technical brief

Truck Stop Electrification: A Cost-Effective Solution to Reducing Truck Idling

Electric Transportation Program

Introduction

About 1.3 million[1] of the nation's 2.5 million heavy-duty trucks are equipped with sleeper berths and operate on U.S. highways and transportation corridors at any one time. Drivers of these long haul trucks are required by the U.S. Department of Transportation to comply with truck driver hours-of-service regulations.[2] These complex regulations fundamentally allow an 11-hour driving period after a 10-hour off-duty (rest) period. During this rest time, drivers typically idle their truck to maintain sleeper cab comforts. Each long-haul truck idles an average of 1,830[3] hours per year. Shorter idling periods occur at warehouses, truck fleet terminals and distribution centers, while longer overnight idling periods occur at designated truck stops (public and private) as well as roadside.

Unfortunately, this idling creates significant pollution and wastes valuable fuel. As a fleet, sleeper truck idling consumes more than 915 million gallons of fuel annually.[4] In addition, truck idling creates a noise problem and emits harmful air pollutants, totaling a combined 272,000 tons per year[5] of oxide of nitrogen (NO_x), particulate matter (PM), hydrocarbons (HC) and carbon monoxide (CO), with an additional 9.2 million tons per year of carbon dioxide (CO_2), a greenhouse gas.[6]

To address these problems, there are a number of programs[7] around the country to ban or restrict idling. For trucks with sleeper cabs, bans are not practical or reasonable, since long haul truck drivers must be able to maintain a comfortable environment for a healthy rest period. Instead, stakeholders are studying workable options to an outright ban on sleeper cab truck idling, including truck stop electrification, or TSE.

Why Truck Drivers Idle During Extended Rest Periods

- For heat or air conditioning for the cab and sleeper berth
- To provide electrical power for appliances such as refrigerator, freezer, microwave and entertainment (i.e., TV, DVD, VCR, CD, laptop, etc.)
- To keep the fuel warm in winter
- To keep the engine warm during cold weather (to address restart concerns)
- A long-practiced habit

Truck Idling Impacts Quantified

Each year an idling sleeper truck:

- consumes an average of 1,830 gallons of diesel fuel per truck,
- emits 18.4 tons of CO_2 per truck,
- emits 0.33 tons of NO_x per truck,
- emits 11.3 pounds of diesel particulate matter, which adds up to nearly 2,800 tons per fleet,
- causes significant noise disturbances for local residents.

---

1 "How Many Sleeper Trucks in the U.S.?", IdleAire Technologies, 2002. This estimate is based on the 1997 U.S. Census Bureau's Vehicle Inventory and Use Survey (VIUS), the 1992 Truck Inventory and Use Survey (TIUS) and a number of interviews with trucking industry leaders, including the American Trucking Association and truck manufacturers.

2 http://www.fmcsa.dot.gov/Home_Files/revised_hos.asp

3 "Analysis of Technology Options to Reduce the Fuel Consumption of Idling Trucks," Department of Energy study by the Center for Transportation Research at Argonne National Laboratory: June 2000. ANL/ESD-43

4 Based on 500,000 sleeper trucks @1,830 hours/yr/truck. Also, diesel engine fuel consumption during idling, for sleeper trucks with accessory loads is about 1 gallon per hour. Source: "Study of Exhaust Emissions from Idling HDD Trucks and Commercially Available Idle-Reducing Devices," Table 7, U.S. EPA, Report Number EPA420-R-02-025, October 2002.

5 These are tank-to-wheels, or tailpipe emissions.

6 Calculations based on 1,830 hours per year per truck, 500,000 trucks in the nation's fleet and the following emissions factors for pre-2007 diesel engines (g/hr): PM = 2.77; NO_x = 165; CO = 90; HC = 12; CO_2 = 9,140. These factors are consistent with other available test data. Source: "Airborne Toxic Control Measure to Limit Diesel-Fueled Commercial Motor Vehicle Idling," Staff Report: Initial Statement of Reasons for Proposed Rulemaking, California Air Resources Board (ARB), July 2004.

