



The following three projects were funded by CT Recovery stimulus funds:

Electrified Truck Stop at the Port of New Haven

In 2009, the City of New Haven received stimulus funding from DEEP for establishment of a TSE facility to reduce emissions from trucks idling in the port district. Fourteen units have been installed at the corner of Alabama and Stiles Streets, in a neighborhood where truck engines currently idle while the drivers await their turns for delivery and pickup at the Port of New Haven. This will relieve a long-standing idling concern in the neighborhood. State, local and federal officials visited the facility on a June 9, 2011. The facility was opened in the fall of 2011.



Select the following links to find out more about these projects:

Installation of Emission Controls on DOT Maintenance Dump Trucks

Engine Upgrade for Cross Sound Ferry MV Susan Anne

Installation of Diesel Emission Controls on Department of Transportation Maintenance Dump Trucks

Funding Amount: \$166,135 for Retrofitting CTDOT Dump Trucks

Amount Spent: \$166,135

Project Description: The Department of Environmental Protection granted \$166,135 in American Recovery and Reinvestment Act funding to the Connecticut Department of Transportation (DOT) to install emission controls on its fleet of dump trucks that are used for highway maintenance, including seasonal snowplowing.

Diesel oxidation catalysts are special mufflers that can remove significant amounts of fine particulates from diesel exhaust. Exposure to fine particulates has been linked to premature death from heart or lung disease. Fine particles, inhaled into the lungs, can aggravate existing heart and lung conditions to cause cardiovascular symptoms, arrhythmias, heart attacks, chronic obstructive pulmonary disease, asthma attacks and bronchitis. The U.S. Environmental Protection Agency has also classified diesel exhaust as a probable human carcinogen. The photo above shows a DOT snow-plowing dump truck with a diesel oxidation catalyst muffler installed.

The Recovery Act funding has allowed DOT to retrofit all of the eligible dump trucks in its fleet with diesel oxidation catalysts. Because these trucks are used throughout the state, this project will benefit citizens across Connecticut.



Protecting Connecticut's Citizens from Exposure to Diesel Pollution

- 149 maintenance dump trucks retrofitted with emission controls for improved air quality throughout Connecticut
- 1.3 lifetime tons of fine particulates from diesel pollution reduced
- \$200,000 in health benefits, which represent the dollar value of avoiding the health effects resulting from exposure to fine particulates
- Two installation mechanics employed for three months each to install the emission control devices.
- Project completed in February of 2010

Cross Sound Ferry Service
***Susan Anne* Tier 2 Upgrade Kit Project**
Final Report

January 2012



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ABSTRACT

Cross Sound Ferry Service (CSFS), undertook a voluntary project to upgrade the propulsion engines in one of its marine ferry vessels, the *Susan Anne*, with EPA Tier 2 certified engine components. This project is the first-in-the-nation installation of a Tier 2 certified upgrade kit on an EMD marine engine in the U.S. CSFS was awarded grant funding, following a competitive process, by the Connecticut Department of Energy and Environmental Protection (CT DEEP), using funds provided by the Diesel Emission Reduction Act (DERA) and American Recovery and Reinvestment Act (ARRA) of 2009 programs and allocated to Connecticut by EPA.



Prior to the project, the *Susan Anne* operated with pre-regulation engines that were manufactured before EPA enacted exhaust emission standards for marine vessels. The original propulsion engines were manufactured in 1977 and 1981. Because of the robust support market for these engines, CSFS did not have a capital asset plan in place that called for installing new engines on this boat, and had planned to continue to repair and rebuild the old engines as necessary to maintain the vessel.

Based on historical operating characteristics of the vessel and manufacturer post-upgrade emission data, CSFS anticipates that annual vessel emissions will be reduced by approximately 47.9 tons nitrogen oxide (NO_x), 1.5 tons particulate matter (PM), and 64 tons carbon dioxide (CO₂). In addition, the upgrade kit and new keel coolers are estimated to realize a 2% benefit in fuel economy for the *Susan Anne*.

A significant goal of ARRA, one of the project funding sources, was to maintain and/or create jobs. Using information provided by project suppliers and vendors, CSFS estimates that 1.5 full-time equivalent (FTE) jobs were retained as a direct result of this project.

At the conclusion of the project, the propulsion engines in the *Susan Anne* were successfully upgraded from a pre-regulation emission level to EPA Tier 2. Typically to achieve this level of emission reduction, a vessel would be repowered with new engines. This project required much less time, cost, and effort than a repower and involved stripping and rebuilding the engines with new parts as part of an EPA Tier 2 certified upgrade kit.

