Program Analysis Methodology

Office of Transportation Technologies

Quality Metrics 2001
- Final Report -

February 23, 2000

Prepared by:

OTT Analytic Team
http://www.ott.doe.gov/facts.html

SCP
Science
Communications
Planning

Prepared for:

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Foreword/Acknowledgement

The Analytic Support Team for the Office of Transportation Technologies, which is responsible for this report, consists of : Phil Patterson of the Office of Transportation Technologies at the U.S. Department of Energy, John Maples of TRANCON, Inc. (subcontractor to Oak Ridge National Laboratory), Jim Moore of TA Engineering, Inc. (subcontractor to Argonne National Laboratory), and Alicia Birky of the National Renewable Energy Laboratory.

In addition to the analytic team, this report reflects the efforts of many program staff persons and researchers of the U.S. Department of Energy, the national scientific research laboratories, and related contractors. The efforts of these individuals are also acknowledged.

Other individuals and organizations assisted this project in a range of capacities. William Shadis of TA Engineering provided contributing authorship, editing and final assembly assistance. Melanie Bennett of TA Engineering once again effectively coordinated inputs from many contributors, and provided timely assistance in producing this report.

Table of Contents

List of Exhibits

Page No.

Executive Summary

Executive Summary

"Quality Metrics" is the term used to describe the analytical process for measuring and estimating future energy, environmental and economic benefits of US DOE Office of Energy Efficiency and Renewable Energy programs. This report focuses on the projected benefits of the forty-one (41) programs currently supported through the Office Of Transportation Technologies (OTT) under EE/RE. For analytical purposes, these various benefits are subdivided in terms of Planning Units which are related to the OTT program structure.

The scope of this report encompasses light vehicles including passenger automobiles and class 1 & 2 (light) trucks, as well as class 3 through 8 (heavy) trucks. The range of light vehicle technologies investigated include electric, hybrid electric, fuel cell, advanced diesel, natural gas-fueled, and stratified charge direct-injection. A future distribution of light vehicle sizes, applications, and performance levels is calculated based on current vehicle stocks and trends, and consumer preferences. The heavy vehicle technologies investigated include hybrid, natural gas-fueled and advanced diesel. The effects of advanced materials technologies across all vehicle types are also analyzed.

Analysis results quantify various national benefits including energy and petroleum consumption reductions, carbon emission reductions, criteria pollutant emissions reductions, and the associated economic impacts on the Gross Domestic Product (GDP) and jobs. Benefit/cost analyses of the various technologies are also included. The time focus of the analysis is from the present to the year 2020.

The programs currently conducted by OTT Offices are shown on the left side of Exhibit E1. OTT is composed of four line-offices managing many separate programs. For Quality Metrics, OTT activities are aggregated into planning units based on specific program activities that are shown in the right side of Exhibit E1.

Exhibit E2 summarizes the specific vehicle technologies and alternative fuel that are evaluated under Quality Metrics. Five light vehicle categories and four heavy vehicle categories are considered. Each technology-vehicle category/type is analyzed separately as to when and how quickly the new technology can enter the market and its effects on energy use, the environment and the economy. The estimated total effect of the OTT programs is then simply the sum of the individual effects.

A variety of analytical models are used to calculate the various projected OTT Program benefits. Five (5) analytical tools are currently used: VSCC Model, The IMPACTT Model, The GREET Model, The HVMP Model, and The ESM Model. Outputs from some of these models become inputs to some of the others. The relationships of the various models are shown in Exhibit E3.

Exhibit E1. OTT Program Structure and QM Planning Units

OTT Offices and Programs				OTT Functions & Planning Units			
Office of Fuels Development (OFD)	**Office of Advanced Automotive Technologies (OAAT)**	**Office of Heavy Vehicle Technologies (OHVT)**	**Office of Technology Utilization (OTU)**	**Fuels Development**	**Vehicle Technologies R&D**	**Materials Technologies**	**Technology Deployment**
Biodiesel Program	Advanced Battery Readiness Ad Hoc Working Group	Advanced Petroleum-Based Fuel Program	AFV Incentive Program	Blends	Hybrid Systems R&D	Propulsion System Materials	Household CNG
Biofuels Program	Alternative Fuels Research and Development	Alternative Fuel Truck Application Program	Alternative Fuels Data Center	Flex-Fuel	Fuel Cell R&D	Light Vehicle Materials-Household EV	EPACT Fleet
Ethanol Conversion Program	Carat Program	Atmospheric Reactions Program	Clean Cities Program	Dedicated Conventional	Advanced Combustion R&D-SIDI	Light Vehicle Materials-Hybrid Vehicle	
Feedstock Development Program	CIDI Program	Diesel Emissions Control-Sulfur Effects	Credits Program	Fuel Cell	Advanced Combustion R&D-Car CIDI	Light Vehicle Materials-Fuel Cell Vehicle	
Regional Biomass Program	Electric Vehicle Program	Fuel and Engine Technologies Program	EPACT Fleet Leadersip Programs		Advanced Combustion R&D-Light Truck CIDI		
	Fuel Cell Program	Heavy Duty Engine Development Program	Federal Alternative Fuels USER Program		Electric Vehicles R&D-Household EV		
	Fuels Research and Development Program	Heavy Vehicle Emissions Reduction Technologies	Federal Fleet Alternative Fuel Vehicle Program		Electric Vehicles R&D-EPACT/ZEV Mandates		
	GATE Program	Heavy Vehicle Emissions Testing Program	Field Operations Program		Heavy Vehicle Systems R&D-Class 3-6		
	HEV Program	Heavy Vehicle Program	Infrastructure Working Group		Heavy Vehicle Systems R&D-Class 7&8		
	PNGV	Transit Bus Program	Local Government and Private Fleets-Regulation and Compliance		Heavy Vehicle Systems R&D-Class 7&8 CNG		
	US Advanced Battery Consortium		Pilot Program				
	Cool Car Program		State and Alternative Provider Fleets-Regulation and Compliance State and Local Incentives Program				

Exhibit E2. Vehicle/Technology Analysis Matrix

Technologies	Light Vehicles					Heavy Vehicles			
	Small Cars	Large Cars	Sport Utility Vehicles	Minivans	Pickup Trucks & Large Vans	Class 3-6 Trucks	Class 7 & 8 Trucks		
							Type 1	Type 2	Type 3
CIDI (Advanced Diesel)									
Hybrid (Gasoline/Battery)		For Each Technology-Vehicle Category/Type Intersection Determine:					■	■	■
Fuel Cell		- Introduction Year				■	■	■	■
SIDI (Advanced SI)		-Introduction and Growth "S curve"				■	■	■	■
Electric (Battery)		-Petroleum/Fuel/Emission/GHG effects projected 2000 through 2020				■	■	■	■
Natural Gas		-Employment/GDP effects projected 2000 through 2020							
Ethanol (neat, flex fuel, blends & extenders)						■	■	■	■

■ = not included

An example of the various technologies applied to one of the light vehicle categories (large cars) is shown in Exhibit E4. Note that the advanced technology attributes are normalized and presented as ratios to the conventional vehicle baseline attributes. These attributes form the basis for the inputs to the VSCC Model. A key output of the VSCC model is market penetrations of the technologies. The projected market penetration of the combined light vehicle technologies is shown in Exhibit E5. Note that these technologies must not only compete with the conventional light vehicles they replace but also with each other. A separate sensitivity study was also conducted in which each light vehicle technology was analyzed separately against conventional light vehicles in order to measure their maximum market penetration potential.

Based on the assumed vehicle technology attributes and the projected market penetrations, the energy and petroleum savings, energy cost savings and carbon emissions reductions attributable to each of the OTT Planning Units were calculated over the analysis period. This comprises the main element of the Quality Metrics reporting requirements and is shown individually and totaled in Exhibit E6.

Exhibit E3. OTT Impact Assessment Process

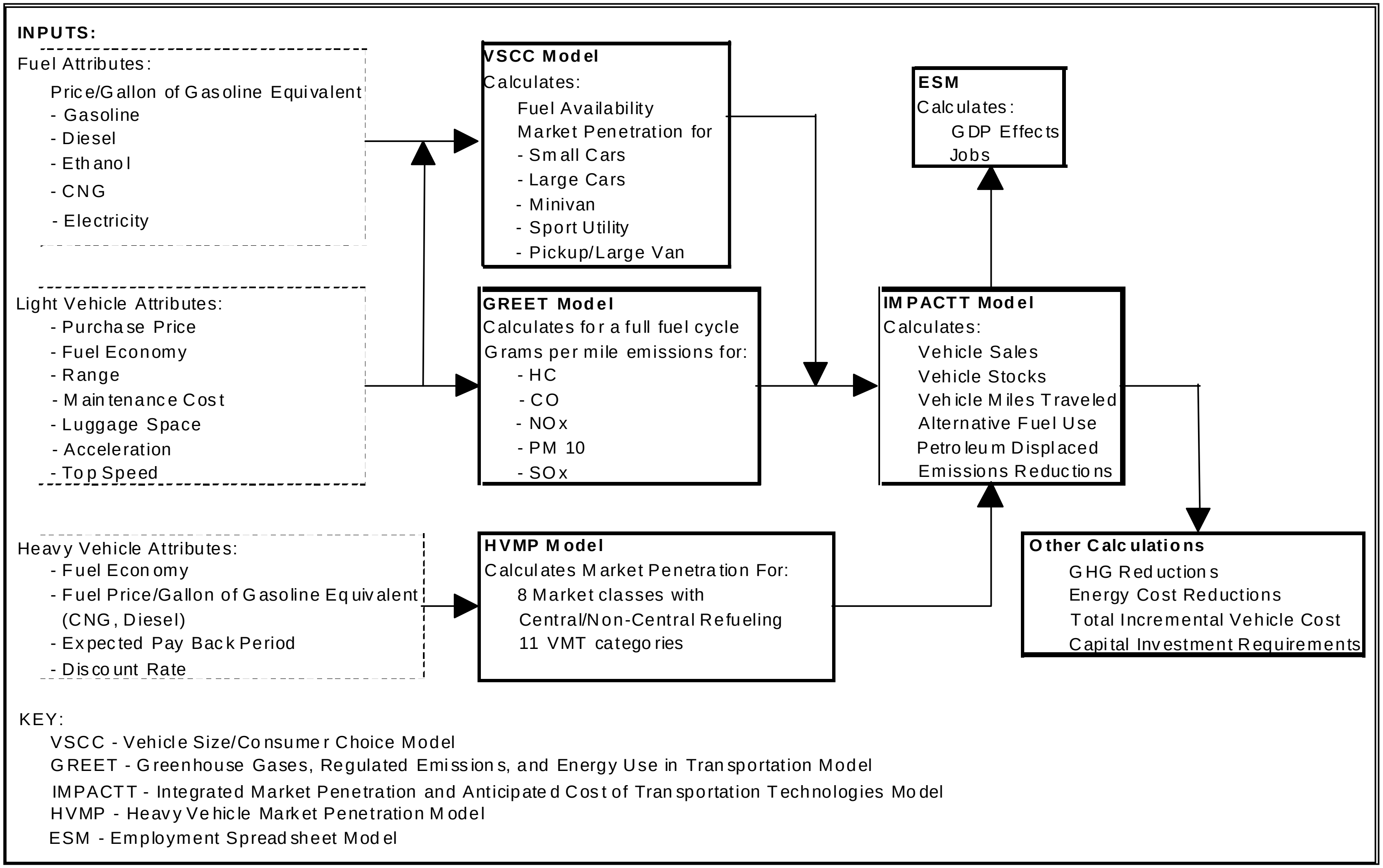


Exhibit E4. Conventional Vehicle Characteristics – Large Cars (1996)

	Year of Intro./ Maturity	Vehicle Cost Ratio	Fuel Economy Ratio	Relative Range (miles)	Mainten-ance cost ($/year)	Trunk Space	Accel. (0-30) sec.	Top Speed (mph)
Conventional	N/A	$23,200	25.9	325	450	1	6.0	131.9
Advanced Diesel	2005 2010	1.07 1.05	1.35 1.35	1.2 1.2	1.0 1.0	1.0 1.0	1.1 1.1	0.8 0.8
Electric	2006 2010	1.9 1.5	4.0 4.0	0.36 0.36	0.6 0.6	0.5 0.8	1.0 1.0	0.53 0.53
Hybrid	2003 2008	1.4 1.2	1.50 2.00	1.2 1.2	1.05 1.05	0.95 0.95	1.0 1.0	0.72 0.72
Fuel Cell	2007 2012	1.5 1.3	2.10 2.10	1.0 1.0	1.05 1.05	0.8 0.8	1.0 1.0	0.72 0.72
Natural Gas	2000 2005	1.105 1.035	1.00 1.00	0.66 0.75	0.9 0.9	0.75 0.85	1.0 1.0	1.0 1.0
SDI	2004 2009	1.05 1.03	1.25 1.25	1.0 1.0	1.0 1.0	1.0 1.0	1.0 1.0	1.0 1.0

