Section 2
Idle Reduction Technologies

2.1 Truck Technologies

2.1.1 Technology Description

2.1.1.1 Commercial Technologies

There are several types of systems on the market that allow heavy trucks to reduce their long-duration idling. Some are available as optional original equipment for purchase on new trucks, and all can be retrofitted onto existing trucks. (Note: the word "truck" will be used to refer to the tractor unit; if the entire tractor semi-trailer unit is meant, that term will be used.) The services provided by idle-reduction equipment vary from simply turning the engine off when it is not needed to the full range of hotel and engine services, including cab and block heating, air conditioning, lighting, power for appliances, telephone and computer hook-ups, and cable TV. Devices are available for stand-alone installation on-board the truck or to plug into wayside installations. However, many of these devices have drawbacks that limit market acceptance. Other technologies are less mature but promise to eliminate the drawbacks. This section discusses commercially available devices; the next section will discuss those in R&D.

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Costs tend to increase along with quality of service provided, so owners must evaluate their needs carefully before selecting equipment. Economics of idle-reduction equipment will be discussed in a later section. There are numerous equipment manufacturers offering different features; we do not attempt in this report to evaluate different products. Instead, we will describe the different types of equipment and compare their characteristics, providing information to allow a purchaser to determine the type of system that best suits his needs. Although we use data from specific equipment for the generic comparisons, this should not be interpreted as an endorsement of any manufacturer's product. For the reader's convenience, a partial list of products of each type is provided in Table 2.1; there may be other manufacturers as well. Additional details of specific products can be obtained from the manufacturers.

On-Board Devices. On-board devices have the advantage of being available wherever and whenever the truck is stopped. They have the disadvantage of adding weight to the truck, which may decrease the revenue-producing load that can be carried (unless weight waivers are enacted– see Section 3). Technological alternatives that could be used anywhere include (1) automatic shut-down/turn-on systems (start-stop), (2) direct-fired heaters (heating only), (3) air conditioners, (4) auxiliary power units (APUs) and generators, and (5) inverter/chargers. Some of these devices are already available as factory options on new trucks; all could be installed on new trucks or retrofitted on operating trucks.

Automatic Start-Stop. The simplest and cheapest device to reduce idling is a control system that simply shuts the truck's engine off when the truck is parked for more than some set period of time, typically 5-15 minutes. The system then monitors the condition of the engine and coolant, and

restarts the engine as necessary to maintain acceptable temperatures. Engine manufacturers offer and warrant this lightweight option on new engines and for retrofits. Similar devices are also available for locomotives (see below). These devices monitor key parameters like oil and cooling water temperature and battery state-of-charge and restart the engine if any of these goes beyond pre-specified limits. Sleeper temperature may also be included. The period of shut-down varies with the ambient temperature; in cold weather, the engine may need to remain on all of the time. Cab-comfort services are available while the engine is on, but not while it is off. In addition, the noise of the engine turning on and off may disturb a driver who is trying to sleep in the truck. Some systems offer a gradual transition to lessen this problem. Fuel use and emissions are avoided for the period that the engine is shut down only. Therefore, this type of device will be seen to produce less fuel savings and emission reductions than other types. One manufacturer reports that some of its customers experienced a 0.5 mpg improvement with this idle management system[1]. Optional data-logging is available on some systems so that fuel savings can be documented. Deactivation of some of the cylinders is another technical possibility, but little relevant information on this was found.

Table 2.1 Commercially Available Devices to Reduce Idling of Heavy Trucks

Device Type	**Manufacturer**	**Product Name**
Automatic start/stop system	Cummins	ICON™ Idle Control System
	Detroit Diesel	DDEC® Optimized Idle
Bunk Heaters	Espar	AIRTRONIC®
	Webasto	Air Top
Engine Heaters	Espar	HYDRONIC®
	Webasto	Thermo Top
Air Conditioners	Webasto	
	Bergstrom	NITE
	Safer Corp.	Viesa
Auxiliary Power Units/Gensets	Pony Pack	Pony Pack
	Auxiliary Power Dynamics	Willis APU
	TruckGen	TruckGen Mini APU
	Teleflex	ProHeat ICE
	RigMaster Power	RigMaster
	Aux Generators	Aux, Genaux 2000, Idle Hawk
Inverter/Charger Systems	Xantrex	

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[1]Ref: http://www.cummins.com/na/pages/en/products/trucks/electronics.cfm ; 11/21/03

