	$ 10,457.96
14		$ -	$ -	$ -	$ 10,771.69
15	$ 4,589.25	$ -	$ -	$ 4,589.25	$ 11,094.85
16		$ -	$ -	$ -	$ 11,427.69
17		$ -	$ -	$ -	$ 11,770.52
18		$ -	$ -	$ -	$ 12,123.64
19		$ -	$ -	$ -	$ 12,487.35
20		$ -	$ -	$ -	$ 12,861.97
21		$ -	$ -	$ -	$ 13,247.83
22		$ -	$ -	$ -	$ 13,645.26
23		$ -	$ -	$ -	$ 14,054.62
24		$ -	$ -	$ -	$ 14,476.26
25		$ -	$ -	$ -	$ 14,910.54
26		$ -	$ -	$ -	$ 15,357.86
27		$ -	$ -	$ -	$ 15,818.60
28		$ -	$ -	$ -	$ 16,293.15
29		$ -	$ -	$ -	$ 16,781.95
30		$ -	$ -	$ -	$ 17,285.41
SUM OF CASH FLOWS				**$ 9,178.50**	**$ 348,965.67**
NET PRESENT VALUE				**$ 7,315.46**	**$ 213,640.78**
DIFFERENCE OF COST				($206,325.32)	
EQUIVALENT ANNUAL COST				**$ 373.23**	
PAYBACK PERIOD				**0.63**	

WANG - Truck Owner Costs					
Data Year	2007				
Capital Cost in 2015	$ 4,589.25				
O&M/Year in 2015	$ 5,162.91				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 4,589.25			$ 4,589.25	
1		$ -	$ 5,162.91	$ 5,162.91	$ 7,335.00
2		$ -	$ 5,317.80	$ 5,317.80	$ 7,555.05
3		$ -	$ 5,477.33	$ 5,477.33	$ 7,781.70
4		$ -	$ 5,641.65	$ 5,641.65	$ 8,015.15
5		$ -	$ 5,810.90	$ 5,810.90	$ 8,255.61
6		$ -	$ 5,985.23	$ 5,985.23	$ 8,503.28
7		$ -	$ 6,164.78	$ 6,164.78	$ 8,758.37
8		$ -	$ 6,349.73	$ 6,349.73	$ 9,021.12
9		$ -	$ 6,540.22	$ 6,540.22	$ 9,291.76
10		$ -	$ 6,736.42	$ 6,736.42	$ 9,570.51
11		$ -	$ 6,938.52	$ 6,938.52	$ 9,857.63
12		$ -	$ 7,146.67	$ 7,146.67	$ 10,153.36
13		$ -	$ 7,361.07	$ 7,361.07	$ 10,457.96
14		$ -	$ 7,581.91	$ 7,581.91	$ 10,771.69
15	$ 4,589.25	$ -	$ 7,809.36	$ 12,398.62	$ 11,094.85
16		$ -	$ 8,043.64	$ 8,043.64	$ 11,427.69
17		$ -	$ 8,284.95	$ 8,284.95	$ 11,770.52
18		$ -	$ 8,533.50	$ 8,533.50	$ 12,123.64
19		$ -	$ 8,789.51	$ 8,789.51	$ 12,487.35
20		$ -	$ 9,053.19	$ 9,053.19	$ 12,861.97
21		$ -	$ 9,324.79	$ 9,324.79	$ 13,247.83
22		$ -	$ 9,604.53	$ 9,604.53	$ 13,645.26
23		$ -	$ 9,892.67	$ 9,892.67	$ 14,054.62
24		$ -	$ 10,189.45	$ 10,189.45	$ 14,476.26
25		$ -	$ 10,495.13	$ 10,495.13	$ 14,910.54
26		$ -	$ 10,809.98	$ 10,809.98	$ 15,357.86
27		$ -	$ 11,134.28	$ 11,134.28	$ 15,818.60
28		$ -	$ 11,468.31	$ 11,468.31	$ 16,293.15
29		$ -	$ 11,812.36	$ 11,812.36	$ 16,781.95
30		$ -	$ 12,166.73	$ 12,166.73	$ 17,285.41
SUM OF CASH FLOWS				**$ 254,806.04**	**$ 348,965.67**
NET PRESENT VALUE				**$ 153,311.56**	**$ 213,640.78**
DIFFERENCE OF COST				($60,329.22)	
EQUIVALENT ANNUAL COST				**$ 7,821.84**	
PAYBACK PERIOD				**2.11**	

