STATE OF RHODE ISLAND
DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
OFFICE OF AIR RESOURCES

SOURCES OF AND STRATEGIES FOR THE CONTROL OF DIESEL EMISSIONS

submitted to

THE HONORABLE GOVERNOR, DONALD L. CARCIERI

and

THE RHODE ISLAND GENERAL ASSEMBLY

in compliance with RIGL subsection 23-23-29.4

January 2007

STATE OF RHODE ISLAND
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Sources of and strategies for the control of diesel emissions.

The 2006 anti-idling legislation amended RIGL Section 23-23 and added 23-23-29.4, requiring the Department of Environmental Management (DEM) to identify sources of diesel pollution in Rhode Island and strategies for reducing pollution from the identified sources and report the findings to the Governor and General Assembly. This document presents the results of DEM's efforts to compile the required information and to provide an overview of issues related to diesel emissions.

Diesel engines emit a highly complex mixture of gaseous and particulate air pollutants. These pollutants include particulate matter, nitrogen oxides, volatile organic compounds and carbon monoxide. Of particular concern is diesel particulate matter (DPM), which is emitted as very small particles that can travel deep into the respiratory system. DPM consists of an elemental carbon core embedded with a variety of organic and inorganic substances, many of which are highly toxic. The Environmental Protection Agency (EPA), the National Toxicology Program, and other international, federal and state organizations have determined that diesel particulate matter is a potent air toxic, causing both cancer and non-cancer health effects.

Exposure to elevated levels of DPM has been linked to a variety of health effects, including respiratory symptoms, chronic bronchitis, aggravation of asthma, increased respiratory and cardiovascular-related hospital admissions and emergency room visits, and premature death. Those most vulnerable to these effects include children, whose lungs are still developing, the elderly and people with chronic heart or lung diseases. Children are at particular risk because they are frequently exposed to elevated levels of DPM in and around school buses.

Nitrogen oxide (NO_x) emissions from diesel vehicles are also of concern because NO_x is a precursor to ground level ozone. Rhode Island does not meet the National Ambient Air Quality Standard for ozone and administers a number of programs designed to reduce NO_x emissions.

In addition to controlling diesel exhaust emissions for public health concerns, there is a high health care cost attributable to air pollution from diesel vehicles. Health cost impacts, per ton of emitted pollutant, have been estimated as follows:

Pollutant	**Associated Health Costs (per ton emitted)**
$PM_{2.5}$	$109,000
NO_x	$11,332
VOCs	$718
CO	$50

Source: *Journal of Transport Economics and Policy, September 1999*

Rhode Island has been developing its program of regulatory and voluntary measures to reduce the emissions from diesel powered vehicles and equipment for the past few years. There are federal and state laws and regulations currently in place covering some sources of diesel emissions.

Federal controls include regulations on the sulfur content of diesel fuel used in diesel engines. Beginning in 2006, at least 80% of the highway diesel fuel sold in the United States must meet ultra low sulfur diesel (ULSD) standards, restricting sulfur content to less than 15 parts per million (ppm), and by 2010, all highway diesel fuel must meet this standard. ULSD must be used in all diesel on-road vehicles with 2007 and newer engines. Beginning in 2010, ULSD will also be required for most non-road diesel equipment.

