Appendix C: Long-Range Projections of Market Penetration for Light Duty Hybrid Electric and Diesel Vehicles, and Impact on Oregon's Highway Fund Revenue

Data Tables, Assumptions and Methodology to Develop Fuel Economy Scenarios and Revenue Projections

Background

Information in Appendix C is provided in support of Figure 2I, *Potential Impacts of Fuel Efficiency increases & Alternative Fuel Vehicles on Oregon Gasoline Tax Revenue (2004-2024).* That figure illustrates projected trends in revenue for four defined scenarios:

- Scenario A: Revenue without Mile Per Gallon (MPG) Improvement
- Scenario B: Revenue with Small Fuel Economy Increase
- Scenario C: Revenue with Medium Fuel Economy Increase ("The Best Guess")
- Scenario D: Revenue with Large Fuel Economy Increase

The main assumptions that are included within those revenue forecasts relate to:

- MPG improvements to the conventional (gasoline-powered) light vehicle fleet
- Timing and extent of introduction of hybrid electric and clean diesel passenger vehicles
- Hybrid electric vehicle and diesel vehicle fuel economy improvements over time
- Fleet turnover rates

Since the late 1990s, Oregon Department of Transportation (ODOT) has closely monitored advances in automobile propulsion systems. Major advances in these systems would have the potential to eliminate the reliability and capacity of the fuel tax to support highway programs. At present, electric vehicles and fuel cell vehicles[1] do not appear to be capable of capturing significant market share at any time in the near- or medium-term future. In addition, as Oregon taxes liquid and gaseous fuels used for highway propulsion under its Use Fuel statutes, alternative fuel vehicles are not an immediate threat to Highway Fund revenue.

[1] While General Motors believes fuel cell vehicles may go into mass production by 2010, most auto manufacturers and industry analysts believe 2020 is a more realistic date. When they appear, they will compete with diesel and HEVs.

However, the Toyota Prius and the Honda Civic hybrid demonstrate the level of fuel efficiency that hybrid-electric vehicle (HEV) technology can achieve in the near-term[2].

In addition to HEV technology, clean diesel passenger cars offer a viable near-term alternative to conventional gasoline-powered vehicles. Diesel automotive engines have fuel economy (in terms of miles per gallon) that is about 35 percent greater than similar vehicles with gasoline engines. In the European Union, the proportion of new light vehicles powered by diesel engines is approaching 50 percent. Most analysts believe diesel vehicle sales in the U.S. will dramatically increase once refiners begin producing "clean diesel" fuel and Tier 2 emissions requirements are met.

Diesel and HEVs are expected to compete against each other for market share. Diesel engines are likely to win greater market share in the light truck segment, while HEVs are likely to win greater market share in the car segment of the light vehicle market. Typically, these vehicles cost $2,000-$4,000 more than comparable gasoline-only vehicles, with HEVs being somewhat more costly than diesel vehicles. Diesel vehicles are already mass-produced, and currently capture about 1.6 percent of the U.S. market. HEVs have just begun to be mass-produced. HEVs can be made to be considerably more efficient than current models. Various rates of HEV improvement are incorporated into the scenarios listed on page C-1, and described in detail below.

Methodology

Scenario Development

Table C1, page C-5, shows the assumptions that provide the technical basis for Scenarios A, B, C and D. ODOT Financial Services acknowledges that Scenarios B, C and D presented and described below are substantially based on the work of other analysts[3] with some major modifications where appropriate[4].

Scenarios B, C and D incorporate the expectation that incremental improvements to internal combustion engines will continue into the future. These improvements will affect diesel and HEV efficiency as well as traditional gasoline engines. In order to show the net effect of increased dieselization, the current market share of diesel vehicles (1.6 percent) is subtracted from each year's share. Light vehicle sales forecasts often project continual record-high sales increasing with economic growth. In view of increasing interest rates, increasing vehicle longevity, the aging of the "baby boom" generation, and past patterns of vehicle sales, these projections do not seem realistic. Instead, ODOT chose to assume a constant long-run average sales rate of 17.1 million light vehicles per year. The fuel economy of HEVs is expected to

