Diesel Engine Idle Reduction in Class 8 Trucks Using On-Vehicle Equipment with Optional Shore Power

A National Demonstration Project

Technical Report

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A National Demonstration Project

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PRODUCT DESCRIPTION

In 2003 the trucking industry consumed nearly one billion gallons of diesel fuel during idling of truck engines. Much of the idling was required to provide for driver comfort during federally mandated driver rest periods—by powering truck sleeper cabin heating or air conditioning, lighting, and appliances for cooking meals or entertainment. Idling the main truck engine to provide for these relatively small power requirements is inefficient and highly polluting. A number of technologies are available that provide driver comfort far more efficiently and less expensively. This project was conceived to demonstrate the potential cost savings and emission reductions that could be realized through the use of alternatives to idling truck main engines during driver rest periods. With grant funding from the EPA and cost sharing by the fleets, electrical air conditioning equipment was installed on 34 trucks from nine fleets and used by drivers during rest periods.

Results & Findings

Trucks specially equipped with battery-powered air conditioning equipment are realizing total annual cost savings of at least $46,248 on an investment of $226,561. Fuel savings of more than 16,968 gallons per year and extended engine life are driving these savings. In addition, these trucks are reducing NO_x emissions during rest periods by 6,555 pounds per year. The best-performing fleet realized a 70% reduction in idling hours for a 2.2-year simple payback period, but on average, the project reduced idling a 50% of fleet baseline idling hours, extending the payback period to 4.9 years.

The project leveraged federal grant funds by cost sharing initial equipment installations and then requiring fleets to reinvest savings in additional equipment. From a total project grant of $200,000, federal funds of $113,400 were spent on truck equipment to match funding from the nine fleets. Perhaps the most successful aspect of the project is that the fleets have invested more than five times the annual savings generated by the project in idle-reduction equipment, $266,247 as of the last tally.

Challenges & Objectives

The project emphasized getting equipment into the hands of drivers and fleet managers in order to learn about their needs and start generating cost savings. This approach meant less emphasis on acquiring data and more emphasis on maximizing the number of fleets and trucks involved.

Applications, Values & Use

This project shows that the potential for shore-power use as an alternative to engine idling is high. Drivers value the quiet rest period with no engine noise or fumes while residing in their bunks. Although very little shore power was actually used, the project demonstrates that fleets and owner-operators alike are highly motivated to adopt cost-saving and comfort-enhancing solutions to the problem of engine idling during rest periods. If it were available, drivers and fleets would be likely to use shore power to realize further cost savings.

The project proposal was written when diesel fuel cost $1.50 per gallon. In the third and fourth quarters of 2004 the price rose briefly to $2.50 per gallon, and interest in the project and the potential cost sharing from grant funds soared. Although the original intent of the project was to work with two or possibly three fleets and to install more units per fleet, 34 systems were installed in trucks from nine fleets. As a result of the limited state of knowledge about idle-reduction systems, fleets across the country, with few exceptions, continue to experiment with solutions on a few trucks rather than installing them fleet-wide. Truckers still need to be sold on the benefits of changing behavior related to idling, and on-truck systems need to be improved to better meet the needs of truckers by enabling comfortable, low-cost rest periods in the truck.

EPRI Perspective

The project has yielded a number of lessons about the trucking industry and idle-reduction efforts. Perhaps the most important lesson is that idle-reduction efforts need to emphasize driver education and training. It is the drivers who make the choice to use or not to use the equipment. The project demonstrated that even with equipment that appeared adequate in the hands of some drivers, other drivers still chose to idle the engine a large part of the time.

Approach

Although the original hope was to install electric air conditioning systems that would use shore power for extended rest periods, fleets universally elected to install larger battery packs that would enable grid-autonomous rest periods of 8 to 10 hours. The result of this choice was an increase in air conditioning system complexity and cost and a decrease in the number of trucks actually outfitted compared to the original plan. The eventual systems installed included electric air conditioners, inverter-chargers, batteries, and controllers and were cost competitive with auxiliary power units (APUs) or generator sets currently under consideration as an alternative to truck main-engine idling.

Keywords

Idle reduction
Shore power
Truck stop electrification
Mobile emissions reductions
Heavy-duty trucks

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1
INTRODUCTION

In 2003 the trucking industry consumed nearly one billion gallons of diesel fuel during idling of truck engines. Much of the idling was required to provide for driver comfort during federally mandated driver rest periods—by powering truck sleeper cabin heating or air conditioning, lighting, and appliances for cooking meals or entertainment. Idling the main truck engine to provide for these relatively small power requirements is inefficient and highly polluting. A number of technologies are available that provide driver comfort far more efficiently and less expensively. One potentially attractive approach is the use of electricity to power equipment and appliances in the truck cab, allowing the driver to shut off the main engine while parked. These devices can be inexpensively and efficiently powered from onboard battery storage or by an off-board electrical connection known as "shore power" from its use in the marine industry.

Shore-power idle-reduction technology for heavy-duty trucks has the potential to provide very large cost savings to truckers, in addition to reducing the amount of diesel exhaust emitted, with its associated pollution. The savings in fuel costs could amount to more than $1 per hour or approximately $2,000 per year per truck without sacrificing driver comfort. Shore-power use also improves rest periods by providing quieter rest and cleaner air.

Because it offers both a cost-savings benefit to the trucking industry and an emission-reduction benefit to the public, idle reduction for heavy-duty trucks has received significant attention from agencies such as the U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy (DOE), the U.S. Department of Transportation (DOT), and the California Air Resources Board (CARB). Often, use of emission-reduction equipment (for example, diesel particulate matter filters) increases costs without the prospect of paying back the equipment operator for those costs. Use of idle reduction, by contrast, offers the prospect of potentially significant savings by fleets that find workable alternatives to idling the main engine.

There are three barriers to adoption of onboard idle-reduction systems and use of shore power by drivers during rest periods:

- Most trucks do not have engine-independent equipment to keep the driver comfortable.
- Most places trucks stop during rest periods do not provide electrical receptacles.
- Using shore power will require truck drivers to adopt new behaviors, which will require outreach and training by industry groups.

This project addresses the first barrier. It demonstrates a cost-sharing and reinvestment approach to installing engine-independent equipment, it evaluates such equipment available for trucks, and it quantifies the cost and emission savings resulting from installing shore power capable idle-reduction equipment in 34 trucks from nine fleets, along with battery energy storage to allow operation when shore power is not available. The hope is that this project complements efforts by others to address the other barriers.

The focus of this project is the demonstration of electric-powered onboard idle-reduction equipment. In general, the basic set of equipment required to provide for the comfort of the long-haul truck driver during mandated rest periods includes an auxiliary electric heating, ventilating, air conditioning (HVAC) system, an electric inverter-charger capable of providing both 120-volt AC and 12-volt DC electricity, and the wiring and controller needed to operate the system.

This onboard equipment can be powered in two ways—from onboard battery storage or via an off-board shore-power AC electrical connection. There are advantages and limitations to each mode of power. The use of auxiliary battery storage allows a truck to reduce or eliminate rest period idling regardless of its location while parked. To date, the vast majority of truck parking locations do not have electrical outlets available—and many favored locations (public rest areas, roadsides, shopping center parking lots) may be difficult to electrify. Therefore, grid-independent operation was a requirement of this project for each installed system.

Auxiliary battery storage is inherently limited by capacity. The batteries are extremely heavy and may add several hundred pounds to the weight of the truck. While it is possible to design a system to provide for a comfortable nominal 8-to-10-hour rest period, extremely hot or cold conditions may result in shorter system run times. In addition, the truck alternator must recharge these batteries during the next driving shift, causing a slight increase in fuel consumption (but still a fraction of the idling fuel consumption). The use of an AC shore-power connection will power these types of systems indefinitely at the lowest possible cost per hour to the operator. Compatibility with shore power is not a requirement of this project, but all of the technologies demonstrated are fundamentally compatible with a shore-power connection.

The following four key elements were critical components of the project plan:

- company financial participation
- fleet partnerships
- calculation of actual cost savings and a reinvestment requirement
- technology development

This final report discusses these elements. It first outlines company financial participation and the nature of the fleet partnerships undertaken. It then presents calculations of the actual hours of idling time saved, along with fuel and maintenance savings, to evaluate the relative success of the project in reducing idling and the reinvestment commitment of the trucking fleets. It briefly describes hardware from four different equipment suppliers. Finally, it discusses emission reductions and reviews lessons learned from the project.

2
COMPANY FINANCIAL PARTICIPATION

The nine trucking fleets involved in this project contributed 50% of the cost of the idle-reduction equipment installed in the trucks. This requirement was incorporated to leverage federal grant funds from the EPA to gain as large a sample of experience with idle reduction as possible. The fleets involved were also required to report idling activity for the fleet and the project vehicles, and to reinvest the actual first-year savings from equipment installation in additional idle-reduction equipment.

Table 2-1 shows the total costs reported for the project, before reinvestment of savings by the fleets. This table shows how the project funds were expended. Grant funds in the amount of $200,000 were matched by $113,161 in fleet expenditures for equipment and system installation. EPRI program costs of $50,830 and SMUD program costs of $97,740 bring the total project expenditures to $461,731. Equipment and its installation accounted for 51% of reported project costs. Project management and data collection and analysis accounted for the balance of the costs.

Table 2-1
Total Project Costs

Expenditure Item	Amount
EPA Grant Funds Expenditures	
Truck equipment	$113,400
Project management labor	$ 49,886
Other direct costs	$ 714
Other indirect costs	$ 36,000
EPA Subtotal	**$200,000**
EPRI In-Kind Expenditures	
Project management labor	$ 50,830
EPRI Subtotal	**$ 50,830**
SMUD In-Kind Expenditures	
Truck equipment	$ 7,129
Project management labor	$ 84,988
Other direct costs	$ 5,623
SMUD Subtotal	**$ 97,740**
Fleet Equipment Cost Share	
Truck equipment	$113,161
Fleet Subtotal	**$113,161**
Total Project Costs	**$461,731**

In addition to the documented in-kind and cost-share expenditures, significant contributions to the project were made by technology suppliers. Dometic Corporation and its distributor, AAP, trained personnel to install the HVAC systems for seven of the nine fleets involved in the project. The costs of this training and installation work are not included in the project costs but were an important contribution to the overall success of the project. Similarly, Xantrex Technologies, the manufacturer of the inverter-charger systems used on the trucks, contributed significantly to the development and design of the all-electric, grid-independent onboard system at the inception of the project.

