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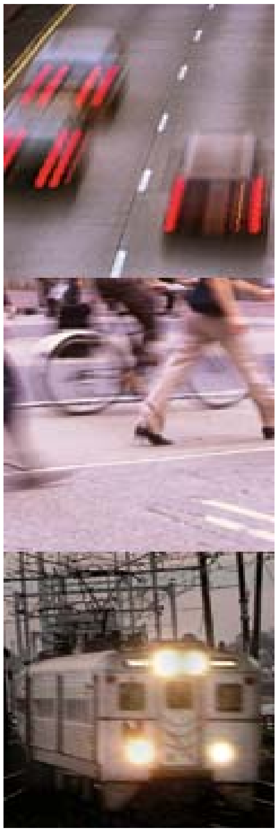

An Evaluation of Public-Private Incentives to Reduce Emissions from Regional Ferries

Technical Memorandum Two

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EXECUTIVE SUMMARY

Market-based instruments are policy approaches that encourage behavior through market signals rather than through explicit directives regarding pollution control levels or methods (Stavins 2002; UNEP 2002). They aim to modify environmental behaviors to reduce the impact of human activities on natural resources and the environment by harnessing the power of market incentives (Seik 1996; Austin 1999; Caribbean Planning for Adaptation to Climate Change 2000; Stavins 2002). Economic incentives are defined broadly by the US EPA as "instruments that use financial means to motivate polluters to reduce the health and environmental risks posed by their facilities, processes, or products" (EPA 2001).

The Federal Transit Administration (FTA) has set aside funds to provide incentives for private ferry operators in New York and New Jersey to adopt emission control measures on their vessels. The New York State Energy Research and Development Authority (NYSERDA) established a Private Ferry Emissions Reduction Program to manage the distribution of these funds. FTA also contracted a team of researchers at Rutgers, the State University of New Jersey, University of Delaware, and Rochester Institute of Technology to assist in evaluating economic incentives that might encourage adoption of potential control technologies to meet program goals. This memorandum is the second deliverable under the Rutgers contract, and evaluates economic incentives in general, with regard to the maritime industry, and in terms of the evaluation of possible incentives for the New York and New Jersey private ferry system.

If well designed and implemented, economic incentives offer a more cost-effective, flexible and dynamic form of regulation than traditional measures, often referred to as "command-and-control" regulations, and encourage firms (and/or individuals) to undertake pollution control efforts that are in their own interests and that collectively meet policy goals. When stakeholder groups have an economic self-interest in meeting environmental goals, they are more likely to comply with those regulations and, depending on further incentives, even reach beyond them. These fundamental principles are intrinsic to the goals of the FTA-funded, NYSERDA-led effort with regard to private ferries.

This report discusses how economic incentives can be used to meet environmental performance goals (Section 2) and how incentives can complement traditional regulatory approaches (Section 3). Through a thorough review of the literature on incentives, the report summarizes general types of incentive instruments used to achieve environmental objectives (Section 4), and the lessons learned from experiences with economic incentives in other industry sectors (Section 5). The report then focuses on the maritime industry (Section 6) to identify and discuss how economic incentives are being used to achieve better environmental performance sooner than command-and-control regulation. Various perspectives on the application of these incentives to the marine transportation industry are summarized (Section 7). Lastly, the report presents a description of the model developed to evaluate emission control for the private ferry fleet of vessels in the New York and New Jersey metropolitan region (Section 8), including example results. This model will be fully applied according to the FTA scope of work under project NJ-42-0002-00 in the final deliverable.

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1 INTRODUCTION

Policy instruments for achieving environmental objectives are divided into "command-and-control" approaches and market-based or incentive-based mechanisms (Hahn and Stavins 1992). Depending upon the characteristics of the sources of pollution and the damages, some tools of environmental management are likely to be more cost-effective than others. Cost-effective tools achieve environmental goals for the least cost (EPA 2001).

For decades (from 1920 when Pigou introduced corrective taxes to the discussion of transferable rights by J. Dales in 1928), economists have been extolling the virtues of market-based or economic-incentive approaches to environmental protection (Hahn and Stavins 1992). Interest in environmental policy instruments that utilize or improve market forces has grown considerably over the past decade (U.S. Congress Office of Technology Assessment 1995; Austin 1999). Surveys show that about 100 economic instruments were in place in 14 Organization for Economic Cooperation and Development (OECD) countries by 1987, rising to 150 by 1993 (Austin 1999). The importance of economic instruments for environmental policy is stressed in both the Rio Declaration and Agenda 21 (Panayotou 1994).

Market-based instruments are policy approaches that encourage behavior through market signals rather than through explicit directives regarding pollution control levels or methods (Stavins 2002; UNEP 2002). They aim to modify environmental behaviors to reduce the impact of human activities on natural resources and the environment by harnessing the power of market incentives (Seik 1996; Austin 1999; Caribbean Planning for Adaptation to Climate Change 2000; Stavins 2002). Economic incentives are defined broadly by the US EPA as "instruments that use financial means to motivate polluters to reduce the health and environmental risks posed by their facilities, processes, or products" (EPA 2001).

Economic instruments encompass a range of policy tools from pollution taxes, charges, and marketable permits to government subsidy, deposit-refund systems and performance bonds (Stavins 2002; UNEP 2002). Any instrument that aims to induce a change in behavior of economic agents by internalizing environmental or depletion cost through a change in the incentive structure that these agents face (rather than mandating a standard or a technology) qualifies as an economic instrument (Panayotou 1994).

Economic instruments provide a means of enhancing the capacity of governments to deal with environmental and development issues in a cost effective manner, promoting technological innovation, influencing consumption and production patterns, as well as providing an important source of funding (Panayotou 1994).

If well designed and implemented, economic instruments offer a more cost-effective, flexible and dynamic form of regulation than traditional measures, often referred to as "command-and-control" regulations, and encourage firms (and/or individuals) to undertake pollution control efforts that are in their own interests and that collectively meet policy goals (Austin 1999; Stavins 2002). When stakeholder groups have an economic self-interest in meeting environmental goals, they are more likely to comply with those regulations and, depending on further incentives, even reach beyond them (Caribbean Planning for Adaptation to Climate Change 2000).

2 ECONOMIC INCENTIVES AS AN ENVIRONMENTAL INSTRUMENT

Over the past 30-years, the U.S. Congress and the U.S. Environmental Protection Agency (EPA) have relied most heavily on uniform, nationally applicable regulations derived from environmental law as single-source tools[1] with fixed pollution reduction targets (U.S. Congress Office of Technology Assessment 1995; EPA 2001). Of the 30 major pollution control programs, about four out of five use design standards and half use harm-based standards, typically in combination with design standards (U.S. Congress Office of Technology Assessment 1995).

EPA increasingly considers a much broader array of tools, including economic incentives, to manage environmental quality (U.S. Congress Office of Technology Assessment 1995; Austin 1999; EPA 2001). They have been used most prominently to control sulfur dioxide (SO_2) emissions under the Clean Air Act (2003). As yet many applications of economic instruments are relatively small-scale in nature, and have often been introduced for the sole purpose of raising revenue (Austin 1999). However, there is a growing familiarity and comfort with using such instruments which suggests more extensive and more large-scale use of such instruments is in the offing (Austin 1999).

From the early days of the EPA, policy makers have recognized that economic instruments had the potential to improve the cost effectiveness of environmental management, and the commitment to expanding the use of innovative, cost-effective approaches to environmental management has been growing since the 1970s (EPA 2001). At the beginning, the initiative proposed by the Nixon administration to use emission fees to limit sulfur dioxide failed in Congress. In the early 1980s EPA began to experiment with the use of economic incentives, introducing emissions trading. The Clean Air Act Amendments of 1990, a product of the George H.W. Bush administration, greatly increased the use of economic incentives in environmental management. The Clinton administration continued strong support for the use of economic incentives in environmental management (EPA 2001).

Economic incentives are being used now by the U.S. EPA as the principal instrument for controlling a growing number of environmental problems (EPA 2001). To varying degrees, federal, state, and local governments are promoting the use of economic incentives as an

[1] According to Environmental Policy Tools: A User's Guide, single source tools and multi-source tools are the two types environmental policy tools that directly limit pollution. Single-source tools require the sources themselves to comply with an emissions limitation or face associated civil or criminal penalties. These tools are often called "traditional" approaches because historically they are the most heavily used category of tools, or "command-and-control" because they can be less flexible than multi-source tools. Single-source tools include harm-based standards, design standards, technology specifications, and product bans or limitations. Multi-source tools allow a regulated entity additional flexibility in how it complies with specific pollution reduction targets. A facility can change its own behavior to fit within the emissions limits, or can make an arrangement with another entity for it to comply with the limitation on the facility's behalf. Multi-source tools include tradeable emissions, challenge regulation, and integrated permitting.

environmental management tool because of the perceived advantages and effectiveness of these incentives (EPA 2001).

There is a longer history of the use of economic incentives in the European Union (EU) than in most other parts of the world, and the predominant type of economic incentive in Europe is emission fee (Kolstad 2000). There has also been a trend in countries in transition towards a more consistent and extended use of economic instruments in environmental policy since the adoption in 1992 of ECE recommendations on the application of the OECD Guidelines and Considerations for the Use of Economic Instruments in Environmental Policies in these countries (ECE 1998).

