eNow's solar powered idle reduction systems are designed to meet a wide range of auxiliary energy needs for medium and heavy duty trucks and buses.

**Highlights**

- High fuel costs, stringent anti-idling regulations, and state and federal emissions reductions targets are boosting demand for idle reduction technologies. A typical long-haul truck can use 2,400 gallons of fuel per year idling its engine to run auxiliary equipment. Fuel used for this idling costs $9,600 per truck per year assuming $4/gal diesel. This avoidable idling fuel cost erodes a trucker’s bottom line (see Figure 1).

- Conventional idle reduction systems include diesel, battery and grid-powered technologies. Performance of these idle reduction systems varies greatly in terms of fuel and other operating and maintenance (O&M) costs, emissions, and performance (see pages 2-3).

- eNow’s solar powered eCharge System for In Cab HVAC offers the lowest O&M costs, zero emissions, and superior performance compared with conventional idle reduction systems (see Figures 2-5).

- The operating costs of producing a kilowatt-hour (kWh) of electricity using eNow's solar powered system is $0, compared with between $2-3 for truck stop electrification and a diesel auxiliary power unit (APU), and $0.75 for a battery-only APU due to fuel costs associated with over-the-road battery charging (see Figure 5).

- Solar powered APU systems provide additional savings of $400 to $3,400 per year compared with conventional battery-only APU systems (see Figure 6).
Background

Heavy-duty vehicles are less than 5% of registered vehicles on the road in the US, but they account for approximately 25% of fuel use and 20% of greenhouse gas emissions coming from the transportation sector due to their significantly higher use rate compared to other vehicle types. In addition to over-the-road fuel use, trucks use a considerable amount of fuel to power auxiliary loads by idling the engine while at rest. The primary reasons truck drivers idle are to heat and cool the cab and sleeper compartment, protect the engine in cold weather, and operate on-board electrical appliances (i.e., “hotel loads” like computer, television, radio, phone, global positioning system, microwave, mini-refrigerators, and coffee makers). The US EPA estimates that idling a heavy duty truck’s engine consumes about 1 gallon of diesel fuel per hour. Therefore, a typical long haul truck without idle reduction technology that idles 8 hours a day for 300 days per year can be expected to use 2,400 gallons of diesel fuel for idling each year, which is over 10% of the truck’s total fuel use. This idling results in fuel costs of $9,600/year or $800/month when diesel fuel is $4/gallon. Can you imagine getting a utility bill for $800/month for one small room in your home? Annual fuel use and costs for various idling and fuel cost assumptions are presented in Figure 1. In addition to increasing fuel use and cost, running an engine at low speed (idling) causes greater wear on internal parts compared to driving at regular speeds. According to the ATA Technology Maintenance Council (TMC 2003), a truck idling for one hour suffers wear equal to about seven miles on the road.

Conventional Idle Reduction Approaches

Shutting down idling engines is the law in over 20 states and in numerous cities and counties throughout the US. Fines for non-compliance can be large—reaching $10,000 or more and jail time for repeat offenders in some locations in the US (ATRI 2013). These anti-idling regulations, tighter emission regulations, rising fuel prices, and an increasing realization of the impact that idling fuel use has on the truck operator’s bottom line have triggered growth in the truck idle reduction market. There are several conventional idle reduction technologies that are currently available either through third party vendors or as add-on options to trucks directly through manufacturers. However, these systems vary in terms of O&M savings, emissions, noise, reliability, operating time, and power output. Below is a summary of the approach, PROs and CONs of conventional systems:

1. Idling fuel use varies with engine type, engine RPM, and accessory loading and has been measured to be as high as 1.65 gal/hour. The weighted average value (70% High RPM, 30% Low RPM) is calculated to be 1.0 gal/hour (Lim 2002).
2. Assuming annual fuel use for a truck that travels 120,000 miles at 6 MPG is 20,000 gallons.
3. In cold climates, direct fired heaters are often integrated directly from the manufacturer, or can be installed as a retrofit, but they do not address cooling and other hotel loads (e.g., appliances) typically required by a long-haul truck.
- **Automatic engine start/stop systems** – Power and heat supplied from the truck’s engine when needed by intelligently turning the engine on and off throughout the rest period. PROs: Reliable and can provide the full amount of cooling power by using the truck’s air conditioner. CONs: Use of the truck’s engine limits total fuel and emissions savings, can add to engine wear, reduce truck (crank) battery life, and can be disruptive (noisy) compared to other approaches. Fuel savings can be minimal in extreme temperatures.

