Agencies' Technical Report

Responding to

Jobs and Transportation Act (2009) Section 37, Part (7)
and Chapter 85 Oregon Laws (2010), Section 5

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Prepared for the:

Oregon Department of Transportation (ODOT);
Oregon Department of Environmental Quality (DEQ); and
Oregon Department of Energy (ODOE)

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A. Executive Summary

The Oregon Legislature in 2009, passed House Bill 2001 (Jobs and Transportation Act) and in 2010, passed Senate Bill 1059 (codified as Chapter 85 Oregon Laws), requiring the development of planning methods to reduce Greenhouse Gas (GHG) emissions from light motor vehicles within areas served by Metropolitan Planning Organizations (MPOs).

The Jobs and Transportation Act (2009) and Chapter 85 (2010) refers to Oregon Revised Statutes (ORS) 468A.205 that establishes statewide GHG emissions reduction goals of a 10 percent reduction in GHG emissions by 2020 from 1990 levels, and a 75 percent reduction in 2050 levels from the 1990 levels. Oregon Department of Transportation (ODOT), Department of Environmental Quality (DEQ), and Oregon Department of Energy (ODOE) are tasked with providing estimates of GHG reduction from metropolitan light motor vehicle transportation needed in 2035 to aid Oregon in the achievement of its year 2050 statewide GHG reduction goal.

This report fulfills the requirements codified in the Jobs and Transportation Act (2009), Section 37, Part (7); and Chapter 85 (2010), Section 5.

Metropolitan GHG reduction goals determined though Land Conservation and Development Commission (LCDC) rulemaking (as required in the legislation) will be expressed as per capita reductions allocated across all metropolitan areas in Oregon. This report provides estimates of the potential light motor vehicle GHG reductions needed for each of the six MPO regions.

Highlights of the results include the following:

- To achieve the statutory goal of a 75 percent reduction from 1990 GHG levels by 2050, it is estimated that overall GHG levels for 2035 would need to be reduced by 52 percent (or 75 percent on a per capita basis), in order to account for large population growth from 1990 onward.
- The average 1990 daily VMT per capita for all metropolitan areas is approximately 18 miles, resulting in 4.0 metric tons of carbon dioxide equivalents (CO_2e) per capita annually.
- In 2035, GHG emissions per capita from light motor vehicle transportation need to be reduced to an average of 1.03 metric tons of CO_2e per capita annually across all metropolitan areas.

B. Introduction

The Oregon Legislature passed House Bill 2001 (2009), and Senate Bill 1059 (2010), requiring the development of a Statewide Transportation Strategy (STS) for the reduction of transportation sector GHG emissions, and the development of planning methods to reduce GHG emissions from light motor vehicles for possible future application by local governments within areas served by Metropolitan Planning Organizations (MPOs). This legislation, codified as the Jobs and Transportation Act (2009) and Chapter 85 Oregon Laws (2010), imposes several requirements upon the Oregon Department of Transportation (ODOT), the Department of Land Conservation and Development (DLCD), the Department of Environmental Quality (DEQ), and the Oregon Department of Energy (ODOE), including:

- Developing the STS, for adoption by the Oregon Transportation Commission (OTC), to reduce GHG emissions from the transportation sector. The STS is led by ODOT and includes input from stakeholders, local governments, MPOs, and other state agencies;
- Developing guidelines for metropolitan area transportation scenario planning, led by ODOT and DLCD;
- Assembling a Toolkit to assist local governments and MPOs in defining strategies to reduce GHG emissions from the transportation sector, led by ODOT and DLCD;
- Providing information to the Land Conservation and Development Commission (LCDC) to aid them in setting GHG reduction targets for regions served by MPOs, led by ODOT, DEQ and ODOE; and
- Conducting public outreach and education on the importance of reducing GHG from transportation, led by ODOT and DLCD.

The Jobs and Transportation Act (2009) and Chapter 85 (2010) require that ODOT, DEQ, and ODOE prepare a report providing estimates of the light motor vehicle GHG reductions needed in each of the six MPO regions to reflect statewide GHG reduction goals.[1]

This report includes the following data as required in Chapter 85 (2010) Section 5, Paragraphs (a) through (f) (the language in these paragraphs from Chapter 85 (2010) is the same for the purposes of this report to the language in the Jobs and Transportation Act (2009), Section 37, Part (7), Paragraphs (a) through (f)). The data can be found in Tables 3 through 8 in Section F of this report:

- 1990 average light motor vehicle VMT by metropolitan area (paragraph (a));
- The rate at which new vehicles will replace existing light motor vehicles (paragraph (b));
- 1990 average light motor vehicle GHG emissions by metropolitan area(paragraph (c));

[1] Emissions resulting from freight and interregional travel will be addressed in subsequent efforts.

- 2035 average light motor vehicle GHG emissions by metropolitan area(paragraph (d));
- The percentage reduction in light motor vehicle emissions by 2035 needed to achieve 2050 statewide GHG goals (paragraph (e));
- The estimated light motor vehicle VMT by metropolitan area needed to meet the 2035 goal (paragraph (f)).

The report also identifies modeling tools and methods used to adjust recommended light motor vehicle VMT goals to account for congestion and congestion-reduction measures (paragraph (g)).

These data are intended to assist LCDC in fulfilling its statutory obligation to adopt year 2035 GHG emissions reduction targets for Oregon's six metropolitan areas by June 1, 2011. The adopted targets are intended to guide future land use and transportation scenario planning in metropolitan areas.

C. Background

In response to the legislative requirements described in the previous section, ODOT and DLCD organized and hosted several policy committees, technical committees and interagency workgroups. This work focuses on the statewide level and is supplemented through additional outreach to stakeholders, local governments, commissions, MPOs, other state agencies, and the public. Some of these groups are involved in developing the STS that focuses on identifying various long range transportation scenarios that reduce GHG emissions from transportation. The STS will be consistent with the GHG reduction goals established as part of this process. ODOT and DLCD have worked closely with Portland Metro to incorporate similar work required by the 2009 Jobs and Transportation Act.

This report focuses on fulfilling the requirements of Jobs and Transportation Act (2009), Section 37, Part (7), and Chapter 85 (2010), Section 5. Key data and assumptions used to develop the GHG emission estimates are categorized into 3 specific areas: (1) population growth estimates; (2) vehicle technology assumptions; and (3) vehicle fleet mix and fleet turnover assumptions. Many other technical and policy issues, including income, transportation system characteristics, and land use, are being examined as part of the STS process and considered by the Target Rulemaking Advisory Committee. However, these factors are not directly tied to the required data calculations and are not addressed in this report.

Over the past six months, these committees and workgroups have met regularly to develop, review, and provide direction on the assumptions, methodology, data, and analysis results that underlie this report. The committees and workgroups are summarized below.

- **Policy Committee (PC) –** The PC provides high-level oversight of the STS; and reviews modeling methodology, assumptions and policy implications, and makes recommendations. Membership includes representatives from OTC, ODOE, LCDC, the Environmental Quality Commission, advocacy groups, Metro Council, Union and Jackson Counties, Cities of Bend and Monmouth, Port of Portland, Portland State University, Associated Oregon Industries, Oregon Environmental Council, Oregon Trucking Associations, and AAA of Oregon.

- **Technical Advisory Committee (TAC) –** The TAC advises on alternatives to model for the STS and has consistently reviewed STS modeling results. Membership includes representatives from ODOT, DLCD, DEQ, ODOE, agencies and jurisdictions within the six MPO areas, Umatilla County, Astoria, Federal Highway Administration (FHWA), TriMet, South Metro Area Regional Transit, and the Bicycle and Pedestrian Advisory Committee.
- **Scenario Planning TAC –** The Scenario Planning TAC advises ODOT and DLCD in developing Scenario Planning Guidelines to assist local governments in planning to meet GHG emission reduction goals. Membership includes representatives from ODOT, DLCD, League of Oregon Cities, MPOs, Deschutes County, 1,000 Friends of Oregon, Business Oregon, Oregon Home Builders Association, Association of Oregon Counties, American Planning Association, TriMet, and Winterbrook Planning.
- **Target Rulemaking Advisory Committee (TRAC) –** The TRAC provides policy advice to LCDC in the development of targets for land use and transportation alternative planning to reduce GHG emissions from light motor vehicles in each metropolitan area. Membership includes representatives from LCDC, OTC, agencies and jurisdictions within the six MPO areas, the Metro council, Lane Transit District, environmental commissions and advocacy groups, a private-sector lobbyist, Portland State University, and the legislature.
- **Core Technical Team –** The Core Technical Team is responsible for the development of the technical aspects of the analysis required for this report and the eventual completion of the Statewide Transportation Strategy. This workgroup is composed of technical experts from ODOT, DEQ, ODOE, DLCD, and Metro, many of whom are charged with developing and supplying agency data and assumptions to be used in the development of the STS and this report.
- **GreenSTEP Peer Review Panels –** ODOT has developed the GreenSTEP model to estimate VMT and GHG emissions both statewide and within the various metropolitan areas in Oregon. GreenSTEP also provides estimates regarding the effectiveness of different combinations of policy options that might reduce VMT and GHG emissions. The Peer Review Panels have provided expert review in the development and use of the GreenSTEP model. The first panel consisted of representatives from affected state agencies, Metro, Port of Portland, Washington DOT, the Federal Highway Administration (FHWA), Sacramento Council of Governments, and the Mid-Willamette Council of Governments. A second panel consisted of experts from Portland State University; University of California – Davis; FHWA; and private transportation consultants from Oregon, Vermont, and Germany.

As work progresses, the advisory committees will continue to solicit public comments to inform and guide the discussions. Technical work groups consisting of agency staff and consultants have also held joint meetings to review and coordinate work products in order to produce the reports required by law.

In addition to the committee efforts, work has commenced on two related projects - the Scenario Planning Guidelines and the Transportation GHG Reduction Toolkit. The Scenario Planning Guidelines will serve as a "how to" guide, providing comprehensive instructions for local and metropolitan areas to conduct scenario planning with the aim of reducing transportation-related GHG emissions. The Transportation GHG Reduction Toolkit will be a database of policies and actions that local agencies can implement to reduce GHG emissions. The Toolkit will also describe a range of analysis tools that are available to assess the effectiveness of GHG emissions reduction actions, and to help track progress toward meeting state emissions reduction goals.

D. Key Issues and Considerations in Establishing GHG Emissions Reduction Goals

This section summarizes the salient issues that have been identified in fulfilling the requirements set forth in the Jobs and Transportation Act (2009), Section 37, Part (7), and Chapter 85 (2010), Section 5.

Estimating a 2035 Statewide GHG Reduction Goal

ORS 468A.205, referred to in the Jobs and Transportation Act (2009) and Chapter 85 (2010) establishes two statewide GHG emissions reduction goals from 1990 levels for all economic sectors: a 10 percent reduction by 2020, and a 75 percent reduction by 2050. Agencies are tasked with estimating an intermediate goal for statewide GHG reduction from light motor vehicle transportation for 2035 that will allow for the achievement of the 2050 statewide goal.

Chapter 85 (2010) suggests no method for establishing the 2035 goal for GHG reduction and the Jobs and Transportation Act (2009) suggests an initial 2035 goal halfway between the 2020 and 2050 goals. State agencies examined various ways to establish the 2035 goal and have ultimately recommended a method that assumes an equal percentage reduction per year from 2010 to 2050. This approach results in a 52 percent GHG reduction goal by 2035. Additional information related to the process used to determine this goal is provided in Appendix A.

Similarly, the Legislature did not assign sector-by-sector responsibilities for GHG reduction, and the reduction capabilities of non-transportation sectors are not known at this time. State agency staff have proposed that preliminary transportation sector goals mirror the overall statutory goals for GHG reduction described in this section.

Estimating Reductions to be Met by Light Motor Vehicles Versus Other Transportation Modes

Only light motor vehicle transportation within areas served by MPOs is addressed in this report. However, in addition to light motor vehicles (under 10,000 lbs GVWR[2]), the transportation sector is comprised of heavy vehicles such as trucks, and other non-road transportation modes such as rail, air, and sea travel. As in the estimation of sector-wide GHG emissions, insufficient data exists to determine the precise share of overall GHG reduction efforts that is required of individual transportation modes. Therefore, state agencies assume light motor vehicle emissions reduction goals follow the same trajectory as overall statewide goals: 10 percent reduction by 2020, 52 percent reduction by 2035, and 75 percent reduction by 2050.

[2] Gross vehicle weight rating.

Estimating GHG Emission Reductions for Metropolitan Areas and Other Areas

The Jobs and Transportation Act (2009) and Chapter 85 (2010) only require assessing light motor vehicle transportation within metropolitan areas. Using GreenSTEP, various unique combinations of statewide and metropolitan area policies and strategies will be assembled, modeled, and assessed according to an evaluation framework developed with input from the STS advisory committees. This process is best suited to meet the goal of achieving statewide light motor vehicle reduction goals while ensuring that the plans, policies, and actions selected to meet reduction goals are plausible.

Once a set of alternatives are identified, the GreenSTEP model has the capability to determine the amount of light motor vehicle GHG emissions reduced in metropolitan areas, and the proportional changes in GHG reduction over time. Final goals for the share of light motor vehicle reduction efforts by metropolitan and non-metropolitan area will be developed as part of the STS subsequent to this Agencies' Technical Report.

Equitably Allocating Reductions across Metropolitan Areas

Oregon encompasses a diversity of regions, each with unique land use distributions, populations, and future growth potential. No two metropolitan areas are likely to have the same potential for GHG emissions reduction, and distributing estimated reductions equitably across metropolitan areas is critical to achieving the statewide objectives of the Jobs and Transportation Act (2009) and Chapter 85 (2010). To do this, the metropolitan GHG reduction goal will be expressed as per capita reductions allocated across metropolitan areas. This allows metropolitan areas to account for population growth while meeting the absolute goal of a 75 percent reduction by 2050. Due to large growth in population since 1990, per capita reduction percentages will necessarily be higher than absolute percentages of tons reduced.

Data Limitations and Related Assumptions

The estimates in this report utilize the best available data for 1990, with some data such as VMT extrapolated backwards from more recent data where 1990 data was not available. The estimates also assume the continuation of average growth trends for population. These trends estimate that the State's 2050 population will be almost 6 million.

Travel Outside of Metropolitan Areas

Travel outside of MPO areas will be addressed in the STS, and not in this Technical Report. The Jobs and Transportation Act (2009) and Chapter 85 (2010) require LCDC to adopt rules identifying a reduction goal for GHG from light motor vehicles for each region served by a MPO.

In order for LCDC to adopt these rules, ODOT, DEQ, and ODOE must provide estimates of the VMT within the boundaries of each MPO in 1990 by light motor vehicles. This includes the portion of light motor vehicle travel that originates, terminates or passes through each MPO area. These estimates utilize the best available data records and GreenSTEP model calculations. ODOT, DEQ, and ODOE have collaborated on the development of the model to estimate the light motor vehicle VMT that may be accommodated in 2035 within the boundaries of each MPO in order to meet the GHG reduction goals set forth in ORS 468A.205.

The Jobs and Transportation Act (2009) and Chapter 85 (2010) do not require rulemaking for travel that is totally outside the boundaries of MPOs. However, travel outside of MPO areas is recognized as a significant contributor to GHG emissions.[3] The Statewide Transportation Strategy, scheduled for adoption in 2012, will address such travel.

E. Agencies' Technical Report Assumptions

While there are numerous inputs considered in developing VMT and GHG estimates for the Agencies' Technical Report, the three major factors driving the technical analyses are:

1. Population growth;
2. Vehicle technology; and
3. Fleet mix and fleet turnover.

Since multiple alternatives are identified for vehicle technology, fleet mix and fleet turnover, a low, medium, and high alternative were defined to represent the range of potential outcomes for the combinations.

Population Growth

Role in Analysis – The population and population growth of the metropolitan areas in Oregon play a significant role in VMT growth and increases in GHG emissions. Both the population and the population age group forecasts are critical GreenSTEP inputs.