WANG - Investor Costs					
Data Year	2007				
Capital Cost in 2015	$ 6,883.88				
O&M/Year in 2015	$ -				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 6,883.88			$ 6,883.88	
1		$ -	$ -	$ -	$ 7,335.00
2		$ -	$ -	$ -	$ 7,555.05
3		$ -	$ -	$ -	$ 7,781.70
4		$ -	$ -	$ -	$ 8,015.15
5		$ -	$ -	$ -	$ 8,255.61
6		$ -	$ -	$ -	$ 8,503.28
7		$ -	$ -	$ -	$ 8,758.37
8		$ -	$ -	$ -	$ 9,021.12
9		$ -	$ -	$ -	$ 9,291.76
10		$ -	$ -	$ -	$ 9,570.51
11		$ -	$ -	$ -	$ 9,857.63
12		$ -	$ -	$ -	$ 10,153.36
13		$ -	$ -	$ -	$ 10,457.96
14		$ -	$ -	$ -	$ 10,771.69
15	$ 6,883.88	$ -	$ -	$ 6,883.88	$ 11,094.85
16		$ -	$ -	$ -	$ 11,427.69
17		$ -	$ -	$ -	$ 11,770.52
18		$ -	$ -	$ -	$ 12,123.64
19		$ -	$ -	$ -	$ 12,487.35
20		$ -	$ -	$ -	$ 12,861.97
21		$ -	$ -	$ -	$ 13,247.83
22		$ -	$ -	$ -	$ 13,645.26
23		$ -	$ -	$ -	$ 14,054.62
24		$ -	$ -	$ -	$ 14,476.26
25		$ -	$ -	$ -	$ 14,910.54
26		$ -	$ -	$ -	$ 15,357.86
27		$ -	$ -	$ -	$ 15,818.60
28		$ -	$ -	$ -	$ 16,293.15
29		$ -	$ -	$ -	$ 16,781.95
30		$ -	$ -	$ -	$ 17,285.41
SUM OF CASH FLOWS				**$ 13,767.76**	**$ 348,965.67**
NET PRESENT VALUE				**$ 10,973.18**	**$ 213,640.78**
DIFFERENCE OF COST				($202,667.59)	
EQUIVALENT ANNUAL COST				**$ 559.84**	
PAYBACK PERIOD				**0.94**	

APPENDIX D.4 NET PRESENT VALUE CALCULATIONS FOR ATSES BY SOURCE

GINN - Truck Owner Costs					
Data Year	2004				
Capital Cost in 2015	$ 12.59				
O&M/Year in 2015	$ 4,721.51				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 12.59			$ 12.59	
1		$ -	$ 4,721.51	$ 4,721.51	$ 7,335.00
2		$ -	$ 4,863.15	$ 4,863.15	$ 7,555.05
3		$ -	$ 5,009.05	$ 5,009.05	$ 7,781.70
4		$ -	$ 5,159.32	$ 5,159.32	$ 8,015.15
5		$ -	$ 5,314.10	$ 5,314.10	$ 8,255.61
6		$ -	$ 5,473.52	$ 5,473.52	$ 8,503.28
7		$ -	$ 5,637.73	$ 5,637.73	$ 8,758.37
8		$ -	$ 5,806.86	$ 5,806.86	$ 9,021.12
9		$ -	$ 5,981.06	$ 5,981.06	$ 9,291.76
10		$ -	$ 6,160.49	$ 6,160.49	$ 9,570.51
11		$ -	$ 6,345.31	$ 6,345.31	$ 9,857.63
12		$ -	$ 6,535.67	$ 6,535.67	$ 10,153.36
13		$ -	$ 6,731.74	$ 6,731.74	$ 10,457.96
14		$ -	$ 6,933.69	$ 6,933.69	$ 10,771.69
15	$ 12.59	$ -	$ 7,141.70	$ 7,154.29	$ 11,094.85
16		$ -	$ 7,355.95	$ 7,355.95	$ 11,427.69
17		$ -	$ 7,576.63	$ 7,576.63	$ 11,770.52
18		$ -	$ 7,803.93	$ 7,803.93	$ 12,123.64
19		$ -	$ 8,038.05	$ 8,038.05	$ 12,487.35
20		$ -	$ 8,279.19	$ 8,279.19	$ 12,861.97
21		$ -	$ 8,527.57	$ 8,527.57	$ 13,247.83
22		$ -	$ 8,783.39	$ 8,783.39	$ 13,645.26
23		$ -	$ 9,046.89	$ 9,046.89	$ 14,054.62
24		$ -	$ 9,318.30	$ 9,318.30	$ 14,476.26
25		$ -	$ 9,597.85	$ 9,597.85	$ 14,910.54
26		$ -	$ 9,885.79	$ 9,885.79	$ 15,357.86
27		$ -	$ 10,182.36	$ 10,182.36	$ 15,818.60
28		$ -	$ 10,487.83	$ 10,487.83	$ 16,293.15
29		$ -	$ 10,802.46	$ 10,802.46	$ 16,781.95
30		$ -	$ 11,126.54	$ 11,126.54	$ 17,285.41
SUM OF CASH FLOWS				**$ 224,652.80**	**$ 348,965.67**
NET PRESENT VALUE				**$ 133,534.24**	**$ 213,640.78**
DIFFERENCE OF COST				($80,106.54)	
EQUIVALENT ANNUAL COST				**$ 6,812.82**	
PAYBACK PERIOD				**0.00**	

