WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Diesel Particulate Emission Reduction Strategy for Washington State

Washington State Department of Ecology
Air Quality Program

December 2006

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Executive Summary

The Washington State Department of Ecology (Ecology) has identified diesel exhaust as the air pollutant most harmful to public health in Washington State. Seventy percent of the cancer risk from airborne pollutants is from diesel exhaust. It makes healthy people more at risk for respiratory disease and worsens the symptoms of people with health problems such as asthma, heart disease, and lung disease. More than four million people in Washington live or work close to highways and other major roads where they are most likely to be exposed to diesel exhaust.

The harmful effects of diesel exhaust

Diesel engines emit a complex mixture of gaseous pollutants and fine particles that include over forty cancer causing substances. Diesel exhaust contains several regulated air pollutants such as oxides of nitrogen and volatile organic carbons (ozone precursors), and unregulated pollutants such as carbon dioxide (a greenhouse gas). Worst of all, diesel exhaust contains toxic microscopic particles that are less than 2.5 microns in diameter (also know as $PM_{2.5}$).

Diesel $PM_{2.5}$ poses the most serious risk from diesel exhaust because of its toxicity. $PM_{2.5}$ from diesel exhaust is more toxic than other forms of $PM_{2.5}$, such as wood smoke. Recent research shows that diesel $PM_{2.5}$ can cause very serious health effects even at levels much lower than what air quality standards allow. This is due to both the toxic nature of the particles and the fact that they can be breathed deep into the lungs where they remain lodged. Exposure to diesel $PM_{2.5}$ causes both immediate and long-term health effects. Healthy children and adults become more at risk for respiratory diseases. People with pre-existing heart disease or circulatory problems are more likely to have a heart attack or stroke. Short-term exposure to diesel exhaust can irritate the eyes, nose, and throat, and cause coughing, labored breathing, chest tightness, and wheezing. Diesel exhaust can also lead to lung cancer, as well as cancers of the bladder and soft tissues.

Ecology estimates that over 4 million people in Washington live and work very near major urban roads, where diesel engine exhaust is most common. These people can be exposed to harmful levels of diesel exhaust every day. Within these areas, there are about 4,000 day care centers, 1,500 kindergarten through grade 12 schools, 100 hospitals, and 200 nursing homes. These places all house the people most sensitive to diesel exhaust. In addition, a higher percentage of economically disadvantaged people live very near major urban roads than the population in general.

Major urban areas are not the only places where people come in contact with harmful levels of diesel exhaust. A small town near a rail yard, a rural school near a busy truck stop, and any place where a community and a major road meet – people at all these places can be exposed to harmful levels of diesel exhaust.

The federal Environmental Protection Agency recently adopted a new, more stringent, air quality standard for $PM_{2.5}$. All areas of Washington meet the old federal standard for $PM_{2.5}$, but Ecology expects some areas will not meet the new 2006 standard. Even if the new standard is met, adverse health effects from diesel $PM_{2.5}$ occur at levels well below what is allowed by the standard.

Ecology's strategy to reduce diesel exhaust

Ecology's Air Quality Program developed this strategy to guide its work on reducing diesel exhaust. In developing this strategy, Ecology analyzed the many sources of diesel exhaust and identified the ones most likely to affect public health. The goals of this strategy are to:

- decrease the amount of diesel pollution emitted into the air; and
- reduce the negative health effects of diesel pollution, especially for:
    - children, the elderly and people whose existing health problems put them at risk (sensitive populations); and
    - economically disadvantaged communities (environmental justice communities) that are exposed to a higher amount of air pollution than the general population.

Key actions in the strategy

Address existing diesel engines

To significantly reduce diesel pollution, we must clean up emissions from the large number of existing diesel engines (pre-2007 model year). These existing engines -- with higher emissions -- have a long life span, and we expect them to continue polluting for decades. New federal engine standards require on-road diesel engines (beginning with the 2007 model year) to have very low emissions of the small particles and other pollutants in their exhaust (phased in later for non-road equipment such as construction equipment). But because the existing pre-2007 diesel engines will be around for such a long time the new engine standards will take decades to significantly reduce the adverse effects of diesel exhaust overall.

The most significant existing sources of diesel exhaust in Washington are:

- Heavy duty on-road (highway) vehicles
- Non-road construction equipment
- Marine vessels and port related equipment
- Locomotive emissions (especially at switchyards near population centers)

Ecology will use a phased approach to reduce diesel emissions from existing vehicles and equipment. This approach will first focus on reducing diesel exhaust from the above sources in areas where the most people are located. Areas with sensitive populations and economically disadvantaged communities will have priority.

Put new technologies on old engines

The first step in reducing diesel exhaust from existing engines will involve using technologies and programs that are both cost effective and relatively easy to implement:

- Installing pollution reducing technologies such as particulate filters or oxidation catalysts on existing engine exhausts – often called "exhaust retrofitting"
- Reducing vehicle idling through technologies such as auxiliary power units, electrified truck parking and operational changes
- Installing add-on technologies, such as aerodynamic fairings and single wide tires, that increase fuel efficiency, thereby decreasing diesel emissions
- Replacing older engines and vehicles

Ecology's strategy will focus on these technologies first, but other emission reducing technologies and programs will be evaluated and used where appropriate.

There are nearly 134,000 existing diesel engines in Washington that are suitable for exhaust retrofitting, idle reduction, add-on fuel efficiency technology, or vehicle and engine replacement. Nearly 90 percent of these engines are owned and operated by the private sector. Many of the public sector engines have been addressed. Proposals to address the remaining suitable public fleet are part of the Governor's 2007/2009 budget request. Funding and programs to address the private sector fleet are still needed. If the private fleet is not addressed a whole generation of Washingtonians will continue to be adversely affected by diesel pollution.

Accomplishments so far

Several projects are currently underway to help reduce diesel exhaust emissions from existing engines, mostly in the public fleet. The major Ecology directed projects are:

- The Washington Clean School Bus Program has retrofitted the exhausts of 5,000 school buses, with the remainder of the fleet scheduled to be retrofitted over the next three years.
- The Washington Local Government Diesel Grant Program has funded exhaust retrofits for more than 900 public vehicles and equipment. Additional retrofits are expected for the 2007/2008 period.
- As a demonstration project, Ecology will electrify 75 commercial truck parking spaces in Washington, so that truckers can turn off their main engines and plug in for power needed to run cab amenities and equipment while taking their rest period. This project compliments a similar effort in Oregon where 200 truck parking spaces will be electrified.

Although these projects represent a significant effort to reduce diesel emissions, much more needs to be done, especially with private sector diesel vehicles and equipment.

Next steps

The Air Quality Program is actively seeking sources of funding to install exhaust retrofits, idle reduction equipment and fuel efficiency technology on private diesel vehicles. In the past, funding has come from federal grants, money provided by the Washington State Legislature, and private matching funds.

The Air Quality Program is also working cooperatively with the Puget Sound Clean Air Agency (PSCAA), the Ports of Tacoma and Seattle, and other agencies to develop a strategy and projects for reducing port-related diesel exhaust.

The Air Quality Program will continue to track and evaluate other technologies and programs for reducing diesel exhaust, and will implement them as appropriate.

Is reducing diesel exhaust worth the cost?

The benefits to human health outweigh the costs of reducing diesel pollution. The California Air Resources Board has found that every dollar invested in reducing diesel emissions results in three to eight dollars in savings in improved health, avoided health problems, or lower operating and maintenance costs for diesel fleets. The Union of Concerned Scientists estimates that, for every dollar invested in diesel retrofits, 9 to 16 dollars are returned to society.

1.0 Goal

The goals of this strategy are to ***decrease the amount of diesel pollution*** *being emitted into the air and* ***reduce the negative health impacts*** *of these pollutants, especially on sensitive populations and environmental justice communities.*

Diesel engines and equipment typically have a long life and replacement is expensive. Turn-over of the existing fleet to new, clean vehicles takes decades. At regular turnover rates for diesel vehicles, federal requirements for engine technology upgrades will take a long time (25-30 years) to impact overall emissions. Addressing existing diesel engines, known as the "legacy diesel fleet" (generally pre-2007 model year engines for on-road and pre-2010 for non-road engines other than locomotives and marine vessels), is essential to improving health and reducing the health costs of diesel pollution.

The goal of the diesel emission reduction strategy (the Diesel Strategy) is to reduce diesel fine particulate matter ($PM_{2.5}$) and reduce exposure to the sensitive populations, environmental justice communities and the public in general by reducing the emissions from the legacy diesel fleet. This will be accomplished through the use of exhaust retrofits, idle reduction, add-on fuel efficiency technologies, engine or vehicle replacement (accelerated fleet turnover), clean fuels, alternative fuels and other technologies, measures and programs that reduce emissions from existing diesel engines. These technologies are discussed in more detail in section 6.0.

1.1 Milestones

Emission reducing exhaust retrofits, idle reduction programs, add-on fuel efficiency technology and engine or vehicle replacements have been shown to be cost effective ways to reduce emissions from legacy diesel engines and are relatively easy to implement. Because of this, the strategy we undertake will address diesel emissions in a phased approach, starting with implementation of exhaust retrofit, idle reduction programs, add-on fuel efficiency technology and vehicle or engine replacement programs first. The milestones expected under this approach are:

1. Install emission reduction exhaust retrofits on fifty percent of the public legacy diesel fleet in four years.

2. Install emission reduction exhaust retrofits and add-on fuel efficiency technologies on fifty percent of the private legacy diesel fleet in eight years.

3. Evaluate, develop and implement an idle reduction program that addresses and remedies unnecessary idling through on-board retrofits, on-the-ground infrastructure and anti-idling regulations.

4. Replace twenty-five percent of older (pre-1990 for on-road and pre-1996 for non-road) legacy vehicles in the private fleet in eight years.

Other emission reducing technologies and programs will be tracked, evaluated and implemented where appropriate, but the initial focus will be on exhaust retrofits, idle reduction, add-on fuel efficiency technology and vehicle or engine replacement.

2.0 Why Reduce Diesel $PM_{2.5}$ Emissions?

Diesel engines emit a complex mixture of gaseous pollutants and fine particles that include over forty cancer causing substances. Diesel exhaust contains several regulated air pollutants such as oxides of nitrogen and volatile organic carbons (ozone precursors), and unregulated pollutants such as carbon dioxide (a greenhouse gas). Worst of all, diesel exhaust contains toxic microscopic particles that are less than 2.5 microns in diameter (also know as $PM_{2.5}$).

Diesel $PM_{2.5}$ poses the most serious risk from diesel exhaust because of its toxicity. $PM_{2.5}$ from diesel exhaust is more toxic than other forms of $PM_{2.5}$, such as wood smoke. Recent research shows that diesel $PM_{2.5}$ can cause very serious health effects even at levels much lower than what air quality standards allow. This is due to both the toxic nature of the particles and the fact that they can be breathed deep into the lungs where they remain lodged. Exposure to diesel $PM_{2.5}$ causes both immediate and long-term health effects. Healthy children and adults become more at risk for respiratory diseases. People with pre-existing heart disease or circulatory problems are more likely to have a heart attack or stroke. Short-term exposure to diesel exhaust can irritate the eyes, nose, and throat, and cause coughing, labored breathing, chest tightness, and wheezing. Diesel exhaust can also lead to lung cancer, as well as cancers of the bladder and soft tissues.

It has been estimated that there are 4.2 million citizens of Washington living and working very near major urban highways and major urban arterials where the operation of diesel engines is most prevalent[1]. These citizens are exposed to harmful levels of diesel emissions on a daily basis. Within these near highway/arterial areas are 4,036 daycare centers, 1,481 K-12 schools, 73 hospitals and 184 nursing homes. These facilities house the populations most sensitive to diesel emissions. Major urban areas are not the only places that citizens come in contact with harmful levels of diesel emissions. A small town near a rail yard, a rural school near a busy truck stop, and any place where a community and a major road meet – people at all these places can be exposed to harmful levels of diesel exhaust.

The federal Environmental Protection Agency recently adopted a new, more stringent, air quality standard for $PM_{2.5}$. All areas of Washington meet the old federal standard for $PM_{2.5}$, but Ecology expects some areas will not meet the new 2006 standard. Even if the new standard is met, adverse health effects from diesel $PM_{2.5}$ occur at levels well below what is allowed by the standard.

To significantly reduce diesel pollution, we must clean up emissions from the large number of existing (legacy) diesel engines (pre-2007 model year). These existing engines -- with higher emissions -- have a long life span, and we expect them to continue polluting for decades. New

[1] Ecology GIS services conducted an analysis of populations within a 300 meter zone either side of the centerline of major highways and 200 meters of the centerline of major arterials within the boundaries of the metropolitan and micropolitan statistical areas of Washington listed in appendix B.

federal engine standards require on-road diesel engines (beginning with the 2007 model year) to have very low emissions of the small particles and other pollutants in their exhaust (phased in later for non-road equipment such as construction equipment). But because the existing pre-2007 diesel engines will be around for such a long time the new engine standards will take decades to significantly reduce the adverse effects of diesel exhaust overall.

To protect the health of Washington's citizens it is necessary to accelerate the rate of diesel emission reductions from the entire fleet by cleaning up the existing legacy diesel fleet. Therefore a strategy is necessary to reduce diesel $PM_{2.5}$ from existing legacy diesels beyond what is mandated by law. Reaching the milestones discussed above will result in reduced health costs associated with impacts from diesel $PM_{2.5}$.

Although the cost of implementing diesel $PM_{2.5}$ reduction strategies for the legacy fleet is high, the benefits to human health out weigh the costs. The California Air Resources Board has determined that for every dollar invested reducing legacy diesel emissions through a variety of measures (exhaust retrofits, vehicle replacements, clean fuels, idle reduction, etc) a three to eight dollar economic return in improved health, avoided health problems or lower operating and maintenance costs for the diesel fleets can be realized.[2] The Union of Concerned Scientists has estimated that for every dollar invested in legacy diesel emission reduction exhaust retrofits, nine to sixteen dollars are returned to society.[3] The Clean Air Act Advisory Committee states that the benefits from retrofitting the legacy fleet is significant, that the cost of implementing measures to reduce diesel emissions from the legacy fleet is high, but represents a small fraction (as little as 5%) of the total cost of operating and maintaining the legacy fleet over a 10 year period.[4]

3.0 Tasks Necessary to Implement the Strategy

Given the nature of the problem and the priorities laid out later in this document, the Air Quality Program should carry out the following projects and tasks. Managers would need to reassign existing staff as needed to do these projects and/or work diligently on securing outside funds for contractors, local air agency grants, or project employees. Who develops and implements the projects will be worked out on a case by case basis and should be based in part on the capacity to accomplish the task within the intended timeframe.

3.1 Summary of Projects and Tasks Needed

The most significant sources of diesel $PM_{2.5}$ emissions for Washington are:

- heavy duty on-road vehicles
- non-road construction equipment
- marine vessels and port related equipment

[2] "Emission Reduction Plan for Ports and Goods Movement in California – Proposed", California Environmental Protection Agency, Air Resources Board, March 21, 2006.
[3] "Sick of Soot: Reducing the Health Impacts of Diesel Pollution in California", Union of Concerned Scientists, Cambridge, MA, 2004.
[4] "Recommendations for Reducing Emissions from the Legacy Diesel Fleet – Report from the Clean Air Act Advisory Committee", April 10, 2006.

Therefore, the initial focus of our strategy will target efforts to reduce $PM_{2.5}$ from these sectors. Recognizing the significance of emissions from locomotive engines for specific locations where sensitive and environmental justice populations may be exposed, an effort will also be undertaken to target locomotive idle reduction retrofits and an early switch to ultra-low sulfur diesel fuel. Finally, to gather data to better understand the sectors contributing diesel $PM_{2.5}$, our initial focus will also include efforts to improve the diesel inventory and our understanding of areas of exposure. This information will then be used to refine longer term strategy targets.

Note that the tasks listed below do not include specific focus on the marine sector. Because the majority of marine sector diesel emissions are associated with ports that fall under the jurisdiction of Puget Sound Clean Air Agency (PSCAA) who has been an active player in this sector on a regional level, we have elected to focus our efforts on other sectors of concern for the state. However, we are not precluding the possibility of developing marine projects and will coordinate with PSCAA, other local air agencies and port authorities to develop a comprehensive strategy for the marine sector.

1. Continue to develop and refine the inventory of the number and kind of existing diesel engines in the public and private fleets. Identify which of these diesel engines are most suitable for exhaust retrofits, add-on fuel efficiency technology, engine or vehicle replacement and idle reduction retrofits and programs. This is necessary to understand where the potential for emission reduction exists, the potential for reduction of exposure to diesel, and to better understand the costs and necessary funding to accomplish the emission reductions. We will use this information to refine future selection of emission reduction projects and the long term direction of the diesel strategy.

2. Expand local government heavy duty diesel and transit bus exhaust retrofit program. Seek additional funding from a variety of sources. Target accomplishing all the appropriate exhaust retrofits within four years.

3. Complete the school bus exhaust retrofit program[5]. Expand the program to include crank case ventilation systems and seek additional funds for replacing the oldest buses in the fleet.

4. Develop and fund programs that provide incentives such as tax breaks or loans for retrofitting the private fleet with emission reducing and fuel efficiency technologies.

5. Expand truck electrified parking (TEP) projects to locations strategically placed around the state. Evaluate and implement other on-road idle reduction projects.

6. Identify locomotive switchyards that pose significant exposure risk to sensitive populations, environmental justice communities and the population in general. Retrofit locomotives with idle reduction technologies at the identified “problem” locations.

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[5] While the school bus exhaust retrofit program predates the development of the Diesel Strategy, it is consistent with the goal of protecting sensitive populations.

7. Expand the public information campaign advocating that diesel operators reduce their idling. Make this campaign more effective by securing grant money that could fund one or more of the following steps:
    a. Improve outreach materials (glossy brochures, broader distribution, etc).
    b. Purchase radio ads.
    c. Purchase advertisements in selected publications.
    d. Identify and target anti-idling message and materials to specific high-idling areas or fleets.

8. Evaluate the costs and benefits of an anti-idling statute similar to California's (idling limited to five minutes). Assess whether such a statute would need to be combined with a state fund to assist truck owners with idle reduction retrofits or whether versions of an anti-idling statute could be effective and acceptable without retrofit support. EPA has developed a model anti-idling rule to assist states that want to pursue such an avenue and to provide uniformity across the nation.