3 COMMAND-AND-CONTROL APPROACH Vs. ECONOMIC INCENTIVES

3.1 Pros and Cons of Command-and-Control Approach

Command-and-control regulations achieve environmental management goals by setting uniform standards for sources of pollutants (Stavins 2002). There are various categories of regulatory instruments: emission or effluent standards, environmental quality standards, product controls, process and equipment standards, performance standards, planning and building controls, and extraction restrictions (Seik 1996). The most prevalent regulatory instruments are technology- and performance-based standards (Stavins 2002). Technology-based standards specify the method, and sometimes the actual equipment, that sources must use to comply with a particular regulation. A performance standard sets a uniform control target for firms, while allowing some latitude in how this target is met (Stavins 2002).

In contrast to economic instruments, conventional approaches allow relatively little flexibility in the means of achieving goals (Hahn and Stavins 1992; Stavins 2002). Such regulations tend to force firms to take on similar shares of the pollution control burden, regardless of the cost (Stavins 2002).

The major advantages of command-and-control regulations are much greater certainty of the results, and more flexibility in regulating complex environmental processes (Seik 1996; Kolstad 2000). Another advantage is the simplicity of monitoring of compliance (Kolstad 2000).

Because the costs of controlling emissions may vary greatly among sources, the appropriate technology in one situation may not be appropriate (cost-effective) in another (Stavins 2002). One of the biggest problems is difficulty in satisfying the equimarginal principle; this is the principle that with multiple polluters whose emissions all contribute damage in the same way, the marginal cost of control be equated across polluters to achieve an emission reduction at the lowest possible cost (Kolstad 2000). This is why implementing "command-and-control" regulations can be expensive and, in some circumstances, counterproductive. While standards may effectively limit emissions of pollutants, they typically exact relatively high costs in the process, by forcing pollutant sources to use expensive means for controlling pollution (Hahn and Stavins 1992; Seik 1996; Stavins 1996; Kolstad 2000; Stavins 2002). One survey of eight empirical studies of air pollution control found that the command-and-control approach is significantly less efficient on a cost basis using the ratio of actual, aggregate costs of the conventional, command-and-control approach to the aggregate costs of least-cost benchmarks that could be incentivized (Stavins 2002). Such a regulatory system can also be very costly to administer (Kolstad 2000).

Under command-and-control regulations, owners of sources of pollution have an incentive to comply to avoid penalty. But releasing pollution has little negative economic cost to the owner (EPA 2001). Consequently, owners of these sources of pollution normally have no incentive to go beyond what the regulations require (EPA 2001). In contrast, with market incentives, sources of pollution can see an economic value in reducing pollution because doing so saves them money. Consequently, the difference between a traditional regulatory system and economic incentives can lead to multiple public health, environmental, and economic benefits (EPA 2001).

Furthermore, command-and-control regulations tend to freeze the development of technologies that might otherwise result in greater levels of control (Kolstad 2000; Stavins 2002). Little or no financial incentive exists for businesses to exceed their control targets, and both technology-based and performance based standards discourage adoption of new technologies. A business that adopts a new technology may be "rewarded" by being held to a higher standard of performance, but is not given the opportunity to benefit financially from its investment, except to the extent that its competitors have even more difficulty reaching the new standard (Stavins 2002).

3.2 Pros and Cons of Economic Incentives

Economic incentives have several advantages that make them attractive environmental management tools. The key benefit of economic instruments is that they would allow a given pollution target to be met at lower overall cost than traditional regulations (Hahn and Stavins 1992; Austin 1999). Economic instruments provide incentives for the greatest reductions in pollution by those firms that can achieve these reductions most cheaply. Probably the biggest advantage of economic incentives is that the equimarginal principle will hold for most types of economic incentives (Kolstad 2000). In theory and with growing evidence, if properly designed and implemented, market-based instruments allow any desired level of pollution cleanup to be realized at the lowest overall cost to society by providing flexibility to polluters or users of natural resources to chose the most cost-efficient and environmentally effective measures (ECE 1998; Kolstad 2000; EPA 2001; Stavins 2002; UNEP 2002). At least 40 studies based on computer modeling of different scenarios for controlling pollution show that economic incentives should be more cost-effective than traditional regulations (EPA 2001).

In contrast to command-and-control regulations, market-based instruments have the potential to provide powerful incentives for companies to adopt cheaper and better pollution-control technologies – and to adopt these technologies sooner than typically required by regulation. This is because with market-based instruments, it always pays firms to clean up a bit more if a sufficiently low-cost method (technology or process) of doing so can be identified and adopted (Seik 1996; Stavins 2002).

Market-based instruments have other benefits too. Properly designed and implemented economic instruments grant firms and individuals greater autonomy in deciding how to meet targets; they create ongoing incentives for firms to design new and improved abatement technologies ensuring that pollution control becomes ever cheaper, thus provide a valuable spur to technological innovation; they reduce the information burden on regulators; they often can do a better job of controlling large numbers of small sources; they increase prices of environmentally-damaging goods and services, as well as increase the returns to more sustainable approaches leading to more sustainable production and consumption patterns; they allocate property rights and responsibilities of firms, groups, or individuals so that they have both the incentive and the power to act in a more environmentally-responsible manner; and they provide potential revenue sources for state or federal governments. In addition, economic instruments may provide greater flexibility in dealing with smaller and diffuse emissions sources which collectively contribute large amounts of pollution, but which until now have been largely ignored in favor of controlling the pollution from more obvious sources (Seik 1996; Austin 1999; EPA 2001; UNEP 2002).

Over the long term, while economic incentives can help improve environmental decision making, they can also serve to educate all public sectors to behave more environmentally-friendly (Caribbean Planning for Adaptation to Climate Change 2000). Furthermore, economic instruments can contribute to effectively integrating environmental and economic policies and achieving sustainable development (ECE 1998).

Economic incentives also have limitations. The marked preference economists have shown for incentive-based instruments over command-and-control is largely based on the theoretical efficiency advantages (Hahn and Stavins 1992). But this should not leave the impression that market-based instruments have replaced, or have come anywhere close to replacing, the conventional, command-and-control approach to environmental protection. Given political and technological constraints, there are some environmental problems for which incentive-based approaches are poorly suited (Hahn and Stavins 1992). One of the most significant disadvantages is that they are often inappropriate for dealing with environmental issues that revolve around equity concerns (EPA 2001). By relying on the market, they may benefit stakeholders with stronger market power and leave stakeholders without the capacity to participate at some disadvantage.[2] Another problem is the uncertainty of the impacts on polluters and the uncertainty of the outcome of most economic incentive approaches (Seik 1996; Kolstad 2000). Further, even when and where these approaches have been used in their purest form and with some success, such as in the case of tradable-permit systems in the United States, they have not always performed as anticipated (Stavins 2002). While economic incentives as an instrument in environmental policy are not likely to replace command-and-control regulations, they can serve as a significant complement to them, if not a more effective approach in some cases (Caribbean Planning for Adaptation to Climate Change 2000).

[2] "Many types of environmental standards are designed to protect individuals around the site of a polluting facility; in some cases the specific purpose is to protect individuals exposed to the highest pollutant concentrations. In general, people are not willing to accept higher risks to their health because it is "more economical" to reduce risks to others" (EPA 2001). Another example might be locating a clean-fuel depot more central to a major user's routes at the disadvantage of smaller operators who may service outlying routes.

4 TYPES OF ECONOMIC INSTRUMENTS IN ENVIRONMENTAL POLICY

Increasingly over this last decade, countries throughout the world have been adopting various types of economic instruments as a complement to command and control regulation as a means for achieving policy objectives; they have had some demonstrable success (Caribbean Planning for Adaptation to Climate Change 2000). Most economic instruments that are being employed by governments worldwide can be categorized into charges, fees or taxes, tradable permits, charge-permit hybrids, government subsidies, and market barriers reductions (Seik 1996; Caribbean Planning for Adaptation to Climate Change 2000). Table 1 presents a brief summary of pros and cons of economic incentives instrument in the U.S.

Table 1. Summary of Pros and Cons of Economic Incentives in the U.S. (EPA 2001)

Incentive	Examples	Pros & Cons
Pollution Charges & Taxes	Emission charges Effluent charges Solid waste charges Sewage charges	Pros: stimulates new technology; useful when damage per unit of pollution varies little with the quantity of pollution Cons: potentially large distributional effects; uncertain environmental effects; generally requires monitoring data
Input or Output Taxes & Charges	Leaded gasoline tax Carbon tax Fertilizer tax Pesticide tax Virgin material tax Water user charges CFC taxes	Pros: administratively simple; does not require monitoring data; raises revenue; effective when sources are numerous and damage per unit of pollution varies little with the quantity of pollution Cons: often weak link to pollution; uncertain environmental effects
Subsidies -capital costs -annual subsidies	Municipal sewage plants Land use by farmers Industrial pollution	Pros: politically popular, targets specific activities Cons: financial impact on government budgets; may stimulate too much activity; uncertain effects
Deposit-Refund Systems	Lead-acid batteries Beverage containers Automobile bodies	Pros: deters littering; stimulates recycling Cons: potentially high transaction costs; product must be reusable or recyclable
Marketable Permits	Emissions Effluents Fisheries access	Pros: provides limits to pollution; effective when damage per unit of pollution varies with the amount of pollution; provides stimulus to technological change Cons: potentially high transaction costs; requires variation in marginal control costs
Reporting Requirements	Proposition 65 SARA Title III	Pros: flexible, low cost Cons: impacts may be hard to predict; applicable only when damage per unit of pollution does not depend on the quantity of pollution
Liability	Natural resource damage assessment Nuisance, trespass	Pros: provides strong incentive Cons: assessment and litigation costs can be high; burden of proof large; few applications
Voluntary Programs	Project XL 33/50 Energy Star	Pros: low cost; flexible; many possible applications; way to test new approaches Cons: uncertain participation

4.1 Charges, Fees or Taxes

Economic incentive is either a stick or a carrot. Environmental tax is often characterized by the industry as negative economic incentive because one has to pay for the emissions or use of resources, while a rebate or grant is positive (Oftedal 2000).

