Transportation Strategies to Improve Air Quality

Researchers:

Thomas D Schuster   **Megan Schuster**
Abhijit Banerjee   **Anisha Shankar**

Supervised by:

John Byrne, Director
Leigh Glover, Policy Fellow

Center for Energy and Environmental Policy
University of Delaware

July 2004

Table of Contents

List of Tables

List of Figures

Forward

On behalf of the Center for Energy and Environmental Policy, I hereby submit this report under the Science, Engineering and Technology Services Program to the Delaware General Assembly. Delaware suffers from problems of degraded air quality and of particular importance are periodic episodes of ozone concentrations that exceed the National Ambient Air Quality Standard. Ozone pollution is harmful to human health and the natural environment, and can be detrimental to the state's economy. Although much of the state's ozone problem is caused by other states, at least part of the State's high ozone concentrations results from social and economic activities within the state. Emissions from Delaware's transport sector are the state's major contributor to the ozone problem. This report describes and analyzes a range of transport policy measures that could be undertaken in Delaware to reduce the severity of its ozone pollution.

As part of the research, data collection, data analysis and interpretation conducted for this project, the CEEP research team received advice and assistance from many individuals, and state and federal agencies and their employees. These include: Professor Arde Faghri, Director, Delaware Center for Transportation, University of Delaware; Phil Wheeler, Delaware Department of Natural Resources and Environmental Control; Terry Barton, Jr., Delaware Fleet Services; Mark A. McNulty, Delaware Department of Transportation; Charlie Smisson, Delaware Energy Office; Daniel Blevins, WILMAPCO; and Ann Lyon, Delaware Insurance Department. We thank them for their assistance. We are also grateful to Drs. Cynthia Stahl and Alan Cimorelli (EPA), Dr. John DeCicco (Environmental Trust), and Therese Langer (American Council for an Energy-Efficient Economy), for their advice.

I trust this report will assist policymakers and decisionmakers in the state in their deliberations over this issue and will serve as a source of information for citizens, planners and community organizations, all of whom have a vital role to play in this complex issue.

John Byrne
Director

EXECUTIVE SUMMARY

1. Overview

All three Delaware counties, particularly New Castle and Kent, experience ozone concentrations that exceed national air quality standards. Pollutants that form ozone are primarily emitted from transportation sources. In this report, we examine a number of transportation strategies with potential to reduce these emissions. We estimate the amount of emissions reductions that could occur in 2010 if Delaware implements these policies. Using these estimates, we employ computer air quality models to determine the effect that these emissions reductions would have on future ozone concentrations in Delaware.

2. Air Quality

In passing the Clean Air Act (CAA) in 1970 and amending it in 1990, Congress recognized the importance of controlling the negative health and environmental effects of air pollution (see Table ES-1 for common terms). The CAA established National Ambient Air Quality Standards (NAAQS), for six major pollutants. These criteria pollutants are indicators of overall air quality. The most important of these to Delaware is tropospheric ozone (O_3), a major component of smog, as it is the only criteria pollutant for which Delaware does not currently meet the NAAQS standard. All three Delaware counties are in violation (or non-attainment) of the NAAQS for ozone, especially New Castle and Kent Counties, which are in "severe" non-attainment (US EPA 2002a).

High levels of ozone can be dangerous to humans, particularly children and the elderly. Ozone can cause shortness of breath, dry cough or pain when taking deep breaths, tightness in the chest, wheezing and nausea. Ozone aggravates asthma and other respiratory illnesses like pneumonia and bronchitis (Allen

> **Table ES-1. Definitions of Common Terms Related to Air Quality.**
>
> **NAAQS** (National Ambient Air Quality Standards) are the allowable concentrations of criteria pollutants in a geographic area for a specified time.
>
> **Criteria pollutants** include Ozone (O_3), Particulate matter (PM), Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2), and Lead (Pb). The allowable levels for these pollutants represent the National Ambient Air Quality Standards (NAAQS).
>
> **Non-attainment** designates a geographic area with concentrations of one or more criteria pollutants that exceed levels allowed by the NAAQS.
>
> **Area sources** are locations where air pollutants are emitted from a well-defined area in which there are several sources (e.g., agricultural areas sprayed with herbicides).
>
> **Mobile sources** are emitters of air pollutants that move from place to place (e.g., cars).
>
> **Point sources** emit pollutants from one or more controllable sites (e.g., smokestacks).
>
> **Stationary sources** include both area and point sources.
>
> Source: Botkin and Keller (1995)

2002). Ozone also reduces the productivity of plants, which causes hundreds of millions of dollars worth of crop losses annually, and impacts visibility (US EPA 2002b).

Ozone is formed by a chemical reaction of oxides of nitrogen (NO_x) and volatile organic compounds (VOCs, often called hydrocarbons) (Friedrich and Reis 2000). This reaction is dependent on light and heat, so ozone concentrations are highest on hot summer days. Emissions of NO_x and VOCs (known as ozone precursors) come from point sources (such as power plants and factories), area sources (collections of smaller stationary sources), and biogenic (natural) sources. However, the largest source type for ozone precursors is mobile sources. For this reason, this report focuses on policies relating to the transportation sector in an effort to improve air quality.

3. Transportation Policies to Improve Air Quality

There are three contributing factors to transportation emissions: 1) number of vehicle miles traveled (VMT); 2) gallons of fuel per VMT (or fuel efficiency); and 3) emissions per gallon of fuel (or fuel quality). The relationship between these factors is presented in the following identity (from Difiglio and Fulton 2000):

$$\text{Vehicle emissions} = \text{VMT} \times \text{emissions/gal} \times \text{gal/VMT}$$

This identity demonstrates that policies aimed at controlling one or two of the emissions factors will not be successful if the uncontrolled factors continue to rise; policies must control all three factors at once. For example, policies aimed at controlling emissions on a per vehicle basis have been quite successful, but NO_x emissions continue to rise as increasing VMT negates efficiency gains. Because of this effect, we review state or local level policy options that address all three key areas: VMT, fuel quality, and efficiency. A summary of these policies is presented in Table ES-1.

Policies to Reduce VMT

Nationwide, VMT has increased at an average rate of 3% per year since 1970 (Davis and Diegel 2002). Delaware VMT has grown at an even faster rate. From 1980 to 2001, VMT increased by 103%, which is an annual increase of nearly 4.7% (DELDOT 2002). We examined two types of strategies to help control VMT: employer-based transportation demand management strategies (TDMs), and mileage-based vehicle insurance.

Employer-based TDMs: TDM is a general term for strategies that result in more efficient use of transportation resources (VTPI 2003). TDMs that involve employers can be especially effective, because the worst road congestion occurs when most people commute to and from work (see Table ES-2). Governments can work with employers, who in turn work with

Table ES-2. Examples of Employer-based TDMs.	
Type	**Examples**
Financial incentives	Parking cash-outs
	Transit fare
Site improvements	Preferential parking
	Bike racks, lockers, showers
Support programs	Ride-matching
	Transit information
Alternative scheduling	Telecommuting
	Compressed work week
	Staggered hours

their employees to reduce the number of trips they take to work in a single-occupancy vehicle.

Mileage-Based Vehicle Insurance: Motor vehicle insurance can be linked to VMT, and used to provide an incentive to reduce vehicle use. Vehicle insurance typically amounts to 18% of the internal costs of vehicle ownership (Litman 1997). It is one of the largest fixed costs of vehicle ownership, i.e., it does not vary substantially with VMT. Insurance rates could be determined on a cents/mile basis, rather than a dollar/vehicle-year basis. These rates would then be multiplied by VMT to determine the premium. This approach would provide financial incentive for drivers to reduce their VMT, and in turn, reduce their emissions and accident risk. State governments and insurance regulators can provide financial incentives and remove regulatory barriers to encourage insurers to offer this type of insurance plan.

Policies to Promote Clean Fuels
Alternative fuels, defined as any transportation fuels that are not petroleum-based, can be an important means of reducing air pollution from road transport. Although most alternative fuels offer some environmental (e.g. reduction of greenhouse gases) and/or economic (e.g. domestic fuels) advantages over gasoline and diesel, not all boast substantial reductions in emissions of ozone precursors (see Table ES-3). Natural gas is the cleanest available alternative fuel. Compressed natural gas (CNG) emits fewer ozone precursors than propane (LPG), ethanol (E85) (see Table ES-3), methanol (Guthrie et al 1997), and biodiesel (US EPA 2002c).

Table ES-3. Results from EPA Federal Test Procedure.			
		Emissions	
Vehicle Type	**Alt. fuel**	**NO$_x$**	**VOC**
3/4 ton pickup	CNG	-81%	-99%
Compact sedan	CNG	-69%	-96%
3/4 ton pickup	Bi (CNG)	-34%	-67%
3/4 ton pickup	bi (LPG)	96%	160%
Minivan	bi (E85)	29%	23%
Full size sedan	bi (E85)	33%	0%
Shaded numbers are increased emissions compared to gasoline.			
			Source: NREL (1999)

Natural gas is well suited to relatively large fleets of centrally fueled vehicles. Transit operators are converting a large number of buses to natural gas (Eudy 2002). A number of states have also taken measures to encourage its use in personal light duty vehicles.

Policies to Promote Vehicle Efficiency

Fuel efficiency can play a very important role in reducing emissions as well. In the late 1970s, after passage of the federal Corporate Average Fuel Economy (CAFE) standards, efficiency rose so quickly that it more than offset rapidly increasing VMT and reduced overall fuel consumption (Figure ES-1). However, federal efforts to increase fuel efficiency in the past 15 years have stagnated, and various states have attempted their own policy initiatives in this area.

Figure ES-1. Effect of Fuel Efficiency on Total Highway Energy Consumption, 1975-2000.

Source: Davis & Diegel (2002)
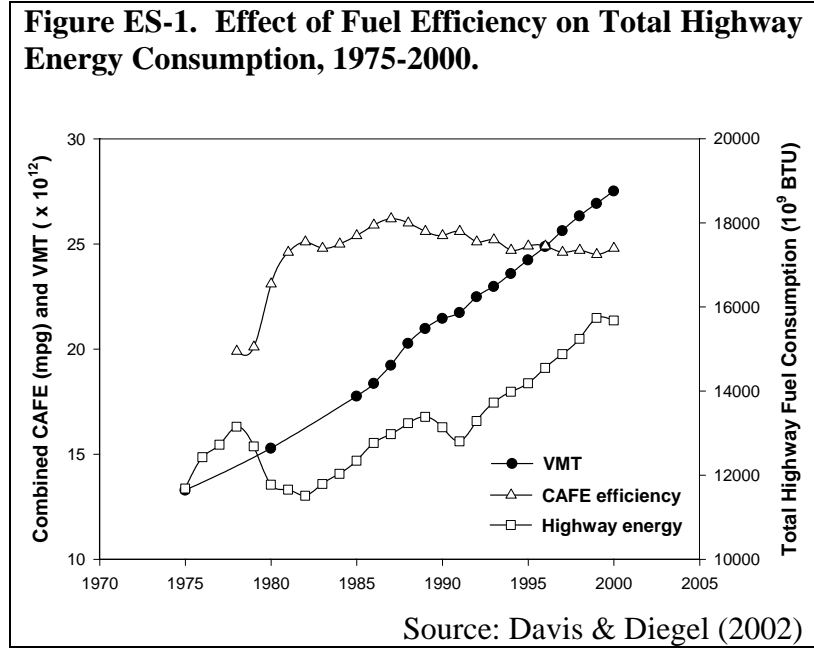
Feebates: Since CAFE prevents states from setting their own fuel efficiency standards, state efforts typically involve financial incentives. An example is the "feebate", which combines a cash rebate for purchase of vehicles of above average efficiency, with a fee for purchase of a "gas guzzler". Such incentives based on fuel efficiency have been attempted, but as yet, not successfully implemented.

Accelerated Vehicle Retirement: Another method of improving efficiency is to remove old, less efficient vehicles from the road. As engines wear, or are not properly maintained, they burn fuel less efficiently. Emissions control devices, such as catalytic converters, often do not function properly in older vehicles. These older vehicles contribute substantially to total on-road mobile emissions. It is estimated that 10% of the vehicle fleet can contribute up to 50% for a given criteria pollutant (US DOT 2002). Accelerated vehicle retirement (or "scrapping") programs offer a bounty for these inefficient vehicles and take them off the road. These programs have prematurely retired thousands of highly polluting vehicles in several states, including Delaware.

4. Emissions Reductions and Recommendations for Delaware

The transportation strategies outlined above, if implemented in Delaware, have the potential to reduce on-road NO_x emissions by nearly 10%, and VOC emissions by 14.5% by 2010 (Table ES-4). The strategies include a

Table ES-4. Summary of Transportation Strategies and Emissions Reductions for 2010.

Strategy	NO_x reduction (tons/day)	VOC reduction (tons/day)	% NO_x red.	% VOC red.
Empl. TDMs	1.31	0.61	2.78	2.99
MBI	2.14	1.47	4.54	7.15
CNG	1.17	0.46	2.47	2.22
AVR	0.03	0.44	0.06	2.14
Total	**4.65**	**2.98**	**9.85**	**14.50**

comprehensive employer-based TDM program, promotion of mileage-based vehicle insurance, increased use of CNG in buses and light-duty vehicles, and a short-term accelerated vehicle retirement program.

Employer TDMs

We estimate that a comprehensive, state-sponsored employer-based TDM program in Delaware could reduce emissions of NO_x and VOC by 2.78% and 2.99% respectively. This estimate was derived using EPA's COMMUTER model. Specific programs included in this estimate are: financial incentives (including incentives for transit use, car/vanpooling, and disincentives for parking), site improvements (including bicycle amenities and preferential parking for high occupancy vehicles), support programs (which provide information on alternative transportation), and alternative scheduling (which eliminates some commute trips and shifts other off-peak).

The Transportation Management Association of Delaware (TMA Delaware) is a collective of private employers and state agencies that facilitates some of these programs, but membership is voluntary, and there are no performance expectations. TMA Delaware assists employers in developing commuter choice programs, which are specially tailored to the employers' needs. It also facilitates a ridesharing program, and guarantees emergency rides home for carpoolers. TMA Delaware also provides literature on transit options.

Based on experiences in other states, and in order to achieve further emissions reductions from employer TDMs, we suggest that the following strategies be considered:

- ***Set targets for VMT or SOV reduction.*** These targets could be mandatory (with penalties for noncompliance), or optional (with sufficient incentives to encourage high participation rates).
- ***Allow flexibility of programs, but require documentation of success.*** Different TDMs will work better for different employers, so documentation of how targets are being met is important.
- ***Expand collaboration between public and private sectors.*** In successful programs, governments have worked with participating employers to find the best solutions, and have effectively communicated benefits to employers and the public.
- ***Target transit improvements to compliment the employer TDM program.*** New bus routes could be added or existing routes improved specifically to serve employers committed to achieving VMT reduction targets.

Mileage-based Insurance

If all Delaware motorists had the option of purchasing mileage-based insurance, we estimate that NO_x and VOC would be reduced 4.54% and 5.65%. This assumes that all drivers with below average VMTs (who can therefore save money with this option) would choose MBI, and would therefore have financial incentive to further reduce VMT. MBI is currently legal in Delaware – any company that chooses to offer such a rate would simply have to submit a plan to the Insurance Commission for approval. However, no company has yet done so. Insurers face high administrative costs associated with the rate approval process, and there is risk involved in offering any new premium. There are several actions that Delaware could take to bring MBI to the market more quickly:

- *Offer incentives to insurers to provide MBI.* Tax credits or grant programs could buy down the risk and cost associated with filing a new rate plan.
- *Require provision of an MBI option.* The state has the authority to dictate what types of vehicle insurance are mandatory, and what a company must offer. Delaware could require that all vehicle insurance companies doing business in the state offer a mileage-based insurance option.
- *Provide legal and logistic framework to facilitate MBI.* MBI requires mileage verification of the participating vehicles. The state can remove this burden from insurers by offering to conduct odometer audits during emissions/safety inspections, and by establishing a licensing program for private technicians who perform audits and report data.

Conversion to Compressed Natural Gas

A conversion to CNG of certain heavy- and light-duty fleets could reduce emissions of NO_x and VOC by 2.48% and 2.22% respectively. This assumes that all new transit and school bus purchases are CNG vehicles, and that all new light-duty vehicle purchases by the University of Delaware, DelDOT, and Delaware Fleet Services run on CNG. It also assumes that 1.8% of private light-duty vehicles are converted to CNG. All light-duty vehicle conversions represent the approximate level of conversion called for in the "major commitment" scenario of the Delaware Climate Change Action Plan (CEEP 2000). In order to achieve these conversions, we recommend that the following options be considered:

For buses:

- *Apply for federal funding to finance conversion.* The Federal Transit Administration's Clean Fuels Program provides funding for vehicles and fueling infrastructure.
- *Consider leasing fueling infrastructure.* One transit company expects to save $1 million in cost and 6-12 months in construction time through their lease agreement with a local utility.

For light-duty vehicles

- *Offer grant-based incentives for CNG vehicle purchases.* These tend to work better than tax-based incentives, as individuals or organizations with low tax liability can still take advantage of them.
- *Encourage dedicated CNG use.* Incentives that encourage dedicated CNG vehicles will work better at reducing emissions than those that allow flexible-fueled vehicles, since gasoline is typically used in flexible-fueled vehicles.
- *Cover full incremental cost of CNG.* Incentives that cover the full incremental cost of the AFV are an effective approach as they relieve purchaser/owner concerns over new technology.
- *Encourage infrastructure expansion.* Provide incentives for conventional fueling stations to install CNG pumps. Also, fleets that own their own equipment could be encouraged to open their station to the public.

Accelerated Vehicle Retirement

A short-term accelerated vehicle retirement program could reduce NO_x and VOC emissions by 0.06% and 2.14% respectively. This assumes the program retires about 640 vehicles, most of which have received emissions waivers, and is based on survey results from

the last such program in Delaware (Albernini et al 1996). We recommend that another "scrapping" program be considered that would have the following characteristics:

- *It is funded by the state and does not create emissions credits.* Programs that generate these credits to offset emissions elsewhere in the region do not necessarily improve air quality.
- *Allow salvaging on non-emissions related parts.* This will reduce the opposition to the program by classic car enthusiasts, who claim that such programs increase the cost of their hobby.
- *Offer targeted bounties.* Payments in the form of incentives for alternative transport modes (such as transit or bicycles) may improve the cost effectiveness of avoided emissions by encouraging cleaner replacement transportation.

5. Air Quality Modeling

Air quality is a function not only of emissions, but also of outside factors such as meteorology and ozone transport. Air quality modeling (AQM) is an essential tool for the scientific evaluation of air quality policies, because the causal links between changes in emissions and changes in air quality are so complex. The effectiveness of the CEEP transport policies on Delaware's future air quality can be assessed quantitatively using established air quality models, SMOKE and CMAQ. Both are EPA approved, and are used by EPA Region III, which includes Delaware. Assessment of the CEEP policy package using AQM was undertaken to determine its effect on improving the worst-case event of ozone pollution in Delaware, which occurred in July 1995. Such an approach is common in air quality studies. This approach applies four emissions scenarios (Table ES-5) to the meteorological event.

Table ES-5. Air Quality Modeling Scenarios.
All scenarios are based on a worst-case meteorological event that occurred in July 1995. **Scenario 1 – Base Case:** 1996 emissions inventory (most recent available) used in AQM. **Scenario 2 – No Delaware emissions:** 1996 emissions inventory used in AQM, with Delaware anthropogenic emissions removed. **Scenario 3 – 2010 BAU:** Emissions inventory projected to 2010, with effects of current regulations taken into account. **Scenario 4 – CEEP Transportation Policies:** Emissions inventory projected to 2010, with regional emissions adjusted according to estimated impacts of the recommended policies.

Results of AQM

The model results are spatial, and a value denoting the highest one-hour mean ozone concentration was assigned to each $12km^2$ or $36km^2$ tract of land in the domain (either Delaware and EPA Region III). An average value for the entire domain is also computed, so it is possible to judge changes to the region as a whole.

Scenario 1 (Base Case) shows one-hour maximum ozone concentrations between 120 – 160 ppb for all of New Castle County and most of Kent County (the one-hour standard

is 120 ppb). During this episode, Sussex County does not experience maximum one-hour ozone concentrations over 120 ppb, but the average for Delaware as a whole is 128 ppb.

Scenario 2 (no Delaware emissions) removes anthropogenic Delaware emissions, and shows an average ozone concentration for Delaware of 126 ppb, still higher than the one-hour standard for the entire meteorological episode. This indicates that for the episode as a whole, Delaware was responsible for about 1.2% of its ozone. On one day during the episode, it was responsible for about 12% of its ozone. Therefore, the bulk of Delaware's ozone problems is due to ozone transport, and led us to assume, in Scenario 4, that regional reductions should be achieved in ozone precursors.

Scenario 3 (2010 BAU) includes the anticipated effects of federal emissions reduction programs already in place (E.H. Pechan & Associates 2000). This inventory does not include the transportation policies outlined above. The average ozone concentration (the spatial field indicator) drops from 128 ppb (in the base case) to 104 ppb. However, parts of New Castle and Kent Counties still have concentrations above 120 ppb, which is the one-hour ozone standard.

Scenario 4 (CEEP transportation policies) subtracts the emissions reductions expected from the proposed CEEP policies (Table ES-4), from the 2010 BAU. This was done for Delaware and surrounding states, assuming that other states would achieve similar reductions from their own policies. In this scenario, one-hour maximum ozone values in Delaware improve on average 1.4%. The improvement areas are mainly in New Castle and Kent counties. Improvement in those areas is important because the base case shows high maximum one-hour ozone concentrations in both of those counties.

Discussion and Conclusions

This analysis shows that the recommended transportation policies impact air quality in Delaware. A summary of these transportation policies is shown at Table ES-6. A 1.4% improvement over the 2010 baseline represents improvement in air quality over the Federal mandated programs that will be in effect. A fractional improvement of 1.4% sounds small, but it could be a significant improvement in terms of helping Kent and New Castle Counties work toward attainment. Since these two counties are in severe non-attainment, Delaware is required to submit a Rate of Progress Plan to the US EPA that models target emissions levels necessary to meet attainment. If the counties can meet and maintain emissions targets for 2005 for each source, as defined by the Rate of Progress Plan, they should reach attainment. The 2005 targets for on-road mobile sources in Kent and New Castle Counties were 20.22 tons/day of VOC, and 29.7 tons/day of NO_x (DNREC 2003). Our 2010 projected emissions inventory suggests that the two counties will still be within their budget for VOCs by 2010. However, by that year they will emit 34.54 tons/day of NO_x, which is 4.84 tons/day above the 2005 budget. Our proposed policies could yield nearly a 10% reduction in on-road NO_x emissions. This would reduce the budget shortfall of 4.84 tons per day to 1.39 tons/day, an improvement of 71.4%. By this measure, the proposed policies could have a significant effect in working toward attainment.

Table ES-6. Summary of State Transportation Policies to Improve Air Quality.

State	Employer TDM Initiatives	Mileage-based Insurance Initiatives	AFV Initiatives	Feebate Initiatives	Accelerated Vehicle Retirement
California	Home of 67% of nationwide trip reduction ordinances. The San Francisco Bay area "Commuter Check" program provides subsidized transit passes to employees commuting by transit. Commuter Checks worth $15 million have been sold to over 35,000 employees representing about 2000 employers. The Southern California Association of Governments has had flextime and a compressed workweek program since 1980 with 95% of their employees participating.		10% of all cars sold by major auto manufacturers have to be ZEV/AFVs from 2003. All public fleets in non-attainment areas are required to run on LEV/AFVs. $18 million fund grants 90% of the incremental cost of ZEV/AFV purchase. $50 million program to replace/retrofit school buses with clean/alternative fuels. Carl Moyer program provides funds for alternative fuel based technology/infrastructure development. Vehicle licensing fees reduced for AFVs. AFVs can use HOV lanes.	DRIVE+ feebate proposal based on vehicle emissions and fuel efficiency introduced in 1990. Reintroduced in 1991, 1992, and 1993.	First program, operated by Unocal in 1990, retired 8400 pre-1971 vehicles in the Los Angeles area. SB 501 instituted state-funded scrapping program to run for 10 years, targeting 75,000 fifteen year-old vehicles per year. Program was suspended last year due to statewide fiscal crisis.
Arizona	20,000 state employees in Phoenix are offered ridesharing, car/van pool, subsidized transit, bike/walk facilities through a state program. Private employers have been included since 1995 through the Maricopa County Trip Reduction Program. The Pima Association of Governments has a mandatory travel reduction program for employers with more than 100 employees. In 1995 the program covered nearly 100,000 employees.		Conversion costs for heavy-duty vehicles to AFVs covered by grants up to a maximum of $30,000. Vehicle licensing fees reduced for AFVs. AFVs can use HOV lanes after obtaining special license plates.	Fuel economy based feebate proposal for six car classes introduced in 1991. Simplified version with flat fee/rebate structure introduced in 1992.	General Motors required to fund a Phoenix area scrapping program in 1997. Program retired 1200 pre-1987 vehicles, with a bounty of $500-$600 per vehicle.

Table ES-6 (continued). Summary of State Transportation Policies to Improve Air Quality.

State	Employer TDM Initiatives	Mileage-based Insurance Initiatives	AFV Initiatives	Feebate Initiatives	Accelerated Vehicle Retirement
Oregon	The Employee Commute Options (ECO) program was launched in 1996 to reduce work related commutes. Employers with more than 50 employees have to meet targeted reductions in employee commutes. A tax credit worth 35% of project costs is offered to businesses who achieve a 25% reduction in work related commutes. The State has committed $1.5 million to the "Minerva" Dynamic Ridesharing system dedicated to reduction/elimination of solo travel.	First state to offer tax credit to insurers who offer MBI. Credit is worth $100 per vehicle on mileage-based plan, with overall cap at $1 million (supports 10,000 policies).			CHOICES program offered annual transit pass, $500 credit toward bicycle purchase, or $500 credit toward carsharing in exchange for scrapping a vehicle that failed emission inspection.
Maryland	Businesses get tax credits worth half of the costs of offering employees transit/vanpool benefits and parking cash-out. The Commuter Choice program works with employers to create alternative commuting programs suited to their employees. The Live Near Your Work program provides $3,000 in direct assistance to home buyers moving to designated neighborhoods surrounding major employers.		Flex-fuel vehicles must use 50% alternative fuels. Tax credits up to $2,000 for EVs and up to $1,000 for HEVs available. Flexible incentives for businesses/public agencies to switch to alternative fuels.	Revenue generating feebate proposal passed the legislature in 1992. Put on hold due to legal challenge by federal government.	

Table ES-6 (continued). Summary of State Transportation Policies to Improve Air Quality.

State	Employer TDM Initiatives	Mileage-based Insurance Initiatives	AFV Initiatives	Feebate Initiatives	Accelerated Vehicle Retirement
New Jersey	The voluntary "Smart Moves For Business" program provides assistance to employers to provide alternative commuting options to their employees. In return, participating companies get tax credits worth $100 per participating employee.		AFV acquisition goals exceed EPAct requirements by 5% per year. Beginning 2007, all transit buses shall be either LEV/AFV. Sales tax on LPG/ CNG for transportation reduced to half. Rebates covering incremental cost of AFV purchase/ conversion up to $12,000 available depending on vehicle weight and whether dedicated or bi-fuel.		
Pennsyl-vania	The Employer Trip Reduction program for the Philadelphia area was launched in 1994. Employers in the region are required to meet vehicle occupancy targets for their employees based on size and location. Targets can be met through a range of alternative commuting options and each employer has to submit an annual report on performance.		Grants covering 20% of project costs for AFV purchase/ conversion and refueling infrastructure development are available to eligible applicants.		In 1993, Sun Company funded 1993 program to retire 166 pre-1980 vehicles, at a cost of $700 per vehicle. Later, it used remote sensing to identify high emission vehicles, and helped finance their repair.

I. Purpose of the Report

The purpose of this report is to provide recommendations to the Delaware General Assembly regarding the implementation of a suite of transportation strategies to reduce emissions of ground level ozone precursors. The recommendations are based on a review of programs in various states, with a focus on our immediate neighbors who face similar air quality problems. This report describes a number of "best practices" from these states, as well as lessons learned for policies in three main categories: travel demand management programs, alternative fuels, and vehicle efficiency. Estimates of potential emissions reductions that could be expected from a number of these programs if they were implemented in Delaware are provided. Then, using an air quality model developed by the US Environmental Protection Agency (EPA), estimates of the impact of these emissions reductions on the overall ground level ozone situation in Delaware are given. In addition, because air quality is a regional issue, this study estimates the regional air quality impact of these policies if implemented by our neighboring states in the Mid-Atlantic region.

We would like to acknowledge the cooperation and advice of the EPA's Region III Office, the Delaware Department of Transportation, the Delaware Transit Corporation, and the University of Delaware. The Center for Energy and Environmental Policy is solely responsible for the findings and recommendations of the report.

II. Introduction

In passing the Clean Air Act (CAA) in 1970 and amending it in 1990, Congress recognized the importance of controlling the negative health and environmental effects of air pollution. The CAA established National Ambient Air Quality Standards (NAAQS) for six major pollutants: ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), lead (Pb), sulfur dioxide (SO_2), and particulate matter (PM-10 and PM-2.5). These criteria pollutants are indicators of overall air quality. The most important of these to Delaware is tropospheric ozone (O_3), a major component of smog, as it is the only criteria pollutant for which Delaware does not currently meet the NAAQS standard (US EPA 2002a).

Air pollution comes from three main types of sources: point, mobile, and area (Table 2.1). Most emissions of pollutants that lead to ozone formation come from mobile sources. For that reason, we have chosen to focus on the transportation sector in an effort to improve air quality in Delaware.

Table 2.1. Definitions of Common Terms Related to Air Quality.
Area sources are locations where air pollutants are emitted from a well-defined area in which there are several sources (i.e., agricultural areas sprayed with herbicides).
Criteria pollutants include Ozone (O_3), Particulate matter (PM), Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2), and Lead (Pb). The allowable levels for these pollutants represent the National Ambient Air Quality Standards (NAAQS).
Mobile sources are emitters of air pollutants that move from place to place (i.e., cars).
Point sources emit pollutants from one or more controllable sites (i.e., smokestacks).
Stationary sources include both area and point sources.
Source: Botkin and Keller (1995)

2.1 Negative Effects of Ozone

High levels of tropospheric ozone can be dangerous to humans and animals, and harmful to agriculture. Human lung function can be seriously impaired by ozone (NRC 1991). Ozone can cause shortness of breath, dry cough or pain when taking deep breaths, tightness in the chest, wheezing and nausea. Ozone irritates the respiratory system by reacting with molecules in the lining of airway tissue. Ozone also aggravates asthma and other respiratory illnesses like pneumonia and bronchitis. High ozone concentrations can make airways more sensitive to cold, dust and dry air, which can increase allergic response in vulnerable people (Allen 2002).

Although short-term exposure effects are often reversible, longer-term exposure to ozone can cause irreversible effects on the human respiratory system. Studies in animals have shown that exposure to ozone at levels that the public commonly encounters can permanently scar lung tissue. During a mandated review of the NAAQS, the US Environmental Protection Agency (EPA) found that exposure to ozone at relatively low

levels and for longer periods of time can cause severe adverse affects to human health[1] (Allen 2002).

Ozone is particularly harmful to children, and the elderly—two groups with weaker respiratory systems. Children are more susceptible than adults because their respiratory defenses are not fully formed and they take in more air (and thus more ozone) per pound of body weight than adults. Because ozone is more prevalent during summer months, those who spend more time outside during these high ozone periods are also at higher risk of exposure. This can include healthy adults, in addition to children and the elderly (Allen 2002).

Ozone also reduces the productivity of plants by causing an array of problems in the plant photosynthetic and metabolic pathways. Researchers have studied ozone's effects on different crops to see how it affects the agriculture economy. Between 1970 and 1990, ozone damage resulted in $23 billion in estimated crop losses in the US (Portney 2000). In 2001, these losses totaled about $500 million (US EPA 2002b). Long-term exposure to ozone can also decrease forest value in terms of timber and recreational resources due to shortening of forest life. This loss in value has been difficult to calculate, however there are growing concerns and research continues (NESCAUM 1998).

Table 2.2. Ozone Formation Reaction.

$NO_2 + sunlight \rightarrow NO + O \ (photons)$ Eq. 1
$O_2 + O \ (photons) \rightarrow \boldsymbol{O_3 \ (ozone)}$ Eq. 2

Without the presence of VOCs, ozone is reduced as shown in Equation 3.

$NO + O_3 \rightarrow NO_2 + O_2$ Eq. 3

However, if VOCs are present the following reactions occur and nitrogen oxides are regenerated which in turn regenerates ozone (as shown in equations 1&2).

$OH + RH \ (+O_2) \rightarrow RO_2 + H_2O$ Eq. 4
$RO_2 + NO \rightarrow NO_2 + RO$ Eq. 5

RH represents VOCs or hydrocarbons where H represents the hydrogen and R the rest of the molecule.
Source: Friedrich and Reis (2000)

2.2 Ozone Formation

Ground level or tropospheric ozone forms when nitrogen oxides (NO_x) and volatile organic compounds (VOCs) react photochemically (Table 2.3). Ozone is therefore considered a secondary pollutant, because it is not emitted directly from a source as in the case of a primary pollutant. The precursors of tropospheric ozone, rather than ozone itself, are therefore regulated at sources. Thus it is important to understand how ozone is formed, transported and removed in order to develop effective abatement strategies.

