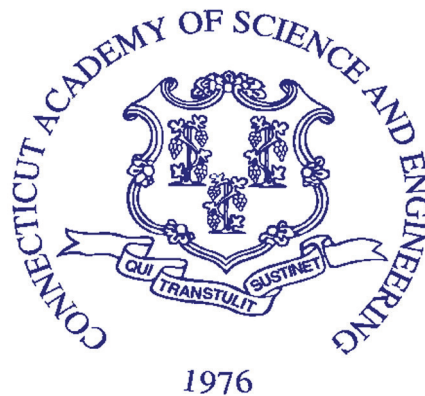# ENERGY EFFICIENCY AND RELIABILITY SOLUTIONS FOR RAIL OPERATIONS AND FACILITIES

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A REPORT BY

THE CONNECTICUT ACADEMY OF SCIENCE AND ENGINEERING

FOR

THE CONNECTICUT DEPARTMENT OF TRANSPORTATION

Energy Efficiency and Reliability Solutions For Rail Operations and Facilities

A Report By

The Connecticut Academy of Science and Engineering

Origin of Inquiry:	The Connecticut Department of Transportation
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This study was initiated at the request of the Connecticut Department of Transportation on October 25, 2013. The project was conducted by an Academy Study Committee with the support of the UConn Transportation Institute/UConn Center for Clean Energy Engineering, with Ray Necci serving as Study Manager and Technical Lead. The content of this report lies within the province of the Academy's Transportation Systems and Energy Use and Production Technical Boards. The report has been reviewed by Academy Members A. George Foyt, ScD, and Herbert S. Levinson, DrEng, PE. Martha Sherman, the Academy's Managing Editor, edited the report. The report is hereby released with the approval of the Academy Council.

Richard H. Strauss
Executive Director

Disclaimer

The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Connecticut Department of Transportation. The report does not constitute a standard, specification, or regulation.

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ENERGY EFFICIENCY AND RELIABILITY SOLUTIONS
FOR RAIL OPERATIONS AND FACILITIES

16. Abstract: The objectives of the study included examining energy consumption of the facilities comprising the three major rail yards on the New Haven Rail Line as well as platform stations and identifying energy efficiency and cost savings opportunities for rail operations/facilities. This study will focus on identifying opportunities and options to improve energy efficiency and reliability. Solutions for reducing energy costs and reliance on fossil fuels that take into account the needs of Connecticut's rail operations/facilities will be recommended. The primary conclusions include the following: CTDOT should assign a staff person to serve as an energy manager tasked with leading energy efficiency and conservation efforts for all rail facilities/stations and incorporating the importance of these efforts into the culture of the department. Under the energy manager's leadership, CTDOT should implement a comprehensive process to exploit energy efficiency and reliability opportunities for rail facilities/stations. This process should include conducting periodic energy audits of facilities, developing an energy management plan, and incorporating the findings into an asset management plan. Project planning, engineering and design, and construction, as well as rail operations that are conducted at the facilities/stations should be integrated into this process. Importantly, initiatives and projects should be evaluated with results integrated into future planning.

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EXECUTIVE SUMMARY

This study was conducted for the Connecticut Department of Transportation (CTDOT) by the Connecticut Academy of Science and Engineering (CASE). The objectives of the study included examining energy consumption of the facilities comprising the three major rail yards on the New Haven Rail Line as well as platform stations and identifying energy efficiency and cost savings opportunities for rail operations and facilities. This study focused on identifying opportunities and options to improve energy efficiency and reliability. Additionally, solutions for reducing energy costs and reliance on fossil fuels that take into account the needs of Connecticut's rail operations and facilities will be recommended. The report includes the following:

- Literature Review

- Connecticut Practices

- Best Practices

- Recommendations and Conclusions

BRIEF STATEMENT OF PRIMARY CONCLUSION

CTDOT should assign a staff person to serve as an energy manager tasked with leading energy efficiency and conservation efforts for all rail facilities/stations and incorporating the importance of these efforts into the culture of the department. Under the energy manager's leadership, CTDOT should implement a comprehensive process to exploit energy efficiency and reliability opportunities for rail facilities/stations. This process should include conducting periodic energy audits of facilities, developing an energy management plan, and incorporating the findings into an asset management plan. Project planning, engineering and design, and construction, as well as rail operations that are conducted at the facilities/stations should be integrated into this process. Importantly, initiatives and projects should be evaluated with results integrated into future planning.

LITERATURE REVIEW

An extensive literature search was conducted to identify previous studies in this field, including research on new energy saving, clean energy, and energy reliability technologies. Common findings from the literature reviewed include:

- The largest energy loads consistently identified for typical commercial buildings were heating ventilating, and air conditioning (HVAC), and lighting. Since the facilities that comprise the rail yards in Connecticut are not typical commercial buildings further analysis of the load profiles for these buildings is required before this finding can be confirmed.

- Renewable energy sources have been successfully utilized to help reduce utility purchased energy. Since the various suggested systems are not ideal for every

geographical location, Connecticut-specific factors such as weather, wind and sun availability must be evaluated. Additionally, a cost-benefit analysis should be conducted as part of the decision making process for renewable energy project

- Funding options are available for reducing the cost of energy upgrades.

- Internal policies, procedures, and practices, including use of an energy management system, are inexpensive solutions to reduce energy consumption, thereby reducing cost.

- Division of loads into categories expands the understanding of a system's total energy consumption identifying which components or subsystems require the most energy.

CONNECTICUT PRACTICES

Current practices regarding rail facility energy use, including existing loads and Connecticut practices were identified through research team site visits to the New Haven, Stamford and Bridgeport rail facilities to gather information. Metro North Railroad (MNR), Connecticut Light and Power (CL&P) and United Illuminating (UI) provided documentation related to electricity bills and meters for analysis. Southern Connecticut Gas and Yankee Gas provided natural gas information and billing information.

Based on industry best practices, the operations and energy loads that comprise the rail facilities have been divided into initial subcategories based on research team visits to the New Haven, Stamford and Bridgeport Rail Yards and the West Haven and Milford platform stations. Electricity and gas bills were analyzed to determine the energy cost paid for the three major rail yards and the Milford platform station. Further information is required before accurate estimates can be made regarding how much energy is being used by specific load categories and by individual facilities. For load categories, the duty cycle of equipment and the measurement of electricity consumption need to be determined and monitored over time.

BEST PRACTICES

Commonalities identified in the studies and reports that were reviewed indicate several best practices that are critical to understanding, managing and improving existing facilities and systems with respect to energy efficiency. Before improvements can be made the entire system, both at the overall level and subsystems level, must be understood in terms of current energy consumption. In several previous studies, this information was obtained by conducting an energy audit to identify loads and areas of cost savings opportunities. Various loads that exist in a facility in terms of numbers present, frequency of use (or duty cycle), and the energy consumption profile must be identified.

A common strategy among most of the large-scale studies reviewed was to divide unique load profiles into categories; benefits include simplification of complex systems and the ability to identify the size of the load relative to others at a particular facility. This allows the focus to be directed toward the largest loads first, which will more significantly reduce energy consumption; smaller loads can then be addressed for a holistic approach.

Simulations were a recurring practice implemented in order to understand loads, air flow, scheduling and other impacts on energy efficiency. Once the system is divided into categories and methodically analyzed and understood, conservation opportunities will become more apparent.

Internal policies which promote sustainable energy and smart energy use, where applicable under feasibility and safety standards, must be developed setting various goals, such as saving energy, protecting ecosystems, and enhancing resiliency, followed by long-term targets that are monitored over time. These policies and procedures can become part of a workplace culture that ingrains energy-saving behaviors into daily tasks. Among the common best practices is to establish an energy management system that is a framework of authority inside an organization for determining who will manage the implementation and changes to energy-saving policies. It is important to understand the cost and benefit and the total cost of ownership, which includes costs associated with: purchase, installation, maintenance and disposal, encompassing the entire life cycle of the investment. HVAC and lighting were the two areas that were most commonly the largest loads of a commercial facility. More specifically average energy use distribution in commercial buildings is estimated to be 20% lighting, 16% space heating, 15% space cooling, 9% ventilation, 7% refrigeration, 4% water heating, 4% electronics, 4% computers, 1% cooking, 15% other, and 5% unattributed.

RECOMMENDATIONS

The following recommendations are intended to provide CTDOT with guidance to further enhance the efficiency and reliability of rail facilities and rail stations.

The recommendations are based on industry best practices and available information gathered through site visits, interviews, a focus group session, data on electricity and natural gas usage, and expert guidance from the CASE study committee. These recommendations are based solely on the issue of energy savings; the question of whether or not an initiative or project will save money must be determined by a total cost of ownership analysis.

Further detailed information is needed to gain a complete understanding of rail yard facility and rail station energy usage and to develop an energy profile for each facility. This will provide a foundation for conducting energy audits of the facilities and stations that can then be used to develop and prioritize energy efficiency initiatives and projects.

Conduct an Energy Audit: Before any upgrades can be considered a thorough energy audit should be conducted based on data for a minimum of 12 – 18 months, and possibly longer to determine changes and trends in operations, usage and cost. The audit should include the monitoring of individual facilities and their respective energy usage over time, rail operations, billing, energy procurement, and submetering. Analysis of the duty cycle of machinery/ tools should be included in order to identify both usage and opportunities to reduce energy consumption while maintaining ability to conduct maintenance operations effectively.

This process will identify energy savings opportunities, and will provide a method to aid in prioritization for use of available funds for initiatives and projects. It will provide a baseline for energy consumption for the overall rail network, facilities, equipment and various operations. This baseline will enable an accurate total cost of ownership analysis to be conducted to

quantify energy and cost savings, and will be useful for monitoring the impacts of future initiatives and upgrades will have on these savings. Computer modeling can be used in the analysis of energy consumption to establish this baseline.

Lighting: A preliminary estimate of the number of light fixtures at rail facilities was made through site visits conducted during this study. However, the type of lighting technology installed in the fixtures was not determined. Once this information is obtained it will be possible to calculate the percentage of energy use and cost attributable to lighting, and the cost savings and payback period that could be achieved through installation of energy efficient lighting. Although the exact energy profile for each rail facility is not known the following recommendations have been proven to reduce energy use:

- LED technology was cited in multiple reports. Recent advances that improve the spectrum of lighting have made it a viable option.

- Control systems have the capability of dimming lights or turning some or all fixture off when a room is not occupied. Since lights operate 24/7 at all facilities opportunities for improvement exist.

- For better temperature control, paint the pit walls of the Stamford Maintenance of Equipment Facility a light color that reflects illumination, as compared to the current dark color that absorbs illumination.

- The West Haven Rail Station has an excessive number of lights energized even though it has adequate natural daylighting. Consideration should be given to reducing lighting during daylight hours.

HVAC: Further analysis of how the HVAC systems in the rail facilities are controlled should be investigated before accurate estimates can be made regarding their energy consumption. For example, factors that affect energy use, including controllers that operate HVAC systems (i.e., temperature settings and programmability features) should be identified and assessed. This information along with average local temperatures, can be used to estimate the current duty cycle of the HVAC systems. Also, air and water leaks at all facilities should be repaired to help reduce the demand on HVAC systems. Additionally, radiant floor heating for work areas should be analyzed as an option for reducing heating cost and improving the work environment in rail yard shops.

Solar PV Systems: The New Haven Rail Yard has adequate roof space and Connecticut is located at a latitude that is appropriate for installation of a PV system to supplement purchased electricity. Net metering and battery storage options should be assessed to determine the best option for this application. Additional PV system opportunities should be assessed for rail stations, platforms stations and other rail facilities.

New Haven Rail Yard Electricity System: An analysis of the power distribution system for the New Haven Rail Yard should be conducted to gain a more complete understanding of how each building receives power and to identify if there are additional electrical paths served by the UI feeder. Also, further analysis is needed to identify if there are additional submeters in use for rail yard facilities, which would be helpful in determining the kWh usage for the buildings serviced by each meter. Once the submetering is understood more detailed monitoring will be

useful to manage and analyze energy usage and the impacts that future initiatives will have on electricity consumption. More intelligent meters that are properly calibrated will help provide further insight into specific facility energy profiles. Additionally, the naming convention for yard buildings is inconsistent and makes analysis of the yard's complex electrical system challenging. A single name for each facility, such as the common name referred to by staff, should be adopted for official documents and signage.

Natural Gas: Based on 2013 billing information, natural gas is currently less expensive than electricity in terms of price per kWh (to enable a direct comparison between natural gas and electricity, energy units for natural gas were converted from BTUs to KWh), although this may not necessarily be the case universally. Also, natural gas is available at all three rail yards. A detailed technical and cost-benefit analysis of the value of using combined heat and power (CHP) for onsite production of electricity and use of waste heat for heating and cooling using microturbines or fuel cells should be conducted. A hybrid system that primarily relies on electricity provided by the utilities, supplemented by a PV system, and possibly a natural gas-fueled CHP system, will increase reliability by producing electricity onsite. It has the additional benefit of using waste heat for heating and cooling.

Other: The past practice of turning off the power for rail car operation at the Stamford Car Wash Facility on weekends should be reinstated.

9bYf[n·A UbU[Ya Ybh· It is recommended that CTDOT develop and implement an energy management plan and assign a staff person to serve as an energy manager with overall responsibility for leading conservation efforts for all rail facilities and rail stations. The energy manager should interface with the Department of Energy and Environmental Protection (DEEP) in support of energy procurement contracts for the state's rail system and participation in the state's Lead by Example efficiency program. This will ensure that CTDOT is fully aware of and participates in the state's electric and gas procurement process, and is able to use and benefit from existing programs for saving energy. The energy manager should also be a part of CTDOT's asset management review team to provide input regarding those projects that will provide a positive energy savings for rail facilities and rail stations. This will allow projects to be ranked with appropriate priority and be considered with other safety, operational and maintenance projects. Also, this will provide for consistency across all of the state's rail facilities regardless of the individual property manager for each facility. Additionally, the energy manager should issue annual reports to the department's management to demonstrate the progress made in reducing energy use and to encourage energy efficient construction for both new facilities and renovation of existing facilities.

As previously stated, additional information is needed to fully assess electricity usage at the rail yards and stations before developing a plan to reduce energy consumption at rail facilities. A detailed energy audit should be conducted for each rail facility for which CTDOT is responsible. A review of existing energy meters and the need for additional submeters should be included as part of all energy audits. A fully developed metering scheme will allow for a proper analysis of energy use, permitting a comprehensive analysis of energy distribution and use and helping focus energy conservation efforts on those projects that have the greatest return on investment.

CONCLUSIONS

The best practices gathered from the literature review detailed in Section 2 offer solutions that have been proven successful at increasing energy efficiency for facilities. Based on industry best practices, energy usage should be analyzed in detail as an initial step in the decision making process. Dividing the entire system into load categories aids analysis by helping to simplify complex systems and allowing for more accurate estimates to be calculated for each category's energy consumption profile.

Total cost of ownership including purchase, installation, fuel cost and escalation rate, maintenance and disposal/salvage value, encompassing the entire life cycle of any initiative, should be determined. This analysis is used to prioritize and select the energy efficiency and reliability initiatives included in a facility capital plan, and determine if an initiative actually saves money over the long term.

Connecticut's current practices were observed during several onsite visits to rail yards and rail stations conducted by the research team. The various loads have been reviewed and sorted into broad categories. However, these facilities are large and active, resulting in the possibility that some specific tools or equipment that comprise the load profiles may not have been included in the analysis.

Studies identified in the literature review have shown that lighting and HVAC systems are typically the largest loads; therefore, it is important to conduct energy audits to understand these existing systems thoroughly and provide a more accurate picture of how each facility consumes energy.

The utility bills, supporting consumption documentation, and the research team's site visits have been a good start, but there is still conflicting information regarding submeters. Diagrams of the distribution building at New Haven Rail Yard have shown that additional documentation required to answer these final questions concerning power flow and metering exists. The spreadsheets that the MNR electrician maintains need to be examined in order to determine how much power is consumed by individual buildings. This information, along with the utility bills, will provide an understanding of which buildings consume the most energy, as well as guidance for focusing energy saving initiatives.

1.0 INTRODUCTION

This study was conducted for the Connecticut Department of Transportation (CTDOT) by the Connecticut Academy of Science and Engineering (CASE). The objectives of the study included examining energy consumption of the facilities comprising the three major rail yards on the New Haven Rail Line as well as platform stations and identifying energy efficiency and cost savings opportunities for rail operations and facilities. This study focused on identifying opportunities and options to improve energy efficiency and reliability. Additionally, solutions for reducing energy costs and reliance on fossil fuels that take into account the needs of Connecticut's rail operations and facilities will be recommended. The report includes the following:

LITERATURE REVIEW

- Section 2.1 focuses on studies conducted by either the federal government or individual transit agencies.

