King County Fleet Conversion Plan
Summary

In November 2001, The King County Council requested the Executive to prepare a cost-benefit analysis of converting a portion of King County's transit fleet to ultra-low sulfur diesel (ULSD). Staff in the Department of Transportation has prepared this response to the Council's request.

Air pollution represents a serious public health issue in the Pacific Northwest. The Seattle Times recently wrote that "despite the Seattle area's damp, marine and mountain environment, unreleased test results for the first time show air toxics — primarily diesel exhaust — may be boosting cancer risks 700 times above EPA standards. That puts our air in the worst 5 percent in the country"[1]

King County's dirty air is in part caused by very small diesel particulates, less than 2.5 microns in size. **Trucks, buses, vessels, and non-mobile sources all contribute to these pollutants. King County's fleet of transit buses are a contributor to the region's particulate problems. Reducing emissions from these buses has been a priority of Metro as evidenced by Metro's conversion to low sulfur diesel in 1993.** In 2001, in response to significant air quality concerns, King County Executive Ron Sims proposed retrofitting existing diesel buses with particulate filters and using ULSD fuel to reduce particulate emissions.

In the past it has been difficult to make a cost benefit comparison of regulating air pollution emissions with human health impacts of no regulation. The University of Washington has developed a tool, the Fast Environmental Evaluation Tool (FERET) to calculate the health impacts and the cost benefits of various changes in air quality. It is a tool that is used to provide a good assessment of regulatory actions. In this analysis, benefits are composed of two discrete amounts. First, they include the benefits that occur prior to fuel conversion (in this case < 2005). Second, benefits include the additional benefits of mufflers (over just fuel conversion) which occurs after 2005 when the fuel conversion occurs.

The costs of retrofitting buses include muffler replacement and additional fuel costs. Based on an evaluation of the current Metro fleet, 367 buses would be converted with mufflers. All buses would operate on ULSD. The cost of this action is composed of the muffler price, $1.8 million, and the additional fuel cost of $1.4 million per year for 2002 – 2004, based on current fuel prices, for a total cost in 2002 of 4.8 million. The costs of not retrofitting buses is measured in human health costs including premature death, asthma, chronic bronchitis, hospitalizations, restricted activity and lost work days. Using the FERET tool, these impacts are valued in monetary terms at approximately $5.1 million. In addition to the direct benefits of the Metro action, other benefits may accrue to the region due to the early adoption of this technology by other diesel users. The conversion of the Metro fleet is likely to lower the fuel price making the technology more attractive to other users. Should this occur, the estimated benefits would be larger.

[1] Seattle Times, May 5, 2002, http://seattlepi.nwsource.com/opinion/69340_envired.shtml

An alternative to retrofitting buses for particulates is using the cost of the retrofit, or $5 million, to add additional bus service. If additional service is added air quality benefits would be realized by eliminating automobile trips. Private automobiles are not a source of particulates since they burn gasoline. However, cars do emit Nitrous Oxides (NOx) which is a contributor to air pollution. In the Puget Sound area NOx is not a pollutant of concern. Using the FERET model, only very small change in health impacts can be attributed to reductions in NOx from the diverted car trips. In addition to examining these benefits, the current monetary value, as calculated from publicly traded values, of the reduced NOx is about 15% of the monetary value of particulates.

Finally, as noted in the proviso, we considered the no-action scenario. As defined in this exercise, there are no benefits and no costs associated with that scenario. All results here are compared to that scenario.

FERET indicates the following public health benefits:

Public Health Benefits of ULSD Retrofit 2002$			
	Baseline Incidence	Change in Cases	PV Value
Mortality	0.0130135	0.11	$4,825,586
Chronic Bronchitis (CB)	0.0518	0.13	$118,019
Chronic Asthma (CA)	0.0462	0.00	$0
Restricted Activity and Work Loss Days			
1. WLDs-work loss days	3.122	14.60	$10,370
2. MRADs-minor respiratory restricted	2.438	686.36	$196,439
3. RAD-Restricted Activity Day	5.947	42.82	$0
All Other			$7,194.19
Total Benefits			$5,157,608

The benefits of the proposal ($5.1 million) exceed the costs ($4.8 million) by nearly $333,000 dollars for the base case in 2002.

Department of Transportation Response to Budget Proviso

Air pollution represents a serious public health issue in the Pacific Northwest. The Seattle Times recently wrote that "despite the Seattle area's damp, marine and mountain environment, unreleased test results for the first time show air toxics — primarily diesel exhaust — may be boosting cancer risks 700 times above EPA standards. That puts our air in the worst 5 percent in the country"[2]. King County's dirty air is in part caused by very small diesel particulates, less than 2.5 microns in size. In 2001, King County Executive Ron Sims proposed retrofitting existing diesel buses with particulate filters and using ULSD fuel to reduce particulate emissions.