9. Develop a program with the Washington Department of Transportation (WSDOT) to reduce diesel emissions on large road projects in populated areas (for all vehicles that serve the project).

10. Seek other opportunities for retrofit projects with the construction sector, including potential partnerships with equipment rental fleets and/or private sector construction companies.

11. Develop a funding plan to implement projects and tasks and submit this plan to the 2007 legislature.

12. Develop performance measures for the programs and projects initiated under the Diesel Strategy.

13. Calculate health and other benefits of the emission reduction measures initiated under the Diesel Strategy.

Table 3.1 is a summary of potential source sector related emission reduction approaches, funding approaches and potential funding options. The list of approaches and options will be further refined and put into a funding plan to take to the legislature.

Table 3.1 – Summary of potential emission reduction approaches, funding approaches and funding options

Sector and emission reduction approach	Funding approach	Funding options
School Buses: Exhaust retrofits – DOC's and DPF's Crank Case Ventilation Systems Replace pre-1990 buses	Grants	1. Extension and expansion of the school bus fund derived from vehicle title transfer fees
Transit Buses: Exhaust retrofits – DOC's and DPF's Crank Case Ventilation Systems	Grants	1. Create a grant fund with an operating or capital appropriation 2. Extension and expansion of the school bus fund derived from vehicle title transfer fees 3. Additional funds from the Local Toxics Control Account
Refuse Vehicles: Exhaust retrofits – DOC's	Grants	1. Create a grant fund with an operating or capital appropriation 2. Extension and expansion of the school bus fund derived from vehicle title transfer fees 3. Additional funds from the Local Toxics Control Account
Local Government Equipment: Exhaust retrofits – DOC's	Grants	1. Create a grant fund with an operating or capital appropriation 2. Extension and expansion of the school bus fund derived from vehicle title transfer fees 3. Additional funds from the Local Toxics Control Account
On-Road Heavy Duty: Exhaust retrofits – DOC's and DPF's Fuel efficiency retrofits – aerodynamics, light weight wheels, single wide tires, auto-tire inflation, etc.	Low cost loans and tax incentives	1. Create a loan fund from one of the existing funds that have been established from taxes on oil or fuels 2. Create a loan fund from the Local Toxics Control Account 3. Create a loan fund with a capital budget appropriation 4. Create a loan fund with SIB money (requires match) 5. Create new fees or taxes on engines or emissions to support a loan program 6. Tax incentive for purchase of exhaust retrofit
Non-Road Heavy Duty: Exhaust retrofits – DOC's	Low cost loans and tax incentives (initial focus on highway construction projects in high exposure areas)	1. Create a loan fund from one of the existing funds that have been established from taxes on oil or fuels 2. Create a loan fund from the Local Toxics Control Account 3. Create a loan fund with a capital budget appropriation 4. Create new fees or taxes on engines or emissions to support a loan program 5. Tax incentive for purchase of exhaust retrofit
On-Road Idling: Onboard retrofits – APU's, shore power enabling kits, thermal storage, auto start/stop systems, etc.	Low cost loans and tax incentives	1. Create a loan fund from one of the existing funds that have been established from taxes on oil or fuels 2. Create a loan fund from the Local Toxics Control Account 3. Create a loan fund with a capital budget appropriation 4. Create a loan fund with SIB money (requires match) 5. Create new fees or taxes on engines or emissions to support a loan program 6. Tax incentive for purchasing on-board idle reduction retrofits (done for shore power retrofits but not for other forms of on-board idle reduction retrofits. Should be expanded to include other forms)
On-Road Idling: Truck electrified parking infrastructure	Low cost loans and tax incentives	1. Create a loan fund from one of the existing funds that have been established from taxes on oil or fuels 2. Create a loan fund from the Local Toxics Control Account 3. Create a loan fund with a capital budget appropriation 4. Create a loan fund with SIB money (requires match) 5. Create new fees or taxes on engines or emissions to support a loan program 6. Tax incentive for establishing and selling truck electrified parking (done)
On-Road Heavy Duty: Replace vehicles (accelerated fleet turnover)	Tax incentive with requirement to junk replaced vehicle	1. Reduce sales and use tax for specified period
Non-Road Heavy Duty:	Tax incentive with requirement to	1. Reduce sales and use tax for specified period

Replace vehicles (accelerated fleet turnover). Note: Wait until 2011 when Tier 4 non-road engines will become available to replace older engines.	junk replaced vehicle	
Locomotives: Idle reduction retrofits on switchyard locomotives	Low cost loans and tax incentives	1. Create a loan fund from one of the existing funds that have been established from taxes on oil or fuels 2. Create a loan fund from the Local Toxics Control Account 3. Create a loan fund with a capital budget appropriation 4. Create new fees or taxes on engines or emissions to support a loan program 5. Tax incentive for purchase of idle reduction retrofit
Locomotives: Early switch to ultra low sulfur diesel (ULSD) for switchyard and line haul locomotives	Tax incentive for early switch to ULSD	1. Provide tax credit on the cost difference between high sulfur fuel and ULSD 2. Require railroads receiving idle reduction loans (described above) to obligate a portion of the fuel cost savings for purchasing ULSD
Marine Vessels: TBD	TBD	1. Coordinate with PSCAA, other local air agencies and port authorities to develop a comprehensive emission reduction strategy and funding package

3.2 Summary of Projects Underway

Several projects are currently underway to help reduce diesel exhaust emissions from existing engines, mostly in the public fleet. Table 3.2 summarizes most of the major projects in Washington.

Although these projects represent significant efforts to reduce diesel emissions, much more needs to be done, especially with private sector diesel vehicles and equipment.

Table 3.2 – Summary of major diesel emission reduction projects in Washington State[6]

Washington State Local Government's Diesel Retrofits Grants Program Cities, counties, ports, and transit authorities are retrofitting their diesel fleets with $2 million in funding from Ecology. Ecology granted awards to 28 recipients to retrofit more than 900 vehicles. The retrofits, combined with the use of ultra-low sulfur diesel, reduce diesel emissions from each vehicle by 40 to 90 percent.	**Washington State Clean School Bus Program** Ecology and the state's seven local air quality agencies have retrofitted nearly 5,000 school buses with emission reducing technology. The state legislature granted $5 million per year for five years to retrofit 100% of school buses suitable for retrofits. The retrofits, combined with readily available ultra-low sulfur diesel, reduce emissions on individual buses by 40 to 90 percent. Since 2002, a portion of the funding has also been used to retrofit public fleet vehicles.
Washington State Ferries' Clean Fuel Initiative With funding from EPA and the Puget Sound Clean Air Agency, Washington State Ferries began a year-long pilot test of ultra low sulfur diesel (ULSD) on the M/V Elwha. Completing this pilot test helps users understand whether marine diesel engines can effectively burn ULSD over the long-term. It will also eliminate three tons of sulfur dioxide and approximately one-half ton of particulate matter.	**Washington Department of Transportation Maintenance Vehicle Retrofits in Yakima** With an $84,000 grant, WSDOT is working with the Yakima regional air agency, EPA, and Ecology, to reduce over 30 percent of its engine and exhaust emissions on 29 maintenance vehicles. Vehicles include dump trucks, sweepers, and loaders that operate around the city of Yakima.
The Eastern Washington Farmers Diesel Emissions Reductions Program The Upper Columbia Resource Conservation & Development Council is using $500,000 in EPA and matching funds to promote no-till/direct seeding techniques for Eastern Washington farmers. The project will conserve an estimated 56,660 gallons of diesel fuel, reducing diesel emissions, and educates state farmers about the financial and environmental benefits of no-till/direct-seeding.	**Locomotive Idle Reduction** Four switchyard and short haul locomotives will be retrofitted with idle reduction equipment using $200,000 in public and Tacoma Rail funds. This will save over 42,000 gallons of diesel and eliminate 20 tons of air pollution and 550 tons of carbon dioxide per year. In 2003, using public and private funds, the Burlington Northern Santa Fe Railway also retrofitted three switchyard locomotives with idle reduction equipment in Vancouver, Washington.
The Puget Sound Clean Air Agency's Diesel Solutions Program The Diesel Solutions Program, an initiative to make diesel engines in the Central Puget Sound region significantly cleaner, has installed over 2,000 retrofits in nearly 50 school districts with funding from the State School Bus Program. They have also utilized more than $780,000 in EPA grants and other funding to retrofit 1,260 public fleet engines and provide funding for other regional diesel emission reduction projects.	**The Princess Cruise Shore Power Project at Port of Seattle** In 2004, the EPA, Princess Cruises, Port of Seattle, Puget Sound Clean Air Agency, and Seattle City Light invested in shore power technology so that two cruise ships don't have to run diesel engines while docked at port. Approximately 35 metric tons of turbine engine fuel will be eliminated per ship call by connecting to shore side power, reducing the air emissions from dockside cruise ships in Seattle by more than a third.
The Puget Sound Maritime Air Emissions Inventory and Diesel Emissions Reduction Project With $410,000 in an EPA grant and matching funds, the Puget Sound Maritime Air Forum is creating an activity-based inventory of all maritime-related air emission sources in the Greater Puget Sound region. The Port of Seattle will also implement projects that are identified as priorities in the emissions inventory project with $105,000 in EPA and matching funds.	**Washington Department of Transportation Uses Biodiesel in Maintenance Vehicles** In 2005, WSDOT started using five percent biodiesel (B5) mixed with regular diesel in maintenance vehicles operating in the Central Puget Sound area. B5 is now being pumped at 16 WSDOT fueling stations. By 2009, WSDOT plans to use 20 percent biodiesel (B20) in all feasible applications.
The Truck Idle Reduction Project 75 Truck Electrified Parking (TEP) spaces will be installed at three truck stops in Washington with nearly $400,000 in funds from the EPA, Ecology, Climate Trust and private companies. This is part of a joint effort to reduce idling along the West Coast. A total of 275 parking spaces in Washington and Oregon will be electrified, saving an estimated six million gallons of diesel over five years. In addition, a tax incentive is available for installing TEP or purchasing TEP equipment.	**Washington Department of Transportation Maintenance Vehicle Retrofits and Idle Reduction in Puget Sound** In 2006, the Puget Sound Regional Council approved $1.5M in federal funding for WSDOT to install engine filters and exhaust retrofits on about 150 vehicles and replace power burning incandescent lights with light emitting diodes (LED) on about 700 vehicles. LED's reduce pollution by allowing lights to work with the engine shut off.

[6] Information provided by the U.S. Environmental Protection Agency, the Washington Department of Transportation, the Puget Sound Clean Air Agency and the Washington Department of Ecology

4.0 Scope of the Problem

4.1 Health Effects of Diesel Exhaust

A body of published scientific studies shows that diesel exhaust has a profound effect on public health. Susceptibility to diesel exhaust depends on the amount of exposure and on who the exposed people are. People are more susceptible to damage from pollutants based on their age, their state of health, and their genetic predisposition. The young are vulnerable because their lung, immune and brain defenses may not be fully formed, while the old may have diminished capacity to fight off environmental toxicants. Those who have illnesses such as heart or lung disease, diabetes, or respiratory infections are also more susceptible to diesel particle exposure. Many Washingtonians are members of one of these sensitive age groups or have one or more medical conditions aggravated by air pollution. About 500,000 Washington residents have asthma, and 125,000 of these are children (DOH, 2005). Approximately 7% of adults in Washington report having cardiovascular disease (DOH, 2004).

Exposure to diesel exhaust results in both long term and immediate health effects. Those with pre-existing heart disease or circulatory problems are more likely to suffer a heart attack or stroke, or have symptoms like chest pain, fatigue or extreme weakness related to impending cardiovascular events. Associations between respiratory health endpoints and diesel exhaust exposure are stronger than for circulatory system endpoints. However, more people suffer from cardiac and circulatory system disease than respiratory disease, so that the public health impact is greater. Diesel also profoundly affects the lungs.

Short-term exposure to diesel exhaust can irritate the eyes, nose and throat and cause respiratory symptoms such as cough, labored breathing, chest tightness and wheezing. Diesel particles are irritating to respiratory membranes and cause inflammation, allergic reactions, and worsening of allergic reactions to other allergens such as pollen or dust mites. Diesel particles affect the health of all who breathe them, but are especially problematic to those with lung disease such as asthma, chronic bronchitis, or emphysema. People with asthma may have an immediate reaction to diesel exhaust exposure such as an asthma attack or worsening of asthma symptoms. Over time, those exposed may develop more severe disease, with permanent changes in their airways, and more severe asthma attacks and symptoms requiring more medical intervention. Children developing asthma as a result of exposure to air pollutants are more susceptible to developing serious chronic obstructive lung disease like emphysema or chronic bronchitis in later life.

Diesel exhaust causes an increase in respiratory symptoms and decreased lung function and lung growth in children living near roadways in California. Exhaust from diesel contributes chemicals such as nitrogen oxides and solvent molecules that react with ultraviolet light in sunlight to form ozone, which also has been shown to decrease lung growth and function in children, and to initiate asthma, as well as make asthma worse.

Diesel exhaust can also be responsible for lung cancer, as well as cancers of the bladder and soft tissues. EPA has stated that diesel particles are likely to be causal for lung cancer. Department of Ecology is using the cancer unit risk factor developed by California Department of Health Services Office of Environmental Health Assessments of 3×10^{-4} (an excess of 3 cancers in an exposed population of 10,000 per $\mu g/m^3$ of diesel particles breathed) in diesel particle risk assessments. This unit risk number was developed based on a meta-analysis of occupational studies of diesel-exposed workers, and is supported by other epidemiological and animal studies. Washington State incidence of lung cancer (2002) was 3,777 and 3,093 died from lung cancer that year. Bladder cancer incidence in the same time period was 1,349, while 229 people died from this type of cancer in that year (DOH 2002). It is probable that diesel exhaust had a role in this incidence of cancer and cancer deaths.

Diesel exhaust affects the immune system by lowering resistance to infectious organisms like viruses and bacteria. It also inhibits the cells that cleanses the airways allowing infectious organisms more chances to get established and cause infections. When people are exposed to diesel exhaust and infectious organisms at the same time, they are more likely to succumb to pneumonia or influenza or other respiratory infection.

Animal experiments indicate that diesel exhaust exposure is responsible in changes in reproductive function. Effects on the development of embryos and fetuses have also been shown in animal studies. At least one epidemiological study relates reduced sperm quality in men with exposure to air pollution, primarily diesel exhaust.

A more detailed discussion of diesel health effects can be found in Appendix A.

4.2 Sources of Diesel $PM_{2.5}$ Emissions

In Washington State existing legacy diesel engines emit 8,403 tons per year of particulate matter of which 7,873 tons per year fall into the fine particulate size range (less than 2.5 microns in diameter, known as $PM_{2.5}$)[7]. Fine particulate emissions are of particular concern because they can travel deeper into the lungs where they remain lodged, where there are fewer defenses and cause more cancer and non-cancer health effects then larger particles.

A variety of sources contribute to the total amount of $PM_{2.5}$ from diesels. The key sources are:

- Heavy Duty On-Road Vehicles
- Marine Vessels
- Construction Equipment
- Agricultural Equipment
- Locomotives

These sources can be found in both urban and rural areas. On a statewide basis heavy duty on-road vehicles, marine vessels and construction equipment dominate the contribution to diesel $PM_{2.5}$, accounting for 67 percent of the total. On a state wide basis agricultural equipment and locomotives are also fairly significant contributors to total diesel $PM_{2.5}$ (12 percent and 8 percent respectively).

[7] Washington State 2002 Baseline County Inventory, Washington State Department of Ecology, July 15 2004

The relative amount that sources contribute to diesel $PM_{2.5}$ varies across the state. In the Puget Sound region (defined here as Snohomish, King, Pierce and Kitsap counties), where population is greatest, 41 percent of the total statewide diesel $PM_{2.5}$ emissions occur. Sources of diesel $PM_{2.5}$ emissions in the Puget Sound region are dominated by heavy duty on-road vehicles, construction equipment and marine vessels. These three source categories account for 79 percent of the total in the Puget Sound region.

In Spokane County, a highly populated eastern Washington urban county, 5 percent of the statewide diesel $PM_{2.5}$ emissions occur. The dominant sources of diesel $PM_{2.5}$ are heavy duty on-road vehicles, construction equipment and agricultural equipment. These three sources account for 72 percent of the total in Spokane County.

In Clark County, another major urban county of Washington, 4 percent of the statewide diesel $PM_{2.5}$ emissions occur. The dominant sources of diesel $PM_{2.5}$ are heavy duty on-road vehicles, construction equipment and marine vessels. These three sources account for 76 percent of the total for Clark County.

Figures 4.1, 4.2, 4.3 and 4.4 show the relative source contribution to diesel $PM_{2.5}$ emissions on a state-wide basis, in the Puget Sound region, in Spokane County and in Clark County, respectively.

Locomotive switchyards are often adjacent to environmental justice communities (low income and minority dominated communities). Environmental justice communities are of special concern because it has been shown that they are exposed to a higher amount of air pollution than the general population.

Agricultural equipment is typically found in rural areas which typically have low population density. Exposure to emissions from this source may be minimal because diesel $PM_{2.5}$ does not react with other pollutant species once emitted and typically falls out within 300 meters of the emission source. Nonetheless, local pockets of rural populations may still be significantly and adversely affected and it should not be assumed that a general low population density on a county level means low risk of exposure. Therefore, it is important to understand the relationship between the location of the emission source and exposed pockets of population in rural areas.

The relative source contribution to total diesel $PM_{2.5}$ varies in different regions of the state, both urban and rural. It is important to understand which sources are most responsible for emissions in a given area and which populations are most exposed before designing emission reduction priorities and projects. This underscores the need for a generic approach that is easily modified for local circumstances so as to achieve desired emission reductions that meet the overall goal of reduced exposure to sensitive populations, environmental justice communities and the public in general. We will discuss our generic approach in section 6.1.

Figure 4.1 – Sources of Diesel $PM_{2.5}$ in Washington State – Year 2002[8]. Total TPY = 7,893.