- **Truck stop electrification (including shore power)** – Power (and sometimes cable TV and/or internet) supplied from off-board electricity (i.e., grid power) for properly equipped vehicles. PROs: Quiet and provides long periods of cooling and auxiliary power. CONs: Lack of vehicle integrated capability and availability of shore power hook-ups throughout the US limits the total fuel savings and emissions reductions that are possible. It also requires users to pay for the service on an hourly basis, reducing overall savings.

- **Diesel APU** – Power and heat supplied from small, dedicated diesel engine generators. PROs: Provides long periods of cooling and auxiliary power because it can use the truck’s main diesel fuel tank. CONs: Auxiliary power is generated from a small engine that requires more maintenance ($200-$250 every 1,000-2,000 hours), needs to be replaced more often (every 15,000-20,000 hours), uses more fuel, and creates more emissions compared to other approaches. The downtime associated with APU maintenance and replacement can have a major impact on availability and truck downtime. In addition, California requires diesel particulate filters on any 2007 and newer technology. These filters can add thousands of dollars to the price of the APU.

- **Battery powered APU** – Power supplied from auxiliary battery pack, which is charged by the main engine or shore power. PROs: Quiet, reliable, and uses less fuel and generates less emissions than other approaches. CONs: Limited operating time on battery-only power (usually between 8-10 hours), increased engine alternator loads during over-the-road operation, and typically lower cooling power output compared to other approaches.

With no clear market leader among conventional systems and in some cases a lack of driver incentive, only a portion of trucks have installed idle reduction technologies, and a smaller portion actually use them regularly. A national survey conducted by the American Transportation Research Institute (ATRI 2006), which gathered information on the use of idle reduction technologies on more than 55,000 trucks, found that about 36% of respondents with sleeper cabs used onboard idle reduction technologies. Battery-powered air conditioning systems were used by 24% of respondents, while diesel auxiliary power units were used by 12% of respondents with sleeper cabs. Battery-powered APUs were found to be the least expensive auxiliary power technology to purchase and maintain. Innovative solar powered idle reduction systems that came on the market after this survey offer truckers the potential to exceed the comfort, performance and fuel savings associated with battery or diesel systems.

### Solar Powered Approach

eNow Inc. designs and sells solar power idle reduction systems for medium and heavy duty vehicle applications. These products are designed to reduce fuel and maintenance costs, save energy, and reduce emissions. eNow’s solar photovoltaic (PV) panels are mounted on top of a vehicle’s roof to capture sunlight and convert it to direct current (DC) electricity. The DC electricity goes to a solar charge controller, which maximizes the power output of the PV panels and then sends the power to an auxiliary load (e.g., HVAC) or battery system. When the auxiliary battery is fully charged and the vehicle is not at rest, the system will direct any excess power from the PV panels to power truck accessory loads (e.g., radio, lights, fuel pump), thereby improving over-the-road fuel economy. If solar power alone is insufficient to meet the auxiliary load requirements and charge the battery, the eCharge system uses the truck’s alternator to charge the auxiliary batteries during normal over-the-road operation just like a conventional battery-based No-Idle
HVAC system. In addition, the eCharge system is capable of seamlessly integrating with both automatic engine start/stop systems and shore power systems to charge the HVAC auxiliary batteries via the truck’s alternator at rest and off-board power when connected to shore power. A diagram of how eNow’s charging system harvests and stores energy in a heavy duty truck application is presented in Figure 2.

The eCharge system improves the performance and economics of battery-only APUs by:

- **Larger O&M savings** – significantly reduces truck O&M costs, including over-the-road diesel fuel costs, regular maintenance costs, and alternator and battery replacement costs.
- **Extended operating times** – extends no-idle periods from 8-10 to 14+ hours when rest period includes daylight hours.
- **Lower fuel and engine alternator use** – reduces fuel used to recharge the truck’s auxiliary batteries via the engine alternator.
- **Higher cooling power output** – can operate with a 24V (or higher) auxiliary HVAC system to provide twice the cooling power of current 12V systems.
- **Reduced truck downtime** – increases the life of the truck’s alternator and auxiliary battery system by reducing the alternator load (at idle and over-the-road), and charging the battery more efficiently at its optimal voltage. In addition, the eCharge system can keep the truck’s (crank) battery fully charged, which can reduce the need for emergency jump starts.