GINN - Investor Costs

Data Year	2004				
Capital Cost in 2015	$ 12,590.68				
O&M/Year in 2015	$ -				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 12,590.68			$ 12,590.68	
1		$ -	$ -	$ -	$ 7,335.00
2		$ -	$ -	$ -	$ 7,555.05
3		$ -	$ -	$ -	$ 7,781.70
4		$ -	$ -	$ -	$ 8,015.15
5		$ -	$ -	$ -	$ 8,255.61
6		$ -	$ -	$ -	$ 8,503.28
7		$ -	$ -	$ -	$ 8,758.37
8		$ -	$ -	$ -	$ 9,021.12
9		$ -	$ -	$ -	$ 9,291.76
10		$ -	$ -	$ -	$ 9,570.51
11		$ -	$ -	$ -	$ 9,857.63
12		$ -	$ -	$ -	$ 10,153.36
13		$ -	$ -	$ -	$ 10,457.96
14		$ -	$ -	$ -	$ 10,771.69
15	$ 12,590.68	$ -	$ -	$ 12,590.68	$ 11,094.85
16		$ -	$ -	$ -	$ 11,427.69
17		$ -	$ -	$ -	$ 11,770.52
18		$ -	$ -	$ -	$ 12,123.64
19		$ -	$ -	$ -	$ 12,487.35
20		$ -	$ -	$ -	$ 12,861.97
21		$ -	$ -	$ -	$ 13,247.83
22		$ -	$ -	$ -	$ 13,645.26
23		$ -	$ -	$ -	$ 14,054.62
24		$ -	$ -	$ -	$ 14,476.26
25		$ -	$ -	$ -	$ 14,910.54
26		$ -	$ -	$ -	$ 15,357.86
27		$ -	$ -	$ -	$ 15,818.60
28		$ -	$ -	$ -	$ 16,293.15
29		$ -	$ -	$ -	$ 16,781.95
30		$ -	$ -	$ -	$ 17,285.41
SUM OF CASH FLOWS				**$ 25,181.37**	**$ 348,965.67**
NET PRESENT VALUE				**$ 20,070.06**	**$ 213,640.78**
DIFFERENCE OF COST				($193,570.72)	
EQUIVALENT ANNUAL COST				**$ 1,023.96**	
PAYBACK PERIOD				**1.72**	