7 Summary of State Anti-Idling Regulations, EPA420-S-03- 002, February 2003 http://www.epa.gov/otaq/smartway/documents/statelaws.pdf

Additionally, sleeper truck idling necessitates more frequent maintenance—shorter oil change and engine overhaul intervals—at a cost of $1.13 per day, or over $300 annually.[8]

Per Truck Equivalency. Replacing one sleeper truck's idle hours per year with electric power reduces the same amount of NO_x emissions as removing 360 passenger cars from the road each year,[9] and saves an average of 1,830 gallons of diesel fuel, annually. In addition, the CO_2 reductions per year are the equivalent of removing three cars from the road or planting over 1,500 full size trees.[10]

Per Space Equivalency. Electrifying one truck stop parking space that is used 16 hours[11] per day (5,840 hr./yr., assumes multiple shifts per day at each space) can provide NO_x reductions equal to removing nearly 1,150 new passenger cars per year, and can cut annual diesel fuel consumption by more than 5,840 gallons.[12] Electrifying one space can also reduce CO_2 emissions equal to removing nearly 10 cars from the road or planting nearly 5,000 full-size trees, annually.[13]

Truck Driver Benefits From TSE

TSE allows truck drivers to turn off their engine and still maintain cab comforts. Drivers benefit in the following ways:

- No engine vibration or noise, resulting in a better night's sleep
- No exposure to harmful emissions, including increased CO_2 concentrations, which have been linked to driver headaches, nausea, and dizziness[14]
- No diesel powered auxiliary power unit (APU) that cycles on and off during the rest period, interrupting sleep
- Extended oil change intervals and engine life resulting from less wear on the engine, resulting in maintenance cost savings estimated by EPA to be $1.13 per day
- Significant annual fuel cost savings[15] ($3,220 on average, per year)[16]
- The ability to use appliances without an adverse affect on truck charging and battery systems.

Two Major Types of Truck Stop Electrification

Off-board TSE systems have extensive infrastructure, including HVAC systems. Any of today's sleeper cabs, including more modern sleeper cabs that are shorepower-equipped with plugs and on-board HVAC, can use off-board TSE systems. The off-board HVAC is located in a structure above the truck parking spaces. A hose from the HVAC system and a module containing AC power outlets and Internet connection are connected to the truck window, while a computer touch screen provides control, enables payment, and offers premium entertainment options. Stand-alone systems are owned and maintained by private companies that charge an hourly usage fee.

Shorepower TSE systems have on-board HVAC systems (and other amenities) and plugs on the truck so the truck can use AC power from any 120 V outlet. However, many places that trucks idle do not have convenient outlets. Infrastructure for this type of TSE is much less extensive than with off-board TSE. The main challenge for shorepower TSE systems is solving the so-called "chicken and egg" problem[17]. Sleeper cabs must either be retrofitted to be shorepower-capable, or more and more factory-equipped new trucks must have plugs. Current industry trends suggest that trucks will in the future be equipped with diesel auxiliary power units and wired to

What is TSE?

Truck stop electrification (TSE) allows truckers to "plug in" their vehicles while stopped, in order to operate air conditioning, heating, and appliances without any engine idling. Truck stop electrification technologies fall into two major categories: "off-board" and "on-board" systems. Off-board systems are fixed, stand-alone units installed at the truck parking space. These systems provide heating, ventilating, and air conditioning (HVAC), and may also include AC electrical power and entertainment, communications, or Internet features. With an on-board system, the HVAC equipment and electrical inverter/charger is mounted on the truck, which only requires an off-board electrical source to power this equipment and maintain cab comforts.

---

8 http://www.epa.gov/smartway/idlingimpacts.htm

9 Calculation: Truck idling NO_x per year: 1,830 hr/yr * 165 g/hr = 665 lbs/yr. New passenger car emissions: 0.07 g/mi * 12,000 mi/yr = 1.85 lbs/yr. Note: 0.07 g/mi is the 2004 Federal average tailpipe NO_x standard. http://www.fhwa.dot.gov/environment/aqfactbk/factbk12.htm.

10 Calculation: Truck idle CO_2 is 9,140 g/hr * 1,830 hr/yr = 18.4 tpy; CO_2 for a 2009 passenger car is 449 g/mi, at 12,000 mi/yr = 5.94 tpy. According to the Tree Canada Foundation, about 500 full-sized trees absorb the carbon dioxide produced by a typical car driven 12,427 mi/yr. http://www.treecanada.ca/publications/trivia.htm (CO_2 emission factor source: CARB Staff Report: Initial Statement of Reasons for Proposed Rulemaking to Control Greenhouse Gas Emissions from Motor Vehicles, Table ES-1, page iv, August 6, 2004.)

11 In their Idle Reduction staff report, CARB's benefits analysis assumes 20 hours per day of idling at a commercial truck stop space, an average of 80 percent of the time (0.8 * 20 = 16).