Exhibit E5. Market Penetration Summary

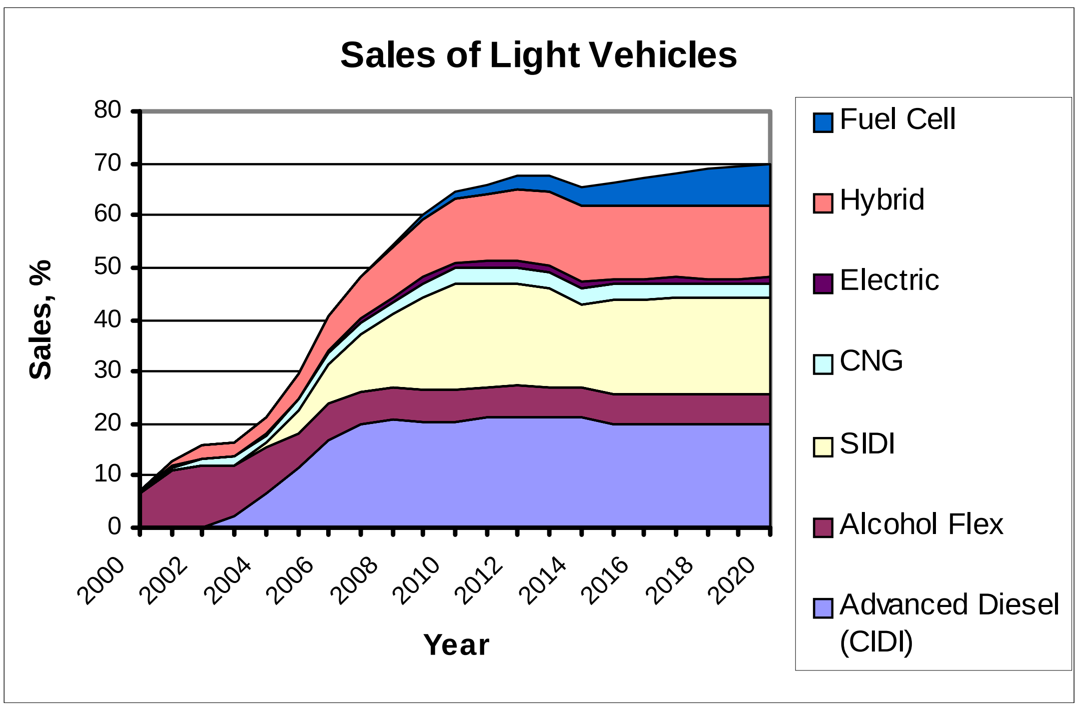


Exhibit E6. QM 2001 Summary

	Primary Energy Displaced (quads)					Primary Oil Displaced (quads)					Energy Cost Savings (billions of 1997 $'s)					Carbon Reductions (million metric tons)				
PLANNING UNIT	**2000**	**2005**	**2010**	**2015**	**2020**	**2000**	**2005**	**2010**	**2015**	**2020**	**2000**	**2005**	**2010**	**2015**	**2020**	**2000**	**2005**	**2010**	**2015**	**2020**
Vehicle Technologies R&D	**0.007**	**0.152**	**0.740**	**1.350**	**1.768**	**0.011**	**0.156**	**0.851**	**1.517**	**1.977**	**0.055**	**1.299**	**7.516**	**14.107**	**18.564**	**0.174**	**2.914**	**14.087**	**25.942**	**34.179**
Hybrid Systems R&D	0.000	0.045	0.246	0.498	0.624	0.000	0.001	0.246	0.498	0.624	0.008	0.442	2.564	5.191	6.493	0.018	0.871	4.785	9.660	12.118
Fuel Cell R&D	0.000	0.000	0.014	0.082	0.220	0.000	0.000	0.014	0.082	0.220	0.000	0.000	0.143	0.850	2.288	0.000	0.000	0.263	1.554	4.194
Advanced Combustion R&D	0.000	0.064	0.394	0.639	0.727	0.000	0.064	0.394	0.639	0.727	0.000	0.634	4.100	6.668	7.559	0.000	1.161	7.188	11.696	13.316
SIDI	*0.000*	*0.006*	*0.085*	*0.164*	*0.199*	*0.000*	*0.006*	*0.085*	*0.164*	*0.199*	*0.000*	*0.058*	*0.882*	*1.711*	*2.070*	*0.000*	*0.115*	*1.646*	*3.184*	*3.863*
Car CIDI	*0.000*	*0.028*	*0.163*	*0.248*	*0.264*	*0.000*	*0.028*	*0.163*	*0.248*	*0.264*	*0.000*	*0.102*	*0.945*	*1.437*	*1.403*	*0.000*	*0.461*	*2.758*	*4.194*	*4.440*
Light Truck CIDI	*0.000*	*0.031*	*0.147*	*0.227*	*0.264*	*0.000*	*0.031*	*0.147*	*0.227*	*0.264*	*0.000*	*0.473*	*2.274*	*3.520*	*4.086*	*0.000*	*0.585*	*2.784*	*4.318*	*5.013*
Electric Vehicles R&D	0.000	0.001	0.004	0.009	0.010	0.002	0.047	0.114	0.175	0.219	-0.011	-0.137	0.007	0.341	0.633	0.000	0.033	0.218	0.567	0.828
Household EV	*0.000*	*0.001*	*0.004*	*0.009*	*0.010*	*0.000*	*0.007*	*0.031*	*0.059*	*0.071*	*0.001*	*0.040*	*0.208*	*0.415*	*0.511*	*0.000*	*0.020*	*0.118*	*0.287*	*0.384*
EPAct/ZEV Mandates	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.002*	*0.040*	*0.083*	*0.116*	*0.147*	*-0.011*	*-0.177*	*-0.201*	*-0.073*	*0.122*	*0.000*	*0.012*	*0.101*	*0.280*	*0.444*
Heavy Vehicle Systems R&D	0.007	0.042	0.082	0.123	0.187	0.009	0.044	0.083	0.124	0.187	0.058	0.360	0.701	1.057	1.591	0.156	0.849	1.633	2.465	3.723
Class 3-6	*0.000*	*0.000*	*0.000*	*0.001*	*0.002*	*0.000*	*0.000*	*0.000*	*0.001*	*0.002*	*0.000*	*0.003*	*0.004*	*0.010*	*0.015*	*0.000*	*0.006*	*0.009*	*0.023*	*0.035*
Class 7&8	*0.007*	*0.042*	*0.081*	*0.122*	*0.185*	*0.007*	*0.042*	*0.081*	*0.122*	*0.185*	*0.057*	*0.354*	*0.695*	*1.047*	*1.577*	*0.149*	*0.831*	*1.617*	*2.441*	*3.688*
Class 7&8 CNG	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.001*	*0.002*	*0.001*	*0.000*	*0.000*	*0.001*	*0.004*	*0.002*	*0.000*	*0.000*	*0.006*	*0.011*	*0.006*	*0.002*	*0.001*
Rail	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
Materials Technologies	**0.000**	**0.001**	**0.009**	**0.024**	**0.043**	**0.000**	**0.002**	**0.012**	**0.029**	**0.049**	**0.000**	**0.017**	**0.111**	**0.285**	**0.490**	**0.001**	**0.027**	**0.180**	**0.480**	**0.851**
Propulsion System Materials	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Light Vehicle Materials	0.000	0.001	0.009	0.024	0.043	0.000	0.002	0.012	0.029	0.049	0.000	0.017	0.111	0.285	0.490	0.001	0.027	0.180	0.480	0.851
Household EV	*0.000*	*0.000*	*0.000*	*0.001*	*0.001*	*0.000*	*0.001*	*0.003*	*0.006*	*0.007*	*0.000*	*0.004*	*0.020*	*0.040*	*0.049*	*0.000*	*0.002*	*0.011*	*0.028*	*0.037*
Hybrid Vehicle	*0.000*	*0.001*	*0.007*	*0.014*	*0.018*	*0.000*	*0.001*	*0.007*	*0.014*	*0.018*	*0.000*	*0.013*	*0.075*	*0.151*	*0.189*	*0.001*	*0.025*	*0.139*	*0.281*	*0.353*
Fuel Cell Vehicle	*0.000*	*0.000*	*0.002*	*0.009*	*0.024*	*0.000*	*0.000*	*0.002*	*0.009*	*0.024*	*0.000*	*0.000*	*0.016*	*0.093*	*0.251*	*0.000*	*0.000*	*0.029*	*0.171*	*0.461*
Technology Deployment	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.070**	**0.278**	**0.414**	**0.484**	**0.498**	**0.026**	**0.394**	**0.784**	**0.977**	**0.959**	**0.293**	**1.204**	**1.832**	**2.177**	**2.251**
Household CNG	0.000	0.000	0.000	0.000	0.000	0.002	0.073	0.183	0.254	0.271	0.004	0.230	0.591	0.794	0.822	0.009	0.363	0.904	1.257	1.340
EPAct Fleet	0.000	0.000	0.000	0.000	0.000	0.068	0.204	0.231	0.229	0.227	0.021	0.164	0.192	0.183	0.137	0.284	0.842	0.928	0.920	0.911
Fuels Development	**0.000**	**0.023**	**0.182**	**0.430**	**0.683**	**0.000**	**0.023**	**0.182**	**0.430**	**0.683**	**0.000**	**-0.006**	**0.006**	**0.113**	**0.126**	**0.001**	**0.438**	**3.426**	**8.096**	**12.861**
Blends and Extenders	0.000	0.019	0.147	0.332	0.578	0.000	0.019	0.147	0.332	0.578	0.000	0.000	0.000	0.000	0.000	0.000	0.365	2.762	6.242	10.890
Flex-Fuel	0.000	0.004	0.035	0.098	0.105	0.000	0.004	0.035	0.098	0.105	0.000	-0.006	0.006	0.113	0.126	0.001	0.072	0.664	1.854	1.971
Dedicated Conventional	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	**0.008**	**0.177**	**0.932**	**1.805**	**2.494**	**0.081**	**0.459**	**1.459**	**2.460**	**3.207**	**0.081**	**1.704**	**8.415**	**15.482**	**20.139**	**0.468**	**4.583**	**19.524**	**36.695**	**50.141**

Note:

1) Advanced Materials - metrics shown for Light Vehicle Materials are derived from percentages of total metrics estimated for Electric, Hybrid and Fuel Cell vehicles

Electric: 8.8% of total

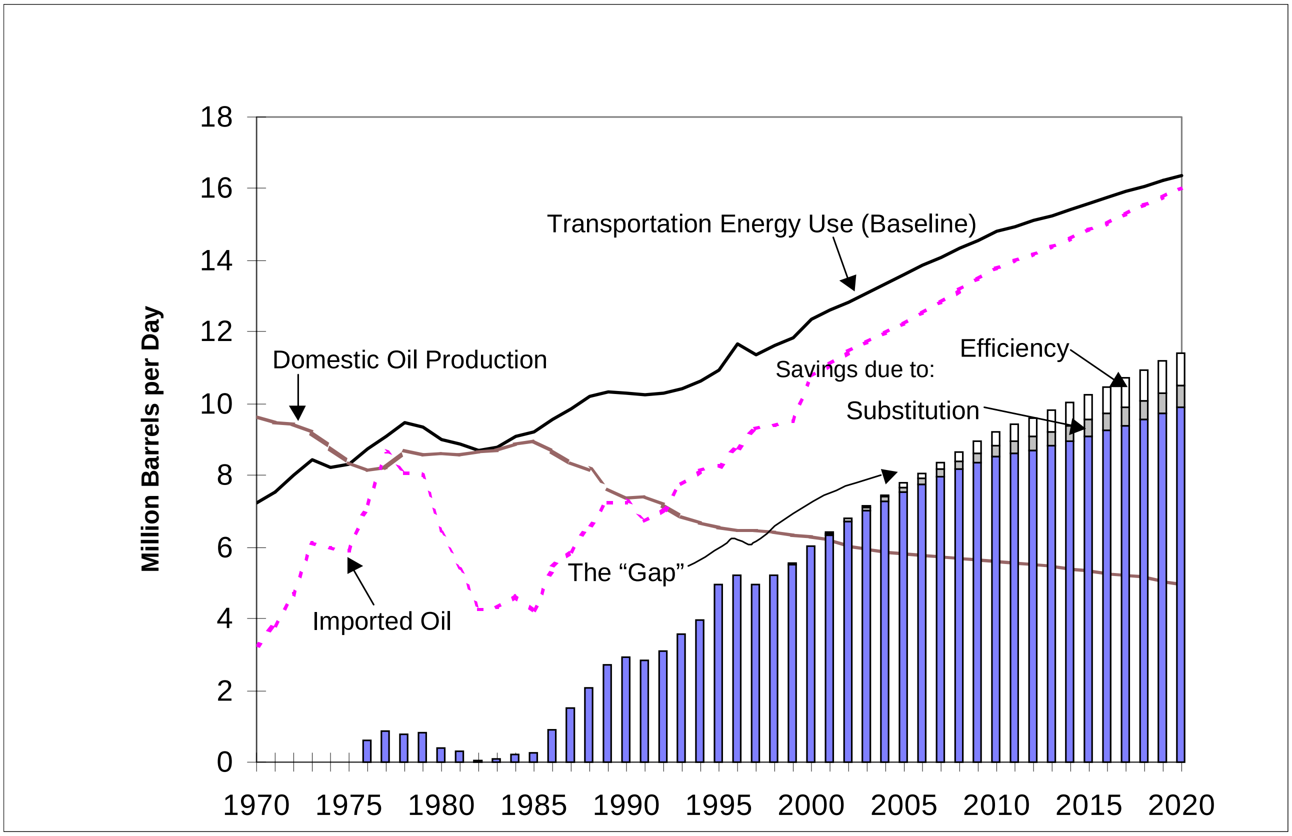
Hybrid: 2.8% of total

Fuel Cell 9.9% of total

2) EPAct/ZEV Mandate EVs are not included in Materials Technologies Planning Unit

The projected effect of the OTT program on U.S. transportation system energy use is shown in Exhibit E7. The petroleum "Gap" is defined here as the difference between transportation energy use and domestic petroleum production. In the baseline case, note that the gap approaches 12 million barrels per day by Year 2020. The OTT program impact is projected to reduce this shortfall by nearly 1.5 million barrels per day, or about twelve percent (12%). About two thirds of this reduction is in the form of efficiency improvements. The remaining third is obtained via substitution of non-petroleum energy sources.

Exhibit E7: Transportation Petroleum Use Projection



Summary program benefits and costs are shown in Exhibit E8. There are four criteria for which benefits and costs are calculated: energy, environment, economy, and national security. These are accumulated over four time intervals: 2000-2005, 2000-2010, 2000-2015, and 2000-2020. The ratio of the various benefits to the OTT program cost are also shown. The Benefit-Cost Ratios shown are with respect to the OTT program costs only: costs born by others are considered negative benefits (dis-benefits) and are subtracted from the numerator rather than added to the denominator of the benefit-cost ratio calculation.

Exhibit E8: Benefit-Cost Summary

Item	2005	2010	2015	2020
OTT Budget Costs	$1,250	$2,500	$3,250	$3,250
Net Energy Benefits	$5,353	$34,007	$97,301	$188,732
Benefit/Cost - Energy	4.28	13.60	29.94	58.07
Net Environment Benefits	$1,652	$10,385	$31,355	$62,528
Benefit/Cost - Environment	1.32	4.15	9.65	19.24
Net Economic Benefits	$12,204	$29,918	$59,470	$103,372
Benefit/Cost - Economy	9.76	11.97	18.30	31.81
Net Security Benefits	$365	$4,015	$12,775	$25,915
Benefit/Cost - Security	0.29	1.61	3.93	7.97
Total Benefits	**$ 19,574**	**$ 78,325**	**$ 200,901**	**$ 380,547**
Cumulative Benefit/Cost Ratio: Energy	**4.28**	**13.6**	**29.9**	**58.1**
Cumulative Benefit/Cost Ratio: Energy + Environment	**5.60**	**17.8**	**39.6**	**77.3**
Cumulative Benefit/Cost Ratio: Energy + Environment + Economy	**15.4**	**29.7**	**57.9**	**109**
Cumulative Benefit/Cost Ratio: Energy + Environment + Economy + Security	**15.7**	**31.3**	**61.8**	**117**

(1) All values in Millions of U.S. 1997$.

Section 1.0: Introduction

1.0 Introduction

1.1 Purpose and Scope

The purpose of this report is to describe the methodology and results obtained from a continuing DOE Office of Transportation Technologies (OTT) activity to estimate future effects of OTT projects on national energy use, petroleum consumption, criteria emissions, greenhouse gas emissions, and various measures of national income and employment. Assumptions are made about the future costs and characteristics of alternative vehicles and fuels. Computer models that take into account the value that vehicle buyers place on various vehicle characteristics are used to estimate the market penetration of new vehicle technologies. A different set of assumptions would yield results that are different from what is presented here.

Analysis results quantify benefits including energy and petroleum reductions, carbon equivalent greenhouse gas emissions, criteria pollutant emissions reductions, and the associated economic impacts on the Gross Domestic Product (GDP) and jobs. Life-cycle cost analyses also are in progress to define advanced technology economic performance compared to conventional technology estimates.

The scope of this report includes the following highway vehicles: light vehicles including passenger automobiles, class 1 & 2 trucks, and heavy trucks (classes 3 through 8). The time focus of the analysis is from current conditions projected through the year 2020. All energy savings start from baseline projections of transportation sector energy use obtained from the "Annual Energy Outlook," issued annually by the US Department of Energy, Energy Information Administration (Ref. 1).

The range of light vehicle technologies investigated includes electrics, hybrid, fuel cell, advanced diesel (CIDI), natural gas-fueled, and stratified charge direct-injection (SIDI) prime movers. A representative distribution of light vehicle sizes, applications, and performance levels is postulated based on current and projected vehicle stocks and trends. The heavy vehicle technologies investigated include hybrid, natural gas-fueled and advanced diesel power plants. All of these light and heavy vehicle technologies are projected to become mature and grow significantly over the next two decades.

This report meets two programmatic purposes. First, it constitutes the **OTT final documentation for the Quality Metrics 2001 (QM 2001)** analytical process of the DOE Office of Energy Efficiency and Renewable Energy (EE/RE). Quality Metrics has been an active annual DOE EE/RE-wide analysis and review procedure since 1995. QM seeks to monitor and measure the impacts of all DOE EE/RE programs and to summarize their overall national effects. The Quality Metrics process is described in more detail in Section 1.2 below.

Second, this report serves as an internal OTT program management tool. This report was initially developed to meet the reporting requirements set forth in the EPACT 2021 Report to Congress in 1992 and has been since updated annually for internal reporting and management purposes (Ref. 2). This dual purpose led OTT to the development of the analysis methodology described in Section 1.3 below.

The report updates also reflect annual changes in the DOE/EIA Annual Energy Outlook and in OTT program structure, goals and milestones (Ref. 1). Each publication includes projections for the budget year identified in the report title. This specific issue is named QM 2001 because the impacts and benefits are consistent with the FY ***2001*** budget report to Congress.

1.2 Background-The EE/RE Quality Metrics Review Process

"Quality Metrics" evaluations are conducted annually in the U.S. DOE Office of Energy Efficiency and Renewable Energy (EE/RE) to assess and project the energy and environmental benefits of EE/RE programs. The Quality Metrics program of EE/RE and the preparation of the EPACT 2021 report to Congress led to the development of an impacts assessment methodology for the Office of Transportation Technologies (OTT), which is continually improved and updated.

Within OTT, the QM methodology is applied to four major functions. Each function relates to an element of the transportation system associated with one or more of the technologies addressed by the OTT organizational structure.

Each major function is further subdivided into Planning Units that are separately analyzed. An element may be a separate technology or a separate transportation sector or both. The total energy savings and emissions reductions attributable to OTT programs is equal to the sum of the savings from each of these separate elements. Planning Units are similar, but not identical to the OTT program structure. The OTT Quality Metrics Functions and Planning Units are listed and described below:

1. **Technology Deployment:** This area includes OTT projects that involve moving new technologies into the public and private sectors. These include: EPAct **Fleet** Mandates and penetration of CNG vehicles in the **household** market.

2. **Fuels Development:** This area involves the development of transportation system technologies to make use of some of the more promising fuels that may substitute for gasoline in the future. These currently include biomass-based ethanol used in flexible-fuel vehicles and utilized in fuel blends.

3. **Vehicle Technologies R&D:** This area includes all light and heavy vehicle technologies currently supported in OTT that are intended to increase engine efficiency or reduce parasitic losses and that result in higher vehicle fuel economy in concert with lower criteria and greenhouse gas emissions. Currently, this includes Light Vehicles (cars and Class 1 and 2 trucks) and **Heavy** Vehicle Technologies (Classes 3-6, 7 & 8) as follows:
    - Fuel Cell R&D: Gasoline-fueled vehicles with 2.0-2.1 times conventional vehicle fuel economy.

- Hybrid Vehicle R&D: Gasoline fueled, with 1.24 to 2.0 times conventional vehicle fuel economy (depending on vehicle category).
- Light Vehicle Engine R&D: Spark Ignition Direct Injection (SIDI) vehicles with 1.25 times conventional fuel economy and Compression Ignition Direct Injection (CIDI) vehicles with 1.35 to 1.45 times conventional fuel economy, depending upon vehicle size class.
- Electric Battery Vehicle R&D, including Zero Emission Vehicle (ZEV) mandates.
- Heavy Vehicle Technologies.

4. **Materials Technologies:** This area deals with more fundamental issues concerning the use of advanced materials in light and heavy vehicles. Some of these (such as ceramics) promise higher engine efficiencies while others reduce structural weight and hence increase fuel economy. The planning units include the following project areas:
    - Propulsion System Materials: Ceramics,
    - Light Vehicle Materials for electric, hybrid, and fuel cell vehicles, and
    - Heavy Vehicle Materials.

    It is assumed that the electric, hybrid, and fuel cell vehicle technologies will require the use of light weight materials to achieve program goals for fuel efficiency.

Prior Quality Metrics (QM 2000) analyses and results are described in Reference 3. The Analytic Team has continued to improve the modeling process with improved market penetration modeling. Hybrid technology has been added to the heavy vehicle sector, and a major modeling tool, GREET, has been updated. For QM 2001, the number and designation of light vehicle classes was maintained at five (5) as shown below:

1. Large Cars (EPA size classes Large and Midsize; 110 ft^3 of passenger and luggage volume and larger, e.g., Dodge Stratus and larger)
2. Small Cars (all other EPA size classes ; < 110 ft^3 of passenger and luggage volume, e.g., Nissan Altima and smaller);
3. Sport Utility Vehicles;
4. Minivans; and
5. Pickup trucks and large vans.

It is the intent of this analysis that these vehicle classes be utilized as building blocks to produce a reasonable simulation of the current and projected light vehicle fleet in the U.S. over the next two decades.

1.3 Background-The Office of Transportation Technologies (OTT)

The OTT seeks to develop and promote advanced highway transportation vehicles, systems and alternative fuel use technologies that lead to reduced imported oil, lower regulated emissions and reduced emission of atmospheric gases that may add to the greenhouse effect. To these ends, OTT develops partnerships with elements of the domestic transportation industry and private and public research and development organizations.

The analytic impacts methodology is referred to as "OTT Impacts Assessment." The scope of the OTT Impacts Assessment contains analyses that supplement those required by QM. These include:

- Comprehensive end-use criteria and carbon pollutant reductions (QM requires carbon as a CO_2 equivalent, hydrocarbon, CO, and NO_x reduction benefits only);

  - OTT Impacts consider the fuel cycle carbon savings (QM benefits are limited to the end-use, fuel economy benefits);

- Gross Domestic Product/Jobs (in the QM process, macroeconomic effects are determined by others);
- Cost analyses, including the capital/infrastructure estimates, and oil security cost valuations; and
- The determination of benefit to cost ratios for the target technologies.

All OTT functions and projects are subdivided among four (4) functions:

- **Fuels Development** strives to increase the use of biologically-derived fuels in highway vehicle applications.

- **Advanced Vehicle Technologies** develops advanced technologies for automobiles and other light vehicles including electric and hybrid technologies, advanced heat engines, alternative fuels utilization, and advanced high strength/lightweight materials. The office also works on technologies applied to heavy duty trucks and buses, and other large highway vehicles.

- **Materials Technologies** explore the potential for petroleum conservation through the development and application of materials technologies that enable propulsion systems with high energy efficiency, and vehicle structures that reduce weight.

- **Technology Utilization** works to develop and promote user acceptance of advanced transportation technologies and alternative fuels within the U.S. highway vehicle transportation sector.

The relationship between the various OTT Program Elements and the Quality Metrics Planning Units is shown in Exhibit 1-1 below.