BOECKENSTADT

Data Year	2005				
Capital Cost in 2015	$ 21,932.73				
O&M/Year in 2015	$ 2,922.74				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 21,932.73			$ 21,932.73	
1		$ -	$ 2,922.74	$ 2,922.74	$ 7,335.00
2		$ -	$ 3,010.42	$ 3,010.42	$ 7,555.05
3		$ -	$ 3,100.74	$ 3,100.74	$ 7,781.70
4		$ -	$ 3,193.76	$ 3,193.76	$ 8,015.15
5		$ -	$ 3,289.57	$ 3,289.57	$ 8,255.61
6		$ -	$ 3,388.26	$ 3,388.26	$ 8,503.28
7		$ -	$ 3,489.90	$ 3,489.90	$ 8,758.37
8		$ -	$ 3,594.60	$ 3,594.60	$ 9,021.12
9		$ -	$ 3,702.44	$ 3,702.44	$ 9,291.76
10		$ -	$ 3,813.51	$ 3,813.51	$ 9,570.51
11		$ -	$ 3,927.92	$ 3,927.92	$ 9,857.63
12		$ -	$ 4,045.76	$ 4,045.76	$ 10,153.36
13		$ -	$ 4,167.13	$ 4,167.13	$ 10,457.96
14		$ -	$ 4,292.14	$ 4,292.14	$ 10,771.69
15	$ 21,932.73	$ -	$ 4,420.91	$ 26,353.64	$ 11,094.85
16		$ -	$ 4,553.53	$ 4,553.53	$ 11,427.69
17		$ -	$ 4,690.14	$ 4,690.14	$ 11,770.52
18		$ -	$ 4,830.84	$ 4,830.84	$ 12,123.64
19		$ -	$ 4,975.77	$ 4,975.77	$ 12,487.35
20		$ -	$ 5,125.04	$ 5,125.04	$ 12,861.97
21		$ -	$ 5,278.79	$ 5,278.79	$ 13,247.83
22		$ -	$ 5,437.16	$ 5,437.16	$ 13,645.26
23		$ -	$ 5,600.27	$ 5,600.27	$ 14,054.62
24		$ -	$ 5,768.28	$ 5,768.28	$ 14,476.26
25		$ -	$ 5,941.33	$ 5,941.33	$ 14,910.54
26		$ -	$ 6,119.57	$ 6,119.57	$ 15,357.86
27		$ -	$ 6,303.16	$ 6,303.16	$ 15,818.60
28		$ -	$ 6,492.25	$ 6,492.25	$ 16,293.15
29		$ -	$ 6,687.02	$ 6,687.02	$ 16,781.95
30		$ -	$ 6,887.63	$ 6,887.63	$ 17,285.41
SUM OF CASH FLOWS				**$ 182,916.05**	**$ 348,965.67**
NET PRESENT VALUE				**$ 117,610.56**	**$ 213,640.78**
DIFFERENCE OF COST				($96,030.22)	
EQUIVALENT ANNUAL COST				**$ 6,000.40**	
PAYBACK PERIOD				**4.97**	

GAINES - Truck Owner Costs for ATSE Pedestal Technology

Data Year	2009				
Capital Cost in 2015	$ 11.09				
O&M/Year in 2015	$ -				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 11.09			$ 11.09	
1		$ -	$ -	$ -	$ 7,335.00
2		$ -	$ -	$ -	$ 7,555.05
3		$ -	$ -	$ -	$ 7,781.70
4		$ -	$ -	$ -	$ 8,015.15
5		$ -	$ -	$ -	$ 8,255.61
6		$ -	$ -	$ -	$ 8,503.28
7		$ -	$ -	$ -	$ 8,758.37
8		$ -	$ -	$ -	$ 9,021.12
9		$ -	$ -	$ -	$ 9,291.76
10		$ -	$ -	$ -	$ 9,570.51
11		$ -	$ -	$ -	$ 9,857.63
12		$ -	$ -	$ -	$ 10,153.36
13		$ -	$ -	$ -	$ 10,457.96
14		$ -	$ -	$ -	$ 10,771.69
15	$ 11.09	$ -	$ -	$ 11.09	$ 11,094.85
16		$ -	$ -	$ -	$ 11,427.69
17		$ -	$ -	$ -	$ 11,770.52
18		$ -	$ -	$ -	$ 12,123.64
19		$ -	$ -	$ -	$ 12,487.35
20		$ -	$ -	$ -	$ 12,861.97
21		$ -	$ -	$ -	$ 13,247.83
22		$ -	$ -	$ -	$ 13,645.26
23		$ -	$ -	$ -	$ 14,054.62
24		$ -	$ -	$ -	$ 14,476.26
25		$ -	$ -	$ -	$ 14,910.54
26		$ -	$ -	$ -	$ 15,357.86
27		$ -	$ -	$ -	$ 15,818.60
28		$ -	$ -	$ -	$ 16,293.15
29		$ -	$ -	$ -	$ 16,781.95
30		$ -	$ -	$ -	$ 17,285.41
SUM OF CASH FLOWS				**$ 22.17**	**$ 348,965.67**
NET PRESENT VALUE				**$ 17.67**	**$ 213,640.78**
DIFFERENCE OF COST				($213,623.10)	
EQUIVALENT ANNUAL COST				**$ 0.90**	
PAYBACK PERIOD				**0.00**	