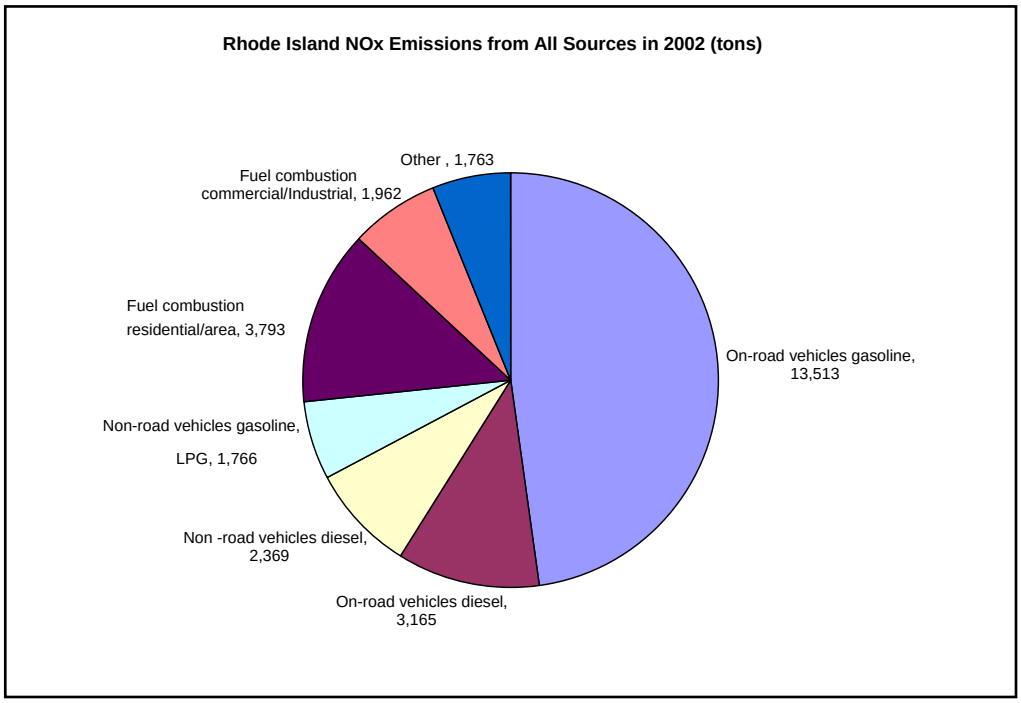
Stringent engine design standards governing the amounts of NO_x and DPM that 2007 heavy duty diesel engines can emit are also in place and will require further emissions controls for 2010. These new federal standards will improve emissions from new diesel engines and other diesel equipment using the ULSD fuel. EPA, however, cannot mandate any new controls on existing vehicles or engines or their operation (such as anti-idling requirements or mandatory pollution equipment retrofits).

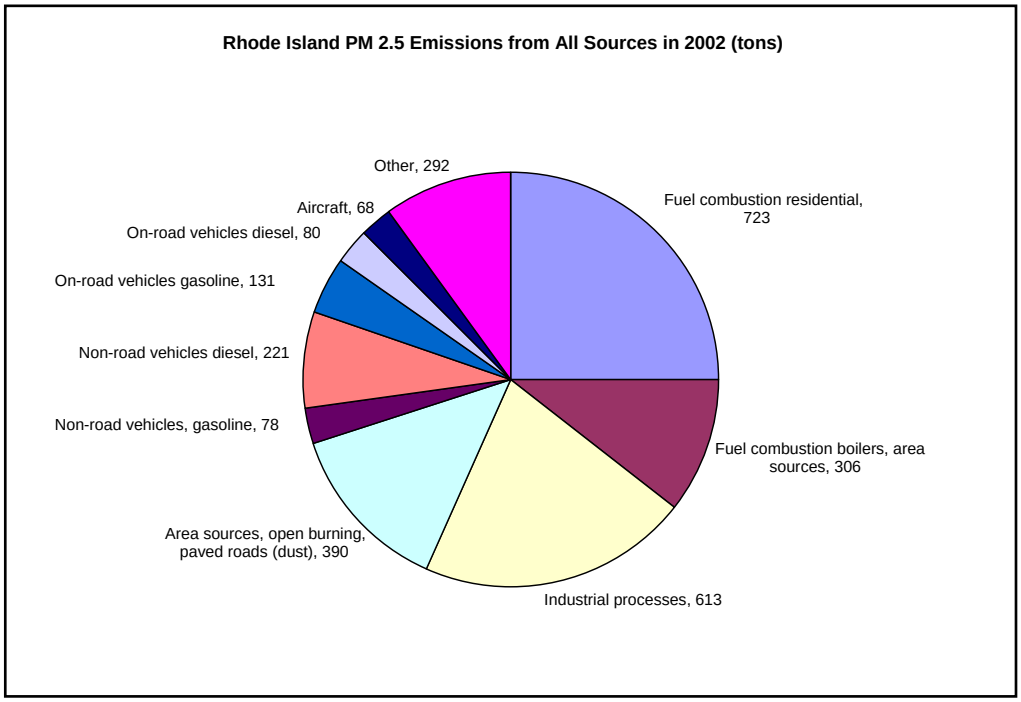
Rhode Island's regulations currently include standards for opacity of diesel exhaust, written under the authority of RIGL section 31-42.7. This law is also the basis for roadside checks by the State Police and will be the legal basis for the implementation of a future heavy-duty diesel emissions inspection and maintenance (I/M) program.