Exhibit 1-1: Relationship Between Quality Metrics Planning Units and OTT Program Activities

Quality Metrics Planning Unit	Related OTT Program Activities

Technology Deployment
    Household CNG
    EPAct Fleet
	<u>Technology Utilization</u>
	Clean Cities
	Testing and Evaluation
	Energy Policy Act Replacement Fuels Program
	Advanced Vehicle Competitions

Fuels Development
    Blends and Extenders
    Flex Fuel
    Dedicated Conventional
    Fuel Cell
	<u>Fuels Development</u>
	Biofuels
	  a) Ethanol Production
	  b) Biodiesel Production
	  c) Feedstock Production
	  d) Regional Biomass Energy Program

Vehicle Technologies R&D
    Hybrid Systems R&D
    Fuel Cell R&D
    Advanced Combustion R&D
        SIDI
        Car CIDI
        Light Truck CIDI
    Electric Vehicles R&D
        Household EV
        EPAct/ZEV Mandates
 	
    Heavy Vehicle Systems R&D
        Class 3-6
        Class 7 & 8
        Class 7 & 8 CNG
        Rail
	<u>Advanced Vehicle Technologies</u>
	Light Vehicles - Hybrid Systems R&D
	  a) Light Vehicles Propulsion & Ancillary Sys.
	  b) High Power Energy Storage
	  c) Advanced Power Electronics
	Fell Cell R&D
	  a) Systems
	  b) Components
	  c) Fuel Processor
	Electric Vehicle R&D
	  a) Advanced Battery Development
	  b) Exploratory Research
	Advanced Combustion Engine
	  a) Hybrid Direct Injection Engine
	  b) Combustion and Aftertreatment R&D
	Cooperative Automotive Research For Advanced Technologies
	Heavy Vehicles
	Hybrid Systems R&D
	Advanced Combustion Engine R&D
	Materials Technologies
	Fuels Utilization
	  a) Advanced Petroleum Based Fuels
	  b) Alternative Fuels
	    Fueling Infrastructure

Materials Technologies	Propulsion Materials Technologies Lightweight Materials Technologies High Temperature Materials Laboratory

The Quality Metrics and OTT Impacts Assessment are conducted using the Reference Case projections of the Energy Information Administration to define the world energy market characteristics, U.S. energy consumption by economic sector and energy prices. The reader is referred to Publication DOE/EIA-0383 (99), "Annual Energy Outlook 1999, With Projections Through 2020." (Ref. 1) The current version of this report is available at the following website address: http://www.eia.doe.gov/oiaf/aeo99/homepage.html.

A number of scenarios are formulated and analyzed in executing the OTT Impacts methodology. Such impacts estimates are needed to accompany each annual budget submission, with final estimates prepared at the end of each calendar year.

Readers are also referred to recent reports on other related OTT analytic initiatives. These include:

- "Historical Benefits of Five Office of Transportation Technologies Programs: Methodology and Assumptions," Office of Transportation Technologies, U.S. Department of Energy, December 1999.
- Maples, Moore, Patterson and Schaper, "Alternative Fuels for U.S. Transportation in the Next Millennium," Transportation Research Board Committee, January 2000. http://www.stncar.com/altfuel/00005.pdf
- Birky, Maples, Moore, and Patterson, "Future World Oil Prices and the Potential for New Transportation Fuels," prepared for the Transportation Research Board's 79th Annual Meeting, January 2000. http://www.ott.doe.gov/facts/publications/TRB2000.pdf

OTT also continues to evaluate consumer attitudes toward transportation alternatives, and alternative fuels program strategy options. A description of the Office of Transportation Technology as well as the results of many DOE OTT analytical efforts are also available on the Internet at http://www.ott.doe.gov/facts.html

1.4 Report Structure/Organization

This report consists of seven principal sections. An overview of the technical analysis process is described in Section 2. The various analytical models used in the analysis are also summarized here. Section 3 contains a description of the vehicle choice analysis simulation tools and results. As noted above, the QM 2001 analytical scope includes heavy as well as light vehicles. Section 4 discusses the analysis results in terms of energy and petroleum reductions, environmental and economic benefits, and also includes a benefit/cost analysis of OTT programs. References and supporting information including a glossary of technical terms and acronyms as well as energy unit conversion factors follow in Sections 5 and 6, respectively. Where available, website addresses for references are included.

Detailed results of the Quality Metrics analyses are presented in Appendix A. Results contained in this Appendix include:

- QM 2001 benefits summary by Planning Unit (Tables A-1, A-6)

- GPRA Inputs and Analytical Results (Tables A-2 to A-5)
- Market Penetration Estimates – percentages and vehicles sold and in use in the fleet (Tables A-8 to A-13, A-15)
- Energy benefits – gasoline displaced, biofuels demand, EPAct fuel use, ZEV and EPACT electricity use (Tables A-7, A-14 to A-19)
- Emissions impacts – carbon, NO_x, CO, and HC reductions in both physical units and dollars (Tables A-21 to A-28), and
- Cost effects – vehicle purchase, aggregate consumer investment, and corporate expenditures (Tables A-29 to A-32).
- Light Vehicle Fuel Economy Projections (Table A-33)
- Medium and Heavy Truck Results (Tables A-34 to A-42)

A discussion of the vehicle choice model used to estimate market penetration of light vehicle technologies is contained in Appendix B.

Section 2.0: Technical Analysis Overview

2.0 Technical Analysis Overview

2.1 Background

The analysis process involves the following four activities:

1) Definition of vehicle characteristics for advanced technologies;
2) Market penetration analysis estimated by vehicle size class;
3) Energy savings, petroleum displacement, environmental and economic benefits quantification via motive source and vehicle efficiency improvements and alternative fuel use; and
4) Development of summary documentation.

The time frame for the study spans the present to 2020.

2.2 Vehicle/Technology/Fuel Baseline Assumptions

The fuel and vehicle characteristics can be considered in three categories: fuel attributes, light vehicle attributes and heavy vehicle attributes. These attributes are defined by program staff and are subjected to external peer review. The light and heavy vehicles attributes used in this analysis are presented in Exhibit 2-1. Note that there are five classes of light vehicles and two "class groupings" of heavy vehicles with three market segments of class 7 & 8 vehicles. Heavy vehicle costs are in the form of incremental costs and are discussed in Section 3.2.

Exhibit 2-1: Conventional Vehicle Characteristics (1996)

	Market Segment	Fuel Economy (MPG)[1]	Acceleration (0-30 MPH)	Top Speed (MPH)	Vehicle Cost ($)
Light Vehicles					
Large Car	All	25.9	6.0	131.9	$23,200
Small Car	All	31.3	7.0	121.1	$14,800
Sport Utility Vehicle	All	21.1	7.0	108.3	$21,300
Minivan	All	22.7	7.0	108.3	$22,060
Pickup Truck & Large Van	All	19.5	7.0	122	$15,000
Heavy Vehicles					
Class 3-6 Trucks	All	7.9	-----	-----	See Sect. 3.2
Class 7&8	Type 1 Trucks	4.5	-----	-----	See Sect. 3.2
Class 7&8	Type 2 Trucks	6.1	-----	-----	See Sect. 3.2
Class 7&8	Type 3 Trucks	7.7	-----	-----	See Sect. 3.2

[1] Gasoline Equivalent

The five classes of light vehicles areas follows:

- Large Car
- Small Car
- Sport Utility Vehicle
- Minivan
- Pickup Truck

The six heavy vehicle classes (3-8) are divided into two groups (see below) and three market segments that differ from each other with respect to end use, average fuel economy and average annual miles traveled. This is discussed in more detail in Section 3.2 – Heavy Vehicles.

- Class 3-6 Trucks (10,000 – 26,000 lbs. gross vehicle weight (GVW))
- Class 7&8 Trucks (26,001 lbs. and greater GVW)

Three market segments of Class 7 & 8 trucks have been identified.

- Type 1 – multi-stop, step van, beverage, utility, winch, crane, wrecker, logging, pipe, refuse collection, dump, and concrete delivery;
- Type 2 – platform, livestock, auto transport, oil-field, grain, and tank;
- Type 3 – refrigerated van, drop frame van, open top van, and basic enclosed van.

The various technology options considered are as follows:

Light Vehicles:

- Compression Ignition/Direct Injection (CIDI-Diesel)
- Electric (battery)
- Flex-Fuel (gasoline/alcohol)
- Hybrid-Electric (battery/gasoline)
- Fuel Cell (gasoline)
- Natural Gas-Fueled
- Stratified Charge Direct-Injection (SIDI)

Heavy Vehicles:

- Advanced Diesel Engine
- CNG Fueled
- Hybrid-Electric

The vehicle attributes summaries for the five light vehicle classes are indicated in Exhibits 2-2 through 2-6.

Exhibit 2-2: Technology Characteristics - Large Car (1996)

	Year of Intro./ Maturity	Vehicle Cost Ratio	Fuel Economy Ratio	Relative Range (miles)	Mainten-ance cost ($/year)	Trunk Space	Accel. (0-30) sec.	Top Speed (mph)
Conventional	N/A	$23,200	25.9	325	450	1	6.0	131.9
CIDI	2005	1.07	1.35	1.2	1.0	1.0	1.1	0.8
	2010	1.05	1.35	1.2	1.0	1.0	1.1	0.8
Electric	2006	1.9	4.0	0.36	0.6	0.5	1.0	0.53
	2010	1.5	4.0	0.36	0.6	0.8	1.0	0.53
Hybrid	2003	1.4	1.50	1.2	1.05	0.95	1.0	0.72
	2008	1.2	2.00	1.2	1.05	0.95	1.0	0.72
Fuel Cell	2007	1.5	2.10	1.0	1.05	0.8	1.0	0.72
	2012	1.3	2.10	1.0	1.05	0.8	1.0	0.72
Natural Gas	2000	1.105	1.00	0.66	0.9	0.75	1.0	1.0
	2005	1.035	1.00	0.75	0.9	0.85	1.0	1.0
SIDI	2004	1.05	1.25	1.0	1.0	1.0	1.0	1.0
	2009	1.03	1.25	1.0	1.0	1.0	1.0	1.0

Conventional vehicle attributes are projected to change with time. For example, purchase price is expected to escalate in real terms (See Appendix Table A-29). Flex alcohol vehicles also are considered in the analysis, but these vehicles are assumed to have the same attributes as the conventional vehicles. The reference year for conventional vehicles attributes is 1996. Fuel economy values are assumed to be combined values (fifty-five percent (55%) City Cycle and forty-five percent (45%) Highway Cycle per EPA emissions certification test data).

Exhibit 2-3: Technology Characteristics - Small Car (1996)

	Year of Intro./ Maturity	Vehicle Cost Ratio	Fuel Economy Ratio	Relative Range (miles)	Mainten-ance cost ($/year)	Trunk Space	Accel. (0-30) sec.	Top Speed (mph)
Conventional	N/A	$14,800	31.3	372	400	1	7.0	121.1
CIDI	2003	1.07	1.4	1.2	1.0	1.0	1.1	0.85
	2008	1.07	1.4	1.2	1.0	1.0	1.1	0.85
Electric	2000	2.7	4.0	0.19	0.6	0.6	1.0	0.6
	2005	1.9	4.0	0.32	0.6	0.6	1.0	0.6
Hybrid	2000	1.7	1.4	1.0	1.05	0.9	1.1	0.64
	2005	1.2	1.6	1.0	1.05	0.95	1.1	0.9
Fuel Cell	2015	1.3	2.0	1.0	1.05	0.9	1.1	0.9
	2022	1.3	2.0	1.0	1.05	0.9	1.1	0.9
Natural Gas	2000	1.075	1.0	0.66	0.9	0.75	1.0	1.0
	2000	1.075	1.0	0.66	0.9	0.75	1.0	1.0
SIDI	2005	1.05	1.25	1.0	1.0	1.0	1.0	1.0
	2009	1.03	1.25	1.0	1.0	1.0	1.0	1.0

Exhibit 2-4: Technology Characteristics – Sport Utility Vehicle (1996)

	Year of Intro./ Maturity	Vehicle Cost Ratio	Fuel Economy Ratio	Relative Range (miles)	Mainten-ance cost ($/year)	Trunk Space	Accel. (0-30) sec.	Top Speed (mph)
Conventional	N/A	$21,300	21.1	300	450	1.0	7.0	108.3
CIDI	2004	1.075	1.45	1.2	1.0	1.0	1.1	1.0
	2009	1.07	1.45	1.2	1.0	1.0	1.1	1.0
Electric	2004	1.9	4.0	0.43	0.6	1.0	1.0	0.66
	2010	1.5	4.0	0.58	0.6	1.0	1.0	0.66
Hybrid	2003	1.4	1.40	1.0	1.06	1.0	1.1	0.75
	2015	1.2	1.75	1.0	1.05	1.0	1.1	0.75
Fuel Cell	2013	1.3	2.1	1.0	1.05	0.8	1.1	0.66
	2020	1.3	2.1	1.0	1.05	0.8	1.1	0.66
Natural Gas	2002	1.05	1.0	0.75	0.9	0.75	1.0	1.0
	2002	1.05	1.0	0.75	0.9	0.75	1.0	1.0
SIDI	2004	1.05	1.25	1.0	1.0	1.0	1.0	1.0
	2009	1.03	1.25	1.0	1.0	1.0	1.0	1.0

Exhibit 2-5: Technology Characteristics - Minivan (1996)

	Year of Intro./ Maturity	Vehicle Cost Ratio	Fuel Economy Ratio	Relative Range (miles)	Mainten-ance cost ($/year)	Trunk Space	Accel. (0-30) sec.	Top Speed (mph)
Conventional	N/A	$22,060	22.7	350	450	1	7.0	108.3
CIDI	2004	1.075	1.45	1.2	1.0	1.0	1.1	0.8
	2009	1.07	1.45	1.2	1.0	1.0	1.1	0.8
Electric	2004	1.9	4.0	0.28	0.6	1.0	1.0	0.66
	2010	1.5	4.0	0.4	0.6	1.0	1.0	0.66
Hybrid	2005	1.2	1.40	1.0	1.05	1.0	1.1	0.75
	2015	1.2	1.75	1.0	1.05	1.0	1.1	0.75
Fuel Cell	2013	1.3	2.1	1.0	1.1	0.8	1.1	0.66
	2020	1.3	2.1	1.0	1.1	0.8	1.1	0.66
Natural Gas	2002	1.05	1.0	0.75	0.9	0.8	1.0	1.0
	2002	1.05	1.0	0.75	0.9	0.8	1.0	1.0
SIDI	2004	1.05	1.25	1.0	1.0	1.0	1.0	1.0
	2009	1.03	1.25	1.0	1.0	1.0	1.0	1.0

Exhibit 2-6: Technology Characteristics – Pickup Trucks and Large Vans (1996)

	Year of Intro./ Maturity	Vehicle Cost Ratio	Fuel Economy Ratio	Relative Range (miles)	Mainten-ance cost ($/year)	Trunk Space	Accel. (0-30) sec.	Top Speed (mph)
Conventional	N/A	$15,000	19.5	350	500	1	7.0	122
CIDI	2002 2007	1.1 1.07	1.35 1.35	1.2 1.2	1.0 1.0	1.0 1.0	1.1 1.1	1.0 1.0
Electric	2000 2010	2.7 1.5	2.50 2.50	0.22 0.2	0.6 0.6	1.0 1.0	1.0 1.0	0.58 0.58
Hybrid	2005 2015	1.2 1.2	1.24 1.87	1.0 1.0	1.05 1.05	1.0 1.0	1.0 1.0	0.84 0.84
Fuel Cell	2008 2013	1.3 1.3	2.10 2.10	0.8 0.8	1.05 1.05	0.8 0.8	1.0 1.0	0.76 0.7
Natural Gas	2000 2005	1.11 1.05	1.0 1.0	0.75 0.9	0.9 0.9	0.75 0.75	1.0 1.0	1.0 1.0
SIDI	2004 2009	1.05 1.03	1.25 1.25	1.0 1.0	1.0 1.0	1.0 1.0	1.0 1.0	1.0 1.0

The exhibits show year of technology introduction (intro.) and year of maturity. Technology maturity is determined from OTT Program Manager input and varies by the complexity of the technologies, as well as goals set forth by the offices. In some cases, the technology may be assumed to be mature when introduced into the vehicle class.

Years of introduction vary among the car and truck size classes to account for market growth and development. As Exhibits 2-2 through 2-6 indicate, in some cases, technology characteristics also vary among the size classes both for conventional gasoline and alternative technologies.

2.3 Market Penetrations and Benefits Analyses

Market maturity is determined by "S-curves" which reflect consumer acceptance of advanced technologies over a specified period of time (represented in years) beginning after initial market acceptance. Years of introduction and “S-curve” assumptions are indicated in Exhibit 2-7. Although technology commercialization might be specified as year 2003, as shown for hybrid large cars, the vehicle choice model may not estimate market penetration until a later date. The Vehicle Size/Consumer Choice (VSCC) model adjusts the estimated market penetration by the appropriate correction factor as determined by the length (time period) of the S-curve. Subsequent market penetration estimates are adjusted as time moves along the length of the curve. The amount that the advanced vehicle market share is reduced due to the S-curve adjustment is added to the conventional vehicle market share.