Statement of the Assumption – GreenSTEP assumes continued population growth in the state's urban regions from 1.6 million in 1990 to over 3.7 million by 2050. Persons 65 years and older are projected to be the largest cohort.

Alternative Outcome – The most likely alternative outcome is that growth in population will be lower than anticipated, leading to lower than estimated levels of total VMT and GHG. However, per capita estimates are unlikely to change significantly.

Sources – The Office of Economic Analysis of the Department of Administrative Services for counties outside of the Portland metropolitan area and the Metro Research Center for counties in the Portland metropolitan area (Clackamas, Multnomah, Washington) were the sources for population projections in GreenSTEP.

Additional information supporting the alternative outcome that growth in population will be less than previous estimates can be found in *The Case for Moderate Growth in Vehicle Miles of Travel: A Critical Juncture in U.S. Travel Behavior Trends* (US Department of Transportation, 2006).

Vehicle Technology

Role in the Analysis – Vehicle technology, including the average fuel economy of vehicles, the efficiency of electric vehicles, and the carbon content of fuel, is a major determinant of GHG

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[3] See *Background Report: The Status of Oregon Greenhouse Gas Emissions and Analysis*, ODOT Transportation Planning Analysis Unit, October 2009, Section 2, Magnitudes of Transportation Emissions.

emissions per mile of travel. The primary questions regarding vehicle technology are the pace at which changes occur over time, and the potential types and ranges of vehicle technologies. The GreenSTEP analysis included four levels of technology adoption that are described in detail in Appendix D.

Statement of the Assumption – The four levels of technological improvement are displayed in Table 1 below. All of the alternatives assume a significant improvement in fuel efficiency for traditional internal combustion engine autos and light trucks.

Table 1. Vehicle Technology Alternatives by 2035

Characteristic	Technology Level			
	1	2	3	4
Auto Fuel Economy – Internal Combustion Engine (MPG)	60	64	68	68
Light Truck Fuel Economy – Internal Combustion Engine (MPG)	41	46	48	48
Auto Plug-In Hybrids Fuel Economy(MPG)	75	81	81	81
Light Truck Plug-in Hybrids Fuel Economy (MPG)	52	56	56	56
Percent of Autos Which are Plug-In Hybrids or Electric Vehicles	8	8	8	56
Percent of Light Trucks Which are Plug-In Hybrids or Electric Vehicles	2	2	2	16
Carbon Content of Fuels (Percentage Improvement from Current Levels by 2035)	10	20	20	20
Electrical Power Sources Meet or Exceed Current Renewable Portfolio Standard	Meet	Meet	Meet	Exceed

Alternative Outcomes – As this analysis includes a range of potential outcomes, no alternative has been defined.

Sources – *Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2017-2025*, Office of Transportation and Air Quality, US Environmental Protection Agency; Office of International Policy, Fuel Economy, and Consumer Programs, National Highway Traffic Safety Administration, US Department of Transportation; California Air Resourced Board; and California Environmental Protection Agency, September 2010. http://www.epa.gov/oms/climate/regulations/ldv-ghg-tar.pdf.

Plotkin, Steve & Margaret Singh, *Multi-Path Transportation Futures Study: Vehicle Characterization and Scenario Analysis,* Energy Systems Division, Argonne National Laboratory ANL/ESD/09-5, July 2009.

Fleet Mix and Fleet Turnover

Role in the Analysis – Fleet mix refers to the percentage of vehicles classified as automobiles compared to light trucks. This distinction is important given significant differences in auto and light truck fuel economy. This is particularly relevant in Oregon given the relatively high percentage of vehicles classified as light trucks.

Fleet turnover refers to the rate of vehicle replacement or the turnover of older vehicles to newer vehicles. Since newer vehicles are typically more fuel efficient than older vehicles, newer fleets will yield greater GHG reductions. The analysis assumes three potential levels of fleet mix and fleet turnover.

Statement of the Assumption – Table 2 presents the potential alternatives for the fleet mix in 2035, with information for 1990 (projected) and 2005 (data-based) presented for reference. Under the Level 1 alternative, mix of autos to light trucks remains the same as currently observed. The Level 2 alternative assumes that the percentage of trucks drops by approximately 1/6 from current levels, while Level 3 assumes the truck percentage drops by 1/3. Under the Level 1 alternative, the average age of vehicles remains at current levels (10 years) while Level 2 and Level 3 see a reduction in average vehicle age mirroring those currently found in the Northeastern United States.

Table 2. Light Trucks as a Percentage of Overall Fleet Mix

Characteristic	1990	2005	Percentage of Fleet Which Are Light Trucks for 2035 by:		
			Level 1	Level 2	Level 3
Bend	37%	55%	56%	46%	36%
Corvallis	31%	45%	46%	38%	30%
Eugene-Springfield	32%	47%	48%	40%	31%
Metro	30%	43%	44%	36%	29%
Rogue Valley	35%	50%	52%	42%	34%
Salem-Keizer	33%	47%	49%	41%	31%
Average Vehicle Age (years)	10	10	10	8	8

Alternative Outcome – As this analysis includes a range of potential outcomes, no alternative outcome has been defined.

Source – ODOT Analysis of Vehicles Registered in Oregon.

Combination of Vehicle Technology and Fleet Mix/Turnover

Since multiple levels of vehicle technology and fleet mix/turnover are identified as potential analysis alternatives, a combined range of low, medium, and high outcomes are presented to better facilitate review of the results. The low, medium, and high alternatives are defined as follows:

- **Low –** Vehicle technology Level 1, Fleet mix/turnover Level 1;
- **Medium –** Vehicle technology Level 3, Fleet mix/turnover Level 1; and
- **High –** Vehicle technology Level 4, Fleet mix/turnover Level 3.

The medium alternative was devised to produce emission reductions that were approximately halfway between the high and low estimates based on the analytical work detailed below.

F. GHG Emission Reduction Technical Information

This section presents VMT and GHG estimates related to light motor vehicle travel within the six MPOs in Oregon. The VMT and GHG estimates were estimated by ODOT using the GreenSTEP model. This information is presented for use by the LCDC in considering GHG emissions reduction goals for each MPO in Oregon.

Pursuant to the statutory requirements, metropolitan area GHG reduction targets will address only those GHG emissions that result from light motor vehicle travel within metropolitan area boundaries.[4]

Table 3 provides the total and per capita estimates of VMT for each MPO region for 1990. The majority of the VMT in 1990 occurred within the Portland metropolitan area with significant contributions from the MPO for the Eugene-Springfield region, the Salem-Keizer MPO, and the Rogue Valley MPO. The Bend and Corvallis Area MPOs had limited VMT as compared to the other MPOs. Per capita VMT for all of the MPOs are similar with the exception of the Corvallis Area MPO. This is likely the result of several factors including the attraction of many Corvallis household trips to Albany, Salem and Eugene, a large student population relative to the metropolitan area population, no interstate highway running through the metropolitan area, and a small metropolitan area.

Table 3. 1990 VMT by MPO Region
As Required by Chapter 85, Section 5, Paragraph (a)

MPO Region	Population	Average Daily VMT	Daily VMT Per Capita
Bend	37,800	725,898	19.2
Corvallis	52,700	626,182	11.9
Eugene-Springfield	197,500	3,203,161	16.2
Metro	1,062,000	20,262,310	19.1
Rogue Valley	105,000	1,989,642	18.9
Salem-Keizer	166,500	2,869,480	17.2
Total for metropolitan areas	1,621,500	29,676,673	18.3

Table 4 provides an estimate of the rate at which new vehicles will replace existing vehicles for each MPO region. The low replacement rate is assumed to be constant for all MPOs at ten years,

[4] Travel within metropolitan area boundaries represents approximately 55 percent of total statewide travel.

which is consistent with the current replacement rate observed statewide. Medium and high levels of technology and fleet mix alternatives assume an average of eight years for vehicle replacement. Please see the section on Fleet Mix and Fleet Turnover Assumptions for further information.

Table 4. Rate of Vehicle Replacement for Low, Medium, and High Technology/ Fleet Mix Alternatives
As Required by Chapter 85, Section 5, Paragraph (b)

All regions	Low – 10 Years to Replace Vehicle
	Medium – 8 Years to Replace Vehicle
	High – 8 Years to Replace Vehicle

Table 5 provides 1990 GHG emissions estimates for the MPO regions resulting from light motor vehicle travel. Based on the existing vehicle replacement cycle GHG emissions follow the same trend as the VMT estimates identified in Table 3.

Table 5. 1990 GHG Emissions by Region
As Required by Chapter 85, Section 5, Paragraph (c)

MPO Region	Population	GHG Emissions (Metric Tons of CO_2e Per Day)	Annual GHG Emissions Per Capita (metric tons CO_2e)
Bend	37,800	428	4.1
Corvallis	52,700	366	2.5
Eugene-Springfield	197,500	1,898	3.5
Metro	1,062,000	12,259	4.2
Rogue Valley	105,000	1,181	4.1
Salem-Keizer	166,500	1,712	3.8
Totals for metropolitan areas	1,621,500	17,844	4.0

Table 6 documents the estimated emission factors (grams per CO_2e per mile) produced within each MPO region at the low, medium, and high level of vehicle technology and fleet mix/turnover. As indicated in this table, vehicles are anticipated to produce fewer emissions in 2035, as compared to 1990.

Once these emission rates are identified, it is important to determine whether changes in emission rates alone can yield the desired reduction in regional GHG. This determination requires several additional calculations beyond those already identified.

The averages in the last column of Table 6 were computed as the arithmetic means of all 12 of the technology and fleet combinations. These average values should not be interpreted as the most likely values. What actually occurs will depend on policy decisions made at the federal, regional (e.g. Western Climate Initiative), state and local levels, along with a number of other factors such as fuel prices and scarcity, the pace of technological improvements, and changes in consumer preferences.

Table 6. 2035 Emission Rates by Region with Implementation of Vehicle Technology and Fleet Mix Alternatives
As required by Chapter 85, Section 5, Paragraph (d)

MPO Region	1990 Emission Rates (grams CO_2e per mile)	2035 Emission Rates (grams CO_2e per mile)			
		Low Technology/Mix Alternative	Medium Technology/ Fleet Mix Alternative	High Technology/ Fleet Mix Alternative	*Average of Technology/ Fleet Mix Alternatives
Bend	590	251	213	170	196
Corvallis	585	240	204	170	190
Eugene-Springfield	592	242	205	149	185
Metro	605	252	214	176	199
Rogue Valley	594	250	213	177	198
Salem-Keizer	596	244	207	170	193
Population-Weighted Average	601	250	212	173	197

*Figures represent the computed average of all technology and fleet combinations, which should not be interpreted as the most likely values. What actually occurs will depend on policy decisions.

For 2035, a 52 percent reduction goal was established for total GHG emissions. This goal equates to a per capita GHG reduction goal of 75 percent by 2035. The process used to estimate the per capita reductions for 2035 is described in Appendix A.

The per capita GHG emissions reduction values associated with the 2035 goal are provided in Table 7. This table also presents the 2035 emissions per capita that would occur under the low, medium, and high technology and fleet mix alternatives. As shown in Table 7, the per capita reduction in GHG emissions resulting from implementing vehicular technology improvements is insufficient alone to meet the 2035 per capita reduction goal. If the values for all six of the metropolitan areas are averaged, an additional 12 percent in per capita GHG emissions would be needed to meet the 2035 reduction goal. Under the average technology and fleet mix alternative, an additional 23 percent per capita GHG emissions reduction is needed to meet the 2035 goal.

The averages in the last row of Table 7 based on the arithmetic means of all 12 of the technology and fleet combinations, should not be interpreted as the most likely values. Actual results will depend on policy decisions made at the federal, regional (e.g. Western Climate Initiative), state and local levels, along with a number of other factors such as fuel prices and scarcity, the pace of technological improvements, and changes in consumer preferences.

Table 7. 2035 Emission Reductions Needed by Metropolitan Region Needed to Reach GHG Reduction Goal
As required by Chapter 85, Section 5, Paragraph (e)

		Bend	Corvallis	Eugene-Springfield	Metro	Rogue Valley	Salem-Keizer	Weighted Average of Metropolitan Areas
1990 GHG Emission Per Capita		4.1	2.5	3.5	4.2	4.1	3.8	4.0
GHG Emissions Per Capita to Meet 2035 Goal		1.09	0.72	0.86	1.06	1.10	0.96	1.03
% Reduction in Per Capita GHG Emissions from 1990 Level		74%	72%	75%	75%	73%	74%	74%
Low Alternative	Emissions Per Capita	1.75	1.04	1.43	1.75	1.72	1.53	1.68
	% Additional Reduction to Reach 2035 Goal	38%	31%	40%	39%	36%	37%	39%
Medium Alternative	Emissions Per Capita	1.49	0.88	1.21	1.49	1.40	1.29	1.42
	% Additional Reduction to Reach 2035 Goal	27%	18%	29%	29%	21%	26%	28%
High Alternative	Emissions Per Capita	1.19	0.74	0.88	1.23	1.21	1.07	1.17
	% Additional Reduction to Reach 2035 Goal	8%	3%	2%	14%	9%	10%	12%
Average Technology Alternative	Emissions Per Capita	1.37	0.82	1.09	1.39	1.37	1.21	1.33
	% Additional Reduction to Reach 2035 Goal	16%	14%	27%	31%	24%	26%	23%

Table 8 shows the estimated VMT by region that could be accommodated while meeting the reduction goals identified in Table 7. These VMT data are illustrative, and VMT goals are not required to be set by statute. The tabular results indicate that vehicle technology alone would be insufficient to meet the 2035 GHG reduction goal—regional VMT per capita would also need to be reduced by 2 percent to 40 percent. The STS planning process, now underway, is identifying the range of potential measures available to achieve these reductions, possibly including transportation pricing, balanced transit and highway investments, strategies to encourage walking and bicycling, and land use policies.

The averages in the last column of Table 8 were computed by dividing the GHG emissions per capita in the second row of Table 7 by the average emissions per mile figures in the last column of Table 6, following conversion of the Table 6 values to tons per mile. As in Table 6, these average values should not be interpreted as the most likely values. Actual results will depend on policy decisions made at the federal, regional (e.g. Western Climate Initiative), state and local levels, along with a number of other factors such as fuel prices and scarcity, the pace of technological improvements, and changes in consumer preferences.

Table 8. VMT Per Capita that can be Accommodated by MPO Region to Meet 2035 GHG Goal
As Required by Chapter 85, Section 5, Paragraph (f)

		2035 Accommodated VMT per Capita			
MPO Region	**1990 VMT**	**Low Technology/ Fleet Mix Alternative**	**Medium Technology/ Fleet Mix Alternative**	**High Technology/ Fleet Mix Alternative**	***Average Technology/ Fleet Mix Alternative**
Bend	19.2	11.8	13.9	17.5	15.2
Corvallis	11.9	8.2	9.7	11.6	10.4
Eugene-Springfield	16.2	9.7	11.5	15.8	12.7
Metro	19.1	11.5	13.5	16.5	14.6
Rogue Valley	18.9	12.1	14.2	17.1	15.2
Salem-Keizer	17.2	10.7	12.6	15.4	13.6
Population-Weighted Average	18.3	11.2	13.2	16.3	14.3

*Figures represent the computed average of all technology and fleet combinations, which should not be interpreted as the most likely values. What actually occurs will depend on policy decisions.