12 Calculation: Trucks idle 16 hours per day at the space, 365 days per year at the rate of 1.0 gallons per idle hour.

13 All calculations similar to previous example, but with 5,840 hours instead of 1,830 hours.

14 http://www.nyserda.org/Press_Releases/PressRelease.asp?i=18&d=2004

15 Note that fuel cost savings are partially offset by the operating cost of the TSE; however, there remains a significant net savings in operating costs of TSE as long as the per gallon cost of diesel fuel is above the hourly cost of TSE power.

16 Trucks that idle 300 days per year, 13 hours per day (3,900 idle hours per year) could save as much as $6,864 in reduced fuel costs (based on $1.76 per diesel gallon).

17 Which comes first? Electrification infrastructure or on-board plug-in capability?

Figure 1. Truck Plugged Into Shorepower at the 49er Truck Stop in Sacramento.

Figure 2. IdleAire TSE Installation.

accept shorepower. This preserves the ability to run appliances when shorepower is not available, while providing the opportunity to take advantage of lower cost and lower maintenance shorepower when available. Another approach is the inclusion of a small deep cycle battery pack along with shorepower equipment so that grid autonomous operation of appliances on electricity is enabled. These battery based systems can easily be recharged using an inverter charger system, or by fitting a larger alternator to the engine.

Societal Benefits From TSE

There are many important societal benefits associated with reduction of extended (i.e., overnight) truck idling, including[18]:

- toxic air pollutant reductions, including formaldehyde and diesel PM,
- health and safety benefits of well-rested truck drivers,
- CO_2 emission reductions, important in the effort to mitigate global climate change,
- fuel consumption reductions resulting in a decrease in foreign oil import dependence,
- cost savings (i.e., fuel savings, decreased maintenance costs, and longer engine life) to truck owners that translate to lower cost of goods,
- reduced noise at truck stops, distribution centers, and other areas,
- responding to environmental justice concerns since truck stops are often located near low-income and minority populations.

Emission Reduction Benefits of TSE

Table 1 summarizes the range of emission and fuel reduction benefits achievable from idle reduction that uses TSE, based on low and high case utilization rates. The low case is conservative and is based on a usage of five hours per day, 365 days per year. The high case is based on an assumed 16 hours per day of idling, previously noted. Of course, as the trucking industry's interest in TSE grows, so will its utilization.

Capital and Life-Cycle Costs/Savings of TSE

Table 2 provides an overview of current TSE technology options and an estimate of their associated costs. The cost-effectiveness of TSE implementation, based only on capital costs, is summarized in Table 3. It should be noted that cost-effectiveness is a tool used by air pollution control agencies to rank air quality pollution projects' ability to reduce emissions at the least cost. When evaluating cost-effectiveness, the lower the value, the better. TSE implementation is an extremely cost-effective air quality improvement strategy, even if only the capital costs are evaluated, when compared to existing emission reduction grant incentive programs.[19]

As noted earlier, if the full life-cycle benefits of fuel and maintenance savings from TSE are included in the TSE cost analysis, there is a net savings to the overall project. The range of annual savings for the low and high cases for the off-board scenario is $251 to $3,021 per year. The range of annual savings for the low and high cases for the shorepower with on-board HVAC is $2,373 to $7,834. Note that this savings is likely to be distributed over multiple trucks/ shifts. It is also important to realize that, depending upon what TSE technologies are chosen and how they are financed; the savings may not directly accrue to the persons who are bearing the cost. For example, fuel and maintenance savings accrue to the truck owner/operator, but the cost of installing TSE infrastructure may fall on the truck stop owner or on a third party. These situations may require fee and billing systems between the parties. Additionally, although there are savings over the full life cycle of TSE equipment, the initial cost

Table 1. Range of Benefits From TSE

Description	Low Case: 1,825 Hr/Yr (One Truck per Space)	High Case: 5,840 Hr/Yr (Multiple Trucks per Space)
PM (Pounds/Yr) Pre-2007	11.14	35.66
PM (Pounds/Yr) 2007 & Later	1.13	3.61
CO_2 (Ton/Yr)	18.4	58.84
NO_x+HC (Ton/Yr)	0.36	1.14
Diesel Gallons per Year	1,825	5,840

18 Guidance for Quantifying and Using Long Duration Truck Idling Emission Reductions in State Implementation Plans and Transportation Conformity, Office of Transportation and Air Quality, EPA420-B-04-001, January 2004 http://www.epa.gov/smartway/documents/420b04001.pdf

19 For example, a sample of current air pollution reduction grant programs fund PM reductions for between $7 and $89, NO_x for between $423 and $60,000, and CO_2 for between $4 and $11 per metric ton.