Exhibit 2-7: Technology Introduction Assumptions

Technology	Small Car		Large Car		Minivan		Sport Utility		Pickup Truck/ Large Van	
	Intro. Year	S-curve	Intro. Year	S-curve	Intro. Year	S-curve	Intro. Year	S-curve	Intro. Year	S-curve
CIDI	2003	3	2005	3	2004	3	2004	3	2002	3
SIDI	2004	6	2004	6	2004	6	2004	6	2004	6
CNG	2000	10	2000	10	2002	10	2002	10	2000	10
Electric	2003	10	2006	10	2004	10	2004	10	2000	10
Hybrid	2006	10	2003	10	2011	10	2011	10	2005	10
Fuel Cell	2015	10	2007	10	2013	10	2013	10	2008	10

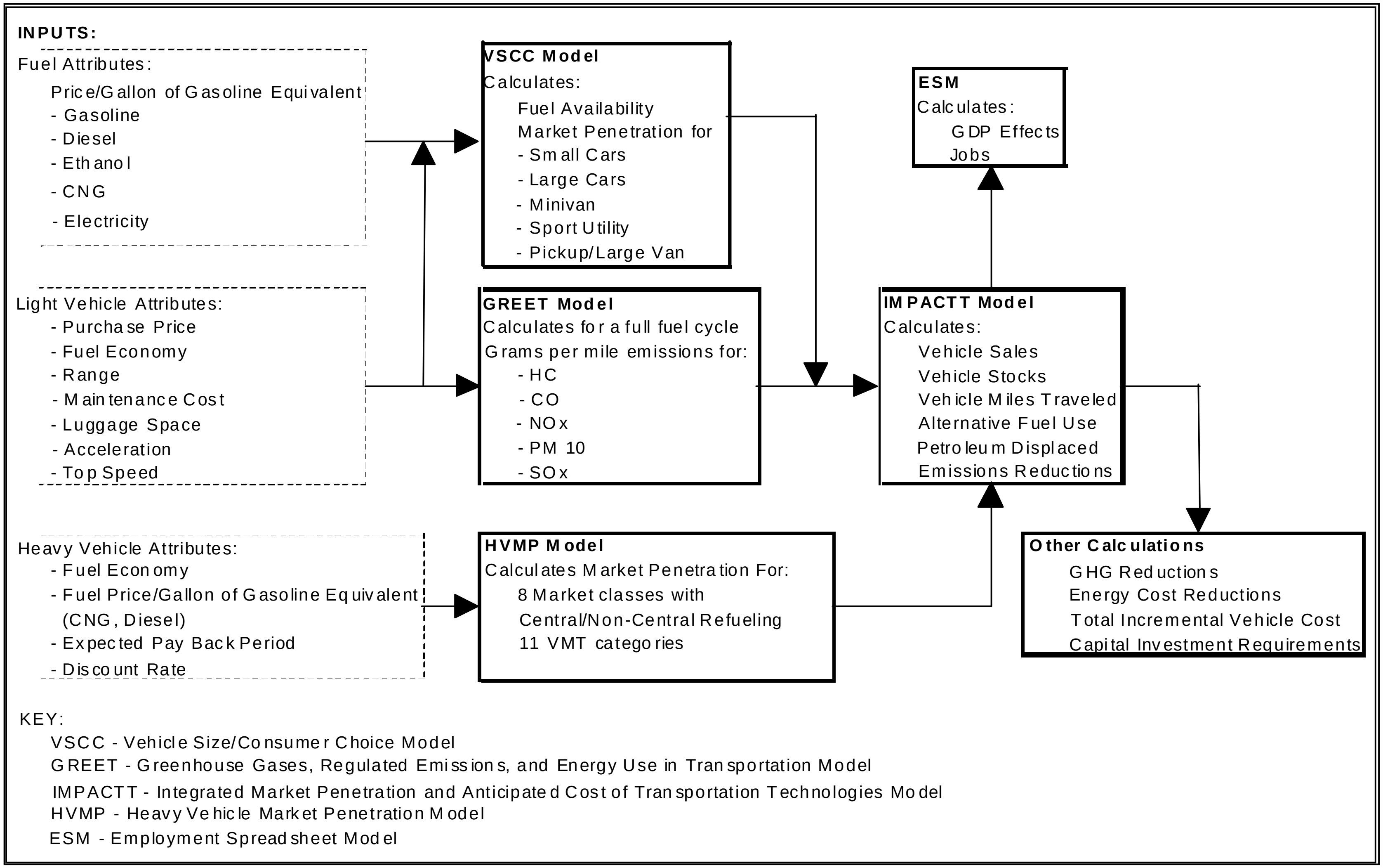
2.4 Summary of Modeling Assumptions and Structures

The modeling process is illustrated in Exhibit 2-8. The vehicle attributes for the advanced technologies are input into the vehicle choice model and emissions models. The light vehicle choice model then estimates market penetration by size class. The emissions model estimates tailpipe and upstream emissions on a grams per mile basis for each technology. For light vehicles, the market penetrations and emissions rates are then input into the Integrated Market Penetration and Anticipated Cost of Transportation Technologies, or IMPACTT, the vehicle stock/energy/emission model. Finally, energy and vehicle stock information is input into the economic model to estimate GDP and jobs impacts.

The heavy vehicle choice model estimates market penetration by market class. For heavy vehicles, the market penetrations are input into IMPACTT, then energy and vehicle stock information is input into the economic model to estimate GDP and jobs impacts.

All models shown in Exhibit 2-8 operate in Microsoft Excel.

Exhibit 2-8: QM Impact Assessment



2.4.1 VSCC Model

Vehicle **S**ize/**C**onsumer **C**hoice Model

The VSCC Model is an excel-based spreadsheet model developed by John Maples of Trancon, Inc. that predicts the future market penetration of light vehicles with new technologies based on the measured or estimated attributes of those technologies such as cost, fuel economy, range, and maintenance cost. The model also calculates alternative fuel consumption and incremental costs borne by purchasers of advanced technology vehicles.

Inputs:

The model, as now operated, has a universe of five (5) light vehicle types/sizes: large car, small car, sport utility vehicle, minivan and pickup truck/large van. It also has seven (7) technology groupings: conventional (gasoline-fueled, spark ignition), CIDI, electric, hybrid-electric, fuel cell, natural gas fueled (spark ignition), and SIDI. More technologies could be added.

The choice among technologies is made by a logit model that has influence coefficients determined in a national survey (Ref. 4). The model includes influence coefficients for purchase price, range, maintenance cost, 0-30 mph acceleration time, top speed, luggage space, fuel cost ($/mi), whether home refueling is available, whether multiple fuels are available, whether or not the vehicle can use gasoline and the gasoline range. In addition, fuel-specific factors and alternative fuel availability are also part of the evaluation process.

A more detailed discussion of the VSCC Model can be found in Section 3.1

2.4.2 IMPACTT Model

Integrated **M**arket **P**enetration and **A**nticipated **C**ost of **T**ransportation **T**echnologies

The IMPACTT model is a spreadsheet model developed by Marianne Mintz of ANL that calculates the effects of advanced-technology vehicles and market penetration on baseline fuel use and emissions. It accepts the market penetration data output from the VSCC model and determines the vehicle stock and miles traveled as a function of time for each technology. In addition, it calculates fuel use and emissions reduction effects using EPA Mobil 5A and GREET Models.

A more detailed discussion of the IMPACTT Model can be found in Section 4.1.1.

2.4.3 GREET Model – Version 1.5

Greenhouse **G**ases, Regulated **E**missions, and **E**nergy in **T**ransportation Model

GREET is an analytical tool developed by Michael Wang of ANL for estimating criteria and greenhouse gas emissions. It calculates total fuel cycle emissions from feedstock extraction through final combustion. It includes both light and heavy vehicles. It has the capability of analyzing up to sixteen (16) fuel cycles and twelve (12) vehicle technology/fuel combinations. A more detailed discussion of the GREET Model can be found in Section 4.2.4.

2.4.4 HVMP Model

The **H**eavy **V**ehicle **M**arket **P**enetration Model developed by John Maples of Trancon, Inc. serves the same purpose as the VSCC model except that it applies to potential market impacts of new technologies in the medium and heavy truck transportation sectors. This sector is subdivided into two categories with classes 7 & 8 disaggregated into 3 types according to application characteristics. Historical market penetration data for energy conservation technologies were used to calibrate the model. Cost effectiveness of the energy conservation investment is considered a prime determinant in its introduction and growth rate.

A more detailed discussion of the HVMP Model can be found in Section 3.2.

2.4.5 ESM Model

The **E**conomic **S**preadsheet **M**odel developed by NREL calculates the employment effects of the OTT programs by industry sector for each OTT technology.

A more detailed discussion of the ESM Model can be found in Section 4.2.1.

2.4.6 Other Calculations

As required, off-line market penetration and benefits analysis is required. Examples are ZEVs and alternative fuel vehicles commercialized under EPAct “Fleet” provisions. In addition to all of the above models and calculations, results from the IMPACTT model are used to calculate infrastructure incremental capital requirements for the vehicle manufacturing industry and energy cost reductions from OTT technologies.

Section 3.0: Vehicle Choice Analysis

3.0 Vehicle Choice Analysis

3.1 Light Vehicles

Vehicle Size/Consumer Choice Model

The VSCC model was developed to define the successful introduction of technologies in light vehicles by vehicle size class. This modeling exercise acknowledges that the introduction of advanced technologies is a gradual one. The VSCC model is a discrete choice, multi-attribute logit model designed to simulate the household market for alternative-fuel light vehicles. The model forecasts, to the year 2020, the future sales of conventional and alternatively fueled light vehicles by size class, technology and fuel type. Market penetration estimates are based on consumer derived utilities related to vehicle attributes that are associated with the different alternative fuels and advanced propulsion technologies. As such, the model is "household" based. Other market sectors are considered in various "off-line" calculations.

The vehicle demand function used in this model is based on the utility-maximization theory in which the consumer demand for alternative vehicles is defined as a function of the attributes of these vehicles and the fuels they use. The total utility of each light vehicle technology and fuel makeup is determined by the sum of the attribute utilities of that vehicle for each size class. The size class market share penetration estimates for the different technologies are a function of each technology's total utility compared to the total utility of other vehicles and technologies in that size class. The technology's total utility is calculated by summing attribute input values that have been multiplied by their corresponding coefficient. A discussion of the model structure, including the vehicle attributes and attribute coefficients is presented in Appendix B.

The attributes of conventional and alternative vehicle technologies were defined for five vehicle classes:

- small car
- large car
- minivan
- sport utility vehicle
- pickup and large van.

Technologies considered include:

- Conventional -- spark ignition, gasoline
- CIDI – which offers at least a thirty-five percent (35%) fuel economy improvement with the same tailpipe emissions as conventional gasoline vehicles. This emissions performance assumption is significant, given historical experience that diesel engines pollute more than comparable gasoline-fueled, spark ignition engines.
- Hybrid-Electric – grid-independent, parallel or series configuration, using gasoline.

- Fuel cell – proton exchange membrane, fueled with gasoline, ethanol or hydrogen. Currently, only the gasoline fuel cell vehicle is modeled.
- Natural gas – spark ignition-powered vehicle, similar to conventional, but fueled with natural gas (dedicated).
- SIDI – spark ignited vehicle with gasoline injected directly into the combustion chamber. This technology also is referred to as spark-ignition direct injection.
- Electric Vehicles
- Flex-fuel vehicles which run on any combination of gasoline and ethanol.

It was assumed that all technologies apply to all vehicle classes, although the maximum potential in some classes is restricted due to the various attribute characteristics assumptions. The maximum potentials are fifty percent (50%) for electric vehicles, fuel cell vehicles, hybrid electric vehicles in all light truck classes.

LPG and methanol were not considered in this analysis because: 1) OTT conducts minimal R&D efforts with these fuels; and 2) DOE Policy Office analysis indicates that these fuels would be imported in large amounts if they were used on a large scale in the transportation sector (Ref. 4). As a result, replacing imported petroleum with imported LPG or methanol would not help the U.S. balance of trade.

Of principal concern to the analysis is the alternative vehicle fuel economy, cost, relative range and maintenance cost in comparison to conventional vehicles. Fuel economy ratio assumptions are indicated in Exhibit 3-1. In the QM 2000 analyses, fuel cell vehicle relative fuel economy started at 2.1 times conventional and increased to 3.0 at maturity. Based on a peer review of the preliminary work, the relative fuel economy attribute range was reduced to 2.0 to 2.2 when the fuel cell operates on gasoline. For electric vehicles, the values reflect comparisons at the plug and the fuel tanks.

The cost ratios are shown in Exhibit 3-2. Exhibit 3-3 shows the comparison of relative ranges. Exhibit 3-4 shows the comparison of relative maintenance.

As indicated in Exhibit 3-1, the electric, CIDI, hybrid-electric, and fuel cell vehicles have significantly better fuel economies than conventional vehicles. All technology fuel economy ratios are applicable to the point of use.

The cost comparison indicates that the non-conventional vehicle technologies are consistently more expensive than conventional with SIDI being the least expensive. When comparing ranges, electric and natural gas-fueled vehicles are found to have significant range penalties. CIDI vehicles however, have a range benefit, due in part to the higher volumetric energy content of diesel fuel compared with gasoline. Maintenance does not appear to differ greatly from conventional vehicles with ratios ranging from 0.6 to 1.10.

Exhibit 3-1: Fuel Economy Ratio

TECHNOLOGY	STATUS	SMALL CAR	LARGE CAR	MINIVAN	SPORT UTILITY VEHICLE	PICKUP & LARGE VAN
ELECTRIC	**INTRO.**	4.00	4.00	4.00	4.00	2.50
	MATURITY	4.00	4.00	4.00	4.00	2.50
CIDI	**INTRO.**	1.40	1.35	1.45	1.45	1.35
	MATURITY	1.40	1.35	1.45	1.45	1.35
HYBRID	**INTRO.**	1.40	1.50	1.40	1.40	1.24
	MATURITY	1.60	2.00	1.75	1.75	1.87
FUEL CELL	**INTRO.**	2.00	2.10	2.10	2.10	2.10
	MATURITY	2.00	2.20	2.10	2.10	2.10
NATURAL GAS	**INTRO.**	1.00	1.00	1.00	1.00	1.00
	MATURITY	1.00	1.00	1.00	1.00	1.00
SIDI	**INTRO.**	1.25	1.25	1.25	1.25	1.25
	MATURITY	1.25	1.25	1.25	1.25	1.25

Exhibit 3-2: Cost Ratio

TECHNOLOGY	STATUS	SMALL CAR	LARGE CAR	MINIVAN	SPORT UTILITY VEHICLE	PICKUP & LARGE VAN
ELECTRIC	**INTRO.**	2.70	1.90	1.90	1.90	2.70
	MATURITY	1.90	1.50	1.50	1.50	1.50
CIDI	**INTRO.**	1.07	1.07	1.75	1.75	1.10
	MATURITY	1.07	1.05	1.07	1.07	1.07
HYBRID	**INTRO.**	1.70	1.40	1.20	1.40	1.20
	MATURITY	1.20	1.20	1.20	1.20	1.20
FUEL CELL	**INTRO.**	1.30	1.50	1.30	1.30	1.30
	MATURITY	1.30	1.50	1.30	1.30	1.30
NATURAL GAS	**INTRO.**	1.075	1.105	1.05	1.05	1.11
	MATURITY	1.075	1.105	1.05	1.05	1.05
SIDI	**INTRO.**	1.05	1.05	1.05	1.05	1.05
	MATURITY	1.03	1.03	1.03	1.03	1.03

Exhibit 3-3: Relative Range Ratio

TECHNOLOGY	STATUS	SMALL CAR	LARGE CAR	MINIVAN	SPORT UTILITY VEHICLE	PICKUP & LARGE VAN
ELECTRIC	INTRO.	0.19	0.36	0.28	0.43	0.22
	MATURITY	0.32	0.36	0.40	0.58	0.20
CIDI	INTRO.	1.20	1.20	1.20	1.20	1.20
	MATURITY	1.20	1.20	1.20	1.20	1.20
HYBRID	INTRO.	1.00	1.20	1.00	1.00	1.00
	MATURITY	1.00	1.20	1.00	1.00	1.00
FUEL CELL	INTRO.	1.00	1.00	1.00	1.00	0.80
	MATURITY	1.00	1.00	1.00	1.00	0.80
NATURAL GAS	INTRO.	0.66	0.66	0.75	0.75	0.90
	MATURITY	0.66	0.75	0.75	0.75	0.90
SIDI	INTRO.	1.00	1.00	1.00	1.00	1.00
	MATURITY	1.00	1.00	1.00	1.00	1.00

Exhibit 3-4: Relative Maintenance

TECHNOLOGY	STATUS	SMALL CAR	LARGE CAR	MINIVAN	SPORT UTILITY VEHICLE	PICKUP & LARGE VAN
ELECTRIC	INTRO.	0.60	0.60	0.60	0.60	0.60
	MATURITY	0.60	0.60	0.60	0.60	0.60
CIDI	INTRO.	1.00	1.00	1.00	1.00	1.00
	MATURITY	1.00	1.00	1.00	1.00	1.00
HYBRID	INTRO.	1.05	1.05	1.05	1.06	1.05
	MATURITY	1.05	1.05	1.05	1.05	1.05
FUEL CELL	INTRO.	1.05	1.05	1.10	1.05	1.05
	MATURITY	1.05	1.05	1.10	1.05	1.05
NATURAL GAS	INTRO.	0.90	0.90	0.90	0.90	0.90
	MATURITY	0.90	0.90	0.90	0.90	0.90
SIDI	INTRO.	1.00	1.00	1.00	1.00	1.00
	MATURITY	1.00	1.00	1.00	1.00	1.00

The overall light vehicle sales penetration forecast is a weighted average of the sales penetration estimates provided by the VSCC Model by size class. Exhibit 3-5 details the sales and stocks of advanced light vehicle technologies in years 2000, 2010, and 2020. The analyses show that at aggressive market penetration rates, advanced technologies will comprise more than half (64.6%) of light vehicle sales by 2010. In fact, advanced vehicle technologies reach seventy percent (70%) aggregate market penetration in 2020 although stock of advanced vehicles in 2020 is just over fifty percent (50%) as shown in Exhibit 3-5. (See Appendix A, Table A-8). Exhibit 3-6 is a graph that was developed from the same sales data in Exhibit 3-5.

Exhibit 3-5: Market Penetration of Alternative Light Vehicles in Sales and Stocks

TECHNOLOGY	YEAR 2000		YEAR 2010		YEAR 2020	
	SALES, %	STOCKS, %	SALES, %	STOCKS, %	SALES, %	STOCKS, %
CIDI	0.0	0.0	20.5	7.7	20.1	15.9
SIDI	0.0	0.6	20.2	4.9	18.4	4.7
ALCOHOL FLEX	6.8	0.0	6.1	5.1	5.6	14.7
CNG	0.2	0.0	3.0	1.3	2.7	2.2
HYBRID	0.3	0.0	12.3	0.3	13.8	1.0
ELECTRIC	0.0	0.0	1.3	3.9	1.2	10.3
FUEL CELL	0.0	0.0	1.3	0.2	8.2	3.4
TOTAL	**7.2**	**0.6**	**64.6**	**23.4**	**70.0**	**52.2**

Exhibit 3-6: Market Penetration of Alternative Light Vehicle Sales

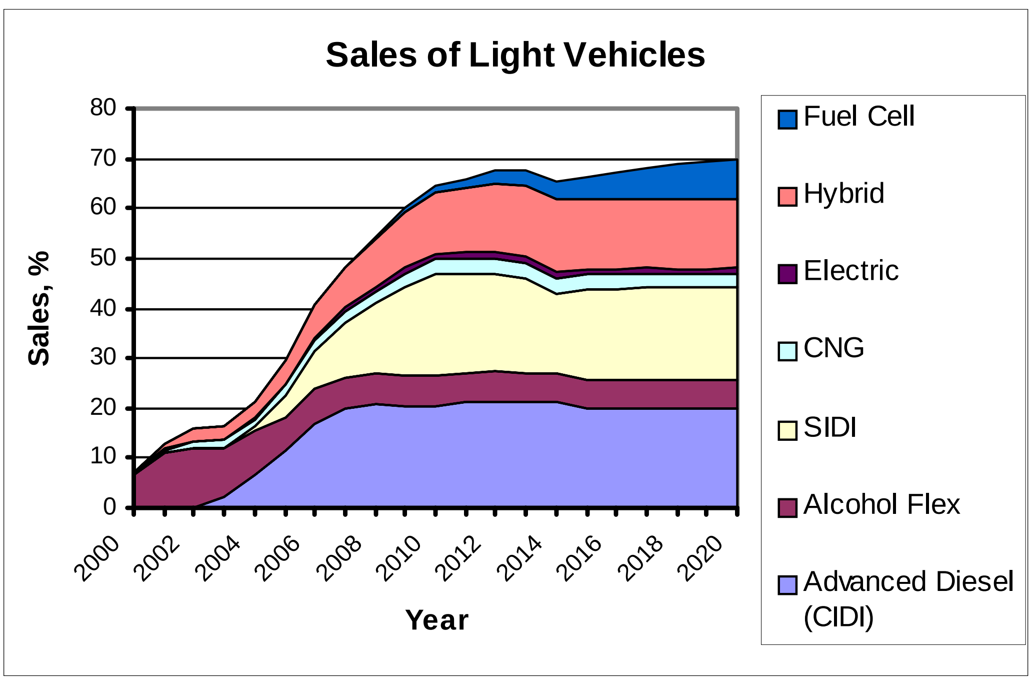


Exhibit 3-6 shows that advanced technology light vehicle sales decrease slightly in year 2015 and resume an increasing market share thereafter. This market share anomaly is the result of a very successful technology's initial market share being reduced by the S-curve adjustment (see Appendix B for a full discussion on the vehicle choice model).