ACKNOWLEDGEMENTS



Grant funding for this project was provided by CT DEEP to CSFS through a competitive process using state allocation grant funds provided by the U.S. Environmental Protection Agency through the National Clean Diesel Funding Assistance Program, and American Recovery and Reinvestment Act. CSFS would like to thank CT DEEP and EPA for funding this project, and acknowledge the contributions of Ellen Pierce and Patrice Kelly, at CT DEEP for their assistance in making this project a success. Also, CSFS would like to recognize the efforts of M. J. Bradley & Associates, LLC for their assistance as the project technical consultant.



PROJECT TEAM

[Connecticut Department of Energy and Environmental Protection](#)

The Connecticut Department of Energy and Environmental Protection (CT DEEP) is charged with conserving, improving and protecting the natural resources and the environment of the state of Connecticut, as well as making cheaper, cleaner and more reliable energy available for the people and businesses of the state. The agency is also committed to playing a positive role in rebuilding Connecticut's economy and creating jobs – and to fostering a sustainable and prosperous economic future for the state.

CT DEEP was established on July 1, 2011 with the consolidation of the Department of Environmental Protection (DEP), the Department of Public Utility Control, and energy policy staff from other areas of state government. The DEP had been established in 1971 at the dawn of the environmental movement, while the public utilities regulatory authority traces its roots back more than 150 years to the state's Railroad Commission.

[Cross Sound Ferry Service, Inc.](#)

CSFS operates a ferry service, providing year-round passenger and vehicular service between New London, CT and Orient Point, NY. Each one-way trip covers a distance of 16 miles and takes approximately 80-90 minutes (40 minutes by fast ferry). CSFS operates over 12,000 annual one-way trips and their fleet burns over 2 million gallons of diesel fuel annually. The fleet consists of eight vessels, seven of which accommodate passengers and vehicles (including commercial trucks), plus one dedicated high-speed passenger-only ferry.

[Marine Systems, Inc.](#)

Marine Systems, Inc. (MSI), a wholly owned subsidiary of Kirby Corporation, was established in 1966 with the goal of becoming the best in its field and providing premium service in support of marine vessel operations. The principal medium-speed diesel engines they service are those manufactured by Electro-Motive Diesel, Inc. ("EMD"), like those installed on the *Susan Anne*. MSI has a 45-year relationship with EMD, currently serving as the authorized distributor in 17 Eastern states and the Caribbean.

Today, MSI is recognized for its leadership in on-location, problem-solving service for diesel engine repair, remanufacturing and replacement parts, as well as reduction gear repair for a wide range of vessels. With a network of strategically located facilities that provide 24-hour support, MSI can quickly dispatch experienced technical personnel, tooling and material to meet customers' needs.

CROSS SOUND FERRY ROUTE



WHY REDUCE DIESEL EMISSIONS

Reducing diesel emissions is an important part of the CT DEEP strategy to ensure that Connecticut is positioned to attain and maintain the EPA's health based National Ambient Air Quality Standards. The emission reductions resulting from this program are an integral part of CT DEEP's air quality attainment efforts, and important as part of a balanced strategy that includes reductions from stationary, area and mobile source sectors to ensure that Connecticut attains these National Ambient Air Quality Standards. Based on recent data, mobile sources are responsible for approximately 25% of particulate pollution and over 2/3 of NOx emissions in Connecticut.

In addition to CT DEEP's state-focused efforts, EPA has also sought a way to encourage fleet owners to voluntarily reduce diesel emissions in order to achieve more immediate emission reductions. One impetus behind this is that because diesel engines can have such a long operating life (7 yr / 500,000 mile+ for on-road trucks and 10-20 years or longer for locomotive and marine engines), EPA realized that implementing cleaner regulations for new diesel engines would take a significant length of time to make an impact on

local air quality. As a result, Congress authorized funding for clean diesel initiatives with the Diesel Emissions Reduction Act (DERA) as part of the 2005 Energy Policy Act.

Diesel engines are a significant source of particulate matter (PM) pollution due to the chemical nature of diesel fuel and the engine's mechanism of compression ignition. Diesel engines also tend to have high emissions of nitrogen oxides (NOx) due to the high temperature and lean conditions within the cylinder. In the atmosphere NOx reacts with volatile organic compounds (VOC) to produce ground-level ozone, a serious respiratory irritant. NOx also contributes to the formation of secondary particulate matter in the atmosphere.

