ELECTRIC-POWERED TRAILER REFRIGERATION UNIT DEMONSTRATION

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Prepared for:

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ENERGY RESEARCH AND DEVELOPMENT AUTHORITY

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NOTICE

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Section 1:
INTRODUCTION

1.1 BACKGROUND

In the U.S., trailer refrigeration units (TRUs) powered by small diesel engines have traditionally provided the trailer cooling required for transport of fresh and frozen foods. Small diesel engines are notoriously high emitters of nitrogen oxides (NOx), particulate matter (PM), and carbon monoxide (CO) pollution. While these pollutants are now regulated, diesel-powered TRUs remain significant contributors to air quality issues in and around truck stops, distribution terminals and, to a lesser extent, grocery stores. In addition, operation of TRU diesel engines creates noise pollution. This can be a significant concern in populated areas, as these commodity deliveries often occur during the late evening and early morning hours. The on/off cycling of these diesel engines generates the emissions and noise most urban areas are attempting to reduce

There are currently no New York State regulations in place to limit TRU operation. In fact, regulating these units may not be practical in that shipping companies would put refrigerated loads at risk. However, The State of California has been proactively restricting emissions of TRUs beyond the EPA small engine emission regulations. As the regulatory activity in California directly affects the TRU industry's research and development activities, their regulatory actions is discussed here in detail.

<u>California Air Resources Board's Transport Refrigeration Unit Airborne Toxic Control Measures</u>

On February 26, 2004, the California Air Resources Board (CARB) adopted the Transport Refrigeration Unit Airborne Toxic Control Measure (ATCM) and directed its staff to closely monitor progress and development of emissions control technology as it applies to TRUs and TRU generator set emission standards set forth in the TRU ATCM. The Board further directed staff to report on the feasibility of complying with the standards in the time specified in the regulation. The rulemaking became effective December 10, 2004, and was codified under title 13 California Code of Regulations (CCR), section 2477. On March 28, 2005, ARB requested the U.S. Environmental Protection Agency (U.S. EPA) to grant a waiver of preemption under the federal Clean Air Act. Pending U.S. EPA's decision, which they have indicated will occur by the end of 2007, CARB will continue to implement the TRU ATCM in accordance with California state law.

CARB has been tracking diesel emission control strategy (DECS) manufacturers' efforts to develop and demonstrate DECS for TRUs and TRU generator sets. ARB conducted technology review workshops and a report is being prepared and is expected to be available January 2008. The Low-Emission TRU In-Use Performance Standard (LETRU) and Ultra-Low-Emission TRU In-Use Performance Standard (ULETRU) apply to all TRUs that operate in California on a phased compliance schedule, beginning December 31,

2008. CARB feels that there will be sufficient compliance options available in time for compliance and compliance deadline extensions will not be offered. (Source: TRU ATCM Status Update, California Environmental Protection Agency, Air Resources Board, October 2007.)

The use of “alternative technologies” can be used to meet the California TRU In-Use Performance Standards if diesel PM emissions are eliminated while at a distribution facility. Electric standby meets this requirement but must meet the defined limitations and requirements. To use electric standby, the infrastructure and operating procedures at distribution facilities must produce zero TRU engine emissions at all distribution facilities it visits, with limited exceptions (e.g. during an emergency or normal yard maneuvering related to ingress and egress). TRU engine operations at distribution facilities, other than during these narrow exceptions, would be a violation, subject to fines and penalties. This compliance option may only work for captured fleets (e.g. fleets that only visit the fleet owner's distribution facilities), where the owner can assure the necessary infrastructure is available and all the TRU engine operations of the specific TRU are eliminated at all distribution facilities in California. CARB requires records to document compliance. The records would need to clearly show that electric standby is used when at the facility and the diesel engine is used only when away from the facility. (Source: “How Do I Comply with the TRU ATCM for Operators of TRUs and TRU Generator Sets, and Facilities where TRUs Operate?,” California Environmental Protection Agency, Air Resources Board, Stationary Source Division, Emissions Assessment Branch, July 2007.)

<u>Electric TRU Development</u>

To address the inefficiencies associated with regular diesel-driven TRUs, manufacturers have developed hybrid diesel-electric units and other alternative technologies. Many of the units that are capable of being powered by grid-supplied electricity are belt-driven mechanical models with additional electric motors that allow the diesel engine to be switched off when the unit is plugged into electric power (shore power). This is referred to as “standby” operation. Some new all-electric TRU models (eTRU) have fully electric components that can use shore power or be powered by small diesel generator-sets for over-the-road use and are now commercially available in the United States. However, shore power connection infrastructure for eTRUs and standby TRUs is unavailable at most warehouse and truck stop locations. To support the deployment of these connections, standards development is being led by the Electric Power Research Institute (EPRI) to ensure uniformity across the industry. Standby-capable reefer units (whether electric-driven mechanical units or eTRU) generally require three-phase electricity input for large capacity trailer models due to high power requirements. Most deployed shore power infrastructure to date provides only single-phase power for engine block heaters and cab “hotel” loads. However, some refrigerated warehouses and distribution centers have electricity connections installed, usually for smaller refrigerated box trucks equipped with a mechanical-driven electric-standby connection. A photo of this type of connection is shown in Figures 1-1 and 1-2. Therefore, at the current time, the ability to plug-in to shore power electricity is limited.

Figure 1-1: Refrigerated Box Truck Capable of using Electric Connections

Figure 1-2: Refrigerated Box Truck Connected to Electric Power

One of the primary benefits of the eTRU technology is the reduced number of mechanical components they contain, when compared to conventional TRU systems. This approach is expected to lead to reduced maintenance costs and fuel consumption while increasing product life, reliability, and unit resale value. The demonstration of this technology will illustrate any anticipated as well as unanticipated benefits and shortcomings of this technology.

1.2 PHASE 1 eTRU FEASIBILITY ASSESSMENT

Shurepower was tasked in September 2004 by NYSERDA to perform a feasibility analysis of eTRU technology. This assessment was completed in June 2005 and can be found at http://www.nyserda.org/publications/ElectricPoweredTrailerRefrigeration.pdf. The results of the study were as follows:

- **eTRUs appear to be a promising technology whose time in the U.S. has arrived.** This conclusion is based upon the operational cost analysis of diesel-driven TRUs, the localized emission and noise elimination benefits, the successful operation of these units in Europe, and the interest demonstrated by the refrigerated transport industry.

- **Warehouses and trailer parking areas can be easily retrofitted to incorporate the electrical service required to operate eTRUs on electricity**. High-voltage service exists at many of these facilities due to the electrical requirements of the refrigeration equipment. The engineering and installation of the electrical distribution and wiring may be provided to the facility at a reduced cost to the owner of the refrigerated warehouse. This conclusion is based on discussions with electric utilities indicating that the increased use of electricity can offset the cost of engineering and installation.

- **Regulations may require the adoption of these units in environmentally sensitive areas.** The California Air Resources Board (CARB) and the U.S. Environmental Protection Agency (EPA) have proposed stringent emission regulations and local regions have discussed restricting the operation of diesel-powered TRUs.

- **New York State is an excellent location for the demonstration of eTRUs.** This conclusion is based upon its proximity to major U.S. food distribution centers and the high number of refrigerated warehouses, which makes it an outstanding site for this technology. The ambient conditions in New York State require the TRU to provide heating and cooling, which can ensure the technology is fully proven prior to the final product release.

- **Cost of diesel fuel use and associated maintenance implications of diesel-engine-driven TRUs offer the potential of operator savings and rapid payback of the incremental price difference.** As diesel prices average near $2.50 per gallon, the payback on an eTRU can be obtained in 8 months for an incremental capital cost increase of 10% and up to 23 months for an incremental capital cost increase of 30%. This brisk payback provides a significant economic incentive for the purchase and use of these units. In addition, as the units are more reliable and require less maintenance, additional saving can be achieved through productivity gains. In addition, these units may have the advantage of being allowed to operate in restricted areas, further increasing their value.

- **Electrical connection improvements should reduce market barriers.** Trailers should be equipped with hardware to allow connections to be made from the electrified facility to the eTRU. This approach eliminates the requirement of connecting the eTRU directly to the electricity supply, a difficult endeavor for high-voltage cabling.

- **Partnerships have been established to demonstrate eTRUs in New York State.** The targeted demonstration partner, Maines Paper & Food Service Inc. in Conklin, NY, has expressed interest in participating in a demonstration of eTRUs. The electric utility for the MAINES facility, New York State Electric and Gas (NYSEG), has indicated their interest to participate in this demonstration.

- **An eTRU demonstration should be pursued to confirm the results of this assessment and validate cost assumptions for the installation of the electrical connections and operation of**

the eTRUs. This demonstration would provide information on the actual value of eTRUs to the trucking company, the impact of eTRUs on profit margins of the trucking company, and the actual payback period for eTRUs.

Following in the advice of the feasibility assessment, a Phase 2 demonstration project was proposed and awarded by NYSERDA to Shurepower.

1.3 PROJECT BACKGROUND

In September of 2005, the New York State Energy Research and Development Authority (NYSERDA) awarded a cost-shared contract to Shurepower, LLC (Shurepower) for the design, installation, and field demonstration of electrified loading docks and parking spaces for heavy-duty diesel trucks and refrigerated trailers. With co-funding from the U.S. Environmental Protection Agency Smartway Transport Partnership, this project demonstrated eTRUs and documented their ability to reduce air pollution, noise, maintenance costs, and diesel fuel use. The new Carrier-Transicold TRU featuring Deltek™ hybrid diesel electric technology, which can be directly powered by electricity, was used to demonstrate this capability.

As the operational benefits to fleet operators of electric TRU systems are currently difficult to quantify, a demonstration of this technology can further illustrate these economic and operational benefits to the refrigerated transport community. The environmental benefits of eTRUs (emit no on-site pollutants when they operate on electricity and are quieter when operated on electric and diesel fuel) are not tangible benefits to fleet operations. Fleets emphasize operational costs, product reliability and maintenance costs when specifying equipment. However, the longer term benefits like product reliability and maintenance costs can not be verified on a one year demonstration project. Therefore, operational costs were the focus of this shorter-term demonstration. It is believed that when fleet operators see the actual operational costs and an unbiased, acceptable approach to calculating the payback period of eTRUs, fleets will be more inclined to adopt this technology. Therefore, a one year demonstration of these units in a successful refrigerated trailer operation in the New York State is critical to illustrate to the industry that eTRUs can be a cost-effective investment.

The demonstration project location was selected as the Maines Paper & Food Service, Inc. (MAINES) distribution facility in Conklin, NY. This first of its kind facility supplies grid power to over-the-road eTRUs while parked. Ten parking spaces have been electrified to serve as a staging area for the trailers and two loading dock bays have eTRU power connections installed. Ten demonstration trailers have been equipped with the Deltek™ eTRUs. A patent-pending under-trailer wiring system was installed to transmit electricity from the rear connection point at the loading bay side to the eTRU mounted on the front of the trailer. Several assessments were also performed during the demonstration to determine possible improvements in the current design as well as future systems.

1.4 PHASE 2 eTRU DEMONSTRATION APPROACH

The results from Phase 1 indicated that it would indeed be beneficial to perform a demonstration of the eTRU technology in a real world operation and thus a second phase, Phase 2, was proposed by Shurepower LLC to NYSERDA. Project Team members for this Phase 2 demonstration project included NYSERDA, MAINES, NYSEG, Carrier-Transicold, Great Dane Trailers, Penske Truck Leasing Company, New West Technologies, LLC, and the U.S. Environmental Protection Agency. NYSERDA notified Shurepower of the project award in August 2005.

Phase 2 was separated into two distinct phases (Phase 2A and Phase 2B) working towards demonstrating the technology. Phase 2A (System Design and Site Assessment) was the design aspect of the demonstration that was responsible for the design of the shore power connections as well as the design of the electrification interface among other things. Phase 2B (Site Construction and Data Collection) implemented the design, constructing the site and collected data during a 12 month demonstration of this technology. Once Phase 2A was completed, it was necessary to obtain NYSERDA's approval to move onto Phase 2B activities.

Phase 2A: System Design and Site Assessment

Task 1: Design of shorepower connections: Shurepower in conjunction with NYSEG, evaluated the existing infrastructure at the host site and designed the eTRU shorepower system. Activities included in this task consist of assessment of current electric infrastructure, engineering of any upgrades to the electrical distribution system, and engineering of the on-site shorepower electrical distribution and connection system.

Task 2: Assessment of Host-site sleeper cab tractor fleet for cab power through shorepower connections (replaced with expanded scope of electrical facility): Shurepower worked with MAINES to determine the current shorepower and upgrade capability of the fleet of long-haul tractors being used by Maines for refrigerated transport. Since the host-site does not procure sleeper cab tractors, this task activity was modified and the electrical facility design scope was expanded to include (2) eTRU electrical connection installed for access by trailers servicing the loading dock.

Task 3: Detailed Cost Assessment for eTRU to Shorepower-Capable Tractor Connection: Shurepower completed an assessment to determine if a business case exists for the development of a control system modification to Carrier-Transicold's eTRU Vector technology. An economic and market assessment was performed in conjunction with team member input to verify if an electrical connection from the TRU to the shorepower-equipped sleeper cab is a product feature desired by the refrigerated transport industry. It was determined that this was not a viable option at this time. The full assessment is included as Appendix A.

Task 4: Design of Integrated eTRU Electric Supply with Refrigerated Trailer System: In this task, the Shurepower Team provided 5 pre-commercial eTRU units for test operations. To ensure connectivity to eTRU stanchions at the rear of the trailer, an embedded electrical connection was designed for installation along the frame of the trailer. The design of this system is discussed in more detail in the design section of the report.

After these four (4) Phase 2A tasks were completed, NYSERDA approved the Phase 2A design work and effort continued into the Phase 2B construction and data collection efforts.

Phase 2B: Site Construction and Data Collection

Task 5: Installation of shorepower connections: After the shorepower connections were fully designed and specified in Task 2A, it was necessary to implement this design. Twelve (12) shorepower connections were installed on site at the Maines facility in order to provide adequate electric capabilities to the site so that electrification of the eTRUs could occur.

Task 6: Integration of eTRU Electric Supply with Refrigerated Trailer System: As part of this task, Shurepower Team member Carrier-Transicold completed the order, delivering the final five (5) eTRU-equipped trailers to MAINES, for a total of ten (10) test trailers. To permit connectivity to electric power, ten (10) embedded electrical connections were procured and installed along the frame of the trailer. The cost for the system was developed and an OEM installed cost was estimated.

Task 7: Over the road assessment: For a period of one (1) year, MAINES worked with the Shurepower Team to ensure all trailer refrigeration equipment functioned as designed and as desired to meet MAINES' stationary and over the road needs. The purpose of a 12 month test period was to document the integrated system operation in all four seasons and resolve any issues that emerged during the over-the-road assessment. Also, Shurepower and NYSEG monitored the warehouse shorepower electrical services; assessed the level and timing of electricity usage at the site, and the adequacy of the supplied electrical connection pedestals and supporting electrical infrastructure. Peak shaving approaches, if needed, could also be investigated for implementation at the site. Operational data were collected by MAINES on-site personnel and analyzed by the Shurepower Team. In addition, electrical use data were collected remotely via the data collection system and analyzed. The Shurepower Team monitored and collected data from the control fleet using wireless data collection approaches, including cellular transmissions from the eTRU via a third party interface.

1.5 STRUCTURE OF REPORT

This report has been structured to respond to the requirements of the NYSERDA scope of work as well as provide the reader an overview of the chronological activities performed as part of this assessment. This report is separated into sections starting with background, followed by system design, construction and installation, data analysis and results, issues encountered, outreach and technology transfer activities, and finally conclusions and recommendations. Also, several appendices are attached which include comprehensive assessment reports and other detailed information.

Section 2:
PRE-INSTALLATION SITE AND TRAILER DESIGN ACTIVITIES

After the initial project scope was developed, several activities needed to be completed prior to the start of the installation of the electrical connections. These included the site selection, site design layout, trailer wiring and connection design, and facility data collection system. These are discussed in detail in this section.

2.1 SITE SELECTION

The site selection for the Phase 2 demonstration was based upon the results and activities for Phase 1's feasibility assessment. During the Phase 1 assessment, criteria were identified to determine the best possible host site for the Phase 2 demonstration project. After considering all criteria, six specific criteria were identified and from these criteria it was determined that Maines Paper and Food would be the best possible site for this demonstration. The six criteria are as follows:

Criterion #1: Fleet is based in New York State

MAINES is headquartered in New York State and transports refrigerated cargo across the Mid-Atlantic and Northeastern United States. They operate a major refrigerated distribution warehouse in Conklin, NY, 80 miles south of Syracuse, NY.

Criterion #2: Fleet uses refrigerated trailers to transport cargo

MAINES transports beverages, processed foods, and other materials via refrigerated trailers.

Criterion #3: Fleet operates at least 10 refrigerated trailers for cargo transport

MAINES has a total of 125 trailers, far exceeding the minimum of 10 trailers needed for this demonstration. Although the data used did not segregate the non-refrigerated trailers from the refrigerated trailers, it was assumed and later confirmed that MAINES does have more than 10 trailers equipped for transported refrigerated goods.

Criterion #4: Fleet has purchased or plans to purchase Carrier-Transicold Trailer Refrigeration Units (TRUs) for trailer refrigeration

Carrier indicated that MAINES is a current customer of theirs and possesses in excess of 10 refrigerated trailers.

Criterion #5: Fleet is committed to demonstrating new and innovative high-technology solutions and integrating these into operations

MAINES states as their mission "This mission is being pursued by drawing on the synergies between the skilled and dedicated MAINES workforce and the *utilization of leading edge technologies and equipment.*" In addition, information technology (IT) is a core competency at MAINES Paper & Food Service Inc. MAINES uses state-of-the-art technologies and facilities to achieve operational excellence and to "deliver the best customer service in the industry." MAINES works very closely with their foodservice operator and vendor partners to improve system integration and to increase efficiencies in their supply chain. This is an indicator of their ability to act as a beta test fleet for the Electric Trailer Refrigeration Units. Their ability to participate as a test fleet for this technology was confirmed by Carrier-Transicold and through subsequent discussions with MAINES' management. Also, MAINES has been at the forefront on technology integration as demonstrated by the many technology assessment case studies performed on this organization. They have integrated logistical and scanning application technology and have been commended by the Governor of New York. In addition, this technology adoption has permitted MAINES to experience exceptional operational growth. MAINES is ranked as the number 6 food distributor in the nation and is one of the fastest-growing national food distributors (third-fastest in percent sales increase and fifth-fastest in dollar sales increase). All data show that MAINES was a preferred candidate to test and integrate new technology in their operations and their operations have improved as a result. MAINES Paper & Food Service, Inc. thus met criterion #5.

Criterion #6: Fleet's refrigerated warehouse has or can install high-voltage electric power for eTRU operation

The high-voltage electrical infrastructure required for the 480-volt 3-phase connections was confirmed acceptable by New York State Electric and Gas, the electricity supplier for MAINES. Therefore the existing infrastructure was satisfactory for the installation of high-voltage electric power for operation of eTRUs. Therefore, the sixth and final criterion was successfully met by MAINES.

After determining that MAINES was an ideal location, negotiations were performed with facility management to ensure they would participate in this demonstration. An agreement was established between all parties to perform the demonstration at the MAINES facility in Conklin, NY.

2. 2 PRE-DESIGN ASSESSMENT OF FACILTY AND OPERATIONS

In order to properly construct the site, it was necessary to complete several design tasks, involving both site and trailer modification designs. First, it was necessary to determine the overall site layout. This process included assessing the current site design and determining the number of electrical connection points and their locations. This layout assessment was completed in conjunction with MAINES management to ensure that any future expansion would not require the displacement of the electrical connections. This information led to the development of an overall site layout. Second the design of the interface between the trailer and the electrification system needed to be completed. Decisions had to be made to determine whether or not the trailer connection was to be hard wired and identifying where the pedestals would be located in relation to the existing wiring and trailers. It was also necessary to identify and design the enclosure that would contain the electric connection for the Vector power connection and the data collection hardware. Both the site layout design and trailer modifications are discussed in detail below.

2.2.1 CURRENT FACILITY INFRASTRUCTURE

Since the identified site already had 110 VAC power for block heaters distributed to twenty (20) parking spaces in the staging area, the existing hardware was integrated into the installation plan. The power receptacles are mounted on an I-beam on the centerline between two adjacent parking stalls (Figures 2-1 and 2-2). The pedestal provides power for both trailers. The electric service for these pedestals comes from the main building through two 2 inch diameter conduits to a distribution panel (Figure 2-3). Power is routed to the pedestals through 1 inch conduit. The initial design for upgrading the facility power was left up to the electrical contractor. The electrical upgrades have significantly higher power than the existing system. So, when possible, existing infrastructure, such as buried conduit, was used to keep costs low and to disturb the property the least. The design included running a new power line from the center of the building to a junction box on the exterior of the building.

The existing conduit run from the warehouse to the parking area was reused in the design. An assessment of the conduit's integrity was performed and confirmed that the conduit is in a condition that permitted the power cable installation.

Figure 2-1: Pre-Existing I-Beam Mounts at MAINES

Figure 2-2: Close up of Pre-Existing I-Beam Mounts at MAINES

Figure 2-3: Existing Electrical Distribution Panel in Trailer Parking Lot

One (1) inch PVC conduit was in place from the outdoor breaker box to each I-Beam mount. Sections of the undamaged conduit were reused when found intact.

2.3 FACILITY SITE DESIGN

The overall site design was determined by Project Team and MAINES management in order to provide the best overall design for optimal use of the connections. The Shurepower Team originally selected trailers that were target for cruise ship delivery routes. These routes are repetitive and would permit the eTRUs to

Figure 2-4: Overhead view of MAINES Facility (googlemaps.com)

be connected to the electrification system at the MAINES site, as well as possibly at the cruise ship delivery site. It was determined that ten (10) electrical connections would be installed in the staging area, which is located at the far end of the parking lot away from the warehouse (Figure 2-4). Ten electrical connections were selected as trailers were preloaded earlier in the week and would idle for extended periods in the parking lot until the shipment was ready to be delivered.

To be as cost efficient as possible, these ten electrical connection locations would be located in 5 pedestal boxes, each containing two connection receptacles. The "dual gang" enclosures provided adequate space for the electric connection and data collection equipment. A schematic of the facility design is shown in the one line diagram in Figure 2-5.

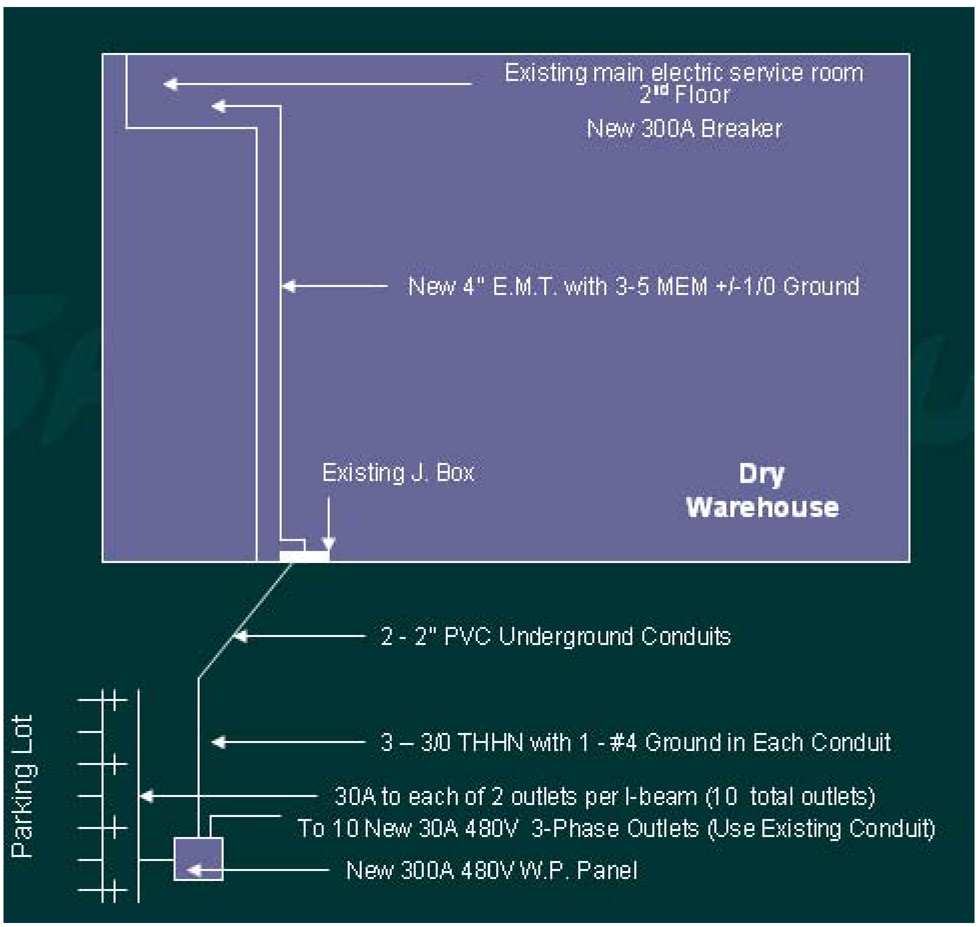

Figure 2-5: One-line Drawing of 300 AMP Service to the Parking Area

In addition to the staging area, two dock locations were identified for eTRU power connections. This would enable these trailers to use electrical power during loading/unloading operations at the dock. A dual gang unit was also selected for use at the dock locations. A nearby breaker box with sixty (60) Amp capacity was available and was utilized as the power feed for the dock locations. No significant design work was required for this installation.

2.4 TRAILER WIRING AND CONNECTION DESIGN

An approach must be developed to connect the eTRU to the electrical power source. Based on discussions with Carrier, it was determined that the best approach would be to minimize the number of electrical connections from the grid power to the eTRU to minimize voltage drop issues. An initial design proposed by Carrier was to hardwire a power cable to the eTRU, route it underneath the trailer and store a length of cable in box at the rear of the trailer. The cable length of approximately 10 to 15 feet would be coiled and stored inside a storage box at the rear of the trailer. This approach was discussed with Great Dane, the trailer manufacturer, which indicated that a standard box product does not exist to fulfill this need. They also stated that a manufactured storage box would cost at least several hundred dollars for materials alone. As MAINES made clear that all modification must appear to be an original equipment manufacturer (OEM)-like install, this retrofit design would not be acceptable. Instead, a removable extension cable was used to make the connection between the trailer and the power receptacle at the dock/pedestal.

As a result, a design was developed to hard wire connect the eTRU to a plug located at the rear of the trailer. The location of the plug at the back end of the trailer permitted a more convenient connection point to the eTRU. To accomplish this, a wire was installed under the trailer (Figure 2-6). The electrical connector installed on every Vector eTRU was removed and reinstalled at the rear of the trailer. The eTRU was then directly connected to the under trailer wire and via this wire, the reinstalled Vector plug was connected at the rear of the trailer. This design permitted a single connection point to the eTRU and reuses the original Vector connector at the rear of the trailer. The detailed under trailer wiring system design is located in Appendix B.

Figure 2-6: Under Carriage of a Great Dane Trailer

A 120VAC electrical connection for shore power tractor power was also considered in the design. In order to accommodate an additional 120V extension along trailer, an additional hole in the upper coupler assembly of the trailer was required. The current 1.5 inch diameter hole in the upper coupler assembly was sufficient only to accommodate the three-phase cable. Available options were discussed with trailer manufacturer Great Dane and it was determined that an additional hole could possibly be added to the trailer; however, this would significantly delay manufacturing and deliver of the trailers. An additional month would have to be added to the schedule, and after consultation with the project partners it was determined that the benefit to such a modification did not justify the schedule delay. As such, it should be noted that future design considerations be taken to investigate the 120VAC requirements.

2.4.1 TRAILER WIRE SELECTION

Identification of the correct type and lengths of wires used in the under-trailer wiring system was critical to ensure that all power and environmental exposure requirements were met. The Shurepower Team worked with the Carrier-Transicold engineering department to investigate the details of the three-phase eTRU connection. It was determined that the loading characteristics of the unit were balanced and as such, only the phase conductors and ground were needed (i.e. the neutral currents are canceled and therefore an extra conductor is not required). It was determined that the fifth pin on the plug was to be tied within each connector to ground and passed along a single conductor. A cable manufacturer was contacted to investigate available 8AWG, 4 conductor cable designs. The conductor size was ultimately determined to be 8AWG based on amperage calculations at the maximum anticipated current. The SOOW and SEOOW cable bundles offered the type of protection required for the given environment. Several cable samples were received from Comp Cable Inc. including a 0.780 inch diameter General Cable Carolprene SOOW, a 0.98 inch water-resistant General Cable Carolprene SOOW, and a 0.783 inch water-resistant Coleman Cable Seoprene SEOOW that is less flexible than the same diameter SOOW cable. It was decided that the water resistant properties were critical for this installation since the cable will be exposed to the environment, so the larger diameter 0.98 inch water-resistant General Cable Carolprene SOOW cable was selected as the primary cable choice for the under-trailer wiring system (Figure 2-7). A full, further in-depth write-up concerning wire selection is included as Appendix C.

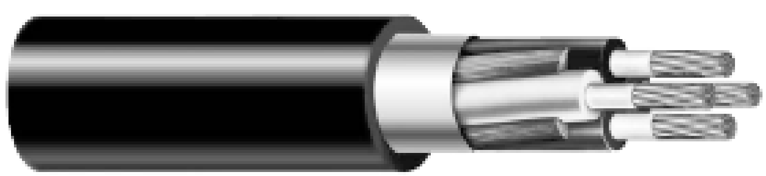

Figure 2-7: Water-Resistant General Cable Carolprene SOOW, 0.98 Inch Diameter

2.5 TRAILER TO ELECTRICAL FACILITY CONNECTION DESIGN

In order to allow the eTRUs to properly connect to the grid-supplied electric power, an appropriate plug interface design was needed to make the connection from the trailer plug to the electrical facility. This design, as shown in Figure 2-8, incorporates specific cable specifications, including cable length to ensure

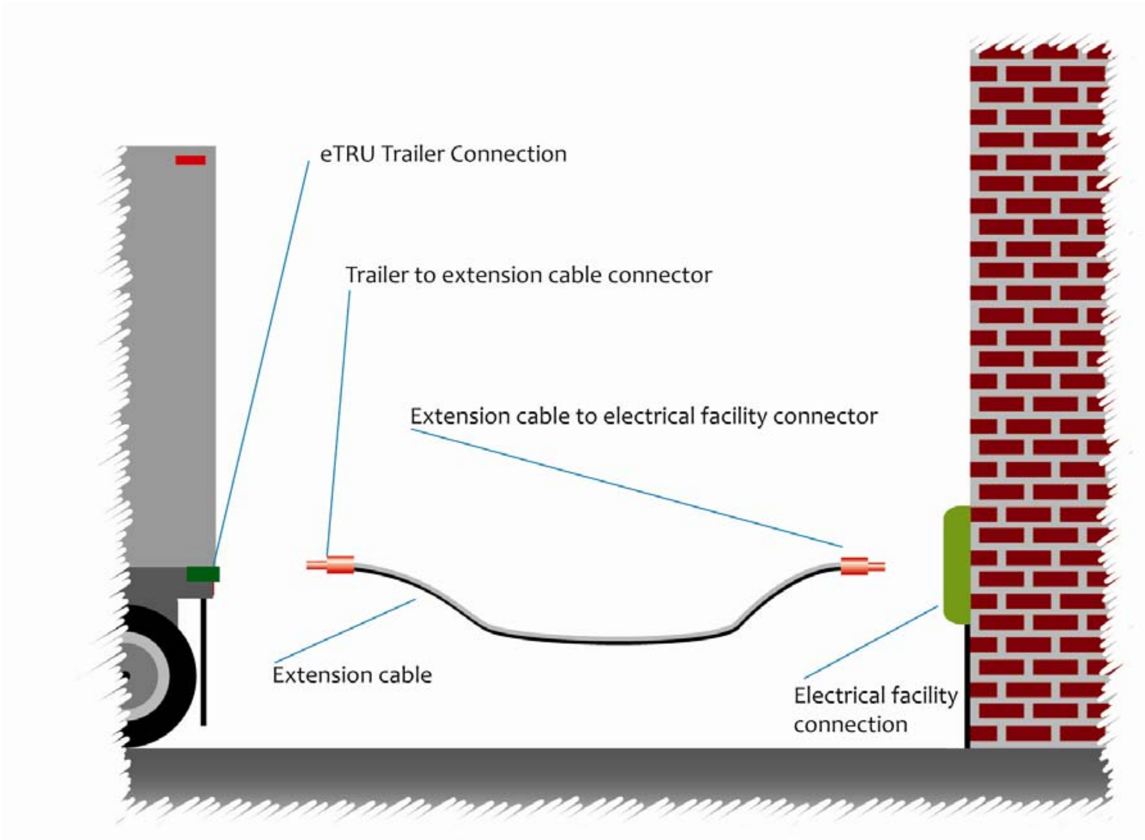

Figure 2-8: Trailer to Pedestal Connection Schematic

that the power provided to the eTRU from the electrical facility remained within the accepted parameters for the Vector electrical operation.

2.5.1 TRAILER CONNECTOR TO EXTENSION CABLE DESIGN

The interface had to meet several different design specifications. First and foremost, the connection needed be rated at a minimum of least 480 VAC 3-phase power and 30 Amps, the maximum level of power needed by the Vector eTRU. Also, the connection pins must mate to the standard plug installed on the Vector unit. As the plug connections were required to be left outdoors, these connectors must be at a minimum designed to be waterproof or be capable of being slightly modified to become water/weatherproof. The plug connector was also required to be robust in design and last several years in an environment that would require multiple connections and disconnection as well as weather environments. Finally, the connection must integrate a breakaway capability to ensure that a drive-off situation will not result in exposure to significant damage to the system. After considering all design criteria, it was decided that a Hubbell 4 prong connector, shown in Figure 2-9,

Figure 2-9: Hubbell 4 Prong Connector

would meet these criteria. The connector includes a spring loaded cover that is capable of protecting the connector for the weather. It is rated for 480 VAC and 30 Amps, so it meets all design requirements.