The Jobs and Transportation Act (2009), Section 37, Part (7), Paragraph (g) and Chapter 85 (2010), Section 5, Paragraph (g) require DEQ and ODOE to recommend to LCDC modeling tools or other methods that each region served by a Metropolitan Planning Organization (MPO) may use to adjust its recommended number of miles of travel to account for additional greenhouse gas emissions resulting from increased traffic congestion or reductions in emissions resulting from measures that reduce traffic congestion. This report considers the impact of traffic congestion on vehicle fuel economy and GHG emission. Slow traffic from traffic congestion leads to inefficient operations for internal combustion engines and may lead to less efficient routing as vehicles attempt to avoid congested areas. The GreenSTEP model accounts for some congestion effects on GHG emissions by predicting the proportion of travel on congested and uncongested roadways in a given area. However, since GreenSTEP directly predicts daily VMT and does not contain a roadway network, the model cannot directly consider the effects of trip rerouting or bottlenecks. In addition, while GreenSTEP can model the impacts of additional lane miles of freeways and arterials (which will reduce the proportion of congested travel), it is not sensitive to small-scale congestion relief projects like bottleneck removals, nor is it sensitive to non-capacity congestion relief projects like traffic signal coordination, high occupancy vehicle lane conversions, or ramp meters.

There are several options that MPOs could use to adjust VMT or GHG emissions estimates to better account for congestion impacts and congestion relief projects. The most promising options are listed below:

- MPOs could use traditional four-step travel demand models to obtain a more accurate distribution of VMT by speed and by different facility class. In this case, the MPO model would be run with land use information that is as close to the GreenSTEP input data as possible to develop a VMT-speed profile for the region. The GreenSTEP VMT estimate would then be allocated based on the proportion of speed and facility type predicted by the four-step model. Some congestion relief projects such as HOV lane conversions and bottleneck removal projects could also be evaluated using this technique.
- This technique could be enhanced if MPOs adopted more advanced travel models that included features such as smart-growth trip generation adjustments, travel demand management adjustments, and dynamic traffic assignment. In addition, the performance of GreenSTEP could be enhanced to include sensitivity to congestion on VMT generation via a feedback loop from the four-step model output.
- If VMT-speed output was generated by a four-step model, the GHG emissions estimate could be further enhanced using the EPA MOVES air quality model. While MOVES output is used for GreenSTEP's internal GHG emissions calculation, the more refined VMT/speed data from the four-step model will better account for the effects of congestion and congestion relief projects. Improved analysis techniques or models will also need to account for other factors including expected changes in vehicle technology that will reduce emissions from idling and low speed operation and the potential for reductions in congestion to result in increases in vehicle travel.

For a description of GreenSTEP model, see Appendix B. Appendix C provides GreenSTEP calibration and validation information. Portland State University has documented several potential adjustments that could be made to GreenSTEP to increase its sensitivity to congestion relief projects. These adjustments involve adding sensitivity to the fuel consumption/speed curves, lane mile capacity, average speed estimates, and VMT generation estimates, to better account for projects like ramp meters, HOV lanes, variable speed limits, and transit priority.

Appendix A. 1990 and 2035 Estimates and Projections of Metropolitan Area Light Vehicle GHG Emissions

SB 1059 and HB 2001 require the Department of Transportation (ODOT), Department of Environmental Quality (DEQ), and Department of Energy (ODOE) to provide information to "provide the Land Conservation and Development Commission with the information or projections necessary to determine the proposed greenhouse gas emissions reduction target for 2035."[5] This information must be provided to the Land Conservation and Development Commission (LCDC) by March 1, 2011.

SB 1059 and HB 2001 describe in detail what information is to be provided by ODOT, DEQ and ODOE. The two laws are nearly the same but not identical in their wording with respect to these requirements, which are listed below. Language that is unique to SB 1059 is enclosed in square brackets while language unique to HB 2001 is enclosed in curly brackets.

> *(a) The Department of Transportation shall provide the Department of Environmental Quality and the State Department of Energy with an estimate of the vehicle miles traveled [within the boundaries of each metropolitan planning organization] {in the metropolitan service district} in 1990 by motor vehicles with a gross vehicle weight rating of 10,000 pounds or less, based on available records.*
>
> *(b) The Department of Transportation shall provide the Department of Environmental Quality and the State Department of Energy with an estimate of the rate at which new vehicles will replace existing vehicles among the vehicles described in paragraph (a) of this subsection.*
>
> *(c) The Department of Environmental Quality and the State Department of Energy shall estimate the greenhouse gas emissions for 1990 for each [region served by a metropolitan planning organization] {metropolitan service district} resulting from the travel by motor vehicles described in paragraph (a) of this subsection, using available records of the average emissions per mile emitted by the motor vehicles in 1990 and the estimates provided by the Department of Transportation under paragraph (a) of this subsection.*
>
> *(d) The Department of Environmental Quality and the State Department of Energy shall estimate the average greenhouse gas emissions in 2035 emitted by motor vehicles described in paragraph (a) of this subsection[. The estimate must take into account the motor vehicles that the Department of Transportation predicts will have replaced existing vehicles as described in paragraph (b) of this subsection. The estimate must be based on available reasonable data provided by public or private entities concerning the improvements in vehicle technologies that will be available for use by 2035.]*

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[5] Subsection (1) or SECTION 5 establishes the requirement in SB 1059 while Subsection (6) of SECTION 37 establishes the requirement in HB 2001. The language is almost, but not quite identical. SB 1059 speaks about a "greenhouse gas emissions reduction target" while HB 2001 speaks to "greenhouse gas reduction goals".

{predicted to comprise the motor vehicles on the highways in 2035 based on the predicted rate of replacement of the vehicles as described in paragraph (b) of this subsection and based on available reasonable estimates provided by public or private entities of the improvements in vehicle technologies that will be available for use by 2035.}

(e) The Department of Environmental Quality and the State Department of Energy shall recommend to the Land Conservation and Development Commission a percentage by which the emissions from motor vehicles described in paragraph (a) of this subsection [need to be reduced below their 1990 emission levels by 2035 in order to achieve the reduction in emissions from vehicles necessary to achieve the total greenhouse gas emissions reduction goals set for 2050 by ORS 468A.205.] {should be reduced below their 1990 emission levels by 2035 in order to achieve a reduction in emissions from the vehicles as part of the overall achievement of total carbon reduction set for 2050 by ORS 468A.205 and shall explain their reasons for any recommendations other than the midpoint between the 2020 and the 2050 emission reduction targets established by ORS 468A.205.}

(f) The Department of Environmental Quality and the State Department of Energy shall calculate the estimated miles of travel by motor vehicles described in paragraph (a) of this subsection that may be accommodated in 2035 [by each region served by a metropolitan planning organization] {in each metropolitan service district} based on the estimates performed under paragraphs (a) to (d) of this subsection and the recommendation required by paragraph (e) of this subsection.

(g) The Department of Transportation, Department of Environmental Quality and the State Department of Energy shall recommend to the Land Conservation and Development Commission modeling tools or other methods [that each region may use to] {by which a metropolitan service district may} adjust [its] {the district's} recommended number of miles of travel as described in paragraph (f) of this subsection, to account for additional greenhouse gas emissions resulting from increased traffic congestion or reductions in emissions resulting from measures that reduce traffic congestion.

(h) On or before March 1, 2011, the Department of Transportation, the Department of Environmental Quality and the Department of Energy shall submit the information required by paragraphs (a) to (g) of this subsection to the Land Conservation and Development Commission, including but not limited to citations to sources relied on and calculations made.

The remainder of this appendix is organized in the order of these requirements.

Estimating Vehicle Miles Traveled (VMT) in Metropolitan Areas

ODOT is required to provide an estimate of the vehicle miles traveled by vehicles weighing less than 10,000 pounds (light vehicles) within the boundaries of each metropolitan planning organization and metropolitan service district (Metro). For the purposes of this report, the area within the boundaries of a metropolitan planning organization (or metropolitan service district) is referred to as the metropolitan area. The specific requirement is as follows:

(a) The Department of Transportation shall provide the Department of Environmental Quality and the State Department of Energy with an estimate of the vehicle miles traveled [within the boundaries of each metropolitan planning organization] {in the metropolitan service district} in 1990 by motor vehicles with a gross vehicle weight rating of 10,000 pounds or less, based on available records.

The estimate of 1990 light vehicle travel was made using the GreenSTEP model. GreenSTEP was developed by ODOT for the specific purpose of estimating and forecasting the effects of various policies other influences on the amount of vehicle travel, the types of vehicles and fuels used, and the resulting greenhouse gas emissions. Since statuatory greenhouse gas emission goals are stated as changes relative to 1990 estimates and since a valid analysis of changes requires the use of a consistent methodology for the time periods being compared, the GreenSTEP model was used both for estimating light vehicle VMT and emissions in 1990 and for forecasting VMT and emissions in the future. The calibrated and validated GreenSTEP model produces reasonable estimates of light vehicle VMT and fuel consumed. Appendix B describes the structure of the GreenSTEP model. Appendix C describes the calibration and validation of the GreenSTEP model.

Light vehicle VMT was estimated for metropolitan areas by providing as inputs to GreenSTEP the metropolitan area population and income characteristics estimated for 1990 as well as all of the other model inputs (e.g. per capita income, gas prices) that affect VMT and the calculation of VMT. Based on those inputs, the GreenSTEP model estimates the average daily VMT of households in all parts of the state. The household VMT of households located in each metropolitan area is summed to produce household VMT totals by metropolitan area. Since the metropolitan area GHG target requirements are for light vehicle travel on metropolitan area roads, calibrated factors are applied to calculate metropolitan area road light vehicle VMT from metropolitan area household light vehicle VMT. Appendix C describes the derivation of these factors. Table A.1 contains the resulting estimates of light vehicle VMT on metropolitan area roads in 1990 as required by (a) above.

Table A.1 Estimates of Light Vehicle VMT on Metropolitan Area Roads in 1990

Metropolitan Area	Population	Average Daily Vehicle Miles Traveled (DVMT)	Average DVMT per Person
Bend	37,800	725,900	19.2
Corvallis	52,700	626,200	11.9
Eugene-Springfield	197,500	3,203,200	16.2
Metro	1,062,000	20,262,300	19.1
Rogue Valley	105,000	1,989,600	18.9
Salem-Keizer	166,500	2,869,500	17.2

It should be noted that the per capita values in Table A.1, do not represent the average amount of travel of persons living in each metropolitan area. The averages are simply the ratio of metropolitan area road light vehicle daily vehicle miles traveled (DVMT) to metropolitan area population. Some of the light vehicle VMT of metropolitan area households occurs outside of the metropolitan area boundary. Likewise, some light vehicle VMT on metropolitan area roadways is from travel of people who reside outside of the metropolitan area. Furthermore, some light vehicle VMT on metropolitan roadways is for business purposes.

The metropolitan area ratios shown in Table A.1 vary as a result of differences in how much travel is on metropolitan area roads from metropolitan area households, non-metropolitan area households, and business travel, in addition to differences in the travel patterns of households living in the metropolitan area. Of particular note is the relatively low ratio for the Corvallis metropolitan area. This is likely the result of several factors including the attraction of many Corvallis household trips to Albany, Salem and Eugene, a large student population relative to the metropolitan area population, no interstate highway running through the metropolitan area, and a small metropolitan area.[6]

Estimating the Vehicle Replacement Rate

The Department of Transportation is required to provide an estimate of the rate at which new light vehicles will replace existing light vehicles in the vehicle fleet. This is an important consideration because it affects the rate at which new technology gets incorporated into the vehicle fleet. The specific requirement is a follows:

[6] In 2005, the cities of Corvallis, Philomath and Adair Village which make up the large majority of the Corvallis MPO area had a combined population of 58,470. The city of Albany, located about 10 miles from Corvallis had a population of 45,360. Corvallis is about 35 miles from Salem and about 40 miles away from Eugene.

(b) The Department of Transportation shall provide the Department of Environmental Quality and the State Department of Energy with an estimate of the rate at which new vehicles will replace existing vehicles among the vehicles described in paragraph (a) of this subsection.

The vehicle replacement rate is an input to the GreenSTEP model and affects calculations of fuel consumed and greenhouse gases produced. This input is specified in terms of the amount of change to the 95th percentile vehicle age. Although this is a good way to specify the model input, it may be difficult for non-modelers to understand, therefore average vehicle age is used as a surrogate measure of the replacement rate in the explanation below. The current average age for both automobiles and light trucks in Oregon is about 10 years.[7]

It is very difficult to say what the average vehicle age will be in the future since that will depend on a number of things which are not determined. If autos and light trucks become more durable and/or more expensive, then people will tend to hold on to them longer and the average age will increase. Also, people will tend to hold on to their vehicles longer if they become less prosperous. On the other hand, substantial increases in gas prices and vehicle fuel economy will encourage households to retire older vehicles and replace them with more fuel efficient ones. Vehicle turnover is also affected by public policies and programs such as the "cash for clunkers" program. Given the amount of GHG reduction needed and the effect of vehicle age on fuel economy, such programs may be necessary in the future.

An estimate of the light vehicle replacement rate can be made by assuming that the current average vehicle age (10 years) will hold constant into the future. This is not unreasonable since the average vehicle age has been fairly constant in recent years. This estimate might be considered the default case and was one of the future conditions modeled with GreenSTEP.

An alternative estimate can be made to estimate the effect of faster vehicle turnover on GHG emissions. The magnitude of the effect will vary with rate of vehicle technology improvement. To estimate this effect an average vehicle life of 8 years was also modeled. That is the average life of light vehicles in the northeastern U.S.[8]

Several assumptions were made about the mix of automobiles and light trucks and about the ages of vehicles in the fleet in the three fleet scenarios. In the 1st level it is assumed that the mix of autos and light trucks and the distributions of vehicle ages remains at current levels. In the 2nd level, it is assumed that the percentage of light trucks in the fleet reduces by about 17%. In the 3rd level it is assumed that the percentage of light trucks in the fleet reduces by about a third. The vehicle age assumption for the 1st level is that the distribution of vehicle ages will be the same as the current distribution. For the 2nd and 3rd levels it is assumed that the 95th percentile age will decrease to be similar to that of vehicles in the Northeastern U.S. The distribution of

[7] ODOT analysis based on 2009 DMV motor vehicle registration records.

[8] ODOT analysis using 2001 National Household Travel Survey.

ages is adjusted accordingly. Table A.2 shows key characteristics of the vehicle fleet for the 3 fleet levels.

Another equally important consideration, although not required by (b), is the split of the light vehicle fleet between automobiles and light trucks (e.g. pickup trucks, sport utility vehicles, vans). Vehicle size and weight has a significant bearing on fuel economy. The default case for the light truck proportion might be considered the current light truck proportions.[9] These are shown in Table A.2 and compared with the estimated values in 1990 and 2005. Table A.2 shows two plausible alternative scenarios for the 2035 light truck percentages.

Table A.2 Key Vehicle Fleet Characteristics Assumed for 2035 and Compared to Estimates for 1990 and 2005

Characteristic	1990	2005	Fleet Level		
			1	2	3
Bend	37	55	56	46	36
Corvallis	31	45	46	38	30
Eugene-Springfield	32	47	48	40	31
Metro	30	43	44	36	29
Rogue Valley	35	50	52	42	34
Salem-Keizer	33	47	49	41	31
Average Vehicle Age (years)	10	10	10	8	8

All-in-all, three possible scenarios were modeled which combine plausible combinations of average vehicle age the light truck percentages. They are designated as three fleet levels. Fleet level 1 could be considered a default estimate that might occur if there are no changes to current conditions. There may well be substantial changes to current conditions since Oregon and the world as a whole enter into very dynamic times that could witness large changes in fuel prices, technology, and policies to curb greenhouse gas emissions. Therefore the two other fleet levels may be equally likely in the future, depending on how conditions change.

Calculation of 1990 Metropolitan Area Light Vehicle Emissions

The Department of Environmental Quality and the Oregon Department of Energy are required to estimate the greenhouse gas emissions for 1990 for each metropolitan area consistent with the estimates of VMT documented above. The specific requirement is as follows:

> *(c) The Department of Environmental Quality and the State Department of Energy shall estimate the greenhouse gas emissions for 1990 for each [region served by a metropolitan planning organization] {metropolitan service district} resulting from the travel by motor vehicles described*

[9] ODOT analysis based on 2009 DMV motor vehicle registration records.

in paragraph (a) of this subsection, using available records of the average emissions per mile emitted by the motor vehicles in 1990 and the estimates provided by the Department of Transportation under paragraph (a) of this subsection.