Pollution charge systems assess a fee or tax on the amount of pollution that a firm or source generates (Caribbean Planning for Adaptation to Climate Change 2000; Stavins 2002). These are prices paid for discharges of pollutants to the environment, based on the quantity and/or quality of the pollutant(s) (Austin 1999). To be most effective the charge is levied directly on the quantity of pollution ('emissions tax or charge'), though if this is difficult to measure or monitor, it may be necessary to levy a charge on a proxy for the emissions, typically on the resource that causes the pollution ('product tax or charge').

Product charges occur at different usage points. They have been levied on products either as they are manufactured (e.g. fertilizers), consumed (e.g. pesticides) or disposed of (e.g. batteries) (Austin 1999).

Consequently, it is worthwhile for the firm to reduce emissions to the point where its marginal abatement cost is equal to the tax rate. A challenge with charge systems is identifying the appropriate tax rate. Ideally, it should be set equal to the benefits of cleanup at the efficient level of cleanup, but policy makers are more likely to think in terms of a desired level of cleanup, and they do not know beforehand how firms will respond to a given level of taxation.

How effective product charges are depends on how well 'linked' the input, or product, is to the eventual stream of pollution. In the case of taxing carbon fuels as a proxy for carbon dioxide emissions, the 'linkage' is very strong as virtually all the carbon contained in fuels is released during combustion. Taxing the fuel is thus little different than taxing the emissions. On the other hand, taxing pesticides as a proxy for release of certain chemicals into water systems is less well linked as the degree of chemical infiltration will depend on a mixture of variables relating to soil and slope conditions, the timing of applications, etc (Austin 1999).

4.2 Tradable Permits

Tradable permits are similar to charges and taxes except that they operate by fixing an aggregate quantity of emissions rather than charging a price for each unit of emissions. Instead of being charged for releases, one needs to hold a 'permit' to emit or discharge. By controlling the total number of permits, the aggregate pollution quantity is effectively controlled (Austin 1999; Caribbean Planning for Adaptation to Climate Change 2000; Stavins 2002). Under a tradable permit system, the allowable overall level of pollution is allocated among sources of pollution in the form of permits. Sources that keep their emission levels below their allotted level may sell their surplus permits to other sources or use them to offset excess emissions in other parts of their facilities (Caribbean Planning for Adaptation to Climate Change 2000; Stavins 2002). Tradable permits can achieve the same cost-minimizing allocation of the control burden as a charge system, while avoiding the problem of uncertain responses by pollution sources (Stavins 2002).

It is well known that over the past decades tradable permit systems have been adopted for pollution control with increasing frequency in the United States, but it is also true that this market-based environmental instrument has begun to be applied in a number of other countries as well (Stavins 2002). World wide, these programs are of two basic types: credit programs and cap-and-trade systems. Under credit programs, credits are assigned (created) when a source reduces emissions below that which is required by existing, source specific limits; these credits can enable the same or another firm to meet its control target. Under a cap-and-trade system, an allowable overall level of pollution is established and allocated among firms in the form of permits, which can be freely exchanged among sources (Stavins 2002).

4.3 Charge-Permit Hybrids

The quantity-based permit approach and a price-based charge or tax approach can be blended to try to harness their different strengths while avoiding their weaknesses (Austin 1999). A good example is a proposal by Resources for the Future (RFF) to use a hybrid mechanism to control CO2 emissions in the U.S. This would consist primarily of a permit program that would require domestic energy producers (and importers) to obtain permits equivalent to the volume of carbon dioxide eventually released by the fuels they sell. However, by setting the overall permit quantity, one has no idea what price permits will sell for –this will only be revealed as businesses and consumers begin to reduce their CO2 emissions. In order to guard against excessively high permit prices that might arise – the very prospect of which may prevent the program being implemented in the first place – the second aspect of the proposal would be for the government to release an unlimited number of permits at $25 per ton of carbon should the market price of permits reach that level. This effectively sets up a charge system of $25 per ton, capping the possible market price (Austin 1999). Charge-permit hybrids attempt to control on the basis of quantity, which is the most desirable goal, while creating an 'escape valve' should costs rise too high (i.e., if the costs rise too high, the permit quantity can be raised to lower the costs of control). Even if the escape valve is utilized, the program amounts to the institution of a charge on carbon (Austin 1999).

4.4 Subsidies

Subsidies are payments or tax concessions that provides financial assistance for pollution reduction or plans to mitigate pollution in the future (Caribbean Planning for Adaptation to Climate Change 2000). Where taxes or charges can be used as a penalty on discharges, subsidies can be used to reward the reduction of discharges in a similar manner. The financial incentive is effectively the same, though the flow of funds is in a different direction. A subsidy program will involve a transfer of funds from the government to the industry. Subsidies may be relatively explicit in the form of grants and soft loans, or be somewhat indirect, such as in adjusted depreciation schedules (Austin 1999). In theory, subsidies can provide incentives to address environmental problems. In practice, however, many subsidies promote economically inefficient and environmentally unsound practices (Stavins 2002).

4.5 Market Barrier Reductions

Market barrier reductions can also serve as market-based policy instruments. In such cases, substantial gains can be made in environmental protection simply by removing existing barriers to market activity. Three types of market barrier reductions stand out: (1) market creation, as with measures that facilitate the voluntary exchange of water rights and thus promote more efficient allocation and use of scarce water supplies; (2) liability rules that encourage firms to consider the potential environmental damages of their decisions; and (3) information programs disclosing to final consumers regarding environmental performance, such as energy efficiency product labeling requirements, eco-labeling (Caribbean Planning for Adaptation to Climate Change 2000; Stavins 2002).

5 LESSONS LEARNED FROM EXPERIENCES

Most environmental policy debates reflect three broad, but at times conflicting, themes: 1) costs and burdens, 2) environmental results, and 3) technological change (U.S. Congress Office of Technology Assessment 1995).

The performance of market-based instruments for environmental protection provides valuable evidence for environmentalists and others who have resisted these innovations that market based instruments can achieve major cost savings while accomplishing their environmental objectives (Stavins 2002). Emissions trading in North America has been very successful, in particular, sulfur dioxide trading. Reductions in emissions have surpassed environmental targets. Companies participating in the trading schemes have been able to adopt the most cost-effective strategies to reduce emissions. The outcome for the environment and society as a whole has, therefore, fulfilled expectations (Swedish Shipowners´ Association 2002).

The performance of these systems also offers lessons about the importance of flexibility, simplicity, the role of monitoring and enforcement, and the capabilities of the private sector to make markets of this sort work (Stavins 2002). With regard to flexibility, it is important that market-based instruments be designed to allow for a broad set of compliance alternatives, in terms of both timing and technological options. In regard to simplicity, unique formulae—whether for permit allocation or tax computation—are difficult to contest or manipulate. Rules should be clearly defined up front, without ambiguity (Stavins 2002). Experiences with market-based instruments also provide a powerful reminder of the importance of monitoring and enforcement. These instruments, whether price or quantity based, do not eliminate the need for such activities, although they may change their character. In the many programs reviewed in the literature where monitoring and/or enforcement have been deficient, the results have been ineffective policies (Stavins 2002).

Improvements in instrument design will not solve all problems. One potentially important cause of the mixed performance of implemented market-based instruments is that sources of pollutant are simply not well equipped internally to make the decisions necessary to fully utilize these instruments. Since market-based instruments have been used on a limited basis only, and sources of pollutant are not certain that these instruments will be a lasting component on the regulatory landscape, most companies have chosen not to reorganize their internal structure to fully exploit the cost savings these instruments offer. Rather, most firms continue to have organizations that are experienced in minimizing the costs of complying with command-and-control regulations, not in making the strategic decisions allowed by market-based instruments (Stavins 2002).

The focus of environmental, health, and safety departments in private firms has been primarily on problem avoidance and risk management, rather than on the creation of opportunities made possible by market-based instruments. This focus has developed because of the strict rules companies have faced under command-and-control regulation, in response to which companies have built skills and developed processes that comply with regulations, but do not help them benefit competitively from environmental decisions. Absent significant changes in structure and personnel, the full potential of market-based instruments may not be realized (Stavins 2002).

Experience with market-based instruments demonstrates that legal and institutional considerations are singly important in any proposal to employ market-based instruments for achieving environmental objectives. There must be effective laws and regulations in place with commensurate penalties for not meeting them (Caribbean Planning for Adaptation to Climate Change 2000). Moreover, economic instruments must have political feasibility. In general, there is often resistance to change — for this reason, a clearly defined program of outreach and education at all levels must be an integral component of market-based incentives (Caribbean Planning for Adaptation to Climate Change 2000). Another major consideration in developing market-based incentives as a component of regulatory policy is how to ensure their long-term financing (Caribbean Planning for Adaptation to Climate Change 2000).