- Section 2.2 addresses general relevant information with focus on heating, ventilation, and air conditioning (HVAC).

- Section 2.3 provides an overview of general strategies and options available for increased energy efficiency and reliability.

- Section 2.4 highlights other technological innovations for increased efficiency and reliability.

- Section 2.5 discusses the economics of project development with focus on financial or economic options to fund energy efficiency and reliability strategies.

- Section 2.6 addresses planning and organizational aspects of increasing energy efficiency and reliability.

- Section 2.7 provides concluding remarks.

CONNECTICUT PRACTICES

- Section 3.1 reports the findings of current Connecticut practices and loads identified by the research team during site visits.

- Section 3.2 examines the electricity usage for the New Haven, Stamford and Bridgeport rail yards and rail stations based on utility bills and supporting documentation.

- Section 3.3 examines the natural gas usage for the New Haven, Stamford and Bridgeport rail yards based on utility bills and supporting documentation.

- Section 3.4 provides concluding remarks.

BEST PRACTICES

- Section 4.0 provides an overview of the best practices identified in previous studies.

- Section 4.1 details the pros and cons of successful industry practices.

RECOMMENDATIONS AND CONCLUSIONS

- This section of the report identifies recommendations (Section 5) and conclusions (Section 6) for basic energy savings measures, as well as an overall strategy for managing and implementing change.

2.0 LITERATURE REVIEW

The research team conducted an extensive literature search to identify previous studies in this field, including research on new energy saving, clean energy, and energy reliability technologies. Most of this literature focused on traction power, which is the propulsion power for multiple unit trains ("trains"), with less information in the areas of building and facility energy efficiency and reliability.

2.1   PRIOR FEDERAL TRANSIT STUDIES

A large number of prior studies were identified through an extensive literature search. These studies range from large transit agencies, with up to 250 million unlinked trips per year, to smaller ones, with up to five million unlinked trips per year. Unlinked trips are defined as the total number of passengers using any of the transit vehicles. Among the studied literature is a report on "Energy Saving Strategies for Transit Agencies" [1] that is of major interest to this study. The report was sponsored by the Federal Transit Administration and is summarized as follows:

- *Energy Usage*: Energy consumed by transit agencies is split into energy used for train propulsion and energy used in facilities. The average commercial building has HVAC as its main load followed by the lighting system and a broad load category labeled as 'other.' This category can include energy for maintenance facilities, service equipment, or administrative buildings' computers and auxiliaries.

- *Planning*: Energy saving strategies can be integrated into the building planning phase through implementation of an Energy Management System (EMS) or by creation of internal policies.

- *Case Studies*: Four case studies of transit agencies that differ in size and location are discussed. Key common themes among these studies include having a decision maker who is focused on the goal of energy efficiency, implementing these strategies across the entire agency, involving people, and supporting initiatives and practices. Evaluation of past strategies for necessary updates is shown to be important.

Literature reviewed to establish the foundation of this study ranged from short summaries of efforts made to date in a transit agency ([2], [10], [13]) to larger plans that cover the entire process from planning to implementation ([9], [19], [20], [21]). A common approach in these studies is to split the end goal of 'energy saving' into a number of smaller objectives that when taken holistically, identify the overall energy saving goal.

It is important to note that the focus of major literature reports or studies was on system-wide energy efficiency and cost savings for rail facilities and not on energy reliability. Therefore, further investigation regarding energy reliability for rail facilities should be integrated into larger-scale system reliability in terms of interconnected energy and transportation systems.

2.2   GENERAL INFORMATION

Two broad areas that pertain to this study are HVAC systems and generalized data resources that can be utilized for future energy practices by CTDOT. For HVAC, reference [3] details a number of strategies to reduce HVAC operation cost. These strategies range from 'zoning' a building, or having separate HVAC systems to serve different temperature needs, to taking advantage of passive heating, ventilation, and cooling. Passive heating, ventilation, and cooling use natural sources of temperature control instead of mechanical systems. An example of passive HVAC is simply opening windows and doors when cooling is required and it is cooler outside. These passive HVAC sources can be taken advantage of in conjunction with a mechanical system as a "mixed mode system."

The transportation data book [4] is also a useful resource, as it allows for comparisons between the baseline energy use given, and rail facility energy use.

2.3   GENERAL STRATEGIES

This section outlines a number of general energy saving strategies in the following categories: energy savings at stops, stations, and facilities; energy reliability in these buildings and facilities; energy savings in vehicle technologies; and enhancement of vehicle operation and maintenance.

2.3.1 Energy Saving Strategies for Stops, Stations, and Facilities

The most common ways to save energy at stops and stations involve improving the energy efficiency of the lighting and HVAC systems. Lighting efficiency enhancement can be addressed through appropriate scheduling when applicable, or utilization of new and emerging technologies such as compact fluorescents or LEDs.

Additional opportunities that are specifically applicable to facilities include:

- Avoiding continuous operation of electronics and computers when not being used. Often not accounted for, this is a significant source of wasted energy and excess heat production.

- Upgrading facility systems, such as installation of more efficient boilers, or using variable frequency drives (VFDs) in air condensers and other rotating machinery when applicable.

- Seeking a minimum requirement of LEED Silver (Leadership in Energy and Environmental Design) certification for energy efficiency when planning facilities.

Other options to increase energy efficiency for stations include the installation of more efficient HVAC systems, incorporation of passive or natural HVAC sources, appropriate scheduling and automatic control of loads. Energy costs could be reduced through utilization of off-peak hours, when applicable.

Another strategy that deserves consideration is ensuring that all energy projects are conducted in a comprehensive manner to achieve combined energy saving and cost benefits.

2.3.2 *Energy Reliability Enhancement*

Availability is a very important factor when evaluating renewable energy sources. When evaluating renewable energy reliability, working life and maintenance cycle of systems must be taken into account, as well as other technology-specific factors. Although solar photovoltaic (PV) systems are the most reliable renewable due to their low maintenance and high useful life [32], their dependence on environmental factors makes them less predictable than traditional energy sources.

Solar panels typically have 20 to 25 year warranties, but many manufacturers claim that panels can still produce acceptable power for 40 years and beyond. These claims are based on accelerated testing but this technology is still relatively new and few installations have been operating for that time span. There are several environmental factors that contribute to the reduction in power output of solar panels such as temperature fluctuations, humidity and UV exposure. The definition of a failed solar panel is one that has a 20% drop in power output after 30 years of operation. Conservative estimates are a 3% reduction after the first year and less than 1% per year reduction thereafter, but solar panels most often are more reliable than these estimates. The inverter is another component of a solar array to consider; 117 of them were required for the new Lehrter Rail Station in Berlin, Germany (Lehrter Station) [15]. Inverters are typically warrantied for 10 or more years and during their lifetime are expected to be down 1%of the time (2-3 days per year), requiring maintenance to restore operation. Solar PV systems installed in Connecticut are expected to produce between 3 to 4.5 kWh//day according to National Renewable Energy Laboratory (NREL) data.

Additional resources:

- http://www.solarpowerworldonline.com/2013/10/reliable-inverters-power-best-solar-installations/

- http://www.renewableenergyworld.com/rea/news/article/2009/12/pv-durability-and-reliability-issues

Implementation of a secondary energy system to supplement utility power, not replace it, increases reliability significantly. This will ensure operation continues during diminished energy generation or malfunctions in the primary system as well as reduce the energy purchased from the utility provider.

2.3.3 *Renewable Energy Strategies*

Installing renewable energy sources is becoming a common transit agency practice. The most common is use of a solar PV system to reduce the cost of electricity through an initial investment. For example, a large (1870 m²) solar PV array [15] was installed at the Lehrter Station that completely covers the cost of electricity for the station. If the PV array is large enough, smaller stations and stops can even become grid-independent. Review of several studies ([1], [9], [15], [19], [20], [21], [32]) shows that in many cases, a large-sized array of PV modules can provide all the required power for certain facilities. Although a number of these facilities are independent, the majority are connected to the grid to improve reliability during poor weather conditions that reduce the energy output of PV panels or system outages due to maintenance or failure.

The second most common renewable energy source is wind turbines. However, there have been issues with installation of wind turbines in populated areas due to their large size and noise generation. In addition, depending on the size of the turbine, the area around them must be cleared to maximize the effect of the wind and avoid interference.

Other options that could be attractive but have not been reported in rail transit applications include geothermal and biomass systems, as well as fuel cells, which are considered a clean energy source and were the topic of a prior CASE study, "Feasibility of Utilizing Fuel Cells to Generate Power for the New Haven Rail Line."

For most renewable energy strategies mentioned above, availability and reliability need to be carefully evaluated. NREL provides a table to approximate the useful life of several different renewable energy sources. This table has shown that the average useful lifetime for a PV system is 25 to 40 years. Although this would indicate that PV systems are one of the most reliable renewable technologies, this is just a measure of the average lifetime of the system, and does not take into account the availability of the system, which is entirely dependent on weather conditions and geographical location.

2.3.4 Vehicle Technologies

Even though vehicles are not within the scope of this study, it is helpful to understand vehicle technologies in rail applications for future consideration and to better understand the purpose of facilities. Recent advances in vehicular technologies reflect a trend towards changing the fuel source of the vehicle to increase vehicle energy efficiency and reduce environmental impact. Compressed natural gas (CNG), liquefied natural gas (LNG), liquefied petroleum gas (LPG), biodiesel, and electric traction are among the options gaining popularity over the past 15 years.

Electric traction using hybrid electric, battery electric, or hydrogen fuel cell technologies has been shown to increase energy efficiency even more. The major drawback to using these technologies is the upfront capital cost for these vehicles, with savings being projected over the life cycle of the vehicle.

Other opportunities to improve energy efficiency of vehicles include:

- Optimizing a vehicle's auxiliary systems. Using separate electrical systems can increase energy efficiency significantly, as opposed to using one unified mechanical system for vehicle propulsion, lighting, HVAC, and door operation.

- Reducing the total weight of the vehicle to improve mileage. This can be done by replacing older materials with newer, lighter weight ones, or eliminating unnecessary system redundancies.

- Installing regenerative braking systems.

2.3.5 Vehicle Operation and Maintenance

Several options have been explored to increase the energy efficiency and savings for vehicle operation and maintenance. One option is to encourage anti-idling implementation, including improved driver training, enforcement of anti-idling policies established by the agency,

and installation of an on-board anti-idling system. Connecticut Department of Energy and Environmental Protection (DEEP) regulations based on state law limit idling under most conditions to no more than three minutes. Other options to improve energy efficiency and promote savings include using alternate power supplies rather than idling engines when performing vehicle maintenance; such as using an electric power supply or a battery-powered unit for vehicle heating and lighting. Other options to improve energy efficiency and promote savings include using alternate power supplies (e.g., an electric power supply or a battery-powered unit} rather than idling engines for vehicle heating and lighting when performing vehicle maintenance.

2.4   Other Technical Innovations

In addition to existing technologies and strategies, there are a number of other technical innovations that can help achieve energy efficiency and savings goals. For example, simulations can be conducted for individual transit stations and facilities to better understand how energy can be saved in the project planning/strategy assessment phase. This provides agencies with an opportunity to identify an approximation of net energy savings for each strategy. Additionally, modeling can be used to more accurately estimate the energy requirements for complex systems. For example, the Nanjing South Railway Station (NSRS) [7] in China had challenges identifying their HVAC needs due to the design of the station (large facade, skylight, and air infiltration). Therefore to aid in the analysis of the station's HVAC needs, a simulation of NSRS's HVAC load for a year was conducted by Tsinghua University. The simulation enabled a more complete understanding of how the air flowed throughout the station's voluminous space—an otherwise complex task to measure and analyze—for more effective HVAC upgrades to address the specific aspects of the system that require attention.

Training rail facility employees to implement best practices related to energy efficiency is also recommended. These practices should be aligned with facility safety rules and regulations, especially in cases where interrupting machinery or lighting can cause safety hazards. Commercial energy saving software and controls should also comply with facility safety rules and regulations.

2.5   Economics of Project Development

Implementations of many energy saving strategies that have been identified require significant capital investments. A life cycle cost-benefit analysis can be useful in identifying the payback period for improvements and projects to determine the worthiness of the investment.

2.5.1 Federal Government AND State Funding

Federal and state programs may be available to finance energy saving strategies.

Examples of federally funded programs include the USDOT TIGER (Transportation Investment Generating Economic Recovery) and the Federal Transit Administration's TIGGER (Transit Investments for Greenhouse Gas and Energy Reduction) programs.

Examples of Connecticut's current state and ratepayer-funded programs for state facilities include

- Several Connecticut energy efficiency programs
  http://www.energizect.com/businesses/solutions/Existing-Buildings-Equipment

- Connecticut Property Assessed Clean Energy (C-PACE), an innovative program that is helping commercial, industrial and multi-family property owners access affordable, long-term financing for smart energy upgrades to their buildings. Note that this is of interest to facilities of tax-paying entities only.
  http://www.c-pace.com/

- DEEP solar installation funding
  http://www.ct.gov/deep/cwp/view.asp?a=4120&Q=481698

- Incentive payments for equipment upgrades
  http://www.energizect.com/businesses/programs/Energy-Opportunities

- Solar thermal up to $500,000 in incentives
  http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=CT97F&re=0&ee=0

- Energy efficiency programs for Connecticut municipalities
  http://programs.ccm-ct.org/Plugs/energy-efficiency-programs.aspx

- CERT-140 tax exemption form
  http://www.ct.gov/drs/lib/drs/forms/2007forms/salesandusetax/cert-140.pdf

- Net Metering
  http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CT01R&re=0&ee=0

- Reduction of peak power use, retrofits and new construction, lighting, motors, air compressors, refrigeration, manufacturing processes
  http://www.ameresco.com/page/connecticut-energy-efficiency-incentive-program

2.5.2 *Energy Performance Contracting*

Alternatively, transit agencies have entered into financing agreements with utilities or third-party energy companies to cover the initial capital investment of a project. The transit agency then pays back the cost of the project to the utility or third-party energy company with the money from energy savings. This type of agreement is typically referred to as an energy performance contract and is provided by an energy service company (ESCO).

2.6 PLANNING

The literature identified several approaches to consider. Best practices indicate that a detailed planning process should be developed to assess options and to implement efficiency solutions and technical innovations to achieve projected energy savings. This process should formalize the review of energy efficiency upgrades or modifications. The process would include performing an energy audit, reviewing industry standards for lighting and ensuring that building components such as HVAC systems and windows meet current federal and state efficiency standards. In the case of new rail station platforms, standards should be developed for using state of the art lighting systems. When possible, new passenger platforms should be oriented to ensure that maximum use of PV generation is available. Energy loads should be inventoried to understand the need for self-generation, smart grid connections and energy storage.

2.6.1 Energy Management System

An energy management system (EMS) is "the strategy of adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements." [5]. One significant aspect of, and challenge for, an effective EMS is that any energy conservation effort must be user friendly, cost effective, and not time consuming. These approaches should help facilitate energy saving goals.

2.6.2 Division of Objectives

Another common theme that has been identified is splitting energy savings into several objectives and goals. For example, Sound Transit, Seattle, Washington [19] split their sustainability goal into the following three sections: people, conservation, and operating efficiency. Each of these sections has several objectives. For example, objectives for operating efficiency include providing mobility necessary for strong economic growth by connecting regional urban centers, integrating sustainability into agency decision-making processes, and enhancing staff participation in sustainability initiatives. By doing this, a goal that is very open–ended, such as saving energy, can be split into focused initiatives, each with its own objectives and goals.

2.7 CONCLUDING REMARKS

The following are common findings from the literature reviewed:

- The largest energy loads consistently identified for typical commercial buildings were HVAC and lighting. Since the facilities that comprise the rail yards in Connecticut are not typical commercial buildings, further analysis of the load profiles for these buildings is required before this finding can be confirmed.

- Renewable energy sources have been successfully utilized to help reduce utility purchased energy. Since the various suggested systems are not ideal for every geographical location, Connecticut-specific factors such as weather, wind and sun availability must be evaluated. Additionally, a cost-benefit analysis should be conducted as part of the decision making process for renewable energy projects.

- Funding options are available for reducing the cost of energy upgrades.

- Internal policies, procedures, and practices, including use of an EMS, are inexpensive solutions to reduce energy consumption, thereby reducing cost.

