



CONFIDENCE REPORT:

Idle-Reduction Technologies

ABSTRACT This report documents the confidence that North American Class 8 trucking should have in pursuing Idle-Reduction Solutions. The study team engaged the entire industry in the data that is presented here. Thanks to all of those who contributed to this important work.

The North American Council for Freight Efficiency (NACFE) is a nonprofit organization dedicated to doubling the freight efficiency of North American goods movement. NACFE operates as a nonprofit in order to provide an independent, unbiased research organization for the transformation of the transportation industry. Data is critical and NACFE is proving to help the industry with real-world information that fleets can use to take action. In 2014, NACFE collaborated with Carbon War Room, founded by Sir Richard Branson and now a part of Rocky Mountain Institute, to deliver tools and reports to improve trucking efficiency.

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Confidence Report on Idle-Reduction Technologies

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IDLE-REDUCTION TECHNOLOGIES

The fuel costs faced by the trucking industry are a significant part of the expense to operate a tractor-trailer in North America. Fuel costs are now approximately \$0.37 per mile, accounting for 22% of a fleet's total operating costs—the second-largest expense for fleets behind only driver wages. The price per gallon for diesel as of May 2019 is around \$3.16 per gallon, and all indications are that fuel prices will continue to be volatile. Thus, the industry is in need of solutions that reduce its fuel dependency if it is to remain profitable.

In addition, the United States Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) have enacted greenhouse gas emissions regulations on commercial vehicles, extended

to 2030, which require manufacturers to develop and sell technologies to improve efficiency. These factors have driven fleets, manufacturers, and others to improve the efficiency of over-the-road tractor-trailers.

Fortunately, myriad technologies that can cost-effectively improve the fuel efficiency of Class 8 trucks are readily available on the market today. Unfortunately, multiple barriers have stymied industry adoption of such technologies, including a lack of data about the true performance gains these technologies offer and a lack of confidence in the payback for investment into these technologies. To overcome those barriers and facilitate the industry's trust in and adoption of the most promising cleaner operating technologies, the North American

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Council for Freight Efficiency (NACFE) produces a series of Confidence Reports, of which this report on idle-reduction technologies is the latest.

To operate their sleeper tractors, fleets in the United States used over a billion gallons of diesel while idling in 2017, approximately 8% of the total fuel burned. Due to the volatility of fuel prices, concern about the impact of diesel emissions on the environment, and a desire to minimize engine wear, the trucking industry is under pressure to reduce or even end the idling of engines. Although some level of idling is unavoidable, a plethora of new idle-reduction systems now on the market is capable of reducing idling significantly below current averages. Unfortunately, most currently have moderate to low rates of adoption. The goals of this Confidence Report are to: (a) explain the importance of reducing idle time; (b) describe the benefits, costs, and challenges of various available idle-reduction technologies; and (c) provide recommendations for adoption of the technologies.

SCOPE OF THE REPORT

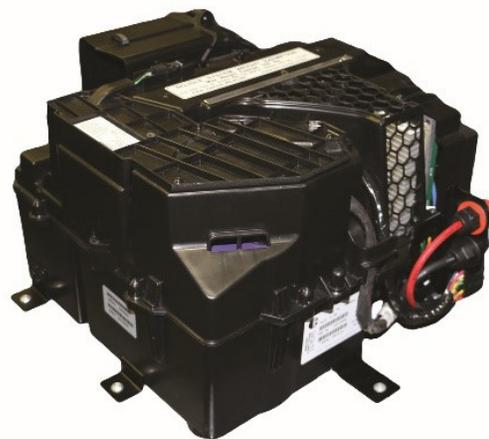
This report only considers idle-reduction technologies that are currently available on the market for over-the-road applications. It focuses on five of the eight reasons for idling in terms of the “benefits” that fleets would seek to obtain from any idle-reduction technology they might adopt. These include cab heating and cooling, battery state of charge, hotel loads, and engine heat. In addition, this report focuses on solo drivers and does not deal with team drivers, as the percentage of team drivers is relatively low.

IDLING OVERVIEW

Idling is important to trucking fleets for various reasons. Idling makes restarting a diesel engine in cold temperatures much easier, as the engine oil is already warm and therefore at a lower viscosity, and it also prevents the cold-weather gelling of diesel fuel. Idling also allows the cab and especially the sleeper berth to have a controlled indoor climate while the truck is parked. And idling helps keep the truck’s batteries charged—an important factor today with drivers relying on lighting, cell phones, laptops, gaming devices, refrigerators, and CPAP machines.

However, over the past two decades—either to meet operating goals or under mandates that cut or eliminated truck idling across North America—reducing idling has become the norm for the industry. Several rounds of EPA-mandated emissions controls have substantially

lowered allowed levels of truck emissions, in addition to requiring diesel particulate filters and selective catalytic reduction systems. Local restrictions on idling have also increased significantly, creating a complicated patchwork of regulations, all of them stricter than what the industry faced in the past. The American Transportation Research Institute periodically publishes a compendium of idle regulations to assist fleets in understanding this complicated patchwork. You can find and download a copy of this report at <https://atri-online.org/2019/01/09/idling-regulations-compendium/>.



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METHODOLOGIES

NACFE’s research for this report included interviewing key people with firsthand knowledge of idle-reduction technologies at fleets, manufacturers, and industry groups. The full report includes a list of references to assist readers interested in pursuing more detail. These references were researched with the same diligence and thoughtful processes NACFE uses with its other technology Confidence Reports and Guidance Reports.

Not only are government regulations intensifying, but the trucking industry has also been impacted by an increased awareness of sustainability among the general society and within the industry itself. This incentivizes serious advances in the adoption of environmentally friendly technologies and practices, including idle reduction.

However, there are countervailing pressures to allow trucks to idle to meet increasing driver expectations for in-cab comfort when the truck is not moving and for infotainment while they are on their mandated rest periods.

This has led fleets to look more closely at how to handle idling to meet emissions standards, achieve sustainability goals, and at the same time make sure drivers are comfortable and have their hotel loads met.

IDLE-REDUCTION TECHNOLOGIES

Idle-reduction technologies can be distinguished at a most basic level by the pathways by which they reduce the need for idling. Some of the systems are “active” in nature and provide a specific set of benefits to the vehicle and driver, while other idle-reduction methods are “passive” and simply work to minimize the need for the active systems.

FUEL-OPERATED HEATERS

Fuel-operated heaters—which include air heaters and coolant heaters—use diesel fuel to provide heat to the sleeper cab (bunk or air heaters) or to provide heat to the truck engine (water or coolant heaters). Both types of heaters can operate when the truck’s engine is off, therefore avoiding idling. These heaters are relatively inexpensive to purchase and maintain, are easy to install (air heaters) or factory installed (coolant heaters), and operate very quietly. However, they do not provide any cooling (and coolant heaters do not provide bunk heating), do not provide AC power for hotel loads, and create some emissions while operating.

AUXILIARY POWER UNITS

Auxiliary power units (APUs)—either diesel or battery-powered units that do not source their energy from a truck’s main diesel engine—are a key component of the idle-reduction strategy of many fleets, as they can provide cooling, heating, and electric power when the truck’s main engine is shut off. Diesel APUs can operate as long as the truck has fuel, while battery APUs—typically called battery HVAC systems—are limited in the hours of cooling they can provide before truck engine restart and battery

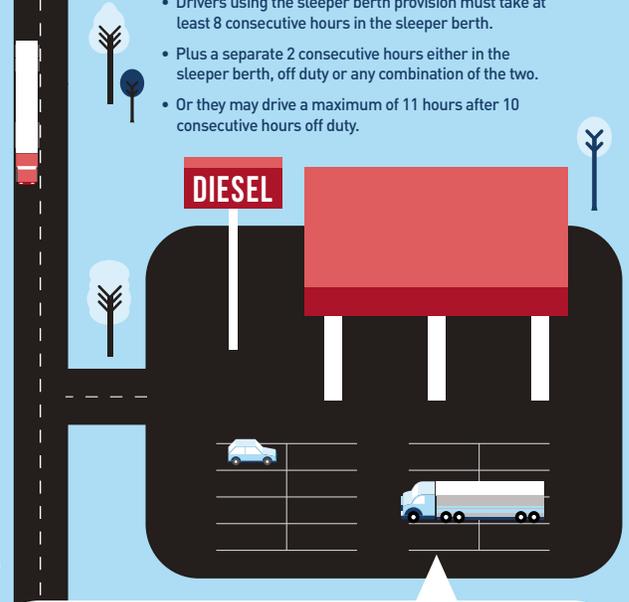
IDLE SOLUTIONS:

HOW THE TRUCKING INDUSTRY CAN SAVE MILLIONS OF GALLONS OF FUEL PER YEAR



Long-haul truck drivers work long hours transporting goods around the country. When they're on the road, commercial motor vehicle drivers must follow these HOS regulations:

- Drivers using the sleeper berth provision must take at least 8 consecutive hours in the sleeper berth.
- Plus a separate 2 consecutive hours either in the sleeper berth, off duty or any combination of the two.
- Or they may drive a maximum of 11 hours after 10 consecutive hours off duty.



AFTER A FULL DAY OF DRIVING, DRIVERS NEED TO

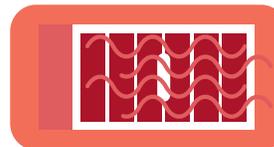


EAT

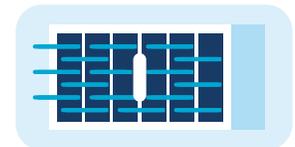
RELAX

CONNECT

SLEEP



STAY WARM



KEEP COOL

HOW DO MOST TRUCKERS POWER EVERYTHING THEY NEED?

BY IDLING THEIR ENGINES

recharging are required. Diesel APUs can also operate in more extreme temperatures, while extreme hot and cold weather negatively affect the capability of battery systems. However, diesel APUs are more expensive to purchase, install, and maintain than battery HVAC systems and other idle-reduction technologies. And while diesel APUs need fuel to operate, thus generating emissions and noise, battery HVAC systems have been described as true zero-idle solutions since they do not use any type of engine while in operation. Many truck OEMs offer battery HVAC systems as factory options.

AUTOMATIC ENGINE START/STOP SYSTEMS

Automatic engine start/stop systems start and stop the main diesel engine in an unattended fashion to provide a variety of features without requiring the truck's engine to idle continuously. These systems have a set of inputs to ensure that it is safe to start the engine without anyone at the controls, such as checking that the truck is not in gear and that no one is working under the hood. There are two types of automatic engine start/stop systems—one that maintains a cab's interior temperature while the vehicle is occupied and one that maintains the batteries' state of charge. These systems do not require additional HVAC components, can be combined with other technologies, and can avoid violating idle regulations. However, the noise and vibration of these systems can interrupt driver sleep, and by requiring the main engine to idle they create additional hours of wear on the main engine.

VEHICLE CONTROLS AND DRIVER BEHAVIOR

The vehicle itself can help in a fleet's idle-reduction efforts via electronic engine parameter settings. In addition, the way drivers manage their vehicles, both while moving and while stationary, has a huge impact on the vehicle's fuel economy. Fleets can motivate desired behavior or penalize/prevent undesired behavior to obtain optimal reductions in idling via electronic controls and by training and incentivizing drivers to follow best practices.

ELECTRONIC ENGINE IDLE PARAMETERS

Programmable engine parameters can play a major role in the various idle-reduction strategies and technologies that fleets employ. These parameters not only control the exact speed at which an engine will idle, they also set the idle timer length and establish boundaries for when idling

ONE LONG-HAUL COMBINATION TRUCK IDLES OVERNIGHT

OFTEN BETWEEN 5 AND 8 HOURS PER DAY, OVER 300 DAYS PER YEAR, COSTING:



1,200 GAL
OF DIESEL
PER YEAR



24,000 LBS
OF CO₂
PER YEAR



\$3,900
SPENT
PER YEAR

... AND THERE ARE 1.7 MILLION TRUCKERS EMPLOYED IN THE U.S., WHICH MEANS



ABOUT 1 BILLION
GALLONS OF DIESEL
PER YEAR ARE CONSUMED BY IDLING

THERE ARE MORE EFFICIENT SOLUTIONS

AUTOMATIC IDLE SHUTDOWN SYSTEMS

Trucks can be programmed to shut down after a certain amount of time. Extreme temperatures will override the program.

DIESEL APUS

Diesel APUs can provide cooling, heating and electric power to the sleep cab while the truck's engine is off.

BATTERY HVAC SYSTEMS

Battery HVAC systems provide climate control for sleeper cabs and are described as zero-idle solution.

AUTOMATIC ENGINE START/STOP SYSTEMS

Automatic engine start/stop systems start and stop the engine.

FUEL-OPERATED/DIESEL-FIRED HEATERS

These units use diesel to provide heat to the sleeper and to the truck engine in an unattended fashion, and to provide a variety of features without requiring the truck's engine to idle continuously.

is allowed for cold and hot temperature extremes. The exact parameter names, ranges, and defaults differ among engine OEMs. Since these are now standard equipment, there is no cost for using them. However, there are some challenges, including the possibility of being able to modify the settings outside of desired ranges, the diversity of terminology among engine manufacturers, and the difficulty in getting buy-in from drivers who may feel the fleet is trying to restrict the way they drive.

DRIVER TRAINING

For idle-reduction systems to be effective, drivers must know how to operate them properly. Some fleets provide ongoing education via drivers' meetings, newsletters, emails, or videos downloaded directly to the truck via an onboard satellite system. Some systems are more complicated to operate than others, and some require drivers to periodically do minor maintenance checks while on the road. Regardless of the system, drivers can help optimize its capabilities by following some general rules such as precooling the cab before shutting the truck down at night and parking on concrete instead of asphalt. Other rules are described in the full report.

DRIVER INCENTIVES

Due to the large impact that drivers have on idle reduction, many fleets have incentive systems to encourage drivers to be involved in reducing the fleet's fuel expenses by sharing the savings between the truck owners and the drivers. These incentives may cover many different elements of fuel use, including vehicle speed, time spent in top gear, percent idle time, and use of idle-reduction solutions. Fleets



“There are a lot of really good reasons to limit the idling of the main engine in a truck—providing the driver with the most comfortable conditions to spend his or her breaks, saving a little fuel, saving a little wear and tear on the engine, and, last but not least, it’s good for the environment.”

—Kevin Otto, Team Lead for NACFE Idle-Reduction Technologies Confidence Report

should select incentive programs and benefits that fit their driver demographics and characteristics to ensure the biggest impact.

ADDITIONAL SOLUTIONS

Other technologies that can be beneficial in a fleet's idle-reduction efforts include additional cab insulation, light-colored paint on the outside of the cab and sleeper, an additional CPAP battery, ultracapacitor starting systems, solar panels, using shore power, and even having the driver stay in a hotel or dormitory instead of sleeping in the vehicle.

COMPLEMENTARY IDLE-REDUCTION TECHNOLOGY PACKAGES

The most efficient and effective idle-reduction solution for a fleet will entail a combination of complementary technologies among those cataloged in this report. For instance, several of the technologies, namely electronic engine parameters, driver incentives, and extra cab/sleeper insulation, are going to contribute positively to almost any solution chosen. The right combination will depend on a given fleet's routes, fuel costs, climate in the fleet's area of operation, shop costs, maintenance cycles, training methods, driver support, fleet policies, and other factors.

The industry is having the most success by choosing one of four technologies as the “anchor” of their overall idle-reduction strategies, and then adding other technologies that best complement or support the anchor. In this way, the full system best suits each fleet's needs.

The four anchor choices are:

1. Driver Controls + Fuel-Operated Heater
2. Diesel APU + Fuel-Operated Heater
3. Battery HVAC + Fuel-Operated Heater
4. Automatic Engine Start/Stop System



“Drivers are not interested in this technology to save fuel and reduce idling. They are interested in staying comfortable in the truck while they are required to be in it.”

—Ben Curtis, fleet maintenance, J. P. Noonan Transportation, and formerly fleet manager, Boyle Transportation

Once one of these options has been identified as the best for a fleet's specific needs and goals, ancillary solutions can be evaluated for their potential to reduce idling even further. Finally, fleets should consider the conditions under which sleeping in the truck for an hours-of-service restart is not the optimal solution. If the main engine will need to idle for the entire restart period to maintain comfortable temperatures and provide hotel loads, especially in very hot weather, a hotel room or dormitory may actually be a more cost-effective choice for the fleet, not to mention a preferable option for the drivers.

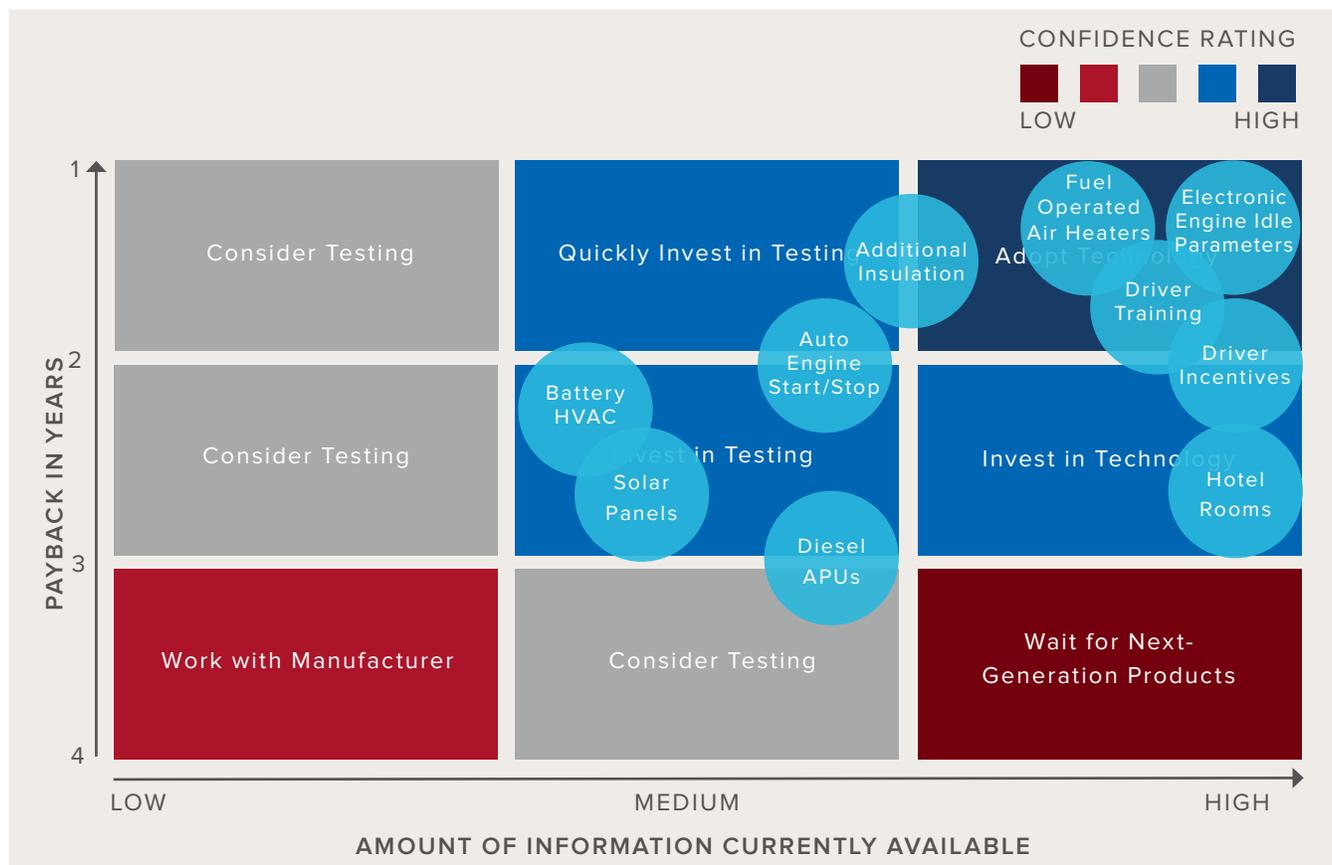
CONFIDENCE RATING

The technologies covered in each of NACFE's Confidence Reports are plotted on a matrix in terms of the expected payback in years compared to the confidence that the study team has in the available data on the technology—that is, not only how quickly fleets can expect payback on their investment but also how certain NACFE is in the assessment of that payback time.