The formation and destruction of ozone is dependent on many factors, including atmospheric concentrations of NO_x and VOCs, sunlight, temperature, and cloud cover. NO_x mainly originates from the combustion of fossil fuels, as a result of a variety of human activities. Anthropogenic sources include motor vehicles, power plants, and industrial

---

[1] The results from this mandated review prompted the EPA to revise the NAAQS to an 8-hour standard in addition to the 1-hour standard set in 1979. The 1-hour standard only protects against peak exposure, whereas the 8-hour standard protects against lower level, chronic exposure while at the same time removing those peak periods.

facilities. To a lesser extent, NO_x is released from biomass burning, soil, and lightning. From 1982 to 2001, total US NO_x emissions increased by 9% (US EPA 2002b). VOCs (often referred to as hydrocarbons or non-methane hydrocarbons) are emitted from vegetation, industrial and commercial facilities, and motor vehicles. Anthropogenic VOC emissions make up a larger portion of urban area emissions, whereas biogenic VOCs are a relatively larger portion of rural VOC emissions (NESCAUM 1997). VOCs have decreased by 16% over the last 20 years (US EPA 2002b).

Ozone is largely considered a seasonal pollutant due to its dependence on high temperatures and sunlight. Ozone concentrations typically do not reach harmful levels at temperatures below 70-80 degrees Fahrenheit. However, ozone readily accumulates at temperatures above 90 degrees Fahrenheit (NRC 1991) and therefore poses the greatest threat during the summer months. Table 2.2 shows how ozone forms in the presence of NO_x (in this case NO_2). These chemical reactions are initiated by solar radiation (Eq. 1) in a process known as photodissociation or photolysis.

Because ozone formation is dependent on sunlight, as well as NO_x and VOC emissions, a general 24-hour pattern is seen. Overnight and early morning ozone concentrations are quite low. Concentrations tend to peak around noon as sunlight and temperatures increase, and there is often a second peak in the later afternoon as emissions rise during rush hour (OTC 1998).

Generally, the worst ozone episodes in the eastern US occur when high-pressure systems and stagnant air reside over the area. Stagnant air allows ozone concentrations to build up and high-pressure systems are typically without clouds or strong winds. Clouds, through a process known as venting, can mix pollutants through different levels of the atmosphere. They can also affect chemical transformation rates and photolysis rates. For example, on sunny, cloudless days the photolysis rate may be higher than on cloudy days due to the filtration and venting effect of clouds. Clouds allow for vertical transport of ozone from the boundary layer (or ground level) into upper layers of the troposphere (NRC 1991). This process of vertical transport can help relieve ground level ozone concentrations. Wind and storms promote the dispersion of ozone as well.

Deposition plays an important role in determining ozone concentration. Dry deposition is the process by which airborne chemicals are absorbed directly by sinks, such as vegetation, soil, and water, and are thus removed from the atmosphere. VOCs and NO_x can also be absorbed through wet deposition, wherein the pollutants become dissolved in clouds, fog, and rain, and are deposited during precipitation (NRC 1991). Deposition causes ecological damage to forests, bays, and estuaries.

The VOC to NO_x ratio in the atmosphere is another important factor contributing to the formation of ozone and to consider when developing strategies for ozone abatement. The process of ozone formation is highly nonlinear (Sillman 1999). Ozone formation can be described as either occurring in a NO_x sensitive regime or a VOC sensitive regime, depending on the chemistry of the atmosphere. A NO_x sensitive regime is an atmosphere in which a percent reduction in NO_x results in a significantly greater decrease in ozone relative to the same reduction in VOC. Conversely, a VOC sensitive atmosphere responds with a greater decrease in ozone from a reduction in VOC relative to the same reduction in NO_x (Sillman 1999). VOC sensitive regimes are many times referred to as NO_x saturated regimes. Urban areas are generally characterized as having VOC sensitive chemistry, or a NO_x

saturated atmosphere, whereas rural areas are characterized as demonstrating NO_x sensitive atmospheric chemistry.

Precursor emissions and ozone formation do not always occur in the same location. Transport can carry ozone or its precursors from one domain to another up to 500 miles away. This long-range regional transport has been identified by the Ozone Transport Assessment Group (OTAG), a group of stakeholders, scientists and policy-makers that was formed to evaluate the effects of ozone transport in the Northeastern section of the United States. In their findings, they report that there are three levels of transport: local, sub-regional and regional. Local transport, in the 30-50 mile range, contributes most to ozone non-attainment[2] in the Northeast. Sub-regional transport occurs over the 100-300 mile range, and regional transport can occur over the 300-500 mile range. Regional transport tends to be produced by nocturnal jet streams aloft. High levels of transport that occur at night can be seen during the day as the top ozone rich layer moves downward as the sun heats the atmosphere. Thus, transport aloft effects ground level ozone downwind of source areas (NESCAUM 1997).

Table 2.3. National Ambient Air Quality Standards.			
	STANDARD		
Pollutant	**Time Frame**	**Concentr -ation**	**Type of Standard**
Ozone (O_3)	8-hr mean	0.08	Primary & Secondary
	1-hr mean	0.12	Primary & Secondary
Carbon Monoxide (CO)	8-hr mean	9	Primary
	1-hr mean	35	Primary
Nitrogen Dioxide (NO_2)	Annual mean	0.053	Primary & Secondary
Lead (Pb)	Quarterly mean	1.5	Primary & Secondary
Particulate < 10 μm (PM-10)	Annual mean	50	Primary & Secondary
	24-hr mean	150	Primary & Secondary
Particulated < 2.5 μm (PM-2.5)	Annual mean	15	Primary & Secondary
	24-hr mean	65	Primary & Secondary
Sulfur Dioxide (SO_2)	Annual mean	0.03	Primary
	24-hr mean	0.14	Primary
	3-hr mean	0.5	Secondary
* All values are in parts per million except Pb, PM-10, and PM-2.5, which are in μg/m³			
			Source: US EPA (2002e)

Ozone transport depends heavily on meteorology and therefore varies day-to-day, from place to place and from source to source. Wind speed and wind direction play important roles in ozone transport. Human activity can create a mass of ozone covering a large area even if the emissions of ozone precursors occur in a relatively small area. This mass can spread depending on how fast and in what direction the wind is blowing. Therefore, unhealthy ozone can occur in rural and undeveloped places due to upwind urban areas. In 2001, the highest one-hour peak ozone readings were found at suburban monitoring sites due to ozone that was transported from center cities. In addition, from 1995-2001, average ozone readings at rural sites were greater than urban sites, but still lower than suburban areas (US EPA 2002b).

---

[2] "Ozone non-attainment" refers to the Clean Air Act's National Ambient Air Quality Standard.

2.3 Ozone Standards

Ozone is one of the six criteria pollutants established in the NAAQS. States are responsible for devising and implementing emission reduction plans to meet the NAAQS. The CAA bases its pollutant program on ambient standards. That is, criteria pollutants have been selected as indicators of air quality, and standards for the concentration of each in the air have been set. These standards can be either primary or secondary. Primary standards are set to protect public health, including the health of susceptible populations such as asthmatics. Secondary standards are set to protect the public welfare from known or anticipated adverse effects of a pollutant including impaired visibility (US EPA 1998a).

There are currently two standards set for ozone: 1-hour and 8-hour. The 1-hour ozone standard is set at 0.12 parts per million (ppm). The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is equal to or less than one (US EPA 1998a). If an area does not meet these

Figure 2.1.   Ozone Non-Attainment Classifications, and Number of Counties (Nationwide) Currently in Each Category.

Source: US EPA (2002a)
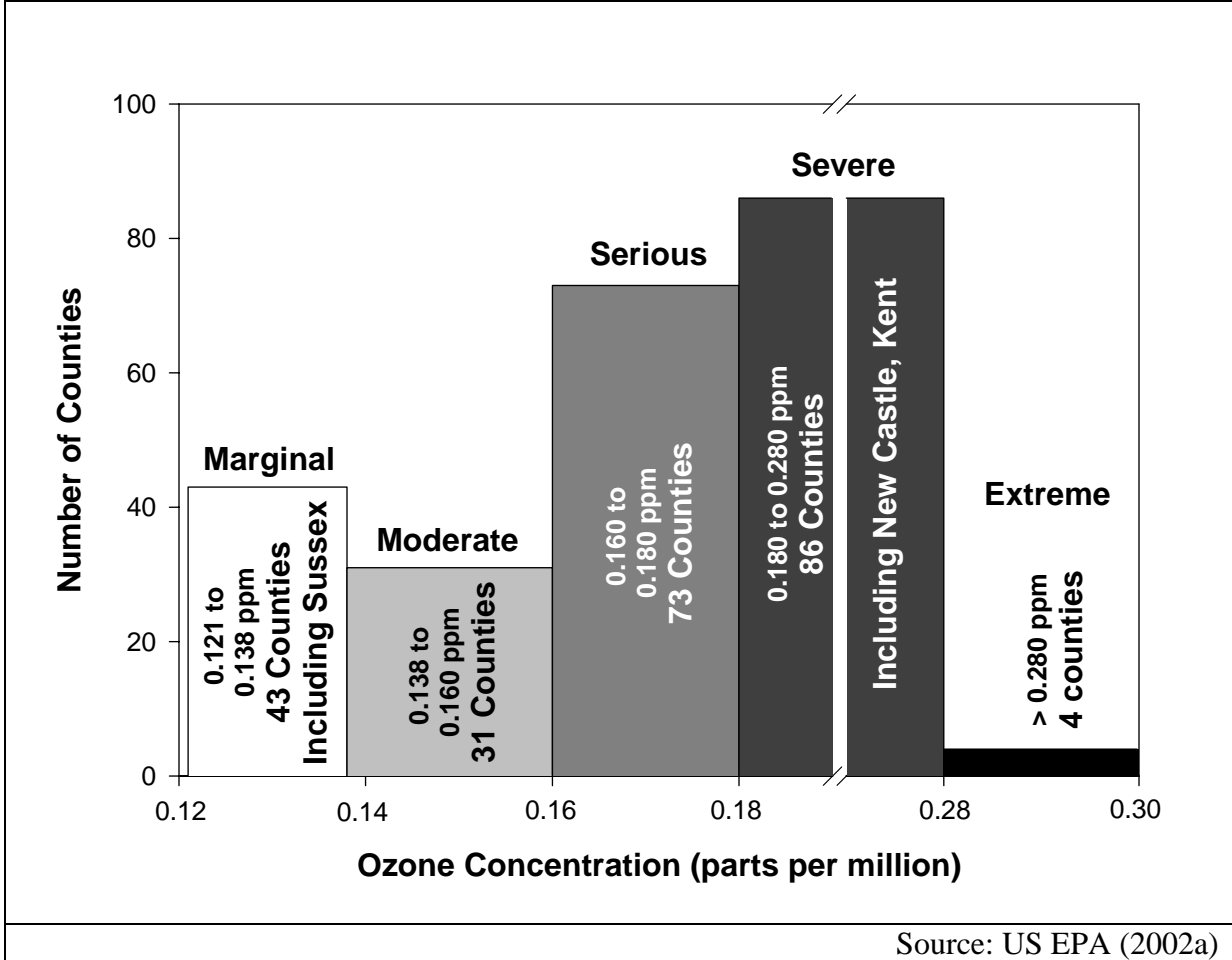
standards, it is designated "non-attainment". One-hour non-attainment areas are further classified as shown in Figure 2.1 (US EPA 2002a). As of July 2002, there were a total of 254

counties across the US that were designated non-attainment areas for the one-hour standard. The 8-hour ozone standard is set at 0.08 ppm and is defined as the 3-year average of the annual fourth highest daily maximum 8-hour ozone concentration. A classification system has yet to be set for the 8-hour standard.

2.4 Response to the Ozone Standards

Attainment of the ozone standard was difficult for many states because of phenomenon of ozone transport. Under "conjoint federalism" in the CAA, states downwind of major out-of-state sources of pollution are still responsible for meeting national standards even though significant amounts of pollution comes from upwind jurisdictions. The 1990 Amendment to the CAA addressed the issue of ozone transport through Section 176 which permitted the creation of Transport Commissions designed to deal with regional air quality problems and to recommend control measures for the transport region if necessary. In October 1997, the EPA formally established the Ozone Transport Assessment Group (OTAG), to address the problem between upwind and downwind states.

The OTAG process included state agencies, industry representatives and environmental groups, and covered 37 states. They spent approximately $20 million in order to study ozone transport and ran over 400 simulations over four different meteorological episodes (Farrell and Keating 2002). OTAG studies supported the belief of the EPA and the downwind states that transport contributed to their non-attainment status.

Based on the findings from OTAG, the EPA instituted a NO_x SIP Call. In January of 1997, the NO_x SIP Call identified 22 states that needed to reduce their emissions because of their contribution to ozone concentrations in downwind states (Farrell 2001). Each state was directed to reduce emissions to a certain level, however the states had the ability to decide which sources to regulate. Table 2.4 shows each state's allowed emissions under the CAA versus under the newly revised SIP Call. The process for reducing emissions had to be modeled in a SIP and submitted to the EPA. The NO_x SIP Call will reduce emission from point sources by approximately 25% across the 22 states involved by 2007 (US EPA 2002d).

Every county in the state of Delaware is in non-attainment for the one-hour ozone standard. Kent and New Castle counties are classified as severe non-attainment areas, whereas Sussex is considered marginal non-attainment. Because of their severe classification, Kent and New Castle counties must submit a SIP to the US EPA that contains modeled results from emission reduction programs, and a revised SIP every 3 years showing adequate rate-of-progress.

In addition to the NO_x SIP Call (which mainly regulates point sources), there are two Federal regulations that are going into effect to reduce NO_x and VOCs from mobile sources—Tier II standards and the new Heavy-Duty Diesel standards. Tier II will require stricter tailpipe emissions standards for new automobiles (including SUVs and light-duty trucks) and a cap on sulfur levels in gasoline (US EPA 1999a). The new Heavy-Duty Diesel standards will go into effect by 2007 and requires all new heavy-duty vehicles to meet national emission standards (US EPA 2000a). These federal programs are all aimed at reducing emissions in order to help states meet or maintain the ozone NAAQS.

Air quality modeling is essential for determining the impact that emission reduction policies will have on air quality because the atmospheric system is highly non-linear. A percent reduction in emissions will rarely lead to the same percent reduction in ozone formation. There are many factors contributing to ozone formation in the atmosphere such as the severity of emissions and meteorology including wind and sunlight. Air quality models are used by government agencies to determine how to meet attainment in future years.

Table 2.4. NO_x SIP Call State by State NO_x Budgets (tons /year).			
State	**2007 Base (BAU)**	**2007 Budget (NO_x SIP Call)**	**% Reduction**
Alabama	236,867	172,037	27
Connecticut	46,220	43,081	7
Delaware	23,512	22,789	3
District of Columbia	6,485	6,672	0
Georgia	253,489	189,634	25
Illinois	375,250	274,799	27
Indiana	355,433	238,970	33
Kentucky	238,412	155,619	35
Maryland	103,558	81,625	21
Massachusetts	87,563	85,296	3
Michigan	288,000	224,582	22
Missouri	189,737	128,146	32
New Jersey	108,584	100,133	8
New York	253,659	240,123	5
North Carolina	228,600	168,373	26
Ohio	378,418	250,930	34
Pennsylvania	346,900	257,441	26
Rhode Island	9,895	9,810	1
South Carolina	153,465	124,211	19
Tennessee	257,962	197,664	23
Virginia	224,521	185,027	18
West Virginia	184,947	91,216	51
Wisconsin	175,061	136,172	22
Total	**4,526,538**	**3,384,350**	**25**
Source: US EPA (2002d)			

2.5 Controlling Ozone with State Level Transportation Management

These federally mandated regulations will reduce emissions from both point and mobile sources. However, states are responsible for the further emission reductions that are needed to either maintain or reach the ozone standards. One major area that states can use to address this problem is through transportation planning. Highway vehicles (both light and heavy-duty) accounted for 33.8% of total US NOx emissions and 29.2% of total VOC

emissions in 1999 (Davis & Diegel 2002). As Figure 2.2 illustrates, significant gains have been made in reducing highway VOC emissions, but NO_x emissions from highway vehicles have risen since 1970. Increasing vehicle miles traveled (VMT) and congestion are two major problems contributing to increasing NO_x emissions from vehicles. In 2001, VMT increased to an all time high of 2.778 trillion, up from 2.75 trillion in 2000 (US DOT 2001: 15). In the last 30 years, VMT has grown by 147% across the US, nearly 4.5 times the population growth of that period (Davis & Diegel 2002).

There are three contributing factors to transportation emissions: 1) number of vehicle miles traveled; 2) gallons of fuel per VMT (or fuel efficiency); and 3) emissions per gallon of fuel (or fuel quality). The relationship between these factors is presented in the following identity (from Difiglio and Fulton 2000):

Figure 2.2. Mobile NOₓ and VOC Emissions Since 1970.

Source: Davis & Diegel (2002)

$$\text{Vehicle emissions} = \text{VMT} \times \text{emissions/gal} \times \text{gal/VMT}$$

This identity makes clear the fact that policies aimed at controlling one or two of the emissions factors will not be successful if the uncontrolled factors continue to rise; policies must control all three factors at once. Policies aimed at controlling emissions on a per vehicle basis have been quite successful, but NO_x emissions continue to rise as increasing VMT negates efficiency gains. Because of this effect, this report will analyze state level policy options that address all three key areas: VMT, efficiency, and fuel quality.

10

III. Policies to Improve Air Quality

This section examines specific policies that exemplify the three major aspects of emissions control, as presented in the vehicle emissions equation: VMT management, clean fuels, and vehicle efficiency. Each subsection will contain a description of how the policy works, a generalization of its emissions impacts, and a summary of state (and federal, if applicable) experiences with the policy. Some key terms are defined in Table 3.1.

3.1 Reducing Vehicle Miles Traveled (VMT)

Nationwide, VMT has increased at an average rate of 3% per year since 1970 (Davis and Diegel 2002). Delaware VMT has grown at an even faster rate. From 1980 to 2001, VMT increased by 103%, which is an annual increase of nearly 4.7% (DELDOT 2002). During this time, the state population grew 32% (Hobbs and Stoops 2002). Therefore, this VMT growth may be driven by a combination of population growth and an increase in per capita driving (perhaps due to continuing low-density suburban development).

In order for transportation policy to be successful in reducing emissions, VMT must be directly managed. Even if efforts at reducing emissions on a per mile or per gallon of fuel basis are successful, an increase in the total number of miles traveled can negate those gains (the first term in the equation of vehicle emissions). Also, when vehicles become more efficient, the cost of fueling the vehicle decreases. This decrease can lead to an increase in VMT, which can negate a significant portion of the emissions reductions. This phenomenon is known as the "rebound effect" (Greening et al 2000).

Table 3.1. Definition of Terms.
Internal Costs of automobile travel are those that are borne directly by the driver.
External Costs are those that are caused by the driver but are borne by society as a whole.
Fixed Costs are internal costs that do not vary with mileage, and therefore affect auto ownership but not VMT.
Variable Costs are internal costs that vary directly with VMT, and therefore are considered by the driver when travel choices are made.
Transportation Demand Management (TDM) attempts to make more efficient use of transportation resources without adding to road capacity.

VMT and Emissions

Although vehicle emissions as a whole increase with VMTs, the relationship is complex as several factors are involved. Most emissions result from driving (known as tailpipe emissions), but these are not the only source. There are two other types: cold-start emissions, and evaporative emissions. When a vehicle is started, the emission control equipment does not function properly until it reaches a certain temperature. Therefore, a vehicle emits a disproportionately high amount of pollutants (particularly NO_x and CO) right after it is started. Cold vehicle starts generate 16% more NO_x and 40% more CO than warm starts (US DOT 2002). Evaporative emissions consist primarily of VOCs, and are the result of direct evaporation of fuel. These emissions occur constantly, whether the vehicle is running or not, but increase in intensity when the vehicle is running or just afterward ("hot-soak" emissions). They also occur during vehicle

refueling. Even if all driving ceased, the existence of a vehicle with fuel in it accounts for about 2.6 grams/day of VOC emissions (US DOT 2002). Based on this estimate, about 5% of Delaware VOC emissions in 1996 were from parked, cool vehicles.

Therefore, reducing the number of trips taken will result in greater emissions reductions than simply keeping the number of trips constant but reducing trip length. This is because when a trip is eliminated, its associated cold-start emissions and "hot-soak" evaporative emissions are also eliminated. Reducing the length of a trip only reduces tailpipe and running evaporative emissions.

Figure 3.1. Distribution of Automobile Costs.
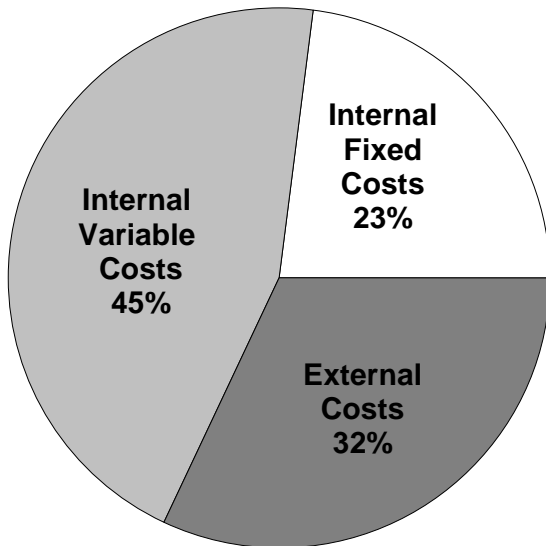
Fixed costs and external costs are a majority of vehicle ownership costs. If these costs are transformed to internal variable costs, there will be financial incentive for motorists to decrease their VMT.
(Reprinted with permission from Litman 2000.)

VMT Reduction Policies

Policies aimed at controlling VMT often attempt to do so by internalizing external cost. External costs are those that are caused by driving, but are not borne directly by the driver. Because of this, higher proportions of external costs lead to higher than optimal VMTs. Examples of external costs include air and water pollution, climate change, hydrologic change due to paved surfaces, and the portion of transportation infrastructure maintenance not funded by direct vehicle taxes or fees. Methods of internalizing external cost include fuel taxes, road tolls, and elimination of free parking.

Another method of controlling VMT is the transformation of fixed costs to variable costs. Fixed costs do not vary with mileage, and include insurance, depreciation due to age, and most registration fees. Variable costs are directly related to mileage, and include fuel, most types of maintenance (such as oil and tire changes), tolls, and accident risk. If the ratio of variable cost to fixed cost increases, there is greater financial incentive to reduce VMT. On average, fixed costs, variable costs, and external costs make up 23%, 45%, and 32% respectively of the cost of owning and operating a vehicle (see Figure 3.1).

A third method is to remove barriers that inhibit alternative modes of transportation. These barriers are often non-monetary, such as physical factors as the lack of pedestrian or bicycle access to sites or the absence of convenient transit stops. There are also information barriers, such as a lack of knowledge about available options and their associated benefits.

This report will examine two strategies for reducing VMT. The first is a suite of steps that employers can take (and which the government can facilitate) to reduce the number of trips taken and miles traveled to and from work. These employer-based transportation demand management strategies (TDMs) internalize some costs and remove some barriers to

modes switching. The second seeks to transform a major fixed cost – vehicle insurance – to a variable cost.

Employer-based TDMs

Employer-based transportation programs can be effective tools in reducing commuter VMTs, principally through transportation demand management (TDM). TDM is a general term for strategies that result in more efficient use of transportation resources (VTPI 2003). Such strategies seek to do this without adding additional road capacity, but rather attempt to modify travel behavior to make better use of existing capacity. Those who employ TDM strategies recognize that capacity additions are extremely costly, and can even be self-defeating because they induce more traffic and do little to relieve congestion in the long run (Mogridge 1997).

In most transportation systems, the worst congestion occurs for about 3 hours in the morning and 3 hours in the afternoon when most workers are commuting to and from work. Rush-hour congestion greatly reduces the efficiency of the road system, increasing trip times and causing greater vehicle emissions per mile. If a large number of employers in a given region can influence their employees commuting habits, it will have a noticeable effect on rush-hour traffic. If more employees carpool or use transit to commute, these changes will also reduce ozone-forming emissions.

There are a number of TDMs that lend themselves well to commuters (see Table 3.2). Some involve directly reducing the number of employee VMTs. Others do not reduce VMT, but rather shift travel from peak time to off-peak time. This reduces congestion, and therefore emissions, because idling and low-speed vehicles emit more per mile than faster moving vehicles. Some examples of employer TDMs follow (Carlson et al 2000). The list includes the major types of programs that we will examine specifically for Delaware.

Table 3.2. Examples of Employer-Based TDMs.	
Type	**Examples**
Financial incentives	Parking cash-outs
	Transit fare
Site improvements	Preferential parking
	Bike racks, lockers, showers
Support programs	Ride-matching
	Transit information
Alternative scheduling	Telecommuting
	Compressed work week
	Staggered hours

Financial incentives can be offered directly to employees. These incentives usually center around parking and transit. Parking "cash-outs" can be used, wherein an employee receives the cash equivalent of a free parking permit. The employee can then either spend the cash on parking fees, or use other modes and save money. Employers can also offer incentives for users transit or carpool riders.

Site access improvements change the amount of time it takes for an employee to get from their chosen mode of transportation to their workspace. Slight changes in walking time are important; transportation planners recognize that for most commuters, walk time from

vehicle to entrance is twice as onerous as in-vehicle time (US EPA 2000b). Site access improvements include preferential parking for carpools and vanpools. They also include improved transit access to the workplace (such as covered stops close to the entrance), and improved bicycle access (such as lanes and racks) and amenities (such as lockers and showers). These changes make modes of transport other than the personal vehicle more comfortable.

Employer support programs make information about transit and carpool options readily available to all employees. They are not financial or time-related incentives, but serve to remove information barriers that inhibit use of alternative transport modes. This can involve actively matching prospective carpoolers within an organization, and ride-matching between employees of different organizations.

Alternative work schedules allow trip reduction and reduce peak traffic, and hence reduce time spent in commute. Trip reduction can be achieved by telecommuting and compressed work weeks (such as four 10-hour days instead of the typical five 8-hour days). The latter type include staggered hours and "flex-time". Commuting time can also be reduced with trip elimination through staggered hours and "flextime". Staggered hours involves the scheduling of employees such that they come and go at different times (i.e., some work 8:00-4:00, some 9:00-5:00, and some 10:00-6:00). Flex-time is similar, but the employee is allowed more control over his/her scheduling.

Some employers recognize that reducing congestion during peak traffic times is in their own best interest. If employees spend less time in traffic, they may be more productive at work. However, actions of individual employers (unless they are extremely large) are not likely to have an effect on the regional transportation system. Local or state governments may step in to encourage participation. This often comes in the form of incentives or rewards for employers that achieve a measurable reduction in VMTs by employees commuting to work. Sometimes it comes in the form of a mandate – employers are either required to take specific steps, or they must document that their own TDM programs are effective.

Effects of employer-based TDMs on emissions

Emissions reductions from employer-based TDMs will vary widely depending on the number of employers and employees that participate, regional demography, fleet characteristics, and the specific TDMs employed. In addition, there may be synergistic effects among various TDMs – the effect of several together may be different than the sum of each individually. Therefore, it is hard to draw general conclusions about the emissions reductions possible from employer TDMs.

The EPA has developed a spreadsheet model called "COMMUTER" which accounts for the variables above and others. It predicts plausible VMT, trip, and emissions reductions for a given suite of TDMs. We employ this model in our analysis, and discuss it in greater detail in Section IV.

Federal and State Experiences with Employer-based TDMs

Employer based trip reduction programs are primarily conceived and implemented at the local and regional level and that is where most of the case studies are. Since Delaware is a small state (compared to say, California) many local/regional experiences in other states could provide insight and be applicable to Delaware or parts of Delaware. Besides, the

14

federal government and many state governments have tried to promote employer based trip reduction through their own efforts, primarily through policies such as tax benefits and recognition for employers.

Federal Programs/Incentives for Employer-based TDMs

The *Clean Air Act Amendments* of 1990 include TDM measures such as trip-reduction ordinances, ridesharing, and commute trip reduction, as ways through which states can attain compliance with federal air quality standards. The Federal Highway Administration offers funding to state and local governments to plan and implement such TDM measures under its Congestion Mitigation and Air Quality program.

The *Transportation Equity Act for the 21ˢᵗ Century* (1998), provides employers and commuters new incentives for saving money while reducing congestion and decreasing air pollution. Employees can get benefits up to $100 per month for transit/carpool/vanpool expenses and up to $190 per month for parking related to transit, carpool, or vanpool. Employees can show such benefits as non-taxable income, while employers get tax deductions for the paid benefits, thus creating financial incentives for both sides (NCTR 2003).

Executive Order 13150 on Federal Workforce Transportation was passed in April, 2000. According to the Executive Order, all federal employees in the National Capital Region will receive a benefit equal to their commuting costs, not to exceed $65 per month, in the form of transit passes or vanpool vouchers, purchased by the agency with appropriated funds. Outside the National Capital Region, the Executive Order will apply to federal employees of selected agencies only, namely, the Department of Transportation, the Department of Energy, and the Environmental Protection Agency. The benefit is to be increased and expanded in the future (NCTR 2003).

The *Commuter Choice Leadership Initiative* is a recent effort by the federal government to target employer based trip reduction. Established by the EPA and the federal Department of Transportation, this initiative helps employers address limited or expensive parking, reduce traffic congestion, improve employee recruiting and retention, and minimize the environmental impacts associated with drive-alone commuting. Participating companies earn the designation "Commuter Choice Employer"—a mark of excellence for environmentally and employee-friendly organizations. So far the initiative is limited to only a few metro areas (Denver/Boulder, Washington DC, Houston, Sacramento, and San Francisco Bay), but it is expanding quickly to other parts of the country (US DOT & US EPA 2003).

State/Local Initiatives for Employer-based Trip Reduction
California

Due to its historic air quality problems, in 1987 the California's Air Resources Board identified TROs as a useful approach for meeting California state air quality standards. Their use began accelerating even before the Clean Air Act Amendments of 1990 (CAAA). When the 1990 CAAA advocated TROs in non-attainment areas, the incidence of TROs increased nationwide, and especially in California. A recent study found that 67% of TROs are concentrated in California, which continues to have the most significant experience with TROs (US EPA 2003a).

The Alameda County (East San Francisco Bay area) Congestion Management Program enlisted four major employers to provide financial incentives to encourage reduced driving. Various incentives were used ranging from a daily allowance of $1.50 to a monthly transit pass of $40. The program managers concluded that financial incentives alone typically reduce automobile commute trips by 16-20%, and significantly more if combined with other TDM strategies (ACCMA 2003).

The San Francisco Bay Area *Commuter Check* Program provides subsidized transit benefits to employees. *Commuter Check* began in the Bay Area in 1991, and by August 1999, *Commuter Checks* worth $15 million had been sold to over 35,000 employees representing about 2000 employers. Through the mid-1990s, the program was expanding by approximately 35% a year. Since the pre-tax employee-paid option became available in June 1998, the rate of growth has exceeded 100%. A 1994 survey of Bay Area employers provided the following results (CommuterCheck 2003):

- About a third (31%) of the employees who receive *Commuter Checks* increased their use of transit. These employees reported an average increase of 3.24 transit trips per week. New transit trips were reported for both commuting and non-work purposes. Most of the users who increased transit riding as a result of *Commuter Check* had been non-users or infrequent users.

- The increase in transit use as a result of *Commuter Check* was more pronounced at employers outside San Francisco. Employees outside San Francisco reported an increase in transit commute trips of 48% compared to 25% in San Francisco.

- Trips amounting to an estimated 17 million vehicle miles were removed from Bay Area roads in 1994 due to *Commuter Check*, and an estimated 61 million tons of criteria pollutants were avoided.

- A large majority (79%) of respondents noted improved opinions of their employer as a result of receiving *Commuter Checks*, a third (35%) noted reduced stress from not driving to work or driving less often, and a third (33%) said job satisfaction had improved. Improvements in on-time arrival and productivity were also noted.

Several local governments in California also offer successful parking cash-out programs. The City of West Hollywood began cashing out parking in 1990. City Hall employees receive cash benefits of up to $65 per month for not driving to work. In 1997, the City of Oakland successfully implemented Parking Cash Out as a short-term solution to the loss of 88 employee parking spaces due to construction. All employees at the site were offered $40 a month in Commuter Checks to not drive to work at least three days a week, and $20 a month for not driving to work just one day a week. In one year, the program saved 14,650 commute trips, 12,306 gallons of gasoline and approximately 123 tons of CO_2. The suburban City of Pleasanton offers $1.50 per day to employees who use a commute alternative instead of driving to work alone. All city employees are eligible to participate with no minimum days required. The program has resulted in an annual savings of 20,625 trips, which translates into 12,375 gallons of fuel and 123 tons of CO_2. In 1993, the year before the program was implemented, only 28 employees were commuting to work using alternative modes. Average participation in 1994 was 55 employees per month and grew to 66 participants in 1995 (ICLEI 2003).