These estimates were made using the GreenSTEP model using estimates of vehicle fuel economy by model year provided by the Department of Environmental Quality and estimates of fuel carbon intensity[10] provided by the Oregon Department of Energy. Using the GreenSTEP model assures that estimates of greenhouse gas emissions are consistent with estimated characteristics of vehicles, fuels, and household travel. Table A.3 shows the results.

Table A.3 Estimated 1990 Metropolitan Area Light Vehicle Greenhouse Gas Emissions

Area	GHG Emissions (metric tons CO_2e per day)	Per Capita GHG Emissions (metric tons CO_2e per person per year)	Vehicle GHG Emission Rates (grams CO_2e per mile)
Bend	428	4.1	590
Corvallis	366	2.5	585
Eugene-Springfield	1,898	3.5	592
Metro	12,259	4.2	605
Rogue Valley	1,181	4.1	594
Salem-Keizer	1,712	3.8	596

Estimation of the Average Greenhouse Gas Emissions in 2035 Emitted by Motor Vehicles

The Department of Environmental Quality and the State Department of Energy are required to estimate the average greenhouse gas emissions in 2035 emitted by motor vehicles. The specific requirement is as follows:

(d) The Department of Environmental Quality and the State Department of Energy shall estimate the average greenhouse gas emissions in 2035 emitted by motor vehicles described in paragraph (a) of this subsection[. The estimate must take into account the motor vehicles that the Department of Transportation predicts will have replaced existing vehicles as described in paragraph (b) of this subsection. The estimate must be based on available reasonable data provided by public or private

[10] The fuel carbon intensity values are based on the life cycle values which include the carbon dioxide equivalents of the fuel itself and the carbon dioxide equivalents produced by the production and distribution of the fuel.

entities concerning the improvements in vehicle technologies that will be available for use by 2035.] {predicted to comprise the motor vehicles on the highways in 2035 based on the predicted rate of replacement of the vehicles as described in paragraph (b) of this subsection and based on available reasonable estimates provided by public or private entities of the improvements in vehicle technologies that will be available for use by 2035.}

There is much uncertainty about the future of vehicle technology and vehicle fleet characteristics (vehicle mix and vehicle age). What the future will hold will depend very much on policies and laws that are adopted at state and federal levels in addition to changes in fuel prices and public preferences. In recognition of this inherent uncertainty, 4 levels of possible future technology were developed and modeled for the year 2035 in combination with the 3 fleet levels (described in section B. above).

Assumptions for key vehicle characteristics for 2035 model year vehicles are shown in Table A.4 for the 4 technology levels.[11] The 1st level assumes that the fuel economy standards proposed by CARB/NHTSA/EPA are put into place but no additional improvements are made after 1995. The 2nd level assumes that fuel economy continues to grow an additional 7% from 2025 to 2035 in accordance with lowest Argonne improvement scenario. The 3rd level assumes that fuel economy will grow an additional 14% from 2025 to 2035 based on an Argonne scenario which assumes a greater increase in hybrid electric vehicles. The 4th level assumes that in addition to the 3rd level improvements, the proportion of 2035 model year vehicles that are either plug-in hybrid electric vehicles (PHEV) or electric vehicles (EV) increases greatly. Several assumptions were made regarding the carbon intensities of vehicle fuels and electric power as well. For level 1 it is assumed that the proposed low carbon fuel standard is adopted and that the carbon intensity of vehicle fuels will be 10% below the current average by 2035. For the other three levels, it is assumed that vehicle fuel carbon intensity will decline to a level 20% below the current average by 2035. For electric power, it is assumed that utilities will meet the renewable portfolio standards (RPS) in levels 1, 2, and 3. For level 4 it is assumed that beyond 2025 a new RPS will be phased in at 5% additional renewable power generation each 5 years until that state reaches 50% renewable power by 2050.

[11] Assumptions about vehicle fuel economy were derived from several sources. These include the joint proposal by the California Air Resources Board (CARB), National Highway Transportation Safety Administration (NHTSA), and Environmental Protection Agency (EPA) for increasing fuel economy, and "Multi-Path Transportation Futures Study: Vehicle Characterization and Scenario Analyses", Argonne National Laboratory, Energy Systems Division, July 22, 2009, ANL/ESD/09-5.

Table A.4 Key Vehicle Technology Characteristics Assumed for 2035 Model Year

Characteristic	Technology Level			
	1	2	3	4
Auto ICE fuel economy (MPG)	60	64	68	68
Light truck ICE fuel economy (MPG)	41	46	48	48
Auto PHEV fuel economy in charge sustaining mode (MPG)	75	81	81	81
Light truck PHEV fuel economy in charge sustaining mode (MPG)	52	56	56	56
Auto Percent PHEV or EV in 2035 model year	8	8	8	56
Light Truck Percent PHEV or EV in 2035 model year	2	2	2	16
PHEV battery range (miles)	35	35	35	35
EV battery range (miles)	175	175	175	175

The GreenSTEP model was run with all combinations of these inputs and with assumptions for other inputs corresponding to reference case levels for other model inputs (described in Appendix D). The VMT and GHG emissions were tabulated for each metropolitan area and then from these values the average emissions rates in grams per mile were calculated. The values are shown in Table A.5, 1990 values are included for comparison.

Table A.5 Estimated 1990 and 2035 Range of Light Vehicle GHG Emission Rates for Assumed Technology and Fleet Levels (grams CO_2e per vehicle mile)

	Bend	**Corvallis**	**Eugene-Springfield**	**Metro**	**Rogue Valley**	**Salem-Keizer**
1990 Values	590	585	592	605	594	596
Tech 1, Fleet 1	251	240	242	252	250	244
Tech 1, Fleet 2	223	215	215	225	223	218
Tech 1, Fleet 3	214	208	208	219	215	211
Tech 2, Fleet 1	217	206	207	217	215	210
Tech 2, Fleet 2	190	183	183	193	190	186
Tech 2, Fleet 3	183	178	177	187	184	180
Tech 3, Fleet 1	213	204	205	214	213	207
Tech 3, Fleet 2	187	180	180	189	187	183
Tech 3, Fleet 3	180	174	173	184	181	177
Tech 4, Fleet 1	206	200	186	208	210	202
Tech 4, Fleet 2	178	176	157	182	184	177
Tech 4, Fleet 3	170	170	149	176	177	170
Average of All Combinations	196	190	185	199	198	193

Table A.5 also shows an overall average emissions rate for each metropolitan area. These averages were computed as the arithmetic means of all the technology and fleet combinations. These average values should not be interpreted as the most likely values. What actually happens will depend on what policy decisions are made at the federal, regional (e.g. Western Climate Initiative), state and local levels, along with a number of other factors such as fuel prices and scarcity, the pace of technological improvements, and changes in consumer preferences.

Recommendation of the Percentage by Which Metropolitan Area Light Vehicle Greenhouse Gas Emissions Should be Reduced

The Department of Environmental Quality and the Oregon Department of Energy are required to make a recommendation regarding the percentage by which metropolitan area light vehicle GHG emissions should be reduced below their 1990 levels by 2035. The specific requirements are as follows:

> *(e) The Department of Environmental Quality and the State Department of Energy shall recommend to the Land Conservation and Development Commission a percentage by which the emissions from motor vehicles described in paragraph (a) of this subsection [need to be reduced below their 1990 emission levels by 2035 in order to achieve the reduction in emissions from vehicles necessary to achieve the total greenhouse gas emissions reduction goals set for 2050 by ORS 468A.205.] {should be reduced below their 1990 emission levels by 2035 in order to achieve a reduction in emissions from the vehicles as part of the overall achievement of total carbon reduction set for 2050 by ORS 468A.205 and shall explain their reasons for any recommendations other than the midpoint between the 2020 and the 2050 emission reduction targets established by ORS 468A.205.}*

The statutes which set the state's GHG emissions reduction goals do not allocate reductions to different sectors. Moreover, no comprehensive analysis and planning has been done to determine the most efficient and equitable way to allocate emission reductions among different sectors or places. Therefore there is no statutory or other guidance on what reductions in metropolitan area light vehicle emissions are necessary in order to achieve the overall state GHG emissions reduction goals. It is assumed that the target reduction in statewide light vehicle emissions is the same as the statutory goals (10% reduction by 2020 and 75% reduction by 2050).

It was initially anticipated that metropolitan area reduction levels could be established in concert with work on the development of the statewide transportation strategy for reducing GHG emissions. Several rounds of modeling and analysis were planned to be done to explore a range of plausible visions for reducing light vehicle greenhouse gas emissions and to develop a consensus about the best vision or visions. Unfortunately, it will take more time to do this work than is available to meet the March 1, 2011 deadline for submitting this report. To date, an initial round of modeling has been done to evaluate the potential for making large cuts in light vehicle GHG emissions by 2050. 144 scenarios were developed having different combinations of policy and technology assumptions (Appendix D) in order to explore this potential and to identify key areas where changes are needed in order to make substantial reductions. Although, the work on the statewide transportation strategy is far from complete, the preliminary results were used to estimate metropolitan area targets for GHG reduction. The steps are as follows:

1. The averages of the future GHG emissions were calculated by metropolitan area for all scenarios predicted to reduce statewide light vehicle GHG emissions by 60% or more from 1990 levels by 2050. The statewide average was computed as well. The results are shown in Table A.6.
2. The proportions of statewide emissions occurring from light vehicle travel on the roads in each metropolitan area were computed from these averages. The results are shown in Table A.7.
3. Statewide light vehicle emissions for a 75% reduction from 1990 were calculated. Table A.8 shows the results.
4. The 2050 target statewide emissions were multiplied by the percentages in Table A.7 to arrive at 2050 targets by metropolitan area. The results are shown in Table A.9.

Table A.6 Estimated Future Light Vehicle Emissions in 2050 for Top Performing Scenarios

	Bend	Corvallis	Eugene-Springfield	Metro	Rogue Valley	Salem-Keizer	State Total
Annual Metric Tons	96,540	45,696	163,643	1,555,452	197,892	225,772	5,112,085

Table A.7 Percentage of Estimated Future Light Vehicle Emissions in 2050 Resulting from Travel on Metropolitan Area Roads

	Bend	Corvallis	Eugene-Springfield	Metro	Rogue Valley	Salem-Keizer
Annual Metric Tons	1.9	0.9	3.2	30.4	3.9	4.4

Table A.8 Calculating Statewide Light Vehicle GHG Emission Given a 75% Reduction from 1990 Estimated Emissions (metric tons)

1990 Emissions	2050 Target Emissions
1990 Emissions	14,362,900
1990 Population	2,852,600
1990 Per Capita Emissions	5.03
2050 Emissions Target	3,590,700
2050 Population	5,982,500
2050 Per Capita Emissions	0.60

Table A.9 Metropolitan Area Light Vehicle GHG Emissions in 2050 Corresponding to a 75% Reduction in Statewide Light Vehicle GHG Emissions

	Bend	Corvallis	Eugene-Springfield	Metro	Rogue Valley	Salem-Keizer	State Total
Annual Metric Tons	67,810	32,097	114,943	1,092,550	138,999	158,583	3,590,728

Table A.10 compares the implications of these emissions reductions in percentage terms (absolute and per capita). It can be seen that percentage reductions in total emissions vary substantially between the metropolitan areas. There is a 26 percentage point difference between the lowest and highest percentage reductions. In contrast, the estimates of percentage reductions in per capita emissions vary little. There is only a 4 percentage point difference between the lowest and highest values. Estimating emission reductions on a per capita basis reduces the differences between metropolitan areas because it accounts for differences in population growth rates among metropolitan areas.

Table A.10 Summary of Metropolitan Area Emissions (metric tons) and Emission Reductions, 1990 & 2050

Value	Bend	Corvallis	Eugene-Springfield	Metro	Rogue Valley	Salem-Keizer
Population 1990	37,800	52,700	197,500	1,062,000	105,000	166,500
Population 2050	138,300	88,100	338,000	2,476,400	269,100	388,700
Emissions 1990	156,300	133,600	692,600	4,474,500	431,200	624,700
Emissions 2050	67,800	32,100	114,900	1,092,600	139,000	158,600
Per Capita Emissions 1990	4.13	2.53	3.51	4.21	4.11	3.75
Per Capita Emissions 2050	0.49	0.36	0.34	0.44	0.52	0.41
% Emissions Reduction	57	76	83	76	68	75
% Per Capita Emissions Reduction	88	86	90	90	87	89

The overall average percentage reduction in metropolitan area per capita emissions in 2050 is 89%. The percentage reduction on a per capita basis is greater than the percentage reduction as a whole because the state's population is growing. In order to achieve a 75% percent reduction in total emissions with a growing population, emissions per capita must decline at an even greater rate. The following calculation illustrates this:

If: 2050 emissions need to be 25% of 1990 emissions
And: 2050 population is 2.1 times 1990 population
Then: 2050 emissions per capita would need to be 12% of the 1990 rate
So: An 88% reduction in emissions per capita would be required

Since SB 1059 requires that LCDC's rules "take into consideration methods of equitably allocating reductions among the metropolitan areas given differences in population growth rates" [12] it is recommended that the 2035 target be set on a per capita emissions basis. As the results in Table A.10 show, estimating values calculated on a per capita basis reduces the variation among metropolitan areas. Setting the target on per capita emissions basis also makes sense from the standpoint of reflecting the level of effort required to reduce emissions since light vehicle emissions are a function of the amount of personal travel and types of personal vehicles owned and used. It is harder to gauge the difficulty in reducing total light vehicle emissions as a whole because that depends on population growth as well.

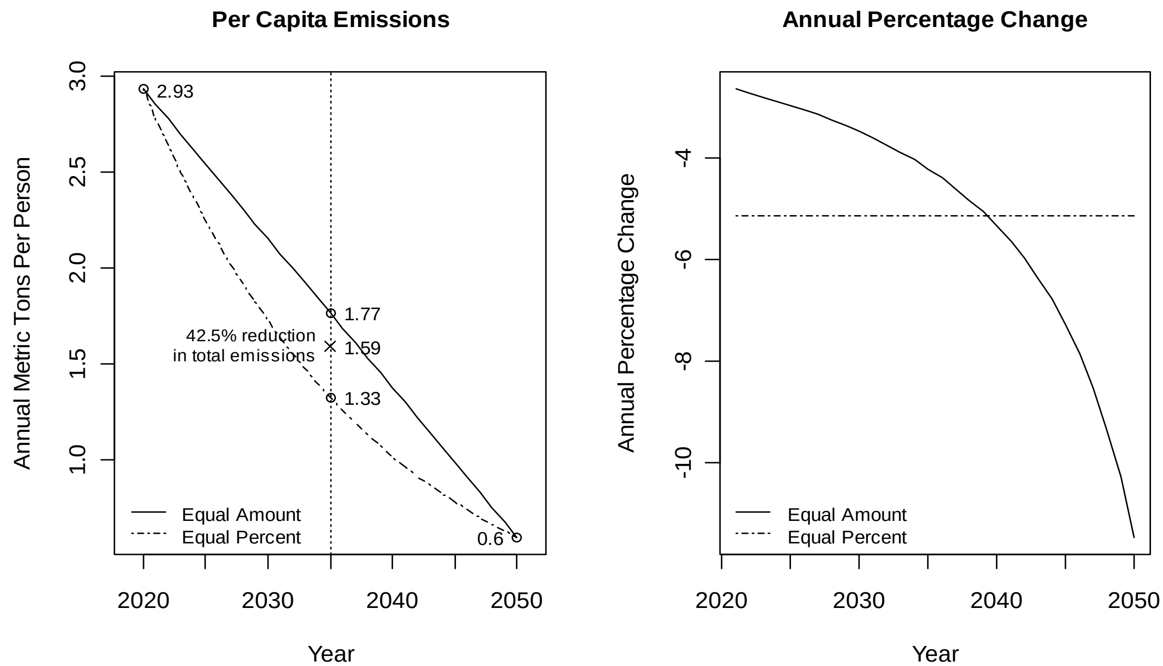
There are no statewide goals for GHG emissions reduction by 2035. The statutory requirement, however, is that the 2035 target recommendation be what the reduction should be in order to achieve the 2050 reduction goal. In other words, the 2035 recommendation needs to be a value that will enable the 2050 goal to be achieved. For example, it would be unacceptable to recommend a value equal to the 2020 goal (10% reduction) because such a trajectory would make it highly unlikely that the 2050 reduction goal could be met. HB 2001, but not SB 1059, establishes a presumption that the 2035 target be the midpoint between the 2020 and 2050 reduction goals.