Heaters. Diesel-fired heaters are simple, compact, lightweight devices that provide heat for the sleeper and/or the engine at low cost (See Figure 2.1). No other services are provided, but heaters can be coupled with air conditioners (see below) if the trucker is to rest overnight in hot weather. Diesel heaters can be easily retrofitted onto existing trucks. They are also suitable for boats and buses, which would use the larger units. One manufacturer offers units with heat outputs ranging from 6000 BTU to 41,000 BTU and higher; their weights vary from 6-44 lb. Electrical loads must rely on the truck's batteries, leading to some concerns about restarting if many appliances are in use. Fuel use and emissions by diesel heaters are very low, typically under 10% of those from idling, because they supply heat directly from a small combustion flame to a heat exchanger. Standard diesel fuel is used; this is in contrast to some of the novel technologies under investigation that might require a separate fuel. Diesel heaters are very quiet.

Figure 2.1 Typical heater (Source: Espar website)

Air Conditioners. Air conditioners can be installed alone, or in conjunction with heaters. Various technologies have been proposed, from thermal storage to vapor compression, to evaporation, to heat pumps. Several systems are currently on the market that provide cooling with lightweight units (70-90 lb), generally mounted on the cab roof or under the bunk. These systems run off 12 V or 24 V DC current, and typically use 250-430 Watts, for a total energy use overnight of 3-5 kWh, although one manufacturer claims considerably lower consumption. They can be run off the truck's existing batteries or from additional batteries, generally weighing on the order of 120 lb. In either case, the energy for cooling is supplied to the batteries when they are recharged by the truck's engine during operation. The engine uses more fuel than it would if it were not charging batteries while it ran (see estimate below). Systems are also available to run off 110 V from shore power via an inverter. The cost of a typical system is about $1200, with no batteries.

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One system that has been developed is sold in conjunction with an insulated sleeping compartment, similar to a small tent (see Figure), so that a much smaller volume can be cooled, with correspondingly lower energy use. The compressors can be run off 12, 24, or 120 V, and total energy use for a night's sleep would typically be under 1 kWh, so the drain on the truck's batteries would be minimal. The area above the occupant's head can be left open, as the cooled air is heavier than the air outside the compartment. This allows the occupant to read or watch television from an inclined position. The manufacturer suggests coupling this with a heated mattress (a widely available item) for use in cold weather. This system provides comfort only to the occupant of the limited area.

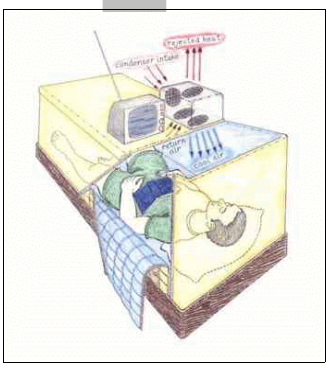
Figure 2.2 Sleep Genie cooling system (Source: Larry Schlusser, SunFrost, 12/9/03)

Auxiliary Power Units (APUs). APUs and generator sets, which have slightly different components, are mounted externally on the truck cab or sleeper. An APU consists of a small internal combustion engine (usually diesel-fueled) equipped with a generator and heat recovery to provide electricity and heat. A typical APU is shown in Figure 2.3. An electrically-powered air-conditioner unit is normally installed in the sleeper area, although some units use the truck's existing air-conditioning system. Cab/sleeper heat is provided by an electric heater in the unit, and the engine

coolant is circulated in the same unit for additional heat. These units supply all of the services the trucker requires to be comfortable anywhere in any weather. They supply heating (bunk and engine), air conditioning, and electric power for lighting, television, microwave oven, and any other appliances, but do not supply direct cable hook-ups (only advanced truck stop electrification does). APUs can also serve as survival systems in emergencies. The Army sees benefits of using an APU during silent watch because it is quieter, vibrates less, and has a lower thermal signature than idling the primary engine, making the vehicle less detectable while providing reduced fuel consumption and maintenance costs.

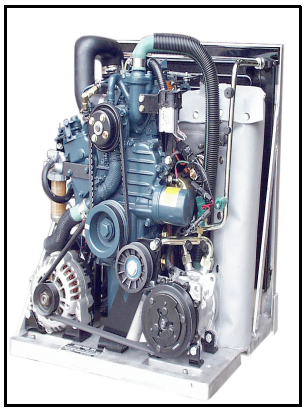

Figure 2.3 Typical APU (Source: PonyPack website)

However, APUs are expensive (typically about $7000) and heavy (up to 400 lb), reducing the load that can be carried legally (until weight waivers are enacted). And while they are quieter than the main engine, they are noisier than heaters. In addition, some concern has been expressed about the possibility of maintenance intervals not matching those of the truck itself, and about the availability of parts and service for the units on the road. Fuel consumption and emissions for the APU, which runs on diesel fuel, are about a factor of 5 smaller than those for the idling truck. Emissions are compliant with standards for small engines. Several manufacturers produce APUs; these have many design features in common, but differ in details. For instance, one includes an air compressor. Although several truck manufacturers are looking into the option, none routinely supplies APUs on new trucks. Cummins announced an original-equipment APU at the March 2004 Mid-America Truck Show. OEM-installed units are expected to be less expensive, lighter, and serviced at the same time as the vehicle.

