EPRI

fact sheet

Transport Refrigeration Equipment: Cost-Effective Emissions Reduction

Electric Transportation Program

Shippers use refrigerated trucks, trailers, and oceangoing containers to transport foods and other perishable items. These vehicles and containers are essentially refrigerators on wheels. Known as transport refrigeration units (TRUs), they sometimes remain stationary for hours or even days while awaiting transport or unloading. During these periods, an auxiliary diesel engine typically powers the refrigeration compression unit.

The problem is that these TRUs contribute to high concentrations of pollutants and particulates at large distribution centers. Because the nearby communities that suffer the impact of these pollutants are typically low-income neighborhoods and communities of color, use of these engines raises environmental justice issues.

One way that air pollution at and around distribution centers can be significantly reduced is through the use of grid-connected electric standby (E/S) transport refrigeration units, or e-TRUs. Electric standby can be used while a TRU is stationary, although an auxiliary engine is still required during transport. The use of e-TRUs can improve local air quality and at the same time generate a market opportunity for utilities.

Before E/S can be widely adopted, though, questions about the costs and benefits of e-TRUs must be answered. EPRI launched a study to explore the projected emission reductions, capital costs, and feasibility of adding E/S auxiliary motors—powered by a dockside electric supply infrastructure—to operate TRUs while stationary at warehouse or terminal locations.

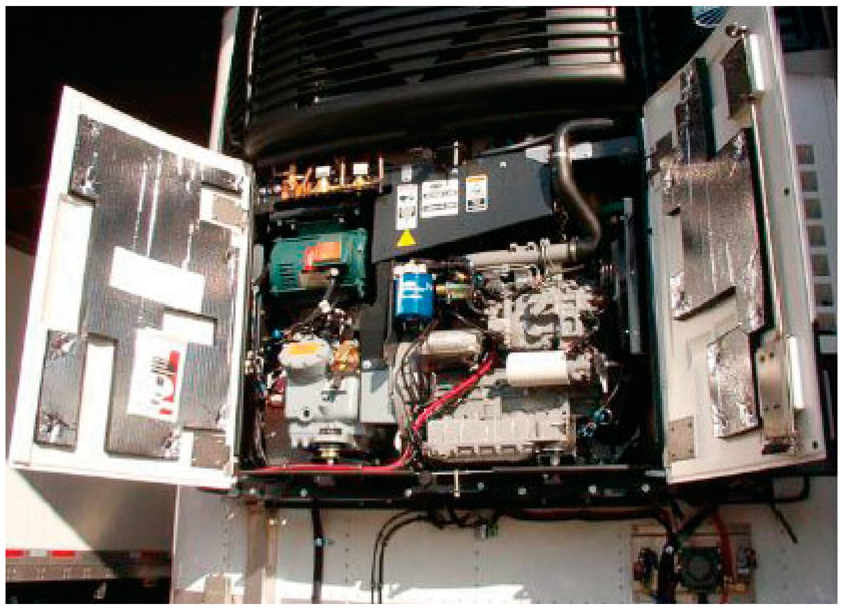

Figure 1. e-TRU in Trailer at LA Unified School District

Background

The EPRI study, *Transport Refrigeration Equipment Analysis of Emissions and Economics of Electrification,* Product ID 1008783, builds on an emissions analysis of TRUs prepared by the California Air Resources Board (ARB). The study's impetus was the Air Toxic Control Measure (ATCM) recently adopted by ARB as well as new non-road engine standards announced by the Environmental Protection Agency (EPA) in May 2004.

Before 1995, TRU engines were not regulated by either the federal or state governments. However, the new federal non-road regulations impose increasingly stringent new-engine standards on manufacturers. These regulations are expected to reduce PM emissions by about 95% and NO_x and ROG emissions by about 65% between 2004 and 2014. The use of e-TRUs could help truckers meet the new standards.

Emissions Benefits of e-TRUs

A semi-trailer diesel TRU engine can emit more oxides of nitrogen (NO_x) than the truck's main engine when idling, even though both use a similar amount of diesel fuel. This means that providing a cleaner source of power for the TRU can potentially reduce emissions more than cleaning up the vehicle's main engine. For example, for a 34-hp TRU, replacing the diesel engine with an electric motor powered by grid electricity just for one hour of operation reduces toxic particulate matter (PM), NO_x, and reactive organic gases (ROG) by more than 209 grams, which is 30% better than emission reductions achieved by eliminating idling of the main truck engine. These benefits are tempered by the fact that the TRU may run more or less than an idling truck over the course of a year, and trucks and trailers with E/S will still need to use the auxiliary diesel engine when away from the grid.