3
FLEET PARTNERSHIPS

The EPA grant agreement specified that EPRI would negotiate agreements with private trucking fleets to purchase and install idle-reduction technologies. A participation agreement was developed and executed with each of the nine participant fleets. This agreement is attached as Appendix A. The agreement stipulated that the fleet would cooperate in supporting the project by

- selecting and installing idle-reduction equipment,
- providing baseline idling percentages and engine computer downloads to track performance,
- assisting with driver surveys, and
- reinvesting actual energy and maintenance cost savings from the first year of operation in additional idle-reduction equipment.

The project commenced in early 2003 with one fleet agreement. This fleet was a relatively small regional carrier with a high level of interest in idle reduction. EPRI and SMUD were able to work very closely with this fleet to define a shore power capable yet grid-independent system with sufficient auxiliary battery capacity to allow for a minimum of 6 hours of continuous grid-independent air conditioner operation in hot weather. This was usually sufficient for a single 10-hour rest period.

In 2003, SMUD contacted more than a dozen fleets to solicit participation in the project. The project description presented to fleets is attached as Appendix B.

None of the fleets contacted in 2003 joined the project—a discouraging finding for the project. A second fleet partner was finally added in January 2004 and a third in June 2004. During the summer of 2004, the price of fuel briefly rose to more than $2.50 per gallon and interest in the project suddenly increased. Six more fleets signed participation agreements.

As of April 2004, 16 months into the project, only six trucks had been outfitted with idle-reduction systems. By the end of 2004, an additional 28 trucks had been equipped, for a total of 34 systems in the demonstration project.

4
COST SAVINGS AND REINVESTMENT

According to the terms of the participation agreement, the trucking fleets involved in this project were to provide baseline data on idling times prior to technology installation. This enabled calculation of the actual fuel and maintenance cost savings achieved by installing the idle-reduction equipment, which in turn provided the basis for calculating the annualized amounts that the fleets were required to reinvest in additional idle-reduction equipment. This chapter presents that data.

Fleet Idle-Reduction Data

Trucking fleets routinely track fleet performance using engine computer data or other tracking systems such as Qualcomm's SensorTRACS and PeopleNet Communications' PerformX systems. Fleet managers use this data to plan and manage operations and to minimize operating costs. By using the fleets' existing data collection capabilities, this project avoided the cost and complexity of installing and using data loggers.

We formulated a method of estimating reduction in idling hours using engine control module (ECM) data. Three different ECM types—from Cummins, Detroit Diesel, and Caterpillar—were used. Cummins ECMs report power takeoff (PTO) and idle time as discrete hour values that have to be added to arrive at total idling time. Detroit Diesel ECMs include the PTO time in the idling time, although PTO time is also reported. Caterpillar ECMs, for the engine types encountered in this project, do not report PTO time at all.

To provide a baseline, average idling rates were calculated for the project trucks before installation of the shore power onboard package. Dividing the idling time recorded in the ECM by the mileage driven during a given period determined this idling rate (which differs from the idling percentage, the percentage of engine time spent idling). The baseline idling rates calculated this way ranged from 0.024 hours per mile to 0.005 hours per mile. Knowing the baseline hours of idling per mile driven allowed evaluation of ECM data following installation of the idle-reduction equipment.

For some of the fleets, the baseline idling hours for the entire fleet were simply not available, or the fleet manager stated the average as something like "49% idling percentage." Where data was unavailable, a best estimate of 0.015 hours of idling per mile of driving was used. This figure corresponds to 1,800 idling hours per year (150 per month) for 120,000 miles per year of driving. If the driving takes place at an average of 55 mph, the total annual driving time is 2,182 hours, the annual engine hours are 3,982, and the idling percentage is 45%. These figures appear to well represent the behavior of many drivers and are consistent with the original Argonne National Laboratory study on idling.[1]

Table 4-1 provides monthly engine data for the project fleets before and after equipment installation. Note that data is provided here for only six of the nine fleets that participated in the project. Data was incomplete or unavailable for fleets B, D, and F.

Table 4-1
Monthly Engine Data Before and After Idle-Reduction Equipment

Fleet Designation:	**A**	**C**	**E**	**G**	**H**	**I**
Before Equipment Installation						
Mileage	8,496.38	12,255.12	9,114.26	7,332.04	10,314.25	15,396.93
Average idling rate (hrs/mi)	0.0150	0.0150	0.0144	0.0150	0.0150	0.0077
Engine hours	281.93	406.65	296.95	243.29	342.25	398.06
Driving hours (at 55 mph)	154.48	222.82	165.71	133.31	187.53	279.94
Idling hours	127.45	183.83	131.24	109.98	154.71	118.12
Idling percentage	45%	45%	44%	45%	45%	30%
After Equipment Installation						
Mileage	8,496.38	12,255.12	9,114.26	7,332.04	10,314.25	15,396.93
Average idling rate (hrs/mi)	0.0104	0.0046	0.0068	0.0083	0.0052	0.0050
Engine hours	242.77	278.70	227.33	193.95	241.11	356.98
Driving hours (at 55 mph)	154.48	222.82	165.71	133.31	187.53	279.94
Idling hours	88.29	55.88	61.61	60.64	53.58	77.04
Idling percentage	36%	20%	27%	31%	22%	22%

The program achieved on average a 50% idling reduction compared to baseline, while the best-performing fleet was able to eliminate 70% of its baseline idling.

Actual Idle-Reduction Hours and Cost Savings

Next we examine fuel and maintenance cost savings due to idle reduction. Previous work by the EPA[2] revealed that fuel-consumption values recorded in the ECM are not representative of actual fuel consumption. The EPA study showed a fuel-consumption range of 0.39 to 1.65 gallons per hour and an average of 0.82 gallons per hour. For this reason, a conservative value of 0.82

[1] F. Stodolsky, L. Gaines, and A. Vyas, *Analysis of Technology Options to Reduce the Fuel Consumption of Idling Trucks* (Argonne, IL: Argonne National Laboratory, 2000; ANL/ESD-43).
[2] Han Lim, *Study of Exhaust Emissions from Idling Heavy-Duty Diesel Trucks and Commercially Available Idle-Reducing Devices* (Washington, DC: U.S. Environmental Protection Agency, October 2002; EPA420-R-02-025).

gallons per hour of idling was consistently assumed in order to evaluate the savings resulting from reduction in idling hours.

The figure of 0.82 gallons per hour of idling represents an average of idle speeds, which might be obtained with very light air conditioner needs or with low electric power consumption by appliances in the cab. By contrast, some drivers run the engine at high-idle or power takeoff (PTO) settings to provide sufficient air conditioner output during their rest periods. This practice increases fuel consumption to an estimated 1.2 to 1.3 gallons per hour,[3] making the assumption of 0.82 gallons per hour a significantly lower estimate. (For more on this topic, see "A Note on Fuel-Consumption Estimates" later in this chapter.)

Maintenance cost savings were calculated based on the number of days alternate equipment was used, in accordance with figures provided by the Technology and Maintenance Council (TMC).[4] Each day of avoided idling during the duration of the project is assumed to represent $0.72 per day in avoided maintenance costs and $0.41 per day in avoided engine overhaul costs, for a total of $1.13 per day, based on this procedure. No effort was made to confirm the validity of this cost savings number. However, most fleet operators do place significant value on the reduction of idling as key to longer engine life.

Reduction in idling hours for each truck in the project was estimated by subtracting the idling hours per mile traveled during the reporting period from the baseline idling hours per mile, and then multiplying the result by the mileage in the period. The resulting hours reduction was then multiplied by the figure mentioned earlier (0.82 gallons of fuel per hour) to calculate period gallons of fuel saved, for a total of 16,968 gallons. The gallon savings were multiplied by the price of fuel, mainly taken as $2 per gallon for the latter half of 2004. Maintenance savings were calculated at $1.13 per day of alternate equipment use.

Table 4-2 presents the results of these calculations for each truck for the duration of the project. Again, data from fleets B, D, and F was not received or was missing, so calculations could not be done for four of the 34 trucks. Note that some drivers, in fleets G and I, idled more after installation of the equipment than they did before. The manager of fleet G indicated that training and behavior modification were at least as important as new equipment.

[3] According to trucker Robert Jordan on his Web site, www.idlefree.net.
[4] Technology and Maintenance Council, TMC-1108, Appendix 3.

Table 4-2
Actual Project Savings

ND= No Data

Fleet and Truck #	Date of Installation	Date of Last Data	Idle Reduction (hrs)	Fuel Savings (gals)	Cost Savings
A 52	12/24/04	5/28/05	61	50	$157
A 56	9/28/04	5/28/05	9	8	$71
A 57	11/28/04	5/28/05	302	247	$698
A 61	11/19/04	5/28/05	59	49	$241
B 2655	9/22/04	11/2/04	ND	ND	ND
C 1302	9/15/04	4/1/05	849	696	$1,613
C 1316	8/14/04	4/1/05	1328	1089	$2,435
C 1319	7/23/04	4/1/05	970	795	$1,873
C 1360	9/23/04	4/1/05	1048	859	$1,927
C 1361	10/3/04	4/1/05	319	262	$725
C 1362	10/21/04	4/1/05	739	606	$1,394
D 247	9/30/04	4/8/05	644	528	$1,165
D 538	11/19/04	11/19/04	ND	ND	ND
E 506	4/12/04	4/1/05	281	231	$721
E 563	12/16/04	4/1/05	476	390	$930
E 572	4/12/03	4/1/05	1694	1389	$3,908
E 596	4/16/03	4/1/05	1068	876	$2,720
F 20	5/27/04	1/1/05	ND	ND	ND
F 21	5/27/04	1/1/05	ND	ND	ND
G 2738	10/15/04	4/20/05	–167	–137	–$92
G 2739	10/15/04	4/22/05	56	46	$275
G 2740	10/15/04	4/20/05	138	113	$402
G 2741	10/15/04	4/20/05	156	128	$430

Fleet and Truck #	Date of Installation	Date of Last Data	Idle Reduction (hrs)	Fuel Savings (gals)	Cost Savings
G 2742	10/15/04	5/2/05	–135	–110	–$46
H 1289	11/8/04	4/8/05	455	373	$893
H 1336	6/30/04	4/11/05	923	757	$1,833
I 1241	12/23/04	3/7/05	5	4	$94
I 2020	12/23/04	2/23/05	–24	–20	$21
I 2043	12/23/04	6/7/05	193	158	$571
I 2075	1/29/04	6/1/05	548	449	$1,508
I 2082	12/23/04	3/1/05	30	25	$136
I 2154	12/13/04	1/5/05	55	45	$136
I 2187	1/29/04	1/1/05	782	641	$1,806
I 3970	12/13/04	6/6/05	187	153	$573
Totals			**13,050**	**10,701**	**$29,119**

Annualized Idle-Reduction Hours and Cost Savings

Calculation of the reinvestment obligation incurred by each fleet under the participation agreement required an estimate of annualized savings based on the data submitted. This was calculated by estimating an average monthly savings during the demonstration period and then multiplying that by 12. As shown in Table 4-2, many of the installations have not experienced a full year of operation. Thus, the annualized savings shown in Table 4-3 are larger than the project totals.

