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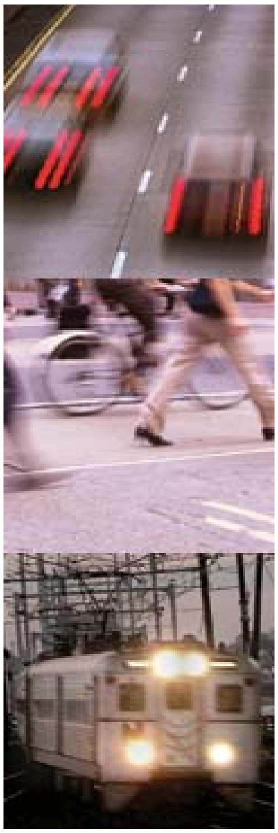

An Evaluation of Public-Private Incentives to Reduce Emissions from Regional Ferries

Technical Memorandum One

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EXECUTIVE SUMMARY

Ferry services play an important and critical part of the overall transportation network in New York Harbor. However, regional ferry vessels also account for a significant proportion of emissions from commercial vessels based on recent emissions inventory reports for the Port Authority of New York and New Jersey. Mitigating ferry emissions represents a complex technology-policy problem. Emissions reductions of existing ferries are needed to serve to offset emissions that may result from other necessary projects. Reductions in emissions from both existing and new ferries may enable expansion of ferry service and overall regional mobility (for both passengers and freight) while still conforming to air quality objectives required under the Clean Air Act (2003). And importantly, ferry emissions reductions may contribute to net reduction of air pollution that benefits human health and the environment.

The Evaluation of Public-Private Incentives to Reduce Emissions from Regional Ferries project will assist local agencies in meeting the environmental stewardship commitment for these funds by providing analysis of the available incentives to achieve maximum participation by private ferry operators. This project will evaluate potential and proposed technology rollout strategies to predict their performance according to several important criteria.

This technical memorandum summarizes the criteria for evaluating technology-policy alternatives to achieve program objectives related to the public-private effort to reduce emissions from regional ferries in the New York and New Jersey metropolitan region. Some criteria address public policy goals, such as achieving air quality goals and conformity requirements through direct reduction of regional ferry emissions. Other criteria address fiscal constraints by identifying which technologies are most cost-effective, thereby maximizing the benefits of public funds. Lastly, some criteria may influence participation of vessel operators and the overall quality of the public-private partnership.

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1 INTRODUCTION

Ferry services play an important and critical part of the overall transportation network in New York Harbor. Over the past two decades, New York and New Jersey have coordinated policy approaches to the public and private ferry services operating in the region. Regional ferry vessels account for a significant proportion of emissions from commercial vessels based on recent emissions inventory reports for the Port Authority of New York and New Jersey. For example, ferries are estimated to contribute approximately 17% of NOx emissions and approximately 10% of PM emissions from commercial marine totals for the region (Starcrest Consulting Group and Allee King Rosen & Fleming 2002).

Mitigating ferry emissions represents a complex technology-policy problem. Emissions reductions of existing ferries are needed to serve to offset emissions that may result from other necessary projects. Reductions in emissions from both existing and new ferries may enable expansion of ferry service and overall regional mobility (for both passengers and freight) while still conforming to air quality objectives required under the Clean Air Act (2003). And importantly, ferry emissions reductions may contribute to net reduction of air pollution that benefits human health and the environment.

Emissions reduction goals can only be achieved without active participation by the privately operated ferry fleets in New York and New Jersey. The New York Harbor Private Ferry Emissions Reduction Program, led by the New York State Energy Research and Development Authority (NYSERDA), aims to cut pollution from the diesel-powered private vessels by identifying and implementing technologies that dramatically reduce harmful emissions. The current phase of the NYSERDA project is demonstrating emissions reductions strategies on four vessels operated by each of the major, regional commuter ferry service operators. This first phase of the NYSERDA project aims to provide information to ferry operators with respect to capital costs and direct expenses related to monitoring and verification of the pollution reductions.