The *SmartTraveler* is a statewide ride-matching program of the California Department of Transportation. The program has 11 administrative zones that cover the entire

16

state, each partnering with local government agencies, commuter service networks, and businesses. The ridesharing service allows users to obtain lists of potential ride matches via touch-tone telephone. Users must pre-register, which entails giving some personal information, including their usual commute times and preferred pick-up and drop-off locations. Upon request, the system can call the people in the list and deliver a user-recorded message. The system had 68,000 users in the Los Angeles area alone (CA DOT 2003).

The City of San Francisco imposes a 25% tax on all commercial parking transaction ("any rent or charge required to be paid by the user or occupant of a parking space"). The city collects nearly $50 million annually from this tax and expects this revenue to increase if parking operators implement better revenue control systems. Revenues are divided between the city's general revenue, public transportation and senior citizen funds (City of San Francisco 2003).

The Southern California Association of Governments (SCAG) has had flextime and a compressed workweek program since 1980. SCAG has 125 employees, of whom 100 are professionals and 25 are support personnel. All employees are eligible for compressed workweeks, and 95% take advantage of the option. Employees work 9-hour days and get every other Friday off. They schedule which Fridays they have off with their supervisors, who maintain coverage in the various departments. The program was introduced as a pilot project but proved immediately popular with employees (VTPI 2003).

Ride-On, the Transportation Management Association for San Luis Obispo County in Central California, offers door-to-door Guaranteed Ride Home (GRH) service anywhere in the area on weekdays between 8 am and 7 pm. Employers can set up a GRH program to fit their needs. In the event of an emergency, authorized staff call Ride-On to request a ride home and the TMA will send a vehicle within 15 minutes. This program is insurance against ever being at work without a car in order to help increase the appeal of rideshare commuting. The cost of the rides home range from $5 to $20 depending on the distance traveled. Some businesses pay the fare for the actual ride or let the employee pay the fare. The GRH program has proven to be a significant benefit for employees (SLORR 2003).

Washington

Washington State's 1991 *Commute Trip Reduction Law* (CTR), a part of the Washington Clean Air Act, is designed to improve quality of life by reducing traffic congestion, air pollution and fuel consumption. To achieve these goals, employers are asked to develop CTR programs that encourage employees who drive alone to work to consider using an alternative commute mode such as buses, vanpools, carpools, biking, or walking. Teleworking and working a flexible work schedule such as the compressed workweek are other elements employers can implement to reduce single-occupant vehicle trips to the worksite. The law affects public and private employers in urban counties that have 100 or more full-time employees at a single worksite who begin their workday between 6 and 9 am on at least two weekdays for at least 12 continuous months. State agencies are encouraged to implement CTR programs at all of their worksites statewide, not just at worksites affected by the law. On an average workday morning in 2001, CTR removed 19,950 vehicles from the state's roadways, a 12% increase in trip reduction over 1999. If the 15,900 vehicles removed in Puget Sound each morning were added back onto the region's highways, the equivalent of 16 additional lane miles would be needed to accommodate the demand. The cost to the state just to construct these roadways could approach $92 million. CTR also prevented 5,130 tons

of criteria pollutants in 2001 and reduced petroleum consumption by 6.4 million gallons, saving Washington citizens over $10 million in fuel costs (WA DOT 2003).

The King County (Seattle area) METRO Transit Agency has developed a comprehensive commute trip reduction program. This comprehensive program includes a wide range of features including ridematching for car/vanpooling, carsharing, parking cash-out, preferential parking, subsidized transit passes and rideshare vouchers, guaranteed ride home, alternative work schedules, and tax incentives. METRO also provides general support and resources to employers to develop commute trip reduction programs and integrate these efforts with parking, land use and transit management activities (King County 2003).

King County METRO's region-wide vanpool ride-matching services are considered one of the most successful in North America. It operates dozens of self-financing vanpools that account for 2% of commute trips and 7% of 20-mile-plus commute trips in the region. There are more than 1,000 active vanpools. About 90% of vanpools are driven to worksites with mandatory commute trip reduction programs, which are required by state law (King County 2003).

King County METRO pioneered one of the first self-serve, public, internet-based rideshare matching services in the nation in association with regional carpool/vanpool providers. RideshareOnline.com instantly matches commuters with carpool or vanpool partners with a similar daily commute in nine Puget Sound area counties, including King, Pierce, Snohomish, Kitsap, Thurston, Island, Mason, Skagit and Whatcom counties. After registering online, users enter their commuting times and locations. They can instantly see a list of rideshare matches to whom they may e-mail a rideshare request (King County 2003).

RideshareOnline also offers ridematching services for a host of special events such as sporting events, concerts and conferences, that work the same way as regular commute ridematching. The Seattle Center and the University of Washington are helping to promote the service in King County, hoping it will attract more attendees to events at their venues (King County 2003).

RideQuest is a similar online ridematching service provided by the Greater Redmond Transportation Management Association. Users enter a street address or intersection, and the software produces a map showing that location. If the location is correct, it is entered into the database along with information on the users travel needs and preferences. They can send an automatic email to other registered commuters who may be able to rideshare (GRTMA 2003).

Commuter Challenge is a non-profit organization that provides business leaders with expertise and support to create innovative solutions that reduce commute trips, while recognizing business needs and improving quality of life in the Puget Sound region. It partners with the Economic Development Council of Seattle & King County, and various city and state agencies. *Commuter Challenge* provides resources to employers to support alternative work schedules and holds workshops and forums on regional transportation demand issues. The *Commuter Challenge* website has detailed descriptions of more than two-dozen Puget Sound area employers that offer alternative work schedules. Each case study describes the type of employer, the policies and resources they offer, the program's effectiveness, and feedback from administrators who manage the programs. It also sponsors an annual employer recognition program (Commuter Challenge 2003).

The *Puget Sound Telecommuting Demonstration Project* was initiated in 1990 by the Washington State Energy Office (WSEO). It included 25 public agencies and private firms

in the Seattle area. These groups signed a memorandum of understanding that outlined the projects polices and procedures. WSEO staff provided assistance to employers in establishing telecommuting programs. After two years the project found the following results. Most participants telecommute an average of one day a week. Benefits by teleworkers included increased job satisfaction, enhanced performance, and greater flexibility. Supervisors generally rated telecommuters' performance the same or better as days spent in the office. An average of 26 fewer annual commute trips were recorded. Approximately 61% of participants drove to work, 18% carpooled, and 17% rode transit. The results indicate that each teleworker reduced an average of 1,900 annual kilometers of vehicle travel (VTPI 2003).

Way to Go, Seattle is a new initiative by the City of Seattle to show people they can save money and make their communities more livable by making more conscious transportation choices, just as they do now with recycling and water conservation. A variety of programs such as the *Car Smart Communities* encourage neighborhood projects that help residents use cars less often for errands and other personal and family trips. The programs provide a variety of resources and incentives to encourage less automobile-dependent communities and lifestyles (City of Seattle 2003).

Oregon

The state of Oregon has an *Employee Commute Options* program to help the state to meet federal air quality standards in the Portland region by reducing work related automobile commutes. The Oregon Department of Environmental Quality launched the program in 1996, which requires employers with more than 50 employees in the Portland area to make a good faith effort to encourage employees to reduce automobile commute trips through alternative travel arrangements. There is a target of a 10% commute reduction over three years. Employers that fail to make such an effort may be fined. In the Portland area nearly 500 employers participate in the program, which translates into over 150,000 employees (OR DEQ 2003a).

The Oregon Department of Energy offers the *Business Energy Tax Credit* to those who invest in energy conservation, recycling, renewable energy resources and less-polluting transportation fuels. Projects that reduce employee commuting or work-related travel such as investments in trip-reduction activities, including telework equipment for their employees, vans for vanpooling, and bus passes, may qualify for a tax credit. Projects must reduce work-related travel by 25% to be eligible. To date, more than 5,500 Oregon energy tax credits have been awarded. Altogether, those investments save or generate energy worth about $100 million a year. The tax credit is 35% of the eligible project costs - the incremental cost of the system or equipment that is beyond standard practice. The credit can be received over five years: 10% in the first and second years and 5% each year thereafter, with any unused credit carried forward up to eight years. Those with eligible project costs of $20,000 or less may take the tax credit in one year (OR DOE 2003).

The *"Minerva" Dynamic Ridesharing System* in Oregon uses cellular phones, palmtop computers, and wireless data communications to provide low-cost alternatives to transportation in low-density areas and low travel corridors. The service can be integrated with conventional transit, paratransit, and ridesharing services, plus consumer services such as home shopping, telebanking, and e-mail, to help reduce the need for some trips altogether. The Oregon State legislature has committed $1.5 million to this project, with additional

commitments of $3 million in matching funds from local pilot sites, and $1 million in in-kind support from private management consulting outfits (VTPI 2003).

The Tri-County Metropolitan Transportation District, which manages transportation in the Portland, Oregon area, has implemented various parking management strategies around transit stations to minimize costs and support transit-oriented development. These include:

- Arranging shared parking with Park & Ride and other types of land uses, including apartments, churches, movie theaters and government buildings near transit stations.
- Using lower minimum parking requirements around transit stations.
- Allowing Park & Ride capacity near transit stations to be reduced if the land is used for transit oriented development, thus allowing car trips to access transit to be replaced by walk/bike trips (TriMet 2003).

Arizona

The State of Arizona has promoted ridesharing for its 20,000 state employees for more than a decade through its *Capitol Rideshare* program. The program has evolved into a number of directions and since 1995 has included other employers through the *Maricopa County* (in which the capital Phoenix is located) *Trip Reduction Program*. The rideshare is promoted through a "Commuter Club" which employees can join if they agree to commute by an alternative mode at least twice a week. Over 4000 employees have joined the club of whom 60% are carpoolers, 30% are bus riders, and the rest are bikers and walkers. The club offers a guaranteed ride home service for members in case of emergencies and operates a 24-hour free ride-matching service (ACT 1997).

The program also promotes bus use through a subsidized Bus Card. Bus ridership increased 66% after the subsidy was increased from 50% to 100%. The Capitol Bike Club program has established bike-on-bus facilities, trails, and bike racks and has over 200 members. The State offers qualified employees subsidies for vanpooling. Twelve vanpools are currently operating. To support the 2,500 employees using carpools and vanpools and to encourage others, the program offers them preferential parking. Telecommuting has also been started from 1993. All these programs are actively promoted though publications, media and employee orientation (ACT 1997).

The Phoenix area holds the *Annual Clean Air Challenge* every winter to persuade employers to have their employees cut down on regular commutes. The 1995-96 campaign drew the participation of 32% of the 20,000 state employees in Phoenix, cut annual VMT by 870,000 miles, saved 41,000 gallons of gas, and kept 16 tons of criteria pollutants out of the region's air (ACT 1997).

The Pima Association of Governments, which encompasses Pima County, City of Tucson, Town of Marana, Town of Oro Valley, and Town of Sahuarita, adopted a mandatory travel reduction program in 1985 for employers with 100 or more employees at a single site. This ordinance requires employers to persuade their employees to use alternative commute modes at least one day a week and sets targets for employee alternative mode use and vehicle miles traveled. Progress toward the goals is gauged through an annual employee survey which must be submitted for oversight. In 1995, the program covered 226 sites with 99,189 employees. The Pima Association of Governments reported that in 1995 the program led to an annual savings of 60 million VMT, 3 million gallons of gas, $25 million, and 2.4 million pounds of criteria pollutants (PAG 2003).

Maryland

In 1999 the state of Maryland passed a law giving employers a strong positive incentive to pay their employees extra for giving up their parking spot at work. The law also extends tax credits to non-profit organizations such as schools or medical centers if they pay for employee transit benefits or other alternatives to driving. The tax credit is valued at half of whatever an employer pays toward an employee's transit or vanpool commuting costs, up to $30 each month. Supported by both business and environmental groups, the measure will help address traffic and air pollution problems (VTPI 2003).

Commuter Choice Maryland is jointly sponsored by the Maryland Department of Transportation and the Maryland Transit Administration. *Commuter Choice Maryland* is the "umbrella" term for a wide variety of commuter benefits programs. The organization works with employers to create and implement alternative commuting programs tailored to a particular employer's needs in ways that is financially attractive to both employers and employees (MD DOT 2003).

The state of Maryland's *Live Near Your Work* program provides $3,000 in direct cash assistance to homebuyers moving to designated neighborhoods surrounding major employers. Local governments designate the LNYW areas and administer the program within their jurisdictions. Participating employers—businesses, non-profits, colleges or universities, or government agencies—must set eligibility requirements, promote the program to their employees, and provide matching resources. This is expected to strengthen neighborhoods through increased homeownership, reduce total commuting costs (including traffic congestion), and help develop better relationships between employers and their surrounding communities (MD DHCD 2003).

Commuter Connections is a network of Washington DC metropolitan commuter transportation organizations coordinated by the Metropolitan Washington Council of Governments. It is the main commuter information resource for Maryland, Virginia, and the District of Columbia. It helps businesses identify opportunities for voluntarily complying with the Clean Air Act guidelines to reduce vehicle emissions and provides the following services (MWCOG 2003):

- Promoting telework programs and other pollution reduction activities
- Using Geographic Information System software to match commuters for ridesharing
- Offers a regional Guaranteed Ride Home program, and
- Operates a regional system of Traveler Information kiosks, InfoExpress.

New Jersey

The New Jersey Department of Transportation launched the voluntary *Smart Moves for Business* program in 1997 aimed at reducing statewide traffic congestion. The program offers employees commuting choices such as carpooling, vanpooling, transit passes, telecommuting, and flex hours. In return, participating companies can get tax credits on their state corporate tax worth up to $100 per participating employee. In addition, the Department also provides employers funding grants and assistance setting up their programs. Prominent local companies such as Merck, L3 Communication Systems, Bellcore, and ETS are among the participants (NJ DOT 2003).

Pennsylvania

Pennsylvania launched an Employer Trip Reduction program for the Philadelphia metropolitan area in 1994. Employers in the region are required to meet vehicle occupancy targets for their employees. Different employers have different targets to meet based on size and location. Employers with more than 1000 employees at a single site have to achieve 50% of their allotted targets in one year, 80% in 2 years, and 100% in years thereafter. Employers with less than 1000 employees at a single site have to achieve 50% of their allotted targets in 2 years and 100% in years thereafter. Employers can meet their targets by promoting any combination of car/vanpooling, subsidized transit, telework, flextime, biking, or walking. Each employer has to submit annual reports to the Department of Environmental Protection for verification of progress (PA Code 2003).

Policy Lessons from State Employer Based Trip Reduction Programs

Studies suggest that employer based trip reduction programs seem to work best in areas that share one or more of the following characteristics: high population/employment density (e.g., downtown), restricted or constricted parking facilities, long commutes in heavy traffic, and frequent and widespread public transit (US DOT 1993). However, some key factors that can make trip reduction programs more effective stand out as universally applicable.

Surveys indicate that the number one reason employers cite for starting their trip reduction programs are trip reduction ordinances. It is no coincidence then that both the highest number and most successful of trip reduction programs are located in areas that have trip reduction ordinances (Pollution Probe 2001). Mandatory trip reduction ordinances appear to be the best way to bring about employer based trip reduction programs. However, before such an ordinance is passed it is necessary to consider in detail local transportation status and options, baseline vehicle occupancy figures, reasonably achievable targets, and modes of monitoring, verification, and penalties for non-compliance. Since enforcement is usually difficult, trip reduction ordinances should provide incentives to employers for compliance such as state/local tax benefits and recognition of good corporate citizenship through honors and awards.

Employers can also use alternative commuting programs to enhance their employee benefits package and improve worker morale, which would help them to attract/retain better employees. Serious commitment from senior management is necessary to plan and implement a long-term trip reduction program. Employers who offer significant financial incentives to employees for alternative commuting are most likely to have successful trip reduction programs (Pollution Probe 2001). Such incentives can be in the form of subsidized transit passes, subsidized carpool/vanpool costs, free ridematching, increased fee or limited parking for solo commuters, and free/preferential parking for car/vanpoolers.

Finally, trip reduction programs are more likely to have a significant effect if a comprehensive effort is made involving a combination of multiple options, rather than starting with just one or two options. The chances of success increase when a regional/local transportation management association (TMA) is in place (as is the case in Delaware) (VTPI 2003). TMAs coordinate all alternative transport options, resulting in the pooling of all available resources.

22

Mileage-Based Insurance (MBI)

Motor vehicle insurance can be linked to vehicle usage and used to provide an incentive to reduce vehicle use. Vehicle insurance typically amounts to 18% of the internal costs of vehicle ownership (Litman 1997) and can be a substantially higher proportion for owners of less expensive vehicles. It is one of the largest fixed costs of vehicle ownership. Many insurance companies use a mileage rate factor when calculating premiums. This generally involves adjusting premiums up or down based on the average annual mileage reported by the policyholder. However, since mileage is self-reported, the driver has an incentive to underreport in order to save money. Hence, insurers do not place much weight on this factor; the effect is typically only a $25-$50 change, and is not enough to affect driving behavior (ICF & VTPI 2001). Insurance is therefore considered a fixed cost that does not significantly increase or decrease with VMTs, so it offers no incentive for motorists to minimize costs by driving less.

MBI bases all or most of the cost of vehicle insurance on vehicle use by charging a premium per mile, rather than the current premium charged per vehicle-year (Litman 1997). This decision is based on the logic that each individual's accident risk varies directly with VMT, i.e., the more any individual person drives in a given year, the greater the probability that person will be involved in an accident that year. Many existing rating factors (such as age, driving history, and type of vehicle) would still be incorporated, so higher risk drivers would pay more per mile than lower risk drivers. The charge per mile would be based on these factors, and this charge would be multiplied by VMT to determine the insurance payment. A driver of average risk would pay about 6 cents per mile (Litman 1997).

Drivers who continue to travel the average number of miles for a given geographical area would pay the same insurance premium under this proposed system as they do under the current system. Those who drive less than average would pay lower premiums and those who drive more than average would see a premium increase. All drivers on an MBI plan would have a financial incentive to reduce their VMT.

In order for this system to work, driver-reported mileage must be verified. Odometer audits must be performed, which would be similar to meter readings that are taken by utilities. An auditor would record mileage and check for signs of tampering. The audit would take 5-10 minutes to perform, would cost $5-$10 (based on average labor rates) and would be performed annually or semi-annually. In order to minimize inconvenience to the driver, it could be performed during regular vehicle maintenance, such as oil changes and safety/emissions inspections. If a discrepancy were found between reported and actual mileage, the driver would make an extra payment or receive a credit for the difference.

Effects of MBI on Emissions

If the fixed cost of vehicle insurance were transformed into a variable cost, the effect would be a reduction in VMT, because drivers would have the opportunity to save a significant amount of money by driving less. MBI has the potential to reduce NO_x emissions by 8% and VOC emissions by 7.6% by 2010 (ICF & VTPI 2001). This estimate is based on the well-studied price elasticity of fuel consumption with respect to gasoline prices (the most significant current variable driving cost). The introduction of $0.06/mile variable insurance premium would be the equivalent of a permanent 80% increase in the price of gasoline for participating drivers.[3] The estimate also assumes that MBI is offered to everyone, and that

---

[3] This assumes a 20mpg vehicle and $1.50/gallon fuel price.

50% of drivers take advantage of it. This portion represents those who currently accumulate below average annual mileage and therefore stand to save money with MBI.[4]

In the short term, we assume this reduction would be realized predominantly through the elimination of vehicle trips by carpooling, combining trips, using transit, walking/biking, or completely foregoing low value trips. In these cases, a hypothetical 1% reduction in VMT results in a 1% reduction in NO_x emissions and a 0.95% reduction in VOC emissions, because trip reduction eliminates tailpipe, cold start, and evaporative emissions (except those from parked vehicles)[5].

In the long term, if the incentive is strong enough, some people may chose to live closer to work and commercial centers, which would eliminate some trips and shorten others. A long-term analysis that considers effects on land-use patterns is beyond the scope of this report, and therefore we consider only short-term impacts.

The emission reduction potential of MBI is substantial compared to many other government-funded programs. A hypothetical MBI incentive program was analyzed in a paper presented at a recent Transportation Research Board meeting. In this scenario, the federal government provided 10% of the value of new mileage-based or parking pricing initiatives (of which MBI is an example). When considering only the environmental benefits, this hypothetical program was more cost effective per ton of emissions avoided than 18 of 19 strategies of the Congestion Mitigation and Air Quality Improvement Program (CMAQ) (Greenberg 2003). The cost of the average CMAQ program is $66,300 per ton of avoided emissions, while the cost of this mileage-based initiative was only $2700 per ton. The only program that was more cost effective was basic inspection and maintenance, which Delaware already employs.

Beyond Emissions: Safety and Equity Issues

MBI has many potential benefits that are not related to the environment. First, it is likely that traffic accidents will be reduced at a rate greater than VMT reduction. This is because drivers with poor accident records will be charged higher per mile premiums than drivers with good records, and will therefore have a greater than average incentive to reduce their VMT. As long as insurance is a fixed cost, no such incentive exists because high risk drivers cannot directly reduce their premium by driving less.

Second, MBI is expected to increase equity in a number of ways. Studies show that risk increases with VMT (ICF & VTPI 2001), but current insurance pricing schemes do not adequately account for this variable. Therefore, motorists who drive fewer miles unfairly subsidize the risk of those who drive more miles. In particular, women (Butler et al 1988), and low-income people tend to drive less and hence overpay for insurance. Such equity issues have been the primary factors for MBI initiatives in Texas and Philadelphia.

---

[4] In reality, more than half the population accumulates below average mileage, because VMT is not normally distributed, but rather is skewed to the left. A small number of people have very high VMT. Therefore, the 50% participation rate could be considered a conservative estimate.

[5] Some suggest that emissions reduction might exceed VMT reduction in congested urban areas, because when congestion is relieved, the remaining vehicles increase average speed, which decreases emissions per vehicle (ICF & VTPI 2001). However, this effect is too complicated to consider here. Also, an increase in transit ridership could force expansion of service, which would increase transit related emissions, but this would most likely be negligible, compared to the LDV emission reductions.

Federal and State MBI Policies and Initiatives

As of this writing, there are no insurance companies that offer rates primarily based on mileage, partly because of state-level regulatory barriers. Another barrier has been the lack of reliable, third party-verified mileage data that can be used to clearly illustrate the link between miles traveled and risk. However, several companies are in the process of devising such rates, and the EPA and several state and local governments have officially endorsed and are developing MBI programs.

EPA PAYD Insurance Initiative

The EPA's Pay-As-You-Drive (PAYD) Initiative seeks to promote the conversion of vehicle insurance to mileage-based pricing as an incentive to reduce vehicle travel, and thereby reduce air pollution and GHG emissions (ICF & VTPI 2001). The goal is to increase awareness of this pricing option among insurance regulators, providers, and brokers. The program will provide publicity for efforts made by providers of mileage-based insurance in the form of a logo, similar to the Energy Star program. It also examines the feasibility and impacts (travel, safety, and environmental) of the pricing scheme through pilot projects and disseminates this information by holding forums for researchers and insurers.

Texas

In some states, the insurance code prohibits the use of mileage-based rate plans. In May 2001, the Texas legislature passed H.B. 45, which amended the Insurance Code to specifically allow insurers to offer rates based on distance as a unit of risk. Because of the unique nature of these rates, it also required the insurance commissioner to adopt rules pertaining to odometer audits and other proofs of financial responsibility. Although the bill passed two years ago, no company has yet offered such a rate. A lobbying campaign is now underway to require insurance companies that operate in the state to offer distance- or time-based rate options to their customers (Marston 2002).

Oregon

Distance-based insurance is already legal under the Oregon Insurance Code. In June 2003, Oregon became the first state to offer a financial incentive for insurers to provide mileage-based insurance (OEC 2003a). Under this program, an insurance company will receive a tax credit of $100 per vehicle on an MBI plan. The hope is that such a credit will encourage experimentation on the part of insurers by buying down part of the risk inherent in establishing a new rate structure. The total cost to the state is capped at $1 million (supporting a total of 10,000 policies) and the credit will be available from 2004 to 2008 (OEC 2003b). The bill was introduced at the request of the Oregon Environmental Council (OEC) and was supported by a broad range of organizations, including the National Association of Independent Insurers, regional governments, the Oregon/Idaho chapter of the American Automobile Association, the Oregon Consumer League, various citizen transportation reform groups, and the Interfaith Global Warming Campaign. OEC estimates that if half of Oregon drivers adopted MBI, state highway costs could be reduced by $1.5 billion over 20 years.

Massachusetts

Massachusetts has instituted a new program that allows insurers to collect mileage data from drivers. Odometer readings are now a component of annual vehicle inspections that were already required by the state and the information will be made available to insurance companies (Funderberg et al 2003). For years, Massachusetts has allowed insurers to offer discounts to drivers who drove less than 7,500 miles per year. Until recently, this discount usually depended on the honor system, as the mileage was self-reported and not independently verified. Therefore, there was likely a good deal of cheating by drivers.

Insurers can now base the mileage discount on information provided by state inspectors. The mileage discount is currently quite small – 10% for driver who accumulate less than 5,000 miles per year, and 5% for drivers who accumulate between 5,000 and 7,500 miles. It is likely that the discounts have been small to date because insurers suspected customers of underreporting mileage. This is the first state assisted mileage verification program, and it is likely that insurers will offer larger mileage-based discounts in the future, since they can now trust the data. Larger discounts would be needed to provide enough incentive to reduce VMT.

GMAC Insurance-Onstar Partnership

This private sector initiative has created an MBI pilot that offers insurance discounts of up to 40% to subscribers in three states, including Oregon (see above). Because the pilot was initiated in late-January, there was no available information on performance in time for this report. However, it is an encouraging development since it means that MBI will be offered to more than 2.5 million subscribers.[6]

Policy Lessons from State and Federal MBI promotion programs

Policies to promote mileage-based insurance are a relatively recent phenomenon, and as such have yet to result in the provision of MBI. It may therefore be a bit premature to say that many lessons have been learned. It is clear, however, that simply removing regulatory barriers to MBI is not enough to entice insurers to offer that type of rate structure. Some incentive must be provided to lower the risk to insurers inherent in any new rate structure. This incentive could be direct, in the form of a tax credit or grant, as has recently been initiated in Oregon. It could also come in the form of logistic support, as has been done with odometer readings in Massachusetts.

---

[6]For details, please see:
http://onstar.internetpressroom.com/pressreleasesetail.cfm?ID=262&printmode=true

3.2 Conversion to Alternative Fuels

Alternative fuels, defined as any transportation fuels that are not petroleum-based, can be an important means of reducing air pollution from road transport. An alternative fuel may be a fossil fuel (as are natural gas and propane), a fossil fuel-derived chemical (as methanol often is), or a fuel that is mixed with gasoline or diesel in significant quantities (e.g. 85% ethanol or E85), (see table 3.3). The key is that alternative fuels are not derived from *petroleum*, but rather on domestic (if not always renewable) energy sources (NREL 2001).

The second term in the equation of transport emission factors indicates that fuel properties play an important role in reducing emissions of air pollutants. However, not all alternative fuels have been demonstrated to have emissions benefits. If emissions reduction is the main goal of an alternative fuel policy, natural gas emerges as the preferred fuel.

Natural gas use in buses is growing rapidly. In 2001, approximately 9% of the nationwide transit bus fleet was operating on natural gas and about 25% of the transit buses currently on order are NGVs (Eudy 2002). More than 73 transit fleets currently use at least six NGVs and on average

Table 3.3. Definitions of Alternative Fuel Terms.	
Alternative Fuel	Any transportation fuel that is not petroleum based.
Biodiesel	Biomass derived diesel substitute, often made from soybean oil or recycled cooking oil. Can be blended with conventional diesel.
CNG and LNG	Compressed Natural Gas and Liquid Natural Gas consist mostly of methane (the simplest hydrocarbon). Our supply comes almost exclusively from North America, and predominantly from within the US.
Ethanol (E85)	Alcohol fuel derived from corn or other biomass. Can be blended with conventional gasoline.
Propane or LPG	A gaseous byproduct of the petroleum refining process.

NGVs make up over 30% of these fleets. As of 2000, there were two agencies that operated 100% natural gas buses, in Tempe, AZ, and Thousand Palms, CA. A number of transit agencies have committed to purchasing only natural gas buses in the future, including the Los Angeles, Sacramento, Cleveland, and Atlanta transit authorities, and New York City's Department of Transportation (Cannon & Sun 2000). Natural gas penetration of the light-duty vehicle market has not been as rapid, but it is the second most popular alternative fuel (behind propane) in terms of consumption in light-duty vehicles (Davis & Diegel 2002).

Potential for emission reduction
Light duty vehicles

Ozone is the air pollutant of greatest concern to Delaware, as discussed in the introduction. Of currently available alternative fuels, natural gas [compressed natural gas (CNG), or liquid natural gas (LNG)] offers the greatest potential reduction in emissions of ozone precursors.

A number of tests and experiments have examined the emissions associated with each of the major alternative and conventional fuels. According to the Department of Energy's (DOE) Alternative Fuel Data Center, natural gas has the potential to reduce ozone precursors by 80% relative to reformulated gasoline (RFG) (AFDC 1998). By comparison, reductions in emissions by liquefied petroleum gas (LPG or propane), methanol (M85), and ethanol (E85) are 60%, 40% and 25% respectively. The realized emission reduction of a vehicle on the road is a function not only of fuel characteristics but also of engine design and calibration, and of driving conditions. Empirical tests consistently show, however, that natural gas vehicles outperform other AFVs in terms of reducing ozone-causing emissions.

CNG outperforms other alternatives in the EPA Federal Test Procedure for emissions (NREL 1999). Table 3.3 compares the results for two dedicated CNG vehicles, a bi-fuel CNG truck, a bi-fuel LPG truck, and two bi-fuel E85 vehicles[7]. The percentages represent the emissions of the AFV relative to a comparable gasoline model. Shaded values indicate the AFV had higher emissions than its gasoline counterpart. These results confirm that CNG is superior to bi-fuel LPG and E85 in terms of reducing emissions.

Table 3.4. Results from EPA Federal Test Procedure.			
		Emissions	
Vehicle Type	Alt. fuel	NO$_x$	VOC
3/4 ton pickup	CNG	-81%	-99%
Compact sedan	CNG	-69%	-96%
3/4 ton pickup	bi (CNG)	-34%	-67%
3/4 ton pickup	bi (LPG)	96%	160%
Minivan	bi (E85)	29%	23%
Full size sedan	bi (E85)	33%	0%

Shaded numbers are increased emissions compared to gasoline.

Source: NREL (1999)

Table 3.4 also suggests that dedicated CNG vehicles offer greater emissions reductions than bi-fueled CNG vehicles. These results are supported by a comparison of dedicated CNG, bi-fuel CNG, and gasoline 15-passenger vans used as shuttles over a one-year period (Eudy 2000).

Dedicated CNG vans showed a reduction of NO$_x$ and VOC (relative to gasoline) of 83% and 95%, respectively. Bi-fuel CNG vans showed a similar reduction of VOC, but no significant reduction in NO$_x$. These results suggest that in order for the full emissions benefits of CNG to be realized, a commitment must be made to dedicated CNG vehicles rather than bi-fuel vehicles.

In an air quality simulation conducted by the National Renewable Energy Laboratory (NREL), natural gas vehicles showed great potential for improving air quality (Guthrie et al 1997). Air quality simulations were run for Los Angeles and Baltimore through year 2020 under four scenarios: no emissions, complete transition to reformulated gasoline, complete transition to CNG, and complete transition to methanol (M85). In both cities, the CNG scenario showed significantly lower ozone than the reformulated gasoline or M85 scenarios (which were similar). In fact, the CNG scenario closely approached the "no gasoline emissions" scenario. This suggests that from an air quality standpoint, replacing a gasoline-fueled vehicle with a CNG-fueled vehicle is nearly as effective as taking the gasoline vehicle off the road entirely.

---

[7] No manufacturer currently offers dedicated AFVs for any fuel other than CNG.

Heavy-duty vehicles

Natural gas is a proven and widely-used fuel for heavy-duty vehicles in the U.S. (particularly buses), offering a number of environmental benefits over diesel, including cleaner emissions. According to the U.S. Department of Energy, natural gas-powered school buses can reduce NO_x and VOC by 87%, and CO by 70% (US DOE 2000). A review of nine studies showed that CNG transit buses emit 40-86% less particulate matter, and 38-58% less NO_x than conventional diesel (Cannon & Sun 2000). A European study found that CNG reduced emissions of NO_x and VOC by 70%, CO by 10%, and particulates by more than 90% compared to diesel (Rabl 2002). In addition to these emissions benefits, CNG also offers upstream emissions reductions (those associated with fuel extraction, production, and transportation) of 71% for CO and NO_x, 69% for VOC, and 27% for particulates (Rabl 2002).

New advancements in diesel technology and stricter regulations may make future heavy-duty diesel engines cleaner (US EPA 2000a). Beginning with model year 2007, high-efficiency catalytic exhaust emission control devices (or equivalent control devices) will be required on 50% of new diesel vehicles, and by 2010 they will be required on 100% of new vehicles. In order for these devices to function properly, low-sulfur diesel must be available by mid-2006. The effect of these new regulations could be to lower heavy-duty diesel emissions of PM and NO_x by 90 and 95% respectively by the year 2030. Under the new regulations, emissions by future heavy-duty diesels could be comparable to current heavy-duty CNG vehicles.