GAINES - Truck Owner Costs for ATSE Gantry Technology					
Data Year	2009				
Capital Cost in 2015	$ 11.09				
O&M/Year in 2015	$ 8,148.29				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 11.09			$ 11.09	
1		$ -	$ 8,148.29	$ 8,148.29	$ 7,335.00
2		$ -	$ 8,392.74	$ 8,392.74	$ 7,555.05
3		$ -	$ 8,644.52	$ 8,644.52	$ 7,781.70
4		$ -	$ 8,903.85	$ 8,903.85	$ 8,015.15
5		$ -	$ 9,170.97	$ 9,170.97	$ 8,255.61
6		$ -	$ 9,446.10	$ 9,446.10	$ 8,503.28
7		$ -	$ 9,729.48	$ 9,729.48	$ 8,758.37
8		$ -	$ 10,021.37	$ 10,021.37	$ 9,021.12
9		$ -	$ 10,322.01	$ 10,322.01	$ 9,291.76
10		$ -	$ 10,631.67	$ 10,631.67	$ 9,570.51
11		$ -	$ 10,950.62	$ 10,950.62	$ 9,857.63
12		$ -	$ 11,279.14	$ 11,279.14	$ 10,153.36
13		$ -	$ 11,617.51	$ 11,617.51	$ 10,457.96
14		$ -	$ 11,966.04	$ 11,966.04	$ 10,771.69
15	$ 11.09	$ -	$ 12,325.02	$ 12,336.10	$ 11,094.85
16		$ -	$ 12,694.77	$ 12,694.77	$ 11,427.69
17		$ -	$ 13,075.61	$ 13,075.61	$ 11,770.52
18		$ -	$ 13,467.88	$ 13,467.88	$ 12,123.64
19		$ -	$ 13,871.92	$ 13,871.92	$ 12,487.35
20		$ -	$ 14,288.07	$ 14,288.07	$ 12,861.97
21		$ -	$ 14,716.71	$ 14,716.71	$ 13,247.83
22		$ -	$ 15,158.22	$ 15,158.22	$ 13,645.26
23		$ -	$ 15,612.96	$ 15,612.96	$ 14,054.62
24		$ -	$ 16,081.35	$ 16,081.35	$ 14,476.26
25		$ -	$ 16,563.79	$ 16,563.79	$ 14,910.54
26		$ -	$ 17,060.71	$ 17,060.71	$ 15,357.86
27		$ -	$ 17,572.53	$ 17,572.53	$ 15,818.60
28		$ -	$ 18,099.70	$ 18,099.70	$ 16,293.15
29		$ -	$ 18,642.69	$ 18,642.69	$ 16,781.95
30		$ -	$ 19,201.97	$ 19,201.97	$ 17,285.41
SUM OF CASH FLOWS				**$ 387,680.37**	**$ 348,965.67**
NET PRESENT VALUE				**$ 230,433.96**	**$ 213,640.78**
DIFFERENCE OF COST				$16,793.19	
EQUIVALENT ANNUAL COST				**$ 11,756.57**	
PAYBACK PERIOD				**-0.01**	