The matrix below indicates how confident the NACFE study team believes trucking fleets should be in the investment case for idle-reduction technologies. Given these conclusions, NACFE believes that fleets should seriously consider investing in idle-reduction technologies following the best practices described in this Confidence Report.



FIGURE ES1
CONFIDENCE MATRIX FOR IDLE REDUCTION



CONCLUSIONS AND RECOMMENDATIONS

Reducing idle time, particularly on sleeper cabs, saves fuel, improves a fleet's "green image," and probably saves a small amount of wear and tear on the main engine. In terms of fuel savings, a 10% annual reduction in idling is worth about 1% in fuel economy, translating to about \$500 to \$700 annually at \$3.00/gallon fuel prices and 100,000 miles/year. And a reduction of 20% is not unreasonable if the right combination of technologies is employed and managed. Drivers are also a very important—if not the most important—part of successful management of idle times.

There is no "one-size-fits-all" solution to idle reduction. Many technologies are available and well proven, but each has pros and cons that need to be evaluated. Every fleet and operation has different goals. Therefore, the costs, benefits, and challenges of each of the technologies need to be weighed along with overall fleet objectives. The good news is that there are a large number of choices to satisfy the needs of individual fleets, and many can be combined to provide the optimal solution for the fleet.



"To me, idle reduction is simple: We have to get a technology figured out to support the battery system. I don't think anyone wants to idle just to be idling; they do it because we have to provide those creature comforts."

—Mike Jeffress, Vice President of Maintenance, Maverick Transportation LLC



NACFE

The North American Council for Freight Efficiency (NACFE) is a nonprofit organization dedicated to doubling the freight efficiency of North American goods movement. NACFE operates as a nonprofit in order to provide an independent, unbiased research organization for the transformation of the transportation industry. Data is critical, and NACFE is helping the industry with real-world information that fleets can use to take action. In 2014, NACFE collaborated with Carbon War Room, founded by Sir Richard Branson and now a part of Rocky Mountain Institute (RMI), to deliver tools and reports to improve trucking efficiency. These reports include a series of Confidence Reports that detail the solutions that exist, highlight the benefits and consequences of each, and deliver decision-making tools for fleets, manufacturers, and others. As of June 2019, NACFE and RMI have completed 17 such reports, covering nearly all the 85 technologies available.

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www.rmi.org

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Learn more at: www.nacfe.org

Or contact: Mike Roeth at mike.roeth@nacfe.org

Confidence Report on Idle-Reduction Technologies

1 Introduction

This Confidence Report forms part of the continued work of the North American Council for Freight Efficiency (NACFE) highlighting the potential of fuel efficiency technologies and practices in over-the-road (OTR) goods movement. Prior Confidence Reports and initial findings on nearly 85 available technologies can be found at www.nacfe.org.

The fuel costs faced by the tractor-trailer industry rose steadily to a peak of \$4.12 per gallon in March 2012. As Figure 1 shows, fuel costs are now approximately \$0.37 per mile, the second largest expense for fleets, behind only driver wages, according to the American Transportation Research Institute (ATRI). [1] Fuel is 22% of a fleet’s total operating costs so regardless of the price per gallon, it is a significant expense. The price per gallon for diesel as of May 2019 is \$3.16, which remains about the same as the 2018 yearly average of \$3.18. [2, 4] See Figures 2 and 3. All indications (including the potential impacts of IMO 2020) are that fuel prices will continue to be volatile, thus the industry is in need of solutions that reduce its fuel dependency if it is to stay profitable. As diesel prices rise, the payback periods shorten, so a payback analysis completed while diesel prices are low should be revisited when there has been a significant increase in fuel cost. Conversely, as fuel prices drop, analyses should also be reviewed.

Motor Carrier Costs	2009	2010	2011	2012	2013	2014	2015	2016	2017
<i>Vehicle-based</i>									
Fuel Costs	\$0.405	\$0.486	\$0.590	\$0.641	\$0.645	\$0.583	\$0.403	\$0.336	\$0.368
Truck/Trailer Lease or Purchase Payments	\$0.257	\$0.184	\$0.189	\$0.174	\$0.163	\$0.215	\$0.230	\$0.255	\$0.264
Repair & Maintenance	\$0.123	\$0.124	\$0.152	\$0.138	\$0.148	\$0.158	\$0.156	\$0.166	\$0.167
Truck Insurance Premiums	\$0.054	\$0.059	\$0.067	\$0.063	\$0.064	\$0.071	\$0.074	\$0.075	\$0.075
Permits and Licenses	\$0.029	\$0.040	\$0.038	\$0.022	\$0.026	\$0.019	\$0.019	\$0.022	\$0.023
Tires	\$0.029	\$0.035	\$0.042	\$0.044	\$0.041	\$0.044	\$0.043	\$0.035	\$0.038
Tolls	\$0.024	\$0.012	\$0.017	\$0.019	\$0.019	\$0.023	\$0.020	\$0.024	\$0.027
<i>Driver-based</i>									
Driver Wages	\$0.403	\$0.446	\$0.460	\$0.417	\$0.440	\$0.462	\$0.499	\$0.523	\$0.557
Driver Benefits	\$0.128	\$0.162	\$0.151	\$0.116	\$0.129	\$0.129	\$0.131	\$0.155	\$0.172
TOTAL	\$1.451	\$1.548	\$1.706	\$1.633	\$1.676	\$1.703	\$1.575	\$1.592	\$1.691

Figure 1– Fleet Cost Per Mile, 2009-2017 (ATRI) [1]

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U.S. On-Highway Diesel Fuel Prices* (dollars per gallon)

	05/06/19	05/13/19	05/20/19	Change from	
				week ago	year ago
U.S.	3.171	3.160	3.163	↑ 0.003	↓ -0.114
East Coast (PADD1)	3.190	3.176	3.176	0.000	↓ -0.095
New England (PADD1A)	3.245	3.238	3.238	0.000	↓ -0.044
Central Atlantic (PADD1B)	3.379	3.365	3.375	↑ 0.010	↓ -0.045
Lower Atlantic (PADD1C)	3.051	3.035	3.030	↓ -0.005	↓ -0.133
Midwest (PADD2)	3.064	3.046	3.049	↑ 0.003	↓ -0.169
Gulf Coast (PADD3)	2.927	2.905	2.907	↑ 0.002	↓ -0.148
Rocky Mountain (PADD4)	3.186	3.181	3.192	↑ 0.011	↓ -0.156
West Coast (PADD5)	3.765	3.790	3.794	↑ 0.004	↑ 0.029
West Coast less California	3.345	3.355	3.352	↓ -0.003	↓ -0.151
California	4.097	4.136	4.145	↑ 0.009	↑ 0.172

*prices include all taxes

Figure 2 – On-Highway Diesel Fuel Prices Per Gallon (EIA) [2]

Weekly U.S. No 2 Diesel Retail Prices

Dollars per Gallon



Figure 3 – Weekly Diesel Fuel Prices Per Gallon (EIA) [2]

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Investment in proven technologies and practices that allow a truck or fleet to increase their fuel efficiency — meaning that they can do the same amount of business while spending less on fuel — is a hugely promising option for the industry in light of the fact that fuel prices are volatile and also represent a significant portion of a fleet’s operating budget regardless of what fuel costs.

To understand, and thereby better facilitate, the uptake of such technologies, NACFE conducts an annual review, the “Fleet Fuel Study,” of the industry-wide adoption rates of nearly 85 fuel efficiency technologies currently available for Class 8 tractors and trailers. This work, available at www.nacfe.org, is highly anticipated by the industry. “I look forward to this report and read it each year within days of it being published,” said Rob Reich, Senior Vice President, Equipment, Maintenance & Driver Development, Schneider, Inc. “It is important to Schneider’s efforts and it can be a critical resource to any fleet or owner-operator as well as manufacturers and others who are working to improve Class 8 efficiency.”

The primary finding of the most recent Fleet Fuel Study, completed in 2018, is that fleets are increasing their rate of adoption of these technologies and that they are enjoying improved fuel economy as a result. The overall adoption rate for the technologies studied in this report has grown from 17% in 2003 to 44% in 2017.

The fleet-wide average efficiency for these fleets in 2017 reached 7.28 mpg, a 2% improvement over the same fleet in 2016, an 11th consecutive year efficiency improvement.

The 20 fleets surveyed, representing both regional and long-haul tractors and trailers, in both dry goods and refrigerated cargo movement, and boasting a combined inventory of 71,8444 trucks saved \$636,791,023 in 2017 compared to the national average of all trucks on the road.

Figure 4 and 5 show the adoption curves for various idle-reduction technologies used by the fleets that participated in NACFE’s Annual Fleet Fuel Study. [16] The future years in Figure 5 show what the expected adoption levels following Greenhouse Gas Phase 2 regulations are anticipated to be by the authors of the regulations.

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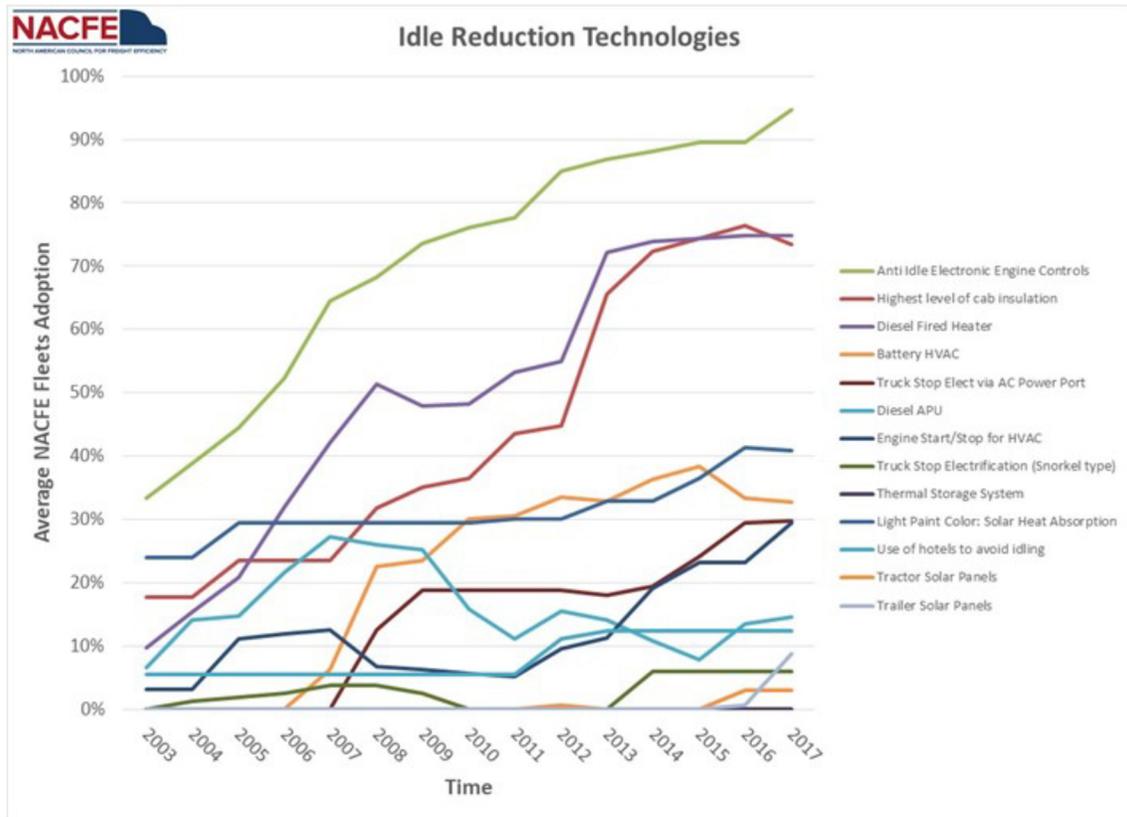


Figure 4 – Idle-Reduction Technologies (NACFE) [16]

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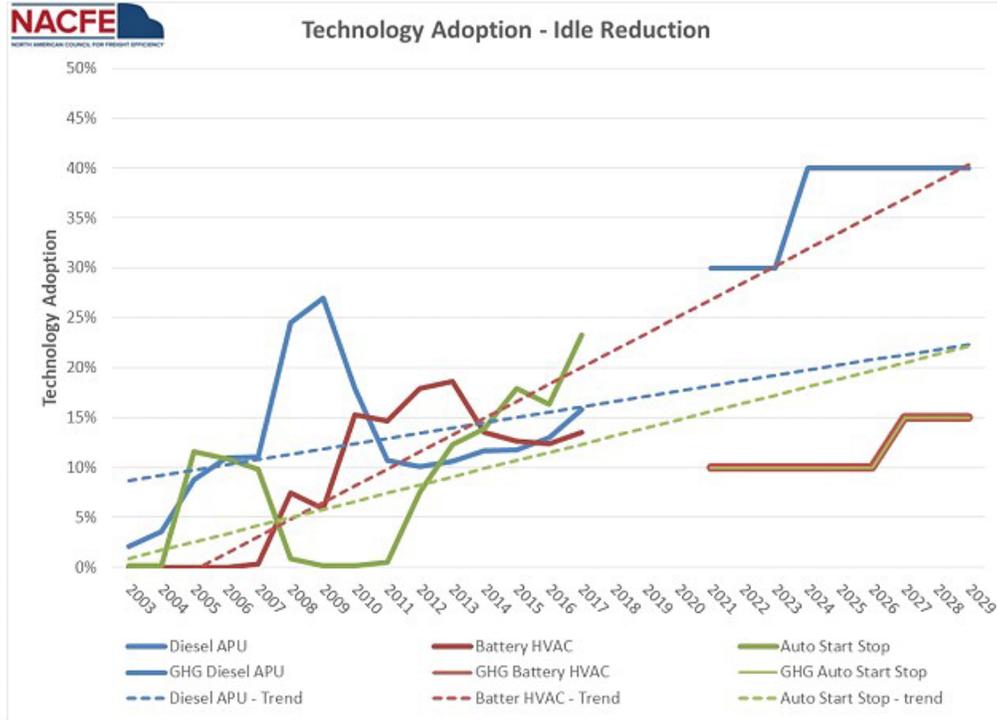


Figure 5 – Idle-Reduction Technology Adoption (NACFE) [16]

2 Scope

This report only considers idle-reduction technologies that are currently available on the market for over-the-road applications. This Confidence Report focuses on just five of the eight reasons for idling in terms of the “benefits” that fleets would seek to obtain from any idle-reduction technology they might adopt. The five benefits considered in this report are:

1. Cab heat
2. Cab cooling
3. Battery state of charge (maintaining a charge in the truck engine battery)
4. Hotel loads (TV, refrigerator, microwave, gaming console, CPAP, fan, laptop, electric blanket, cell phone charger, etc.)
5. Engine heat (keeping the engine warm)

In addition, this report focuses on solo drivers and does not deal with team drivers as that percentage of team drivers is relatively low.

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3 NACFE’s Mission

NACFE’s overriding principle in reporting on technologies is to provide an unbiased perspective. NACFE recognizes that it also has vested interests and an agenda. NACFE’s mission is simply to improve the efficiency of North American goods movement. NACFE pursues this goal in two ways: By improving the quality of the information flow and by highlighting successful adoption of technologies. The Confidence Reports published by NACFE serve to assist in information flow while the Run on Less demonstrations and Annual Fleet Fuel Studies highlight adoption success and provide benchmarks for fleets.

Several years ago, NACFE recognized that emerging and future technologies need an unbiased review to help fleets consider them and for manufacturers to learn and adapt their products and solutions to better meet the fleets’ needs. To that end, NACFE started publishing Guidance Reports that look at emerging and future technologies. As of mid-2019, NACFE has published three Guidance Reports on electric trucks. These reports can be found at <https://nacfe.org/>.

4 Report Methodology

NACFE’s research for this report included interviewing key people with first-hand knowledge of idle-reduction technologies at fleets, manufacturers, and industry groups as well as reviewing what others had already written on the subject of idle reduction. The report includes a list of references to assist readers interested in pursuing more detail. These references were researched with the same diligence and thoughtful processes NACFE uses with its other technology Confidence Reports and Guidance Reports.

5 Background on Idle Reduction

5.1 Why Idle?

Restarting a diesel engine in cold temperatures is much easier if the engine oil is already warm and therefore at a lower viscosity, and idling also prevents the cold-weather gelling of diesel fuel.

Second, the introduction of sleeper berths into the trucking industry meant truck drivers needed a controlled indoor climate while the truck was parked in all weather conditions. Idling is used by some drivers of sleeper tractors to simply provide white noise and a gentle vibration as they attempt to get some rest in the middle of a truck stop parking lot, with vehicles pulling in and out around them all night.

Third, over the past two decades, the growth in personal electronic usage among off-duty drivers has placed additional loads on truck batteries, given the use of gaming devices, cell phones, and laptops in sleeper cabs. Driver health is also causing an uptick in personal electronic usage, as the average driver is now over the age of 55. [25]

According to several sources, two-thirds (69%) of drivers are obese (BMI of 30+) and 17% are morbidly obese (BMI of 40+). By comparison, one-third of all working adults in the U.S. were reported obese and

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7% morbidly obese [15, 17] These demographics have created at least two additional loads on batteries — one being a wider use of refrigerators in cabs to allow for the storage of healthier food such as fresh fruits and vegetables, and the other being use of a CPAP machines to provide quality rest for drivers suffering from sleep apnea. See Figure 6 for details on health risks for trucks drivers.