There are two commonly accepted methods for computing an intermediate value for values that change over time. The first method assumes that an equal amount of change will occur annually. The second method assumes that an equal percentage change will occur annually. Figure A.1 illustrates the results of these two methods.

It can be seen in the first graph that the straight line method results in a per capita emissions target of 1.77 annual metric tons per capita while the equal percentage method results in a lower target of 1.33 annual metric tons per capita. The figure also shows what the per capita emissions target would be (1.59 annual metric tons per capita) if the target was set based on a 42.5% reduction in total emissions. It can be seen in the second graph that the assumption of a constant quantity of reduction per year means that the percentage decrease needs to grow larger every year. A larger percentage reduction would occur from 2035 to 2050 (66%) than would occur from 2020 to 2035 (40%).

[12] SECTION 5. (1)

Figure A.1 Comparison of the Results of Two Methods for Finding the 2035 Recommended Value for Average Statewide Per Capita Emissions



Key to the decision about which method to use is the consideration of what the implications are for meeting the 2050 goal. Implicit in the equal annual percentage reduction method is the assumption that there will be constant returns in GHG reduction for the effort expended. Implicit in the straight line method is the assumption that there will be increasing returns on investment. While there may be technological breakthroughs that greatly increase returns in the future, it is also likely that there will be diminishing returns in a number of respects. The easy things will be done first and the difficultly of making gains will increase over time. Therefore, the target set on the basis of an equal annual percentage reduction is more likely to achieve the 2050 goal than the target set on a straight line basis.

The method used for calculating the midpoint reductions for each metropolitan area is as follows:

1. The statewide light vehicle GHG emissions total for 2020 is computed (10% less than 1990 emissions) and the corresponding statewide average per capita emission rate is calculated.
2. The annual percentage change in statewide average per capita emissions from 2020 to 2050 is calculated.
3. The statewide average of per capita emissions for 2035 is calculated by applying the annual percentage rate of change to the time period from 2020 to 2035.
4. The percentage reduction in 2035 statewide average per capita emissions is calculated from the 2035 statewide average per capita emissions value and the 1990 statewide average per capita emissions estimate.
5. The ratio between the 2035 statewide average per capita emissions reduction value and the 2050 statewide average per capita emissions reduction value is calculated.

6. The 2050 metropolitan area per capita emissions reduction values in Table A.10 are multiplied by the ratio calculated in step #5 to compute the 2035 recommended metropolitan area emissions reduction values.

The results of the first 5 steps are shown in Table A.11.

Table A.11 Calculation of 2035 Statewide Percentage Reduction in Per Capita Light Vehicle Emissions and Ratio of 2035 to 2050 Percentage Reductions

Measure	Quantity
1990 Statewide Light Vehicle Emissions (metric tons)	14,362,900
2020 Statewide Light Vehicle Emissions (metric tons)	12,926,600
2050 Statewide Light Vehicle Emissions (metric tons)	3,590,700
1990 Population	2,852,600
2020 Population	4,408,600
2050 Population	5,982,500
1990 Per Capita Emissions (metric tons)	5.03
2020 Per Capita Emissions (metric tons)	2.93
2050 Per Capita Emissions (metric tons)	0.60
Annual Rate of Per Capita Emissions Reduction (2020 to 2050)	-5.1%
Per Capita 2035 Emissions (metric tons) (15 yrs. @ -5.1% from 2020)	1.33
Percentage Reduction in Per Capita Emissions by 2035 (from 1990)	73.7
Percentage Reduction in Per Capita Emissions by 2050 (from 1990)	88.1
Ratio of 2035 to 2050 Percentage Reductions	0.84

The results of applying the statewide ratio in percentage per capita reductions (0.84) to the metropolitan area 2050 percentage reductions in per capita emissions (Table A.10) are shown in Table A.12. The table also shows corresponding estimates of per capita light vehicle emissions by metropolitan area and total light vehicle emissions by metropolitan area given assumed 2035 metropolitan area populations.

Table A.12 2035 Metropolitan Area Percentage Reductions in Light Vehicle Emissions

Value	Bend	Corvallis	Eugene-Springfield	Metro	Rogue Valley	Salem-Keizer
2050 Percentage Reduction in Per Capita Emissions	88	86	90	90	87	89
2035 Percentage Reduction in Per Capita Emissions	74	72	75	75	73	74
2035 Population	119,600	78,400	298,500	2,110,900	228,100	333,900
2035 Per Capita Emissions	1.09	0.72	0.86	1.06	1.10	0.96
2035 Emissions	130,000	56,500	256,400	2,235,400	251,800	319,100

The 2035 percentage reductions in per capita emissions shown in Table A.12 are the estimated reductions necessary to achieve a 2050 reduction in total statewide light vehicle emissions of 75% below the 1990 level. The percentage reductions in per capita emissions needed in 2035 are very similar among the metropolitan areas. The overall metropolitan average is 74%. The metropolitan area values differ from this overall average by no more than 2 percentage points.

Reductions in Metropolitan VMT Necessary to Meet Light Vehicle GHG Emission Reductions

DEQ and ODOE are required to calculate the estimated miles of travel by light vehicles that may be accommodated consistent with the estimates made in previous sections of this report. The specific requirements are as follows:

> *(f) The Department of Environmental Quality and the State Department of Energy shall calculate the estimated miles of travel by motor vehicles described in paragraph (a) of this subsection that may be accommodated in 2035 [by each region served by a metropolitan planning organization] {in each metropolitan service district} based on the estimates performed under paragraphs (a) to (d) of this subsection and the recommendation required by paragraph (e) of this subsection.*

The calculation of metropolitan area VMT necessary to meet light vehicle greenhouse gas emission reductions is straightforward. The 2035 light vehicle emission values in Table A.12 are divided by the estimated emissions rates in Table A.5. The results are shown in Table A.13. Table A.14 shows the results on a per capita basis.

Table A.13 Estimated VMT Consistent with Meeting 2035 Greenhouse Gas Reduction Recommendation (Table A.12) Assuming Plausible Greenhouse Gas Emissions Rates (Table A.5)

	Bend	Corvallis	Eugene-Springfield	Metro	Rogue Valley	Salem-Keizer
Tech 1, Fleet 1	1,416,400	645,700	2,906,400	24,289,500	2,760,200	3,586,200
Tech 1, Fleet 2	1,596,000	720,900	3,260,400	27,162,100	3,098,500	4,004,100
Tech 1, Fleet 3	1,662,100	745,700	3,383,000	28,004,800	3,211,400	4,148,600
Tech 2, Fleet 1	1,643,600	750,400	3,390,400	28,229,000	3,215,100	4,165,100
Tech 2, Fleet 2	1,870,000	845,400	3,830,200	31,786,300	3,630,200	4,690,500
Tech 2, Fleet 3	1,943,300	871,500	3,972,100	32,699,800	3,747,500	4,849,600
Tech 3, Fleet 1	1,668,200	758,100	3,426,400	28,568,000	3,246,600	4,216,200
Tech 3, Fleet 2	1,903,300	861,100	3,901,500	32,361,800	3,695,200	4,774,500
Tech 3, Fleet 3	1,981,500	886,800	4,053,100	33,334,500	3,819,200	4,940,300
Tech 4, Fleet 1	1,728,500	773,100	3,782,600	29,405,200	3,287,000	4,322,500
Tech 4, Fleet 2	2,002,700	878,000	4,463,700	33,608,300	3,747,200	4,931,900
Tech 4, Fleet 3	2,094,800	908,000	4,723,200	34,761,500	3,889,400	5,133,600
Average of All Combinations	1,817,200	814,700	3,797,100	30,775,800	3,484,200	4,529,800

Table A.14 Estimated Per Capita VMT Consistent with Meeting 2035 Greenhouse Gas Reduction Recommendation Assuming Plausible Greenhouse Gas Emissions Rates, Compared to 1990 and 2005 Estimates

	Bend	Corvallis	Eugene-Springfield	Metro	Rogue Valley	Salem-Keizer
1990 Value	19.2	11.9	16.2	19.1	18.9	17.2
2005 Value	19.9	13.2	17.6	19.7	20.0	17.8
Tech 1, Fleet 1	11.8	8.2	9.7	11.5	12.1	10.7
Tech 1, Fleet 2	13.3	9.2	10.9	12.9	13.6	12.0
Tech 1, Fleet 3	13.9	9.5	11.3	13.3	14.1	12.4
Tech 2, Fleet 1	13.7	9.6	11.4	13.4	14.1	12.5
Tech 2, Fleet 2	15.6	10.8	12.8	15.1	15.9	14.0
Tech 2, Fleet 3	16.2	11.1	13.3	15.5	16.4	14.5
Tech 3, Fleet 1	13.9	9.7	11.5	13.5	14.2	12.6
Tech 3, Fleet 2	15.9	11.0	13.1	15.3	16.2	14.3
Tech 3, Fleet 3	16.6	11.3	13.6	15.8	16.7	14.8
Tech 4, Fleet 1	14.4	9.9	12.7	13.9	14.4	12.9
Tech 4, Fleet 2	16.7	11.2	15.0	15.9	16.4	14.8
Tech 4, Fleet 3	17.5	11.6	15.8	16.5	17.1	15.4
Average of All Combinations	15.2	10.4	12.7	14.6	15.2	13.6

Tables A.13 and A.14 also show the values computed when the averages of the emissions rates of all the modeled scenarios shown in Table A.5 are used. It should be noted as before that these average values should not be interpreted as the most likely values. What actually occurs will depend on policy developments at the federal, regional, state and local levels and on other factors that affect technological developments and consumer response.

Recommended Models and Methods to Account for the Effect of Traffic Congestion on Greenhouse Gas Emissions

ODOT, DEQ and ODOE are required to recommend models and methods that may be used to account for additional greenhouse gas emissions resulting from traffic congestion and reductions in emissions resulting from the relief of traffic congestion. The specific requirements are as follows:

> *(g) The Department of Transportation, Department of Environmental Quality and the State Department of Energy shall recommend to the Land Conservation and Development Commission modeling tools or other methods [that each region may use to] {by which a metropolitan service district may} adjust [its] {the district's} recommended number of miles of travel as described in paragraph (f) of this subsection, to account for additional greenhouse gas emissions resulting from increased traffic congestion or reductions in emissions resulting from measures that reduce traffic congestion.*

Traffic congestion has a substantial impact on vehicle fuel economy and GHG emissions. Slow traffic leads to inefficient operations for internal combustion engines and may lead to less efficient routing as vehicles attempt to avoid congested areas. The GreenSTEP model accounts for some congestion effects on GHG emissions by predicting the proportion of travel on congested and uncongested roadways in a given area. However, since GreenSTEP directly predicts daily VMT and does not contain a roadway network, the model cannot directly consider the effects of trip rerouting or bottlenecks. In addition, while GreenSTEP can model the impacts of additional lane miles of freeways and arterials (which will reduce the proportion of congested travel), it is not sensitive to small-scale congestion relief projects like bottleneck removals, nor is it sensitive to non-capacity congestion relief projects like traffic signal coordination, HOV/HOT lane conversions, or ramp meters.

There are several options that MPOs could use to adjust VMT or GHG emissions estimates to better account for congestion impacts and congestion relief projects. The most promising options are as follows:

- MPOs could use traditional four-step travel demand models to obtain a more accurate distribution of VMT by speed and by different facility class. In this case, the MPO model would be run with land use information that is as close to the GreenSTEP input data as possible to develop a VMT-speed profile for the region. The GreenSTEP VMT estimate would then be allocated based on the proportion of speed and facility type predicted by the four-step model. Some congestion relief projects such as HOV lane conversions and bottleneck removal projects could also be evaluated using this technique.

- The previous technique could be enhanced if MPOs adopted more advanced travel models that included features such as smart-growth trip generation adjustments, travel demand management adjustments, and dynamic traffic assignment. In addition, the performance of GreenSTEP could be enhanced if included sensitivity to congestion on VMT generation via a feedback loop from the four-step model output.

- If VMT-speed output was generated by a four-step model, the GHG emissions estimate could be further enhanced using the EPA MOVES air quality model. The more refined VMT/speed data from the four-step model will better account for the effects of congestion and congestion relief projects.

- Portland State University (PSU) researchers are working on several potential adjustments that could be made to GreenSTEP to increase its sensitivity to congestion relief projects. These adjustments involve adding sensitivity to the fuel consumption/speed curves, lane mile capacity, average speed estimates, and VMT generation estimates, to better account for projects like ramp meters, HOV lanes, variable speed limits, and transit priority. The PSU researchers are also working on adjustments to make GreenSTEP more sensitive to how variations in travel speed affect electric and hybrid vehicles differently than standard internal combustion engine vehicles. Once the PSU researchers have completed their research, the GreenSTEP model will be modified to incorporate the research results.

Appendix B. Overview of the GreenSTEP Model

Introduction

The Greenhouse Gas Statewide Transportation Emissions Planning model (GreenSTEP) is a model for forecasting greenhouse gas (GHG) emissions from the transportation sector. At this time, the model does not include emissions from long-distance passenger travel or from all modes of freight transport. Work on those travel components is under way.

Model Objectives

The GreenSTEP model was developed by the Oregon Department of Transportation (ODOT) Transportation Planning Analysis Unit (TPAU) as a modeling tool to assess the effects of a large variety of policies and other factors on transportation-sector GHG emissions. ODOT will use GreenSTEP to help the Department meet the requirements of Section 2 of Chapter 85 Oregon Laws (2010) passed by the Oregon Legislature and signed into law in 2010:

> *The Oregon Transportation Commission, after consultation with and in cooperation with metropolitan planning organizations, other state agencies, local governments and stakeholders, as a part of the state transportation policy developed and maintained under [Oregon Revised Statute] ORS 184.618, shall adopt a statewide transportation strategy on greenhouse gas emissions to aid in achieving the greenhouse gas emissions reduction goals set forth in ORS 468A.205. The commission shall focus on reducing greenhouse gas emissions resulting from transportation. In developing the strategy, the commission shall take into account state and Federal programs, policies and incentives related to reducing greenhouse gas emissions.*

Existing transportation, land use, and emissions models used in Oregon could not address the broad range of potential policies and other factors that affect transportation sector GHG emissions. The GreenSTEP model was developed to address the following factors, among others:

- Changes in population demographics (age structure);
- Changes in personal income;
- Relative amounts of development occurring in metropolitan, urban and rural areas;
- Metropolitan, other urban, and rural area densities;
- Urban form in metropolitan areas (proportion of population living in mixed-use areas with a well interconnected street and walkway system);
- Amounts of metropolitan area transit service;
- Metropolitan freeway and arterial supplies;
- Auto and light truck proportions by year;
- Average vehicle fuel economy by vehicle type and year;
- Vehicle age distribution by vehicle type;
- Electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs)

- Light-weight vehicles, such as bicycles, electric bicycles, electric scooters, etc.;
- Pricing – fuel, vehicle miles traveled (VMT), parking;
- Demand management – employer-based and individual marketing;
- Car-sharing;
- Effects of congestion on fuel economy;
- Effects of incident management on fuel economy;
- Vehicle operation and maintenance – eco-driving, low rolling resistance tires, speed limits;
- Carbon intensity of fuels, including the well to wheels emissions; and
- Carbon production from the electric power that is generated to run electric vehicles.