Experiences with market-based instruments offer some guidance to the conditions under which such approaches are likely to work well, and when they may face greater difficulties (Stavins 2002). First, where the cost of abating pollution differs widely among sources, a market-based system is likely to have greater gains, relative to conventional, command-and-control regulations (Stavins 2002). Second, the greater the degree of mixing of pollutants in the receiving airshed or watershed, the more attractive a market-based system will be, relative to a conventional uniform standard (Stavins 2002). Third, tradable permits will work best when transaction costs are low, and experience demonstrates that if properly designed, private markets will tend to render transaction costs minimal (Stavins 2002). Finally, considerations of political feasibility point to the wisdom of proposing market-based instruments when they can be used to facilitate aggregate emissions reductions, as opposed to cost effective reallocations of the status quo burden (Stavins 2002).

Little is known empirically about the impact of these instruments on technological change. Also, much more empirical research is needed on how the preexisting regulatory environment affects performance, including costs (Stavins 2002). Despite these and other uncertainties, market-based instruments for environmental protection now enjoy proven successes in reducing pollution at low cost (Stavins 2002).

5.1 Principal Considerations for Employing Economic Incentives

Although market-based instruments (MBI) are cost-effective in general, they are no substitute for command and control. For MBIs to be effective, they must be part of a command and control strategy with enforceable penalties (Caribbean Planning for Adaptation to Climate Change 2000).

The most effective regulations will likely be those in which regulated parties act in an environmentally beneficial way because they recognize it is in their own self-interest. While appeals to altruism can be made, economic self-interest is essentially the driving force (Caribbean Planning for Adaptation to Climate Change 2000). These instruments must demonstrate to different stakeholders, including politicians, how they will benefit from the use of economic incentives (Caribbean Planning for Adaptation to Climate Change 2000).

Develop market-based instruments (MBIs) that have political feasibility. There is often a disconnect between short-term political needs and long-term environmental requirements. Develop MBIs that have political payoffs. (Education and outreach strategies are important here.) Political will is informed by education and outreach, directly and indirectly (Caribbean Planning for Adaptation to Climate Change 2000).

Education and outreach must be an integral component of any regulatory and policy strategy. Sustained education at all sectors, ministerial, legislative, industry and business — both large and small — is critical. Without a clearly defined comprehensive education and outreach strategy, market-based instruments are not likely to be successful in changing the behavior of either corporations or individual consumers (Caribbean Planning for Adaptation to Climate Change 2000).

Link market-based instruments to economic analysis and human health. Economic analysis can be critical in making the case for market-based instruments (e.g., cost-benefit analysis, cost-effectiveness, economic impact analysis) (Caribbean Planning for Adaptation to Climate Change 2000).

5.2 Considerations for Selecting Regulatory Instruments

When considering regulatory instruments there are two main aspects that must be understood to develop a balanced approach that reflects the characteristics of both the source of pollution and the damage caused by the pollution. The following set of questions reflect these considerations.

Characteristics of the sources of pollution (EPA 2001)

- Are the costs of control known with certainty? If not, how great is the uncertainty?
- Is the technology of pollution control static, or is it likely to change over time?
- Can the quantity of pollution from each source be measured (or approximated) easily?
- How many sources are there for each pollutant?
- Are incremental control costs similar for different sources, or is there considerable variation?

Characteristics of the damage caused by pollution (EPA 2001)

- Does a unit of pollution from each source have the same impact on health and the environment, regardless of where it is released?
- Are the impacts on health and the environment known with certainty? If not, how great is the uncertainty?
- What are the major sources of uncertainty? What is known regarding the effect of pollution on environmental quality, exposures, physical effects, or the economic valuation of effects?
- How many parties are experiencing damage from pollution?
- Is it critical to control pollution within narrow limits to achieve environmental goals, or is the damage caused by pollution such that there is a continuum of effects from less serious to more serious, with no obvious unacceptable level and no obvious safe level of pollution?

An ideal environmental policy instrument would (U.S. Congress Office of Technology Assessment 1995):

- be cost-effective and fair;
- place the least demands on government;
- provide assurance to the public that environmental goals will be met;
- use pollution prevention when possible;
- consider environmental equity and justice issues;
- be adaptable to change; and
- encourage technology innovation and diffusion.

6 MARITIME INDUSTRY APPLICATIONS OF ECONOMIC INCENTIVES

Comprehensive calculations on the cost-effectiveness of numerous measures for reducing sulfur and nitrogen oxides show the cost-effectiveness of numerous measures for reducing emissions from ships (Kågeson 1999; Swedish Shipowners´ Association 2002). It was argued that the regulatory approach on the shipping industry had, until 2002, not been very successful (Swedish Shipowners´ Association 2002). The second conference on Sustainable Transport Solutions in the Baltic Sea Area - focus on Maritime Transport advocates to introduce strategies to abate air pollution, e.g. environmentally differentiated fairway and/or harbor dues in all Baltic Sea nations and seaports (Coalition Clean Baltic, WWF Baltic Programme et al. 2001).

Currently, shipowners who do not invest in environmentally friendly equipment are economically favored against those who undertake respective investments (Volk, Hader et al. 2000). The economical basis of decision-taking as to environmental behavior and investments in the maritime industry can be changed by a number of actions of participants in the transportation chain (Volk, Hader et al. 2000). A number of direct and indirect incentives, which favor environmentally friendly shipping and puts those who do not comply with it at an economic disadvantage, are already available (Volk, Hader et al. 2000).

The reasoning behind the proposal of economic incentives for ships to implement the polluter pays principle is to stimulate green behavior by introducing economic incentives as a supplement to minimum regulations, and to introduce a counterweight to "Grandfather Clauses". Often new technical requirements only apply to new ships, and not to existing. By giving an economic advantage to the ships to which the new environmental requirement applies, the environmental burden of the grandfather clauses will not be that heavy (Oftedal 2000).

Table 2 provides the six basic alternatives, including an indication of some existing non-shipping programs as well as shipping programs and programs where relevant, summarized in this report (Harrison, Radov et al. 2004).

6.1 Environmental Differentiation of Fairway and Port Dues

In the case of controlling emissions from maritime vessels, regulation does not appear to be the best option, according to both the Swedish Committee on Transport Policy and the EU Green Paper on Pricing in the Transport Sector recommend incentive-based environmental regulation of the transport sector (Carlsson 1999).

The Swedish Maritime Administration, the Swedish Port and Stevedores Association and the Swedish Shipowners' Association in 1996 arrived at a Tripartite Agreement to use differentiated fairway and harbor dues to reduce emissions of NOx and sulfur by 75 percent within five years. The parties concluded that vessels engaged in dedicated trade and other frequent vessel traffic involving Swedish ports, regardless of flag, should reduce emissions of nitrogen oxides by installing SCR or other cost-effective NOx-abating technologies, and should shift to low sulfur bunker fuels to reduce sulfur emissions (Kågeson 1999; Volk, Hader et al. 2000). The parties agreed to apply economic incentives in the form of environmentally differentiated fairway and harbor dues to stimulate ships to take measures to reduce emissions (Volk, Hader et al. 2000).

Table 2. Selected Examples of Trading and Charging Programs (Harrison, Radov et al. 2004)

	Non-Maritime Examples	Maritime Programs/Proposals
Trading		
Credit	EPA Emissions Trading Netherlands ERUPT/CERUPT	Swedish Shipowners Proposal RECLAIM (Marine Credits)
Benchmarking	Averaging, banking and trading for mobile sources (ABT)	SEAaT Proposal (mentioned)
Cap-and-Trade	Acid Rain Trading (SO2) RECLAIM (SO2, NOx)	SEAaT Proposal
Charging		
Fuel Tax	Various EU Programs in EU member states	Norway Programs (sulfur)
En Route	Eurocontrol (aviation)	
Differentiated Dues		Swedish Maritime Program Mariehamn Finland Rotterdam Green Award Port of Hamburg (Discontinued)

In 1998, Sweden unilaterally introduced environmentally differentiated fairway and port dues, which give shipping lines financial incentives to buy low- sulfur fuel and invest in technologies to reduce emissions of nitrogen oxides (Kågeson 1999; Volk, Hader et al. 2000). Environmental differentiation means that each ship pays for the gross tons related fairway dues on the basis of its individual emissions of nitrogen oxides and sulfur (Volk, Hader et al. 2000). Fairway dues being paid for a five year period will be reimbursed to encourage the installation of catalytic converters (Volk, Hader et al. 2000). The Swedish Maritime Administration also offers grants towards the fitting of catalytic converters aboard vessels which frequently call at Swedish ports in addition to the reimbursement of fair dues (Volk, Hader et al. 2000). The cost of installations, which qualify for the reimbursement, can be as high as 40 % of the investment cost if catalytic converters are installed before the year 2000, and up to 30 % for installations thereafter (Volk, Hader et al. 2000).

In addition to the fairway dues, about 20 Swedish ports have introduced rebates in their dues, based on NOx and sulfur reductions. Ships with lower emissions get a discount on Harbor dues, while ships with higher emissions must pay higher dues (Volk, Hader et al. 2000). The Swedish Maritime Administration claims that by using this new structure of fairway dues the polluter pays, the principle is fully amortized (Volk, Hader et al. 2000).

The Swedish differentiated fairway and harbor dues system has already shown to be effective, especially in reducing sulfur emissions. They have proved to be a powerful instrument for making shipowners shift to low-sulfur bunker fuels and start investing in NOx abatement techniques (Kågeson 1999; Robinson 2001). In 1999, close to 1,300 ships calling at Swedish ports ran on low-sulfur bunker oils (generally with a sulfur content between 0.5 and 0.9 per cent) (Kågeson 1999).