In 2006 the Rhode Island General Assembly passed a bill requiring DEM to develop regulations to control excessive idling and therefore control emissions of diesel pollutants, as well as greenhouse gases, from these vehicles and non-road diesel equipment. EPA has developed a model anti-idling rule for states to consider adopting to provide interstate consistency and will form the basis for the development of DEM's regulations. Other exemptions from the idling restrictions include emergency equipment (police, fire, rescue, etc.) and vehicles loading and unloading or delivering fuel or energy products.

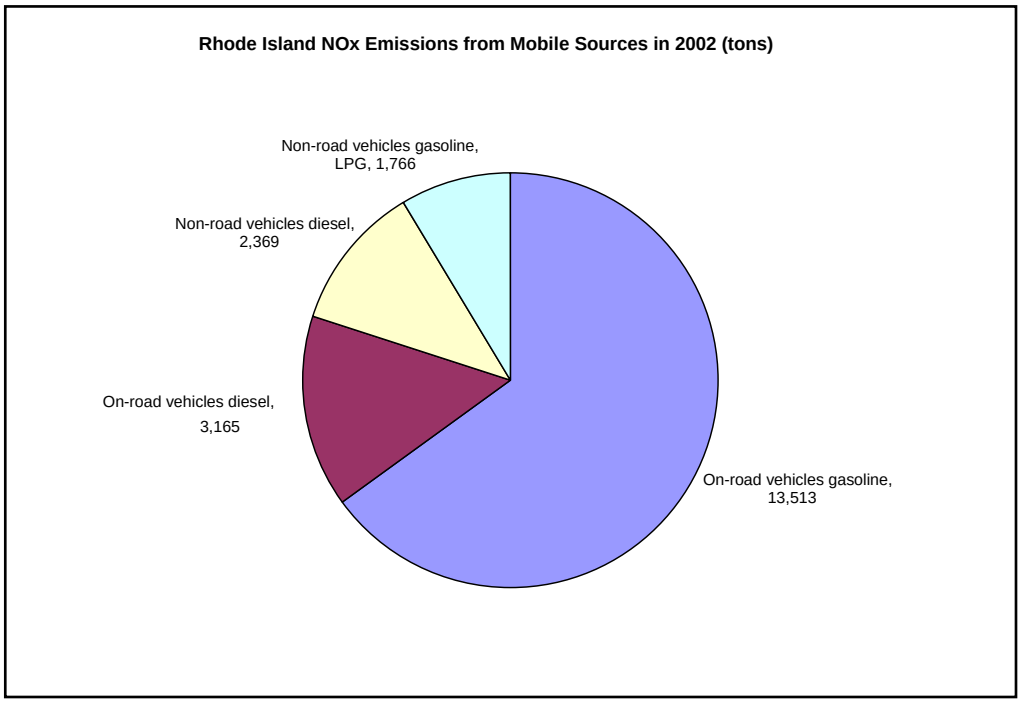
SOURCES OF MOBILE DIESEL EMISSIONS

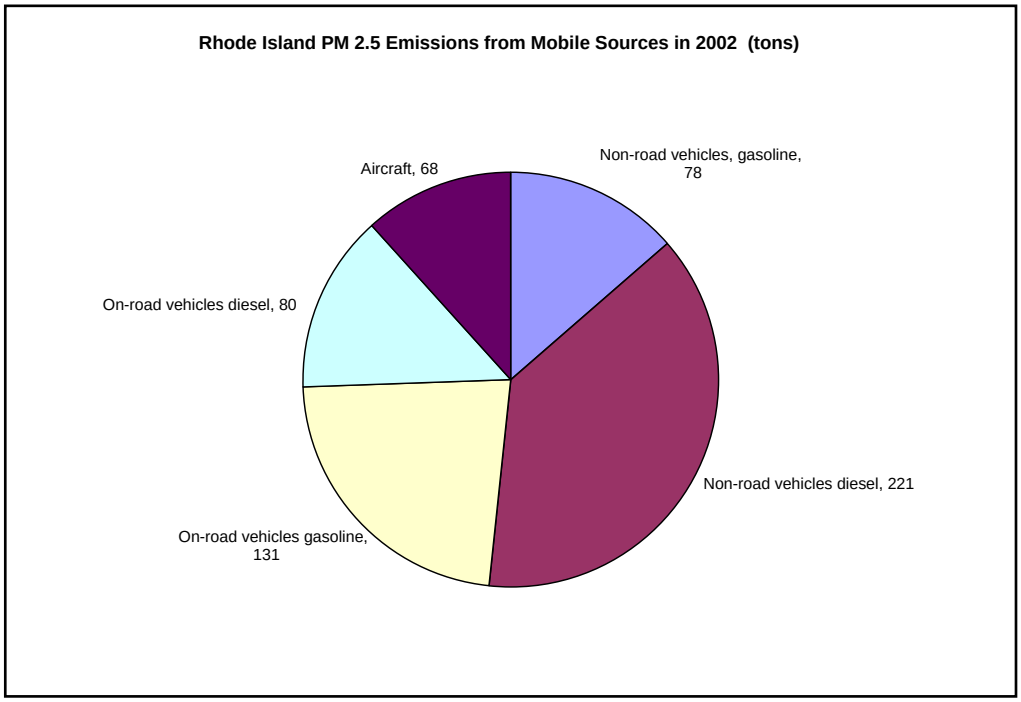
The quantities of various 2002 air pollutant emissions in Rhode Island and other northeast states were compiled by the Mid-Atlantic Regional Air Management Association (MARAMA), during a regional study investigating haze issues in the northeast. The various sources of NO_x and $PM_{2.5}$ (particulate matter less than 2.5 micrometers in diameter, associated with combustion of fossil fuel) were investigated and the annual emissions from these sources were estimated. The annual emissions estimates for Rhode Island were reported as: 28,331 tons/year of NO_x and 2,902 tons per year of $PM_{2.5}$. The following charts illustrate the various sources of these pollutants and corresponding quantities emitted from those sources. Additional details are available on the MARAMA web site at:
http://www.marama.org/visibility/Inventory%20Summary/2002EI-Ver3Sum.html