In this case, fuel cell vehicles are introduced in the small car size class in 2015 and the model estimates, before the s-curve adjustment, that consumer demand for the fuel cell technology represents approximately fifteen percent (15%) of new small car sales in that year. Consequently, the success of fuel cells comes at the loss of market penetration for other advanced technologies as well as conventional technology. Each of the technologies competing against fuel cells loses approximately fifteen percent (15%) market share. For conventional vehicles, this amounts to 3.2 percentage points.

After the initial estimation of market demand, the model then calculates the S-curve adjustment. For the fuel cell technology, market penetration is reduced from fifteen percent (15%) to one – half percent (0.5%). As stated in Section 2.3, market share reductions from the S-curve adjustment are applied to the conventional technology. So, although all competing technologies lost market share to fuels cells, only conventional vehicle market share is increased after the S-curve adjustment. This results in a 14.5 percentage point increase in conventional technology from the initial loss of 3.2 percentage points in the small car size class. Thus creating the dip in advanced vehicle market penetration in year 2015.

Exhibits 3-7 through 3-11 are graphical representations of the market penetration of each vehicle class. In 2010, CIDI vehicles comprise the largest percentage (32%) of alternative small cars (Exhibit 3-7). This share is reduced to thirty percent (30%) by 2020. Hybrid and SIDI reach twenty-one percent (21%) and nineteen percent (19%), respectively, in 2010, and these shares are reduced slightly by 2020. As shown in Exhibit 3-8, the scenario for alternative large car penetration indicates that hybrid cars reach sixteen percent (16%) in 2010, and SIDI is at eighteen percent (18%) in 2010. As shown in Exhibit 3-9, CIDI is the best performer in the minivan class, reaching a twenty-seven percent (27%) market share.

Exhibit 3-7: Market Penetration of Small Cars

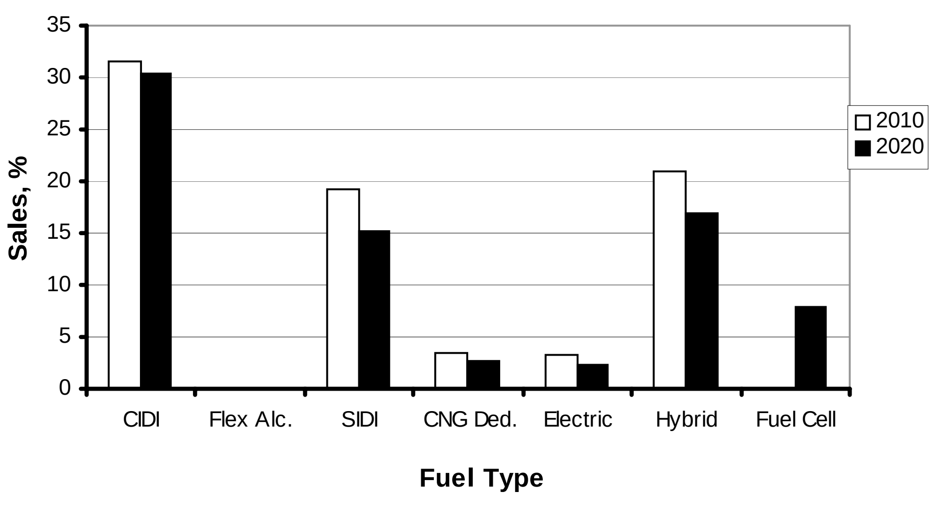


Exhibit 3-8: Market Penetration of Large Cars

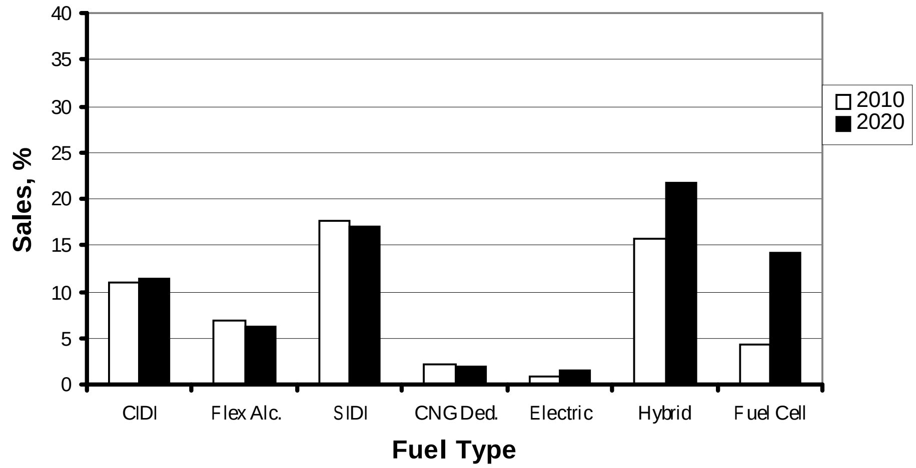


Exhibit 3-9: Market Penetration of Minivans

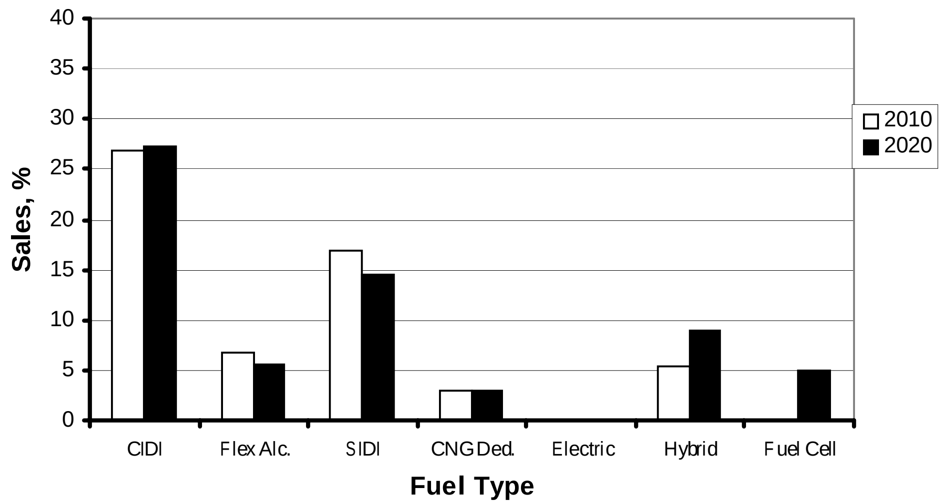


Exhibit 3-10 shows that sport utility buyers are highly receptive to both CIDI and SIDI advanced technologies, which perform well in both 2010 and 2020. Flex alcohol and hybrids also show lower but still significant market potential.

CIDI and SIDI dominate the pickup and large van market in both 2010 and 2020, as indicated in Exhibit 3-11, with penetration exceeding fifteen percent (15%) and twenty percent (20%).

Exhibit 3-10: Market Penetration of Sport Utility Vehicles

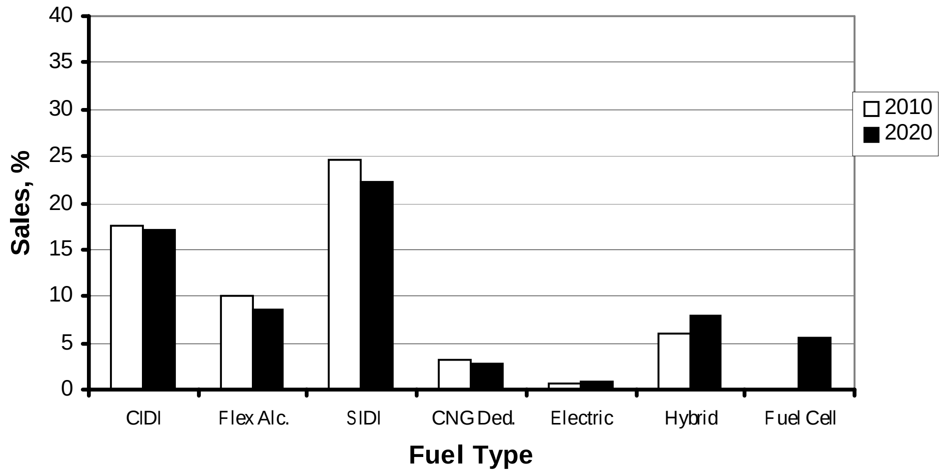


Exhibit 3-11: Market Penetration of Pickups & Large Vans

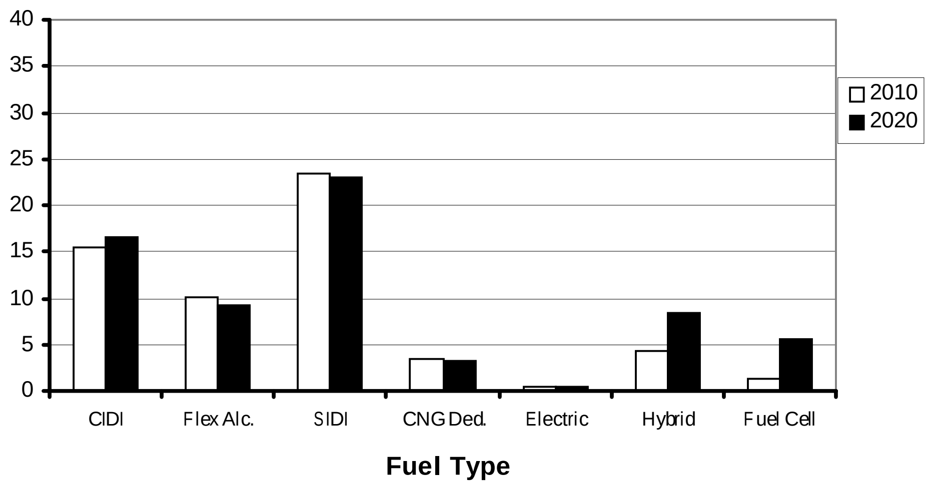


Exhibit 3-12 shows the penetration for the combined five vehicle classes for the year 2010. Exhibit 3-13 does the same for the year 2020. Cumulative vehicle "stocks" for each technology also are indicated. Note that sales are a percent of overall sales for that year, whereas stocks are a percent of the overall vehicle fleet in that year. In a growth market, sales shares will tend to be greater than the stock share.

Exhibit 3-12: Penetration of Alternative Light Vehicles in Sales and Stocks, 2010

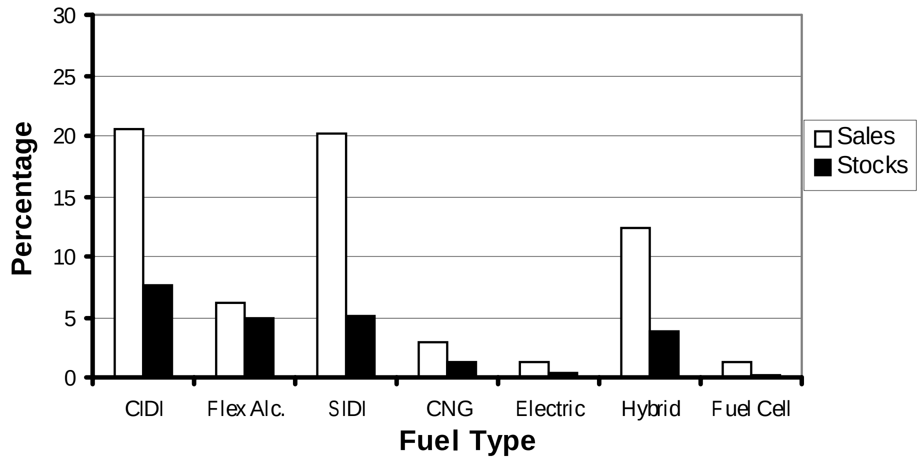
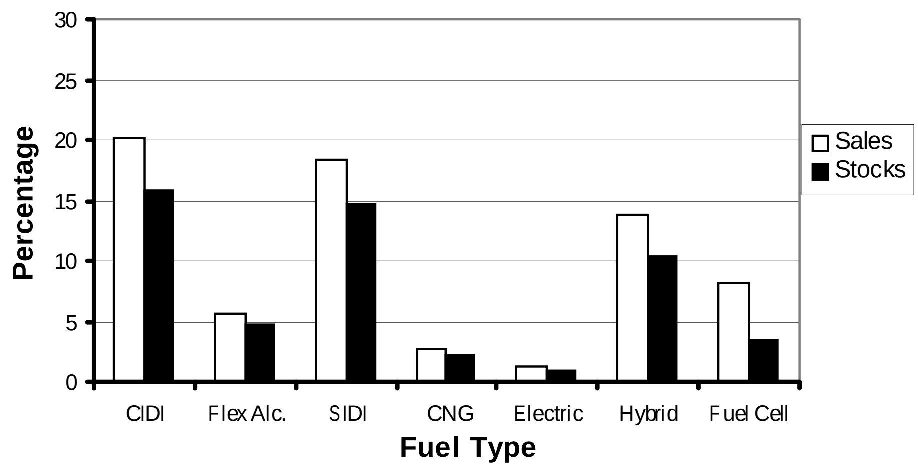


Exhibit 3-13: Penetration of Alternative Light Vehicles in Sales and Stocks, 2020



3.2 Heavy Vehicles

The Heavy Vehicle Market Penetration Model (HVMP) was developed to estimate the potential market impacts of new technologies on the medium and heavy truck market as follows.

- Medium - Classes 3 through 6 and,
- Heavy - Classes 7 and 8 are further subdivided by end-use characteristics:
  - Type 1 – multi-stop, step van, beverage, utility, winch, crane, wrecker, logging, pipe, garbage collection, dump, and concrete delivery;
  - Type 2 – platform, livestock, auto transport, oil-field, grain, and tank;
  - Type 3 – refrigerated van, drop frame van, open top van, and basic enclosed van.

The HVMP was configured using the 1992 Truck Inventory and Use Survey (TIUS)(Ref. 6). Data were examined for all vehicles in use and vehicles two years old or less. The HVMP model utilizes the data constructed from the two years old or less data base. The heavy vehicle market was analyzed to develop market segments with similar operation and use patterns. Refueling and travel characteristics were specifically addressed by vehicle body type and major use classification for the two market segments.

Heavy vehicle characteristics are summarized in Exhibit 3-14. In the medium truck market segment (Classes 3 through 6), all vehicle types, with the exception of auto transport, on average travel less than 30,000 miles per year. The average miles traveled for medium trucks is less than 15,000 and they have a useful life of about nine and one half years. Heavy trucks, depending on type, travel from 37,600 miles to 86,500 miles per year and are kept in use for approximately 6 to 10 years. One of the more interesting findings was the significant difference in fuel economy among the vehicle types.

Exhibit 3-14: Heavy Vehicle Characteristics

Vehicle Type	Average Annual Miles (1)	Average Age, years	Fuel Economy, mpg	Percent Centrally Refueled (1)
Class 3-6	14,450	9.62	7.9 mpg	46.5%
Class 7&8 -Type 1	37,600	9.65	4.5 mpg	61.0%
Class 7&8 -Type 2	64,600	9.57	6.1 mpg	48.5%
Class 7&8 -Type 3	86,500	6.13	7.7 mpg	43.5%

(1) Vehicles 2 years old or less.

In the HVMP model, the truck classes are further segmented according to refueling location (i.e. central or multiple locations). As shown in Exhibit 3-14, all vehicle segments have central refueling occurring at least forty-three percent (43.5%) of the time. As vehicles age, central refueling declines. This may be explained by the transition from larger fleet operations to small independent owner operators as centrally refueled vehicles age.

Overall market characteristics for vehicle stock, travel, and fuel use were also examined using the TIUS data (Exhibit 3-15). The data revealed that although medium trucks account for almost fifty-eight percent (57.6%) of the combined medium and heavy vehicle stock, they account for just over twenty-seven percent (27.3%) of vehicle miles traveled and twenty-one and a half percent (21.5%) of fuel use. As expected, the data show that Class 7&8 vehicles account for a significant amount of travel and fuel use in the heavy vehicle market, over seventy-two percent (72.7%) and seventy-eight percent (78.5%) respectively. It is also important to note that Type 3 vehicles show the greatest utilization, accounting for forty-one percent (41%) of all fuel use and thirty-nine percent (38.9%) of all travel in the heavy vehicle market, while accounting for only fourteen percent (14.1%) of the stock.

In addition to the market characterization, historical market penetration data was obtained from TIUS surveys for energy conserving technologies including radial tires, aerodynamic devices, and fan clutches. This data was utilized in the calibration of the rate of efficiency technology adoption in the model. (Ref. 6).

Exhibit 3-15: Market Characteristics

Vehicle Type	Percent of Total Vehicle Stock	Percent of Total VMT	Percent of Total Fuel Use
Class 3-6	57.6%	27.3%	21.5%
Class 7&8	42.4%	72.7%	78.5%
Type 1	12.1%	11.8%	13.6%
Type 2	16.1%	22.2%	23.9%
Type 3	14.1%	38.9%	41.0%

The HVMP model estimates market penetration based on cost effectiveness of the new technology. Cost effectiveness is measured as the incremental cost of the new technology less the discounted expected energy savings of that technology over a specified time period.