Table 4-3
Annualized Savings

ND = No Data

Fleet and Truck #	System Brand	Idle Reduction (hrs)	Cost Savings	Fleet Total Savings
A 52	Dometic	442	$1,128	
A 56	Dometic	67	$514	
A 57	Dometic	600	$1,388	
A 61	Dometic	165	$674	$3,704

Fleet and Truck #	System Brand	Idle Reduction (hrs)	Cost Savings	Fleet Total Savings
B 2655	Dometic	ND	ND	
C 1302	Idling Solutions	1543	$2,933	
C 1316	Idling Solutions	2078	$3,811	
C 1319	Idling Solutions	1386	$2,676	
C 1360	Idling Solutions	2029	$3,730	
C 1361	Idling Solutions	638	$1,450	
C 1362	Idling Solutions	1643	$3,097	$17,698
D 247	Dometic	1226	$2,218	
D 538	Dometic	ND	ND	$2,218
E 506	Dometic	713	$1,829	
E 563	Dometic	1289	$2,517	
E 572	Dometic	845	$1,949	
E 596	Dometic	552	$1,405	$7,699
F 20	Idling Solutions	ND	ND	
F 21	Idling Solutions	ND	ND	
G 2738	Dometic	–331	–$182	
G 2739	Dometic	109	$539	
G 2740	Dometic	285	$827	
G 2741	Dometic	323	$890	
G 2742	Dometic	–277	–$94	$1,979
H 1289	Dometic	1250	$2,453	
H 1336	NITE	1166	$2,316	$4,769
I 1241	NITE	26	$455	
I 2020	NITE	–140	$123	
I 2043	NITE	418	$1,238	
I 2075	Dometic	407	$814	

Fleet and Truck #	System Brand	Idle Reduction (hrs)	Cost Savings	Fleet Total Savings
I 2082	NITE	159	$721	
I 2154	Proheat	862	$2,128	
I 2187	Dometic	843	$1,543	
I 3970	Proheat	378	$1,159	$8,181
Annual Totals		**20,693**	**$46,248**	
Truck Averages		**690**	**$1,542**	

The total annualized savings for the 30 trucks for which data was reported is $46,248. This result is not seasonally adjusted. Some of the data is for trucks operated during winter months, when the electrical HVAC might not be used. With this system, higher idling reductions probably occur during the summer months due to air conditioner use.

Whereas the average truck in the project experienced a reduction in idling hours of 690 hours per year, the best-performing project truck reduced idling by 2,078 hours per year. This shows the degree of variation in equipment use and idling practice. This variation appears to be a function of equipment utilization, seasonal variation, and driver behavior, and possibly other factors.

Reinvestment of Savings

Table 4-4 shows how the fleets have reinvested their savings from idling reductions realized through this project. The table also shows the total cost to each fleet for equipment and installation and how the costs were shared between federal (“Project Cost”) and fleet funds. Fleets B and F have not yet reported their savings, and fleets B, E and G have not yet reported how they will reinvest their savings.

Table 4-4
Fleet Expenditures, Savings, and Reinvestment

Fleet	Total Cost	Project Cost	Truck Fleet Cost	Annual Savings	Reinvestment
A	$25,321	$12,000	$13,321	$3,704	$5,997
B	$8,871	$4,436	$4,436		
C	$39,000	$21,000	$18,000	$17,698	$136,000
D	$14,119	$7,060	$7,060	$2,218	$10,365
E	$32,972	$16,486	$16,486	$7,699	
F	$15,440	$7,000	$8,440		$30,880
G	$39,752	$19,876	$19,876	$1,979	
H	$10,253	$5,127	$5,127	$4,769	$70,485
I	$40,832	$20,416	$20,416	$8,181	$12,520
Totals	**$226,561**	**$113,400**	**$113,161**	**$46,248**	**$266,247**

The following describes the reinvestment activities of the participating fleets:

- Fleet A invested its savings in one NITE system, complete with batteries and DC air conditioner.
- Fleet B has not yet reported how it will reinvest its savings.
- Fleet C is satisfied with its Idling Solutions systems and has reinvested in 17 more Idling Solutions systems at $8,000 each. This fleet purchased an additional 38 Idling Solutions systems, for which costs are not shown.
- Fleet D purchased two additional Dometic systems.
- Fleet E is attempting to purchase Dometic Tundra electric air conditioners with Xantrex inverters in their new trucks scheduled for delivery from Freightliner later this year.
- Fleet F purchased an additional four Idling Solutions systems.
- Fleet G has not yet decided how to reinvest its savings.
- Fleet H purchased 64 Webasto Air Top 2000 bunk heaters and 2 Tri-Pac auxiliary power units (APUs) for an approximate cost of $60,000 in 2004. In 2005 it purchased an additional 15 Webasto Air Top 2000 bunk heaters at a cost of $10,485.
- Fleet I purchased two Proheat generator sets that produce 120 volts AC directly to run electric air conditioning systems.

The total reinvestment by the fleets is more than five times the savings to date.

A Note on Fuel-Consumption Estimates

As mentioned earlier, the original hope for this project was to install electric air conditioning systems that would use shore power for extended rest periods, but the trucking fleets universally elected to install larger battery packs that would enable grid-autonomous rest periods of 8 to 10 hours. Although a few of the trucks were occasionally plugged in to charge the batteries, most of the time the batteries were charged while driving, causing a slight increase in fuel consumption. This raises the question: Is the assumption of 0.82 gallons of fuel saved per hour of idling reasonable, since some incremental fuel is used to recharge the batteries?

The auxiliary battery energy capacity is about 7.8 kilowatt-hours (kWh). If we assume typical working efficiencies for the key system components, including the alternator (55%[5]), lead-acid battery (round-trip efficiency of 75%), and engine (brake-specific fuel consumption of 300 g/kWh), the estimated additional fuel consumed to completely recharge the auxiliary battery during a driving shift is 1.76 gallons of fuel. This results in an equivalent fuel consumption of 0.22 gallons per hour of idling.

To save 0.82 gallons per hour during rest periods with alternative equipment installed, the before-installation idling fuel consumption for a resting truck with the air conditioner operating must be, at a minimum, 1.04 gallons (0.82 + 0.22 gallons). As noted earlier, many trucks rest with the engine set in PTO or high-idle mode, consuming about 1.2 gallons per hour, so the assumption of an average savings of 0.82 gallons per hour, even with battery charging occurring during the driving shift, is still reasonable.

Table 4-5 provides a comparison of rest period costs. These are calculated for idling at three different consumption rates, for recharging the battery during the driving shift, for recharging the battery from the grid so that appliances can be operated later, and for operating appliances directly from the grid. The costs assume power is consumed for eight hours, fuel costs $2.50 per gallon, electricity costs 0.15 per kWh, battery efficiency is 75%, and inverter-charger efficiency is 85%.

Table 4-5
Comparison of Costs for an Eight-Hour Rest Period

Case	Idle rest, 0.82 gal/h	Idle rest, 1.00 gal/h	Idle rest, 1.20 gal/h	Batteries charged in drive shift	Batteries charged by grid	Direct shore power use
Cost	$16.40	$20.00	$24.00	$4.41	$1.84	$1.20

As shown in the table, using direct shore power would cost the least, and the grid-autonomous battery pack system is less expensive than idling the main engine. In addition, if an auxiliary power unit (APU) consuming 0.2 gallons per hour were substituted for the battery system charged by the engine, operation costs would be about $4 to $5 for a single rest period, comparable to the operation cost of batteries charged during the driving shift.

[5] Robert Bosch, *Bosch Automotive Handbook*, 5th edition (Cambridge, MA: Bentley Publishers, 2003), p. 881.

5

EMISSION REDUCTIONS

This chapter discusses the emission reductions achieved by the project. Reductions were calculated by multiplying the reduction in idling hours for each truck in the project (shown earlier in Tables 4-2 and 4-3) by average emission factors for idling trucks as determined by the EPA.

The EPA study referred to in Chapter 4[6] revealed an average NOx emission rate of 135 grams per hour (g/h) for the trucks tested. A subsequent EPA study[7] showed particulate emissions, and an assumed rate of 3.68 g/h for idling trucks was used to evaluate particulate emission reductions from this project. Estimates of emission reductions arrived at in this manner are believed to be conservative.

Project total and annualized emission reductions are shown in Table 5-1. Some of the participant fleets collected data for less than a full year. In these cases, the annualized totals may not be representative, as a full four-season data set is not available.

Based on these annualized emission reductions and assuming a five-year equipment life, the projected cost savings of the project was $10,679 per actual ton of emissions reduced. The best-performing fleet had a cost savings of $4,420.

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[6] Han Lim, *Study of Exhaust Emissions from Idling Heavy-Duty Diesel Trucks and Commercially Available Idle-Reducing Devices* (Washington, DC: U.S. Environmental Protection Agency, October 2002; EPA420-R-02-025).
[7] J.M.E. Storey, J. F. Thomas, S. A. Lewis, Sr., T. Q. Dam, and K. D. Edwards, *Particulate and Aldehyde Emissions from Idling Heavy-Duty Diesel Trucks* (Warrendale, PA: Society of Automotive Engineers, 2003; SAE 2003-01-0289).