A summary of how the eCharge system compares to other idle reduction technologies is presented in Figure 3 (next page). The superior savings and performance of a solar powered system is further illustrated in Figures 5 and 6. Figure 5 compares the fuel cost of each kilowatt hour (kWh) of power delivered to the auxiliary equipment via solar power and conventional systems, showing that eNow’s eCharge system yields $0/kWh compared with more costly truck stop electrification and diesel APUs ($2-$3/kWh), and battery-only APUs ($0.75/kWh). Figure 6 demonstrates the additional annual savings of $400 to $3,400 possible with eNow’s eCharge system compared with a conventional battery-only system.
Projected fuel use based on 3,000 hours of powering auxiliary loads per year, annual fuel costs assuming $4/gal diesel, and cost of producing the auxiliary power (i.e., “cost of electricity”) based on fuel costs for truck idling and the various idle reduction technologies are presented in Figure 5. Automatic engine start/stop systems can save fuel and
reduce operating costs compared to constant idling, but the amount of savings is very dependent on outside temperatures. On very hot days, fuel savings will be minimal because the truck will idle almost continuously to meet cooling demands. Similarly, truck stop electrification has potential to save fuel and reduce fuel costs compared to idling, but annual savings will depend on the availability of shore power hookups throughout the US. Figure 5 assumes 100% use of each technology, so in this best case scenario fuel use is eliminated with the truck stop electrification approach. Annual service cost and the equivalent cost of electricity, which are not zero due to hourly shore power hookup charges, are lower compared to idling, but high compared to other idle reduction approaches. Diesel APUs can provide fuel cost savings similar to using shore power, and don’t have the same availability issues, but annual fuel costs are still not as low as battery powered systems and annual maintenance costs (not shown) can be significant.

<table>
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<tr>
<th>APPROACH TO POWERING AUXILIARY LOADS</th>
<th>ANNUAL DIESEL FUEL USE, GAL</th>
<th>ANNUAL FUEL (OR TSE SERVICE) COST</th>
<th>EQUIVALENT COST OF ELECTRICITY, PER kWh</th>
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<td>eNow’s eCharge System</td>
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FIGURE 5: FUEL SAVINGS AND EQUIVALENT COST OF ELECTRICITY FOR POWERING TRUCK AUXILIARY LOADS

Battery powered systems take advantage of charging an auxiliary battery during normal truck operation, which is much more efficient than idling the engine. The resulting annual fuel cost is lower than operating a diesel APU, but the equivalent cost of electricity is estimated to be $0.75/kWh when diesel fuel is $4/gal, which is still much higher (6 times higher) than the cost of powering electric loads in your home. Once installed, eNow’s solar-powered system provides a completely free source of energy to power truck auxiliary loads directly or recharge an auxiliary battery system. In addition to fuel savings, maintenance costs for the truck’s engine and alternator are reduced due to fewer operating hours. Reduced maintenance and delayed replacement costs for oil/filter changes, emissions equipment, alternator, crank batteries, and engine overhauls can save truck owners between $0.30 and $0.60 per hour of avoided idling as well as reduce downtime for maintenance and repairs. These savings, combined with fuel savings calculated based on expected operating conditions (i.e., less than 100% annual use), results in simple payback for the eCharge System of less than a year for auxiliary load (“hotel load”) requirements of 2,500 hours per year or more.