2.5.2 EXTENSION CABLE DESIGN

The extension wire that connects the electrification unit to the eTRU is a very critical part of the power transfer process. When specifying the wire type, it was vital that the wire meet all electrical requirements as well as ensure it would be robust enough to survive outdoor use in upstate New York. It was determined that the extension cable would be best is made from the same wire type and gauge size used for the under-trailer wiring. This wire gauge was specified with Carrier to permit the extension cable voltage drop to match the electrical feed requirements of the Carrier Vector eTRU.

Storage of the extension cable evolved into an issue and as a result, these cables are now stored on-site. The cables do not require storage in a weatherproof enclosure since these cables are designed to be weatherproof and both connectors have weatherproof connectors. As such, the cables can be located at the electrical facility plug in connection and hung on a wire hanger above the expected maximum snow level at the location. These extension cables will be hung at a point at least 5 feet above ground level. This approach probably would not be feasible at a public facility as these cables would not remain located at the pedestals; however, since access to the MAINES facility is limited, this approach can be used.

2.5.3 EXTENSION CABLE TO ELECTRICAL FACILITY CONNECTOR DESIGN

The connector used to connect the extension cable to the electric power connection must also be properly specified. This connector must be a male type plug to connect to the female connector within the pedestal box. As far as performance specifications, again the primary concern is to meet all electrical requirements, therefore the plug must be certified for use with 480 VAC 30 Amp 3-phase power. The specifications must also require the component to be designed for harsh environments as it will be stored outdoors year round. It also must be capable of attaining a watertight connection. Durability will also be a requirement since the connector will most likely be dropped and poorly treated during its lifespan. The chosen connector was a CEE-17 3H configuration, watertight when mated plug. This non-metallic connector is designed for use in harsh marine environments.

Figure 2-10: ESL Extension Cable Connector to Electric Power

2.5.4 HIGH POWER ELECTRIC FACILITY CONNECTION DESIGN

Three (3) phase 480 VAC 30 Amp electricity is a very dangerous level of power. The utmost care must be taken when developing the interface to connect to this amount of electricity. For this reason, a proven power connection module was selected. A two (2)-gang wall mounted assembly was selected (see Figure 2-11.) The enclosure material is 304 Stainless Steel and powder-coated to resist oxidation. Installed within the enclosure are (2) safety-interlocked power modules rated at 32A 480VAC. The receptacle is CEE-17 3H configuration and meets IEC 309-1,2 specifications. The module is mechanically interlocked, contains an integral 30A trip circuit breaker rated 22KAIC @ 480VAC. The assembly is UL certified and has been used in the marine environment for years. This type of proven technology with an excellent safety record is the type of product preferred for this installation. The enclosure is rugged and can function in the cold temperatures and extreme weather experienced in upstate New York. This unit is waterproof and is large enough to permit the inclusion of data collection hardware. The double gang enclosure was selected to ensure all data collection equipment can be located inside the module. Using a double gang unit reduced the cost for construction/installation, cut the number of assembly units in half, and reduced the need for some data collection hardware in half. The enclosure also contains an internal fuse panel for an extra level of safety.

Figure 2-11: Two-Gang I-beam mounted electric connection assembly

2.6 FACILITY DATA COLLECTION SYSTEM DESIGN

After finalizing the design and layout of the facility, the design for the data collection system was required. A need exists for the electrical use data collected from the site to be transmitted from the facility to a remote database via the internet. This design will also need to incorporate the size constraints of the two-gang enclosure. Due to the fact that the MAINES facility's plug-in connections were to be located far from the building and IT infrastructure, it was determined that a wireless data transmission system would be the preferred design. This would eliminate the need to run additional control wiring from the warehouse to the pedestals. The dock mounted electrical connection design incorporated hard wire infrastructure since the dock connections were very close to the MAINES IT interface. A wireless data collection system was designed by using wireless data transmitters, as well as a wireless range extender. The data collection system also included a pulse counter, which reads the electricity being provided to the units, as well as a data logger, which records these pulses. The data that are logged are transferred to the wireless transmitter and on to a router, which transmits the data set through the internet to enable real time data viewing.

Section 3:

TRAILER RETROFIT, SITE CONSTRUCTION AND SYSTEM UTILIZATION

3.1 UNDER-TRAILER CONNECTION SYSTEM INSTALLATION

The retrofit of the trailers occurred when the trailers were delivered from the Great Dane factory. The under-trailer wiring system was installed in conjunction with the mounting and installation of the Vector TRUs at Penn Detroit Diesel Allison (PennDDA), a certified installer of Carrier-Transicold products. This installation of the trailer wiring system occurred from March 2006 through May 2006. A detailed discussion of the wiring system installation is provided as part of Appendix B.

3.1.1 COSTS FOR UNDER-TRAILER SYSTEM INSTALLATION

Cabling and installation labor were the major cost components of the under trailer wiring system. Originally, the trailer connection plug was taken from the Vector and used as part of the under-trailer wiring system. However, this approach was later modified and will be discussed later in the report. Since the Vector trailer connection plug was used in this design, there is no additional cost for this connector. Therefore, the cost for the connector was not integrated into this estimate. It is believed that Carrier will offer the improved plug as part of the future Vector offering so the cost estimate should be considered accurate.

Trailer Wiring Costs on a Per Trailer Basis

Hardware: Connector mounting hardware	$45.00
Hardware: PennDDA trailer cable install hardware	$21.35
Wiring: Graybar cable	$168.88
Contract Labor: PennDDA/Install Trailer cable & Plugs	$544.32
Cost per trailer - Retrofit installation	**$779.55**
Cost per trailer - OEM installation (25% discount)	**$584.66**

OEM installation cost estimates are considered more accurate for future installations; however, this cost can vary significantly as copper and labor prices fluctuate.

3.2 ELECTRICAL CONNECTION FACILITY CONSTRUCTION

After the site construction plan was approved by the host site, construction began soon thereafter. After receiving three bids for this work, per NYSERDA requirements, the lowest cost and best value contractor was selected. The electrical contractor, John P. Rogers, completed the new installation of electrical cable and conduit through the interior of the warehouse section that feeds 300 Amp, 480VAC, 3 phase power to the trailer parking area outlets. Installed in the parking area was a new 300 amp, 480 VAC 3 phase weatherproof distribution panel with ML breakers. This was centrally located between the pedestals adjacent to the electrified parking spaces. To provide this power to the parking area, a new 300 amp breaker was installed at the main service feed. Since it was determined that the existing conduit (previously used for a block heater system in the same location) was still useable, the wiring run for the electrical service from the warehouse to the distribution panel was fed through this conduit. Reusing this conduit reduced the installation cost significantly since trenching was not required.

Figures 3-1 through Figure 3-5 show the installation of the electrical facility wiring run through the warehouse to the junction box and through the existing conduit to the 300 Amp breaker panel. Figures 3-1 and 3-2 are photographs of the inside of the warehouse wall on the dock side. Conduit and wire were run across the warehouse to feed the electrical facility in the parking lot. Figure 3-3 shows the junction box on the inside wall of the warehouse and Figure 3-4 shows the exact same view from outside the warehouse. The existing conduit shown in Figure 3-4 was used to run the wire to the 300 Amp breaker panel shown in Figure 3-5.

From the distribution panel to the I-Beam pedestal location, electrical contractors reused much of the existing conduit and replaced sections that could not be reused. The wire was then connected to the pedestal boxes for electrical power flow control. The module was then mounted to the I-Beam (see Figure 3-6), which provides a level of protection against a direct hit by a trailer.

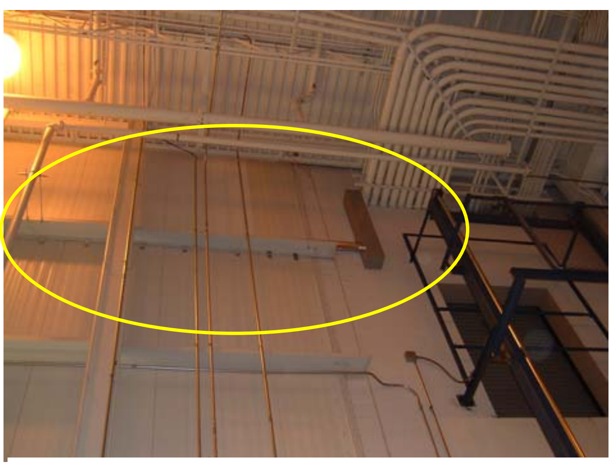

Figure 3-1: Warehouse Installation of Conduit Containing 300 Amp 3 Phase 480 VAC Power (1 of 2)

Figure 3-2: Warehouse Installation of Conduit Containing 300 Amp 3 Phase 480 VAC Power (2 of 2)

Figure 3-3: Warehouse Installation of Conduit Containing 300 Amp 3 Phase 480 VAC Power – Junction Box to 2 Inch Conduit

Figure 3-4: Electrical Facility Installation – Reutilization of Existing 2 Inch Conduit

Figure 3-5: Electrical Facility Installation – 300 Amp 480 VAC 3 Phase Breaker Panel

For the dock mounted pedestal connection, conventional connections were installed as the power was routed from an existing nearby breaker panel to the power connection box. This module is shown mounted to the warehouse in Figure 3-7.

Figure 3-6: I-Beam-Mounted Electrical Power Module

Figure 3-7: Warehouse-Mounted Electrical Power Module

3.2.1 COSTS FOR FACILITY CONSTRUCTION

There are three primary elements of the electrical facility that will be costed in this section; facility hardware, supplemental equipment, and data collection system.

<u>Electric Facility Costs</u>

The electrical facility hardware consisted of four primary components including wiring, electrical connections modules, and electricity control/breaker panel and labor. The electrical facility hardware included all materials for the installation, including lift rental, and miscellaneous mounting materials. The cost of the breakers was included in the panel price from the electrical contractor. Tax was charged on all materials; however there was no tax charged on labor. In addition to the actual installation of the service feed, hanging the modules and connecting them, there were labor costs to run a conduit test on the existing conduit from the building to the new panel that accommodated the 110VAC lines for block warmer outlets at the I-beams. This test determined that the conduit was good and the new wiring for the modules was pulled through them. This saved the cost of trenching, new conduit, backfilling and blacktop patching. These costs are listed below:

Electric Facility Hardware Installation Cost Breakdown:

The electrical facility hardware consisted of four primary components including wiring, electrical connections modules, and electricity control/breaker panel and labor. These electric facility costs are listed below:

Electrical connection ports: Modules	$5,632.00
Electrical connection ports: Miscellaneous hardware	$57.46
Wire: Indoor	$25,863.84
Wire: Outdoor	$1,944.00
Wire: Miscellaneous hardware/labor/equip rental	$11,507.40
Electricity Control: Breaker panel with breakers	$8,920.80
Labor: Electrician	$17,917.00
Total Cost: Electrical Facility:	**$71,842.50**
Cost per connection:	**$5,986.88**

Supplemental Equipment Costs:

The supplemental equipment needed for this facility included only the extensions cables to connect the electric power to the eTRU trailer connector. The extension cables were constructed by a third party vendor. The eTRU female connectors were used in the assembly of ten (10) 25 foot, 8/4 gauge SOW cables connecting to a power system male plug. It should be noted that after learning of the unsuitability of the original Mennekes plugs, both on the tractor and on the extension cord connectors, a replacement trailer connector and the associated extension cable plug was specified. Carrier-Transicold engineering personnel researched replacements and installed new Hubbell plug sets as part of the Vector trailer connection system. These sets included a male and female plug, a locking tethered cap and a box on the trailer. These components were purchased separately and installed by the Carrier dealer. The cost for the extension cables includes the female connector for the trailer side connection. The supplemental equipment costs are listed below:

Supplemental Equipment Cost Breakdown:

10 - 25 foot cables, including assembly labor and Power connector	$1,045.00
10 – Trailer connectors (estimated, provided in-kind)	$2,480.00
Total for 10 power-to-trailer connection cables	**$3,525.00**
Cost per cable	**$352.50**

Data Collection System Costs:

As for the data collection system, there are two separate systems being used for the collection of fuel and electrical facility data. The cost for the electrical facility data collection system designed by the Shurepower Team is required for the documentation of electrical energy use. The cost of this system on a per connection basis was $2,230. This system utilized off-the-shelf components to keep costs reasonable. All off-the-shelf components worked well, with the exception of the wireless transmitters. The next generation wireless system will need to integrate a redesigned transmitter system to improve future data collection, which will increase the cost of the system.

The fuel data collection system is based upon the PAR LMS Refrigerated Trailer Tracking Unit (RT-100). This product is a GPS/cellular-based system with many capabilities that were not utilized for data collection in this demonstration project. This system was installed as an in-kind donation to help validate fuel consumption data. The retail price of this system, including a full year of data service fees cost $1,140 per trailer. The control fleet trailers also required an interface upgrade since the system processor could not be directly fitted to the TRU. Capabilities such as trailer tracking via GPS satellite were not utilized for this demonstration; however, these tracking services could have assisted in a more detailed assessment of route optimization and ambient environment exposure. These units were also only installed on five (5) control trailers and five (5) test trailers to manage costs. This number of trailers was large enough to validate the fuel consumption data. These data collection system costs are listed below:

Data Collection System Cost Breakdown:

Hardware: On trailer LMS data collection system (10 units)	$8,000.00
Hardware: On site electrical data collection system (12 connections)	$11,817.36
Labor: LMS installation (10 units)	$2,000.00
Labor: On-site data system installation and support (12 connections)	$14,460.00
Fees: LMS tracking service (10 units for 1 year)	$2,400.00
Fees: Internet access (provided in-kind, shared access)	$480.00
Data collection system, as installed including all fuel data collection system hardware	**$ 38,157.36**
Data collection system, electrical infrastructure only	**$26,757.36**
Electrical data collection cost per connection	**$2,229.78**
Fuel data collection cost per trailer	**$1,140.00**

3.3 SYSTEM TRAINING AND UTILIZATION

On September 7, 2006, Shurepower, New West Technologies, and Carrier-Transicold completed the training of the MAINES Paper and Food facilities operations personnel. The training included two parts: a classroom presentation and a field demonstration of the system operation. The presentation was held in the Transportation Division conference room and was attended by the management from MAINES

Transportation Division. The presentation provided a background of the project, the project partners, the Carrier Deltek eTRU technology, electrical safety warnings, system components, system components, a detailed system connection/disconnection and operation instructions, as well as precautions to prevent/limit an unattended drive-away while still connected to the power pedestal. The presentation included a copy of the instruction sticker that was affixed to each pedestal and to the nose of the trailers as well as a copy of the warning sticker that was attached at the trailer electrical connector. Each person received a copy of the presentation as well and a copy of the instruction presentation is included as Appendix D.

Following the presentation, the MAINES personnel who attended were joined by three of the yard truck drivers, safety personnel, and other pertinent personnel for a hands on demonstration of the eTRU connection/disconnection procedure along with the eTRU operation. This equipment demonstration during the training session was performed under the direction of Carrier-Transicold. A copy of the attached reference presentation was given to each MAINES employee that did not attend the classroom session. Questions from MAINES personnel were addressed during the demonstration to ensure all operators understood how to properly operate the system. Discussions with MAINES personnel, especially the yard drivers, occurred regarding additional possible precautions that could be implemented to prevent an unattended drive-away while the trailer was still connected to the eTRU power pedestal. Several ideas were suggested, such as using wheel chocks to prevent the truck from being driven away or possibly hanging a tag on the door handle or steering wheel while the trailer is plugged in to remind/warn drivers of the trailer's plugged-in status. These ideas were provided to MAINES for consideration.

Section 4:
DATA ANALYSIS AND RESULTS

4.1 APPROACH

In order to properly assess the financial and operational impacts of the eTRU system, it was necessary to benchmark them against a control fleet that consisted of MAINES' most recent trailer purchase which is made up of Carrier Genesis TRUs installed on Great Dane trailers. These Genesis units were a fair comparison because they were newer 2005 models, which ensured that 1) the TRU technology was state-of-the-art and 2) the trailer insulation has not degraded. Also, these Genesis units were used in the same operational manner as the Vector units, which made certain that operational differences did not influence the results. It was decided that the control fleet would consist of ten (10) trailers, which would match the number of Vector trailers that was included in the control fleet. This quantity of test vehicles permitted the collection of enough data to identify data outliers and minimize any effect these may have on the data set. The data collection activity was conducted over a one (1) year period to expose the trailers to the weather experienced annually in upstate New York. The length of data collection permitted the analysis of trends that may be related to operational conditions. A twelve (12) month data collection period also provided for the collection of a sufficient amount of data that would magnify operational trends. In order to properly assess the results, fuel consumption and electrical use data were also collected. The collection of fuel consumption data permitted an analysis of on-the-road operations and a direct comparison of fuel efficiency between the control and test fleet. The electrical use data permitted the assessment of eTRU electrical demand as well as an assessment of the eTRU's operational efficiencies when connected to grid-electric power. These data were organized and summarized in data spreadsheets which are shown in Appendix E.

4.2 FUEL CONSUMPTION DATA

The raw diesel fuel consumption data were collected by on-site maintenance personnel and transmitted to the Shurepower Team for analysis. The maintenance personnel collected these data by connecting to the MAINES Fuel database system and downloading the monthly fuel data set. On a monthly basis, the average fuel consumption was calculated on a gallon per hour basis for each control and test fleet TRU. Once calculated, the values were compared to the other test and control trailer data for that month. After all data were collected and analyzed for outliers, the average fuel consumption was plotted against several different variables, such as ambient temperature, heating degree days, cooling degree days. These plots permitted the identification of any underlying trends that may exist in the data. Also, additional outliers that affected the data trends were also identified.

To determine the affects of environmental exposure on the diesel fuel consumption, the fuel consumed by the TRU was compared to several measures of ambient temperature. By plotting the fuel consumption as a function of temperature, any correlation between the two parameters can be graphically observed. Although other factors, such as the amount of solar gain on the trailer could contribute to fuel consumption of the TRU, it and other similar factors are difficult to consistently quantify. Therefore, it is assumed that ambient temperature is an adequate indicator of the environmental exposure and can be used to identify these impacts on the fuel consumption of the TRU.

4.2.1 DATA QUALITY ASSURANCE

In order to properly analyze the data, it was necessary to examine data quality by comparing the data to projected values. As more data were collected, these data were also compared to previous data sets. If a significant discrepancy was identified, the source of the variation was investigated. Each data element was assessed to ensure the quality of the data collection and transmission. If the monthly data set follows previous trends and does not appear to be a drastic outlier, further confirmation of the data set integrity was performed by reviewing operation and identifying any variances that may have affected the data set. These operational conditions were reviewed with on-site personnel to determine if any variances in operations occurred, such as an accident or significant under-utilization. If a trailer did experience one of the preceding, it was assessed further to determine if the collected data were outliers. If the data were identified as outliers, they were removed from the monthly analysis.

4.2.2 ANALYSIS OF FUEL DATA

After all data were collected, it was plotted against several key elements, such as temperature, in order to uncover any trends that existed within the data. By discovering these trends, operational changes can be made to maximize all benefits of the advanced technology eTRUs, including cost savings to the operator.

From the analysis of the collected data, it can be seen that the Vector trailers are more efficient than the Genesis trailers for all months as well as for all values of heating, cooling and general degree days and temperatures. (Cooling degree days are a measure of how much warmer a day is than 65°F; heating degree days are a measure of how much colder a day is than 65°F.) The Vector units range from 2% to nearly 40% more fuel efficient than the Genesis units and can be seen in Figure 4-1. Over the entire test period (excluding April 2007 data which were unverifiable and excluded from all analyses), the Vector trailers have, on average, a 15.75% advantage in fuel efficiency over the Genesis trailers. Figure 4-2 illustrates the direct correlation between the average monthly fuel use of the trailers and the average temperature of the month. Further analysis of the data Figure 4-2 illustrates that the Vector units operate more efficiently during colder ambient temperatures than warmer temperatures.

From the data, trends have developed illustrating that as the heating degree days (HDD) increase, the Vector's efficiency improves which is shown in Figure 4-3. Again, it should be noted that degree days are directly correlated to the ambient temperature deviation from 65°F. No such relationship is seen by the

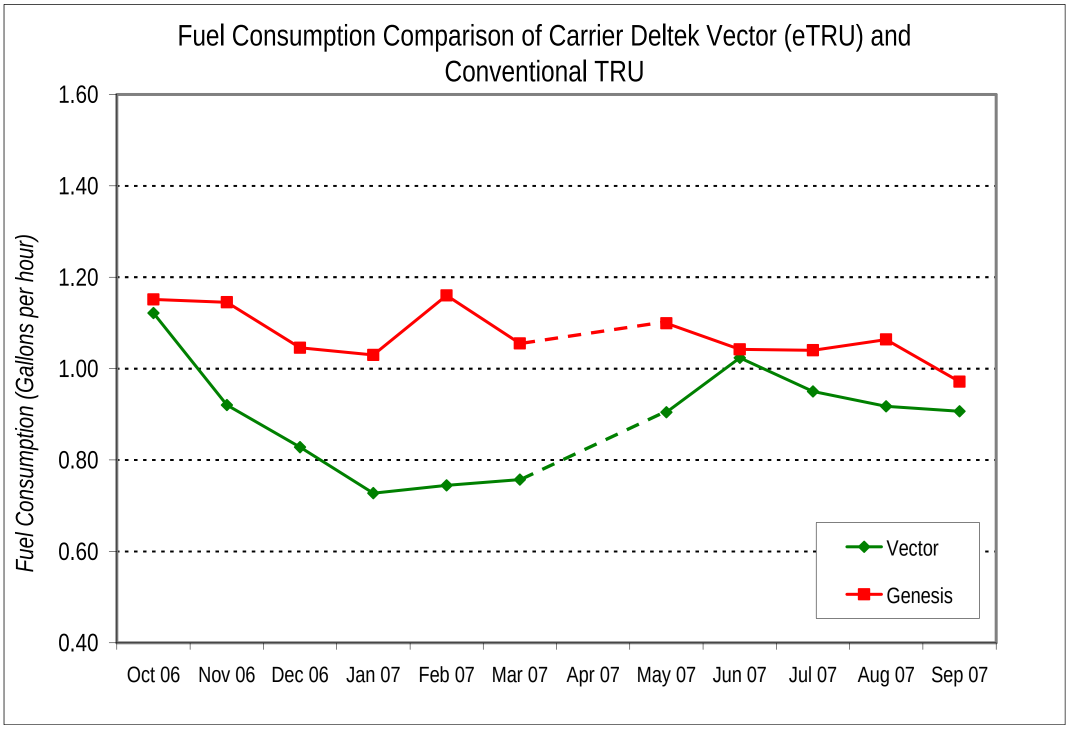

Figure 4-1: Monthly Fuel Consumption Comparison

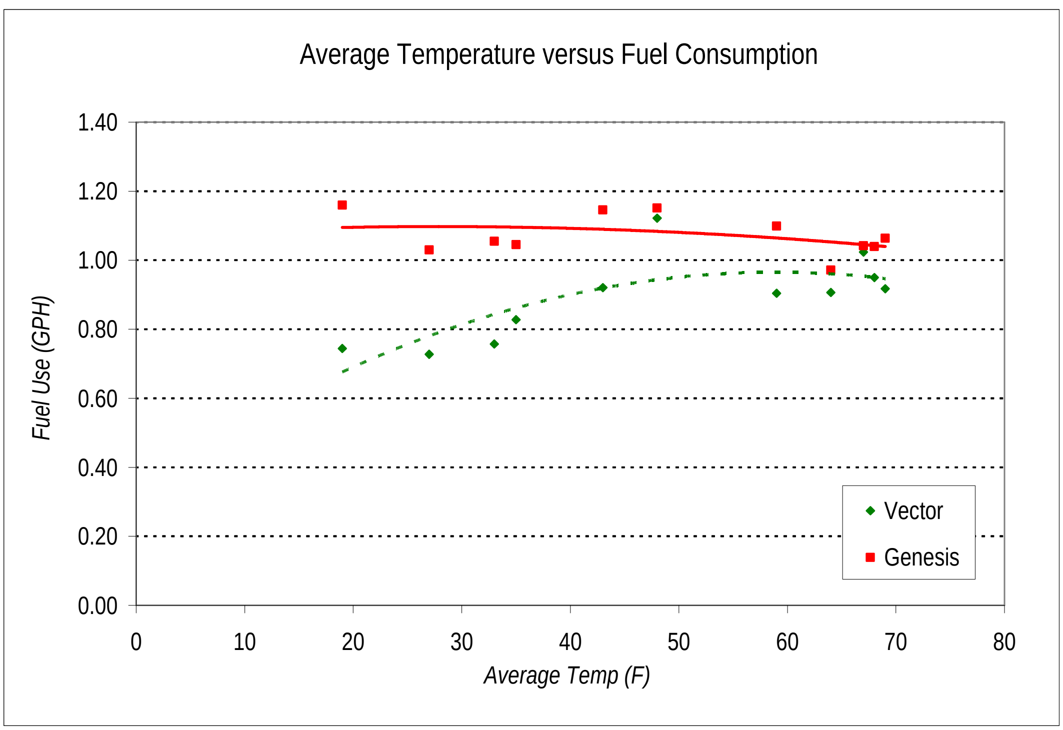

Figure 4-2: Average Ambient Temperature versus Fuel Consumption

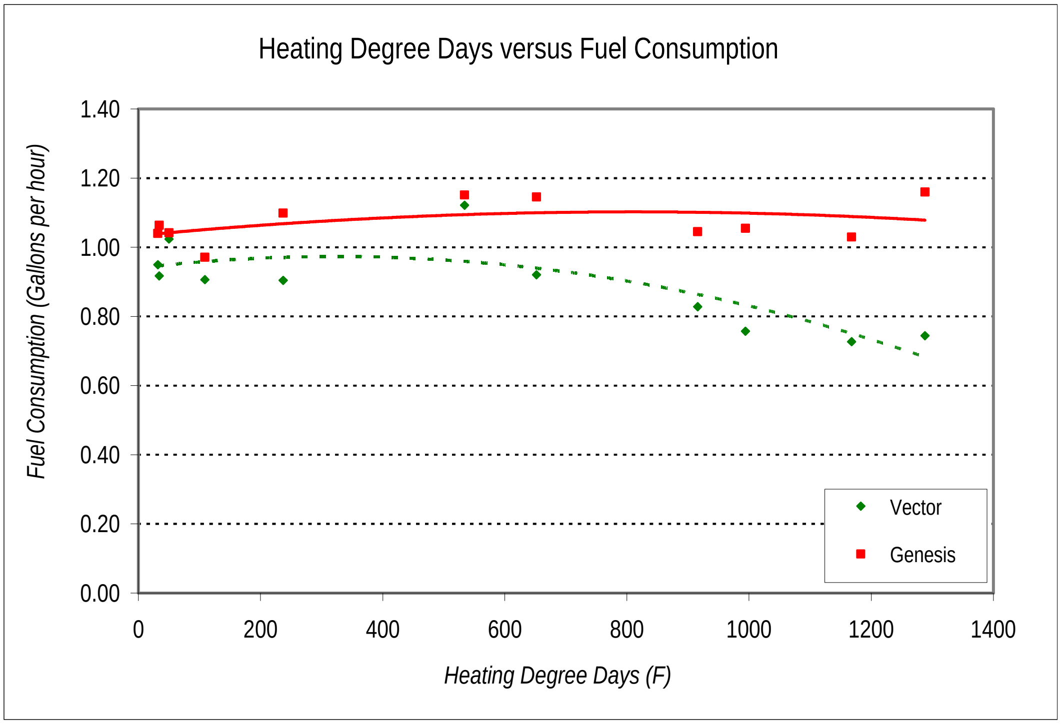

Figure 4-3: Heating Degree Days versus Fuel Consumption

Genesis trailers as their efficiency remains relatively constant for all ambient temperatures. This figure illustrates the trend of improved Vector efficiency as the ambient temperatures decrease, which results in a greater fuel consumption rate disparity between the two TRU types when exterior temperatures decrease.

Carrier-Transicold engineering indicated that the Vector 1800 Multi-Temperature eTRU has more options to shed capacity and save on fuel versus the Genesis. One significant reason for the eTRU's increased fuel efficiency at cold ambient temperatures is the unit's ability to provide heat to the trailer via electric resistive heaters in all compartments; this is opposed to the Genesis TRU's remote evaporator only having electric heat capability. Electric heat is "instant on" and is not affected by ambient temperature unlike a conventional TRU that uses "hot gas." As the ambient temperature decreases, hot gas is less efficient because it is transmitted to each compartment and may be exposed to the cold ambient temperatures before it reaching the intended trailer compartment. In very cold temperatures, this heat loss can have a very significant affect on the fuel efficiency of the TRU. The advanced microprocessors capacity of the Vector eTRU to fine tune compressor operation is another reason for the fuel efficiency advantage over the Genesis TRU. This level of control permits the generator to operate a lower speeds and the compressor to operate more frequently at highly efficient operation points, thus resulting in higher efficiency operation.

There also appears to be a correlation between the efficiencies of the Vector units and the amount of cooling degree days (CDD). From the collected data, it appears that the efficiency of the Vector units decreases slightly as the ambient temperature increases (See Figure 4-4), but that this levels off slightly under one gallon per hour. However, it appears from the data collected, that the Genesis unit's efficiency does not change significantly and may in fact increase slightly as the cooling degree days increase.

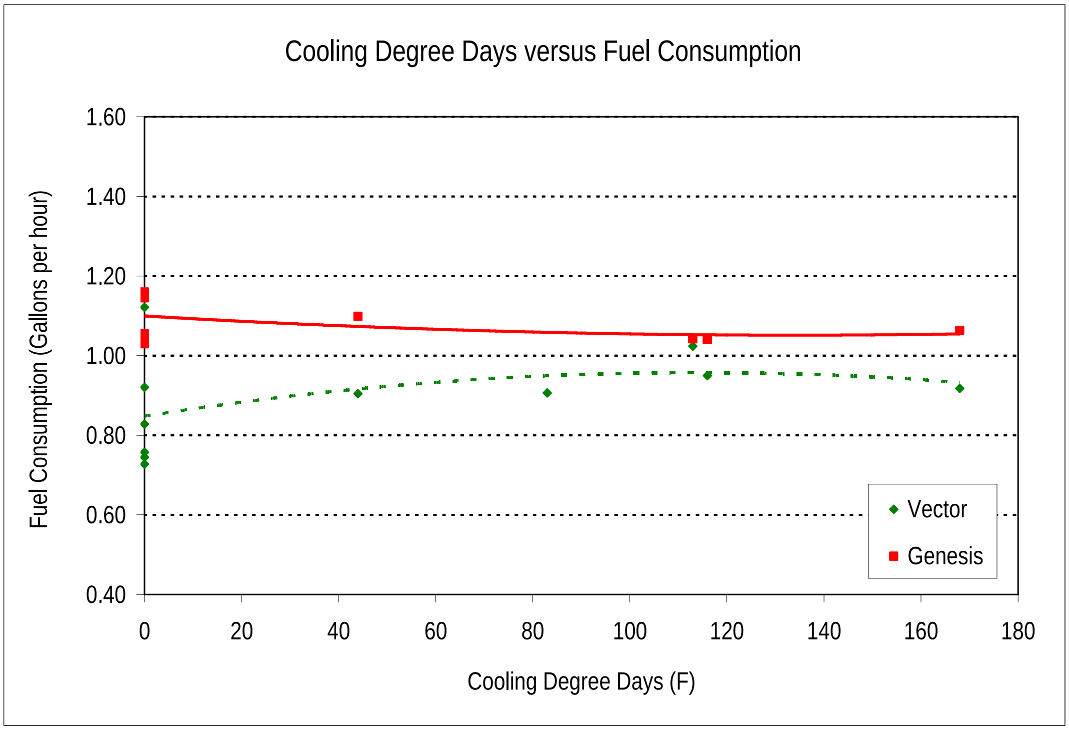

Figure 4-4: Cooling Degree Days versus Fuel Consumption

4.3 ELECTRICAL FACILITY DATA

Raw electrical data was first collected remotely an archived in an off-site database. Each monthly report contained a breakdown by pedestal (slots 1-10 and docks 1-2) of the average power consumption at a shore power connection. The electric power data collection system stores energy consumption data every five (5) minutes and is reported as the average power consumption for the five-minute interval.

4.3.1 ELECTRICAL DATA ANALYSIS

From the data set, five key parameters were defined: Minutes Plugged In, Minutes Operational, Energy Usage–Plugged In, Energy Usage–Operational, Average Power–Plugged In, and Average Power–Operational. *Minutes Plugged In* refers to the amount of time that an eTRU spent connected to the power system. This amount of time must exceed fifteen minutes for the eTRU to be considered connected. *Minutes Operational* is defined as the amount of time that an eTRU was plugged in and electrical draw exceeded the energy required to power the data collection system. *Energy Usage–Plugged In* refers to the total amount of electrical energy consumed while an eTRU was connected. *Energy Usage–Operational* is defined as the total amount of energy used while an eTRU was connected to the electrical facility and power consumption exceeded the power required for the data collection system. *Average Power–Plugged*

In refers to the average power used while an eTRU was connected to the electrical facility. *Average Power–Operational* is defined as the average power used while the eTRU was plugged in and the system recorded energy usage above the system data collection system requirements.

Using an approach similar to the diesel fuel consumption assessment, the affects of environmental exposure on the electrical power draw was investigated. This assessment reviewed the amount of power consumed while an eTRU was connected to the electrical facility and compared it to several measures of ambient temperature. By plotting this power consumption as a function of temperature, any correlation or trend between the two parameters can be observed graphically. Like with the fuel consumption assessment, other environmental factors may contribute to a change in power consumption for an eTRU; however, these again are difficult to consistently quantify. Therefore, it is again assumed that ambient temperature is an adequate indicator of the environmental exposure and can be used to identify these impacts on the power requirements of an eTRU.