Hearings were held during the fall of 2001 concerning the proposal and the budgetary impacts to the Transit Division. During final adoption of the Transit Budget, the Council inserted the following proviso into the budget:

No further expenditures shall be made to retrofit the King County Metro Transit bus fleet for operation on ultra-low sulfur diesel fuel until the executive has submitted a fleet conversion plan and the council has approved it by motion. The plan shall address the costs and benefits of the conversion as well as the consequences of choosing instead to proceed with the conversion according to the federally-established timetable…

Council debate around this proviso centered on member concern about the cost of the retrofit and additional fuel cost compared to the cost of providing additional bus service. Then-Councilmember Fimia noted that additional service might reduce automotive emissions more than diesel particulate emissions and produce greater benefits.

This memo provides the response to that proviso. It uses the tool of cost benefit to evaluate the proposed use of ULSD fuel, and associated vehicle modifications, as compared with other actions that could be pursued to reduce particulate emissions and improve air quality in the Puget Sound region. Because of identified Council concerns, this analysis will evaluate these two options: ULSD compared to additional bus service.

Cost benefit analysis is widely used in evaluating whether a proposed action increases public welfare. The fundamental purpose of the analysis is to enable decision-makers to select the alternative which produces the greatest net benefit. Generally, cost benefit encourages the selection of projects where benefits exceed costs. Cost effectiveness is related but indicates which action, from a set of actions, produces the result at least cost; i.e. the money is spent to achieve the benefit most effectively.

Background

Heavy-duty vehicle emissions have been a cause of concern for many years. Diesel engines contribute to air quality problems and cause serious public health problems, particularly in urban

[2] Seattle Times, May 5, 2002, http://seattlepi.nwsource.com/opinion/69340_envired.shtml

areas. In December 2000, the Environmental Protection Agency issued regulations restricting particulate emissions from diesel cars and trucks beginning with the 2007 model year. Refiners will be required to start producing ULSD fuel for highway vehicles with a sulfur content of no more than 15 parts per millions (ppm) beginning June 1, 2006.

The primary benefit from the EPA action is improved public health. There are small additional benefits from reduced fuel consumption. The EPA "finds that diesel exhaust is likely to be carcinogenic to humans by inhalation at occupational and environmental exposure levels. Similar conclusions have been reached by the International Agency for Research on Cancer, the World Health Organization, the U.S. Department of Health and Human Services National Toxicology Program, the National Institute for Occupational Safety and Health, and the California Office of Environmental Health Hazard Assessment"[3]. A recent study in the Journal of the American Medical Association concludes that people living in the most heavily polluted metropolitan areas have a 12 percent increased risk of dying of lung cancer than people in the least polluted areas[4]. The California Air Resource Board estimates that cancer risks associated with PM emissions are 500 cases per million population. In the South Coast Air Basin, the potential risk associated with diesel PM emissions are estimated to be 1000 per million population.[5]

According to the Puget Sound Clean Air Agency, implementing an "aggressive" ULSD in the region would result in health benefits of a reduction of 30-34 deaths, 69 cases of acute bronchitis, and 21 cases of chronic bronchitis, 1522 cases of respiratory symptoms in asthmatic children, and 5,872 lost workdays on an annual basis.[6]

Proposed Action: The proposal is to retrofit 367 Metro transit buses with catalyst based particulate filters and to consume ultra low sulfur diesel fuel. These filters have been shown to reduce particulate emissions by 85-97%[7].

Study Methodology

This study examines the direct costs to Metro Transit of installing particulate filters and the added fuel costs of burning ULSD fuel in all Metro buses. Discounting is used to account for the installation over time of the filters and the extended duration of the benefits. The discount rate for these costs and benefits is 5.5%, the County's current cost of money. This analysis has not considered the role of Metro as a "market leader" who may create markets for ULSD fuel. Metro's actions may increase the supply of fuel and/or drive down the price for the fuel or the filters thus increasing local acceptance and cumulatively reducing particulate emissions further. These effects are speculative and are not considered.