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Inverter/Charger Systems. An inverter simply converts the 110 V AC current from a shore power plug (see wayside units, below) to the DC voltage required to run any of a truck's appliances that run on electricity. Some of these may have required conversion or replacement. The inverter can be combined with a charger to utilize power from the truck's main engine during driving to charge a battery pack. The hotel load can then run off this battery pack instead of idling the engine. Although no fuel is used during the rest period, some additional fuel is required during truck operation to charge the batteries (see estimate below in energy section). The mass and cost of the system plus batteries are generally lower those of an APU, but additional costs may be incurred to install electrical appliances.

Wayside Units. Electrification of truck stops can provide parked vehicles electricity for heating, cooling, and other purposes. Wayside units have the advantage of adding little or no weight to the truck and therefore not impacting freight capacity. However, they have the disadvantage of only being available at truck stops where they have been installed. Even if such installations are eventually widespread, there are likely to be times or places where a trucker is unable to find a place to plug in, and will therefore need to idle. EPA and DOT conducted several workshops around the country educate states and energy providers about the potential of TSE.

Two basic types of wayside units have been developed and demonstrated for supplying power and hotel services to trucks at rest. One (truck stop electrification [TSE]) is simply a plug at a parking spot so that the trucker can tap into the electric power grid. The other is a system that supplies all needed services through a duct inserted into the cab window. Energy use and emissions depend on the fuel mix and efficiency of the local utilities; this report will use US utility averages. Primary energy use by electrical options is generally somewhat higher than for those supplying heat directly, because of the losses in conversion to electricity.

Truck Stop Electrification. The trucker would simply "plug in" the truck to outlets like the one shown in Figure 2.4, at the truck stop to power heaters, air conditioners, marker lights, and accessories like microwave ovens, refrigerators, computers, and entertainment equipment. Electrification involves modifying the truck stop by installing ground electric outlets (or plates in case of the induction power transfer approach) at each parking space. Currently, there are few truck stops that provide plug-in power, and it is difficult to foresee that sufficient spaces could be provided to serve all trucks all the time. TSE also involves retrofitting trucks with an inverter/charger, electric engine block heater, electric fuel heater, and electric heating/cooling device for cab and sleeper conditioning, and electric automatic idle control. In a related effort that could make TSE easier to adopt, engine manufacturers are replacing engine shaft-driven pumps and accessories with electrically-driven devices that can be operated on demand, thereby reducing overall parasitic loads. DOE's OFCVT is supporting research on the MorElectric Truck concept that employs many of these approaches. This concept is planned for a 2004 introduction by one of the 21st Century Truck Partners and also includes an optional APU.

Figure 2.4 Mock-up of shorepower plug-in (Source: T. Perrot, Antares, April 2004)

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Advanced Truck Stop Electrification. Another truck stop electrification concept being demonstrated requires no retrofit of the truck, but simply feeds conditioned air and electricity through the truck window. A typical installation is shown in Figure 2.5. This system, pioneered by IdleAire and getting considerable press coverage, requires no modifications at all to the truck. The only equipment required is an inexpensive template that fits into the window and allows the service conduit to be attached and sealed in place. Early tests show good acceptance of this approach but there have been problems with trucks driving away with the equipment still attached. In addition, it has proven necessary to have staff available to assist installation and maintain the system; this impacts the economic viability of the system. Energy efficiency is lower than for TSE because of heat losses in the air conduits. EPA and NYSERDA have both funded projects involving this technology.