The approach taken to plot these data is identical to the approach used for the diesel fuel consumption analysis. Several conclusions may be drawn from the electrical usage data that were gathered. First, a higher ambient temperature correlates to an increased use in energy (Figure 4-5). Comparisons between the number of cooling degree days in a month and the average power consumption (Figure 4-5) as well as between the number of heating degree days in the month and the average power consumption (Figure 4-7) agree with this conclusion. The total degree days, the sum of the heating and cooling degree days plotted against the average power consumption shows a strong trend towards a linear relationship. This indicates high correlation between these two parameters. Ideally, these trends can be used to modify operational procedures to ensure the best possible performance of the eTRU units when connected to electrical power.

In reviewing Figures 4-5 through 4-7, key conclusions are:

- As the amount of cooling degree days increases (and thus the ambient temperature increases), the average electrical energy use increases.
- As the amount of heating degree days increases (and thus the ambient temperature decreases), the average electrical energy use decreases.
-

Throughout the testing period, several operating characteristics were noted while observing the electrical usage of the eTRUs. The overall maximum peak draw that the eTRUs pulled during the entire testing period was 15.1 KW, which is in range of the electrification system and confirmed the design specification of the unit. The range of electrical power draw during *Energy Usage–Operational* periods varied from a low of 4 KW to a peak of 15.1 KW. The typical electrical draw (mode) for five (5) minute *Energy Usage–Plugged In* period was between 8 KW and 11 KW. Because the trailer refrigeration system operates by thermostatic control, electric power was provided as needed and the length of time the power was required

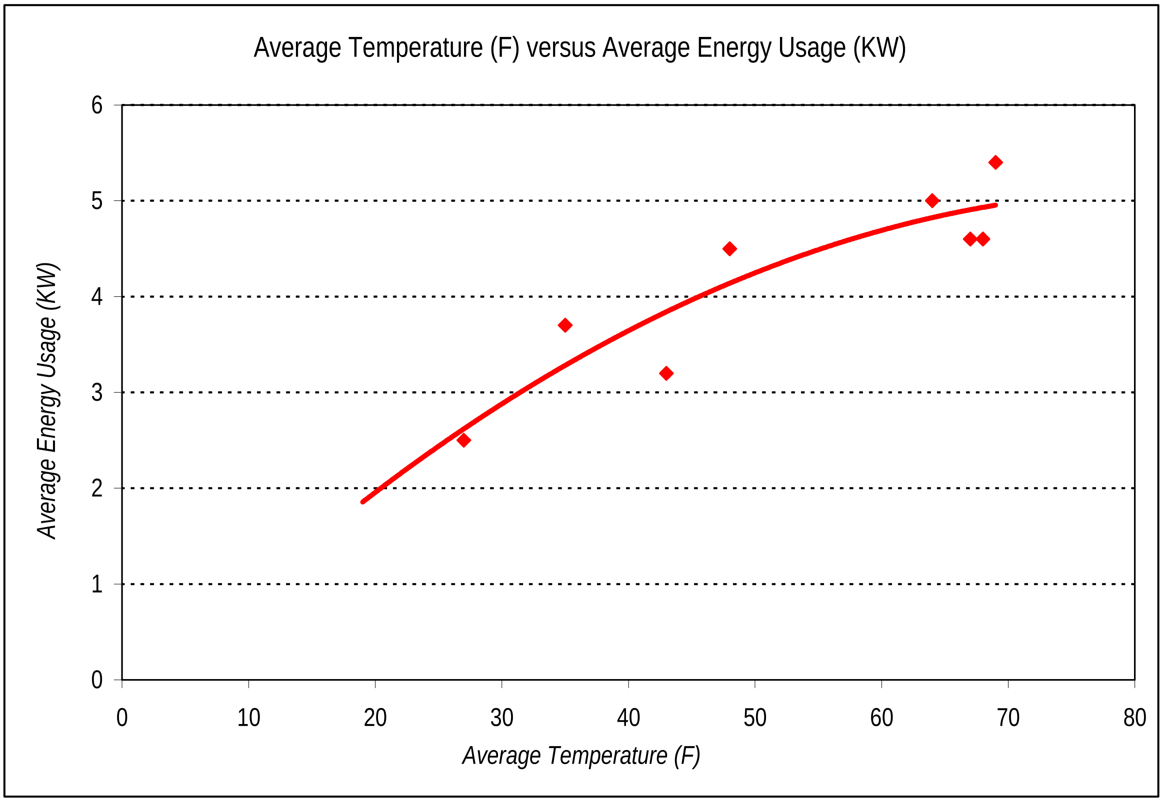

Figure 4-5: Average Temperature versus Average Energy Usage

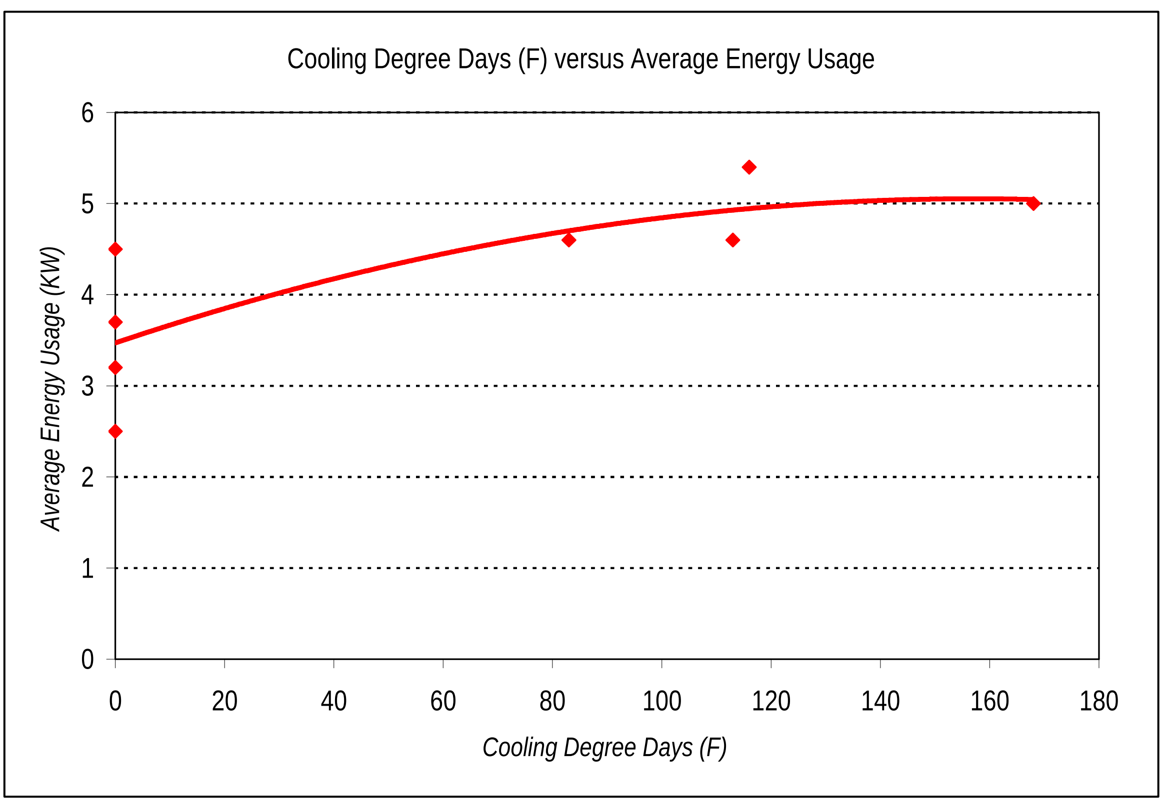

Figure 4-6: Cooling Degree Days versus Average Energy Usage

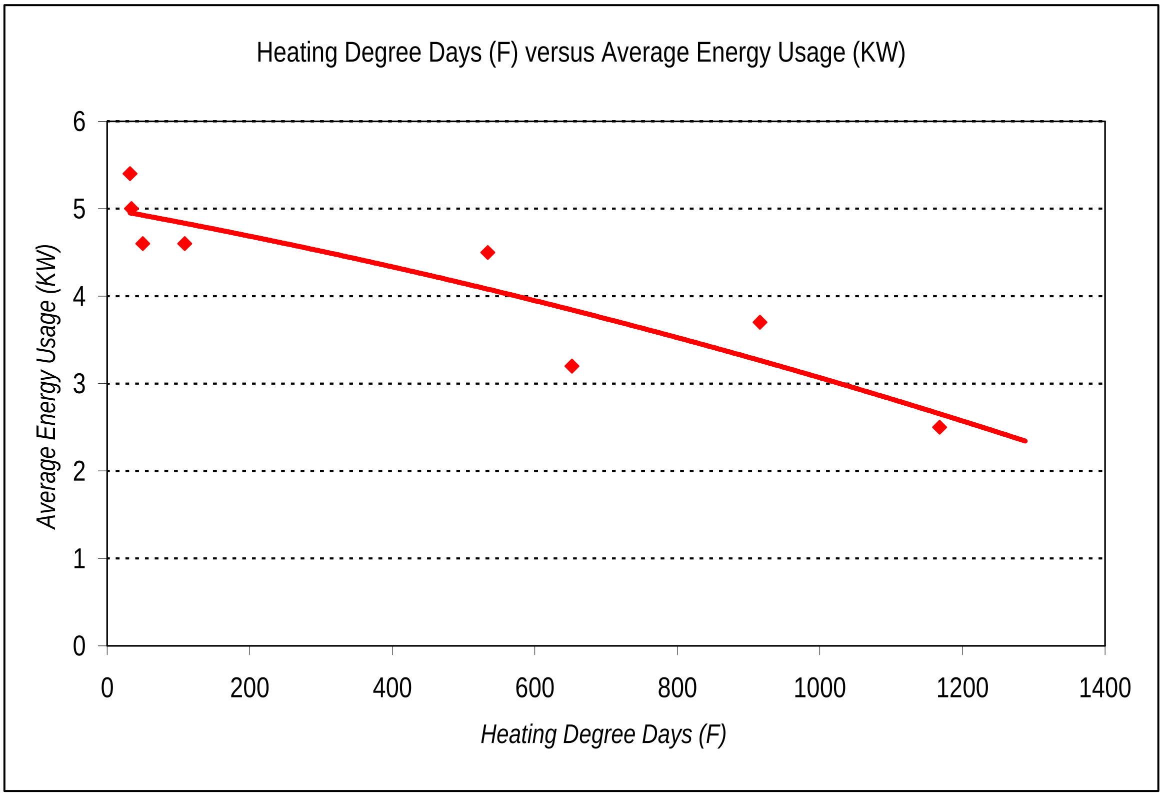

Figure 4-7: Heating Degree Days versus Average Energy Usage

varied from 5-30 minutes. This was the amount of time required for the trailer to reach the target temperature range. The length of time required to reach the targeted temperature was shorter as heating degree days increased. This was expected since when the ambient temperature decreases, less heat enters the trailer and a shorter period of time would be needed to reduce the temperature in the trailer to the set temperature range. The peak power draw of 15.1 KW only lasted, on average, 5 to 10 minutes, but in some cases during summer months, this was exceeded and in one case by as much as one (1) hour and further verifies the trend that the higher the temperature, the longer and more intense the electrical power draw. However, it should be noted that peak electrical draw was not temperature dependant, as the eTRUs reached the maximum power draw during a wide range of ambient temperatures.

4.4 ENVIRONMENTAL BENEFITS

Since the emission levels of the TRUs could not be tested (as this was not proposed and was outside the project scope), an emissions analysis was performed to compare the certified U.S. EPA emissions levels for diesel fueled TRU engines to the Vector eTRUs operating on electric power. Using the current U.S. EPA Tier 2 standards for engines in the 19-37 kW range (the size range for these TRU diesel engines), approximately 7.5 grams of NMHC+NOx (most of which is NOx), 0.6 grams of PM, and 5.5 grams of CO are emitted per kilowatt-hour by the average TRU. Since there were no data collected on the power output of the TRU when powered by diesel fuel, it was assumed that the power required to operate the unit would be equivalent to operating on electric power. Since the eTRU required 7.7 kW per hour when operating on electricity, we used this value to estimate diesel emissions from these engines. Table 4-1 below illustrates the EPA standards and the projected emissions for units operating on diesel fuel.

Category of Pollutant	Tier 2 Off Road Engine Standard (grams/kWh)	Emissions Average @ 7.7 kW (grams/hr)
NMHC+NOx	7.5	57.75
PM	0.60	4.62
CO	5.5	42.35

Table 4-1: U.S. EPA Emission Standards for Off-Road (including TRU) Diesel Engines up to 37kW in Size

This type of comparison must also consider any emissions created by the electric power plants generating the electricity to power the Vector eTRUs. The power generation mix specific to New York State was used to develop the associated emissions from electricity generation (Sources: EPA and DOE/EIA). This table is shown in Table 4-2 below.

Category of Pollutant	New York State Electricity Generation Emissions (grams/kWh)	Emissions Average @ 7.7 kW (grams/hr)
NOx	0.518	3.99
PM10	0.078	0.60
CO	0.073	0.56

Table 4-2: New York State Electricity Generation Emissions

The net emission reductions from using the eTRU electric power connection are shown in Table 4-3. This table also integrates the actual number of hours the eTRUs were powered by grid-supplied electricity as well as some projected emission benefits if the eTRUs were connected to electric power more often.

Category of Pollutant	Net emissions reduction (g/kWh)	Percentage Emissions Reduction versus TRU operation	Emissions Reduction Average @ 7.7 kW (g/hr)	Annual Net Emission Benefits at MAINES (kg) *	Annual Net Emission Benefits at 10% (876 hours) utilization (kg) **	Annual Net Emission Benefits at 25% (2190 hours) utilization (kg) ***
NOx	6.982	93.1 %	53.76	63.60	470.94	1,177.34
PM10	0.522	87.0 %	4.02	4.76	35.22	88.04
CO	5.427	98.7 %	41.79	49.44	366.08	915.20

* Based on 1183 actual eTRU operational hours on grid electricity at MAINES,
** Based on 876 hours per eTRU, for a total of 8760 hours for the fleet of 10 eTRU-equipped trailers
*** Based on 2190 hours per eTRU, for a total of 21900 hours for the fleet of 10 eTRU-equipped trailers

Table 4-3: Emissions Reduction Benefits by Powering eTRUs on Grid-Supplied Electricity in New York State

The utilization of eTRUs on grid-supplied electricity was lower than anticipated at 1183 hours (2.0% for 8 months of operation). This low utilization was due to a number of factors which included this electric operation capability into transportation operations. Also, since the electrical connection facility was powered down for four months, transportation personnel had concerns over the electrical connection system after modifications were made to the trailer connections. These issues as well as other operational issues are discussed in more detail in Section 5.

Although not quantified in this report, it is believed that the eTRUs produce significantly less emissions than TRUs while running on diesel for two reasons. First, these units consume 15.75% less diesel than conventional TRUs when both units operate on diesel fuel. This results in an equivalent amount of emissions reduction of carbon dioxide as well as reductions in other criteria pollutants. Second, when a diesel engine is operated at constant speed, like the eTRU generator does when it produces electricity; this enables the ability of engineers to optimize the engine operation for both overall fuel efficiency as well as engine out emissions. The control of both the engine speed and compressor operation via the Vector's advanced microprocessor may also contribute to the reduction of emissions from unit when operating on diesel fuel; however, this was not be verified as it was outside of the scope of the project. For these two reasons, it is expected that the eTRU diesel generator engines do produce less emissions than a conventional TRU diesel engine.

4.5 FINANCIAL ANALYSIS

As part of this demonstration project, economic benefits of this technology were also assessed. Significant operational cost reductions occurred because of the Deltek Hybrid TRU technology. The cost reductions were observed for both diesel fuel operation as well as grid-electric operation. Table 4-4 below summarizes the overall savings that were attained by using grid-supplied electricity to power the Vector eTRUs at the MAINES facility.

Economic Analysis of Carrier-Transicold's Multi-Temperature Deltek Vector eTRU Operation at MAINES	
Cost of Operation on Diesel Fuel	
Fuel Consumption	0.91 gallons per hour
Cost of Diesel Fuel	$2.45 per gallon (excluding road tax)
Cost per hour of operation on Diesel Fuel	$2.23
Cost of Operation on Electricity	
Voltage	460 volts
Power	7.70 kW
Cost of Electricity	$0.1298 per kWh
Cost per hour of operation on Electricity	$1.00
Savings on Electric Standby Operation = 55.2% ($1.23 per hour)	

Table 4-4: Economic Analysis of eTRU Operation on Diesel Fuel and Electricity

In addition, Figure 4-8 shows the contribution, on a monthly basis, to the total savings of each mode of operation from a direct comparison of the operational costs of the Vector and Genesis test and control fleet units. The figure illustrates the cumulative savings obtained via use of ten (10) Vector eTRUs as compared to the ten (10) traditional Genesis TRUs. This graphic illustrates only saving obtained from diesel fuel displacement through increased efficiency and electricity use and does not incorporate the savings obtained via maintenance reductions and trailer uptime. These cumulative savings are based on a diesel fuel cost of $2.45 per gallon which was representative of the cost of diesel fuel in the New York area (excluding road tax). In addition, when calculating savings from the use of grid-electricity, the actual electricity cost for MAINES of $0.01913 per KWH was used.

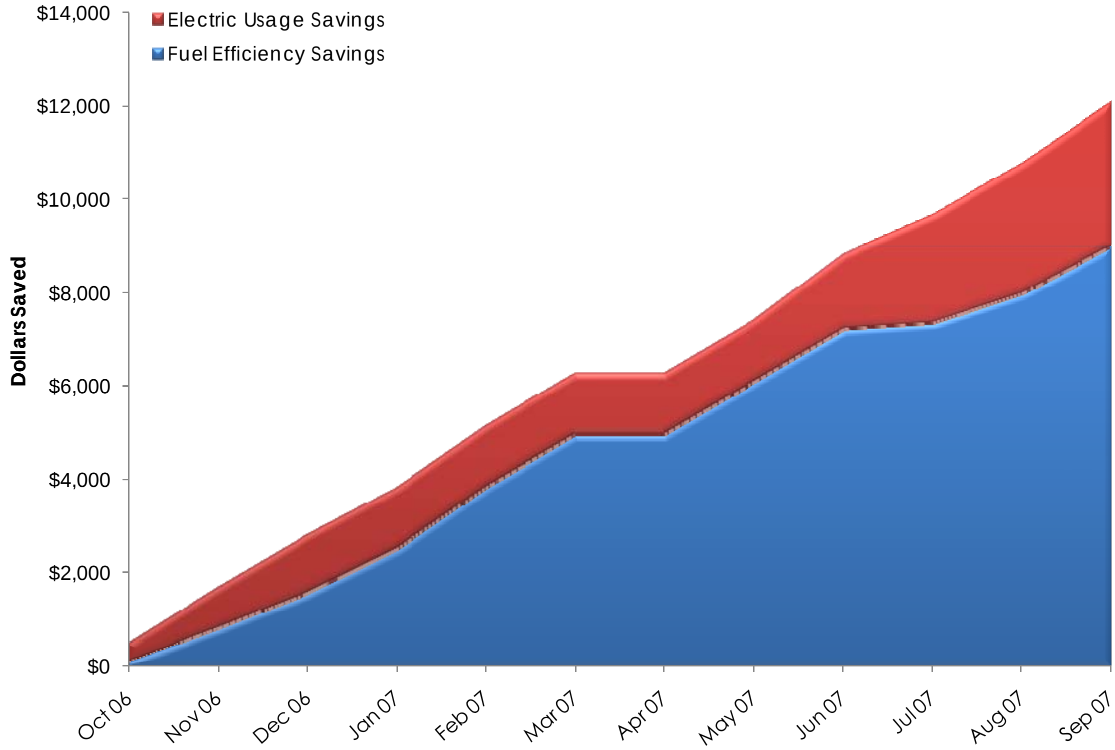

Figure 4-8: Operational Cost Savings Obtained via Carrier Deltek Technology versus Traditional (Carrier Genesis) TRU Technology

By using the ten (10) Vector units with the increased efficiency of the Hybrid Deltek technology, monthly diesel fuel savings varied from 45 and 540 gallons per month for the demonstration period (excluding April 2007 monthly data). The amount of diesel fuel saved for the 11 months of operational data totaled 3,380 gallons. This amount of fuel translates to saving $115 to $1,300 per month and a total of $8,282, again based on a diesel fuel cost of $2.45 per gallon.

Maines also experienced a significant reduction in diesel fuel use by utilizing grid-electricity and connecting the Vector eTRUs to the electrification system. When the Vector trailers' were powered through the electrical connections, this resulted in displacing between 31 and 291 gallons of diesel fuel per month, totaling 1,240 gallons of diesel fuel saved. The calculation of the amount of fuel saved is based upon the average fuel economy of the control fleet (Genesis TRU). This translates into monthly savings of $78 to $711 per month, accumulating $3,089 in total savings (at $2.45/diesel fuel gallon and electricity at a cost of $0.01913/KWH) by using the electrical connections.

During the demonstration period of 11 months of diesel fuel operation and 8 months of electrical facility use, MAINES has saved $11,371 by using the Vector trailers. Extrapolating the demonstration data, an annual savings of $1,367 per trailer would be obtained through a combination of electrical facility utilization and efficiency savings per trailer. This would result in a payback period of the approximate $3,000 incremental cost of the Vector unit and Vector related trailer upgrades and the trailer wiring system of $585, totaling $3,585 in 31.5 months.

Factors such as the temporary shut down of the electric connection facility and operational strategies that did not optimize the use of the electricity significantly impacted the potential for diesel fuel reductions and cost savings during the demonstration period. However, if the operational strategies are modified to maximize the use of the electric power connections, the amount of diesel fuel displaced can be significantly increased and the payback period reduced significantly.

4.6 GPS TRAILER TRACKING AND DATA COLLECTION

The GPS system installed on the TRU test fleet has many capabilities that were not utilized to the maximum extent possible. For example, the ability to track by county the actual emissions of these TRUs, and whether connected to the grid-supplied electricity or powered by diesel fuel may permit the U.S. EPA to assign Mobile Emission Reduction Credits (MERCs) to the TRUs. However, because TRUs are mobile emission sources that are ubiquitous and transient, additional data collection systems are necessary to ensure the MERCs are in fact generated in specific counties and can therefore be banked. This is of keen interest as MERCs have monetary value and can be traded or sold by the entity that possesses them.

This technology appears to be capable of providing the U.S. EPA with the data needed to satisfy the data collection and verification process that is required. These data are needed to be reported to the U.S. EPA on a county by county basis for credits to be assigned. A U.S. EPA county-level criteria pollutant emission map of the Northeast and Mid-Atlantic states is shown in Figure 4-9. The PAR LMS output can be used to track the movement of the refrigerated trailers and their operation. The output from the Refrigerated Trailer Tracking Unit (RT-100) is shown in Figure 4-10. This output, combined with geo-fencing technology that uses software technology to separate counties, can enable regulators the ability to track where pollutants from these mobile units are being emitted. As eTRUs can readily pay for itself in operating and maintenance costs, these MERCs can be valuable in helping defer the cost of installing the high power electrical connection system required to operate the eTRUs on electric power.

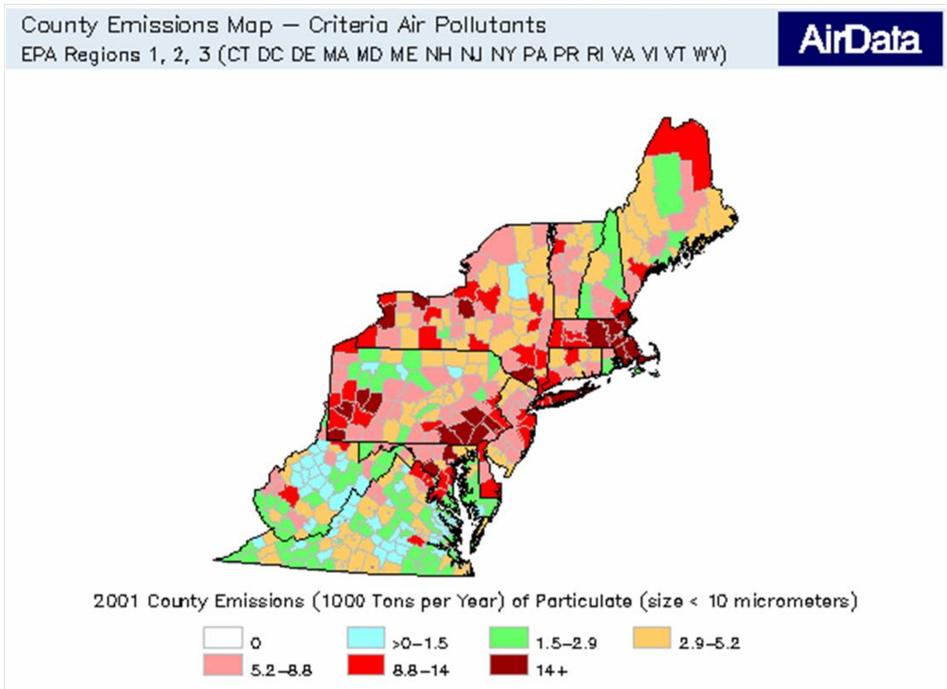

Figure 4-9: U.S. EPA County Emission Map of the Northeast and Mid-Atlantic States

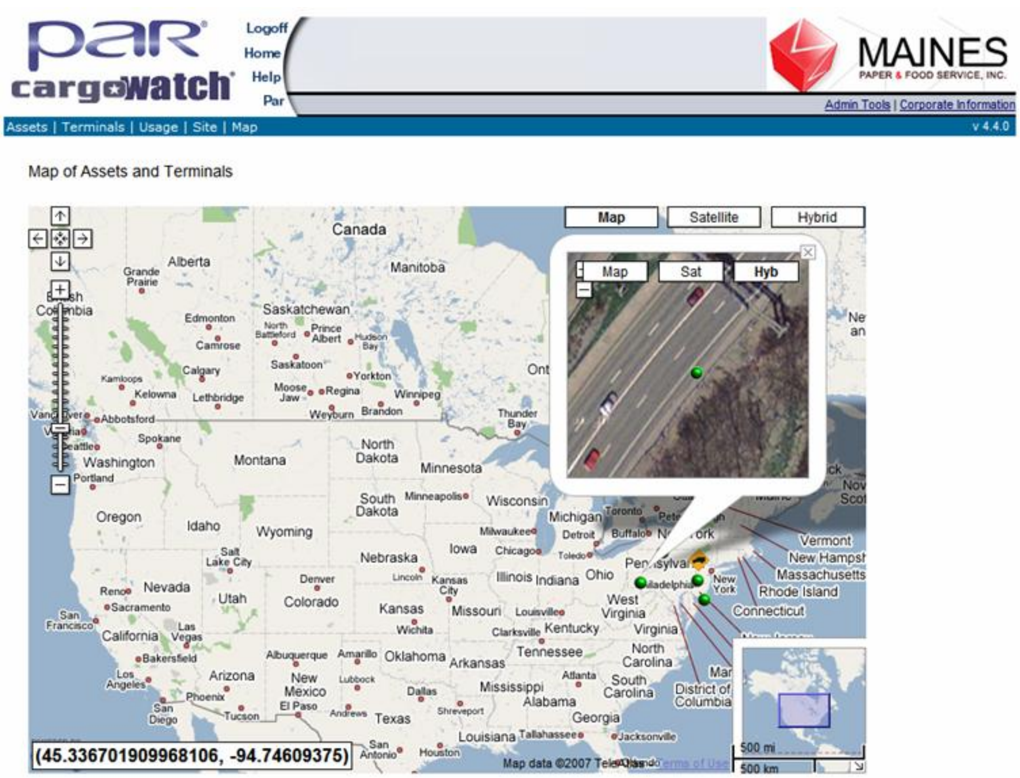

Figure 4-10: PAR LMS CargoWatch Refrigerated Trailer Tracking Unit (RT-100) Output

Section 5:

OPERATIONAL ISSUES AND SOLUTIONS

Several operational issues occurred during the twelve month demonstration period. Issues developed that impacted data collection and electric facility system utilization. The Shurepower Team addressed each issue and developed solutions for each. This section addresses these specific issues and explains the proposed approach to resolving the issue.

5.1 WIRELESS TRANSMITTER OPERATIONS

Issue 1: During periods of extended low temperatures, real-time data reporting was interrupted from some of the pedestals. This was a concern because this type of data reporting is the most desirable for remote data access. The data collection process was not interrupted during these extended periods of low temperature. All of the unreported data remained in storage on the data loggers. After consideration of all of the possible failures, it was suspected that the wireless transmitters within the pedestals were experiencing problems because of temperatures outside their optimal thermal operation range. It was originally believed after speaking to several experts in the field that that the outdoor temperatures experienced in New York would not significantly affect the consumer grade transmitters. The transmitters were designed primarily for consumer indoor use, not outdoor commercial applications. The transmitters had been chosen because they were the most cost effective. Commercial grade units contained many other features which were not necessary for the scope of this project and were significantly more expensive.

To confirm that the transmitters were in fact the component that failed, further investigation was performed. Since the operational temperature ranges for the system data logger and pulse counter (also installed in the pedestal) were both within the temperature variances experienced at the site, the component failure was identified as the wireless transmitter since the lowest operational range for the transmitter was 32°F. As the failure condition occurred when the ambient temperature for the site was lower than 32°F for an extended period, it was determined that the failure was linked to the wireless transmitter in temperatures under 32°F.

To further ensure that this was indeed the problem, New West Technologies conducted testing on these wireless units to ensure that the temperature issue was indeed causing the problem. As expected, the low temperatures did have an adverse effect on the operation of the bridge. Low temperatures caused the wireless transmitter to fail.

Resolution 1: In order to attempt to alleviate this problem, the data logger's manufacturer was consulted for advice. They suggested to design and install an active heating (resistance heater) and cooling (exhaust system) to maintain the temperature of the enclosures within operational ranges. (It should be noted that the high temperatures conditions experienced at the site did not cause any data transmission failure; however, extremely high ambient temperatures may cause data transmission failures if the system is installed in the southern United States. New West Technologies was tasked by Shurepower to design a retrofitable system that could be installed at the MAINES location. This system included a heater, as well as a fan to create a ventilation system. However, as this cost of this system was outside the established budget for this project and data could be collected onsite, the temperature control system was not installed. In future NY installations requiring wireless data transmission, a heating and insulation system will be considered. For hard-wired systems, a wireless transmitter is not needed and a temperature control system would not be required.

Issue 2: Another operational issue encountered during the project was that the wireless transmitter would randomly malfunction at temperatures above 32°F. This occurred sporadically throughout the data collection period (however it did occur more frequently during cold temperature periods). This random data transmission failure prevented the real-time transmission of data to the web-based database. In order to correct this problem, the wireless transmitter's power had to be cycled, which must be performed on-site. The power breaker needed to be turned off manually for at least 30 seconds and then repowered. The cause of this failure may be that the unit, like many other routers used today, requires an occasional power cycle to return the device to an operational state.

Resolution 2: Other more expensive equipment may or may not improve wireless transmitter malfunction. The heating system may improve this as well. If neither solves the problem, and on-site representative will need to cycle the power or a remote system to cycle power can be installed.

5.2 FUEL DATA ACCURACY CONCERNS

Issue 1: With the exception of April 2007 fuel data, the data set collected by Penske was accurate and could be validated. However, the April 2007 fuel data was unable to be verified and validated. Fuel use during April 2007, for both the eTRUs and TRUs, appeared to be approximately half of the projected fuel consumption value and therefore was not included as part of the analysis.

Resolution 1: The Project Team investigated this low fuel usage by examining the eTRU and TRU operational factors including ambient temperature and load types. However, the Shurepower Team was unable to discover sufficient operational differences between April 2007 and other months to justify such a significant drop in fuel use. Due to these factors, the fuel data from April 2007 were not included in the data analysis. Inclusion of these data would have significantly skewed results and these data were treated as an outlier.

To improve the quality of the collected data, a Refrigerated Trailer Tracking Unit (RTTU) was installed on five test and five control trailers to provide an additional level of data validation. PAR Logistics Management Systems (LMS) of Yorkville, NY agreed to install a total of 10 PAR LMS RT-100 RTTUs; five on the Carrier Deltek Vector test fleet units and five on the Carrier Genesis control fleet units.

The PAR LMS Refrigerated Trailer Tracking Unit (RT- 100) installed on these trailers included:

- GPS antenna and module
- Cellular Satellite antenna
- Motion, Power, and Temperature Sensors
- Customizable web based reporting
- Real time Reefer alert message (e-mail and text messaging)
- Reefer Temperature Sense and Control Option (Remote communications interface to refrigeration controls)
- Communications electronics
- Self Contained Power Supply Source (5 years)
- Fuel level monitoring and reporting

PAR Technologies originally installed three RT-100 RTTUs (two Vector test fleet trailers and one Genesis control fleet trailer) to demonstrate the capability of these units to the MAINES transportation managers. The RT-100 RTTUs record and transmit a variety of operational data at regular intervals and error messages as they occur. The critical component of the data collection for this project was the capability to monitor fuel levels. This capability provided an additional mechanism to calculate the amount of fuel consumed by the TRUs, providing a mechanism to authenticate and validate the collected data. However, several issues occurred with this validation process. First, the fuel sensor data were not accurate enough to determine specific fuel consumption rates and second, the units that were installed did not provide a statistical significant number of units to validate the data.

To permit the ability to validate the fuel consumption data at a higher statistical significance, PAR LMS installed the improved fuel sensors and the additional RT-100 RTTUs on the test and control fleet. The installation went as planned and was completed without issue on July 22, 2007.