In spite of this, the use of CNG in heavy-duty vehicles is still favorable from an emissions standpoint. Natural gas is an inherently cleaner fuel, which has several implications. First, there is no indication as yet how durable the new emissions traps are, and it is likely that they will become less effective with age (as do catalytic converters on automobiles). Since natural gas can achieve low levels of emissions without special emissions traps, CNG vehicles are more likely to produce emissions benefits throughout their useful lives. Second, past diesel regulations have not always lowered heavy-duty diesel emissions as promised, and their effectiveness depends on constant monitoring and enforcement. For example, throughout the 1990's heavy-duty diesel engine manufacturers illegally circumvented emissions regulations by electronically disabling emissions control devices under strenuous driving conditions, resulting in emissions far above what was allowed (AFDC 1999). Third, regulations are subject to changes in political climate and may be repealed or delayed. This particular regulation was approved under the Clinton administration, then initially tabled by the subsequent Bush administration. As of this writing, it is scheduled to be implemented as planned, but this could still change. Finally, comparable emissions traps could be designed for CNG vehicles which could lower their emissions well below those of "clean diesel."

Delaware is currently pursuing biodiesel as an alternative fuel, rather than CNG (Livable Delaware 2003). Biodiesel shares many of the non-emissions related advantages over diesel with CNG (see "Beyond Emissions" below) and it has the advantage of not requiring major infrastructure changes. However, biodiesel does not offer the emissions benefits that CNG offers. A recent study released by the EPA found that pure biodiesel (B100) can reduce CO and particulates by about 48%, and VOCs by about 67% compared to conventional diesel. Emissions of NO_x may increase by 10% (US EPA 2002c). However,

pure biodiesel is rarely used; it is more commonly blended with conventional diesel. If 20% biodiesel is used (B20), the emissions benefits relative to diesel decrease proportionately, and it becomes clear that CNG is the more advantageous alternative fuel in terms of emissions.

Beyond Emissions

Natural gas offers many benefits relative to diesel in addition to its lower emissions of regulated substances. It is a domestic fuel, with 90% of supply coming from the U.S., and most of the remainder coming from Canada (EIA 2001). In contrast, less than 50% of oil supply is domestic, and is therefore subject to price shocks that result from political and economic instability in the regions of production: the Middle East, Africa, and South America.

Natural gas produces less fuel-cycle greenhouse gas emissions than petroleum derivatives, such as gasoline and diesel (Wang 1999). Although natural gas is a potent greenhouse gas (being primarily composed of methane), when properly sealed and dispensed, and considered over the cycle from extraction to combustion, it has emits approximately 25% fewer greenhouse gases than conventional fuels (Wang 1999). As natural gas fueling infrastructure matures, it is likely that methane loss will be substantially reduced. State and local governments have initiated a wide range of policies and strategies to reduce their greenhouse gas emissions in response to the climate change issue. Greater use of CNG and other alternative fuels offers a ready means to assist Delaware's on-going efforts to reduce its greenhouse gas emissions (CEEP 2000).

Natural gas is more environmentally benign than oil-derived fuel. In the event of a spill, evaporating diesel and gasoline produce toxic evaporative fumes, and can contaminate ground water (Canon & Sun 2000). Natural gas, although it is an asphyxiate, is not toxic and dissipates quickly in properly ventilated areas. There are no major local environmental hazards associated with natural gas—the primary environmental problem with leaks is that natural gas is a greenhouse gas.

Federal and State Policy Experience with Alternative Fuel Vehicles

Alternative fuels and alternative fuel vehicles (AFVs) are promoted by an array of federal laws, regulations, and incentive programs. Some of these policies directly promote alternative fuel use, while others, such as those to protect air quality, provide indirect support for alternative fuels. Typical of transport and other complex policy matters, responsibilities are allocated among different federal agencies and institutions.

State governments have a key role in promoting the use of alternative fuels and alternative fuel vehicles and many important policy measures operate in the exclusive domains of state government authority. Progressive states have taken advantage of federal initiatives to complement their own efforts. State experiences in promoting alternative fuel vehicles vary widely and a selection of prominent ones are described.

FederalExperience

Energy Policy Act of 1992: In 1992 Congress passed the Energy Policy Act (EPAct) with the goals of enhancing our nation's energy security and improving environmental quality through increased use of domestically produced alternative fuels. DOE's overall mission was to replace 10% of petroleum-based motor fuels by 2000 and 30% by 2010. EPAct

mandates federal, state, and alternative fuel provider fleets to purchase AFVs (US DOE 2003).

Tax Incentives: The EPAct provides for a Clean Fuel Vehicle Tax Deduction for the purchase of a new qualified clean fuel vehicle, or for the conversion of a vehicle to use a clean burning fuel. The maximum allowable deductions can vary from $2,000 for cars to $50,000 for buses, trucks, or vans. A tax deduction of up to $100,000 per location is available for qualified clean fuel refueling property, including recharging property for electric vehicles. A tax credit for the purchase of qualified electric vehicles (EVs) and hybrid electric vehicles (HEVs) is also provided under the EPAct. The size of the credit is 10% of the cost of the vehicle, up to a maximum credit of $4,000. All dedicated EVs, as well as most HEVs qualify for the tax credit, which is available for both business and personal vehicles (US DOE 2003).

Clean Cities Program: DOE's Clean Cities Program coordinates voluntary efforts, funding mechanisms and incentives between local governments and industry to accelerate the use of alternative fuels and expand AFV refueling infrastructure (US DOE 2003).

State and Alternative Fuel Provider Fleets Program: EPAct established this DOE regulatory program that requires state and alternative fuel provider fleets with 50 or more light-duty vehicles to purchase AFVs as a portion of their annual light duty vehicle acquisitions. Fleets earn credits for each vehicle purchased and credits earned in excess of their requirements can be banked or traded with other fleets, thus providing a lot of flexibility (US DOE 2003).

State Energy Program: Under DOE's State Energy Program, individual states promote energy conservation, demand reduction, and renewable energy technologies though the development and implementation of a comprehensive State Energy Plan. States may choose to allocate grants funds to various transportation related activities, including programs to accelerate the use of alternative fuels for government vehicles, fleet vehicles, and privately-owned vehicles (US DOE 2003).

DOE/Urban Consortium Funds: DOE's Municipal Energy Management Program funds projects in cities and counties that demonstrate innovative energy technologies and management through the Urban Consortium Energy Task Force (UCETF). Each year the task force requests proposals from urban jurisdictions and after a review process, funds those projects that best demonstrate urban America's efforts to become more energy efficient and environmentally responsible. In the past, the UCETF has funded over 300 projects nationwide including many that featured AFVs (US DOE 2003).

Petroleum Violation Escrow (PVE) Funds: PVE funds became available as a result of oil company violations of federal oil pricing controls that were in place from 1973-1981, and have been made available to states for use in energy efficiency programs. These funds may be used in one or more of three federal energy related grant programs: the State Energy Program, the Weatherization Assistance Program, and the Low-Income Home Energy Assistance Program. To date more than $4 billion in PVE funds has been made available to states (US DOE 2003).

Congestion Mitigation and Air Quality (CMAQ) Improvement Program: The CMAQ program of the Federal Highway Administration was reauthorized in the recently enacted Transportation Equity Act for the 21st Century. The CMAQ program funds projects and programs in non-attainment areas to reduce transportation related emissions (US DOE 2003).

Clean Fuels Grant Program: This Federal Transit Administration program was designed to accelerate the deployment of advanced bus technologies by supporting the use of low-emission vehicles and AFVs in transit fleets. The program assists transit agencies in purchasing alternative fuel buses and related equipment, and the development of refueling and maintenance infrastructure (US DOE 2003).

Clean Fuel Fleet Program: This is an initiative implemented by the U.S. EPA in response to the Clean Air Act Amendments of 1990 and requires fleets in cities with significant air quality problems to incorporate vehicles that will meet clean fuel emission standards (US DOE 2003).

National Low Emission Vehicle (NLEV) Program: The NLEV program is a voluntary program between the U.S. EPA, nine of the Ozone Transport Commission states, and automobile manufacturers. The program is designed to reduce unhealthy levels of smog and other toxic air pollutants formed from vehicle tailpipe emissions. Automobile manufacturers will provide cars and light-duty trucks that are cleaner burning than currently required by law (US DOE 2003).

Air Pollution Control Program: This U.S. EPA administered program, also known as the Section 105 grants, assists state and municipal agencies in planning, developing, establishing, improving, and maintaining adequate programs for prevention and control of air pollution or implementation of national air quality standards. States and municipalities may receive up to 60% of their project costs through federal funding (US DOE 2003).

Pollution Prevention Grants Program: This U.S. EPA administered program supports the establishment and expansion of state pollution prevention programs in various sectors of concern and may be used to support innovative programs in energy and transportation. State agencies are required to contribute at least 50% of the total cost of the project (US DOE 2003).

State Experience
California

Due to its historic air quality problem California was one of the first states to adopt policies to promote low-emission vehicles (LEVs) and AFVs. Building on this early start California has become by far the most successful state in LEV and AFV promotion at the turn of the century. Its LEV and ZEV standards have actually prompted changes in the automobile industry and many states have adopted such standards (van Vorst and George 1997). The California Air Resources Board (CARB) and the California Energy Commission (CEC) offer a wide variety of incentives for AFV acquisition, infrastructure and technology development. Local Air Pollution Control Districts (APCDs) and Air Quality Management Districts (AQMDs) administer several incentive programs funded by the state and often have their own initiatives. California is the home of 11 Clean Cities Coalitions under the DOE

Clean Cities Program. Many of these cities, e.g., Sacramento, offer their own set of incentives for AFVs. California's leadership position in AFV promotion is easily seen from the following table.

The Federal *Clean Air Act Amendments* (CAAA) of 1990 allow California to continue to set its own standards for vehicle emissions due to the state's severe air pollution problems, so long as the standards are equal to, or more stringent than, those set by the CAAA (US DOE 2003). As part of the state's clean fuel program, California opted to phase-in its own standards and set four levels of low-emission vehicles:

Table 3.5. Number of AFVs and Refueling Stations in Selected States, Year 2000.			
State	**AFVs**	**Refueling Stations**	**Population per AFV**
California	67,556	1,103	477
New York	16,485	166	1,326
Colorado	11,435	140	476
Arizona	10,364	175	649
Maryland	6,118	45	1,010
New Jersey	7,262	47	1,375
Pennsylvania	14,741	155	888
Delaware	513	4	1,452
Source: Brown and Breckenridge (2001)			

- TLEV (Transitional Low Emission Vehicle)
- LEV (Low Emission Vehicle)
- ULEV and SULEV (Ultra and Super Ultra Low Emission Vehicle), and
- ZEV (Zero Emission Vehicle).

Currently, only electric vehicles meet the ZEV requirement. CARB originally required that, beginning in 1998, 2% of all vehicles sold in California by major automakers must be ZEVs. By 2003, 10% of sales were mandated to be ZEVs. In March, 1996, CARB suspended the 2% requirement for the years 1998-2002, but the requirement of 10% for 2003 and beyond was maintained (CARB 2003). In 1998, CARB modified the ZEV mandate further. These modifications include:

- Major automakers (those that sell 35,000 or more passenger cars and light trucks annually in California) can satisfy up to 6% of their ZEV requirement with automobiles that, while not pure ZEVs, are clean enough to qualify for partial ZEV credits. These automobiles must meet CARB's SULEV standard, but can do so with any technology using any type of fuel. The remaining 4% of the requirement must be met with pure ZEVs.
- Intermediate automakers (those that sell 4,501 to 35,000 passenger cars and light trucks annually in California) can meet their entire ZEV requirement with partial ZEV credits.
- Manufacturers that sell fewer than 4,500 vehicles annually in California do not have to meet the ZEV requirement (CARB 2003).

State fleets are encouraged to purchase AFVs that meet the ULEV and ZEV standards. Districts in non-attainment areas are allowed to require public and private fleet operators to purchase LEVs and operate them on clean fuels. APCDs in California that have not attained state and federal air quality standards may collect an annual surcharge of up to $4 per vehicle as part of the California Department of Motor Vehicles' (DMV) registration fee. These funds are used for projects related to reducing pollution from motor vehicles (CARB 2003).

A new public transit bus rule adopted by CARB in February 2000 regulates public transit fleets and sets emission reduction standards for new urban transit buses. The rule allows transit fleets to choose one of two paths in order to reduce their emissions to the required levels: the alternative fuel path and the diesel path. Transit fleets are then provided incentives to purchase AFVs or LEVs according to their chosen path (CARB 2003).

There is an $18 million fund designed to encourage the purchase and lease of AFVs in California. The program is administered by CARB in conjunction with the State Energy Resources Conservation and Development Commission and distributes grants worth 90% of the incremental cost above $1,000 of an eligible new AFV, up to a maximum of $9,000 per vehicle. These grants are available to individuals, local governments, state agencies, and private businesses (CARB 2003).

The *Carl Moyer Memorial Air Standards Attainment Program* consists of the *Advanced Technology Development Program* (ATDP) and the *Fuel Infrastructure Demonstration Program* (FIDP). The ATDP is administered by CARB and the CEC and had a $2.2 million budget for 2001 (US DOE 2003). The program is designed to assist companies with grants to develop new advanced technologies that lower heavy-duty and off-road vehicle NO_X emissions. These technologies must have the potential for commercialization within five years and provide significant emission reductions in a cost-effective manner. The Program funds projects that reduce emissions at a cost of up to $12,000 per ton, although some programs have been able to achieve a $3,000 per ton cost-effectiveness (Brown and Breckenridge 2001).

The goal of the FIDP is to develop a limited number of infrastructure projects that dispense a qualifying fuel. Qualifying fuels include electricity or any liquid or gaseous fuel, other than gasoline or diesel that provide NO_X reductions. Grants are issued locally by APCDs and AQMDs that receive FIDP funding and participate in the program. As part of the Clean Transportation Fuels Initiative, the CEC also provides technical assistance for the establishment of publicly accessible clean fuel refueling facilities to serve clean fuel fleets and vehicles in California. Eligible projects include all non-petroleum fuels such as natural gas, alcohol and hydrogen (CEC 2003).

The *Bus Replacement and Infrastructure Program* has $50 million to implement programs to help school districts replace and retrofit older school buses. $12.5 million of the funds will be used by CARB to implement a school bus retrofit program, while the other $37.5 million will be administered by the CEC for the school bus replacement program. So far more than 800 school buses have been replaced or retrofitted through this program (CARB 2003).

In order to equalize the vehicle license fee between AFVs and conventionally-fueled vehicles, the incremental cost of purchase of an AFV is exempt from the vehicle license fee when it costs more than the most comparable conventionally-fueled vehicle, as determined by the CEC. This reduction applies to new, light-duty AFVs that are certified to meet or exceed ULEV standards (CEC 2003). From July 2000, certain AFVs can use high occupancy vehicle (HOV) lanes. An identification sticker must first be obtained from the California DMV. Several cities, such as Los Angeles and Sacramento, also offer special incentives to AFV users like free parking and free recharging for EVs.

New York was one of the first states in the northeast to adopt the California auto emission standards and mandates. The state has one of the nation's more successful AFV programs and is easily the leader in the region with 16,485 AFVs and 166 refueling stations in 2000 (EIA 2003). Governor Pataki has been an outspoken advocate of alternative fuels and his strong leadership has been instrumental in the state's success with AFVs. New York's alternative fuel programs are mostly coordinated by the New York State Energy Research and Development Authority (NYSERDA). New York is the home of six Clean Cities Coalitions, of which New York City has a substantial incentive program of its own to promote AFVs, and has achieved notable success in the conversion of transit buses and taxi-fleets to CNG.

New York's *Zero Emission Vehicle Mandate* orders each auto manufacturer's sales fleet of passenger cars and light-duty trucks (weighing up to 3,750 lbs.), produced and delivered for sale in New York, be at least 10% ZEV starting in 2003 (US DOE 2003). The state has mandated that clean-fueled vehicles make up 50% of all state agency fleets by 2005 and 100% by 2010, with accountability requirements for the actual amount of alternative fuels used (Brown and Breckenridge 2001). The New York *Clean Water/Clean Air Bond Act* has established funding mechanisms for AFV programs and $40 million has already been raised toward AFV programs. New York provides a partial sales and use tax exemption for the sale of new AFVs and for vehicles that are converted to run on alternative fuels (US DOE 2003).

New York's *Alternative Fuel (Clean Fuel) Vehicle Tax Incentive Program* offers a range of incentives for AFVs (NYSERDA 2003):

- Purchasers of electric vehicles (EVs) are eligible for a tax credit worth 50% of the incremental cost, up to a maximum of $5,000 per vehicle. All dedicated EVs, as well as hybrid-electric vehicles (HEVs) qualify for this credit
- Purchasers of CNG, LPG, methanol, ethanol, and hydrogen-powered vehicles are eligible for a tax credit worth 60% of the incremental cost. The maximum value for vehicles with a gross vehicle weight under 14,000 lbs. is $5,000 and for vehicles over 14,000 lbs. is $10,000, and
- The installation cost of clean fuel vehicle refueling equipment (including EV recharging stations) is eligible for a tax credit worth up to 50% of the project cost. There is no limit on this incentive.

The *Clean-Fueled Vehicle Program*, funded by the Clean Water/Clean Air Bond Act, is building 16 large CNG refueling stations and 30 smaller fueling stations for mid-day fill ups in New York metropolitan areas and along major highways. These stations are on state owned land and are accessible to the public (Brown and Breckenridge 2001).

The *Clean-Fueled Bus Program*, also funded by the Clean Water/Clean Air Bond Act and administered by NYSERDA, provides funds to state and local transit agencies, municipalities, and schools for up to 100% of the incremental cost of purchasing new alternative fuel buses and associated infrastructure. Project selection is based on the emissions reduction potential (NYSERDA 2003).

The *New York State Clean Cities Challenge*, administered by NYSERDA, awards funds to members of New York's Clean Cities Coalitions that acquire AFVs and/or refueling infrastructure. Funds are awarded on a competitive basis, and can be used to cost-share up to 75% of the proposed project, including the incremental cost of purchasing AFVs, the cost of

installing refueling and recharging equipment, and the incremental costs associated with bulk alternative fuel purchases (NYSERDA 2003).

The *New York State Clean Cities Sharing Network*, run by NYSERDA, provides technical, policy, and program information on AFVs. Membership is open to all organizations, businesses, and individuals interested in AFVs. The Network publishes information on upcoming funding opportunities and events, tax incentives, refueling stations, case studies, and contact information for members, and also organizes technical workshops. NYSERDA offers the *Flexible Technical (Flex-Tech) Assistance Program* to fleet managers that want to evaluate the feasibility and cost of adding AFVs and refueling facilities to their operations. Low-cost training for vehicle mechanics is available through certified institutions (NYSERDA 2003).

Colorado

Colorado's AFV promotion policy is based mainly on a combination of tax credits and rebates that vary according to the emission level of an AFV. Basing incentive amounts on certifiable emission levels allows the state to reward consumers for producing less pollution. AFV initiatives are coordinated among various state agencies and departments, the Department of Revenue, the Department of Transportation, the Department of Environment, and the Office of Energy Conservation. Colorado has the highest "AFV: Population ratio" in the nation (Brown and Breckenridge 2001). Colorado is the home of three Clean Cities Coalitions, of which the City of Denver has the most substantial AFV promotion initiatives.

For tax years beginning on or after July 1, 1998, an income tax credit is available from the Colorado Department of Revenue for the incremental cost of purchasing an AFV or for the conversion of a vehicle to run on an alternative fuel. Vehicles using a hybrid propulsion system also qualify for this incentive. For an AFV purchase or conversion that permanently replaces a motor vehicle that is ten years old or older, the percentage of tax credit specified in the table below is multiplied by two, up to a limit of 100%. To the extent that the allowable credit exceeds the person's tax liability for that year, the excess may be carried forward for up to five years. This credit expires July 2011. The value of the credit is based on the EPA emissions classification of the vehicle as depicted in Table 3.6.

Table 3.6. Percentage of Tax Credit Based on Type of Vehicle.			
Type of Vehicle	**1998-2006**	**2006-2009**	**2009-2011**
LEV	50%	25%	0%
ULEV/ILEV	75%	50%	25%
SULEV/ZEV	85%	75%	50%
			Source: US DOE (2003)

For tax years beginning on or after January 1, 1998, the Colorado Department of Revenue offers an income tax credit for the construction, reconstruction, or acquisition of an alternative fuel refueling facility that is directly attributable to the storage, compression, charging, or dispensing of alternative fuels to motor vehicles. The credit has a value of 50% for the years 1998-2006, 35% for 2006-2009, and 20% for 2009-2011. For an alternative fuel refueling facility that will be generally accessible for use by the public, the percentages specified are multiplied by 1.25. For an alternative fuel refueling facility that dispenses an alternative fuel derived from a renewable energy source, the credit percentages specified above are multiplied by 1.25 with certification that at least 70% of the alternative fuel dispensed annually is derived from a renewable energy source for a period of ten years. The

credit has a maximum value of $400,000 in any consecutive five-year period for each refueling facility and expires July 2011 (CO DOR 2003).

For tax years beginning on or after July 1, 1998 but prior to July 1, 2012, a rebate is available from the Colorado Department of Revenue for the purchase of an AFV or for the conversion of a vehicle to run on an alternative fuel. However, the vehicle must be owned by a state or local government agency or a tax-exempt organization, and be used in connection with the official activities of the entity. Vehicles using a hybrid propulsion system also qualify for this incentive. The rebate is a percentage of the incremental cost if used toward purchasing a new AFV, or is a percentage of the conversion cost if used towards the cost of converting a vehicle to run on alternative fuel. The percentages for rebates are similar to those for tax credits shown in the table above. Each qualified entity is limited to $350,000 per state fiscal year in total rebates paid (CO DOR 2003).

Vehicles, vehicle power sources, or parts for vehicles over 10,000 lbs. gross vehicle weight that are certified to federal Low Emission Vehicle standards or better are exempt from state sales tax. Fuel tax exemptions are also granted to CNG and LPG vehicle owners. Owners of CNG and LPG-fueled vehicles have to purchase an annual tax decal for $70, $100, or $125 based on the vehicle's gross vehicle weight to participate in the exemption. Non-profit transit agencies are exempt from the fuel tax altogether (CO DOT 2003).

Vehicles that meet or exceed the EPA Inherently Low Emission Vehicle (ILEV) classification and have a gross vehicle weight of 26,000 lbs. or less, may be operated in HOV lanes regardless of the number of persons in the vehicle and without payment of a special toll or fee. A special sticker must be obtained from the state Department of Transportation. Bi-fuel vehicles or hybrids that utilize gasoline as a back-up fuel source are not eligible (CO DOT 2003).

Arizona

Arizona achieved initial prominence in AFV promotion by putting into place the nation's most ambitious AFV program. However, later events showed that many of these policies were not well designed, which led to a huge drain on the exchequer with little improvement in air quality or amount of alternative fuel use. Consequently, an indefinite moratorium was placed on many of these incentives from October 2000. However, some aspects of Arizona's policies generated immediate and enormous response from consumers and thus provide important policy lessons for AFV promotion initiatives.

Through most of the 1990s, Arizona's incentives for AFV promotion consisted of a package that included tax credits for AFV purchase/conversion, grants for fueling infrastructure, school districts and municipalities, sales tax exemption, reduction in licensing fees, and HOV lane access. Until 1998, tax dollars claimed from AFV incentives gradually increased and more than $9 million had been spent on grants that translated into more than 60 public refueling stations and more than 600 fleet vehicles (Brown and Breckenridge 2001).

However, far-reaching changes were enacted in 1999 and 2000 that completely changed the AFV market in the state. In 1999, the amount of incentives was increased dramatically to levels never before seen in the country. Going above and beyond the incremental cost, these new incentives covered a significant portion of the total cost of an AFV as shown in Table 3.7.

Table 3.7. Design of Arizona's AFV Tax Credit.		
Emission Level	**New AFV** (based on total vehicle cost)	**Used AFV** (based on total vehicle cost)
LEV	Greater of 30% of cost or $5,000	Greater of 15% of cost or $2,500
ULEV/ILEV	Greater of 40% of cost or $7,500	Greater of 20% of cost or $3,750
ZEV/SULEV	Greater of 50% of cost or $10,000	Greater of 25% of cost or $5,000
Heavy Duty LEV (gvw>12,000 lbs.)	Greater of 30% of cost or $30,000	Greater of 15% of cost or $15,000
		Source: Brown and Breckenridge (2001)

These incentives also applied to conversion of gasoline/diesel vehicles to alternative fuel and covered the entire conversion cost plus at least 30% of the vehicles cost. Thus, if a vehicle cost $30,000 and the conversion cost was $6,000, then the tax credit was worth $9,000 + $6,000 = $15,000. This dramatic rise in the incentive level led to a sharp increase in response. While in 1998 only 82 people had claimed tax credits worth $70,000, in 1999 the number of people jumped to more than 1,000 and the amount claimed exceeded $8 million (Brown and Breckenridge 2001). However, since the incentives were limited to the tax liability of an individual in a given year, the number of claimants was limited to a few relatively wealthy individuals.

In April 2000, small but important changes were made to the 1999 package that had dramatic consequences. The tax credit was converted to a "refundable tax credit" which meant that an individual would get the entire incentive amount as a single check from the state irrespective of the person's tax liability for that year. Simultaneously, the incentives were made available for both dedicated and dual fuel vehicles, with no requirement that the vehicle actually run on an alternative fuel. As a result, merely fitting a propane tank (or something similar) to a new vehicle enabled the purchaser to claim from the state the entire retrofit cost plus at least 30% of the new car's cost. This perverse incentive gave rise to a huge car buying and retrofitting spree that had little to do with alternative fuels. Another important development was the certification of "neighborhood electric vehicles" (NEVs) as ZEV. These NEVs were small golf-cart like vehicles with limited speeds and were worth $6,000-$8,000. However, since they were classified as ZEVs, they were eligible for a $10,000 incentive. This meant that anyone buying a NEV was in fact getting a free vehicle plus $2,000-$4,000 from the state (Brown and Breckenridge 2001).

As a combined result of these new changes, more than 21,000 claims were received, and over $100 million was paid from the state exchequer in a span of just 6 months before a moratorium was ordered in October 2000 on all light-duty vehicle incentives. It has been estimated that, had the programs been continued and all submitted claims honored, it would have cost the state nearly $500 million (Brown and Breckenridge 2001). Currently, the state is only continuing its incentives for heavy-duty vehicles and fleets.

Maryland

Maryland has recently revised its AFV promotion policy according to the recommendations of the Maryland Task Force on Energy Conservation and Efficiency report in 2001. The state has set targets to meet LEV and AFV mandates of the federal EPAct

through new purchasing guidelines that offer more flexibility, as well as for developing alternative fuel refueling infrastructure through financial and technical assistance. Most importantly, the state has set a goal to ensure that an average of 50% of the fuel used by flex-fuel vehicles is alternative fuel (US DOE 2003).

The *Maryland Clean Energy Incentive Act*, effective 2002 through 2004, provides tax credits against the 5% vehicle excise tax, up to $2,000 for EVs and up to $1,000 for qualifying HEVs for model year 2000 and later.

The maximum credit amount detailed above may be increased for HEVs that actively employ a regenerative braking system that supplies to the rechargeable energy storage system at least 20% of the energy available from braking in a typical 60 mph to 0 mph braking event.

Table 3.8. HEV Credits According to the Proportion of Electric Component.	
Portion of Maximum Available Power Supplied by Rechargeable Energy Storage System	Amount of Credit
5 to 10%	Up to $250
10 to 20%	Up to $500
20 to 30%	Up to $750
At least 30%	Up to $1,000
Source: US DOE (2003)	

Qualifying vehicles must be four-wheeled, registered in Maryland, original equipment manufactured, and not more than 8,500 lbs. unloaded Gross Vehicle Weight. They must also meet the current vehicle exhaust standards set under the National Low Emission Vehicle Program for gasoline powered passenger cars (US DOE 2003).

Table 3.9. HEV Credits According to the Proportion of Regenerative Braking.	
Portion of Energy Available Supplied to Energy Storage System by Regenerative Braking	Additional Credit Allowed
20 to 40%	$125
40 to 60%	$250
At least 60%	$500
Source: US DOE (2003)	

The Metropolitan Washington Council of Governments administers the *Advanced Technology Vehicle Program – The Clean Alternative*, which is funded by the Maryland Department of Transportation and offers flexible incentives to private companies and local governments to cover the incremental cost of dedicated CNG or other clean fuel vehicles. In order to qualify for these incentives, interested businesses/organizations must meet certain criteria: the business/organization must have been in operation at least 5 years and have more than 10 vehicles in their fleet; fuel use must be greater than 3,000 gallons, or more than 45,000 miles traveled per year/per vehicle; and the vehicles must be registered in Maryland and operate either in the Washington DC or in the Baltimore metropolitan area (MWCOG 2003).

New Jersey

In 1997, the New Jersey Department of Environmental Protection submitted a State Implementation Plan (SIP) revision to the U.S. EPA, in which they proposed the *New Jersey Clean Fleets Program* that is committed to exceeding the federal EPAct's AFV acquisition mandates for state fleets by 5% per year. It presents a four-pronged strategy consisting of the DOE's Clean Cities Program, the EPAct mandates, an Incentive Development Program, and an Advanced Technology Vehicle (ATV) Program. EPA approved New Jersey's SIP revision in 1998 (US DOE 2003). An ATV Task Force was created in order to assist the

Department of Treasury in coordinating AFV/ATV acquisition, developing a refueling infrastructure to support AFV/ATV use, and creating an incentive program to defray the incremental costs of AFVs/ATVs for public entities. In addition, the tax paid upon the sale and use of LPG and CNG when used as transportation fuels has been reduced to one-half the tax paid for other fuels. Beginning 2007, all buses purchased by the New Jersey Transit Corporation shall be buses with improved pollution controls or buses powered by alternative fuels (US DOE 2003).

New Jersey's *AFV Rebate Program* offers rebates to local government entities (including schools and universities) that convert vehicles to run on alternative fuels or purchase original equipment manufacturer AFVs. The rebate amounts, shown in Table 3.10, can be used to cover the conversion or incremental cost and vary according to the vehicle weight class and whether the vehicle is dedicated, hybrid, or bi-fuel. This program is funded with $500,000 of federal Congestion Mitigation and Air Quality Improvement (CMAQ) funding (US DOE 2003).

Table 3.10. New Jersey AFV Rebates According to Vehicle Type.		
Vehicle Weight	**Rebate Amount (dedicated or hybrid)**	**Rebate Amount (bi-fuel)**
Light-duty (<8,500 lbs.)	Up to $4,000	Up to $2,000
Medium-duty (8,500-14,000 lbs.)	Up to $7,000	Up to $4,000
Heavy-duty (>14,000 lbs.)	Up to $12,000	Up to $6,000
		Source: US DOE (2003)

The New Jersey Department of Transportation, in conjunction with New Jersey Transit and different Transportation Management Associations (TMAs), has implemented a $1.6 million pilot project to promote commuter alternatives, decrease traffic congestion, and improve air quality. *Project Power Commute* uses EVs as shuttles driven by employees of participating businesses between their place of employment and the train station (NJ DOT 1997).

Pennsylvania

The *Alternative Fuels Incentive Grant Program* was created by the Pennsylvania Energy Office in 1992 to reduce the state's dependence on imported oil and improve air quality through the use of alternative fuels. The Program is implemented by the Pennsylvania Department of Environmental Protection, Bureau of Air Quality, and provides financial assistance for, and information about, alternative fuels and AFVs. Eligible applicants for incentive grants include schools, local government entities, businesses, non-profit entities, and individuals. After July 1, 2001, qualified projects may receive funding for 20% of eligible project costs. Projects eligible for funding include: purchasing AFVs including hybrid-electric vehicles, converting or re-powering existing vehicles to operate on an alternative fuel, developing innovative AFVs, and developing or installing AFV refueling/recharging infrastructure. No more than 10% of the funds may go to any one applicant each year and no more than 15% may go to any one county. Applications must be submitted during an open opportunity and prior to incurring any costs (PA DEP 1999).

Policy Lessons from State Alternative Fuel Vehicle Programs

The success of different AFV programs have varied widely from state to state and even from program to program in states that have multiple programs. A critical examination of the programs that have been more successful reveals certain characteristics that appear to have contributed to their success. A successful AFV promotion program should have one or more of the characteristics that are discussed below.

1) *Focused on reducing emissions or petroleum use*: A successful AFV program should be tied to emission/ petroleum use reduction. For example, in Colorado, the incentive levels were tied to emission levels where buyers could claim 50-85% of the incremental costs of a vehicle depending on whether the vehicle was a LEV, a ULEV, or a ZEV. Although the Arizona incentive structure was similarly conceived, the program failed to tie AFV purchase with actual alternative fuel use. Coupled with an unusually broad definition of AFVs, the program led to a situation where people bought bi-fuel vehicles or retrofitted regular vehicles, but then drove them on regular gasoline, remained eligible for the state's rebates. This program thus caused a huge loss to the state without any gains for the environment and ultimately had to be discontinued.

2) *Grant-based initiatives*: Most incentive programs are tax based and have thus not been able to sufficiently appeal to key adopters. Government fleets, the most important target, do not benefit from tax incentives because they do not pay taxes at all. Non-profits or individuals often have a small tax liability and thus benefit little from tax-based incentives. In contrast, grants offer certainty and immediate benefit since they do not depend on an individual's/organization's tax liability. In some cases, tax incentives can work well. An example is the refundable tax credit, which is paid to the taxpayer regardless of tax liability, and thus in effect acts like a grant. Arizona's program was based on the refundable tax credit and achieved a high response rate.