GAINES - Investor Costs for ATSE Pedestal Technology					
Data Year	2009				
Capital Cost in 2015	$ 11,086.11				
O&M/Year in 2015	$ -				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 11,086.11			$ 11,086.11	
1		$ -	$ -	$ -	$ 7,335.00
2		$ -	$ -	$ -	$ 7,555.05
3		$ -	$ -	$ -	$ 7,781.70
4		$ -	$ -	$ -	$ 8,015.15
5		$ -	$ -	$ -	$ 8,255.61
6		$ -	$ -	$ -	$ 8,503.28
7		$ -	$ -	$ -	$ 8,758.37
8		$ -	$ -	$ -	$ 9,021.12
9		$ -	$ -	$ -	$ 9,291.76
10		$ -	$ -	$ -	$ 9,570.51
11		$ -	$ -	$ -	$ 9,857.63
12		$ -	$ -	$ -	$ 10,153.36
13		$ -	$ -	$ -	$ 10,457.96
14		$ -	$ -	$ -	$ 10,771.69
15	$ 11,086.11	$ -	$ -	$ 11,086.11	$ 11,094.85
16		$ -	$ -	$ -	$ 11,427.69
17		$ -	$ -	$ -	$ 11,770.52
18		$ -	$ -	$ -	$ 12,123.64
19		$ -	$ -	$ -	$ 12,487.35
20		$ -	$ -	$ -	$ 12,861.97
21		$ -	$ -	$ -	$ 13,247.83
22		$ -	$ -	$ -	$ 13,645.26
23		$ -	$ -	$ -	$ 14,054.62
24		$ -	$ -	$ -	$ 14,476.26
25		$ -	$ -	$ -	$ 14,910.54
26		$ -	$ -	$ -	$ 15,357.86
27		$ -	$ -	$ -	$ 15,818.60
28		$ -	$ -	$ -	$ 16,293.15
29		$ -	$ -	$ -	$ 16,781.95
30		$ -	$ -	$ -	$ 17,285.41
SUM OF CASH FLOWS				**$ 22,172.21**	**$ 348,965.67**
NET PRESENT VALUE				**$ 17,671.71**	**$ 213,640.78**
DIFFERENCE OF COST				($195,969.07)	
EQUIVALENT ANNUAL COST				**$ 901.60**	
PAYBACK PERIOD				**1.51**	

GAINES - Investor Costs for ATSE Gantry Technology					
Data Year	2009				
Capital Cost in 2015	$ 18,513.80				
O&M/Year in 2015	$ -				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 18,513.80			$ 18,513.80	
1		$ -	$ -	$ -	$ 7,335.00
2		$ -	$ -	$ -	$ 7,555.05
3		$ -	$ -	$ -	$ 7,781.70
4		$ -	$ -	$ -	$ 8,015.15
5		$ -	$ -	$ -	$ 8,255.61
6		$ -	$ -	$ -	$ 8,503.28
7		$ -	$ -	$ -	$ 8,758.37
8		$ -	$ -	$ -	$ 9,021.12
9		$ -	$ -	$ -	$ 9,291.76
10		$ -	$ -	$ -	$ 9,570.51
11		$ -	$ -	$ -	$ 9,857.63
12		$ -	$ -	$ -	$ 10,153.36
13		$ -	$ -	$ -	$ 10,457.96
14		$ -	$ -	$ -	$ 10,771.69
15	$ 18,513.80	$ -	$ -	$ 18,513.80	$ 11,094.85
16		$ -	$ -	$ -	$ 11,427.69
17		$ -	$ -	$ -	$ 11,770.52
18		$ -	$ -	$ -	$ 12,123.64
19		$ -	$ -	$ -	$ 12,487.35
20		$ -	$ -	$ -	$ 12,861.97
21		$ -	$ -	$ -	$ 13,247.83
22		$ -	$ -	$ -	$ 13,645.26
23		$ -	$ -	$ -	$ 14,054.62
24		$ -	$ -	$ -	$ 14,476.26
25		$ -	$ -	$ -	$ 14,910.54
26		$ -	$ -	$ -	$ 15,357.86
27		$ -	$ -	$ -	$ 15,818.60
28		$ -	$ -	$ -	$ 16,293.15
29		$ -	$ -	$ -	$ 16,781.95
30		$ -	$ -	$ -	$ 17,285.41
SUM OF CASH FLOWS				**$ 37,027.60**	**$ 348,965.67**
NET PRESENT VALUE				**$ 29,511.75**	**$ 213,640.78**
DIFFERENCE OF COST				($184,129.03)	
EQUIVALENT ANNUAL COST				**$ 1,505.67**	
PAYBACK PERIOD				**2.52**	