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4. Assumes an annual average auxiliary electric load of 350 W based on hourly modeling of typical auxiliary loads for TMY conditions in Kansas City, MO assuming a rest period between 8 pm and 6 am.
5. Based on $1.00/hour for the shore power hookup, which typically includes 3 receptacles and cable TV. In the shore power case, “fuel cost” is the cost of providing the service.
6. Based on 0.23 gal/hour diesel APU fuel use (Lim 2002). Actual fuel use will depend on size of the auxiliary load and type of APU system. There is not good information on fuel consumption under various load conditions for these APUs. Centramatic claims average diesel consumption is 0.30 gal/hour for their 2-cylinder water cooled Kubota engine, while Carrier claims average diesel consumption is 0.20 gal/hour for their Comfort Pro, which also uses a 2-cycle Kubota engine.
7. Based on engine and alternator charging efficiency of 14% during over-the-road operation (assuming average efficiencies of: engine = 34% (LHV), belt drive = 98%, alternator = 50%, and battery = 86% round trip) and diesel fuel energy density is 37.64 kWh/gal (LHV).
8. Engine and alternator charging efficiency increases from less than 2% for idling to 14% during over-the-road operation.
9. Assumes an average residential electricity rate of $0.12/kWh.
10. Assumes one hour of idling results in engine wear equal to seven miles on the road (TMC 2003), and average miles driven per year is 120,000.
Net annual savings for the eCharge and battery-only APU systems compared to no anti-idling device (i.e., engine idling) is presented in Figure 6. Net savings are the sum of the expected fuel cost savings, plus maintenance cost savings, minus the annualized APU installed costs. Annual fuel and maintenance savings are adjusted for times when the auxiliary batteries and solar power are not sufficient to meet all auxiliary power demands (i.e., less than 100% annual use). Auxiliary power demands and the availability of solar power were modeled using conditions (e.g., temperature, solar radiation) representative of Kansas City, Missouri every hour of a typical meteorological year (TMY) assuming a typical 10-hour “night rest” period from 8 pm to 6 am (figure on left) and “day rest” period from 6 am to 4 pm (figure on right). While long haul trucks have traditionally idled at night more often than during the day, long-duration daytime idling is common at ports and terminals, busy delivery sites, border crossings, and restaurants. Day rest periods will be increasingly more common with new Hours of Service (HOS) rules that took effect, which effectively require drivers to rest for between 34 and 48 hours continuously once a week.

**FIGURE 6: NET ANNUAL SAVINGS FOR NIGHT REST** (LEFT) AND **DAY REST** (RIGHT) PERIODS USING BATTERY-ONLY AND ECHARGE APU SYSTEM FOR KANSAS CITY TMY

**eNow Innovation**

eNow’s eCharge solar powered systems work with industry leading battery-based idle reduction technologies to replace engine idling with quiet and clean solar power. Surplus power from the solar panels can be directed to the truck’s main battery to offset truck loads or charge the truck batteries, which will extend battery life and reduce downtime and emergency jump starts. To compensate for days or times when solar energy production is low, eCharge can seamlessly switch to other energy sources like shore power or the truck’s alternator. In addition, eNow’s control systems have been designed to optimize the battery charge cycle and charge methods based on the battery state of charge and the solar power available. Therefore, the battery will last longer as it is optimally charged and kept in a better state of charge as compared to charging intermittently from the truck’s alternator.¹³

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¹¹ Assumes an annual average auxiliary electric load of 414 W based on hourly modeling of typical auxiliary loads for TMY conditions in Kansas City, MO assuming a rest period between 6 am and 4 pm.

¹² Includes the annualized cost of purchasing and installing a typical battery-power APU and 900W eCharge system based on monthly lease payments assuming two months down payment, 15.91% APR, and 30% Federal Energy ITC. Solar power availability is calculated using NREL’s PVWatts for conditions representative of Kansas City with 0 degree PV array tilt (i.e., flat roof surface), 900W PV panel rating, and 0.862 panel derate factor (NREL 2014). Fuel Savings calculations are consistent with earlier fuel use calculations and assumptions. Maintenance savings assume $0.43/hour of avoided idling.

¹³ The eNow system can extend the life of the truck’s main battery and auxiliary batteries because it will maintain the batteries in a full state of charge even when the truck is not in use for extended periods.
The eCharge system is unique due to its innovative PV panel design that is rugged, lightweight, aerodynamic, and flexible enough to be mounted on curved surfaces like the roof fairing of a Class 8 truck. The proprietary charge control system uses a Maximum Power Point Tracking (MPPT) technique to get the maximum possible power from the PV panels for any given environmental condition. Integrated safety features provide a highly reliable system that prevents electronic component failures. These and other unique features of the eCharge system are highlighted below.