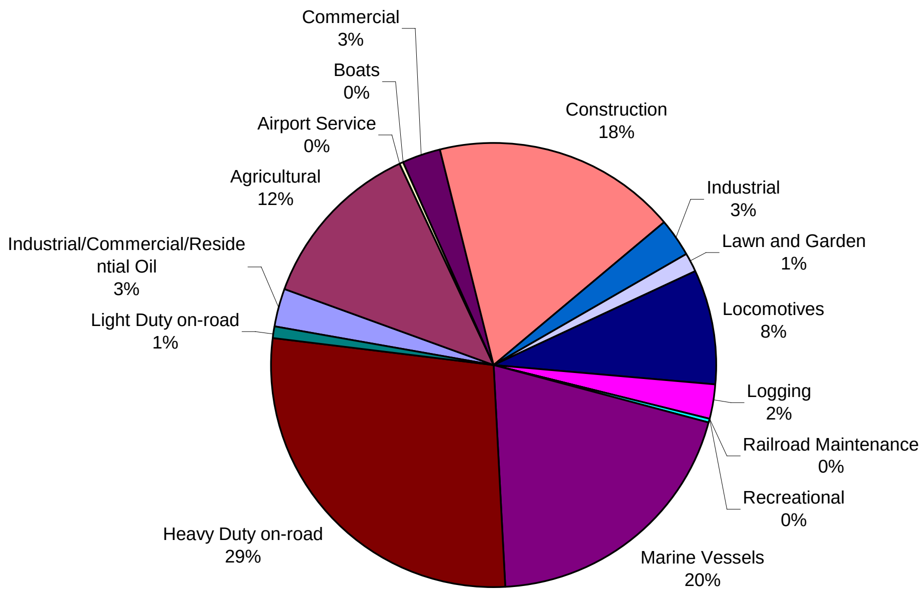
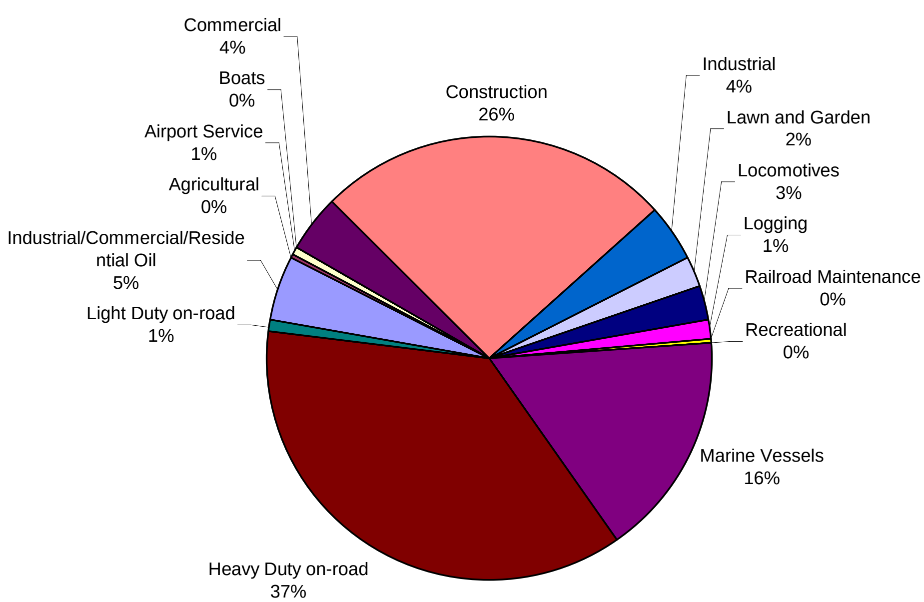


Figure 4.2 – Sources of Diesel $PM_{2.5}$ in the Puget Sound Area (Snohomish, King, Pierce and Kitsap counties) – Year 2002[9]. Total TPY = 3,221.



[8] Washington State 2002 Baseline County Inventory, Washington State Department of Ecology, July 15 2004
[9] ibid

Figure 4.3 – Sources of Diesel $PM_{2.5}$ in Spokane County – Year 2002[10]. Total TPY = 377.

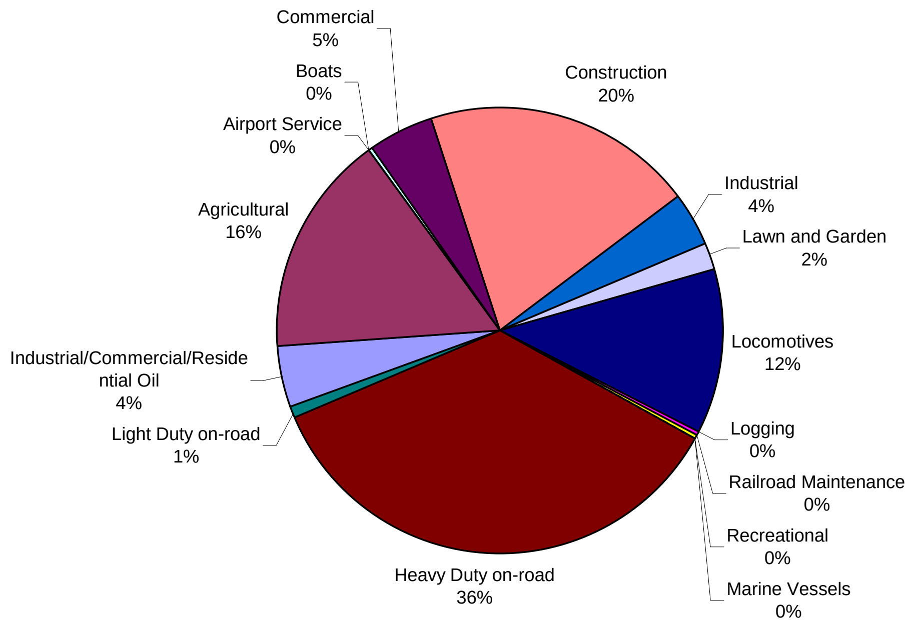
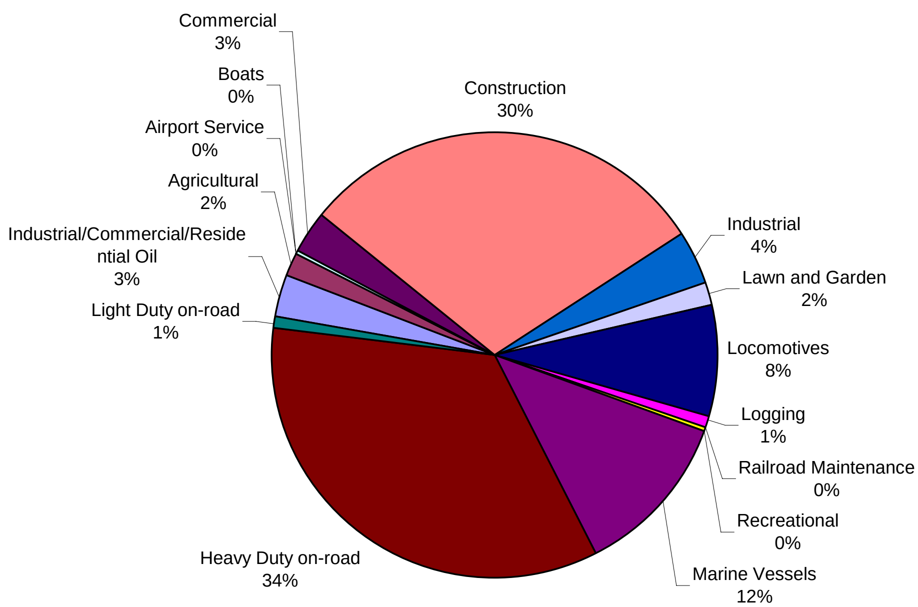


Figure 4.4 – Sources of Diesel $PM_{2.5}$ in Clark County – Year 2002[11]. Total TPY = 316.



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[10] Washington State 2002 Baseline County Inventory, Washington State Department of Ecology, July 15 2004
[11] ibid

4.3 How Many Existing Legacy Diesel Engines Are There?

Diesel engines are considered the work horse of the industrial, transportation, construction, commercial and agricultural industries and are used for many applications. The following is a brief discussion of the number of engines in the existing fleet, types of engines, and suitability of engines for exhaust retrofits, fuel efficiency technology, engine or vehicle replacement, and idle reduction programs. Exhaust retrofits, fuel efficiency technology, engine or vehicle replacement, idle reduction and other emission reducing technologies and programs are discussed in more detail in section 6.0.

4.3.1 On-Road Mobile Engines

It is estimated that there are over 180,000 on-road legacy diesel vehicles registered in Washington State and over 85,000 of these are in the heavy duty on-road category (heavy duty is defined as > 14,000 lbs GVW and not registered as personal use trucks)[12]. Heavy duty on-road vehicles contribute the most diesel $PM_{2.5}$ of all the on-road sources, and the heaviest of the heavy duty (>33,000 lbs GVW) contribute 78 percent of the on-road heavy duty diesel $PM_{2.5}$. Figure 4.5 shows the number of heavy duty on-road vehicles in the various classes. [Note: Although light duty passenger vehicles, light duty passenger trucks and light duty commercial trucks account for 45 percent of all on-road diesel vehicles, they only account for 1 percent of the total diesel $PM_{2.5}$ emissions. Therefore, this strategy does not concern itself with the light duty class of on-road vehicles.]

Not all of these heavy duty vehicles are suitable candidates for exhaust retrofits. As a general first cut to which vehicles are suitable candidates, only engines that are 1990 or newer should be considered. Vehicles 1990 and newer meet the federal Tier 1 emissions standards and generally will not clog or cause maintenance problems in exhaust retrofits. Older and dirtier engines tend to clog typical exhaust retrofits and are often not suitable candidates. There are over 62,000 heavy duty on-road vehicles that are 1990 and newer. Approximately 4,700 new heavy duty on-road vehicles enter the fleet each year. Figure 4.6 shows the number of heavy duty on-road vehicles in the various classes that meet the first cut for being suitable exhaust retrofit candidates.

The criteria for what constitutes a suitable exhaust retrofit candidate are not hard and fast and case by case exceptions may occur. Some of the engines identified as technically suitable for exhaust retrofit may be low priority because of low usage rates, no or limited use in populated areas (low exposure risk), exhaust configurations unsuitable for retrofits, or maintenance problems such as excessive oil consumption. For instance, vehicles used exclusively for logging may be operated in areas where significant exposure to human population is not expected. Conversely, some engines not identified may be good candidates because the engine and associated emissions may be Tier 1 or better even though they were manufactured prior to implementation of the Tier 1 standards.

Older heavy duty on-road vehicles predating Tier 1 emission standards are more suitable for replacement (either engine or entire vehicle) rather than exhaust retrofits. Using vehicles built

[12] Data developed from EPA MOBILE6.2 emission model and Washington State Department of Licensing data base query, February 2006.

prior to Tier 1 as a first cut, there are over 22,000 heavy duty on-road vehicles potentially suitable for replacement. Figure 4.7 shows the number of heavy duty on-road vehicles in the various classes that meet the first cut for being suitable replacement candidates.

Fuel efficiency add-on technology and idle reduction programs such as truck electrified parking (TEP) are particularly suitable for commercial heavy duty long haul trucks. EPA estimates there are over 24,000 commercial heavy duty long haul trucks registered in Washington.[13] Assuming that 10 percent of existing trucks are already equipped with on-board electrification technology (a technology that allows them to plug into truck electrified parking when available) that leaves around 22,000 potentially suitable candidates for on-board electrification retrofits.

TEP requires infrastructure on the ground that supplies electrical power from the grid. A report by the Transportation Research Board of the National Academies of Science estimates that there are 2,665 commercial overnight truck parking spaces and 455 spaces at public rest areas in Washington State.[14] Each of these overnight truck parking spaces is a potential candidate for installation of TEP. TEP should only be installed if parking space frequency of use, duration of use and prevalence of truck idling justifies installation. Therefore, careful evaluation of the parking and idling activity should be conducted prior to committing to any projects that install TEP infrastructure.

4.3.2 Non-Road Mobile Engines

It is estimated that there are over 127,000 non-road legacy diesel engines in Washington State and over 43,000 of these are in the heavy duty category (heavy duty defined as >= 175 horse power)[15]. Figure 4.8 shows the number of heavy duty non-road vehicles in the various classes in Washington State. Estimates on the number of these engines is based on national engine populations then shrunk proportionately based on Bureau of Census information such as county human population size and business patterns.

Similar to the case for on-road vehicles, not all of these heavy duty non-road engines are suitable candidates for exhaust retrofits. Non-road engines 1996 and newer meet Tier 1 emission standards and have clean enough emissions suitable for use with a typical exhaust retrofit without the problems of clogging that older engines may present. In addition, horse power of the engine is an indirect indicator of physical size and configuration of engine and/or vehicle layout. Engines and vehicles with lower than 175 horse power (HP) generally do not have suitable on-board locations for an exhaust retrofit without the risk of physical damage being done to the retrofit during the engine or vehicle's typical work. In other cases, there is no room for the retrofit and the cost of a modification needed to accommodate the retrofit is prohibitive. Therefore, those non-road engines newer than 1996 and greater than or equal to 175 HP are considered potentially suitable candidates for exhaust retrofits. Based on this, there is estimated to be over 24,000 heavy duty non-road engines suitable for exhaust retrofits. Figure 4.9 shows

[13] EPA emission model "MOVES2004". Email communication with David Brzezinski, USEPA – Office of Transportation and Air Quality, February, 2006.
[14] Trombly, Jeffrey W. "Dealing with Truck Parking Demands", NCHRP Synthesis 317, Transportation Research Board, Washington D.C., 2003
[15] Data developed from EPA NONROAD2004 model, February, 2006.

the number of heavy duty non-road diesel engines in the various classes that are potential candidates for exhaust retrofits.

As was noted for on-road vehicles, the criteria for what constitutes a suitable exhaust retrofit candidate are not hard and fast and case by case exceptions may occur and careful evaluation is warranted. The reasons for this are the same as mentioned for on-road vehicles. For instance, agricultural equipment such as tractors and combines are usually operated in areas with low population density and may not be suitable for exhaust retrofits based on low human exposure potential.

Older engines predating Tier 1 emission standards for non-road engines (1995 and older) are more suitable for replacement (either engine or entire vehicle) rather than exhaust retrofits. Using heavy duty engines built prior to Tier 1 as a first cut, there are over 19,000 heavy duty engines that are potentially suitable for replacement. Figure 4.10 shows the number of heavy duty non-road engines in the various classes that meet the first cut for being suitable replacement candidates. It should be noted that ultra clean Tier 4 non-road engines will not be available until 2011. Any replacement program for older non-road engines should be postponed until Tier 4 engines are available.

4.3.3 Locomotive Engines

Although there are not nearly as many locomotive diesel engines in Washington compared to on-road and non-road vehicles and engines, the size, horse power and fuel consumption of locomotive engines and locations of rail switchyards with respect to environmental justice communities make them prime candidates for emission reduction measures. Union Pacific (UP) and Burlington Northern Santa Fe (BNSF) railroads operate an estimated 700 line haul locomotives engines and 130 switchyard engines in Washington that consume over 94 million gallons per year of high sulfur diesel fuel. Amtrak operates another 24 locomotive engines in Washington. There are at least another 40 locomotive engines operated by smaller short haul and switchyard rail roads in Washington.[16]

4.3.4 Marine Vessels, Harbor Craft and Cargo Handling Equipment

Estimates on diesel engines in Washington's commercial marine vessels, harbor craft and port operations related equipment are being developed by the Puget Sound Maritime Air Forum but are not yet available. However, on a national level EPA estimates there are 65,443 category 1 commercial vessel propulsion engines, 43,888 category 1 auxiliary vessel engines, 1,966 category 2 propulsion engines and over 44,000 category 3 vessel engines. Category 3 vessel engines are difficult to estimate accurately as the majority of them are foreign flagged.[17] Category 1 engines are the smallest commercial engines with less than 5 liters displacement per cylinder and category 3 are the largest with 30 liters or greater displacement per cylinder.

Once the marine inventory is completed we will update the strategy accordingly.

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[16] Data extracted from Washington State 2002 Baseline County Inventory, Washington State Department of Ecology, July 15 2004. Supplemented with information gathered from personal communications with Mike Stanfill, Burlington Northern Santa Fe Railway and Jon Germer, Union Pacific Railroad, January, 2006.

[17] Email communication with David Brzezinski, USEPA – Office of Transportation and Air Quality, February, 2006.

4.3.5 Public versus Private Fleets

The vast majority of diesel vehicles and diesel engines are owned by the private sector. As part of a recent Washington State Department of Ecology grant program for retrofitting local government heavy duty diesel engines an analysis of the number of diesel engines owned by public agencies and authorities was conducted. This information, combined with information on public school buses and transit vehicles, indicates that of the total on-road and non-road vehicles and engines, only 8 percent are owned by the public. Of the on-road and non-road engines that are suitable for emission reduction programs, only 11 percent are owned by the public. Figures 4.11 and 4.12 present this information graphically. Because of the prohibition on using public funds for private fleets, this disparity between the size of the private fleet versus public fleet may have significant implications on our ability to implement a successful and comprehensive emission reduction strategy. This issue is discussed further in section 11.3.