- Division of loads into categories expands the understanding of a system's total energy consumption by identifying which components or subsystems require the most energy.

3.0 CONNECTICUT PRACTICES

This chapter provides the results of information collected on the current practices regarding rail facility energy use. The research team conducted site visits to the New Haven, Stamford and Bridgeport rail facilities to gather information about existing loads and Connecticut practices. Metro North Railroad (MNR), Connecticut Light and Power (CL&P) and United Illuminating (UI) provided documentation related to electricity bills and meters for analysis. Southern Connecticut Gas and Yankee Gas provided natural gas information and billing information.

3.1 SUMMARY OF CONNECTICUT PRACTICES: SITE VISIT FINDINGS

3.1.1 New Haven Facilities

The majority of the train maintenance for the Metro North Railroad's (MNR) Connecticut operations is conducted at the New Haven Rail Yard. In addition to Union Station, the yard buildings currently include:

- Storage Facility (Building 10) for short-term storage

- Wheel Mill Shop for grinding and smoothing wheel surfaces to increase wheel and track life, as well as improve traction power efficiency

- Critical System Repairs (CSR) Shop is conjoined with the Diesel Shop for repairs on diesel trains

- Service and Inspection (S&I) Shop

- M2 Shop for M2-type and M4-type car maintenance

- Electrical Multiple Unit (EMU) Shop for maintenance on electric trains

- Running Repair Shop for electric train repairs

- Fueling Facility for filling trains with fuel and sand (for traction on the rails during winter)

The New Haven Rail Yard currently has two buildings under construction, the Component Change Out Shop (CCO) at 293,000 square feet, and the Independent Wheel Truing facility. Other buildings will be built in the near future and some will be demolished. Plans for future renovations for the EMU and CSR facilities include upgrading the HVAC systems, adding exterior lighting, and installing alarm systems, all of which impact energy usage.

3.1.1.1 THE M2 SHOP

The M2 shop (57,500 sq. ft.), operational since 1974, has three tracks that enter and exit the facility, and six bay doors, each of which is operated via a ¾ horsepower (hp), three phase (φ) motor. Maintenance performed on M2 and M4 series train cars is conducted at this facility, which operates 24/7, includes running repairs and removal of heavy components. The frequency of specific jobs was unknown due to the variety of tasks and scheduling. The shop was designed to house two train cars completely inside; however, frequently, three or four train cars are serviced

at the same time, resulting in the large bay doors remaining open to accommodate this operation. This practice results in a heating loss in the winter months. During the summer months, since there is no air conditioning in this shop, the bay doors remain open for ventilation.

This vintage building is not constructed to the highest energy efficiency standards, but over the past three years, CTDOT has completed several energy efficiency improvements, including changing the lighting to compact florescent lighting (CFL), eliminating the air conditioning, and placing hot air blowers at the entrances of the building pointed inward to help keep heat inside the shop during the winter. Table 3-1 depicts the various loads that were identified during the visits to the M2 shop conducted by the research team.

TABLE 3-1: LOADS OBSERVED AT THE M2 SHOP

Load	Description	Notes
Lighting	These bulbs include: • 200A 3 pole 600VAC • T12 60W bulbs • T12 40W bulbs • High pressure sodium S54 100W bulbs	• Based on pictures taken of the facility, there are well over 40 fixtures • Overhead lights remain on 24/7 • Several different types of light bulbs were found in the rectifier room, but the types installed in the fixtures were not identified.
HVAC & Heat	• Six Rooftop Exhaust Fans • Fantech • Trane Electric Heater • Natural Gas-Fired Heaters • Air Conditioner	• Additional ventilation is provided by a Fantech unit that is located inside the shop, which consumes 81 Watts (W). • The Trane unit for office space heating had a power draw of 249W on the label. • The heat for the shop space is provided by several natural gas-fired heaters that are mounted on the wall. It was not determined if these heaters run constantly during work hours or if they are thermostatically controlled. • A small AC window unit was installed in an office that is located in the M2 shop.
Machinery & Tools	• Cranes • Electric Floor Jacks • Turntable • Electric Power Tools: • Welder • Drill Press • Shears • 50-Ton EnerPac • Air Compressor • Lifts	• Two 30-ton cranes were present but used very rarely. • The smaller cranes were either a 3-ton or a 7.5-ton variety, both of which were powered by 60 AMP (A) 3φ motors; a half ton crane was located on the roof. All are used often. • Floor jacks were the most common method of transporting components; specifications were not identified. • A large turntable machine operated by a 3φ 60A motor is used to lift and turn entire train cars. • Pneumatic tools receiving compressed air from an Ingersoll Rand unit, which reportedly is "always on," are used. • Several forklifts and scissor lifts were observed, but it was not determined if their batteries are charged through the electrical service or fueled by other means.
Rectifiers & Power	• Rapid Power rectifier • Sorsel rectifier • Buggers	• The rectifiers provide DC equipment, such as buggers and stingers with DC voltages ranging from 600V to 700V. Input power provided by the utility was observed to be 600 volt (V) at 600A for the Rapid Power rectifier. • Two buggers operating at 200A maximum provide power to the train cars. Buggers are mobile units that provide train cars with 600V to 700V DC for energized tests when traction power is not available.

Figures 3-1 through 3-11 are photos taken by the research team during the two site visits that correspond to various loads listed in Table 3-1.

FIGURE 3-1: M2 SHOP INTERIOR AT NEW HAVEN

FIGURE 3-2: BAY DOORS

FIGURE 3-3: HEAT LAMPS

FIGURE 3-4: PRESS AND SHEARS

FIGURE 3-5: AIR COMPRESSOR

FIGURE 3-6: MILLER WELDER

FIGURE 3-7: RECTIFIER (AT TIME OF THE PICTURE THE METERS READ 620V AND 475A)

FIGURE 3-8: SECOND RECTIFIER (WHEN PHOTO WAS TAKEN 650V WAS DISPLAYED AND THE CURRENT METER WAS BROKEN)

FIGURE 3-10: DRILL PRESS

FIGURE 3-9: SEVEN AND A HALF TON CRANE

FIGURE 3-11: VENTILATION FANS

3.1.1.2 SERVICE AND INSPECTION (S&I) SHOP

The S&I shop, constructed in 2007, has two tracks with large bay doors and can hold up to six train cars. Routine maintenance and inspections are conducted in this facility. Three shifts operate this facility 24/7 with overhead lights and lights under the tracks being energized constantly. Train cars enter and exit the building twice per day, per track, for inspections consisting of two, four-hour inspection periods; the first offline (no power applied) and the second online (with auxiliary power applied to the train cars). Table 3-2 outlines the loads that were observed during the research team visits.

TABLE 3-2: LOADS OBSERVED AT THE S&I SHOP

Load	Description	Notes
Lighting		• More lighting is installed in the S&I Shop than in the M2 Shop, but the number and type of lighting was not identified. Additional lighting is installed underneath the tracks.
HVAC & Heat	• Heating Units • HVAC • Portable Oil Fired Heaters	• The temperature is regulated by: • Five rooftop heating units • Three high-efficiency HVAC units • Several portable Dayton, 400,000 BTU, oil fired heaters
Machinery &Tools	• Cranes • Bench Grinders	• Several six-ton cranes • The maintenance in the S&I Shop requires fewer tools, and shop staff indicated that the bench grinders were the only power tools used in the shop.
Rectifier & Power	• Stinger • Rectifier • Battery Bank	• The stinger power is 700VDC and 13kVAC at 4A, which is connected to each truck on an M2 train car for four-hour intervals during inspection. Stingers are smaller versions of buggers. • The rectifier labels specified a 1500kW capacity; the input was 13kVAC at 100A and the reading on the gauges, with two train cars running at the time, indicated 700V at 570A. • There is a battery bank that powers a SCADA monitoring system that receives a trickle charge at 130.8V and 1.14A.

Figures 3-12 through 3-17 are photos taken of the S&I shop during the site visits that correspond to Table 3-2.

FIGURE 3-12: S&I SHOP INTERIOR LIGHTING

FIGURE 3-13: UNDER TRACK

FIGURE 3-14: BENCH GRINDER
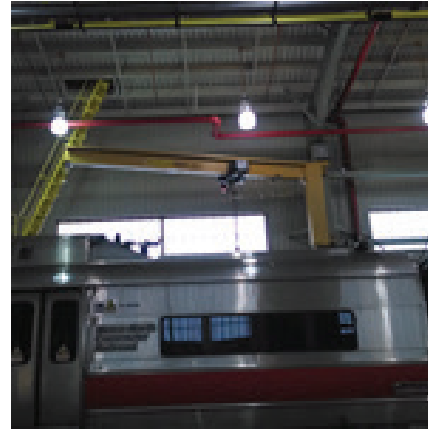
FIGURE 3-15: SIX-TON CRANE

FIGURE 3-16: RECTIFIER (700VAT 570A)

FIGURE 3-17: BLOWER BY BAY DOOR

3.1.1.3 CRITICAL SYSTEMS REPAIR (CSR) SHOP

The CSR shop is leased by CTDOT to Kawasaki. It has three tracks, two of which have lighting underneath. Additionally, as reported by a facility employee, the facility also includes at least four offices, but these spaces were not visited by the research team. Future plans include converting the facility to handle heavy repairs as well as adding two non-electrified tracks. Table 3-3 summarizes the loads observed at the CSR Shop.

TABLE 3-3: LOADS OBSERVED AT THE CSR SHOP

Load	Description	Notes
Lighting		• Undetermined
HVAC& Heat	• Natural Gas-Fired Heaters • Larger Oil-Fired Heaters	• Heat is provided by the same natural gas fired lamps that were observed in the M2 shop. • Two Hastings oil fired heaters with exhaust fans are used; a label on the equipment indicated 480V and 4W of power.
Machinery & Tools	• Floor Jacks • Cranes • Lifts • Air Compressor	• The repairs that are conducted in this facility require the train cars to be elevated. Each car is lifted by four 25-ton jacks at the corners. There are 16 total jacks that are used regularly, each powered by a 3φ, 25 foot pound motor • Two 30-ton cranes that are used rarely, and three 10-ton cranes were present for moving components. • Several forklifts and two SkyJack scissor lifts were parked inside the shop. • Power tools were likely present, but not observed.
Rectifier & Power	• Large Transformer • Isolation Transformer • Rectifier • Bugger • Stinger	• In the electrical room a large transformer had a label that read 280V, 131A and 93kW. • An isolation transformer, 480V to 480V, operated at 1210kVA. • The rectifier, model number 0017SOA 2000A, operated at 850VDC and 1100kW. • The bugger supplies 600V, and the stinger voltage is only needed for auxiliary power.

Figures 3-18 through 3-21 are CSR Shop photos taken during the research team's site visits.

FIGURE 3-18: CSR SHOP WITH TWO 30-TON CRANES IN THE BACKGROUND MOUNTED ABOVE, AND ONE OF THE 25-TON JACKS TO THE RIGHT OF THE PHOTO

FIGURE 3-19: TRANSFORMER

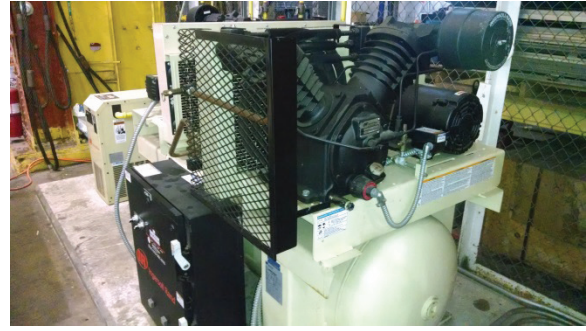FIGURE 3-20: HASTINGS OIL-FIRED HEATER AND NATURAL GAS-FIRED HEATERS

FIGURE 3-21: AIR COMPRESSOR

3.1.2 Stamford

The research team found from their visit to the Stamford rail facility that there was much less activity in terms of train maintenance and more office space compared to the New Haven Rail Yard facilities. The average number of days with power outages is one-half to one day per year.

3.1.2.1 MAINTENANCE OF EQUIPMENT FACILITY

The Maintenance of Equipment Facility has 22,500 square feet of shop space and three floors of office space. Each floor was 25% of the size of the shop. Operation is 24/7 over three shifts with approximately 100 employees. Observations by the MNR staff pertaining to energy efficiency were relayed to the research team. The effectiveness of the facility lighting was reduced due to dirty light fixtures that needed cleaning and, in some cases, bulb replacement.

Additionally, the pit was painted a dark color that absorbs light, further reducing visibility. Poor insulation and significant roof and wall water leaks, both of which indicate air drafts that cause the HVAC to work harder, were identified by MNR staff. Table 3-4 summarizes the findings during the visit to the Maintenance of Equipment Facility.

TABLE 3-4: LOADS OBSERVED AT THE MAINTENANCE OF EQUIPMENT FACILITY

Load	Description	Notes
Lighting	• Overhead Lights • Pit Lights • Additional Lighting for Jacks	• 48 overhead lights, similar to those observed at the M2 shop • 40 fluorescent tube lights for the pit • Two 100W fluorescent lights per jack are on twice a day when jacks are in use. • Store room has automatic light control. • Offices do not have automatic light control.
HVAC & Heat	• Gas Boilers • Heat Lamps • Heating Unit • HVAC Units • Heat Exchangers • Fans • Small AC	• 3 boilers provide heat • 18 total electric and gas heaters are hung from the ceiling • Four heaters: McQuay RAH077 CYA (34A-45A at 460V 3φ and 15A at 120V 1φ) • Three HVAC units kick on when the outside air temperature reaches 70°F; no additional control. One unit is a McQuay RWS800BA, the other two are McQuay RPS040BA units. • Three McQuay RBS806BB heat exchangers • Six ¼ hp fans, 4 exhaust fans with 30A breakers • Two small AC units in the rectifier room (possibly 9000 BTU) • Yard Master's Office has a separate AC unit.
Machinery & Tools	• Jacks • Cranes • Air compressors	• There are twelve 35-ton jacks that operate once or twice a day (duration of on time was not identified). • A 15-ton crane is used from once a week up to 4 to 5 times a day. • Two air compressors; when one operates the other is off. • Other tools were present in photographs, but were not significant in number or in terms of load.
Rectifier & Power	• Rectifier • Transformer • Bugger	• Rectifier: 520V, 1883A, 3φ input and a 650V, 2308A, 1500kW output • Liquid filled transformer 1667kVA, three high voltage outputs: I) 498V, 1935A, II) 480V, 2005A, III) 462V,2083A and one low voltage output 511/295V 1884A • 700V bugger supplies power to cars

Figures 3-22 through 3-27 are photos taken during the Stamford Maintenance of Equipment Facility site visit.

FIGURE 3-22: MAINTENANCE OF
EQUIPMENT FACILITY

FIGURE 3-23: SEVERAL 35-TON JACKS LIFTING TRAIN
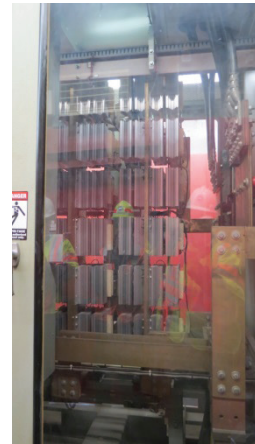

FIGURE 3-24 BOILERS

FIGURE 3-25: RECTIFIER
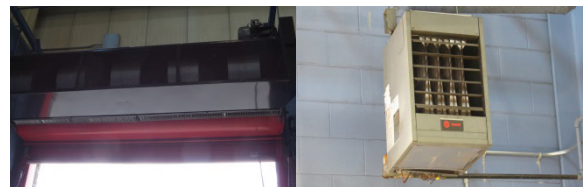

FIGURE 3-26: LIQUID FILLED TRANSFORMER

FIGURE 3-27: CEILING MOUNTED HEATERS

3.1.2.2 HEAVY REPAIR SHOP

The Heavy Repair Shop in Stamford operates Monday through Friday from 8:00 am to 4:00 pm and is staffed by four to five employees. Table 3-5 is an overview of the loads identified during the site visit to this shop.