Market Opportunity

Extrapolating ARB's estimate of the number of TRUs in California, researchers determined that there were approximately 300,000 trailer-mounted TRUs of all sizes in the U.S. in 2000. The electrical load created by these trailer-mounted e-TRUs provides a significant market opportunity for electric utilities.

For example, the energy load of a semi-trailer e-TRU varies from 5 kW to 19 kW, depending on the evaporator return-air temperature. With a projected average energy use of 8 kWh per hour, annual usage would be between 8,000 kWh and 24,000 kWh. The projected average energy use for a box van e-TRU is 2.5 kWh per hour (roughly 2,500 to 7,500 kWh per year). Peak loads might be as high as 15 kW for a semi-trailer e-TRU and 6 kW for a box van e-TRU. These are larger peak loads than expected with truck stop (idle reduction) electrification and are similar to the load from a battery electric vehicle.

Study Approach

EPRI's analysis examined four strategies for shifting diesel TRUs to e-TRUs.

- Strategy 1 focuses on scrapping an existing diesel early and buying a new TRU with a cleaner diesel engine and E/S.
- Strategy 2 suggests retaining the normal TRU replacement schedule and adding the E/S option when buying a new TRU.
- Strategy 3 involves retrofitting an existing diesel TRU to add E/S.
- Strategy 4 proposes that if the TRU already has E/S, an infrastructure be added at additional locations to increase the amount of zero-emission run time.

The study examined all four strategies using a 20-year life cycle for a refrigerated trailer or box van.

Investigators developed spreadsheets to compare three cases with varying assumptions (vehicle type, operating profile, equipment age, and so on) in order to assess emission reductions and cost-effectiveness of E/S compared to natural retirement cycles and installation of exhaust after-treatment systems.

- Case Study 1 assumed a 34-hp semi-trailer TRU operating 3,000 hours per year, a high-use scenario, 50% of that time in E/S mode.
- Case Study 2 assumed a 34-hp semi trailer TRU operating 1,200 hours per year, a low-use scenario, 50% of that time in E/S mode.
- Case Study 3 assumed a 10-hp van TRU operating 1,038 hours per year, and 50% of that time in E/S mode.

Table 1. Results of Applying Strategy 1: Retiring a MY 2001 TRU in 2008 and Replacing With a New e-TRU

Description	Semi-Trailer (34 hp) With 3,000 hrs/yr and 50% E/S Operation	Semi-Trailer (34 hp) With 1,200 hrs/yr and 50% E/S Operation	Van (10 hp) With 1,038 hrs/yr and 50% E/S Operation
Number of years diesel engine was retired early	3	13	13
Incremental NO_x, ROG, and PM PM emission reductions 2008–2020 compared to federal scenario (lifetime tons)	3.3 tons	2.7 tons	0.71 tons
Incremental cost per pound of NO_x, ROG, and PM reduced versus EPA	$0.43	–$0.24	$4.92
Incremental NO_x, ROG, and PM emission reductions 2008–2020 compared to CA-ATCM scenario (lifetime tons)	3.1 tons	2.42 tons	0.66 tons
Incremental cost per pound of NO_x, ROG, and PM reduced versus CA-ATCM	–$0.07	$0.98	$2.68

Note: Negative cost-effectiveness indicates a cost savings to achieve the additional emission reductions.

The research team developed the TRU Spreadsheet Analysis Tool (TRUSAT), a model to aid in the analysis of costs, emissions, and petroleum consumption reduction benefits. The TRUSAT model enables analysts to draw conclusions about the impact of regulatory decisions and potential market niches for E/S. Using the TRUSAT model, researchers compared the incremental results of the E/S strategy to two other scenarios: one that assumes compliance with the federal non-road engine standards only, and one that assumes compliance with the federal non-road engine standards, as well as the California ATCM.

Study Results

The analysis concludes that the incremental cost-effectiveness of the two semi-trailer e-TRU cases is far better than that of many on-road vehicle emission reduction approaches. The E/S van case also reduces emissions at a reasonable cost-effectiveness. One reason is that these scenarios involve replacing a diesel TRU three to thirteen years earlier than otherwise expected.

Table 1 summarizes the results of implementing Strategy 1, starting with a MY 2001 TRU and assuming early retirement of the TRU in 2008, and replacing a new TRU with E/S that is retired in 2021.