3) *Large enough to entice buyers*: Most fleet managers seem to think of AFVs as extra trouble and are often suspicious of their performance, and will not willingly pay extra for them. Successful incentives need to be large enough to offset much or all of the incremental cost of AFVs. Successful states, such as California and New York, have incentives that cover much of purchase or retrofit costs for AFVs. Arizona has gone a step further and had designed incentives tied not to the incremental cost but the total cost of the vehicle. Although the Arizona incentives could have been better targeted, they still demonstrate that large incentives will have a fast and big response.

4) *Easy to administer*: AFV incentives should be easy for consumers to obtain and for state governments to administer and monitor. Badly designed incentives often have consumers complaining about paperwork and delays. Some incentives, such as that provided by the South Coast Air Quality Management District in California, may offer a good model. This incentive is administered through auto manufacturers. Auto dealers advertise a vehicle price that includes the incentive, and simply pass on the invoice for the incentive to the manufacturer. The manufacturer immediately

reimburses the dealer, and then applies for reimbursement from the Air Quality Management District.

5) *Offer a long-term commitment*: States that have successful AFV programs without exception have adopted a long-term commitment toward alternative fuels. Steady support from leaders, backed by consistent financial allocation and adequate monitoring, have proven to be key ingredients for success. New York Governor Pataki's role has been exemplary in this regard. Another important factor in promoting AFVs has been the simultaneous development of alternative fuel infrastructure. New York's funding of refueling station development through their Environmental Bond Act has stimulated AFV purchase. In contrast, although Connecticut has incentives for AFV purchase, it has generated little response in the absence of a refueling infrastructure.

3.3 Increasing Vehicle Efficiency

The third major factor in determining vehicle emissions is fuel efficiency, measured as gallons of fuel used per vehicle mile traveled (more commonly referred to as miles per gallon (mpg)). Fuel efficiency first came under the national spotlight in 1973, during the first oil price shocks. As a response, the Corporate Average Fuel Economy (CAFE) standards came into being as part of the Energy Policy and Conservation Act of 1975 (Bamberger 2002). CAFE set minimum standards for sales-weighted average fuel efficiency for new vehicles. If a manufacturer's average is below the minimum, it has to pay $5 per 0.1 mpg, multiplied by the number of vehicles sold (NHTSA 2002). Separate standards are in place for cars and light trucks. The standard for cars is currently 27.5 mpg (since 1990), and 20.7 for light trucks (since 1996) (Davis and Diegel 2002). The truck standard will be raised to 22.2 by 2007.

Given the economic climate of the time of passage, the CAFE standards were relatively non-controversial, and rose rapidly from 1978 to 1985. Automakers found it easy to comply and fleet fuel efficiency rose accordingly. Figure 3.2 illustrates the effect that this increase in efficiency had on total highway fuel consumption. In a time when VMT was steadily increasing, fuel consumption actually decreased in the late 1970's and early 1980's as more fuel-efficient vehicles went on the road. As new vehicle efficiency leveled off, fuel consumption rose again.

Figure 3.2. Effect of Fuel Efficiency on Total Highway Energy Consumption, 1975-2000.
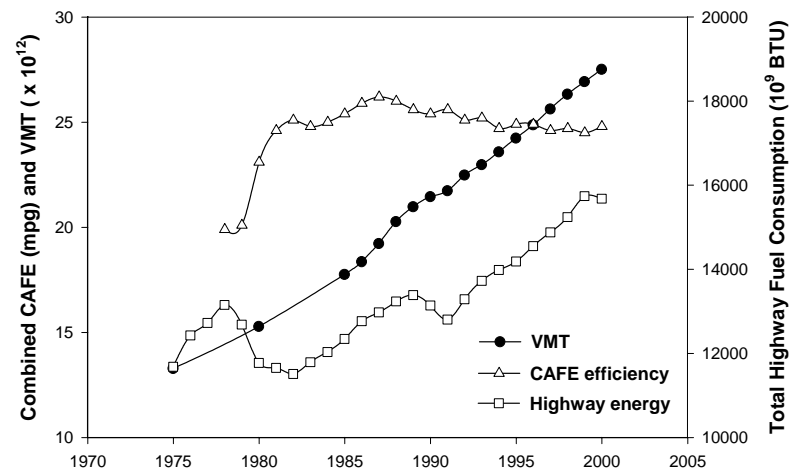
This figure demonstrates the importance of new vehicle fuel efficiency on highway energy consumption. As efficiency rises quickly, consumption falls even as VMTs increase. As efficiency levels off, fuel consumption rises with VMT.

Source: Davis & Diegel (2002)

During the late 1980's and through the last decade, lower oil prices removed incentive for further efficiency increases. From 1996 to 2001, House appropriations bills included riders prohibiting expenditures by the Department of Transportation on any recommendations to increase CAFE standards (Bamberger 2002). However, fuel efficiency has become a concern for environmental and health reasons, if not for economic ones, and the inaction of the federal government with regard to increasing CAFE standards led some states to look for ways to address the issue on their own. CAFE prohibits states from setting fuel efficiency standards different than federal standards. Therefore, some states have attempted to use financial incentives rather than regulations to encourage efficiency. We examine an example of this, the "feebate", in this section.

Although increasing fuel efficiency can be a very effective means of controlling emissions, the preemption clause in CAFE limits states ability to do this. Instead, many states (including Delaware) have instituted inspection programs that directly monitor emissions. Such programs improve emissions per mile (rather than fuel consumption per mile), another type of vehicle efficiency. We examine below an additional program that compliments emissions inspection programs: old vehicle scrapping programs.

Feebates

A feebate (the term is a combination of "fee" and "rebate") is a sliding-scale financial incentive that is added to, or subtracted from, the purchase price of a vehicle (DeCicco et al 1993). The magnitude of the feebate is determined by the relative fuel efficiency of the vehicle, so that inefficient vehicles are charged fees while efficient vehicles get rebates. Feebates are intended to encourage both the purchase and the manufacture of more fuel-efficient vehicles. Consumers respond directly to the price signal generated by the feebates by purchasing more fuel-efficient vehicles, while manufacturers respond to such consumer choice by shifting their production in favor of greater fuel efficiency. Theoretical studies have predicted that, if properly designed, feebates can achieve significant improvement in fuel economy accompanied by decreased air emissions, and fuel and cost savings for consumers (Train et al 1997).

There are several issues regarding the design and implementation of feebates. The most straightforward basis for a vehicular feebate is fuel consumption. Vehicles would be evaluated against a chosen "zero-point" and a fee or rebate would be applied depending on whether the vehicle's fuel efficiency is below or above the zero-point. The zero-point can be chosen based on the average fuel efficiency according to CAFE regulations or can be set at a desired higher level. A fuel economy range rather than a zero-point could also be chosen, so that vehicles with fuel economies falling within that range do not get either fees or rebates, and only vehicles above or below the chosen range are evaluated for feebates.

Since CAFE standards held vehicles classified as light trucks to a lower standard, highly fuel-inefficient pickups, SUVs, and minivans have become very popular in the market over the last decade. If environmental considerations are the sole criteria for evaluation, feebates should be designed to operate across all vehicle classes so that there is always an incentive to choose the most efficient vehicle. However, an across class feebate, if made to work, could make these kinds of vehicles face a severe economic disadvantage, that would disproportionately affect domestic auto manufacturers who tend to produce fleets with more of such vehicles than their foreign counterparts (DeCicco et al 1993). To avoid this politically difficult situation, feebates can be designed to operate within vehicle classes, say with separate classes for cars and trucks. Each class would have its own zero-point and all vehicles within a class would be evaluated against its own zero-point.

An important advantage of feebates is that they can be revenue-neutral, i.e., the rebates would be paid for through the fees charged. Fees and rebates could also be adjusted in a way that only enough net revenue is generated to cover associated administrative costs. Revenue neutrality can be quite important in determining public opinion about a feebate; anything other than neutrality could be perceived negatively as a new tax. Yet in difficult economic times state legislatures are often interested in fresh sources of revenue (Bernow 2002). Revenue enhancing feebate programs could be made more acceptable if a part of the revenues generated can be diverted to worthy programs that appeal to the public.

44

Some critics have opposed feebates on the ground that a state feebate alone would be insufficient to cause any appreciable market transformation toward efficient cars, since any particular state (with the probable exception of California) accounts for an insignificant part of the total automobile market. Besides, without a nationwide feebate there would always be the problem of leakage, whereby consumers can avoid the fee by purchasing a vehicle in a neighboring state without a feebate program. The leakage problem can be easily avoided by switching feebate implementation from the time of purchase to the time of registration (Bernow 2002). Although a federal feebate is theoretically ideal, given the difficulties of reforming the CAFÉ standards, a national feebate is unlikely to receive acceptance by the legislators. In such a situation feebates can become an effective instrument for states to complement efforts to improve air quality by targeting fuel efficiency. If more and more states take the lead by developing successful programs, others are much more likely to follow, so that in the long run a significant market transformation could be achieved, particularly if there is regional coordination between neighboring states.

Finally, feebates must be designed to avoid legal pitfalls, as recent experience has shown. State feebates may be challenged on the grounds that they are pre-empted by federal fuel efficiency regulations. Such a case is discussed in the following section. However, even if such legal challenges prove valid they can be avoided by basing feebates on criteria other than fuel efficiency such as air emissions.

Effect of feebates on emissions

Feebates elicit two types of responses to incentives based on efficiency. The demand-side response involved consumers choosing a more efficient vehicle because of the incentive. The supply-side involves manufacturers improving the efficiency of their fleet to avoid having extra fees charged to their product. The supply-side response would only occur if feebates were enacted at the federal level, or if a several states (including larger ones like California, Texas, and New York) enacted feebates independently. The supply-side response is crucial to the effectiveness of feebates, as it tends to be much larger than the demand-side response.

Train et al (1997) analyzed a number of feebate scenarios, covering different incentive magnitudes and different zero-points. They estimate that plausible feebates would increase fuel efficiency (and thereby decrease emissions, assuming constant control technology) by 9-13% by 2010. In each case, about 1% of the improvement was from demand response; the rest was from supply response.

Federal and State Policy Experiences with Feebates
Federal Experience

A federal feebate in the form of a fuel efficiency credit was proposed in the 1970s when CAFE standards were being considered. However, concerns about the way such a program would favor imported vehicles at the expense of domestic vehicles led to its rejection. The Energy Tax Act of 1978 instituted the "gas guzzler tax" on low efficiency vehicles (US DOE 1995). This tax is half of a feebate—it levies a fine on low-efficiency vehicles, but offers no incentive for higher efficiency. Consumers pay the tax to the IRS when they purchase vehicles that have a combined city and highway fuel efficiency of below 22.5 mpg. The current tax ranges from $1000 dollars for vehicles just under 22.5, to $7700 for vehicles below 12.5 mpg. The gas-guzzler tax applies only to passenger cars, not to light

duty trucks. It doubled in 1991, but has remained constant ever since. The receipts from this tax in 2000 were about $70.8 million, down from a high of about $232 million in 1986 (Davis and Diegel 2002).

Several other initiatives have since been proposed, although none have passed. The Safe and Efficient Vehicles Incentive Act would have introduced feebates based on fuel consumption and a composite safety factor, to avoid the criticism that fuel-economy legislation could reduce the size and thus the safety of vehicles. The Fuel-Efficient Vehicle Purchase Incentive Act and the Clean Domestic Fuels Enhancement Act of 1991 included feebates that would be based on the vehicle's carbon dioxide emissions. The World Environmental Policy Act of 1991 would have increased the gas-guzzler tax, payable by vehicle manufacturers, and would have instituted a consumer tax credit for purchase of vehicles that were at least 15% more efficient than average (US DOE 1995).

State Experience
California

As the state with the most pressing air quality problems in the nation, it is not surprising that California was the first state to propose feebate legislation. California's DRIVE+ program (Demand-based Reductions in Vehicle Emissions Plus reductions in carbon dioxide) is regarded as the original feebate proposal on which most others are based. Originally developed by the Union of Concerned Scientists in 1990, DRIVE+ targeted both vehicle emissions and fuel consumption through feebates (NCSL 1996).

DRIVE+ feebates were based on a vehicle's tailpipe emissions of criteria pollutants and CO_2. Vehicles that are cleaner and more fuel-efficient than the average new car sold in California were to be eligible for tax credits that would reduce sales taxes while vehicles that had higher emissions and lower fuel-efficiency were to have higher sales taxes. The feebates were to be calculated by estimating the sales-weighted average for certified levels of pollutants and the average cost of emissions reductions from stationary sources. Manufacturers would have to warranty their vehicles for reduced pollutant emissions for 50,000 miles to make the vehicles eligible for the rebate.

To publicize the program automobile dealers would have to display stickers on all new cars and light trucks, showing the size of the applicable DRIVE+ fee or rebate. Under the DRIVE+ plan, automobile dealers would have sent fees collected from the purchase of gas guzzlers to the California Department of Motor Vehicles (DMV). Consumers would receive rebates directly from the DMV. The feebate formula would average $200 for each mpg above or below the zero point. The DRIVE+ proposal was designed to be revenue neutral even accounting for DMV administrative costs. A DRIVE+ fund was to be established to collect fees and distribute rebates, with a special reserve account to ensure revenue-neutrality even in cases of sales fluctuations (NCSL 1996).

First introduced in the California Legislature in 1990 by State Senator Gary Hart as Senate Bill (SB) 1905, it passed overwhelmingly but was vetoed by then-Governor George Deukmejian on his last day in office. Subsequently, DRIVE+ legislation was reintroduced by Senator Hart in virtually identical form in 1991 (SB 431), 1992 (SB 1843) and 1993 (SB 378), but on each occasion it failed to garner enough support to pass the legislature (NCSL 1996).

Maryland

In 1992 Maryland became the first state where a feebate program (HB 685) was actually passed by the legislature and is still the only state with such distinction. The Maryland feebate program divided vehicles into three categories: "gas-guzzlers", with fuel economies below a specified 'guzzler' level, "gas-sippers," with fuel economies above a specified sipper level, and other vehicles, with fuel economies between the guzzler and sipper levels. Guzzlers and sippers would get fees and rebates respectively on the existing 5% titling tax, while all other vehicles would continue to pay the existing level of tax (NCSL 1996).

The program was designed to be introduced in two stages. For cars purchased in 1993 and 1994, there was a tax surcharge of $100 if fuel efficiency was below 21 mpg and a rebate of $50 if it was above 35 mpg. For cars purchased in 1995 and later, the fee for inefficient cars was $50, times the number of mpg less than 27, and the rebate was $50 times the number of mpg above 35. A cap of 1% of the car price applied. The fee or credit amount was to be displayed on the vehicle window in the form of a sticker. The program was designed to be revenue generating with the revenues allocated for the expansion of the Washington DC area Metrorail system. It was estimated that the program would bring in at least $15 million annually (NCSL 1996).

Although the program was enacted its implementation was put on hold by a legal challenge from the National Highway Traffic Safety Administration which found that the Maryland statute violated the federal preemption provision of the 1975 Federal Energy and Conservation Act. That provision required that no states could establish fuel efficiency related laws or disclosures that were in conflict with the federal CAFE standards. The Maryland Attorney General replied that the Maryland statute only partially conflicted with federal law. Although Maryland could not require the sticker displaying the fuel efficiency, federal law does not preempt the state from using federal fuel efficiency to compute state taxes. Subsequently, although Maryland's position could have been vindicated, the perceived legal difficulty surrounding the case prompted a loss of political interest and the feebate proposal was never revived (NCSL 1996).

Arizona

The Arizona Legislature has considered two feebate bills. HB 2425, introduced in 1991, would have established fuel efficiency based feebates for six different vehicle size classes, with a separate schedule for AFVs. In 1993, a simplified version was proposed through HB 1234, in which a flat $200 tax would be applied to any non-commercial vehicle with a fuel efficiency rating below 21 mpg and a flat $200 tax credit for vehicles rated above 35 mpg. Vehicles with fuel efficiency ratings between 22 and 34 mpg were exempt from both the surcharge and the credit. However, neither of the bills were passed (NCSL 1996).

Massachusetts

In Massachusetts feebate legislation was introduced in 1991 to promote the purchase of fuel efficient vehicles. HB 2086 established feebate schedules that compared each vehicle to others within its size class and imposed a tax or rebate depending on relative fuel efficiency performance within class. The "zero-point" of the feebate schedule would change as federal fuel efficiency ratings changed for each vehicle class. The 0-10% sliding scale would apply to the sales tax paid on new vehicles (the current base rate being 5%) with the

most efficient vehicles paying nothing and the least efficient paying 10%. The program was designed to reward customers for picking the most efficient vehicle within a class but not necessarily the most efficient vehicle overall. This step was deemed necessary to placate domestic auto manufacturers who are at a disadvantage in the compact car class. Although the bill did not pass in 1991 it was re-introduced in 2001 by Rep. Marzilli as HB 3649. This time too the bill failed to win approval largely because it was branded as an "SUV tax", in spite of the within class design of the feebate (NCSL 1996).

Wisconsin

The Wisconsin Legislature considered a bill in 1991 that did not pass, which placed an excess gasoline consumption fee on vehicles with a fuel efficiency below the federal standard set for that vehicle type. Under HB 577, the owner of any new automobile would pay a fee to the Department of Transportation when the vehicle is first titled. The fee would equal $20, times the number of mpg that the vehicle's fuel efficiency falls below the standard. This program did not include a rebate component because the revenue gained was to be used to fund an energy development and demonstration grant program (NCSL 1996).

Maine

The Maine Legislature considered replacing the state's current 5% sales tax on motor vehicles with a feebate. Introduced in 1992, LD 1709 placed a variable sales tax, between 0 and 10%, on the sale in Maine of any new passenger automobile. Fuel efficiency ratings for each vehicle model within each size class were to be based on federal mpg ratings. This bill also accounted for AFVs separately. The system of fees that were part of the program was introduced first, before any rebates. As a result, public opinion quickly turned against the program and it was subsequently scrapped (NCSL 1996).

Policy Lessons from State Feebate Programs

While the concept of feebates is attractive and they make a lot of sense from an environmental policy perspective, various political and legal hurdles have bogged down feebate legislation at the state level in the US. To begin with, feebates are usually perceived as new taxes, and strong lobbying by vested interests often make them appear to be "SUV taxes" to the public (Bernow 2002). In the early 1990s, even though feebates were talked about widely, feebate legislation was very difficult to enact successfully with many states struggling for several years. Even as the idea was gaining ground with legislative successes in California and Maryland, the legal challenge to the Maryland program proved to be a serious blow to budding feebate legislation nationwide. Since the outcome of the legal challenge was generally perceived as inconclusive, legislators in many states including Maryland lost the enthusiasm to pursue an issue that they considered both politically difficult and legally uncertain (Bernow 2002). Since then there has been little progress on feebate legislation anywhere.

However, as current events have reaffirmed, fuel inefficiency continues to extract a huge toll on our environment, energy security, as well as national security. In other words, the problem hasn't gone away, it has only gotten worse. The need to complement CAFE standards is even more urgent today and feebates continue to be an attractive policy tool. If the challenges identified over the past decade can be met head on, there is no reason why feebate legislation cannot be enacted in the near future.

It is clear from previous experience that feebate programs would have to be revenue neutral (or at least close to it) and that cars and trucks would have to be treated in separate categories for public acceptability. It is also of crucial importance to begin a public outreach and education program well before actual legislation is debated, so as to circumvent popular misconceptions that might arise in the minds of the public.

Most importantly, the risk of federal preemption under CAFE can be avoided by using surrogates for fuel efficiency as the basis for designing feebates. Such alternative criteria include emissions of air pollutants, vehicle size, or vehicle weight. Criteria such as these are closely related to fuel efficiency and incentives to reduce them would have a similar effect as incentives that target efficiency directly. States with chronic air pollution problems can use automobile emission based feebates to their advantage by including them in their State Implementation Plans for meeting federal air quality standards. Since many states already base vehicle registration fees on vehicle weight, it would be a small step to design a feebate based on some measure of vehicle weight. The American Council for an Energy Efficient Economy (ACEEE) suggests engine displacement as an attractive attribute on which to base a feebate. Several European countries use engine displacement as the basis for vehicle taxes. Smaller engine displacement would mean smaller, more efficient cars because technologically advanced engines can achieve higher efficiencies at smaller displacements (DeCicco et al 1993).

Accelerated Vehicle Retirement

As vehicles age, they emit more criteria pollutants. Older (typically 10 to 15 year-old) vehicles burn fuel less efficiently as engine parts wear. Emissions control devices, such as catalytic converters, often do not function properly in older vehicles. These older vehicles, along with some newer ones that are poorly maintained, contribute substantially to total on-road mobile emissions. It is estimated that 10% of the vehicle fleet can contribute up to 50% for a given criteria pollutant (US DOT 2002). Many states, including Delaware, have recognized this phenomenon and have attempted to correct it using inspection and maintenance programs. While such programs do reduce emissions, many states grant waivers to vehicle owners who perform emission-related repairs, but continue to fail the test. Nationally, an estimated 10-27% of vehicles that fail inspection never pass (US DOT 2002). In Delaware, an emissions waiver can be obtained after $650 has been spent on emissions repairs, but the vehicle still does not pass[8] (Delaware DMV 2003). These waived vehicles can continue to pollute.

Accelerated Vehicle Retirement (or "scrapping") programs address this "gross emitter" problem. Under such systems, a bounty (usually $500-$1000) is offered to owners of high-emission vehicles in exchange for taking those vehicles permanently off the road (US EPA 1998b). Generally, a subset of vehicles are actively targeted, such as those over 12 years old, or those that have failed inspection and have been granted a waiver. A typical requirement is that vehicles must be driven to the scrapping site, because a vehicle that is not functional is not contributing to air pollution (Hahn 1995).

Vehicle scrapping programs typically run for short periods of time—usually not longer than a year at a time, or until a target number of vehicles has been retired. An indefinite scrapping program would be less effective because owners of polluting vehicles
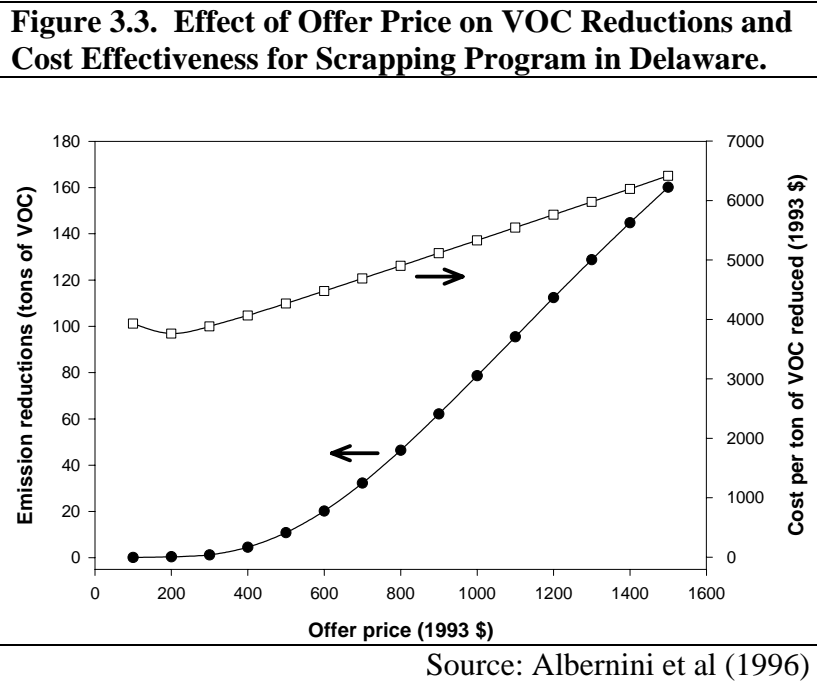
---

[8] The waiver threshold is substantially smaller in Sussex County ($200), and for model years older than 1981 ($75).

would know that they can keep on the road longer and still be able to collect the bounty at some point in the future. Most programs have been run by industries, which obtain emissions reduction credits for the vehicles they remove, which can be used as offsets for other emissions for which the industry is responsible. However, such programs could be run by states as a means of directly reducing emissions.

Delaware has past experience with vehicle scrapping. In 1992-1993, the US Generating Company voluntarily ran the Delaware Vehicle Retirement Program to offset emissions from its tugboat traffic on the Delaware River. The program offered $500 to owners of pre-1980 vehicles. The offers were first targeted at vehicles that had failed the emissions test and granted a waiver. They were then expanded to a random set of owners of pre-1980 vehicles that were not waivered. A total of 125 vehicles were retired (64 of which had been granted waivers). The cost per ton of VOC reduction was estimated to be $4000. Surveys were conducted of both participants and non-participants to whom offers were made in order to study scrapping behavior (Albernini et al 1996).

Emissions Benefits of Scrapping

The emissions gains from vehicle scrapping depends on the number and condition of vehicles scrapped. This, in turn, depends on such factors as the size of the bounty and eligibility criteria. A high bounty will cause more people to participate and take more vehicles off the road. However, it will result in higher cost per unit of avoided emissions, as the vehicles that require the higher bounty often pollute less than those that would be traded in for the lower bounty. The emissions of the replacement vehicle must also be considered. Generally, the replacement will be newer and emit fewer pollutants per mile. However, if it is in better condition, the replacement vehicle may also be driven more, thus offsetting some of the gains in emissions per mile.

Figure 3.3. Effect of Offer Price on VOC Reductions and Cost Effectiveness for Scrapping Program in Delaware.

Source: Albernini et al (1996)

Through a survey of participants in the Delaware scrapping program in 1992, Albernini et al (1996) constructed plausible assumptions about replacement showing a net emissions reduction that varies with price offered. A summary of these findings are shown in Figure 3.3. Scrapping programs generally reduce VOCs to a greater extent than NO_x. Assuming that replacement vehicles have fleet average emissions, a typical replacement vehicle in the 1992 Delaware scrapping program emitted 83% less VOC and 31% less NO_x per mile than a typical scrapped vehicle (Albernini et al 1996).

50

Policy experiences with vehicle scrapping
California

The first scrapping program was implemented in California in 1990. The program was operated by Unocal and was responsible for retiring nearly 8400 per-1971 vehicles in the Los Angeles area (US EPA 1998c). The program was implemented in three phases, with the last phase allowing Unocal to receive emission reduction credits. In 1993, Chevron operated Project C.A.R. in Los Angeles. This program paid $700 for pre-1972 vehicles, and generated emissions credits to offset emissions from a refinery.

In 1997, SB 501 was passed, which required an ambitious statewide scrapping program. The program was to run for a full decade, from 2001-2010. It would target vehicles over 15 years of age, and retire 75,000 per year at an annual cost of about $100 million. One study concluded that the cost effectiveness of this program (about $13,000 per ton of emissions reductions) compared favorably with many other air quality improvement measures, including switching to reformulated gasoline and low emission vehicles (RAND 2001). However, the program was suspended last year due to California's fiscal crisis.

Arizona

In 1997, a scrapping project in the Phoenix metropolitan area removed 1200 gross emitters from the road (US EPA 1998d). The program was funded by General Motors, under a consent decree with the EPA that required the company to undertake environmental projects in the Los Angeles and Phoenix areas. Owners of pre-1987 model year cars and trucks were offered $500 ($600 for pre-1972 models) to scrap their vehicle. Vehicles had to be registered in Maricopa County, be fully functional, and driven to the trade-in site. The program was forecast to reduce VOCs by 57.6 tons, and NO_x by 45 tons over three years.

Objections to scrapping programs are often raised by car collectors, who claim that by reducing the number of old vehicles of the road, the programs make it difficult for them to obtain parts for their vehicles. The Arizona program allowed collectors to salvage scrapped vehicles by paying $200 more than the $500 to $600 trade-in price.

Pennsylvania

Sun Company ran two scrapping programs in the Philadelphia area in the early 1990's (EPA 1998e). In 1993, it offered $700 to owners of pre-1980 vehicles. The program removed 166 vehicles from the road. The following year, Sun identified high-polluting vehicles using remote sensing and offered owners of the identified vehicles up to $450 for emission system repairs. Sun used both programs to generate emissions credits to offset emissions from expansion of refinery operations and postponement of emission controls.

Oregon

The *CHOICES* program is a unique vehicle scrapping initiative that has run each summer from 2001-2003. This program did not offer cash bounties as most others do. Instead, owners of vehicles that failed emissions tests and had been continuously insured for at least a year could trade in their vehicle for either a year-long bus pass (worth $615), or a $500 credit toward the purchase of a bicycle or membership in a carsharing organization[9]

---

[9] A carsharing organization essentially rents vehicles for use by the hour and is an alternative to car ownership that is currently available in select cities. Members reserve a time for vehicle use and pay an all-inclusive fee by the hour and/or mile.

(OR DEQ 2003b). Seventy people participated in the program in 2002. Although participation rates are lower without cash incentives, this type of program promotes a cleaner form of replacemen—t transportation. Emissions reductions in this program were not creditable to emissions elsewhere, and hence represented a net improvement.

Policy Lessons from Accelerated Vehicle Retirement Programs

The success of vehicle scrapping program is dependent on the details of the program. Policies should be constructed so that "gross-emitting" vehicles are not only removed from the road, but also so that their emissions are not simply replaced by emissions from other vehicles or industrial sources. Maximum reductions can be attained if no emissions credits are allowed by the program. The emissions characteristics of the replacement vehicle are important and the Oregon program offers an innovative approach to this problem, by encouraging participants to switch to less polluting modes such as transit and bicycling. The opposition of car-collectors to this type of program can be reduced if scrapped vehicles are made available for salvage. However, salvagers should not be able to reuse any emissions-related equipment. Most importantly, successful programs remove gross-emitters that are *actually used* for transportation. Participants must be able to document that the vehicle has been continuously registered and insured for a significant period of time, and the vehicle should be in sound working condition except for its high emissions. Remote sensing has been used to identify polluters—this method targets vehicles that are actually driven rather than sitting around waiting to be scrapped.

IV. Implementing Transportation Policies in Delaware

This section addresses how the various types of transportation policies examined in Section III might be implemented in Delaware. An overview of the relevant characteristics of the current transportation system in the state is provided. Emissions reductions that could reasonably result from the implementation of the policies are estimated. Suggestions for suitable policies for future implementation, based on the experience of other states, are offered.

4.1 Current Delaware Transportation Characteristics[10]

Private Personal Transportation

Delaware's population was 786,189 in 2000, of which 64% live in New Castle County. In 2001, Delware had 569,143 licensed drivers, which is 71% of the total 2001 estimated population. VMT is increasing more rapidly than population. From 1990 to 2000, VMT has grown by 25.2%, while population has grown by only 17.5%. Fuel consumption has closely tracked VMT growth, as vehicles in DE have not become more fuel-efficient.

In 2001, there were 733, 207 registered vehicles in Delaware—29% more vehicles than licensed drivers. Ninety-two percent of the 298,731 households in the state owned at least one vehicle and 58% owned two or more. Data on vehicle type was not readily available, as the Division of Motor Vehicles only keeps records on vehicle make, and vehicle class is not apparent from the registration. A light truck, for example, could be registered as either a passenger car or a commercial vehicle. In 1997, the Census Bureau conducted the Vehicle Inventory and Use Survey and found that light trucks accounted for about 29% of total registrations. This number is likely to be higher now, as the market share of light trucks has increased substantially at the national level since 1997 (Davis & Diegel 2002).

In 2000, there were 373,070 employed residents in Delaware. Of these, nearly 80% drove alone to work. Only 11.5% rode in carpools/vanpools, 2.8% took transit, and 2.6% walked or biked. The mean travel time to work was 24 minutes.

Public Transportation

Delaware Area Rapid Transit (DART) offers statewide bus service. DART maintains a fleet of about 400 buses, which consume about 6.9 million gallons of diesel fuel annually (C. Coleman, personal communication). This represents about 11% of all diesel fuel consumed in Delaware in 2002 (Nigro 2003). Buses are kept in operation for 7-10 years. In 2002, DART ridership was over 8.2 million people and the regular fare was $1.15.

School buses are a significant component of the Delaware transportation system. About 1650 buses currently operate in the state (R. Love, personal communication, 4/21/03). They travel 19.2 million miles annually, and with a fuel efficiency of about 6.7 miles per gallon, consume nearly 2.9 million gallons of diesel per year. This represents close to 5% of Delaware's diesel consumption. The majority of buses in the fleet are operated by private contractors. The fleet is younger than most—although buses in some states are in service for over 20 years, the typical Delaware school bus is kept in service only 8-9 years.

---

[10] Information in this sections is from DelDOT (2002), unless otherwise stated.

VMT management

The Transportation Management Association of Delaware (TMA Delaware) is a collective of private employers and state agencies with the goal of increasing mobility while decreasing congestion and air pollution (Roy 2000). About 75 major employers in the state are voluntary members of TMA Delaware. TMA Delaware assists employers in developing commuter choice programs, which are specially tailored to the employers needs. This includes mapping where employees live, so that viable alternatives to single-occupancy vehicle travel can be identified. TMA Delaware facilitates RideShare Delaware, which helps employees interested in carpooling to find partners, and the HomeFree program, which guarantees emergency rides home for carpoolers. TMA also information about alternative transportation in the form of rack and table displays called CommuniCorners at major employers.