TABLE 3-5: LOADS OBSERVED AT THE HEAVY REPAIR SHOP

Load	Description	Notes
Lighting		• 17 overhead fixtures • Three typical (3 tubes each) office light fixtures in the attached office
HVAC & Heat	• Gas-fired heaters • Furnace • Air Conditioner • HVAC	• 6 gas heaters • McQuay110SRA0gas fired furnace • AC in office • Rooftop McQuay HVAC units
Machinery & Tools	• Fans • Air compressor • Jacks • Power Tools • Lifts • Crane	• Four 1/4hp fans • Ingersoll Rand 10hp compressor • Four jacks 480V, 7.5hp; each runs approximately once or twice a year • Tools: drill press, sanders, various types of power saws, shears, vacuum cleaners with an average use of 1 hour per day for each • Several different types of welders that are used 4 to 6 hours a day • Lifts and cranes identified in photographs; specifications were not identified

Figure 3-28 through 3-34 are photos of the Heavy Repair Shop equipment observed during the Research Team site visit and summarized in Table 3-5.
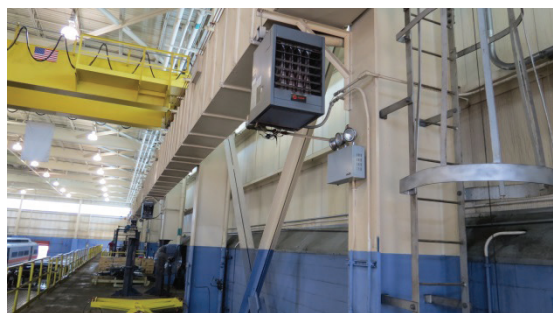
FIGURE 3-28: HEATER AND LARGE CRANE
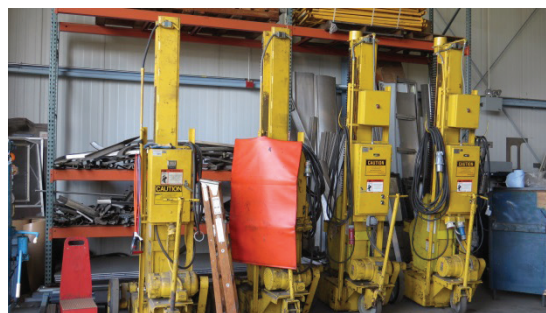
FIGURE 3-29: JACKS (SELDOM USED)

FIGURE 3-30: BELT SANDER, WELDERS AND SAW
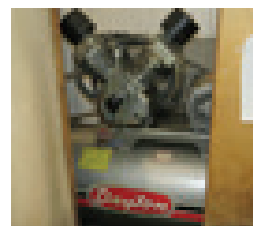
FIGURE 3-31: AIR COMPRESSORS

FIGURE 3-32: GAS FURNACE

FIGURE 3-33: OFFICE SPACE WITH AC UNIT

FIGURE 3-34: HVAC

3.1.2.3 CAR WASH FACILITY

The train Car Wash Facility is a fully automated system that operates about six hours a day, and it is the only such facility on the New Haven Rail Line that is fully operational. The wash station is utilized principally during the spring, summer and fall months, and otherwise if temperatures are above freezing. The manager of the facility that conducted the site visit for the research team reported that more than a decade ago, an energy conservation procedure—turning off the power for rail car operation from Friday night to Sunday night to reduce electricity consumption—was practiced, but this practice is no longer followed. The washer comprises the following energy consuming components:

- Four gas heaters, two of which are as long as the building

- Five pumps for acid, alkaline and water ranging from 5hp to 40hp

- Five heaters (gas and electric)

- Six bristles each requiring a motor (estimate 1hp motor/bristle)

- Eight blowers

- Lightin

Figures 3-35 and 3-36 depict the car wash facility located at Stamford rail yard.

FIGURE 3-35: CAR WASH BRISTLES

FIGURE 3-36: BLOWERS

3.1.3 Bridgeport

A maintenance crew hub is located in East Bridgeport. This facility includes typical office and storage space and is operational on a 24/7 basis. It serves as a dispatch center for worker assignments at other locations. Although there was not much activity observed by the research team at this location, HVAC vents blew cool air and all hallway lights were switched on. One small mechanical night crew services train car lavatories at this location. The second floor of the facility includes additional office space that is occupied by CTDOT consultants. Also, a Metropolitan Transportation Authority (MTA) police office is attached to the building.

3.1.4 Platform Stations

The research team conducted site visits to the Milford and West Haven platform stations to obtain load information. Platform stations throughout the rail network have very similar load profiles.

3.1.4.1 MILFORD

The Milford station has a platform on either side of the track with a canopy covering, a stairway and ramp under a canopy leading from a street below, and a small building with a waiting area and restrooms. Approximately 40 light fixtures containing two bulbs each, eight security cameras, 10 speakers and eight information signs are mounted on the ceilings of the canopies. Additional platform lighting is provided by 50 lamp posts. It was observed that LED lighting is installed on some lamp posts that were further down the platform, but the majority, including those closer to the platform, use less energy-efficient lighting. Since it was daylight and the platforms are outside, all the lights were off at the time of the site visit. Three ticket kiosks are installed on the platforms but there were no labels that identified power specifications. An Ice Qube, Inc., Industrial Cooling Equipment unit (S/N 1A312707-4) was observed under the platform operating at 120V at 3.9A, 1φ, and a design pressure between 88 psi and 200 psi. The station building is lit with approximately 10 fluorescent tube-type light fixtures. Electrical devices located in the building include two televisions, one information sign, three coolers for drinks, a heater cabinet for food, several coffee makers, and a cash register. The building

basement is used to store bulbs for platform lamp posts and has other rooms but access was not granted since this visit was impromptu.

3.1.4.2 WEST HAVEN

The West Haven Station opened to passengers in 2013 and is one of the newest stations on the New Haven Line. This station is much larger than the Milford Station. The platforms had approximately 300 light fixtures, 50 speakers, 10 information signs, five ticket kiosks, and eight electronic parking pay stations (120VAC at 8.5A; S/N 500013210846). An elevator and stairwell lead to an enclosed passenger bridge that crosses the tracks and ends in the station building, which houses restrooms, two vending machines, automatic doors, and a ticket booth. There were a few doors, one of which was labeled "electrical room," but access was not granted. Air vents were located on the ceiling indicating an HVAC system was used for building heating and cooling. There were no passengers during the entire 20- to 30-minute visit. The station building is large and cavernous with large floor to ceiling windows accounting for the majority of wall space, allowing plenty of natural light to fill the space. Regardless of the windows and the lack of activity, numerous light fixtures mounted on the ceiling and walls were all energized, some of which were purely aesthetic. Many security cameras are installed throughout the building and platforms.

3.2   ANALYSIS OF ELECTRICITY BILLS

3.2.1 Rail Yard Electricity Usage

Each of three major rail yards—Bridgeport, New Haven and Stamford—receives power through a single main feeder or usage meter which is maintained by the utility that generates the electric bills monthly. Although New Haven and Bridgeport Yards are both supplied by UI, prices per kilowatt hour (kWh) differ between them and fluctuate often due to market conditions. UI defines "on peak" hours for commercial accounts as Monday through Friday from 10:00 a.m. to 6:00 pm; for power consumed outside this time frame, the price per kWh is assessed at the "off peak" rate. The shoulder rate is a third category that is defined as three hours before and five hours after on-peak hours, but according to UI, the shoulder rate usage is typically billed at the same rate as off peak. The Stamford Yard is serviced by CL&P. Peak hours run from 12:00 pm to 8:00 pm; during daylight saving time, peak hours shift to 1:00 pm until 9:00 pm, Monday through Friday. Power consumed outside this time frame is considered off peak, and the shoulder rate is not available from CL&P. The main feeder meter numbers for these yards are as follows:

- Bridgeport: UI – 014017922

- New Haven: UI - 016040531

- Stamford: CL&P – 891606072

Initially, a single billing period of December 2012 to January 2013 was provided for analysis. To gain a broader understanding of electricity consumption over time, further documentation detailing monthly kWh and cost was provided by UI for the Bridgeport and New Haven Rail Yards (August 2011 – July 2014) and by CL&P for the Stamford Rail Yard (January 2013 – June 2014). Table 3-6 depicts selected data from these periods as noted.

TABLE 3-6: YEARLY COST AND CONSUMPTION OF ELECTRICITY AT THE
THREE MAJOR RAIL YARDS

Rail Yard	Year	Meter kWh	Yearly Cost
Bridgeport (1)	2014	431,040 kWh	$61,366
	2013	741,240 kWh	$102,281
	2012	704,640 kWh	$102,315
New Haven	2014	5,502,000 kWh	$741,009
	2013	9,237,200 kWh	$1,247,742
	2012	8,475,600 kWh	$1,071,494
Stamford (2)	2014	984,960 kWh	$109,538
	2013	1,956,960 kWh	$270,097
Totals for Rail Yard Facilities *(Stations not included)*	**2013**	**98,963,499 kWh**	**$1,620,120**
Notes: (1) Bridgeport and New Haven Rail Yards: 2014 is for the period of January – July only. (2) Stamford Rail Yard: 2014 is for the period of January – June only.			

For the Bridgeport Rail Yard during this period, the yearly kWh consumption increased slightly with no cost difference. The New Haven Rail Yard consumption shows a greater increase in kWh consumption and a cost increase of approximately $176,000, with the 2014 partial year appearing to continue this trend. It should be noted that the New Haven Rail Yard is undergoing significant construction that may account for this increase in usage rather than changes to operations. Since 2012 consumption data was not provided for the Stamford Rail Yard, definitive observations cannot be drawn about year-to-year usage and cost trends. Figure 3-37 and Figure 3-38 depict the cost comparison for the New Haven, Bridgeport and Stamford Rail Yards for 2013 and the 2014 partial year, respectively.

2013 Electricity Cost Comparison For The Major Rail Yards

Stamford $270,097 17%

Bridgport $102,281 6%
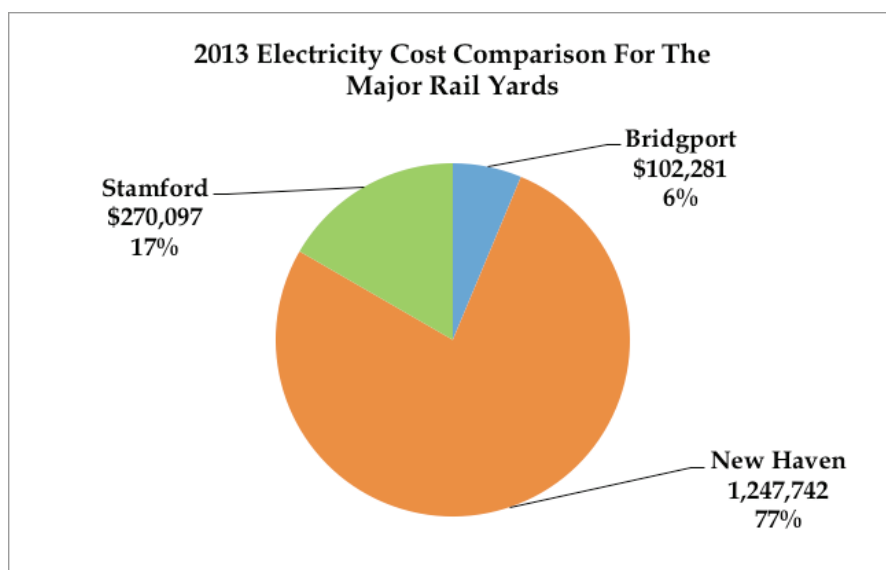
New Haven 1,247,742 77%

FIGURE 3-37: ELECTRICITY COST COMPARISON IN DOLLARS AND PERCENTAGE OF TOTAL RAIL YARD COST FOR THE BRIDGEPORT, NEW HAVEN, AND STAMFORD RAIL YARDS FOR 2013
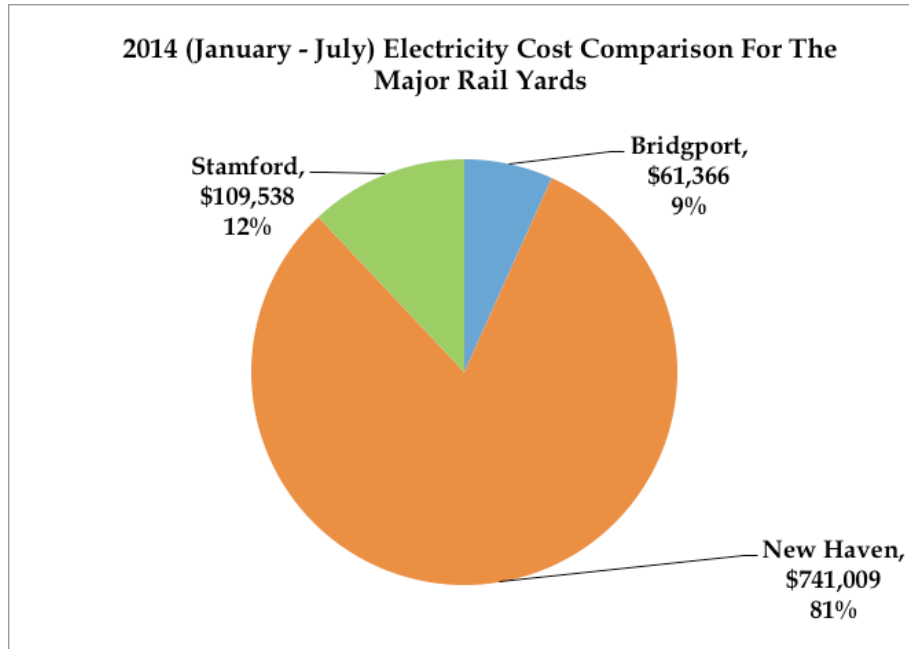
FIGURE 3-38: ELECTRICITY COST COMPARISON IN DOLLARS AND PERCENTAGE OF TOTAL RAIL
YARD COST FOR THE BRIDGEPORT, NEW HAVEN, AND STAMFORD RAIL YARDS FOR 2014

Data from the main feed meters for the rail yards for the December 2012 to January 2013 billing
cycle were used to generate Table 3-7 and Figures 3-39, 3-40 and 3-41. The price per kWh
changed for all three locations during this billing period due to a rate change as of January 2013
that resulted in a rate reduction for Bridgeport and an increase for Stamford and New Haven,
with Table 3-7 depicting the final rate for each location for this period. Bridgeport had the most
stable pricing, experiencing an approximate two cent per kWh swing for the year, with the
other two yards having a four cent per kWh change over the same time period.