It is important to note that nearly all ferry services are operated by private owner operators; the exception is the New York City Department of Transportation Staten Island Division, which operates public ferry service covering over 50% of the passenger volume but approximately 3% of total ferry route miles in the region. Additionally, ferry services operate between two states that have different governance, approaches and degree of control over ferry operations, therefore when designing any public-private program, additional specific analyses that involve innovative approaches may be needed.

1.1 Project Scope and Task One Summary

The *Evaluation of Public-Private Incentives to Reduce Emissions from Regional Ferries* project will assist local agencies in meeting the environmental stewardship commitment for these funds by providing analysis of the available incentives to achieve maximum participation by private ferry operators. This project will evaluate potential and proposed technology rollout strategies to predict their performance according to several important criteria.

This technical memorandum summarizes the criteria for evaluating technology-policy alternatives to achieve program objectives related to the public-private effort to reduce emissions from regional ferries in the New York and New Jersey metropolitan region. Some criteria address public policy goals, such as achieving air quality goals and conformity requirements through direct reduction of regional ferry emissions. Other criteria address fiscal constraints by identifying which technologies are most cost-effective, thereby maximizing the benefits of public funds. Lastly, some criteria may influence participation of vessel operators and the overall quality of the public-private partnership.

1.2 Decision Analysis Context

The decision to adopt emission reduction technologies is not a simple one. There are many factors that an operator needs to consider before choosing a technology to improve environmental performance. Quoting the Diesel Technology Forum (Diesel Technology Forum 2003):

> "Creating a successful retrofit project begins with careful selection of engine candidates. Some engines and vehicle applications make much better retrofit candidates than others, and certain engines and vehicles may simply be inappropriate for investment in an upgrade. In other cases, retrofit may be technologically infeasible. Once appropriate candidates are identified, it is equally important to match those engines with the right enhancement technology. Proper technology matching helps ensure that emissions performance meets a project's air quality improvement goals, and ensures that vehicle reliability is not negatively impacted."

Decision analysis tools are often used in engineering or economic studies, and increasingly applied to policy decisions. Quantitative decision tools offer stakeholders the ability to structure alternatives and apply their own context to technology decisions in the process of achieving environmental performance goals.

Choosing how to reduce emissions from regional ferries requires three decision elements:

Objectives: An objective is something that a decision maker wants to achieve (Keeney 1992). Many important decisions are made under the mistaken assumption that people clearly know what they want, that the objectives are clearly understood by all people affected. Sometimes a single objective can drive the decision; however, in many situations multiple objectives are present and may be in conflict.

Alternatives: Once the objectives are defined (at least at the first iteration), one can begin to consider alternatives. Identifying alternatives is a natural and familiar step in any decision, but it is important to avoid narrowly identifying the obvious while ignoring creative solutions.

Criteria (Attributes): Perhaps the most important purpose in identifying alternatives early on is to define important attributes relating alternatives to objectives. Attributes may be considered the "criteria", or performance measures used to judge preferences for one alternative versus another (Keeney 1992). Simply, criteria connect alternatives with objectives.

1.3 Objectives of the New York Harbor Private Ferry Emissions Reduction Program

Specifying objectives is not as easy as it may appear. For example, maximizing profit over a near-term period (say, one or two years) may not achieve long-term profits. Similarly, setting clear environmental objectives for the next generation vessel may not achieve environmental goals in the near term. In fact, objectives that may appear similar can actually result in conflicting strategies. For example, expensive designs for cleaner replacement vessels may create incentives to continue operating existing vessels longer than originally planned, until an operator can justify the additional capital (or financing). Or, a decision to retrofit a vessel for a demonstration that will be removed in several months may select different technologies than a choice to permanently retrofit a vessel.[1]

For this project, four primary objectives have been identified by the New York Harbor Private Ferry Emissions Reduction Program (NYSERDA 2003).