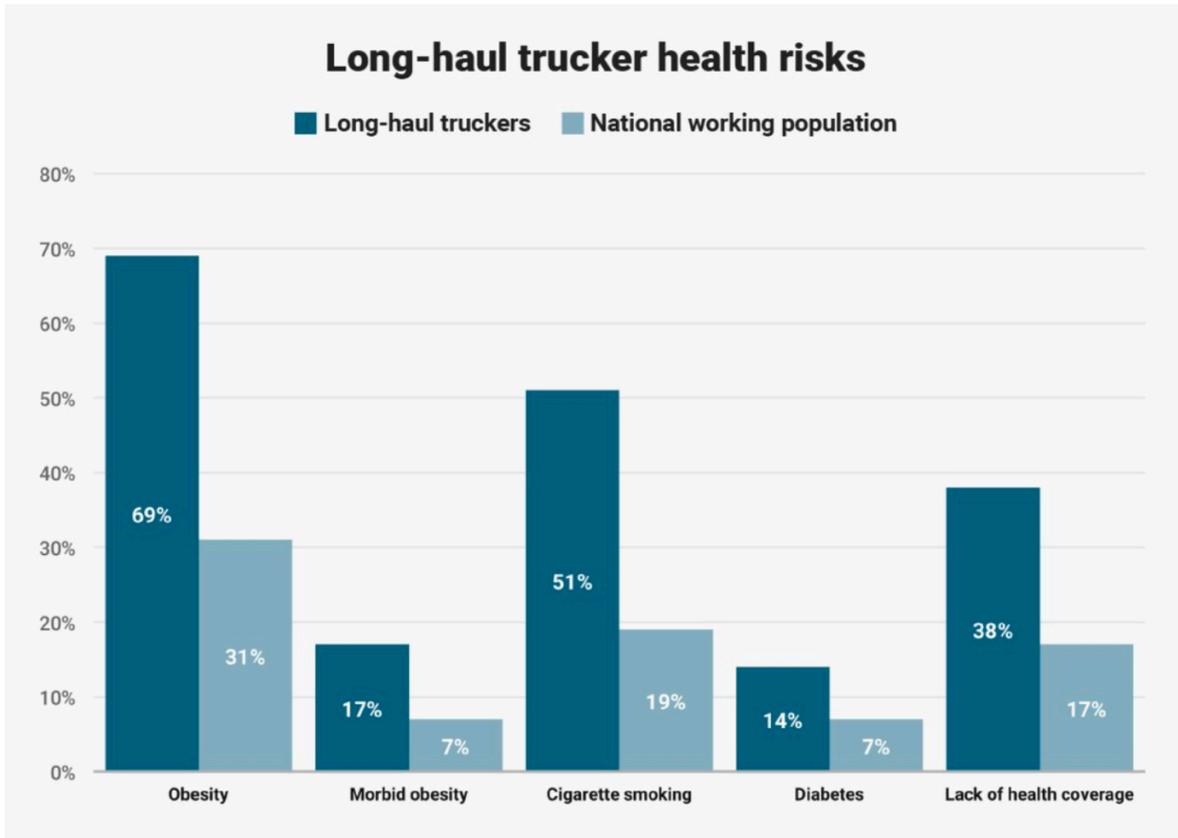


Figure 6 – Long-haul Trucker Health Risks (Business Insider, CDC, NIOSH, FMCSA) [17]

This growth in the use of the batteries to power electronics is behind what is perhaps the most compelling reason for idling — engaging the alternator — to keep a truck’s batteries charged to a level sufficient for restarting the vehicle.

Also inherent to the trucking industry is idling in queues, for example while waiting in line for a dock to open, or for an inspection, especially at border crossings. Idling at docks or when making deliveries is especially a problem for operators of day cabs. [See Section 7.2 for more information on idle reduction and day cabs.] Finally, a few unique instances within the trucking industry create a need for continuous idling, to supply needs such as in-transport heat to warm liquid bulk trailers. However these applications are the exception and not the rule.

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Based on conversations with the trucking industry, this study team breaks the aforementioned reasons for idling behavior into eight specific instances. (See Section 2 for information on the scope of this report, which will only focus on five of the reason drivers idle their vehicles.)

- Cooling the cab/sleeper
- Heating the cab/sleeper
- Maintaining battery charge
- Powering electronic devices for driver comfort/convenience
- Keeping the engine warm for improved startability
- Preventing diesel fuel from gelling
- Waiting for a dock spot
- Vocational application requirements
- Engine white noise and vibration

5.2 A Brief History of Methods Used to Reduce Idling

The first device to help diesel-powered tractors avoid unnecessary idling was the electric block heater, created in the 1940s and designed to keep engine fluids warm, enabling better starting in cold weather conditions.

In 1952, Webasto created fuel-operated heaters that functioned independently of the main engine for use in passenger cars and buses. At some point these technologies made the jump into the trucking industry and have been going strong ever since. Today, fuel-operated heater systems are capable of heating the cab's air as well as the engine's fluids.

Diesel auxiliary power units (APUs) have been in existence since World War I, and it is unclear when they were first used on a truck. However, they have long been the preferred tool of truck owner-operators in need of more fully functioning sleeper amenities as they often lived in their trucks at nearly all times. Escalating fuel prices led to large-scale adoption by fleets in the mid-2000s.

The considerable growth of diesel APUs led to some quality issues in that industry, as demand was so high that diesel APU manufacturers and their supply base struggled to satisfy it. The resultant dip in diesel APU reliability stimulated the growth of a simplified battery-powered HVAC (Heating, Ventilation & Air Conditioning) system (which is itself also a type of APU), that avoided the complexity and maintenance of the diesel APU.

The Bergstrom Nite, a battery HVAC system, hit the market in 2006. It further widened the selection of options available to combat excessive idling by providing a solution that didn't use any diesel fuel while providing cold air to the sleeper. These systems do, however, consume diesel fuel, because the larger alternators they require place a large load on the engine to charge their battery packs when the truck is being driven. People refer to these systems using a variety of terms including battery APUs, electric APUs, battery EPU, and e-APUs. For the purposes of this report we will refer to them as battery HVAC systems.

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The conversion to electronically controlled diesel engines began in the mid-1980s, with the introduction of programmable parameters that could monitor and control idling practices. These now include the exact idle RPM a fleet desires, the temperatures where idling is timer-controlled, and the temperatures that are considered so hot or cold that unlimited idling is acceptable.

The concept of an automatic diesel engine start/stop system was first introduced in the 1990s. These began as add-on systems, but the patents were licensed to several diesel engine OEMs who integrated the functionality into their engine control system. Both OEM-integrated and aftermarket add-on systems are still in use today.

The general usage of AC power for vehicles started with block heaters. It is difficult to say when the first driver started using AC power for other functions while stopped, but it probably started when the drivers were home for a few days and they determined that plugging in household heating or air conditioning systems could get the vehicle to a comfortable temperature. This concept has long been used by boats and ships, creating the name “shore power,” since the AC power was only available when a boat was in dock along the shore.

Volvo introduced shore power connections as a factory option with the VN model in 1996. The company Shorepower Technologies (a specific brand name and not to be confused with these systems generally, which are also called shore power) entered the picture in 2006, and initially provided AC power to test locations in New York.

The first truck stop electrification system was introduced by IdleAire in 2000, offering not only 120-volt AC power, but also HVAC, Internet, and cable TV. These systems are distinct from off-board AC power systems as they require greater investment in and construction of infrastructure, but little to no modifications to the truck itself. The benefits of such systems are obvious, but limited infrastructure/access to their portals has hampered initial acceptance. In 2014 when the first Confidence Report on idle-reduction technologies was published, this technology seemed to have more promise as a solution to idling; that has not proven to be the case in the ensuing years and it is not a viable option for most fleets today.

In 2008 the California Air Resources Board (CARB) introduced “Clean Idle” stickers, which signified that a given engine system met the CARB requirements for extended idling. This has since grown to include a separate sticker that indicates a diesel APU has a Diesel Particulate Filter (DPF) and meets more stringent requirements for California. These stickers allow drivers to idle the certified component beyond the 5-minute limit in California.

5.3 Why Minimize Idling?

Trucks have been idling since the invention of diesel engines. The volatility of diesel fuel prices, concern about the impact of diesel emission on the environment and an attempt to minimize engine wear led to some efforts by the trucking industry to limit idling. Also, occasionally, citizens would protest the noise or smell of idling vehicles, and create “no idle zones” in their areas.

Over the past two decades either to meet operating goals or under mandates that cut or eliminated truck idling across North America, reducing idling has become the norm for the industry. Several

Confidence Report on Idle-Reduction Technologies

rounds of EPA-mandated emissions controls have substantially lowered allowed levels of truck emissions, as well as requiring DPFs and Selective Catalytic Reduction (SCR) systems. Local restrictions on idling have also increased exponentially, creating a patchwork of regulations, all of them stricter than what the industry faced in the past. [See Section 5.6 for more information on idling regulations.]

Not only are government regulations intensifying, still more recently the trucking industry has been impacted by an increased awareness of sustainability among general society and within the industry itself. For example, freight customers are now asking large fleets to provide documentation of their sustainability effort and the results of those efforts. This incentivizes serious advances in the adoption of environmentally friendly technologies and practices including idle reduction.

All of these factors combine to put substantial pressure on the trucking industry to reduce or even end the idling of engines.

5.3.1 Driver Comfort & Satisfaction

Today, the most prominent reason to reduce idle centers around drivers and their comfort. In fact, in ATRI's annual industry survey to determine the top 10 critical issues facing the trucking industry, the driver shortage has been near the top of the list for many years. See Figures 7 and 8. And in 2018 the driver shortage was firmly at the top of the list along with driver retention and driver health and wellness. Fuel prices did not show up on the list at all, although in previous years fuel was a concern. [5]

	Issue Rank									
	1	2	3	4	5	6	7	8	9	10
2018	Driver Shortage	Hours-of-Service	Driver Retention	ELD Mandate	Truck Parking	CSA	Driver Distraction	Infrastr./ Congestion/ Funding	Driver Health/ Wellness	Economy
2017	Driver Shortage	ELD Mandate	Hours-of-Service	Truck Parking	Driver Retention	CSA	Cumulative Impacts of Regs.	Driver Distraction	Infrastr./ Congestion/ Funding	Driver Health/ Wellness
2016	ELD Mandate	Hours-of-Service	Cumulative Impacts of Regs.	Truck Parking	Economy	CSA	Driver Shortage	Driver Retention	Infrastr./ Congestion/ Funding	Driver Distraction
2015	Hours-of-Service	CSA	Driver Shortage	Driver Retention	Truck Parking	ELD Mandate	Driver Health/ Wellness	Economy	Infrastr./ Congestion/ Funding	Driver Distraction
2014	Hours-of-Service	Driver Shortage	CSA	Driver Retention	ELD Mandate	Truck Parking	Infrastr./ Congestion/ Funding	Driver Health/ Wellness	Economy	Driver Distraction
2013	Hours-of-Service	CSA	Driver Shortage	Economy	ELD Mandate	Truck Parking	Driver Retention	Fuel Supply/ Fuel Prices	Infrastr./ Congestion/ Funding	Driver Health/ Wellness
2012	CSA	Hours-of-Service	Economy	Driver Shortage	Fuel Supply/ Fuel Prices	ELD Mandate	Driver Retention	Truck Parking	Driver Health/ Wellness	Congestion/ Truck Bottlenecks
2011	Economy	Hours-of-Service	Driver Shortage	CSA	Fuel Issues	Congestion	Transportation Funding	Tort Reform	Onboard Truck Technology	Truck Size and Weight
2010	Economy	CSA	Government Regulation	Hours-of-Service	Driver Shortage	Fuel Issues	Transportation Funding/ Infrastr.	Onboard Truck Technology	Environmental Issues	Truck Size and Weight
2009	Economy	Government Regulation	Fuel Issues	Congestion/ Highway Infrastr.	Hours-of-Service	Commercial Driver Issues	Environmental Issues	Tolls/ Highway Funding	Truck Size and Weight	Onboard Truck Technology

Note: **Bold** indicates first year in top ten.

Figure 7 – Top Industry Issues Rankings 2009-2018 (ATRI) [5]

Confidence Report on Idle-Reduction Technologies

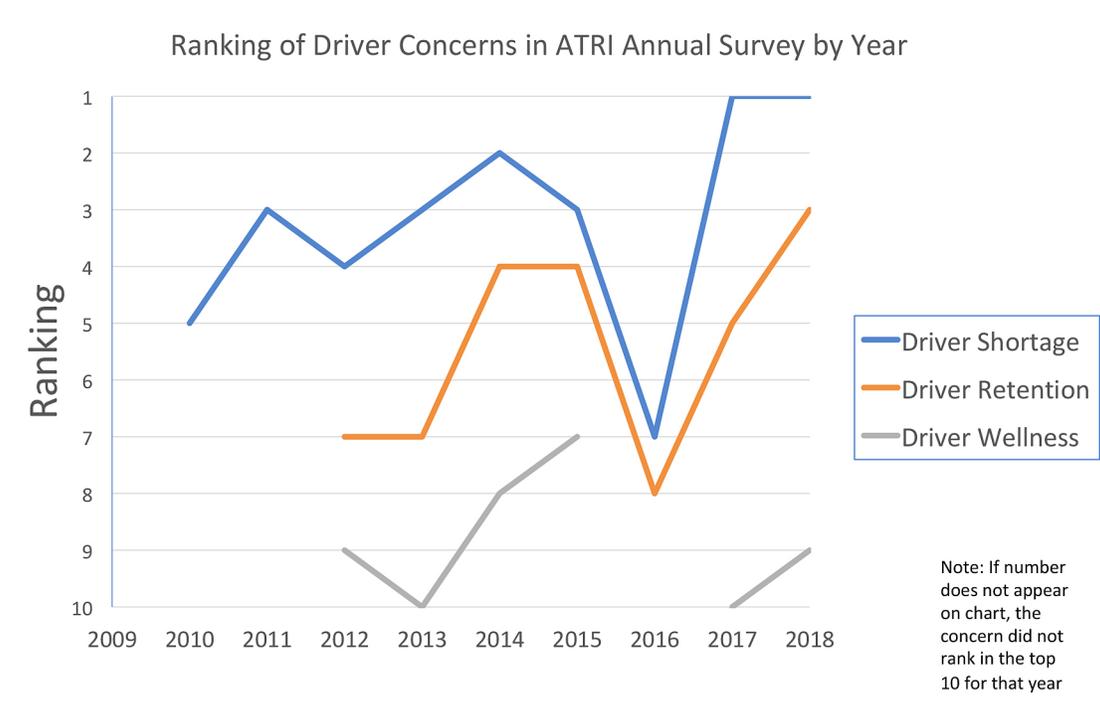


Figure 8 – Ranking of Driver Concerns in ATRI Survey By Year 2009-2018 (ATRI/NACFE) [5]

Historically, rising fuel prices are a motivator for actually reducing idling. While fuel prices are definitely a concern of fleets, the issue has not entered into the top 10 issues since 2013, when diesel prices were high. When fuel prices are very high, fleets are more concerned about fuel cost and supply. But when it is low, fuel prices do not receive very much attention, even though fuel costs are a significant piece of a fleet’s total operating cost per mile.

The driver shortage, driver retention, and driver health issues, all serve to give drivers more leverage over the industry and therefore a greater voice in determining which features are or are not spec’d on their vehicles — and while this is wholly positive for the drivers, it poses a challenge to idle-reduction efforts.

As one former fleet manager said, “Drivers are not interested in [idle-reduction] technology to save fuel and reduce idling. They are interested in staying comfortable in the truck while they are required to be in it.”

Another fleet executive said, “I don’t think anyone wants to idle just to be idling. They do it because it provides creature comforts.” And with a driver shortage of 60,000, according to the American Trucking Associations, possibly growing to 100,000 in a few years and driver turnover rates in the 80+% range, keeping driver happy has taken on increased importance at fleets. [38]

In addition, keeping drivers happy is actually good for the whole society, as the need to take care of drivers and ensure they are able to sleep properly was demonstrated in a 2007 Large Truck Crash

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Causation Study by the US DOT, wherein 13% of all crashes were found to involve driver fatigue. [7, 8, 26]

The second biggest concern of truck fleets is the Hours of Service regulations, which went into effect July 1, 2013 and included a mandatory “restart” that calls for a period without driving to occur at least once a week which lasts at least 34 hours and includes two stretches of rest time between 1 a.m. and 5 a.m. Depending on when a driver pulls over to begin such a restart, it could actually be nearly 48 hours long, if the regulations are to be met. These longer rest periods necessitate an increase in engine idling, both to keep the truck’s batteries charged and to keep the drivers comfortable. The regulations also cause greater waiting times for open parking spaces, since any given space is now being used for longer periods of time. [6]

In December 2014, The Consolidated and Further Continuing Appropriations Act of 2015 suspended enforcement of requirements for use of the 34-hour restart, pending a study. Based on the findings from the CMV Driver Restart Study, the 34-hour restart rule in operational effect June 30, 2013, was restored to full force and effect. However, the requirement for two off-duty periods of 1 a.m. to 5 a.m. in the hours-of-service rules will not be enforced, nor will the once-per-week limit on use of the restart. The Federal Motor Carrier Safety Administration is expected to issue a new proposed ruling in late July 2019. The original release date was June 7, 2019 but was delayed due to continuing questions from the White House Office of Management and Budget.

5.4 Extended Idle and Increased Maintenance Cost

One of the claims that is frequently made by manufacturers of idle-reduction equipment is that reducing idle time reduces maintenance costs for the fleets. The components brought up most often in these discussions are the components of the aftertreatment systems — the Diesel Oxidation Catalyst (DOC), DPF and the SCR system. These components are quite expensive to replace, and it is no secret that they have caused an increase in maintenance costs for fleets since their introduction. However, in conducting many interviews with manufacturers and fleet personnel about idle-reduction equipment, we have never been able to gather any data that definitively shows the connection between reduced idle time and reduced maintenance costs.

An average fleet, employing a suite of idle-reduction technologies along with the proper engine parameter settings, driver training and processes, will likely reduce idle percent on a fleet-wide, annualized basis by about 20% (from 30% to 10%). Of course, the results would vary by fleet depending on a number of factors, but the 20% reduction represents a typical estimate of the overall effect of idle-reduction technologies.

The question we are trying to answer is whether that amount of idle reduction will substantially reduce maintenance costs. Of course, answering that question definitively will take a large sample size of vehicles of the same vintage with and without the idle-reduction technologies running over several years. To our knowledge, no such study has been conducted by any fleet or manufacturer.

Two engine manufacturers we interviewed for the report indicated they have not been able to make this connection between reduced idle and reduced maintenance cost definitively either. However, they

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did mention other reasons aftertreatment maintenance costs were high and that most of those issues have been addressed in the newest iterations of diesel engines that are currently being produced. They mentioned some of the following as issues, which did affect the reliability or durability of the aftertreatment systems as now being solved:

- **Exhaust Gas Recirculation (EGR) cooler failures** — Coolant making its way to the aftertreatment system from a leak can affect the aftertreatment system
- **EGR valve failures** — Failure of the EGR valve to properly control EGR can affect the amount of smoke the engine generates, thus potentially overloading the DPF
- **Turbomachinery issues** — Certain malfunctions of the turbomachinery can affect what goes into the engine’s exhaust causing downstream issues
- **Controls calibrations that manage DOC and DPF** — This would include “face plugging” of the DOC due to fuel dosing and exhaust temperature management (both at idle and engine under power). This would also include DPF regeneration management at proper intervals.
- **Catalytic coatings to optimize operation** — These coatings have evolved over time to improve operation

Many of the items listed above are really “upstream” of the aftertreatment system. In many cases, an EGR cooler failure would result in fixing the cooler and nothing else. However the aftertreatment system might have been damaged in a way that would not show up until thousands of miles later. Thus, the aftertreatment becomes a victim of what is happening upstream. In this case, it is very easy to associate the failures to other factors like higher engine idling.

The good news is that the engine manufacturers have been hard at work addressing these issues and the newest aftertreatment systems are not incurring the same maintenance costs as in the past. Figure 9 from a presentation by CARB shows the significant improvements in reliability of some of the system components over time.