TABLE 3-7: SUMMARY OF THE DECEMBER 2012 TO JANUARY 2013 BILLING CYCLE
FOR THE THREE MAJOR RAIL YARDS

Yards	Price per kWh ($)			Percentage of Total Bill		Total ($)
	On Peak	*Off Peak*	*Shoulder*	*Generation*	*Distribution*	
Bridgeport	.097831	.067831	.067831	59.73%	40.27%	$ 8,608
New Haven	.092340	.092340	.092340	58.37%	41.63%	$114,047
Stamford	.081070	.081070	NA	55.65%	44.35%	$ 23,216

Figure 3-39 illustrates the distribution of power usage between the three yards and time of day
it was consumed. This chart only reflects the single billing cycle that was provided by MNR
for the December 2012 to January 2013 period. On-peak usage comprises 22.8% of the total
electricity consumed for all three sites.
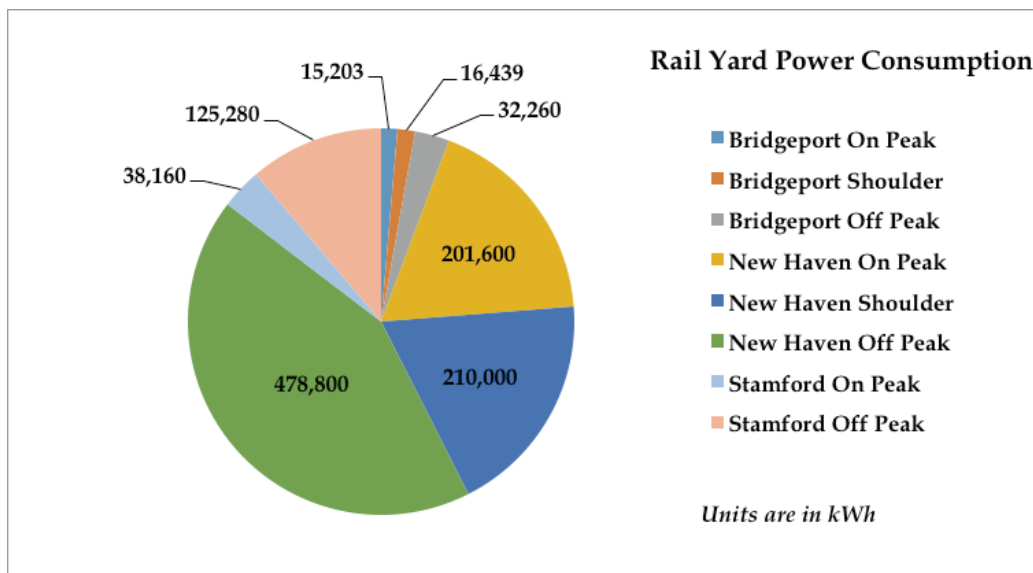
FIGURE 3-39: DISTRIBUTION OF ELECTRICITY USAGE FOR THE BRIDGEPORT, NEW HAVEN, AND STAMFORD RAIL YARDS WITH RESPECT TO TIME OF DAY

Figures 3-40 and 3-41 show the average daily usage for the period of January 2012 – January 2013. Figure 3-40 shows that the New Haven Yard is the largest consumer, and Figure 3-41 more accurately scales usage for the two other rail yards. These figures indicate that electricity usage at the New Haven and Bridgeport Rail Yards was highest during the winter, with the summer being the second highest period of daily demand. Comparatively, Stamford's consumption is the reverse, with summer having a slightly higher demand than winter.
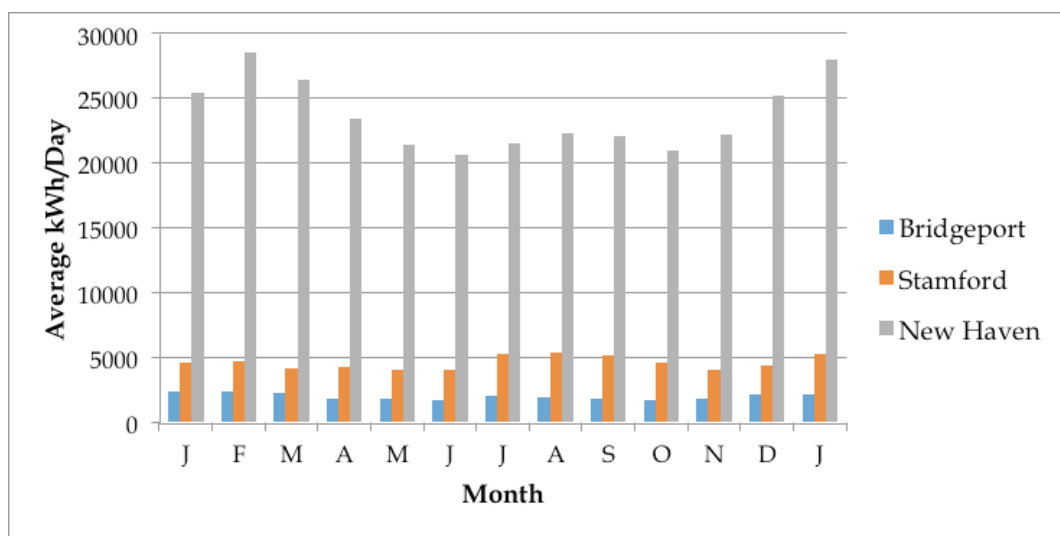
FIGURE 3-40: AVERAGE DAILY ELECTRICITY USAGE FROM JANUARY 2012 - JANUARY 2013 FOR BRIDGEPORT, NEW HAVEN, AND STAMFORD RAIL YARDS
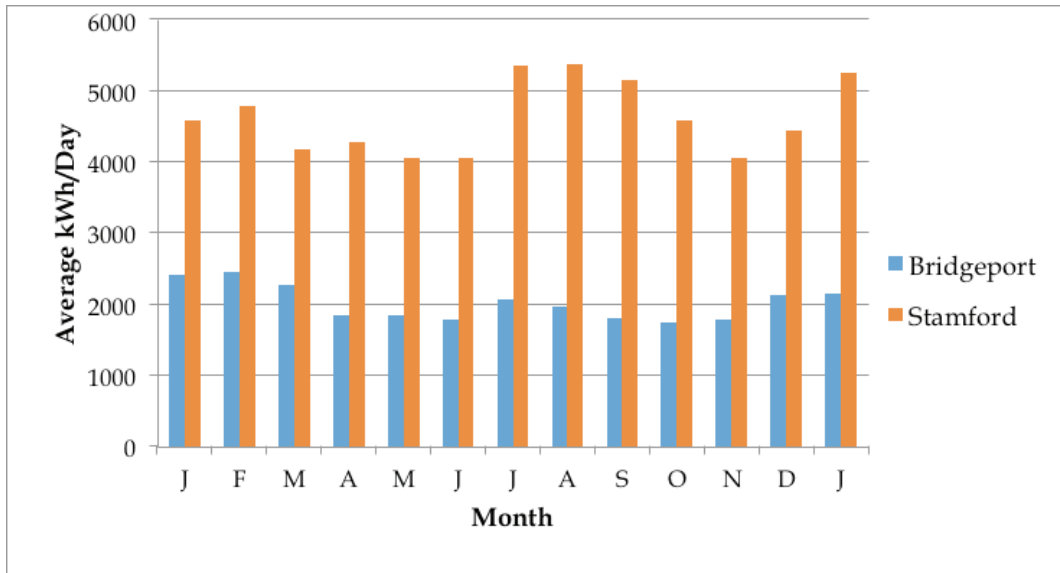
FIGURE 3-41: AVERAGE DAILY ELECTRICITY USAGE FROM JANUARY 2012 - JANUARY 2013
FOR BRIDGEPORT AND STAMFORD RAIL YARDS

The research team met with an MNR electrician who is responsible for the submeters at the New Haven Rail Yard to gain additional information about New Haven's unique metering configuration. For New Haven exclusively, the main meter is actually three meters (meter numbers 16040529, 16040530 and 16040531), all of which are Itron Sentinel meters, type IT9SL. The first two are separate feeder meters that supply a distribution building, and the third meter is the sum of the two feeders and it is monitored by the MNR electrician. All three meters are demand meters and are operated by UI.

Seventeen of the electrical paths exiting this building pass through submeters, three of which are for the purpose of billing separate entities that consume electricity at the rail yard. These three meters are:

- M2 Overhaul Shop meter, located at the CSR Shop, with Kawasaki billed for usage. This type of meter allows for access to some consumption data, but specifics are unknown and not checked by the electrician.

- M8 Trailer Compound meter, with Kawasaki billed for usage. This is a simple meter without data access capabilities.

- Shore Line East meter, located at the CTDOT building, used by Amtrak and billed to the State of Connecticut. This type of meter allows for access to some consumption data, but specifics are unknown and not checked by the electrician.

The remaining submeters are simple E-MON D-MON mechanical counter meters that include:

- Power Trailer Compound meter: monitors seven mobile home trailers that are used as office space for MNR staff.

- Bubble Tent WO meter: the bubble tent is a tent that contains pumps and filters to separate water from oil.

- B&B Snow Shed meter, located at a small building (approximately 400 square feet) that stores snow blowers. Lighting and a heat source are the only loads in this shed.

- Building 10 (Storage Facility) has a total of eight submeters that are located inside the building. The building is divided into seven bays, each of which contains a meter; the eighth meter was added in bay four more recently. In addition to lighting and possibly an HVAC system (not confirmed), additional loads include part washing equipment and a Lazy Suzan conveyer belt (480V, 30A) that stores parts and is used a couple of times a day. The eight submeters are named as follows on the data sheets provided by MNR:

  1. Training Department

  2. Storehouse (Sect.2)

  3. B&B Plumbers, Tin Knockers

  4. Storehouse (Sect.4)

  5. M2 Storehouse (Sect.5)

  6. M2 Storehouse (Sect.6)

  7. M2 Storehouse (Sect.7)

  8. Hallock Ave Support Shop

The 17 submeters are visited monthly by the MNR electrician, who records the data into a spreadsheet. The values recorded for some of the meters are kWh data. For other meters the data are unitless numbers that are automatically converted to kWh through a spreadsheet multiplier operation. The MNR electrician did not know which meters require this additional operation. Table 3-8 was created based on the readings taken during February, March, April, and May of 2014. The data shown are the raw numbers recorded by the meter, not the spreadsheet numbers with the multipliers (some entries in Table 3-8 have units of kWh, but which ones are not known).

TABLE 3-8: SUBMETER RECORDS FOR THE NEW HAVEN RAIL YARD

METER #	LOAD	Available Reading Dates During 2014			
		2/11	3/12	4/11	5/12
16040531	UI Main Feeder	14015.00	14318.00	14598.00	14828.00
70048586	Power Trailer Compound	34842.00	35965.00	36834.30	37243.20
70048730	M8 Trailer Compound	49438.50	51368.00	52740.40	53135.80
03100482	Hallock Ave Support Shop	1558243.00	1570510.00	1582327.00	1594621.00
214953	Shore Line	5228.79	5354.37	5467.98	5565.41
530855-2	M2 Overhaul Shop	7434.90	7502.84	7560.60	7603.06
70447BOP	Storehouse (Sect 4)	9842.00	0041.00	212.00	339.00
78492599	Training Department	494.00	498.00	595.00	661.00
8552602	M2 Storehouse (Sect 5)	93692.00	96477.00	99251.00	2205.00
8553095	M2 Storehouse (Sect 6)	84568.00	87295.00	89978.00	92843.00
8553106	M2 Storehouse (Sect 7)	87140.00	92813.00	97522.00	2042.00
8606907	Storehouse (Sect 2)	95172.00	97259.00	99219.00	1211.00
8606955	B&B Plumbers, Tin Knockers	14707.00	17438.00	20311.00	23339.00
10041736	Bubble Tent WO	1663965.00	1746295.00	1826555.00	1842948.00
98080349	B&B Snow Shed	307.00	410.00	460.00	496.00

Although 17 submeters are monitored by the MNR electrician, there may be more since Table 3-9, generated from an Excel spreadsheet that was provided to the research team as supporting documentation, clearly shows a meter number not listed in the MNR electrician's records. It is possible that this meter has been discontinued, but the MNR electrician also has records of other discontinued meters, and none are a match with this additional meter. One of the New Haven Rail Yard submeters is for the parking facility at the New Haven Station that is operated by the New Haven Parking Authority. Table 3-9 shows the electricity consumed and the total amount billed to the authority. The year pertaining to the billing periods shown is not known.

TABLE 3-9: NEW HAVEN STATION BILLS TO NEW HAVEN PARKING AUTHORITY UI METER 014014301 GS TIME OF USE RATE, 13.07 CENTS PER KWH, LOAD FACTOR 0.50

Billing period	kWh peak	kWh shoulder	kWh off peak	Total kWh	Total Bill ($)
4/13-5/09	48600	41400	79200	169200	$19,085
5/10-6/08	56100	48600	85500	190200	$ 22,467
6/09-7/10	69900	59400	116100	245400	$ 30,599
7/11-8/08	76800	66000	119100	261900	$ 33,456
8/09-9/08	70200	59700	102300	232200	$ 29,066
9/09-10/06	60300	50400	98100	208800	$ 23,073
10/11-11/08	52200	44400	78900	175500	$ 17,837
11/09-12/08	53400	45300	80400	179100	$ 18,493
12/09-1/09	54600	45900	90000	190500	$ 26,209
1/10-2/07	49800	43200	77400	170400	$ 37,919
2/08-3/09	52500	45300	79800	177600	$ 38,099
3/10-4/10	54300	45600	88200	188100	$ 34,474
			TOTALS:	2388900	$312,284

Examination of the power distribution single line diagram pertaining to the New Haven Rail Yard shows that more circuits exist and further documentation will be needed to gain a complete understanding of this system. In addition to the 17 meters monitored by the MNR electrician (three of which comprise the UI main feeder and the remaining 14 correspond to various facilities), eight other electrical paths exit the power distribution room. The UI main feeder meters connect to two main bus bars dividing the electricity into paths for distribution to the facilities. Figure 3-42 shows the paths leaving the two bus bars and the facilities they supply. Table 3-10 details the individual facilities that each path supplies.
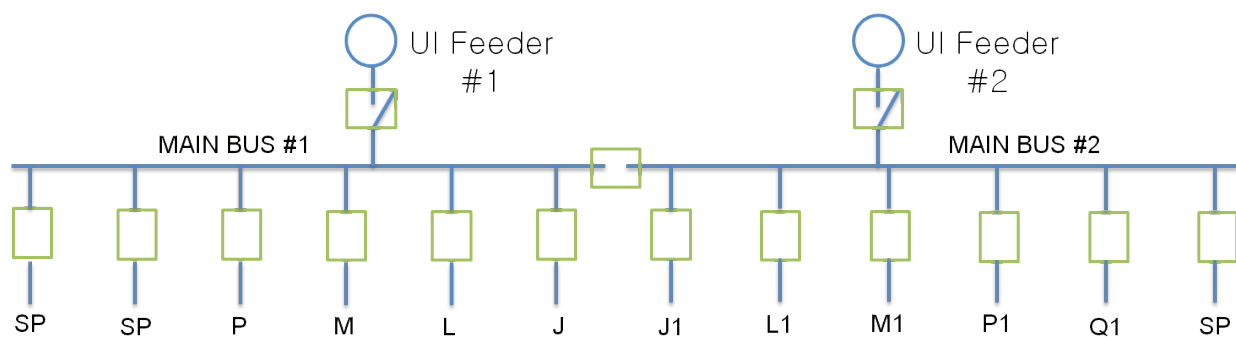

FIGURE 3-42: NEW HAVEN RAIL YARD POWER DISTRIBUTION:
PATHS LEAVING THE TWO BUS BARS

TABLE 3-10: NEW HAVEN RAIL YARD POWER DISTRIBUTION

Main Bus Bar	Path	Facility Being Supplied
#1	J	US-6
		Signal Sub 1091 (Fair ST.)
	L	Diesel Shop
		Lighting Transformer
	M	Running Repair Shop
		Dewatering Treatment Plant
		Training Facility
		Material Storage Building
		M of B Support Shop
		MN Trailers
		US-1
		Trans Building
		US-2
		US-3
	P	Component Change Out Shop (CCO)
#2	J1	US-6
		Signal Sub 1091 (Fair ST.)
	L1	M-8 Test Trailers
		US-5
		Car Shop
		Independent Wheel Truing Facility (IWT)
	M1	Independent Wheel Truing Facility (IWT)
		US-4
		Stand By Power
	P1	Component Change Out Shop (CCO)
	Q1	US-4

According to the diagram all 22 paths pass through a transformer, but submeters are not depicted in the document; the 14 paths monitored by MNR that were previously identified are the only paths that are confirmed to have submeters. Two additional documents outline the specifics for the transformers that serve US-1 through US-6 facilities. The drawings referenced on the power distribution diagram are US-NHY-001 and US-NHY-002, but these documents were not provided to the research team. Both US-6 and the Signal Sub 1091 (Fair ST.) have an additional transformer. Paths J, L and M form circuits via switches with J1, L1 and M1, respectively off of which the individual facilities branch. According to the diagram, paths P and P1 do not connect to form a circuit, but rather each appears to connect to two separate transformers within the CCO. The IWT and US-4 are connected to two paths simultaneously as shown in Table 3-10 and Figure 3-42.

Throughout the study, the research team encountered issues resulting from inconsistent naming conventions for diagrams, signs and terminology used by MNR staff. For example the building

called "The Bubble Tent" by the staff and labeled "Bubble tent WO" in the MNR electrician's paperwork, is referred to as "Water Treatment Bld 10A" on a sign within the rail yard and "Dewatering Treatment Plant" on the power distribution diagram. This is one of the more straightforward examples, but others are not as clear, such as the building commonly known as the M2 shop, where this identifier does not appear on any signs in the yard nor official documents provided to the research team. Only one of the 14 submeters that are monitored shares a common name with the power distribution diagram, three others are close enough to determine, and the rest are not identifiable.

The meter data that is collected monthly by an MNR electrician is entered into a spreadsheet for further calculation by another MNR staff person in order to obtain kWh usage. The exact calculations were not specified by MNR staff. Instead, the following information was provided:

- No calculations are performed by MNR staff, and whether or not calculations are performed using the spreadsheet as indicated by the MNR electrician was not addressed.

- Meter data is received for:

    1. Volts

    2. Volt-Amperes

    3. Watts

- kW = Watts/1000

- kW=kWh/(730x.5) , where 730 is hours in a month and .5 is a load factor of 50% average

- "Electric meters spin at a slow rate to prevent meters from flying. Meters will have a multiplier to calculate kW. For example if a multiplier is 100 and the reading is 10, then multiply 100 x 10 which equals 1,000 kW. The same process is used for calculating kWh, (kWh reading) x multiplier =kWh."