Exhibit 3-16 shows the payback distribution assumed in the HVMP model. This payback distribution was generated using data taken from a survey of 224 motor carriers conducted by the American Trucking Association. (Ref. 7)

Exhibit 3-16: Payback Periods

Number of Years	Percent of Motor Carriers
1	16.4%
2	61.7%
3	15.5%
4	6.4%

The new technology cost and the expected efficiency improvements are exogenous inputs. Energy savings are calculated using the following data and assumptions:

- Annual vehicle miles traveled;
- Fuel efficiency (mpg) without new technology (Ref. 6);
- Fuel efficiency (mpg) with new technology;
- Projected fuel price – diesel, ethanol, and CNG (Ref. 8);
- Incremental cost of new technology over time (economies of scale);
- Discount rate; and
- Payback period.

Eleven travel distance categories for medium trucks and twenty-one (21) for heavy trucks are represented in the model. These categories were determined using travel distributions developed with the TIUS data by ORNL (Ref. 9). Graphs of the actual data are shown for each market segment, with central refueling and not-central refueling shown separately.

As Exhibits 3-17 and 3-18 show, the majority of medium trucks travel less than 40,000 miles per year, with about seven percent (7%) more in the non-centrally refueled portion. Note that the percentages on the central and non-central refueling exhibits must be added to characterize 100% of the vehicle market.

Exhibit 3-17: Medium Vehicle Travel Distribution – Central Refueling

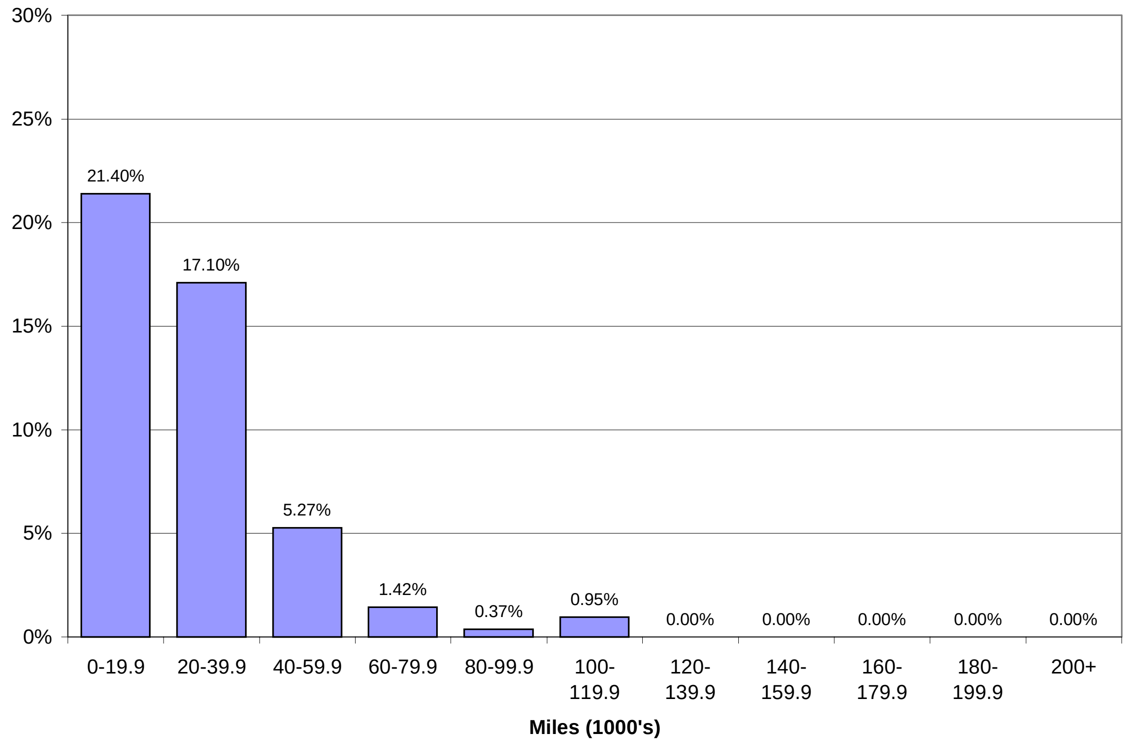
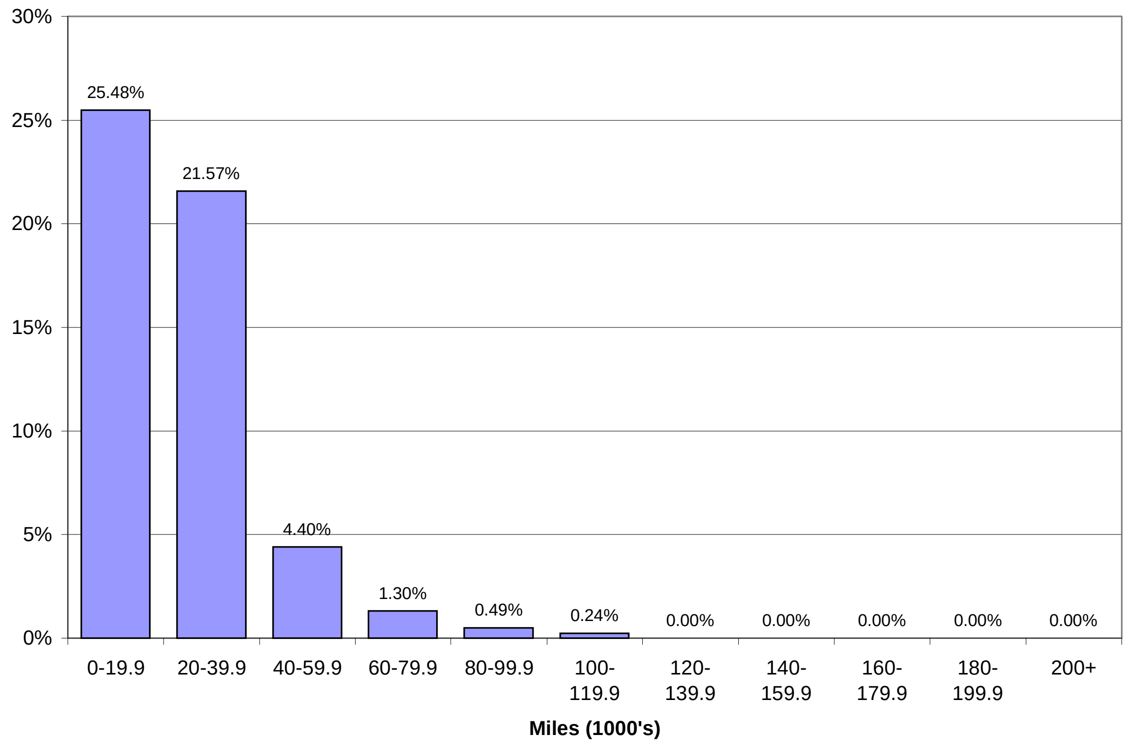


Exhibit 3-18: Medium Vehicle Travel Distribution – Non-Central Refueling



As shown in Exhibits 3-19 and 3-20, Type 1 vehicles exhibit travel patterns similar to that of medium vehicles. The majority of travel is less than 60,000 miles per year. There are fewer non-centrally refueled vehicles in the Type 1 market segment, but both segments have very similar travel characteristics.

Exhibit 3-19: Type 1 Vehicle Travel Distribution – Central Refueling

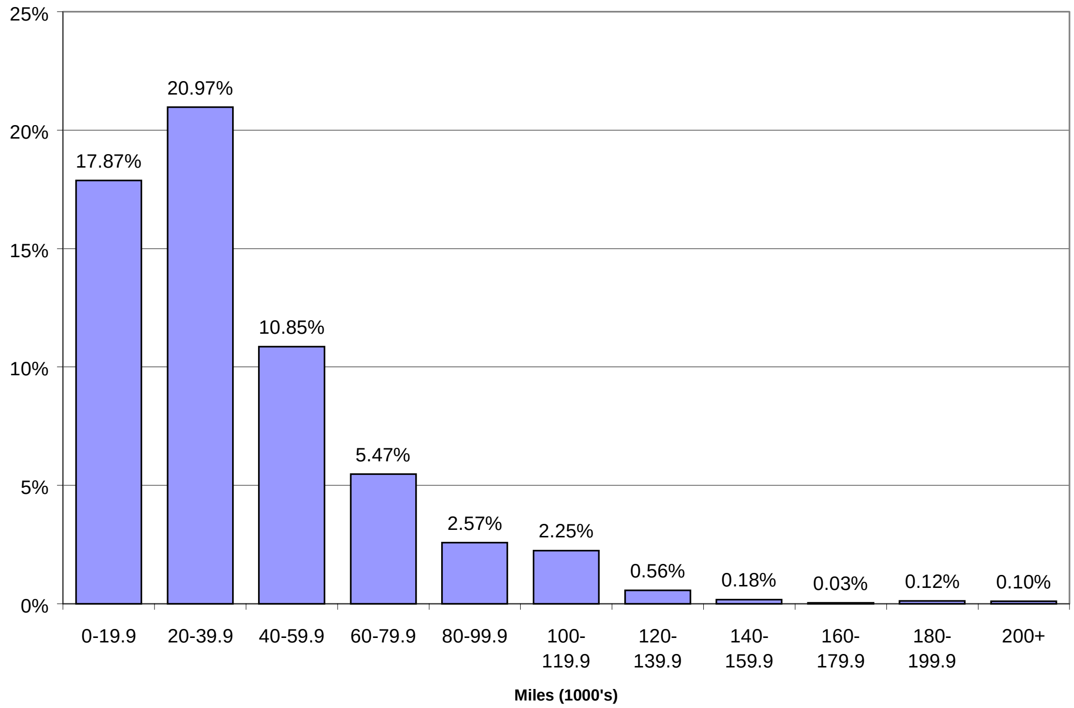
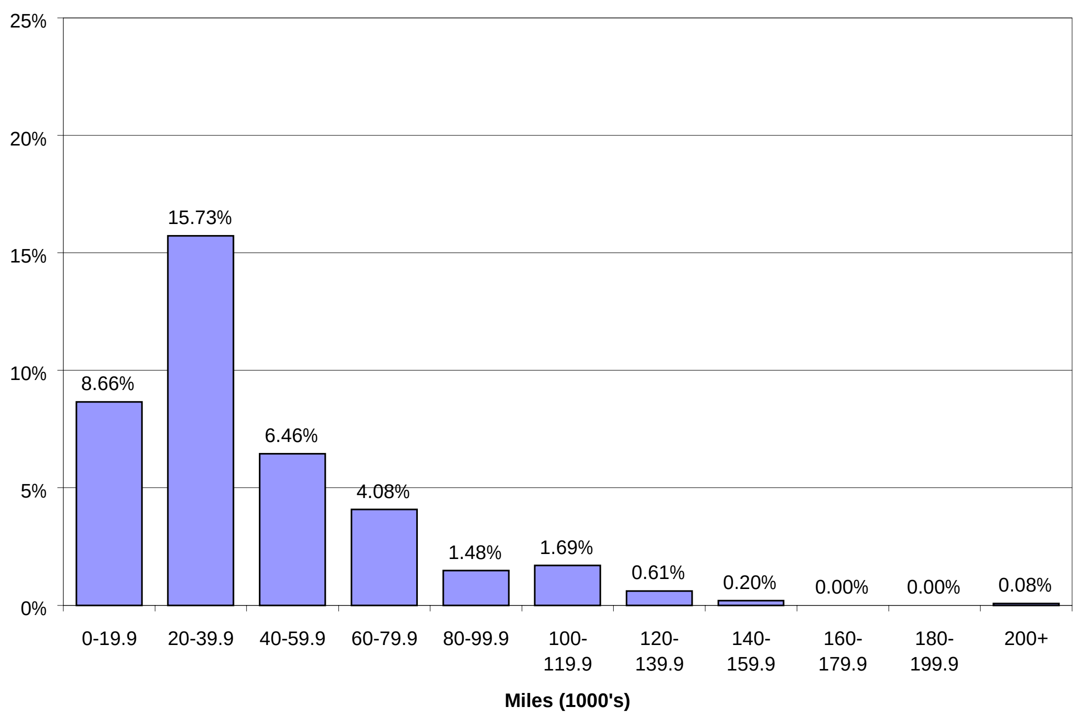


Exhibit 3-20: Type 1 Vehicle Travel Distribution – Non-Central Refueling



As shown in Exhibits 3-21 and 3-22, the Type 2 vehicle travel distribution shows travel peaks at both the upper and middle ranges. Further analysis may reveal that some vehicle types in this segment may fit better in the Type 1 or Type 3 segment. As expected, travel in this market segment increases significantly for both the central and non-centrally fueled vehicles.

Exhibit 3-21: Type 2 Vehicle Travel Distribution – Central Refueling

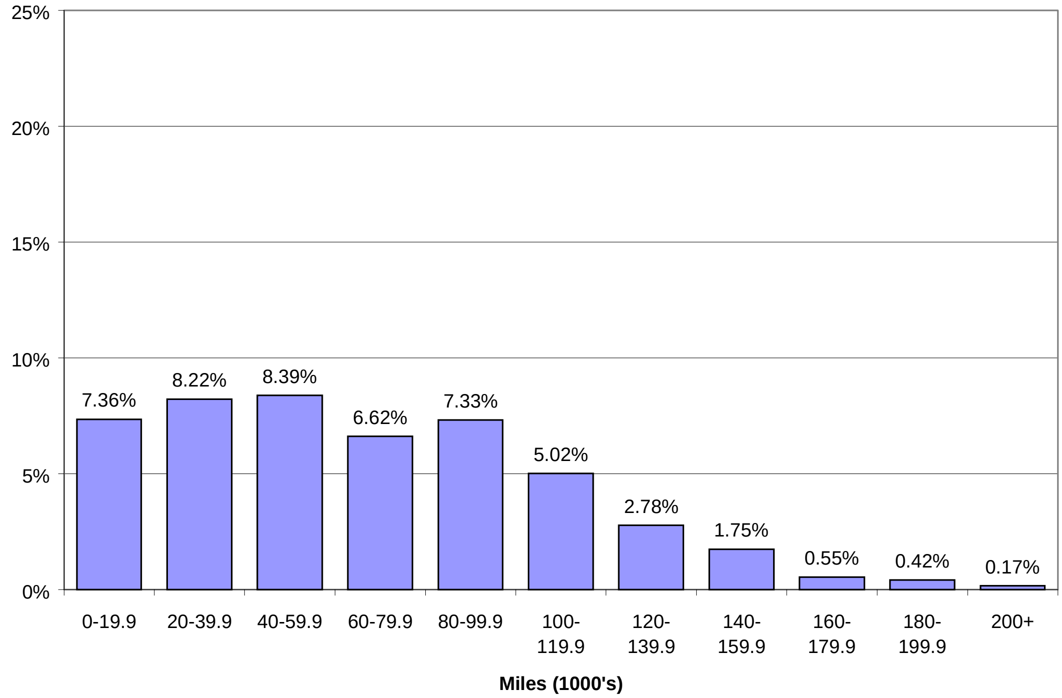
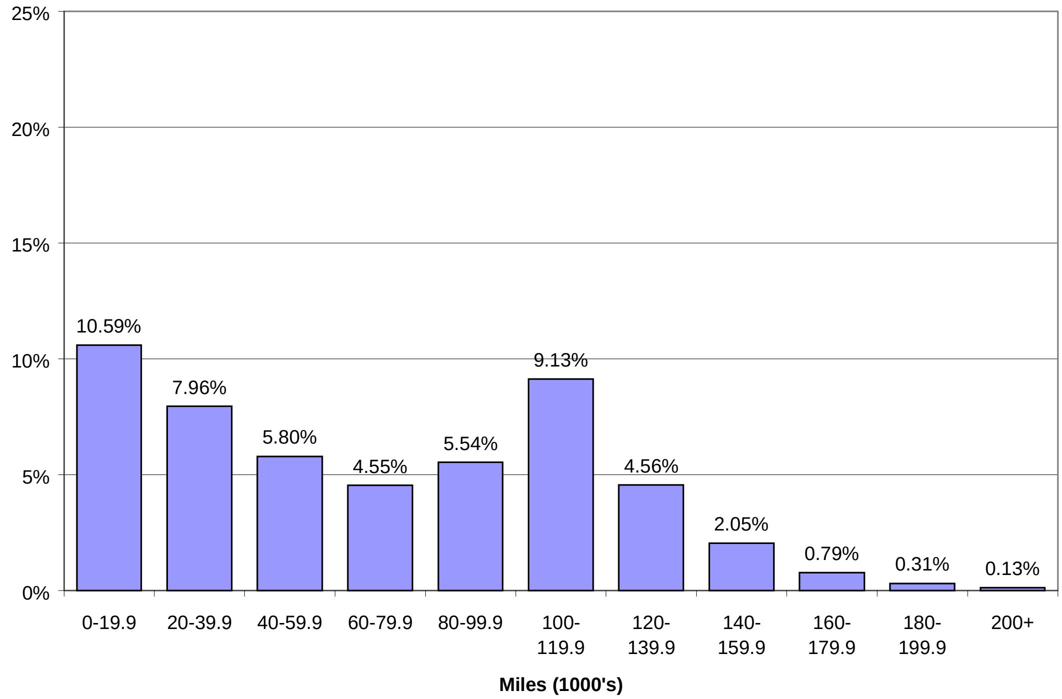


Exhibit 3-22: Type 2 Vehicle Travel Distribution – Non-Central Refueling



As shown in Exhibits 3-23 and 3-24, type 3 vehicles experience the greatest amount of annual travel. Centrally refueled vehicles travel less per year than non-centrally refueled vehicles. In the non-centrally refueled vehicle segment, the majority of travel occurs from 100,000 to 140,000 miles per year. In the central refueling segment, the majority of travel occurs below 140,000 miles per year.