SHANCITA					
Data Year	2007				
Capital Cost in 2015	$ 11,473.13				
O&M/Year in 2015	$ 4,302.42				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 11,473.13			$ 11,473.13	
1		$ -	$ 4,302.42	$ 4,302.42	$ 7,335.00
2		$ -	$ 4,431.50	$ 4,431.50	$ 7,555.05
3		$ -	$ 4,564.44	$ 4,564.44	$ 7,781.70
4		$ -	$ 4,701.37	$ 4,701.37	$ 8,015.15
5		$ -	$ 4,842.42	$ 4,842.42	$ 8,255.61
6		$ -	$ 4,987.69	$ 4,987.69	$ 8,503.28
7		$ -	$ 5,137.32	$ 5,137.32	$ 8,758.37
8		$ -	$ 5,291.44	$ 5,291.44	$ 9,021.12
9		$ -	$ 5,450.18	$ 5,450.18	$ 9,291.76
10		$ -	$ 5,613.69	$ 5,613.69	$ 9,570.51
11		$ -	$ 5,782.10	$ 5,782.10	$ 9,857.63
12		$ -	$ 5,955.56	$ 5,955.56	$ 10,153.36
13		$ -	$ 6,134.23	$ 6,134.23	$ 10,457.96
14		$ -	$ 6,318.25	$ 6,318.25	$ 10,771.69
15	$ 11,473.13	$ -	$ 6,507.80	$ 17,980.93	$ 11,094.85
16		$ -	$ 6,703.04	$ 6,703.04	$ 11,427.69
17		$ -	$ 6,904.13	$ 6,904.13	$ 11,770.52
18		$ -	$ 7,111.25	$ 7,111.25	$ 12,123.64
19		$ -	$ 7,324.59	$ 7,324.59	$ 12,487.35
20		$ -	$ 7,544.33	$ 7,544.33	$ 12,861.97
21		$ -	$ 7,770.66	$ 7,770.66	$ 13,247.83
22		$ -	$ 8,003.78	$ 8,003.78	$ 13,645.26
23		$ -	$ 8,243.89	$ 8,243.89	$ 14,054.62
24		$ -	$ 8,491.21	$ 8,491.21	$ 14,476.26
25		$ -	$ 8,745.94	$ 8,745.94	$ 14,910.54
26		$ -	$ 9,008.32	$ 9,008.32	$ 15,357.86
27		$ -	$ 9,278.57	$ 9,278.57	$ 15,818.60
28		$ -	$ 9,556.93	$ 9,556.93	$ 16,293.15
29		$ -	$ 9,843.63	$ 9,843.63	$ 16,781.95
30		$ -	$ 10,138.94	$ 10,138.94	$ 17,285.41
SUM OF CASH FLOWS				**$ 227,635.87**	**$ 348,965.67**
NET PRESENT VALUE				**$ 139,952.06**	**$ 213,640.78**
DIFFERENCE OF COST				($73,688.72)	
EQUIVALENT ANNUAL COST				**$ 7,140.25**	
PAYBACK PERIOD				**3.78**	

WANG - Truck Owner Costs

Data Year	2007				
Capital Cost in 2015	$ -				
O&M/Year in 2015	$ 6,023.39				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ -			$ -	
1		$ -	$ 6,023.39	$ 6,023.39	$ 7,335.00
2		$ -	$ 6,204.10	$ 6,204.10	$ 7,555.05
3		$ -	$ 6,390.22	$ 6,390.22	$ 7,781.70
4		$ -	$ 6,581.92	$ 6,581.92	$ 8,015.15
5	$ -	$ -	$ 6,779.38	$ 6,779.38	$ 8,255.61
6		$ -	$ 6,982.76	$ 6,982.76	$ 8,503.28
7		$ -	$ 7,192.25	$ 7,192.25	$ 8,758.37
8		$ -	$ 7,408.01	$ 7,408.01	$ 9,021.12
9		$ -	$ 7,630.25	$ 7,630.25	$ 9,291.76
10	$ -	$ -	$ 7,859.16	$ 7,859.16	$ 9,570.51
11		$ -	$ 8,094.94	$ 8,094.94	$ 9,857.63
12		$ -	$ 8,337.79	$ 8,337.79	$ 10,153.36
13		$ -	$ 8,587.92	$ 8,587.92	$ 10,457.96
14		$ -	$ 8,845.56	$ 8,845.56	$ 10,771.69
15	$ -	$ -	$ 9,110.92	$ 9,110.92	$ 11,094.85
16		$ -	$ 9,384.25	$ 9,384.25	$ 11,427.69
17		$ -	$ 9,665.78	$ 9,665.78	$ 11,770.52
18		$ -	$ 9,955.75	$ 9,955.75	$ 12,123.64
19		$ -	$ 10,254.42	$ 10,254.42	$ 12,487.35
20	$ -	$ -	$ 10,562.06	$ 10,562.06	$ 12,861.97
21		$ -	$ 10,878.92	$ 10,878.92	$ 13,247.83
22		$ -	$ 11,205.29	$ 11,205.29	$ 13,645.26
23		$ -	$ 11,541.45	$ 11,541.45	$ 14,054.62
24		$ -	$ 11,887.69	$ 11,887.69	$ 14,476.26
25	$ -	$ -	$ 12,244.32	$ 12,244.32	$ 14,910.54
26		$ -	$ 12,611.65	$ 12,611.65	$ 15,357.86
27		$ -	$ 12,990.00	$ 12,990.00	$ 15,818.60
28		$ -	$ 13,379.70	$ 13,379.70	$ 16,293.15
29		$ -	$ 13,781.09	$ 13,781.09	$ 16,781.95
30		$ -	$ 14,194.52	$ 14,194.52	$ 17,285.41
SUM OF CASH FLOWS				**$ 286,565.46**	**$ 348,965.67**
NET PRESENT VALUE				**$ 170,328.79**	**$ 213,640.78**
DIFFERENCE OF COST				($43,311.99)	
EQUIVALENT ANNUAL COST				**$ 8,690.05**	
PAYBACK PERIOD				**0.00**	