[2] The four-cylinder Toyota Camry has a composite EPA rating of about 29 miles per gallon. In contrast, the mid-size Prius has a composite EPA rating of about 56 miles per gallon; an improvement of 93%. Consumers' Union tests rated the four cylinder Camry at 24 miles per gallon and the Prius at 44 miles per gallon; an improvement of 83%.
[3] Greene, David L.; K.G. Duleep and Walter McManus. *Future Potential of Hybrid and Diesel Powertrains in the U.S. Light-Duty Vehicle Market*, Oak Ridge National Laboratory, Oak Ridge, TN, August 2004.
[4] Greene et al. (op cit.) generally assume a price of $1.50 per gallon in 2004 $s of both gasoline and diesel fuel.

significantly improve over time. Therefore, the scenarios below include different rates of increasing fuel efficiency.

Long-term forecasts are often presented on a periodic but intermittent basis, as in this case, for 2008 and 2012. In the scenarios below, interpolation between these years was the norm. Market shares were estimated for calendar years and subsequently adjusted to reflect fiscal year impacts. This effort assumes alternative propulsion systems are equally applied to vehicles across the fuel economy spectrum. In reality, these systems will tend to be applied to vehicles with relatively low levels of fuel economy. Therefore, the reductions in fuel consumption projected here are likely to be slightly understated. Finally, the pattern of Oregon vehicle purchases is assumed to be the same as the nationwide pattern. Oregon's tax credit for HEV purchases is assumed not to have any effect.

Scenario A: Revenue without Mile Per Gallon (MPG) Improvement
Existing 2004 MPG stays the same through 2023.

Scenario B: Revenue with Small Fuel Economy Increase
HEVs captured about 0.5 percent of the light vehicle market during 2004. The expected 2005 market share is 1.6 percent. A 2004 J.D. Power and Associates report projected a 2008 market share of 2.5 percent and a 2013 market share of 3.2 percent. This was extrapolated to 3.5 percent in 2016. These estimates are the lowest identified by a reputable source. New HEVs are not expected to exceed 2004 Prius levels of fuel economy relative to comparable vehicles until 2015.

Diesel vehicles maintain a constant market share until 2008. In 2008, clean diesel fuel and vehicles meeting Tier 2 emissions standards become more widely available. At that time, the diesel share increases by 0.8 percentage points. After that, diesel vehicle purchases increase to 2.6 percentage points above current market share (1.6 percent) in 2012, and 14.4 percentage points above current market share in 2016. The 2008 and 2012 figures are based on the low end of an Oak Ridge National Laboratory study[5]. The 2016 figure is a J.D. Power and Associates estimate.

In essence, this scenario assumes the diesel engine becomes the alternative propulsion system of choice, but at market penetration rates well below those of present-day Europe. By 2016, the combination of diesel and HEVs sales reaches 19.5 percent. Under this scenario, HEVs and increased diesel vehicle market share, as a result of increased fuel economy, reduce Highway Fund fuel tax revenues by about 1.7 percent in FY 2017 compared to the ODOT standard forecast (Table C3).

Scenario C: Revenue with Medium Fuel Economy Increase (The "Best Guess")
The medium case scenario uses the same 2004 and 2005 starting points as the other scenarios. However, projections are based on a lower growth scenario contained in the Oak Ridge National Laboratory study that assumes much less effective product selection and market targeting on the

[5] Greene, David L.; K.G. Duleep and Walter McManus. *Future Potential of Hybrid and Diesel Powertrains in the U.S. Light-Duty Vehicle Market*, Oak Ridge National Laboratory, Oak Ridge, TN, August 2004.

part of vehicle manufacturers than assumed in Scenario D. The 2016 figure uses the market share achieved if diesel vehicles were the only alternatives to traditional vehicles (the third highest of four "beyond 2012" scenarios). These assumptions should also remove most production/supply constraints. With these assumptions, HEV market share reaches 4.6 percent by 2008 and 10.2 percent by 2012. Even though competition with diesels intensifies, HEVs reach a market share of 14.7 percent by 2016. New HEVs exceed 2004 Prius levels of fuel economy relative to comparable vehicles in 2013.

Similar to the other scenarios, diesel vehicles maintain a constant market share until 2008. In 2008, clean diesel fuel and vehicles meeting Tier 2 emissions standards become more widely available. At that time, the diesel share increases by 0.8 percentage points. After that, diesel vehicle purchases increase to 2.5 percentage points above current market share (1.6 percent) in 2012, and 14.7 percentage points above current market share in 2016.