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[3] Napolitano, Sam "Diesel Exhaust: Health, Environmental, and Economic Effects: An Overview"
[4] Washington Post, "Study Ties Pollution, Risk of Lung Cancer", March 6, 2002
[5] Risk Reduction Plan to reduce particulate matter emissions from diesel fueled engines and vehicles, California Air Resources Board, October 2000, page 1 Cancer risk is defined as "The theoretical probability of contracting cancer when exposed for a lifetime..." See appendix 1.
[6] PSCAA Agency, 3/30/01
[7] Risk Reduction Plan to reduce particulate matter emissions from diesel fueled engines and vehicles, California Air Resources Board, October 2000, page 19

No adjustments have been made in the discounting process for project risk. The technology associated with the mufflers is well known and the cost estimates are deemed accurate. Risk associated with the benefits is not incorporated as benefit estimates are wide ranging and this analysis presents a range of monetary estimates rather than a single point estimate.

Cost Estimation

The costs for retrofitting buses to use ULSD includes the cost of filters and the costs of using higher priced fuel. The cost of filters is estimated at approximately $5,131 per bus including the cost of installation.

ULSD fuel currently is sold at a higher price than traditional diesel. Prices for diesel fuel in the Northwest are very difficult to forecast as they are subject to refinery capacity and local and world market conditions. Currently refiners in northern Washington do not have the technology to produce this fuel and would require additional investments to produce sufficient quantities for King County Metro use.

Recently, Golden Gate Transit issued a RFP to procure ULSD. This resulted in a five-cent premium for ULSD because of the high volume of purchases. The market continues to evolve and it is expected that the fuel price differential will diminish and that it will be effectively eliminated in 2006 when current fuels are no longer sold. In estimating costs for fuel in the future, the price differential has been forecast to decline from the current 16 cents (in 2002) and 10 cents in future years. Because Metro's plans to convert to using ULSD in the entire bus fleet after 2004, the differential has not been considered after 2004 (nor have the reduced emission benefits for non-converted buses).

The cost for the immediate installation of the filters and conversion of the bases to ultra-low sulfur diesel has a present value of $4.8 million with a 2002 cash need of $3.3 million. The actual schedule of installation will depend on the availability of labor, delivery schedule for the mufflers, and fuel availability.

King County will receive some grant funds to offset this conversion. The Puget Sound Clean Agency has received a $250,000 grant and has recently applied for a $500,000 grant; both of which would be transferred to King County if granted.

Summary of Cost Estimates

The discounted value of the costs, in 2002 dollars, is as follows:

Muffler Costs: $1.89 million
Fuel Costs $3.0 million

Total project costs (2002): $4.8 million

Benefit Estimation

Benefits are traditionally included in cost benefit analysis in a number of manners. First, they can be quantified in monetary terms. Second, they can be expressed in some non-monetary units, which are in turn used to compare actions. For example, if measure X saves Y lives, it is preferred to a similar cost investment which saves less than Y lives.

In calculating the benefits, the FERET tool developed by the Center for the Study and Improvement of Regulation at Carnegie Mellon and the University of Washington was used.

> FERET is a template to produce a benefit-cost and impact statement on the basis of a regulatory design to reduce air pollution or accidents. FERET has several sections and databases: a health section, whose purpose is to estimate the change in disease incidence from a change in baseline air pollutant concentration, and an economics section, whose purpose is to value the benefits of reducing disease. In both sections, quantitative databases of the research literature are provided. FERET then estimates the health impacts, the present value of benefits, costs, net benefits and provides access to diagnostic and reporting capabilities.

For this analysis, staff estimated the number of individuals who would be exposed to particulate matter, the current pollutant concentrations in the region and future concentrations with the conversion of 367 buses to ULSD. The model then evaluated the health impacts of the proposed change and the mortality and morbidity consequences of the change. The model then used a sampling of the economic and health studies to provide monetary values for the impacts.

The model outputs are contained in the following table:

Present Value Benefit (millions)	**5.16**
Present Value Costs (millions)	**4.81**
Net Present Value = (millions)	**0.35**

The model outputs indicate that the estimated benefits of the proposal exceed $5.1 million and that the costs, in 2002, are $4.8 million. As such, the benefits exceed the costs by over $333,000 and the proposal should be accepted. This does not include any grant fund received by the County. In the appendix, other methods of evaluating the proposal were evaluated all of which produced net benefits.

Added Service Option

In conformance with the proviso, this analysis evaluated the costs and benefits of implementing an additional $5 million in service hours. The benefit of the additional service is reduction in vehicle trips. Using service data from Metro, the generous assumption that new service attracted all new riders, and vehicle emissions data from California, a comparable amount of service reduced NOx by about ten tons. In Puget Sound, NOx is not an emittant of concern[8]. Furthermore, the amount of prevented NOx is about 1/6 as much as the particulate matter which is reduced. The current market prices for these two emittants is about equal (approximately $40,000 per ton) and as such the proposal which reduces particulates by six times the quantity should be preferred. For this reason, we have not modeled the added service scenario in FERET.