Delaware has structured its tolls to attempt to relieve congestion and encourage carpooling (TMA Delaware 2003). Tollbooths on Route 1 and I-95 offer discounts to high-occupancy vehicles (HOVs). Assuming equal weight for all tollbooths in the state, HOVs get a 65% discount compared to cash tolls. Discounts are also offered to users of E-ZPass, the regional electronic toll collector. Although automatic toll collection does not reduce VMTs[11], it can reduce emissions by shortening idle time in toll lines. E-ZPass users receive a 28% average discount compared to cash tolls.

Clean Fuels

Delaware has thus far not made a substantial commitment to alternative fuel vehicle (AFV) use beyond fulfilling its EPAct obligation. In 2001, it ranked 44th among states in AFVs per capita (Brown and Breckenridge 2001). The State of Delaware owned 681 flexible fuel vehicles as of fall 2002, all of which run on gasoline due to the dearth of alternative fueling infrastructure (Terry Barton, Delaware Fleet Services, personal communication, 10/15/2002). Delaware has no heavy-duty alternative fuel vehicles. Beginning in August 2002, the Transportation Fuels Work Group, part of the Delaware Energy Task Force, began discussing plans to make biodiesel and ethanol more widely available in the state (Livable Delaware 2003). As discussed previously, biofuels have some advantages over fossil fuels, but they do not reduce emissions of ozone precursors.

Efficient Vehicles: I&M Program

Delaware operates vehicle emissions inspections in all three counties. New Castle and Kent Counties, as severe nonattainment areas, have a "low-enhanced" program, while Sussex County operates a "basic" program (Phil Wheeler, DNREC, personal communication 6/18/2003). The tests consist of a two-speed idle test, fuel system pressure test, and an emission control device inspection. On 1996 and newer vehicles, an on-board diagnostic systems check is done. Vehicles of the last five model years are exempt from the test, as are vehicles older than model year 1968. Model years 1968-1980 are only subject to the idle test (Delaware DMV 2003).

---

[11] It is possible that automatic toll collection could actually increase VMT compared to cash toll collection, because it reduces travel time.

Emissions Reductions Due to Transportation Strategies in Delaware

The transportation strategies outlined in Section III, if implemented in Delaware, have the potential to reduce on-road NO_x emissions by nearly 10%, and VOC emissions by 14.5% by 2010 (see Table 4.1). The strategies include a comprehensive employer-based TDM program, promotion of mileage-based vehicle insurance, increased use of CNG in buses and light-duty vehicles, and a short-term aging vehicle scrapping program. The following sections discuss the level of implementation necessary to achieve such reductions and presents some suggestions for implementation based on the experiences of other states.

	NO_x reduction (tons/day)	VOC reduction (tons/day)	% NO_x red.	% VOC red.
Table 4.1. Summary of Transportation Strategies and Emissions Reductions.				
Strategy				
Empl. TDMs	1.31	0.61	2.78	2.99
MBI	2.14	1.47	4.54	7.15
CNG	1.17	0.46	2.47	2.22
Scrapping	0.03	0.44	0.06	2.14
Total	**4.65**	**2.98**	**9.85**	**14.50**

4.2 Reducing VMTs in Delaware

Employer-based TDMs in Delaware

Employer-based TDM strategies have the potential to reduce on-road NO_x emissions by 3.2%, and on-road VOC emissions by 3.6% by 2010, based on the results of the COMMUTER model. A summary of the results is shown in Table 4.2. The results listed alongside the individual programs represent those programs implemented in the absence of any other change in TDMs. The summary lines at the bottom show the sum of the individual results (assuming no synergy), and the model results of all the programs implemented simultaneously. It is clear that there is a synergistic effect—the programs provide complimentary incentives that produce greater results when implemented together.

Table 4.2. Results of EPA's COMMUTER Model Simulation of Employer-based TDM Strategies on an Individual and Collective Basis.

Strategy	% employees affected	# employees affected	% VMT reduction	% trip reduction	NOx reduction tons/day (%)	VOC reduction tons/day (%)
Site Access Improvements	13	69,445	0.5	0.6	0.018 (0.04)	0.009 (0.04)
Financial Incentives	24	125,001	26.3	26.7	0.904 (1.91)	0.419 (2.04)
Parking SOV charge			*12.7*	*14.4*	*0.438 (0.93)*	*0.208 (1.01)*
Transit credit			*6.5*	*6.5*	*0.224 (0.47)*	*0.104 (0.50)*
Carpool/Vanpool credit			*4.4*	*3.8*	*0.150 (0.37)*	*0.068 (0.33)*
Employer Support Programs	11	55,556	4.1	3.8	0.141 (0.30)	0.064 (0.31)
Alternative Work Schedules	13	69,445	0.6	0.7	0.023 (0.05)	0.011 (0.05)
All Strategies Together	27	138,890				
Synergy not Accounted for (Sum)			31.5	31.8	1.086 (2.30)	0.503 (2.45)
Synergy Accounted for			**38.3**	**37.3**	**1.314 (2.78)**	**0.606 (2.95)**

TDM Programs Examined in this Analysis

Site access improvements are those programs that change the amount of time it takes for an employee to get from their chosen mode of transportation to their workspace. Examples of this include preferential parking for carpools and vanpools, improved transit access to the workplace, and improved bicycle access (such as lanes and racks) and amenities (such as lockers and showers). For the model, we specified an increased access time of 2 minutes for single occupancy vehicles and a decreased (improved) access time of 2 minutes for other transportation modes. Thirteen percent of the working population was affected by this strategy.

We considered *financial incentives* that would affect 24% of the working population and comprise the backbone of the employer TDM suite. These incentives included 3 main components. First, an additional parking fee of $3 per day was charged to single-occupant vehicles. Second, a credit of $2.30 per day was provided for use of transit, which amounts to a free roundtrip DART pass. Third, a credit of $1 per passenger per day was given to employees who participated in car or vanpools. When the shift in mode shares that result from all employer TDMs is accounted for, employers stand to collect a net average amount of $40 per 100 employees per day, which could be used to cover some of the administrative costs of the program. Parking cash-out programs could have a similar effect, except that instead of charging a fee for SOVs, they offer corresponding incentives for other travel modes.

Employer support programs would affect 11% of the working population. These programs are not financial or time-related incentives, but serve to remove information barriers that inhibit mode switching. Our analysis started with the assumption that about 10% of large employers currently provide ride-matching and transit information through the TMA Delaware program and/or a part time commute coordinator. Under the new policy, 40% of large-employers provided in-house ride-matching and transit information service to a much greater degree, through a full-time commute coordinator. For more information regarding these programs, consult Carlson et al (2000).

Alternative work schedules are assumed to affect 13% of the working population in our scenario. There are several types of schedules that the model considers, which fit into 2 general categories: those that allow trip reduction (such as telecommuting and compressed work weeks) and those that reduce peak traffic, and hence time spent in commute (such as staggered hours and flextime). COMMUTER assumes that the schedule types are mutually exclusive (i.e., each employee is only eligible for one option) and we assumed that the total eligibility of this type of scheduling doubled.

Policies to promote employer TDMs

We offer the following recommendations for implementing a comprehensive employer-based TDM program in Delaware:

Set targets for VMT or SOV reduction. These targets could be required for large employers (for example, those with 100+ employees). Mandatory programs tend to be substantially more effective than voluntary programs at reducing VMT (Kadesh & Roach 1997). If the targets were optional, the success of the program could be enhanced by offering substantial incentives for employers to participate. This type of incentive has been recently proposed in the Delaware Senate (SB 284). If enacted, it would exempt employers from the gross receipts tax if their employees maintain a vehicle occupancy rate of 3.5 or greater.

Whether accomplished through mandates or incentives, specific targets set by the state would achieve higher participation rates in employer-based TDMs.

Allow flexibility of programs, but require documentation of success. Employers will have varying experiences with different TDM strategies, depending on their employee base. A statewide TDM program can allow employers to choose which programs work best for them and their employees. However, for the flexible program to work, each employer will have to provide documentation that their chosen suite of programs allows them to meet the targets required by law or to qualify them for a financial incentive.

Foster collaboration between public and private sectors. The Commute Trip Reduction law in King County, WA set mandatory targets for large employers. However, it is guided by the principal of collaboration, rather than "command and control." Employers are not penalized for failing to meet targets, as long as they demonstrate a "good faith effort." The Task Force which oversees the program and develops guidelines for implementation has a number of business representatives. A stated goal of the program is that CTR plans must be developed such that benefits to the community, employers, and employees are clear (Kadesh & Roach 1997).

Target transit improvements to compliment the employer TDM program. Improved transit could compliment employer TDMs. New bus routes could be added or existing routes improved to serve employers committed to achieving VMT reduction targets. Decreases in transit ride time and for frequent service at key stops could make bus transit a more viable alternative to commuting in personal vehicles. However, simply improving bus service does not guarantee improvements in air quality even if ridership increases, because the buses themselves emit pollutants. Transit improvements could be developed in conjunction with surveys of employees of companies participating in VMT reduction. This would help identify areas where improvements would be most effective.

Mileage-based Vehicle Insurance in Delaware

If mileage-based insurance were available to all Delaware drivers, half would likely participate (those who drive less than the average VMT/year in the state). Based on moderate price elasticities, this would likely reduce light-duty vehicle VMT by 8% in the short term (ICF & VPTI 2001). If this is accomplished through trip elimination, LDV NO_x emissions would be reduced by 8% and LDV VOC emissions would be reduced by 7.6%. In Delaware, this would amount to a reduction of NO_x and VOC by 782 tons and 536 tons, respectively, in 2010. Relative to total on-road emissions, these reductions represent 4.54% and 5.65% for NO_x and VOC respectively.

Policies to Promote MBI

MBI is currently legal in Delaware—any company that chooses to offer such a rate would simply have to submit a plan to the Insurance Commission for approval. However, no company has yet done so. Insurers face high administrative costs associated with the rate approval process, and there is risk involved in offering any new premium. There are several actions that Delaware could take to bring MBI to the market faster.

Offer incentives to insurers. The state could offer a tax credit to providers of MBI. This would offset a portion of the risk and administrative cost involved in devising a new rate scheme. The benefits of such an offer should far outstrip the costs, which is why Oregon is currently considering such a strategy. Delaware could follow the developments in Oregon

58

and see whether the $100 state tax credit per policy is sufficient incentive. Alternatively, an incentive could be provided through a grant program. This could entice insurers that may have a very small Delaware tax liability.

Require a MBI option. The state has the authority to dictate what types of vehicle insurance are mandatory and what a company must offer. Delaware could require that all vehicle insurance companies doing business in the state offer a mileage-based insurance option. There would probably be considerable consumer support for this option, because mileage-based insurance will likely save the average motorist money. However, some high-mileage drivers are likely to oppose it, since it would end the subsidy of their premiums by low-mileage drivers, and would indirectly raise their rates. Insurers would likely be opposed to it for the same reasons as stated above—new administrative costs and increased risk. Although this option is more politically sensitive, it would provide deeper and more rapid market penetration and better emissions results.

Provide legal and logistic framework to facilitate MBI. In changing its insurance code to allow MBI, Texas recognized that certain rules must be adopted to deal with mileage verification. A state could chose to facilitate odometer audits, which would remove some of the administrative costs to the insurer, and thus would make MBI more attractive. If insurance companies are required to perform their own audits, they may fight the program harder, and may charge customers more to perform the service. It would also be an added inconvenience to the motorist. This cost and inconvenience could be largely eliminated if odometer audits were performed during regular vehicle maintenance or inspections. Delaware already requires all vehicles over 5 years of age to be inspected on a biennial basis. During this inspection, an odometer audit could be performed to reconcile reported and actual mileage, and to verify that the device was not tampered with. The process takes only a few minutes. However, biennial inspections may not be frequent enough to satisfy insurers, and newer vehicles must also be audited. Therefore, the state could license private mechanics to perform the audits when a vehicle is brought in for regular service (such as an oil change). The results could then we entered into a secure database, and the database as a whole would only be accessible to the insurers and certain state officials. Alternatively, the reading could be sent directly to the insurer on a form along with the auditor's information and signature. Licensed odometer auditors could display a standard logo at their establishment, which could help them attract business and would allow motorists to easily locate an auditor. Some states (e.g., New York) employ a very similar system for the performance of annual vehicle safety inspections.

4.3 Use of Alternative Fuels in Delaware

Our analysis in Section III concluded that compressed natural gas (CNG) is the cleanest of the currently available alternative fuels, in terms of emissions of ozone precursors. Table 4.3 summarizes the emissions benefits that are possible if the state commits to CNG conversion. NO_x can be reduced by 2.48% and VOC can be reduced by 2.22%. The following sections illustrate how these reductions are possible.

Table 4.3. Emissions Reductions from Conversion to CNG (Relative to Statewide Total On-road Emissions).		
Fleet	**Emissions Reduction**	
	NO_x	**VOC**
DART	1.17%	0.25%
School Buses	0.48%	0.10%
Diesel Total	**1.65%**	**0.35%**
Udel	0.01%	0.02%
Fleet Services	0.05%	0.12%
DelDOT	0.03%	0.06%
Private	0.74%	1.67%
Gasoline Total	**0.83%**	**1.87%**
Grand Total	**2.48%**	**2.22%**

Conversion of Bus Fleets

As of 2000, there were two agencies that operated 100% natural gas buses, one in Tempe, AZ, and the other in Thousand Palms, CA. A number of transit agencies have committed to purchasing only natural gas buses in the future, including the Los Angeles, Sacramento, Cleveland, and Atlanta transit authorities, and New York City's Department of Transportation (Cannon & Sun 2000). Our emissions reduction estimates show what can be expected if Delaware joins these agencies, and all new school bus and transit bus purchases run on CNG. If normal replacement schedules are followed and CNG purchases begin in 2005, each fleet would be nearly 55% CNG by 2010. Emissions of CNG buses were assumed to be 45% and 70% less for NO_x and VOC, respectively, than their diesel counterparts. This is a conservative estimate compared to present day emissions differences, but it accounts for the fact cleaner diesel engines will experience some market penetration by 2010.

The conversion of these fleets does carry with it a significant cost. CNG buses cost 15-25% more than conventional buses and the Federal Transit Administration (FTA) estimates that a typical refueling station for a fleet of 200 buses costs about $1.7 million (Cannon & Sun 2000). Funding for both bus and infrastructure purchases is available through the FTA's Clean Fuels Grant Program. Delaware may also want to consider leasing fueling infrastructure rather than owning it. Several transit agencies, including ones in Atlanta and Los Angeles, have entered into lease agreements with local utilities. The utilities build, own, and operate the facility, and the transit company pays fuel costs and monthly lease payments. The Los Angeles County Metropolitan Transit Authority expects to save $1 million in costs and 6-12 months in construction time through their lease agreement.

Conversion of Light Duty Vehicles

The emissions reductions for light duty vehicles as shown in Table 4.3 represent a 2% conversion of the entire light duty vehicle fleet by 2010. We estimated the results if the state took the lead, with all new LDVs purchased for the University of Delaware, Fleet Services, and DelDOT running on CNG. By 2010, roughly 54% of each fleet would run on CNG, representing about 0.22% of the total LDV fleet in Delaware. The remaining 1.88% of converted vehicles in this estimate would be privately owned.

We suggest that the University of Delaware fleet be converted because, for the most part, it is centrally fueled. Experience has shown that by starting with large, centrally fueled fleets, the cost of building fueling infrastructure is reduced. The larger DelDOT and Fleet Services fleets, on the other hand, are not centrally fueled. To pursue their conversion would require construction of more fueling sites than would the University fleet. Grants for construction of these stations could be sought through federal sources outlined in Section III.

Should the state choose to purse the 2% conversion to CNG, the bulk of CNG vehicles will be privately owned. We suggest that to begin this conversion, Delaware could offer incentives to taxi and shuttle companies to convert their fleets. They tend to be centrally fueled as well and several agencies across the country have successfully made this conversion (Whalen 1999, Eudy 2000). The state could encourage these companies to make their refueling stations available to the public as well, which could reduce the cost to the state of building CNG infrastructure, and also provide extra income to the fleet operator through the sale of fuel.

In order to reach the 2% goal, some market penetration of personal CNG vehicles must occur. As outlined in Section III, many states offer tax incentives or grant programs to individuals who purchase AFVs for personal use, with varying degrees of success. Several lessons can be learned from those experiences:

- Emissions will only be reduced if alternative fuels are actually used. Incentives that encourage dedicated CNG vehicles will work better than those that allow flexible-fueled vehicles
- Grant-based incentives tend to work better than tax-based incentives, individuals or organizations with low tax liability can still take advantage of them
- Incentives that cover the full incremental cost of the AFV tend to be most effective, since few are willing to pay extra for something unfamiliar to them, and
- States which can convince buyers that they are committed to the alternative fuel in the long run experience better participation rates.

4.4 Improving Vehicle Efficiency in Delaware

Feebates

We have demonstrated that efficiency is an extremely important component of efforts to reduce emissions (see Figure 3.2). However, the preemption clause of the federal CAFE standard does not allow states to set their own standards. Feebates are an attempt to get around this preemption, as they use state taxes or registration fees as an incentive for efficient purchases in place of a standard. But even this has met legal obstacles in Maryland. It might be possible to avoid Maryland's problem by basing a feebate on something other than fuel efficiency, such as EPA certified emissions, vehicle size or weight, or engine size.

Accelerated Vehicle Retirement

Vehicle scrapping aims to take old, inefficient vehicles off the road. It has experienced more success than feebates, especially in California. Based on Delaware's past experience with scrapping, we estimate that Delaware could achieve a 2.14% VOC reduction and a 0.06% NO_x reduction by initiating another round. This is based on the retirement of about 640 vehicles. The program could target waivered vehicles as in the past, since these vehicles are more cost effective to scrap in terms of emissions. The program could also

improve on the past program by not offering emissions credits. That way, emissions from vehicles taken off the road represent true net gains. In order to reduce opposition to the program by classic car enthusiasts, salvage of non-emissions components of scrapped vehicles could be allowed. The state could also consider offering a non-monetary benefit, such as transit passes or other such incentives for alternative travel modes. This strategy could help ensure that the replacement travel offers a clear emissions benefit compared to the scrapped vehicle.

V. Air Quality Modeling

The effectiveness of the CEEP transport policies on Delaware's future air quality can be assessed quantitatively using established EPA air quality models. Air quality modeling (AQM) is an essential tool for the scientific evaluation of air quality policies. Because the causal links between changes in emissions and any change in air quality are so complex, it is difficult determine empirically whether a change in emissions has altered air quality. As described in the introduction, a primary reason for this complexity is the transport of air-borne pollutants, obscuring the link between pollutant sources and the effects of resulting pollution. AQM provides a means to take into account the complex factors of distance, weather, topography, pollutant characteristics, and other factors that determine the effects of pollutants on air quality. These air quality models are highly complex, mathematical representations of the major characteristics involved. By changing the emission profiles of pollutants due to policy changes, these models make predictions of air quality resulting from changes in emissions.

Assessment of the CEEP policy package was undertaken to determine its effect on improving the worst-case event of ozone pollution in Delaware, which occurred in the summer of 1995. Such an approach is common in air quality studies. It is appropriate to examine the worst-case, because the one-hour standard targets such extreme events. Four scenarios were developed for this analysis, and are described in detail in the methodology section to follow. Outputs from the air quality models for each scenario were subject to analysis to determine the effects of air quality under each scenario, drawing on assistance from evaluation models and procedures. Results from this analysis are provided in Section VI.

5.1 Air Quality Models

Two air quality models were used in this study, both of which have been used by the EPA for several years for air quality studies in this region, known as SMOKE and CMAQ. Both SMOKE and CMAQ modeling systems are EPA approved, and are used by EPA region III, which includes Delaware.

SMOKE (Sparse Matrix Operator Kernel Emissions model) was introduced in 1996 and has since been upgraded several times by the EPA. The basic role of SMOKE is to allocate a wide variety of emissions data to a spatial format, so that emissions from mobile, point, and biogenic sources are placed into geographically defined and time dependent cells. The result is an emissions grid that incorporates time. SMOKE uses a number of processing algorithms to accomplish this. For a detailed description of each processor within SMOKE please refer to the Appendix.

CMAQ (Community Multi-Scale Air Quality) models the movement, transformation, and deposition of pollutants at a variety of scales, from the urban air shed to the regional scale (i.e. multiple states), and can do so for a number of pollutants simultaneously (US EPA 1999b). For a pollutant such as ozone, which results from the interaction of several precursor substances and local conditions, models such as CMAQ are important scientific and policy tools.

CMAQ is modular and broken down into six interface processors: a Meteorology-Chemistry Interface Processor (MCIP), an Emissions-Chemistry Interface Processor (ECIP),

a Land Use Processor (LUPROC), Initial and Boundary Conditions Processor (ICON and BCON), a Photolysis Rate Processor (JPROC), and a CMAQ Chemical Transport Model Processor (CCTM). These interface processors integrate the output from emissions and meteorology preprocessing systems as well as prepare input initial and boundary conditions and photolysis rates. Each processor is built and executed separately. Many times not all processors are needed. Refer to the Appendix for a description of CMAQ processors.

Emissions inventories were processed through SMOKE in order to produce CMAQ ready emissions files. The initial domain covers the eastern states[12] with a 36-km resolution grid. The second domain is nested within the larger grid and covers a smaller area: Virginia, Delaware, Pennsylvania, New Jersey, Ohio, Indiana, West Virginia and parts of New York. This grid has 12 km. resolution cells. SMOKE was run for each source category (area, biogenic, point and mobile) in each grid domain (36 km and 12 km resolutions). For each domain, all source categories' emissions files were merged together to create one emission file that was CMAQ ready. This process was done for every day in the meteorological episode (July 5-17, 1995, see meterology section below). Each emission file was then run through CMAQ.

Output from both of these models can be visualized and manipulated using the Package for Analysis and Visualization of Environmental data (PAVE). In addition to the air quality modeling, this research utilized the Geostatistical Indicator Module (GIM)[13]. The GIM is used to reduce data that varies across a spatial area down to one number. This number is known as the spatial field indicator. The GIM can also compare two different scenarios or cases through the Fractional Improvement Indicator (FII). This indicator measures the change, either positive or negative, between scenarios[14].

---

[12] The 36 km resolution domain covers Maine, Vermont, Massachusetts, New Hampshire, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Ohio, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Alabama, Florida, Louisiana, Arkansas, Florida, Tennessee, Kentucky, Illinois, Indiana, and Michigan.

[13] This module is part of the Multi-Integrated Resource Assessment (MIRA) decision framework designed by EPA Region III (Stahl et al 2002).

[14] The FII is the normalized volume of the base case minus the evaluation case divided by the base indicator. If the FII is greater than zero, the evaluation case is an improvement over the base, and if the FII is less than zero, there is a deterioration from the base to the evaluation case. For each scenario, the maximum one-hour ozone concentrations for the meteorological episode (July 9-17) were run through GIM and a spatial field indicator was created for the entire episode. Next, comparative cases (NET 1996 vs. NET 1996 without DE emissions, NET 1996 vs. 2010 projected inventory, and 2010 projected inventory vs. 2010 policy controlled inventory) were run through GIM to create a percent difference in spatial field indicators and spatially allocated percent difference maps.

5.2 Methodology

Scenarios

Four emission scenarios were analyzed. All scenarios are based on a worst-case meteorological event that occurred in July 1995. Scenario 1 was modeled using the most recent available emissions inventory. This represents the base case. Because considering a state in isolation of those other states that influence its air quality will produce misleading results, the construction of an appropriate base case against which to assess the impact of future emissions reductions is critical. For this purpose, the overall base case must reflect the regional circumstances.

Scenario 2 uses the same emissions inventory as scenario 1, except that all anthropogenic emissions from Delaware sources are removed. This scenario allows us to assess the extent of the ozone transport problem. Scenario 3 uses a projection of the most recent emissions inventory to 2010 (as described below). This scenario represents a "business as usual" (BAU) projection for the region.

Scenario 4 allows us to assess the effect of the transportation policies proposed in the previous section to the BAU scenario. It subtracts the expected emissions reductions resulting from those policies (10% NO_x reduction, 15% VOC reduction) from the 2010 projected inventory. This is done at a regional level, i.e., the emissions reductions are assumed to occur not only in Delaware, but also in the surrounding states of Maryland, Virginia, West Virginia, and Pennsylvania, and Washington DC.

Table 5.1. Air Quality Modeling Scenarios.
All scenarios are based on a worst-case meteorological event that occurred in July 1995.
Scenario 1 – Base Case: 1996 emissions inventory (most recent available) used in AQM.
Scenario 2 – No Delaware emissions: 1996 emissions inventory used in AQM, with Delaware anthropogenic emissions removed.
Scenario 3 – 2010 BAU: Emissions inventory projected to 2010, with effects of current regulations taken into account.
Scenario 4 – CEEP Transportation Policies: Emissions inventory projected to 2010, with regional emissions adjusted according to estimated impacts of the recommended policies.

Data Sources

Input data for scenarios 1 and 2 are from the National Emissions Trends (NET) 1996 version 3.11. Released in 2000, NET 3.11 represents a major effort by states to estimate their emissions. EPA's Emission Factor and Inventory Group created the NET with support from state and local air agencies, tribes and industry. NET 3.11 contains information on stationary and mobile emission sources of criteria pollutants (including the ozone precursors NO_x and VOC) for each state. States provide most of the data for stationary source emissions, including area and off-road mobile sources. Point source emissions information, such as emissions from electric generating units, comes from the EPA's Emission Tracking System/ Continuous Emissions Monitoring Data (ETS/ CEM) and the Department of Energy fuel use data. On-road mobile source information is supported by the Federal Highway Administration's estimates of vehicle miles traveled and emissions factors from EPA's MOBILE model (US EPA 2003b).

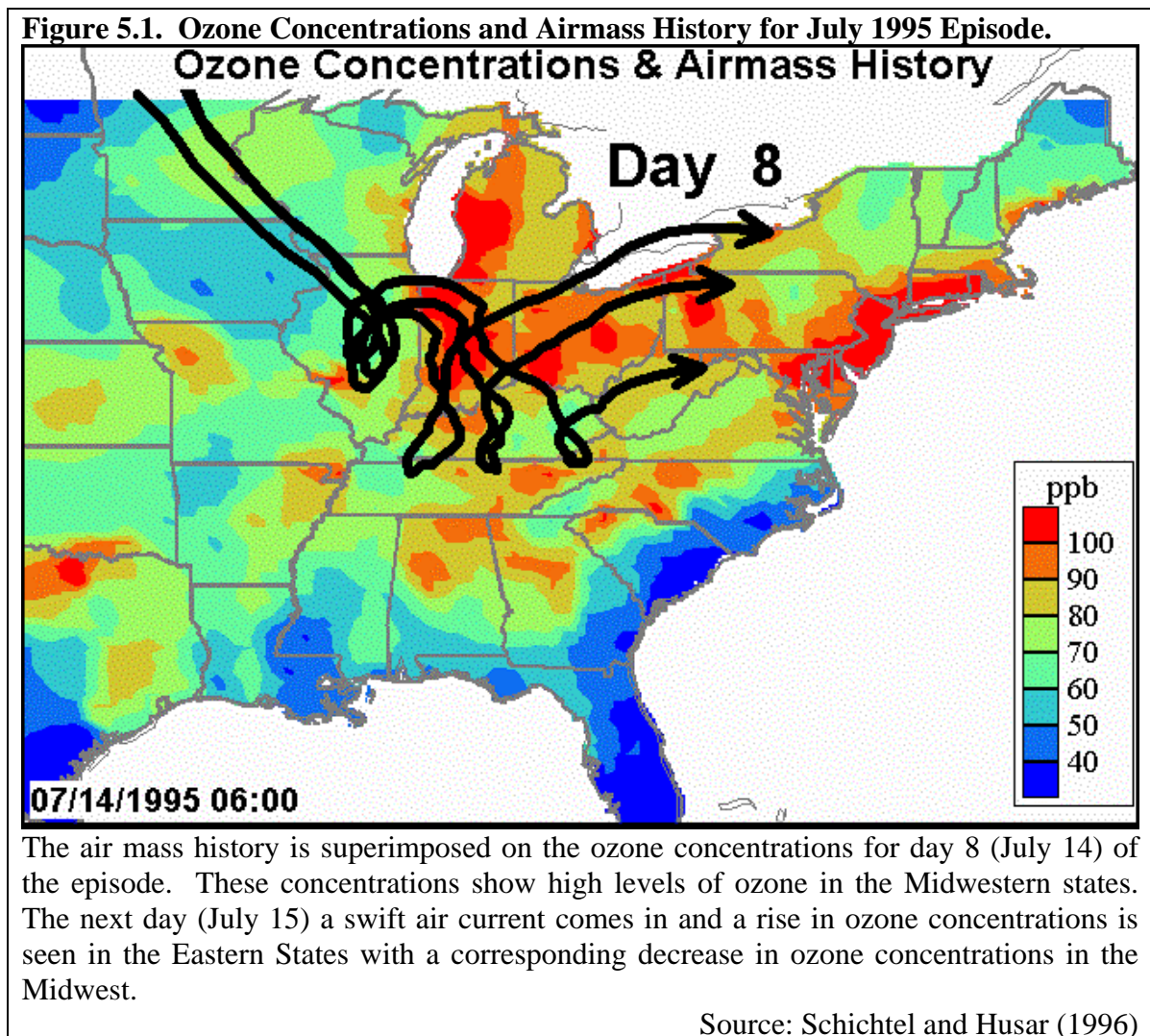| Table 5.2. Aggregate Delaware Emissions (tons) Data used in the AQM Scenarios.				
Scenario	**NO_x annual**	**NO_x daily**	**VOC annual**	**VOC daily**
Scenario 1 (Base Case)	25551	67.27	15980	41.17
Scenario 2 (No DE emissions)	0	0	0	0
Scenario 3 (2010 BAU)	17239	47.23	7493	20.53
Scenario 4 (CEEP policies)	15543	42.58	6406	17.55
These data are highly aggregated and are meant to provide only a rough representation of the difference among the input data for the various scenarios.				

Input data for scenarios 3 and 4 were based on a projection of NET 3.11 to 2010. EPA projected the inventory for use in the Clear Skies Initiative analysis. This 2010 projected inventory is an adjustment of the NET 3.11 inventory, to account for regulations that will be in place by 2010. These include the NO_x SIP Call, Tier II standards for light duty vehicles, and the Heavy-Duty Diesel standards[15]. It does not include the Clear Skies Initiative impacts.

Meteorology

Meteorology is a very important factor in ozone formation and transport. Air quality analysis generally uses the meteorology of a severe ozone episode in order to study a worst-case scenario. In July 1995, a serious ozone episode occurred. This meteorology has been used in many regional OTAG and EPA studies. It is characterized by relatively clean air coming from Canada into the Ohio River Valley, followed by a stagnating period of 5 days over the Ohio River Valley causing an accumulation of ozone in that area. The Ohio River Valley is a large producer of nitrogen oxides. The air is then transported eastward with a corresponding decrease in ozone in the Ohio River Valley and an increase in ozone concentrations in eastern states a day later. Temperatures during this period exceeded 100

---

[15] The NO_x SIP Call is a federal regulation that is aimed at reducing the amount of ozone transport from upwind states, Tier II standards are new mobile standards that will reduce emissions from automobile starting in 2007, and the Heavy-Duty Diesel standards will reduce emissions from heavy duty vehicles through new fuel sulfur content standards and new emissions trapping devices.

66

degrees Fahrenheit for several days in the Midwest and Northeast regions. Figure 5.1 depicts the air movement and the ozone concentrations.

Figure 5.1. Ozone Concentrations and Airmass History for July 1995 Episode.

The air mass history is superimposed on the ozone concentrations for day 8 (July 14) of the episode. These concentrations show high levels of ozone in the Midwestern states. The next day (July 15) a swift air current comes in and a rise in ozone concentrations is seen in the Eastern States with a corresponding decrease in ozone concentrations in the Midwest.
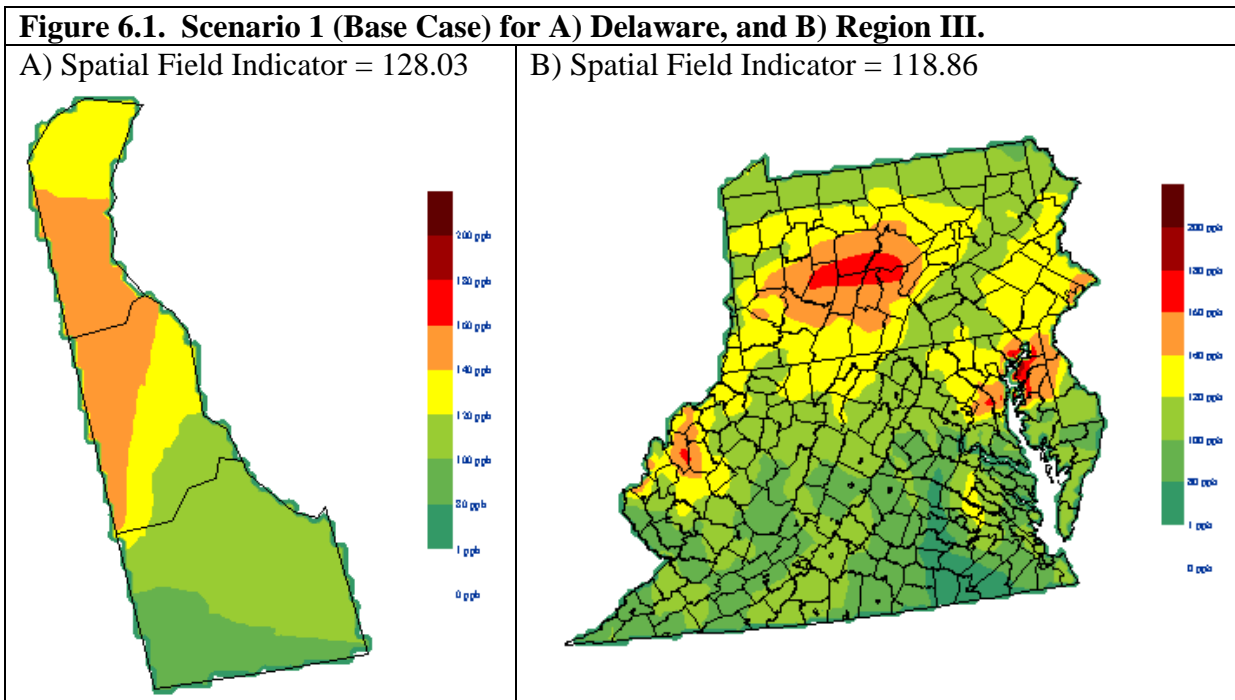
Source: Schichtel and Husar (1996)

VI. Air Quality Modeling Results and Analysis

This section presents the results of the four scenarios discussed in the previous section. All scenarios use the same meteorological episode, which produced very high ozone concentrations in violation of the one-hour ozone standard in July 1995. Scenario 1 (base case) uses the emissions inventory from 1996 (the most recent available). Scenario 2 (no Delaware emissions) uses the same inventory, but Delaware emissions are removed. Scenario 3 (2010 BAU) uses the emissions inventory projected to 2010, with effects of current regulations accounted for. Scenario 4 (CEEP Transportation Policies) uses the 2010 projected emissions inventory, with regional emissions adjusted according to estimated impacts of the recommended policies.