The GreenSTEP model addresses the entire state on a county basis to be responsive to regional differences. It distinguishes between households living in metropolitan, other urban, and rural areas to reflect the different characteristics of those areas in terms of density, urban form, transportation system characteristics, and transportation demand management (TDM) programs.

Model Design

GreenSTEP is designed to operate at a county level due to the availability of long-range population projections by age at the county level, and the need for the model to be sensitive to regional differences.

It was originally conceived as a "sketch-planning" model, starting with a base-level forecast of VMT that reflects the population forecast. A series of factoring tables were then to be used to adjust the VMT to reflect land use and transportation policies. The most uncertain and challenging portion of the design was to determine how to adjust VMT based on increasing fuel or other costs.

Using factoring tables in a model is not as desirable as estimating a consistent set of models from data. The factoring approach requires the review of studies to identify general factors that describe the proportional effect that one variable (e.g. population density) has on another variable (e.g. VMT). A limitation of this approach is that since factors can vary significantly from one study to another due to differences in data and methods, judgment is required in order to choose the factor values to be used in the model. Inconsistencies between studies can make it difficult to choose a set of factor values that avoid the double counting of effects. Accounting for the range of factors of interest and avoiding double counting is a significant challenge for a factor-based model.

Because of the problems that factoring models pose, GreenSTEP was redesigned to eliminate the need for most of the factoring elements and replaced them with disaggregate household-level models. This was done to take advantage of the available data, resolve technical difficulties, and create a more behaviorally consistent model. These changes to the model design moved GreenSTEP out of the realm of sketch-planning models. Most of GreenSTEP operates at an individual household level where each household has individual attributes, and where vehicle ownership and use is predicted on an individual household basis.

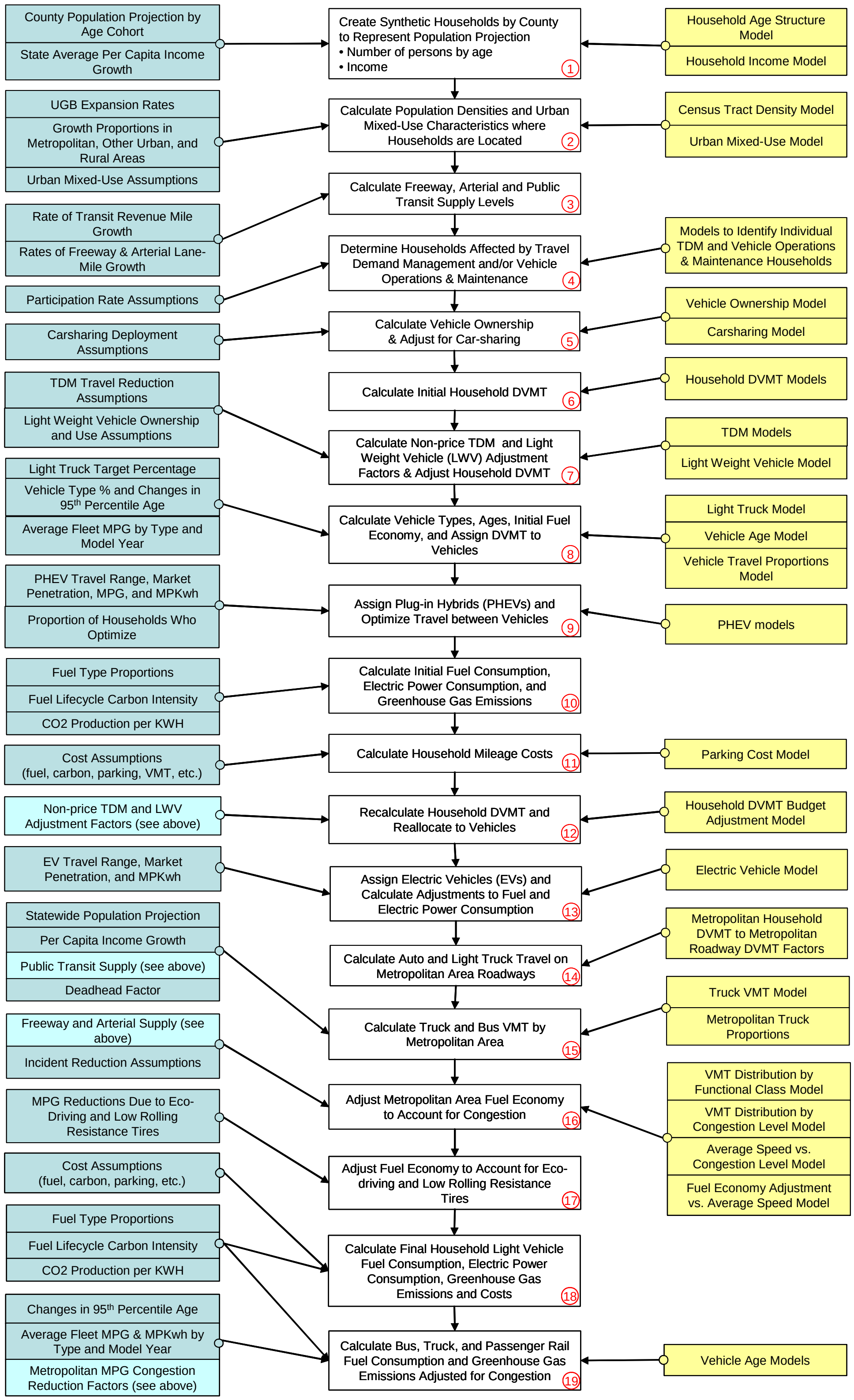
An advantage of this approach over a sketch planning approach is that it better accounts for interactions between policies. For example, a policy that increases urban area density decreases household daily vehicle miles traveled (DVMT) by increasing shortened trips and increasing nonauto travel. Higher densities also increase the market for car sharing. Increased car sharing in turn reduces household vehicle ownership, which also reduces household DVMT. Reducing household DVMT also increases the likelihood that a household vehicle could be replaced by an EV and/or increases the proportion of household PHEV mileage that can be traveled on an electric charge. Modeling these types of interactions is not possible with a sketch-planning model approach.

Another benefit of the disaggregate approach is that it provides a means for accounting for the effects of changes in fuel prices and a number of other costs of household travel in a consistent manner. Because household fuel costs are a function of household vehicle fuel economy, the model accounts for increases in travel that would occur with gains in fuel economy (rebound effect).

Finally, modeling at the individual household level allows for better analysis of how different households would be affected by policies in a number of ways.

Figure B.1 shows an overview of the current GreenSTEP model design. The white boxes in the middle of the figure identify the major steps in the model execution. The number in the lower right-hand corner of each box corresponds to paragraph numbering in the description that follows. The blue boxes on the left side of the figure show the input assumptions on which the calculations are based and that may be altered to represent different policies. The yellow boxes on the right side of the figure identify the models and calculation methodologies that used in the calculations. These models and how they were estimated and calibrated are explained in the technical documentation for the model.

Figure B.1 Design of the GreenSTEP Model



Following is an explanation of major steps in the model execution shown in the white boxes in Figure B.1:

1. **Create Synthetic Households.** A set of households is created for each forecast year that represents the likely household composition for each county given the county-level forecast of persons by age. Each household is described in terms of the number of persons in each of six age categories residing in the household. A total household income is assigned to each household given the ages of persons in the household and the average per capita income of the region where the household resides.

2. **Calculate Population Densities and Other Land Use Characteristics.** Population density and land use characteristics are important variables in the vehicle ownership, vehicle travel, and vehicle type models. These models were estimated using the values of density and land use characteristics at the Census tract level. Models were developed to estimate density and land use characteristics at a Census tract level given more aggregate policy assumptions about metropolitan and other urban area characteristics.[13] Each household is assigned to a metropolitan, other urban, or rural development type in the county where it is located based on policy assumptions about what proportions of population growth will be of each type. The overall densities for metropolitan and other urban areas in each county are calculated based on policy assumptions for urban growth boundary expansions. Households assigned to metropolitan areas are assigned to population density drawn from a likely household density distribution corresponding to the overall metropolitan area density. Households assigned to other urban areas are assigned the overall population density for nonmetropolitan areas in the county. Households assigned to rural areas are assigned a population density reflecting the predominant rural population density of the county where it is located. Households in urban areas are also assigned to an urban-mixed-use setting or not, based on a model using population density. This can be adjusted based on input assumptions to simulate policy objectives for greater amounts of urban mixed-use development.

3. **Calculate Freeway, Arterial and Public Transit Supply Levels.** The number of lane-miles of freeways and arterials is computed for each metropolitan area based on base-year inventories and policy inputs on how rapidly lane-miles will be added relative to the growth of metropolitan population. For example, a value of one for freeways means that freeway lane-miles grow at the same rate as population growth. If population doubles, freeway lane-miles would double as well. For public transit, the inputs specify the growth in transit revenue miles relative to the base year. Inputs for each metropolitan area also specify the revenue mile split between electrified rail and buses.

4. **Determine Households Affected by Travel Demand Management and/or Vehicle Operations and Maintenance Programs.** Each household is assigned as a participant or not in a number of travel demand management programs (e.g., employee commute options

[13]GreenSTEP could be modified to operate at a metropolitan level with data being input for each Census tract.

program, individualized marketing) and/or to vehicle operations and maintenance programs (e.g., eco-driving, low rolling resistance tires) based on policy assumptions about the degree of deployment of those programs and the household characteristics.

5. **Calculate Vehicle Ownership and Adjust for Car-sharing.** Each household is assigned the number of vehicles it is likely to own based on the number of persons of driving age in the household, whether only elderly persons live in the household, the income of the household, and the population density where the household lives. For metropolitan households, vehicle ownership depends on the freeway supply, transit supply and whether the household is located in an urban mixed-use area. Households are identified whether as car-sharing participants or not based on household characteristics and policy assumptions about the deployment of car sharing. The car-sharing model adjusts the number of vehicles owned by car-share households.

6. **Calculate Initial Household DVMT.** The average DVMT for each household is modeled based on household information determined in previous steps. There are different models for households residing inside and outside of metropolitan (urbanized) areas. The metropolitan model is sensitive to household income, population density of the neighborhood where the household resides, number of household vehicles, whether the household owns no vehicles, the levels of public transportation and freeway supplies in the metropolitan area, the driving age population in the household, the presence of persons over age 65, and whether the neighborhood is characterized by mixed-use development. The nonmetropolitan model is similar, but does not include the transit supply, freeway supply, or mixed-use variables.

7. **Calculate Nonprice TDM and Light Weight Vehicle Adjustment Factors and Adjust Household DVMT.** Nonprice TDM policies are grouped into two categories, workplace-oriented commute options programs and household-oriented individualized marketing programs. Household DVMT adjustment factors are calculated based on participation in these programs (determined in Step #4) and assumptions regarding the average reductions in household DVMT that the programs produce. Adjustment factors are also calculated to account for the potential substitution of light-weight vehicle (LWV) travel for household DVMT. LWVs are bicycles, electric bicycles and similar vehicles. The model predicts the potential amount of household DVMT that could be diverted to LWV travel using a model of the amount of household vehicle travel occurring in single-occupant vehicle tours less than various specified lengths. This model is sensitive to household income, population density, household size, urban mixed-use character, and average household DVMT. The amount of diversion is a function of this potential, assumptions about light motor vehicle ownership rates, and assumptions about the proportion of the potential diverted vehicle travel that may be suitable for light weight vehicle travel. After the TDM and LWV factors have been calculated, they are applied to the initial household DVMT estimates to produce adjusted estimates.

8. **Calculate Vehicle Types, Ages, Initial Fuel Economy, and Assign DVMT to Vehicles.** Two body styles of household vehicles are considered – automobiles and light trucks. The latter includes pickup trucks, sport-utility vehicles and vans. A model predicts the probability that a household vehicle is a light truck based on the number of vehicles in the household, the household income, the population density where the household resides,

and whether the household lives in an urban mixed-use area. This probability is then used as a sampling probability to determine stochastically whether each household vehicle is an automobile or light truck. Once the type of vehicle has been assigned to each vehicle, the age of each vehicle is determined. This is done by sampling from vehicle age distributions by vehicle type and household income group. These distributions may be changed based on input assumptions about changes in fleet turnover rates. Once vehicles ages have been determined, initial assignments of vehicle fuel economy are made based on input assumptions about average vehicle fuel economy by model year and vehicle type. Fuel economy is adjusted in later steps for vehicles identified as plug-in hybrid electric vehicles (PHEVs) and electric vehicles (EVs) and to reflect the effects of congestion and vehicle operation and maintenance on fuel economy. Vehicles are assigned a proportion of the estimated household DVMT based on distributions of how annual household mileage is allocated among multiple vehicles. The distributions vary with the number of vehicles owned by the household. Average household DVMT is assigned to vehicles based on these proportions. This is done randomly without regard to vehicle characteristics. Later, in Step #10, the allocations are optimized to maximize household fuel economy.

9. **Assign PHEVs and Optimize Travel between Vehicles.** Household vehicles are assigned as PHEVs based on input assumptions about market penetration by model year and vehicle type (auto vs. light truck) using a Monte Carlo process. Vehicles that are assigned as PHEVs will be used as the candidate pool in Step #13 to identify EVs. Once PHEVs have been assigned, travel is optimized. The input assumption on the proportion of households that are optimizers is used in a Monte Carlo process to determine which households will optimize vehicle usage to maximize fuel economy. For optimizing households, VMT proportions are ordered in the order of vehicle fuel economy. It should be noted that this process does not change the sizes of the proportions of household VMT. It only changes which household vehicle is assigned with each proportion. For PHEVs, a fuel economy equivalent is calculated based on the battery range of the PHEV, a fuel economy equivalent for electric operation, and the MPG for nonelectric operation. Also for PHEVs, the proportion of travel "fueled" by the power grid vs. on-board hydrocarbon fuels is calculated. This is done using a model which predicts the proportion of PHEV travel that is likely to be powered by electricity stored in the vehicle battery based on the range of battery operation, household income, population density, number of household vehicles, transit service level, number of driving age persons in the household, number of elderly persons in the household, and whether the household is located in an urban mixed-use neighborhood.

10. **Calculate Initial Fuel Consumption, Electric Power Consumption, and GHG Emissions.** Fuel consumption is calculated for internal combustion engine (ICE) vehicles based on the fuel economy values assigned to each vehicle in Step #9 and the annual VMT for the vehicle. Similarly, the electric power consumption for the electric portion of PHEV travel is based on the power efficiency of the vehicle and annual vehicle miles traveled powered by electricity. Fuel consumption is converted to GHG emissions based on the assumed fuel mix for the future year and the carbon intensity for each fuel. Electric power consumption is converted to GHG emissions based on the amount of electrical power consumed and the assumed rates of GHG emissions per unit of power consumed. The emission rates for fuel

and electric power include emissions arising from production and transmission of the fuel or power, as well as emissions from the vehicle itself as a result of combusting the fuel.

11. **Calculate Household Mileage Costs.** Total variable vehicle costs (costs that vary based on vehicle usage) are calculated for each household. These costs include the cost of fuels and electrical power. They may also include, depending on policy assumptions, carbon taxes, VMT taxes, pay-as-you-drive (PAYD) insurance rates, and parking charges. For metropolitan areas, a model is applied to determine how many working age persons in each household pay for parking at their worksite, based on input assumptions about the proportion of employees in the metropolitan area have employers who charge for parking or who must pay for parking at commercial lots, and how easily the parking charges may be avoided by parking for free on the street or free parking lots. The model also estimates the portion of nonwork household trips that another model calculates daily parking charges for households paying for employment parking and other trip parking.

12. **Recalculate Household DVMT and Reallocate to Vehicles.** A household budget model is used to adjust household DVMT to reflect the effect of variable vehicle costs on the amount of household travel. The adjusted household DVMT is allocated to vehicles in proportion to the previous allocation. The travel reduction proportions from TDM and LWV use calculated in Step #7 are applied.