Figure 2.5 Advanced TSE installation (Source: IdleAire)

2.1.1.2 Technologies Under Development

Fuel Cell APU. In the future, it might be possible to use a fuel cell as an APU. A demonstration of a hydrogen-fueled and a methanol-reformer proton exchange membrane (PEM) fuel cell has already been conducted by one of the 21st Century Truck partners. The need for gaseous hydrogen currently limits the viability of this concept; however, work is underway on diesel fuel reformers that may make this approach more feasible, although reformer durability and cost-effectiveness have not been demonstrated. More advanced fuel-cell technology, such as gasoline or diesel-reformed hydrogen-powered solid-oxide fuel cells (SOFC), may be more applicable as the power source for truck APUs; DOE's Office of FreedomCAR and Vehicle Technologies (OFCVT) is currently investigating SOFC technology for this application. EPA is currently negotiating a methanol-reformed fuel cell APU project with industry leaders. US Army TACOM National Automotive Center had two Class 8 fuel cell APU programs: a direct-methanol SOFC (no longer active) and a direct-hydrogen PEM, both integrated into vehicles with diesel-fueled ICEs. Fuel cell APUs would be particularly desirable for military use, because they are very quiet (or will be when the air compressors are made quiet). It is important for troops in the field to minimize any signature by which they could be located by an enemy. Note that greenhouse gas emissions are not significantly reduced by use of fuel cells reforming fossil fuels; this is only accomplished by direct use of hydrogen produced from non-fossil sources. Reformers are viewed as a temporary expedient until such time as a viable hydrogen infrastructure is in place.

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MorElectric Truck. The MorElectric Truck (MET) system supplies all of the services that might be required by a trucker at rest, without use of the main engine. It does this either with an APU or via a plug-in system. But it includes much more. By electrifying many of the truck's auxiliary devices, it increases the overall efficiency of operation.

The performance has been evaluated using SAE Type II testing. The MET achieved 2% better fuel economy on the road than the standard truck. This means that typical truckers can expect an 8% reduction in diesel fuel consumption (including that from idle reduction) using the on-board auxiliary power unit, and 10% if shore power is available. The DOE-sponsored "More Electric (Truck) Initiative" (MEI) project was led by Caterpillar with participation of Kenworth, Emerson Electric, and Engineered Machined Products. The three-year project replaced many of the belt-driven components with more efficient electrically-driven ones. The MEI also utilizes an integral-starter generator, a vastly improved HVAC unit, an inverter to connect to shore power, and an auxiliary power unit to supply power for cab comfort instead of idling. Additional increases in fuel efficiency can be expected by fine tuning the electronics and using an electro-turbocompounder. Caterpillar and DOE displayed the MorElectric Truck at the 2004 Mid-America Truck Show (see Figure 2.6). It will be commercially available in the 2005 model year. DOE has also funded a demonstration project.

Figure 2.6 MET on display at truck show

Thermal Storage Air Conditioner. A phase-change cold storage device was briefly marketed and proven to be an effective no-idle driver comfort system, but the particular storage technology was expensive to manufacture. A less expensive storage technology is now being actively tested prior to production. This system[2] consists of an insulated cold-storage unit, a small DC circulating pump, and a heat exchanger. It weighs less than 150 lb and occupies about 5 cubic feet under the bunk.

The storage material is cooled below 0 C, utilizing the excess capacity of the truck's air conditioning. The system cools in about 4-5 hours of driving time. Once fully charged, the system stores 5 kWh for cooling. When the truck is turned off, a small DC pump circulates a water/glycol mixture through the storage unit, where it is chilled. This water/glycol is then circulated through the heat exchanger. A low-speed fan blows air through the heat exchanger and out HVAC vents into the sleeping area. If the cooling is limited to the mattress area only, the driver can be kept cool for 7-8 hours on a typical summer night.

No fuel is used directly. In normal operation, the truck's A/C compressor clutch cycles off and on to maintain the correct temperature. When the compressor would normally be cycled off, this system holds the clutch engaged and, with solenoid valves, directs the refrigerant from the truck's evaporators to the storage system. Some extra fuel is consumed by the truck's engine to operate the compressor continuously.

The system is targeted to achieve a payback within two years of operation, based on the expectation of similar savings to cab heaters' $90-$100 per truck per month. Slightly higher savings are possible if the truck is typically set on "hi idle" when it is idled for cooling. The system can be used alone for driver cooling, or in conjunction with a fuel-fired cab heater to provide both cooling and heating. (Ref: R. Partlow, Webasto, personal communication December 2003)

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Novel Technologies. Several small businessmen and inventors have developed novel ideas or variations of existing technologies for reducing truck idling. Information about the devices produced by entrepreneurs is often incomplete and undocumented because of proprietary concerns, lack of funding for documentation of both concept and performance, and for independent testing, as well as inexperience of the participants with scientific data handling. These limitations also make it difficult to obtain support from government agencies. This section summarizes the available information.