Judging from the information provided, some meters are recording real power with a unit of watts (W), while others are recording apparent power with the unit of volt-amperes (VA). Apparent power is the magnitude of the total real power in W and reactive power in VAR. The equation,, converts apparent power to kW, where is power in kW, is apparent power in VA and PF is power factor.

The UI feeder meter has units of kWh with a multiplier of 2,800 as indicated on the electricity bill for this meter. The units for this meter were determined using the bill in conjunction with the electrician's data from Table 3-8. Table 3-11 was determined as follows:

- UI Main Feeder Monthly Reading is the difference of the meter readings over the specified period

- Monthly kWh is that value multiplied by the 2,800 multiplier

- Daily average is monthly kWh divided by 30 (average days in a month per a UI customer service representative)

- Daily averages for 2013 are derived from Figure 3-40.

Table 3-11 depicts the result of this procedure, which supports the assumed units for the UI Main Feeder Meter #16040531 since the calculated daily average for 2014 is very close to the known kWh during the same periods of 2013.

TABLE 3-11: SUPPORT FOR kWH AS THE UNITS FOR UI MAIN FEEDER METER LOCATED AT THE NEW HAVEN RAIL YARD

Period	UI Main Feeder Meter Monthly Reading	Monthly kWh	Daily Average	Daily Average for the Same
	Meter #16040531			Period of 2013
January - March 2014	303	848,400	28,280	28,512
March- April 2014	280	784,000	26,133	26,414
April- May 2014	230	644,000	21,466	23,406

Although the UI meter appears to have units of kWh, the information provided regarding sub-meters does not include this unit. The other meters are most likely a combination of W and VA, but since the units are not identified for individual meters and the multipliers are unknown, it is not possible to determine the percentage of the utility bill that represents each facility's consumption.

3.2.2 Platform Station Electricity Usage

Several platform stations, including the Milford station, were included in the additional electricity consumption documentation provided by the utilities. The Milford station is the only one presented in this report, since the platform stations all have similar load profiles consisting primarily of lighting.

The Milford platform station has four UI meters that are billed separately. Electricity usage and cost summary for the period of 2012 through July 2014 is outlined in Table 3-7.

TABLE 3-12: MILFORD PLATFORM STATION ELECTRICITY YEARLY CONSUMPTION AND COST
(NOTE: *2014: JANUARY – JULY ONLY)

Meter #	Year	Meter kWh	Yearly Cost
016010315	2014*	3,758 kWh	$688
	2013	5,447 kWh	$990
	2012	4,929 kWh	$965
011135737	2014*	505 kWh	$219
	2013	1,963 kWh	$572
	2012	3,145 kWh	$799
011096252	2014*	544 kWh	$228
	2013	951 kWh	$374
	2012	952 kWh	$363
011077782	2014*	1,966 kWh	$485
	2013	3,053 kWh	$803
	2012	2,849 kWh	$739

The average yearly electricity usage and cost for the Milford platform station (derived from Table 3-12) is 11,645kWh and $2,803, respectively. It is noted that there are 33 platform stations serving the New Haven Rail Line and that utility providers and electricity rates are not the same for all of the platform stations. However, based on the Milford platform station's annual usage and cost averages, a preliminary estimate for the combined annual electricity usage and cost for all platform stations would be approximately 384,285kWh and $92,500, respectively. An energy audit of all platform stations would provide further analysis to refine this preliminary estimate.

3.3   ANALYSIS OF NATURAL GAS BILLS

Natural gas is available at all three major rail yards, as follows:

- Southern Connecticut Gas (SCG) supplies Bridgeport (Meter 644036) and New Haven (Meters 715346, 757853 and 756122)

- Yankee Gas supplies Stamford (Meter 0500650)

The natural gas consuming loads identified in Section 3.1 are the wall-mounted heaters, water heaters and boilers.

Natural gas billing includes delivery and sales charges, and other factors such as

- Purchased Gas Adjustment (PGA): this amount reflects the total unit cost of gas purchased

- Peak: a charge applied to a customer's highest one day usage for system capacity made available for that customer

- Conservation Adjustment Mechanism (CAM): A charge on firm customer's bills that is a rate making tool that either refunds or collects the difference between actual and allowed conservation expenses compared to that allowed in base rates.

These definitions are taken verbatim from the gas bills and a Southern Connecticut Gas document explaining tariffs. In addition, a Correction Factor, specific to each individual meter location, is used that is based on temperature and atmospheric fluctuations; even the three New Haven meters have different Correction Factors.

The unit for gas is centum cubic feet (ccf). The root word, "cent," means 100; in other words, one ccf of natural gas equals 100 cubic feet of natural gas. Since the dimensions for ccf are length^3 and the dimensions for kWh are or energy
it is necessary to convert ccf to kWh to accurately compare the cost of energy at the rail yards.

The common conversion is the British Thermal Unit (BTU), 1 kWh =3412.142 BTU and 1ccf = 102,500 BTU; therefore, 1 ccf is approximately 30 kWh. Due to the significant differences in billing methods between gas and electricity, the out of pocket expense for each utility will be compared by total cost per kWh. The out of pocket expense is the total dollar amount that is paid to each utility, and includes all taxes, fees and any other subcategory that appears on the bill. There were several billing periods of gas bills provided to the research team and only one billing period for electricity. A spreadsheet provide by UI recorded the last three years of billing

history for Bridgeport and New Haven Rail Yards. Although CL&P provided a similar chart, the cent/kWh was not included. Therefore, a range of pricing is not given for Stamford's electric rate, but rather this price was taken from the single bill that was provided. Table 3-13 shows the comparison of total cost per kWh for gas and electricity.

TABLE 3-13: COST PER KWH COMPARISON BETWEEN NATURAL GAS AND ELECTRICITY FOR BRIDGEPORT, NEW HAVEN, AND STAMFORD RAIL YARDS

(NOTE: ASSUMING 100% CONVERSION: ONE MILLION BTUS = APPROXIMATELY 293KWH)

Rail Yard	Cents/kWh for Natural Gas	Cents/kWh for Electricity
Bridgeport	3.52 to 3.66	13.13 to 15.67
New Haven	2.47 to 3.77	11.33 to 15.47
Stamford	2.68 to 3.95	24.47

It is noted that for the summer months of July and August, the New Haven Rail Yard billing rate for gas was 9.28 and 46.7 cents/kWh for a total cost of $1,949 and $1,780, respectively. This rate was greater than the range specified in Table 3-13, as it appears that the July and August billing periods experienced a higher rate due to distribution of annual costs, thereby reducing the larger winter bills and shifting some of the cost to the summer months when gas consumption is lower.

The following Tables 3-14 through 3-16, detail the gas bills paid by the CTDOT for natural gas at the major rail yards.

TABLE 3-14: BRIDGEPORT RAIL YARD DECEMBER 2012 - NOVEMBER 2013 GAS BILLING CYCLE
(*NOTE: METER READING RESETS AT 100,000 TO 0)

Billing Period	Total Gas Charges	Meter 644036 Start	Meter 644036 End	Meter 644036 Correction Factor	Meter 644036 Total ccf
Dec-12	$5,170	96632 (*)	1329	1.3394	6291.162
Jan-13	$5,610	1329	6538	1.3394	6976.935
Feb-13	$4,420	6538	11399	1.3394	6510.823
Mar-13	$2,770	11399	15019	1.3394	4848.628
Apr-13	$1,830	15019	16783	1.3394	2362.702
May-13	$1,060	16783	17425	1.3394	859.895
Jun-13	$829	17425	17605	1.3394	241.092
Jul-13	$814	17605	17752	1.3394	196.892
Aug-13	$810	17752	17900	1.3394	198.231
Sep-13	$881	17900	18205	1.3394	408.517
Oct-13	$1,780	18205	19747	1.3394	2065.355
Nov-13	$2970	19747	23036	1.3394	4405.287
Totals	**$ 28,944**				**35,366**

TABLE 3-15: NEW HAVEN RAIL YARD DECEMBER 2012 - NOVEMBER 2013
GAS BILLING CYCLE: TOTAL ALL METERS

Billing Period	Total Gas Charges	Meter 715346 Total ccf	Meter 756122 Total ccf	Meter 757853 Total ccf	All Meters Total ccf
		Correction Factor: 1.0		*Correction Factor: 1.3394*	
Dec-12	$12,481	5035	57	10099.076	15191.08
Jan-13	$13,790	5708	74	11502.767	17284.77
Feb-13	$9,823	5331	133	8783.785	14247.79
Mar-13	$6,426	4155	62	6978.274	11195.27
Apr-13	$7,137	N/A	N/A	N/A	13915
May-13	$2,737	N/A	N/A	N/A	2933
Jun-13	$1,949	222	43	435.305	700.305
Jul-13	$1,780	39	38	50.897	127.897
Aug-13	$1,770	39	37	77.685	153.685
Sep-13	$2,373	711	43	1343.418	2097.418
Oct-13	$4,846	1767	51	5186.157	7004.157
Nov-13	$8,321	4308	52	9614.213	13974.21
Totals	**$73,433**				**81,977**

TABLE 3-16: STAMFORD RAIL YARD DECEMBER 2012 - NOVEMBER 2013 GAS BILLING CYCLE

Billing Period	Total Gas Charges	Meter 0500650 Start	Meter 0500650 End	Meter 0500650 Correction Factor	Meter 0500650 Total ccf
Dec-12	$818	40381	41071	N/A	690
Jan-13	$974	41071	41963	N/A	892
Feb-13	$1,550	41963	43635	N/A	1672
Mar-13	$1,860	43635	45947	N/A	2312
Apr-13	$1,090	45947	47092	N/A	1145
May-13	$417	47092	47142	N/A	50
Jun-13	$415	47142	47192	N/A	50
Jul-13	$393	47192	47192	N/A	0
Aug-13	$393	47192	47192	N/A	0
Sep-13	$452	47192	47298	N/A	106
Oct-13	$537	47298	47545	N/A	247
Nov-13	$890	47545	48358	N/A	813
Totals	**$ 9,789**				**7,977**

A summary of natural gas cost and consumption for the New Haven, Bridgeport, and Stamford Rail Yards for the period of December 2012 – November 2013 is shown in Table 3-17.

TABLE 3-17: NATURAL GAS COST AND CONSUMPTION ALL THREE RAIL YARDS
DECEMBER 2012 - NOVEMBER 2013

Rail Yard	Cost	Consumption (ccf)	Cost per ccf
New Haven	$ 73,433	98,824	$ 0.743
Bridgeport	$ 28,944	35,366	$ 0.818
Stamford	$ 9,789	7,977	$ 1.23
Totals	**$112,166**	**142,167**	**Average = $ 0.93**

The following Figures 3-43, 3-44 and 3-45 show the comparison of daily kWh consumption for the gas and electric utilities for the Bridgeport, New Haven, and Stamford Rail Yards.
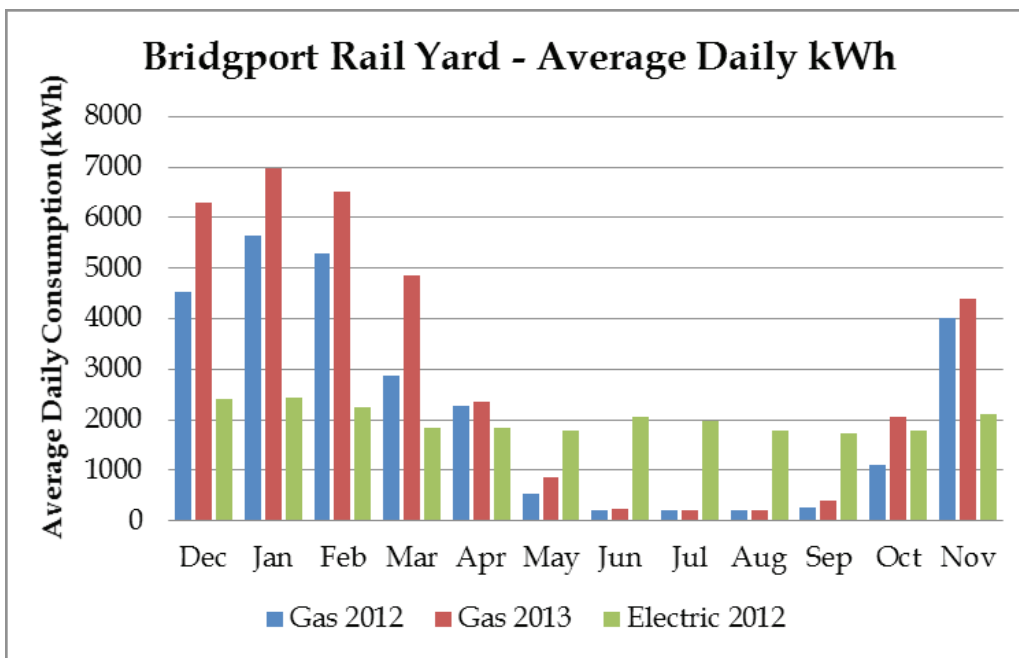
FIGURE 3-43: AVERAGE DAILY GAS AND ELECTRICITY CONSUMPTION
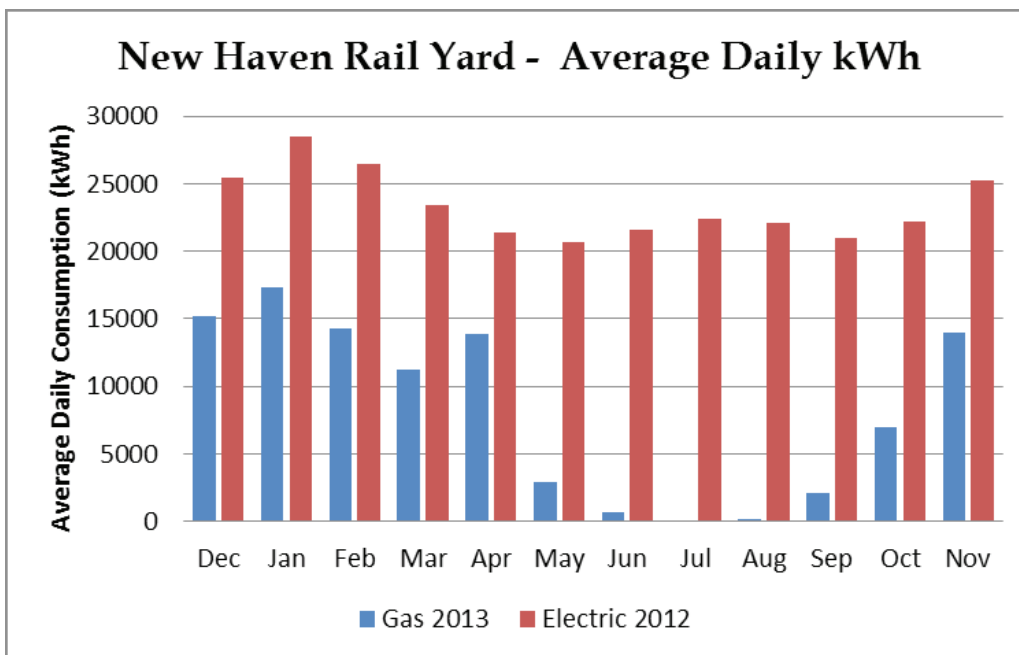(WITH GAS CONVERTED FROM CCF TO KWH) — BRIDGEPORT RAIL YARD

FIGURE 3-44: AVERAGE DAILY GAS AND ELECTRICITY CONSUMPTION
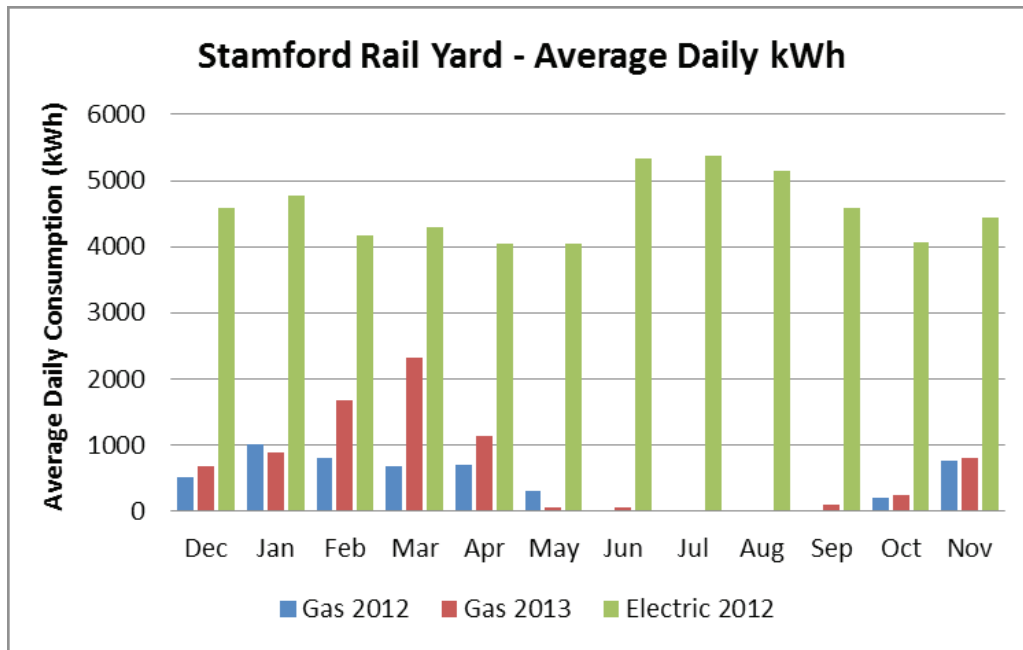(WITH GAS CONVERTED FROM CCF TO KWH) — NEW HAVEN RAIL YARD

FIGURE 3-45: AVERAGE DAILY GAS AND ELECTRICITY CONSUMPTION
(WITH GAS CONVERTED FROM CCF TO KWH) — STAMFORD RAIL YARD

3.4 CONCLUDING REMARKS

In accordance with industry best practices, the operations and energy loads that comprise the rail facilities have been divided into initial subcategories based on research team visits to the New Haven, Stamford and Bridgeport Rail Yards and the West Haven and Milford platform stations.