Table 5-1
Emission Reductions

ND = No Data

	Project Emission Reduction		Annualized Emission Reduction	
Fleet and Truck #	**NOx (lbs)**	**PM (lbs)**	**NOx (lbs)**	**PM (lbs)**
A 52	19	0	140	1.69
A 56	3	0	21	0.26
A 57	96	1	190	2.30
A 61	19	0	52	0.63
B 2655	ND	ND	ND	ND
C 1302	269	3	489	5.91
C 1316	421	5	658	7.95
C 1319	307	4	439	5.30
C 1360	332	4	643	7.77
C 1361	101	1	202	2.44
C 1362	234	3	520	6.29
D 247	204	2	389	4.69
D 538	ND	ND	ND	ND
E 506	89	1	226	2.73
E 563	151	2	408	4.93
E 572	537	6	268	3.23
E 596	338	4	175	2.11
F 20	ND	ND	ND	ND
F 21	ND	ND	ND	ND
G 2738	–53	–1	–105	–1.27
G 2739	18	0	35	0.42
G 2740	44	1	90	1.09

	Project Emission Reduction		**Annualized Emission Reduction**	
Fleet and Truck #	**NOx (lbs)**	**PM (lbs)**	**NOx (lbs)**	**PM (lbs)**
G 2741	50	1	102	1.24
G 2742	–43	–1	–88	–1.06
H 1289	144	2	396	4.79
H 1336	292	4	369	4.46
I 1241	2	0	8	0.10
I 2020	–8	0	–44	–0.54
I 2043	61	1	132	1.60
I 2075	174	2	129	1.56
I 2082	10	0	50	0.61
I 2154	17	0	273	3.30
I 2187	248	3	267	3.23
I 3970	59	1	120	1.45
Totals	**4,134**	**50**	**6,555**	**79.21**
Truck Average	**137.8**	**1.67**	**218.5**	**2.64**

6
TECHNOLOGY REVIEW: ELECTRIC IDLE-REDUCTION EQUIPMENT

This chapter focuses on the on-vehicle equipment that was installed during the project to reduce the need for engine idling. It describes the systems that were installed from four different manufacturers and summarizes the technology evaluation and development efforts undertaken during the project to define solutions that would work for trucking fleet partners and be compatible with shore power. At the beginning of the project, the amount of energy consumed during rest periods and the complexity of setting up an electric air conditioner with batteries and inverter were largely unknown.

The shore-power system proposed is compatible with any 120-volt AC outlet. Because all of the trucking fleets were concerned about locating electrical outlets at their favored rest sites, all elected to install an auxiliary battery pack to power the electrically operated air conditioning for a full eight-hour rest period when a shore power connection is not available. This approach requires three large lead-acid batteries, connected in parallel, with a minimum capacity of 250 amp-hours. Three Group 8D (a large-format lead-acid battery with a volume of 1.5 cubic feet) batteries were selected for the auxiliary battery system to provide sufficient energy for a rest period in demanding climate conditions. Each battery weighs 160 pounds, for a total battery mass of 480 pounds.

While this chapter focuses on a review of electric idle-reduction technology, it is worthwhile to note that one established idle-reduction alternative is the installation of a small auxiliary diesel engine on the truck for use during rest periods. There are two different types of auxiliary engine-powered systems, engine-driven electrical generators (“gen-sets”) and auxiliary power units (APUs). An APU is configured for the auxiliary diesel engine to drive a mechanical air conditioning compressor and a 12-volt alternator. A gen-set uses the auxiliary engine to generate electrical power, typically 120-volt AC, to energize electrical onboard accessories like air conditioning. From the perspective of encouraging the use of shore power, a gen-set is preferable to an APU because a gen-set is easily made shore-power compatible through provision of a 120-volt AC, 30-amp connection, while an APU powers mechanical accessories that are not shore-power compatible. One of the systems reviewed here, the Proheat system, is a gen-set. Additionally, as noted in the previous chapter, one fleet chose to reinvest its savings from idling reductions realized through this project in bunk heaters and APUs.

The first two systems installed were Dometic systems installed on trucks operated by fleet E. These were Freightliner Century Class trucks with a dual bunk sleeper. These systems were fitted with data loggers to help assess system use and understand driver needs and habits. Dometic indicated that three Group 8D batteries were needed, and one truck was outfitted this way, while the other was outfitted with a battery pack of seven Group 31 deep-cycle batteries.

There was also a question about the size of the inverter-charger unit required to handle the starting current for the air conditioner, whether 2,500 or 3,000 watts. Table 6-1 shows the configuration of these first two trucks.

Table 6-1
Comparison of System Configurations for First Two Trucks

	Truck E 596	Truck E 572
Air Conditioner	7,000 Btu/h	10,000 Btu/h
Battery	3 AGM Group 8D	7 AGM Group 31
Inverter-Charger	2,500 W Xantrex	2,500 W Xantrex
Heating Equipment	Heat pump function in AC	2,500 W resistance heater

The systems were tested to confirm that the air conditioning performed adequately during hot weather. After being parked inside at a temperature of approximately 85° F, truck E 572 was parked in direct sunlight with an outside temperature of 104° F. The curtain between the seats and the bunk was closed, and the air conditioner was operated to cool the sleeping space. A temperature difference between the outside and the bunk area of at least 26° was maintained for the one-hour test period, as shown in Table 6-2. The thermal performance of the system was judged adequate, provided that the truck was pre-cooled by running the engine-driven air conditioner while driving and that the driver closed the curtain to minimize heat gain from the windshield and door glazing.

Table 6-2
Results of Air Conditioning Cooling Test, Truck E 572

Time	Outside Temp	Driver's Seat Temp	Bunk Temp
15:00	104.1° F	87.1° F	76.5° F
15:25		86.8° F	77.0° F
15:30	102.8° F	88.6° F	76.8° F
15:45		86.8° F	77.4° F
16:00	102.6° F	88.1° F	76.3° F

This finding is consistent with calculations by PACCAR, Inc., that estimate the air conditioning power required, as shown below:[8]

40° temperature difference:	6,700 Btu/h
Solar load through windows:	3,000 Btu/h
Heat from appliances:	700 Btu/h
Heat from occupants:	400 Btu/h
Total:	10,800 Btu/h

[8] B. Warf, "Truck Sleeper Cab Energy Requirements," presentation to Infrastructure Working Council, Truck Stop Electrification Codes and Standards Workshop, October 27, 2003.

Truck OEMs generally size their air conditioners assuming that the curtain is not always closed and the air conditioner's performance is a bit less than the certified value. Table 6-3 shows estimates by PACCAR of peak and typical loads.

Table 6-3
Sleeper Cab Hotel Loads Summary

Source	Peak Load (watts)	Typical Load (watts)	Duty Cycle	Average Load (watts)
Audio system	350	50	25%	13
Television/VCR	75	75	15%	11
Satellite or other communication system	160	50	10%	5
Laptop computer	65	65	25%	16
Microwave oven	1,400	1,400	3%	42
14,000 Btu/h air conditioner	4,400	1,700	70%	1,190
Refrigerator	85	85	50%	43
Coffee maker	250	250	2%	5
Lighting	100	60	50%	30
Miscellaneous	100	50	25%	13
Inverter losses @ 15% of load	300	290		20
Totals	**7,285**	**4,075**		**1,387**

The systems were also tested to verify that they could provide adequate air conditioning for the duration of an eight-hour rest period. Figure 6-1 shows a test confirming up to six hours of continuous air conditioner operation and 2,500-watt electric heater capability. In practice, the air conditioner often cycles on and off, and six hours of continuous air conditioner operation on battery power provides a cool resting environment for eight hours except in the hottest weather. Normally, fleet E operates in an environment where it cools off at night, and this electric air conditioner is adequate.

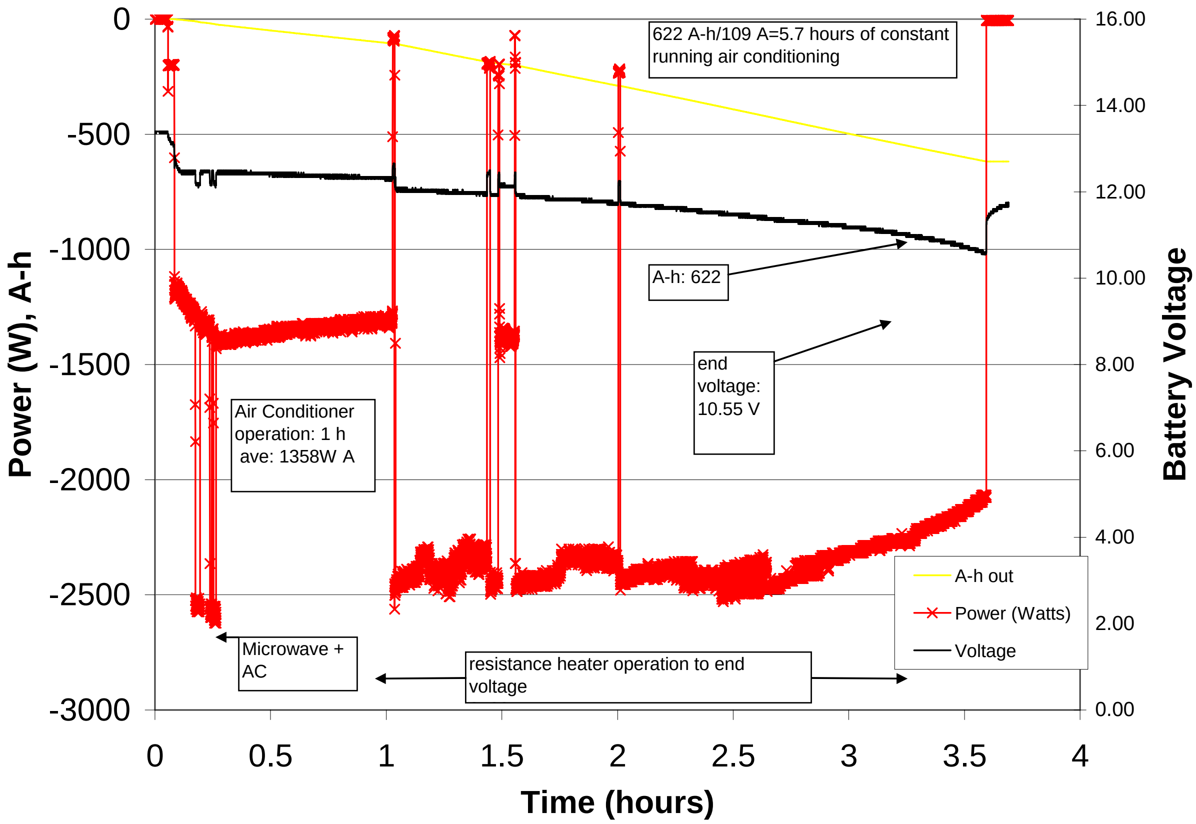

Figure 6-1
Results of Air Conditioning Duration Test, Truck E 572

Notice that in Table 6-3 the power required for a 14,000 Btu/h air conditioner is estimated as 1,700 watts. Subsequent testing of truck E 572 using data acquisition equipment provided by Xantrex showed power consumption of 1,358 watts average for its 10,000 Btu/h air conditioner. It further showed that the 2,500-watt inverter was adequate to support simultaneous operation of the air conditioner and the microwave oven. This Xantrex Freedom 458 inverter-charger includes a transformer and has a high-surge capability suitable for starting electric motors. A different model of inverter, a switching power supply type, was used with the Idling Solutions system, and with this alternate design, a 3,000-watt inverter is used to assure air conditioner motor starting.