Under this scenario, the popularity of diesel vehicles surpasses that of HEVs in 2016. By 2016, the combination of diesel and HEV market penetration reaches 31 percent. In the medium case scenario, HEVs and increased diesel vehicle market share reduce Highway Fund fuel tax revenues by about 3.6 percent in FY 2017 compared to the ODOT standard forecast (Table C3).

Scenario D: Revenue with Large Fuel Economy Increase

The high case scenario uses the same 2004 and 2005 starting points as the low case scenario. Rapid growth is based on an Oak Ridge National Laboratory consumer choice modeling study that assumes perfect market timing and product selection by vehicle manufacturers, and no supply/production constraints on those manufacturers[6]. Their "beyond 2012" figures were assumed to apply to 2016. With these assumptions, HEV market share reaches 7.1 percent by 2008 and 15 percent by 2012. As competition with diesels intensifies, HEVs reach a market share of only 16.5 percent by 2016. New HEVs exceed 2004 Prius levels of fuel economy relative to comparable vehicles in 2009.

Similar to the low case scenario, diesel vehicles maintain a constant market share until 2008. In 2008, clean diesel fuel and vehicles meeting Tier 2 emissions standards become more widely available. At that time, the diesel share increases by 2.3 percentage points. After that, diesel vehicle purchases increase to 5.6 percentage points above current market share (1.6 percent) in 2012, and 22.2 percentage points above current market share in 2016.

Under this scenario, the popularity of diesel vehicles surpasses that of HEVs in 2015. By 2016, the combination of diesel and HEVs sales reaches 40.3 percent, approaching the market penetration rate of diesel vehicles in present-day Europe. In the high case scenario, HEVs and increased diesel vehicle market share reduce Highway Fund fuel tax revenues by about 5.5 percent in FY 2017 compared to the ODOT standard forecast.

[6] Greene, David L.; K.G. Duleep and Walter McManus. *Future Potential of Hybrid and Diesel Powertrains in the U.S. Light-Duty Vehicle Market*, Oak Ridge National Laboratory, Oak Ridge, TN, August 2004.

Revenue Calculations

Revenue projections for the four scenarios were created by multiplying scenario factors and fuel consumption trend data by the existing 24 cents/gallon Oregon state fuel tax on gasoline, as shown in Table C3.

Table C1: Assumptions Used in Scenario Development

Assumptions for Scenarios (2004-2023)[7]	**Scenario A** **Revenue Without MPG Improvement** **(Global Insight)**	**Scenario B** **Small Fuel Economy Increase** **(JD Power)**	**Scenario C** **"Best Guess"— Moderate Fuel Economy Increase** **(Greene, et al., DOE Report)**	**Scenario D** **Large Fuel Economy Increase** **(Greene, et al., DOE Report)**
19 Year Change in Oregon Light Duty On-Road Fleet Average MPG[8]	0 mpg	1.84	2.74	4.07
20 Year % Change in Oregon Light Duty On-Road Fleet Average Fuel Economy	O%	9%	14%	21%
Hybrid market penetration by 2008	0%	2.5%	4.6%	7.1%
Hybrid market penetration by 2012	0%	3.1%	10.2%	15%
Diesel (light duty) market penetration by 2008 (net of existing 1.6%)	0%	0.8%	0.8%	2.3%
Diesel (light duty) market penetration by 2012 (net of existing 1.6%)	0%	2.6%	2.5%	5.6%

Source: Oregon Department of Transportation (May 2005)
Data Sources indicated in table heading.

[7] Greene, Duleep & McManus, *Future Potential of Hybrid and Diesel Powertrains in the U.S. Light-Duty vehicle Market*, August 2004 (ORNL/TM-2004/181) Obtained electronically in May 2005 from Oak Ridge National Laboratory website at http://cta.ornl.gov/cta/Publications_Index.shtml

[8] Note that changes in existing on-road fleet fuel economy occurs much slower than the annual changes in new vehicle fuel economy standards, because of the effect of averaging a small percentage of each successive year's more fuel-efficient vehicles with the majority of the fleet, consisting of older, less fuel-efficient vehicles.