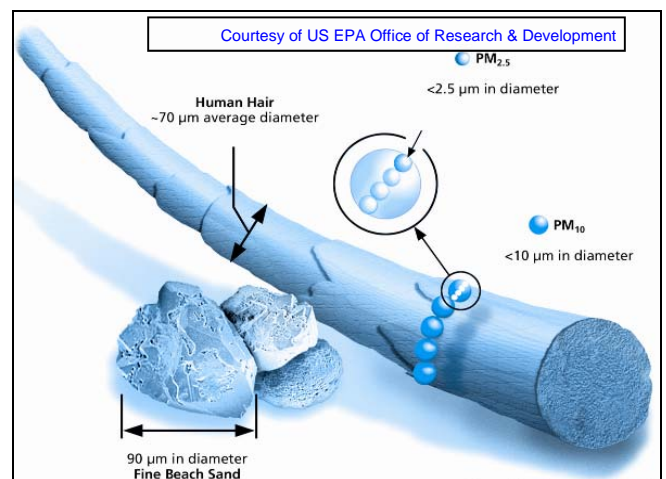
EPA Concludes Fine Particle Pollution Poses Serious Health Threats

- Linked to early death (both short-term and long-term exposure)
- Linked to cardiovascular harm (e.g. heart attacks, strokes, heart disease, congestive heart failure)
- Likely to cause respiratory harm (e.g. worsened asthma, worsened COPD, inflammation)
- May cause cancer
- May cause reproductive and developmental harm

—U.S. Environmental Protection Agency, *Integrated Science Assessment for Particulate Matter*, December 2009. EPA 600/R-08/139F.

PM particles formed by combustion of fossil fuels are a complex mixture of elemental carbon (EC), unburned or partly combusted fuel as organic carbon (OC), sulfate from fuel sulfur, and lubricant products (i.e., ash and additives). PM emissions are of substantial concern because they contribute to poor visibility and they negatively impact human health. According to EPA's latest assessment of the scientific evidence, fine particle pollution is linked to respiratory and cardiovascular problems, and early death.

The particulate matter of greatest concern are fine particles with diameters of 2.5 microns or less; this portion of PM is referred to as PM_{2.5}. In comparison, a human hair has a diameter of approximately 70 microns - 25 times greater than that of a PM_{2.5} particle. At this size, particles stay suspended in the air stream, and can bypass the body's mechanical respiratory defenses and can embed deep in the alveoli of the lungs when inhaled; the smallest of these particles can also enter the bloodstream directly through the lungs. The vast majority of PM particles emitted by diesel engines are small enough to be classified as PM_{2.5}.



MARINE REGULATORY DRIVERS AND TIER 2 UPGRADE KITS

US EPA

In 1999 the U.S. Environmental Protection Agency adopted the first numerical emissions limits for new commercial marine engines, denoted as “Tier 1” and “Tier 2” standards. The Tier 1 standards were applied beginning with engine model year 2004 and only set limits on NOx emissions, with the allowed level varying depending on engine speed (RPM). The more stringent Tier 2 standards for Category 2 marine engines (e.g., EMD 645) were first applied in Model year 2007. In addition to setting lower limits on NOx emissions, the Tier 2 standards introduced PM limits for the first time. Tier 2 standards vary by engine size (horsepower and displacement) as well as whether the engine is similar to a land-based construction engine (Category 1) or a locomotive engine (Category 2).

In March 2008, EPA adopted even more stringent Tier 3 and Tier 4 standards for new engines, which phase in between model year 2009 and 2017 depending on engine size. The most stringent Tier 4 standards apply only to engines larger than 600 kw (800 hp). The Tier 4 requirements also specify that beginning in October 2008, older engines larger than 600 kw must be “upgraded” to reduce their PM emissions by 25% when they are remanufactured or rebuilt.

California Air Resources Board

In January 2009, the California Air Resources Board (CARB) implemented the commercial harbor craft regulation that was designed to significantly reduce diesel emissions from those vessels operating in regulated California waters. The types of vessels affected are private, commercial, government, or military marine vessel including, but not limited to, passenger ferries, excursion vessels, tugboats, ocean-going tugboats, towboats, push-boats, crew and supply vessels, work boats, pilot vessels, supply boats, fishing vessels, research vessels, U.S. Coast Guard vessels, hovercraft, emergency response harbor craft, and barge vessels that do not otherwise meet the definition of ocean-going vessels or recreational vessels .