Table 2. Estimated Costs for Idle Reduction Electric Technology Options[20]

TSE Technology Options	Description	Examples	Infrastructure Cost Per Space	On-Board Cost Per Truck	Operating Costs	Notes
Off-board TSE	AC power and HVAC available at parking spaces, no truck modification required, system also includes internet, entertainment	IdleAire	$15,000[21]	$10 for window template one-time charge	$1.25 per hour charged to user	Hourly charge does not include Internet and premium entertainment options
Shorepower TSE with on-board HVAC	AC power at parking spaces, allowing HVAC and appliance to run on shorepower	Shurepower, 49er Plaza	$2,600 to $6,000	$189 to $3,500	$0.50 per hour to $1 per night	Usually requires inverters and electrically driven HVAC
On-board battery packs[22]	Advanced on-board power pack system, battery powered for hotel and auxiliary loads; works independently of main engine	Idling Solutions, Dometic, Shurepower	$0	$3,500 to $8,000	$0 for shorepower but battery replacement could be expensive.	Power availability and run time is limited
Independent designs adaptable to shorepower that allow two to four hours of cab heating or cooling.	Use of off-the-shelf components (for example an $88 A/C unit and $10 heater), could be designed to use shorepower	Robert Jordan Orbit System at www. idlefree.net	$2,600 to $6,000 (assumed to be same as other Shorepower infrastructure)	As low as $88	$0.50 per hour to $1 per night	
Combination: shorepower TSE where on-board diesel APU has plug-in capability	Installation of a diesel APU with plug-in capability		$2,600 to $6,000 (assumed to be same as other Shorepower infrastructure)	$8,500 for the APU (includes HVAC plus incremental cost for plug-in capability)	$0.50 per hour to $1 per night	

[20] Based on industry literature and interviews (Bill Warf (Sacramento Municipal Utility District), Bob Wilson (IdleAire), Mark Duvall (EPRI)), CARB staff (John Kato and John Gruszecki) and literature research of TSE-related websites.)

[21] Value provided by R. Cromie (Southern California Edison) based on notes taken during the meeting discussion associated with a presentation by Tom Badgett (IdleAire) at the May 17–19, 2004 National Idling Reduction Conference in Albany, NY, where Mr. Badgett indicated Idle Aire pays $15,000 per space.

[22] This is an idle reduction strategy, not a TSE technology. It is included here because it is easily adaptable to incorporate TSE.

Table 3. TSE Cost-Effectiveness Based Only on Capital Costs[23]

Pollutant	Shorepower w/ On-Board HVAC	Shorepower w/ On-Board HVAC	Off-Board TSE	Off-Board TSE
	One Truck per Space (Early Years)	Multiple Trucks per Space (Later Years)	One Truck per Space (Early Years)	Multiple Trucks per Space (Later Years)
	1,825 hours[24]	5,840 hours	1,825 hours	5,840 hours
PM ($/lb) Pre-2007	$23	$16	$90	$28
PM ($/lb) 2007 & Later	$226	$160	$895	$280
NO_x + NMHC ($/Ton)	$716	$506	$2,832	$885
CO_2 ($/Ton)	$14	$10	$55	$17

can be quite large, and can be a barrier to implementation in the trucking industry which is extremely cost-sensitive. So public incentives may be necessary to overcome these barriers and achieve the emissions reductions and other societal benefits that TSE provides.

Even when TSE is compared against diesel trucks that are equipped with diesel APUs, TSE is cost-effective. For example, when sleeper trucks that are equipped with diesel APUs are instead operated at off-board TSE sites for a total of 5,840 hours, it results in a NO_x +NMHC cost effectiveness of $5,105 per ton (compared to $885 per ton for displacing main engine idling).[25]

An Alternative Approach to Incentives

The trucking industry is extremely competitive, with low margins and high fixed costs, including fuel prices, capital equipment, labor competition, and insurance. Consequently, a truck fleet's investment in a new technology must realize a relatively short payback period of two to three years. Incentives for TSE would help to ensure that the short payback period required by the trucking industry can be realized. Grants or emission reduction credit programs for TSE may best be targeted to different industry participants. Specifically, incentives to the truck stop could be based on the NO_x, HC and PM reductions at the truck space (which are a local "criteria pollutant" concern), while incentives to the truck owner could be based on the CO_2 benefits (which are a national, even global issue). Under this scenario, a truck stop could receive $4,600 per space per year for a 20-year project life for reducing its criteria pollutants.[26] Similarly, the trucker could receive a grant of about $588 per year for reducing his annual CO_2 emissions over a seven-year project life (at $10 per ton[27]). A number of grant programs throughout the country, including Congestion Mitigation and Air Quality (CMAQ) funds (nationwide), the Carl Moyer Program in California and the Climate Trust in Oregon, fund TSE projects.