Figure 6-2 shows the cycling behavior of the air conditioning system during testing of truck E 596. Also shown is a power consumption of about 1,000 watts (85 amps at 12 volts DC) for the 7,000 Btu/h air conditioner in truck E 596. This system ran for 15 hours in a test run at ambient temperatures of 80° to 90° F. Battery capacity testing showed a capacity for the three 8D batteries of 670 amp-hours, suggesting that in 100° F weather, a continuous running time of around 6.7 hours was possible.

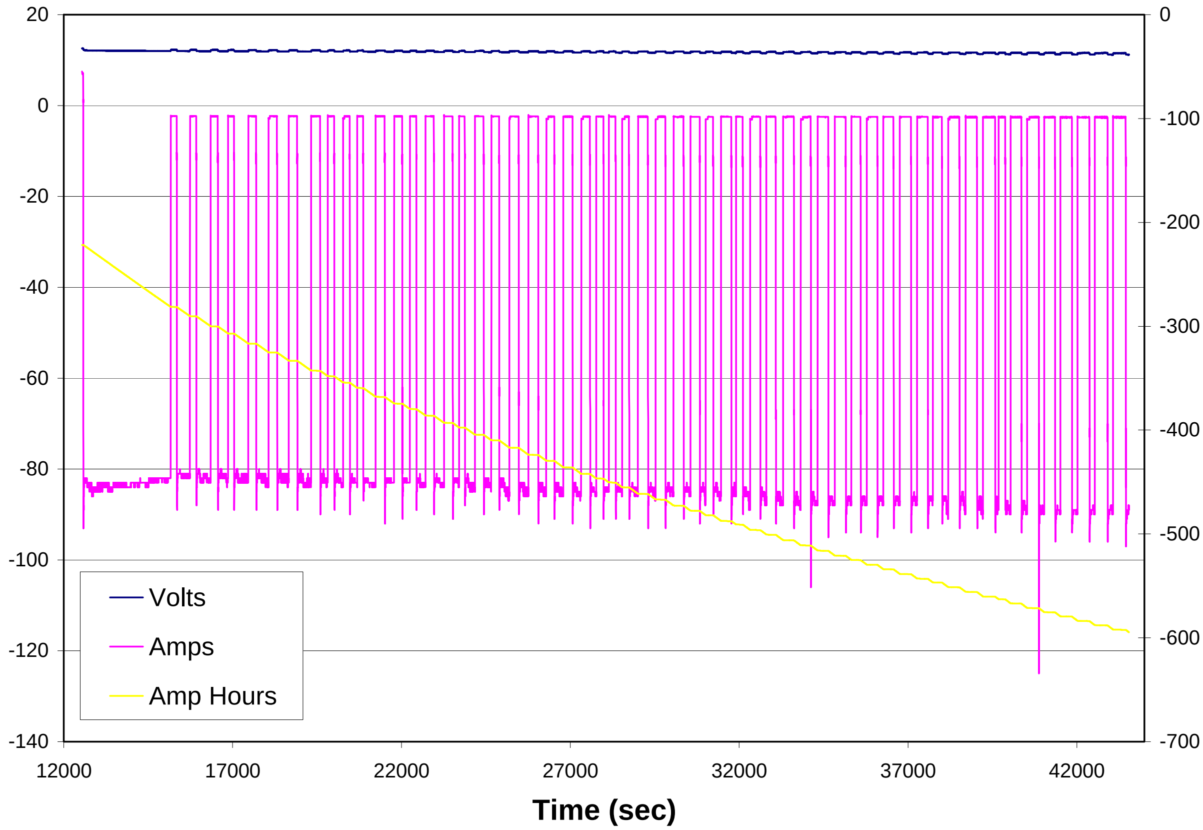

Figure 6-2
Cycling of Air Conditioner During Testing of Truck E 596

Ultimately, this system became the basis for all 19 of the Dometic installations performed in the project. The project focused on using the battery pack assembled with three Group 8D batteries because these provided more energy and a cleaner installation than the higher number of smaller batteries used in truck E 572. Figures 6-3 and 6-4 show the air conditioner installed under the bunk and one of the battery boxes installed on the frame rails. It was somewhat difficult to provide adequate air flow to and from the Dometic air conditioning system installed under the bunk in the sleeper cab. Ducting was carefully installed to the bulkhead to prevent short-circuiting and to provide adequate air circulation within the sleeper.

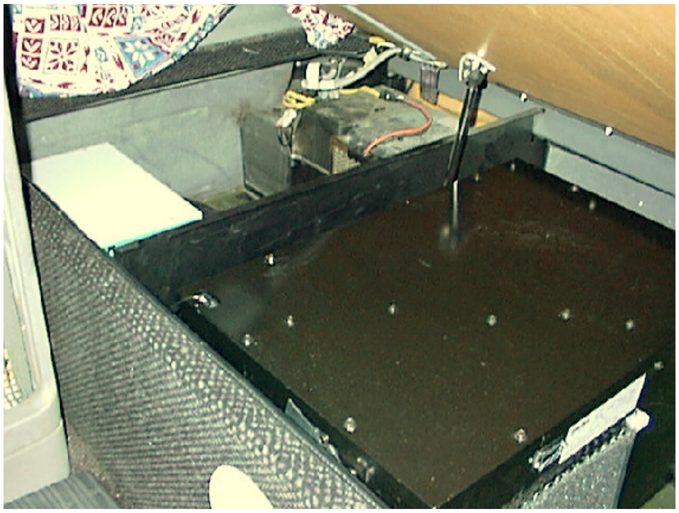

Figure 6-3
Dometic Air Conditioner and Xantrex Inverter (White) in Truck E 596

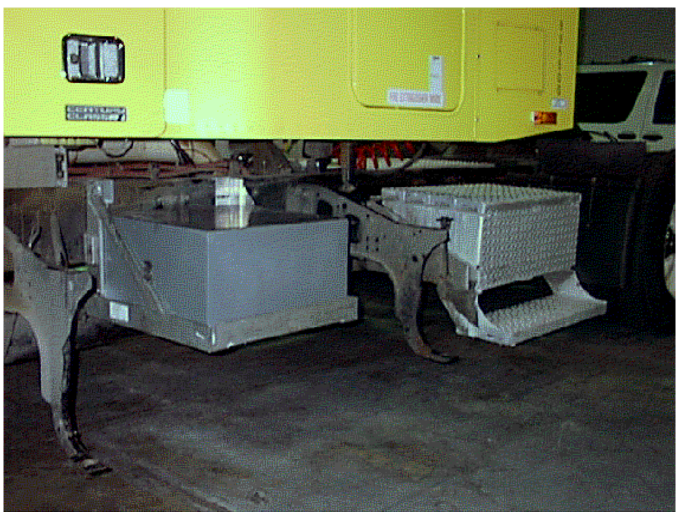

Figure 6-4
Box Holding Deep-Cycle Batteries on Truck E 596

Bergstrom NITE

The Bergstrom NITE (no-idle thermal environment) system is a 4,000 Btu/h air conditioner that operates at 12 volts DC. It can be operated directly from the truck's starting battery, although Bergstrom suggests installing the system with a 220-amp-hour deep-cycle battery. The system has the advantage of fewer components, and it does not need an inverter for operation. These systems were installed in four trucks from fleet I and one truck from fleet H.

The system has a lower power output than the Dometic Tundra and therefore has difficultly maintaining a comfortable cabin temperature when outside temperatures exceed 85° to 90° F. The NITE system is generally used with a fuel-fired heater for heating the sleeper. Using the NITE system with shore power could be accomplished by installing an AC-DC converter (like a battery charger) to provide 12-volt DC power to the air conditioner, auxiliary battery, and any 12-volt accessories or lights in the sleeper.

Idling Solutions

Air conditioning systems from Idling Solutions were not available when the project commenced, but the system design was fairly similar to the Dometic Tundra. The system consists of an 8,300 Btu/h air conditioner that is mounted on the back of the cab. The system is operated using seven 100-amp-hour Horizon batteries arranged in a 12-volt battery pack and connected to a Xantrex inverter, as shown in Figure 6-5. The Horizon battery pack serves as both the starter and the auxiliary battery on the truck.

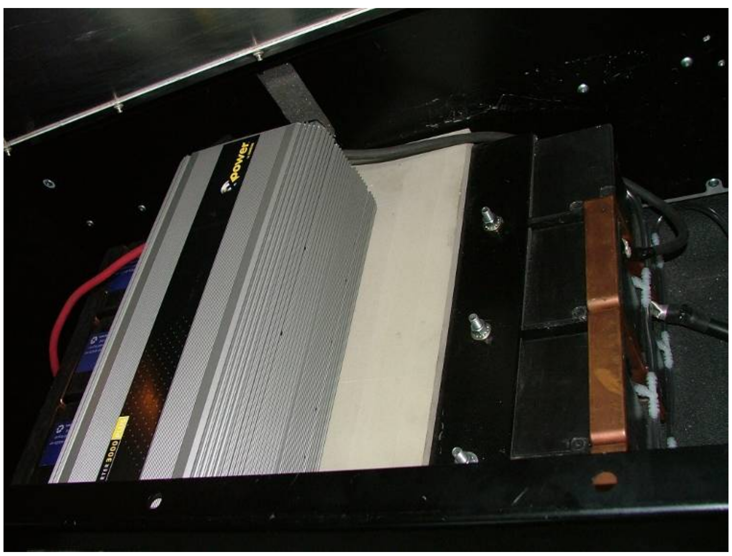

Figure 6-5
Idling Solutions System with Xantrex Inverter and Horizon Battery Pack

The Idling Solutions system used currently does not feature shore-power compatibility. Substitution of a different, higher-cost model of the Xantrex inverter-charger and shore-power wiring would enable shore-power use. Idling Solutions spent significant effort developing a charging algorithm for the truck alternator and was concerned that grid charging might be at a power level too low for optimum battery life.

The Idling Solutions system also includes an 11,600 Btu/h heating capability, using a combination of heat pump and resistance heating. The weight is managed by using the Horizon batteries to start the truck in addition to operating the HVAC, so the original starting batteries can be removed. The system uses a 270-amp alternator to charge the batteries.

Trucking fleet C has had great success using the Idling Solutions system. It appears that mounting the air conditioner on the back of the sleeper cab offers an air distribution benefit within the cab. One installation is shown in Figure 6-6.