A company in Germany has developed a steam engine APU that can run on any liquid or gaseous fuel. It is expected to be available for licensing in 2005. The fuel is burned under controlled conditions to minimize emissions; steam is produced and fed to an innovative piston engine to generate up to 6 kW of electric power as well as heat. Water is recirculated when the steam condenses. The unit uses low-friction materials, so no lubrication is needed. It is quiet, compact, and weighs only about 70 lb (32 kg). The unit would be suitable for use in trucks, boats, and off-highway vehicles. No air conditioning is provided, but it could be run off the electricity generated. The developers project the cost to be a factor of ten lower than that of a comparable gas turbine or fuel cell

[2] called Accusphere II, or more commonly Parking Cooler

system.(Refs: enginion flier on Ezee Technology [3/01] and http://www.enginion.com/en/index.html [2/10/04])

An independent trucker in Wisconsin has demonstrated systems that allow him to eliminate his truck's idling. Two of the components are novel. A simple modification continues engine coolant circulation to the cab and bunk after the truck is shut off. This provides heat for several hours when the truck is waiting to be loaded or unloaded at a dock. It also cools down the engine. The system is available for $250. Another system, for which he has also applied for a patent, allows the reefer's power to maintain battery charge. (Ref: http://www.idlefree.net/index.htm [2/10/04])

The Department of Energy's Office of FreedomCAR and Vehicle Technologies tried to fund research on a small, lightweight APU for use in Class 8 trucks, but the collaboration fell through. If successful, the device would have produced 30kW, weighed only 20kg, and occupied a 15 liter volume. It would have reduced APU fuel consumption and emissions and avoid the weight penalty that hinders adoption of currently commercial systems.

2.1.2 Technology Comparison

Before comparing energy savings or economics, it is useful to clarify the basic differences among the available devices for reducing long-duration idling. They do not all supply the same services, and so their relative merits will depend on several factors, including services required and number of hours of idling that would be avoided. The following table (2.2) summarizes the basic differences among the technologies and points out any particular advantages or disadvantages of each.

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Technology	Benefits	Drawbacks
Automatic start/stop	Intermittent services anywhere	Noise disrupts rest; uses main engine
Direct-fired heater	Heat anywhere; small and inexpensive	Cannot supply cooling; uses battery
Auxiliary power unit (APU)	HVAC and power anywhere	High cost and weight
Truck stop electrification (TSE)	All services; no local emissions	Only at fixed locations; limited potential
Integrated electrical accessories with APU	HVAC and power anywhere	In development (2005 intro); only on new trucks

Table 2.2 Benefits and drawbacks of truck idle-reduction technologies

2.1.2.1 Energy Use and Emissions

Energy Use. Diesel fuel saved by reducing idling is fairly simple to estimate; it is simply the difference between the fuel that would have been used idling and that consumed by the alternative system. For the automatic start/stop systems, the fuel saved is simply that percent of idling fuel use that corresponds to the period of time when the engine is off. Emissions are similarly reduced. If the idle-reduction technology burns diesel fuel, savings are reduced by the device's own fuel consumption, typically 5-25% of the savings. Emissions may be reduced by more or less than the same percentage, depending on how clean the idle-reduction technology is. Such devices all meet appropriate small engine standards, but these are generally less stringent than those for truck engines. Emissions from several devices have been measured by the EPA. For devices that plug in, all of the idling diesel fuel use and emissions are avoided, but the fuel use and emissions from electricity generation at the power plant must be accounted for. Several earlier publications have neglected to do this.

Finally, there is the more complicated case of devices that run off of power from batteries that have been charged during the vehicle's operation. No information was found about the additional fuel consumed due to battery charging. Because systems that run off a battery do not burn fuel while they are providing services, vendors generally do not recognize and report fuel use for their systems. We estimate it here. If the unit draws a maximum of 8 Amps at 12 V, and we assume that it operates at 75% capacity for 8 hours, for an average power draw of 72 W, consuming 2074 KJ of energy directly. From the Bosch Automotive Handbook, automotive alternators are approximately 50% efficient - meaning that 50% of the rotational energy from the accessory-drive belt is converted into electrical power. The charging efficiency of typical automotive-style charging systems is between 50 and 65%, meaning that 50-65% of the electrical power delivered to the battery actually goes into increasing its state of charge, and the rest is lost as heat. The faster the battery charges, the more inefficient the process becomes. We assume that the battery is charged relatively slowly while the truck is operating, and charges efficiently (65%).

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That means that the engine-work-to-battery-charge efficiency is 32.5%. Therefore, the amount of energy the engine must provide to make up for what the air conditioner consumed is 6382 kJ. That amounts to 221 W of engine power. This is the most optimistic case, assuming a separate battery pack for this purpose. If the starting battery is used, the minimum level of charge needs to be maintained to insure starting, so the charging rate must be higher, which means lower efficiency.