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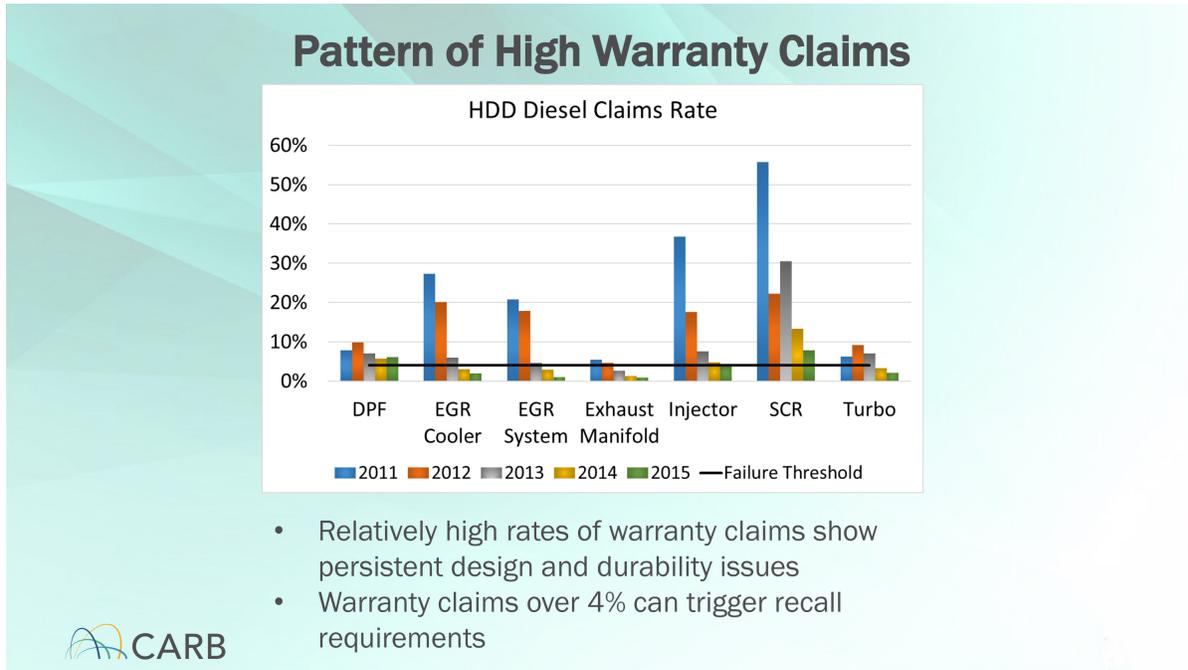


Figure 9 – Pattern of High Warranty Claims (CARB) [27]

Figure 9 represents all engine manufacturers combined, but gives a picture of improvements that have been made. Given the changing reliability picture from year to year, it is impossible to conclude that any fleet maintenance cost improvements that might be seen are directly related to an idle-reduction strategy as opposed to other factors.

It is hard to argue that idling the engine fewer hours per year does not decrease at least some wear and tear on the engine. However, the associated effect on maintenance costs are probably relatively small.

5.5 Current State of Idling

Most industry stakeholders, including fleets, technical trade associations, systems suppliers, original equipment manufacturers, and government administrators, agree that the idling of truck engines should be minimized, as doing so is best for the fleet’s profitability as well as for the environment. However the commonly used term for efforts at doing so — “anti-idling” — implies that there should be no idling at all. Given that the occupants of a truck require a comfortable place to obtain quality sleep, on top of the fact that it is reasonable to expect the vehicle to restart upon command, some level of idling is absolutely required for the foreseeable future. This report therefore proposes the use of the term “idle-reduction” in speaking about these technologies, as opposed to “anti-idling.”

Various surveys provide different numbers on how many tractors have some idle-control devices installed presently, as there is no standard definition of such a device. For example, virtually all electronically-controlled diesel engines today have programmable parameters to control idle speeds, idle time before shutoff, and temperatures under which idling is allowed. As these systems have been

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in production for more than 25 years, the vast majority of vehicles in operation are now equipped with them. A main feature of such systems today is to control idle speeds, as the actual rate of diesel fuel used while idling depends on the engine as well as the engine speed during idle, per Figure 10 published by Cummins. [22]

Engine Speed (Revs Per Minute)	Average Fuel Consumption
650 RPM	~ 0.5 gallons/hour
1,000 RPM	~ 1.0 gallons/hour
1,200 RPM	~ 1.5 gallons/hour

Figure 10 – Secrets of Better Fuel Economy (Cummins) [18]

Although Figure 10 makes the argument for idling at lower speeds to save fuel, the Technology & Maintenance Council (TMC) of the American Trucking Associations (ATA), in their “Recommended Practice 1108: Analysis of Costs from Idling and Parasitic Devices for Heavy Duty Trucks,” demonstrated that running at lower speeds creates additional wear on the engine’s internal parts compared to driving at highway speeds, so overall cost savings will not depend on engine speed alone, and therefore these electronic engine parameters, by far the most common technologies today, may not be truly optimizing a fleet’s idle behavior. [28]

A plethora of newer idle-reduction systems now on the market and covered in this Confidence Report have much lower rates of adoption, yet they are capable of reducing idling significantly below current averages. Assuming that the survey work for this Confidence Report is accurate, fleets in the United States average, at best, about 10% of a truck’s time spent idling.

One fleet manager we spoke with said that prior to investing in idle-reduction technology his fleet’s idle percentage was in the 38% to 42% range. Today idle percentage is down in the 10% to 12% range.

Another fleet said, “We are satisfied with 15% idle right now because of the driver shortage. You can’t get too overbearing on a driver.”

An OEM guesstimated that over all fleets are averaging 30% idle before adding idle-reduction technologies. “When they start adding technologies that number drops down dramatically and typically will be under 20%.”

A truck manufacturer said that 70% to 80% of the sleeper trucks it produces today have some form of idle management that goes beyond programmable engine parameters. About 15% of its trucks are sold with battery HVAC systems on them and another 15% leave the plant with a diesel APU prep kit. “Nearly half the sleepers going out of the plant do so with either a battery HVAC system or a prep kit for a diesel APU,” an executive from an OEM said.

When combined with statistics on the size of the trucking industry in the United States published by the ATA — such as 3.63 million registered Class 8 tractors, 38.8 billion gallons of diesel fuel consumed

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per year, 10.77 billion tons of freight per year moved by truck, and more than 181.5 billion miles logged by Classes 6 through 8 of trucks in 2017 — the study team finds that, in order to operate their sleeper tractors, fleets in the United States uses over a billion gallons of diesel while idling, approximately 8% of the total fuel burned. [11, 13]

Some idling is realistically unavoidable, but other idling can be reduced. By investing in idle-reduction technology, a fleet can save 1,800 gallons of fuel per truck per year. If we extrapolate that over 400,000 trucks that may have a need to idle, that is a little over 700 million gallons of fuel. This is based on the following assumptions:

- Average idle times of about 1000 hours/year
- Realistic idle reduction with an investment in an APUs is about 600 hours per year
- 600 hours at \$3/gallon diesel fuel and burning 1 gallon per hour equals 1800 gallons/truck where technology is employed
- The take rate on diesel APUs and battery HVAC systems doubles from today (estimate from 40% to 80% of sleeper cabs or about 20% of total vehicles on the road).
- That nets a decrease in idle percent of about 10% overall from 35% to 25%

5.5.1 Fleet Survey Results

As part of the research for this report, the study team sent a survey to fleets via the internet. Fleets were asked about the idle-reduction technologies they used (Figure 11), their preferred idle-reduction solution (Figure 12), the annualized fleet-wide idle percentage (Figure 13), whether they saw a positive financial payback from these technologies (Figure 14), and what was the main reason they chose to invest in idle-reduction technology (Figure 15).

What idle reduction techniques and equipment do you use? (Check all that apply.)

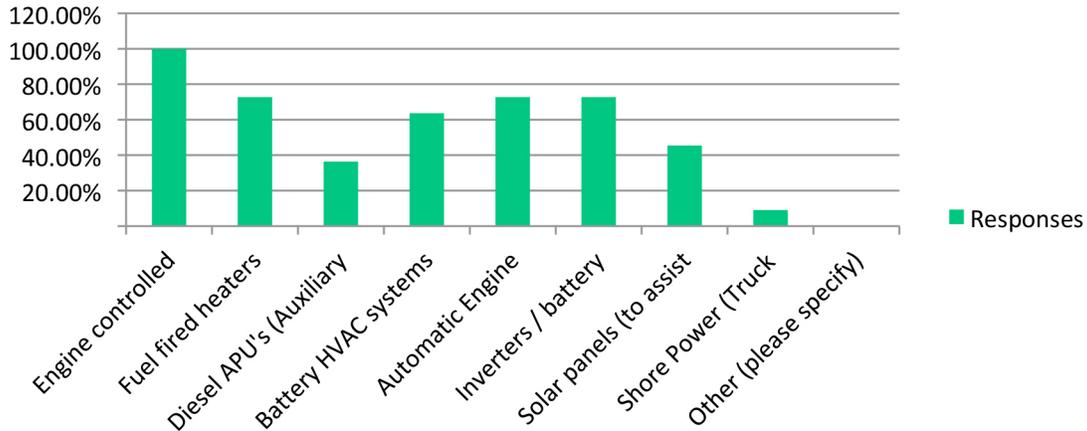


Figure 11 – Idle Technology Use (NACFE Fleet Survey)

What is your preferred Idle Reduction solution? (Check all that apply)

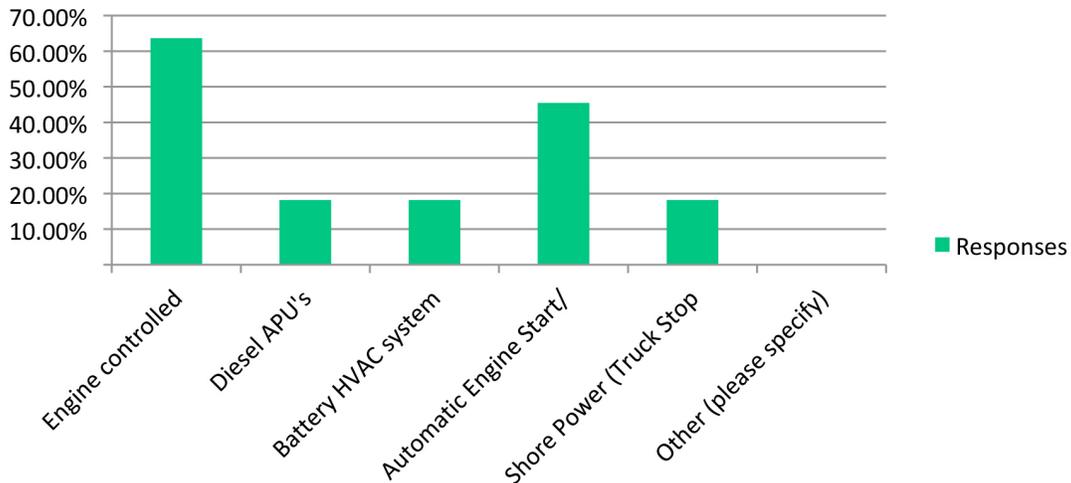


Figure 12 – Preferred Idle Technology Use (NACFE Fleet Survey)

What is your annualized fleet Percent Idle Time?

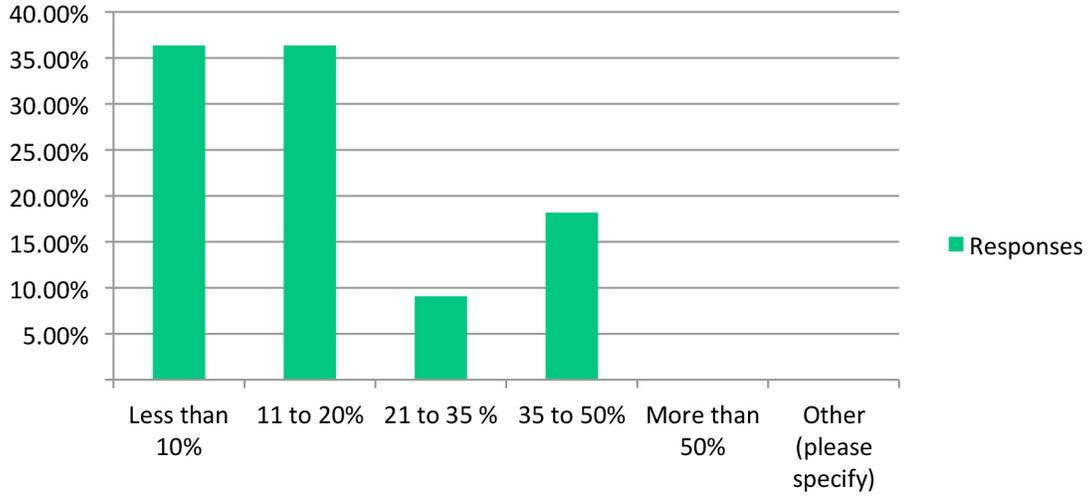


Figure 13 – Annual Idle Percent (NACFE Fleet Survey)

For your preferred solution, what is the financial payback for your fleet?

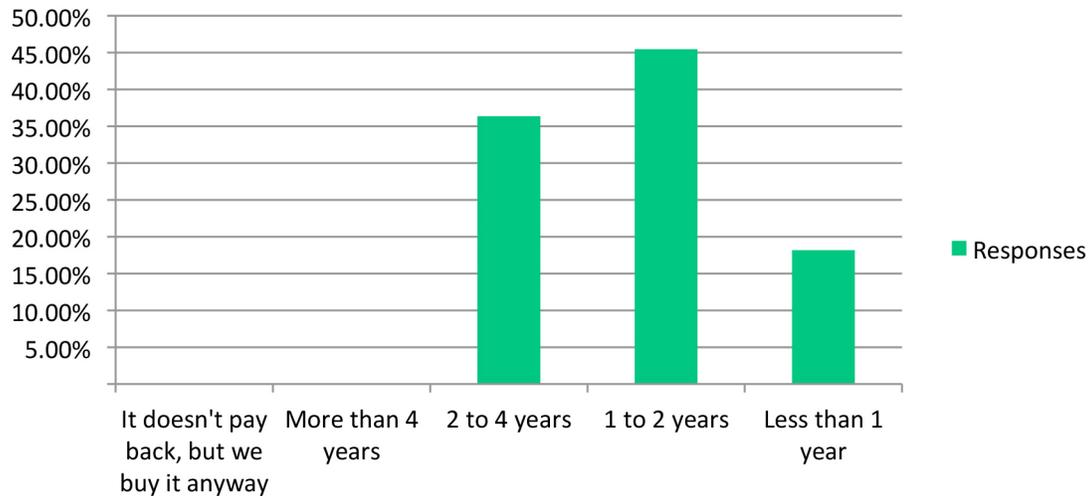


Figure 14 – Idle Technology ROI (NACFE Fleet Survey)

What is the most important driver in your fleet for investment in Idle Reduction technologies?

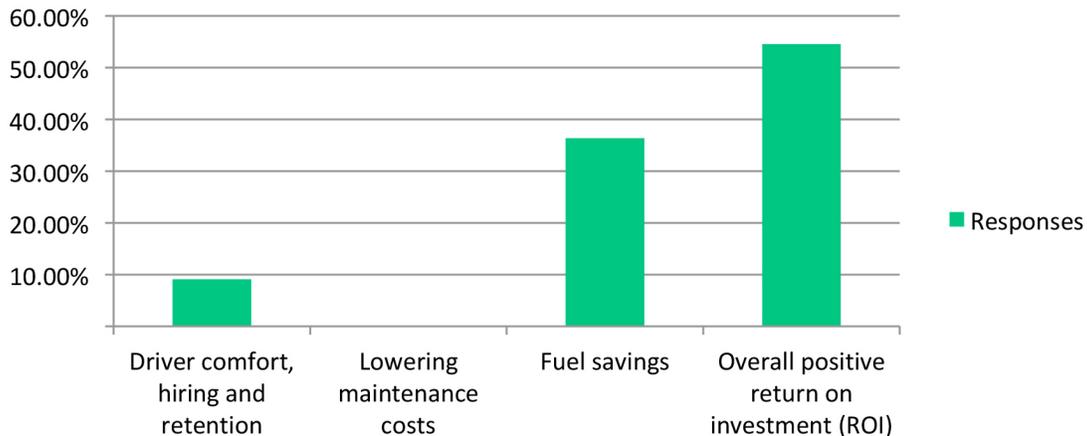


Figure 15 – Idle Technology Selection Criteria (NACFE Fleet Survey)

Key takeaways from the survey include:

- If a fleet does not use APUs, their idle percent tends to be in the 30% to 50% range.
- If a fleet uses APUs, idle percent is in the single digits to 20%
- Fleets seem to be split on diesel APUs vs. battery HVAC systems with some fleets using both (but not on a single vehicle)
- Use of auto start-stop systems is increasing
- Almost everyone uses fuel-fired heaters
- Most fleets are looking for positive ROI, but most of them also think there is significant value in driver retention and hiring
- No one rates avoiding maintenance costs as their top driver for investing in idle-reduction technology
- Almost every fleet looks for investment payback in two years or less

5.6 Current Government Idling Regulations

No single, blanket federal regulation covers the idling of Class 8 trucks in the United States or Canada. See Figure 16 for an overview of states with idling regulation. Instead, a multitude of different idling regulations, which determine maximum idling time, fines, and exemptions, exist across the country, and they vary widely — by state, county, and even municipality. Permitted idle times range from zero to 20 minutes, with first-time fines ranging from \$25 up to \$500, and maximum penalties up to \$25,000. Typical exemptions from such rules for idling include under certain traffic or weather

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- Clean Cities, a U.S. Department of Energy (DOE) agency, also has information on engine idling laws and ordinances in a database called Idlebase. See: <https://cleancities.energy.gov/technical-assistance/idlebox/>
- The Alternative Fuels Data Center provides information on federal, regional, state, and local laws with an interactive map of all the states. See: <https://afdc.energy.gov/laws>
- The U.S. Environmental Protection Agency's (EPA) covers regulations and compliance information via its SmartWay publications. See: <http://www.epa.gov/smartway/>
- Idling Reduction for Long-Haul Trucks: An Economic Comparison of On-Board and Wayside Technologies. See: <https://www.anl.gov/es/reference/economics-of-idling-reduction-options-for-longhaul-trucks>

6 Idle-Reduction Systems

This chapter includes a deep dive description of the various idle-reduction technologies including an overview of the technology, its benefits and challenges, comparison to other solutions and some recommendations for adoption.

6.1 Key Features of Idle-Reduction Systems

Idle-reduction technologies can be distinguished at a most basic level by the pathways by which they reduce the need for idling. Some of the systems are “active” in nature and provide a specific set of benefits to the vehicle and driver, while other idle-reduction methods are “passive” and simply work to minimize the need for the active systems. See Figure 17.

The wide range of options poses a challenge, or barrier, to the adoption of idle-reduction systems overall, in that each fleet must evaluate the costs and benefits of the various systems related to their particular operation to assess which combination of technologies will allow them to best achieve their goals.

“Passive” options covered in this report include: additional insulation, curtains, light-colored paint, and other simple tips such as parking in the shade and avoiding parking on blacktop in the summer sun. “Active” systems are primarily distinguished among one another by the energy sources they use as alternatives to an idling engine.

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BENEFITS	ON TRUCK ENERGY SOURCES		OFF TRUCK ENERGY SOURCES	
	DIESEL FUEL	BATTERIES (12VDC)	120 VAC (SHORE POWER)	OFF BOARD HVAC
CAB HEAT	Diesel APU		Household Space Heater	Truck Stop Electrification
	Fuel-operated Air Heater			Hotel
	Automatic Engine Start/Stop			Dorm
ENGINE HEAT	Diesel APU		Block Heater	
	Fuel-operated Coolant Heater			
	Automatic Engine Start/Stop			
CAB COOLING	Diesel APU	Battery HVAC	Electric Air Conditioning	Truck Stop Electrification
	Automatic Start/Stop			Hotel
				Dorm
BATTERY STATE OF CHARGE	Diesel APU	Battery HVAC	Inverter With Charger	
	Automatic Engine Stop/Start		Battery Charger	
HOTEL LOADS	Diesel APU	Inverters	AC Wiring	Hotel
		CPAP Battery	CPAP Battery	Dorm
		Battery HVAC		

Figure 17 – Matrix of Energy Sources with Provided Benefits (NACFE)

6.2 Detailed Overview of Idle-Reduction Technologies

This section provides in-depth information on the various idle-reduction technologies including an overview of the technology and the benefits and challenges of the technology. This is a technology overview and does not include technical details of the products offered by specific technology suppliers. A list of idle-reduction technology suppliers is found in Appendix A at the end of this report.