5.3 UNDERUTILIZATION OF ELECTRIC POWER CONNECTIONS

Issue 1: Another reoccurring issue at the MAINES facility is the underutilization of the electrification system. Since the installation of this system, only four of the twelve plug-in ports have been used. On average, one stall is used per month and this single stall is normally only used 4 or 5 days of the month, which is drastically less than what was expected. At the beginning of the project, MAINES management discussed approaches to integrate operational changes to maximize use of the electrification system, but these changes were never fully implemented for several reasons. When the electrical system was taken off-line, trailers that are not electric-powered TRUs were stored in many of the connection berths in the parking lot (see Figure 5-1). Also, as MAINES operations changed, the fleet of trailers originally assigned to scheduled delivery routes servicing the cruise ship terminals on the New England and Mid-Atlantic coast we rerouted. As these trailers were rerouted to other clients and were no longer dedicated to the cruise ship clients, this change in operations significantly affected utilization of the electric connections as the cruise ship trailers were loaded several days in advance for just in time delivery at the terminals. The considerable amount of idle time at the facility would have significantly increased the utilization of the electrical system.

<u>Resolution 1:</u> A possible resolution to this issue is continue to work with operational and senior management to modify current procedures to improve the opportunity for electric power usage by the Vector-equipped trailers. Also, relocation of the non-eTRU trailers to other parking spaces would open up additional connection berths.

Figure 5-1: Older Trailers Stored in Electrified Trailer Spaces

5.4 MANAGEMENT ISSUES

Issue 1: A significant commitment by senior management is needed to successfully demonstrate new technologies. This is especially true when these technologies may affect operations, and may require a modification in approach to doing business. Hands-on management by the host site is required for these types of projects to provide managerial support for operational and design changes. In addition, communication with senior management must also occur to assist in the timely resolution of any issues that may arise during the demonstration. During the 12 month demonstration of this technology, there was a managerial change at MAINES that affected this demonstration project. The change in management temporarily severed the communication between the demonstration partners and the host site. This communication gap negatively affected system utilization as delivery routes could not modified for increased system utilization in a timely fashion.

Resolution 1: Unfortunately, the Project Team was unable to resolve these issues prior to the completion of data collection activities. However, positive results were made as senior management understands the project benefits and will promote the use of the electrical connections. In order to prevent this communication breakdown from occurring in the future, project activities should be continuously coordinated through senior management through regular meetings to prevent a gap in project awareness. This level of awareness will help keep the project activities as a visibility element of the host site's operations. The continual promotion of the project to these decision makers will permit the project to remain a priority and as a result, maximum utilization can occur and maximum benefits attained.

5.5 TRAILER PLUG CONNECTION ISSUES

Issue 1: A plug failure occurred on February 2, 2007 when the trailer connectors on two separate trailers began smoking and operating on diesel fuel when connected to electric power. This resulted in the inspection of the system as well as suspension of use of the electrification system for four (4) months. This issue resulted in a re-designed trailer-side plug-in receptacle. A full write up is included below.

Background of occurrence: Two Vector trailers were connected to electric power in parking stalls #4 and #5 on Friday February 2, 2007. One of the trailers was #TR350, the other trailer number was not noted. MAINES yard personnel noticed on Saturday February 3, 2007 that one of the Vector units connected to the electrical facility had switched to operating on diesel fuel and the circuit breaker had been tripped. When the driver examined the second trailer, the electrical connection at the rear of the trailer was smoking. An original trailer connection is shown in Figures 5-2 and 5-3 and a contaminated plug is shown in Figures 5-4 and 5-5. This is the connection point between the trailer installed wiring and the extension cord connecting the pedestal to the trailer. The driver tried plugging in one of the two trailers into another outlet to determine if the problem was isolated to stalls 4 & 5, but this also caused the plug to smoke within a few minutes. Once the issue was brought to the attention of the Shurepower Team, electrical power was immediately terminated to the pedestals. This was done to ensure the safety of the warehouse personnel. Shurepower then interviewed the MAINES personnel who identified the problem.

Figure 5-2: Original Trailer Plug Connection – Front View

Figure 5-3: Original Trailer Plug Connection – Side View

Figure 5-4: Front View of Original Plug Mounted on TR350

Figure 5-5: Side View of Original Plug Mounted on TR350

Preliminary Investigation of Issue: To confirm the cause of the problem, Shurepower and Team member New West Technologies, developed an action plan (included in Appendix F) to determine the cause of the problem. Shurepower directed an on-site electrical contractor to implement these actions to determine the cause of the smoking plugs. The electrical contractor performed the original system installation and is familiar with the design. The first step was to recreate the problem to witness the effect firsthand. The electrical contractor and MAINES connected another trailer to the electrical facility and within a few minutes, the plug began smoking. At that point, it was decided by all parties that the electrical facility must remain shut down until the problem is resolved. Shurepower directed the electrical contractor to continue his investigation. Initially, the electrical contractor believed that the smoke may have been steam from moisture left in the plug from road spray or precipitation, but when connected, the plug smelled like burning wire insulation or rubber. The electrical contractor disassembled and examined the trailer connection side of the extension cable that was used when the incident occurred and found that the wires, connections, and plastic housing were not damaged.

Another possible cause of the problem would be if one, or more, of the trailer wiring and connectors were wired improperly with the connector pins not correctly connected. Shurepower did not believe that this would cause the plugs to smoke because if the connector was improperly wired with one of the phases connected to the ground, the breaker would throw immediately. The trailer wiring was confirmed by Penn Detroit Diesel Allison, a Carrier-Transicold maintenance facility in Syracuse, NY that performed the trailer wiring and connector installation.

Variable voltage levels supplied from the electrical grid was also identified as a possible cause of the plug smoke. The belief was that a higher current demand would be necessary to draw the required power. The plug design specifications could be exceeded causing the smoke problem. This premise was eliminated as a possible cause of plug smoke since a low voltage condition would cause the Vector units to switch over to diesel power.

It was therefore concluded that the problem of the smoking plug could have been caused by environmental exposure to two specific connectors: 1) trailer plug and/or 2) extension cable connector. The more likely of the two is environmental exposure of the trailer plug to slush, road salt, or other chemicals. Also, water in the extension cord connector was identified as a possible cause of the smoking plug issue. These two possible causes are discussed in more detail in the following sections.

Detailed investigation: Module heads were opened and no damage or moisture was evident inside. The power was turned on to each of the pedestal heads through the parking lot breaker panel. The extension cords were connected to each of the two outlets on every module head, including the one at the dock. All of the conductors were tested: phase-to-phase and phase to ground. All of the line tests were positive: phase-to-phase at 480V and phase-to-ground at 277V. This established that the voltage through to the ends of the extension cords are correct as is the continuity of each conductor. Access could not be gained to the connecting point inside the Vector units. This will be necessary to test the continuity of the trailer cable.

MAINES delivered a trailer (#TR348) to the parking lot site which was tested on electric-power; the Vector unit operated on electric standby continuously for approximately 15 minutes without smoking. Earlier, the plugs smoked “almost immediately” according to on-site personnel. The amperage draw was test and found to vary from 21 to 23 amps, which is within operational specifications. MAINES on-site personnel felt that since the system was being tested under dry condition, there would be no evidence of problems and believed that the plugs smoked earlier due to “too much moisture around” (exposure to winter road spray).

After performing and inspection of this trailer (TR348) plugs' prongs, they were assessed as clean. The prongs were not a shinning copper color and had a thin film on them, but they were dry. Shurepower Team members felt confident that the main problem is the salt solution being sprayed on the plugs in winter and the winter road "gunk" accumulating in the plug causing a poor connection. The rubber slip-on cap on this plug was very loose and not likely to stay attached to the plug during road vibration and high velocity winds.

The extension cords were also tested for water infiltration. Water was poured over each extension cord plug as they hung down from the module hangers. No water entered the inside connector section of the plugs. Water did accumulate in the cover cap. This could explain the cap freezing on in the winter. The Team also examined the drenched plugs and did not see any water in the plugs. Also it is believed that this is not the cause of the smoking plug problem. A small amount of water in the spring-loaded cap would not affect the performance of the plug.

After performing this detailed assessment, it was determined that the plug covers were faulty and a redesigned trailer plug would need to be developed/acquired to replace the existing plugs. It was determined that the smoking plug problem was caused by road salt and resulted in a short circuit between pins inside the trailer connector. As a safety precaution, it was decided that the system would remain shut down until the trailer plugs were replaced.

Resolution 1: Carrier investigated the trailer mounted plug in further detail. The Carrier Deltek Vector standard equipment electrical power connector was relocated from the TRU unit and reinstalled the rear of the trailer as the trailer wiring connector. The connector pins are exposed in this installation; however, the plug is protected from the environment by the unit's housing cover in the Vector OEM installation, so environmental exposure is not a concern. When this connector was relocated to the rear of the trailer, the plug was exposed to environmental conditions when the slip cover was not attached to protect the plug opening. When installed at the rear of the trailer, it was hoped that a tethered rubber slip on cover that was designed to address this concern would adequately protect the connector. The cover did not fit tightly and would not stay on the plug, even when the trailer was parked. As the ambient temperature dropped throughout the winter, the rubber cover was even looser than originally tested and as a result, the cover would not remain on the plug.

When the original design was performed for the wiring system, the Shurepower Team believed that rubber cover issues may become a problem so alternatives were investigated. The connector's original equipment manufacturer (Mennekes) was contacted earlier in the project for pricing of the spring hinged cover version of the connector, but the additional cost of replacing the plug (approximately $120 per plug) was deemed too high so the OEM installed Vector plug with the rubber cover was used (no additional cost per plug).

Other opportunities for environmental exposure for the trailer mounted plugs were discussed. The red plastic plug connector body is mounted to a flat metal plate that is part of the mounting bracket. A rubber gasket is installed in between the plate and connector for waterproofing, so this is likely not a path for environmental exposure. A tight fitting rubber grommet is used to seal the hole where the electric cable passes into the connector body/mounting bracket assembly, so this again would not be a likely path for environmental exposure.

Carrier used the information gathered during this investigation to develop a new plug system in order to ensure that this issue would not occur again. Carrier engineers worked for 2 months to design and test the new design to ensure that all needs would be met, including durability to ensure that it would be commercially ready for installation on all Vector TRUs. The new assembly consisted of a metal housed plug with a tethered plastic cap that can be tightened to create a water tight seal. The new plugs were installed on all Vector-equipped trailers by August 1, 2007. This is also when the electrification system was deemed fully operational. The system was partially operational from June 1, 2007 through July 31, 2007 with limited utilization during the redesigned plug installation. No issues have been encountered to date with the trailers equipped with the redesigned connectors. Pictures are shown of the new plug housing below in Figures 5-6 and 5-7.

Figure 5-6. Side View of New Trailer Plug Assembly

Figure 5-7. Underside View of New Trailer Plug Assembly

5.6 PEDESTAL COLLISION CONCERNS

Issue 1: During a site visit that took place in May 2007, the Shurepower Team encountered a situation where a pedestal had been involved in a collision with a trailer. Upon arriving to the site, the pedestals were inspected and pedestal 2 was found to be pushed away from the I-Beam mount, which appeared to be the result of a collision with a trailer. The two mounting brackets were severely bent and the pedestal was slightly separated from the I-Beam as shown in Figures 5-8 and 5-9. The pedestal box itself did not appear to be damaged though and after further inspection it was determined that the components of the pedestal were still in-tact and operating safely and correctly, despite the collision.

Figure 5-8. Top View of Pedestal 2 after Collision with Trailer

Figure 5-9. Side View of Pedestal 2 after Collision with Trailer

Resolution 1: In order to alleviate this problem and due to the fact that the internal components of the pedestal were still intact, it was only necessary to replace the mounting brackets in order to properly re-mount the pedestal. A possible means to prevent future collisions from occurring was also investigated and it was determined that in order to protect parking area pedestals; either bollards or wheel stops should be installed to stop a trailer from colliding with a pedestal. Due to this investigation, it was also determined that in order to protect future dock-side pedestals, either bollards or bumpers should be installed. Both of these recommendations will be taken into account in future system installations.

Section 6:

TECHNOLOGY TRANSFER AND OUTREACH ACTIVITIES

As technology transfer is critical to disseminating the results of NYSERDA-funded activities, several specific activities were performed to promote the technology and results of the demonstration to New York State residents as well as interested parties across the nation. Specifically, a significant press event was held, project activity statements were written and released to the press, papers were written and briefing were presented.

6.1 PRESS EVENT

On April 11, 2007, an EPA-sponsored press event was held to promote the project. The press event was located at the Cruise Ship Terminal in Manhattan, New York. Media coverage was diverse including reporters from the trucking industry as well as members of the national media, including CNN. Project partner attendees included Maines Paper and Food, Carrier Corporation, New West Technologies, NYSERDA, NYSEG, and the U.S. Environmental Protection Agency. The press event consisted of several speeches given by:

- Thomas Spina – Director of Cruise Operations for New York City Economic Development Corp.
- Alan J. Steinberg – Regional Administrator, U.S. Environmental Protection Agency, Region 2
- Joseph Tario – NYSERDA
- John Penizotto – Eastern Region Sales Manager, Carrier Corporation
- Jeff David – Director of Transportation, Maines Paper and Food
- Mike Panich – Chairman, Shurepower, LLC

After the speeches were given, a demonstration of the eTRU and its plug-in capabilities was given. Pictures from the event are shown below in Figures 6.1 and 6.2. The EPA press release concerning this press event is included in Appendix G.

Figure 6-1: eTRU Connection Technology Demonstrated by Shurepower

Figure 6-2: EPA-Sponsored Press Event

6.2 PROJECT PRESS RELEASES

Press releases were created by both Shurepower and the EPA in order to promote the eTRU and hybrid electrification technology to a wider audience by presenting the technology's positive operational effects as well as their roles in the project. The Shurepower press release was mainly focused on announcing the project and explaining the potential benefits that can be seen by using eTRU technology instead of standard TRU technology, including reduced emissions, fuel use and noise. This press release, attached in Appendix H, also explained the role and described the expertise of each partner involved in the project.

The focus of the U.S. EPA press release was towards the agency's role in this project. EPA recognizes that this hybrid eTRU technology is a method of reducing diesel fuel use and emissions of TRUs and included a brief description of the eTRU technology. This press release was distributed to the media immediately prior to the previously mentioned press event. Both press releases are being included in

6.3 TECHNICAL PAPERS AND POSTERS

Several technical papers and posters have also been written concerning the technology utilized in this project, most notably a paper published and presented at the American Council for an Energy-Efficient Economy (ACEEE) in White Plains, NY and a paper and poster presented at the Transportation Research Board's (TRB) 86th Annual Meeting in Washington, DC.

The ACEEE paper, entitled "eTRU Refrigerated Warehouse Technology Demonstrations" was presented by Joseph Tario, the NYSERDA project manager at the 2007 ACEEE Summer Study on Energy Efficiency in Industry in July 2007. The paper, authored by several members of the Shurepower Team described the benefits of the eTRU hybrid technology. In addition, project status and preliminary results were also presented. This paper can be obtained directly from ACEEE at ACEEE_Publications@aceee.org.

The TRB paper and poster entitled "Real-World Demonstration of Grid-Powered Electric Trailer Refrigeration Unit Technology" explains the background of the project as well as a general outline of the project's activities and goals. It also displays the results of the project as well as future locations of demonstrations of this technology. A copy of the paper can be obtained through TRB at http://pubsindex.trb.org/orderform.html and referencing *Source Data: Transportation Research Board Annual Meeting 2007 Paper #07-0408.* An image of the poster presented at TRB is included in Appendix I.

In addition, Carrier-Transicold published a detailed project summary entitles "Maines Paper & Food Service Pilots Program Proving Effectiveness of Electric Transport Refrigeration Units" in their internal publication. A copy of the article from the 2006 Issue 2 *Extra Mile* publication is included as Appendix J.

Section 7:
CONCLUSIONS AND RECOMMENDATIONS

From the results, it is clear that the hybrid technology utilized by the Deltek Vector multi-temperature eTRU offers many benefits over conventional mechanically-driven TRUs. However, this demonstrated illustrated that to take full advantage of the benefits; several hurdles will need to be crossed. At the MAINES facility, these units were underutilized and even so, there were significant fuel savings, operational savings, and emission reductions. When used away from the facility, these units proved that the hybrid technology is more efficient than conventional TRU technology. The Vector-equipped trailers were more efficient than the Genesis-equipped trailers during the demonstration period. The eTRUs consumed between 2% and 40% less fuel per month than the conventional control fleet TRUs.

The eTRUs performed more fuel efficiently than the conventional mechanically-driven TRUs

Throughout the study, the eTRUs continued to obtain better on-road fuel efficiency than the conventional mechanically-driven TRUs. This trend held true for every month and through every range of temperatures encountered by the trailers. Traditionally, TRU equipped with a mechanical interface for electric standby are less efficient than conventional TRUs without his option. This is one of the reasons why this option is not popular with refrigerated fleets. The eTRU technology is able to not only compete with conventional TRU fuel efficiency but exceed it.

The colder the ambient air, the less electrical power the eTRUs consume

Through the demonstration of the eTRU technology, it was determined that the ambient temperature decrease, the more efficient the eTRUs become. This is especially beneficial in the upstate New York area where temperatures are often very low. Lower energy demands by the eTRUs equate into lower operational costs for the fleet.

A power management system should be developed

A power surge caused by eTRU start up may become a problem with larger fleets. If several eTRU-equipped trailers were connected to a grid-electric power facility, a power demand spike could occur. This could result in a temporary brown out condition as well as an electricity demand surcharge from the utility. An energy management system should be developed to control power flow and eliminate the possibility of a power surge caused by operating multiple units.

The redesigned trailer connection has been significantly improved to survive the upstate New York environment

After determining the cause to the malfunction concerning , the trailer electrical connection was redesigning to ensure the connections remains clean and dry. The connection is now more robust and can withstand exposure to snow and road debris. The plug cover will not loosen nor disengage during over the road operations. This new plug design will be offered by Carrier for future eTRU electric power under-trailer wiring systems.

The under-trailer wiring system has been proven and should be commercialized

From observations, it is clear that the under-trailer wiring system designed as part of this demonstration project can perform as designed. This system successfully served as a conduit for electricity from the rear of the trailer to the eTRU on the front of the trailer. There were no issues with the wiring whatsoever and after one year there appears to be no noticeable wear on the wiring.

A warehouse connection system should be designed and implemented

Concerns regarding a drive-off situation at the dock connections surfaced during the demonstration. An incident of this nature would be especially dangerous in dock locations where the electrical connection may not be apparent. To resolve this issue, a dock connection safety system should be investigated.

It is vital to ensure proper training of the personnel responsible for operating the electrification system in order to limit drive-off situations

Although the MAINES facility did not experience any documented “drive-offs” (where the trailer is moved away from the electrification pedestal while connected), an improved system of securing the trailer preventing a drive-off situation should be investigated. Until this system is developed and implemented, the proper training of all personnel using the system is critical and should continue regularly. From this demonstration project, it was determined that if procedures are followed, drive-offs will not happen. However, a universal approach should be researched to prevent drive-offs from parking area electrification sites. The Shurepower Team is currently investigating tactics to prevent drive-offs, however, until this can be completed, operational personnel should continue to be carefully instructed.

The data collection system must be improved to operate in the upstate New York environment

The remote collection of data was difficult due to the indiscriminate loss of the wireless transmission to the internet connection. In order for the data collection and transmission to be more reliable, it should either be hardwired, to eliminate the need for a wireless transmitter, or the wireless transmission system should be redesigned. Either a more robust, wireless transmitter or environmental controls should be used. This redesign should improve system reliability. In addition, a method to remotely reset the wireless transmitter should be employed to enable a remote reset capability.

Improve and maintain communications with all host site management

Unfortunately, a transition in management at MAINES may have affected the utilization of the electrification system to its maximum potential. In the future, communication should be continuously maintained with all current and new management personnel that may have the ability to affect the project activities. In future projects, senior management must continue to support to a demonstration projects and commit to making the operational changes if needed.

The location of the electrification system should be optimized

In order to maximize the benefits of the electrification system, it is vital to install the electric connections in an area that will be easily and regularly used by trailers equipped with eTRUs. Also, if possible, the electric connections should be installed as close to the power connection as possible to minimize installation costs.

APPENDIX A:

BUSINESS CASE ASSESSMENT

BUSINESS CASE ASSESSMENT AND NEW PRODUCT EVALUATION: PROVIDE ELECTRICITY FROM ETRU TO SHOREPOWER-CAPABLE SLEEPER CABS

Reference: NYSERDA Agreement 8485-1-2 Task 4: Detailed Cost Analysis to Determine if a Business Case Exists for a TRU Capable of Providing Electric Power Directly to Shorepower Equipped Sleeper Cabs

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A-1 EXECUTIVE SUMMARY

Electric trailer refrigeration units (eTRUs) are an advanced refrigerated trailer technology that uses electricity to power the compressor and other refrigeration components. Electric power can be supplied either by an on-board diesel fuelled generator or by a grid-connected power source. The on-board diesel engine operates an electric generator to produce electric power the eTRU components when operating over the road or while parked. The generator's maximum power is selected to provide sufficient power for pull down capability. Pull downs are seldom performed after the initial event, which results in the underutilization of the full power capacity of the eTRU generator.

Stationary electrical plug-in facilities, such as the one currently operating at Maines Paper and Food Service, Inc. in Conklin, NY, present an opportunity for refrigerated trailers equipped with eTRUs to use grid-supplied electricity instead of using the eTRU's on-board diesel generator. This approach significantly reduces diesel usage, overall operating expenses, and on-site noise and exhaust emissions. The available power at this type of facility is adequate for pull down operations. As with the on-board generator power, the excess power when the eTRU is in a temperature maintenance mode is available for other purposes.

Truck tractors are under increasingly stricter regulations to limit main engine idling, and a variety of alternatives to idling are being actively developed. In today's environment, both regulatory and economic drivers influence fleet equipment selection decisions. It is important that all idle reduction opportunities are researched to understand the environmental influence on product and equipment selections. Idle restrictions, small engine exhaust emission, and record-high diesel fuel prices have forced fleet managers to consider options that they may not have considered even a few years go. A proposal was developed for this reason to investigate the business case for a system that could provide electricity to a shore power-capable truck cab via an electrical device interface between either the eTRU generator or a stationary electrical plug-in facility.

This business case assessment addresses the following areas: relevant market background; overview of the technology proposition; investigates markets, customers and competitors; implementation; financial case summary; and overall conclusions.

It was determined that there is an economic advantage to installing this electrical connection between the trailer mounted eTRU and a shore power-capable tractor. The fuel savings alone from operating the eTRU to provide electric power to the tractor pay back the initial purchase price difference between an auxiliary power unit (APU) and the cost for the proposed eTRU electric connection device. The savings between an APU and the electric connection device are increased by a wide margin when the maintenance costs are accounted for. Using a conservative estimate for APU maintenance costs, the eTRU connection saves roughly $3,300 during the first 2 ½ years, and $7,700 over five years of ownership. Limiting factors such as the amount of time the tractor is not connected to a trailer (bobtail setup) and how often the tractor is transporting a non-refrigerated trailer or a refrigerated trailer without the electrical phase converter should also be considered. These factors will influence the amount of time that the driver can actually utilize this connection. Since the primary reason for equipping a trailer with this capability is to replace a truck-mounted APU, the assessment also focused on factors that would influence a fleet or driver's decision to adopt one technology over the other.

In addition to idle reduction, the electrical connection between the trailer and truck tractor has the potential to provide electrical power to electrically driven accessories (e.g. water pump, oil pump, fans, HVAC, electrical subsystems, etc.) to reduce over-the-road fuel consumption. These systems are in the research and development stages, so are not yet commercially available. As electrified auxiliary system technology becomes commercially available, the preferred approach would be for truck OEMs to integrate an electrical supply connection for providing power to the on-board auxiliary systems into the truck tractor. The cost effectiveness of the truck tractor to eTRU generator connection becomes even stronger.

At this time, there appears that a viable market may be developing for this type of product and further investment may be warranted to integrate it into the existing Deltek design. The maintenance cost and fuel savings achieved by using the eTRU Connection for idle reduction can achieve a two year payback period, which may approach the minimum payback period of some fleets. In addition, as truck and tractor designs evolve, the market for this type of product feature will also increase. The MorElectric technology will permit improved fuel economy via a connection to the eTRU generator. Carrier Transicold should closely track the evolution of truck tractor technology to identify the point in time when sufficient numbers of on-board MorElectric systems are introduced into the trucking market to determine the timing of future engineering and product development efforts. The decision to move forward on this engineering effort should also integrate other factors such as idle reduction technology and fuel costs which may substantially decrease the payback period to a point that is acceptable to the majority of refrigerated transportation fleets.

A-2 BACKGROUND

Before truck refrigeration units (TRUs) were developed in the late 1930s, refrigerated transport amounted to the shipment of perishable goods alongside blocks of ice. The invention of the TRU dramatically changed the way food was distributed, and its design remained largely unchanged until the 1980s. It was at this time that an "on-off" switching capability was introduced that allowed the unit compressors to shut down when proper temperatures were reached, dramatically reducing the unit's fuel consumption. TRUs typically consist of a small diesel engine that powers the refrigeration unit via belts connected to the engine. These refrigerated units are typically also referred to as "reefers".

Diesel fuel prices have been unstable over the past couple of years. The U.S. Department of Energy projects both in their Short-Term Energy Outlook[1], and the Annual Energy Outlook[2] are forecasted to continue to be in the mid- to high- $2/gallon range through 2030. Many states and localities have implemented idle-reduction regulations that restrict the idling of over-the-road tractor engines[3]. These localized anti-idling measures are rarely uniform.

Sleeper cabs trucks idle primarily to supply the cab with the necessary power driver convenience locals, also referred to as "hotel-loads", such as heating/cooling systems and other driver comforts such as television, microwave, computers, etc. during mandated driver rest periods[4]. As a result, trucking companies use a variety of technologies to reduce their idling. There are idle reduction systems that address a portion of the drivers need, such as providing heat (direct-fired diesel heaters); however, these types of systems have a limited usefulness to drivers. The available idle-reduction technologies for providing heat, cooling, and power includes diesel-fueled auxiliary power units (APUs) and generator sets (gensets), battery-based APU systems, and electrified parking spaces (i.e. shore power, which is also referred to as Truck Stop Electrification, or TSE)[5]. Trucks with these types of idle reduction systems typically have a 120 VAC/single-phase electrical system to allow common household type devices, such as televisions, microwaves, laptop computers, etc. to be used. Some states, including California, are looking into implemented even stricter emission controls for onboard devices, including APUs/gensets and TRUs.[6]

[1] U.S. Department of Energy, Energy Information Act, "Short-Term Energy Outlook – August 2006", (http://www.eia.doe.gov/emeu/steo/pub/4tab.html) (accessed September 5, 2006).
[2] U.S. Department of Energy, Energy Information Act, "Annual Energy Outlook – February 2006", (http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_12.xls) (accessed September 5, 2006).
[3] U.S. Environmental Protection Agency SmartWay Program website; Idling Reduction-State and Local Laws (http://www.epa.gov/otaq/smartway/idle-state.htm), (accessed August 29, 2006).
[4] U.S. Department of Transportation, "Hours-of-Service Regulations", (http://www.fmcsa.dot.gov/rules-regulations/topics/hos/hos-2005.htm) (accessed August 31, 2006).
[5] EPA SmartWay Program website; Idling Alternatives (http://www.epa.gov/otaq/smartway/idlingtechnologies.htm), (accessed August 29, 2006).
[6] California Air Resources Board, "Article 8. Off-Road Airborne Toxic Control Measures", (http://www.arb.ca.gov/regact/trude03/fro1.pdf) (accessed September 12, 2006).

The refrigerated trailer industry is again in a state of flux as a result of increasing fuel costs and stricter CARB and EPA emissions regulations.[6,7] The industry is responding several ways, including the development of electric powered Truck Refrigeration Units (eTRUs). This technology is the equivalent of a series-hybrid vehicle. The diesel engine has an electric generator on the output shaft and has no mechanical connection to the rest of the system, but rather serves only to produce the required electric power. As a result, the traditional mechanical refrigeration components (e.g. compressors, fans, etc.) have been replaced by electrically powered versions. This allows the eTRU to be powered either by a 480VAC/3-phase grid-connected power source, such as shore power, or by the onboard diesel generator. The Carrier Transicold Vector 1800MT™ is the only eTRU currently available in the United States.

The load on a TRU varies greatly between the temperature pull-down and temperature-maintenance modes. Temperature pull-down requires all of the available power, approximately 15kW. The temperature maintenance mode requires roughly 15% of the power capacity, leaving roughly 13kW of excess capacity from the eTRU's diesel generator. This excess power would meet most of the tractor's hotel-load requirements while the driver is resting. Typical tractor installed APUs/gensets used for main engine idle reduction typically have 4kW-6kW of output power. This study examines the technical feasibility and market potential of producing an electrical connection device installed on the trailer that would distribute excess power from the trailer's eTRU to the tractor to put the power to use as an idle reduction solution. The connection device must be able to function either when the eTRU is plugged into an electrical outlet or when the diesel generator is providing power. The particulars of this will be discussed in this paper.

This power interface device could positively impact truck operations in four specific areas:

- Using a single on-board power-generation system could permit increased available load carrying capacity, since the eTRU unit with the necessary electrical interface device will likely be lighter than the combination of an APU and an eTRU. Although the Federal government has instituted a waiver of 400 pounds for truck-mounted APUs, it is up to states to modify their regulations to reflect this waiver. To date, many states have not adopted this weight waiver.[8]
- A stationary 480VAC/3-phase connection could power both the trailer (480 VAC/3-phase) and the tractor (120VAC/single-phase) with a single land-side electrical connection. This would reduce setup and operating costs compared to operating a diesel APU/genset and would simplify the driver's interaction with the system. This would require only a single cable connection to provide shore power electricity to both cab (120VAC/single-phase) and eTRU (480VAC/3- phase).
- The eTRU generator could be used to power a portion of the tractor auxiliary electrical loads, such as the water pump, oil pump, fans, HVAC, and electrical subsystems during over-the-road operation when the unit has unused electrical capacity. This would reduce the parasitic loads on the main propulsion engine and lead to improved fuel economy and lower overall operation costs.

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[7] U.S. Environmental Protection Agency, "Control of Emissions of Air Pollution From Nonroad Diesel Engines and Fuel Final Rule – June 29, 2004", (http://www.epa.gov/otaq/url-fr/fr29jn04.pdf) (accessed September 12, 2006)
[8] The Library of Congress, "Energy Policy Act of 2005 – August 8, 2005", (http://thomas.loc.gov/cgi-bin/bdquery/z?d109:HR00006:@@@L&summ2=m&) (accessed September 12, 2006)

- Traditional APUs used for tractor idle reduction are fueled by the main truck fuel tanks filled with taxed onroad diesel fuel. Drivers pay the fuel taxes upfront and then must document the APU fuel use to recover the taxes paid on fuel used by the APUs. TRUs use off-road fuel that is exempt from federal and state taxes, thus this simplifies the accounting and documentation that drivers need to do as a side benefit.

A-3 OVERVIEW OF PROPOSITION

The purpose of this assessment was to evaluate the business case for an electrical connection device to satisfy the requirements of delivering excess electrical power from the eTRU generator to a shore power equipped tractor as an idle reduction solution. Interviews with refrigerated fleets were conducted to verify that this type of product is desired by the refrigerated transport industry. Several companies specializing in these types of electrical components were contacted to discuss potential technical solutions and to generate the product specifications and price proposals. The associated costs of this technology were used as inputs for determining whether this electrical connection would be an economically feasible feature for future Carrier Transicold eTRU models. A value gap analysis was used to identify market opportunities. The following sections contain an outline of the proposed marketing approaches and the necessary future development and economic variables impacting the success of this technology.

A-3.1 BUSINESS MODEL

An electrical interface device for supplying 120VAC/single-phase power to a shore power capable sleeper cab presents a number of potential benefits for Carrier Transicold's eTRU models. The financial benefits of adding this capability would result in and higher unit sales prices and would enhance eTRU marketability due to the lower diesel fuel and maintenance costs of the combined system approach. This type of connection device would combine the functionality of two pieces of equipment, APUs/gensets and TRUs, into a single package, which would improve Carrier's position in both markets. Refrigerated fleets may be encouraged by the financial and non-financial benefits inherent to this technology. Most significantly, the lower emission and noise levels of shore power ready equipment compared to an APU/genset may help reefer units legally operate in non-attainment, residential areas, and other areas where noise and emissions are restricted. While these benefits are difficult to quantify, current policy trends suggest that the refrigerated transport industry will be interested in technologies that allow them to operate freely within restricted zones.

A-3.2 SALES APPROACH

The eTRU electrical connection to the shore power tractor presents a number of challenges for marketing this type of product feature and the benefits of the connection will need to be clearly emphasized. This technology removes the need for fleets to purchase and maintain a separate tractor installed APU/genset. Diesel APUs/gensets have an average purchase cost of $6,500. This will reduce fuel costs (a typical diesel APU uses 0.2-0.3 gallons per hour [gph]) while the eTRU is operating on electric standby power and will decrease the total weight of onboard auxiliary equipment by roughly 300 lbs. compared to an APU. Periodic APU/genset maintenance costs can be significant over the lifetime and need to be included into the lifecycle cost analysis. These figures will be discussed in detail later in this report. The eTRU electrical connection device will also allow the eTRU generator to be used to power some of the tractor auxiliary electrical loads (e.g. heating and cooling equipment, air compressor, fans, electrical devices, etc.) during over-the-road operations will reduce overall fuel costs by increasing the fuel efficiency of the main engine and to a lesser degree because the eTRU uses off-road diesel fuel that is not subject to the Federal Highway Taxes of $0.18 per gallon. A recent study by the Southwest Research Institute found that supplying power to tractor auxiliary electrical systems from a separate source, a fuel cell APU in this case, increased the tractor fuel economy by as much as 13%.[9] The noise and emissions reduction benefits of this combined use of the eTRU should be stressed. Drivers will no longer need to operate two separate diesel engines (APU and eTRU) which will reduce both noise and emissions, and will result in a less restrictions on their operating range.