- Electricity and gas bills have been analyzed to determine the energy cost paid by the State of Connecticut for the three major rail yards and the Milford platform station.

- Further information is required before accurate estimates can be made regarding how much energy is being used by specific load categories and by individual facilities. For load categories, the duty cycle of equipment and the measurement of electricity consumption need to be determined and monitored over time. If the meters are properly calibrated and accurately recording electricity usage, then the multipliers and units for each submeter are all that is needed. Calculations to determine the percentage of the total bill each facility is responsible for can be made for each facility equipped with a submeter.

4.0 BEST PRACTICES

This section of the report provides a more detailed summary of successful upgrades and strategies that have been recommended and implemented by previous studies identified in the literature review. Additional research was conducted to investigate the pros and cons of the various upgrades and energy savings strategies.

Commonalities identified in the studies and reports that were reviewed indicate several best practices that are critical to understanding, managing and improving existing facilities and systems with respect to energy efficiency. Before improvements can be made, the entire system, both at the overall level and subsystems level, must be understood in terms of current energy consumption. In several previous studies, this information was obtained by conducting an energy audit to identify loads and areas of cost savings opportunities. Various loads that exist in a facility in terms of numbers present, frequency of use (or duty cycle), and the energy consumption profile must be identified.

A common strategy among most of the large-scale studies was to divide unique load profiles into categories; benefits include simplification of complex systems and the ability to identify the size of the load relative to others at a particular facility. This allows the focus to be directed toward the largest loads first, which will more significantly reduce energy consumption; smaller loads can then be addressed for a holistic approach.

Simulations were a recurring practice implemented in order to understand loads, air flow, scheduling and other impacts on energy efficiency. Once the system is divided into categories and methodically analyzed and understood, conservation opportunities will become more apparent. There may be procedures that are unnecessary and energy waste that can be eliminated, such as air-conditioning a room that is rarely occupied and does not contain temperature-sensitive equipment, or shifting scheduling of large power consuming operations to lower-cost off peak hours.

Internal policies which promote sustainable energy and smart energy use, where applicable under feasibility and safety standards, must be developed setting various goals, such as saving energy, protecting ecosystems, and enhancing resiliency, followed by long-term targets that are monitored over time. These policies and procedures can become part of a workplace culture that ingrains energy-saving behaviors into daily tasks.

Among the common best practices is to establish an energy management system that is a framework of authority inside an organization for determining who will manage the implementation and changes to energy-saving policies.

The implementation of controllers and sensors will improve many types of systems, such as lighting, HVAC, switching circuits on or off, and automated blinds, by more accurately managing systems and reducing human error in management. Locations of sensors are also an important consideration that has been previously studied. For example, a temperature sensor

that is in the direct path of sunlight will misread the ambient temperature of a room, causing the HVAC to work harder and waste energy. Motion sensors can be linked to any control system to detect the presence of people and perform adjustments accordingly. The staff must be periodically trained in the proper monitoring and programming of control systems, as well as maintenance of equipment to ensure efficient operation. Another successful control system for energy reduction is smart grid technology, which monitors the electrical network and reconfigures aspects of power flow to minimize losses, as well as further identify energy usage of a facility. It is noted that cybersecurity is still a concern in applying smart grid technologies and should be appropriately addressed before implementation.

When considering upgrades, the best practice is to understand the cost and benefit of upgrades and the total cost of ownership, which includes costs associated with purchase, installation, maintenance and disposal, encompassing the entire life cycle of the investment. Another best practice is using both federal and state programs as well as incentives to reduce out-of-pocket expenditures. Upgrades can be structural, such as windows and insulation, or updates to equipment such as more efficient HVAC, furnaces and tools. HVAC and lighting were the two areas that were most commonly the largest loads of a commercial facility, and therefore the areas that were the main focus in the literature. More specifically, average energy use distribution in commercial buildings is estimated to be 20% lighting, 16% space heating, 15% space cooling, 9% ventilation, 7% refrigeration, 4% water heating, 4% electronics, 4% computers, 1% cooking, 15% other, and 5% unattributed.

Light emitting diode (LED) technology has recently progressed, extending the light spectrum of operation and making it an optimal upgrade for lighting.

Creating zones in a building with separate HVAC systems is a best practice that also successfully reduces energy usage. Passive measures to aid in ventilation and temperature control include the opening and closing of windows and blinds to reduce the demand imposed on the HVAC system.

Energy losses will also be present during the transmission, rectification and transformation of power. Alternative energy options need to be examined carefully when choosing the type of system to be installed to supplement the utility as a source of electricity. A photovoltaic (PV) system is the most common alternative energy system identified in the literature review, but in some cases, wind turbines may be a better fit depending on location. PV panels that are placed far away from a site equate to larger losses in power during transmission. Since they only produce power during daylight hours, storage or net metering also need to be addressed.

4.1   Pros and Cons of Successful Practices

4.1.1 Lighting

4.1.1.1 MORE EFFICIENT LIGHTING

- LEDs, Compact Fluorescent (CFL) and induction lighting are three lighting technologies that are preferable to incandescent lighting for nearly identical reasons.

- Lighting is estimated to represent 20% of average energy use distribution in commercial buildings.

- Several sources outline a strategy for implementing LED lighting in buildings with incandescent lighting that involves simply replacing the incandescent lighting with LEDs at the end of its natural life.

Table 4-1 compares the cost of using incandescent, CFL and LED lighting technologies. Table 4-2 outlines the pros and cons of lighting upgrades.

TABLE 4-1: LIGHTING TECHNOLOGY COMPARISON [33]

Bulb Type	60W Traditional Incandescent	43W Energy-Saving Incandescent	15W CFL	12W LED
Energy $ Saved (%)	-	25%	75%	75-80%
Annual Energy Cost*	$4.80	$3.50	$1.20	$1.00
Bulb Life	1,000 hrs	1,000-3,000 hrs	10,000 hrs	25,000 hrs

*Based on 2 hrs/day of usage and an electricity rate of 11 cents per kW^h

TABLE 4-2: PROS AND CONS OF LIGHTING UPGRADES [1, 21, 23, 22]

Pros	Cons
• Higher efficiency (LEDs are approximately 75% more efficient than incandescent lighting) • Much longer lifespan (LEDs last approximately 40 times longer than incandescent lighting and 2-3 times longer than CFLs) • Lower maintenance frequency • Accessible technology • Less expensive in the long term	• High initial investment and installation labor, even if cost recovery is rapid

4.1.1.2 RENEWABLE ENERGY SOURCES FOR LIGHTING LOADS

- Lighting for very small stations and/or facilities may provide enough electricity from renewable energy conversion, such as solar photovoltaics, to operate largely off of the grid with minor utility connection and base fees.

- According to Public Act No. 11-80, clean energy sources in Connecticut include, but are not limited to, solar power, wind power, geothermal power, and fuel cells.

- A PV system comprising 780 PV modules, with each module consisting of 100 cells and 117 inverters, covering 20,100 ft^2 of roof area is installed at the Lehrter Station. "When cell-output-module coverage effectiveness (surface related) is 63%" [15] the system will produce 160MWh.

- The estimated roof area of the existing buildings at the New Haven Rail Yard (296,000 ft2) is approximately 15 times greater than that of the Lehrter Station.

- PV power production at Berlin, Germany's latitude is estimated at 150W/m2 as compared to New Haven, Connecticut's, which is estimated at 200 W/m2.

- PV systems can be grid tied with net metering and/or energy can be stored.

TABLE 4-3: PROS AND CONS FOR RENEWABLE ENERGY INSTALLATIONS WITH MAJOR LIGHTING LOADS [1, 11, 15, 32]

Pros	Cons
- Environmentally friendly sources - Zero emissions or near-zero emissions for fuel cells - Possible financial incentive programs to offset purchase cost	- May not be sufficient for larger stations/ facilities with high energy consumption - Dependent on geographic location and variable atmospheric conditions - Non-dispatchable resources with solar and wind energy - Lower efficiency than conventional generation

4.1.1.3 Daylighting

- Involves admitting natural light into a building in a controlled manner.

- Incorporates wall or roof apertures such as windows and skylights to allow daylight into the building, shading and reflecting elements to control solar heat gain and decrease glare, and control systems to modulate the interior electrical lighting, as necessary.

- Can be integrated in the design phase for new buildings, and analyzed for potential retrofitting for existing buildings.

TABLE 4-4: PROS AND CONS FOR DAYLIGHTING FACILITIES [32]

Pros	Cons
- Natural light / renewable energy source - Reduces energy costs - Automatic controls and dimmable fixtures can reduce energy consumption for lighting between 35% - 60% - Decreases cooling loads with appropriate orientation	- Availability varies with geographic location and atmospheric conditions - Requires site planning - Purchase cost and possibly high retrofitting cost for existing buildings

4.1.2 HVAC

4.1.2.1 HVAC VARIABLE FREQUENCY DRIVES (VFDS)

- Install VFDs (also referred to as adjustable speed drives) on the HVAC supply fan motors. A VFD will reduce power consumption of supply fans depending on the return air temperature.

- By installing a VFD on each HVAC supply fan, energy savings can be obtained due to the fact that the fan motor will no longer be consuming 100% of its rated power.

TABLE 4-5: PROS AND CONS FOR HVAC UPGRADES [27]

Pros	Cons
▪ Reduced energy consumption and electricity cost ▪ Cost effective in the long term (payback period is approximately 8.8 years)	▪ High initial investment

4.1.2.2 BUILDING INSULATION

- Improve insulation in work spaces to reduce HVAC loads

- Install insulated doors and windows

- South-facing windows can add heat in the winter, but north-facing windows do not

- Use plastic strips as a curtain to prevent air infiltration for large openings

TABLE 4-6: PROS AND CONS FOR BUILDING INSULATION [35]

Pros	Cons
▪ Reduced energy consumption and electricity/ fuel cost for heating and cooling ▪ Reduced heat loss/retention in colder and warmer weather, respectively	▪ Initial capital cost for improvements

4.1.2.3 TRANSPIRED SOLAR COLLECTORS

- The transpired solar collector is an air preheating system. Sunlight strikes and warms a south-facing vertical wall. Heat is transferred to air as it passes through tiny holes or slits in the wall for ventilation.

- During the heating season, the system collects solar energy and recaptures wall heat loss

- During the cooling season, collector bypass vents can be opened, allowing the wall to dump heat, thus reducing cooling loads

TABLE 4-7: PROS AND CONS FOR TRANSPIRED SOLAR COLLECTORS [32, 36]

Pros	Cons
▪ Uses renewable energy sources to reduce electrical loads ▪ Reduces energy cost	▪ Requires a suitable south-facing wall and access to the building's ventilation system ▪ Dependent on geographic location and atmospheric conditions ▪ Collector requires a large area ▪ High initial investment

4.1.2.4 RADIANT HEATING

- Radiant heating heats a surface such as a wall or floor, as opposed to convection heating, which heats the air

- Radiant-floor heating turns a floor into a large-area, low-temperature radiator. In most modern radiant-floor heating systems, warm water circulates through plastic tubing that is either embedded in a floor slab or attached to the underside of subflooring.

- Works well in buildings with large open spaces and tall ceilings and in buildings where air-flushing is common, such as garages, fire stations, airplane hangars, and industrial spaces.

TABLE 4-8: PROS AND CONS FOR RADIANT HEATING [34]

Pros	Cons
▪ Provides a comfortable work environment	▪ Initial capital cost
▪ Quiet operation	▪ Some difficulty with cooling
▪ Increased boiler life	▪ Not much data to support reduced energy cost
▪ Better indoor air quality	
▪ Reduces energy consumption	

4.1.3 Improved Policies and Procedures

- High-level leadership support for increasing awareness of energy efficiency practices in order to affect staff behavior is critical for achieving energy efficiency goals.

- The accumulation of various inefficient energy-related policies and procedures can result in unnecessary energy costs.

- Policies and procedures for energy-consuming loads (e.g., lighting, HVAC, machinery, etc.) should be reviewed and modified as needed to achieve energy efficiency goals.

- Energy audits, as cited in best practices, should be conducted periodically, with strategies then formed for making improvements based on audit results.

- Average energy use distribution in commercial buildings is estimated to be 16% space heating, 20% lighting, 16% space heating, 15% space cooling, 9% ventilation, 7% refrigeration, 4% water heating, 4% electronics, 4% computers, 1% cooking, 15% other, and 5% unattributed.

- Policies regarding temperature and lighting control for air conditioning and heating as well as recommended employee behavior in the management of these systems reduces HVAC and lighting costs.

- Examples of recommended practices for buildings include:

- Night cooling

- Passive solar heating

- Determining if thermostats falsely read data because of solar radiation

- Use of brighter, more reflective paint to take advantage of natural sunlight to reduce use of electricity for lighting

- Use of automated interior lighting to ensure that energy isn't wasted when there is no activity in a facility or an area of a facility.

- Regular cleaning and maintenance of light fixtures

TABLE 4-9: PROS AND CONS FOR IMPROVED POLICIES AND PROCEDURES [1, 5, 19]

Pros	Cons
▪ Minimal or zero cost ▪ Reduces energy costs ▪ Encourages energy awareness ▪ Allows energy consumption and cost information to be tracked on a regular basis	▪ Changing human behavior can be difficult

4.1.4 Other

4.1.4.1 WATER USE – HEATING WATER

- Train Car Wash Facility: water can be heated, if necessary, with renewable energy sources such as solar/thermal energy

TABLE 4-10: PROS AND CONS FOR HEATING WATER [1]

Pros	Cons
▪ Reduces energy cost ▪ Reduces electricity use	▪ May be a slower process

4.1.4.2 WATER USE – IMPROVED PLUMBING

- Use high efficiency plumbing fixtures and faucets to reduce excess water usage

TABLE 4-11: PROS AND CONS FOR WATER USE [1]

Pros	Cons
▪ Reduces water usage	▪ Initial capital cost of replacement plumbing fixtures

4.1.4.3 MACHINERY USE

- Audit machinery to decide which are efficient/inefficient

- Special focus on motors

- Replace inefficient components/machinery

TABLE 4-12: PROS AND CONS FOR MACHINERY USE [1, 35]

Pros	Cons
▪ Reduced energy use and electricity cost ▪ May improve machine performance	▪ Initial capital cost of replacement components/machinery

4.1.4.4 SMARTGRID TECHNOLOGY

- "Computerize" the electric utility grid

- Use two-way digital communication technology for devices associated with the grid

- Each device on the network can be given sensors to gather data (power meters, voltage sensors, fault detectors, etc.); two-way digital communication between the device in the field and the utility's network operations center

- Automation technology to allow the utility adjust and control each individual device or millions of devices from a central location

TABLE 4-13: PROS AND CONS FOR SMART GRID TECHNOLOGIES [18]

Pros	Cons
▪ Improves electric reliability ▪ Reduces peak electricity demand ▪ Reduces system losses ▪ Can be integrated with renewable energy applications ▪ Can identify where most energy loss occurs	▪ Can be difficult to implement ▪ Concern regarding cybersecurity

5.0 RECOMMENDATIONS

The following recommendations are intended to provide CTDOT with guidance to further enhance the efficiency and reliability of rail facilities and rail stations.