Finally, the no action scenario represents neither benefits or costs. The other options evaluated above only represent changes from that action (i.e. they do not consider fuel benefits > 2005). Retrofit benefits are considered after 2005 as that benefit would not have occurred without action.

Conclusion

The reduction of diesel particulates resulting from the proposal to convert 367 buses to ULSD fuel provides very significant public health benefits. According the FERET model, the value of emissions reductions exceeds the proposed costs by over $.3 million. The alternative action of increasing service hours produces a much smaller public health benefit. The proposed action is the most cost-effective measure which Metro can take to improve air quality.

Using EPA and peer reviewed mortality and morbidity estimates, the proposed action meets the cost-benefit test.

This analysis has not considered other benefits of the low sulfur plan. These include higher visibility, better smelling air, and health benefits (lost workdays, etc.). It has also not considered the role of King County as a "market leader". There is significant evidence that if King County implements this proposal, other consumers of diesel fuel will purchase the new fuel. This action will further reduce particulate emissions and regionwide mortality and morbidity.

[8] According to 1998 data, the total quantity of NOx emitted in King, Kitsap, Snohomish and Pierce counties is 161,000 tons per year. The proposed reduction is approximately 10 tons. The comparative figure for PM2.5 is 3055 tons for the region with a reduction of 57 tons. Adding additional service makes no significant alternation in NOx concentrations whereas a reduction in PM2.5 makes a significantly larger contribution.

Appendix: Calculation of emittants

ULSD Particulate emissions

The EPA's regulations to reduce diesel exhaust take effect in 2006. The new standards are estimated to reduce diesel particulate emissions by nearly 90% and to reduce NOx emissions as well[9]. Beginning in June 1, 2006, refiners will be required to start producing diesel fuel with no more than 15 parts per millions sulfur content. Terminals will be required to sell this fuel by July 15, 2006 while retail stations must meet the standard by September 1, 2006. Flexibility is provided to refiners in that up to 20 percent of highway diesel may meet old standards but it must be segregated in the distribution system and may only be used for pre-2007 model year heavy vehicles.

Conventional diesel emissions are approximately .46 grams per mile[10]. Installation of the particulate filters reduces these emissions by 90% (see above). Each bus is assumed to travel 30,000 miles per year and have a lifespan from the present of 10 years. This produces a total reduction, per bus, of .01369 tons.[11]

Auto emissions from additional service

During discussions in King County Council it was suggested that additional service would provide greater environmental benefits. These benefits result from removing single occupant vehicles from the roadway. In this analysis we have made several simplifying assumptions in modeling the emissions from expanded service. These assumptions are:

- New riders board at the same frequency and travel the same distance as existing riders.
- The expanded service attracts only new riders. Clearly this assumption dramatically overstates the benefits but it provides a benchmark from which to measure the maximum gains from additional service.
- New service costs the same as existing service and there are no additional capital costs associated with new service.

These assumptions were used to calculate the total number of vehicles removed from the road and the distance traveled by those vehicles.

Emission factors for removed vehicles were calculated from statewide values in California, as provided by the EMFAC model developed by the California Air Resource Board. This model is widely used to model emissions coefficients and includes a large number of modeling equations

[9] Page 3, EPA Regulatory Announcement, "Heavy Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur control requirements", December 2000.

[10] Figure 3.2, Hybrid Electric Drive Heavy Duty Vehicle Testing Project, Final Emissions Report, Feb 2000, page 16, and Appendix A, Table A.2, page A-2, NovaBus RTS Diesel Series 50

[11] To check this estimation, the regionwide estimate from the Puget Sound Clean Air Agency was consulted. The Clean Air Agency estimates that regionally 86,000 vehicles produce 3,055 tons of PM2.5 emissions. Thus on average, each vehicle produces .03 tons per year. This number is larger than the estimated emissions because King County buses are cleaner than the average diesel vehicle. Using the average value, 369 buses which were retrofit would reduce emittants by 11.79 tons per year, or 118 tons over 10 years. This differs by about twice compared to the estimated values of METRO buses.

and assumptions. This model, along with the EPA's MOBILE model, are the two leading tools to model vehicle emissions. Although a number of problems have been noted with these models, such as improving data on the driving profile, number of cold and hot stars, time and location of starts, and other factors, the data from this model was deemed appropriate for this analysis[12].

The California data was used to estimate the quantities of pollutants which would be removed from King County air if additional service were provided. The total number of miles traveled and gasoline consumption (based on PSRC data) was used to estimate the reduced emissions. For simplicity, all vehicle trips were assumed in light duty passenger automobiles[13].