A-3.3 DEVELOPMENT ROADMAP

The development of this technology will proceed in a series of logical steps that will investigate the questions of the concept's technical feasibility and market potential. The results provided in the *Implementation* section will follow a similar organization.

The first concern is to determine if it is technically feasible to develop the necessary hardware with current off-the-shelf technology. Will there be adequate power to support both the eTRU and the shore power connection while the eTRU is in temperature-maintenance mode? It needs to be determined if it is feasible to split the input three-phase power source into single-phase power for the tractor while maintaining the three-phase power supply to the eTRU within Carrier's acceptable voltage balance operating range. It must be determined if it is feasible for the connection to support input from both the eTRU generator and from a stationary plug-in electrical connection. These questions will need to be carefully considered to determine if it warrants proceeding to the market assessment phase.

Assuming the connection is technologically feasible, it will be necessary to verify that a suitable potential market exists and that the technology will be economically competitive in the current TRU and APU markets to warrant further development. The analysis will include an estimate of the implementation costs, for a limited production run and full commercial production, as well as the annual operating and maintenance costs for comparison to current technology. The financial investment required by Carrier to integrate this hardware and capability into the Vector 1800MT™ line will be assessed and be incorporated into the business model development.

A-3.4 KEY ASSUMPTIONS

The financial market assessment will depend on key assumptions derived from industry feedback and typical reefer truck operating procedures. These assumptions will be used to evaluate the economics of this technology and to determine the potential market penetration.

A conventional Genesis TRU with comparable cooling capacity to the Vector unit costs $23,595; the Vector eTRU retails for $26,095. The $2,500 incremental price between these units must be included in the calculations along with the additional equipment costs for an valid comparison[10]. The trucking industry is very sensitive to higher upfront costs for new technologies. This will be a significant market barrier for this technology, regardless of the projected fuel and maintenance cost savings throughout the equipment's lifetime. Diesel-fueled APUs/gensets typically range from $5,000-$8,500, with an average price of approximately $6,500.[11] The U.S. Department of

[9] Sunline Transit Agency, "Fuel Cell-Assisted Truck Completes Cross-Country Trek," http://www.sunline.org/templates/printer_version.asp?page=126 (accessed July 21, 2006).
[10] Personal communication with Tracy Mattice, Territory Manager for Carrier Transicold of Upstate New York State, September, 15, 2006.
[11] U.S. Department of Energy's National Renewable Energy Laboratory (NREL), "Idle Reduction Technology Demonstration Plan," http://www.nrel.gov/docs/fy03osti/34872.pdf (accessed July 31, 2006).

Energy's Energy Information Administration (EIA)[12] shows the current average nationwide diesel fuel prices currently at $3.02 per gallon. The cost analysis will considers three diesel fuel price scenarios: $2.50/gallon, $3.00/gallon, and $3.50/gallon to represent near-term prices. Electricity costs are necessary for calculating the annual operating expenses of an eTRU and a tractor using shore power. The most recent data from the EIA (from 2004) shows that New York State has the second highest commercial use electricity costs in the United States of $0.13/kWh[13]. Specific pricing information regarding the eTRU to shore power capable cab connection will be included within the *Implementation* section.

TRU and eTRU operating characteristics must to be considered. Typical fuel consumption for both TRUs and eTRUs are considered equal since the engine technology is similar and ranges from approximately 0.715 gph for normal temperature maintenance operation to 1.0 gph during temperature pull-down mode. Approximately 95% of the TRU/eTRU operating time is spent in the temperature maintaining mode. The remaining 5% is spent in temperature pull-down mode where a warm or hot trailer is brought down to the required temperature for loading and storing food. The electric power required by the eTRU during pull-down is 15kW. The temperature maintenance mode requires roughly 15% (2.25kW) of this power, resulting in an average TRU/eTRU diesel use of 0.715 gph, or 2.89kW of electrical energy when operating on the shore power connection. A typical average electrical load for a tractor during rest periods is 3kW. Thus, the eTRU engine would not need to be operated at full load to supply the necessary power. Interpolating between the temperature maintenance mode and pull-down mode power output and fuel use gives an additional estimated fuel use of 0.0.067 gph, for a total fuel use. If we conservatively assume an additional fuel use of 0.1 gph, the total fuel required to supply power to both the eTRU and tractor is 0.815.

[12] U.S. Department of Energy, Energy Information Administration, "Gas and Diesel Fuel Update" http://tonto.eia.doe.gov/oog/info/gdu/gasdiesel.asp (accessed August 30, 2006).
[13] U.S. Department of Energy, Energy Information Administration, "State Electricity Profiles, 2004 Edition (released June 2006)", http://www.eia.doe.gov/cneaf/electricity/st_profiles/e_profiles_sum.html, (accessed August 30, 2006).

A-4 MARKETS, CUSTOMERS AND COMPETITORS

A-4.1 OVERVIEW OF MARKET

Refrigerated transportation is a $1 billion a year industry in the United States and continues to grow.[14] In 2000 there were approximately 225,000 refrigerated trailers in operation in the United States, 15,200 are registered in New York.[15,16] Annual reefer sales in the United States are between 25,000 and 35,000.[17] Forty-eight foot long reefer trailers are the current industry standard, although 53-foot trailers are becoming more common due to the fact that "a 53-foot trailer weighs only 750 pounds more than a 48-footer and only costs around $1,000 more".[18] Larger reefer trailers, although restricted in certain states, are desired by refrigerated trucking companies because they reduce operating costs by allowing the use of fewer trucks to haul the same amount of product.

Reefer trailers tend to be concentrated in areas with large populations, since the majority of their loads are frozen, processed or fresh food. This creates noise and emission pollution which is an increasingly politically sensitive issue. Many communities have lodged complaints against idling trucks and reefer units at truck stops and rest areas. Regulations have been enacted across the country restricting the allowable times that truckers can idle the main diesel truck engines. Diesel engines used in TRUs and eTRUs are considered "nonroad" engines by the United States Environmental Protection Agency (EPA) and are subject to different emissions and idle-reduction regulations than the main engines. New stricter EPA emissions regulations for nonroad engines go into effect starting in 2008.[7] Idle reduction regulations for nonroad engines, such as TRUs, may be the next step, as has started in California.[6]

Some TRU models, typically those on smaller straight trucks, are available with an optional electric plug-in feature, referred to as "standby". Unlike a fully-electric eTRU, traditional mechanically driven reefer units operating in standby mode only have sufficient power to perform temperature-maintenance operations (as mentioned earlier, temperature maintenance requires much less power than pull-down mode). This ability to utilize electrical power instead of diesel can result in significant fuel and emissions savings. Unfortunately, fleet operators typically view TRUs with the standby feature as having too high of a purchase price and requiring more maintenance than traditional diesel TRUs. Standby equipped TRUs also weigh more and have lower cooling capacities compared to standard diesel-powered TRUs. This additional weight can be a significant disadvantage for truckload carriers where every pound of load equals $10 in annual revenue. For example, if an electric standby unit equipped TRU weighs 100 pounds more than the diesel TRU, it could cost the truckload carrier $1,000 in revenue per year if their loads are weight-limited which is the case with frozen food loads. As a

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[14] Lang, Dan. "Customer Demands Unfreeze Potential of Refrigerated Trailers". Transport Topics. July 1999

[15] American Trucking Associations, Inc. (ATA). American Trucking Trends 2003 (Booklet Publication). Alexandria, VA, 2004.

[16] Electric Transportation Program, EPRI. "Case Study: Transportation Refrigeration Units". December 2004. <www.epri.com>.

[17] Americas Commercial Transportation Research Company, LLC. State of the Industry Series III: U.S. Trailers. Columbus: ACT Research, 2003.

[18] Bald, Jim. "Hot reefers for cold loads." Overdrive. June 1997. <www.etrucker.com/default.asp?magid=1>.

result, electric standby equipped TRUs have not achieved significant market penetration in the United States.

eTRUs have sufficient cooling capacity to perform temperature pull-downs while operating on a grid-connected power source. These units offer the benefit of maintenance costs that are reduced by roughly 30% as a result of the design using 66% fewer, high reliability electric components[19]. Similar eTRUs are commonly being used in Europe with much success. A major factor for this success is due to the strict control on noise pollution, more so than because of exhaust emission regulations. The units operate much quieter when operating on grid-connected electricity than on diesel, which eliminates the noise concerns. Shore power connections are rarely, if ever, available at truck stops in Europe. However, many warehouses and distribution centers are powered by 3-phase grid electricity, which is needed to power eTRUs. Additionally, many trucks are partially transported by ferry, and while aboard the TRU engines are not permitted to operate. As a result, electrical connections are available on these ferries. At least 40-50% of European TRUs are capable of being driven electrically.[20] Current indicators suggest this figure may be over 70%.[21] While the market in the United States consists of approximately 90% trailer transport, only 60% of the European market is trailer-based. Carrier Transicold is the only manufacturer currently offering an eTRU in the United States. The units are currently only available by special order.

The environmental benefits of eTRU systems are difficult to quantify to fleet operators. The units are quieter than traditional TRUs and have no on-site emissions while operating on electricity. Unfortunately; these environmental benefits have little influence on truck operators purchasing decisions due to the thin profit margins. At this time, particularly due to a lack of an electrical infrastructure to plug into, truck operators and fleets will find it difficult to recapture the incremental purchase cost of eTRUs. The emissions and noise benefits will not benefit the fleets economically unless they operations are restricted. However, in these cases the fleet they may opt for less restrictive areas for warehouse their operations. It is important that the environmental and noise benefits realized by the community make a positive economic impact on the trucking company or warehouse facility undertaking the investment.

Reefer truck operators typically spend an average of more than five hours waiting to load and unload at the shipper's location, and another five hours or more waiting at the receiver's dock to unload. Drivers average 3.5 pickups and 4.65 drop-offs per week, equating to upwards of 43 hours each week spent simply waiting[14]. These significant wait times highlight the point that there may be an additional, significant market for a multi-service shore power TSE/eTRU approach at large refrigerated warehouses and food distribution centers. Noise regulations may provide an additional opportunity for these vehicles to use shore power at warehouse locations in densely populated areas. However, reduced noise engine-driven reefer units are also currently available, lessening the potential demand for electric units based solely on noise-related issues.

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[19] Carrier, "Vector Marketing Presentations", PowerPoint Presentation, January 19, 2006

[20] California Air Resources Board (CARB). "Airborne Toxic Control Measure for In-Use Diesel-Fueled Transport Refrigeration Unites (TRU) and TRU Generator Sets, and Facilities Where TRUs Operate (TRU ATCM)", http://www.arb.ca.gov/diesel/documents/rrpapp2.pdf, October 2003.

[21] Lavrich, Phil. Email correspondence to Jean Paul Tait, New West Technologies, May 2005.

Carrier Transicold, Wabash National, and other major refrigerated trailer manufacturers supplied data on the average operating times and diesel fuel use for a typical full-length refrigerated trailer. Reefer engines typically operate between 1,500 to 1,700 hours a year. However, the hours of engine operation are not the same as the total hours the TRU operates. The reefer's diesel engine, refrigeration compressor, and control system have been optimized to reduce fuel use for mobile refrigeration. Even though the TRU may be switched on for a large amount of the time, the engine and compressor may be active for only a portion of that time. This represents the temperature maintenance mode described earlier. During temperature maintenance, the engine duty-cycle is approximately 15%; meaning the engine is operating only for that portion of the time. For the remaining time, airflow is provided but the compressor is not running, drastically reducing the fuel consumption rate. So even though a TRU may be switched on maintaining a given temperature for a large portion of the year, the engine will be operating for only 1,500 to 1,700 hours of that time. This is referred to "engine/compressor" operating hours in the remainder of this report). In pull-down mode, all of the unit's equipment is at full power operation.

The energy and environmental benefits from using electricity to power the trailer TRUs are considerable. Diesel TRUs use an average of 0.7 gallons of diesel fuel per hour to maintain the commonly used temperature of 0°F. A typical refrigerated trailer is used an average of 6 days a week, 50 weeks per year, totaling 7,200 total hours of use annually. This equates to 5,000-6,500 gallons of annual diesel fuel use. This figure will be higher if temperature pull-downs make up a larger portion of the operating conditions than the typical 5% mentioned earlier. This is the case with local distribution as opposed to long-haul. An eTRU would allow for pull downs to be performed using electric power in some locations where electric connections were available, saving diesel fuel and emissions. An eTRU plugged in during the mandated 10-hour driver rest period and/or a portion of the loading/unloading time, would displace 60 hours of TRU diesel engine operation per week, leading to an annual savings of 2,100-2,700 gallons, nearly 42%. To put this number in perspective, this is equivalent to removing two SUVs that each travel 15,000 miles per year from the road. The benefit of decreased diesel fuel consumption is augmented by the emission and noise reductions. Assuming the best case scenario with all refrigerated trailers having electric standby capability, this could result in the annual displacement of approximately 32 to 41 million gallons of diesel fuel in New York and 472 to 608 million gallons of diesel fuel nationally.

A product literature review was conducted and included an investigation of the full line of reefer units from both major manufacturers, spoke with sales engineers, and examined the relevant product manuals. The highest reefer system standby electrical power loads, are those for trailer systems, generally 48- or 53-foot. The unique aspect of supplying standby power for reefer units is the variety and range in the required electric power specifications for meeting the requirements of both the refrigerated straight truck and trailer fleets. In fact, many of the reefer system manufacturers consulted explained that their units generally operate under lower voltage (240VAC) 3-phase power requirements; however, the inputs are selected based on a wide range of customer needs. In other words, while a large reefer unit in standby mode may require only 240VAC/3-phase, with a ±15% voltage tolerance, the power input might actually be 460VAC/3-phase due to the grid supply at the customer facility. Thus, the problem with reefer standby power lies in the significant diversity of reefer system electrical equipment represented in refrigerated trailers and straight trucks. The range of requirements includes: 480VAC/3-phase/30 amps, 240VAC/3-phase/50 amps, 240VAC/single-phase/20 or 40 amps, and 120VAC/single-phase/30 amps. This variety makes the design and cost of the reefer electrical connections significantly more expensive than a shore power connection used for a standard sleeper cab hotel load TSE installation. This study focuses on 460VAC/3-phase input only since this is the power requirement for the current Carrier Transicold Vector 1800MT™, which is the only eTRU currently available.

A-4.2 MARKET OPPORTUNITY

A survey of large refrigerated transport fleets across the United States was conducted that consisted of sixteen questions regarding fleet and contractor/owner-operator owned sleeper cab tractor and reefer unit inventories. Questions were asked to gather idle-reduction related usage information such as APU ownership, shore power connections, and whether reefer units have standby capabilities. The survey also asked what payback period that each fleet required for considering adopting any new fuel-saving technology.

Few fleets chose to participate in the survey, whether fully or in part. Owners were often unsure of the number of idle-reduction technologies being used within their fleet, or how these technologies were used in conjunction with their reefer trailers. Some survey respondents were unable to offer estimates regarding what their required payback period would be for them to consider purchasing new technologies. There did not seem to be a standard financial break-even point. Thus, fleets would consider new technologies, including idle-reduction technology, on a case-by-case and fleet-by-fleet basis.

The success of deploying a new technology within the refrigerated trucking industry will ultimately hinge upon the initial incremental cost and the overall cost-effectiveness. A Recent survey results published by the American Transportation Research Institute (ATRI) citing feedback including over 55,000 trucks in the United States, found that of the major benefits cited for idle-reduction-technology use by survey participants, "fuel savings was mentioned most often, followed by less engine wear and less pollution."[22] Additionally, 26% of the respondents indicated that they were either "likely or very likely" to make future purchases of idle-reduction equipment given a payback period of two years or less. The number of interested fleets increased to 48% when financial incentives were available to pay for half of the initial purchase price. The average maximum price respondents were willing to pay for idle-reduction equipment was $2,165. This amount is well below the cost of traditional diesel-fueled APUs/gensets, which typically range from $5,000-$8,500 even accounting for available incentive funding. Thus, as previously eluded to, the initial affordability of idle-reduction technologies, such as the proposed eTRU connection, will have a strong impact on the potential market penetration.

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[22] American Transportation Research Institute (ATRI), "Idle Reduction Technology: Fleet Preferences Survey,"http://atri-online.org/research/results/Idle%20Reduction%20Technology%20Fleet%20Preferences%20Survey.pdf, (accessed July 26, 2006).

A-4.2.1 TARGET CUSTOMERS

As previously mentioned, there are roughly 225,000 reefer units operating in the United States; 15,200 of which are registered in New York State. Of the fleets opting to participate in the refrigerated transport survey in the previous section, only a small percentage had trucks currently equipped with idle-reduction technology. Very few fleets reported use of APUs. Even fewer fleets indicated that their tractors and trailers were equipped with anything other than electrical standby capabilities. As mentioned earlier, electric standby is restricted to smaller straight trucks so does not apply to the tractor population. The survey responses were very sparse, with many of the questions being answered. The resultant findings were inconsistent with current similar studies. The ATRI Idle Reduction Technology survey found that 19% of the surveyed sleeper cab population has direct fired diesel heaters, while only 0.4% has an APU or genset[22]. The ATRI survey incorporated market penetration results from an EPA SmartWay Transport Partnership survey, which indicated that 2% of trucks participating in the program use direct-fired heaters and 0.05% using APUs. These figures are likely a much more representative result and will be used in place of the survey done for this project. Shore power-capable tractors are required for the eTRU connection to be a useful addition and worth pursuing. Shurepower sources estimate the number of shore power capable cabs in the United States to be approximately 4,000 including both OEM and aftermarket equipment installations. The associated costs for the setup and installation of a basic on-board shore power equipment system including the electrical distribution wiring and heating equipment will be determined and will be included in the costs considered in the *Implementation* section.

It is unlikely that fleets that have already invested in an idle-reduction technology would be interested in transitioning to one that would require additional capital purchases. Marketing efforts for the proposed eTRU to shore power should focus on refrigerated transport vehicles that currently do not have any idle-reduction equipment installed; or approximately 80% of existing reefer tractors. Larger fleets should be targeted, since they will likely be best able to absorb the significant upfront investment, and will have a better comprehension of the cost/benefit relationship of this technology.

A-4.2.2 COMPETITORS

The Thermo King division of Ingersoll-Rand is Carrier Transicold's major competitor in the refrigerated equipment industry in the United States; however Thermo King does not currently offer an eTRU line. Another competitor is Zanotti, an Italian company operating its North American business out of Ontario, Canada. Zanotti is a major European reefer manufacturer that is gaining market share in the North American market. A majority of Zanotti's products are designed for straight trucks due to their prevalence in their primary European market. However, Zanotti also has a trailer-mounted reefer unit that directly competes with Carrier Transicold and Thermo King. Zanotti also does not have an eTRU line.

Of greater concern to the application of the providing single phase power from the eTRU to the tractor for hotel loads during rest periods is the wide range of idle-reduction equipment on the market.. The idle reduction industry already has various technologies available, including shore power, direct-fired heaters, battery-based heating/air conditioning/power equipment, and no less than a dozen diesel-fueled APU and genset manufacturers[23]. Diesel-fueled APU/genset and battery-based APUs are the most comparable functionally to the eTRU to shore power cab connection since all provide electric power to the cab independent without a physical electric connection such as a shore power facility requires. It will be necessary for the proposed eTRU connection to be economically competitive with these idle-reduction technologies, both in terms of initial expenses and annual operating and maintenance costs.

There is currently only one commercially available idle-reduction product with the ability to use the reefer diesel engine to provide power to the cab. The system, the Idle Free Reefer Link System[24], was designed and patented by truck driver and inventor, Robert Jordan[25]. The Reefer Link System provides 12VDC power to the tractor cab via an electrical connection between the trailer reefer unit's alternator and the tractor. Mr. Jordan developed the concept further into the Idle Free Hybrid System. The Idle Free Hybrid System that is essentially a battery based APU system that can use either the tractor's alternator, a shore power connection, or the Reefer Link System to provide power to cab hotel loads or to charge a battery pack mounted in the cab. Mr. Jordan has installed several complete systems to date at a cost of between $6,000 and $8,500, which is similar to the cost of an APU.

The system is conceptually similar to the Bergstrom NITE battery based APU system. The difference is that the Idle Free Hybrid System uses an upgraded TRU alternator to produce the power, whereas the NITE system uses an upgraded truck engine alternator. The Idle Free system has the benefit that it can charge the batteries even while the truck is parked and the main engine must remain off; the NITE system cannot.

The relevant portion of the Idle Free system for comparison to the single-phase power system described later in this report is the Reefer Link System portion. The Reefer Link system replaces the standard TRU alternator with a larger, 120 Amp model. A 2/0 cable connects the high-capacity TRU alternator to an inverter/battery charger installed in the tractor cab. The Reefer Link System controller module manages the power transfer between the TRU alternator and the inverter/charger. This power is used either to charge the absorbed glass mat marine deep cycle lead-acid batteries, or to directly power hotel loads. However, due to the cyclical operation of a TRU engine it is likely more beneficial to use the power to charge the battery pack and to power the loads through the battery. Power is available while the truck is parked, or while it is traveling over the road, as long as the cable is connected. The Reefer Link System does not seem to be available as a standalone system, so the cost for this part of the system is unknown.

Mack Trucks is the first heavy-duty truck OEM to offer the Idle Free Hybrid System as an option on all new Mack models starting in 2007[26,27]. The system cost reduction compared to the early system costs is unknown since it will likely have much higher sales volumes than initially. According to Mack, "Idle Free has advantages over traditional auxiliary power units. The total

[23] U.S. Environmental Protection Agency (EPA), "Idling Reduction Technologies," http://www.epa.gov/otaq/smartway/idlingtechnologies.htm (accessed July 10, 2006).
[24] Idle Free, website, http://www.idlefree.net/products/ReeferLink.html.
[25] U.S. Patent # 7,151,326, December 19, 2006.
[26] Mack Trucks Website Press Release, May 24, 2007, http://www.macktrucks.com/default.aspx?pageid=2092.
[27] Mack Trucks Website Press Release, August 10, 2007, http://www.macktrucks.com/default.aspx?pageid=2167.

weight of the system, with five batteries, inverter, HVAC and controls is 370 pounds, which is less than many APUs. It is also quiet, does not consume fuel, requires no maintenance, and is not subject to local idling restrictions". Mack also states that "The batteries can be recharged three different ways: by the truck's alternator when the engine is running; through a shore power connection when the vehicle is stopped; or through an available connection to the reefer unit for tractors hauling refrigerated trailers. When the truck is not moving, the driver can use battery power or shore power to run heating, air conditioning and amenities[26]." Another press release describes the system's capabilities in a slightly different way, stating that "The Idle Free "key-off" HVAC system provides driver comfort and electrical power for amenities without idling the truck's engine, using shore power, a connection to reefer units or a special bank of batteries"[27]. The first description gives the impression that the Reefer Link cannot provide power while the truck is stationary, however the second description says that the Reefer Link can be used while stationary. The ability to use the TRU diesel engine to provide power to the cab is a positive; since it means that another engine (e.g. and APU) is not needed to provide the cab with power if a 110 VAC shore power connection is not available.

Several of Mr. Jordan's presentations are available online that describe the Idle Free Hybrid System and Reefer Link System, including a high level description of the new and upgraded components[28,29]. The major components described in the aforementioned presentations, along with cost estimates for the most expensive components, are shown in the following list and are also shown schematically in Figure A-1.

- 2/0 cable
- Power cords w/ connectors
- Bosch 120 amp alternator
- One 175 amp fuse
- One 250 amp connector between the truck and trailer
- Three-phase transformer
- Hubbel switch box
- GFI protection
- Circuit breaker
- Controller
- Programmable 2kW Xantrex inverter/charger
- Relay/circuit board (ready for controller plug-in)
- Dometic 120 VAC HVAC unit (air conditioner only; no heat)
- Webasto diesel fired heater
- Two or four Group 31 Hawker Odyssey absorber glass mat (AGM) batteries.

The most significant design differences between the Idle Free Reefer Link System and the system for using a portion of the standby power from the Vector eTRU (described in detail in the next section) is the manner in which the power is extracted from the TRU and how it is transferred to the cab. The Idle Free Reefer Link System applies an additional load to the TRU's uprated alternator to charge the battery pack. The 12VDC power is transferred to the

[28] Idle Free Presentation on Cascade Sierra Solutions website, https://secure.cascadesierrasolutions.org/downloads/css_library/IDLE_FREE.pdf.
[29] Idle Free Presentation on Smartidle.com website, http://www.smartidle.com/great_lakes_presentation.pdf.

inverter/charger in the cab. This is a simple and effective way to produce and transmit power to the cab. The power is transmitted at low voltage, however, the potential downside is that the current is high since it is being transmitted at 12 VDC. The diesel engine in the Vector eTRU is not operating while the truck is plugged into grid power, so using the method of applying an additional load to the alternator does not work. Therefore the power must be taken from the main electrical connection. The Vector is powered by 460VAC/3-phase power. Carrier engineers provided the information that the electric motors must be operated in a narrow range of voltage imbalances between the phases of roughly ±5%. The impacts of operating at higher levels of voltage imbalance are lower efficiency operation and higher electricity usage. Therefore, power for the cab cannot simply be taken from one of the phases and still maintain the voltage differences. For this reason, as described in a later section, a phase-converter was determined to be the best option for extracting power for the cab power. The phase converter outputs single-phase 120 VAC power to the cab. The voltage is higher than the 12VDC for the Idle Free System, however is at a much lower current and is essentially the same as a household outlet. Due to the tight packaging of the Vector unit, adding a phase converter into the current system would require that the device be installed outside of the TRU housing. It would likely be required to be wired in-line between the shore power connection plug and the main electrical box. In this configuration, the single-phase power for the cab hotel loads would only be available while the eTRU was connected to the grid. In a more integrated system, Carrier could integrate the phase converter module and/or the electrical connections into the electrical system in a way that would allow for transferring power produced by the diesel engine while travelling over the road to the cab. This would allow for charging of a battery pack as in the Bergstrom NITE or Idle Free Hybrid System. Due to the cycling nature of a TRU engine, electric power would not be available at all times for the cab, however this is the same case as for the Idle Free System.

The Idle Free Hybrid System with the Reefer Link System provides power to the cab to eliminate the need for main engine idling or for an additional APU. This is beneficial, however diesel fuel is still being used to charge the battery pack or provide power directly either while the vehicle is stopped or on the road. The operation of the Bergstrom NITE system provides essentially the same function, using a larger alternator on the main engine instead of the TRU engine. It is unclear what the fuel use impacts of this additional electrical load on the TRU engine or main engine are. It would be interesting to determine the fuel use impact the system has compared to a TRU without the system. The NITE system allows for complete idle elimination provided there is enough charge in the batteries. If the power required is above the stored energy, either the engine must start to recharge the batteries, or the engine must be idled. The Idle Free System The eTRU to cab shore power connection allows for complete idle elimination while the truck is parked at an electrical connection facility.

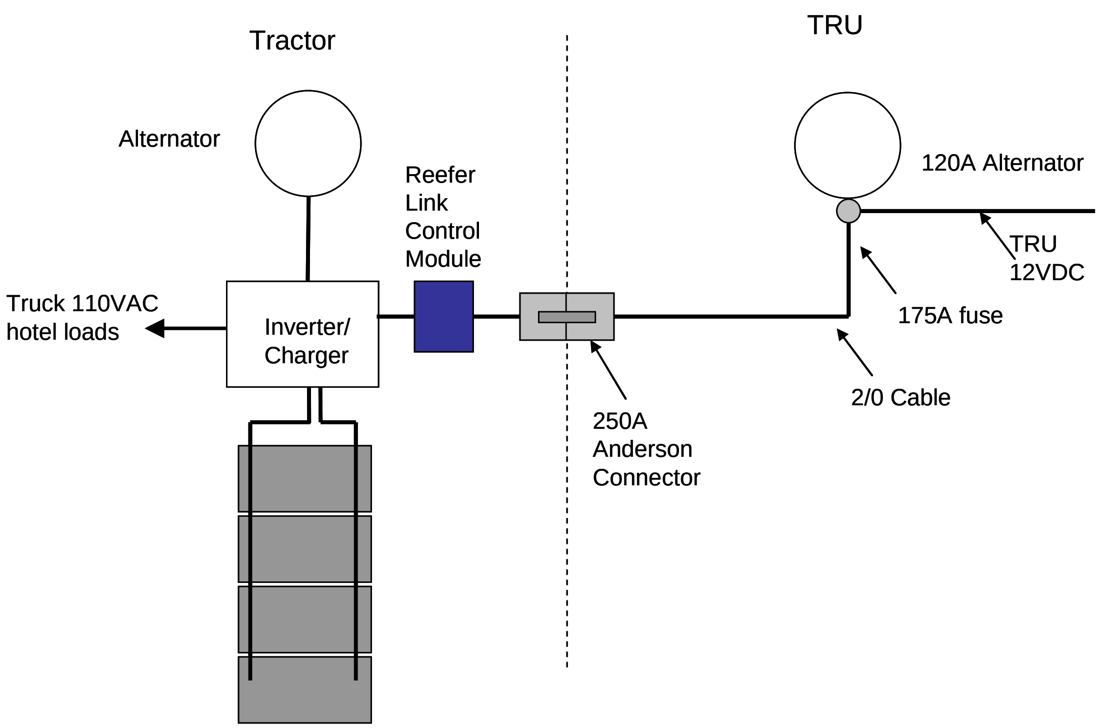


Figure A-1: Schematic of Major Components of Idle Free Reefer Link System

A-5 IMPLEMENTATION

A-5.1 DEVELOPMENT

The technical feasibility aspect of this study investigated solutions that would allow for input power to come from either the eTRU generator or from a shore power stationary plug-in facility. The shore power facility will be the more difficult for the eTRU connection to balance to be able to provide the appropriate output power to the eTRU and the shore power-capable cab, since it does not have the benefit of the eTRU generator's internal impedance. During temperature maintenance mode, a significant amount of excess power from the shore power connection will be available to the eTRU connector to provide power to the tractor cab. The proposed eTRU connection design will need to be able to accommodate these conditions. Given the manner in which the eTRU generator will respond to varied loads, any eTRU connection that satisfies the phase-balancing needs for operating at an electrical plug-in facility will be able to operate with the eTRU generator as well. The Vector 1800MT™ requires a balanced electrical input of 460VAC/3-phase, 30-amp power, so the eTRU connection must provide this. This standard power input was discussed with various phase-converter companies.

The *Key Assumptions* section mentioned some of the eTRU power requirements. The Carrier eTRU requires 460VAC/3-phase, 23-amp power during pull-down mode. Approximately 95% of the time, however, the eTRU is in temperature maintenance mode operates at 15% of the power needed for pull-down. During this time, there is excess available power for powering the hotel-load requirements of a shore power-capable cab. These loads, as previously mentioned, operate on 120VAC/single-phase power typically with a 25 amp maximum. The eTRU will be given priority over the cab; thus all of the power will go to the eTRU during a temperature pull down. In this case, the power being provided to the tractor cab will be interrupted. Shore power equipped cabs commonly use an inverter which will automatically switch to battery power during these short interruptions.

The phase-converter equipment market focuses predominantly on standard 3-to-1 (i.e. 3-phase to single-phase) or 1-to-3 phase conversions. Three-phase power is significantly more expensive to transmit over power lines than single-phase, and so residences and companies often in rural areas often need to purchase a phase converter to satisfy their 3-phase power needs. There is a wide range of products available, including: static, rotary, and digital phase converters. In the case of 1-to-3 phase conversion, the cost depends strongly on how balanced the 3-phase output needs to be. This is ultimately determined by the power quality requirements of the equipment that will be using the converted power.

Conversations with Carrier Transicold technicians indicate that the Vector eTRU can safely tolerate voltage imbalances of about ±5%, perhaps as much as ±10-15%. This voltage balance requirement is the same for pull-down and temperature-maintenance operations. The eTRU will operate slightly less efficiently when supplied with an off-balance 3-phase power input, resulting in a 5-10% change in power efficiency according to an estimate provided by Carrier. This will increase the electricity use during temperature-maintenance mode, when power the excess power is being supplied to both the eTRU and the shore power-capable cab, and will decrease the cost savings.

Several phase-converter companies who do custom design work were contacted to discuss the electrical (e.g. 460VAC/3-phase, 30-amp shore power based electrical source; a 460VAC/3-phase balanced (±5%) input into the eTRU and 120VAC/single-phase outputs) and design requirements for the proposed eTRU connection device to develop a cost proposal for the design and building of the devices. The companies included Pulizzi Engineering (www.pulizzi.com), Marway Power Systems (www.marwaypowerdistribution.com), Boostek, Inc. (www.boostek.com), Phase Technologies, LLC (www.phaseperfect.com), and TEMCo (www.phaseconverter.com). All of the companies indicated that the phase-converting scenario described above is technically feasible, and that the unit's design and overall cost would depend greatly upon how balanced the 3-phase output would need to be. Pulizzi Engineering, Marway Power Systems, and Phase Technologies, LLC all quoted prices at, or above, $6,000. Pulizzi Engineering and Marway Power Systems suggested using a large toroidal transformer, which contributed much of the cost and the weight of their designs. Phase Technologies, LLC suggested using a digital phase converter to balance the power outputs. Boostek, Inc. offered the most promising design at the lowest cost. Their proposal includes a 4-stage PhaseBalancer™ setup and uses a "binary switching system of capacitors and inductors to balance the three phase load [to within ±3%]. No moving parts and no cooling required." This eTRU connection device would use a transformer to convert the 480VAC supply down to 120VAC. The transformer would be rated for outdoor use and would be mountable on the end of the refrigerated trailer where the eTRU is mounted. The device would weigh approximately 100-150 pounds and would measure approximately 16"x16"x7". The connection would be able to use power from either a stationary plug-in facility or from the eTRU generator. Boostek estimates the system energy efficiency to be 96%. The device could be configured to fit inside of the housing of one of Carrier Transicold's eTRUs if offered by Carrier for volume production. Boostek estimated a design and delivery time of 8-10 weeks, with discounts available for quantities of 50 (25%), 100 (30%), and 250 units (35%). The quoted price is $4,898 per unit for an initial order of ten units to accommodate the eTRU demonstration fleet at Maines Paper and Food Service, Inc. in Conklin, NY. For comparison, Boostek also developed a quote for an eTRU connection providing 3-phase power that had a voltage balance tolerance of ±6% using a 3-stage PhaseBalancer™ setup of $4,176 per unit.