The specific contributions of these pollutants from only mobile sources in Rhode Island are further illustrated in the following two charts. For mobile sources the annual emissions estimates are: 20,813 tons/year of NO_x and 578 tons/year of $PM_{2.5}$.





As can bee seen from these figures, diesel exhaust contributes significantly to the mobile source totals for both NO_x and $PM_{2.5}$.

Different approaches have been and are being used by other states and by regional collaboratives to develop strategies to control diesel emissions. As a first step, it is helpful to develop a grouping of these mobile sources, either by types of vehicle or vehicle use (sectors). The evaluation must also include some specific understanding of the vehicles in question, including engine information, vehicle and/or engine year, the

duty cycle of the vehicle, vehicle activity and operating locations, vehicle ownership, etc. One major issue with diesel equipment is the long service life of the engines. These engines and the equipment that they power are built and maintained in such a way that the service life can easily reach 20 years. An additional concern exists relative to construction equipment, in that the duty cycle of this type of equipment can extend the useful life well beyond similar on-road vehicle engines.

For the purpose of this report, the following groups (and sub groups) are considered:

1. On-road Vehicles
    a. Rhode Island registrations
    b. Transients

2. Non-road Construction Equipment
    a. Public
    b. Private

3. Buses
    a. Transit
        i. Public
        ii. Tour
    b. School
        i. Publicly owned
        ii. Contracted

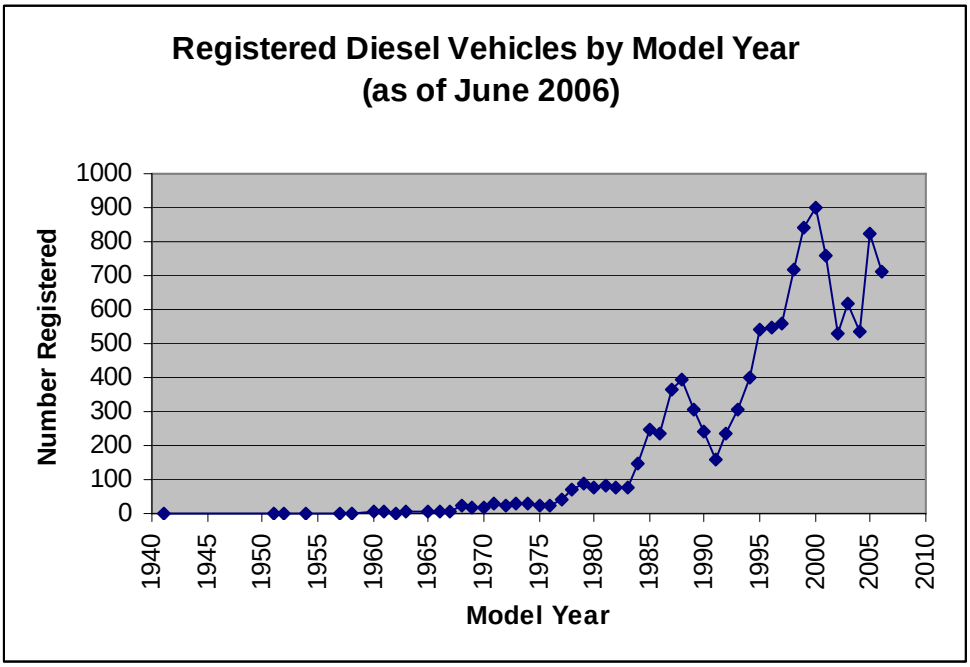
4. Solid Waste Collection Vehicles (SWCVs)
    a. Private
    b. Publicly owned