Figure 4.5 – Number of Heavy Duty On-road Diesel Engines in Washington State

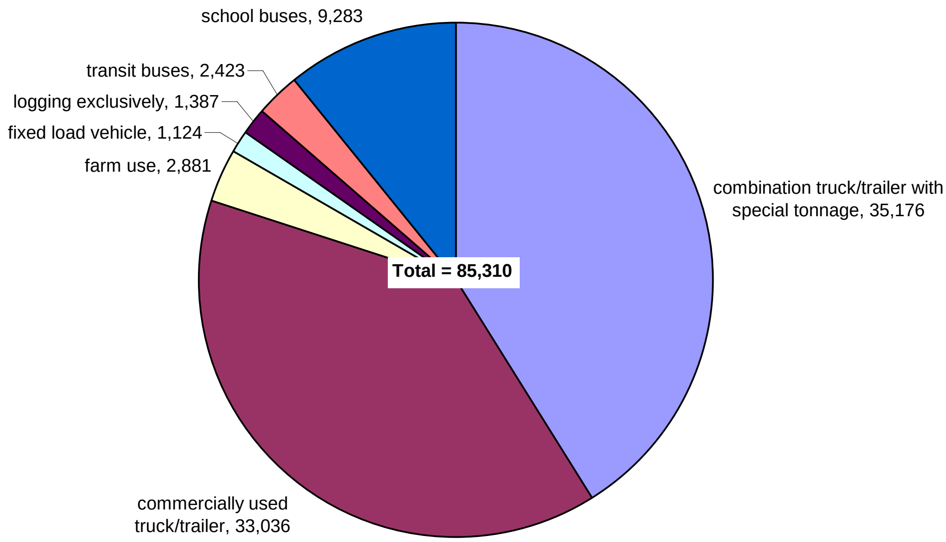


Figure 4.6 – Number of Heavy Duty On-road Diesel Engines that are Potentially Suitable Candidates for Exhaust Retrofits (MY 1990 and newer)

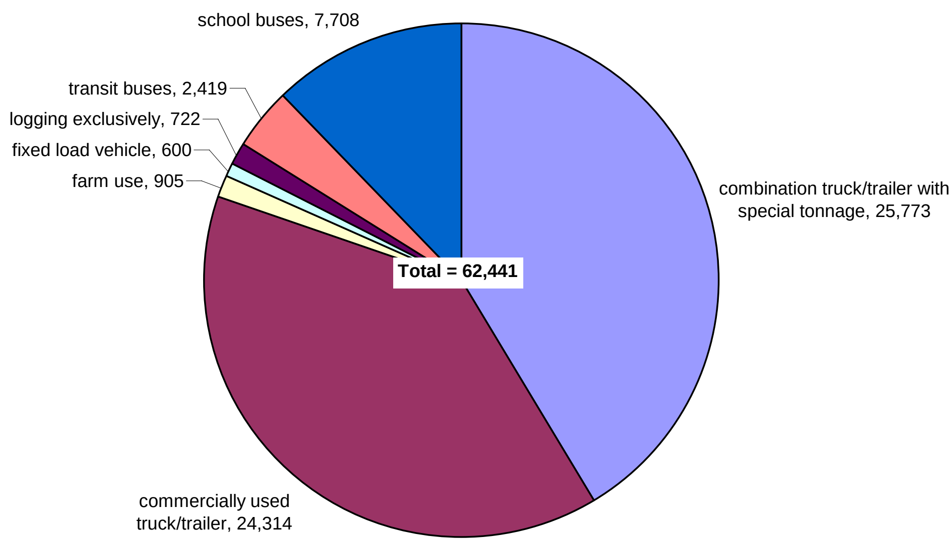


Figure 4.7 – Number of Heavy Duty On-Road Diesel Engines that are Potentially Suitable for Replacement (MY 1989 and older)

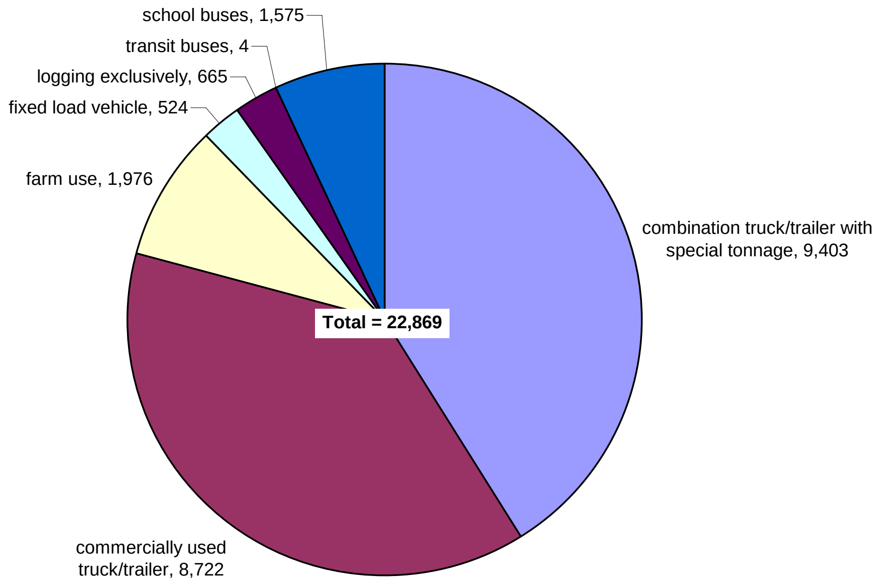


Figure 4.8 – Number of Heavy Duty Non-Road Diesel Engines in Washington State (Does not include commercial marine vessels, harbor craft and cargo handling equipment)

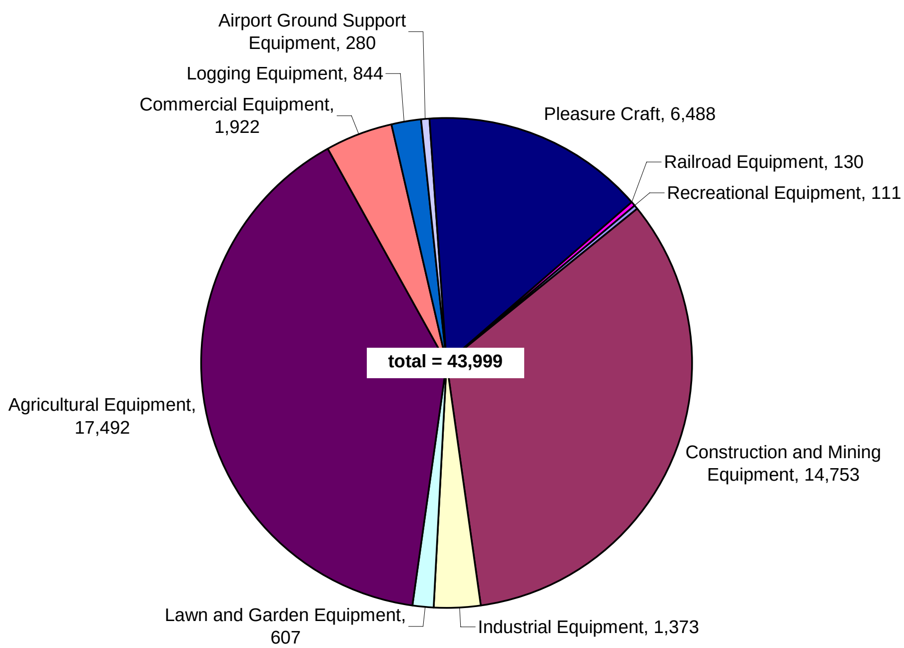


Figure 4.9 – Number of Heavy Duty Non-Road Diesel Engines that are Potentially Suitable Candidates for Exhaust Retrofits (MY 1996 and newer, >= 175 HP)

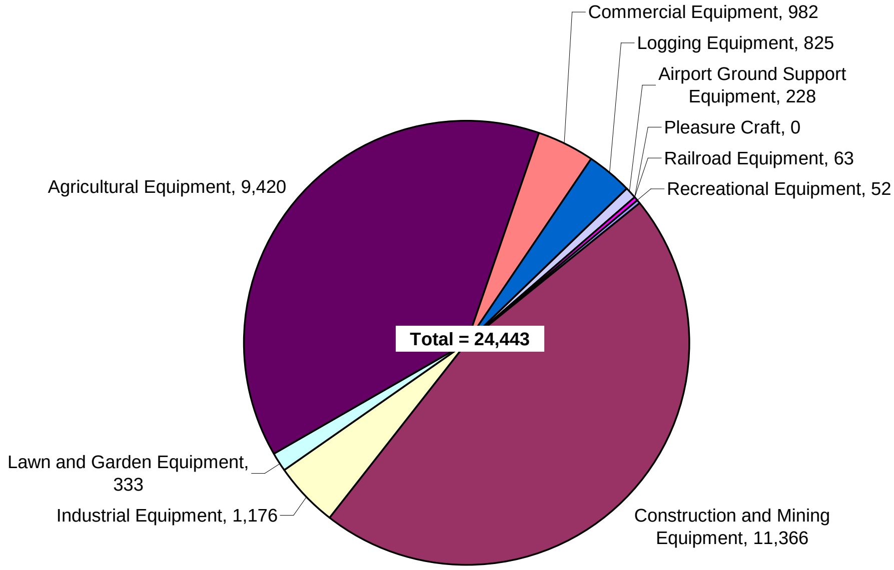


Figure 4.10 – Number of Heavy Duty Non-Road Diesel Engines that are Potentially Suitable for Replacement (MY 1995 and older)

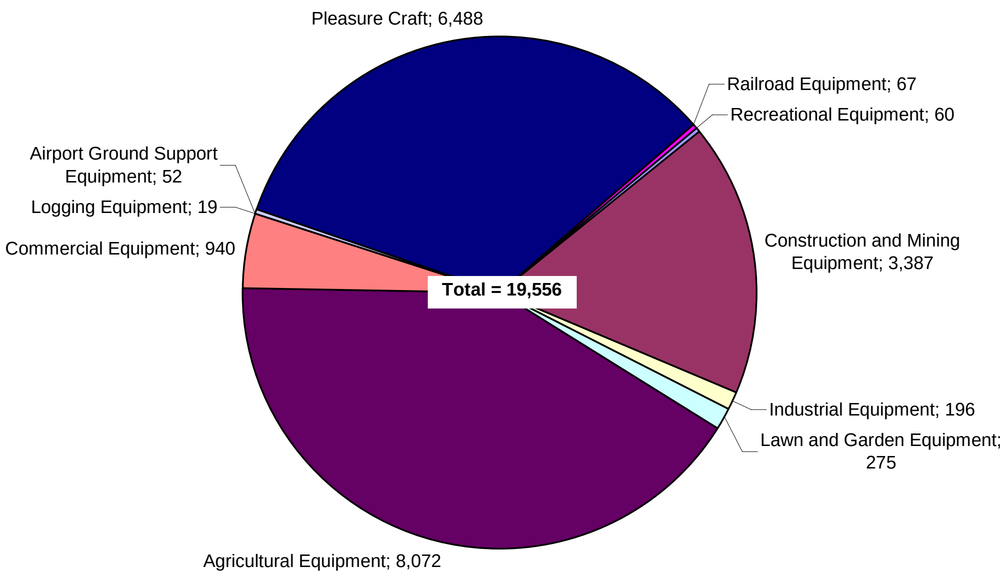


Figure 4.11 – All Heavy Duty and Light Duty On-road and Non-road Engines in the Public Fleet Versus the Private Fleet

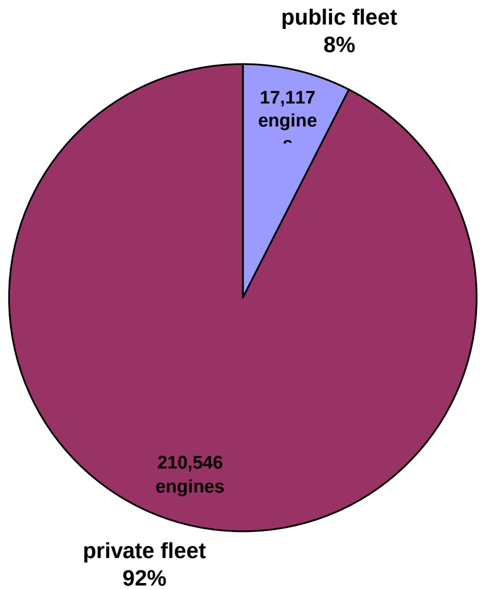
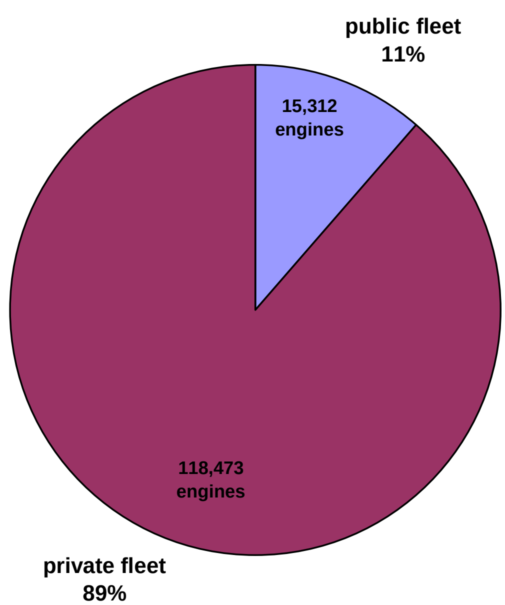


Figure 4.12 – Heavy Duty On-road and Non-road Engines Suitable for Emission Reduction Programs in the Public Fleet Versus the Private Fleet



5.0 Phased Approach for Reducing Diesel $PM_{2.5}$

As discussed in section 1.0, emission reducing exhaust retrofits, add-on fuel efficiency technology, engine or vehicle replacements and idle reduction programs have been shown to be cost effective ways to reduce emissions from legacy diesel engines and are relatively easy to implement. Because of this, the strategy we undertake will address diesel emissions in a phased approach, starting with implementation of exhaust retrofit, add-on fuel efficiency technology, vehicle and engine replacement, and idle reduction programs first.

Other emission reducing technologies and programs will be tracked, evaluated and implemented where appropriate, but the initial focus will be on exhaust retrofits, add-on fuel efficiency technology, vehicle and engine replacements and idle reduction.

6.0 Fuels, Technologies, Programs and Other Control Measures for Reducing Diesel PM2.5

6.1 Upcoming Programs to Reduce Emissions from Future Diesel Engines

Federal programs to reduce emissions from new diesel engines are planned to take effect beginning in 2007 for on-road engines and 2011 for non-road engines and will reduce future emissions from new diesel engines through measures focused on engine technologies and clean fuels. However, given that the lifespan of a legacy diesel engine is typically 20 to 30 years or more, older uncontrolled or poorly controlled diesel engines will continue to significantly contribute to the total $PM_{2.5}$ from diesel engines. It will take decades to completely turnover the nation's pre-2007 legacy diesel fleet. Lowering emissions from the older legacy fleet will reduce the time it takes to reach diesel $PM_{2.5}$ levels that are sufficiently protective of human health.

6.2 Fuels and Technologies for Reducing Diesel $PM_{2.5}$

Technologies that reduce diesel $PM_{2.5}$ exist and are in use in many parts of the country and other parts of the world. Although the initial focus of this strategy is on exhaust retrofits, add-on fuel efficiency technology, vehicle and engine replacements, and idle reduction, all general categories of technologies for reducing $PM_{2.5}$ emissions from existing diesels are listed and briefly discussed below.[18]

6.2.1 Fuels

- **Low Sulfur and Ultra-Low Sulfur Diesel Fuels –** Ultra-low sulfur diesel (ULSD) fuels alone can provide direct $PM_{2.5}$ reductions in the order of a few percent to as much as 29 percent when used in heavy duty trucks and construction equipment. Additionally, ULSD allows for the use of exhaust after-treatment devices like diesel particulate filters that can achieve $PM_{2.5}$ reductions in excess of 90 percent. In addition to the direct tail

[18] "Assessment of Potential Strategies to Reduce Emissions from Diesel Engines in Washington State", Kim Lyons, Ecology Publication 05-02-005, December 31, 2003

pipe reductions, additional reductions in ambient particle loading will be realized because of less sulfur available for secondary particle formation. By federal regulation, ULSD will be the only petroleum based diesel fuel available to on-road vehicles beginning in 2007 and for non-road vehicles beginning in 2010. However, acceleration of availability of this fuel into the marine market is not mandated and needs to be encouraged to achieve further marine diesel $PM_{2.5}$ emission reduction. For instance, the Washington State Ferry system (WSF) switched its entire fleet to low sulfur fuel and received a federal grant to test the use of ULSD on one of its ferries. Low sulfur diesel cost the WSF system less then a penny per gallon more then the old high sulfur fuel, while the ULSD costs seven cents per gallon more.

Low sulfur (also known as highway or on-road diesel) or ultra-low sulfur diesel can also be used to reduce emissions from locomotive engines. Locomotive engines typically use diesel fuels with high sulfur contents similar to non-road diesel fuel (greater than 3,000 ppm sulfur is common). Switching to low sulfur highway fuels (not greater than 500 ppm sulfur, although highway fuels sold in WA average about 350 ppm sulfur) or ULSD (15 ppm sulfur) from high sulfur non-road diesel can achieve $PM_{2.5}$ reductions of 13 to 38 percent, depending on the locomotive engine make and the specific sulfur content of the non-road fuel being switched from.

- **Biodiesel –** Biodiesel is a direct fuel substitute that can be used with little or no modifications to the existing diesel engine. For B20, a blend of 80 percent petroleum diesel and 20 percent biodiesel, $PM_{2.5}$ reductions of 10 percent or more can be realized. Biodiesel is a sustainable fuel, but the burning of it may produce slightly more NOx formation. Depending on the percent of biodiesel to petrodiesel blend (B0 to B100), the compression ratio and load rate of the engine during sampling, NOx emissions could be neutral to 10 percent higher than if the engine was operating on straight petrodiesel. Specific testing of NOx during actual use would have to be done to know actual amounts or emissions.

  Due to the solvent/oxidation nature of biodiesel, it is essential that all handling procedures are strictly followed and all fuel tanks thoroughly cleaned of all water and sediments before using any bio or bio-blends. Care and inspection of the fuel system, hoses and filters is necessary and must be monitored to correct any plugging or hose deterioration issues before problems occur. Possible gelling and fuel filter plugging at cold temperatures is a concern. To attain good low ambient temperature engine performance may require blending with No. 1 petrodiesel or fuel additives to modify the cloud and pour point temperature of the fuel.

- **Fuel/Water Emulsions –** Fuel/water emulsions, such as PuriNox, are diesel blended with 20 percent water with additives that maintain the emulsion. $PM_{2.5}$ reductions of 40 percent or more can be realized. A reduction in NOx can also be realized due to cooling of engine operating temperatures. Use of fuel/water emissions can lead to declined performance, reduction in fuel efficiency and power loss. Fuel/water emulsions are more suitable for marine vessel engines that maintain a fairly constant power level and engine rpm when operating.