The current Swedish system provides a limited incentive for ships that make frequent calls at Swedish harbors. The impact, however, would be much greater if similar systems were introduced in other countries (Kågeson 1999). In cases when ships plying the North Sea and/or the Baltic Sea never or only rarely call at Swedish ports, there is at present no incentive at all for shifting to low-sulfur fuel or investing in means for reducing NOx. As Sweden is the destination of only a small part of the total shipping in the North Sea and the Baltic, its differentiated fairway and port dues will have only a limited effect on the overall emissions from shipping in this region. To make a real difference a much broader incentive, based on differentiated fairway and/or port dues in all countries, is needed (Kågeson 1999).

The port dues were identified as best suited for an environmental differentiation. Among these were the fairway dues and the berth dues which seemed to be most appropriate for further environmental differentiation. Also the coastal dues would partly offer such possibilities. In 1997, at the 40th MEPC session Norway presented a new proposal for the environmental indexing of ships. Differentiation is made for five categories of ships: oil tankers, chemical tankers, passenger vessels, reefers and other ships (Volk, Hader et al. 2000). Abatement of NOx and sulfur emissions makes up six out of the system's 10 maximum points for tankers, general cargo vessels and passenger ships. For "other ships" (including towboats, fishing vessels, research ships, barges and supply and standby ships related to Norwegian off-shore activities) all 10 points refer to emissions of NOx and sulfur (Kågeson 1999). A ship evaluated by the system will be given an environmental factor ranging from 0-10 where 10 is the best score. In December 1999 the Norwegian Parliament decided to introduce the voluntary system of environmental differentiation on the tonnage tax from 1. January 2000. The tonnage tax applies to all shipping companies which are subject to taxation in Norway. A ship which has an environmental factor 10, will get a 25 % reduction in the tonnage tax (Oftedal 2000). For earlier information on the development of this index, see Environmental indexing of ships, Note by Norway, MEPC 37/21/6, 16 June 1995, p. 1.

Other, similar examples of financial benefits for environmentally friendly ships have been identified (Volk, Hader et al. 2000). Passenger vessels in a regular public service receive a reduction of 40 % of the port fees in Helsinki if within the Finnish territory they use fuel with a sulfur content of below 1 % (Volk, Hader et al. 2000). The Port of Mariehamn on the Finnish Island of Åland planned to differentiate its basic dues with regard to ships' emissions of NOx and sulfur (Kågeson 1999).The port of Västeras plans to reduce its port fee by 50 % for ships which install and use catalytic converters (Volk, Hader et al. 2000). The ports of Kaliningrad and Szczecin-Swinoujscie stated that they offer a financial stimulus to ships to reduce air pollution, however, failed to give more information as to the scheme applied and the height of the rebates (Volk, Hader et al. 2000).

6.2 Ship Environment Index System and Differentiated Tonnage Tax

Norway has for some years used economic instruments to stimulate green shipping. Environmental taxes on sulfur and CO_2 emissions are levied on ships in domestic trade, and there are grants for NOx measures on existing ships (Oftedal 2000).

In early 1994 a project on environmental indexing of ships was initiated in Norway under the Norwegian Green Ship Research Program. The aim was to identify and analyze the ship pollution potential, to the sea and to the atmosphere. It was shown by the research project that the pollution from ships can be substantially reduced by a number of measures. Within the project an attempt has been made to evaluate the effect of various ways and means to reduce pollution. The research should have resulted in a scientifically based system for the evaluation of the environmental performance of ships (Volk, Hader et al. 2000).

The Green Tax Commission appointed by the Norwegian Government concluded in the report published in June 1996 that a green tax shift is positive for the economy, employment and the environment, if it is introduced in correct manner. One of the proposals in the report was to introduce environmentally differentiated taxes and charges for the maritime industry (Oftedal 2000). The Norwegian Government has responded to the report by establishing a Green Tax policy as one of the main pillars in its environmental policy. Bunker fuel used by ships in Norwegian domestic trade is subject to a CO_2 tax and a sulfur tax (Oftedal 2000).

In 2000, the Norwegian government presented a proposal for a voluntary differentiated tonnage tax (Proposition No 1 1999/2000). The differentiation is based on a Ship Environment Index System (SEIS) which is based on up to seven different environmental parameters, including sulfur and NOx emissions, and ships that meet all requirements can at best receive 10 environmental points (Kågeson 1999; Oftedal 2000; Volk, Hader et al. 2000). The environmental index system will be used for differentiating the Norwegian tonnage tax, which is a substitute for corporate taxation in the Norwegian shipping sector, and could in the future also be used for environmental differentiation of port and fairway dues (Kågeson 1999). The Norwegian approach to differentiated tariffs for environmentally friendly ships is intended for international application (Volk, Hader et al. 2000).

6.3 The Green Award

The Green Award scheme has been developed by the Green Award Foundation in collaboration with the Port of Rotterdam and some ports in Portugal and South Africa in 1994 and put into force in 1995 (Volk, Hader et al. 2000). The Green Award Foundation offers reduced harbor dues for tankers of more than 20 000 DWT (Dead Weight Tones) (Kågeson 1999). The certification procedure consists of audits of crew and management procedures and technical provisions. The emphasis is on safe and environmentally friendly management and crew competence. To earn the award, the shipowner and the vessel must comply with national and international laws and regulations. On top of this basic requirement the shipowner must demonstrate environmental and safety awareness in a number of areas affecting management and crew competence, as well as technical provisions. These include manning, maintenance systems, tank and hull arrangements, oil leakage prevention, vapor emission control, accidental oil pollution prevention, spill collection, bilge water treatment, waste disposal, tank cleaning and exhaust emissions (Kågeson 1999).

The Green Award incorporates existing quality assessment and certification schemes, such as ISO 9002, ISM, etc. It is an open and dynamic system with annual evaluation and monitoring of new developments. The aim of the scheme is to favor shipowners for environmentally friendly (quality) ship operation on the basis of differentiated port tariffs/fees and procedures. The foundation also strives for harmonizing surveys and inspections (Volk, Hader et al. 2000).

6.4 Emission Trading

The Swedish Shipowners' Association proposes an emission trading system that covers the European Community as a financial incentive for the reduction of sulfur dioxide and nitrogen oxides emissions, where the maritime industry will participate in the trading on a voluntary basis (Swedish Shipowners´ Association 2002). Shipowners will be encouraged to make investments to create emissions reductions, since the selling of emission reduction credits will generate an additional payback (Swedish Shipowners´ Association 2002). It is possible to obtain substantial emissions reductions, at a short time horizon, and at a comparable low cost by using market-based mechanisms (Swedish Shipowners´ Association 2002).

Emission reductions are accomplished at sea by ships on a voluntary basis. In order to obtain a marketable credit of the reduction, it should be verified and after that approved by an EU Board of Emission Reduction Credits. The credits are sold on the market to the capped land-based emitters. The credits have the same function and value as the emission allowances. Consequently the capped sources can use the credits for compliance in the same way as allowances are used (Swedish Shipowners´ Association 2002).

6.5 Green Tax

Where sulfur is concerned an alternative option to differentiated fairway dues would be to enforce a green tax on high-sulfur bunkers taken on in European ports. The tax rates then have to equal the price differential between bunker fuels with a content of no more than 1% sulfur and bunker fuel containing more than 1 per cent. This means all ships will have an incentive to choose low sulfur bunkers, including those that are involved in transatlantic trade (Kågeson 1999). It is noted that levying taxes and charges on shipping might constrain the use of maritime transport (Swedish Shipowners´ Association 2002).

6.6 Indirect Incentives

The success of the direct incentives so far is limited. One initiative partly failed because its demands in general and also to ports were too far-reaching (Volk, Hader et al. 2000). There are also programs that can be identified as indirect incentives to ships to behave environmentally-friendly.

For an increasing number of shippers it belongs either to the philosophy of the respective company and/or it is seen as a marketing instrument to organize its environmentally friendly transports. There is also a growing consumer demand for more environmentally friendly products which leads the shippers to set stricter environmental requirements when purchasing freight services (Volk, Hader et al. 2000). The Swedish forest industry has reduced sulfur emissions by 70 % from ships carrying its products through a voluntary transition to bunker oil with a low sulfur content (Volk, Hader et al. 2000).

A number of Oil Companies International Marine Forum (OCIMF) members operate long established tanker inspection and vetting systems which are used to assess the quality of ships before they are accepted for charter. The inspections primarily refer to ship safety but not necessarily to operational air or sea emissions. They are intended to avoid chartering ships with the danger of accidental outlets. The inspections can be considered as an indirect incentive for shipowners to invest in safe and - in some ways - in environmentally friendly ships (Volk, Hader et al. 2000). Another example is provided by the chemical industry through the establishment of the Chemical Distribution Institute (CDI). The principle of CDI is that vessels are inspected by independent, accredited inspectors. Vessels are not charterted if they do not comply with the company's safety and environmental standards (Volk, Hader et al. 2000).