WANG - Investor Costs					
Data Year	2007				
Capital Cost in 2015	$ 18,357.01				
O&M/Year in 2015	$ 2,868.28				
Fuel Cost/Year in 2015	$ -				
Idling Fuel Cost/Year in 2015	$ 7,335.00				
Discount Rate	3.00%				
Electricity Cost Growth Rate	3%				
Year	Capital Cost	Fuel Cost	O&M Cost	Total	Avoided Idling Fuel Cost
0	$ 18,357.01			$ 18,357.01	
1		$ -	$ 2,868.28	$ 2,868.28	$ 7,335.00
2		$ -	$ 2,954.33	$ 2,954.33	$ 7,555.05
3		$ -	$ 3,042.96	$ 3,042.96	$ 7,781.70
4		$ -	$ 3,134.25	$ 3,134.25	$ 8,015.15
5		$ -	$ 3,228.28	$ 3,228.28	$ 8,255.61
6		$ -	$ 3,325.13	$ 3,325.13	$ 8,503.28
7		$ -	$ 3,424.88	$ 3,424.88	$ 8,758.37
8		$ -	$ 3,527.63	$ 3,527.63	$ 9,021.12
9		$ -	$ 3,633.45	$ 3,633.45	$ 9,291.76
10		$ -	$ 3,742.46	$ 3,742.46	$ 9,570.51
11		$ -	$ 3,854.73	$ 3,854.73	$ 9,857.63
12		$ -	$ 3,970.37	$ 3,970.37	$ 10,153.36
13		$ -	$ 4,089.49	$ 4,089.49	$ 10,457.96
14		$ -	$ 4,212.17	$ 4,212.17	$ 10,771.69
15	$ 18,357.01	$ -	$ 4,338.53	$ 22,695.54	$ 11,094.85
16		$ -	$ 4,468.69	$ 4,468.69	$ 11,427.69
17		$ -	$ 4,602.75	$ 4,602.75	$ 11,770.52
18		$ -	$ 4,740.83	$ 4,740.83	$ 12,123.64
19		$ -	$ 4,883.06	$ 4,883.06	$ 12,487.35
20		$ -	$ 5,029.55	$ 5,029.55	$ 12,861.97
21		$ -	$ 5,180.44	$ 5,180.44	$ 13,247.83
22		$ -	$ 5,335.85	$ 5,335.85	$ 13,645.26
23		$ -	$ 5,495.93	$ 5,495.93	$ 14,054.62
24		$ -	$ 5,660.80	$ 5,660.80	$ 14,476.26
25		$ -	$ 5,830.63	$ 5,830.63	$ 14,910.54
26		$ -	$ 6,005.55	$ 6,005.55	$ 15,357.86
27		$ -	$ 6,185.71	$ 6,185.71	$ 15,818.60
28		$ -	$ 6,371.28	$ 6,371.28	$ 16,293.15
29		$ -	$ 6,562.42	$ 6,562.42	$ 16,781.95
30		$ -	$ 6,759.30	$ 6,759.30	$ 17,285.41
SUM OF CASH FLOWS				**$ 173,173.76**	**$ 348,965.67**
NET PRESENT VALUE				**$ 110,370.77**	**$ 213,640.78**
DIFFERENCE OF COST				($103,270.01)	
EQUIVALENT ANNUAL COST				**$ 5,631.03**	
PAYBACK PERIOD				**4.11**	

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