Carrier Transicold and larger trucking fleets desiring to use the eTRU connection as a aftermarket add-on would be able to take advantage of the bulk order discount prices offered by Boostek. This would result in a shorter payback period and design optimized for the Vector application. The price quote for a ten unit production run, $4,898, will be used since this will be the cost for outfitting the Maines eTRU demonstration fleet will be used for assessing the financial case of the eTRU connection. The financial assessment follows in the *Summary of Financial Case* section.

The Idle Free Hybrid System first discussed in the Competitors section (4.2.2) has a significantly higher price than the Boostek phase-converter technology, however this is not an accurate cost comparison since the Reefer Link portion of the system is the competing technology for the Boostek device. A battery pack, charge inverter could be installed on a Boostek equipped tractor as with the Idle Free Hybrid System for similar operation and results. As mentioned earlier, a cost estimate for the Reefer Link System was not available. This system suggests a different way to approach the problem of power management. The approach throughout this analysis was to find power management devices that take a balanced 460VAC/3-phase electrical shore power input and then split this into a balanced 460 VAC/3-phase output (within ±5%) and a 120VAC/single-phase output. As stressed earlier, the eTRU power balance requirement from Carrier-Transicold was the major hurdle encountered by this approach. The degree of phase voltage balance has a significant effect on the overall cost of these devices. Reducing the phase balancing requirement from ±3% to ±6% decreases the Boostek model cost by $722, or about 15%.

The technology behind the Idle Free Hybrid System, on the other hand, splits the 12 VDC alternator power between the TRU engine's SLI (starting lighting-ignition) battery and the Idle Free Hybrid System AGM battery pack. An inverter is used to convert the 12 VDC power from the AGM batteries to 120 VAC current for the cab hotel loads such as the air-conditioning, heating, etc. while the truck is idle.

A-5.2 KEY PARTNERS

Boostek, Inc. is the most promising partner for the hardware development of the eTRU to shore power capable cab connection device. The company has expressed a great deal of interest in the project and seems very willing to work with Carrier Transicold to reduce costs and custom-design the eTRU connection. Pulizzi Engineering, Marway Power Systems, and Phase Technologies, LLC also offered designs that would satisfy the eTRU power-supply requirements, but at generally higher design costs. It may also be worthwhile to explore a partnership with Xantrex Technology, Inc. (www.xantrex.com) or Vanner Incorporated (www.vanner.com), both are major suppliers of AC power inverters since a large-scale partnership would serve to reduce per-unit costs.

The most obvious choice for organizing a technology demonstration fleet would be to expand the partnership with Maines Paper and Food Service, Inc. in Conklin, NY, since they are currently performing a technology demonstration of ten Vector 1800MT™ eTRU equipped refrigerated trailers along with a stationary electrical plug-in facility. Such a partnership would allow an assessment of the eTRU connection operating from both the eTRU generator and a stationary power supply. There may also be interest in a technology demonstration from various government agencies, such as New York State Energy Research and Development Authority (NYSERDA, www.nyserda.org).

A-5.3 IMPLEMENTATION SCHEDULE

The following chart is meant to indicate a preliminary implementation schedule for the development of an eTRU-to-shore power-capable-cab connection. Carrier Transicold would likely make a decision whether or not to go forward with the technology at the end of the assessment period, shown as a dotted line in the chart below.

TASK	MONTH														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	…
Assessment															
Design															
Product Development															
Marketing															
Sales															

Figure A-2: Proposed Implementation Schedule

A-6 SUMMARY OF FINANCIAL CASE

The additional eTRU connection hardware will add a significant cost to the unit; increasing the purchase price from $26,095 to $30,995, a difference of $4,900 above the base eTRU price. As a result, the incremental price difference between the conventional TRU ($23,595) and eTRU widens by a factor of three. The resultant gap of $7,400 between the purchase prices of a conventional TRU and an eTRU with the connection hardware is $900; 13% greater than the average cost of an APU/genset. Thus, a trucker or fleet owner could purchase a conventional TRU and an APU/genset for approximately the same price as an eTRU with the proposed connection hardware. The higher initial purchase price may make it difficult to effectively market this optional equipment, even though there is the potential for considerable fuel savings resulting from the use of the eTRU shore power connection.

It will be important to emphasize the annual fuel and maintenance cost savings this new technology offers.

Both uses of the eTRU connection, over-the-road and while parked, will result in fuel savings. During over-the-road operations, the connection would be capable of supplying power to electrically powered auxiliary systems. The Sunline Transit Agency study mentioned in the *Sales Approach* section used a fuel-cell APU to provide electric power to electrified engine accessories in a similar approach. The project demonstrated a fuel efficiency increase of 13% simply by removing these parasitic loads from the main engine. Over the road tractors driven by skilled drivers typically average approximately 7.0 miles/gallon (mpg) in steady-state highway operations. Using the eTRU connection device could improve the fuel efficiency by nearly 1 mpg. The eTRU generator would need to operate a higher load setting, to produce enough power for the eTRU and for the tractor cab, thus the fuel use would increase from 0.715 gph to a maximum of 1.0 gph at maximum load. The ATRI Fleet Preferences Survey stated that an average refrigerated truck travels 130,000 miles each year at an average of 54 miles per hour, equating to 2,407 hours. Under these conditions, the incorporation of the eTRU connection device into a truck with electrified accessories would result in an annual diesel fuel savings of 1,499 gallons. The annual over-the-road fuel consumptions are summarized in Table 1 below.

Table A-1: Annual Over-the-Road Diesel Fuel Consumption in Gallons

	Main Engine		eTRU Engine		Total Gallons
	Gallons	mpg	Gallons	gph	
Without eTRU connection	18,571	7.00	1,721	0.715	20,292
With eTRU connection	16,435	7.91	2,407	1.00	18,753
Difference	-2,136		+687		-1,499

Using the ATRI survey average operating conditions for long-haul trucks along with the current taxed on-road diesel fuel prices of approximately $3.00 per gallon and untaxed off-road diesel fuel prices of $2.82 per gallon, the eTRU connection providing power for electrified auxiliary systems of a shore power-capable tractor would result in annual fuel savings of $4,470.

Unfortunately, the electrified auxiliary systems that this scenario requires are not currently available. However, work being performed at the National Renewable Energy Laboratory's Advanced Vehicle Testing Activity that includes the Caterpillar MorElectric™ Technology program is helping to introduce and promote this fully-electric approach.[30] The estimated annual fuel savings offered by this technology suggest a significant price window and short payback period for this and similar auxiliary system conversions. The eTRU connection device will allow the Carrier Transicold units to seamlessly support this approach when they are available.

For loading/unloading/idling operations, the eTRU connection will allow the tractor to operate its auxiliary driver comfort systems while the eTRU is plugged-in at a stationary electrical facility. Tractors that do not have shore power capabilities can install basic shore power connection system that includes an electrical distribution system and electric heater for around $300 including the equipment and 1-2 hour installation costs. The eTRU connection would allow the Carrier Transicold Vector 1800MT™ units to directly compete with both main-engine idling and diesel APUs/gensets.

Using the operating characteristics cited in the *Key Assumptions* section, an eTRU uses the maximum power of 15kW during pull-down mode (5% of operating time) and 2.25kW of energy during temperature-maintenance mode (95% of operating time). As mentioned earlier, the eTRU connection will supply approximately 3kW to the shore power connection during temperature-maintenance mode, resulting in an average overall power use of 5.7kW, at an estimated fuel use of 0.827 gph; 0.10 gph higher than temperature maintenance mode alone. The ATRI Survey estimates annual tractor idling times to be approximately 1,600 hours. eTRU electricity usage, diesel fuel consumption rates, and costs for both main-engine idling and commercially-available APU/genset use, are shown in Table 2. Off-road diesel costs were used for the APU and eTRU engines. It is assumed that the eTRU diesel engine service interval is not affected since the operation hours are not affected. It is also assumed that the eTRU equipped trailer is connected to a shore power equipped tractor during all of its annual operating hours and that it is transporting refrigerated loads at all times. This may not be the case in practice, but provides an upper bound to the potential savings.

Table A-2: Annual Idling Fuel/Energy Use and Costs

Idling Method	Fuel/Energy Use	Annual Costs		
		Low	Mid	High
Main Engine Idling	1,312 gallons (0.82 gal/hr)	$3,280	$3,936	$4,592
Diesel APU/genset	400 gallons (0.25 gal/hr)	$928	$1,128	$1,328
eTRU Connection (diesel)	160 gallons (0.10 gal/hr)	$371	$451	$531
eTRU Connection (electric power)	4,800 kWh (3 kW)	$624		

The comparison uses on-road diesel fuel costs of $2.50, $3.00, and $3.50/gallon, off-road (un taxed) diesel fuel costs of $2.32, $2.82, and $3.32/gallon and an average New York State

[30] National Renewable Energy Laboratory, "Caterpillar MorElectric Technology," http://www.nrel.gov/vehiclesandfuels/fleettest/ avta_caterpillar.html (accessed August 29, 2006).

electrical cost of $0.13/kWh. The results show that the eTRU connection will offer annual fuel costs lower than both main-engine idling and APU/genset use. In fact, using the mid-price case, fuel savings in the first two years ($902) equals the purchase price difference between the APU and the Boostek device. Another positive for the Boostek device's design is that it has no regular maintenance costs, no moving parts, no additional cooling requirements, and a very long expected lifespan. Boostek's primary market is with stationary equipment so they are unsure how the vibration and environment on a trailer will affect the device's longevity. Boostek suggested a including a long-term return policy for any eTRU connection device that would need to be replaced while any necessary product improvements were made to achieve the necessary long lifetimes needed for this application. This long useful life also allows the device to be moved to another trailer when it is retired. Due to this, additional maintenance costs are considered to be zero.

APUs/gensets typically have periodic maintenance (oil drain, etc.) intervals of 500 hours to match the tractor engine maintenance interval. The EPA lists the useful life for these engines as 3,000 hours, which equates to roughly one year and eight months. Kubota, the major APU engine supplier, was contacted to inquire about the maintenance, service and durability of these engines. Their engineering and service department representatives said that the life can be significantly longer depending on how well the engine is maintained. They quoted that an average engine overhaul costs between $1,500 and $2,000, while a new engine costs $2,500[31]. The APU engine maintenance and rebuild/replace costs accumulate quickly over the useful life of the truck and trailer and help to improve the economic case for the Boostek type connection device. For a conservative example, assume that the APU engine was well maintained, had the oil changed at the recommended 500 hour interval, and required no additional maintenance. Assume that the engine was run for 4,000 hours (2 ½ years), instead of the 3,000 hours mentioned earlier before any major service was required. Also, assume the driver performed the oil change themselves, so the only cost would be the oil ($4) and an oil filter ($6); a total of $10 per oil change. Over the 4,000 hours this results in eight oil changes, or $80 in supplies. Assume that the engine is rebuilt at the 4,000 hour mark, rather than being replaced using the low-cost rebuild estimate from Kubota of $1,500. If the lifecycle cost calculation are extended to 5 years after purchase, an additional $80 in oil change costs (eight additional oil changes) and $2,700 would be required to install a new engine ($2,500 for the engine and $200 for installation). Table 3 summarizes the maintenance costs.

Table A-3: APU and eTRU Connection Device Maintenance Cost Comparison

Idle-Reduction Device	Time after purchase	Oil ($)	Rebuild/ Replace ($)	Total Maintenance Costs ($)
APU	2.5 years	80	1,500	1,580
	5 years	160	4,200	4,360
Boostek Device	2.5 years	0	0	0
	5 years	0	0	0

[31] Phone conversation with Dave Young at Engine Distributors, Inc., the regional Kubota distributor.

The cumulative lifetime operating and maintenance costs are summarized in Table 4. The calculations take into account two cases: one where the eTRU is powered entirely by the diesel engine and another for when the eTRU is powered entirely by a grid-connected electric source. This clearly shows that the maintenance-free design of the Boostek being used in conjunction with the eTRU engine is superior to an APU for reducing lifecycle costs. An interesting result in this example is that the cost for operating on grid-connected electricity is higher than operation on diesel. This may be a result of the estimated the additional fuel use required by the eTRU to provide the additional power for the shore power connection. However, the main reason for the higher price is due to the fact that New York State has the second highest electricity price in the country. Electricity rates across the country, statewide, vary between $0.0463/kWh to $0.157/kWh, with a nationwide average price of $0.762/kWh. Thus the forty states with electricity rates less that $0.094/kWh would have lower energy costs than diesel.

Table A-4: Summary of Lifecycle Operating Costs for APU versus eTRU Shore Power Connection Device

Time	Idle Reduction Technology	Fuel / Energy Cost ($)	Maintenance Cost ($)	Total Cost ($)	Savings ($)
2.5 years	APU (diesel)	2,820	1,580	4,400	
	eTRU Connection (diesel only)	1,128	0	1,128	3,272
	eTRU Connection (electric only)	1,560	0	1,560	2,840
5 years	APU (diesel)	5,640	4,360	10,000	
	eTRU Connection (diesel only)	2,256	0	2,256	7,744
	eTRU Connection (electric only)	3,120	0	3,120	6,880

To successfully market the eTRU connection as an added-value technology with the current 1800MT™ eTRU line, it will be necessary to emphasize the versatility that this connection would offer for saving both fuel and maintenance costs. Since companies such as Boostek produce the required components it would seem that the financial investment required by Carrier Transicold to develop and integrate this technology into the Vector unit design would likely be minimal. Boostek, Inc. has expressed interest in developing a technology demonstration for the eTRU connection device and is willing to alter their current configuration to meet the Carrier Transicold's specifications.

A-7 CONCLUSIONS

The electrical operating characteristics of Carrier Transicold's Vector 1800MT™ model offers two distinct scenarios where excess power, either from the eTRU's on-board diesel generator or from a stationary electrical plug-in facility, could be used on a shore power-capable tractor. The first scenario would provide electric power to the tractor as an idle reduction feature. The second scenario would help power electrically powered auxiliary engine systems while the truck was on the road. This approach would reduce parasitic engine loads and increase the over-the-road fuel economy. This business case assessment looked specifically at the technology requirements and market possibilities for introducing this feature into Carrier Transicold's eTRU product line.

Several phase-converter equipment companies that offer custom-design work were approached to discuss potential phase-controlling solutions for this application. The electrical designs needed to satisfy the following requirements. The eTRU load maintains the highest load priority so during pull-down operations the eTRU requires all of the available electric power, so the connection device would distribute the available power only to the eTRU. During temperature maintenance operations, power output would be split between the eTRU and the shore-power connection. The eTRU would be supplied with balanced (within ±5-10%) power. The tractor shore power connection would be supplied with the required excess single-phase power. Boostek, Inc. produced the best preliminary device design that satisfies these power requirements. The initial cost quote for the device is $4,898 per unit (assuming ten units). The design includes no moving parts or cooling devices and has no required maintenance intervals, unlike traditional truck APUs which are the main competitor.

Using the eTRU connection while traveling over-the-road will require the tractor's auxiliary systems (e.g. water pump, oil pump, fans, HVAC, etc.) to be redesigned from the conventional mechanically belt driven designs to electrically driven versions. While initiatives such as the U.S. Department of Energy-sponsored MorElectric program and the Sunline Transit Agency fuel cell APU study suggest that this technology may gain a much wider commercial appeal, there currently is not an established vehicle infrastructure that will support the eTRU connection being used in this way. The fuel savings from increased fuel efficiency resulting from this approach, however, may significantly improve the market position of the connection device once electrically driven engine accessories become standard features on tractors.

The immediate financial benefits of the eTRU connection device would come during idle periods, either when the eTRU equipped trailer is using grid-supplied electric power or when the eTRU generator is producing electricity. The performance of this new technology was compared to both main-engine idling and operating a diesel-fueled APU, the most likely current competition. Using ATRI survey operational data, the annual idling costs for a shore power-capable tractor powered through an eTRU connection would be $624 compared to $3,936 for main-engine idling, and $1,128 for a diesel APU using the middle fuel price case. The initial purchase price of an eTRU connection (~$7,400) is somewhat more expensive than a typical APU/genset (~$6,500).

Even though the market of refrigerated trucks with access to electrical plug-in facilities is still rather limited, substantial cost savings can be seen realized by using the eTRU shore power connection device, either while connected to a grid-connected electric supply, or while using the excess power generation capacity of the eTRU generator while in temperature maintenance mode.

At this time, there appears that a viable market may be developing for this type of product and further investment may be warranted to integrate it into the existing Deltek design. The maintenance cost and fuel savings achieved by using the eTRU Connection for idle reduction can achieve a two year payback period, which may approach the minimum payback period of some fleets. In addition, as truck and tractor designs evolve, the market for this type of product feature will also increase. The MorElectric technology will permit improved fuel economy via a connection to the eTRU generator. Carrier Transicold should closely track the evolution of truck tractor technology to identify the point in time when sufficient numbers of on-board MorElectric systems are introduced into the trucking market to determine the timing of future engineering and product development efforts. The decision to move forward on this engineering effort should also integrate other factors such as idle reduction technology and fuel costs which may substantially decrease the payback period to a point that is acceptable to the majority of refrigerated transportation fleets.

A-8 BOOSTEK PHASE CONVERTER COST PROPOSAL

Boostek can provide two options which will balance your 24Amp 120V single phase load on a 30Amp 480V three phase system.

Option #1: 4 stage PhaseBalancer with a current symmetry of +-3%. Quantity of 10 price $4,898.00 EA.

Option #2: 3 stage PhaseBalancer with a current symmetry of +-6%. Quantity of 10 price $4,176.00 EA.

Both of the above options will include a transformer from 480V to 120V approx. 11" X 9" X 7" (approx. 60 lbs), primary and secondary over current protection and a control enclosure of approx. 16" X 16" X 6" (approx. 45 lbs). The units will be outdoor rated and ready to mount on the end of the trailer. Each unit will include 3' 14/4 SO cord with a weather tight 15Amp three phase 480V twist lock plug and a 30A single phase 240V weather tight receptacle.

- Delivery is 8 to 10 weeks.
- Discount of 25% for quantities of 50.
- Discount of 30% for quantities of 100.
- Discount of 35% for quantities of 250.

This PhaseBalancer will keep the current symmetry on the three phase system over the full load range of 0 to 24Amps on the 120V single phase system. We are using a binary switching system of capacitors and inductors to balance the three phase load. No moving parts and no cooling required. We could design a system just for your application and even have an exclusive labeling and reduce the cost with a contract for volume quantities. Our unit could also be configured to install inside of the Carrier unit. As I mentioned before, we could also use the generator in the Carrier unit to run the truck.

Larry A Walters
Boostek, Inc.
307-234-2366

Appendix B:

UNDER TRAILER WIRING ROUTING SYSTEM DESIGN

The initial design for this system was developed after speaking with Great Dane, the manufacturer of the trailers which the eTRUs in this study were installed on. The initial design was to route the electric power 3-phase cable along the trailer undercarriage by utilizing an electrical conduit and an upper coupler assembly pass through. Figure B-1 shows a view of the upper coupler cross member with three holes, a fuel line for the eTRU passes through one of the holes. The trailer manufacturer, Great Dane, initially agreed to install a conduit through the upper couple assembly; however the full electrical conduit would be aftermarket installed. For maximum protection, it was determined that this conduit should be an Intermediate Metal Conduit or Rigid Metal Conduit that will provide a corrosion-proof environment for the power cable. Generally, this type of conduit is aluminum, silicon bronze alloy, or plastic-coated. Aluminum conduit is used due to its light weight and corrosion-resistant properties. Aluminum conduit is generally regarded as the standard for most weather conditions and will resist salt water corrosion, which is of particular interest in an over-the-road trailer application. Rigid aluminum conduit should require no painting or protective treatment. As it is a non-magnetic metal, aluminum conduit also reduces the chance for voltage drop due to AC-induced currents. Silicon bronze alloy has special corrosive-resistance characteristics for use in environmentally exposed conditions. Plastic-coated conduit is a galvanized-steel conduit with a polyvinyl chloride (PVC) plastic. The PVC coating is flame-retardant and highly resistant to oils, grease, acids, alkalies, and moisture. It also provides protection again abrasion, impact, and other mechanical wear.

The cable conduit requirements were re-evaluated after the cable selection was made. Staff evaluated the design to determine whether a fully enclosed design would be necessary since the SOOW or SEOOW cable offer adequate protection against standing water and corrosion from corrosive elements in the over-the-road environment. It was determined that a U-shaped channel conduit (i.e. not fully enclosed) would be sufficient to secure the three-phase cable and offer adequate protection for the cable. The method of securing the conduit to the underside of the trailer was that the U-channel would be hung from the cross members using the existing holes. This method provides a nearly constant force along the cable length and minimizes the strain on the cable. The

Figure B-1: View of upper coupler assembly with holes for fuel line and power cable pass through

channel was also designed with drainage for any trapped water. The design however was designed to trap any road debris such as road salt and other debris leaving it in constant contact with the casing with no way to easily clean the cable and channel. The design would also increase the project cost since the channel and hangers would need to be designed and built. Maines request to maintain a design that appears to be an OEM installation was difficult to accomplished with this design.

The person that was responsible for the installation is an employee at Penn Detroit Diesel Allison, and has previous experience installing cable on a container trailer from a similar, previous project for the New York State Department of Corrections. This installation used the holes in the cross members to route and support the cable along the trailer's length. Rubber grommets were installed in the holes to prevent the wire from resting/rubbing on a rough metal surface that would likely cut through the insulation when the trailer vibrates over the road. Since it was determined that the cabling was properly weatherized for this application it was decided that this design was the preferred method.

As the trailers were not specified during procurement to be delivered with pass through holes installed in the cross members, another design was needed. This was confirmed when the first trailer arrived at Penn Detroit Diesel Allison during the first week in February. Great Dane was not comfortable with the retrofit installation of the pass through holes on the cross members since the holes may weaken the cross member structure. During the installation of the Deltek unit, the installer used the designated electric cable pass through for the diesel fuel line. As this was the first installation, the installer was not aware of the need for the electric power cable and used the pass through for the fuel line. This was corrected and the pass through is now available to be used for the electric power cable.

Figure B-2: View of under-trailer inverted channel and cross members

Since Penn Detroit Diesel Allison personnel was now to be used for the install, a cable sample was to be obtained for a test install of the cable. However, a cable sample was not obtained prior to the transfer of the trailer to Maines in Conklin, NY for a training session. This initial trailer was returned to Syracuse for the installation of the under-trailer wiring system when Maines and Carrier-Transicold had completed the training activities. The delivery of the remaining nine trailers was subsequently delayed in order for Great Dane to complete Deltek installation modifications. As another method for routing the wire needed to be developed, two specific designs were discussed. The first was to move back to the original idea of hanging a U-shaped channel conduit from the cross-members to support the cable in, but the additional cost and aesthetics of the final installation eliminated this design again. The second method was to use an existing channel in the underside of the trailer to route the wire along the trailer's length. The channel is an inverted U-channel (i.e. the bottom side is open) that is empty and is not used for any other wiring. The trailer cross- members form the bottom of the channels. Although this does not form a continuous bottom to the channel, it does create a minimum channel size. Figure B-2 shows the inverted channel and two adjacent cross members. Therefore, the dimensions of this channel are critical because they determine the maximum allowable cable size. The trailer was at Northern Great Dane when this design was being evaluated, and unfortunately, project management staff was unable to take these measurements at that time. The trailer was transferred to the Penske facility in Conklin that shares its property with Maines. The channel dimensions were then taken by Penske staff and supplied to Shurepower. The channel dimensions are approximately 2.5 inches wide by 1.25 inches high. The trailer cross-members are 2.25 inches wide where they support the trailer body and are spaced roughly every 12 inches near the front of the trailer and 8 inches at the rear. The weight of the cable would be supported by the cross-members, and it would be loosely constrained laterally and vertically by the channel. Additional supports will have to be designed and installed to limit this motion in the channel to minimize the rubbing on the cable casing and to provide strain relief. The Mylar film is attached to the top of the cross-members to electrically isolate the aluminum trailer body from the steel chassis to prevent galvanic corrosion resulting from contact of dissimilar metals. The Mylar sheet described in the previous section has adhesive on both sides for optimal contact with both metal surfaces. Penn Detroit Diesel Allison has expressed concerns that routing a cable through this channel may be problematic because of the cable length and the adhesive due to very high friction along with the weight of the cable. Using the thinner SEOOW cable discussed in the previous section alleviated these concerns however.

APPENDIX C:
DETAILED WIRING SELECTION PROCESS

New West staff researched UL and NEMA standards and spoke with support staff with expertise in the field to discuss cable and connector requirements. It was determined that an insulated, bundled cable should be used as opposed to separate stranded conductor wires for each phase and ground. Separate cords, while less expensive, would place more restrictive requirements on the electrical conduit used to mount the conductors. Considerations for the conduit such as water and oil resistance, electrical insulation, temperature rating, and corrosion can be minimized by choosing a protective **SOW** type corded bundle. The final cable selection (using bundled 8AWG wire conductors) should fall under type SOW, SOOW, SEOW, or SEOOW and be rated up to 600 volts. These rugged cables are acceptable for outdoor use and the insulation rated as **S**evere (or Hard Service) flexible cord (an **SE** might be used to provide Thermoplastic Elastomer insulation), **W**ater/moisture and sunlight resistant, **O**il resistant (an **OO** rating might be used in which each conductor's insulation is oil resistant in addition to the overall cable jacket). All of the proposed cables may be used in outdoor settings for temperatures up to 194°F (90°C), although cables for use up to 221°F (105°C) are also available. Lower temperature limits of -58°F (-50°C) are available. Each conductor will be coated with an approximately 1/16 inch (1.52mm) thick Thermoset (S type) or Thermoplastic Elastomer (SE type) insulation. These standards are covered by Underwriters Laboratories code UL 62, "Flexible Cord and Fixture Wire" and listed for use in accordance with Article 400 of ANSI/NFPA 70, National Electrical Code (NEC). The support staff estimated that this type of cable would be in the cost range of $3 per foot (each trailer will require 35-50 feet). The cable diameter may be as little as 0.8 inches, which would specify a conduit size of 1.25 to 1.5 inches in diameter.

The Carrier Deltek eTRUs require 3-phase 460 V_{AC} power to operate and are mounted on the trailer front. The trailers back into the parking stalls, so it was necessary to retrofit all ten demonstration trailers with rear-access electric connections. New West staff began investigation into the design of the trailer wiring systems. Exact eTRU requirements were provided by Carrier-Transicold for the Vector 1800 MT NAO model, which accepts 3-phase 460VAC, 22-amp (current limit) power. The Mennekes plug-in connector for this unit is rated for 380VAC, 32-amp using a 5-pole (3P+N+T) plug; one pole for each of the three phase conductors, one for the neutral conductor for returning current, and one for the ground conductor. A similar or identical 3-phase connector pin and sleeve-style ruggedized weather-proof plug/connector will be installed at the rear of the trailer and at the pedestal. The Mennekes electrical connector used on the eTRU specifies an operational voltage of 380VAC, this is actually due to its original application in a European 50Hz system. Moving to the American standard 60Hz permits adequate function at 460VAC. The issue of voltage drop across the extended trailer cable connection brought up during discussions with Carrier, and Carrier determined that 8AWG conductor would be sufficient for the unit based on a connection length of approximately 60 feet. However, in addition to the under-trailer run, an additional extension cord is needed to reach the building power supply. The current I-beam pedestals have connections for two adjacent trailers, so it is necessary to have this extension cord be 25 feet long to allow for an easy connection where the cable is not suspended between the pedestal and trailer plugs. Carrier staff redid the calculations taking this into account to determine if it was necessary to move up to a larger and less flexible 6AWG cable. Ultimately, this was not necessary and 8AWG cable, rated up to 35A, will be sufficient for the application.

New West staff worked with other contractors to investigate the details of the three-phase eTRU connection. It was determined that the loading characteristics of the eTRUs were balanced and as such, only the phase conductors and ground were needed (i.e. the neutral currents are canceled and therefore an extra conductor is not required). It was determined that most likely, the fifth pin on the plug would be tied within each connector to ground and passed along a single conductor. Therefore, at this point it was determined that a 4-conductor cable will be sufficient for the eTRU connection. Samples of the male/female connectors were requested from Carrier in order to proceed with the under-trailer wiring system design process.

New West staff contacted a cable manufacturer in order to investigate available 8AWG, 4 conductor cable designs. The conductor size was ultimately determined to be 8AWG based on amperage calculations at the maximum anticipated current. The SOOW and SEOOW cable bundles offer the type of protection required for the given environment. Several cable samples were received from a cable manufacturer including a 0.780 inch diameter General Cable Carolprene SOOW, a 0.98 inch water-resistant General Cable Carolprene SOOW, and a 0.783 inch water-resistant Coleman Cable Seoprene SEOOW that is less flexible than the same diameter SOOW cable. Early discussions determined that cable with a SOOW rating was the ideal choice based on the cable diameter and flexibility. The cables were reevaluated to ensure that the cable with the highest water resistant rating was selected. Both SOOW rated cables have the same flexible neoprene casing, a temperature range of -40°C to 90°C., and the same electrical and thermal properties, but the smaller diameter cable is not marked as water resistant. It was decided that the water resistant properties were critical for this installation since the cable will be exposed to the environment, so the larger diameter water-resistant SOOW cable was selected as the primary cable choice. Unfortunately, the cable diameter raised concerns that there would not be enough clearance in the trough (1.25 inches tall and 2.25 inches wide) to pass the wire through. The Penn Detroit Diesel Allison/Carrier-Transicold service representative, who performed the installation, had serious reservations that this would not be enough clearance to allow for an easy installation. The larger diameter cable is also noticeably less flexible than the smaller diameter cable which makes routing the cable more difficult especially when it needs to make bends. The staff member responsible for installation mentioned another complicating fact; there is a Mylar sheet between the aluminum trailer body and the steel chassis to prevent galvanic corrosion. The sheet is fixed with an adhesive that is spread evenly across the surface including where the trough is. The adhesive creates additional friction and makes pulling the cable through more difficult. The combined effect of the cable clearance in the trough and the Mylar adhesive forced another reexamination of the cable. The SEOOW cable is weatherproof, and has a wider temperature range -58°F to 221°F (-50°C - 105°C), the same current carrying ability, a diameter of 0.783 inch, but uses a different casing material that is a denser harder material than the neoprene used in the SOOW cables. This cable was eliminated earlier in the process because it is less flexible compared to the non-water resistant SOOW cable of roughly the same diameter. However, when the cable is compared to the thicker SOOW cable that is water resistant, the flexibility is equal or better. The cable manufacturer was called to discuss the wear resistance of their SOOW and SEOOW cable casing materials in relation to our general application. Their technical sales person’s opinion was that the harder casing of the SEOOW cable is a better choice for the under-trailer wiring application due to its higher wear resistance rating . The company does flexibility and wear testing on the casing, but no tests simulated conditions similar to what was needed for this project. The conclusion was that the SEOOW cable would be the best option, but would need to be monitored to ensure the cable casing is not damaged. This was discussed with the service representative and he was given the specifications on the wire to order.

APPENDIX D

SYSTEM TRAINING AND OPERATING INSTRUCTIONS

CARRIER DELTEK VECTOR – ELECTRICAL CONNECTION OPERATING INSTRUCTIONS

Connecting to Electric Power

If ENGINE is OFF - Place All Compartment Switches to OFF and Move START/RUN Switch to OFF

If ENGINE is ON - Move the START/RUN Switch to the OFF Position

1) Plug Extension Cord End without the Lock Collar into Trailer Connection First.
2) Plug Extension Cord End with Lock Collar into Electric Outlet Connection and Secure Outlet Lock Collar.
3) Push Electric Outlet Module Plunger in to Activate Power.
4) Move STANDBY/ENGINE Switch on Vector Unit to STANDBY, and if ENGINE is OFF Move Desired Compartment Switches to ON.
5) Move the START/RUN Switch to the START/RUN Position.

Disconnecting from Electric Power

1) Move the START/RUN Switch to the OFF Position.
2) Switch STANDBY/ENGINE Switch on Vector Unit to ENGINE.
3) Pull Outlet Module Plunger Out to Disconnect Power.
4) Disconnect Cord at Outlet Module End First.
5) Disconnect Cord at Trailer Last.
6) Roll Up Cord While Returning to Outlet Module.
7) Hang Entire Extension Cord (with Plug Ends Facing Down) on the Outlet Module Hook.
8) Move the START/RUN Switch to the START/RUN Position.

Shurepower eTRU Facility Operation Training (v1.0)

MAINES Paper & Food Service, Inc.