6.1 Scenario 1: Base Case

The NET 1996 inventory run through SMOKE and CMAQ for the meteorological episode of July 1995 shows one-hour maximum ozone concentrations between 120 – 160 ppb for all of New Castle County and most of Kent County (see Figure 6.1). The one-hour ozone standard is set at 120 ppb, and the standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 120 ppb is equal to or less than one (US EPA 2002e). During this episode, Sussex County does not experience maximum one-hour ozone concentrations over 120 ppb. This scenario illustrates a time when high levels of ozone concentrations partially permeated the state of Delaware. The spatial field indicators shown in each figure represent an average ozone concentration for the domain.

Figure 6.1. Scenario 1 (Base Case) for A) Delaware, and B) Region III.

A) Spatial Field Indicator = 128.03

B) Spatial Field Indicator = 118.86

6.2 Scenario 2: NET 1996 Inventory without Delaware Anthropogenic Emissions

Figure 6.2a illustrates the results of Scenario 2, where the NET 1996 inventory is edited to remove all of Delaware's anthropogenic emissions. The average ozone concentration for Delaware is 126.48 ppb, still higher than the one-hour standard. Figure 6.2b compares Scenario 2 with Scenario 1. Delaware's average one-hour maximum ozone concentrations improve by 1.2% for this meteorological episode when all Delaware anthropogenic emissions are removed. The light orange color represents a degradation or an increase in ozone of about 0.03% whereas, the green areas represent about a 15% improvement in ozone. The slight degradation in maximum ozone concentrations in Sussex and Kent counties is most likely due to a change in the NO_x/VOC ratio in that area. Disturbing this ratio even while reducing emissions can cause an increase in ozone concentrations. Even though all anthropogenic emissions were removed, biogenic emissions still remain. These emissions may be the cause of this degradation.

During this period, Delaware is experiencing large amounts of transport from beyond its state borders. Therefore when modeling the recommended transportation policies, an assumption was made that other states in Region III are implementing comparable policies that will achieve similar percent reductions in NO_x and VOCs (Scenario 4).

Although this information supports the concept of ozone transport, one must be careful to realize the limitations of this analysis. This analysis was only run using one meteorological episode (due to data and time limitations); OTAG usually used three to four episodes in modeling. Changing the meteorological episode will in fact change the ozone concentration values.

Comparing a different metric for ozone concentrations, such as the maximum ozone concentrations of one day rather than the entire episode, will show a different percent change between these two scenarios. The maximum ozone concentrations from July 12 show a 12% improvement in air quality when Delaware's emissions are zeroed out. Figure 6.3 illustrates this phenomenon. On this day, Delaware emissions are more responsible for the state's ozone concentration levels than during other days of the ozone episode. As illustrated, changes in meteorological conditions do impact ozone transport and concentration levels. Therefore, on some days emissions in one state do contribute to ozone production in that state and on other days ozone production is highly due to transported emissions. Due to ozone transport and the variability of ozone production, ozone precursor abatement strategies are needed at the state, regional and local levels in order to improve air quality.

70

Figure 6.2. **A) Scenario 2 (No Delaware Emissions). B) Comparison of Scenario 2 and Scenario 1 for the Delaware Domain.**

Spatial Field Indicator = 126.48

Fractional Improvement Indicator = 1.2%
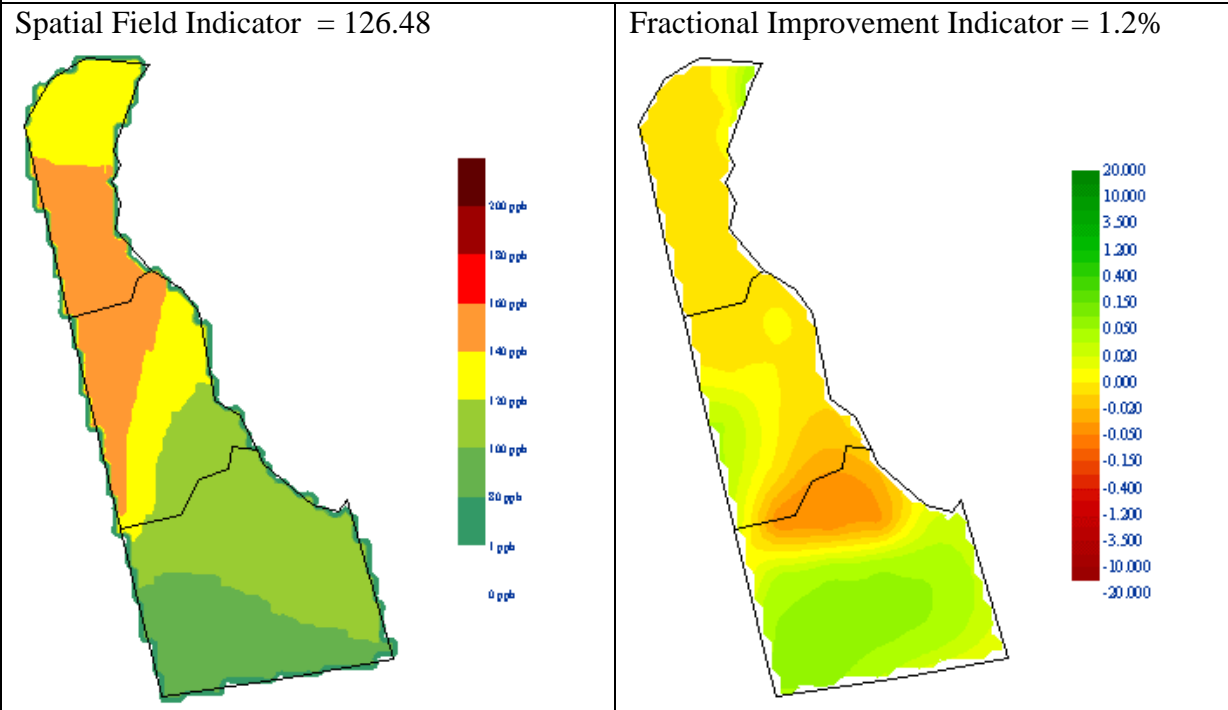
Figure 6.3. Comparison of Scenarios 1 & 2 for July 12th Only (Rather than the Entire Episode).

Fractional Improvement Indicator = 12%
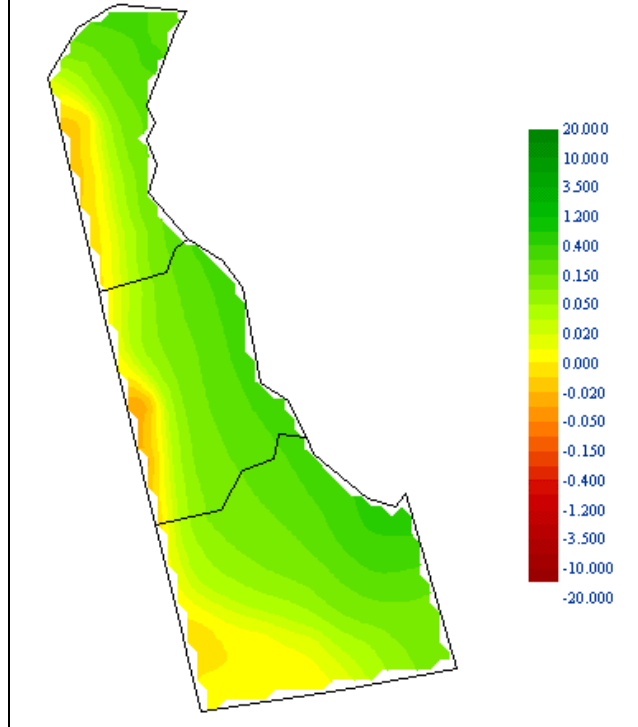
6.3 Scenario 3: 2010 BAU

Figure 6.4 depicts the results from Scenario 3, the 2010 "business as usual" emissions projection (E.H. Pechan & Associates 2000). The 2010 inventory includes within its projections all the federal programs that will be in effect by that year: NO_x SIP Call, Tier II standards, and Heavy-Duty Diesel standards. This inventory does not include the transportation policies outlined in Section IV. The ozone concentrations clearly decrease compared to the base case. The average ozone concentration (the spatial field indicator) drops from 128 ppb to 104 ppb. However, parts of New Castle and Kent Counties still have concentrations above 120 ppb, which is the one-hour ozone standard.

Figure 6.4. One-hour Maximum Ozone Concentrations – 2010 Projected Inventory – July 9-17 1995 on a) Delaware Domain and b) Region III Domain.

a) Delaware
Spatial Field Indicator = 103.87

b) Region III
Spatial Field Indicator = 94.56
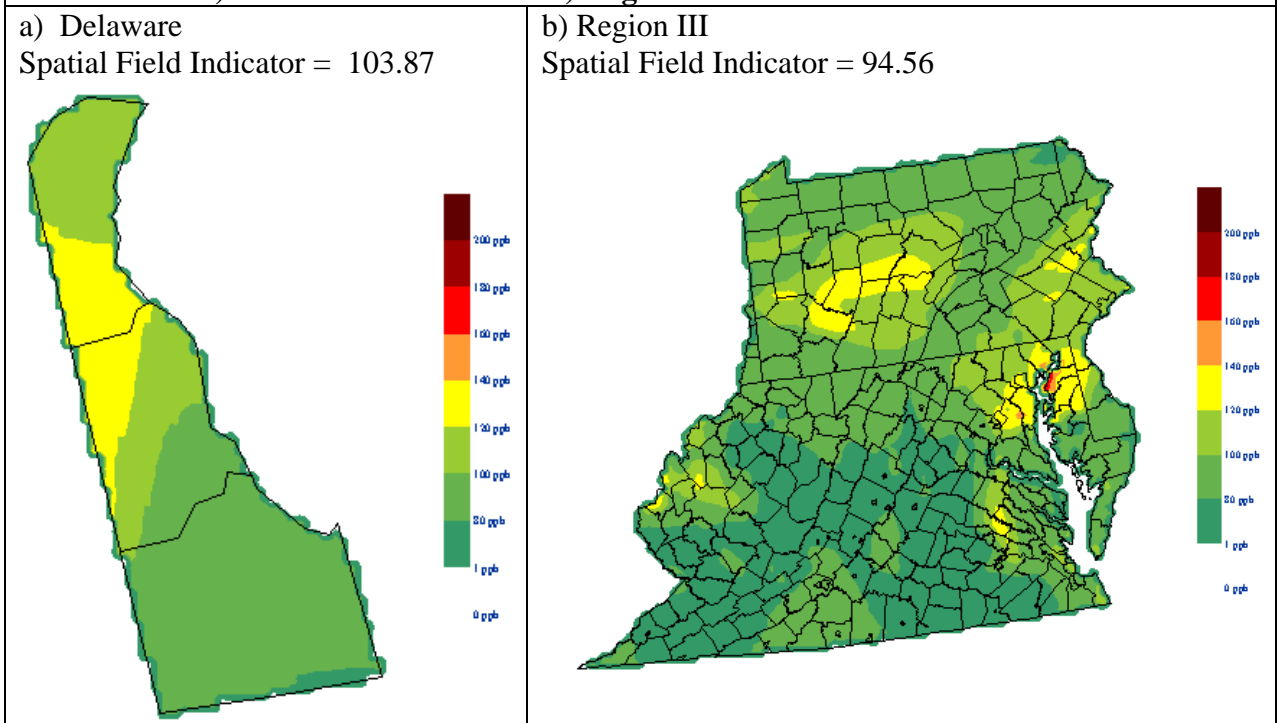
6.4 Scenario 4: 2010 Emissions with CEEP Transportation Policies

The calculated emission reductions from the proposed transportation strategies were modeled in an attempt to determine the impact on air quality compared to the BAU scenario. As stated above, the baseline used was the 2010 projected inventory. Table 6.1 shows the emission reductions in tons per day taken out from each state's mobile inventory. Comparing the BAU case, as shown in Figure 6.52 with Figure 6.5b illustrates the one-hour ozone 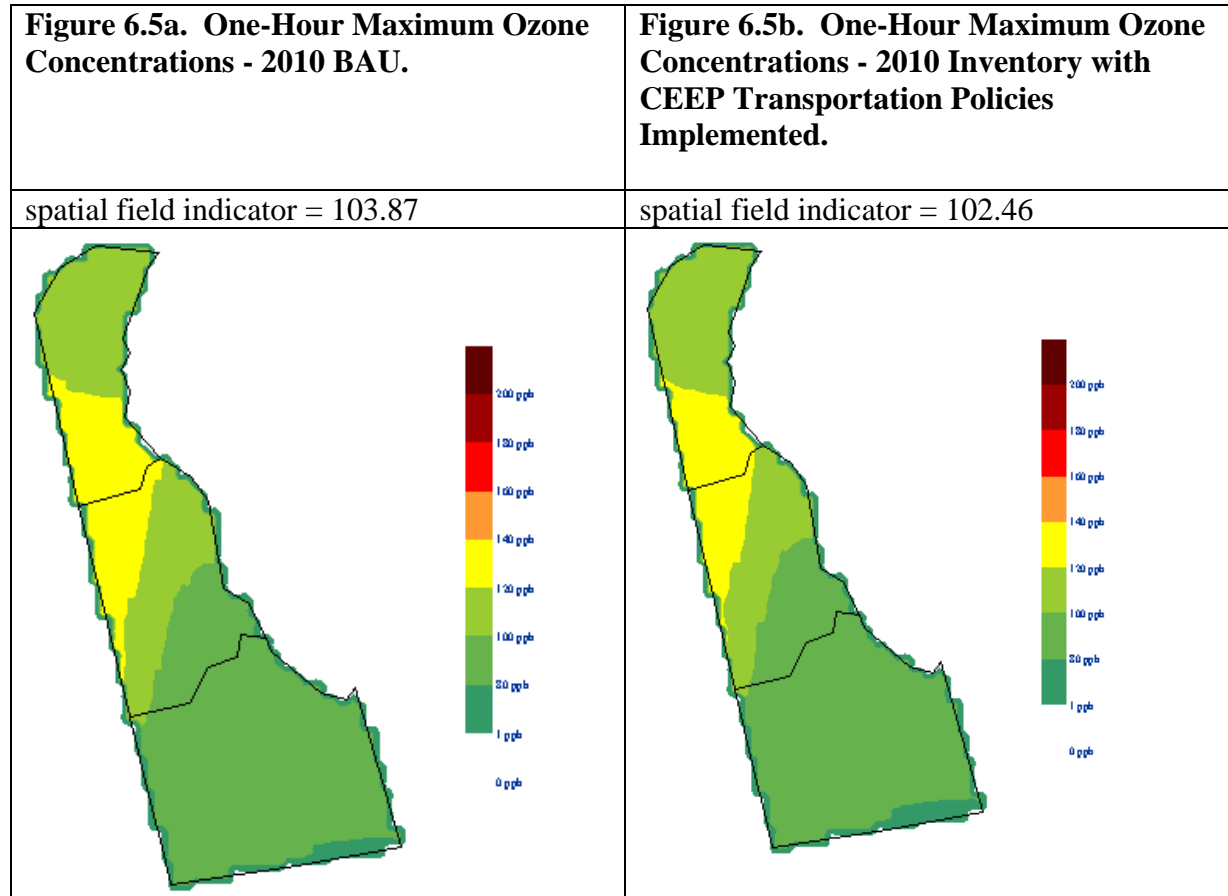maximum concentrations of the 2010 inventory with the recommended transportation policies for the meteorological episode July 9-17, 1995.

Table 6.1. State-by-State Emission Reductions in Tons per Day from Proposed Transportation Policies.

State	10% NO$_x$ Red. (ton/day)	15% VOC Red. (ton/day)
Delaware	4.725	3.080
Maryland	20.009	11.598
Pennsylvania	55.164	40.437
Virginia	40.997	31.653
Washington D.C.	1.327	0.929
West Virginia	11.315	9.659
Total	**133.537**	**97.355**

Figure 6.5a. One-Hour Maximum Ozone Concentrations - 2010 BAU.	**Figure 6.5b. One-Hour Maximum Ozone Concentrations - 2010 Inventory with CEEP Transportation Policies Implemented.**
spatial field indicator = 103.87	spatial field indicator = 102.46

In a scenario where Delaware implements the proposed transportation policies, and other states in Region III achieve similar emission reductions, one-hour maximum ozone values in Delaware improve on average 1.4%. The spatial distribution of those

74

improvements is seen in Figure 6.6. As shown, the improvement areas are mainly in New Castle and Kent counties. Improvement in those areas is important because the baseline shows high maximum one-hour ozone concentrations in both of those counties.

Figure 6.6. Comparison of the Maximum One-Hour Ozone Concentrations for the 2010 BAU vs. 2010 Inventory with a 10% Control on Mobile NO$_x$ and VOC Emissions Across the Mid-Atlantic Region.

Fractional Improvement Indicator = 1.4%
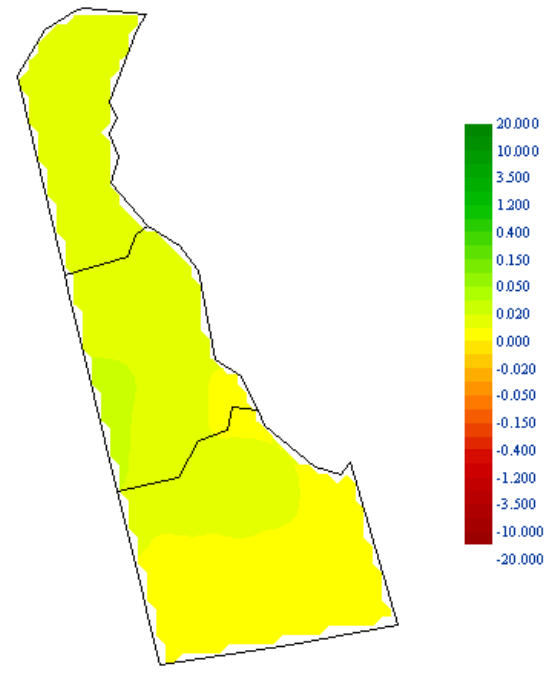
VII. Discussion of Findings and Conclusions

This analysis shows that the recommended transportation policies impact air quality in Delaware. A 1.4% improvement over the 2010 baseline represents improvement in air quality over the Federal mandated programs that will be in effect.

A fractional improvement of 1.4% sounds small, but it could be a significant improvement in terms of helping Kent and New Castle Counties work toward attainment. Since these two counties are in severe non-attainment, Delaware is required to submit a Rate of Progress Plan to the US EPA that models target emissions levels necessary to meet attainment. If the counties can meet and maintain emissions targets for 2005 for each source, as defined by the Rate of Progress Plan, they should reach attainment. The 2005 targets for on-road mobile sources in Kent and New Castle Counties were 20.22 tons/day of VOC, and 29.7 tons/day of NO_x (DNREC 2003). Our 2010 projected emissions inventory suggests that the two counties will still be within their budget for VOCs by 2010. However, by that year they will emit 34.54 ton/day of NO_x, which is 4.84 tons/day above the 2005 budget. Our proposed policies could yield nearly a 10% reduction in on-road NO_x emissions. This would reduce the budget shortfall of 4.84 tons per day to 1.39 tons/day, an improvement of 71.4%. As mentioned previously, the link between air quality and emissions is very non-linear and attempts to reduce improvements to a single number are full of uncertainty. Nevertheless, by this measure, the proposed policies could have a significant effect in working toward attainment.

VIII. References

Alameda County Congestion Management Agency (ACCMA) (2003). *ACCMA Home Page*. http://www.accma.ca.gov/pages/index.shtml. Accessed 6/18/03.

Association for Commuter Transportation (ACT) (1997). *TDM Case Studies and Commuter Testimonials*. Prepared by the Transportation Demand Management Institute of the Association for Commuter Transportation. Washington, DC.

Alternative Fuels Data Center (AFDC) (1998). *Frequently asked questions about alternative fuels*. www.afdc.doe.gov. Accessed 1/8/03.

Alternative Fuels Data Center (AFDC) (1999). Update on EPA Regulations and Heavy-Duty Consent Decree. *Alternative Fuel News, 3*(4).

Albernini, A., Harrington, W., and McConnell, V. (1996). Estimating an emissions supply function from accelerated vehicle retirement programs. *The Review of Economics and Statistics*, 78 (2), 251-265.

Allen, J. (2002). *The Ozone We Breathe*. NASA Earth Observatory. http://earthobservatory.nasa.gov/Library/OzoneWeBreathe/. Accessed 6/18/03.

Bamberger, R. (2002). Automobile and light truck fuel economy: The CAFE standards. *Congressional Research Service Issue Brief*. Updated 12/23/02.

Bernow, S. (2002). *Program Design Features for Feebate Initiative: Survey of Existing Feebate Programs.* Tellus Institute.

Botkin, D. and Keller, E. (1995). *Environmental Science.* New York: John Wiley & Sons.

Brown, M. H. and Breckenridge, L. (2001). *State Alternative Fuel Vehicle Incentives: A Decade and More of Lessons Learned*. Washington, DC: National Conference of State Legislators.

Butler, P., Butler, T. and Williams, L. L. (1988). Sex-divided mileage, accident, and insurance cost data show that auto insurers overcharge most women. *Journal of Insurance Regulation,* 6, 243-284, 373-420.

California Department of Transportation (CA DOT) (2003). *SmartTraveler Information*. http://www.dot.ca.gov/caltrans511/. Accessed 6/18/03.

Canon, J. S. and Sun, C. (2000). *Bus Futures: New Technologies for Cleaner Cities.* Inform, Inc.

California Air Resources Board (CARB) (2003). *Laws and Regulations*. http://www.arb.ca.gov/html/lawsregs.htm. Accessed 6/18/03.

Carlson, T. R., Dulla, R. G. and Kuzmiak, J. R. (2000). *COMMUTER Model User Manual for Analysis of Voluntary Mobile Source Emission Reduction and Commuter Choice Incentive Programs*. EPA420-R-00-016. US Environmental Protection Agency.

California Energy Commission (CEC) (2003). *Alternative Fuel Vehicles and High Efficiency Vehicles*. http://www.energy.ca.gov/afvs/index.html. Accessed 6/18/03.

Center for Energy and Environmental Policy (CEEP) (2000). *Delaware Climate Change Action Plan.* Report for the Delaware Climate Change Consortium, sponsored by the Delaware State Energy Office and the State and Local Climate Change Program of the US EPA.

Census Bureau (1999). *Statistics of U.S. Businesses: All Industries: Delaware*. http://www.census.gov/epcd/susb/1999/de/DE--.HTM. Accessed 6/18/03.

City of San Francisco (2003). *Office of the Treasurer and Tax Collector. City of San Francisco*. http://www.sfgov.org/site/treasurer_index.asp. Accessed 6/18/03.

City of Seattle (2003). *Commute Trip Reduction*. Department of Transportation. http://www.cityofseattle.net/transportation/commute.htm. Accessed 6/18/03.

Colorado Department of Revenue (CO DOR) (2003). *Colorado Statutes*. http://www.revenue.state.co.us/. Accessed 6/18/03.

Colorado Department of Transportation (CO DOT) (2003). *CDOT Home Page.* http://www.dot.state.co.us/. Accessed 6/18/03.

CommuterCheck. (2003). *Impacts of the Commuter Check Program. Commuter Check*. http://www.commutercheck.com/about/studies.html. Accessed 7/1/03.

Metropolitan Washington Council of Governments (MWCOG) (2003). *Commuter Connections*. http://www.mwcog.org/commuter/ccindex.html. Accessed 6/18/03.

CommuterChallenge (2003). *Commuter Challenge Case Studies.* http://www.commuterchallenge.org/cc/partnersfs.html. Accessed 6/18/03.

Davis, S. C. and Diegel, S. W. (2002). *Transportation Energy Data Book: Edition 22.* Report ORNL-6967. Oak Ridge, TN: Oak Ridge National Laboratory.

Delaware Department of Labor (DE DOL) (2001). *Delaware 2001.* Office of Occupational and Labor Market Information.

Delaware Division of Motor Vehicles (DE DMV) (2003). *Exhaust Emission Inspection*. http://www.delaware.gov/agencies/DMV/Vehicle_Services/Registration/ve_reg_emissions. Accessed 6/18/2003.

Delaware Department of Transportation (DELDOT) (2002). *Delaware Transportation Facts 2002.* DelDOT Planning, US Department of Transportation, and the Federal Highway Administration.

DeCicco, J. M., Geller, H., and Morrill, J. (1993). *Feebates for Fuel Economy: Market Incentives for Encouraging Production and Sales of Efficient Vehicles.* Washington, DC: American Council for an Energy-Efficient Economy.

Delaware Department of Natural Resources and Environmental Control (DNREC) (2003). *Proposed Amendments to Delaware 2005 Rate-of-Progress Plan for Kent New Castle Counties.* http://www.dnrec.state.de.us/air/aqm_page/pro_regs.htm. Accessed 1/15/04.

Difiglio, C. and Fulton, L. (2000). How to reduce US automobile greenhouse gas emissions. *Energy,* 25 (7), 657-673.

E. H. Pechan & Associates, Inc. (2000). *Procedures for Developing Base Year and Future Year Mass and Modeling Inventories for the Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Rulemaking.* EPA Contract No. 68-D7-0067.

Energy Information Administration (EIA) (2001). *Annual Energy Outlook 2002.* DOE/EIA-0383(2002). Washington, DC: U.S. Department of Energy.

Energy Information Administration (EIA) (2003). *Estimated Number of Alternative-Fueled Vehicles in Use, by State and Fuel Type, 2000.* http://www.eia.doe.gov/cneaf/alternate/page/datatables/table4.html. Accessed 5/25/2003.

Eudy, L. (2000). *SuperShuttle CNG Fleet Evaluation: Final Report.* Technical Report NREL/TP-540-29226. Golden, CO: National Renewable Energy Laboratory.

Eudy, L. (2002). *Natural Gas in Transit Fleets: A Review of the Transit Experience.* Technical Report NREL/TP-540-31479. Golden, CO: National Renewable Energy Laboratory.

Farrell, A. (2001). Multi-lateral emission trading: Lessons from inter-state NO_x control in the United States. *Energy Policy,* 29 (13), 1061-1072.

Farrell, A. and Keating, T. (2002). Transboundary environmental assessment: Lessons from OTAG. *Environmental Science & Technology,* 36 (12), 2537-2544.

Friedrich, R. and Reis S. (eds.) (2000). *Tropospheric Ozone Abatement: Developing Efficient Strategies for the Reduction of Ozone Precursors in Europe.* New York: Springer.

Funderberg, K, Grant, M, and Coe, E. (2003). Changing Insurance One Mile at a Time. *Contingencies November/December 2003*: 34-38.

Greenberg, A. (2003). *Comparing the Benefits of Mileage and Usage Pricing Incentives with Other Government Transportation Expenditures.* Presented at the 82nd Annual Meeting of the Transportation Research Board, Washington DC, 1/15/03. Available on CD-ROM from the Transportation Research Board.

Greening, L., Greene, D. L. and Difiglio, C. (2000). Energy efficiency and consumption -- the rebound effect -- a survey. *Energy Policy,* 28 (6-7), 389-401.

Greater Redmond Transportation Management Association (GRTMA) (2003). *Welcome to the Greater Redmond TMA*. http://www.grtma.org/. Accessed 6/18/03.

Guthrie, P., Ligocki, M., Looker, R., and Cohen, J. (1997). *Air Quality Effects of Alternative Fuels: Final Report.* NREL/SR-540-23896. Golden, CO: National Renewable Energy Laboratory.

Hahn, R. W. (1995). An economic analysis of scrappage. *The RAND Journal of Economics,* 26 (2), 222-242.

Hobbs, F. and Stoops, N. (2002). *Demographic Trends in the 20th Century*. Census 2000 Special Reports, Series CENSR-4. Washington DC: US Census Bureau.

Houyoux, M. (ed.) (2000). *SMOKE User Manual v1.3.* MCNC-Environmental Modeling Center.

ICF Consulting and Victoria Transportation Policy Institute (2001). *Pay-As-You-Drive Insurance: A Review of the Literature*. Prepared for U.S. Environmental Protection Agency.

International Council for Local Environmental Initiatives (ICLEI) (2003). *Local Government Guide to Parking Cash-out*. http://www.iclei.org/us/cashout/. Accessed 6/18/03.

Kadesh, E. and Roach, W. T. (1997). Commute trip reduction – a collaborative approach. *Energy Policy, 25* (14-15), 1217-1225.

King County. (2003). *King County Metro Online*. http://transit.metrokc.gov/. Accessed 6/18/03.

Litman, T. (1997). Distance based vehicle insurance as a TDM strategy. *Transportation Quarterly,* 51(3), 119-138.

Litman, T. (2000). *Transportation Cost Analysis.* Victoria Transportation Policy Institute. www.vtpi.org. Accessed 6/18/03.

Livable Delaware (2003). *Transportation Fuels Work Group, Meeting Notes.* http://www.state.de.us/planning/livedel/etftrans.htm. Accessed 2/25/03.

Marston, J. (2002). Pay-as-you-go insurance good for customers, environment. *The Dallas Morning News.* 7/7/2002.

Maryland Department of Housing and Community Development (MD DHCD) (2003). *Designated Neighborhoods Program.* http://www.dhcd.state.md.us/dn/index.asp. Accessed 6/18/03.

Maryland Department of Transportation (MD DOT) (2003). *Commuter Choice Maryland.* http://www.mdot.state.md.us/CommuterChoice/commuterchoice. Accessed 6/18/03.

Metropolitan Washington Council of Governments (MWCOG) (2003). *Advanced Technology Vehicle Program – The Clean Alternative.* http://www.mdot.state.md.us/. Accessed 6/18/03.

Mogridge, M. J. H. (1997). The self-defeating nature of urban road capacity policy: A review of theories, disputes and available evidence. *Transport Policy,* 4 (1), 5-23.

National Conference of State Legislatures (NCSL) (1996). *Feebates: State Legislative Report.* Washington, DC.

National Center for Transit Research (NCTR) (2003). *National Transportation Demand Management and Telework Clearinghouse.* http://www.nctr.usf.edu/clearinghouse/. Accessed 6/18/03.

National Highway Traffic Safety Administration (NHTSA) (2002). *Automotive Fuel Economy Program: Annual Update Calendar Year 2001.* DOT HS 809 512. U.S. Department of Transportation.

Nigro, R. (2003). *Delaware Transportation Fuels Forecast.* Spreadsheet provided to Livable Delaware Transportation Fuels Working Group.

New Jersey Department of Transportation (NJ DOT) (1997). NJDOT unveils project power commute. *Press Release.* Available at: http://www.state.nj.us/transportation/framed/press/May%201997/power.htm. Accessed 6/18/03.

New Jersey Department of Transportation (NJ DOT) (2003). *Smart Moves for Business Program.* http://www.state.nj.us/njcommuter/html/smartbus.htm. Accessed 5/25/03.

National Research Council (NRC) (1991). *Re-Thinking the Ozone Problem in Urban and Regional Air Pollution.* Committee on Tropospheric Ozone Formation and Measurement. Washington, DC: National Academy Press.

Northeast States for Coordinated Air Use Management (NESCAUM) (1997). *The Long-Range Transport of Ozone and Its Precursors in the Eastern United States.* Boston, MA: NESCAUM.

Northeast States for Coordinated Air Use Management (NESCAUM) (1998). *The Cost of Ozone Transport: Achieving Clean Air in the East.* Boston, MA: NESCAUM.

National Renewable Energy Laboratory (NREL) (1999). Fact Sheets: *Ford F-250 dedicated CNG* (NREL/FS-540-26519), *GMC Sierra bi-fuel* CNG (NREL/FS-540-26004), *Honda Civic dedicated CNG* (NREL/FS-540-26005), *Ford F-250 bi-fuel propane* (NREL/FS-540-27163), *Dodge Caravan bi-fuel E85* (NREL/FS-540-26006), *Ford Taurus bi-fuel E85* (NREL/FS-540-26578).