6.2.2 Engine and Exhaust After-treatment Technologies

- **New Engine Technologies (rebuild/repower/replace) –** New engine technologies can be implemented by repowering the vehicle (replacing the existing diesel engine with a new low emission engine), purchasing new replacement vehicles with natural gas powered engines or diesel/electric hybrids or rebuilding the engine with lower emission technologies or performance standards. $PM_{2.5}$ emission reductions strictly related to new engine technologies vary but are in the range of 30 percent or more.

  A locomotive engine's service life is typically 40 years and may be rebuilt or remanufactured five to ten times during that service life. Under federal emission standards for new locomotive engines, rebuilt existing engines (post 1973) are required to meet the applicable standard in effect for a *new* engine at the date of rebuild. Therefore, there exists a built-in mechanism for improving the emissions from existing stock.

- **Diesel Oxidation Catalysts (DOC) –** An exhaust after-treatment device, DOC's have been in use for over 20 years and are relatively inexpensive and robust enough to be used in non-road applications. DOC's require diesel fuel to have a sulfur content of less than 500 ppm (on-road diesel fuel) and can achieve $PM_{2.5}$ reductions of 25 percent or more.

- **Diesel Particulate Filters (DPF) –** Also an exhaust after-treatment device, DPF's work best with newer truck and construction equipment engines that achieve higher sustained exhaust temperatures. DPF's also require the use of ultra-low sulfur diesel fuel (less than 15 ppm sulfur content). Although DPF's can cost two to three times more than oxidation catalysts, they can achieve PM reductions in excess of 90 percent. All DPF's require some periodic maintenance, with typical per vehicle maintenance cost ranging from $100 to $500 per year.

  Particulate filters may also have application to switchyard locomotives, although there are space constraints and engine duty cycle issues which may lead to excessive loading and clogging of filters. However, unlike diesel engines in trucks, locomotives have ancillary electrical energy available during normal operations which could power an active filter regeneration system.

- **Crank Case Ventilation System (CCV) –** CCV systems can be retrofitted on engines to eliminate crankcase vent emissions. Historically, turbocharged diesel engines vented crankcase emissions to the engine compartment and below the vehicle. CCV systems separate exhaust from the crankcase and re-rout the filtered air back to the intake thereby preventing crankcase $PM_{2.5}$ from penetrating the cabin of vehicles such as school buses. CCV systems may reduce total $PM_{2.5}$ emissions by 5 to 10 percent or more. Some CCV filters require maintenance, with a typical per vehicle maintenance cost ranging from $40 to $100 per year.

- **Selective Catalytic Reduction (SCR) –** An exhaust after-treatment used for marine applications. It uses ammonia or urea as a reducing agent over a precious metal catalyst.

SCR's can reduce $PM_{2.5}$ in the neighborhood of 40 percent and can be used with high sulfur fuels. It does pose significant weight and space requirements due to the large amount of reducing agent needed.

6.2.3 Idling Reduction Technologies

- **Auxiliary Power Units (APU) –** Reduces emissions from heavy duty truck idling or switchyard locomotives by retrofitting with small auxiliary diesel generators. The main propulsion engine can be shut down and the APU used to supply in cab power requirements in trucks or engine temperature and battery charging in locomotives. $PM_{2.5}$ emission reductions can vary depending on idling cycle, but typically are around 80 to 84 percent of idling emissions. APU's burn far less fuel then the main propulsion engine (80 percent less in most cases) allowing users to also realize fuel cost savings. All APU's emit less $PM_{2.5}$ than pre-2006 on-road engines. After 2007, the main propulsion engine may be cleaner than a typical APU. Therefore care needs to be taken to assure that the APU emits less $PM_{2.5}$ then the main propulsion engine after 2007. Ultra-clean APU's are available.

- **Truck Electrified Parking (TEP) –** TEP, formerly known as truck stop electrification, provides grid-supplied electrical power through electrical outlets mounted on pedestals at the truck parking space. Trucks can plug into these outlets at truck stops, rest areas and distribution centers rather than idle their engines during their rest periods or while waiting to be loaded or off-loaded at distribution centers. Grid supplied electricity is used to operate heating, ventilation and air conditioning (HVAC) and other electrical appliances such as televisions, microwaves and refrigerators. Trucks must come equipped with on-board AC electrical systems or be retrofitted to accept AC power. TEP can reduce emissions from idling by up to 90 percent and realize fuel savings of an average one gallon for every hour the truck does not idle.

- **Advanced Truck Stop Electrification (ATSE) –** The concept behind ATSE is similar to TEP, but the heating, ventilation and air conditioning (HVAC) system is external to the truck cab. The HVAC system is mounted on a truss above the parking space and heated or cooled air is provided to the truck cab via an umbilical that is inserted in a window template. Trucks that are not equipped or retrofitted with AC electrical systems can still use this technology. ATSE can reduce emissions from idling by up to 90 percent and realize fuel savings. Fuel cost savings are typically not as much as TEP as the hourly cost of ATSE service is nearly twice that of a typical TEP service. Infrastructure installation costs are four to five times as much as TEP.

- **Auto Start/Stop Systems –** Automatically starts or stops a truck's main engine based on engine computer module settings. This reduces engine idling time while still maintaining engine temperature and battery voltage. Can also be set to monitor cab air temperature and automatically start or stop based on a presetting. May also be appropriate on switchyard locomotive engines during the warm season when an APU-like diesel generator is not needed to keep engine fluids warm (low temperatures greater than 40F).

- **Battery Packs –** Provides power from an array of deep cycle batteries to directly operate HVAC or circulate engine coolant for truck cab heating. There is a limited amount of time the system can operate before batteries need recharging, especially in extreme temperatures. Battery packs add weight and take up significant space which can affect the amount of freight the truck can carry.

- **Thermal Storage –** A liquid medium is used to store energy which can later be used for heating or cooling the cab. It requires a relatively large space for storage medium and can be used for only a limited amount of time in extreme temperatures.

- **Direct-fired heaters –** These small and light weight diesel fueled heaters are used for heating the cab. Requires battery power for air circulation (fan) and may be unreliable if not combined with an engine auto starting system. Does not cool the cab.

- **Cold-Ironing –** What TEP is to trucks, cold-ironing is to marine vessels. While in port, rather than running the ships engine or an auxiliary ship engine, the vessel plugs into shore-side grid supplied electricity to operate hoteling and other electrical systems on-board. Has been successfully applied to cruise ships in Juneau and Seattle and ocean going container vessels in Los Angeles.

6.2.4 Add-on Fuel Efficiency Improving Technology

Technologies that improve fuel efficiency by improving aerodynamics, reducing weight or reducing rolling resistance also reduce emissions because less fuel is burned. These add-on technologies are particularly suited to long-haul trucks that burn thousands of gallons of fuel per year transporting goods across the nation.

- **Improved Aerodynamics –** Tractor aerodynamics can be improved by adding integrated roof fairings, cab extenders, side fairings and air dams. Trailer aerodynamics can be improved by minimizing tractor-trailer gap, adding side skirts and rear dams.

- **Weight reduction –** Light weight aluminum alloy wheels, axle hubs, clutch housings and cab frame can trim hundreds of pounds from a truck tractor. Thousands of pounds can be reduced from a truck trailer by using light weight aluminum roof posts, floor joists, upright posts, and hubs and wheels.

- **Reducing rolling resistance –** Using single wide tires and automatic tire inflation systems can reduce rolling resistance and improve fuel economy.

6.3 Programs for Reducing Diesel $PM_{2.5}$

Programs or actions can also be implemented that will reduce diesel $PM_{2.5}$ emissions. The programmatic approach differs from projects that might install a technology in that a program is ongoing, such as beginning with a school bus exhaust retrofit, moving to idling reduction and continuing with vehicle maintenance. A key component of a programmatic approach is the inclusion of an education and outreach effort. The programs can be voluntary or mandatory. These programs are briefly discussed below.[19]

6.3.1 Mandatory Smoke Testing or Emission Inspection Programs

Smoke testing and emission inspection programs are intended to identify trucks or locomotives that have high emissions, and then target the high emitting truck or locomotive for improvements. Although actual emission benefits from smoke testing and emission inspection programs have not been well documented, at least one state estimated the $PM_{2.5}$ reduction from trucks resulting from their program to be in the order of 45 percent (small sample of 26 vehicles).

6.3.2 Voluntary Emission Focused Maintenance Programs

Robust diesel maintenance programs that keep the diesel engine in top running condition have been shown to reduce overall emissions.

6.3.3 Voluntary Idling Reduction

Education and outreach to encourage reduced idling can reduce emissions by influencing operator behavior. This can be in the form of public agency education and outreach or fleet owners developing policies or guidelines instructing operators to turn off engines under certain circumstances such as queuing at truck freight distribution centers or non-work modes at locomotive switchyards. Some of these programs, when combined with incentives to provide technologies that aid with compliance (such as TEP or APU's), can result in up to 90 percent less emissions from idling.

6.3.4 Anti-Idling Regulations

Some jurisdictions have mandated reduced idling in certain circumstances through ordinances or rules. A model anti-idling rule has been developed by federal agencies in collaboration with local governments and private industry. States and local governments who choose to adopt the model rule will help the industry comply by providing uniformity of restrictions across the nation. Anti-idling regulations, when combined with incentives to provide technologies that aid compliance (such as TEP and APU's), can result in up to 90 percent less emissions from idling.

7.0 Prioritizing and Ranking Activities to Reduce Diesel $PM_{2.5}$

As described above, a variety of diesel sources exist throughout the state. Because funding for emission reduction technology or programs is limited, a systematic approach is necessary to prioritize which technologies, programs, sources and areas will be addressed first.

7.1 Basic Approach

The basic approach to ranking and prioritizing actions to reduce diesel emissions is to target source categories that emit the most diesel $PM_{2.5}$ and pose the greatest risk to the health of sensitive populations (children, the elderly, and people with existing health problems such as

[19] "Assessment of Potential Strategies to Reduce Emissions from Diesel Engines in Washington State", Kim Lyons, Ecology Publication 05-02-005, December 31, 2003

asthmatics), environmental justice communities (low income and minority populated) and the population in general. As a first cut to ranking, focus should be given to the major source categories in areas with the greatest exposure rates to sensitive populations such as schools, hospitals, medical clinics, nursing homes and environmental justice communities. Information on sensitive populations and environmental justice communities should first be evaluated for the region of concern. For example, figure 7.1 shows the location of environmental justice communities in the Spokane area[20] and Figure 7.2 shows schools, daycare centers, hospitals and nursing home locations relative to major transportation corridors in the Spokane area[21]. Maps like these have been developed for major urban areas of the Washington and are available from the Air Quality Program upon request. Information on sensitive populations should be researched on a case by case basis as a project or program is being developed and evaluated.

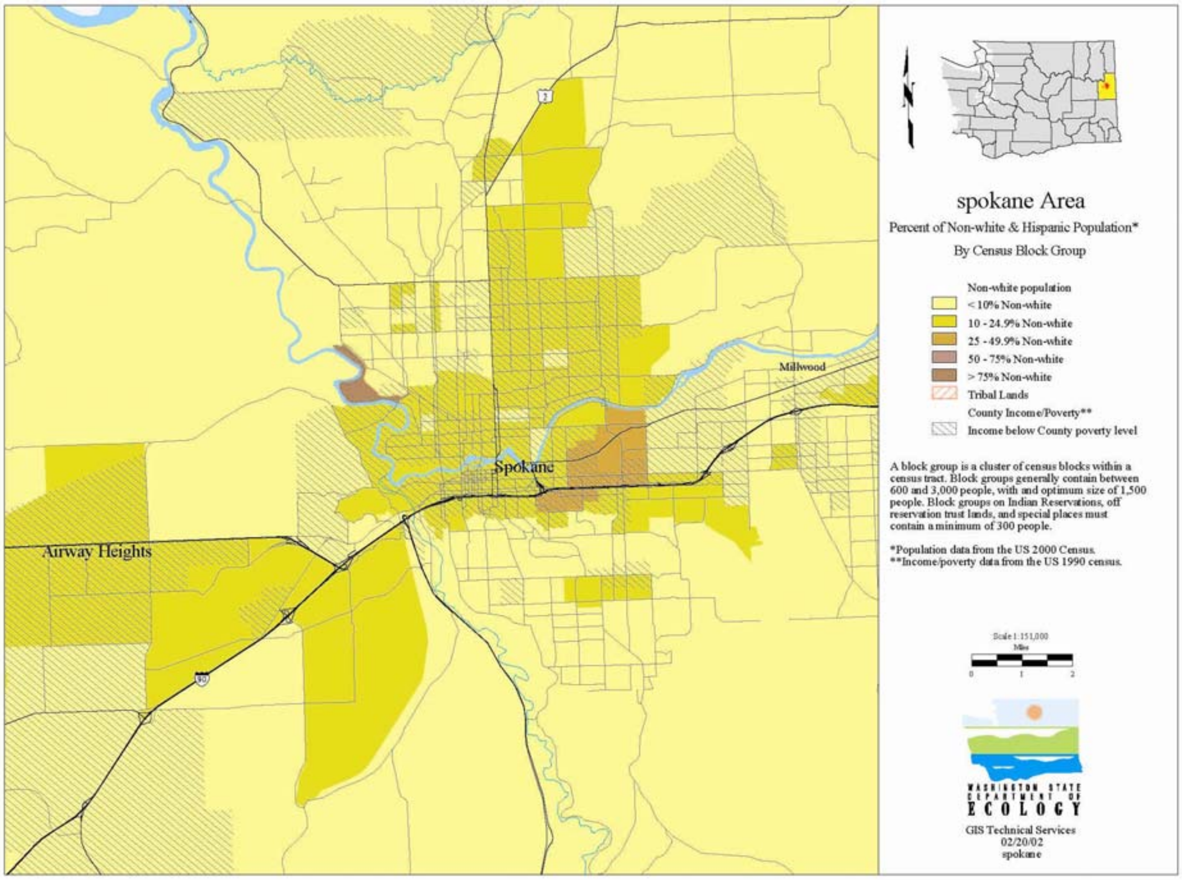
Consideration should also be given to areas that have higher background concentrations and/or expose the most densely populated areas; whether or not sensitive populations are present. Figure 7.3 shows the population density of Washington State. Population density information for Washington counties can be accessed at the Ecology's GIS internet webpage: (http://www.ecy.wa.gov/services/gis/maps/county/popden/popden-co.htm). Figure 7.4 shows the diesel $PM_{2.5}$ emission density on a 12 kilometer grid. Figure 7.5 shows the combined diesel health risk in Washington Counties based on estimated ambient diesel $PM_{2.5}$ concentrations. Combined health risk includes such health issues as premature death, heart attacks, asthma attacks, respiratory ailments, lost work days and restricted activity days. Figure 7.6 shows just the cancer cases per million attributable to diesel exhaust.

Using this basic approach we will target the major sources of diesel emissions in areas with the highest diesel emission density and having sensitive populations and areas of the highest general population density. For instance, in the Puget Sound and Spokane regions we would target heavy duty on-road vehicles and construction equipment. The major sources of emissions should also be targeted in other areas of high diesel emission and population density such as Olympia, Clark County (Vancouver), Longview-Kelso, Yakima, the Tri-Cities (Kennewick, Pasco and Richland), Bremerton, Mt. Vernon, Wenatchee, Asotin County (Clarkston) and Bellingham. Other areas that are smaller, but still contain densely populated neighborhoods include: Aberdeen, Centralia, Ellensburg, Moses Lake, Oak Harbor, Port Angeles, Pullman, Shelton and Walla Walla. Appendix B lists metropolitan and micropolitan statistical areas, dense urban areas and dense urban clusters. These lists may be used to identify cities and towns that are likely to have pockets of dense population.

[20] Source: Washington Department of Ecology Sustainability intranet webpage http://aww.ecology/programs/hwtr/Sustainability/EJ/EJ_Maps.htm

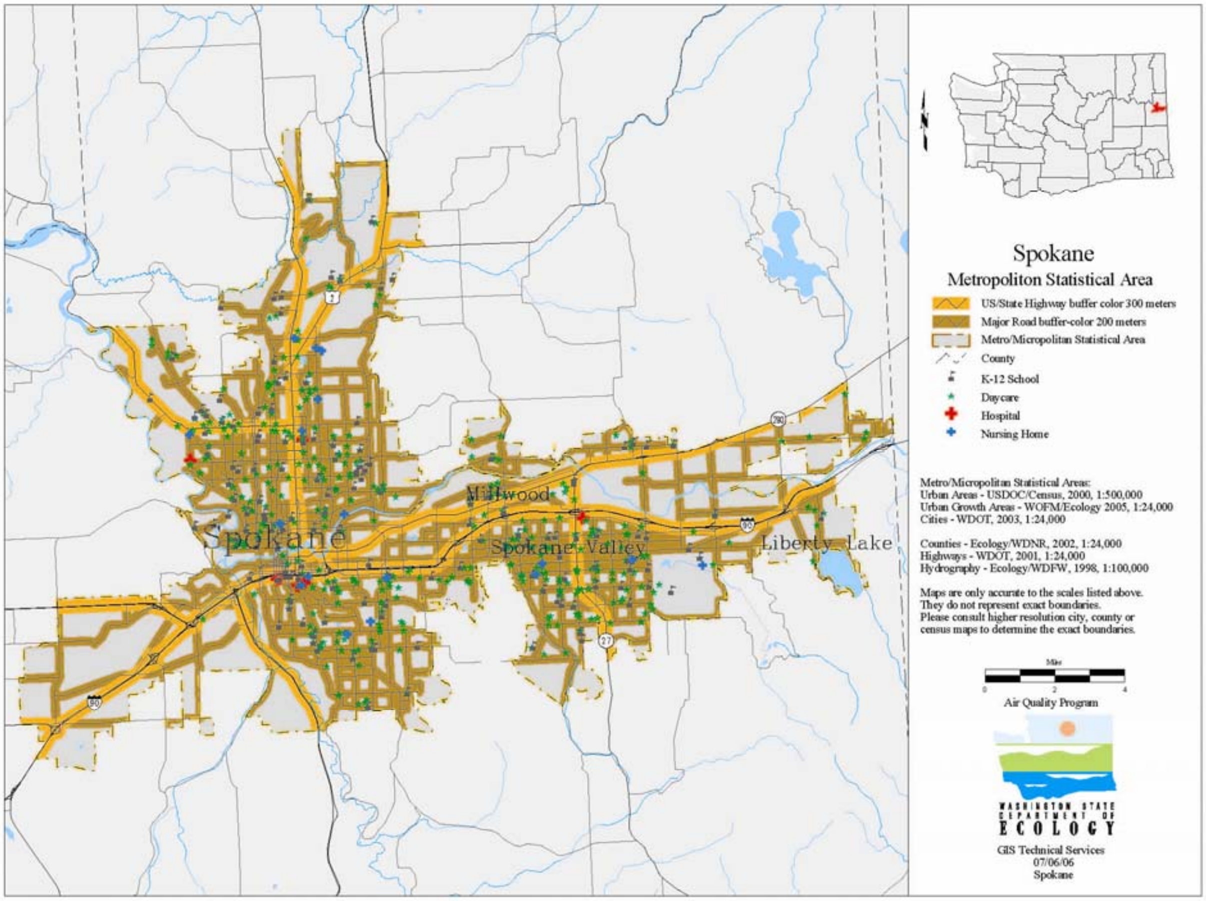
[21] Ecology GIS services conducted an analysis of populations within a 300 meter zone either side of the centerline of major highways and 200 meters of the centerline of major arterials within the boundaries of the metropolitan and micropolitan areas of Washington listed in appendix B. At the same time the location of K-12 schools, daycare centers, hospitals and nursing homes were identified and plotted.