Conklin, NY

September 7, 2006

Agenda

- Background
- Review of Deltek eTRU Operation
- Instructions for Connection to Electric Supply
- Field Demonstration of Electric System
- Questions

Project Background

- Technology demonstration project co-funded by New York State Energy Research and Development Authority (NYSERDA) and U.S. U.S. Environmental Protection Agency (USEPA)
- Project partners include: Shurepower, New West Technologies, Carrier-Transicold, Great Dane Trailers, USEPA, and NYSEG
- Purpose of project → To demonstrate grid-connectable pre-commercial eTRUs in commercial operation
- Goal: to quantify and validate
  - Energy and emissions benefits
  - Economic benefits to MAINES

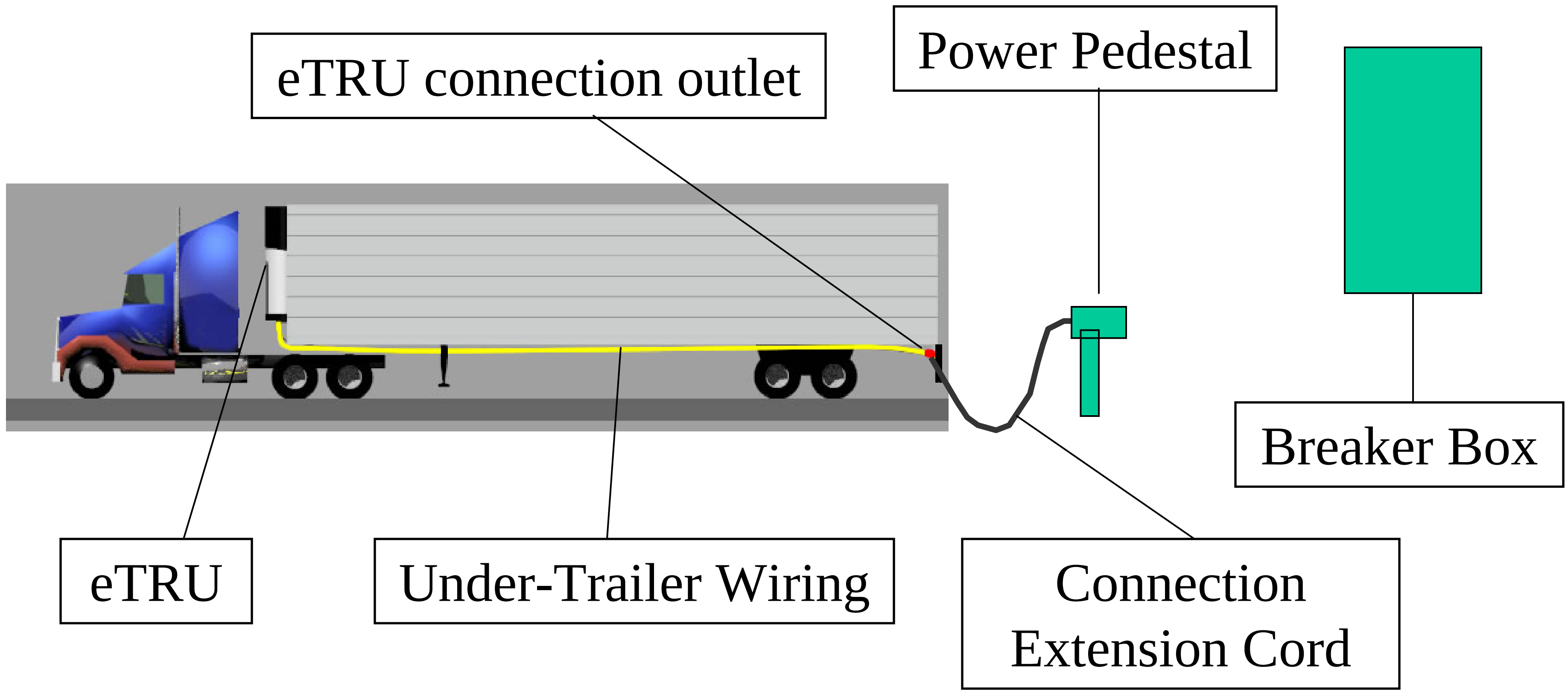
Deltek eTRU - Background

- Electric-based Trailer Refrigeration Unit (eTRU)
- Built-in electric standby capability for fuel savings, emissions and noise reduction, and regulatory compliance at the loading dock and when electrified parking is available.
- Electric heat, instead of hot-gas, for constant heating capacity that is independent of ambient temperature.
- The Advance microprocessor control, features easy-to-use IntelliSet™ commodity programming and an integrated DataLink™ data recorder.
- Improved noise reduction during generator operation.

High Power Electric Supply Warning

- 460VAC 3-phase is power is potentially **DEADLY** if connection procedures are ignored
- The power is equivalent to a typical house
- Detailed directions will be attached to every pedestal
- Know procedure **BEFORE** you attempt to connect
- Trailer and power pedestal equipment can be severely damaged if instructions are not followed

Electrical System Components



Five Primary System Components

1. Power pedestal
   - Dual-head, serves two adjacent parking stalls
   - Extension cords for each stall are hung on separate hangers

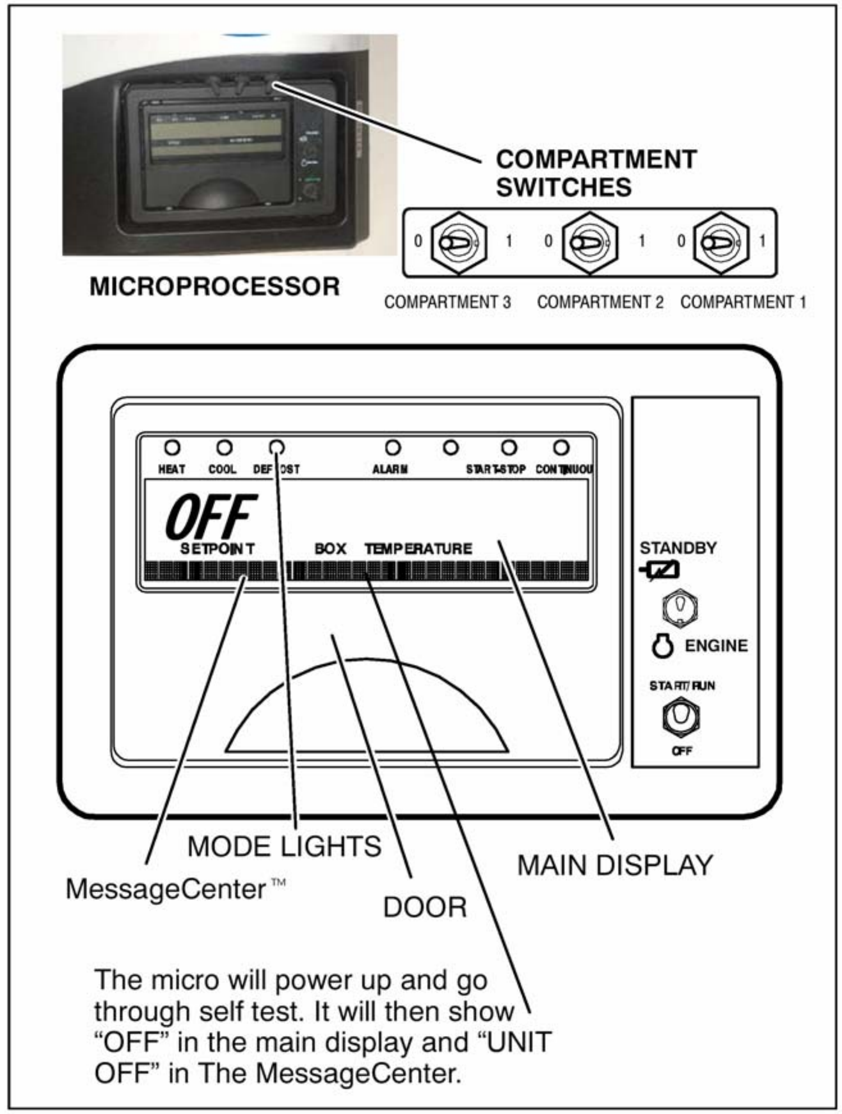
   Note: the picture shows the pedestal side plugs being left connected. This is not the proper procedure.

Five Primary System Components

2. eTRU Trailer Electrical Connector
   - Mounted at rear of trailer on driver's side

Five Primary System Components

3. eTRU switches
   - Located at front of trailer on eTRU
   - Compartment switches
     - ➢ 0 = off
     - ➢ 1 = on
   - STANDBY or ENGINE
   - START/RUN or OFF



Five Primary System Components

4. Extension Cable
   - Each spot has own extension cable hung on bracket
   - Cable has two unique ends
     - ➢ Twist-lock end attaches to pedestal
     - ➢ Spring cover end attaches to trailer connection

Five Primary System Components

5. Electrical System Circuit Breaker Box
   - Circuit breakers for main power supply and for each pedestal
   - Access to circuit breakers not required for normal operation
   - Only necessary for servicing or if the system has a problem
   - Should only be accessed by personnel trained by Shurepower or MAINES authorized trainer

Connecting to Electric Power

If ENGINE is OFF - Place All Compartment Switches to OFF and Move START/RUN Switch to OFF

If ENGINE is ON - Move the START/RUN Switch to the OFF Position

1. Plug Extension Cord End without the Lock Collar into Trailer Connection First.
2. Plug Extension Cord End with Lock Collar into Electric Outlet Connection and Secure Outlet Lock Collar.
3. Push Electric Outlet Module Plunger in to Activate Power.
4. Move STANDBY/ENGINE Switch on Vector Unit to STANDBY, and if ENGINE is OFF Move Desired Compartment Switches to ON.
5. Move the START/RUN Switch to the START/RUN Position.

Disconnecting from Electric Power

1. Move the START/RUN Switch to the OFF Position.
2. Switch STANDBY/ENGINE Switch on Vector Unit to ENGINE.
3. Pull Outlet Module Plunger Out to Disconnect Power.
4. Disconnect Cord at Outlet Module End First.
5. Disconnect Cord at Trailer Last.
6. Roll Up Cord While Returning to Outlet Module.
7. Hang Entire Extension Cord (with Plug Ends Facing Down) on the Outlet Module Hook.
8. Move the START/RUN Switch to the START/RUN Position.

Connecting to Electric Power

If ENGINE is OFF - Place All Compartment Switches to OFF and Move START/RUN Switch to OFF

If ENGINE is ON - Move the START/RUN Switch to the OFF Position

1) Plug Extension Cord End without the Lock Collar into Trailer Connection First.
2) Plug Extension Cord End with Lock Collar into Electric Outlet Connection and Secure Outlet Lock Collar.
3) Push Electric Outlet Module Plunger in to Activate Power.
4) Move STANDBY/ENGINE Switch on Vector Unit to STANDBY, and if ENGINE is OFF Move Desired Compartment Switches to ON.
5) Move the START/RUN Switch to the START/RUN Position.

Disconnecting from Electric Power

1) Move the START/RUN Switch to the OFF Position.
2) Switch STANDBY/ENGINE Switch on Vector Unit to ENGINE.
3) Pull Outlet Module Plunger Out to Disconnect Power.
4) Disconnect Cord at Outlet Module End First.
5) Disconnect Cord at Trailer Last.
6) Roll Up Cord While Returning to Outlet Module.
7) Hang Entire Extension Cord (with Plug Ends Facing Down) on the Outlet Module Hook.
8) Move the START/RUN Switch to the START/RUN Position.

Emergency Procedures

- Driveaway or collision with pedestal
  - **DO NOT TOUCH ANY WIRE – WIRES MAY BE LIVE**
  - Switch circuit breakers in breaker box to OFF position for associated pedestal (both breakers for the pedestal)
  - Immediately call primary MAINES contact
  - MAINES contact will review situation and contact Shurepower
  - Inspection of system must be performed prior to continued use of system

Emergency Procedures

- Power Failure
  - Follow normal disconnect procedures when ready to depart

Field Demonstration

- Demonstrate System Operation → Following presentation out in trailer parking area

Questions / Follow-up

- General questions, please first contact:

  Jeff David
  Transportation Manager
  MAINES Paper & Food Service
  607-779-1294
  607-222-8340 (cell)

  Joseph Licari
  Shurepower, LLC
  (315) 404-5613 (cell)

Appendix E:

DETAILED DATA REPORT

E.1.1 FUEL DATA

VECTOR UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS USED	GALLONS PER HOUR
497676	10/01/2006	10/31/2006	1517	1727	210	232.21	1.106
497677	10/01/2006	10/31/2006	1480	1649	169	195.64	1.158
497678	10/01/2006	10/31/2006	1356	1523	167	215.92	1.293
497679 *	10/01/2006	10/05/2006	1450	1456	6	63.76	10.627
497680	10/01/2006	10/31/2006	1304	1456	152	174.79	1.150
497681	10/01/2006	10/31/2006	1375	1597	222	210.22	0.947
497682	10/01/2006	10/31/2006	1391	1567	176	137.2	0.780
497683	10/01/2006	10/31/2006	891	1087	196	224.55	1.146
497684	10/01/2006	10/31/2006	1229	1385	156	209.56	1.343
497685	10/01/2006	10/31/2006	1427	1574	147	189.11	1.286
				Total	***1595***	***1789.2***	***1.12***

GENESIS UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS USED	GALLONS PER HOUR
510488	10/01/2006	10/31/2006	978	1152	174	178.4	1.025
510489	10/01/2006	10/31/2006	797	956	159	182.44	1.147
510490	10/01/2006	10/31/2006	781	960	179	221.98	1.240
510491	10/01/2006	10/31/2006	793	933	140	213.48	1.525
510492	10/01/2006	10/31/2006	898	1074	176	175.83	0.999
510493	10/01/2006	10/31/2006	580	730	150	214.7	1.431
510494	10/01/2006	10/31/2006	741	965	224	196.65	0.878
510495	10/01/2006	10/31/2006	793	1008	215	230.76	1.073
510496	10/01/2006	10/31/2006	791	969	178	226.4	1.272
510497	10/01/2006	10/31/2006	446	590	144	161.48	1.121
				Total	***1739***	***2002.12***	***1.15***
					Percentage Fuel Decrease		***2.6%***

Table E-1. October 2006 Monthly Fuel data

VECTOR UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS PUMPED	GALLONS PER HOUR
497676	11/1/2006	11/30/2006	1737	1867	140	138.14	0.987
497677	11/1/2006	11/30/2206	1652	1785	136	131.74	0.969
497678	11/1/2006	11/30/2006	1551	1722	199	187.18	0.941
497679	11/1/2006	11/30/2006	1513	1535	79	45.41	0.575
497680	11/1/2006	11/30/2006	1559	1643	187	124.45	0.666
497681	11/1/2006	11/30/2006	1609	1744	147	163.16	1.110
497682	11/1/2006	11/30/2006	1596	1634	67	141.40	2.110
497683	11/1/2006	11/30/2006	1102	1241	154	148.85	0.967
497684	11/1/2006	11/30/2006	1420	1530	145	120.57	0.832
497685	11/1/2006	11/30/2006	1621	1759	185	176.07	0.952
Total				***Total***	***1293***	***1190.16***	***0.92***

GENESIS UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS USED	GALLONS PER HOUR
510488	11/1/2006	11/30/2006	1167	1308	156	179.66	1.152
510489	11/1/2006	11/30/2206	999	1096	140	126.11	0.901
510490	11/1/2006	11/30/2006	987	1106	146	188.33	1.290
510491	11/1/2006	11/30/2006	946	1108	175	188.48	1.077
510492	11/1/2006	11/30/2006	1112	1215	141	157.49	1.117
510493	11/1/2006	11/30/2006	746	918	188	200.72	1.068
510494	11/1/2006	11/30/2006	967	1117	152	165.2	1.087
510495	11/1/2006	11/30/2006	1023	1153	145	151.29	1.043
510496	11/1/2006	11/30/2006	976	1110	141	203.35	1.442
510497	11/1/2006	11/30/2006	622	784	194	246.73	1.272
Total				***Total***	***1578***	***1807.36***	***1.15***
					Percentage Fuel Decrease		***19.6%***

Table E-2. November 2006 Monthly Fuel Data

VECTOR UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS PUMPED	GALLONS PER HOUR
497676	12/1/2006	12/31/2006	1904	2004	137	145.15	1.059
497677	12/1/2006	12/31/2006	1809	1958	173	158.72	0.917
497678	12/1/2006	12/31/2006	1758	1837	115	150.15	1.306
497679	12/1/2006	12/31/2006	1539	1649	114	40.57	0.356
497680	12/1/2006	12/31/2006	1670	1810	167	127.63	0.764
497681	12/1/2006	12/31/2006	1760	1827	83	44.78	0.540
497682	12/1/2006	12/31/2006	1699	1822	188	145.71	0.775
497683	12/1/2006	12/31/2006	1277	1383	142	117.04	0.824
497684	12/1/2006	12/31/2006	1567	1667	137	121.98	0.890
497685	12/1/2006	12/31/2006	1808	1923	164	123.96	0.756
				Total	*1420*	*1175.69*	*0.83*

GENESIS UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS USED	GALLONS PER HOUR
510488	12/1/2006	12/31/2006	1348	1451	143	172.98	1.210
510489	12/1/2006	12/31/2006	1047	1242	146	162.34	1.112
510490	12/1/2006	12/31/2006	1144	1271	165	175.18	1.062
510491	12/1/2006	12/31/2006	1167	1315	207	193.24	0.934
510492	12/1/2006	12/31/2006	1246	1392	177	184.4	1.042
510493	12/1/2006	12/31/2006	941	1092	174	197.82	1.137
510494	12/1/2006	12/31/2006	1188	1276	159	158.94	1.000
510495	12/1/2006	12/31/2006	1206	1315	162	173.06	1.068
510496	12/1/2006	12/31/2006	1158	1353	243	227.56	0.936
510497	12/1/2006	12/31/2006	794	975	191	201.6	1.055
				Total	*1767*	*1847.12*	*1.05*
				Percentage Fuel Decrease			*20.8%*

Table E-3. December 2006 Monthly Fuel Data

VECTOR UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS PUMPED	GALLONS PER HOUR
497676	1/1/2007	1/31/2007	2035	2175	171	124.38	0.727
497677	1/1/2007	1/31/2007	1999	2077	119	96.86	0.814
497678	1/1/2007	1/31/2007	1876	1953	116	78.94	0.681
497679	1/1/2007	1/31/2007	1662	1729	80	62.54	0.782
497680	1/1/2007	1/31/2007	1825	1897	87	78.33	0.900
497681	1/1/2007	1/31/2007	1867	1948	121	86.58	0.716
497682	1/1/2007	1/31/2007	1839	2017	195	153	0.785
497683	1/1/2007	1/31/2007	1417	1511	128	75.66	0.591
497684	1/1/2007	1/31/2007	1667	1759	92	40.5	0.440
497685	1/1/2007	1/31/2007	1949	2081	158	124.69	0.789
				Total	*1267*	*921.48*	*0.73*

GENESIS UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS USED	GALLONS PER HOUR
510488	1/1/2007	1/31/2007	1475	1609	158	150.14	0.950
510489	1/1/2007	1/31/2007	1255	1372	130	145.19	1.117
510490	1/1/2007	1/31/2007	1287	1495	224	143.02	0.638
510491	1/1/2007	1/31/2007	1355	1505	190	212.37	1.118
510492	1/1/2007	1/31/2007	1425	1534	142	143.98	1.014
510493	1/1/2007	1/31/2007	1109	1232	140	160.36	1.145
510494	1/1/2007	1/31/2007	1302	1443	167	183.51	1.099
510495	1/1/2007	1/31/2007	1340	1445	130	190.24	1.463
510496	1/1/2007	1/31/2007	1377	1496	143	149.84	1.048
510497	1/1/2007	1/31/2007	1017	1130	155	147.48	0.951
				Total	*1579*	*1626.13*	*1.03*
				Percentage Fuel Decrease			*29.4%*

Table E-4. January 2007 Monthly Fuel Data

VECTOR UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS PUMPED	GALLONS PER HOUR
497676	2/1/2007	2/28/2007	2175	2283	108	69.66	0.645
497677	2/1/2007	2/28/2007	2077	2260	183	110.02	0.601
497678	2/1/2007	2/28/2007	1953	2056	103	59.72	0.580
497679	2/1/2007	2/28/2007	1729	1888	159	144.97	0.912
497680	2/1/2007	2/28/2007	1897	1976	79	61.35	0.777
497681	2/1/2007	2/28/2007	1948	2149	201	151.11	0.752
497682	2/1/2007	2/28/2007	2017	2161	144	113.6	0.789
497683	2/1/2007	2/28/2007	1511	1660	149	130.49	0.876
497684	2/1/2007	2/28/2007	1759	1759	0	0	#DIV/0!
497685	2/1/2007	2/28/2007	2081	2256	175	127.61	0.729
				Total	***1301***	***968.53***	***0.74***

GENESIS UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS USED	GALLONS PER HOUR
510488	2/1/2007	2/28/2007	1609	1742	133	148.51	1.117
510489	2/1/2007	2/28/2007	1372	1540	168	226.47	1.348
510490	2/1/2007	2/28/2007	1495	1516	21	158.21	7.534
510491	2/1/2007	2/28/2007	1505	1625	120	148.94	1.241
510492	2/1/2007	2/28/2007	1534	1647	113	146.27	1.294
510493	2/1/2007	2/28/2007	1232	1386	154	164.64	1.069
510494	2/1/2007	2/28/2007	1443	1619	176	205.45	1.167
510495	2/1/2007	2/28/2007	1445	1616	171	138.07	0.807
510496	2/1/2007	2/28/2007	1496	1632	136	174.85	1.286
510497	2/1/2007	2/28/2007	1130	1239	109	131.45	1.206
				Total	***1280***	***1484.65***	***1.16***
				Percentage Fuel Decrease			***35.8%***

Table E-5. February 2007 Monthly Fuel Data

VECTOR UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS PUMPED	GALLONS PER HOUR
497676	3/1/2007	3/31/2007	2283	2462	179	116.18	0.649
497677	3/1/2007	3/31/2007	2260	2513	253	218.03	0.862
497678	3/1/2007	3/31/2007	2056	2171	115	79.69	0.693
497679	3/1/2007	3/31/2007	1888	1998	110	92.23	0.838
497680	3/1/2007	3/31/2007	1976	2205	229	176.86	0.772
497681	3/1/2007	3/31/2007	2149	2286	137	116.57	0.851
497682	3/1/2007	3/31/2007	2161	2329	168	126.38	0.752
497683	3/1/2007	3/31/2007	1660	1814	154	82.84	0.538
497684	3/1/2007	3/31/2007	1759	1759	0	0	#DIV/0!
497685	3/1/2007	3/31/2007	2256	2455	199	160.13	0.805
				Total	***1544***	***1168.91***	***0.76***

GENESIS UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS USED	GALLONS PER HOUR
510488	3/1/2007	3/31/2007	1742	1875	133	170.05	1.279
510489	3/1/2007	3/31/2007	1540	1871	331	284.87	0.861
510490	3/1/2007	3/31/2007	1516	1723	207	156.99	0.758
510491	3/1/2007	3/31/2007	1625	1753	128	152.51	1.191
510492	3/1/2007	3/31/2007	1647	1824	177	182.05	1.029
510493	3/1/2007	3/31/2007	1386	1511	125	156.82	1.255
510494	3/1/2007	3/31/2007	1619	1797	178	223.78	1.257
510495	3/1/2007	3/31/2007	1616	1790	174	188.09	1.081
510496	3/1/2007	3/31/2007	1632	1782	150	163.53	1.090
510497	3/1/2007	3/31/2007	1239	1377	138	158.08	1.146
				Total	***1741***	***1836.77***	***1.06***
				Percentage Fuel Decrease			***28.2%***

Table E-6. March 2007 Monthly Fuel Data

VECTOR UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS PUMPED	GALLONS PER HOUR
497676	4/1/2007	4/30/2007	2462	2546	84	36.77	0.438
497677	4/1/2007	4/30/2007	2513	2670	157	42	0.268
497678	4/1/2007	4/30/2007	2171	2317	146	33.11	0.227
497679	4/1/2007	4/30/2007	1998	2127	129	64.75	0.502
497680	4/1/2007	4/30/2007	2205	2353	148	86.53	0.585
497681	4/1/2007	4/30/2007	2286	2423	137	58.4	0.426
497682	4/1/2007	4/30/2007	2329	2481	152	55.79	0.367
497683	4/1/2007	4/30/2007	1814	1956	142	84.69	0.596
497684	4/1/2007	4/30/2007	1759	1894	135	104.14	0.771
497685	4/1/2007	4/30/2007	2455	2709	254	104.01	0.409
				Total	***1484***	***670.19***	***0.45***

GENESIS UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS USED	GALLONS PER HOUR
510488	4/1/2007	4/30/2007	1875	2012	137	84.74	0.619
510489	4/1/2007	4/30/2007	1871	1946	75	25.59	0.341
510490	4/1/2007	4/30/2007	1723	1860	137	69.65	0.508
510491	4/1/2007	4/30/2007	1753	1864	111	81.03	0.730
510492	4/1/2007	4/30/2007	1824	1925	101	76.9	0.761
510493	4/1/2007	4/30/2007	1511	1687	176	85.81	0.488
510494	4/1/2007	4/30/2007	1797	1945	148	87.34	0.590
510495	4/1/2007	4/30/2007	1790	1925	135	79.19	0.587
510496	4/1/2007	4/30/2007	1782	1930	148	103.51	0.699
510497	4/1/2007	4/30/2007	1377	1489	112	64.82	0.579
				Total	***1280***	***758.58***	***0.59***
						Percentage Fuel Decrease	***23.8%***

Table E-7. April 2007 Monthly Fuel Data

VECTOR UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS PUMPED	GALLONS PER HOUR
497676	5/1/2007	5/31/2007	2546	2813	267	206.78	0.774
497677	5/1/2007	5/31/2007	2670	2976	306	242.26	0.792
497678	5/1/2007	5/31/2007	2317	2390	73	88.31	1.210
497679	5/1/2007	5/31/2007	2127	2416	289	213.38	0.738
497680	5/1/2007	5/31/2007	2353	2577	224	178.91	0.799
497681	5/1/2007	5/31/2007	2423	2632	209	218.89	1.047
497682	5/1/2007	5/31/2007	2481	2754	273	258.76	0.948
497683	5/1/2007	5/31/2007	1956	2233	277	299.2	1.080
497684	5/1/2007	5/31/2007	1894	2146	252	274.27	1.088
497685	5/1/2007	5/31/2007	2709	2974	265	243.83	0.920
				Total	***2362***	***2136.28***	***0.90***

GENESIS UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS USED	GALLONS PER HOUR
510488	5/1/2007	5/31/2007	2012	2236	224	256.87	1.147
510489	5/1/2007	5/31/2007	1946	1946	0		#DIV/0!
510490	5/1/2007	5/31/2007	1860	2111	251	281.51	1.122
510491	5/1/2007	5/31/2007	1864	2091	227	259.31	1.142
510492	5/1/2007	5/31/2007	1925	2214	289	268.84	0.930
510493	5/1/2007	5/31/2007	1687	1894	207	243.63	1.177
510494	5/1/2007	5/31/2007	1945	2161	216	221.04	1.023
510495	5/1/2007	5/31/2007	1925	2151	226	221.61	0.981
510496	5/1/2007	5/31/2007	1930	2159	229	311.26	1.359
510497	5/1/2007	5/31/2007	1489	1689	200	209.88	1.049
				Total	***2069***	***2273.95***	***1.10***
						Percentage Fuel Decrease	***17.7%***

Table E-8. May 2007 Monthly Fuel Data

VECTOR UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS PUMPED	GALLONS PER HOUR
497676	6/1/2007	6/30/2007	2813	3075	262	309.39	1.181
497677	6/1/2007	6/30/2007	2976	3225	249	287.63	1.155
497678	6/1/2007	6/30/2007	2390	2677	287	305.94	1.066
497679	6/1/2007	6/30/2007	2416	2741	325	334.38	1.029
497680	6/1/2007	6/30/2007	2577	2800	223	164.44	0.737
497681	6/1/2007	6/30/2007	2632	2877	245	256.66	1.048
497682	6/1/2007	6/30/2007	2754	2985	231	228.32	0.988
497683	6/1/2007	6/30/2007	2233	2592	359	351.07	0.978
497684	6/1/2007	6/30/2007	2146	2447	301	321.45	1.068
497685	6/1/2007	6/30/2007	2974	3324	350	339.58	0.970
				Total	*2832*	*2898.86*	*1.02*

GENESIS UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS USED	GALLONS PER HOUR
510488	6/1/2007	6/30/2007	2236	2541	305	318.79	1.045
510489	6/1/2007	6/30/2007	1946	2266	320	315.03	0.984
510490	6/1/2007	6/30/2007	2111	2409	298	318.63	1.069
510491	6/1/2007	6/30/2007	2091	2392	301	312.67	1.039
510492	6/1/2007	6/30/2007	2214	2469	255	291.77	1.144
510493	6/1/2007	6/30/2007	1894	2212	318	328.3	1.032
510494	6/1/2007	6/30/2007	2161	2467	306	357.79	1.169
510495	6/1/2007	6/30/2007	2151	2411	260	247.96	0.954
510496	6/1/2007	6/30/2007	2159	2500	341	324.83	0.953
510497	6/1/2007	6/30/2007	1689	1967	278	292.16	1.051
				Total	*2982*	*3107.93*	*1.04*
				Percentage Fuel Decrease			*1.8%*

Table E-9. June 2007 Monthly Fuel Data

VECTOR UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS PUMPED	GALLONS PER HOUR
497676	7/1/2007	7/31/2007	3075	3439	364	324.46	0.891
497677	7/1/2007	7/31/2007	3225	3452	227	114.57	0.505
497678	7/1/2007	7/31/2007	2677	2904	227	213.3	0.940
497679	7/1/2007	7/31/2007	2741	3046	305	279.94	0.918
497680	7/1/2007	7/31/2007	2800	3031	231	212.47	0.920
497681	7/1/2007	7/31/2007	2877	3192	315	331.17	1.051
497682	7/1/2007	7/31/2007	2985	3270	285	288	1.011
497683	7/1/2007	7/31/2007	2592	2778	186	215.52	1.159
497684	7/1/2007	7/31/2007	2447	2823	376	399.42	1.062
497685	7/1/2007	7/31/2007	3324	3604	280	272.18	0.972
				Total	*2796*	*2651.03*	*0.95*

GENESIS UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS USED	GALLONS PER HOUR
510488	7/1/2007	7/31/2007	2541	2858	317	352.59	1.112
510489	7/1/2007	7/31/2007	2266	2633	367	327.5	0.892
510490	7/1/2007	7/31/2007	2409	2707	298	340.64	1.143
510491	7/1/2007	7/31/2007	2392	2643	251	285.88	1.139
510492	7/1/2007	7/31/2007	2469	2796	327	279.78	0.856
510493	7/1/2007	7/31/2007	2212	2629	417	406.93	0.976
510494	7/1/2007	7/31/2007	2467	2718	251	237.89	0.948
510495	7/1/2007	7/31/2007	2411	2733	322	310.73	0.965
510496	7/1/2007	7/31/2007	2500	2836	336	396.68	1.181
510497	7/1/2007	7/31/2007	1967	2250	283	366.6	1.295
				Total	*3169*	*3305.22*	*1.04*
				Percentage Fuel Decrease			*9.1%*

Table E-10. July 2007 Monthly Fuel Data

VECTOR UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS PUMPED	GALLONS PER HOUR
497676	8/1/2007	8/31/2007	3485	3782	343	358.36	1.045
497677	8/1/2007	8/31/2007	3559	3895	443	352.69	0.796
497678	8/1/2007	8/31/2007	2940	3280	376	347.77	0.925
497679	8/1/2007	8/31/2007	3114	3406	360	266.61	0.741
497680	8/1/2007	8/31/2007	3055	3198	167	177.26	1.061
497681	8/1/2007	8/31/2007	3206	3533	341	342.51	1.004
497682	8/1/2007	8/31/2007	3311	3521	251	218.88	0.872
497683	8/1/2007	8/31/2007	2797	2855	77	82.93	1.077
497684	8/1/2007	8/31/2007	2831	3039	216	232.29	1.075
497685	8/1/2007	8/31/2007	3645	3910	306	263.08	0.860
				Total	***2880***	***2642.38***	***0.92***

GENESIS UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS USED	GALLONS PER HOUR
510488	8/1/2007	8/31/2007	2884	3183	325	315.96	0.972
510489	8/1/2007	8/31/2007	2647	2901	268	299.55	1.118
510490	8/1/2007	8/31/2007	2739	3049	342	383.61	1.122
510491	8/1/2007	8/31/2007	2740	3073	430	388.91	0.904
510492	8/1/2007	8/31/2007	2828	3159	363	423.29	1.166
510493	8/1/2007	8/31/2007	2655	2897	268	285.86	1.067
510494	8/1/2007	8/31/2007	2749	3003	285	302.19	1.060
510495	8/1/2007	8/31/2007	2753	3030	297	305.76	1.029
510496	8/1/2007	8/31/2007	2868	3168	332	388.59	1.170
510497	8/1/2007	8/31/2007	2271	2560	310	331.04	1.068
				Total	***3220***	***3424.76***	***1.06***
				Percentage Fuel Decrease			***20.1%***

Table E-11. August 2007 Monthly Fuel Data

VECTOR UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS PUMPED	GALLONS PER HOUR
497676	9/1/2007	9/31/2007	3804	4015	233	239.26	1.027
497677	9/1/2007	9/31/2007	3926	4145	250	245.09	0.980
497678	9/1/2007	9/31/2007	3290	3491	211	232.74	1.103
497679	9/1/2007	9/31/2007	3440	3517	111	92.91	0.837
497680	9/1/2007	9/31/2007	3284	3568	370	306.86	0.829
497681	9/1/2007	9/31/2007	3558	3757	224	263.52	1.176
497682	9/1/2007	9/31/2007	3564	3755	234	209.38	0.895
497683	9/1/2007	9/31/2007	2884	3139	284	138.3	0.487
497684	9/1/2007	9/31/2007	3123	3310	271	242.67	0.895
497685	9/1/2007	9/31/2007	3934	4194	284	270.13	0.951
				Total	***2472***	***2240.86***	***0.91***

GENESIS UNITS:

UNIT #	START DATE	END DATE	START HOURS	END HOURS	TOTAL HOURS	GALLONS USED	GALLONS PER HOUR
510488	9/1/2007	9/31/2007	3271	3494	311	261.84	0.842
510489	9/1/2007	9/31/2007	2924	3161	260	285.19	1.097
510490	9/1/2007	9/31/2007	3104	3349	300	228.3	0.761
510491	9/1/2007	9/31/2007	3086	3287	214	242.44	1.133
510492	9/1/2007	9/31/2007	3180	3410	251	249.35	0.993
510493	9/1/2007	9/31/2007	2922	3111	214	180.38	0.843
510494	9/1/2007	9/31/2007	3051	3175	172	170.53	0.991
510495	9/1/2007	9/31/2007	3084	3352	322	302.68	0.940
510496	9/1/2007	9/31/2007	3203	3423	255	289.32	1.135
510497	9/1/2007	9/31/2007	2592	2826	266	281.26	1.057
				Total	***2565***	***2491.29***	***0.97***
				Percentage Fuel Decrease			***3.8%***

Table E-12. September 2007 Monthly Fuel Data

E.1.2 EXPLANATION OF TERMS (TABLES)

Unit # = Trailer unit number

Total Hours – The total hours is the End hours for the month in question minus the End hours for the month prior. This is done to determine the amount of hours the truck was in service for the month in question. It is not End hours – Start Hours because in a lot of cases the start hours for the month would not match up with the end hours from the previous month, causing time that the truck was active to be discarded and not included in analysis. We are not sure how to account for this lapse in collection though, as the two numbers should be equal.