1. *Reduce private ferry fleet emissions*. The program's goal is to cut between 150 and 300 tons of smog-inducing nitrogen oxide and between 30 and 90 tons of particulates each year, based on a per-engine reduction of at least 15% to 30% for NOx, and 20% to 60% for PM. However, one can assume that greater reductions would be welcome by all stakeholders, if achieved along with other objectives. For this project, the objective can be defined either as maximizing emissions reductions from ferries, or as achieving a target reduction level.
2. *Maximize participation of the private ferry fleet*. Currently, all private ferry operators serving transit routes are participating in the NYSERDA demonstration project; in this regard the demonstration project has achieved full participation. This phase of the project is characterizing the fleet and demonstrating emission controls on four vessels. When the technology deployment phase begins, NYSERDA's goal is to involve up to thirty-nine boats; currently, there are some 45 ferry vessels actively serving commuter routes. For this project, the objective can be defined as maximizing the number of vessels that reduce emissions.
3. *Minimize total cost (public and private)*. The New York Harbor Private Ferry Emissions Reduction Program expects to provide between $4.75 Million and $6.05 Million through a subscription-based incentive program. These funds will offset the costs of achieving emissions reductions on private ferries, and help the fleet reduce emissions sooner than federal marine engine standards would require. However, total costs of installing and operating emission reduction technologies over the long term may be greater than the available funds. By minimizing the total cost of achieving reductions, the publicly available funds may provide greater incentive for private ferry participation, and long-term operation of emissions control technologies may be achieved.

[1] The project funds associated with the demonstration task are expected to cover up to 100% of the demonstrations, according to the NYSERDA request for proposal (http://www.nyserda.org/760rfp.html). The deployment phase may not cover 100% of the costs of long-term operation.

4. *Reduce time to achieve reductions*. Federal regulatory action currently limits emissions from commercial marine engines (Environmental Protection Agency 2003). Stricter standards can be expected in coming years. However, these emission standards follow the regulatory model for all other mobile source emissions (except locomotives); they require new engines to achieve lower standards and do not address emissions from existing engines. The program's goal is to achieve reductions sooner than (and perhaps greater than) required by federal law. Therefore, the objective can be defined as minimizing the time to achieve the above goals.

1.4 Emission Control Technology Alternatives

Fundamentally, emission reduction technologies address either primary or secondary control mechanisms (Corbett and Fischbeck 2001). Primary methods affect the engine process directly. Secondary methods reduce emissions without changing the engine from its operationally optimized settings and typically require equipment that is not integrally part of the engine itself. Another way to consider these technologies is by whether in-engine modifications (in-engine technologies) are required or whether reductions can be achieved by modifying the fuel or air systems (pre-engine technologies) or by modifying the exhaust gas itself (post-engine technologies). Combinations of these technologies can represent additional alternatives.

In the context of technology demonstration, the NYSERDA Program initially identified twenty-nine potential technology alternatives (see Table 1). The program has initially classified these technologies according to whether they are in-engine controls (including air treatment), fuel-system modifications (including alternative fuel), exhaust aftertreatment, or a combination of these.

Table 1. Summary of Technology Alternatives under Initial Review by the New York Harbor Private Ferry Emissions Reduction Program

ON-ENGINE MODIFICATIONS: 1. Turbocharger reconfiguration/rematching 2. Injection optimization 3. Common rail, electronic unit, and electronic conventional injection 4. Inlet air fumigation 5. Timing retardation 6. Ceramic coating of engine components 7. Engine replacement/repowering 8. Direct water injection	COMBINATIONS: 1. ULSD, SCR and PM trap 2. ULSD, oxidation catalyst, EGR and PM filter 3. Thermal barrier coatings ULSD, SCR and PM trap 4. ULSD and injection modifications 5. Emulsified ULSD and thermal barrier coatings 6. Emulsified ULSD, EGR and PM filter 7. Emulsified ULSD, SCR and PM trap
ALTERNATE FUELS: 1. Ultra low sulfur diesel (ULSD) 2. Emulsified diesel 3. Gaseous fuels (LPG, CNG, LNG, hydrogen) 4. Biodiesel 5. Synthetic diesel 6. Ethanol, methanol and their diesel blends 7. Dual fuel (liquid and gas) 8. Fuel additives	EXHAUST AFTER TREATMENT DEVICES: 1. Selective catalytic reduction (SCR) 2. Particulate filters and traps 3. Oxidation catalysts (OC) 4. Exhaust gas recirculation (EGR) 5. Lean NOx catalysts 6. NOx absorbers