The 6383 kJ of energy of is required at the drive belt. This energy is supplied by the truck's diesel engine, which is about 40% efficient in turning fuel energy into shaft power. Therefore, it needed to burn 15958 kJ (15196 Btu) of fuel , or about 0.112 gal of fuel (.014 gal/h). This is a best-case estimate; actual fuel use could easily be doubled, depending on conditions and weather (battery-charging efficiency is very low in cold weather). This is still very low energy use, because the 72 W power demand is less than most light bulbs! Even if the unit drew 350 W, total fuel use would only be 0.14 gal/h in cold weather.

Emissions. Until recently, one had to rely on measurements by equipment manufacturers to estimate emission reductions achieved by use of alternative devices. However, recent experiments funded by the U.S. EPA, New Jersey DOT, and DOE at the Army's Aberdeen Test Center carefully measured emissions of CO_2, CO, NO_x, HC, particulates, and aldehydes from idling trucks, and from installed

auxilliary power units and heaters, under several sets of conditions. Measurements were taken at several idling speeds, in hot, cold, and mild atmospheric conditions, and with several different trucks. The results of this work clearly demonstrate the environmental benefits of reducing truck idling. The detailed results are presented in 2 papers[3,4]; we summarize them and draw some conclusions here. The exact numbers vary with truck model; we chose to provide as an example the impact reductions achieved with the newest truck tested (2001 Freightliner), because of the rapid turnover of truck fleets. We determined that it was most meaningful to compare impacts from a heater or APU at 0° F to those from the truck idling at the speed at which it would normally idle to supply heat (700-800 RPM). Therefore, we interpolated the detailed data provided and estimated truck heating emissions at 750 RPM, and similarly estimated idling emissions during cooling at 90° F at 900 RPM. Note that the conditions chosen are somewhat extreme; impacts at more moderate temperatures are expected to be lower. An accurate estimate of annual impacts and benefits would require integration over typical annual conditions and loads. It would also require measurement of APU impacts at 65° F, when it would be run for electrical loads only.

The emissions for the truck and alternatives at these two extreme conditions are shown in Table 2.3. As expected, all of the impacts are very low from the heater, but it is only supplying heat and no electricity.

Table 2.3 Emissions from idling and alternatives

Device	Condition	CO_2 g/h (% red.)	NO_x g/h (% red.)	HC g/h (% red.)	PM g/h (% red.)	CO g/h (% red.)
Truck	Heat	7500	158	26.2	3.43	115
APU	Heat	2146 (71)	8.7 (94)	7.8 (70)	0.478 (86)	25.0 (78)
Heater	Heat	445 (94)	0.2 (99+)	0.04 (99+)	0.055 (98)	0.1 (99+)
Truck	AC	9500	137	35.7	2.0	60
APU	AC	2351 (75)	11.4 (92)	4.2 (88)	0.995 (50)	10.8 (82)

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All of the impacts from the APU are lower than those from idling, for both heating and cooling. It is interesting to note that the emission reductions are greater on a percentage basis (in most cases) than the fuel use reductions (as represented by the CO_2 emissions). This could be because idling represents a non-optimal engine condition, compared to that of the auxiliary device. The one glaring exception is the PM emissions from the APU when supplying air conditioning. These are reduced by only 50%, even though fuel use is reduced 75%. Since only one APU was tested, this may or may not be typical. However, note that the NO_x emissions have been reduced disproportionately, and it is likely that the APU's engine could be adjusted to trade NO_x for PM.

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[3] *Particulate Matter and Aldehyde Emissions from Idling Heavy-Duty Trucks*, J. Storey, et al., SAE Paper 2003-01-0289 (2003)

[4] *Study of Exhaust Emissions from Idling Heavy-Duty Diesel Trucks and Commercially Available Idle-Reducing Devices,* H. Lim, U.S. EPA Office of Transportation and Air Quality, EPA420-R-02-025 (October 2002)

Impacts from those devices that run off the battery would be equal to the marginal emissions from increasing fuel consumption on the road. The impact from shore power are simply the emissions from generation of the electricity that they draw. Although this actually varies by region with fuel mix, we will use the national average for technology comparisons in this report (to be added).