6.2.1 Fuel-operated Heaters

Fuel-operated or diesel-fired heaters use diesel fuel to provide heat to the sleeper cab (bunk or air heaters) or to provide heat to the truck engine (water or coolant heaters). Both types of heaters can operate when the truck’s engine is off, therefore avoiding idling. However, these systems do not provide any cooling or AC electric power to the cab.

6.2.1.1 Fuel-operated Air Heaters

Overview

Fuel-operated air heaters act like small furnaces, with a heating element and blower providing bunk (cab) heat either via direct ducting or via the truck’s factory-installed HVAC ducting.

There are several manufacturers of fuel-operated air heaters, offering various models with a range of heating capacities. Fuel-operated air heaters require up to about 12 amps of battery power while in use to operate the heater and the blower fan. Their maximum blower air flow ranges from approximately 40 cubic feet/minute to more than 80 cubic feet/minute.

Components

Fuel-operated air heaters are about the size of a loaf of bread and weigh approximately 6 to 8 pounds. They are usually mounted under or behind the outside of the sleeper cab, with their fuel pumps

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plumbed directly from the truck's diesel fuel tank. They use the truck's main batteries as a source of electrical power to run their blowers.

Inside the cab these systems include a driver control with an on/off switch, temperature setting, and fan speed selector. Some controls have digital displays, which can display the interior temperature, show the current time, and have timers for pre-setting temperature control prior to the driver entering the cab.

Benefits of Fuel-operated Air Heaters

- **Cost:** Relatively inexpensive to purchase and maintain
- **Fuel efficiency:** Generally burn less than 0.1 gallons of fuel per hour. An idling diesel engine will consume between 0.6 to 1 gallon of fuel per hour. On average a fuel-operated air heater will use approximately a gallon of fuel during a 24-hour period.
- **Easy to install:** Install easily usually under or behind the sleeper, do not require frame free space. Available as factory installed options from all truck OEMs. Integrate with other idle-reduction technologies, and are often sold in combination with other idle-reduction technologies.
- **Reduced noise and emissions:** They operate very quietly and produce minimal emissions.

Challenges of Fuel-operated Air Heaters

- **Limited functionality:** Only provide bunk heat and do not meet the other driver needs — air conditioning or AC power for hotel loads — nor do they provide engine pre-heat.
- **Affect battery state of charge:** Use the truck's main engine batteries for their power, and therefore can drain those batteries over long periods of use.
- **Emissions:** Emit some exhaust as they burn fuel.

One piece of feedback we received from drivers with whom we spoke was that, although bunk heaters provide sufficient heat to warm the bunk area, some systems do not provide a very even distribution of temperature throughout the bunk area. This concern is worth exploring with suppliers as purchase decisions are made.

Pricing

All truck OEMs offer some of the brands of fuel-operated heaters as factory-installed options. They also can be installed locally by their respective truck or heater dealers. Market prices vary based on a variety of factors.

Maintenance is minimal and includes occasionally flushing out the system and checking fuel lines, mechanical parts, and electrical connections.

6.2.1.2 Fuel-operated Coolant Heater

Overview

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These systems provide engine pre-heat without the need to idle the truck engine. Fuel-operated coolant heaters — also known as water or engine heaters — act like a hot water heater, utilizing the truck's supply of diesel fuel to produce the needed heat. The heater's water-pump warms and circulates engine coolant throughout the truck engine's cooling system to transfer heat to the engine. This provides affordable engine pre-heating to aid in cold climate starting. Some higher Btu capacity models of fuel-operated coolant heaters also provide supplemental heating to the cab heater and defroster systems.

Coolant heaters regulate the engine's coolant temperature by cycling the heater between various heat levels, depending upon ambient and coolant temperature. This eliminates difficult truck engine cold starts and also the need for electrical engine plug-ins (like block heaters).

Several manufacturers offer various models with a wide range of heat outputs and control functionality. Heat output ranges from 17,100 Btu/hour all the way up to 45,000 Btu/hour. Electrical consumption runs from 1.9 to 7.5 amps.

Components

Fuel-operated coolant heaters are relatively compact and can be mounted under the hood near the engine or along the frame rail. They are plumbed to the truck's fuel tank and burn between 0.07 and 0.4 gallons of fuel per hour, depending upon the heat output required, the ambient air temperature and the controller setting. Most models weigh approximately 6 or 7 pounds.

Driver controls include an on/off switch and diagnostic codes, and most models offer a 7-day timer providing automatic start-up of the heater without the need for driver interface. Coolant heaters are often required in trucks operating in colder climates and sometimes sold in conjunction with fuel-operated air heaters or other idle-reduction technologies.

Pricing

All truck OEMs offer some of the brands of fuel-operated coolant heaters as factory-installed options. They also can be installed locally by their respective truck or heater dealers. Market prices vary based on a variety of factors.

Maintenance is minimal and includes occasionally flushing out the system and checking fuel lines, mechanical parts and electrical connections.

Benefits of Fuel-operated Coolant Heaters

- **Cost:** Relatively inexpensive to purchase and maintain
- **Vehicle performance enhancements:** Eliminate difficult truck engine cold starts. Pre-warmed engines deliver cab heat and defrost windows more quickly upon engine start up, and warm engines produce fewer engine emissions at start-up
- **No electrical connection required:** Provide higher heating capacity than engine block heaters and do not require AC power electrical connections

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- **Easy to use:** Can be programmed for remote start-up without driver interface
- **Factory installed:** Available as a factory-installed options from all truck OEMs

Challenges of Fuel-operated Coolant Heaters

- **No cooling:** Do not provide cab cooling
- **No bunk heating:** Do not provide bunk heating
- **No AC power:** Do not provide AC power for hotel loads
- **Need fuel:** Use fuel and create some emissions while operating

6.2.2 Auxiliary Power Units

Given that the tractor's main diesel engine is its primary power unit, any additional sources of energy are "auxiliary." Some of these units are diesel-powered and some are battery-powered. Auxiliary power units — either diesel powered or electric — are a key component of the idle-reduction strategy of many fleets as they can provide cooling, heating, and electric power when the trucks main engine is shut off.

6.2.2.1 Diesel APUs

Overview

Diesel APUs can provide cooling, heating, and electrical power to the sleeper cab while the truck's engine is off. Note though that some diesel APUs on the market today provide heating, bunk cooling and AC power for hotel loads, while others provide bunk cooling and AC power only and then also use a fuel-operated air heater for cab heat. All diesel APUs also charge truck batteries and can provide electrical power for a block heater if the engine is so equipped.

They generally burn between 0.1 and 0.5 gallons of fuel per hour depending on their design, the ambient temperature, the sleeper's insulation, and the resulting HVAC load, along with the AC power being generated. They use various brands of two- or three-cylinder water-cooled engines running on diesel fuel from the truck's fuel tank. Engine power runs from 7 to 18 HP.

All diesel APU engines drive an air conditioning compressor to circulate refrigerant to provide bunk cooling. There are two basic types of diesel APUs relative to how electrical power is delivered to the cab. One type has a 4K- or 6K-watt generator providing AC power directly to the cab while a 12V DC alternator delivers power to the truck's electrical system to charge the batteries. The other type generates electrical power with a 12V DC alternator that charges the truck's battery system, with an in-cab inverter providing 110V or 120V AC power to the cab for appliances and other 110V loads.

In addition, some diesel APUs are closed systems (closed loop), that is, they are not plumbed into the truck engine's cooling system, while others are open systems (open loop) connected to the truck engine's cooling systems.

Diesel APUs also can vary depending on where the various heat exchangers are placed based on the supplier and the configuration of the vehicle cab. Finally, some diesel APUs use the truck cab's existing

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air ducting, while others require supplemental ducting. In any case, a complete assembly with power unit, evaporator, condenser, and connections weighs from approximately 400 up to 550 lbs.

Components

Basic components of a diesel APU are the power pack (with or without a generator), evaporator assembly, and condenser/fan assembly. The power pack consists of the diesel engine, alternator, starter, radiator and fan, muffler and tail pipe, air filter, water filter, fuel filter, and electrical components. Diesel APU power packs are mounted inside a cabinet made of steel, aluminum, or stainless steel, which is secured to the truck frame via mounting hardware. The evaporator assembly with blower is usually mounted under the sleeper bunk or the back of the cab. Fuel lines are plumbed to the truck's fuel tank and the diesel APU is wired to the truck's battery bank. The free space needed to install a diesel APU ranges from about 24 inches to 36 inches. Finally, the system's driver-operated control is mounted inside the sleeper cab.

Functionality

Cooling capacity runs from 12,000 to 20,000 Btus. Heat is provided via either heat-strips or coils, or a heat pump. Cab heating is generally provided by a fuel-operated air heater that is integrated with the APU system. Heating capacity runs from 7,500 to 18,000 Btus. Most diesel APUs can also power a truck engine block heater if a vehicle is so equipped. In open-loop systems, where the technology is plumbed into the truck engine cooling system, the running diesel APU can keep the truck engine warm, thus eliminating cold starts, while also serving as the radiator for the diesel APU engine. Other common functions include battery monitoring with automatic diesel APU start-up for battery charging, possible "limp home" capability should the truck engine's alternator fail, and auxiliary AC power source for running items like lights or tools outside of the sleeper.

Driver Controls

Diesel APU controls are mounted inside the sleeper and are used to turn the unit on or off, switch between heat and cooling modes, and regulate fan speed. They can be touch screen, controlled by knobs or switches, or a combination of those. Most units have an hour meter to measure the diesel APU's run time. The displays also monitor battery charge condition, and some can display diagnostic codes and will facilitate diesel APU engine shut down in conditions of high water temperature or low oil pressure. Some manufacturers provide maintenance reminders and the capability to program hour and day automatic diesel APU start-up times to provide pre-trip cab cooling or heating.

Generator vs. Inverter Models

Diesel APUs with generators provide 120V AC power directly to the cab and do not depend on the truck's batteries for this power. They can provide maximum hotel loads (for power both inside and outside the cab without the need to purchase and install an inverter. A disadvantage of the generator-based diesel APU system is that you must run the diesel APU engine and generator for any AC power needs.

Inverter-based diesel APUs depend on the diesel APU's alternator to provide power to the DC truck batteries, which is then converted to AC power via an inverter inside the sleeper. Therefore, with the

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exception of HVAC needs, the only time the engines of inverter-based diesel APUs run is when the system's batteries need to be recharged. Depending on hotel power needs, it is possible that the truck batteries will need to be replaced more often due to the increased charge and discharge cycles inherent in these systems. On the upside, this configuration of diesel APU is usually lighter and less expensive to purchase than a generator-based system, and it typically uses less fuel and requires a bit less maintenance.

Other Options

Some diesel APU manufacturers offer shore power 110/120V AC capabilities for diesel APU engine-off performance. One brand provides an optional air compressor to run pneumatic tools or supplement the truck or trailer air brake systems. Various compartment exterior finishes are available and one manufacturer offers a top of frame rail mounting when there is not enough free space on the side of the frame for mounting. Higher output heaters are available and higher capacity alternators are popular options. Diesel APU controls have many options and can include LCD digital displays and remote diagnostics. Two diesel APU manufacturers offer CARB approved DPF systems.

Summary of Types of Diesel APUs

- APUs where AC electrical power comes from a generator
- APUs where AC electrical power comes from an inverter, via DC power from the truck batteries
- APUs that provide complete HVAC (both heating and cooling)
- APUs that provide cooling only and use a fuel-fired bunk heater for cab heat
- APU engines that have an open cooling system plumbed into the main truck engine to eliminate cold starts
- APU engines that have a closed cooling system and are not plumbed into the main truck engine

Benefits of Diesel APUs

- **Complete solution:** Provide cab cooling, heating, AC power for hotel loads, and battery charging.
- **Long operating time:** Can operate as long as the truck has fuel. This provides nearly an unlimited amount of time for cooling, heating, and AC power without the need to restart the truck engine. Battery HVAC systems are limited in the hours of cooling they can provide before truck engine restart and battery recharging is required. Also, their hotel load AC power capabilities usually are less than that of their diesel-powered counterparts
- **Suited for temperature extremes:** High Btu capacity allows operation in extreme temperatures. Colder weather reduces battery capacity thus negatively affecting hotel load AC power capabilities of battery HVAC systems, while diesel APUs can avoid those issues.

Challenges of Diesel APUs

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- **Purchase price:** Expensive to purchase, install and maintain compared to other idle-reduction technologies. Compared to battery HVACs, for example, diesel APUs require periodic oil and filter changes and have more parts and components to be maintained. A typical service interval for a diesel APU is every 6 to 12 months. With a battery HVAC system, batteries need to be changed approximately every 2 years unless an engine start/stop system is employed to keep the batteries from being discharged too often. It is likely that while diesel APUs need maintenance on a more frequent basis, the cost of that maintenance will be equal to or less than the cost of replacing batteries on battery HVAC systems.
- **Installation issues:** Due to their mounting location, diesel APUs are exposed to road debris, salt and spray, and need adequate frame space to be installed. Additional work is required at installation for an open-loop system.
- **Consume fuel:** Need diesel fuel to operate and generate emissions and noise, while reducing fuel savings less than other idle-reduction technologies.
- **Don't meet zoning restrictions:** Urban municipalities have zoning restrictions prohibiting the use of diesel APU. In California, for example, a fleet may need to add an expensive DPF to make a diesel APU compliant with that state's specific emissions regulations. With the upcoming Greenhouse Gas Phase 2 regulations, the emissions regulations on diesel APUs are likely going to get tighter.
- **Add weight to the vehicle:** Diesel APUs weigh between 450 and 550 lbs. when installed. In addition, you have to add another 20 pounds for fluids. However the Energy Policy Act of 2005 allowed for a national 400-pound exemption for the additional weight of idle-reduction technologies on heavy-duty vehicles. In 2012 the Moving Ahead for Progress in the 21st Century Act increased the weight allowance to 550 lbs.. However, each state can adopt the exemption at its own discretion and not all states have done so. [37] The Office of Energy Efficiency & Renewable Energy has a map showing states that recognize the APU weight exemption. [37]

Pricing

Installed prices vary widely depending on generator or inverter models, diesel APU brand, closed- or open-loop systems, options specified, truck configurations (mounting implications), and local or OEM factory installation. Different diesel APU manufacturers offer different standard and optional warranty coverage and these factors also affect initial purchase price. The diesel APU may be exempt from Federal Excise Tax. [20]

Recommendations and Best Practices

Diesel APUs are best suited for the following:

- Trucks operating in the south and southwest U.S. where day and night temperatures are high

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- Situations where a fleet needs to provide driver comfort without idling the main engine over longer periods of time, such as to comply with the 34 hour HOS restart regulation
- When drivers need maximum AC power loads for multiple in-cab electronic devices
- When optimal driver satisfaction is of high importance
- When drivers have been trained to properly operate this more complex solution
- When a fleet's maintenance shop can meet the required, often shorter, maintenance schedules of diesel APUs
- When the extra weight and frame space required for a diesel APU is not an issue

6.2.2.2 Battery HVAC

Overview

Battery-powered HVAC systems, often also called Battery APUs, Battery EPU's, or E-APUs are designed to provide climate control for sleeper cabs without having to idle the engine. Battery HVAC systems have been described as true zero-idle solutions since they do not use any type of engine while in operation. Some of these systems operate on 12V power generated from a bank of independent Group 31 Absorbed Glass Mat (AGM) batteries, using an inverter, which converts 12V DC battery power into 120V AC power. Other units do not use inverters and simply operate on 12V DC power.

Many truck OEMs including Freightliner, Navistar, Kenworth, and Peterbilt offer battery HVAC systems as factory options.

Functionality

While a truck is running (driving), these systems capture energy produced by the truck engine's alternator and store it in the AGM batteries. Later, when the truck's engine is turned off, the energy stored in the batteries can be used to power air conditioning, hotel loads, and, in some configurations, heating systems. The system's batteries can be recharged either by running the main engine to use the alternator or by plugging into off-board AC power (shore power). Because of the extra load placed on the alternator by battery HVAC systems, trucks on which they have been installed will also need to have a larger alternator (250 amp minimum) installed. Many manufacturers recommend larger alternators in the 270-amp to 320-amp range to ensure that the HVAC batteries get fully recharged before they are to be used again. One of the problems with the early battery HVAC systems with smaller alternators was that the APU batteries would not be fully charged by the end of the workday. This resulted in insufficient battery capacity to compete a typical 10-hour HOS rest period.

One manufacturer of a battery HVAC system said, "If you are going to run a lot of time in no-idle mode, you are going to need a larger alternator."

When the system is on, the inverter converts 12V DC energy that is stored in the AGM battery bank into 120V AC electricity. This provides the electricity needed to power electrical appliances like microwaves, televisions, computers, etc. Using an inverter-charger decreases the available run time for air conditioning systems especially when electrical hotel load devices also are being used.

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Cooling capacity for the units varies from 4,600 to 10,000 Btu/hour, and cooling is influenced by a variety of factors including the size of the sleeper/cab, amount of insulation in the vehicle, size of windows, sun loading (when the sun itself heats up the interior of the cab), and exterior paint color, as well as the ambient temperature in which the vehicle is operating. Most battery HVAC system manufacturers say their units can provide 8-10 hours of cooling capacity. Real-world results vary depending on ambient temperature, whether the driver pre-cooled the vehicle and if the battery HVAC system is also being used to power electrical devices in the sleeper/cab while the truck's engine is off.

When selecting a battery HVAC system, fleets must remember that the higher the Btus the more energy or power it will take to run the unit, and therefore the less run-time that it will offer. Fleets should aim to purchase systems that will meet their cooling needs for 8 to 10 hours.

Components

Components necessary for a battery HVAC system are:

- Deep-cycle batteries (usually 4 AGM batteries)
- High-performance alternator
- A DC-to-AC inverter
- Air conditioning components
- A controller/thermostat.

Most battery HVAC systems are specified with optional heating from fuel-operated heaters.

The air conditioning units can be split or self-contained. With a split system, the condenser is located outside the sleeper/cab, while the evaporator/compressor is inside the sleeper/cab. In a self-contained unit, all components are located in a storage compartment or under the bunk. An additional battery box has to be installed to house the auxiliary batteries needed to operate the battery HVAC system.

There are numerous alternatives for the electrical configuration of the battery HVAC system. In some cases, all batteries of the truck are tied together. In others, the APU batteries are separated from the primary batteries to ensure that the engine can be started again when needed. All systems have a low voltage warning that alerts the operator if the battery state of charge is getting too low. There are various ways to incorporate inverter chargers into the vehicle electrical system. It is best to work closely with the equipment suppliers to ensure that fleet requirements are being met in the optimal way.

Benefits of Battery HVACs

- **Zero emissions:** No emissions produced during operation
- **Fuel cost reduction:** Since they do not burn fuel there is no fuel cost while they are in use
- **Lower purchase price:** Less expensive than some other anti-idling options
- **Quiet operation:** Quieter than diesel APUs
- **Less maintenance:** Fewer moving parts so less opportunity for malfunction and less maintenance training than diesel APUs.