Most of these alternatives represent technologies that have been assessed either generally for marine application or in other specific marine engine demonstration projects. It is unlikely that this large set of alternatives represents the feasible set of contending options that will ultimately be considered for the technology deployment phase. The technology demonstration is expected to select between three and five technologies; however, the deployment phase may include more technologies than the several chosen for short-term demonstration. The scope of this project requires that we consider criteria enabling this flexibility.

1.5 Emission Reduction Policy Alternatives

These alternatives are the focus of Task 2 deliverable, and will be developed into incentive scenarios. The policy scenarios implemented by the New York Harbor Private Ferry Emissions Reduction Program terms is expected to be a "subscription-based incentive program." For the demonstration phase of the project, the program has committed to cover up to 100% of the cost (http://www.nyserda.org/760rfp.html), because "participation of the applicable private ferry operators, as well as potential technology suppliers (engine, fuel, aftertreatment, etc. vendors) [is] a crucial element in the demonstration program."

Ferry operators may "select from the menu of technologies and receive an incentive for the technology or technologies implemented, up to an agreed upon dollar amount." However, technology demonstration projects may be insufficient to motivate large-scale voluntary adoption of emissions control technologies by industry. If the technologies that are recommended by demonstrations and evaluation are costly to the private sector, some incentives may be needed. On the other hand, if certain technology alternatives are consistent with fleet expansion or modernization plans of private operators, then matching public investment with private sector goals could minimize the need for costly subsidies or strict regulatory mandates.

In many cases, this takes the form of a capital cost subsidy, grant, or rebate; however, alternative policy designs could address annual operating costs. Other approaches will be considered, including market-based mechanisms applied in Europe to reduce marine emissions. In order to consider these sorts of alternatives with respect to the objectives, criteria need to be considered at both the vessel-specific and fleetwide levels. Section 2 describes criteria we plan to consider.

2 SUMMARY OF CRITERIA

These criteria will inform the design and evaluation of incentive scenarios to be completed under tasks 2 and 3 of this project. Emissions reduction programs can range from those with very few voluntary incentives (e.g., regulatory mandate) to programs that offset or subsidize environmental costs either directly or through market-based mechanisms. This project will develop incentive scenarios to assist the New York Harbor Private Ferry Emissions Reduction Program in designing a deployment phase that achieves program objectives. Evaluating alternatives in terms of objectives requires that attributes be defined as criteria for judging which incentive designs may be more desirable.

The criteria for this analysis are broader than criteria for selecting technologies for one or several vessels, either in demonstration context or for long-term operation. Primary criteria that will be used to evaluate incentive alternatives are listed in Table 2. Discussion about the criteria follows in Sections 2.1 and 2.2.

Table 2. Summary of Criteria for Considering Technology Deployment Incentive Scenarios

PROGRAM OBJECTIVES (PRIMARY AND SECONDARY)	TECHNOLOGY-BASED CRITERIA	PUBLIC POLICY BASED CRITERIA
Reduce private ferry fleet emissions. 1. Minimize emission per vessel 2. Minimize fleet emissions 3. Achieve fleet-wide emissions target	1.Emissions reduction per vessel 2. n/a 3. Fleet-wide emissions reduction	1. n/a 2. n/a 3. n/a
Maximize private ferry fleet participation 1. Maximize the numbers of vessels 2. Maximize operator participation	1. n/a 2. n/a	1. Vessels adopting controls 2. Operators adopting controls
Minimize total cost (public and private) 1. Minimize capital cost 2. Minimize annual cost 3. Minimize private sector share of cost	1. Capital Cost 2. Annual Cost 3. n/a	1. Net-present-value of capital cost 2. Net-present value of annual cost 3. Cost-share between public/private
Reduce time to achieve reductions 1. Achieve reductions before regulation 2. Achieve program goals within period of FTA funding 3. Sustain reductions over long term	1.Time to install/adopt technology 2. n/a 3. n/a.	1. n/a 2. Time to implement incentives 3. Compare private ferry cost burden over various scenarios