TABLE C2: 2004-2024 FORECAST FOR FUEL ECONOMY IN OREGON ON-ROAD LIGHT VEHICLE FLEET

Column A	Column B	Column C	Column D
FY	**Oregon On-Road MPG Forecast (Light Vehicles)[9]**	**MPG Shift Over 2004**	**MPG Increase Over Previous Year**
2004	19.82	N/A	N/A
2005	19.78	0.997908633	0.997908633
2006	19.76	0.996760045	0.998849005
2007	19.79	0.998389355	1.001634605
2008	19.84	1.000629529	1.002243788
2009	19.87	1.002522151	1.001891431
2010	19.91	1.004215523	1.001689112
2011	19.96	1.006894047	1.00266728
2012	20.01	1.009223001	1.002313008
2013	20.08	1.01307937	1.003821126
2014	20.14	1.015738221	1.002624524
2015	20.21	1.01950127	1.003704743
2016	20.26	1.022009801	1.002460547
2017	20.30	1.023943282	1.001891842
2018	20.33	1.025672973	1.001689245
2019	20.39	1.028408498	1.002667054
2020	20.43	1.03078739	1.002313179
2021	20.51	1.034725981	1.003820953
2022	20.57	1.037441328	1.002624219
2023	20.64	1.041285086	1.003705036
2024	20.68	1.043132814	1.001774469

Source: Oregon Department of Transportation Financial Services (April 2005)

[9] Long range mileage forecast for national light vehicle fleet shown in Column B was provided by Global Insight.

TABLE C3: CALCULATIONS FOR 2004-2024 OREGON GASOLINE TAX REVENUES, BASED ON POSSIBLE FUEL ECONOMY SCENARIOS*

A	B**	C	D	E***	F	G	H
FY	Annual Statewide Light Vehicle Gallons (Millions)	Revenue Without MPG Improvement & Inflation Indexed	Revenue Without MPG Improvement (Scenario A)	Standard ODOT Forecast LV Fuel Tax Revenue	Small Fuel Economy Increase (Scenario B)	Medium Fuel Economy Increase (Scenario C or "Best Guess")	Large Fuel Economy Increase (Scenario D)
2004	1615.0	387.6	387.6	387.6			
2005	1657.1	405.3	396.9	397.7	397.6	397.6	397.6
2006	1695.1	420.7	405.5	406.8	406.6	406.5	406.5
2007	1730.7	438.2	414.7	415.4	415.0	414.8	414.7
2008	1761.5	455.7	423.0	422.8	422.2	421.8	421.5
2009	1792.6	475.1	431.3	430.2	429.4	428.7	428.0
2010	1813.7	493.4	437.1	435.3	434.1	433.0	431.4
2011	1833.3	513.4	443.0	440.0	438.4	436.7	434.1
2012	1853.8	536.5	449.0	444.9	442.8	440.2	436.5
2013	1871.7	560.5	455.1	449.2	446.5	442.9	438.2
2014	1892.0	585.7	461.2	454.1	450.5	445.7	440.0
2015	1910.4	612.0	467.4	458.5	453.8	447.7	441.1
2016	1931.5	639.5	473.8	463.6	457.3	449.8	442.3
2017	1953.8	668.3	480.2	468.9	461.1	451.9	443.3
2018	1976.9	698.3	486.6	474.5	464.6	454.0	443.1
2019	1998.2	729.6	493.2	479.6	467.7	455.5	442.2
2020	2020.5	762.4	499.9	484.9	470.9	456.8	440.8
2021	2040.0	796.7	506.6	489.6	473.0	457.3	438.2
2022	2062.2	832.4	513.4	494.9	475.1	457.8	435.5
2023	2082.3	869.8	520.4	499.7	476.3	457.3	431.8

Source: Oregon Department of transportation Financial Services (April 2005)
**The projected revenues shown are not inflation indexed. That is, they are shown in current dollars, and assume 24 cents/gallon Oregon state fuel tax on gasoline.*
***Column B represents statewide gasoline consumption based on population, per capita VMT trends and the Global Insight fuel economy forecast shown in Table C2.*
****Column E shows official ODOT financial forecast until year 2011; figures from 2012 to 2023 represent trendline data.*
Column E was then used to calculate figures in Scenarios A, B, C and D shown in columns D, F, G and H, respectively.