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- **Integrate with off-board AC power connection:** This will increase the operating time of the unit and will also recharge the batteries more cheaply than doing so with the engine alternator.
- **Easy to operate:** Digital or rotational automotive-style controls provide automatic temperature control. The driver simply turns the switch to heating or air conditioning, and selects a fan speed and a desired temperature.

Challenges of Battery HVACs

- **Limited run time:** Not a viable solution for the 34 consecutive hours of rest without restarting the truck's main engine and running it from time to time. In most cases, however, the batteries of the battery HVAC system will simply be recharged while the truck is driving.
- **Issues in hot temperatures:** Concern that in extremely hot conditions there will not be enough battery power to keep the sleeper/cab cool enough for the driver to be comfortable.
- **Battery replacement:** The AGM batteries in these units do not last forever and will have to be replaced. Two years seems to be the typical life expectancy of these batteries.
- **Added weight:** Including the required four deep-cycle AGM batteries and a fuel-fired bunk heater, battery HVACs will add 500 to 600 lbs. to the weight of the vehicle. This may become less of an issue in the future if other battery technology is developed. However the Energy Policy Act of 2005 allowed for a national 400-pound exemption for the additional weight of idling reduction technologies on heavy-duty vehicles. In 2012 the Moving Ahead for Progress in the 21st Century Act increased the weight allowance to 550 lbs. However, each state can adopt the exemption at its own discretion and not all states have. [37] The Office of Energy Efficiency & Renewable Energy has a map showing states that recognize the APU weight exception. [37]
- **Need for large capacity alternator:** The increased load battery HVACs place on the charging system means a large capacity alternator is needed. Cables of the proper size also must be used, and it is important that all connections be tightened properly for the system to operate.
- **Adds load to the engine:** The alternator for a battery HVAC system puts twice the load on the engine of a normal sleeper tractor's alternator. These higher capacity alternators take up to an additional 7 hp from the engine. Therefore, their use does cause a truck to consume slightly more diesel fuel while driving, but lowers fuel use overall as they can eliminate significant amounts of idling.
- **Can consume fuel:** Systems equipped with fuel-operated heaters will consume diesel fuel during heater operation as well as battery or AC power to run the heater fan.

Service and Maintenance

Very little maintenance is associated with battery HVAC systems other than periodic battery replacement. The batteries need to be checked periodically for signs of corrosion and to make sure all electrical connections are tight. As with any HVAC system, the air filter on a battery HVAC system

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needs to be inspected regularly and cleaned as needed, in order to ensure good airflow across the evaporator. The air path between the return-air grill and the evaporator needs to be inspected to ensure it is not blocked. The condensate drain needs to be checked to ensure it is draining properly, and any clogs that are found need to be removed. Outside wires, cables, and refrigerant lines need to be checked for chafing. The filter on the evaporator needs to be cleaned periodically. Debris needs to be removed from the condenser. Battery HVAC manufacturers recommend that connection tightness be checked during normal preventive maintenance inspections to prevent voltage drops.

Obviously batteries wear out, and Group 31 AGM batteries are no different from other batteries in that regard.

If refrigerant levels are low, service must be performed by an EPA-licensed HVAC technician using proper tools.

Warranties and Support

Battery HVACs that are purchased in the aftermarket take from 5 to 10 hours to install, depending on if they are air conditioning only or heating and air conditioning systems. Warranties vary from 2 years parts and labor to 1-year labor/2-years parts.

Pricing

Battery HVACs prices vary depending on a variety of factors including where they are installed. Installation times are 5 to 10 hours, including installation of the extra battery box, wiring the batteries, mounting the alternator, and mounting the unit itself. The price of the batteries themselves range from \$180 to \$260. System prices will increase with the installation of optional fuel-operated heaters.

Recommendations and Best Practices

- Specify extra cab/sleeper insulation.
- Drivers need to pre-cool their trucks by running the vehicle's air conditioning on high while driving just prior to shutting the truck engine off and turning on the battery HVAC.
- Drivers also should pull the curtain between the cab and sleeper, use window shades, and park on concrete rather than dark asphalt if possible.
- Limiting hotel loads will also significantly extend the available cooling hours of a battery HVAC.

6.2.3 Automatic Engine Start/Stop Systems

Overview

Automatic engine start/stop systems start and stop the main diesel engine in an unattended fashion to provide a variety of features without requiring the truck's engine to idle continuously. These systems have a set of inputs to ensure that it is safe to start the engine without anyone at the controls, such as:

- Transmission Neutral Switch (not in gear)
- Parking Brake Set Switch (won't roll away)
- Hood Closed Switch (no one is under the hood doing checks or service)

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Functionality

Automatic engine start/stop systems provide some key features:

- Heating and/or cooling the sleeper bunk while drivers are on a rest period
- Maintaining adequate battery charge so the engine will start easily when the rest period is over
- Maintaining engine coolant temperature so the engine will start easily when the rest period is over

Once the engine is running, the vehicle’s HVAC systems will warm or cool the sleeper just as it would when the truck is driving down the road. Essentially the vehicle is still idling, keeping the engine warm and the batteries charged, but it is able to do so much more intelligently/efficiently, and automatically.

These systems also can be used in very cold climates, for instance while a truck is in storage for a weekend or other down time, and offer very beneficial results, ensuring the vehicle will start when it is time to go back into freight-hauling operation. Automatic engine start/stop systems perform the work of both a block heater and battery charger without the need for the truck to be connected to outside power.

Types of Automatic Engine Start/Stop Systems

There are two different types of automatic engine start/stop systems. The first has a primary goal of maintaining a cab’s interior temperature when the vehicle is occupied. These may also assist with keeping the engine warm and the batteries charged.

The second type of automatic engine start/stop system focuses solely on maintaining the batteries’ state of charge. Given the growth in the use of battery HVACs, combined with HOS restarts that last far longer than the typical 8 to 10 hours a battery HVAC can operate on one charge, this type of automatic engine start/stop system has grown in popularity. These systems enable battery HVACs to maintain bunk temperatures for longer than a single 8 to 10 hour window, allowing a driver to enjoy air conditioning continuously during a 34-hour restart. This type of automatic engine start/stop system is programmed to recognize the specific type of batteries being used by the battery HVAC system, and monitor their voltage, current draw, and temperature to provide optimal recharging patterns by comparing the inputs they receive to electronically stored battery-life models. It will typically require over 45 minutes of engine operation (which the automatic engine start/stop system will control) to fully recharge a battery HVAC system for an additional 8 to 10 hours of operation.

Currently, most of these automatic engine start/stop systems are aftermarket installed, but one OEM, Freightliner/Detroit, has integrated the feature into its engine controls and vehicle controls.

Benefits of Automatic Engine Start/Stop Systems

- **Little added componentry:** They do not require additional HVAC components, batteries, or engines to accomplish their tasks.
- **Can be combined with other technologies:** It is becoming increasingly common to pair an engine start/stop system with a battery HVAC system. This allows the engine to start

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automatically without driver input when necessary to keep the batteries charged and keep the battery HVAC system from shutting off if it runs low on available power.

- **Can avoid violating idle regulations:** If a vehicle is purchased with a CARB Clean Idle engine, it will have a serial numbered holographic sticker on the driver’s side of the hood or driver’s door. Such stickers allow automatic engine start/stop systems to be used without violating any idling regulations, provided that the vehicle wasn’t also purchased with the tamperproof five-minute timer.

Challenges of Automatic Engine Start/Stop Systems

- **Can interrupt driver sleep:** Noise and vibration of the system starting and stopping can disturb drivers. Drivers did not like the initial automatic engine start/stop systems that came out about two decades ago because when those systems started and stopped the main engine the noise and vibration was enough to wake a sleeping driver. Newer systems have made improvements, such as using the engine brake to create a more rapid and smooth engine shut-off than the cab rocking and engine sputtering which occurs during a normal engine shut down. If there is a large temperature difference between the desired bunk temperature and the outside temperature, the engine starts can become fairly frequent, exacerbating the sleep interruption problem. Another concern is the alarms that may go off as part of the engine starting process. The system manufacturers offer features to suppress these alarms when the start/stop system is enabled.
- **Requires main engine to idle:** Creates additional hours of wear on the main engine.
- **Issues with idle laws:** It is not completely clear how various idle laws relate to some of the operational modes available with these systems. Refer to the resources listed in section 5.6 for the latest information on idling regulations.

Pricing and Warranties

Prices vary based on a variety of factors. Warranties range from two years to a lifetime guarantee.

Recommendations and Best Practices

- If your fleet is dissatisfied with the length of operation of your battery HVAC system, a battery monitoring and charging system such as that offered by automatic engine start/stop systems could be a desirable investment to extend operation.
- For fleets that are challenged from a support aspect to keep diesel APUs systems in operation, the combination of a Clean Idle engine and an automated engine start/stop system could reduce that challenge.

6.3 Vehicle Electrification Trends

Summary

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Vehicle electrification is a trend that has been going on in the industry for many years. Especially in the sleeper cab market, the driver shortage and hiring issues fleet owners face has led to the selection of vehicles and features that are more accommodating to the driver's needs and desires as well as his/her schedule. This means that electrical provisions need to be made in the sleeper compartment for charging electrical devices, televisions, microwaves, refrigerators, CPAP machines, HVAC systems, etc. Collectively, these electrical demands are usually referred to as hotel loads. See Figure 18.

APPLIANCE	POWER IN WATTS
Blender/Juicer	300 to 1000
Cell Phone Charger	2 to 10
Coffee Maker	600 to 1200
CPAP Machine	30 to 60
Laptop Computer	20 to 75
Microwave Oven	1000 to 2000
Refrigerator	500 to 750
Television	50 to 240
Toaster	800 to 1500
Video Game Console	40 to 140

Figure 18 – Estimated Wattage of Common Appliances (Don Rowe) [33]

Federal Hours of Service regulations have also made providing for driver comfort during 10-hour rest breaks and 34-hour resets a priority. The advent of electronic driver logs means that drivers cannot always get to an ideal stopping place when these breaks are required.

Class 8 sleeper cabs typically have four Group 31 batteries to facilitate starting the main engine and taking care of all electrical loads when the vehicle is stopped. Many fleets have added various equipment to avoid idling the main engine during these rest breaks to supply driver needs as well as keeping the batteries charged. This includes all the technologies that have been discussed — fuel operated heaters, APUs and automatic start/stop systems.

Of course, battery HVAC systems add additional battery capacity to the vehicle to provide electrical and air conditioning services to the sleeper bunk. However, even with eight batteries installed on the vehicle, the power stored is not enough to avoid idling the main engine from time to time. In addition, the life of the batteries is tied to the depth of discharge that occurs during the rest periods. Fleets must find the balance between investment in equipment, driver comfort, battery life, breakdowns due to dead batteries and a host of other factors to configure their overall system to best meet the needs of all the parties involved. As we have previously stated and our fleet interviews confirmed, there is no one solution that will best fit the needs of all fleets.

One thing that was emphasized in fleet interviews was the importance of proper electrical system specification, wiring and maintenance to ensure the best possible experience with the equipment that

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is installed on the vehicle. TMC has published a series of Recommended Practices that have guidelines for all of these areas. [28]

- **RP 105D Battery Cable Assemblies** — Gives recommendations for proper selection and installation of battery cables to obtain maximum cranking circuit performance. This RP covers battery cables, terminals, heat shielding, grounding techniques, wire gauge, and replacement wire selection.
- **RP 113B Electrical System Connectors** — Covers minimum general guidelines for the design, performance, and application of connectors and insulators for heavy-duty motor vehicles.
- **RP 114B Wiring Harness Protection** — Covers minimum guidelines for protecting wiring harnesses from the operating and environmental conditions encountered on heavy-duty truck tractors.
- **RP 129B Heavy-Duty Vehicle Cranking And Charging Troubleshooting: 12-Volt Systems** — Provides preventive maintenance and troubleshooting procedures for heavy-duty vehicle starting and charging systems.
- **RP 132B Battery Charging, Testing, and Handling** — This updated RP covers proper procedures for heavy truck battery charging, testing and handling.
- **RP 178 Battery Management and Cable Guidelines for Meeting Hotel Load Requirements** — This RP offers general guidelines for alternator and cable sizing when adding batteries to a commercial vehicle for the purpose of meeting driver comfort or hotel load requirements.

There are some technologies that we have not discussed as they are generally used in conjunction with one or more of the above systems. These include:

- Power Inverters/Chargers
- On-Vehicle Solar Energy Capture
- Truck Stop or Yard Electrification (to plug in A/C power while stopped)

Power inverters/chargers are a necessity if the electrical appliances used in the truck are standard 110V AC appliances. This is generally the case now as the 110V versions of these appliances are generally significantly less expensive than their 12V counterparts. However, the life of these consumer appliances can often be compromised by the vibration and temperature swings of the vehicle environment.

To learn more about on-vehicle solar energy capture, we suggest that you refer to the NACFE Confidence Report: Solar for Trucks and Trailers that was published by NACFE in 2018 and is available as <https://nacfe.org/technology/solar-panels-2/>.

Truck stop electrification was a hopeful trend a few years ago that has never really materialized. There are relatively few parking spaces available at truck stops across the country where a truck can be plugged in to get additional electrical service. However, in some cases, there are 110V electrical connections available on truck yards/home parking so that the vehicle can be plugged in to keep the

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batteries topped off during an extended time. Note that anything a fleet or driver can do to keep the batteries at a high state of charge while the truck is stationary will help battery life.

6.4 Vehicle Controls & Driver Behavior

The vehicle itself can help in a fleet’s idle-reduction efforts via electronic engine parameter settings.

In addition, the way a driver manages his or her vehicle both while moving *and* while stationary has a huge impact on the fuel economy the vehicle will obtain. Fleets have options for motivating desired behavior or penalizing/preventing undesired behavior. This section covers ways to monitor and control undesirable behaviors via electronic controls, as well as options for training and incentivizing drivers to follow best practices, in order to obtain optimal reductions in idling.

6.4.1 Electronic Engine Idle Parameters

Overview

The introduction of electronic engine controls in the mid-1980s included controls for idling behaviors. Over time the number of parameters has grown significantly. The number will continue to increase as we move into the future, and ongoing developments in other aspects of truck design and operation will impact the way fleets should optimize their engine parameters.

Programmable engine parameters can play a major role in the various idle-reduction strategies and technologies that fleets employ. Currently the list of idle settings has grown to look something like that depicted in Figure 19. These idle settings are taken from Cummins Power Spec, an electronic tool that makes it possible for fleets to tailor the operation of a Cummins engine in every on-highway application. [39] Other truck and engine manufacturers have their own names for the programmable parameters on their engines.

2013 ISX 15 400-475 HP Engine Information		
Idle Speed Control Features	Range	Default Setting
Idle Speed Control	ON/OFF	ON
Low Idle Speed	600-800 rpm	600 rpm
Driver's Low Idle Speed Adjustment	ON/OFF	ON
Idle Shutdown	ON/OFF	ON
Idle Shutdown Time	0.5-600 Min	5 Min
Idle Shutdown Ambient Air Temperature Override	ON/OFF	OFF
Idle Shutdown Hot Ambient Air Temperature	Intermediate Value to 100 °F	27 °C (81 °F)
Idle Shutdown Intermediate Ambient Air Temperature	Between Hot and Cold Values	4 °C (39 °F)
Idle Shutdown Cold Ambient Air Temperature	Intermediate Value to -20 °F	-1 °C (30 °F)
Idle Shutdown Manual Override Inhibit Zone	ON/OFF	OFF
Idle Shutdown Hot Ambient Air Temperature Automatic Override	ON/OFF	OFF
Idle Shutdown Manual Override	ON/OFF	OFF
Idle Shutdown in PTO	ON/OFF	ON
Idle Shutdown Percent Engine Loading	0-100%	100%
Idle Shutdown with Parking Brake Set	ON/OFF	OFF

Figure 19 – Sample Electronic Engine Idle Parameters (Cummins)

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These parameters not only control the exact speed at which an engine will idle, they also set the idle timer length, and establish boundaries for when idling is allowed for cold and hot temperature extremes. The exact parameter names, ranges and defaults differ among engine OEMs.

Most engines now have idle control parameters, which set limits on when idling can occur based on outside ambient air temperature. Many idle laws are written with the understanding that idling without interruption is acceptable for running air conditioning when the ambient air is above a certain warm temperature, and likewise acceptable for heating when the outside temperature drops below a certain point. These parameters actually can become very complex, but Figure 20 gives a general idea of the relationship between the three:

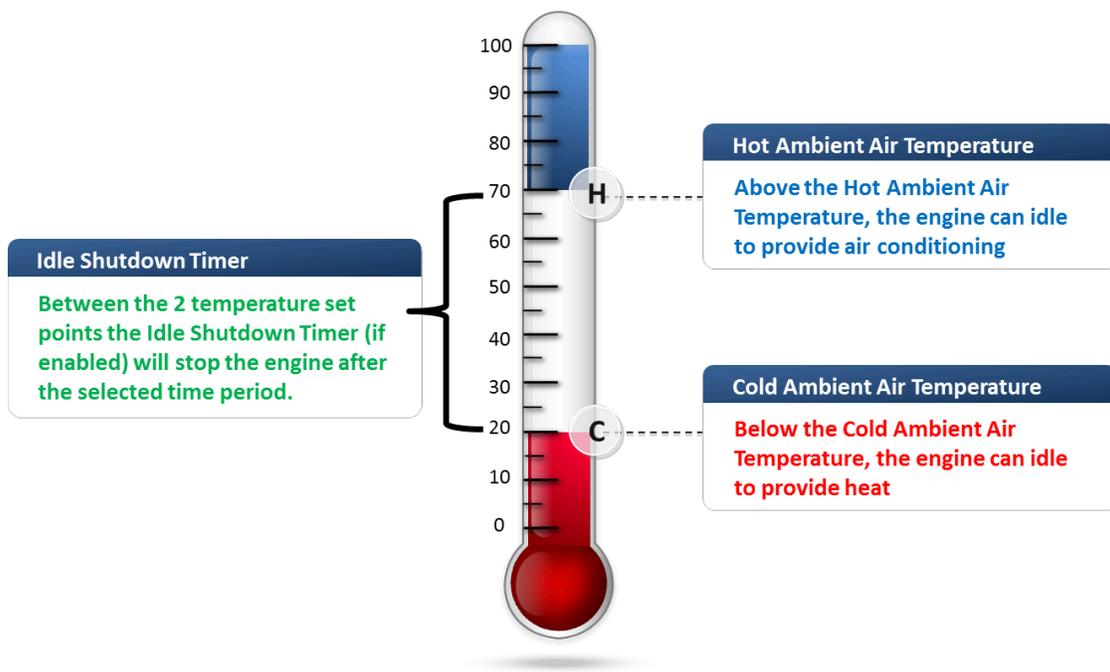


Figure 20 – Idle Shutdown Ambient Air Temperatures (NACFE)

Given the different performance characteristics of idle-reduction systems such as fuel-operated heaters, diesel APUs, battery HVAC systems, and automatic engine start/stop systems, not to mention the different regional climates in which fleets operate, fleets will use different temperatures for these categories of programmable parameters.

The fleets we spoke with had temperature limits above and below which unlimited idling was allowed for temperature extremes. There was no real consensus on what those limits were, but generally they allowed unlimited idling above 80°F and below 30°F. Some allowed unlimited idling at 70°F on the upper end and 40°F at the lower end. All cited driver comfort as reasons for the limits and acknowledged that driver retention factored in to the decision making process when it came to setting temperature limits.