Figure 7.1 – Environmental Justice Communities in the Spokane WA Area[22]



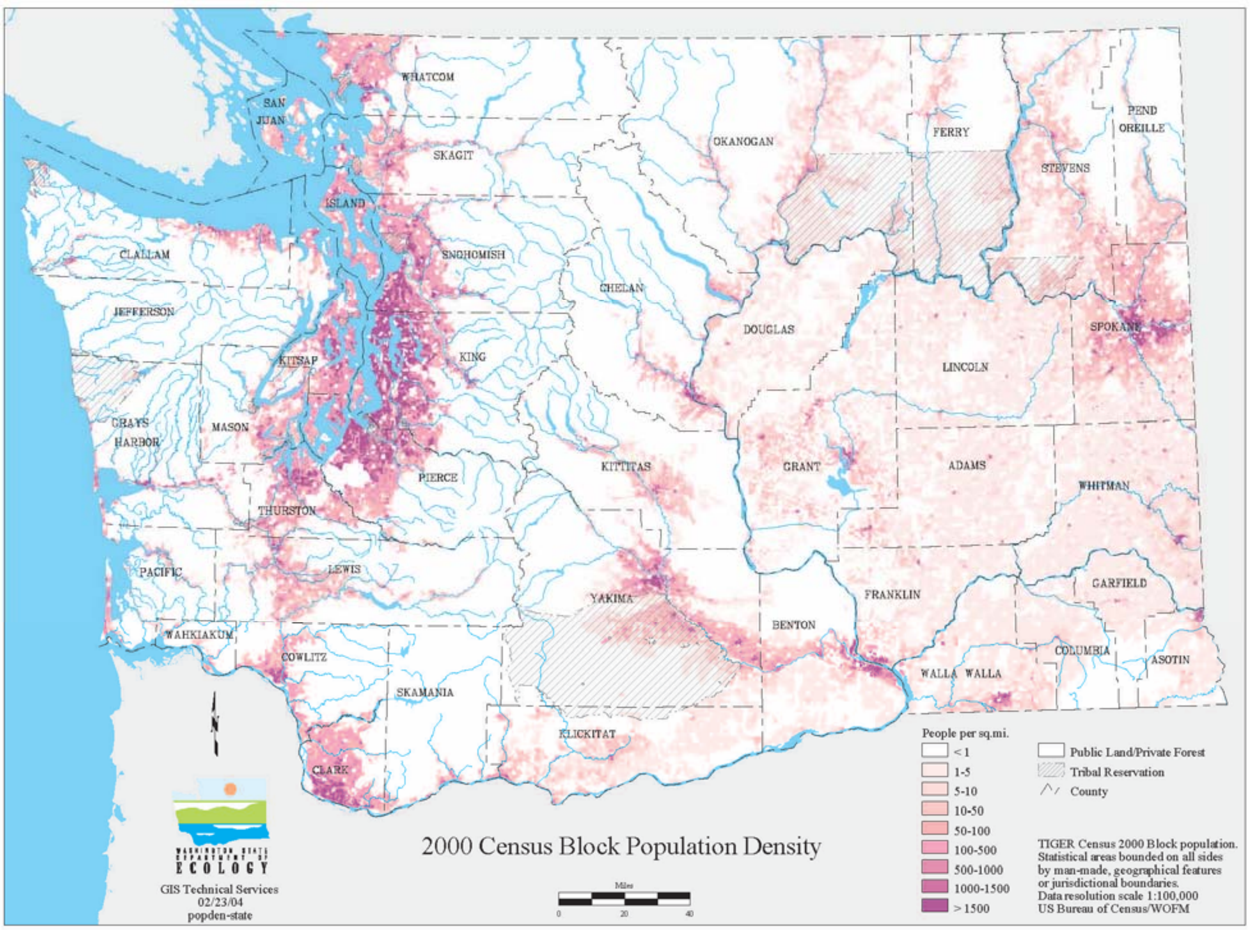
[22] Source: Washington State Department of Ecology Sustainability intranet webpage: http://aww.ecology/programs/hwtr/Sustainability/EJ/EJ_Maps.htm

Figure 7.2 – Schools, daycare centers, hospitals and nursing home locations relative to major transportation corridors in the Spokane area [23]



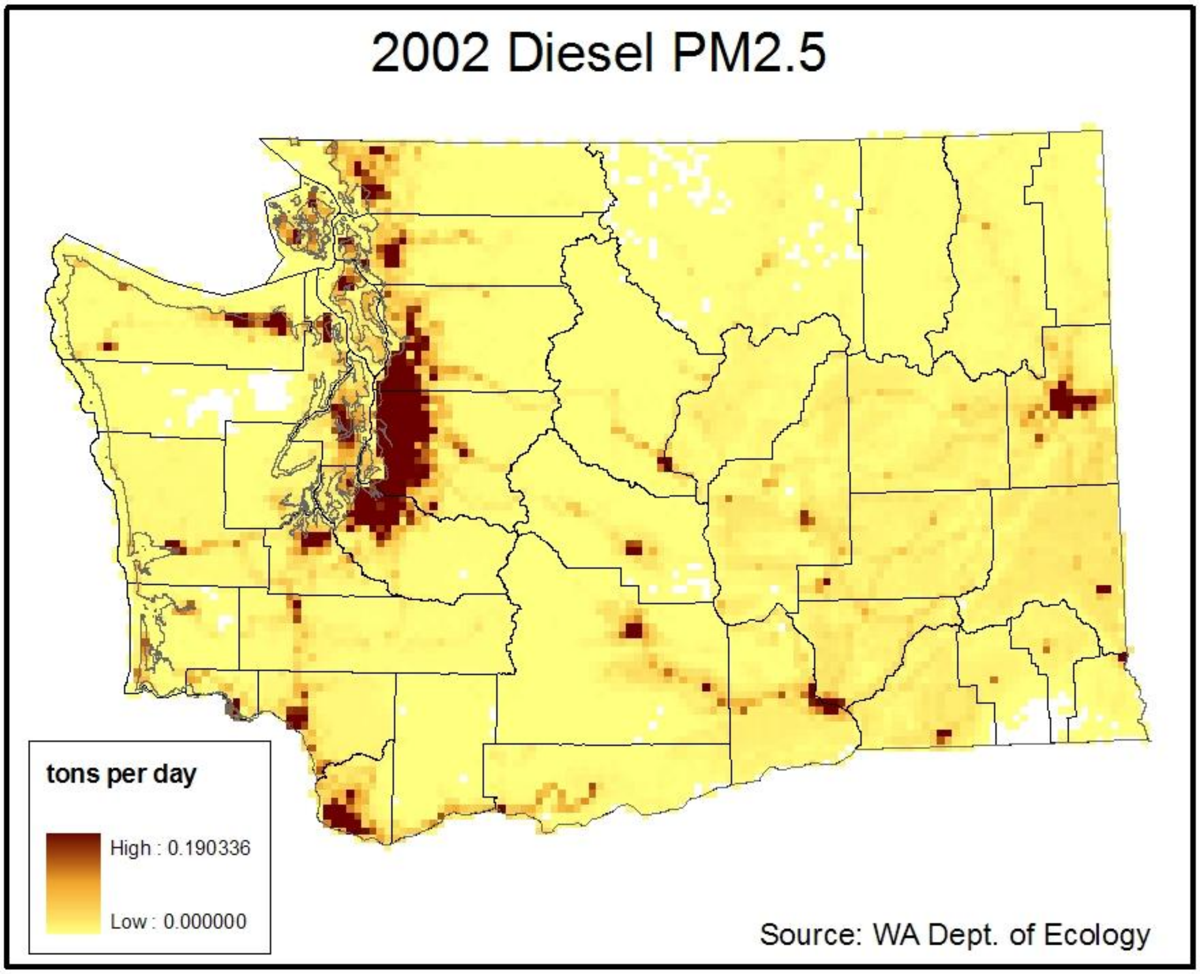
[23]Ecology GIS services conducted an analysis of populations within a 300 meter zone either side of the centerline of major highways and 200 meters of the centerline of major arterials within the boundaries of the metropolitan and micropolitan areas of Washington listed in appendix B. At the same time the location of K-12 schools, daycare centers, hospitals and nursing homes were identified and plotted.

Figure 7.3 – Population Density of Washington State – Census Year 2000.[24]



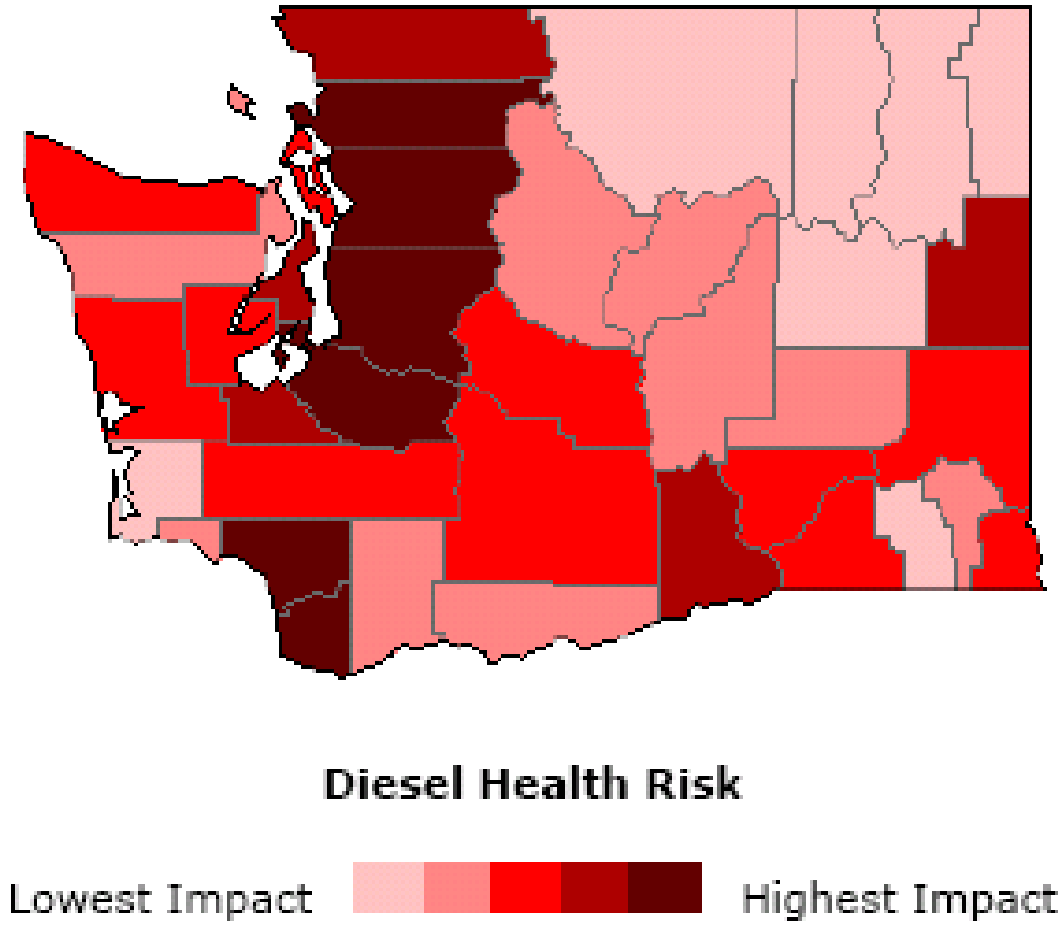
[24] Source: Washington State Department of Ecology GIS webpage, http://www.ecy.wa.gov/services/gis/maps/county/popden/popden-co.htm

Figure 7.4 – Diesel $PM_{2.5}$ Emission Density, 12 Km Grid – 2002[25]



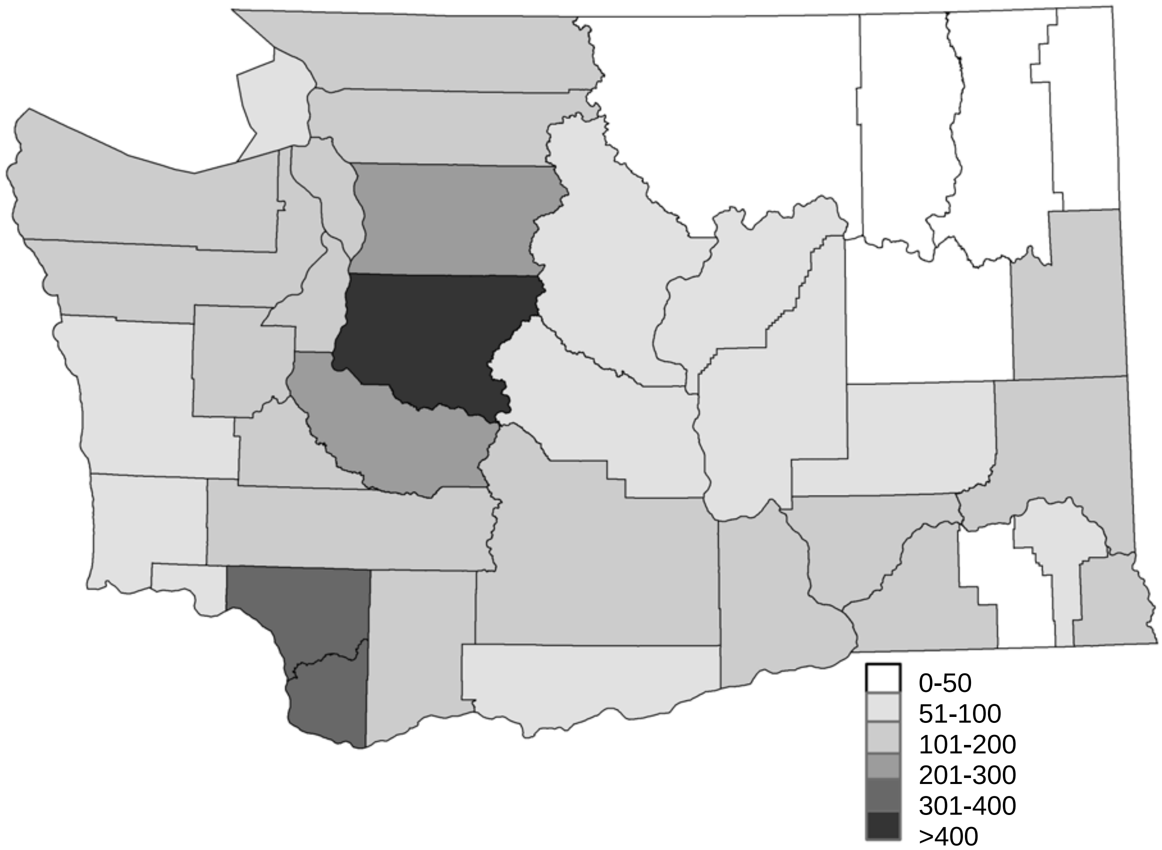
[25] Source: Washington State Department of Ecology, December 2006.