13. **Assign EVs and Calculate Adjustments to Fuel and Electric Power Consumption.** Household vehicles are identified as candidates to be electric vehicles based on how their vehicle usage patterns compare with the average travel range of EVs for their vehicle model years. A vehicle is only considered to be a candidate to be an EV if the vehicle was identified as a PHEV in Step #9 and if the EV range is large enough to accommodate most of the expected usage of the vehicle by the household. To determine this, the 95^{th} percentile DVMT is determined for each vehicle as a function of the average DVMT of the vehicle. Candidate vehicles are then identified as EVs based on input assumptions regarding the market penetration of EVs among candidate vehicles. EVs are only selected from the pool of vehicles previously identified as PHEV so that the cost calculations in Step #11 would be close to representing EV costs.

14. **Calculate Auto and Light Truck Travel on Metropolitan Area Roadways.** Since roadway congestion affects vehicle speeds and fuel economy, it is necessary to calculate roadway VMT in metropolitan areas. This is done by applying a factor calculated for the base year (2005) that is the ratio of urbanized area road auto and light truck DVMT calculated from Highway Performance Monitoring System (HPMS) data and the estimate of household DVMT of urbanized area households calculated by GreenSTEP. This ratio is calculated for each of the 6 metropolitan areas.

15. **Calculate Truck and Bus DVMT and Assign Proportions to Metropolitan Areas.** Statewide truck VMT is calculated based on changes in the total state income. As a default, a one-to-one relationship between state income growth and truck VMT growth is assumed. In other words, a doubling of total state income would result in a doubling of truck VMT. Portions of the statewide truck DVMT are assigned to metropolitan areas based on estimates derived from HPMS data. Bus DVMT is calculated from bus revenue miles that are factored up to total vehicle miles to account for miles driven in nonrevenue service.

16. **Adjust Metropolitan Area Fuel Economy to Account for Congestion.** Auto and light truck DVMT, truck DVMT and bus DVMT in metropolitan areas is allocated to freeways, arterials and other roadways. Truck and bus DVMT are allocated based on mode-specific data derived from the HPMS data. Auto and light DVMT are allocated based on a combination of HPMS derived factors and a model that is sensitive to the relative supplies of freeway and arterial lane miles. Systemwide ratios of DVMT to lane-miles for freeways and arterials are used to allocate DVMT to congestion levels using congestion levels defined by the Texas Transportation Institute for the Urban Mobility Report. Each freeway and arterial congestion level is associated with an average trip speed for conditions that do and do not include incidents. Overall average speeds by congestion level are calculated based on input assumptions about the degree of incident management. Speed vs. fuel efficiency relationships for light motor vehicles, trucks and buses are used to adjust the fleet fuel efficiency averages computed for each metropolitan area.

17. **Adjust Fuel Economy to Account for Eco-driving and Low Rolling Resistance Tires.** The average fuel economy of households identified as eco-drivers is adjusted based on assumed adjustment rates. Adjustment to fuel economy and power consumption is also made for households identified as having low rolling-resistance tires on their vehicles.

18. **Calculate Final Household Light Motor Vehicle Fuel Consumption, Electric Power Consumption, GHG Emissions and Costs.** Fuel consumption, electric power consumption and GHG emissions are recalculated to reflect the adjusted fuel economy and power consumption.

19. **Calculate Bus, Truck, and Passenger Rail Fuel Consumption and GHG Emissions Adjusted for Congestion.** The age distributions of trucks and buses are computed from base year distributions and input assumptions about changes in fleet turnover. The average MPG of the respective fleets is computed from the respective age distributions and respective assumptions about future MPG by model year. These fuel economy values are adjusted for the truck and bus VMT in metropolitan areas using the adjustment factors computed in Step #16.

Appendix C. GreenSTEP Calibration and Validation

Calibration of Annual Light Motor Vehicle Travel

2005 is chosen as a model calibration year because it is the closest model year to the vintage of household travel data used for model estimation (2001 NHTS).

Calibration of GreenSTEP consisted of calculating a factor to convert average daily household VMT calculated by GreenSTEP to annual light motor vehicle VMT. This factor was derived by dividing an independent estimate of annual statewide light motor vehicle VMT by the sum of all household daily VMT calculated by GreenSTEP for the calibration year.

The independent estimate of annual statewide light motor vehicle VMT was calculated from the estimate of total VMT prepared by ODOT for the Highway Performance Monitoring System (HPMS) and the split of VMT between light motor vehicles and medium and heavy trucks produced by ODOT's Finance Section based on fuel sales and weight mile tax records. The Finance Section total estimate of light motor vehicle VMT was not used because the increase in the estimate from 2000 to 2005 is does not reflect HPMS trends and is inconsistent with national trends. Figure C.1 compares the estimates of light motor vehicle VMT computed using the combination of HPMS and Finance Section data with the estimates of light motor vehicle VMT produced by the Finance Section.

Figure C.1 Comparison of Light Motor Vehicle Annual VMT Estimates Derived from HPMS and Finance Section Data

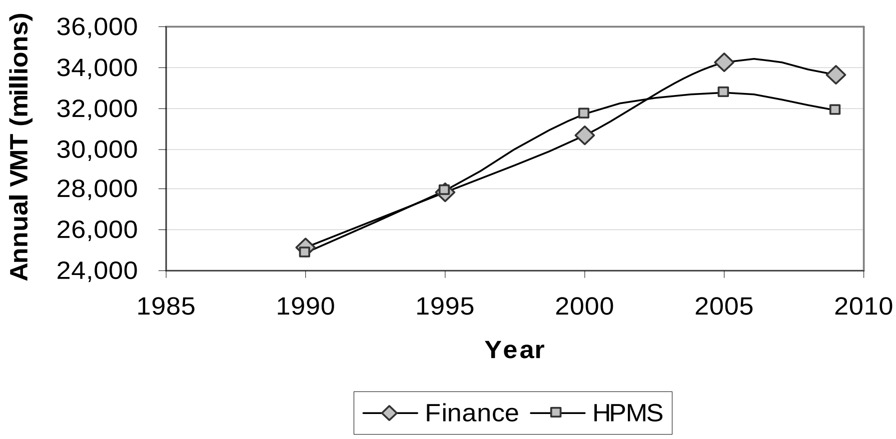


Table C.1 compares the 2005 calibration target for light motor vehicle annual statewide VMT, the GreenSTEP estimate of total average household daily VMT for 2005, and the ratio of the two. This ratio, 410.7, is the expansion factor to convert GreenSTEP household daily VMT to annual light motor vehicle VMT.

Table C.1 Comparison of Estimated and Modeled VMT

Quantity Estimated	Value
Annual Light Motor Vehicle VMT Target	32,796,641,195
GreenSTEP Total Daily VMT	79,853,713
Ratio	410.7

If GreenSTEP calculated all light motor vehicle VMT on Oregon's roads, one would expect the ratio to be 365. However, the current version of GreenSTEP does not calculate light motor vehicle VMT for commercial travel, nor does it calculate long-distance travel. Moreover, some light motor vehicle travel on Oregon's roads comes from out-of-state travelers and some travel by Oregon residents occurs on out-of-state roads. The household light motor vehicle travel computed by GreenSTEP is about 11 percent below the statewide total (365/410.7). This is reasonable considering the components of light motor vehicle travel unaccounted for by GreenSTEP.

The ratio shown in Table C.1 is applied for other years to expand the GreenSTEP daily estimates of VMT, fuel consumption, and GHG emissions to produce annual quantities for all light motor vehicle travel.

Historical Validation of Statewide VMT Estimates

The GreenSTEP estimates of light motor vehicle VMT were historically validated by comparing the estimates with the HPMS light motor vehicle estimates over the period from 1990 to 2005. Figure C.2 compares the calibrated GreenSTEP estimates with the annual HPMS estimates. The results are shown in Figure C.2. The percentages shown in the graph are the ratios of the GreenSTEP estimates to the corresponding HPMS estimates. It can be seen that the GreenSTEP estimates track the HPMS estimates closely.

Historical Validation of Light Motor Vehicle Fuel Consumption

GreenSTEP estimates of light motor vehicle fuel consumption were validated against estimates of gasoline consumption for highway use reported in the Federal Highway Administration's (FHWA) "Highway Statistics" reports. This is a reasonable comparison since almost all light motor vehicles and few heavy trucks use gasoline. Figure C.3 compares the expanded GreenSTEP daily estimates and the estimates reported in Highway Statistics. The percentages shown in the figure are the ratio of the GreenSTEP estimates to the Highway Statistics estimates. It can be seen that the estimates are very close.

Figure C.2 Comparison of Calibrated GreenSTEP and HPMS Estimates of Statewide Light Motor Vehicle Annual VMT

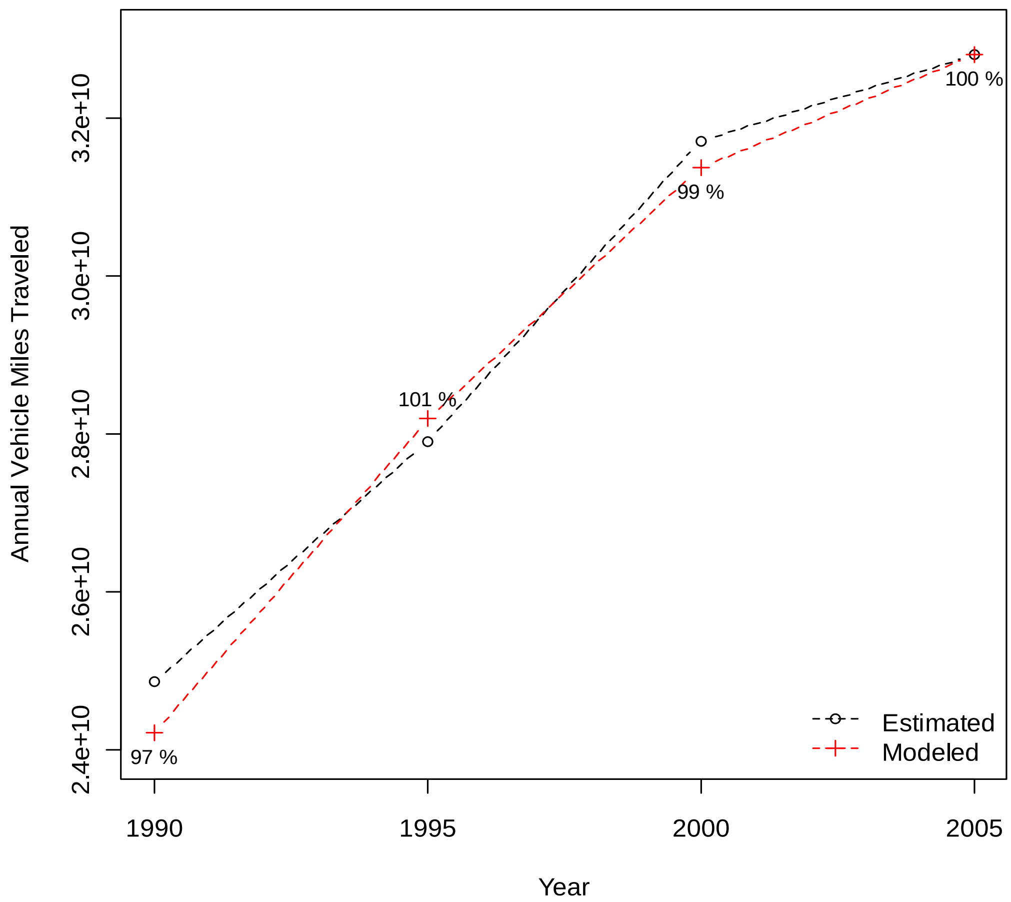
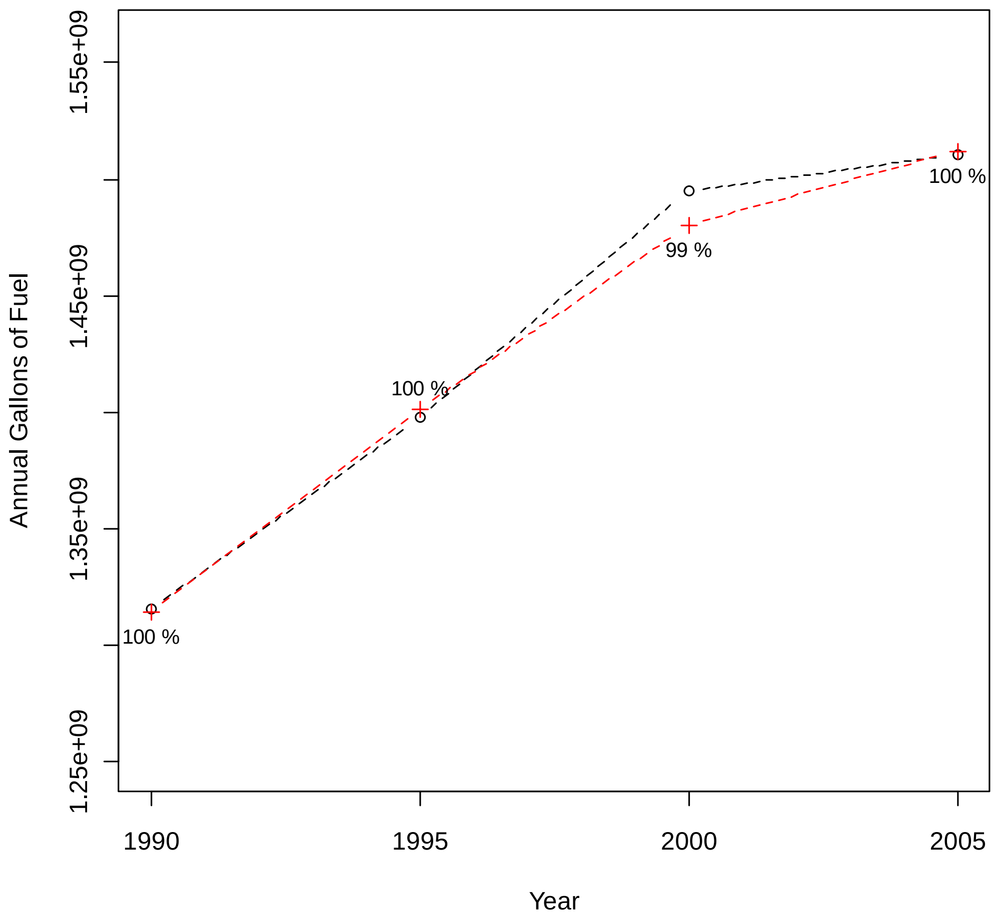


Figure C.3 Comparison of GreenSTEP and Highway Statistics Estimates of Fuel Consumed by Light Motor Vehicles



Comparison of Household Vehicle Travel Estimates at the Metropolitan Level

Results of the GreenSTEP model will be used to estimate GHG emissions at the metropolitan level. Therefore, a test of reasonableness of GreenSTEP VMT estimates is needed at the metropolitan level.[14] This is challenging because GreenSTEP calculates vehicle travel at the household level, not at the road level. Since a lot of metropolitan household travel occurs outside of metropolitan areas where households reside, and some travel on metropolitan area roadways comes from nonmetropolitan area residents, roadway VMT estimates (including estimates from metropolitan models) cannot be compared with GreenSTEP estimates. Since Oregon does not collect annual odometer readings for all metropolitan area households, there is

[14] Here and elsewhere in this report, references to metropolitan areas refer to the urbanized portion of metropolitan statistical areas. This corresponds well to metropolitan area urban growth boundaries.

no direct source of information on household VMT by metropolitan area. As a surrogate, GreenSTEP estimates were compared with independent estimates calculated using ODOT's new statewide integrated model (SWIM). The SWIM model was calibrated and validated using Oregon household travel survey and traffic count data.