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The most common parameter for controlling idling entails controlling the length of time that idling can last, and it is generally known as an “Idle Shutdown Timer” parameter. The Idle Shutdown Timer was offered for many years as an option on all electronic engines. Given ongoing legislative changes, some vehicles now come with the idle timer parameter permanently programmed to a 5-minute maximum, and cannot be reset.

For more information on engine parameters see NACFE’s Confidence Report on Electronic Engine Parameters at <https://nacfe.org/technology/electronic-engine-parameters/>.

Benefits of Electronic Engine Idle Parameters

- **No cost:** Electronic parameters are now standard equipment, so there is no cost for using them to control idling. The failure to use them for this purpose, however, could impose an opportunity cost.
- **Can be adjusted around other technologies:** Fleets will benefit most by adjusting their temperature parameters to fit around the other idle-reduction technologies they have selected. For example, fleets with fuel-operated air heaters may set significantly lower cold temperature limits for unlimited main engine idling, since the heater will serve to keep the driver warm in all but the most severe outdoor temperatures.

Challenges of Electronic Engine Idle Parameters

- **Security concerns:** If modified electronic parameter settings can allow for operation outside of desired ranges. Although there are password protections to prevent such events, shop technicians with service tools and password privileges must know that they are not allowed to alter vehicle settings without management approval.
- **Interrelations between parameters:** Changing one parameter often means having to change other parameters. All parameters must be tailored based on the overall truck specification.
- **Diversity of terminology:** Each engine manufacturer uses its own terminology and/or brand names for its parameters. Parameters may even be called different things from one engine model to the next.
- **Driver acceptance:** It can be difficult to get buy-in from drivers who may feel the fleet is trying to restrict the way they drive.

6.4.2 Driver Training

Overview

The truck driver is an integral part of any idle-reduction initiative. Human intervention is needed to ensure that whichever technology is adopted is also being properly operated and maintained, and that the benefits of the system are being maximized. Fleets need to understand their drivers’ needs for safety, comfort, and convenience and therefore how they will be using the idle-reduction technologies installed on their trucks. Driver education and follow-up training is key to this process, especially given today’s high driver turnover rate.

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For the idle-reduction systems to be effective, drivers must know how to operate them properly. Some fleets provide ongoing education via drivers' meetings, newsletters, emails, or videos downloaded directly to the truck via an on-board satellite system. Some systems are more complicated to operate than others, and some require drivers to periodically do minor maintenance checks while on the road.

One fleet executive said, "[Training on using idle-reduction technology] is part of our on-boarding process and our orientation process. In the last six months I have created a handbook for our drivers. We have weekly drivers' meeting and we talk about idling there. We also have media terminals throughout our main facility with a video loop of current news, weather and company messages. We put information on idling there as well."

Regardless of the system, drivers can help optimize the system's capabilities by following some general rules. Here are some tips on how to optimize any system's cooling capabilities:

- Pre-cool the cab by running the A/C before shutting the truck down for the night
- Park on concrete instead of asphalt
- When parking the truck, try to find a shaded area
- Make sure the cab's windshield is facing away from the sun
- Ensure all doors and windows are tightly closed
- Use reflective covers for the windshield and windows
- Pull down shades and cover sleeper cab windows and skylight
- Fully and tightly close the bunk curtain
- Set the temperature and fan speed on the controller at a reasonable number
- Switch off heat-producing appliances inside the cab
- Turn off the HVAC system as soon as possible after waking up
- Only use the APU when it's truly needed — mainly when sleeping or sitting idle-free for long periods. Do not use the APU when fueling, eating, etc.
- Always plug into off-board AC power (if the truck is so equipped) whenever possible to keep charging the truck's batteries (even when not using your APU)
- Be conservative with hotel power loads especially when maximum cooling is needed

Tips for maintaining an efficient idle-reduction system:

- Daily inspection of the system
 - The system components need to be inspected but that inspection will vary depending on the type of system in use. For example with a diesel APU, check for leaks, and inspect oil level, fuel and refrigerant lines and connections, hoses, belts, electrical cables and connections
- Do not block the air flow between the return air flow duct and the evaporator
- Keep the condenser assembly clean and free of debris or obstructions

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- Keep all high current electrical connections free of corrosion and cover them with a protective coating

6.4.3 Driver Incentives

Due to the large impact that drivers have on idle reduction, many fleets have incentive systems to encourage drivers to be involved in reducing the fleet's fuel expenses, by sharing the savings between the truck owners and the drivers. These incentives may cover many different elements of fuel use, including vehicle speed, time spent in top gear, percent idle time, use of idle-reduction solutions, etc.

Incentives can include cash bonuses, other awards such as prizes and selecting merchandise from catalogs. Fleets should select incentive programs and benefits that fit their driver demographics and characteristics, in order to ensure the biggest impact.

"I think idle reduction really comes down to incentives for the driver," said a former fleet manager. "If you incentivize a program through competition or bonuses, you are going to get further."

TMC Recommended Practice 1113, "Guidelines for Driver Incentive Programs" offers both suggestions on how to implement a program as well as some things to avoid, as they have been known to cause such efforts to fail. [28]

6.5 Additional Idle-Reduction Solutions

The following section focuses on several ancillary technologies that can be very beneficial in a fleet's idle-reduction efforts. Most of these sleeper tractor additions are passive, and can be used in conjunction with the previously discussed active idle-reduction systems, to achieve even better levels of idle reduction.

Additional Cab Insulation decreases the energy demanded by heating and cooling systems. For a sleeper truck that may include insulated bunk curtains, windshield curtains and extra insulation. Several truck OEMs offer optional "Arctic Packages" that provide better insulation. Installing additional cab insulation can save anywhere from 21% to 36% in heating or cooling load, according to a study by the National Renewable Energy Laboratory [35]

Light-Colored Paint is the most simple and straightforward way to help with idle reduction. The paint color on the outside of the cab and sleeper can have a significant impact on the heat loading the sun will cause in the interior of the vehicle. NREL testing revealed that a black vehicle requires 26.3% more energy to cool on a sunny summer day than the same baseline vehicle painted white. A darker-colored paint will not offer similar benefits in cold climates or winter operation. [36] For owners of existing dark colored sleeper cabs, it may be more economical to add a light colored vinyl wrap to the top of the vehicle rather than repainting it.

An Additional (Auxiliary) CPAP Battery will power a CPAP machine through the night, which can help relieve the truck's batteries from having to power the machine, thus reducing the hotel load. This auxiliary battery can be recharged by connecting it via power cord to a 12V DC power plug, or as the vehicle is driven.

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Ultracapacitor Starting Systems can help alleviate the strain on discharged batteries and help start the engine. When truck batteries are discharged there often is not enough power to start the truck engine. When the truck is in an engine-off state, the batteries can be discharged from excessive hotel loads inside the cab. An Engine Start Module (ESM) with ultracapacitor technology (rather than AGM or lead acid componentry) can store energy and deliver power. It integrates with the truck's 12V starting system and replaces one of the existing batteries.

Sleeping Quarters, such as hotels or dormitories, may be the most radical method of reducing idling by getting the driver out of the vehicle altogether. If an HOS restart takes between 34 and 48 hours, using a gallon of \$3 diesel fuel an hour to idle the truck creates an expense of \$102 to \$144 dollars for the restart period. There are likely some situations where it now makes sense to get the driver out of the sleeper to avoid the cost of constant idling.

One fleet management consultant noted, "There are some operations that have gone back to day cabs and to putting their guys in hotels. Staying in a hotel is not too bad an option, especially for driver retention."

Hotels generally offer the driver a quiet sleeping location with a large mattress, power for their CPAP machine and a private bathroom/shower as well as healthier amenities such as a good breakfast and a workout room. Hotels4Truckers offers both discounts as well as a database of hotels that have parking facilities for tractor-trailer combinations.

Truck Stop Electrification is similar to hookups at RV parks and allows trucks to power everything drivers need from an external power source. Some systems require special wiring and equipment. Others provide everything through a console that fits through the window frame. At one time this technology seemed to have more promise as a solution to idle. That has not proven to be the case and is not a viable option for most fleets. Today there are relatively few parking spaces available at truck stops across the country where a truck can be plugged in to get additional electrical service.

Off-board AC Power (also known as shore power) systems combine elements of both vehicle and truck stop electrification, as they require both AC wiring and power ports to be installed inside the sleeper as well as infrastructure to be deployed for an external AC power source. The words "shore power" are frequently used in the industry simply to mean that there is a connector on the side of the vehicle to plug in a 120V AC power cord. Meanwhile this category is distinct from truck stop electrification as the external power source can be installed in other locations, such as a fleet's central parking lot.

Solar Panels in trucks can augment the amount of power generated by the alternator, but they are especially useful for charging the battery HVAC system to allow for a longer running time, and to help prevent hotel loads from draining batteries. A properly wired and managed solar panel system is able to trickle charge the truck batteries, ensuring they maintain a minimum voltage, whether over a 10-hour rest period or a 34-hour restart. Some fleets have even reported longer battery life with the use of solar panels. The cost of solar panels has come down dramatically, and the fact that they require little to no maintenance has made them attractive to some fleets.

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7 Other Considerations

There are several other areas to explore when it comes to idle reduction. This section focuses on residual value of vehicles equipped with idle-reduction technology as well as idle reduction in day cab vehicles.

7.1 Residual Value

As we interviewed fleets during the research process, we asked if they were able to receive any substantial additional trade in value for a vehicle because it was equipped with idle-reduction technologies. The only technologies mentioned that might get extra value on the secondary market were either diesel APUs or battery HVAC systems.

The answers varied from receiving no additional trade in value to a relatively small add on. Fleet managers mentioned that there was generally a great deal of uncertainty on the part of the potential buyers of the used vehicles on how well the systems had been maintained so they were unwilling to pay much of a premium for these additional systems given the fact that they might need significant repairs soon after the second owner purchased them.

For the purposes of making purchase decisions based upon payback, it is safe to assume that there will be no residual value for diesel APUs or battery HVAC systems. Diesel fired air heaters and auto start/stop systems also are unlikely to generate any additional premium at vehicle resale.

A fleet consultant we spoke with said, “I don’t think it matters if trucks have idle-reduction technologies on them. I don’t think the secondary market cares one way or the other.”

7.2 Idling and Day Cabs

The primary focus of this paper was to evaluate and educate the industry on idle-reduction technologies that are used by the typical sleeper cab tractor. These vehicles constitute about 50% of the trucks on the road today and are responsible for a much larger percent of hours that the main engine is idling. The primary reasons for idling these engines is to keep drivers comfortable during 10-hour rest periods and 34-hour resets. Idling while waiting in traffic or waiting to deliver a load constitutes a relatively small percentage of the idle hours for sleeper cab tractors.

By contrast, day cabs used in local and regional haul service generally only idle for long periods of time because they are waiting in traffic or waiting in line to deliver a load. Occasionally, these drivers must idle for other reasons, but that is a relatively rare occurrence. Therefore, the idle-reduction strategies that are followed for these vehicles are quite different from those employed by the fleets that run sleeper cab vehicles.

In most cases, the best solution for day cabs to minimize idle percent is to use the features that are built in to the engine ECM. These features include an idle timer that will automatically shut off the engine after a short time — usually around 5 minutes. The features also allow the vehicle to be set to allow additional idle time if the outside temperatures are above or below preset limits. This generally

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has to be enabled by the driver before he or she exits the vehicle or the engine will automatically shut down at the previously set limits.

Almost all the fleets we talked with about day cabs believe that these features are sufficient for their needs and they are generally able to control idling to less than 10%, and many stated they were below 5%. Of course, there are situations where these controls will not work, so many of the products described in this paper can provide additional features to the fleet if they are required.

8 Payback Calculator

Fleets need to be able to determine ROI of any investment they make and idle-reduction technologies are no different. Not all benefits of an idle-reduction technology can be classified as hard costs, some are soft costs but those can be important reasons to invest in a technology as well.

Here some of the financial and other factors to consider while evaluating idle-reduction technology:

- Fuel savings
- Driver comfort (sleep quality, convenience, productivity, and safety) which impact driver recruitment and retention
- Reduced emissions and increased environmental sustainability
- Reduced truck and engine wear, especially to main engine accessories (fan, alternator, air compressor, belts, HVAC system, electrical components) due to the reduction of engine hours and longer component life due to lower vibration.
- Depending on the frequency and cost of the fleet’s jump starts, some idle-reduction systems will reduce jump starts as both APUs and automatic start/stop systems can monitor and charge batteries
- Potentially avoiding fines for violating idle regulations
- Reduced noise pollution inside and outside the cab
- Reduction of cold starts with some idle-reduction technologies

Costs of idle-reduction technologies include:

- Initial purchase price
- Installation labor costs if not factory installed
- Additional costs for service contracts or interest if financed
- Maintenance costs
- Driver and technician training costs

The fleet’s analysis must also include an understanding of current idle percentages and the associated costs incurred by those instances of idling in order to correctly assess the amount of savings they should reasonably expect from a particular idle-reduction technology.

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Visit this link to access the Payback Calculator: <https://nacfe.org/wp-content/uploads/2018/01/Final-Idle-Reduction-Payback-Calculator-07252019.xlsm>

9 Complementary Idle-Reduction Technology Packages

The most efficient and effective idle-reduction solution for a fleet will entail a combination of complementary technologies among those cataloged in this report. For instance, several of the technologies, namely electronic engine parameters, driver incentives, and extra cab/sleeper insulation, are going to contribute positively to almost any solution chosen. Figure 21 shows, from an engineering perspective, which of the technologies discussed here are technically/physically possible to pair on one vehicle. This diagram is meant to give a high-level overview, to indicate where the consideration of complementary systems might be warranted. Obviously, it is not meant to imply that all of the systems need to be used together, as that would most likely not offer the optimal return on investment. The right combination will depend on a given fleet's routes, fuel costs, climate in the fleet's area of operation, shop costs, maintenance cycles, training methods, driver support, fleet policies, and other factors.

As one manufacturer of an idle-reduction technology said, "There are no real hospital corners in this space. There are a lot of fragmented approaches to idle reduction. There is no one clear proscribed approach to investing."

He added, "No technology implementation is a magic pixie dust that solves the problem. You can't just install technology and think you are done. Integration of several technologies — there are a lot of pieces that can fit together — makes a pretty good solution."

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COMPLEMENTARY TECHNOLOGIES				
ANCHOR TECHNOLOGIES:	Diesel APU	Battery HVAC	Fuel-Operated Air Heaters	Automatic Engine Start/Stop
Diesel APU	–	NO	YES	NO
Battery HVAC	NO	–	YES	YES
Fuel-Operated Air Heaters	YES	YES	–	YES
Automatic Engine Start/Stop	NO	YES	YES	–
Driver Controls	YES	YES	YES	YES
Solar Panels	NEUTRAL	YES	NEUTRAL	YES
Additional Insulation	YES	YES	YES	YES
Engine Parameters	YES	YES	YES	YES
Hotel Rooms/Dorm Rooms	NEUTRAL	NEUTRAL	NEUTRAL	NEUTRAL

- NO Technologies do not make sense to pair together
- NEUTRAL Combined pairing is neutral in benefits
- YES Technologies when combined create a potentially beneficial pairing

Figure 21 – Matrix of Complementary Technology Packages (NACFE)

In the course of conducting the interviews and consultations that went into this Confidence Report, however, it became clear that the industry is having the most success by choosing one of four technologies as the “anchor” of their overall idle-reduction strategies, and then adding the additional technologies that best complement or support the anchor. In this way, the full system best suits each fleet’s needs. These common fleet strategies incorporate both passive and active solutions. These are, of course, not all of the available combinations, but the most common ones noted by solution manufactures, fleets, and others.

Those four anchor choices are:

1. Driver Controls + Fuel-Operated Heater
2. Diesel APU + Fuel-Operated Heater
3. Battery HVAC + Fuel-Operated Heater
4. Automatic Engine Start/Stop System

Once one of these options has been identified as the best for a fleet’s specific needs and goals, ancillary solutions can be evaluated for their potential to reduce idling even further. For example, several fleets stated that their benchmark for idle-reduction technologies is the fuel-operated air

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heater, as they are relatively simple and straightforward to operate, easy to service, and very efficient. So even after settling on one of the above four anchor solutions, it may be beneficial to add a fuel-operated air heater for cold weather operations, depending on the amount of time the fleet's vehicles operate in cold climates.

Or, in another example, if a fleet selects a battery HVAC system as its primary solution, it will need additional technologies to overcome the challenge of HOS restarts, because battery HVAC systems cannot power driver needs for the full 34 plus hours of the restart. The addition of a battery-monitoring automatic engine start/stop system into such a fleet's idle-reduction package would allow continuous use of the battery HVAC system throughout the restart period.

Finally, fleets should consider the conditions under which sleeping in the truck for an HOS restart is not the optimal solution. If the main engine will need to idle for the entire restart period to maintain comfortable temperatures and provide hotel loads, especially in very hot weather, a hotel room or dormitory may actually be a more cost-effective choice for the fleet, not to mention a preferable option for the drivers.

9.1 Driver Controls + Fuel-Operated Heater

A combination of driver controls and a fuel-operated heater allows some control of idle for a very small investment. This strategy is anchored around the adoption of a fuel-operated air heater for cold weather supported by the adoption of some electronic engine idle parameters, such as ambient air shutdown, along with driver training and driver incentives.

Fuel-operated heaters are the cheapest way to keep drivers warm in extremely cold temperatures. Ambient air shutdown settings automatically control idling when the temperature outside is mild, but will still permit unlimited idling in extremely hot weather. This should give the driver confidence that he or she can be comfortable in such conditions. Exact temperature ranges may be set by each fleet depending on the regions they operate in and how aggressive they want to be when it comes to idling.

Drivers can be trained on actions they can take to help reduce idle percentage. Bonuses and incentives can be developed to reward desired driver behavior. See Section 6.4 for more details on driver behavior and controls.

The downside is that the engine must be allowed to idle during any period of hotter temperatures in order to keep the driver comfortable, as this solution does not provide cooling. This makes the use of engine ECM settings for engine shut down less effective and easier to bypass for a driver who wishes to do so.

Fleets electing this as their idle-reduction strategy should have modest expectations of the amount of idle reduction they will be able to achieve.

Figure 22 suggests some solutions to those concerns, either by improving on the main system or converting to a different idle-reduction strategy entirely.

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CURRENTLY USE FUEL-OPERATED AIR HEATERS	
FLEET CHALLENGE:	CONSIDER MAKING THIS CHANGE
Batteries are discharged too soon	<ul style="list-style-type: none"> • Add battery charging automatic engine start/stop system • Minimize any hotel loads that may be draining the system • Utilize battery charger and off-board AC power to keep the batteries charged • Add an auxiliary starting battery system • Utilize an auxiliary CPAP battery to reduce the loading of CPAP to main batteries
Want to lower overall vehicle operating expenses and be more "green"	<ul style="list-style-type: none"> • Add AC outlets, or off-board power, or a truck stop electrification system to your longer stopping points such as distribution centers, near border crossings, etc.

Figure 22 – Fuel-operated Air Heaters Challenges and Changes (NACFE)

9.2 Diesel APU + Fuel-Operated Heater

Conversations with the industry found that the most common idle-reduction strategy for fleets that have selected diesel APUs as their anchor technologies, is to also install extra insulation and a fuel-operated air heater, but still to use the diesel APU to meet their air conditioning needs.