Figure 7.5 – Ranking Diesel $PM_{2.5}$ Health Risks in Washington Counties[26]



[26] Source: Diesel and Health in America, Clean Air Task Force, 2005. webpage: http://www.catf.us/projects/diesel/dieselhealth/

Figure 7.6 – Median Lifetime Diesel $PM_{2.5}$ Associated Cancer Risk (Cases per Million Persons) In Washington Counties[27]



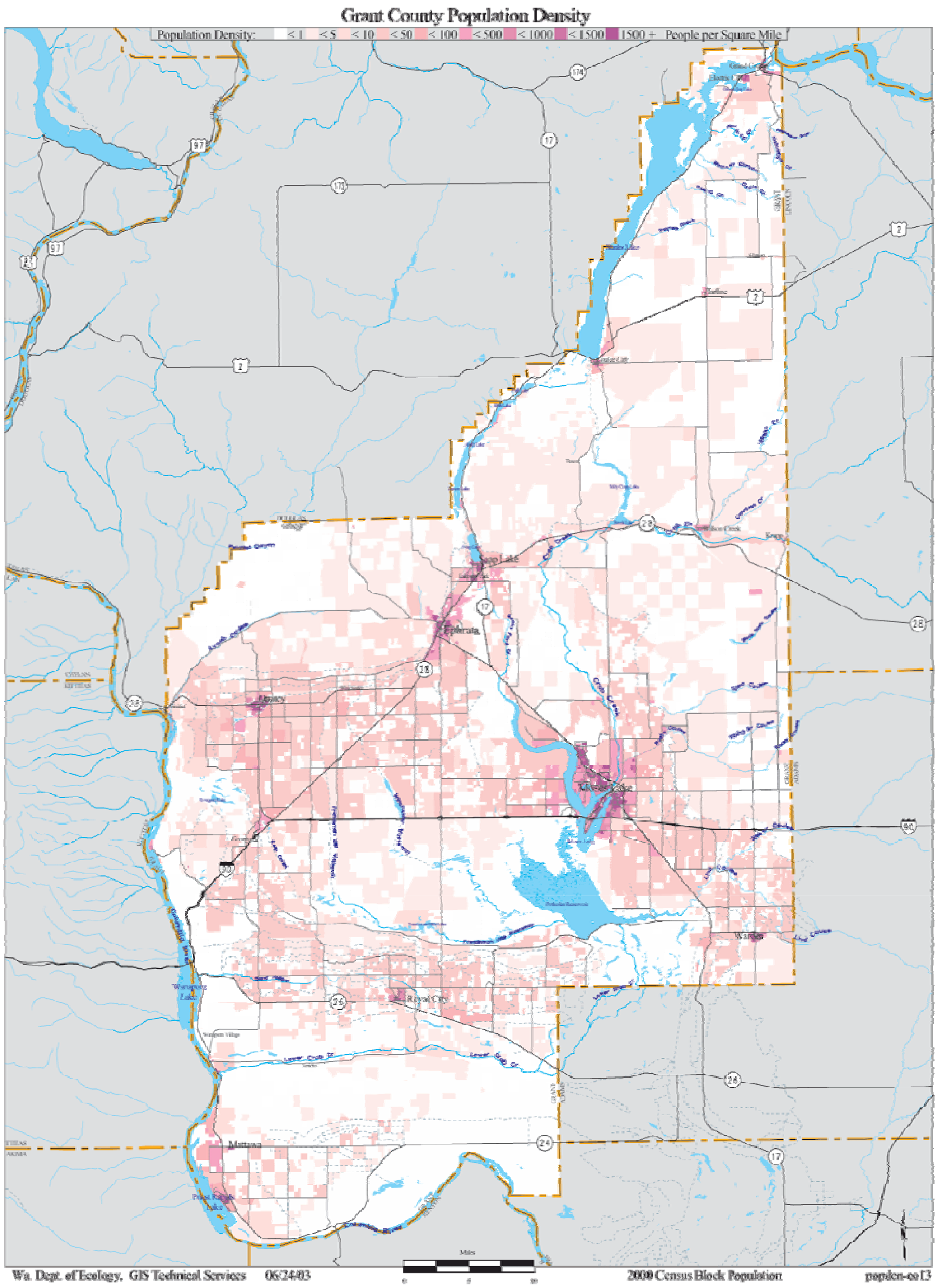
7.2 Case by Case Exceptions to Basic Approach

Although the overall population density of an area such as a city or county and the location of the dominant diesel sources with respect to sensitive populations and the general population is a good indicator of the degree of exposure and potential risk to human health from diesel emissions, there are many cases where small dense pockets of sensitive and general population in generally low density areas are exposed to diesel emissions. These areas may need attention with respect to exposure to diesel emissions from the major source categories or even smaller source categories. Under one scenario, an example might be a small community such as Quincy in Grant County (see figure 7.7), which has a busy truck stop adjacent to a residential neighborhood. Although the county as a whole has a low population density, a significant number of people in the neighborhood are exposed to the diesel coming from trucks idling

[27] Estimates for cancer risk were calculated by using the California Office of Environmental Health Hazard Assessment (OEHHA) diesel particulate matter cancer unit risk factor along with the USEPA's 1999 National-scale Air Toxics Assessment (NATA) population median exposure estimates for Washington state counties.

engines at the truck stop. Under another scenario, an example might be a large locomotive switchyard adjacent to an environmental justice neighborhood in the Puget Sound region. Although locomotives are a relatively smaller contributor to overall total diesel emissions in the Puget Sound region (only 3 percent of total diesel $PM_{2.5}$ emissions), the concentration of locomotives next to the neighborhood significantly raises the health threat to the neighborhood residents and raises the priority for emission reductions because the neighborhood falls under the environmental justice category.

Figure 7.7 – Population Density of Grant County – Census Year 2000[28]. Example of denser pockets of population in a generally rural, lightly populated county.



[28] Source: Washington State Department of Ecology GIS webpage, http://www.ecy.wa.gov/services/gis/maps/county/popden/popden-co.htm

8.0 Selecting Appropriate Control Technologies and Programs

There are several options with respect to control technologies for each of the major source categories of diesel $PM_{2.5}$. It is important that flexibility in selection of control technology is available to owners and operators of diesels as operational conditions, duty cycles, age of engine, and make and model of engine are all factors in selection of the most appropriate emission control devices. These technologies range in cost, cost effectiveness in removing diesel $PM_{2.5}$, maintenance cost, ease of use, durability, applicability to operational conditions and duty cycle, etc.

Programs to reduce diesel $PM_{2.5}$ are also specific to the type of source. Some of the more appropriate technologies and programs for each of the four largest source categories are listed below[29]. It should be noted that this list is not exhaustive and new technologies are arriving and existing technologies are being improved.

- **Heavy Duty On-Road Vehicles**
    - Exhaust after-treatments such as DOC's and DPF's.
    - Crank Case Ventilation systems.
    - Ultra-low sulfur diesel alone and in conjunction with DPF's.
    - Biodiesel.
    - Idling reduction technologies – APU's, TEP, ATSE, auto start/stop, battery packs, thermal storage, direct fired heaters.
    - Idling restrictions (voluntary and regulatory) combined with idling reduction technologies.
    - Add-on fuel efficiency technology – improved aerodynamics, light weight wheels, single wide tires, automatic tire inflation systems.

- **Construction Equipment**
    - Exhaust after-treatments such as DOC's and DPF's. DOC's may be more appropriate for the types of duty cycles and engine temperatures reached with construction equipment.
    - Crank Case Ventilation systems
    - Ultra-low sulfur diesel alone and in conjunction with DPF's.
    - Biodiesel.
    - Fuel/water emulsions (PuriNox).
    - Idling restrictions.
    - Voluntary emissions focused maintenance programs.

- **Marine Vessels**

[29] "Assessment of Potential Strategies to Reduce Emissions from Diesel Engines in Washington State", Kim Lyons, Ecology Publication 05-02-005, December 31, 2003

- Repower engine. Replace existing engine with new lower emission standard engine.
- Exhaust after-treatments such as DPF's and selective catalytic reduction (SCR).
- On-road low sulfur diesel or ultra-low sulfur diesel.
- Biodiesel.
- Fuel/water emulsions (PuriNox).
- Cold ironing.
- CCV systems – some marine vessels may already be equipped with CCV

- **Locomotives**
  - On-road low sulfur diesel or ultra-low sulfur diesel.
  - Auxiliary power units on switchyard locomotives.
  - Auto start/stop systems on switchyard locomotives during the warm season.
  - Diesel particulate filters.
  - Mandatory smoke testing or emission inspection programs.
  - Voluntary idle reduction of switchyard locomotives.
  - Engine rebuild or remanufacture.
  - Multi-truck engine generator sets that power a switchyard locomotive.

9.0 Headquarter and Regional Office Roles

In general, headquarters staff will coordinate the overall approach, provide a planning and technical support function, develop a funding strategy and will evaluate potential projects against the goals, objectives and criteria set forth in the Diesel Strategy. Both headquarter and regional office staff, working with local air agencies and other local governments and communities, will identify needs, develop project proposals and implement projects. A core diesel team, consisting of headquarters staff, will be responsible for evaluating potential projects that are submitted by other headquarter staff, regional staff and staff from local air agencies. Criteria for project evaluation are discussed in section 10.0.

Specific roles of headquarters and regional office staff are listed below. Roles may overlap at times and cross communication and cooperation between headquarter and regional staff is crucial to the successful implementation of the Diesel Strategy.

9.1 Ecology Headquarters

- Coordinate overall planning and related work within the scope of the Diesel Strategy.
- Identify diesel emission reduction needs and develop project proposals that meet the goals, objectives and criteria set forth in the Diesel Strategy.
- Identify federal and other funding opportunities and alert Ecology regional offices, local air agencies and others to these opportunities.
- Develop new state level funding sources and mechanisms for diesel emission reduction projects and programs.
- Evaluate project proposals with respect to the goals, objectives and criteria set forth in the Diesel Strategy. The core diesel team will select proposals. The Air Quality Program Leadership Team (AQPLT) will ratify selected proposals.

- Apply for federal or other grants to fund approved diesel emission reduction projects or provide assistance to others in preparing and applying for grants.
- Establish policy and guidelines as needed for the implementation of programs such as the school bus exhaust retrofit program and the local government grant program.
- Manage and implement approved and funded projects.
- Participate in national and regional level diesel emission reduction strategies and initiatives such as the National Clean Diesel Campaign, the West Coast Diesel Emission Reduction Collaborative and the West Coast Governors Initiative on Global Warming.
- Provide technical support and information on diesel emission exposure and risks, reduction technologies, fuels and programs.
- Report to program wide diesel team and AQPLT.

9.2 Ecology Regional Offices

- Work with other public agencies such as local air agencies, counties, cities and towns, ports, transit agencies, and tribes to identify needs and develop project proposals that meet the goals, objectives and criteria of the Diesel Strategy and the criteria associated with specific funding opportunities.
- Submit project proposals to the core team for evaluation.
- In coordination with headquarters, apply for federal and other grants to fund approved project proposals.
- Manage and implement approved diesel emission reduction projects or assist other public agencies in implementing projects consistent with HQ plans and policy.
- Report on specific project results.

9.3 Relationship with the Local Air Agencies

Local air agencies (LAA's) also have a strong interest in reducing the risk to human health resulting from diesel $PM_{2.5}$. Ecology headquarter and regional office staff will work with the LAA's to identify needs and projects and partner with the LAA's on projects that meet the goals, objectives and criteria of the Diesel Strategy. If the LAA's request assistance and/or resources from Ecology in support of a diesel emission reduction project in their jurisdiction, the proposed project will be evaluated by the core diesel team using the same evaluation criteria applied to Ecology proposed projects (described in section 10.0). Furthermore, if Ecology staff propose a project that is located in the geographic jurisdiction of an LAA, Ecology will coordinate with the LAA on the design and implementation of the project.

10.0 Diesel Emission Reduction Project Evaluation Criteria

In light of limited funding and staff resources, criteria are needed to help Air Quality Program staff and management solicit, develop, evaluate and select projects for reducing diesel $PM_{2.5}$ that meet the goals and objectives of the Diesel Strategy. Regional and headquarters staff will identify diesel emission reduction needs and develop project proposals to submit to the headquarters core evaluation team. The core evaluation team will use table 10.1 to evaluate and rate each project before submitting the project to the AQPLT for decision on whether to proceed. The core evaluation team may choose not to submit a project to AQPLT if the project does not meet the goals, objectives and criteria defined in the Diesel Strategy.

Table 10.1: Project Evaluation Criteria (for use by the core project evaluation team)

Criteria and Assigned Criteria Weight H = 3 M = 2 L = 1		**Relative rating of project's ability to meet the criteria** H = 3 M = 2 L = 1	**Comments**	**Total Score (Criteria's assigned weight times project's relative rating)**
1. Project benefits sensitive populations (including environmental justice neighborhoods)	High (3)			
2. Project impacts area with high population density	High (3)			
3. Project applies to a major source category (source is responsible for a relatively high contribution to total diesel PM)	Medium (2)			
4. Project is easy to administer (few staff resources needed and technically easy to implement)	Low (1)			
5. Project is cost effective ($/ton reduced)	Low (1)			
6. Other – examples might include: total tons reduced; demo or pilot project that would have statewide applicability; builds capacity, potential or infrastructure; has significant non AQ side benefits (like fuel savings).	Low (1) (no more than 3 other criteria may be claimed)			

<u>Givens:</u>

We have the authority to proceed with the project.
We have the staffing to proceed with the project.
Minimal hurdle of $50K investment is met, but exceptions to minimum may be granted on a case by case basis.
We have willing/adept participants.
The project falls within the scope of the AQP goals.

<u>Wants:</u>

The project leverages state/federal monies.
The project provides geographical parity.
The project provides data/measures of exposure.

11.0 Getting the Job Done

In section 3.1 we discussed tasks we believe need to be conducted to reduce emissions from the legacy diesel fleet. There are three broad ways to approach implementing those tasks and programs: education, incentives, and regulations. The most common approach to reducing legacy diesel emissions has been use of incentives in the form of grant funded projects to implement one or more of the technologies or programs described. Partly because of perceived limitations on the use of grant funds, most projects have focused on publicly owned diesel equipment such as school buses, transit buses, road maintenance equipment, and other publicly owned equipment.

Ecology expects to use grant funded and low cost loan projects as the primary means of implementing diesel emission reductions. Educational efforts will also be used where it can be effective to encourage idle reduction which brings a cost savings. Tax credit or tax reduction policies will be investigated and implemented where appropriate. Regulatory approaches may also be considered in situations where there are widespread benefits, where costs of compliance are reasonable and expected benefits exceed the costs.

Grant programs and low cost loans appear to be the best possibility for getting technological improvements installed, such as emission exhaust retrofits, and for being accepted by large numbers of fleet owners. The difficulty is lack of funding for grant or loan programs and constraints on the use of public funds on private fleets. To implement much larger technological improvement projects and programs, additional sources of money are needed.

11.1 Federal Funding

Federal funds for reducing diesel emissions have been a hit or miss opportunity. Previous funding opportunities have been limited in amount of funds available and had specific requirements and criteria that limited the types of sources, areas and technologies that would be eligible for the grant money. Often these criteria didn't match those criteria of state and local government. It was often difficult for a state or local government to make decisions on what grant opportunities to pursue, if grant eligibility requirements did not match those of the state and local decision makers. Furthermore, many of the federal grant opportunities required a percent matching (usually in the range of 30 to 50 percent) or gave preference when leveraging of other non-federal funds was included. In Washington State, acquiring non-federal matching funds for projects involving private sector fleets has been a particular difficulty because state funds available for matching have been earmarked only for public fleets such as school buses, public transit, state owned highway maintenance equipment, and local government vehicles. Most of the diesel fleets within the on-road heavy duty vehicle, construction, marine and locomotive sectors are owned by the private sector.

The new federal energy bill (EPAct) authorizes significant funds (not yet appropriated) for diesel emission reduction programs and projects for the next five years. Over the next five years this bill authorizes over 2.5 billion dollars towards programs that reduce diesel emissions through a variety of targeted sources and technologies. To mention a few: fuel cell buses, public fleet modernization, railroads, truck idling reduction, biodiesel, automobile efficiency, state procurement incentives, marine, nonroad engines, and other diesel engine retrofits. Much of these funds will require 50 percent matching funds from state, local, non-profit and private entities. The money will be administered by the U.S. Department of Energy, the Environmental Protection Agency and the National Highway Transportation and Safety Administration.

11.2 State Funding

Thus far, two sources of state funding have been used for diesel emission reductions in the public sector. Washington's legislature provided approximately $25 million over a five year period for retrofitting public diesel school buses with emission reducing devices and recently expanded the eligibility to other public non-school bus fleets. In addition, in 2005 the state legislature granted an additional $2 million from the Local Toxics Control Account to retrofit local government heavy duty diesel vehicles. Through this grant program, Ecology will focus on retrofitting transit vehicles, garbage trucks and maintenance-type dump trucks.

Even though a significant amount of funding is available through the State, it has been restricted for use on public fleets only. Because of language in the States' constitution prohibiting the use of public funds for private sector projects it has been assumed that private commercial fleets are not eligible recipients for state funds, even though a significant public benefit would be realized. This is discussed in more detail below. The perceived prohibition on the use of public funds has restricted Washington's ability to apply for federal funds to reduce emissions from private commercial fleets when matching or leveraging of non-federal funds is required or given preference.

11.3 Exceptions to the Prohibition against Giving Public Funds to the Private Sector

Washington State's constitution prohibits giving public funds or property to or in aid of any private interest. Because of this, programs developed by the state and local governments and supported by state funds have thus far only focused on diesel engines in public fleets. However, a very large contribution to total diesel emissions comes from diesel engines owned by the private sector. For instance, on a state wide basis the largest contributors to diesel $PM_{2.5}$ are (in descending order): on-road heavy duty diesel (i.e. the trucking industry), construction equipment, commercial marine, agriculture and locomotives. Fleets and equipment in these sectors are predominantly privately owned, (see figures 4.11 and 4.12). ***Without the ability to use state funds to support diesel emission reductions in the private sector we are unable to truly solve the problem.***

The recently passed federal Energy Bill (EPAct) authorizes (but not yet appropriated) significant funds for diesel emission reduction programs, a portion of which will go directly to states in the form of grants and loan programs. A portion of these grants will require non-federal matching funds in the order of fifty percent. Because staff have assumed the state cannot give public funds to the private sector, especially if the private interest realizes a benefit, they have been concerned that they will be limited in how much of the federal money they can leverage for any programs targeting the private sector.

General Counsel for the Puget Sound Clean Air Agency analyzed the provisions of the State constitution and case law related to this provision to determine if there were exceptions that might allow the legal use of public funds to purchase and install diesel emission reduction devices on legacy diesel vehicles owned by the private sector (specifically, funds from the School Bus Exhaust Retrofit Program). In analyzing cases decided by Washington courts it appears that courts apply one or more of three lines of inquiry to the challenged governmental program or activity. Counsel concluded that, with respect to diesel emission reduction devices purchased for the private sector, the line of inquiry that applies is if the activity is carrying out a fundamental government purpose. Counsel further concluded that the authority and responsibility given by the State's Clean Air Act clearly identifies reducing diesel emissions and air pollution in general as a fundamental purpose of the agency and brings broad benefit to a large portion of the population. Although payments made to a private interest may result in a benefit to that private interest, courts have found that the overriding public purpose makes any private benefit "incidental". Lastly, to lessen the risk of the activity being challenged under the constitution, counsel recommended considering imposing on private recipients of funds certain obligations related to the fundamental governmental purposes.

It should also be noted that these conclusions are supported by the Washington State Attorney General's Office.

Despite this legal analysis it appears many legislators are reluctant to approve the use of public funds on private fleets, especially if the private fleet realizes an economic benefit.

Appendix A

Health Effects Associated with Exposure to Diesel Exhaust

Exposure to diesel exhaust results in both immediate and long-term health effects. Human health effects associated with exposure to diesel emissions or diesel fine particles range from cardiopulmonary, immune, endocrine, developmental and reproductive effects to lung cancer, and cancers of the bladder and soft tissues (Sydbom et al. 2001; Selevan et al. 2000; Perera et al., 1999; IPCS (WHO) 1996; U.S. EPA 2000).