To do this comparison, total mileage of household auto tours modeled with the SWIM short-distance travel model were tabulated for households in each metropolitan area and for all households in each state. From this, the proportions of total state household VMT traveled by households residing in each metropolitan area were calculated. The corresponding proportions were also calculated from GreenSTEP model results. Table C.2 compares the two sets of proportions. The ratios of the proportions are also shown. The very similar distributions of household VMT of these two independently calibrated and validated models supports the reasonableness of GreenSTEP's estimates at the metropolitan level.

Table C.2 Comparison of Household VMT Proportions Calculated from the GreenSTEP Model and the Statewide Integrated Model (SWIM)

Metropolitan Area	GreenSTEP	SWIM	Ratio
Bend	2.10 %	2.26 %	0.93
Corvallis	1.78 %	1.62 %	1.10
Eugene-Springfield	6.39 %	6.92 %	0.92
Metro	37.01 %	35.48 %	1.04
Rogue Valley	3.82 %	4.08 %	0.94
Salem-Keizer	5.55 %	5.40 %	1.03
Total	56.65 %	55.76 %	1.02

Conversion of Metropolitan Household VMT to Metropolitan Road VMT

The statutes call for estimates of GHG emissions from light motor vehicle travel on roads within metropolitan areas. Since the GreenSTEP model estimates emissions from light motor vehicles from metropolitan households, it is necessary to calibrate factors to convert metropolitan household VMT to metropolitan road VMT. This was done using HPMS data and federal cost allocation survey data as described below.

HPMS data is the primary source of traffic count data available for past years that is collected by a standardized sampling process. As such, it is the only practical source of data for metropolitan area road VMT for the base year (2005). However, while the HPMS data can be used to provide estimates of total road VMT by metropolitan area and by roadway functional class and metropolitan area, it cannot provide separate light and heavy vehicle VMT by metropolitan area. Since there is no other source of light motor vehicle VMT by metropolitan area, the values were estimated by using a combination of:

1. HPMS estimates of total VMT by roadway functional class and metropolitan areas;[15] and
2. National estimates of VMT by vehicle type and functional class.[16]

The split of total VMT for each metropolitan area by functional class was calculated from the HPMS data. Averages from 2004 to 2006 were used to compute the splits to reduce the effect of sampling errors in the data and the effects of a three-year traffic counting cycle. Table C.3 shows the resulting DVMT (daily VMT) estimates.

Table C.3 Estimated Year 2005 DVMT by Metropolitan area and Functional Class *(in thousands)*

Area	Functional Class*						
	PA-INT	**PA-OFE**	**PA-OTH**	**MINART**	**COLL**	**LOCAL**	**Total**
Bend	0	0	632	472	190	201	**1,496**
Corvallis	0	0	325	300	121	112	**858**
Eugene-Springfield	767	764	904	1,055	455	411	**4,355**
Metro	8,121	2,445	6,244	5,484	3,307	3,347	**28,948**
Rogue Valley	812	0	646	736	397	361	**2,953**
Salem-Keizer	1,082	398	1,615	439	279	343	**4,157**

*Functional classifications are as follows: PA-INT = principal arterial – interstate, PA-OFE = principal arterial – other freeway or expressway, PA-OTH = principal arterial – other, MINART = minor arterial, COLL = collector, and LOCAL = local.

National estimates of VMT by vehicle type and functional class were used to compute the average proportions of light motor vehicle and heavy vehicle VMT by functional class. The resulting proportions are shown in Table C.4.

[15] HPMS data on road VMT by functional class and metropolitan area was provided by ODOT's Traffic Monitoring Unit.

[16] Table II-6, 1997 Federal Highway Cost Allocation Study Final Report, Chapter II, http://www.fhwa.dot.gov/policy/hcas/final/two.htm.

Table C.4 Estimated Average Light and Heavy Motor Vehicle Percentages of VMT by Functional Class

Area	Functional Class						
	PA-INT	PA-OFE	PA-OTH	MINART	COLL	LOCAL	Total
Light Motor Vehicle	91.4%	94.2%	94.3%	95.5%	95.9%	96.1%	94.3%
Truck	8.3%	5.6%	5.4%	4.2%	3.8%	3.6%	5.5%
Bus	0.2%	0.2%	0.3%	0.3%	0.3%	0.3%	0.3%

The average light and heavy vehicle percentage splits by functional class were applied to the metropolitan VMT splits by functional class and the results were summed over all road classes for each metropolitan area to compute the light and heavy VMT splits by metropolitan area. These are shown in Table C.5.

Table C.5 Estimated Year 2005 Light Motor Vehicle DVMT by Metropolitan Area *(in thousands)*

	Light Motor Vehicle DVMT	Percent of Total DVMT
Bend	1,423	95.1%
Corvallis	817	95.2%
Eugene-Springfield	4,112	94.4%
Metro	27,244	94.1%
Rogue Valley	2,783	94.3%
Salem-Keizer	3,905	93.9%

The factors to convert from GreenSTEP metropolitan household DVMT to metropolitan roadway light motor vehicle DVMT were then computed by dividing the values in Table C.5 by the year 2005 GreenSTEP values for the final calibrated base year model run. The results are shown in Table C.6.

Table C.6 Estimated Base Year Ratio of Metropolitan Roadway Light Motor Vehicle DVMT and Metropolitan Household DVMT

Area	Ratio
Bend	0.85
Corvallis	0.57
Eugene-Springfield	0.81
Metro	0.92
Rogue Valley	0.91
Salem-Keizer	0.88

It should be noted that the ratios in Table C.6 are not the same as the ratio of internal-internal VMT to total VMT derived from urban travel demand models. In the latter case, the comparison is of different components of VMT on roads located within the metropolitan area. In the case of Table C.6, light motor vehicle road VMT within the metropolitan area is being compared to total VMT of metropolitan households. A significant proportion of metropolitan household VMT can take place outside of the metropolitan area. This indeed appears to be the case with the Corvallis area, whose ratio is 0.57. It makes sense that the ratio for Corvallis is much lower than other metropolitan areas because Corvallis is a small metropolitan area located near larger metropolitan areas (Salem-Keizer and Eugene-Springfield) and another city that is not much smaller.[17]

[17] In 2005, the Cities of Corvallis, Philomath, and Adair Village, which make up the large majority of the Corvallis MPO area, had a combined population of 58,470. The City of Albany, located about 10 miles from Corvallis, had a population of 45,360.

Appendix D. Description of First Round of Scenarios for Statewide Transportation Strategy for Reducing GHG Emissions

The modeling of scenarios for reducing greenhouse gas (GHG) emissions from light motor vehicles will be done in at least three rounds. Additional rounds of modeling may be done if necessary to develop a final strategy. The objective of the first round of modeling was to identify key factors necessary in order to approach the 2050 GHG reduction goal. In order to do this, a large number of scenarios, which reflect different combinations of urban growth, transportation, price, marketing, fleet, and technology characteristics, were modeled.

Building the First Round of Scenarios

Input variables for the GreenSTEP model fall into two groups. One is composed of socioeconomic factors that are not varied in order to achieve GHG emission reductions, but may be varied to test the resiliency of policy and technology scenarios to changes in conditions. These input factors include population growth, population age structure, per capita income growth, market price of fuel (not including taxes), and market price of electricity. The other factors are policy and technology variables that are defined for different scenarios.

The number of policy and technology factors affecting GHG emissions from light motor vehicles (autos and light trucks) is large. The number of combinations of factors is very large. This poses several substantial challenges:

- How to identify different factor combinations that could meet the GHG reduction goals;
- How to build an understanding of factor combinations that have synergistic effects and combinations that have contradictory effects; and
- How to organize scenarios made up of factor combinations so that they can be communicated fairly easily to decision-makers, advisory groups and the public.

Six categories were identified to group the policy and technology factors. The categories and the factors that are included in each are as follows:

1. Urban:
    a. Proportion of population growth occurring in urban areas;
    b. Urban area growth rates;
    c. Urban mixed-use growth proportions;
    d. Transit system growth;
    e. Parking pricing; and
    f. Growth in use of bicycles and other light-weight vehicles.
2. Roads:
    a. Growth in freeway system capacity;
    b. Growth in arterial system capacity; and
    c. Level of incident management.

3. Marketing:
    a. Employer-based demand management programs;
    b. Household-based demand management programs; and
    c. Promotion of eco-driving and vehicle use optimization.
4. Technology:
    a. Fuel economy of internal combustion engines (ICE);
    b. Battery range, fuel economy, market share, and efficiency of plug-in hybrid electric vehicles (PHEV);
    c. Battery range, market share, and efficiency of battery electric vehicles (BEV);
    d. Mix and carbon intensity of vehicle fuels; and
    e. Carbon intensity of electrical power.
5. Fleet:
    a. Auto and light truck proportions;
    b. Rate of fleet turnover; and
    c. Car-sharing participation rates.
6. Prices:
    a. Fuel use and emissions pricing (gas tax, carbon tax); and
    b. Vehicle travel pricing (VMT tax, pay-as-you-drive insurance).

To carry out the first round of modeling, a limited number of levels were defined for each category and all combinations of levels were modeled. The base level in each category represents the reference case conditions for factors in the category. Therefore, one of the combinations of inputs represents the reference case. The other levels represent alternative conditions that increase factors from the reference case in order to test the effects of changes that are aimed at reducing GHG emissions. Three levels were defined for the urban and technology categories. Two levels were defined for each of the other categories. This required the development of 14 input datasets (2*3 + 2*4) and results in 144 combinations (3^2 * 2^4) that were modeled. This is a manageable number of model runs that will do a reasonable job of exploring the problem space.[18]

[18] It takes one to two hours to run GreenSTEP for the 2050 forecast year on the computers that are available in the Transportation Planning Analysis Unit. Therefore, running 144 scenarios takes from 144 to 288 computer hours.

Defining the Levels for Each Category and the Corresponding Factor Inputs

Urban (Three Levels)

Level 1 (Reference Case)

This level has the following characteristics:

- The split of population between urban and rural areas reflects current policies and trends;
- All urban growth boundaries expand at the rate of population growth (no change in density);
- On average, about 10 percent of households live in mixed-use neighborhoods;
- Current per capita transit service levels are maintained;
- The extent of parking pricing reflects current conditions; and
- Bicycle and light-weight electric vehicle usage is at the current level.

Level 2

This level is the same as Level 1 with the following exceptions:

- All urban growth boundaries expand at one-half the rate of population growth; and
- On average, about 45 percent of households live in mixed-use neighborhoods.

Level 3

The following changes are made to the reference case conditions in addition to the Level 2 changes.

- Per capita transit service levels are increased by three times;
- The percentage of workers paying for parking triples and daily parking fees (in constant dollars) increases by one-third;
- Between 20 percent and 25 percent of all single-occupant vehicle trips having a round trip distance of 5 miles or less shifts to bicycles, electric bicycles, or similar conveyances.

Roads (Two Levels)

Level 1 (Reference Case)

This level has the following characteristics:

- The per capita supplies (lane-miles) of metropolitan area freeways and arterials lane miles grow at rates consistent with the financially-constrained metropolitan area regional transportation plans; and
- Delay due to incidents is at current levels.

Level 2

Level 1 values are changed as follows:

- Equivalent lane-mile capacities of freeways and arterials grow by at least 85 percent of the rate of population growth. This could occur through physical expansion, bottleneck removal, and/or intelligent transportation systems (ITS) improvements.
- Incident management programs are able to eliminate one-half of incident-caused delay.

Marketing (Two Levels)

Level 1 (Reference Case)

This level has the following characteristics:

- Strong workplace-oriented TDM programs reach 50 percent of workers in the Portland metro area, 5 percent in the Salem and Eugene metro areas, and 1 percent in other metropolitan areas;
- Household-oriented individualized marketing programs are implemented only in the Portland metropolitan area and reach 1 percent of households; and
- No households participate in eco-driving programs, and no households optimize their use of vehicles to minimize fuel consumption.

Level 2

Marketing programs expand in the following ways:

- Strong workplace-oriented TDM programs reach 75 percent of workers in all metropolitan areas;
- Individualized marketing programs reach 50 percent of households in all metropolitan areas; and
- Two thirds of households participate in eco-driving and optimize their vehicle use to minimize fuel consumption.

Technology (Three Levels)

Level 1 (Reference Case) (50 mpg by 2025 and 10 percent lower carbon)

This level assumes the following conditions:

- Efficiency of light-duty vehicles improves to 50 mpg by 2025, then stops. (Reductions due to either California's GHG limits (LEV III) or Federal fuel efficiency (CAFE) standards).
- Low Carbon Fuel Standard decreases the carbon intensity of gasoline and diesel 10 percent by 2022 with no further reductions.
- Electric Vehicles (EVs) and Plug-in Hybrid Electric Vehicles (PHEVs) gain market at Business As Usual (BAU) rate through 2050.
- Carbon intensity of electricity decreases as provided by Oregon's Renewable Portfolio Standard.

Level 2 (100 mpg by 2050 and 20% Lower-Carbon Fuel)

This level assumes the following conditions:

- Efficiency of light-duty vehicles improves to 100 mpg by 2050;
- Low Carbon Fuel Standard decreases the carbon intensity of gasoline and diesel 20 percent by 2035 with no further reductions;
- EVs and Plug-in Hybrids gain market share at BAU rate through 2050; and
- Carbon intensity of electricity decreases as provided by Oregon's Renewable Portfolio Standard.

Level 3 (100 mpg by 2050, 20 Percent Lower-Carbon Fuel, High EVRate and Low-Carbon Electricity by 2050)

This level assumes the following conditions:

- 100 mpg light-duty vehicles by 2050;
- Carbon intensity of gasoline and diesel decreases 20 percent by 2035 (no further reductions);
- EVs and Plug-in Hybrids adopted at high rate; and
- No coal-generated electricity and large proportion renewable electricity by 2050.

Fleet (Two Levels)

Level 1 (Reference Case)

This level assumes the following:

- No changes in the age distributions of the auto and light fleets;
- No changes in the composition (light truck vs. auto) of the vehicle fleet; and
- Current levels of car-sharing (~0).

Level 2

The following changes are made with this level:

- The age structure of the fleet is similar to that of the northeastern U.S. (The 95 percent falls to about 75 percent of the current value.).
- The percentage of light trucks in the vehicle fleet falls to be similar to that of the northeastern U.S. (between 40 percent and 45 percent).
- Carsharing rates achieve the maximum deployment levels estimated for the "Moving Cooler" study. (One vehicle per 500 persons in high density areas and one vehicle per 1,000 persons in medium density areas.)

Prices (Two Levels)

Level 1 (Reference Case)

This level assumes only price (not including the market prices for fuel and electricity) to be the gas tax, which remains the same in constant dollars.

Level 2

This level assumes the following prices (in addition to the market prices for fuel and electricity):

- A VMT tax of 12 cents per mile. This is roughly equivalent to the difference between what Europeans and Americans pay in road taxes on a per mile basis.
- Pay-as-you-drive insurance for all vehicles at a rate of 6 cents per mile.[19]

[19] The Policy Committee for the Statewide Transportation Strategy recommended that in the future, pay-as-you-drive insurance should be identified as a marketing strategy rather than a pricing strategy because it is not an additional charge, rather it is an incentive to drive less.

Appendix E. Relevant Links

The following are relevant links to statutory guidelines and state agency implementation efforts:

- **Oregon Sustainable Transportation Initiative web site**. Provides information on ongoing state agency efforts at implementing relevant sections of the Jobs and Transportation Act (2009) and Section 85 Oregon Laws (2010).
  - http://www.oregon.gov/ODOT/TD/TP/OSTI.shtml
- **The Jobs and Transportation ACT** (2009). Full text as codified in Chapter 865 Oregon Laws (2009).
  - http://www.leg.state.or.us/09orlaws/sess0800.dir/0865.htm
- **Chapter 85 Oregon Laws** (2010). Full text.
  - http://www.leg.state.or.us/10ssorlaws/0085.htm
- **Chapter 468A – Air Quality** (2009). Full text. See relevant section 468A.205
  - http://www.leg.state.or.us/ors/468a.html