CA Regulated Waters (24 nautical mile limit)

The current requirement for boat owners that do not qualify for an exemption is to bring the existing pre-Tier 1 and Tier 1 engines into compliance with EPA Tier 2 emission standards. The two primary methods of achieving this are through an engine repower, or installing an upgrade kit. All newly purchased engines must meet the current regulation, whether Tier 2 or Tier 3. Installing an upgrade kit can be accomplished in approximately 3-4 weeks, compared to approximately 12-16 weeks for a new engine repower.

Certified Tier 2 Upgrade Kit

A solution to bring EMD engines up to Tier 2 standards without the significant time and expense of a traditional engine re-power.



Tier 2 Kits for Tier 1 and Older Marine Engines

Technical Changes Yield Lower Emissions

- Electronic Fuel Injection, better injection timing control (lower NOx & PM)
- Better piston rings for lower lube oil consumption (lower PM)
- Improved turbocharger (lower NOx & PM)
- Improved charge-air cooling (even lower NOx; lower fuel consumption)
- Demonstrates better than 25% PM reduction (required for engines at time of rebuild)

SUSAN ANNE PROCUREMENT AND INSTALLATION

In January of 2011, CSFS began the procurement process for the EPA certified upgrade kits for their vessel, the *Susan Anne*. After reviewing the limited offerings for commercially available upgrade kits, CSFS realized that only a single kit was offered for their particular engines that would provide Tier 2 emission levels. This kit was manufactured by Electro-motive Diesel (EMD), the original engine manufacturer. These kits were being sold through EMD's only east-coast representative, Marine Systems Inc. (MSI).

With approval from CT DEEP and EPA, CSFS prepared a purchase order to MSI for (2) EMD Tier 2 electronic upgrade kits, including the labor to install. The major kit components included new power packs (pistons, liners, valves and heads), injectors, turbochargers, intercoolers, wiring and control units.

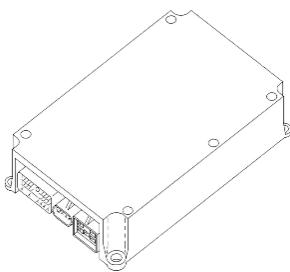


EMD Electronic Unit Injector

In late September 2011, the *Susan Anne* was tied up at a service dock (i.e., not dry-docked) and prepared for the component change out and rebuild. Fluids were drained from the engines in anticipation of the tear-down.

The rebuild began with the removal of the fuel lines, fuel injectors and rocker arm assemblies. Then the individual power packs could be removed. This was followed by the unbolting of the water pumps, fuel pumps, air cleaners and the turbochargers. With all of the main components removed, the engines could be cleaned and prepped for the new components installation.

The new power packs, water pumps, fuel pumps, turbochargers and air cleaners were then installed and connected. The installation of these components also required new seals, gaskets and hardware (i.e. bolts, nuts washers, etc.) to ensure proper operation.



EMD Engine Control Module (ECM)

As part of the Tier 2 upgrade, the engines were being converted from mechanical linkage control to electronic control. This involved installing sensors and wiring to monitor engine parameters. Installed sensors included oil pressure and temperature, crankshaft speed and position, water pressure and temperature, fuel pressure and temperature, and air box pressure and temperature. All of the sensors were connected to the engine control module (ECM),

which adjusts fuel rate to the cylinders based on signals from the sensors.

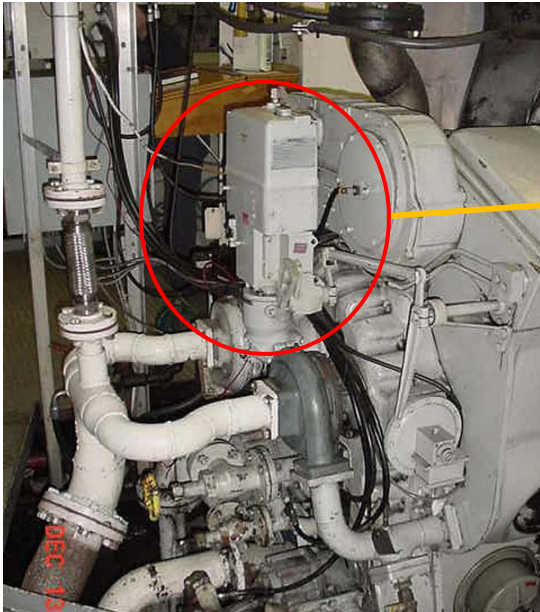
For fuel injection, new high pressure fuel lines were installed and connected to the new electronic unit injectors (EUI) through jumper lines. The jumper lines allowed proper fuel to enter/exit the injectors without obstructing the operation of the engine.