2.1 Technology-based criteria

As discussed in Section 1.4, above, the scope for this work requires that we do not limit our analysis to demonstration technologies selected by the New York Harbor Private Ferry Emissions Reduction Program. This scope considers various technologies, and the criteria are not limited by the demonstration technologies themselves. Our goal is to characterize those attributes that may affect the design of deployment incentives. Considering the range of alternatives identified initially, we recognize that one alternative classified as an in-engine modification may have very similar attributes (such as the emissions reduction and/or cost) as a fuel-based or aftertreatment alternative; for our purposes these technologies may be redundant.

This work considers criteria that would most influence incentive program design. Table 3 summarizes criteria that an operator might consider for selecting emission control technologies, based on analysis conducted for the Maritime Administration (Corbett and Chapman 2003). Technology criteria that will be most important to the design and selection of incentive scenarios include technology cost to the vessel and emission reduction performance. Other technology criteria that may be relevant, depending upon the alternative, include infrastructure requirements and potential revenue impacts. Infrastructure changes could increase the cost of the alternative and loss in revenue (either from displacement of seats or unscheduled downtime) could reduce the incentive of an operator to participate. Table 2 summarizes these criteria, associating them with the program objectives discussed in Section 1.3.

Criteria specific to vessel compatibility may be important to specific selection of technologies for demonstration or for permanent installation, but may be less significant in considering the incentive design. For example, if using a retrofit technology provided by a third-party vendor violates an engine warranty, an operator may refuse to consider it even if it costs less and reduces emissions more than other options. Similarly, if safety standards cannot be met to the satisfaction of U.S. Coast Guard or other certifying body, the technology may not be ready for marine application. The remaining technologies would (at least theoretically) merit further review beyond the first iteration. In this work, we assume that iterative reviews of technologies by operators and policy makers would produce a feasible set of technologies that would merit inclusion in the incentive program.

The technical criteria presented here are consistent with demonstration project criteria developed by Seaworthy Systems under the NYSERDA scope of work. Under the NYSERDA scope of work:

> "[Seaworthy Systems developed] a list of trade-off criteria for emissions reduction strategies, incorporating emissions reduction effectiveness, economic viability, impact on fuel economy, technology readiness, operability impacts, and other factors deemed relevant."

Seaworthy Systems produced a draft matrix of alternatives and criteria for the project advisory group in January 2004; initial criteria they proposed are presented in Table 4. Note the significant overlap in the key criteria between the two matrices. The project team coordinated with the NYSERDA Project Advisory Group, reviewed early drafts of the demonstration downselect criteria, and provided comment. Our analysis will incorporate the demonstration-specific results of NYSERDA's engineering and economic trade-off analysis.

2.2 Policy-based Criteria

In developing an incentive program to encourage voluntary participation by ferry operators, it is important to consider criteria that measure the success of the policy design. In this regard, the technology-based criteria provide necessary but insufficient information. Policy-based criteria are needed to consider whether program participation goals are met, whether they achieve these goals at least cost, and whether they achieve long-term benefits sooner than programs with less incentive for voluntary participation (e.g., federal regulation).

Specific policy-based criteria that will be evaluated are listed in Table 2. The number of vessels and operators involved in deployment of emissions reduction technologies measure different aspects of the participation goal. For example, it may be possible to achieve emission reduction targets without retrofitting every vessel, but still include all operators. Capital and annual costs can be combined using standard discounting techniques to compare costs for each alternative using a net present value (NPV) approach; this helps to evaluate which scenarios cost the least overall. Alternatively, one could convert all costs to equivalent annual costs over a given period; this is used to evaluate cost-effectiveness. By considering how much private cost is relieved through public incentives, one can identify deployment programs that might achieve participation and emissions goals within the shortest time at least public cost.