5. Other
    a. Marine (ferries, tugs, port support equipment)
    b. Locomotives
    c. Airports, including ground support equipment

The following provides some additional details relating to these groups relative to Rhode Island emissions:

1 - ON-ROAD VEHICLES

The following figure is a summary of diesel vehicles registered in Rhode Island as of June 2006, based on Division of Motor Vehicles (DMV) records. That data indicates that approximately 12,131 diesel powered on-road vehicles were registered in Rhode Island. As indicated above, an understanding of the age and use characteristics of these vehicles is important so that these factors can be considered in the development of a strategy to address their emissions. In general, the older vehicles will generate higher emissions than newer, cleaner designed engines, yet on the other hand, may not be operated as much as the newer vehicles. It is also important to note that proper engine maintenance can impact the emissions from all engines during operation.



It is understood that the DMV records of on-road diesel vehicles only represent a portion of the diesel equipment impacting air quality in Rhode Island as transient vehicles and non-road vehicles, also sources of diesel emissions, are not included.

Although this inventory can help in understanding the sources and quantities of diesel emissions, knowing how and where diesel equipment operates is important in order to target the sources presenting the highest risks to the population. As an example, diesel vehicles operating in urban areas, such as buses, SWCVs, local delivery vehicles and possibly construction equipment, are more likely to produce emissions that result in exposure to the surrounding population than diesel equipment operating in remote locations.

Included in this category are over 838 government-owned diesel vehicles (not including school buses). Of these, 293 are emergency or police vehicles. The remaining 545 are public works, highway or construction-type equipment. As publicly owned vehicles, these might be eligible for various government-funded retrofit or replacement funding programs and grants.

2 – NON-ROAD CONSTRUCTION EQUIPMENT

There is no system of registration for non-road construction equipment and the ownership of such equipment may be through direct ownership by individual construction companies, both large and small, government agencies, and ownership by leasing companies. A reasonable approximation of the number of individual pieces of diesel powered construction equipment can be calculated through work done by EPA where the numbers of pieces in an area are based on a population factor. In 2002, EPA estimated that 4,245 pieces of non-road diesel equipment were located in Rhode Island. Examples

include pavers, rollers, scrapers, backhoes, air compressors, etc. Additionally, as many as 4,500 pieces of diesel "industrial equipment" were estimated to be in Rhode Island. These industrial pieces include commercial turf equipment, combines, irrigation sets, pumps, etc.

Because this group of equipment includes very diverse types of diesel engines, the availability of certified pollution controlling retrofit devices is limited. Retrofit equipment, although readily available for installation on most models of on-road equipment, is not necessarily available for the non-road diesel engines. This lack of availability results from the need for each piece of retrofit equipment to pass regulatory certification testing on the specific engine being considered. EPA and the California Air Pollution Board (CARB) certification programs are generally required to ensure that the retrofit will actually achieve the desired emissions reductions. This certification process is time consuming and expensive so equipment manufacturers are careful to select diesel engine applications that will result in high potential sales to recover their certification investments. Only a few non-road engine applications have been certified to date.

3 - BUSES

The DMV June 2006 data indicates that there are 1573 registered diesel-powered buses in the state, of which 1336 are school buses and 181 are public transit buses. Some attempts have been made to address emissions from buses in both of these groups over the past few years.