EMD Piston, Liner and Head (Power Pack)



Fuel lines and jumpers installed

With the control of fuel injection being operated by the ECM, the mechanical governor and linkage could be eliminated. The removal of the governor also facilitated the installation of the high pressure fuel lines to either side of the engine. These fuel lines can be seen in the right side picture below, in the vicinity where the governor used to be.



Mechanical Governor (circled in Red)



Mechanical Governor Removed (circled in Blue)

In conjunction with this project, but not funded by the CT DEEP grant, CSFS will install new keel coolers. This modification is anticipated in 2012 and will require that the vessel be dry-docked. While the upgrade kit that was installed is compatible with the existing jacket water cooling system, the addition of the new keel coolers will allow for separate circuit after cooling (SCAC). This additional cooling capacity ensures that the charge air will stay cooler, which will result in lower NOx emissions and better fuel economy, an economic benefit to the owner.

| Engine Comparison | Propulsion Engines | | | |
|--|--------------------|--------------|---------------|--------------|
| | Port | | Starboard | |
| | Old | New | Old | New |
| Manufacturer | EMD | | EMD | |
| Model | 12-645E7B | | 12-645E7B | |
| Tier Level | Unregulated | Tier 2 | Unregulated | Tier 2 |
| Serial Number | 77-H1-1517 | | 81-F2-1116 | |
| Engine Family Name | * | BEMDN211.TT2 | * | BEMDN211.TT2 |
| Horsepower | 2,300 | | 2,300 | |
| Annual Activity (Hr /Year) | 2,000 | | 2,000 | |
| Fuel Type | Marine Diesel | | Marine Diesel | |
| Annual Fuel Usage (Gal)** | 143,950 | 141,100 | 143,950 | 141,100 |
| Engine In-Service Date | 1977 | Dec 2011 | 1981 | Dec 2011 |
| * The engine was manufactured prior to EPA regulating marine engines and does not have an engine family name. ** Post-Repower fuel consumption is estimated based on manufacturer-estimated fuel rate data. Actual fuel consumption may vary. | | | | |

RESULTS AND OUTCOMES

Recovery Act Priorities

This project contributed to achieving ARRA goals by investing in the U.S. marine transportation system and by preserving jobs in both the manufacturing and local transportation service sectors. Specific goals of the Stimulus Act that were well served by this project are: (1) preserving and/or creating jobs and promoting economic recovery, and (2) investing in the transportation system.

Upgrading the *Susan Anne* represents an investment in the transportation system of more than \$1.33 million and is estimated to have preserved a total of 1.5 full time equivalent jobs (FTE). The majority of these jobs are CSFS employees, (1,700 hours were needed to

disassemble and remove components on the *Susan Anne* before MSI performed the upgrades) and represent skilled trades workers like mechanics, fabricators, welders, and engineers.

CSFS and MSI were able to complete the physical integration of the project within 3-4 weeks. Delivery of the major components (e.g., power packs, turbos, etc.) occurred in October 2011 with installation commencing in late October and upgrade completion in November 2011.

Summary of Project Benefits

| Activities | Outputs | Outcomes |
|---|--|--|
| <ul style="list-style-type: none"> Upgrade the propulsion engines of one marine vessel | <ul style="list-style-type: none"> \$1.33 million expended 2 new EPA Tier 2 Compliant Kits Installed | <ul style="list-style-type: none"> 1.5 FTE positions were preserved Estimated annual emission reductions <ul style="list-style-type: none"> 1.5 tons PM 47.9 tons NOx |

Project Cost Effectiveness

| Pollutant | Life-time Reduction (tons) | Total Project Cost -Effectiveness (\$/ton) | Total Grant Funding (ARRA + DERA) Cost-Effectiveness (\$/ton) |
|-----------|----------------------------|--|---|
| NOx | 479 | \$ 2,777 | \$ 2,127 |
| PM | 15.0 | \$ 88,667 | \$ 67,924 |

remanufacture in approximately 5-10 years. Using 10 years as the project duration, lifetime emission reductions are estimated at 15 and 479 tons of PM and NOx, respectively. In addition to emission benefits, the *Susan Anne* is projected to realize a modest fuel savings due to the new, higher efficiency, electronically controlled engines once equipped with the new keel coolers (SCAC).