Comparison of emission benefits

The following table provides the estimated reductions in the emissions based on these assumptions described above:

Total Reduction (tons)		
	Nox	PM2.5
Added Bus Service	10.35	0.39
Muffler conversion benefit	0.00	42.66
Fuel conversion benefit		7.09
Total ULSD benefit		49.75

This table indicates that the ULSD reduces about five times more particulate emissions than does the added bus service. However, to compare the two emissions, a comparative scale is necessary. This is discussed in the next section which discusses traded values of emissions.

Non-FERET methods of computing the monetary comparison of benefits and costs:

In addition to evaluating and using the FERET tool, we also examined using publicly traded values for NOx and particulates. These values differ dramatically depending on the location of the market, the attainment level of the area, and local policy.

Monetary value of emissions credits

Emissions credits are publicly traded in financial markets. The web site emissionstrading.com provides current prices for 21 areas within the United States. In many areas, only a few types of emissions are priced, such as NOx and Volative Organic Compounds (VOC) whereas other areas have prices for many emissions. The range of prices for a permanent reduction in NOx and PM10 is from over $6,000 per ton to over $40,000 per ton. The most interesting aspect of the

[12] See page 7 and page 26 ff, "Quantifying Air Quality and Other Benefits and Costs of Transportation Control Measures", National Cooperative Highway Research Program, 2001, for a discussion of model improvements.

[13] The California data will understate the benefits of removing vehicles as automobiles in California are cleaner than those in Washington State. Benefits will also be understated since the passenger fleet consists of many vehicles classes, such as sport utility vehicles, which produce higher emissions. However, as will be demonstrated in the results, these differences do not change the conclusions of this analysis.

prices displayed are that these two materials are generally priced within 10% to 20% of each other.

In some jurisdictions NOx is more valuable while PM10 is more valuable in other areas. The following table presents traded prices for permanent reductions in prices as of March 28, 2002.

Emission's Trading Prices for Nox and PM10		
	Nox	PM10
California Bay Area Quality Management District	$ 32,500	$ 40,000
South Coast Air Quality Management District	$ 16,809	$ 19,126
San Joaquin Valley Unified Pollution Control	$ 33,000	$ 23,000
Salt Lake City	$ 6,300	$ 6,300
Source: emissionstrading.com 28-Mar-02		

There are far fewer prices for discrete emissions reductions. A discrete reduction, unlike the prices above, is for a one-time reduction in an emittant. According to Christine Grandstaff, of Cantor Fitzgerald, the general price for PM10 is $5,000 per discrete ton.

The Minnesota Public Utility Commission recently reaffirmed its prices for pollutants[14]. This analysis updated values generated within the last decade. However, this ruling did not update prices for NOx and other emissions. For comparative purposes these emissions are contained in this table as well. The Commission used the framework of four geographic regions for prices: urban, metropolitan fringe, rural, and within 200 miles of Minnesota. The table below provides the prices assigned in this 2001 ruling:

Minnesota Externality Values				
	$/ton			
	Urban	Metropolitan Fringe	Rural	Within 200 miles of Minnesota
2001 Ruling				
CO2	.3-3.10	.30 – 3.10	.3-3.10	.3-3.10
PM2.5	4,462-6,423	1,987-2,886	562-855	562-855
1997 Ruling				
PM10	4,462-6,423	1,987-2,886	562-855	562-855
CO ($/ton)	1.06-2.27	.76-1.34	.21-.41	.21-.41
NOx	371-978	140-266	18-102	18-102
CO2	.3-3.10	.30 – 3.10	.3-3.10	0

[14] Order Updating Externality Values and Authority Comment Periods on CO2, PM2.5, and Application of Externality values to Power Purchases, Minnesota Public Utilities Commission, May 3, 2001

The values from Minnesota indicate that values have not changed significantly between 1997 and 2001. It also indicates that PM2.5 and PM10 are worth significantly more than NOx emissions, by four times in the 1997 ruling.

The publicly traded values reflect the control costs; they do not represent valuation of health impacts. As FERET demonstrates, these health benefits are significantly higher than control costs.

FERET Monetary valuation of health benefits

The FERET model was used to evaluate the monetary benefits of emissions reductions. This model uses a Monte Carlo approach to selecting mortality values. In the model the estimated value of a life is approximately $5 million based on an extensive literature review. The model selects randomly from the literature to select a different mortality value for each session. The projected impacts of the proposed action reduce approximately 1 life and as such the projected valuation is somewhat less than $5 million.