Fifty-five school buses operated in Warwick and Cranston have been retrofitted with emissions-reducing equipment through a grant from EPA. These school buses were equipped with diesel oxidation catalysts (DOCs) and crankcase gas recirculation equipment in an effort to reduce emissions impacting the school children in the vicinity of and riding on these buses. Additionally 61 RIPTA transit buses have been retrofitted. Twenty-five transit buses were retrofitted with DOCs and 36 model year 2005 buses were equipped with advanced filtering systems, resulting in these engines meeting the strict emissions standards dictated for 2007 vehicles.

4 - SOLID WASTE COLLECTION VEHICLES (SWCVS)

A review of the DMV database reveals that over 360 refuse collection vehicles are registered to commercial companies, many of which are used in municipally contracted refuse collection activities. Additionally, several communities provide refuse collection services using government employees and government owned equipment (e.g. Bristol, Central Falls). This fleet of diesel-powered vehicles presents an exposure risk as these vehicles periodically travel through populated neighborhoods to collect the generated waste materials.

5 - OTHER

a - Marine

Site visits and/or contacts with officials were made at the five ports in Rhode Island:

- Port of Galilee/Point Judith
- Port of Newport
- Port of Warren/Bristol
- Port of Providence
- Quonset Point

At the fishing ports (Galilee/Point Judith and Newport) Approximately 95% of the commercial fishing vessels operate on diesel fuel and the ferries from these ports and the Warren/Bristol port are all diesel powered.

Activities at the Quonset Point and Providence ports involve off-loading of materials from ocean-going ships frequenting these facilities. Very little on-shore activity is required with some diesel powered cranes and support equipment which operate only on an as-needed basis. At Quonset, most of the unloading involves driving new vehicles off of the ships and into parking lots, later to be loaded and transported on car-carrier tractor trailer trucks.

Tug boat service in Narragansett Bay and Block Island Sound is provided by a private company operating out of Fall River, Massachusetts. Seven heavy-duty diesel tugboats are used, and, typically several are stationed here in Rhode Island.

b – Locomotives

Four railroad operations use and store locomotives here in Rhode Island:

- AMTRAK
- Providence & Worchester
- MBTA
- Seaview Transportation, Inc.

Because the coolant systems in locomotives cannot be protected from freezing using antifreeze, there can be an issue relating to idling to ensure that the coolant does not freeze during winter months. It is not uncommon for locomotives to continuously idle to avoid freezing problems. Fortunately, the three major operators here in Rhode Island have each addressed the coolant freezing problem without having to rely on continuous idling. AMTRAK has two yard locomotives on hand in Pawtucket to transport track maintenance equipment and personnel covering the Rhode Island and neighboring Massachusetts and Connecticut rail lines. These yard locomotives are equipped with automatic idling-limiting sensors, reducing idling to maintain above-freezing conditions in the engine coolant system. The locomotives housed here for the MBTA commuter rail system are all equipped with electric plug-in facilities to allow the locomotives to be powered down for their overnight stays. The two locomotives assigned to Rhode Island for the P&W operations are housed overnight in heated buildings. The one operating locomotive at Quonset, operated by Seaview Transportation, is stored indoors when not in use and is heated to prevent freezing using a small external boiler.

c – Airports

Aircraft emission standards are set by the Environmental Protection Agency and mirror those of the International Civil Aviation Organization (ICAO), the group that sets worldwide standards. The FAA enforces the EPA's standards. According to a recent article in USA Today, environmentalists and many state and local air pollution officials argue that the standards are too weak. The report states that EPA says limits now in place will slow the growth of aircraft emissions, but more stringent standards "will likely be necessary and appropriate in the future," says Margo Oge, director of the agency's Office of Transportation and Air Quality.

The use of diesel-powered support equipment at the airports can be addressed as part of Rhode Island's strategy. Airplane support equipment and airport operated/contracted passenger courtesy vans can be included in retrofit, replacement, alternate fueling schemes to reduce diesel emissions.

CONTROL STRATEGIES

A matrix of the vehicle types (or sectors) and applicable diesel emission control measures can be used to help prioritize efforts to reduce exposures to diesel emissions. Common control measures to reduce diesel emissions fall under one of five categories: reduce idling, repair/rebuild, replace or re-power, retrofit or re-fuel. These approaches, along with a corrective program concerning on road diesel engine controls, are discussed below and will be considered in the development of a strategy for Rhode Island.