**Superior Durability** - Components are ruggedized for over-the-road operation and can withstand conditions associated with commercial truck use. Laminated solar panels are impervious to scratching and capable of minimizing the effects of an impact. Edge guards around eNow’s PV panels protect them from contact with objects and adhesive mounting can eliminate roof penetrations. Panel lamination has a low adhesion rate so dirt tends to not adhere to the panel and easily washes off in a standard truck wash. The complete system is rugged enough to withstand years of worry-free operation.

**Lightweight, Flexible and Aerodynamic** - eNow’s lightweight and semi-flexible solar panels and mounting system weigh less than 0.9 pounds per square foot, conform to roof contours including roof fairings, are less than 0.2 inches thick, and provide low overhead clearance and wind drag. In addition, the complete on-roof subsystem, including electrical junction box, is aerodynamically designed.

**Maximum Power Output** - eNow’s charge controller uses a Maximum Power Point Tracking (MPPT) technique and multi-cell level diodes to get the maximum possible power from the solar panels including excellent low-light operation. MPPT samples the output of the cells and applies the proper resistance to obtain maximum power for any given environmental condition, including shading. In addition, the charge controller is designed for high efficiency to provide maximum power and return on investment.

**Optimized for Medium and Heavy Duty Vehicles** - Panel sizes, layouts, weight, and installation has been optimized for use by Class 4-8 trucks, buses and military vehicles with 12-24VDC flooded lead acid, absorbed glass mat (AGM), gel, or lithium ion (Li-ion) battery systems. The solar powered charging systems can fully charge auxiliary batteries in less than 9 hours without assistance from any other power source. Systems can be optimized for other classes of vehicles, auxiliary loads, battery types, and battery charge requirements. All components necessary for a proper installation are included with each system.

**High Reliability** - eNow’s panel design has gone through extensive testing, including International Electrotechnical Commission (IEC) certification testing. Built in safety features for short circuit, overload, surge and reverse current (night time) protection provide a highly reliable system that prevents electronic component failures.

**Quiet and Clean** - eNow’s roof-mounted solar panels provide a completely silent and emissions free source of energy to power truck auxiliary loads directly or recharge its battery systems. The system reduces fuel use and emissions associated with charging no-idle batteries to help achieve corporate sustainability, fuel efficiency improvement, emissions, and carbon reduction goals.

**Savings Guarantee** - eNow will work with truck owners to estimate first year savings based on the vehicle’s operating profile. If the truck is operated according to the profile and estimated savings aren’t met, eNow will make up the difference. Incentives - eNow’s eCharge system including factory integrated No-Idle HVAC is eligible for the 30% Federal Energy Investment Tax Credit. With this credit, simple payback on investment is typically between 6 to 18 months.  

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14. Calculated using NREL’s PV Watts for conditions representative of Kansas City in July with 0 degree PV array tilt and 0.862 panel derate factor (NREL 2014). Assumes auxiliary HVAC battery capacity is 420 A-hr, usable capacity is 70%, average charge voltage is 12.8V, roundtrip energy storage efficiency is 85.7%, and PV system has a maximum power output of 1,200W.

15. Customers are encourage to check with their tax advisor to ensure they are eligible for the 30% Federal Energy ITC.
months. In addition, there are a number of federal and state incentives available. Please consult www.dsireusa.org for a complete list by state for these incentives.

**Lease Option** - eNow’s lease program allows truck owners to finance 100% of the equipment cost, plus delivery, installation and other costs so you preserve capital. The lease option is also eligible for the 30% Federal Energy Investment Tax Credit. Net annual savings for leasing the eNow system for various idle reduction assumptions are presented in Figure 6.

**References**


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**About eNow, Inc.**

eNow is a clean tech company which designs, develops, and manufactures solar-based auxiliary power systems. These systems have been specifically developed for the transportation industry. Applications have been developed for medium and heavy duty trucks, commercial buses, school buses, and military vehicles. Visit [www.enowenergy.com](http://www.enowenergy.com) for more information.

eNow’s demonstration truck uses solar to power No-Idle HVAC, liftgate, emergency lighting, air compressor, computer, and other auxiliary loads.
133 Hallene Road, Warwick, RI 02886
p: 866 571 0175 | f: 866 935 4883 | e: info@enowenergy.com

enowenergy.com

PROVIDING RELIABLE SOLAR POWERED SOLUTIONS TO THE TRANSPORTATION INDUSTRY