National Renewable Energy Laboratory (NREL) (2001). *What is EPAct?* Fact Sheet DOE/GO-102001-1306. Battelle: U.S. Department of Energy.

New York State Energy Research and Development Authority (NYSERDA) (2003). *Alternative Fuel Vehicle Programs.* http://www.nyserda.org/afvprogram.html. Accessed 6/18/03.

Oregon Environmental Council (OEC) (2003a). Oregon passes first-of-its-kind bill in nation to promote "pay-as-you-drive" auto insurance. *Press Release*, 6/19/2003. http://www.orcouncil.org/Press%20Releases/6.19.03%20PAYD%20Senate%20Vote%20Release.PDF. Accessed 5/25/03.

Oregon Environmental Council (OEC) (2003b). 2003 Legislative Proposal: Pay-as-you-drive auto insurance. http://www.orcouncil.org/Laws/PAYDFactsheet.PDF. Accessed 5/25/03.

Oregon Department of Environmental Quality (OR DEQ) (2003a). Employee Commute Options Program. Northwest Region. http://www.deq.state.or.us/nwr/ECO/eco.htm. Accessed 6/18/03.

Oregon Department of Environmental Quality (OR DEQ) (2003b). CHOICES Program again offers alternatives to drivers whose vehicles have failed DEQ emission tests. *News Release*, 6/2/2003.

Oregon Department of Energy (OR DOE) (2003). *Oregon Business Energy Tax Credit Program.* http://www.energy.state.or.us/bus/tax/taxcdt.htm. Accessed 6/18/03.

Ozone Transport Commission (OTC) (1998). *Pollution Control Strategies in the Northeast and Mid-Atlantic States to Clean up Ground Level Ozone: Progress to Date and a Look towards the Future.* Ozone Transport Commission, Northeast States for Coordinated Air Use Management, and Mid-Atlantic Regional Air Management Assoiation.

Pennsylvania Department of Environmental Protection (PA DEP) (1999). The Pennsylvania Alternative Fuel Incentive Grant Program. *Fact Sheet*. http://www.dep.state.pa.us/dep/subject/pubs/arr/aq/fs2354.pdf. Accessed 6/18/03.

Pennsylvania Code (PA Code) (2003). Subchapter B. Employer Trip Reduction. http://www.pacode.com/secure/data/025/chapter126/subchapBtoc.html. Accessed 6/18/03.

Pima Association of Governments (PAG) (2003). *Travel Reduction Program*. http://www.pagnet.org/TRP/. Accessed 6/18/03.

Pollution Probe (2001). *North American Workplace-based Trip Reduction Programs.* Pollution Probe Report. Toronto, Canada.

Portney, P. (2000). Air pollution policy. Pp. 77-124. In Portney, P. and Stavins, R. (eds.), *Public Policies for Environmental Protection.* Second Edition. Washington, DC: Resources for the Future.

Rabl, A. (2002). Environmental benefits of natural gas for buses. *Transportation Research Part D: Transport and Environment,* 7 (6), 391-405.

RAND Institute for Civil Justice (2001). Scrapping Old Vehicles Would Improve Southern California Air Quality at Reasonable Cost. *Research Brief* (RB-9033). Available online: http://www.rand.org/publications/RB/RB9033/. Accessed 6/18/03.

Roy, R. (2000). The role of the Transportation Management Association in Delaware. Pp. 13-16. In Moreland, L. and Sappe, N. (eds.). *Moving People: Transportation Options for Delaware.* Institute for Public Administration, University of Delaware.

Schichtel, B. A. and Husar, R. (1997). *Anatomy of July 1995 Regional Ozone Episode*. Center for Air Pollution Impact and Trend Analysis. OTAG. Washington University, St. Louis, MO. http://capita.wustl.edu/otag/reports/o3epi95/o3epi95.html. Accessed 6/18/03.

Sillman, S. (1999). The relation between ozone, NOx and hydrocarbons in urban and polluted rural environments. *Atmospheric Environment,* 33, 1821-1845.

San Luis Obispo Regional Rideshare Progrmam (SLORR) (2003). http://www.rideshare.org/.

Stahl, C., Cimorelli, A. and Chow, A. (2002). A new approach to environmental decision Aanalysis: Multi-criteria integrated assessment (MIRA). *Bulletin of Science, Technology and Society,* 22, 443-459.

Transportation Management Agency of Delaware (TMA Delaware) (2003). *EZPass Benefits*. http://www.tmadelaware.org/ezpass/. Accessed 6/18/03.

Train, K. E. et al (1997). Fees and rebates on new vehicles: Impacts on fuel efficiency, carbon dioxide emissions, and consumer surplus. *Transportation Research-E,* 33 (1), 1-13.

Tri-County Metropolitan Transportation District of Oregon (TriMet) (2003). *TriMet and the Environment.* http://www.trimet.org/environment/index.htm. Accessed 6/18/03.

U.S. Department of Energy (US DOE) (1995). *Effects of Feebates on Vehicle Fuel Economy, Carbon Dioxide Emissions, and Consumer Surplus.* Technical Report. Office of Policy.

U.S. Department of Energy (US DOE) (2000). *Natural Gas School Buses: Driving our Kids to a Cleaner Tomorrow.* Office of Transportation Technologies.

U.S. Department of Energy (US DOE) (2003). Alternative Fuel Vehicle Buyer's Guide for Fleets. U.S. Department of Energy, Clean Cities Program. http://www.ccities.doe.gov/vbg/fleets/. Accessed 6/18/03.

U.S. Department of Transportation (US DOT) (1993). *A Guidance Manual for Implementing Effective Employer-based Travel Demand Management Programs.* Report prepared for the U.S. Department of Transportation.

U.S. Department of Transportation (US DOT) (2001). *National Center for Statistics and Analysis. 2001 Annual Assessment.* www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/Rpts/2002/Assess01.pdf. Accessed 6/18/03.

U.S. Department of Transportation (US DOT) (2002). *Transportation Air Quality - Selected Facts and Figures.* Federal Highway Administration. http://www.fhwa.dot.gov/environment/aqfactbk/factbk14.htm. Accessed 6/18/03.

U.S. Department of Transportation and U.S. Environmental Protection Agency (US DOT and US EPA) (2003). *Best Workplaces for Commuters*. http://www.commuterchoice.gov/. Accessed 6/18/03.

U.S. Environmental Protection Agency (US EPA) (1998a). Finding of Significant Contribution and Rulemaking for Certain States in the Ozone Transport Assessment Group Region for Purposes of Reducing Regional Transport of Ozone. *Federal Register 63*(207): 57355-57404.

U.S. Environmental Protection Agency (US EPA) (1998b). *Transportation Control Measures: Accelerated Vehicle Retirement*. Transportation Air Quality Center Technical Overview. EPA420-S-98-001.

U.S. Environmental Protection Agency (US EPA) (1998c). *SCRAP: South Coast Recycled Auto Program*. US EPA Directory of Air Quality Economic Incentive Programs. http://yosemite.epa.gov/aa/programs.nsf/8231d2bceda4da8a8525651c00502e17/f62a60fcda9a3b648525651c00506e3d?OpenDocument. Accessed 6/18/03.

U.S. Environmental Protection Agency (US EPA) (1998d). *Phoenix Old Vehicle Buyback*. US EPA Directory of Air Quality Economic Incentive Programs. http://yosemite.epa.gov/aa/programs.nsf/0/90495c19c3ec4a568525651c00506e41?OpenDocument. Accessed 6/18/03.

U.S. Environmental Protection Agency (US EPA) (1998e). *Accelerated Vehicle Retirement.* http://yosemite.epa.gov/aa/tcmsitei.nsf/Pages/AccVehInfoDoc. Accessed 6/18/03.

U.S. Environmental Protection Agency (US EPA) (1999a). *EPA's Program for Cleaner Vehicles and Cleaner Gasoline.* Office of Mobile Sources.

U.S. Environmental Protection Agency (US EPA) (1999b). *Science Algorithms of the EPA Models-3 Community Multi-scale Air Quality (CMAQ) Modeling System.* Office of Research and Development.

U.S. Environmental Protection Agency (US EPA) (2000a). *Regulatory Announcement: Heavy-duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements.* EPA420-F-00-057.

U.S. Environmental Protection Agency (US EPA) (2000b). *COMMUTER Model Coefficients.* Office of Transportation and Air Quality. EPA420-F-00-042.

U.S. Environmental Protection Agency (US EPA) (2002a). *Green Book: Ozone Nonattainment Area Summary*. www.epa.gov/oar/oaqps/greenbk/onsum.html. Accessed 6/18/03.

U.S. Environmental Protection Agency (US EPA) (2002b). *Latest Findings on National Air Quality: 2001 Status and Trends.* Office of Air Quality Planning and Standards.

U.S. Environmental Protection Agency (US EPA) (2002c). *A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions: Draft Technical Report.* EPA420-P-02-001.

U.S. Environmental Protection Agency (US EPA) (2002d). *Amendments to State NO_x Budgets*. Office of Air and Radiation Policy and Guidance Information. www.epa.gov/ttn/oarpg/t1/reports/redtab.pdf. Accessed 6/18/03.

U.S. Environmental Protection Agency (US EPA) (2002e). *National Ambient Air Quality Standards (NAAQS).* http://www.epa.gov/reg3artd/airquality/NAAQS.htm. Accessed 6/18/03.

U.S. Environmental Protection Agency (US EPA) (2003a). *Transportation Control Measures: Program Information Directory*. Office of Mobile Sources. http://yosemite.epa.gov/aa/tcmsitei.nsf/. Accessed 6/18/03.

U.S. Environmental Protection Agency (US EPA) (2003b). *National Emissions Inventories for the US.* Technology Transfer Network Clearinghouse for Inventories & Emission Factors. http://www.epa.gov/ttn/chief/net/. Accessed 6/18/03.

van Vorst, W. D. and George, S. (1997). Impact of the California Clean Air Act. *International Journal of Hydrogen Energy,* 22 (1), 31-38.

Victoria Transportation Policy Institute (VTPI) (2003). *Online TDM Encyclopedia*. http://www.vtpi.org/tdm/. Accessed 6/18/03.

Wang, M. Q. (1999). *GREET 1.5 - Transportation Fuel-cycle Model Volume 1: Methodology, Development, Use, and Results*. ANL/ESD-39, Vol. 1. Argonne, IL: Argonne National Laboratory.

Whalen, P., Kelly, K. and John, M. (1999). *Barwood CNG Cab Fleet Study: Final Results.* Technical Report NREL/TP-540-26035. Golden, CO: National Renewable Energy Laboratory.

Washington State Department of Transportation (WA DOT) (2003). *Transportation Demand Management*. http://www.wsdot.wa.gov/TDM/tripreduction/. Accessed 6/18/03.

IX. Contacts

Delaware

Delaware Department of Natural Resources and Environmental Control
http://www.dnrec.state.de.us/dnrec2000/

Phil Wheeler
Planner IV
DNREC Air Quality Management Section
156 South State Street
Dover, Delaware 19901
Philip.Wheeler@state.de.us
(302) 739-4791

Delaware Fleet Services
http://www.state.de.us/admin/Fleet_Services/fleet_services.html

D. Terry Barton, Jr.
Administrator
Fleet Services
820 Silver Lake Blvd, Ste. 100
Dover, DE 19904
Dbarton@state.de.us
(302) 739-3039

Beth Neeman
Management Analyst
Fleet Services
820 Silver Lake Blvd, Ste. 100
Dover, DE 19904
bneeman@state.de.us
(302) 739-5718

Delaware Department of Transportation
http://www.deldot.net/

Mark A. McNulty, Esq.
Special Counsel
DelDOT Headquarters / Administration Center
800 Bay Road, P.O. Box 778
Dover, DE 19903
MMcNulty@mail.dot.state.de.us
(302) 760-2160

Cyette Coleman
Delaware Transit Corporation
Administration
900 Public Safety Boulevard
Dover, DE 19901
(302-577-3278 x3472)

S. Curt Cole
Business Manager
DelDOT Headquarters / Administration Center
800 Bay Road
Dover, DE 19901
CCole@mail.dot.state.de.us
(302) 760-2088

Delaware Energy Office
http://www.delaware-energy.com/

Charlie T. Smisson, Jr.
State Energy Coordinator
Department of Natural Resources and
Environmental Control
146 South Governors Avenue
Dover, DE 19901
charlie.smisson@state.de.us
302-739-1530

Suzanne Sebastian
Energy Program Planner IV
Department of Natural Resources and
Environmental Control
146 South Governors Avenue
Dover, DE 19901
suzanne.sebastian@state.de.us
(302) 739-1530

University of Delaware
http://www.udel.edu/

Charlene H. Benson
Director
Supporting Services
110 General Services Building
Newark, DE 19716
chbenson@udel.edu
(302) 831-2151
http://www.udel.edu/SuppSrvc/

Professor Ardeshir Faghri
Director
Delaware Center for Transportation
Professor, Associate Chairman
Department of Civil and Environmental
Engineering
faghri@ce.udel.edu
(302) 831-2426
http://www.ce.udel.edu/dct/

Wilmington Area Planning Council / MPO (WILMAPCO)
http://www.wilmapco.org/

Daniel Blevins
Senior Planner
Wilmington Area Planning Council
850 Library Ave, Suite 100
Newark, DE 19711
dblevins@wilmapco.org
(302) 737-6205 x21

Delaware Insurance Department
http://www.state.de.us/inscom/

Ann Lyon
Delaware Insurance Department
841 Silver Lake Boulevard
Dover DE 19904
 (302) 739-4251

Arizona

Mark Lewandowski
Rules & SIPS Supervisor
Arizona Department of Environmental
Quality
1110 W. Washington St.
Phoenix, AZ 85007
lewandowski.mark@ev.state.az.us
(602) 771-2230
www.adeq.state.az.us

Dottie Simons
Travel Reduction Program Coordinator
Arizona Department of Transportation,
Planning Division
206 S. 17th Ave. MD 075R
Phoenix, AZ 85007
dsimons@dot.state.az.us
(602)712-3130
www.dot.state.az.us

California

Lisa Kasper
Fleet ZIP Program Manager
California Air Resources Board
1001 "I" Street
P.O. Box 2815
Sacramento, CA 95812
lkasper@arb.ca.gov
(916) 327-2932
http://www.arb.ca.gov/homepage.htm

Irene Salazar
Efficient Vehicle Incentive Program
Manager
California Energy Commission
1516 Ninth Street, MS-29
Sacramento, CA 95814-5512
isalazar@energy.state.ca.us
(916) 657-4046
www.energy.ca.gov

Elizabeth Buddington
Account Representative
Commuter Check
5299 College Ave. Suite E
Oakland, CA 94618
ebuddington@commutercheck.com
(510) 601-1403
www.commutercheck.com

Colorado

Teresa Carrillo
Commercial Vehicle Operations Manager
Colorado Department of Transportation
4201 E Arkansas Ave., Room 277
Denver, CO 80222
teresa.carrillo@dot.state.co.us
(303) 757-9716
www.dot.state.co.us

Maryland

Nat Bottigheimer
Assistant Director, Office of Planning
Maryland Department of Transportation
7201 Corporate Center
Hanover, MD 21076
nbottigheimer@mdot.state.md.us
(410) 865-1285
www.mdot.state.md.us

Karen Saab
Customer Service Manager
Commuter Choice Maryland
7201 Corporate Center Drive
P.O. Box 548
Hanover, MD 21076
ksaab@mdot.state.md.us
(410) 865-1228
www.mdot.state.md.us/CommuterChoice/

New Jersey

Ellen Bourbon
Clean Cities Coordinator
New Jersey Clean Cities Coalition
44 S. Clinton Ave., 7th Floor
Trenton, NJ 08625
ellen.bourbon@bpu.state.nj.us
(609) 984-3058

New York

Patrick Bolton
Associate Project Manager, NYSERDA
17 Columbia Circle
Albany, NY 12203-6399
ppb@nyserda.org
(518) 862-1090
www.nyserda.org

Oregon

Christine Hagerbaumer
Program Director
Oregon Environmental Council
520 SW 6th Avenue, Suite 940
Portland, OR 97204-1535
chris@orcouncil.org
(503) 222-1963
http://www.orcouncil.org/

Pat Vernon
Manager
DEQ Employee Commute Options
Program,
2020 S.W. Fourth Ave., Suite 400
Portland, OR 97201-4987
vernon.pat@deq.state.or.us
(503)229-6480
www.deq.state.or.us

Pennsylvania

Karen Miller
Grant Officer
Pennsylvania Department of Environmental
Protection, Bureau of Air Quality
Rachel Carson State Office Building
12th Floor, P.O. Box 8468
Harrisburg, PA 17105-8468
karenmiller@state.pa.us
(717) 772-3359
www.dep.state.pa.us

Therese Langer
Transportation Program Director
American Council for an Energy-Efficient
Economy
1001 Connecticut Avenue NW, Suite 801
Washington, DC 20036
tlanger@aceee.org
(202) 429-8873
http://www.aceee.org/

Washington

Dave Dye

Administrator, Environmental Services
Washington Department of Transportation
310 Maple Park Avenue SE
Olympia, WA 98504-7323
dyed@wsdot.wa.gov
(206)464-1221
www.wsdot.wa.gov

Darwin Campbell
Acting General Manager
King County Metro Transit
201 S. Jackson St., KSC-TR-0415
Seattle, WA 98104-3856
darwin.campbell@metrokc.gov
(206) 684-1619
www.metrokc.gov

US Environmental Protection Agency
http://www.epa.gov/

Cynthia Stahl
Environmental Scientist
EPA Region III (3AP21)
1650 Arch St
Philadelphia, PA 19103
stahl.cynthia@epa.gov
(215) 814-2180

Alan Cimorelli
Lead Meteorologist
EPA Region III (3AP22)
1650 Arch St
Philadelphia, PA 19103
cimorelli.alan@epa.gov
(215) 814-2189

Alice Chow
EPA Region III (3AP22)
1650 Arch St
Philadelphia, PA 19103
chow.alice@epa.gov
(215) 814-2144

Ed Coe
Regulatory Impacts Analyst
EPA Office of Transportation & Air Quality
Ariel Rios Bldg (6406J)
1200 Pennsylvania Ave NW
Washington, DC 20460
coe.edmund@epamail.epa.gov
(202) 343-9629

Non-Governmental Organizations

Todd Litman
Director
Victoria Transportation Policy Institute
1250 Rudlin Street
Victoria, BC, V8V 3R7, Canada
litman@vtpi.org
(250) 360-1560
http://www.vtpi.org/

John M. DeCicco, Ph.D.
Senior Fellow, Automotive Strategies
Environmental Defense
815 Redeemer Avenue
Ann Arbor, MI 48103
jdecicco@environmentaldefense.org
(734) 827-9744
http://www.environmentaldefense.org/

Therese Langer
Transportation Program Director
American Council for an Energy-Efficient
Economy
1001 Connecticut Avenue NW, Suite 801
Washington, DC 20036
tlanger@aceee.org
(202) 429-8873
http://www.aceee.org/

X. Appendix

The Sparse Matrix Operator Kernel Emissions Software

In order to make SMOKE more flexible than other emission processors, the processes are broken down into steps. The independent steps include data structuring, temporal projection, chemical speciation, spatial allocation, and controls. The data structuring occurs in a process called SMKINVEN. SMOKE reads the emissions inventory provided and organizes the data to be merged with other steps. The temporal processor called TEMPORAL creates hourly pollutant emission output files from temporal profiles, temporal cross-reference files and the time zone of each source. The chemical speciation processor (SPECMAT) creates factors that are used to convert the emissions of inventory pollutants (i.e., CO, NO_x, VOC, etc.) to "model species" that are used in photochemical reactions. These factors are in the form of a matrix and are used by the air quality model. Spatial allocation or gridding (GRDMAT) is used to place inventory emissions into their correct grid cell in the domain. Control factors can be applied to an inventory through CNTLMAT. These steps can be merged together in a final stage of processing called SMKMRG. These tasks are performed for area, mobile and point sources of emissions (Houyoux 2002). Biogenic emission are processed though RAWBIO which structures their emissions accordingly and the temporalization is done in the program TMPBIO.

SMOKE uses the standard emissions cross-reference and profile approach to assign emssions to individual grid cells. Each county and source category code is indirectly assigned a profile number by using a cross-reference file. A given profile number or surrogate is used to find the appropriate temporal profile, speciation profile, or gridded profile that transform the raw data using factors from the profiles. This approach is used for area, biogenic, mobile and point emissions. Mobile and point sources use additional approaches to process data that is specific to that category (described below). The cross-reference and profile files are mainly created by data assimilated by the EPA (Houyoux 2002).

Category of Emissions in SMOKE

Area Source Processing

SMOKE converts aggregated annual or average daily pollutant emissions to hourly and gridded emissions of the chemical species used by an air quality model. The cross-reference and profile approach is used for temporalization, speciation and gridding.

Biogenic Source Processing

Biogenic source processing in SMOKE converts either gridded or county-aggregated land use data into gridded normalized biogenic emissions. This process uses the cross-reference and profile approach for temporalization, speciation and gridding. Biogenic processing is slightly different than other categories, because no anthropogenic activities are considered for modeling these emissions, and because the biogenic inventory pollutants are fixed in the system. All speciation profiles are limited to the four categories which biogenic emissions are grouped: monoterpenes, isoprene, nitrogen oxide and other VOCs (Houyoux 2002).

Mobile Source Emission Processing

For mobile source emissions, temporal allocation is partly dependent on temperature, which means temporal and spatial allocation for mobile sources are linked. However, in order for SMOKE to maintain its flexibility and processing speed, it needs to have source-based processing (one process cannot depend on another). Therefore, "ungridded" temperatures are used. The "ungridding" concept converts gridded temperatures to source-based temperatures. The "ungridded" temperatures are an average of "the temperatures in the grid cells intersecting each mobile source, weighted by the fraction of the source's surrogate fractions (for non-link sources) or length (for link sources) intersecting those grid cells" (Houyoux 2002).

SMOKE can simply use mobile source emission data imported into the system. The processing occurs exactly the same way as in the area processing (i.e., temporalization, speciation, and spatial allocation) (Houyoux 2002).

Point Source Emissions Processing

SMOKE point source emissions processing converts inventory pollutant data for point source stacks from annual, daily or hourly emissions to hourly gridded emissions of the chemical species for use in an air quality model. Point source emissions are three-dimensional and can rise high into the atmosphere. Therefore, the plume rise for these emissions needs to be modeled. There are two methods for calculating plume rise: layer fraction method and cutoff method. The air quality model, CMAQ requires layer fraction data. For this method, plume rise is calculated using meteorological data and then split evenly into layers. The fraction of emissions in each layer is stored in SMOKE (not the actual emissions). This fraction is later used when merging the output files (Houyoux 2002).

The Community Multiscale Air Quality Model

Initial and Boundary Conditions Processor (ICON and BCON)

ICON and BCON processors create the initial and boundary conditions for all model species concentrations. Essentially, this process defines a starting point for the simulation so the model can start from a specified concentration and not a blank domain. The ICON processor creates concentrations for every cell in the domain, whereas the BCON processor generates concentrations of model species for cells immediately surrounding the domain (US EPA 1999b).

CMAQ has the ability to use subset grids. That is, the initial grid may cover a larger domain than needed for analysis purposes, so a subset of that domain can be used. The subset will have a finer resolution. For example, in this case, a 36 km resolution grid was used. It covered states east of the Mississippi river. The analysis intent was just on the Northeastern region of the US, thus the subset grid has a resolution of 12 km and only covers the required area. Therefore the input to the ICON and BCON processors for the 12 km grid can originate from the 36 km grid. The default was used as the input to the ICON and BCON processors for the 36 km resolution grid.

Photolysis Rate Processor (JPROC)

The photolysis rate processor (JPROC) generates a table of photolysis or photodissociation[16] reaction rates at various altitudes, latitudes, and zenith angles. This processor simulates the chemical speciation that occurs when sunlight catalyzes the atmosphere into chemical reactions. By activating NO_2 and VOCs, the sun contributes to the production of ozone. Once activated these precursors begin chemical reactions that may result in the formation of ozone, depending upon the make-up of the atmosphere at that time. This processor assumes clear skies conditions and therefore sunlight is not impeded in anyway by cloud cover. The rates at which chemical species are activated are stored in a photolysis rate table and used in CCTM.

CMAQ Chemical Transport Model Processor (CCTM)

CMAQ Chemistry Transport Model simulates the atmospheric chemistry of air pollutants and estimates pollutant concentrations (i.e., ozone, particulate matter, and carbon monoxide). CCTM can either use Regional Acid Deposition Model (RADM) or carbon bond chemical mechanism (CB4) gas phase chemistry. A chemical mechanism is simply a collection of reactions that transform reactants into products. The RADM and CB4 chemical mechanism differ in the grouping of chemical species. The RADM chemical mechanism uses surrogate species to represent compounds in a similar class, whereas, CB4 chemical mechanism uses chemical bond type to group certain species together.

The CCTM processor simulates cloud coverage and integrates it with the photolysis rate table created by JPROC in order to model the photochemistry of air pollutants. CCTM also uses a plume-in-grid technique and an aerosol module. The plume-in-grid technique takes a simulated plume rise from a point source and simulates the relevant physical and chemical processes specifically for that plume before mixing those emissions with the entire gridded emissions. Plumes from power plant emissions are generally characterized as having VOC sensitive chemistry near the site and NOx sensitive chemistry as the plume is carried away from the source (Sillman 1999). Therefore it is important to have a plume simulation. The aerosol module simulates aerosol dynamics within the atmosphere including advection, horizontal and vertical diffusion. This module is important to model how air mixes and travels within the atmosphere.

CCTM produces a spatial field of air quality design values that can be analyzed and quality assured (US EPA 1999b). Specifically, it creates Environmental Indicators that can be used to compare scenarios in a decision making process. There are several technical components of the Indicator: a Design grid, an Indicator Design Area (IDA) Coverage, a Base File, a Blanking File and a Stressor Weighting Field. The design grid is a rectangular shape around the area that is to be analyzed (i.e. a rectangular shape around the state border of Delaware). The IDA Coverage is the geographical area to be analyzed (i.e. Delaware). The design grid is blanked out to expose only the Coverage using the Blanking File. The Base File is a geographical reference for the IDA Coverage. It houses all of the counties that comprise the IDA.

An Environmental Indicator is a quantifiable measure of the stressor over the entire IDA. It is formed from the combination of an Environmental Case and an Environmental

---

[16] Photodissociation is the conversion of solar radiation into chemical energy that activates and dissociates chemical species. Many chemical reactions with NO_2, O_3 and HCHO in the atmosphere are initiated through this process (Environmental Protection Agency 1999).

Measure. An Environmental Case includes the emissions inventory and meteorology. An Environmental Measure contains a pollutant (i.e. ozone), a Metric that 1- represents some stressor impact (i.e. maximum hour average ozone concentration (ppb)), an IDA coverage (i.e. Delaware), a Threshold (i.e. ozone values over 120 ppb), and a Weighting Field (i.e. population).

An Environmental Indicator is a stressor field that has been reduced to a certain IDA. The stressor field can be produced from either monitored air quality or by modeling pollutant emissions. Each point in the field has three values, two spatial coordinates (x, y) and the stressor value (a third orthogonal coordinate). The stressor field indicator is computed as the normalized volume of the third dimension.

Description of COMMUTER Model

The COMMUTER model was designed by EPA and Sierra Research to estimate travel impacts and emissions reductions of various employer based TDM strategies and transit improvements. COMMUTER uses a logit mode-choice model (known as the "pivot point" approach) to analyze the effects of multiple simultaneous programs. This is important, because the effects of simultaneous TDMs are not necessarily additive – some may be redundant, and some may have a synergistic relationship. A comprehensive description of the model is available in Carlson et al (2000).

COMMUTER calculates the change in VMT, number of trips, and emissions of NO_x, hydrocarbons (or VOCs), CO, and carbon dioxide (CO_2) relative to a baseline. The baseline is determined by the area population, vehicle fleet characteristics, and existing transportation mode shares (i.e. the percent of commuters that drive alone, carpool, use transit, etc.). Data specific to Delaware were not available for some of the parameters, and in these cases the model provides default data, which represent national averages. These averages were deemed by Wilmapco to be reasonable estimates of actual Delaware conditions (Dan Blevins, personal communication, 5/2/03). The variables that appear to have the greatest effect on the results are the number of affected workers and the existing mode shares, and these data are Delaware specific. A complete list of input data is shown in Table 9.1.

The total effected employed population in this for this scenario was 138,890. This estimate is based on 2008 employment projections from the Delaware Department of Labor, which we extended to 2010 (DE DOL 2001). The scenario targets large employers with 100 or more employees. In 1999, 66% of workers were employed by such large employers (Census Bureau 1999). We assumed that this remains constant through 2010. Of these employees, 62% worked in office jobs, which are assumed to be more flexible, and have higher participation rates in the TDM programs. For our scenario, large office employer participation in TDMs was assumed to be 50%, and large non-office employer participation was assumed to be 25%. Therefore, 106,311 office employees participate, and 32,579 non-office employees participate, for a total of 138,890 employees total (Table 9.2).

COMMUTER allows the user to select an inspection/maintenance type. The options are "basic", which is a simple "no-load" idle or 2500 RPM tailpipe emissions test and visual inspection, and "enhanced", which is a loaded IM240 or ASM emission test on a chassis dynamometer with a visual and functional emission control system inspection (Carlson et al 2000). Kent and New Castle Counties, which account for the large majority of vehicle registrations, use a "low-enhanced" I/M program, which is an intermediate of these two

programs (Phil Wheeler, DNREC, personal communication 6/18/2003). We therefore ran the model using both basic and enhanced options, and reported the mean of the results.

Table 9.1. Baseline Parameters for COMMUTER Model.

Variable Name	Value	Notes
Fleet Emission Information		
Calendar year of Analysis	2010	SMOKE/CMAQ model year
Season	Summer	Ozone Season
I/M type*	B/E	Delaware's current program
Fuel volatility type	C	Region 1, northern states
Fuel Control Program	RF	Reformulated gasoline
Employment in Analysis Area		
Office Employees Affected	106,311	Calculated from Census Bureau 1999 and DEDO 2002, Projected to 2010
Non-office Employees Affected	32,579	
Current Mode Shares		
Auto Drive Alone	79.2%	DelDOT 2002
Auto Carpool	11.0%	DelDOT 2002 (Estimated)**
Vanpool	0.5%	DelDOT 2002 (Estimated)**
Transit	2.8%	DelDOT 2002
Bicycle	0.5%	DelDOT 2002 (Estimated)**
Walk	2.5%	DelDOT 2002 (Estimated)**
Other	4.0%	DelDOT 2002
Avg. Work Trip Length (mi)		
Person-trip length	11.4	Default ***
Trip Length (vanpool)	17.7	Default
Trip length (bicycle)	1.8	Default
Trip length (walk)	1.0	Default
Vehicle Occupancy		
Average Carpool	2.2	Default
Average Vanpool	6.0	Default
Transit		
Average speed of transit (mi/h)	19.6	Default

Variable Name	Value	Notes
Peak Travel Characteristics		
% work trips in peak	61.4	Default
Length of peak (hrs)	3	Default (each way)
Peak vehicle speed (mph)	34.8	Default
Off-peak vehicle speed (mph)	39.7	Default
Coefficients		
In vehicle travel time (min)	-0.0241	Default
Out of vehicle travel time (min)		
Walk Time	-0.0472	Default (pop. 750,000-2 mil.)
Transit – Wait	-0.0468	Default (pop. 750,000-2 mil.)
Cost (cents)		
Auto – Parking	-0.0071	Default (pop. 750,000-2 mil.)
Transit – Fare	-0.0064	Default (pop. 750,000-2 mil.)
Cold Start %		
Baseline – Peak	48	Default
Baseline – Off Peak	40	Default
Eliminated trips – Peak	48	Default
Eliminated trips – off peak	40	Default
Vehicle fleet VMT mix by %		
Light Duty Gas Vehicles (Cars)	61.5	Default
Light Duty Gas Trucks 1	19.1	Default
Light Duty Gas Trucks 2	8.6	Default
Heavy Duty Gasoline Vehicles	3.1	Default
Light Duty Diesel Vehicles	0.1	Default
Light Duty Diesel Trucks	0.1	Default
Heavy Duty Diesel Vehicles	6.8	Default
Motorcycles	0.6	Default

* Delaware has a "low-enhanced" program, which is not available in the model. We ran "basic" and "enhanced" separately, and reported the mean result.
** Data for carpool and vanpool were aggregated (11.5% total), as were data for biking and walking (3% total). Disaggregated estimates for Delaware were based on national trends.
*** Commute time was available for Delaware, not length in miles. Therefore, default values were used.

Table 9.2. Derivation of Employee Participation.

Eligible Participants		Notes
DE employed population 2010	519,604	DE DOL 2001
% working for large employers (100+)	66%	Census Bureau 1999
% "Office" jobs (more flexible)	62%	estimate based on DE DOL 2001
Employer Participation (Office)	50%	assumption
Employer Participation (Non-Office)	25%	assumption
"Office" participants	*106,311*	calculated
"Non-Office" participants	*32,579*	calculated
Total participants	***138,890***	calculated