It was noted that financial institutions in principle are absolutely willing to finance ships with a high environmental standard (Volk, Hader et al. 2000). There is also a public pressure that insurance companies can and should charge cargo owners much higher premiums in case substandard ships are chartered. If applying such a recalculation of premiums, cargo owners who charter quality ships would be favored (Volk, Hader et al. 2000). By this an indirect incentive would be given to shipowners employing such ships. However, a problem arises which is similar to the proposed system in respect to port fees. If a single insurance company starts to apply such a calculation of premiums then it risks the loss of customers to its competitors who do not apply such a calculation. This could only be avoided if all insurance companies follow the same policy as to the calculation of premiums. This seems, however, to become a very difficult undertaking (Volk, Hader et al. 2000).

6.7 Carl Moyer Program

The Carl Moyer Memorial Air Quality Standards Attainment Program, started in 1998, is a California subsidy program that provides funds on an incentive basis for the incremental cost of cleaner than required engines and equipment. New purchases, repowers (including diesel to diesel), and retrofits of all marine vessels including ferries, tug/tow/push boats, fishing boats, bulk carrier, passenger ship are eligible (ARB 2003).

The program achieves near-term reductions in emissions of oxides of nitrogen (NOx), which are necessary for California to meet its clean air commitments under the State Implementation Plan. In addition, local air districts use these NOx emission reductions to meet commitments in their conformity plans, thus preventing the loss of federal funding for local areas throughout California. The program also reduces particulate matter (PM), a component of diesel exhaust the Air Resources Board recently identified as a toxic air contaminant (ARB 2003).

In the first three years of the Carl Moyer Program, funded projects reduced NOx emissions by more than 11 tons per day (tons/day) at an average cost-effectiveness of approximately $4,000 per ton of NOx reduced. 182 marine vessel projects accounted for about 8% (698 tons/year) of the total program NOx reductions. This cost-effectiveness compares favorably to other air pollution control programs in California. Project lifetimes range from five to 20 years depending on the type of project. Thus, the program offers necessary and cost-effective near and long-term emission reduction benefits (ARB 2003).

All projects providing real, quantifiable and surplus reductions including repowers, retrofits, and new purchases of vessels are eligible for Mobile Source Emission Reduction Credits (MERCs), which are to offset economic growth-related increased stationary emissions. Four commercial ferries repowered with new lower-emitting diesel engines achieved an annual reduction of 34 tons of NOx for 30 years. Cost effectiveness was greater than $12,000/ton of NOx reduced (Jackson and Kamakaté 2000).

6.8 Congestion Mitigation and Air Quality Program (CMAQ)

CMAQ funding has been traditionally used to fund projects such as traffic flow improvements, transit improvements, and transportation demand management strategies and not projects related to alternative fueled vessels. The Bay Area Air Quality Management District (AQMD) is funding, through CMAQ, the purchase of a new ferry for the Alameda-Oakland service. The New York Metropolitan Transportation Council is providing CMAQ funds to the Port Authority of New York and New Jersey to establish barge services that will ship freight containers to New Jersey across the Hudson River as opposed to trucking the containers across the Verrazano Narrows bridge (Jackson and Kamakaté 2000).

7 QUALITATIVE ASSESSMENTS OF MARKET INCENTIVES FOR SHIPPING

In the report prepared for the European Commission, Harrison et al. provides a detailed specification of six market-based programs, which are classified in two broad categories: (1) emissions trading programs, and (2) emissions charging programs, to regulate atmospheric emissions from seagoing ships in European Union ("EU") sea areas. Multiple approaches for each of the six programs based upon key elements are evaluated using thirteen criteria divided into four broad categories: (1) environmental criteria; (2) efficiency criteria; (3) distributional criteria; and (4) institutional criteria. Table 3 is a brief summary of the qualitative assessments of the approaches (Harrison, Radov et al. 2004).

Since there has been relatively little experience to date with applying market-based instruments in the marine sector, the overall conclusion is that it would be wise to start with more gradual approaches. Although none is perfect, the three approaches, voluntary port dues differentiation, consortia benchmarking approach, and rigorous credit-based approach seem promising for at least the initial use of market-based instruments to promote low-emissions (Harrison, Radov et al. 2004).

Table 3: Qualitative Assessments of Market-Based Approaches for Shipping (Harrison, Radov et al. 2004)

	Environmental		Economic Efficiency			Distributional				Institutional			
	Overall Emissions	*Geographic Coverage*	*Cost effectiveness*	*Dynamic Effects, Innovation*	*Tax Distortions*	*Shipowners Burden*	*Fuel Supplier Impacts*	*Port Impacts*	*Consumer/labor Effects*	*Legal Feasibility*	*Political Feasibility*	*Administrative Feasibility*	*Feasibility of Monitoring*
Economic Instrument													
Credit													
Simple	-1	-2	0	0	-2	2	1	1	2	1	0	0	0
Rigorous	0	0	0	0	-2	1	1	0	2	1	0	-1	-1
Benchmarking													
Universal	1	1	1	1	-2	0	0	0	0	-1	-1	-1	-1
Trading Consortia	0	1	1	0	-2	0	0	0	0	0	0	0	0
Cap-and-Trade													
Exchange Rates	2	1	2	2	-1	0	0	0	0	-1	-1	-2	-2
Geographic Formula	2	2	2	2	-1	0	0	0	0	-1	-1	-2	-2
Taxation/Charging													
Tax at Point of Sale	-2	-2	-2	-2	0	0	-2	-1	0	2	-1	2	2
Fuel-use Tax	-1	-1	-1	-1	2	-1	-2	0	0	-1	-1	0	0
Emissions Tax	2	2	2	2	2	-1	0	0	0	-2	-1	0	-2
En-Route													
Trip-Based Charges	0	1	0	0	2	-1	0	0	0	-1	-1	0	0
Distance-Based Charges	1	2	0	1	2	-1	0	0	0	-1	-1	0	-1
Differentiated Dues													
Voluntary Port Dues	-1	-1	-1	-1	-1	1	-1	0	0	2	1	1	1
Mandatory Port Dues	0	-1	0	0	-1	1	-1	-1	0	1	-2	1	1
Fairway Dues	0	0	0	0	0	0	-1	-1	0	0	01	0	1

Best: 2 Good: 1 Fair: 0 Poor: -1 Worst: -2

8 MODELING POLICY INCENTIVES USING MEOM

In Technical Memorandum One, we discussed the decision framework for identifying and evaluating emission control alternatives in a long-term implementation program for private ferries. As discussed in that report, 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.
4. *Reduce time to achieve reductions*. Federal regulatory action currently limits emissions from commercial marine engines (Environmental Protection Agency 2003), and stricter federal 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.

In modeling incentives, some of these objectives can be explicitly evaluated and others can be inferred. For example, expected reductions in emissions can be calculated directly by estimating emissions with and without control technologies for specific vessels. Similarly, the cost of obtaining reductions across the fleet can be estimated directly by summing the expected costs for technologies that may be adopted by each vessel. Participation levels and time to achieve reductions may not be directly evaluated by the model; rather, the nature and amount of incentives applied may affect these objectives and the targets themselves may be adjusted according to available funds for and design of the incentive program. For example, while most technologies can physically be installed within a very short period, as shown in the NYSERDA demonstration project, an incentive may help an operator make the choice to install a technology sooner than a regularly planned maintenance or upgrade period.

8.1 Description of the Model

Model Summary. The Marine Emissions Optimization Model (MEOM) is a mixed-integer non-linear programming (MINLP) model that identifies least cost emissions control strategies for a fleet of marine passenger ferries. The model is built and solved in the General Algebraic Modeling System (GAMS) software.

In this study, we model a fleet of private passenger ferries operating within the NY/NJ harbor. Recent data identifies a total of 67 ferryboats and excursion vessels operating in the NY/NJ harbor (Anderson and Wells 2003). We focus on the 45 privately-operated ferries providing passenger transportation services in the harbor. These are operated by three companies (35 operated by NY Waterway, 4 by Sea Streak, and 6 by NY Water Taxi). Based on engine characteristics, operating profiles, and emissions control options, the model determines how the ferry fleet can meet emissions reduction targets at least cost. Results of the model provide information to decision makers interested in targeting policies and programs to assist ferry operators in meeting these targets.

The model is a non-linear technology choice model with environmental constraints, examples of which are lacking in the literature. Vessels are assigned the suite of technologies that will achieve user-defined fleet-wide emissions reductions at least cost. There are two general types of technologies that can be employed: (1) engine repowering, and (2) emissions control technologies.

Engine repowering as an emissions reduction tool is an important option for many ferry operators. In the past, vessels have employed unregulated, mechanically-controlled, diesel engines that were tuned to provide optimal performance (with an accompanying high level of NO_x and PM emissions). However, most new engines are now electronically controlled and, beginning in 2004, all new engines for U.S. markets need to meet emissions standards (Tier I). After 2007 more stringent standards will be required (Tier II). Thus, if vessels are repowered (a likely event for some vessels, even without environmental considerations), they will be replacing their existing dirty engines with more efficient, cleaner engines.

The second type of option involves control technologies that are designed explicitly to reduce emissions.(Farrell, Corbett et al. 2002). In MEOM, we currently include the following five options:[3]

- Humidification of Combustion Air (HAM);
- Injection Timing Retard (ITR);

[3] Through coordination with Seaworthy Systems, additional technologies may be modeled. However, to the degree that alternatives not modeled here incur similar capital and/or operating costs to the range of options presented, results of the model may not change substantially in terms of meeting program goals under different scenarios.

- Selective Catalytic Reduction (SCR);
- Catalytic Filter (CF); and,
- Ultra-Low Sulfur Diesel (ULSD) fuel.