Gallons used Per Hour – The “gallons per hour” column is a measure of the average amount of gallons used per hour of operation for the trailer. It is calculated by taking the amount of gallons used divided by the total hours of operation for the trailer. The lower the number, the more efficient the trailer is.

Totals: The totals are the sums of each column. For the “total hours” column, it is simply the sum of all the total hours of each truck. The “total gallons” is the sum of the amount of gallons used by each truck.

The average GPH (Gallons per Hour) is the total gallons used divided by the total hours used. It is not the average of the GPH of each truck because if this method was used, the trucks that were slight outliers would influence the total average too much and give inaccurate results.

Percentage fuel decrease-- is the average GPH of the genesis units minus the average GPH of the vector units (Not shown in picture above) divided by the average GPH of the genesis units. This calculation gives the percent reduction of the vector unit’s average fuel use as a percentage of the average fuel use of the genesis unit. This is somewhat of a rough estimate though, as all factors relating to the average fuel use cannot be taken into account because they are not tracked, such as the exact things that are in the loads inside the trucks.

E.2.1 ELECTRICAL FACILITY DATA

	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7	Slot 8	Slot 9	Slot 10	Dock 1	Dock 2	**Slot Totals**
Total Hours (Plugged In)	63.7	0.0	0.0	0.0	43.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**106.9**
Energy Usage (Plugged In) kW-hr	287.4	0.0	0.0	0.0	148.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**435.8**
Average Power (Plugged In) kW	4.5	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**4.1**
Total Hours (Operational)	*44.6*	0.0	0.0	0.0	20.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**65.4**
Energy Usage (Operational) kW-hr	286.8	0.0	0.0	0.0	148.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**434.9**
Average Power (Operational) kW	6.4	0.0	0.0	0.0	7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**6.6**

Table E-13. September 2006

	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7	Slot 8	Slot 9	Slot 10	Dock 1	Dock 2	Slot Totals
Total Hours (Plugged In)	0.0	0.0	0.0	0.0	137.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**137.8**
Energy Usage (Plugged In) kW-hr	0.0	0.0	0.0	0.0	617.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**617.7**
Average Power (Plugged In) kW	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**4.5**
Total Hours (Operational)	*0.0*	0.0	0.0	0.0	74.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**74.9**
Energy Usage (Operational) kW-hr	0.0	0.0	0.0	0.0	616.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**616.4**
Average Power (Operational) kW	0.0	0.0	0.0	0.0	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**8.2**

Table E-14. October 2006

	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7	Slot 8	Slot 9	Slot 10	Dock 1	Dock 2	Slot Totals
Total Hours (Plugged In)	45.0	44.8	0.0	44.8	37.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**171.9**
Energy Usage (Plugged In) kW-hr	112.1	114.1	0.0	214.7	103.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**544.1**
Average Power (Plugged In) kW	2.5	2.5	0.0	4.8	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**3.2**
Total Hours (Operational)	*21.1*	19.6	*0.0*	29.7	17.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**87.8**
Energy Usage (Operational) kW-hr	111.7	113.2	0.0	214.3	103.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**542.2**
Average Power (Operational) kW	5.3	5.8	0.0	7.2	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**6.2**

Table E-15. November 2006

	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7	Slot 8	Slot 9	Slot 10	Dock 1	Dock 2	Slot Totals
Total Hours (Plugged In)	25.3	56.9	0.0	44.9	14.3	0.0	0.0	0.0	0.0	0.0	0.4	0.0	**141.3**
Energy Usage (Plugged In) kW-hr	214.5	105.8	0.0	124.9	78.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	**523.3**
Average Power (Plugged In) kW	8.5	1.9	0.0	2.8	5.5	0.0	0.0	0.0	0.0	0.0	0.3	0.0	**3.7**
Total Hours (Operational)	*24.0*	21.8	0.0	20.8	9.6	0.0	0.0	0.0	0.0	0.0	0.2	0.0	**76.1**
Energy Usage (Operational) kW-hr	214.5	104.6	0.0	124.5	78.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	**521.7**
Average Power (Operational) kW	8.9	4.8	0.0	6.0	8.1	0.0	0.0	0.0	0.0	0.0	0.7	0.0	**6.9**

Table E-16. December 2006

	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7	Slot 8	Slot 9	Slot 10	Dock 1	Dock 2	Totals
Total Hours (Plugged In)	0.0	28.8	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**29.9**
Energy Usage (Plugged In) kW-hr	0.0	73.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**73.6**
Average Power (Plugged In) kW	0.0	2.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**2.5**
Total Hours (Operational)	0.0	16.4	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**17.3**
Energy Usage (Operational) kW-hr	0.0	72.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**73.2**
Average Power (Operational) kW	0.0	4.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**4.2**

Table E-17. January 2007

	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7	Slot 8	Slot 9	Slot 10	Dock 1	Dock 2	**Slot Totals**
Total Hours (Plugged In)	0.0	50.4	0.0	67.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**117.7**
Energy Usage (Plugged In) kW-hr	0.0	228.2	0.0	314.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**542.9**
Average Power (Plugged In) kW	0.0	4.5	0.0	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**4.6**
Total Hours (Operational)	*0.0*	30.6	*0.0*	38.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**68.9**
Energy Usage (Operational) kW-hr	0.0	227.5	0.0	314.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**541.7**
Average Power (Operational) kW	0.0	7.4	0.0	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**7.9**

Table E-18. June 2007

	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7	Slot 8	Slot 9	Slot 10	Dock 1	Dock 2	**Totals**
Total Hours (Plugged In)	0.0	50.0	0.0	0.0	161.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**211.7**
Energy Usage (Plugged In) kW-hr	0.0	276.9	0.0	0.0	867.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1144.0**
Average Power (Plugged In) kW	0.0	5.5	0.0	0.0	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**5.4**
Total Hours (Operational)	*0.0*	32.2	*0.0*	0.0	100.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**132.3**
Energy Usage (Operational) kW-hr	0.0	276.2	0.0	0.0	866.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1142.3**
Average Power (Operational) kW	0.0	8.6	0.0	0.0	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**8.6**

Table E-19. July 2007

	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7	Slot 8	Slot 9	Slot 10	Dock 1	Dock 2	**Totals**
Total Hours (Plugged In)	0.0	244.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**244.6**
Energy Usage (Plugged In) kW-hr	0.0	1221.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1221.3**
Average Power (Plugged In) kW	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**5.0**
Total Hours (Operational)	*0.0*	182.7	*0.0*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**182.7**
Energy Usage (Operational) kW-hr	0.0	1217.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1217.8**
Average Power (Operational) kW	0.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**6.7**

Table E-20. August 2007

	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7	Slot 8	Slot 9	Slot 10	Dock 1	Dock 2	**Totals**
Total Hours (Plugged In)	0.0	174.3	0.0	0.0	0.0	0.0	36.9	0.0	0.0	0.0	0.0	0.0	**211.3**
Energy Usage (Plugged In) kW-hr	0.0	822.0	0.0	0.0	0.0	0.0	144.8	0.0	0.0	0.0	0.0	0.0	**966.8**
Average Power (Plugged In) kW	0.0	4.7	0.0	0.0	0.0	0.0	3.9	0.0	0.0	0.0	0.0	0.0	**4.6**
Total Hours (Operational)	*0.0*	97.3	*0.0*	0.0	0.0	0.0	20.8	0.0	0.0	0.0	0.0	0.0	**118.2**
Energy Usage (Operational) kW-hr	0.0	819.5	0.0	0.0	0.0	0.0	144.5	0.0	0.0	0.0	0.0	0.0	**964.0**
Average Power (Operational) kW	0.0	8.4	0.0	0.0	0.0	0.0	6.9	0.0	0.0	0.0	0.0	0.0	**8.2**

Table E-21. September 2007

*The electrification system was suspended from February 2007 through May 2006 and thus data was not collected for this time period.

E.3.2 DEFINITON OF TERMS

Average Power- The average power in kilowatts used during each five-minute interval. This value was provided by the raw data.

Minutes (Plugged In / Operational) - It is important to make the distinction between Minutes (Plugged In) and Minutes (Operational). The purpose of the Shurepower pedestal is to enable the eTRU to use electricity rather than diesel fuel in order to bring down the temperature of the trailer to the desired level. Once this temperature is reached, the electrical power is not needed again until the trailer temperature rises above some critical value. After speaking with Shurepower and Maines, it was concluded that although the power readings for some five minute intervals displayed a "0" or low power value, the trailer was still plugged into the pedestal, just not delivering any power. Therefore, it was assumed if there was a power reading of less than 0.2 kilowatts (control box power) for more than fifteen consecutive minutes, then there was no trailer plugged in at the end of that time period. This explanation corresponds to the "0" values in the Minutes (Plugged-In) column of the Excel data summary files. If there were power readings of more than 0.2 kilowatts for more than fifteen consecutive minutes, it was assumed there was a trailer plugged in during that interval and a "5" value was assigned to the Minutes (Plugged-In) column.

The Minutes (Operational) column simply logs whether or not a five-minute interval displayed an Average Power value greater than 0.2 kilowatts, and a "5" or "0" was inserted, respectively, into the corresponding cell in the Minutes (Operational) column.

It is important to note that the Minutes (Operational) should not be taken as an accurate representation of how often the eTRU is operating on electrical power to pull down the trailer's temperature. It is ultimately an overestimate of that value. For the purposes of this data analysis, it serves instead as a numerical placeholder (either "0" or "5") for retrieving the actual Energy Usage (Operational) from the Average Power value of each five-minute interval.

Energy Usage (Plugged In) - This value is the energy usage in kilowatt-hours calculated by taking the product of the Average Power for each five-minute interval and the corresponding Minutes (Plugged In) value. It is the energy usage of the eTRU while it is plugged into the Shurepower pedestal.

Energy Usage (Operational) - This value is the energy usage in kilowatt-hours calculated by taking the product of the Average Power for each five-minute interval and the corresponding Minutes (Operational) value. It is the energy usage of the eTRU while it is undergoing temperature pull-down operations. The Energy Usage (Plugged In) will be larger than the Energy Usage (Operational).

After all of these calculations were completed for every five-minute interval for the duration of each month, a daily and monthly summary were produced. The summary parameters include Total Hours (Plugged In), Energy Usage (Plugged In), Average Power (Plugged In), Total Hours (Operational), Energy Usage (Operational), and Average Power (Operational). The definitions of these terms are given below.

1. Total Hours (Plugged In): For the daily summary, the total Minutes (Plugged In) for each day were summed and divided by 60 min/hour to calculate an hour total. For the monthly summary, the total hours per day were summed.

2. Energy Usage (Plugged In): The sum of Energy Usage (Plugged In) in kilowatt-hours, for the duration of each day and for the duration of the month.

3. Average Power (Plugged In): The Average Power in kilowatts consumed during the time intervals that the trailer was plugged into the pedestal.

4. Total Hours (Operational): For the daily summary, the total Minute (Operational) for each day were summed and divided by 60 min/hour to calculate an hour total. For the monthly summary, the total hours per day were summed.

5. Energy Usage (Operational): The sum of Energy Usage (Operational) in kilowatt-hours, for the duration of each day and for the duration of the month.

6. Average Power (Operational): The Average Power in kilowatts consumed while the eTRU was actively pulling down the trailer temperature.

APPENDIX F:
Action Plan to Address Plug Trailer Connector Failure

INCIDENT: eTRU connection at back of unknown Maines trailer was smoking, other unknown Maines eTRU trailer was operating on diesel when connected t the electrical facility.

Issue 1: Activities surrounding the incident are unclear

Action 1: Contact electrical contractor to review possible causes for this failure (Joe Licari)

Action 2: Identify the trailers in question from Jeff David (Joe Licari)

Action 3: Interview the Maines personnel that witnessed the incident to determine which pedestal(s) the trailers were connected to, which trailers were involved, did the other breaker for the unit running on diesel trip?, time of day, length of time plugged in, other factors (Joe Licari)

Issue 2: Review all possible causes for this incident

Action 1: Contact NYSEG – Jim Harvilla – to determine if a power quality issue occurred at the time of the incident (Joe Licari)

Action 2: Have Carrier perform a check of the two eTRUs involved to ensure they are operating correctly (Joe Licari)

Action 3: Have Penske/Maines inspect entire wiring system of the two trailers involved including connection port at rear of trailer to ensure that the wiring system has not been damaged during use (Joe Licari)

Action 4: Have Carrier perform a continuity test to ensure that the wiring system is in operating condition – Phase connected to ground can cause an issue (Joe Licari)

Action 5: Have Carrier/Penske/other perform a continuity test of the extension cables to ensure that cables were correctly assembled; again Phase connected to ground can cause an electrical problem (Joe Licari)

Action 6: With Maines and Carrier, investigate to determine if these trailer have ever plugged into the system previously (Joe Licari)

EPA Helps Truckers Keep Their Cool While Going Green; Hybrid Diesel Electric Trailer Refrigeration Units Cut Air Pollution

4/11/2007 11:43:31 AM

EPA Helps Truckers Keep Their Cool While Going Green; Hybrid Diesel Electric Trailer Refrigeration Units Cut Air Pollution

Release date: 04/11/2007

Contact Information: Elias Rodriguez (212) 637-3664, rodriguez.elias@epa.gov

(New York, N.Y.) What do chicken dinners, salmon and filet mignon have in common? They could all be found in a state-of-the-art pollution slashing hybrid diesel electric trailer refrigeration unit like the one showcased by the U.S. Environmental Protection Agency (EPA) today at Pier 92. The technology allows refrigerated trucks and trailers to remain icy cold while switching from diesel power to electric power during loading and unloading, reducing diesel emissions to zero. The technology also puts a lid on fuel costs and noise. EPA's Regional Administrator Alan J. Steinberg appeared with representatives from the New York State Energy and Research Development Authority (NYSERDA) and companies that make the technology to observe a low-polluting truck that delivered goods to a Holland America Lines cruise ship at the New York City Economic Development Corporation's facility.

"Hybrid diesel electric power demonstrates that businesses can go green while they keep their cool," said Alan J. Steinberg, EPA Regional Administrator. "Refrigeration is an integral part of America's transportation and delivery system. Thanks to EPA and our partners, businesses now have the power to shrink their environmental footprint while increasing their bottom line."

Paving the way for cleaner and energy efficient alternatives in the trucking industry, Shurepower LLC, Carrier Transicold, Maines Paper and Food Service, Inc., New West Technologies and Great Dane Trailers used money provided by EPA and NYSERDA to help fund the first of its kind demonstration pilot project. The original pilot project, located in a Maines Paper & Food Service, Inc. distribution facility in Conklin, N.Y. involved setting up and operating electrified loading docks and parking spaces for commercial heavy-duty diesel trucks and refrigerated trailers to power the refrigeration. The project was part of a nation-wide effort to reduce pollution from truck fleets known as EPA's SmartWay Transport Partnership.

NYSERDA President and CEO Peter R. Smith noted that since 2000, New York State has committed $2.55 million in cooperation with EPA and the Department of Energy in pursuing technologies to displace the nation's petroleum use that goes to transportation. "NYSERDA projects thrive on cooperation among our federal and private partners. Through hybrid-power technology applications, we can make advances to ensure that motor freight, and especially food, is cared for in the most energy-efficient and environmentally responsive way," Smith said.

Trailer refrigeration units are the standard for preserving and cooling goods during transport and delivery. The demonstration project featured eTRU, also known as hybrid diesel electric trailer refrigeration unit. eTRU technology enables an electric powered source of energy from a loading dock or parking space to keep the truck's load or trailer compartments at a specific temperature without having to run the engine. The technology works by installing an electric device on a loading dock or parking space and equipping a diesel truck or refrigerated trailer with special components that connect the diesel engine to the electric power grid. Once plugged in, the diesel engine can be totally shut down producing zero diesel emissions.

The Carrier Transicold Vector 1800 MT multi-temperature trailer refrigeration system features unique, hybrid diesel-electric technology that enables shippers to effectively regulate the temperature of multiple compartments within the trailer. It combines a diesel engine with an electrical generator to reduce air pollution and sound levels, eliminate many components and maintenance items, and increase reliability and performance. The Shurepower's electrified truck parking system is a low cost alternative to idling that provides drivers with grid-based electricity. Maines Paper & Food Service, Inc. was a key partner in developing the project at its distribution center in Conklin, NY. New West Technologies, LLC assisted Shurepower in the project by providing engineering expertise.

EPA recognizes that various technologies, strategies, and behaviors can effectively reduce long-duration idling while providing the truck driver with essential needs such as heat or air conditioning. Truck stop electrification allows the electrical grid to supply power to truck on-board components or stationary components for heating, cooling and other needs.

Extended idling has a significant impact upon air quality. On a national scale, extended truck idling contributes, annually, 11 million tons of carbon dioxide, 200,000 tons of oxides of nitrogen, and 5,000 tons of particulate matter. Additionally, idling long haul trucks consume over one billion gallons of fuel, costing over $2 billion annually.

The SmartWay Transport Partnership is an innovative program developed by EPA and the freight industry to reduce greenhouse gases and air pollution, and to promote cleaner, more efficient ground freight transportation. The Partnership provides companies with technical assistance, tools for evaluating opportunities, and help locating financing to purchase these technologies.

To learn more about EPA's SmartWay Transport Partnership, please visit: http://www.epa.gov/smartway/

Related Links

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Contact Information:

SHUREPOWER PROJECT PRESS RELEASE

Shurepower, LLC announces an energy efficient alternative to truck and TRU idling at the nation's second largest food distribution center

Thursday, January 19, 2006 2:00 PM

CONKLIN, NY -- (SBWIRE) -- 01/19/2006 -- The New York State Energy Research and Development Authority (NYSERDA) has recently awarded a cost-shared contract to Shurepower, LLC to enable the installation and operation of electrified loading docks and parking spaces for heavy-duty diesel trucks and refrigerated trailers. With co-funding from the U.S. Environmental Protection Agency's Smartway Transport Partnership, this project seeks to demonstrate electric-powered Trailer Refrigeration Units (TRUs) and document their ability to reduce air pollution, noise, and diesel fuel use.

This demonstration project also uses a modified version of Shurepower's Truck Electrified Parking (STEP) technology. As diesel-powered TRUs are a local pollutant source of exhaust emissions, they present an excellent opportunity to improve local air quality. A Carrier-Transicold's new TRU featuring Deltek hybrid diesel electric technology will be used to demonstrate this capability. Providing ?shorepower? electricity to power tractor cabs and trailer refrigeration units can eliminate unnecessary local exhaust emissions and noise pollution.

Located at the Maines Paper & Food Service, Inc. distribution facility in Conklin, NY, the demonstration project is the first of its kind to supply grid power to over-the-road electric hybrid TRU refrigerated trailers. New West Technologies, LLC will be assisting Shurepower in the project by providing engineering expertise. Shurepower will work with the utility company, New York State Electric & Gas (NYSEG), to provide three-phase power to the site. Designated loading docks, along with parking spaces that serve as staging areas for the trailers, will be electrified. Ten (10) demonstration trailers manufactured by Great Dane Trailers will be outfitted with Carrier-Transicold TRUs equipped with Deltek hybrid diesel electric technology that can be directly powered by electricity. Shurepower will provide the design of an under-trailer wiring system to carry electricity from the rear connection point (at the loading bay) to the TRU mounted on the front of the trailer. In addition, truck tractors (supplied by Penske Truck Leasing Co.) will be retrofitted to allow for shorepower plug-in capability for sleeper cab comfort.

Partners with Shurepower, LLC in this demonstration project include NYSERDA, Maines Paper & Food Service, NYSEG, Carrier Transicold, Great Dane Trailers, Penske Truck Leasing Company, and the U.S. Environmental Protection Agency.

Shurepower, LLC is a New York based limited liability company with the corporate goal of improving air quality, reducing U.S. dependence on foreign oil, and improving public safety. Shurepower's shorepower truck electrified parking (STEP) system is a low cost alternative to idling that provides drivers with grid based electricity, cable television and high-speed Internet connections to enable drivers of long-haul heavy-duty trucks to shut down their engines and save fuel during mandated rest periods. Shurepower is currently deploying a national network of STEP facilities at truck stops, rest areas, and fleet terminal facilities along major U.S. Interstate highways. www.shurepower.com

NYSERDA, New York State Energy Research and Development Authority, is a public benefit corporation created in 1975 by the New York State Legislature. NYSERDA's responsibilities, among others, include conducting a multifaceted energy and environmental research and development program to meet New York's diverse economic needs; administering the New York Energy $mart program; making energy more affordable for residential and low-income households; assisting industries, schools, hospital, municipalities; not-for-profits, and the residential sector implement energy efficiency measures; financing energy-related projects that reduce cost for ratepayers. www.nyserda.org

Maines Paper & Food Service is the nation's second largest independently held systems foodservice distributor. Celebrating over 86 years in the foodservice industry, Maines has annual sales in excess of $2 billion. Maines services restaurants, healthcare and educational facilities, and other foodservice customers in 35 contiguous states throughout the Northeast, Mid-Atlantic, Gulf States and Mid-West from nine distribution centers. www.maines.net

Carrier Transicold provides industry-leading transport temperature-control solutions with a complete line of equipment for refrigerated trucks, trailers and containers, and transport air conditioning systems for buses and recreational vehicles. Carrier-Transicold is a division of Farmington, Conn.-based Carrier Corporation, the world's largest heating, air conditioning and refrigeration solutions provider, with operations in 172 countries. It is part of United Technologies Corporation (NYSE:UTX), a Hartford, Conn.-based provider of a broad range of high-technology products and support services to the aerospace and building systems industries. www.trucktrailer.carrier.com

NYSEG, New York State Electric & Gas Corporation, is a subsidiary of Energy East Corp [NYSE:EAS], a super-regional energy services and delivery company in the Northeast. NYSEG serves 854,000 electricity customers and 254,000 natural gas customers across more than 40% of upstate New York. By providing outstanding customer service, promoting competition and focusing on growth, NYSEG will continue to be a valuable asset to the communities it serves. www.nyseg.com

Penske Truck Leasing Co., headquartered in Reading, Pa., is a joint venture of Penske Corporation and General Electric. A leading global transportation services provider, the company operates more than 200,000 vehicles and serves customers from nearly 1,000 locations in the United States, Canada, Mexico, South America, and Europe. Product lines include full-service leasing, contract maintenance, commercial and consumer rental, transportation and warehousing management, and supply chain management solutions. Penske Truck Leasing's annual revenue is approximately US $3.7 billion. www.pensketruckleasing.com

Great Dane Trailers, a manufacturer of dry van, refrigerated and platform trailers, has long been regarded as the industry leader in technology, innovation and quality. The company has headquarters in Savannah, Ga., and Chicago, Ill., with nine strategically located manufacturing plants in the United States. Four of the manufacturing facilities ? Savannah; Terre Haute and Brazil, Ind.; and Wayne, Neb. ? have received ISO 9001:2000 certification. With distribution points across North and South America, Great Dane utilizes a network of company-owned branches and full-line independent dealers as well as parts-only independent dealers. www.greatdanetrailers.com

New West Technologies, LLC is a small native American-owned engineering services company headquartered in Denver, Colorado with a transportation systems and technology practice based in Landover, Maryland. The firm has extensive experience with truck stop electrification and in heavy truck systems. New West supplies technical and engineering services to both Federal and state governments as well as to the private sector. www.newwesttech.us

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Appendix I:
Transportation Research Board Annual Meeting Poster **on eTRU Demonstration Project**

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http://www.shurepower.com

SHUREPOWER

Real-World Demonstration of Grid-Powered Electric Trailer Refrigeration Unit (eTRU) Technology

REFRIGERATED TRUCKING INDUSTRY

Refrigerated Transport Background

- Approximately 225,000 reefers operating in the U.S
- About 75% of U.S. food is produced, packaged, shipped, and stored under temperature control

Current Operational Issues

- EPA and CARB emission regulations
- Often operate and idle in residential areas
- Increasing diesel prices

Current Diesel-fueled TRUs:

- Efficient and reliable
- Versatile enough to keep food cold, frozen, or deeply frozen
- Significant emitters of noise and air pollutants

An assessment of electric TRU commercialization was performed to determine the commercial market for the eTRU in the United States.

http://nyserda.org/publications/ElectricPoweredTrailerRefrigeration.pdf

ENABLING TECHNOLOGY DEVELOPED: NEW DELTEK™ HYBRID DIESEL ELECTRIC TECHNOLOGY FROM CARRIER TRANSICOLD: VECTOR 1800MT™

Promises a Number of Benefits over existing Diesel Technology:

- Unprecedented system reliability
- Reduced operating costs, emissions, and diesel fuel usage
- Reduced maintenance costs

DELTEK™ Technology Operation

- Over-the-road: runs off diesel generator
- Parked at facility: can operate off of electrical power

eTRU REFRIGERATED WAREHOUSE TECHNOLOGY DEMONSTRATIONS

Project Overview

- Real-world demonstration project of Carrier Transicold Deltek™ technology
- Two warehouse test facilities: Maines Paper & Food Service, Inc. (MAINES) in Conklin, NY and Willow Run Foods Inc. (WRF) in Kirkwood, NY
- Funding provided by New York State Energy Research and Development Authority (NYSERDA) and the U.S. Environmental Protection Agency.
- Additional project partners: New West Technologies, LLC, Shurepower, LLC, Carrier Transicold, New York State Electric and Gas (NYSEG), and refrigerated transport partners (MAINES and WRF)

Modifications to Existing Facilities

- 30 Amp connections provided to each eTRU
- 300 Amp, 460VAC 3-phase service was developed by modifying the existing electrical infrastructure
- Power receptacles are mounted in a parking area and on the refrigerated warehouse at the centerline between two adjacent parking spaces delivering two feeds of 30 Amp, 460VAC 3-phase power

Modifications to Existing Trailers

- Cable was hardwired to the DELTEK eTRU and an under trailer cable system was installed
- OEM electric power connector was removed from the eTRU and remounted at the rear of the trailer
- Shore power can now be connected at the rear of trailer as trailers are backed into parking spaces and warehouse docks

Current Activities

- MAINES demonstration:
  - 10 DELTEK test trailers, 10 conventional TRU control trailers, GPS units
  - Interim assessment will be completed in April 2007
  - Final project assessment will be completed in November 2007
- WRF demonstration:
  - 9 DELTEK test trailers, control TRU trailers TBD, modified warehouse dock
  - Final project assessment will be completed in November 2007

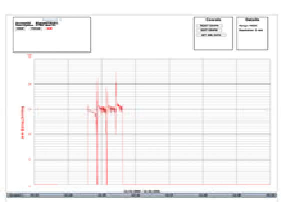
DATA COLLECTION / RESULTS

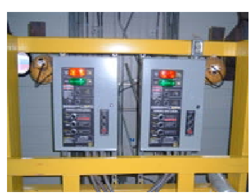
Variables / Measurement Techniques

- Electricity use data: stored in a proprietary wireless data collection that can be accessed by internet
- TRU operational data: trip temperature data, network events, alarms, operational hours
- Fuel use data

Preliminary Results

- Electrical facility is operational and data collection is underway
- Refrigerated warehouse partners have modified operations to take advantage of electric connection





Future Phases and Desired Outcome

- Develop modular system for all refrigerated warehouse facilities
- Enlarge system to permit full facility electrification
- Enhance safety of warehouse and parking area connections

ACKNOWLEDGEMENTS

This poster and corresponding paper were prepared by New West Technologies, LLC, Shurepower, LLC, Carrier Corporation, and New York State Electric and Gas in the course of performing work contracted for and sponsored by the New York State Energy Research and Development Authority, and the U.S. Environmental Protection Agency.

Appendix J:

CARRIER-TRANSICOLD ARTICLE ON PROJECT

Putting Vector 1800MT™ Units to the Test

Maines Paper & Food Service Pilots Program Proving Effectiveness of Electric Transport Refrigeration Units

One of the top independent food service distributors in the country, Maines Paper & Food Service, is playing a leadership role in identifying new technologies and methods to save energy and reduce exhaust emissions through a demonstration project backed by the U.S. EPA and the State of New York.

The project is the first of its kind to supply grid power to electric hybrid trailer refrigeration units, or eTRUs. And Vector 1800MT™ multi-temperature units from Carrier Transicold are playing a key role, potentially saving thousands of gallons of fuel per year for Maines. By its conclusion, the study may ultimately lead to a transformation of how food distribution centers and others manage the loading process for perishable products.

The project is being implemented at Maines' flagship distribution center in Conklin, N.Y., a facility located near Binghamton along the Susquehanna River in south central New York, just north of the Pennsylvania line. It is being put together with co-funding assistance from the U.S. EPA and the New York State Energy Research and Development Authority (NYSERDA).

When the installation is complete later this summer, Maines will be able to start documenting its ability to reduce air pollution, noise and diesel fuel use for NYSERDA and the EPA, agencies that support a variety of trucking industry-related initiatives aimed at meeting current and future environmental and energy needs.

The project brings together numerous leaders in the transport industry working cooperatively on Maines' behalf: Shurepower LLC serving as general contractor; New West Technologies LLC for engineering and consulting services; New York State Electric & Gas Corp. providing three-phase power to the site; Great Dane supplying the trailers, and Carrier Transicold.

"It's all about partnerships," explained John Penizotto, Carrier's regional sales manager on the project.

From Loading Docks to Ship Docks

From nine distribution centers Maines supports restaurants, healthcare and educational facilities and other food service customers in 35 contiguous states throughout the Northeast, Mid-Atlantic, Gulf States and the Midwest. The Conklin facility, which is also headquarters for Maines, is a major provider to the cruise ship industry operating out of the ports in Boston, New York, New Jersey and Philadelphia.

In Conklin, Maines is upgrading and installing electrified loading docks and 10 parking spaces for eTRUs as part of the demonstration project. Ten Vector 1800MT units are being added to the Maines fleet, installed on Great Dane trailers based at the facility.

down, totally eliminating fuel consumption and emissions from the refrigeration system. A 460-volt power supply and proper connections are all that are required.

That's where Shurepower comes into the project, according to Joe Licari, director of Eastern Operations for Shurepower, a company known for its shore-power truck electrified parking system that provides long-haul drivers with grid-based electricity, cable TV and Internet connections so they eliminate idling and save fuel during mandated rest periods – a similar concept.

Maines already had some existing electrical connections, but they needed to be modernized and upgraded for a higher amperage load. Additionally, cabling needed to be run from the Vector units to the back of the trailers so that the units can be plugged into receptacles when backed into the loading docks. Carrier Transicold of Upstate New York handled the trailer wiring needs.

Accountability is Key

For Maines, Shurepower is also setting up a control system to monitor electric consumption and provide third-party verification of emissions reduction.

While fuel savings were a driving force in the rationale for the project, the continued increases in the price of diesel fuel simply strengthen the case.

In laying out the rationale for NYSERDA and the EPA, Shurepower's feasibility study included an economic analysis of the fuel savings likely to result from the project.*

According to the report, a single eTRU switching to shore power during mandated 10-hour rest periods will realize a diesel fuel savings of approximately 2,200 gallons per year. Even after the cost of electricity is factored in, a savings of $3,284 to $5,489 per year, per truck is estimated. The report also points out that because eTRUs require less maintenance than conventional mechanical refrigeration units, the anticipated maintenance costs will be an estimated 30 percent less, resulting in further savings.

With such potential savings, as well as reducing emissions and sound output from idling trucks, it's no wonder Boisson said, "We're eager to start the testing."

**See the full project proposal, including detailed economic analysis, by checking the link at www.shurepower.com/shureRD.htm.*

Claude Boisson, vice president of operations for Maines, has high expectations for the project. He sees it especially helping with the cruise ship work, which "doesn't fall into the mold of regular business."

Trailers destined for ocean liners start loading early in the week for weekend delivery to the ports. "There is a lot of attention to detail," Boisson explained, "double checking and triple checking for accuracy." And all throughout that time, the trailer refrigeration systems need to run to protect the cargo. Without electrification, that means burning diesel.

Vector Technology Makes it Possible

The Vector 1800MT unit is Carrier's new hybrid diesel-electric system for the North American marketplace. It does away with conventional mechanical components such as belts, pulleys and clutches and instead uses electricity from a high-performance generator to run the compressor, evaporator and condenser fans and the heating system.

Because the Vector 1800MT unit is electric, it can be plugged into an AC power supply when the trailer is parked, and the diesel motor that drives the generator can be shut

Maines' flagship distribution center in Conklin, N.Y