2.1.2.2 Economics

The economic benefits of idle-reduction technologies depend on the costs avoided by not idling, and on the costs incurred to purchase or lease and use the idle-reduction technology. And, of course, any benefits are expected to increase as the number of idling hours displaced increases. The largest avoided cost is that for fuel, and it can be calculated simply for on-board technologies that burn diesel fuel, *e.g.* APUs and heaters. For these, the fuel savings are simply the difference in hourly fuel use (in gallons per hour) between idling and APU use, multiplied by the number of hours of idling displaced during the period in question, times the fuel cost per gallon. For devices that plug in, the avoided fuel cost is simply the cost of the diesel that would have been burned idling minus the cost of the electricity purchased. The situation is more complicated for systems that run off of batteries that are charged while the engine is running. In that case, it is appropriate to estimate, and bear the cost for, the extra fuel that is burned during truck operation in order to charge the batteries, as was estimated above.

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In addition to savings from reduced fuel consumption, not idling a truck reduces maintenance costs. Oil changes can be performed less frequently if the engine is operated for fewer hours; thus the cost for oil changes can be reduced. The Technology and Maintenance Council (formerly the Truck Maintenance Council) of the American Trucking Associations has published two Recommended Practice (RP) Bulletins to help truckers estimate maintenance costs due to idling. The first, published in 1985, was superceded by another (RP1108[5]) in 1995, in which the cost estimates were drastically reduced due to the reduction in fuel sulfur and changes in idling practice. Care must be taken to use the updated version; several recent publications have cited the older one. The main difference is the number of "equivalent miles" represented by one hour of idling. The revised RP estimates this from the fuel consumption, *i.e.* each gallon of fuel used idling is accounted for as if it were used at the truck's average miles per gallon. So one hour of idling is typically equivalent to about 6 or 7 miles of driving. Then, if an oil change costs $150 and is done every 35,000 miles, the cost per hour of idling is about $0.03. This calculation should be done more carefully, based on the actual fuel economy and oil change cost and frequency for the truck or fleet to be costed; this can be done using the worksheet included here as Figure 2.7.

A similar calculation can be done for the cost due to overhaul. If a truck requires an overhaul after 500,000 miles, and the overhaul costs $10,000, the cost per our of idling is $0.14. Again, this is simply an example. Some trucks just need part replacements, costing about $2500, while others might need a full engine-out overhaul, costing as much as $20,000. There is also considerable

[5]TMC Recommended Practice 1108, *Analysis of Costs from Idling and Parasitic Devices for Heavy Duty Trucks*, American Trucking Associations, March 1995