Figure 6-6
Idling Solutions System Installed on Back of Cab

Proheat

Proheat is a product of Teleflex Corporation that uses a 120-volt AC air conditioner with a cooling capacity rated at 10,000 Btu/h. The system is normally operated by power generated by an engine-driven generator set mounted on the frame rail. Shore-power capability is provided as an option and is installed with a transfer switch that switches off the gen-set and allows battery charging and air conditioner operation when shore power is available. Fleet I installed two of these systems and was reimbursed by the project for the installation cost of the air conditioner and shore-power kits. Fleet I elected to reinvest savings from its other project trucks in two Proheat gen-set systems. This type of system is also compatible with shore power, as has already been mentioned. The Proheat gen-set system—with gen-set, air conditioner, battery charger, and shore power transfer switch—is slightly lighter than the standard Dometic-based system installed on 19 other trucks in the project. This is primarily due to the weight of the three Group 8D batteries required for grid-independent use of the Dometic system.

7
LESSONS LEARNED

This chapter discusses the following key lessons learned through this project:

- Trucking fleet managers are motivated by cost savings.
- It is difficult to measure the cost savings from idle reduction.
- Data collection methods could be improved beyond ECM data downloads.
- Driver behavior is an important variable.
- Climate is also an important variable.
- A third important variable is differences in the effectiveness of idle-reduction equipment.
- Driver comfort and choices must be considered.
- Financing must be made easier for owner-operators.
- It is important to keep the project simple.
- It is important to keep the technology simple.

Motivating Fleet Managers

Trucking fleet managers are motivated by cost savings. This seems obvious, but the increase in cost of diesel fuel to $2.50 per gallon created more interest in the program than did months of efforts to get fleets to participate. Equipment intended to help reduce fuel consumption becomes interesting when it starts to make economic sense. Fleet managers also stated that they wanted payback periods in the range of two years for the bigger independent fleets to five years for smaller fleets operating mainly for a single retailing organization.

Every trucking fleet involved in this project had to make the cost savings calculation work for it before agreeing to try the equipment. The fleets are highly aware of the significant increases in fuel costs, but it is often difficult to attribute cost savings to the idle-reduction equipment, since the actual savings may be masked by variations in routes, driver behavior, and destination climates. The opportunity to save a minimum of 1,800 gallons of diesel fuel each year and to reduce maintenance costs seems significant—but it is important to understand that adoption of idle-reduction equipment is a change in equipment practice, and not every fleet manager or executive is convinced of the benefit.

Improving Measurement of Savings

Savings in fuel consumption are not easy to measure, and one fleet owner said that his drivers might normally vary by one mile per gallon in a seven-mile-per-gallon truck, depending on the route, the climate, and on driving and idling styles. More than one fleet manager participating in the project expressed uncertainty about the fuel consumption reductions claimed by the project.

Savings of fuel and fuel cost due to idling reduction do not necessarily relate to total fuel consumption. Idling fuel consumption for a truck that idles roughly 1,800 hours per year is roughly 1,800 gallons—out of a total per-vehicle fuel consumption of as much as 24,000 gallons per year. Truck fuel consumption varies with load, terrain, average speeds, and other factors. If improved equipment on the truck allows a reduction in main-engine idling, the fleet may see a consumption savings of 6% or so over a year-long period—a significant cost savings, but possibly difficult to identify and track relative to total truck fuel consumption. This was the primary reason for a reliance on relatively conservative assumptions for calculating the cost savings and reinvestment commitment of the fleet participants.

Improving Data-Collection Methods

The data-collection methodology for this project was unexpectedly problematic. Data collection was the primary method for measuring idling hours and calculating fuel savings. This was important both for determining the fleet cost-share component of the project and for enabling fleet managers to track the benefits of idle reduction. Data was downloaded from three different types of engine computer module (ECM). Although the ECM data downloads provided an inexpensive way to verify idling hour reductions, there were some uncertainties with the data.

ECM data downloads do not indicate what choices the driver is making. They also do not provide any environmental information that might help explain the performance of the idle-reduction equipment. In the future, ECM data downloads should be augmented with component hour meters or inexpensive data acquisition systems that record actual system operation and operating choices made by the drivers.

For limited demonstration programs, tracking the truck location with a global positioning system (GPS) can also be valuable, assuming that driver and fleet concerns about the use of this information can be satisfied. The location of parked trucks is very important to the performance of the onboard shore power capable system and may determine whether a truck operates autonomously off its auxiliary battery or has an AC electrical outlet available. Truck location is also important to understanding the impacts of idling emissions and to siting areas for future infrastructure development.

Acknowledging the Importance of Driver Behavior

Driver behavior is an important variable. As with many new technologies, installing new equipment in the trucks resulted in a high rate of equipment use immediately after installation because of the novelty of the equipment. After a period of time, though, driver enthusiasm waned, and the extent of idle savings tapered off.

Driver behavior is a variable that cannot be ignored in evaluating idle-reduction measures. As Table 4-2 showed earlier, there was quite a lot of variation in the amount of idle reduction from truck to truck and driver to driver. An idle-reduction system in the sleeper cab of one driver allowed a very significant reduction in idling time, while the same system in the cab of another resulted in essentially no change, or even an increase in idling. While it is clear from the aggregate idling data that the onboard equipment provides the capability to potentially eliminate a large fraction of idling, it was not possible to track the experience and behavior of every one of the systems to explain a lack of significant reduction in idling. It is difficult to attribute the variation in the data to anything but a rather broad category of driver behavior.

Although this project did not attempt to quantify the impact of behavior on the effectiveness of idle-reduction technologies, the variability of our results suggests the importance of behavior as a variable. This is a key project result. Maximum idle reduction seems to come from programs that include ongoing training and discussion of idle-reduction savings with drivers at weekly safety meetings.

Acknowledging the Importance of Climate

Another important variable is climate. The trucking industry normally designs air conditioning systems to have the ability to cool the sleeper in extreme climate conditions. This may be excessive for fleets that do not need such high performance, but the nature of the trucking business is that most trucks tend to go all over the country, wherever a customer's freight needs to go. This means that once in a while, trucks may need this peak cooling or heating capability.

On the other hand, an argument can be made for the cost effectiveness of installing systems that might not necessarily meet peak demands. Lower-powered air conditioners function properly when the outside temperature is in a range that does not overwhelm their cooling capacity, and reduce idling through the spring, part of the summer, and through the fall. Idling the main engine might still be necessary during the hottest part of the summer and/or on trips to hotter climates. The smaller air conditioner might therefore result in substantial cost savings and emission reductions even though the driver needs to idle the engine on a few very hot days during the summer.

Acknowledging Differences in Equipment Effectiveness

The effectiveness of idle-reduction equipment in limiting idling costs appears to be a function of the utility of the equipment installed to provide driver comfort. Simple things, like Opti-Idle, reduce idling a little bit. Systems that have more capability to meet driver needs without idling the main engine displace more idling. The utility of different technologies is illustrated in Figure 7-1, which compares the idling hours recorded by trucks in fleet H outfitted with four different systems in the six-month period from November 2004 through April 2005.

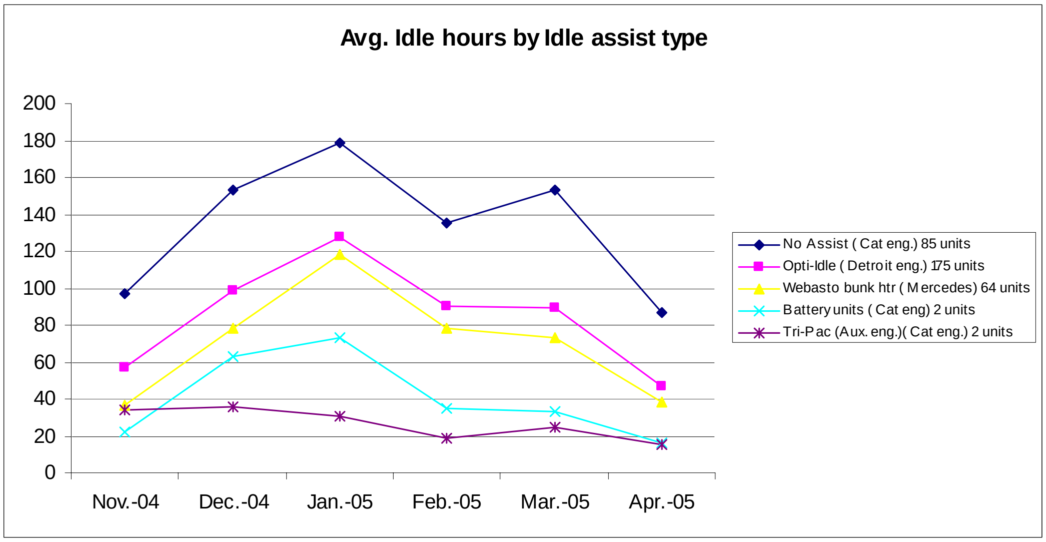

Figure 7-1
Idling Hours by Equipment Type and Month for Fleet H

Idling hours for the period shown were highest in January, presumably the coldest month. The Tri-Pac APU systems installed in two of the trucks reduced idling the most, from the 180-hour fleet baseline in January to about 30 hours. The battery-based HVAC Dometic units were second in effectiveness, reducing idling hours in January to a little more than 50 hours.

Notice that the Opti-Idle system is effective in reducing idling time about 25% to 30% from the fleet average. Opti-Idle works by preventing the engine from idling more than a set time, often programmed for five minutes. Drivers who want heat or air conditioning can activate the engine power-takeoff setting, which operates the engine at a higher speed, which in turn overrides the Opti-Idle equipment. Perversely, the higher speed also means higher fuel consumption and higher emissions, possibly resulting in no net fuel or emission reduction even though the absolute number of hours at idle is reduced.

Taking Into Account Driver Comfort and Choices

This project emphasized understanding the cost equation for installing idle-reduction equipment. This emphasis is valuable for persuading trucking fleets to purchase equipment; however, more consideration of driver comfort and choices might help fleets find solutions that drivers want to use and better understand how to train drivers. Some examples of this kind of data would include rest location choices and preferred ambient temperatures in the sleeper during rest periods.

Making Financing Easy for Owner-Operators

A number of small fleet owners and owner-operators called during 2005 looking for ways to finance idle-reduction equipment. Many truck drivers are interested in receiving support for capital expenditures to reduce idling, as they view the equipment as expensive, and there is not enough operating data so far to establish the reliability of this equipment, which would further reassure truck owners. Significant emission reductions and fuel and cost savings could accrue if a “pay as you save” financing program for APUs, gen-sets, and shore power capable onboard systems was created.