Lessons Learned

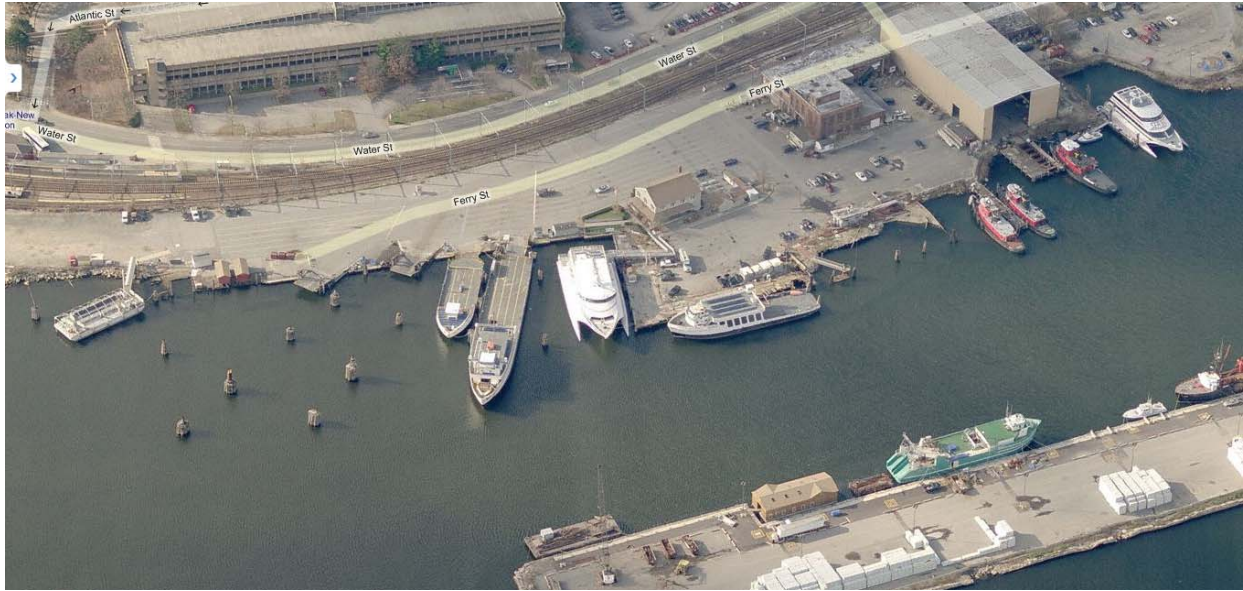
At the outset of the project, CSFS sought to purchase a certified upgrade kit for the *Susan Anne* to avoid having to take the vessel out of service; however, because EPA regulations had just recently come into effect, there were few certified kits in the marketplace. At the time, EMD, the manufacturer of the original engines, was working on a certified upgrade kit, moving from development to certification. CSFS was able to purchase the kits in early 2011. Fortunately for other vessel owners with EMD 645 engines, the upgrade kit is now a commercial EMD product, and readily available. Operations schedule was a key factor in the timeline for this project as the ferry service sees increased ridership in summer months and between Thanksgiving and New Year. In order to accomplish the project on time, the vessel was upgraded over a period of several weeks, ending just prior to Thanksgiving 2011.

Emission Reductions

Emission reductions presented below are estimated at 1.5 and 47.9 annual tons of PM and NOx, respectively. The durable useful life of the *Susan Anne* is well beyond 10 years, although the propulsion engines are expected to require rebuild or



RECOVERY.GOV



*New London, CT, - the home of Cross Sound Ferry.
New London is located on the shore of the Thames River in Connecticut.*

MJB & A

M.J. Bradley & Associates is an environmental consulting firm with a national reputation for helping clients balance environmental goals with business objectives, as well as for demonstrating advanced low emission vehicle technologies. By providing clients with high-quality information and services, and facilitating collaboration, MJB&A assists private and public sector clients in meeting the challenges posed by changes in environmental and energy law and policy, energy markets, technology and business climate.

MJB&A has two offices, an Energy & Environmental Policy Group in Concord, MA and a Technical and Transportation Services Group in Manchester, NH. The Environmental Policy group consults in the fields of energy and environmental policy, electric generating technologies, greenhouse gas policy, and stakeholder groups.

The Transportation Services Group participates in a variety of project areas, with a concentration in advanced vehicle and optimized combustion system technologies. Projects include technology assessments, management of commercially available as well as prototype deployments, strategic analysis, feasibility studies, economic and life cycle cost analyses, emissions testing, emissions inventory development, and retrofit programs for a wide range of vehicle types, including marine vessels, locomotives, transit and school buses, and construction equipment.

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