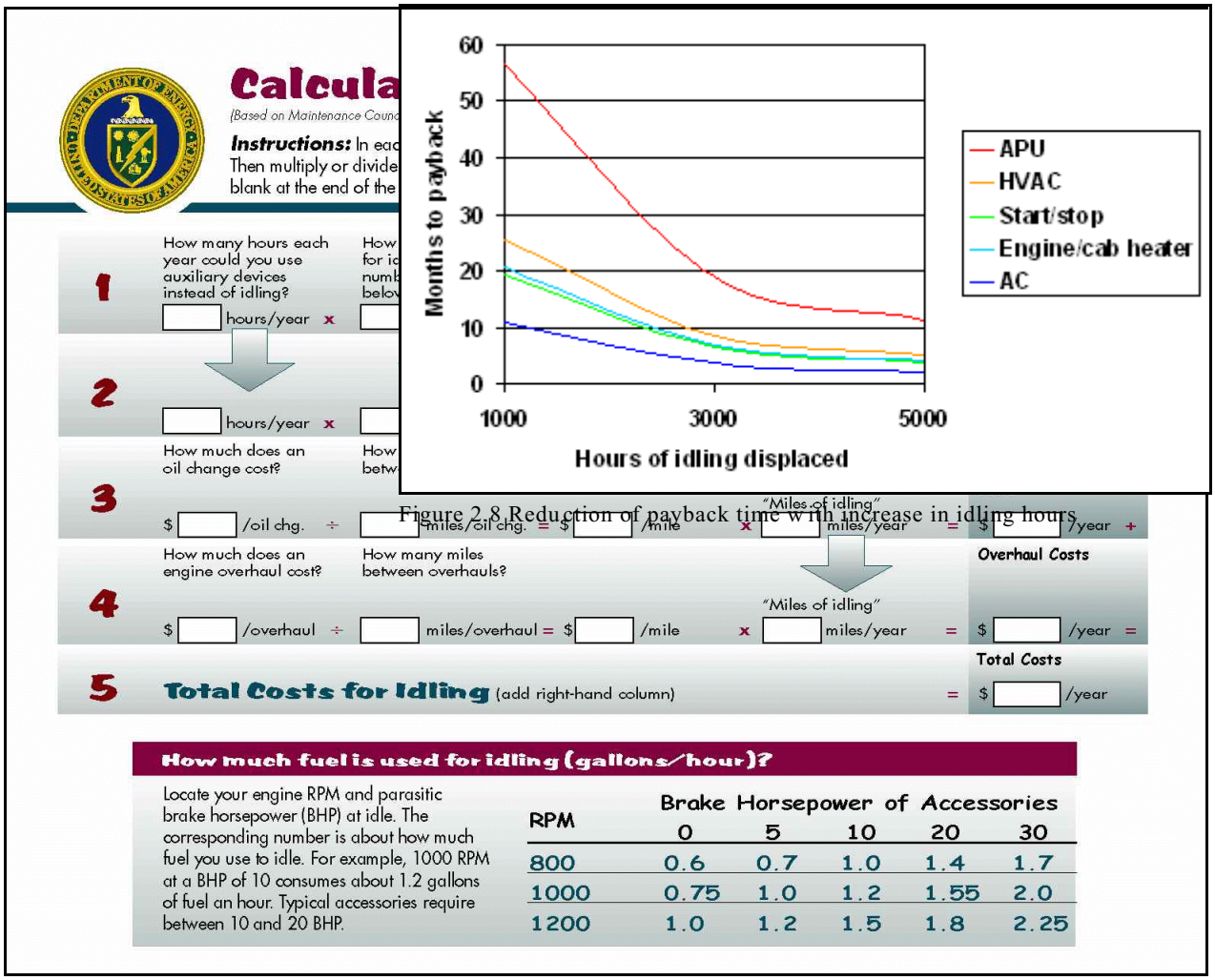

Figure 2.7 Idling cost worksheet

Figure 2.8 Reduction of payback time with increase in idling hours

variation in mileage to overhaul; a typical mileage used to be 300,000, but now may be up to 1,000,000 miles, and no overhaul may ever be performed. (Personal communication, A. Laible, Cox Transfer, January 2004) The worksheet allows the user to select appropriate entries for these parameters. It would be very useful to obtain actual data on the effects of idling on oil quality and engine wear.

Note that many truck owners, especially fleet owners, sell their trucks before it would be time for an overhaul, and therefore may not choose to include this component in their cost estimates. However, if the buyer can see the truck's idling history in its computer records, the purchase price will theoretically be reduced for a truck that has idled excessively. However, mileage does not seem to be a key parameter cited in ads for used trucks.

Once the fuel and maintenance costs for idling have been estimated, the savings and payback times for the various idle-reduction technologies can be estimated. The graph in Figure 2.8 compares costs for idling to those for several alternatives, as a function of idling hours displaced. Note that the

times in the table are durations of device operation; for example, if the device is a heater, those hours are during the winter only, so the months until payback are also winter only, and it may take 2 years to accumulate 12 months of payback time. Note that payback times for a truck with low yearly idling time are very long. Thus, a firm that has reduced its idling by changing its drivers' operating practices, might not find it economical to install equipment to further reduce idling.

TSE costs are slightly complicated because some are borne by the truck owner and some by the owner of the electrified system. Both must see an appropriate payback if the systems are to be installed and used. For standard TSE, the trucker sees the cost of the equipment required to electrify the truck, and the marginal cost of using an electrified space at a truck stop (the extra cost over standard space rental). This is presumably greater than the actual electricity price. The truck stop owner must pay to install and maintain the electric plug system, and also for the actual utility bill. There is little incentive at this time to electrify truck stops; the few that have been demonstrated have rather low utilization because so few trucks are able to use the spaces so far. (Cite Perrot, et. al, TRB 2004).

Advanced TSE is simple for the truck owner to cost out; the avoided idling costs are as above, and the cost to use the advanced TSE is simply the small initial cost of the window template (about $10) plus the hourly charge of $1.50 ($1.25 for subscribers). The economics of the system itself are less clear, because there are several parties involved in the current installations, which are mostly serving as demonstrations. For early installations, it is unlikely that the truck stop owner will invest in the system. The system is therefore installed by its manufacturer, with the truck stop owner receiving a portion of the proceeds. The actual installation cost is unknown at this time, but is generally shared by a government agency in order to demonstrate the technology. Operating revenues are the fees collected for the service, minus any cut to the truck stop owner, minus any maintenance costs. Note that these may not be small, given reports of large numbers of drive-aways[6]. Detailed costs have not been published, but it is likely that high utilization would be required to make the project economical.

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[6]A minor design change, whereby the trucker's template breaks instead of the overhead unit, will reduce the drive-away costs to the owner of the installation.