MEOM minimizes the costs of repowering and/or employing combinations of control technologies while meeting a user-defined fleet-wide emissions reduction target for both NO_x and PM. Details about the model are found in the sections that follow.

Objective Function. For the remainder of this report, we define the following sets. Set members can easily be added within our model:

- *V* *vessels*; made up of the fleet of 45 vessels under analysis;
- *E* *engine types*; made up of three engine types (Existing, Tier I, and Tier II);
- *K* *pollution control technology*; made up of four technology options (HAM, ITD, SCR, CF, ULSD); and,
- *P* *pollutants*; made up of two pollutants (NO_x and PM).

The objective function for the model is defined as:

$$\min\left(\sum_{v}^{V}\sum_{e}^{E} BINE_{v,e}\cdot ETC_{v,e}+\sum_{v}^{V}\sum_{k}^{K} BINK_{v,k}\cdot KTC_{v,k}\right) \tag{1}$$

where, $BINE_{v,e}$ and $BINK_{v,k}$ represent binary variables that dictate whether engine *e* and technology *k* are incorporated on vessel *v* (value of “0” if no, “1” if yes); and $ETC_{v,e}$ and $KTC_{v,k}$ represent the total annualized costs of incorporating engine *e* or technology *k* on vessel *v*. This total cost is determined as follows:

$$KTC_{v,k}=KCC_{v,k}+KOMC_{v,k}+KFC_{v,k} \tag{2}$$

$$ETC_{v,e}=ECC_{v,e}+EFC_{v,e} \tag{3}$$

where, $ECC_{v,e}$ and $KCC_{v,k}$ represent the capital cost of engine *e* and technology *k*, respectively, annualized over its lifetime at a given discount rate (default rate of 15 years and 7%); $KOMC_{v,k}$ is the additional annual operation and maintenance cost (O&M, not counting fuel costs) for the new technology *k* (we assume no additional O&M costs for new engines); and $EFC_{v,e}$ and $KFC_{v,k}$ are additional annual fuel costs (or benefits) due to the new engine *e* or technology *k*. Readers should note that some control technologies require additional fuel consumption, and thus face fuel penalties, while new engine technologies may reduce fuel consumption through increased efficiency and thus have “negative” fuel costs. In our model we assume a temporal relationship between the fuel efficiency gains of repowering and the age of the engine being replaced. This has been shown to be the case in several studies of older engines.(Corbett and Koehler 2003; Koehler 2003)

Energy Use Equations. Annual energy use per vessel is an important element of the model and is a function of operational characteristics and engine type. In MEOM, the annual kWh used by a ferry is calculated by considering both main engines and auxiliary engines.

Total energy used is determined by first multiplying the engine size (kW) by a composite power index (CPI) or load factor. The CPI is measured as a percentage of the rated power used by each vessel on an average route. For example, a CPI of 50% means that on average, the vessel operates at 50% of its rated power during operation. It has been shown that vessels operating on longer routes tend to follow a load profile that has a higher CPI than vessels on shorter routes.(Farrell, Redman et al. 2003; Farrell, Corbett et al. 2004) For our work, we use actual CPI data collected on a set of representative vessels from the harbor.

Once we calculate an average rated load for each vessel (adjusted kW) we multiply by the number of hours the vessel operates annually. This is consistent with a similar approach used by others.(Anderson and Wells 2003)' (Corbett and Koehler 2003) This allows us to determine the total annual kWh for each vessel. This approach is summarized in the following equation.

$$KWH_v = KW_v \cdot CPI_v \cdot HR_v \quad (4)$$

where, KWH_v is the annual kWh generated by the main engines for each vessel; KW_v is the rated power for each vessel's main engines; CPI_v is the composite power index described above; and HR_v is the annual hours of operation for each vessel. This result is added to the kWh generated by auxiliary engines based on auxiliary engine power, annual hours of operation, and a load factor for the auxiliary engines.

Emissions Limit Constraint. The base case emissions for each pollutant by vessel are calculated by multiplying an emissions factor for each existing engine type (in kg/kWh) by the total annual kWh for each vessel. Emissions factors are determined based on published data, emissions testing results from representative vessels, and emissions standards that will take effect in 2004 (Tier I) and 2007 (Tier II).(U.S. Environmental Protection Agency 1999) Separate emissions factors are used for the auxiliary engines based on emissions factors for uncontrolled diesel engines. The emissions equations are given by:

$$EM_{v,p} = EF_{e,p} \cdot KWH_v \quad (5)$$

and

$$AUXEM_{v,p} = EF_{AUX,p} \cdot AKWH_v \quad (6)$$

where $EM_{v,p}$ is the annual base case emissions from vessel *v* of pollutant *p*; $EF_{e,p}$ is the emissions factor in kg/kWh for the existing engine *e* and pollutant *p*; $AUXEM_{v,p}$ is the emissions from the auxiliary engines for vessel *v* and pollutant *p*; $EF_{AUX,p}$ is the emissions factor in kg/kWh for the auxiliary engines; and $AKWH_v$ is the annual kWh used by the auxiliary engines for vessel *v*.

Next, an emissions limit is established by multiplying the base case emissions by a user-defined emissions reduction factor, as follows:

$$EMLIM_{v,p} = \left(EM_{v,p} + AUXEM_{v,p}\right) \cdot \left(ERF_p\right) \tag{7}$$

where $EMLIM_{v,p}$ is the emissions limit by vessel v and pollutant p; and ERF_p is an emissions reduction factor for pollutant p. Here, ERF_p represents the percent of emissions that will be allowed under any new scenario run (from 0%-100%). For example, for our Case 1 run, we set ERF_{NOx} as 70%; the model will thus set a new emissions limit equal to 70% of the base case (i.e., requiring a 30% reduction). For PM, we set ERF_{PM} as 40%, thus requiring a 60% reduction from the status quo.

The emission limit value is then incorporated into the final emissions constraint. In this case, the annual emissions from the fleet of vessels must be less than or equal to the emissions limit prescribed by the user. The emissions for each vessel are calculated based on vessels choosing both an engine type option (e) and a suite of control technologies (k). As mentioned in our discussion of the objective function, the decision variables ($BINE_{v,e}$ and $BINK_{v,k}$) are binary variables that identify what type of engine and what type of control technologies each vessel employs. The following equations demonstrate how the emissions constraint is handled:

$$\sum_{v}^{V}\left\{\left[\sum_{e}^{E} BINE_{v,e} \cdot EF_{e,p} \cdot KWH_v\right] \cdot \left[\prod_{k}^{K}\left(1 - BINK_{v,k} \cdot KEF_{k,p}\right)\right] + AUXEM_{v,p}\right\} \le \sum_{v}^{V} EMLIM_{v,p} \tag{8}$$

$$\sum_{e}^{E} BINE_{v,e} = 1 \tag{9}$$

where the only new variable introduced is $KEF_{k,p}$. This variable represents the percentage reduction of emissions of pollutant p using control technology k. So, for example, suppose SCR technology has demonstrated the ability to reduce NO_x emissions by 80% on marine vessels. For SCR technology we set $KEF_{SCR,NOx} = 0.80$. If the model assigns this SCR technology, then the $BINK_{v,SCR}$ variable equals "1". Reviewing the equation once more, the reader will see that this has an effect of reducing the emissions from the main engines to {1-(1)(0.80)} or to 0.20 (20%) of the original emissions. In this way, we handle not only new engine repowering (e.g., moving from an existing engine to a new Tier I or Tier II engine) but also the application of various control technologies with that engine.

By using the product factor, we can allow multiple control technologies. For example, the model may assign both SCR and ITD technology to a single vessel. In such a case, the emissions reductions are multiplicative. So, if SCR reduces NO_x emissions by 80% and ITD reduces NO_x emissions by 20%, we have a cumulative emissions level of:

$$\{1-(1)(0.80)\} \text{ x } \{1-(1)(0.20)\} = (0.20)(0.80) = (0.16) \tag{10}$$

or an equivalent reduction of (1-0.16) = 84%. Finally, for this constraint, auxiliary emissions are added and the total is set to be equal to or less than the emissions limit identified earlier. In this equation, some vessels may remain at their existing configuration, while others will incorporate repowering and emissions control technologies more aggressively.

Temporal Aspects of the Model. The model has been developed for an annual period, with capital costs annualized over the useful life of the capital equipment. It is possible to modify the model to evaluate emissions reductions and costs over a shorter or longer period of time; this activity is reserved for future work.

Technology Constraints. Other technology constraints can also be included in the model. For example, if a particular vessel is physically unable to install a certain technology (or if we want to run the model for cases where we force engine or technology choice), the decision variable ($BINE_{v,e}$ or $BINK_{v,k}$) for that vessel and technology can be set equal to “0” or “1”.

Minimize Emissions with Budget Constraint. We can also turn the model upside-down by setting the left-hand side (LHS) of the emissions constraint as the objective function and setting the cost equation as the LHS of a budget constraint. This is useful if we want to explore the best way to spend limited dollars to reduce emissions. We explore this idea in Cases 5 and 6 below.

8.2 Example Results of the Model

The model can be used for a number of different purposes. Here we discuss its usefulness in identifying least-cost technology strategies to meet emissions goals. Aside from technical configurations, the model can also identify average cost-effectiveness of emissions reductions ($/tonne), economic costs by vessel, emissions by vessel, and the distribution of costs among ferry operators.