The recommendations are based on industry best practices and available information gathered through site visits, interviews, a focus group session, data on electricity and natural gas usage, and expert guidance from the CASE study committee. These recommendations are based solely on the issue of energy savings; the question of whether or not an initiative or project will save money must be determined by a total cost of ownership analysis.

Further detailed information is needed to gain a complete understanding of rail yard facility and rail station energy usage, and to develop an energy profile for each facility. This will provide a foundation for conducting energy audits of the facilities and stations that can then be used to develop and prioritize energy efficiency initiatives and projects.

5.1   CONDUCT AN ENERGY AUDIT

Before any upgrades are considered, a thorough energy audit should be conducted based on data for a minimum of 12 – 18 months, and possibly longer, to determine changes and trends in operations, usage and cost. The audit should include the monitoring of individual facilities and their respective energy usage over time, rail operations, billing, energy procurement, and submetering. Analysis of the duty cycle of machinery/tools should be included in order to identify both usage and opportunities to reduce energy consumption, while maintaining ability to conduct maintenance operations effectively.

This process will identify energy savings opportunities and will provide a method to aid in prioritization for use of available funds for initiatives and projects. It will provide a baseline for energy consumption for the overall rail network, facilities, equipment and various operations. This baseline will enable an accurate total cost of ownership analysis to be conducted to quantify energy and cost savings, and will be useful for monitoring the impacts of future initiatives and upgrades on these savings. Computer modeling can be used in the analysis of energy consumption to establish this baseline.

5.2   LIGHTING

A preliminary estimate of the number of light fixtures at rail facilities was made through site visits conducted during this study. However, the type of lighting technology installed in the fixtures was not determined. Once this information is obtained, it will be possible to calculate the percentage of energy use and cost attributable to lighting, and the cost savings and payback period that could be achieved through installation of energy efficient lighting. Although the exact energy profile for each rail facility is not known, the following recommendations have been proven to reduce energy use:

- LED technology was cited in multiple reports. Recent advances that improve the spectrum of lighting have made it a viable option.

- Control systems have the capability of dimming lights or turning some or all fixtures off when a room is not occupied. Since lights operate 24/7 at all facilities, opportunities for improvement exist.

- For better temperature control, paint the pit walls of the Stamford Maintenance of Equipment Facility a light color that reflects illumination, as compared to the current dark color that absorbs illumination.

- The West Haven Rail Station has an excessive number of lights energized even though it has adequate natural daylighting. Consideration should be given to reducing lighting during daylight hours.

5.3   HVAC

HVAC system upgrades have been made at some facilities, but many still have outdated systems. Further analysis of how these systems are controlled should be investigated before accurate estimates can be made regarding their energy consumption. For example, factors that affect energy use, including controllers that operate HVAC systems (i.e., temperature settings and programmability features), should be identified and assessed. This information, along with average local temperatures, can be used to estimate the current duty cycle of the HVAC systems.

Also, air and water leaks at all facilities should be repaired to help reduce the demand on HVAC systems.

Additionally, radiant floor heating for work areas should be analyzed as an option for reducing heating cost and improving the work environment in rail yard shops.

5.5   SOLAR PV SYSTEMS

The New Haven Rail Yard has adequate roof space and Connecticut is located at a latitude that is appropriate for installation of a PV system to supplement purchased electricity. Net metering and battery storage options should be assessed to determine the best option for this application. Additional PV system opportunities should be assessed for rail stations, platforms stations and other rail facilities.

5.6   NEW HAVEN RAIL YARD ELECTRICITY SYSTEM

The power distribution single line diagram shows that the UI feeder supplies at least 22 electrical paths, with 14 having submeters that are monitored by MNR staff. This diagram indicates that drawings US-NHY-001 and US-NHY-002 must be analyzed for a more complete understanding of how each building receives power and to identify if there are additional electrical paths served by the UI feeder. Further analysis is needed to identify if there are additional submeters in use for rail yard facilities, which would be helpful in determining the

kWh usage for the buildings serviced by each meter. Units for meter data and the individual multipliers will need to be determined so that a percentage of the New Haven Rail Yard's electricity bill can be accurately attributed to each facility. Once the submetering is understood, more detailed monitoring will be useful to manage and analyze energy usage and the impacts that future initiatives are expected have on electricity consumption. More intelligent meters that are properly calibrated will help provide further insight into specific facility energy profiles. Additionally, the naming convention for yard buildings is inconsistent and makes analysis of the yard's complex electrical system challenging. A single name for each facility, such as the common name referred to by staff, should be adopted for official documents and signage.

5.7   NATURAL GAS

Natural Gas: Based on 2013 billing information, natural gas is currently less expensive than electricity in terms of price per kWh (to enable a direct comparison between natural gas and electricity, energy units for natural gas were converted from BTUs to KWh), although this may not necessarily be the case universally. Also, natural gas is available at all three rail yards. A detailed technical and cost-benefit analysis of the value of using combined heat and power (CHP) for onsite production of electricity and use of waste heat for heating and cooling using microturbines or fuel cells should be conducted.

A hybrid system that primarily relies on electricity provided by the utilities, supplemented by a PV system and possibly a natural gas-fueled CHP system, will increase reliability by producing electricity onsite. It has the additional benefit of using waste heat for heating and cooling.

5.8   OTHER

Reinstate the past practice of turning off the power for rail car operation at the Stamford Car Wash Facility on weekends.

5.9   ENERGY MANAGEMENT

It is recommended that CTDOT develop and implement an energy management plan and assign a staff person to serve as an energy manager with overall responsibility for leading conservation efforts for all rail facilities and rail stations. The energy manager should interface with the Department of Energy and Environmental Protection (DEEP) in support of energy procurement contracts for the state's rail system and participation in the state's Lead by Example efficiency program. This will ensure that CTDOT is fully aware of and participates in the state's electric and gas procurement process, and is able to use and benefit from existing programs for saving energy.

The energy manager should also be a part of CTDOT's asset management review team to provide input regarding those projects that will provide a positive energy savings for rail facilities and rail stations. This will allow projects to be ranked with appropriate priority and be considered with other safety, operational and maintenance projects. Also, this will provide for consistency across all of the state's rail facilities regardless of the individual property manager for each facility. Additionally, the energy manager should issue annual reports to the department's management to demonstrate the progress made in reducing energy use and

to encourage energy efficient construction for both new facilities and renovation of existing facilities.

As previously stated, additional information is needed to fully assess electricity usage at the rail yards and stations before developing a plan to reduce energy consumption at rail facilities. A detailed energy audit should be conducted for each rail facility for which CTDOT is responsible. A review of existing energy meters and the need for additional submeters should be included as part of all energy audits. A fully developed metering scheme will allow for a proper analysis of energy use, permitting a comprehensive analysis of energy distribution and use and helping focus energy conservation efforts on those projects that have the greatest return on investment.

CTDOT should perform an energy assessment and repeat it every five years. This assessment would include a review of all energy use in terms of best practices to ensure that CTDOT is efficiently using the energy it procures, with the results factored into a planning process.

A more definitive planning process should be implemented and possibly managed by planning staff in the Bureau of Public Transportation or the Bureau of Policy and Planning, with energy efficiency as a more central focus. Proposed projects can be evaluated and prioritized based on energy and cost savings. The planning process should include a screening mechanism for reviewing projects to ensure they meet high-level criteria for installing, modifying, and maintaining equipment on the basis of the most efficient use of energy.

There is no standard or best practice that is followed when evaluating proposed energy-related projects, according to findings from a focus group meeting conducted with CTDOT and MNR staff; instead, specific needs are identified by employees and the issue is relayed to the appropriate engineering staff for consideration. Proposed changes are evaluated with regard to efficiency, reliability, the effect on workflow, safety, and materials required. Since technology is rapidly changing, as much flexibility as possible is designed into facilities in order meet the potential needs of future operations. It can take years to decide which projects are implemented, which decisions are driven primarily by safety and day to day functionality of the rail network. Energy efficiency is incorporated into the design of facilities to the extent that the law requires.

The use of an asset management model in conjunction with a planning model will help ensure the best financial return on the equipment and facilities used by CTDOT. The process of monitoring equipment and buildings for energy efficiency at the lowest cost to customers will allow for the most important projects to be completed.

An asset management plan should be established to manage all equipment that is under the purview of CTDOT and MNR. This plan would provide for a review of maintenance, inspection and replacement requirements for all buildings and equipment that utilize energy.

6.0 CONCLUSIONS

The best practices gathered from the literature review detailed in Section 2 offer solutions that have been proven successful at increasing energy efficiency for facilities. Based on industry best practices, energy usage should be analyzed in detail as an initial step in the decision making process. Dividing the entire system into load categories aids analysis by helping to simplify complex systems and allowing for more accurate estimates to be calculated for each category's energy consumption profile.

Total cost of ownership including purchase, installation, fuel cost and escalation rate, maintenance and disposal/salvage value, encompassing the entire life cycle of any initiative, should be determined. This analysis is used to prioritize and select the energy efficiency and reliability initiatives included in a facility capital plan, and determine if an initiative actually saves money over the long term.

Connecticut's current practices were observed during several onsite visits to rail yards and rail stations conducted by the research team. The various loads have been reviewed and sorted into broad categories. However, these facilities are large and active, resulting in the possibility that some specific tools or equipment that comprise the load profiles may not have been included in the analysis.

Studies identified in the literature review have shown that lighting and HVAC systems are typically the largest loads; therefore, it is important to conduct energy audits to understand these existing systems thoroughly and provide a more accurate picture of how each facility consumes energy.

The utility bills, supporting consumption documentation, and the research team's site visits have been a good start, but there is still conflicting information regarding submeters. Diagrams of the distribution building at New Haven Rail Yard have shown that additional documentation required to answer questions concerning power flow and metering exists. The spreadsheets that the MNR electrician maintains need to be examined in order to determine how much power is consumed by individual buildings. This information, along with the utility bills, will provide an understanding of which buildings consume the most energy, as well as guidance for focusing energy saving initiatives.

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APPENDIX A
STUDY COMMITTEE MEETINGS AND GUEST SPEAKERS

The following is a list of study committee meetings, including presentations given to the CASE Study Committee by guest speakers and the CASE Research Team. In the electronic version of this report, links to meeting presentations are highlighted in blue.

DECEMBER 5, 2013 – MEETING 1

- **Welcome and Introductions**
- **CTDOT - Introduction to the Study**, Jayantha Mather, Transportation Principal Engineer, Bureau of Public Transportation, Office of Rail – Design, CTDOT
- **Research Team**, Roles and Responsibilities, Overview, Preliminary Research, and Timeline - Presentation
- **CTDOT/CT Transit – Fuel Cell Decision-Making Process and Operating Experience Mike Arrow**, Assistant General Manager, Maintenance & Technology, CTTransit (Committee Member) and **Jennifer Kritzler**, CTTransit
- **Committee Discussion and Next Steps**

FEBRUARY 6, 2014 – MEETING 2

- **Welcome and Introductions**
- **Guest Speaker, Robert Lorand,** Senior Program Manager, Energy, Environment & Infrastructure Solutions, Leidos, Inc.
  Topic: Renewable Energy Guide for Highway Maintenance Facilities - Presentation
- **Research Team Update** - Presentation
- **Committee Discussion**: Research by Professor Hazem Elzarka, School of Advanced Structures, Department of Civil and Architectural Engineering and Construction Management, University of Cincinnati
  Topic: Evaluation of Renewable Energy Alternatives for Highway Maintenance Facilities

MARCH 31, 2014 – MEETING 3

- **Welcome and Introductions**
- **Guest Speaker, Michael Perry**. Project Leader, Principal Developer, United Technologies Research Center
  Topic: PureStorage: Flow Battery Technology – Presentation
- **Guest Speaker, Joseph Camean**, Vice President, Director of Power and Utility Engineering Services, VanZelm Engineers
  Topic: Control Systems – Presentation

- **Guest Speaker, Professor Hazem Elzarka,** School of Advanced Structures, Department of Civil and Architectural Engineering and Construction Management, University of Cincinnati - Document
  - o Response to Study Committee Questions/Case Study "Evaluation of Renewable Energy Alternatives for Highway Maintenance Facilities"
- Research Team Update and Committee Discussion – Presentation

MAY 5, 2014 – MEETING 4

- **Welcome and Introductions**
- **Guest Speaker, Kate Anderson,** Manager, Technical Assessments and Screenings Group, National Renewable Energy Laboratory
  Topic: Energy Decision Tools - Presentation
- **Guest Speaker, Watson Collins**, Manager, Business Development, Northeast Utilities – Presentation
- **Research Team Update and Committee Discussion**

JUNE 16, 2014 – MEETING 5

- **Welcome and Introductions**
- **Research Team Update – Connecticut Practices and Best Practices**
- **Committee Discussion**

JULY 28, 2014 – MEETING 6

- **Welcome**
- **Research Team Update – CTDOT/Metro North Focus Group**
- **Research Team Presentation – Connecticut Status and Industry Practices**
- **Committee Discussion**

SEPTEMBER 22, 2014 – MEETING 7

- **Welcome**
- **Research Team Update – DRAFT Recommendations and Conclusion**
- **Committee Discussion – DRAFT Recommendations and Conclusion**
- **Next Steps**

MAJOR STUDIES OF THE ACADEMY

2014

- Connecticut Biomedical Research Program: Analysis of Key Accomplishments
- Peer Review of a CL&P/UConn Report Concerning Emergency Preparedness and Response at Selective Critical Facilities
- Connecticut Disparity Study: Phase 2

2013

- Analyzing the Economic Impact of Transportation Projects
- Health Impact Assessments Study
- Connecticut Disparity Study: Phase I
- Connecticut Stem Cell Research Program Accomplishments

2012

- Strategies for Evaluating the Effectiveness of Programs and Resources for Assuring Connecticut's Skilled Workforce Meets the Needs of Business and Industry Today and in the Future
- Benchmarking Connecticut's Transportation Infrastructure Capital Program with Other States
- Alternative Methods for Safety Analysis and Intervention for Contracting Commercial Vehicles and Drivers in Connecticut

2011

- Advances in Nuclear Power Technology
- Guidelines for the Development of a Strategic Plan for Accessibility to and Adoption of Broadband Services in Connecticut

2010

- Environmental Mitigation Alternatives for Transportation Projects in Conecticut
- The Design-Build Contracting Methodology for Transportation Projects: A Review of Practice and Evaluation for Connecticut Applications
- Peer Review of an Evaluation of the Health and Environmental Impacts Associated with Synthetic Turf Playing Fields

2009

- A Study of the Feasibility of Utilizing Waste Heat from Central Electric Power Generating Stations and Potential Applications
- Independent Monitor Report: Implementation of the UCHC Study Recommendations

2008

- Preparing for Connecticut's Energy Future
- Applying Transportation Asset Management in Connecticut
- A Study of Weigh and Inspection Station Technologies
- A Needs-Based Analysis of the University of Connecticut Health Center Facilities Plan

2007

- A Study of the Feasibility of Utilizing Fuel Cells to Generate Power for the New Haven Rail Line
- Guidelines for Developing a Strategic Plan for Connecticut's Stem Cell Research Program

2006

- Energy Alternatives and Conservation
- Evaluating the Impact of Supplementary Science, Technology, Engineering and Mathematics Educational Programs
- Advanced Communications Technologies
- Preparing for the Hydrogen Economy: Transportation
- Improving Winter Highway Maintenance: Case Studies for Connecticut's Consideration
- Information Technology Systems for Use in Incident Management and Work Zones
- An Evaluation of the Geotechnical Engineering and Limited Environmental Assessment of the Beverly Hills Development, New Haven, Connecticut

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VISION

The Connecticut Academy will foster an environment in Connecticut where scientific and technological creativity can thrive and contribute to Connecticut becoming a leading place in the country to live, work and produce for all its citizens, who will continue to enjoy economic well- being and a high quality of life.

MISSION STATEMENT

The Connecticut Academy will provide expert guidance on science and technology to the people and to the State of Connecticut, and promote its application to human welfare and economic well-being.

GOALS

- Provide information and advice on science and technology to the government, industry and people of Connecticut.

- Initiate activities that foster science and engineering education of the highest quality, and promote interest in science and engineering on the part of the public, especially young people.

- Provide opportunities for both specialized and interdisciplinary discourse among its own members, members of the broader technical community, and the community at large.

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