Keeping the Project Simple

This project required both sharing of the original installed system costs and reinvestment of savings. These requirements made the project seem complex to some of the fleet managers. A further indication that the project might have seemed too complex is the fact that to date, no fleet has independently provided a calculation of its cost savings, as required by the participation agreement; all the fleets have accepted the project calculations.

Keeping the Technology Simple

It is possible that some of the limited use of the idle-reduction equipment by drivers during the project was due to the fact that they didn’t fully understand the technology. On the several occasions where a site visit with a truck owner was conducted, some hours were spent explaining the function of the amp-hour counter, how the battery isolator and charging with the alternator worked, and how to determine if the system was working correctly.

Perhaps inclusion of a remote operation device and an instrument panel is not necessary, and the controls accessible to the driver should be minimal—that is, only climate controls. Simpler, more automated controls would certainly help. Better operator training and a simple operation guide may also be necessary.

8
CONCLUSION

This project demonstrated that shore-power onboard technology can provide adequate driver comfort and substantial reductions in idling in sleeper-equipped trucks. The project also demonstrated the motivations of fleet managers relative to idling reduction and to opportunities to reduce costs. While substantial savings and reinvestment of five times the original equipment installation costs have occurred as part of the project effort, the average idling reduction achieved by the project is only 50% of the total idling time for these fleets. This results in a payback period of 4.9 years for the overall project. The best-performing fleet, however, realized a 70% reduction in idling hours from baseline, and a 2.2-year simple payback period.

There was a very significant variability in idle-reduction results. This variability is thought to result from differences in driver behavior, differences in climactic conditions during the data-sampling period, and differences in equipment effectiveness at meeting drivers' needs. Data-collection efforts did not provide adequate information to identify specific causes of variability. In the future, more attention should be given to driver satisfaction, variations in climate and rest period conditions, and driver motivation.

Shore-power onboard technology has a great potential to reduce idling costs. While an average truck might consume $20 worth of fuel for a rest period, using batteries charged by the engine or using an APU for the same period costs about $4.41, and using batteries charged by shore power costs $1.20. These cost savings are attractive to trucking fleets. Drivers seem to like the quieter rest period and the idea of saving fuel and reducing emissions. Additional cost savings would be possible if thermal insulation were installed in the truck sleeper.

Finally, some would say that the low-powered air conditioning systems tested so far are not good enough. Likewise, APUs and gen-sets could be improved. This project shows that cost savings and emission reductions in fact rely on drivers adopting new behaviors. More emphasis should be placed on selling the need to reduce idling to the drivers. Perhaps future projects can include materials for fleet managers to use in facilitating this behavior shift.

A
PARTICIPATION AGREEMENT

PARTICIPATION AGREEMENT

This Participation Agreement (Agreement) is entered into by and between **AnyFleet Inc.,** a _______ Corporation (“**AnyFleet**”), and the Sacramento Municipal Utility District, a municipal utility district in the State of California ("SMUD"). SMUD and AnyFleet are hereinafter referred to collectively as the "Parties" and individually as a "Party."

RECITALS

Whereas, SMUD on submitted a proposal providing financial commitments relative to the **Truck Electrification Project** to the Electric Power Research Institute (EPRI), and this proposal was subsequently submitted to the Federal Environmental Protection Agency on October 15, 2002; and

Whereas, on September 2, 2003 EPRI and SMUD entered into an Agreement under which SMUD will manage the project and enter into subcontracts with trucking fleets to facilitate demonstration of idle reduction equipment by reimbursing a portion of the cost of such equipment; and

Whereas AnyFleet wishes to participate in this program to demonstrate truck electrification equipment on AnyFleet owned and operated trucks; and

Whereas, the Parties agree to act in good faith to incur only costs allowable under applicable federal cost guidelines.

NOW, THEREFORE, AnyFleet and SMUD agree as follows:

1. PROJECT FUNDING

A. The Parties agree that release of EPA funds to SMUD by EPRI is a condition precedent to SMUD’s duty to release any funds under this Agreement.

   SMUD agrees to provide to AnyFleet funds received from EPRI in the amount of up to ___. Conditions for Payment of these funds to AnyFleet are provided in Sections 4 & 5 of this Agreement.

2. PROJECT SCOPE

A. AnyFleet will acquire _____ idle reduction systems that utilize batteries, air conditioners, and an inverter. AnyFleet, working with the system suppliers, is responsible for acquisition and installation of these systems in AnyFleet trucks. The systems shall be installed by _____ 2004. Schematics and instructions for the systems are available from the suppliers.
B. SMUD will reimburse AnyFleet part of the cost of each system installed, as described in Section 5, below.
C. AnyFleet will download engine computers at the time of installation, and no less frequently than quarterly there after for one year following the installation. AnyFleet will provide a paper copy of these ECM downloads to the SMUD Program Manager.

D. AnyFleet agrees to facilitate driver training in system use with assistance from the suppliers.

E. After the first 9 months of the project, AnyFleet agrees to reinvest the projected-annualized fuel savings for one year of operation in additional idle reduction equipment. The amount to be reinvested shall be estimated by AnyFleet with assistance from SMUD using the ECM data. For simplicity, this analysis shall utilize a fuel consumption figure of 0.82 gallons per hour times the actual idle reduction time realized as shown by the ECM data. An additional $1.00 per day for engine maintenance as suggested in TMC1108 shall be included. Fuel cost shall be according to a nationally published fuel cost. Six months after the start of the project, AnyFleet shall submit a letter to SMUD indicating the equipment to be purchased, and providing a copy of an invoice or other documentation of the purpose that will satisfy audit requirements for Federal Grants, as defined by SMUD.

F. AnyFleet agrees to participate in the Truck Electrification Project with SMUD as reasonably needed to evaluate and demonstrate the technology, during the term of this Agreement. Such participation may include showing the truck to other truckers and utilizing the shore power facilities as much as possible.

G. No data or intellectual property will be developed through the work performed under this Agreement. This project is an equipment demonstration project only.

3. TERM OF AGREEMENT

This Agreement shall commence upon the effective date and shall, unless earlier terminated pursuant to Section 18, below, continue in effect until **March 31, 2005.**

4. CONTRACT PRICE

SMUD will reimburse AnyFleet Trucking Inc for up to half of the installed cost of the idle reduction systems utilizing EPA Grant project funding. The anticipated reimbursement is up to ___ to outfit ____ trucks. In no case shall the reimbursement paid to AnyFleet exceed ___(Funds are limited and subject to prior commitment)

5. MANNER AND TIME OF PAYMENT

AnyFleet shall submit an invoice within 30 days after the installation of the equipment.

Each Invoice shall be marked with SMUD contract No. ____ and directed to:

Accounts Payable, MS A302
Sacramento Municipal Utility District
P. O. Box 15830
Sacramento, CA 95852-1830

The invoice shall include copies of invoices for the purchase of the idle reduction equipment. A brief report of labor and other costs incurred shall also be provided, to allow verification that SMUD is reimbursing up to half of the installed system costs.

SMUD shall process and pay all uncontested invoices within 30 days of receipt thereof.

6. ADMINISTRATIVE DATA

A. The following administrative data pertains to this contract:

AnyFleet Project Manager: John Doe
Phone:
FAX:
Email:
Mailing address:
Tax ID ________

SMUD Contract Manager: William R. Warf
Telephone (916) 732-6976
FAX (916) 732-6839
Email: bwarf@smud.org
Mailing address:
SMUD
PO Box 15830 MS A-351
Sacramento, CA 95852-1830

Charge Costs to: Cost Center 518; Work Order No. **21000800**; Cost Element 550030

7. INDEMNITY

A. AnyFleet hereby indemnifies and releases SMUD, and agrees to defend and hold SMUD harmless, from and against any and all claims, causes of action, demands, judicial and administrative proceedings, losses, liabilities, damages, costs and expenses, including without limitation, court costs and reasonable fees and expenses of attorneys and consultants, arising out of AnyFleet's negligent or wrongful acts or omissions in performance of this Agreement. Nothing in this Section imposes on AnyFleet any responsibility to pay, or indemnify SMUD, for any damages resulting solely from SMUD's willful misconduct or gross negligence, but AnyFleet shall have the duty to defend against any losses, claims damages or suits notwithstanding any allegation about the type or extent of SMUD's negligence or misconduct.

B. SMUD hereby indemnifies and releases AnyFleet, and agrees to defend and hold AnyFleet harmless, from and against any and all claims, causes of action, demands, judicial and administrative proceedings, losses, liabilities, damages, costs and expenses, including without limitation, court costs and reasonable fees and expenses of attorneys and consultants, arising out of SMUD's negligent or wrongful acts or omissions in performance of this Agreement. Nothing in this Clause imposes on SMUD any responsibility to pay, or indemnify AnyFleet, for any damages resulting solely from AnyFleet 's negligent, willful or criminal misconduct, but SMUD shall have the duty to defend against any losses, claims damages or suits notwithstanding any allegation about the type or extent of AnyFleet's negligence or misconduct.

C. This indemnity includes all costs and expenses reasonably required to investigate and to defend any such claim or action, any amount paid or required to be paid to settle any such claim or action, any amount paid or required to be paid to settle any such claim or action, and any amount finally awarded by a court as damages or otherwise in any such action, provided that neither party will have an obligation to pay or to reimburse the other party for the amount of any internal expenses (including, but not limited to, compensation paid to employees) that it may incur in connection with its cooperation in the investigation and/or defense of such claim or action. This indemnification obligation shall survive termination of this Agreement.

7. INSURANCE REQUIREMENTS

Without limiting any of the other obligations or liabilities of AnyFleet, AnyFleet shall provide SMUD with evidence of insurance as specified in Appendix A, “SMUD Insurance Requirements for Subcontractors”.

8. RESOLUTION OF DISPUTES

AnyFleet and SMUD shall make a good faith effort to implement this Agreement in a manner that is acceptable to both AnyFleet and SMUD. If AnyFleet and SMUD should disagree over any matter arising out of this Agreement, AnyFleet and SMUD shall endeavor to resolve such disagreement through informal consultation. Any dispute arising under this Agreement that is not settled by agreement of the Parties shall be submitted to the exclusive jurisdiction of the courts of the State of California. SMUD and AnyFleet each waive its right to a jury trial in any dispute arising under this Agreement.

10. PROJECT PROPERTY OWNERSHIP

Title to all nonexpendable and expendable tangible personal property purchased or otherwise acquired through the direct Project work of AnyFleet shall be deemed to have vested in AnyFleet upon purchase, fabrication, or manufacture.