Anti-Idling (reduce-idling)

Rhode Island now has the authority to develop a regulatory program to minimize excessive idling of both on-road and non-road diesel powered vehicles. However, an aggressive outreach effort with an active enforcement program will help vehicle operator compliance and assure a reduction in emissions from regulated vehicles and equipment. Even idling necessary for driver comfort can be minimized through the use of externally powered heating and cooling equipment at layover truck stops or the use of fuel-efficient, truck mounted auxiliary power units to provide cab heating, cooling and power. Anti-idling is the one control strategy that can be applied to almost all diesel vehicles operating in Rhode Island that provides direct reductions in all types of diesel emissions. It is also provides a benefit in fuel savings.

Inspection and Maintenance programs for diesel vehicles (repair)

Mandatory inspection and maintenance regulations help minimize excessive emissions from malfunctioning diesel vehicles. Rhode Island now has the authority to require a diesel exhaust opacity test for Rhode Island registered vehicles, although the actual emissions testing requirement for the existing inspection/maintenance (I/M) program is still being developed. The Rhode Island State Police are conducting road-side checks and issuing penalties for vehicles failing the opacity test. Several states are now in the process of considering lowering the opacity standards for both their road-side pull over testing and their I/M programs.

Fleet Turnover (replace)

Programs to encourage or require the retirement of older equipment and replacement with newer, less polluting equipment can result in significant reductions of emissions. School districts can include specifications relating the age of buses and/or requirements for control equipment to be used when contracting for school bus services.

Retrofit

Various emissions-reducing equipment retrofits are available to control emissions from existing diesel engines. Available technologies to address $PM_{2.5}$ and NO_x, along with two re-fuel options (discussed below) are detailed in the following table.

Technology	$PM_{2.5}$ Reduction	NO_x Reduction	Cost (per typical vehicle)
Diesel oxidation catalyst (DOC)	10%-30%	No reduction	$1,000-$2,000
Diesel particulate filter (DPF)	80%-90%	No reduction	$5,000-$10,000
Flow-through filter (FTF)	50%-76%	No reduction	$3,000-$4,000
Closed crankcase filter system (CCFS)	5%-10%	No reduction	$250-$500
Exhaust gas recirculation (EGR)	No reduction (but DPF also required)	30%-40%	$10,000-$15,000
Selective catalytic reduction (SCR)	No reduction	60%	$10,000-$20,000
NO_x reducing catalyst (NRC)	No reduction	20%-30%	$6,500-$10,000
Bio-diesel fuel	0%-50%	Increase 0%-10%	1.5-2.0 X diesel fuel cost. (B20 - $.05-$.10/gal increase over 100% diesel fuel)
Emulsified diesel fuel (EDF)	20%-50%	5%-30%	$.01-$.10/gal increase over 100% diesel fuel

Source: *Controlling Fine Particulate Matter Under the Clean Air Act, A Menu of Options*, March 2006, STAPPA

It should be noted that many of the retrofit devices also require the use of ULSD to prevent clogging of the equipment. One technology, CCFS, is very effective at reducing emissions from front-mounted diesel engines (like those used in most school bus designs) from directly entering the vehicle interior cabin.

Retrofit programs can be mandatory (required by law/regulation) or voluntary. Many programs to date have relied on voluntary installations of retrofit equipment using grants provided by various government agencies. The mechanisms to require and finance these retrofits must be considered. Publicly owned vehicles, including transit buses and some school buses, refuse trucks, construction and maintenance equipment can be retrofitted through the use of grant monies and even penalties collected from regulated parties under other environmental actions (often called 'supplementary environmental programs', or SEPs). It has been determined that the most cost-effective approach to retrofit projects is to concentrate on the newer legacy vehicles to maximize the effective life of the retrofitted equipment, while considering that any older diesel vehicle retrofitted with the appropriate equipment will result in lower pollutant emissions.

Retrofit Contract Specifications

Several states have been successful in mandating that contractors working on state funded construction projects adhere to emissions specifications developed to control diesel emissions from construction equipment. Specifications and contract language is available to address fuel specifications, requiring ULSD in all construction on-road and non-road equipment, and requirements that all equipment be retrofitted with emissions reduction devices. School buses have also been required to be retrofitted under terms stipulated by school authorities who contract for bus service.