Table 2 summarizes the results of implementing Strategy 2, and illustrates a normal replacement cycle where a new 2008 TRU meeting interim federal Tier 4 standards is purchased with an E/S option. The sensitivity of the analysis to model year is illustrated by the results in Table 2 compared to Table 1. Table 2 contrasts the emissions reductions when all scenarios start with the purchase of a new TRU in 2008, rather than 2001 as shown in Table 1. Table 2 also provides the range of lifetime tons reduced and associated cost-effectiveness for a non-electric TRU scenario.

Strategy 3, which retrofits an existing diesel TRU with E/S, can also result in very large emissions reductions, similar to Strategy 1. Both strategies remove or reduce the use of a relatively dirty diesel engine. Retrofitting also can be a cost-effective use of grant incentives to reduce NO_x, ROG, and PM. However, there are several issues related to e-TRU retrofitting which are discussed further below.

Strategy 4 is based on installing additional electric infrastructure with an existing e-TRU and is a variation on Strategies 1, 2, and 3. It can also be more cost-effective than these other strategies, if targeted at locations where TRUs can plug in for a significant number of hours. To the extent that emissions could be reduced simply by adding infrastructure at additional locations, this would be a cost-effective strategy.

Overall, the analysis concludes that the cost-effectiveness of emissions reductions is sensitive to changes in cost and model-year assumptions rather than changes in engine emissions. In addition, total emissions reductions achieved in a given scenario are very sensitive to percentage of E/S hours versus diesel operation.

Recommendations

The analysis points to several areas where additional study and market strategy development are needed:

1. The efficient use of public funds to maximize public benefits is critically important to ensure long-term success in meeting air quality and energy security enhancement goals. This can be accomplished by considering overall cost-effectiveness based on the total benefits of a project, as opposed to PM reductions only. When public benefits are considered holistically, the case for e-TRUs is more compelling.
2. Public agencies should encourage technologies that exceed the minimum standards (if any) for reducing NO_x, ROG, PM, CO_2, and petroleum consumption, either by revising existing regulations or by using non-regulatory tools, such as incentives.
3. Another type of incentive option is trading of mobile source emission reduction credits (MSERC). Proceeds from the sale of credits can help offset the additional cost of generating the extra emissions reductions. The

Table 2. Results of Applying Strategy 2: Purchasing a New TRU With E/S Option in 2008

Description	Semi-Trailer (34 hp) With 3,000 hrs/yr	Semi-Trailer (34 hp) With 1,200 hrs/yr	Van (10 hp) With 1,038 hrs/yr
E/S Operation = 50%: NO_x, ROG, and PM reductions (lifetime tons)	2.25 tons	0.9 tons	0.28 tons
E/S Operation = 50%: Cost per pound of NO_x, ROG, and PM reduced	$1.68	$4.21	$3.68
CA-ATCM: NO_x, ROG, and PM reductions (lifetime tons)	0.07 to 0.29	0.03 to 0.12	0.01 to 0.04
ICA-ATCM: Cost per pound of NO_x, ROG, and PM reduced	$19.03 to $4.64	$47.56 to $11.60	$121.43 to $35.39

TRUSAT model can be used to evaluate grant incentives or MSERC incentives by testing many key assumptions. It also provides a foundation for creating new scenarios based on the existing spreadsheets.

4. The electro-drive industry and the TRU industry should team with ARB and others to develop one or more E/S demonstration projects. A demonstration project would provide the opportunity to test the assumptions in both the ARB staff report and the TRUSAT model.
5. The analysis did not consider operating costs. A demonstration project that included these costs would determine whether there are offsetting maintenance and fuel savings associated with E/S. In addition, the impact of utility rates on various on-peak and off-peak duty cycles needs to be evaluated.
6. The need for standardization of e-TRU infrastructure must be evaluated. For example, dockside connectors and cabling are not standardized, and dozens of plug, socket and cable combinations are available. Lack of an infrastructure standard creates confusion and slows down the development of the market.
7. Similarly, the power requirements for oceangoing TRUs should be standardized and coordinated with land-based E/S systems. Currently, 460-V 3-phase power is the most typical configuration used in large modern distribution centers. Standardizing on 208/230-V 3-phase power is another possibility and is typical of TRUs in the 10-hp to 17-hp range.
8. The study did not consider potential greenhouse gas emission reductions. It would be useful to quantify these emission reductions for the existing fleet and the potential reductions from various e-TRU usage scenarios.
9. The E/S compliance option under the current ARB regulation requires that there be no diesel operation at any facility, whether home base or a brief delivery stop. Such a strict requirement will place an undue burden on TRU operators who might wish to use E/S for compliance. More work is needed to determine whether this requirement is necessary to achieve the projected emission reductions.
10. EPA and ARB should consider adding e-TRUs to the emissions inventory.

For More Information

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