Regardless of the specific features of the diesel APU a fleet installs as its anchor technology, the additional installation of maximum truck insulation will greatly increase the effectiveness and efficiency of diesel APUs. Specifically, extra insulation in the cab and sleeper area, plus an insulating sleeper curtain and/or window covering, will help retain the heat and air conditioning generated by the APU, thus allowing the APU engine to run less and therefore use less fuel.

The study team also heard some common concerns or challenges from fleets that are either currently using diesel APUs as their main idle-reduction option or who are considering adopting them. Figure 23 suggests solutions to those concerns, either by improving on that main system or converting to a different idle-reduction strategy entirely.

Confidence Report on Idle-Reduction Technologies

CURRENTLY USE APUs	
FLEET CHALLENGE:	CONSIDER MAKING THIS CHANGE
Can't keep sleeper cool enough in summer	<ul style="list-style-type: none"> • Change exterior cab paint to lighter color • Use hotels for HOS restart periods • Make sure to cold soak the sleeper with the main HVAC before shutting off the main engine • Add thermal window curtains • Order new vehicles with extra insulation
Idling costs in winter are too high	<ul style="list-style-type: none"> • Add fuel-operated heater/turn off APU whenever possible • Order new vehicles with extra insulation • Utilize the bunk curtain to keep heat in sleeper • Add thermal window curtains
Maintenance costs and service frequency is too high	<ul style="list-style-type: none"> • Move away from APUs to automatic engine start/stop system with Clean Idle engine • Move away from diesel APUs to battery HVAC and battery charging automatic engine start/stop system
Total vehicle weight is too high	<ul style="list-style-type: none"> • Move away from APUs to automatic engine start/stop system with Clean Idle engine

Figure 23 – Diesel APUs Challenges and Changes (NACFE)

9.3 Battery HVAC + Fuel-Operated Heater

The optimal package to combine with a battery HVAC system as the anchor technology of a fleet's idle-reduction strategy, and the most common strategy currently pursued by the industry, is one which pairs the battery HVAC with:

- Additional insulation

AND:

- A fuel-operated air heater — to most efficiently cover all climate zones for fleets working in regions which have both cool and hot weather

AND:

- An automatic engine start/stop system — to charge the battery when the truck is stopped for extended periods, thereby eliminating one of the most common concerns fleets have with battery HVACs — the limited periods for which they can function with one charge. Some automatic engine start/stop systems can actually be integrated with battery HVAC systems themselves, monitoring their charges and automatically starting the vehicle to recharge batteries when they run low.

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Figure 24 goes into more detail about the common concerns or challenges reported by fleets who are either currently using battery HVACs as their main idle-reduction option or are considering their adoption, and serves to suggest solutions to those concerns, either by improving on that main system or converting to a different idle-reduction strategy entirely.

CURRENTLY USE Battery HVACs	
FLEET CHALLENGE:	CONSIDER MAKING THIS CHANGE
Batteries drain before the sleep period or HOS restart is complete	<ul style="list-style-type: none"> • Assure alternator amperage rating is as high as possible to ensure full battery charge while vehicle is moving • Add a battery charging automatic engine start/stop system • Consider whether wiring all batteries together would allow extra time without compromising battery life or jeopardizing main engine restart • Make sure to cold soak the sleeper with the main HVAC before shutting off the main engine • Minimize any hotel loads that may be draining the system • Utilize off-board AC power to run the HVAC and charge the batteries where possible • Add a solar charging panel to the sleeper or trailer roof to augment battery power available • Switch to a diesel APU for longer run time
Battery replacement costs are too high	<ul style="list-style-type: none"> • Minimize battery charging with any of the bullet points in the previous item
Batteries need to be replaced too frequently	<ul style="list-style-type: none"> • Minimize battery cycling with any of the bullet points in the first item • Maintain all electrical power connections to assure that they are clean, tight and sealed properly
Can't keep the sleeper cool enough in summer	<ul style="list-style-type: none"> • Change exterior cab paint to lighter color • Use hotels for HOS restart periods • Make sure to cold soak the sleeper with the main HVAC before shutting off the main engine • Add thermal window curtains • Order new vehicles with extra insulation • Switch to an APU system with a higher Btu cooling capacity

Figure 24 – Battery HVAC Systems Challenges and Changes (NACFE)

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9.4 Automatic Engine Start/Stop

An automatic engine start/stop system alone will not allow fleets to achieve an ambitious idle-reduction goal of around 10% idling time. But when paired with a Clean Idle engine given that technology’s certified availability to idle at the same emissions levels as a diesel APU, automatic engine start/stop systems make a relatively low-cost nationwide alternative, as they maintain sleeper temperatures and battery charge without adding significant weight or componentry to the vehicle or increasing maintenance requirements. However, in interviews with fleets, the frequency of engine starts and stops to keep the sleeper bunk cool during hot weather can interrupt the driver’s rest and negatively affect driver satisfaction with the system.

It should be noted that for this technology to be fully functional as an anchor technology, any vehicles ordered with both Clean Idle engines and automatic engine start/stop systems should **not** be ordered with the non-adjustable mandatory 5-minute timer installed on those systems. This timer is available as an option for fleets seeking to meet various idling regulations, particularly those in California, and they also are a useful option for fleets pursuing fuel efficiency measures under the 2014 Greenhouse Gas GEM model. Because Clean Idle certifications allow engines to idle for longer than the 5-minute limit, those non-adjustable timers will be counter-productive.

However, these two features alone may not present the most efficient way to operate a vehicle in the winter. The addition of a fuel-operated air heater, which is far more efficient than the main engine for heating the sleeper, will make for a better overall package, and additional insulation always will be beneficial as well.

The study team also heard some common concerns or challenges from fleets that are either currently using automatic engine start/stop systems as their main idle-reduction option or else are considering adopting them. Figure 25 suggests solutions to those concerns, either by improving on that main system or converting to a different idle-reduction strategy entirely.

CURRENTLY USE AUTOMATIC ENGINE START/STOP SYSTEM	
FLEET CHALLENGE:	CONSIDER MAKING THIS CHANGE
Idling costs in winter are too high	<ul style="list-style-type: none"> • Order new vehicles with extra insulation • Add a fuel-operated heater/turn off APU whenever possible
Can't keep the sleeper cool enough in summer	<ul style="list-style-type: none"> • Change exterior cab paint to lighter color • Use hotels for HOS restart periods • Make sure to cold soak the sleeper with the main HVAC before shutting off the main engine • Add thermal window curtains • Order new vehicles with extra insulation

Figure 25 – Automatic Engine Start/Stop Systems Challenges and Changes (NACFE)

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9.5 Most Common Fleet Strategies

Over the course of this study effort, four common fleet strategies emerged that incorporated a fleet choosing an anchor technology for its idle-reduction efforts and then adding various, additional and complementary technologies. As discussed above, these are not *all* of the possible combinations or options, but merely the more common ones that were highlighted by solution manufacturers, fleets, and others. Note that a good starting place for any idle-reduction solution is spec'ing the vehicle with the highest-level insulation package available from the truck OEM. This will help ensure maximum efficiency for whatever heating or cooling option is selected. Also note that fuel-operated air heaters are becoming a basic cornerstone of many of the technology packages currently being widely pursued. See Figure 26.

ANCHOR TECHNOLOGIES	ADDITIONAL TECHNOLOGIES
Diesel APU	<ul style="list-style-type: none"> • Extra Insulation • Fuel-operated Air Heater
Battery HVAC	<ul style="list-style-type: none"> • Extra Insulation • Fuel-operated Air Heater • Automatic Start/Stop System
Automatic Start/Stop System	<ul style="list-style-type: none"> • Extra Insulation • Fuel-operated Air Heater • Clean Idle Engine
Fuel-operated Air Heater	<ul style="list-style-type: none"> • Extra Insulation • Electronic Engine Parameters • Driver Training • Driver Incentives

Figure 26 – Summary of Anchor Technologies and Additional Technology Options (NACFE)

10 Conclusions

Confidence Report on Idle–Reduction Technologies

The report focused on currently available and viable technologies and practices for reducing idling in sleeper cab vehicles. As a result of research and interviews the study team reached the following conclusions concerning idle reduction in the sleeper cab market:

1. Reducing idle time, particularly on sleeper cabs, is good for the environment. It saves fuel, improves a fleet’s “green image” and probably saves a small amount of wear and tear on the main engine.
2. In terms of fuel savings, a good rule of thumb is the following:
 - A 10% reduction in annualized idle percentage (from 30% to 20%) is worth about 1% in fuel economy
 - 1% in fuel economy is worth about \$500 to \$700 annually at \$3.00/gallon fuel prices, and 100K miles/year
 - Depending on your starting point, a reduction of 20% (from 35% to 15%) is not unreasonable if the right combination of technologies is employed and managed. This can be done and still provide excellent comfort and benefits to the driver.
 - Today’s fuel costs do limit the payback on investing in idle-reduction technologies
3. Driver hiring, comfort and retention are mentioned in almost every conversation about idle-reduction technologies. This is one of the top two reasons listed by virtually every fleet for investing in idle-reduction technologies as new vehicles are purchased. Some have said that offering a good solution is a requirement for hiring and retaining drivers.
4. There is no “one size fits all” solution to idle reduction. Many technologies are available and well proven, but each has pros and cons that need to be evaluated. Every fleet and operation has different goals. Therefore, the benefits, costs, benefits and challenges of each of the technologies need to be weighed along with overall fleet objectives. The good news is that there are a large number of choices to satisfy the needs of individual fleets and many can be combined to provide the optimal solution for the fleet.
5. Drivers are still a very important part (If not the most important part) of successful management of idle times. Many fleets offer an incentive to drivers to manage their idle times to meet the fleet’s goals.
6. Depending on “shore power” (outside electrical connection) to be available is not a reasonable idle-reduction solution for most fleets as the number of electrified parking spaces is extremely small compared to the number of trucks that need to be parked at any given time.

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7. Most suppliers of idle-reduction technologies mention that their solution helps minimize maintenance costs, particularly in the vehicle's aftertreatment system. However, we have been unable to uncover any data that actually substantiates those claims. Engine manufacturers tell us that the reliability and durability of the aftertreatment systems has improved significantly since they were introduced, so differentiating lower maintenance costs due to engine manufacturer improvements vs. idle-reduction technologies would be extremely difficult if not impossible to verify.
8. One question that is frequently asked is if idle-reduction technologies provide any residual value to the fleet when the truck is sold or traded. After discussing this question with a number of fleet managers, the answer to this question is still unclear. The only technologies that may add to residual value is if the truck has either a diesel APU or battery HVAC system installed. Fleet managers report that sometimes these technologies give a small bump to residual values while at other times they do not. Certainly, the subject should be discussed with the purchasing party as part of the used truck sales process.
9. Interviews with several fleet maintenance managers emphasized that maintenance of the vehicle's battery connections and electrical systems is critical to getting the best performance out of idle-reduction technologies. This was considered even more critical in the case of a battery HVAC system is installed on the vehicle.

11 Confidence Rating

For each of the Confidence Reports NACFE completes, the technologies that have been assessed are plotted on a matrix in terms of the expected payback in years compared to the confidence that the study team has in the available data on the technology — that is, not only how quickly fleets can expect payback on their investment but also how certain NACFE is in the assessment of that payback time.

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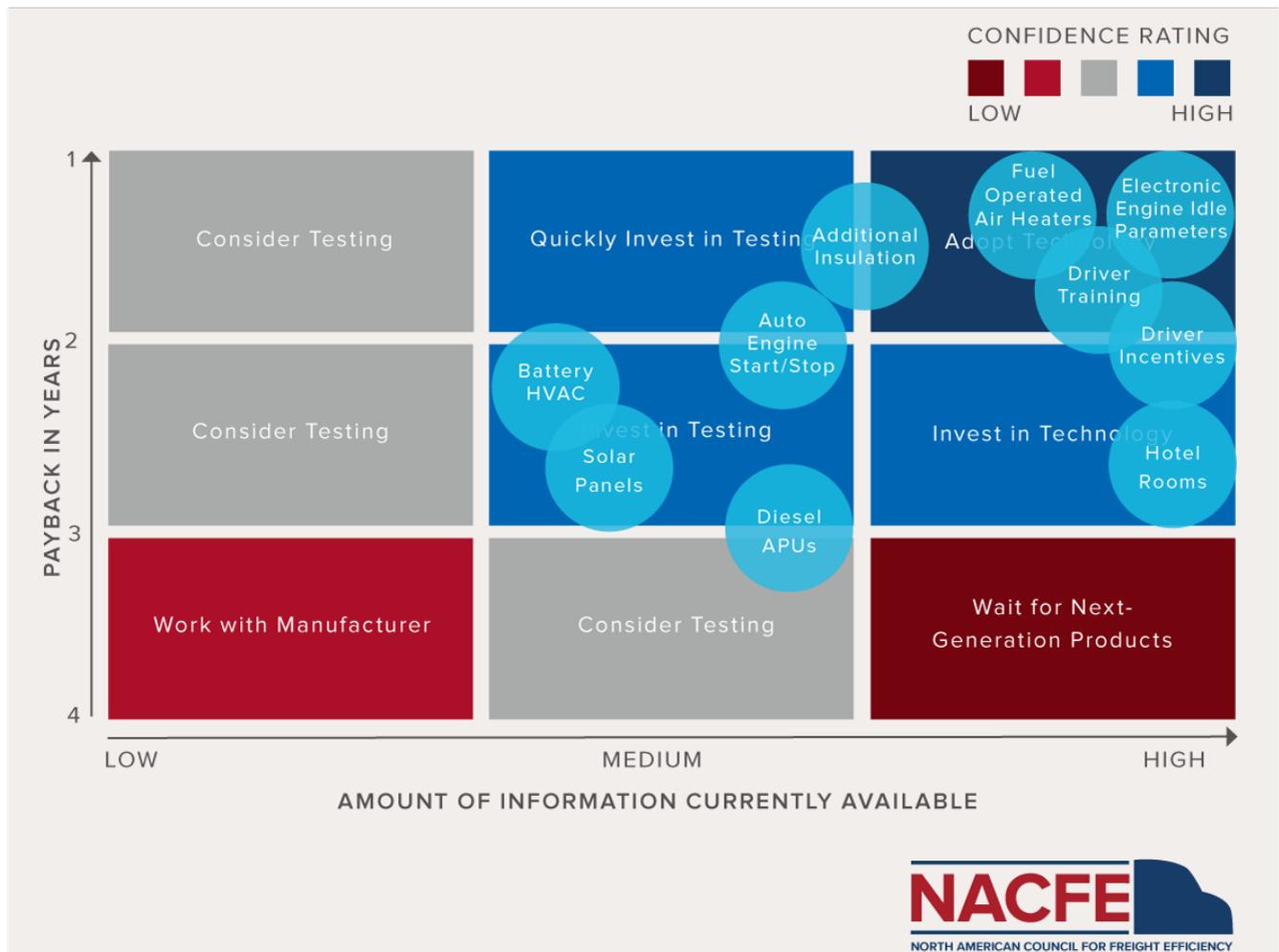


Figure 27 – Confidence Rating (NACFE)

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3. Determining Cost Per Mile — RTS Carrier Services

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7. Large Truck Crash Causation Study — Federal Motor Carrier Safety Administration — updated
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<https://ai.fmcsa.dot.gov/CarrierResearchResults/>
8. Large Truck Crash Causation Study — Analysis Brief — Federal Motor Carrier Safety
Administration
<https://www.fmcsa.dot.gov/safety/research-and-analysis/large-truck-crash-causation-study-analysis-brief>
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<https://www.env.nm.gov/aqb/GHG/documents/IdlingMythsandFacts.pdf>
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<https://www.slideshare.net/RonZima/cummins-idling-myths>
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12. Energy Reports American Trucking Associations
https://www.trucking.org/News_and_Information_Reports_Energy.aspx
13. Gallons of Diesel used while Idling — American Trucking Associations Sustainable America 2015
<https://sustainableamerica.org/blog/tse/>
14. Annual Vehicle Miles — Bureau of Transportation Statistics
<https://www.bts.gov/content/us-vehicle-miles>
15. Obesity Among Truck Drivers Part of National Crisis — National Registry of Certified Medical
Examiners

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<https://www.businessinsider.com/trucking-obesity-high-risk-2018-5>
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http://www.afdc.energy.gov/conserve/idle_reduction_heavy.html
23. Argonne National Laboratory — Energy Systems Division
<https://www.anl.gov/es>
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<http://www.epa.gov/smartway/forpartners/technology.htm>
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28. Technology & Maintenance Council
https://www.trucking.org/Technology_Council.aspx
29. Compendium Of Idling Regulations — American Transportation Research
http://www.atri-online.org/research/idling/ATRI_Idling_Compndium.pdf
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<https://cleancities.energy.gov/technical-assistance/idlebox/>
31. Federal And States Laws And Incentives — U.S. Department of Energy, The Alternative Fuels Data Center
<https://afdc.energy.gov/laws>
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13 Appendix A: Idle-Reduction System Suppliers

The following is a list of companies currently manufacturing idle-reduction technologies.

Diesel APUs

Carrier Transicold

<https://www.carrier.com/truck-trailer/en/north-america/products/na-truck-trailer/apu/>

Centramatic

<http://www.centramatic.com/apu.rhtml>

Dynasys

<https://www.dynasysapu.com/>

Go Green APU

<http://www.gogreenapu.com/>

Green APU

<https://greenapu.com/>

Rig Master Power

<https://www.rigmasterpower.com/>

Thermo King

<https://www.thermoking.com/na/en/road/auxiliary-power-units.html>

Tridako

<https://www.powercubeapu.com/>

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Battery HVAC

Bergstrom

<https://us.bergstrominc.com/>

Carrier Transicold

<https://www.carrier.com/truck-trailer/en/north-america/products/na-truck-trailer/apu/>

DClimate

<https://dclimate.com/>

Hammonds/Arctic Breeze

<https://www.hammondac.com/systems/arctic-breeze/>

Phillips & Temro

<https://phillipsandtemro.com/>

Thermo King

<https://www.thermoking.com/na/en/road/auxiliary-power-units.html>

Each truck OEM offers a battery HVAC solution under its own brand name:

- Kenworth: Kenworth Idle Management System (KIMS)
- Peterbilt: Smartair
- Navistar: Navistar No-Idle Solution
- Volvo: Volvo Parking Cooler
- Freightliner: Battery Powered HVAC System (BPHS)
- Western Star: Rest Star

Fuel-Fired Air Heater

Eberspaecher

<https://eberspaecher-na.com>

Kingtec USA

<http://www.kingtecusa.com/>

Phillips & Temro

<https://phillipsandtemro.com/>

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Proheat

<http://www.proheat.com/>

Webasto

<https://www.webasto-comfort.com/en-us/>

Fuel-Fired Coolant Heater

Eberspaecher

<https://eberspaecher-na.com>

Kingtec USA

<http://www.kingtecusa.com/>

Webasto

<https://www.webasto-comfort.com/en-us/>

Phillips & Temro

<https://phillipsandtemro.com/>

Proheat

<http://www.proheat.com/>

Automatic Engine Start/Stop Systems

Freightliner/Detroit Diesel

<https://freightliner.com/>

<https://demanddetroit.com/>

Idle Smart

<https://idlesmart.com/>

Navistar/International Trucks

<https://www.navistar.com/navistar/>

<https://www.internationaltrucks.com/trucks>

Phillips & Temro

<https://phillipsandtemro.com/>

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Miscellaneous Technologies

Hotels4Truckers

<https://www.hotels4truckers.com/>

Idle Air

<https://www.idleair.com/>

eNow

<https://enowenergy.com/>

Merlin Solar

<https://www.merlinsolar.com/>