But Aren't Diesel Engines Getting Cleaner?

Why do we need to worry about diesel engine emissions, when new engines will be cleaner in a few years? It is true that in 2007 heavy-duty diesel engines are required to meet more stringent emission standards. However, the ARB believes that the 2007 standards will not reduce idle emissions for any pollutant other than PM. Specific to NO_x, ARB says: "NO_x catalysts require a minimum temperature (light-off) for a catalytic reaction to occur. The light-off temperature for NO_x catalysts is generally above 150°C, while exhaust temperatures during extended idling are typically below 110°C. Therefore, it can be concluded that engine-out NO_x and ROG emissions will remain unaffected by the catalysts at the low exhaust temperatures that exist during engine idling." Furthermore, existing dirtier (with respect to PM) trucks will remain in the fleet for many years to come. (ARB Idle Reduction Staff Report, July 2004)

TSE Information and Industry Resources

Please visit the following websites for additional information:

http://www.idlingsolutions.com/Prod.html
http://www.idleaire.com/
http://www.shurepower.com/
http://www.antaresgroupinc.com
http://www.idlefree.net
http://www.eere.energy.gov/vehiclesandfuels/resources/fcvt_national_idling.shtml
http://www.epa.gov/smartway/idling.htm
http://www.epa.gov/smartway/idlingtechnologies.htm
http://www.nyserda.org/transportation/truckstopelec.pdf

23 Capital costs for shorepower with on-board HVAC assumed to be $2,600 for infrastructure and $500 per truck (5 trucks for the later years case); capital costs for off-board TSE assumed to be $15,000 for infrastructure and $0 per truck.

24 This assumption was established based on consideration of a single truck offsetting all idle hours with TSE; in the early years of TSE implementation, it is likely that TSE utilization will be less.

25 This change in cost-effectiveness is primarily due to the assumed lower emissions of diesel APUs. Also assumes that trucks with diesel APUs are wired for shorepower, and are much cleaner than they are today. Emissions factors for 2009 diesel-fueled APUs (g/hr): PM = 0.28; NO_x = 29; CO = 11.66; HC = 1.68; CO_2 = 2,266. Source: John Gruszecki, California Air Resources Board (factors revised from initial staff report).

26 Based on a $3,500 per ton of combined (NO_x +HC+10*PM) annual emissions and the high case of 5,840 hr/yr.

27 Article from Space Daily entitled "Carbon dioxide trading breathes life into futures markets", November 14, 2004, cites $11 per metric ton, which equals $10 per 2,000-pound ton. http://www.spacedaily.com/2004/041114034011.16sleqih.html

For More Information

A. Rogers, EPRI Project Manager, phone: 650.855.2101, email: arogers@epri.com

Cosponsors

California Electric Transportation Coalition (CalETC),
Principal Investigator: D. Modisette

Pacific Gas & Electric Company (PG&E),
Principal Investigator: K. Harris

Southern California Edison Company (SCE),
Principal Investigators: D. Cromie and D. Taylor

Contractors

Southern California Edison Company (SCE), Principal Investigator: D. Taylor

Air Quality Consultant, Principal Investigator: L. Dunlap

About EPRI

EPRI creates science and technology solutions for the global energy and energy services industry. U.S. electric utilities established the Electric Power Research Institute in 1973 as a nonprofit research consortium for the benefit of utility members, their customers, and society. Now known simply as EPRI, the company provides a wide range of innovative products and services to more than 1000 energy-related organizations in 40 countries. EPRI's multidisciplinary team of scientists and engineers draws on a worldwide network of technical and business expertise to help solve today's toughest energy and environmental problems.

EPRI. Electrify the World

EPRI • 3412 Hillview Avenue, Palo Alto, California 94304-1395 USA
PO Box 10412, Palo Alto, California 94303-0813 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com