Re-Fuel

Different fuels can be used to reduce emissions including ULSD (mandatory for on-road use in MY 2007 and newer diesel vehicles beginning in July 2006), bio-diesel, compressed natural gas (CNG), and electricity. Additionally, the use of ULSD in pre-MY 2007 engines and non-road equipment not only reduces direct emissions of pollutants but also allows for the use of various retrofit technologies to further reduce emissions. As mentioned previously, ULSD fuel will be completely phased in for highway use by 2010, and will also be required for non-road equipment (except marine and locomotive uses). ULSD will be required for all uses in 2014. The use of bio-diesel blends, also reduces the emissions of PM and, because they are produced from renewable resources, results in the net reduction of greenhouse gases. Questions remain on the possible slight increase of NO_x emissions from vehicles burning bio-diesel. Results of different methods of testing ranged from no measured increases to slight NO_x increases. Proprietary fuel additives and fuel processing (e.g. emulsified diesel fuel) can lower the emissions from equipment using these fuels. However, mandating the use of special formulations of fuel may be problematic due to unknown formulations of additives and federal restrictions on fuel formulations.

Chip Re-flash

Some engine control computer chips installed in vehicles beginning in 1990 were illegally programmed to pass various diagnostic tests under inspection conditions but readjust the engines to improve mileage but increase emissions in on-road conditions. It has been reported that the resulting engine settings increased NO_x emissions above the legal limit, as much as three-fold. A settlement was reached between EPA and the engine manufacturers in 1998 to correct this issue through a re-programming action (chip re-flash). However, there is no legal mechanism to require truck owners to have the rebuild kits and/or reprogramming installed. To date, only approximately 10% of the engines have been rebuilt nationwide.

NESCAUM (an organization of northeast states' air quality programs) has developed a model rule that states can consider adopting to mandate the re-flash procedure. However, a recent law suit against California over their mandatory program has resulted in court decisions that severely hinder state's ability to require the re-programming of these vehicles. Several states and NESCAUM continue to work with the engine manufacturers to develop a voluntary re-flash program.

PRIORITY MATRIX

The table below presents a priority matrix where a preliminary priority has been assigned to various sources and potential control strategies. The preliminary numeric priority assignment has been made on the basis of reduction in critical health risk exposures, authority to control and ease of implementation.

Control\Sector	On-Road	Non-road Construction	Buses	SWCV	Other
Anti-idling	1	1	1	1	* - Marine * - Locomotives 1 – Airport (support equipment)
Fleet Turnover	3	3	**Transit** 1 - Public 3 - Tour **School** 1	2 - Private 2 - Public	* - Marine * - Locomotives * - Airport (support equipment)
I/M	R - Rhode Island N/A - Transients	3	**Transit** R - Public * - Tour **School** R - Public R - Private	R	* - Marine * - Locomotives * - Airport (support equipment)
Chip Re-flash	2	N/A	**N/A**	2	N/A
Retrofit	3 - Rhode Island N/A - Transients	2	**Transit** 1 - Public	2	N/A - Marine N/A - Locomotives

			3 - Tour **School** 1 - Public 1 - Private		N/A - Airport (support equipment)
Re-Fuel	R	* - Non road R - On road	R	R	* - Marine * - Locomotives * - Airport (support equipment)

1-high; 2-medium; 3-low, N/A, R – regulated, *-TBD

MAXIMIZING CONTROL STRATEGY BENEFITS

Stressing the Health issues

Successful diesel emission control programs have been implemented where control strategies target significant anticipated health impacts. Examples include school bus retrofit programs where the exposed population is known and vulnerable. Retrofit programs can also be successfully implemented to address SWCV fleets, diesel equipment at construction sites near residential areas, urban delivery fleets and transit buses that operate extensively in populated areas.

PRELIMINARY RECOMMENDATIONS

1. Finalize anti-idling regulations to control emissions from most types of diesel equipment. Benefits in reduced emissions of both NO_x and $PM_{2.5}$ are directly proportional to eliminated unnecessary idling.
2. Implement an I/M program to require emissions testing for opacity on all Rhode Island registered diesel trucks to ensure properly functioning engines (already required).
3. Continue and expand school bus retrofit programs
4. Implement State construction project contract provisions to require ULSD fuel use and use of emissions control retrofitted equipment
5. Encourage expedited fleet turnover for RIPTA buses
6. Encourage retrofits/replacements of SWCVs
7. Continue to implement a voluntary chip re-flash program with engine manufacturers.
8. Consider more stringent opacity cut-points for pullover and I/M programs covering the on-road diesels in Rhode Island.