Table 3. List of decision criteria important to an operator considering emission control alternatives. Attributes assigned to example alternatives represent "generic" properties from published literature used for the MARAD report; the NYSERDA demonstration project will generate specific estimates that may update or augment the values used here.

	Capital Cost[1] ($/kW)	Annual Cost ($/kW)		Nominal Emission Reduction		Infrastructure[2]	Volume And/Or Weight		Revenue Impact[2]	Vessel Compatibility Or Reliability[2]
Example Alternative		Maintenance	Fuel Penalty	NOx	Other (PM)	Fuel	Equip-ment	Fuel	Payload or Passengers	Other factors specific to vessel
Option 1: SCR	$100 - $600	$3 - $4	$0	81%	0%	Catalyst supply may be needed	Varies[2]	NA	Assumed not affected	Assumed not affected
Option 2: Water in air	$90 - $290	$0.50 - $5	$4 - $6	28%	1%	Not affected	Minimal	Varies[2]	Assumed not affected	Assumed not affected
Option 3: Water in fuel	$80 - $260	$0.20 - $1.60	$3 - $4	42%	15%	Emulsifier supply may be needed	Minimal	Varies[2]	Assumed not affected	Assumed not affected
Option 4a: EPA Tier 2 engine	$140 - $200	$0	$0	50%	33%	Not affected	NA	NA	Assumed not affected	Assumed not affected
Option 4b: EPA Tier 2 engine with 10% fuel economy	$140 - $200	$0	($12 - $20)	63%	93%	Not affected	NA	NA	Assumed not affected	Assumed not affected
Option 5: Alternative fuel engine CNG	$140 - $200	$0	($30 - $60)	90%	63%	Alternate fuel supply needed	NA	Varies[2]	Assumed not affected	Assumed not affected

1. Costs represent planning level retrofit costs for two main engines per vessel,; actual costs will vary depending on size and number engines.
2. These attributes may be very important, but quantifying can be difficult and specific to the vessel/route/terminal combination. In the example analysis presented here, we assume that these factors are not constraints.
3. Weight and volume may be important constraints. For example, U.S. Navy studies suggest that SCR equipment can add 1200-4500 kg in weight and may require 5-29 cubic meters of space (NAVSEA 1994); some commercial designs (e.g., for ferries) may be much less constraining. The issue is not with the absolute size or weight, but whether the vessel configuration can accommodate the system. In the example analysis presented here, we assume that these factors are not constraints.

Table 4. Summary of draft NYSERDA Technology Demonstration Criteria (per Seaworthy Systems presentation, January 2004).

Candidate Technology	NOx and PM Emission Reduction Potential and Impact on Other Pollutants	Acquisition (Purchase and Installation) Cost	Prior Marine Experience and Probability of Success	Ferry Operating and Related Cost Impacts	Space, Weight and Onboard Utility Support Requirements	Complexity of Installation and Ease of Operation	Safety Impacts/Issues and Crew Training Requirements	Field Service and Consumables Support Requirements	Affinity for Combining with Other Technologies	Impact on Engine Warranties
Example of Technology Combinations										
1. ULSD, SCR and PM trap										
2. ULSD, oxidation catalyst, EGR and										
PM filter										
3. Thermal barrier coatings ULSD, SCR										
and PM trap										
4. ULSD and injection modifications										
5. Emulsified ULSD and thermal barrier										
Coatings										
6. Emulsified ULSD, EGR and PM										
Filter										
7. Emulsified ULSD, SCR and PM trap										

3 APPLICATION OF CRITERIA IN NEXT TASKS

We will evaluate incentive scenarios (to be developed in Task 2) with a Marine Emissions Optimization Model (MEOM) that identifies least cost emissions control strategies for a fleet of marine passenger ferries. This mixed integer, non-linear programming model analyzes the fleet of private passenger ferries operating within the NY/NJ Harbor. Based on engine characteristics, operating profiles, and existing emissions control technologies, the model determines how the ferry fleet can meet emissions reduction targets at least cost. Results of the analysis (provided under Task 3) will provide information to decision makers interested in targeting policies and programs to assist ferry operators meet emissions reduction targets.

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