11. EQUAL EMPLOYMENT OPPORTUNITY

AnyFleet shall not discriminate against any employee or applicant for employment on account of race, religion, gender or sex, color or national origin, handicap or age. AnyFleet shall ensure that this requirement is applied to applicants and employees in actions including, but not limited to employment, upgrading, promotion, demotion or transfer, recruitment or recruitment advertising, layoff or termination, rates of pay or other forms of compensation and selection for training, including apprenticeships.

12. MINORITY/WOMEN OWNED BUSINESS ENTERPRISES

It is the policy of SMUD that minority and women owned business enterprises shall have the maximum opportunity to participate in SMUD's contracts. In this regard, AnyFleet shall take the necessary and reasonable steps to ensure that minority and women owned business enterprises have the maximum opportunity to participate in this Agreement to the extent applicable. AnyFleet shall not discriminate on the basis of race, religion, sex, color or national origin, handicap or age in the award or performance of any contract or subcontract resulting or relating to these services.

13. ASSIGNMENT

Neither Party may assign this Agreement, either in whole or in part, without the prior written consent of the other Party.

14. NO JOINT VENTURE

It is expressly acknowledged and agreed that the Parties have not entered into a joint venture of any kind in regard to the subject matter of this Agreement and this Agreement shall not be construed to constitute a joint venture between the Parties for any purpose whatsoever.

15. FORCE MAJEURE

Neither Party shall be considered in default in the performance of its obligations under this Agreement to the extent that the performance of any obligation is prevented or delayed by any cause, existing or future, which is beyond the reasonable control of the affected Party.

16. CALIFORNIA LAW

This Agreement shall be construed and interpreted in accordance with the laws of the State of California, without regard to its conflict of laws provisions.

17. AMENDMENTS

This Agreement shall be amended only in writing, and any such amendments shall be identified specifically as amendments to this Agreement, and shall be duly executed by both Parties.

18. TERMINATION

Either party may terminate this Agreement for any reason by providing 30 days notice of such termination. Upon termination, SMUD agrees to reimburse AnyFleet for its share of half of the installed truck electrification system costs incurred as of the date of termination.

19. DISCLAIMER OF WARRANTIES

SMUD makes no representations, expressed or implied, regarding the sizing, installation, reliability, efficiency, performance, operation, maintenance, or use of any Idle Reduction Equipment, inverter, air conditioner, battery system, or other component that may be installed in the course of this project. Any decision regarding the selection, design, installation, use and operation of any equipment or system shall be made at the sole discretion of and are the sole responsibility of AnyFleet Trucking Inc.

20. LIMITATION OF LIABILITY

SMUD's liability to AnyFleet for any loss, cost, claim, injury, liability, or expense, including reasonable attorney's fees, relating to or arising from any act or omission in its performance of the Agreement, shall be limited to the amount of direct damages actually incurred or the amount of this Agreement, whichever is less. In no event shall SMUD be liable to AnyFleet for any indirect, special, consequential, or punitive damages of any kind whatsoever, whether in contract, tort, or strict liability.

21. ENTIRE AGREEMENT

This Agreement constitutes the entire agreement between the Parties concerning the subject matter of this Agreement, and supersedes any prior understanding or agreement between the Parties regarding the Project, whether oral or written.

IN WITNESS THEREOF, the parties hereto have caused their duly authorized representatives to execute this Agreement as of the dates shown below.

AnyFleet Inc.

By: ______________________________ ____________
Date

SACRAMENTO MUNICIPAL UTILITY DISTRICT

By: ______________________________ ____________
Jim Parks, Program Manager, Energy Efficiency & Customer R&D Date

B
PRESENTATION TO POTENTIAL FLEET PARTICIPANTS

Idle Reduction Demonstration

A Proposal For Trucking Fleets

Prepared by Bill Warf, SMUD

916-732-6976

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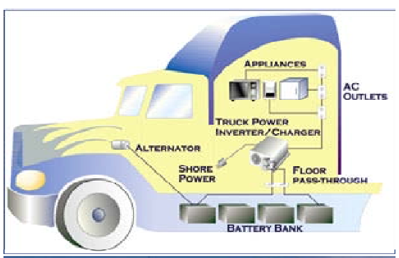
The Power To Do More.℠

Idle Reduction System



- •Quiet, comfortable rest periods- without expense of idling
- •HVAC features set temperature climate control
- •Battery Isolator assures starting batteries are charged
- •Grid connected or grid autonomous Operation
- •Inverter-Charger automatically controls power from grid and batteries
- •In cab wiring for additional appliances

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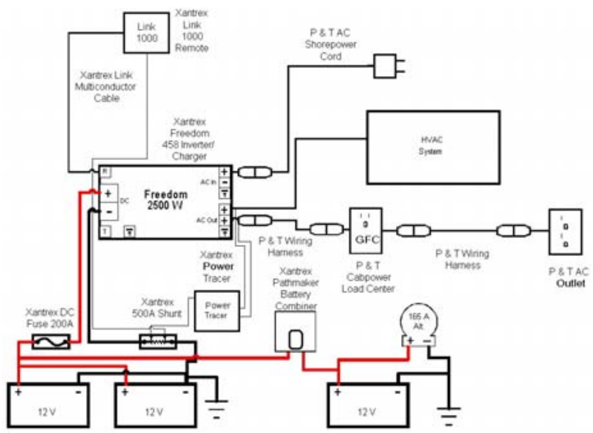
Configuration

Schematic:



Deep cycle batteries

Starting batteries

System Includes:

- Air Conditioner
- Batteries
- Inverter-Charger
- A-h Counter
- Battery Isolator
- In Cab Wiring

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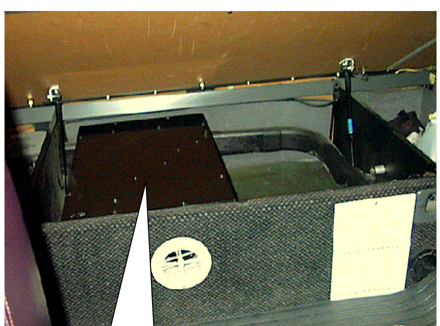
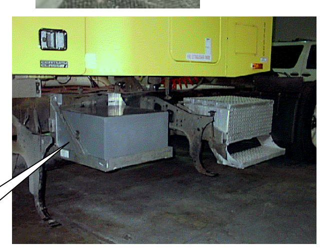
Product History:

- **Five systems installed and tested**
- **34 More Systems on order**



Amp hour counter and Air conditioner control & receptacle



Dometic Air Conditioner

Battery Box- 510 A-h

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System Choices

Air Conditioner	Weight (Lbs)	Run Time (hours)	InstalledCost ($)
Dometic AC	306	2 to 3	$5,688
7500 BTU/h	474	4 to 6	$6,307
with Sealed Batteries	642	8 to 10	$7,050

•Costs include basic system plus

•$1050 installation labor

•$200 cables, small goods

•$700 200 amp alternator

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Financial Details

Costs:

- 1 Battery system: $3738
- 2 Battery system: $4357
- 3 Battery system: $5100
- Installation Labor
  30 h * $35/h = $1050
- Truck install time $200

Subtotal: (2batt) $5600

Grant Funding: $2800

Net cost to Fleet: $2800

Savings:

- Fuel Savings: >$2250/ year
- Engine Oil Change Interval increase: $0.72/ day (TMC-1108)
- Engine Rebuild interval: $0.40/day

Total: > $2500 per year

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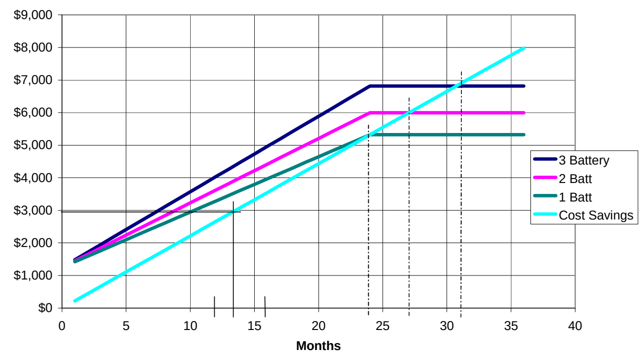
Grant funding reduces Pay Back Period to about one year



36% ROI without Grant Funds >60% with Grant Funds

($1.50/gallon assumed)

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Program Details

- Funding from an EPA Grant will pay half the cost of a climate control and sleeper compartment power system for fleets of Class 8Trucks
- In this project, the Trucking company must
  - assist with installations (labor and equipment cost)
  - Provide Engine Computer downloads to track idle reduction time
  - Assist with driver surveys
  - Reinvest the actual energy and maintenance savings from first year in idle reduction equipment
- Grant Funds are limited and are subject to prior commitment.

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Summary

- With Grant funds the payback period is reduced to about one year before reinvestment of the savings
- Drivers realize quieter more comfortable rest periods
- System technology has been tested and proven
- Trucking Fleets save $2500 per year per truck outfitted with these systems

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Export Control Restrictions

Access to and use of EPRI Intellectual Property is granted with the specific understanding and requirement that responsibility for ensuring full compliance with all applicable U.S. and foreign export laws and regulations is being undertaken by you and your company. This includes an obligation to ensure that any individual receiving access hereunder who is not a U.S. citizen or permanent U.S. resident is permitted access under applicable U.S. and foreign export laws and regulations. In the event you are uncertain whether you or your company may lawfully obtain access to this EPRI Intellectual Property, you acknowledge that it is your obligation to consult with your company's legal counsel to determine whether this access is lawful. Although EPRI may make available on a case-by-case basis an informal assessment of the applicable U.S. export classification for specific EPRI Intellectual Property, you and your company acknowledge that this assessment is solely for informational purposes and not for reliance purposes. You and your company acknowledge that it is still the obligation of you and your company to make your own assessment of the applicable U.S. export classification and ensure compliance accordingly. You and your company understand and acknowledge your obligations to make a prompt report to EPRI and the appropriate authorities regarding any access to or use of EPRI Intellectual Property hereunder that may be in violation of applicable U.S. or foreign export laws or regulations.

The Electric Power Research Institute (EPRI)

The Electric Power Research Institute (EPRI), with major locations in Palo Alto, California, and Charlotte, North Carolina, was established in 1973 as an independent, nonprofit center for public interest energy and environmental research. EPRI brings together members, participants, the Institute's scientists and engineers, and other leading experts to work collaboratively on solutions to the challenges of electric power. These solutions span nearly every area of electricity generation, delivery, and use, including health, safety, and environment. EPRI's members represent over 90% of the electricity generated in the United States. International participation represents nearly 15% of EPRI's total research, development, and demonstration program.

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