Association of Diesel Particles and Lung and Circulatory System Effects

Epidemiological studies have found associations with respiratory effects and lung function decrements in children living near roadways. The California Children's Health Study has found occurrence of new asthma cases, not only exacerbation of asthma in children exposed to particulate air pollution including diesel particulates, and with exposure to ozone which forms from the action of UV light on hydrocarbons (in part from diesel engine emissions) and nitrates formed in high temperature combustion, including that which occurs in diesel engines (Peters et al., 2004).

Studies of human exposed to diesel particles for short periods of time have shown increased airway responsiveness (Nordenhäll et al. 2001) and respiratory symptoms (Brauer et al., 2002; Rudell et al., 1996), markers of allergic response (Gavett and Koren 2001), markers of inflammation (Nordenhäll et al., 2000; Salvi et al., 1999; Salvi et al., 2000). Observed inflammation of the airways (Nightingale et al., 2000), enhancement of allergic response to other allergens such as dust mite and pollen (Fujieda et al., 1998; Svartengren et al., 2000; Fahy et al., 2000) and worsening of asthma (Pandya et al., 2002) have also been associated with exposure. Asthma attacks are more frequent and more severe and the disease progresses towards greater remodeling of the airways with increased exposure to diesel exhaust (Finkelman et al., 2004; Chalupa et al., 2004; Zmirou et al., 2004; Nicolai et al., 20033; Sénéchal et al. 2003).

Epidemiological studies of truckers, railroad employees, heavy equipment operators and other types of work that involves chronic exposure to DPM, and of members of the public, have found associations with chronic diseases, including lung cancer (Boffetta et al. 2001; Dawson and Alkexeeff 2001; Larkin et al., 2000; Nyberg et al. 2000; Saverin et al., 1999; Bruske-Hohlfeld et al. 2000; Steenland et al., 1998; Stayner et al., 1998; Bhatia et al., 1998; Jarvholm and Silverman 2003; Lippsett and Campleman, 1999), bladder and soft tissue cancers (Lee et al., 2003; Crosignani et al. 2004; Nyberg et al., 2000; Seidler et al. 1998; Zeegers et al. 2001), asthma and other chronic obstructive pulmonary diseases, and reproductive dysfunction****2000).

Association between Exposure to Diesel Exhaust and Cancers

In 1996 the International Programme on Chemical Safety (IPCS) stated that diesel exhaust was a probable human carcinogen and developed a unit risk number of 3.4 x 10^{-5} $\mu g/m^3$ (IPCS 1996). The U.S. EPA in its Health Assessment Document for Diesel Exhaust (DE) concludes in 2000 that “DE is likely to be carcinogenic to humans by inhalation at any exposure condition. This characterization is based on the totality of evidence from human, animal, and other supporting studies.” While EPA declined to publish a unit risk value based on uncertainty in the epidemiology literature in 2000, the Agency did describe a range of lifetime lung cancer risk from 1x 10^{-3} to 1 x10^{-5} from exposure to diesel exhaust (U.S. EPA. 2000).

The California Environmental Protection Agency (Cal EPA) Office of Environmental Health Hazard Assessment (OEHHA) completed a comprehensive health assessment of diesel exhaust in 1998 that formed the basis for a decision by the California Air Resources Board (CARB) to formally identify particles in diesel exhaust as a toxic air contaminant that may pose a threat to human health. The assessment included review of *in vitro*, animal experiments and more than 30 epidemiology studies, and performed an epidemiological meta-analysis of these studies to assess potential and actual human health effects from exposure to diesel exhaust. It established a reference concentration (RfC) of 5/$\mu g/m^3$ for chronic non-cancer health effects, and proposed a range of values for the upper confidence limits (UCL) for unit risk to be used for risk assessment. Washington Department of Ecology Air Quality Program agrees with CARB that 3 x $10^{-4}/\mu g/m^3$ (Froines 1998) is a reasonable estimate of unit risk to use for risk assessment of diesel particulate matter, and will use this in determining risk estimates.

CalEPA calculated the pooled relative risk values from a meta-analysis of twelve epidemiological studies which adjusted for smoking were 1.44 (95% C.I. 1.32-1.56) for the fixed effects model, and 1.43 (95% C.I. 1.31-1.57) for the random effects model (CalEPA 1998). These studies, however, did not have direct measurement of exposure.

Exposure for these twelve studies had to be reconstructed so that carcinogenic potency could be bracketed for a life time: a bracket of risk could be calculated that was comparable to results of the meta-analysis. The meta-analysis brackets cancer risks from exposures to 5 $\mu g/m^3$ to approximately 1.3 x 10^{-4} $(\mu g/m^3)^{-1}$ and for 500 $\mu g/m^3$ at 1.3 x 10^{-2} $(\mu g/m^3)^{-1}$.

OEHHA focused on two studies as being especially useful for developing a range of unit cancer risks for lung cancer. These are the nationwide studies of lung cancer risks for U.S. railroad workers. A case control study (Garshick et al., 1987) was used to determine the coefficient of the logistic relationship of the odds of lung cancer for the duration of the worker’s exposure to diesel exhaust. The other Garshick study (1988), a cohort study, was used to calculate a relative hazard of lung cancer for increasing duration of worker exposure, using a proportional hazards model. The case-control study had information on smoking rates, while the cohort study has a smaller confidence interval for the risk estimates. Larkin et al (2000) examined the extent to which smoking may have confounded the risk of the cohort study by developing adjustment factors based on the distribution of job-specific smoking rates. After considering differences in smoking rates between workers exposed and unexposed to diesel exhaust, the authors concluded that there were still elevated lung cancer risks attributable to diesel exposure among these workers.

Garshick (1991) concluded that because shop workers who had no exposure were included in the cohort, their presence in the study diluted the effect of diesel exhaust. . OHHEA therefore excluded them from their analysis for risk, as suggested by participants of the Diesel Exhaust

Workshop in January 1996. Exposure of other workers, specifically train workers are sufficiently low that their lung burden may be assumed to be proportional to atmospheric exposures. Exposure measures for 1982-83 by Woskie et al., (1988) show that the train workers considered in the analysis all experienced approximately the same average concentration of 50 $\mu g/m^3$, (rounded) which could be used for determining unit risk. Using fit and other characteristics of a number of forms of a general model, OEHHA determined that the model using linear and quadratic continuous covariates, age and calendar year was most satisfactory for calculating slope fort relative risk per year of exposure. This slope of 0.015 (95% CI: 0.0086-0.022)yr^{-1}, when divided by the intermittency correction (0.033) and the assumed constant concentration (e.g. 50 $\mu g/m^3$ for 29 years) and multiplied by attained age provides the excess relative hazard to determine the increase of lung cancer rates for the life table calculation of unit risk. Because the populations studied were healthy male workers, and it is not possible to quantify the risk to women, children or other more susceptible individuals, OEHHA uses the 95% upper confidence limit (UCL) on the slope of the dose-response curve in male workers. CARB has estimated the average annual ambient exposure of Californians to be 1.54 $\mu g/m^3$ diesel particulate, and multiplied this exposure concentration by the highest and lowest 95% UCL of cancer risk to estimate the number of excess cancer cases for every one million Californians over a 70-year lifetime. Ecology's Air Quality Program will apply a 3 X 10^{-4} Unit Risk from a smoking-adjusted pooled relative risk derived from OEHHA's meta-analysis of epidemiological data (Smith, 1998).

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Appendix B

Metropolitan Statistical Areas, Urban Areas and Urban Clusters of Washington State

Washington State Metropolitan Statistical Areas

Each metropolitan statistical area must have at least one urbanized area of 50,000 or more inhabitants.

Seattle-Tacoma-Olympia WA Combined Statistical Area

1. Bremerton-Silverdale, WA Metropolitan Statistical Area (Kitsap County)
2. Olympia, WA Metropolitan Statistical Area (Thurston County)
3. Seattle-Tacoma-Bellevue, WA Metropolitan Statistical Area
    a. Seattle-Bellevue-Everett, WA Metropolitan Division (King County, Snohomish County)
    b. Tacoma, WA Metropolitan Division (Pierce County)
    c. Oak Harbor, WA Micropolitan Statistical Area (Island County)
    d. Shelton, WA Micropolitan Statistical Area (Mason County
4. Bellingham, WA Metropolitan Statistical Area (Whatcom County)
5. Kennewick-Richland-Pasco, WA Metropolitan Statistical Area (Benton County, Franklin County)
6. Lewiston, ID-WA Metropolitan Statistical Area (Nez Perce County, ID, Asotin County)
7. Longview-Kelso, WA Metropolitan Statistical Area (Cowlitz County)
8. Mount Vernon-Anacortes, WA Metropolitan Statistical Area (Skagit County)
9. Portland-Vancouver-Beaverton, OR-WA Metropolitan Statistical Area (Columbia County, OR, Multnomah County, OR, Washington County, OR, Yamhill County, OR, Clark County WA, Skamania County, WA)
10. Spokane, WA Metropolitan Statistical Area (Spokane County)
11. Wenatchee, WA Metropolitan Statistical Area (Chelan County, Douglas County)
12. Yakima, WA Metropolitan Statistical Area (Yakima County)

Micropolitan Statistical Areas

Each Micropolitan statistical area must have at least one urban cluster of at least 10,000 but less than 50,000 population.

1. Aberdeen, WA Micropolitan Statistical Area (Grays Harbor County)
2. Centralia, WA Micropolitan Statistical Area (Lewis County)
3. Ellensburg, WA Micropolitan Statistical Area (Kittitas County)

4. Moses Lake, WA Micropolitan Statistical Area (Grant County)
5. Oak Harbor, WA Micropolitan Statistical Area (Island County)
6. Port Angeles, WA Micropolitan Statistical Area (Clallam County)
7. Pullman, WA Micropolitan Statistical Area (Whitman County)
8. Shelton, WA Micropolitan Statistical Area (Mason County
9. Walla Walla, WA Micropolitan Statistical Area (Walla Walla County)

Definitions:

The term "metropolitan area" was adopted in 1990 and referred collectively to metropolitan statistical areas (MSAs), consolidated metropolitan statistical areas (CMSAs), and primary metropolitan statistical areas (PMSAs). The term "core based statistical area" (CBSA) became effective in 2000 and refers collectively to metropolitan and Micropolitan statistical areas. The 2000 standards provide that:

- Each CBSA must contain at least one urban area of 10,000 or more population. Each metropolitan statistical area must have at least one urbanized area of 50,000 or more inhabitants. Each Micropolitan statistical area must have at least one urban cluster of at least 10,000 but less than 50,000 population.

The county (or counties) in which at least 50 percent of the population resides within urban areas of 10,000 or more population, or that contain at least 5,000 people residing within a single urban area of 10,000 or more population, is identified as a "central county" (counties). Additional "outlying counties" are included in the CBSA if they meet specified requirements of commuting to or from the central counties. Counties or equivalent entities form the geographic "building blocks" for metropolitan and Micropolitan Statistical areas throughout the United States and Puerto Rico.

If specified criteria are met, a metropolitan statistical area containing a single core with a population of 2.5 million or more may be subdivided to form smaller groupings of counties referred to as "metropolitan divisions."

As of June 6, 2000, there are 362 metropolitan statistical areas and 560 Micropolitan Statistical areas in the United States.

Source: 2003 Washington State Data Book, http://www.ofm.wa.gov/databook/population/pt05.htm, December 12, 2205

Source of data:
U.S. Bureau of the Census
Data site: http://www.census.gov/population/www/estimates/metroarea.html

Dense Urban Smaller Communities in Washington

County Name	Census 2000 64 Urban Cluster Population >2,5000 <50,000	Census 2000 19 Urban Area Population >50,000	2000 Census Urban Area Code	2000 Census Urban Area Type
Adams	Othello, WA		66268	Urban Cluster
Asotin		Lewiston, ID--WA	49312	Urban Area
Benton	Benton City, WA		07111	Urban Cluster
Benton	Grandview, WA		34381	Urban Cluster
Benton		Kennewick--Richland, WA	44479	Urban Area
Benton	Prosser, WA		72451	Urban Cluster
Chelan	Cashmere, WA		14455	Urban Cluster
Chelan	Chelan, WA		15913	Urban Cluster
Chelan		Wenatchee, WA	93862	Urban Area
Clallam	Forks, WA		30412	Urban Cluster
Clallam	Port Angeles, WA		70939	Urban Cluster
Clallam	Sequim, WA		80686	Urban Cluster
Clark		Portland, OR--WA	71317	Urban Area
Clark	Woodland, WA		97021	Urban Cluster
Columbia	Dayton, WA		22609	Urban Cluster
Cowlitz		Longview, WA--OR	51283	Urban Area
Cowlitz	Woodland, WA		97021	Urban Cluster
Douglas		Wenatchee, WA	93862	Urban Area
Franklin	Connell, WA		19666	Urban Cluster
Franklin		Kennewick--Richland, WA	44479	Urban Area
Grant	Ephrata, WA		27739	Urban Cluster
Grant	Mattawa, WA		55522	Urban Cluster
Grant	Moses Lake, WA		59518	Urban Cluster
Grant	Quincy, WA		73072	Urban Cluster
Grays Harbor	Aberdeen, WA		00172	Urban Cluster
Grays Harbor	Elma, WA		27091	Urban Cluster
Grays Harbor	Montesano, WA		58465	Urban Cluster
Grays Harbor	Ocean Shores, WA		64675	Urban Cluster
Island	Camano West, WA		12727	Urban Cluster
Island	Camano, WA		12700	Urban Cluster
Island	Oak Harbor, WA		64378	Urban Cluster
Jefferson	Port Hadlock-Irondale, WA		71128	Urban Cluster
Jefferson	Port Townsend, WA		71560	Urban Cluster

County Name	Census 2000 64 Urban Cluster Population >2,5000 <50,000	Census 2000 19 Urban Area Population >50,000	2000 Census Urban Area Code	2000 Census Urban Area Type
King	North Bend, WA		63514	Urban Cluster
King		Seattle, WA	80389	Urban Area
Kitsap		Bremerton, WA	09946	Urban Area
Kitsap	Indianola, WA		41293	Urban Cluster
Kitsap		Seattle, WA	80389	Urban Area
Kittitas	Cle Elum, WA		17560	Urban Cluster
Kittitas	Ellensburg, WA		26983	Urban Cluster
Klickitat	City of The Dalles, OR--WA		17020	Urban Cluster
Klickitat	Goldendale, WA		33787	Urban Cluster
Klickitat	Hood River, OR--WA		39916	Urban Cluster
Lewis	Centralia, WA		15076	Urban Cluster
Mason	Shelton, WA		81415	Urban Cluster
Okanogan	Omak, WA		65296	Urban Cluster
Pacific	Long Beach, WA		51148	Urban Cluster
Pacific	Ocean Park, WA		64648	Urban Cluster
Pacific	Raymond, WA		73585	Urban Cluster
Pierce		Seattle, WA	80389	Urban Area
Pierce	Yelm, WA		97642	Urban Cluster
Skagit	Anacortes, WA		02224	Urban Cluster
Skagit	La Conner, WA		45883	Urban Cluster
Skagit		Mount Vernon, WA	60490	Urban Area
Snohomish	Lake Goodwin, WA		46720	Urban Cluster
Snohomish		Marysville, WA	55333	Urban Area
Snohomish		Seattle, WA	80389	Urban Area
Snohomish	Stanwood, WA		84385	Urban Cluster
Snohomish	Sultan, WA		85573	Urban Cluster
Spokane	Airway Heights, WA		00685	Urban Cluster
Spokane	Cheney, WA		15967	Urban Cluster
Spokane	Deer Park, WA		22852	Urban Cluster
Spokane		Spokane, WA--ID	83764	Urban Area
Stevens	Colville, WA		19369	Urban Cluster
Stevens	Nine Mile Falls, WA		63271	Urban Cluster
Thurston	Centralia, WA		15076	Urban Cluster
Thurston		Olympia--Lacey, WA	65242	Urban Area
Thurston	Yelm, WA		97642	Urban Cluster
Walla Walla		Kennewick--Richland, WA	44479	Urban Area

County Name	Census 2000 64 Urban Cluster Population >2,5000 <50,000	Census 2000 19 Urban Area Population >50,000	2000 Census Urban Area Code	2000 Census Urban Area Type
Walla Walla	Walla Walla, WA		91405	Urban Cluster
Whatcom		Bellingham, WA	06652	Urban Area
Whatcom	Birch Bay, WA		07759	Urban Cluster
Whatcom	Blaine, WA		08110	Urban Cluster
Whatcom	Everson, WA		28468	Urban Cluster
Whatcom	Ferndale, WA		29629	Urban Cluster
Whatcom	Lynden, WA		52228	Urban Cluster
Whitman	Colfax, WA		18721	Urban Cluster
Whitman	Pullman, WA		72748	Urban Cluster
Yakima	Grandview, WA		34381	Urban Cluster
Yakima	Sunnyside, WA		85789	Urban Cluster
Yakima	Toppenish, WA		88111	Urban Cluster
Yakima	Wapato, WA		91702	Urban Cluster
Yakima		Yakima, WA	97507	Urban Area

Urban and Rural Classification

Urban - All territory, population and housing units in urban areas, which include urbanized areas and Urban Clusters. An urban area generally consists of a large central place and adjacent densely settled census blocks that together have a total population of at least 2,500 (and less than 50,000) for Urban Clusters, or at least 50,000 for urbanized areas. Urban classification cuts across other hierarchies and can be in metropolitan or non-metropolitan areas.

Rural - Territory, population and housing units not classified as urban. Rural classification cuts across other hierarchies and can be in metropolitan or non-metropolitan areas.

For Census 2000, the Census Bureau classifies as "urban" all territory, population, and housing units located within an urbanized area (UA) or an Urban Cluster (UC). It delineates UA and UC boundaries to encompass densely settled territory, which consists of:

- core census block groups or blocks that have a population density of at least 1,000 people per square mile and
- surrounding census blocks that have an overall density of at least 500 people per square mile.

In addition, under certain conditions, less densely settled territory may be part of each UA or UC.

Data Source: http://www.ofm.wa.gov/pop/smallarea/; http://www.census.gov/geo/www/ua/frmay102.pdf; http://www.census.gov/geo/www/ua/ua_2k.html; retrieved 1/11/06