Exhibit 3-23: Type 3 Vehicle Travel Distribution – Central Refueling

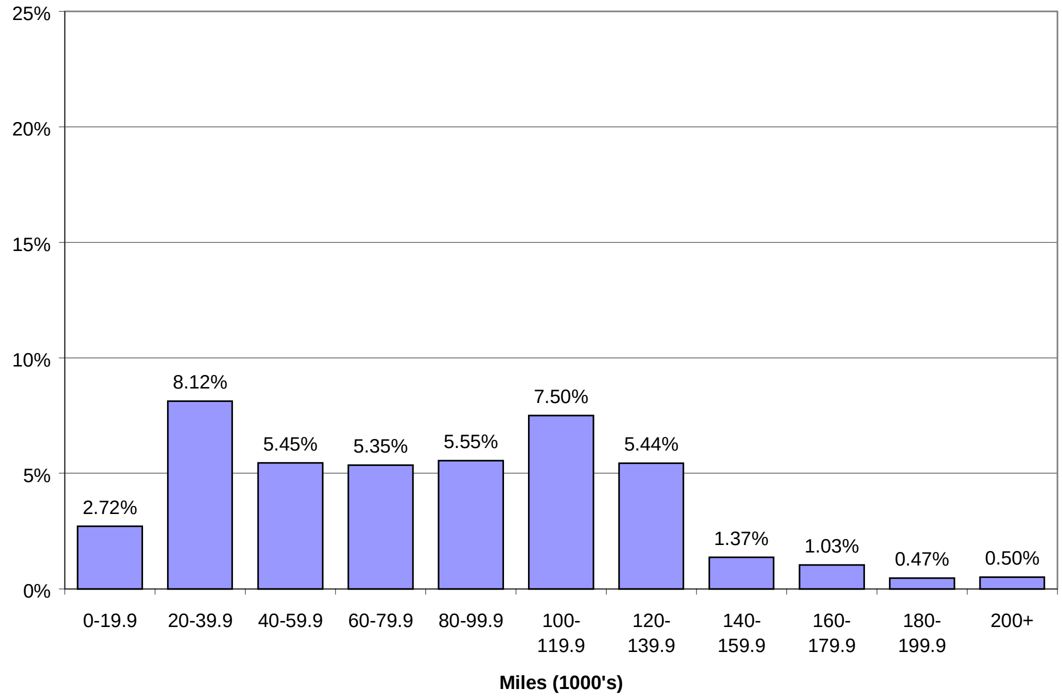
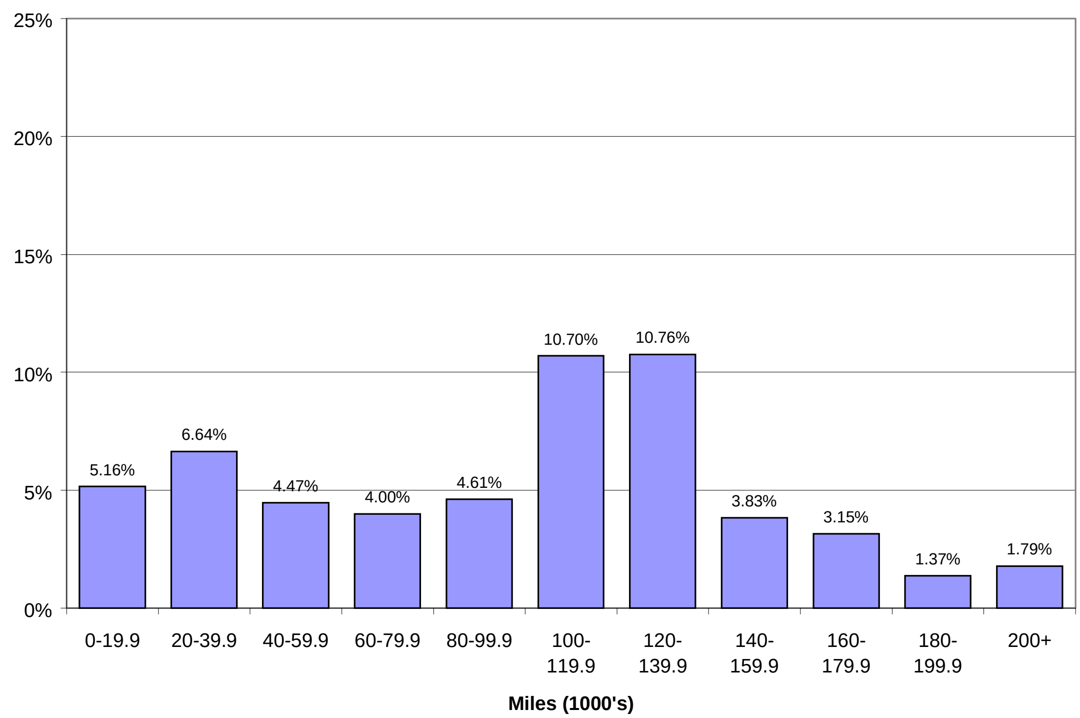


Exhibit 3-24: Type 3 Vehicle Travel Distribution – Non-Central Refueling



Technologies considered in the QM 2001 include natural gas engines, advanced diesel engines that are highly efficient and emit low levels of pollution in all classes and market segments, and hybrid drive trains in the medium class. The incremental vehicle costs and fuel economy ratios of the advanced heavy vehicle technologies are indicated in Exhibit 3-25. The table implicitly indicates the assumption that as a new technology is introduced into the market place and sales shares increase, costs are reduced.

Exhibit 3-25: Incremental Costs and Fuel Economy Improvements for Heavy Vehicle Technologies ($1996)

	2000	2005	2010	2015	2020
Class 7&8					
Advanced Diesel					
Incremental Cost ($)	4000	3500	3000	2500	2000
MPG Ratio	1.22	1.22	1.22	1.22	1.22
CNG					
Incremental Cost ($)	9000	9000	9000	6500	6500
MPG Ratio	0.75	0.75	0.75	0.75	0.75
Class 3-6					
Advanced Diesel					
Incremental Cost ($)	6000	3800	2000	2000	2000
MPG Ratio	1.22	1.40	1.40	1.40	1.40
Hybrid					
Incremental Cost ($)	15000	10000	9000	8000	7000
MPG Ratio	1.35	1.40	1.40	1.40	1.40
CNG					
Incremental Cost ($)	9000	6000	4000	4000	4000
MPG Ratio	0.75	0.75	0.75	0.75	0.75

Exhibit 3-26 illustrates market penetration forecasts for heavy vehicles. For the assumptions utilized, the natural gas truck characteristics are not economically competitive except in the year 2000 in Class 7 and 8 trucks. Advanced diesel technology has the best penetration in Type 3 trucks, which also have the greatest utilization level in terms of miles driven per year. Penetration in Type 2 trucks is also significant.

Exhibit 3-26: Heavy Vehicle Market Penetration Results
(all values are percent of new vehicle sales)

Technology	2000	2005	2010	2020
Class 3-6 Hybrid	0.0%	0.5%	2.0%	2.6%
Class 3-6 Natural Gas	0.0%	0.0%	0.0%	0.0%
Class 7&8 Type 1 Adv. Diesel	2.6%	4.0%	5.6%	12.0%
Class 7&8 Type 1 Natural Gas	0.2%	0.0%	0.0%	0.0%
Class 7&8 Type 2 Adv. Diesel	4.6%	7.0%	10.4%	23.7%
Class 7&8 Type 2 Natural Gas	0.3%	0.0%	0.0%	0.0%
Class 7&8 Type 3 Adv. Diesel	4.3%	6.6%	10.1%	23.8%
Class 7&8 Type 3 Natural Gas	0.1%	0.0%	0.0%	0.0%

3.3 Sensitivity Studies

Implicit in the market penetration analysis for light vehicles to this point is the assumption that all of the advanced vehicle technologies being investigated will enter the market and compete not only with conventional light vehicles but also with each other. This reduces the potential sales and resulting vehicle stocks of any one of the advanced vehicle technologies investigated.

In an effort to gauge the effects of this inter-technology competition, the VSCC model was rerun for each of the technologies separately; that is without competition from the other potential technologies. As expected, this greatly increased the potential energy and petroleum savings, fuel costs and carbon reductions ascribed to each of the technologies. This is shown in Exhibits 3-27 through 3-32. The primary energy displaced, primary oil displaced, energy cost savings, and carbon reductions of each of the OTT technologies and for each of the applicable OTT Planning Units taken separately are compared with the same estimated when all technologies are allowed to freely compete with each other. The savings presented for the Materials Technology Planning Unit combine all technologies.

Note that there is a substantial increase in the potential market penetration of any given technology when it is assumed to be competing only with conventional technology. For instance, in Year 2020, the primary energy savings of HEVs for stand-alone conditions are about 3.4 times higher than when HEV's are forced to compete with all of the other four technologies.

The total savings for all planning units for each technology stand-alone are compared with the total QM 2001 savings when all technologies are permitted to compete with each other is shown in Exhibit 3-33 for Year 2020 estimates. As expected, the total savings of the combined technologies is greater than any of the individual stand-alone savings, but substantially less than the sum of the stand-alone savings. For instance, the primary energy savings for the QM estimate is 2.494 Quads, but the savings for HEV's alone is 2.179 Quads, more than eighty-seven percent (87%) of the total.

Exhibit 3-27. Comparison of Stand-Alone Technology Savings with QM (Combined Technology) Savings:
Planning Unit: Vehicle Technologies R&D
Technology: HEV

Variable	Year							
	2000		2010		2015		2020	
	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate
Primary Energy (quads)	0.000	0.000	0.246	0.689	0.498	1.562	0.624	2.116
Primary Oil Displaced (quads)	0.000	0.000	0.246	0.689	0.498	1.562	0.624	2.116
Energy Cost Savings (1997$)	0.008	0.009	2.564	7.165	5.191	16.292	6.493	22.007
Carbon Reductions (mmtons)	0.018	0.020	4.785	13.373	9.660	30.318	12.118	41.073

Exhibit 3-28. Comparison of Stand-Alone Technology Savings with QM (Combined Technology) Savings:
Planning Unit: Vehicle Technologies R&D
Technology: Fuel Cell

Variable	Year							
	2000		2010		2015		2020	
	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate
Primary Energy (quads)	0.000	0.000	0.014	0.054	0.082	0.331	0.220	0.910
Primary Oil Displaced (quads)	0.000	0.000	0.014	0.054	0.082	0.331	0.220	0.910
Energy Cost Savings (1997$)	0.000	0.000	0.143	0.559	0.850	3.451	2.288	9.466
Carbon Reductions (mmtons)	0.000	0.000	0.263	1.024	1.554	6.307	4.194	17.350

Exhibit 3-29. Comparison of Stand-Alone Technology Savings with QM (Combined Technology) Savings:
Planning Unit: Vehicle Technologies R&D
Technology: SIDI

Variable	Year							
	2000		2010		2015		2020	
	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate
Primary Energy (quads)	0.000	0.000	0.085	0.205	0.164	0.413	0.199	0.519
Primary Oil Displaced (quads)	0.000	0.000	0.085	0.205	0.164	0.413	0.199	0.519
Energy Cost Savings (1997$)	0.000	0.000	0.882	2.127	1.711	4.303	2.070	5.401
Carbon Reductions (mmtons)	0.000	0.000	1.646	3.971	3.184	8.007	3.863	10.081

Exhibit 3-30. Comparison of Stand-Alone Technology Savings with QM (Combined Technology) Savings:
Planning Unit: Vehicle Technologies R&D
Technology: CIDI (Cars & Light Trucks)

Variable	Year							
	2000		2010		2015		2020	
	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate
Primary Energy (quads)	0.000	0.000	0.311	0.707	0.471	1.120	0.528	1.290
Primary Oil Displaced (quads)	0.000	0.000	0.311	0.707	0.471	1.120	0.528	1.290
Energy Cost Savings (1997$)	0.000	0.000	3.219	7.349	4.957	11.681	5.489	13.414
Carbon Reductions (mmtons)	0.000	0.000	5.542	12.656	8.512	20.060	9.453	23.102

Exhibit 3-31. Comparison of Stand-Alone Technology Savings with QM (Combined Technology) Savings:
Planning Unit: Vehicle Technologies R&D
Technology: EV

Variable	Year							
	2000		2010		2015		2020	
	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate
Primary Energy (quads)	0.000	0.000	0.004	0.028	0.009	0.600	0.100	0.810
Primary Oil Displaced (quads)	0.002	0.000	0.114	0.274	0.175	0.534	.0219	0.707
Energy Cost Savings (1997$)	-0.011	0.000	0.007	1.096	0.341	2.867	0.633	4.134
Carbon Reductions (mmtons)	0.000	0.000	0.218	0.835	0.567	2.314	0.828	3.458

Exhibit 3-32. Comparison of Stand-Alone Technology Savings with QM (Combined Technology) Savings:
Planning Unit: Material Technologies
Technology: All

Variable	Year							
	2000		2010		2015		2020	
	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate	QM Estimate (combined)	Stand-Alone Estimate
Primary Energy (quads)	0.000	0.000	0.009	0.466	0.024	0.713	0.043	0.813
Primary Oil Displaced (quads)	0.000	0.000	0.012	0.466	0.029	0.713	0.049	0.813
Energy Cost Savings (1997$)	0.000	0.002	0.111	4.845	0.285	7.435	0.490	8.451
Carbon Reductions (mmtons)	0.001	0.005	0.180	9.042	0.480	13.836	0.851	15.773

**Exhibit 3-33. Comparison of Stand-Alone Technology Savings with QM (Combined Technology) Savings:
Planning Unit: All
Technology: All**

Variable	Year 2020 Comparisons						
	Stand-Alone Technologies (not additive)						Total QM 2001
	HEV	Fuel Cell	SIDI	CIDI	EV	Materials	
Primary Energy (quads)	2.179	1.010	0.519	1.290	0.089	0.813	2.494
Primary Oil Displaced (quads)	2.179	1.010	0.519	1.290	0.761	0.813	3.207
Energy Cost Savings (1997$)	22.663	10.506	5.401	13.414	4.521	8.451	20.139
Carbon Reductions (mmtons)	42.304	19.256	10.081	23.102	3.749	15.773	50.141

Section 4.0: Benefits

4.0 Benefits Estimates

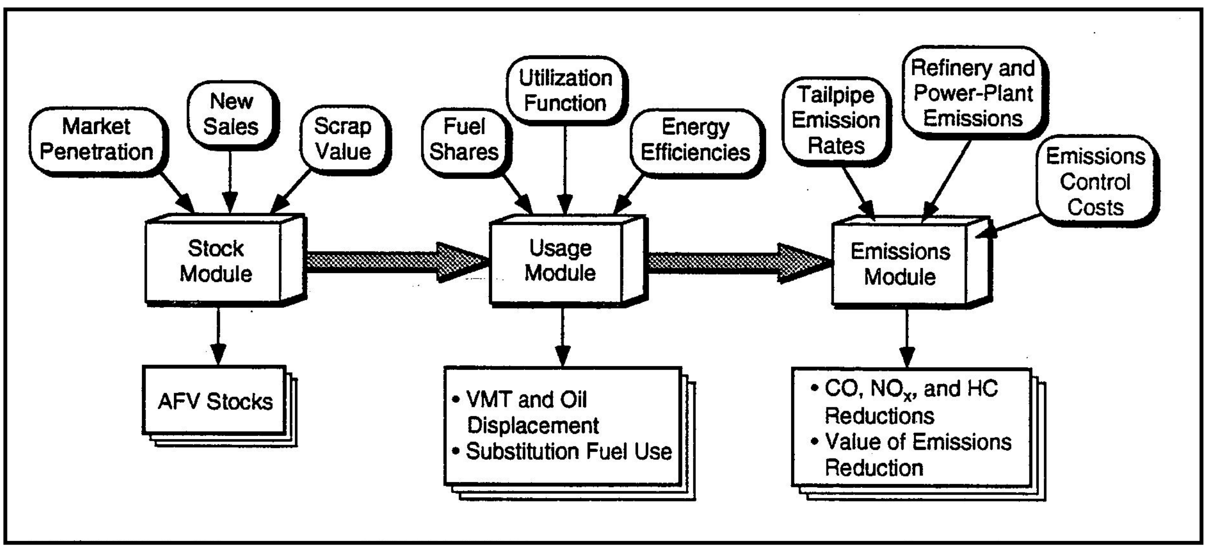
The results of this analysis are presented here and in the appendices. The benefits estimation methodology and assumptions are described, including: petroleum and energy benefits, economic and environmental benefits, and a benefit/cost analysis. The Quality Metrics results are presented in their entirety in Appendix A.

4.1 Petroleum and Other Energy Benefits Analysis

4.1.1 Integrated Market Penetration and Anticipated Cost of Transportation Technologies (IMPACTT) Model

The IMPACTT model is a spreadsheet model that calculates the effect of advanced-technology vehicles and market penetration on baseline fuel use and emissions (Ref. 10). IMPACTT conceptually consists of sixteen (16) modules, the largest of which is the vehicle stock and usage model. In the current version of IMPACTT, up to eight (8) fuel or engine technologies applicable to light vehicles can be modeled by using a three-phase approach. The impact model structure is indicated in Exhibit 4-1.

Exhibit 4-1: IMPACTT Model Structure



Source: Reference 10.

First, the vehicle stock and miles traveled by the advanced-technology vehicle are determined. The vehicle stock and usage module is based on a capital vintaging model developed by Greene and Rathi. It calculates vehicle stock, annual miles traveled, and fuel displaced (Ref. 11).

Second, assumptions about efficiency and fuel shares are used to estimate substitution-fuel use and oil displacement. Technology specific parameters such as gasoline equivalent fuel economy, and conversion efficiency values are used, as appropriate, to compute alternative fuel consumption.

Third, changes in emissions of carbon monoxide, non-methane hydrocarbons, nitrogen oxides, and carbon dioxide are computed. Emissions rates (in grams per mile) are modeled as a function of vehicle age.

Outputs include estimates of the quantity of oil displaced and emissions reduced by advanced-technology vehicles. These estimates are based on exogenous projections of light vehicle sales, advanced-technology market penetration, and the characteristics of new conventional and advanced-technology vehicles. Vehicle characteristics include:

- Fuel efficiency;
- Tailpipe emissions of nitrogen oxides (NO_x), carbon monoxide (CO), and non-methane hydrocarbons (NMHCs) as estimated using the EPA Mobile model 5a; and
- Incremental capital cost of the advanced technology.

Annual petroleum displacement and emission reductions are calculated by projecting the miles traveled by each model year's conventional vehicles, their petroleum use, and their emissions; and then subtracting from this the projections for comparable projections for advanced technology vehicles.

4.1.2 Biomass

Ethanol fuel use estimates are based on supply projections provided by the Office of Fuels Development (Ref. 12). The cellulosic ethanol goals for FY2000 and beyond are indicated below in Exhibit 4-2. All values are in million gallons per year. Initial production is expected to occur at two plants. The Masada Resources' plant is assumed to start up in 2001 and a second plant, BCI/Jennings in 2002. Subsequent plants expected to start ethanol production are:

- Arkenol in 2003;
- Gridley/BCI's (2 plants) in 2004;
- Quincy Library Group's softwoods plant and corn fiber add-ons to corn ethanol plants in 2005;
- Masada's and BCI's new plants in 2006;
- Corn fiber, stover, and softwoods plants in 2007.