Results from the model for a set of example cases are shown in Table 4. Table 5 includes specific technology choices for the vessels under *Case 1* assumptions and Table 6 includes similar results for *Case 2*. For both Table 5 and Table 6, only the vessels that employ emissions control technologies are depicted. The cases are as follows:

- *Base Case* – No reduction requirements; emissions represent the status quo.
- *Case 1* – Minimize cost with 30% NO_x and 60% PM reductions;
- *Case 2* – Minimize cost with 10% NO_x and 25% PM reductions;
- *Case 3* – Minimize cost with 60% PM reductions (no required NO_x reductions);
- *Case 4* – Minimize cost with 30% NO_x reductions (no required PM reductions);
- *Case 5* – Maximize PM reductions within a $10M budget used to offset net present value (NPV) costs of selected technologies;
- *Case 6* – Maximize NO_x reductions within a $10M budget (similar to Case 5).

As shown in Table 5, in no case does a vessel choose to repower with a Tier I engine. This is due to the fact that all the vessels in this particular fleet have repowered their engines since 2000. Thus, the emissions from these engines in most cases meet Tier I standards as is. Only in two cases (Case 4 and 6) do vessels choose to re-power, and that is to engines that meet Tier II standards.

Table 4. Summary of Costs and Emissions for Cases

Case	Total Costs (M$/yr)	NOx Emissions (tonne/yr)	PM Emissions (tonne/yr)	Engine (vessels)			Control (vessels)				
				SQ	T1	T2	ULSD	HAM	ITD	SCR	CF
Base Case	--	2,163	24.2	45	--	--	--	--	--	--	--
Case 1	1.64	1,511	9.7	45	--	--	2	9	3	13	26
Case 2	0.44	1,947	17.9	45	--	--	--	--	6	4	8
Case 3	0.97	2,122	9.6	45	--	--	--	--	--	--	29
Case 4	0.79	1,511	24.1	38	--	5	--	1	1	12	--
Case 5[a]	--	2,117	8.3	45	--	--	--	--	--	--	32
Case 6	--	1,241	25.1	35	--	10	--	--	1	16	--

Note: Vessel counts may add up to more than 45, since some vessels may install multiple technologies. See Table 5 and Table 6 for details. [a] Costs here had a NPV of $10M. See text for more details. Note that in the most recent inventory (conducted for year 2000), emissions from ferry and excursion vessels were determined to be 2,355 tonnes NOx/yr and 60 tonnes PM/yr (compared to our result of 2,163 and 24.2, respectively.) We believe the difference in PM is due to the engine upgrades that have been made in the fleet since year 2000. These upgrades had a significant impact on PM emissions, although only a limited impact on NOx.

Table 5. Technology Choice by Vessel for Case #1

Vessel ID	HAM	ITD	SCR	CF	ULSD
1	•			•	
2				•	
3				•	
4				•	
5				•	
6				•	
11				•	
12				•	
13				•	
14			•	•	
15			•	•	•
16			•		
17			•		
18			•		
19			•		
20			•		
21				•	
22				•	
23				•	
24				•	
25				•	
26				•	
27				•	
28				•	
29				•	
30			•		
31	•			•	
32			•	•	•
33			•		
34			•		
35	•	•			
36	•				
37	•				
38	•				
39	•	•			
40	•	•			
41	•				
42				•	
43				•	
44			•	•	
45			•	•	

Table 6. Technology Choice by Vessel for Case #2

Vessel ID	HAM	ITD	SCR	CF	ULSD
1				•	
3				•	
4				•	
5				•	
6				•	
11			•		
22			•		
31			•		
33			•		
36	•			•	
37	•				
38	•				
39	•				
40	•				
41	•				
44				•	
45				•	

Table 5 and Table 6 demonstrate the differences in technology choice due to emissions limits. Case 1 (Table 5) represents an aggressive emissions reduction target. Here, emissions reductions are met with about one third of the fleet (13 vessels) installing SCR technology, and over one half (26) installing CF technology. In this case, five vessels that install SCR also install CF. Four vessels do nothing. Case 2 (Table 6), on the other hand, represents a less aggressive target, and 28 vessels do nothing.

Case 3 and Case 4 demonstrate cases where reductions of only one pollutant are required. By dividing the total costs of control by the total emissions reductions for each pollutant, one can determine an average control cost ($/tonne) for each pollutant. For NO_x, the average is about $1,200/tonne; for PM, the average is about $65,000/tonne. (Note that there are some minor PM reductions in the NO_x reduction case, and vice versa).

Finally, Cases 5 and 6 present a different kind of model run. Here, we take the LHS of the emissions constraint and set it as the objective function. Then, we take the original least-cost objective function and turn it into a budget constraint. We run the model to *minimize emissions* from the ferry fleet such that NPV for emissions control is *not greater than $10M*. (This would mimic a case where a government agency desires to spend a sum of money on reducing emissions, and wants to know how to spend that money most wisely, which is the case for this project). We run the model for the case of minimizing PM emissions (Case 5) and NO_x emissions (Case 6).

8.3 Extension of MEOM to Other Policy Examples

Table 7 presents a summary of criteria related to these objectives that will be part of the analysis of model results for the private ferry system in the New York and New Jersey metropolitan region. These were presented as part of Technical Memorandum One, and these criteria were considered in the design of the model described in this section. The model explicitly tracks the estimated emissions reduction per vessel and fleet-wide. The model explicitly identifies which vessels and operators may adopt certain controls (and in which order vessels may be retrofit at least cost to meet emission control targets). The model tracks the capital and annual costs and computes the net-present-value of these costs.

There are two major types of questions that can be asked of MEOM:

- TYPE I: What technologies should be employed to meet emissions targets at least cost (i.e., emissions constraint)?
- TYPE II: What technologies should be employed to minimize emissions for a given investment (i.e., budget constraint)?

In the cases explored above, Cases 1-4 are of TYPE I, and Cases 5 and 6 are of TYPE II. In the next and final phase of this project, we will use MEOM to model various policy options. The nature of the policy mechanism under study will determine whether MEOM is employed in a TYPE I or TYPE II setting.

In Table 8, we identify six types of policy mechanisms that may be employed and discuss how these can be modeled in MEOM. These will be fully discussed as part of Technical Memorandum 3.

Table 7. Summary of Criteria for Considering Technology Deployment Incentive Scenarios

PROGRAM OBJECTIVES (PRIMARY AND SECONDARY)	TECHNOLOGY-BASED CRITERIA	POLICY-BASED CRITERIA
Reduce private ferry fleet emissions. 1. Minimize emission per vessel 2. Minimize fleet emissions 3. Achieve fleet-wide emissions target	Emissions reduction per vessel (percent and/or mass-basis) Fleet-wide emissions reduction (percent and/or mass basis)	
Maximize private ferry fleet participation 1. Maximize the numbers of vessels 2. Maximize operator participation		Vessels adopting controls Operators adopting controls
Minimize total cost (public and private) 1. Minimize capital cost 2. Minimize annual cost 3. Minimize private sector share of cost	Capital Cost Annual Cost	Net-present-value of cost Cost-share between public/private Cost per ton pollutant reduced
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	Time to install/adopt technology	Time to implement incentives Compare private ferry cost burden over various scenarios

Table 8. Policy Mechanism Evaluation Using MEOM

Type of Mechanism	Strategy in MEOM
Emissions Quota: Vessel-by-Vessel Quota Based on Reduction from SQ	Establish a vessel-by-vessel emissions constraint based on a stated percentage reduction of NOx and PM; run the model in a Type I condition. Output will provide least cost strategy for meeting vessels meeting their individual emissions reductions. This approach will likely be the most costly and may have enforcement problems.
Emissions Standards: Vessel-by-Vessel Standards Based on Tier II or Other	Establish a vessel-by-vessel emissions constraint as above, but base the emissions limit on an emissions standard (g/kWh) multiplied by kWh energy use by vessel. This would entail running MEOM in a Type I condition. This mechanism is easier to implement and enforce than quotas, but may not get the reductions that are desired (vessels that are already meeting standards will not have to reduce emissions).
Market-Based Allowance Trading with Cap-and-Trade Feature	Establish a fleet-wide emissions constraint, similar to Cases 2-4 discussed above. This entails running MEOM in a Type I condition. Based on what each vessel does (compared to its status quo) and some defined distribution of allowances, MEOM can evaluate how allowances would be traded. Problems involve the allocation and implementation of an allowance trading system; benefit is the cost effective nature of such systems (encourages low marginal cost ferries to put on control devices and high marginal cost ferries to purchase allowances).
Rebate for Capital Equipment	This is a Type II MEOM run. In this case, the objective function would minimize emissions under a cost (budget) constraint. Here, the budget constraint would be applied to capital costs—so MEOM would minimize emissions from the fleet based on a certain maximum expenditure on capital equipment. The value of the budget (e.g., $5 million) can be used assuming a 100% rebate. However, if policy makers envision a rebate of less than 100%, then the budget constrain can be increased. Caution: MEOM will identify those vessels where dollars spent give a maximum “bang for the buck”. This is not necessarily the same set of vessel operators who will apply for a rebate (however the results will provide guidance on what vessels should be encouraged to apply for rebates).
Subsidy for O&M Expenses	This is similar to the previous mechanism, except the budget constraint would apply only to O&M expenses. (This could be further constrained to apply only to fuel or non-fuel expenses).
Subsidy/Rebate for Capital or O&M Expenses	This is similar to the previous two mechanisms, except that the budget constraint would apply to total costs and make no distinction between capital or O&M.

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