Exhibit 4-2: Biomass Fuel Use

ITEM	2000	2010	2020
Direct Biomass Ethanol Use (million gallons per year)	0.6	465.8	1383.3
Blends (million gallons per year)	0	1,734	6,837
Program Supply Goal (million gallons)	0	2,200	8,220
Fuel Availability Assumption E-85*	0%	5.2%	18.2%

Alternative fuel demand is estimated as the amount of fuel required by dedicated fuel vehicles plus fuel demanded by multifuel and flex-fuel vehicles. Alternative fuel choice for multifuel and flex-fuel vehicles is estimated using consumer derived utility values associated with the attributes of the fuel. The fuel attributes include:

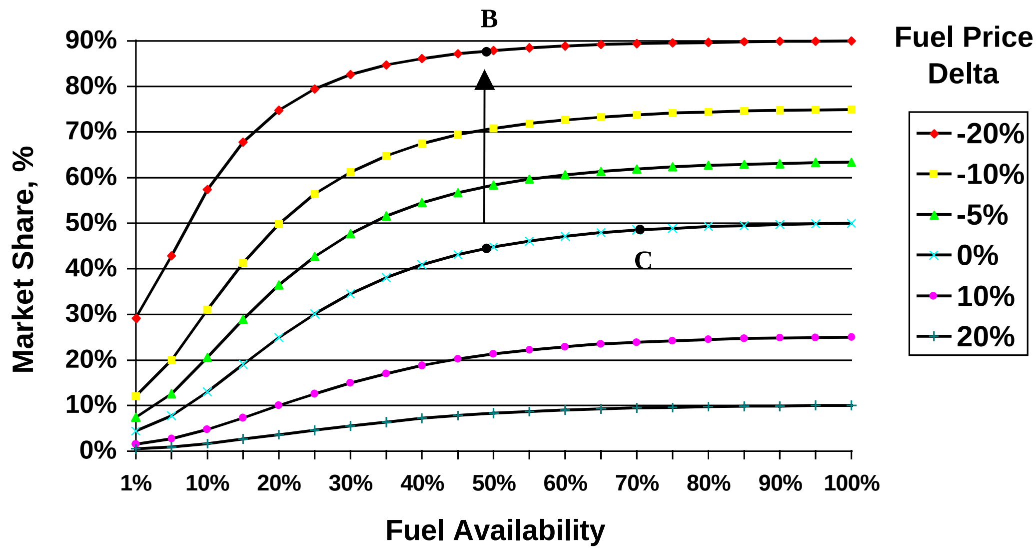
- Fuel price in dollars per gallon of gasoline equivalent (125,000 Btu);
- Fuel availability (percent of stations offering the fuel); and
- Vehicle range associated with the use of that fuel.

Exhibit 4-2 shows the amount of fuel demanded by flex-fuel vehicles and the use of fuel blends. The exhibit summarizes a detailed year-by-year estimate of biofuel demand for each technology which is presented in Appendix A. Fuel demand is constrained to match supply as indicated in the Exhibit. Ethanol is used in *fuel blends* in order to meet EPA requirements such as Reformulated Gasoline (RFG) and winter oxygenation, or to reduce petroleum consumption even in regions of the U.S. that need no RFG or oxygenated fuel.

4.1.3 Fuel Choice for Flex-Fuel Vehicles

Alternative fuel consumer utility values are compared to values for conventional fuels, when fuel choice estimations are made. Exhibit 4-3 shows the market share that an alternative fuel will achieve given a specified price and availability relative to gasoline. This graph illustrates the relationship between fuel availability and fuel price. For example, at fifty percent (50%) availability and a zero cost increment, the alternative fuel should be chosen forty-five percent (45%) of the time (Point A). If the price increment is decreased twenty percent (20%), it is estimated the alternative fuel will be chosen nearly 90% of the time (Point B). Whereas, if fuel availability is increased to seventy percent (70%) only marginal increases in alternative fuel selection occur (to 49% at Point C). The calculations for this graph assume no range penalty for using the alternative fuel.

Exhibit 4-3: Alternative Fuel Market Share as a Function of Fuel Availability and Fuel Price (Ref. 13)



Points A, B, and C are explained in text

4.1.4 Estimates of the Value of Reducing Imported Oil

Many researchers have developed estimates of the magnitude and cause of cost premiums associated with importing oil. The oil import premium exists because the market price of oil does not cover the societal cost incurred by importing. In order to calculate the value of an alternative to imported oil, one must add the market price of oil to the import premium. The "categories" of the oil import premiums, the rationale for including an oil import premium, and the range of estimates for the value of the oil import premium are explained in this section.

Definitions of the Components of an Imported Oil Premium

Externalities associated with imported oil can be defined as follows: demand costs ("market power" or monopsony effects, plus indirect effects such as inflation and balance of payments), disruption costs (economic losses due to price spikes), direct military costs (expenditures to maintain a military presence in oil producing regions), and environmental costs (costs due to oil spills and other environmental problems associated with importing oil). The demand and disruption costs are the most commonly used measure of an oil import premium (Ref. 14).

Demand costs can be broken into a direct and indirect component. The direct component is known as the "market power" or monopsony effects. Monopsony costs occur when the increase in the demand for imported oil causes world oil prices to rise, thus increasing the costs of all imports, not just the incremental demand. Not only is the added cost borne by the demander responsible for the increase, but by all importers equally. The market power premium can be illustrated by a simple example. Suppose the U.S. were importing 5.5 million barrels of oil a day at a price of $30 per barrel. Then the daily import bill would be $165 million. If increasing imports to 6.0 million barrels per day causes prices to rise to $31 per barrel, the daily import bill becomes $186 million. In this situation, the importing country bears an additional cost of $21 million per day in order to import an additional 0.5 million barrels per day. The cost to the economy is $42 per additional barrel of oil imported. Since the individual oil importers initially pay only $30 per barrel, the remainder -- $12 per barrel -- is a cost not borne by those who decide to import more oil. In this case, the market power premium is $12 per barrel.

Indirect costs are the macroeconomic costs of importing oil such as inflation impacts, lowering the level of savings, and terms of trade impacts. Imported oil bills increase the current account deficit in the U.S. balance of trade, leading to an excess supply of U.S. dollars in the foreign exchange market and thus lowering the buying power of U.S. consumers. Higher imported oil costs can lead to "structural" inflation that leads to adverse macroeconomic conditions.

Disruption or "security" costs can also be broken into direct and indirect components. The direct component is similar to the above direct component because it is the monopsony affect that occurs when prices increase due to a disruption. The indirect, or macroeconomic, component of disruption costs are associated with the depressed aggregate demand caused by the disruption and the accompanying higher inflation and unemployment.

The demand and disruption costs are traditional components of the calculation of an oil import premium. Somewhat untraditional and harder to quantify, additional components of the oil import premium are direct military expenditures and environmental costs. The military expenditures are some fraction of the costs to the U.S. to maintain a military presence in the Middle East to ensure continued access to oil. The environmental costs are less straightforward -- they primarily include the costs of oil spills and emissions from oil combustion. At this time, we have no estimates of the environmental costs. There are a variety of estimates of military costs based on the amount of military resources dedicated to the Persian Gulf region. Oak Ridge National Laboratory recently conducted a literature review and assessment of military costs to assure the supply of oil imports to the U.S. The total estimated cost of defending the Middle East Oil supplies is estimated to be about $32 billion per year in Reference 15. This is a difficult value to estimate, since it must be calculated based on allocations of costs to meet various needs. In this respect there is no "real" military cost other than that which is allocated and all allocation schemes are highly subjective. The range of estimates reviewed by Reference 15 is about a factor of ten.

The military cost of Middle East oil is borne by all and it is therefore reasonable to assign this cost to all petroleum consumed in the country whether from domestic, OPEC, non-OPEC or Middle East sources. Since the total U.S. petroleum demand is about thirty-nine (39) Quads or about 6.7 billion barrels per year, the "effective" cost of the military support of the Middle East allocated over all petroleum is about $4.78 per barrel. For purposes of this analysis, a benchmark "military cost" charge of $5.00 per barrel (about eleven (11) cents per gallon of gasoline) has been assumed.

Range of Estimates of Imported Oil Premium

Exhibit 4-4 identifies a range of estimates of an oil import premium (the market price of oil plus the oil import premium equals the value of reducing oil imports). They range from $1 to $225 depending on what is included in the estimate, the price of oil, and other assumptions. These values do not indicate whether or not the price of imported oil has an impact on its premium.

Exhibit 4-4: Value of Reducing Imported Oil ($1996 per bbl)

Source		Value, 1996$			Notes
		Demand Costs	Disruption Costs	Total Costs	
Stobaugh and Yergin (1979)	Low	$32		$32	
	High	$121		$121	
Stobaugh and Yergin (1980)	Low	$62		$62	
	High	$225		$225	
Lemon (1979)		$63	$7	$70	
Lemon (1980)		$104	$25	$129	
Nordhaus (1980)	Low	$0	$18	$18	
	High	$45	$32	$77	
Plummer (1981)	Low	$12	$6	$18	
	High	$12	$38	$50	
Hogan (1981)	Low				
	High	$46	$17	$63	
EMF 6 (1981)	Low	$12		$12	Based on 9 different models
	High	$25	$8	$33	
Totals	**Low**	$0	$7	$12	
	Avg	$58	$19	$61	
	High	$225	$38	$225	

Impacts of Imported Oil

The economic literature suggests that there are indirect economic costs and economic security costs associated with imported oil at prices influenced by a cartel. These costs are not captured in the gross domestic product (GDP) estimates from the economic models that are used in our analysis. Therefore, these costs need to be subtracted from any GDP estimate.

Several types of costs are not captured in the standard economic valuations. These are:

- Demand costs that are caused by the oil price increases that will occur when U.S. demand increases. This will have an effect on GDP.
- Disruption costs which reflect the expected economic costs of sudden shifts in oil price or availability due to possible political unrest in the Mid-East. Also, unpredictable oil costs

tend to suppress innovations that might otherwise have been implemented, thereby reducing petroleum consumption.

- Other costs which include the military costs of protecting Mid-East oil supplies and environmental costs associated with foreign oil production and transport.

The suggested cost associated with the use of imported oil, based on a subjective evaluation of the alternative estimates (Exhibit 4-4), and placing greater weight on estimates since 1990, is a nominal $5/barrel ($1996). This cost is in addition to the military cost of $5/barrel discussed previously.

4.1.5 Petroleum Reduction Estimates

Exhibit 4-5 shows the energy and oil that will be displaced as a result of the OTT programs discussed in this report. It can be seen that the total oil displacement that will occur in the year 2020 is about 1.5 million barrels per day.

Exhibit 4-5: Energy Displaced

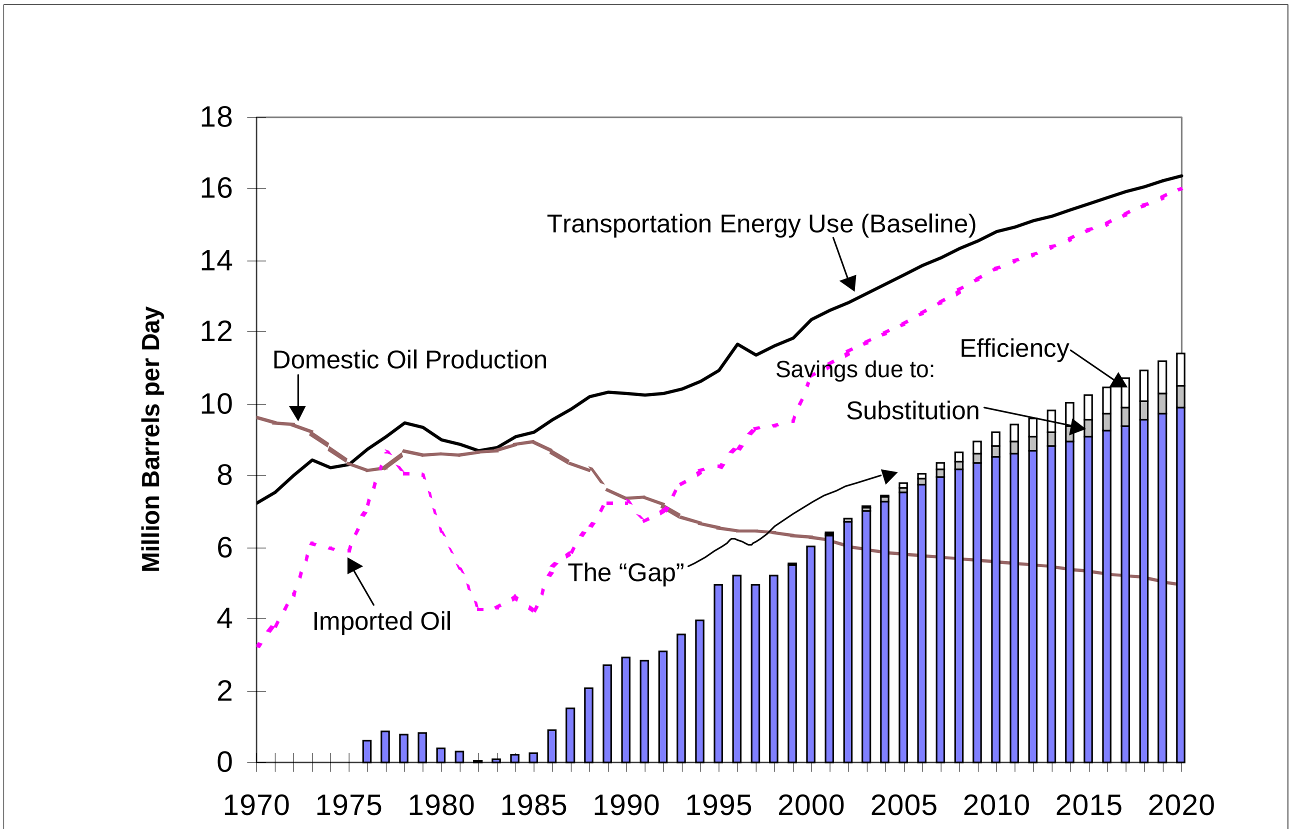
Technology	Primary Energy Displaced MMPD			Primary Oil Displaced MMPD		
	Year 2000	Year 2010	Year 2020	Year 2000	Year 2010	Year 2020
Vehicle Technologies R&D	0.004	0.349	0.836	0.006	0.401	0.935
Hybrid Systems R&D	0.000	0.116	0.295	0.000	0.116	0.295
Fuel Cell R&D	0.000	0.007	0.104	0.000	0.007	0.104
Advanced Combustion R&D	0.000	0.186	0.344	0.000	0.186	0.344
SIDI	*0.000*	*0.040*	*0.094*	*0.000*	*0.040*	*0.094*
Car CIDI	*0.000*	*0.077*	*0.125*	*0.000*	*0.077*	*0.125*
Light Truck CIDI	*0.000*	*0.069*	*0.125*	*0.000*	*0.069*	*0.125*
Electric Vehicle R&D	0.000	0.002	0.005	0.001	0.053	0.104
Household EV	*0.000*	*0.002*	*0.005*	*0.000*	*0.014*	*0.034*
EPAct ZEV Mandates	*0.000*	*0.000*	*0.000*	*0.001*	*0.039*	*0.070*
Heavy Vehicle Systems R&D	0.004	0.038	0.088	0.005	0.039	0.088
Class 3-6	*0.000*	*0.000*	*0.001*	*0.000*	*0.000*	*0.001*
Class 7&8	*0.004*	*0.038*	*0.087*	*0.004*	*0.038*	*0.087*
Class 7&8 CNG	*0.000*	*0.000*	*0.000*	*0.001*	*0.001*	*0.000*
Rail	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
Materials Technologies	0.000	0.004	0.020	0.000	0.005	0.023
Propulsion System Materials	0.000	0.000	0.000	0.000	0.000	0.000
Light Vehicle Materials	0.000	0.004	0.020	0.000	0.005	0.023
Electric Vehicle	*0.000*	*0.000*	*0.000*	*0.000*	*0.001*	*0.003*
Hybrid Vehicle	*0.000*	*0.003*	*0.009*	*0.000*	*0.003*	*0.009*
Fuel Cell Vehicle	*0.000*	*0.001*	*0.011*	*0.000*	*0.001*	*0.011*
Technology Deployment	0.000	0.000	0.000	0.033	0.195	0.235
Household CNG	0.000	0.000	0.000	0.001	0.086	0.128
EPAct Fleet	0.000	0.000	0.000	0.032	0.109	0.107
Fuels Development	0.000	0.086	0.322	0.000	0.086	0.322
Blends and Extenders	0.000	0.069	0.273	0.000	0.069	0.273
Flex-Fuel	0.000	0.017	0.049	0.000	0.017	0.049
Dedicated Conventional	0.000	0.000	0.000	0.000	0.000	0.000
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000
Total	0.004	0.439	1.178	0.039	0.687	1.515
Baseline (AEO 99 -Transportation)	12.82	15.62	17.41	12.34	14.80	16.38
Percent Reduction	0.03%	2.81%	6.77%	0.32%	4.64%	9.25%

The energy use effects of current zero emission vehicle (ZEV) mandates and EPACT requirements are indicated in Exhibit 4-6. Exhibit 4-7 shows that the OTT programs will have the effect of decreasing the rise in oil use by transportation.

Exhibit 4-6: ZEV and EPACT Oil Reductions

Program	2000	2005	2010	2105	2020
ZEV Mandates (thousand barrels/day)	0.34	18.67	40.28	56.60	72.06
EPACT (thousand barrels/day)	0.45	1.09	0.86	0.86	0.89
Total (thousand barrels/day)	0.79	19.76	41.14	57.46	72.95

Exhibit 4-7: Transportation Petroleum Use Projection



4.2 Economic and Environmental Benefits Analysis

In this section, economic and environmental benefits analyses are presented. The scope of the OTT Impacts Assessments contains analyses that supplement those required by QM. These include total fuel cycle criteria and carbon pollutant reductions, while QM requires direct carbon, hydrocarbon, CO, and NO_x reduction benefits only.

The Economic Spreadsheet Model (ESM), a spreadsheet model that estimates employment impacts of OTT's programs, is described first. The next section describes the methodology for estimating vehicle infrastructure capital requirements. A preliminary model for estimating life cycle cost, EV capital and operating costs, is then described. The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model, an analytic tool for evaluating emissions of criteria pollutants and greenhouse gases also is summarized. The next section concerns criteria pollutant emissions reduction values. Finally, estimating reductions in carbon emissions from the commercial utilization of OTT-sponsored technologies is discussed.

4.2.1 Economic Benefit Estimates

The ESM is a spreadsheet model that estimates employment impacts of OTT's programs. The spreadsheet takes economic impacts from the Quality Metrics process and applies them to economic multipliers, developed with Department of Commerce data, to estimate employment impacts of OTT technologies. Key inputs to the model are:

1) incremental vehicle cost of OTT technologies (if any);
2) money spent on alternative fuels associated with OTT's technologies; and
3) money saved from decreased spending on gasoline or diesel.

Exhibit 4-8 shows a summary of job impacts by sector of the economy. The multipliers used to provide these numbers are industry specific at an aggregate level. The multipliers are derived from the Regional Input-Output Modeling System (RIMS II) developed by the Bureau of Economic Analysis (BEA), U.S. Department of Commerce. They are based on an aggregate U.S. industry structure and updated with 1995 regional data. A detailed analysis of how the multipliers were calculated is presented in Appendix C.

The multipliers are used to calculate net jobs and GDP by multiplying them with the spending quantities associated with the advanced technologies. Expenditures considered are:

- spending on vehicles;
- decreased spending on oil;
- fuel cost savings; and
- increased spending on alternative fuels.

Exhibit 4-8 shows that the mining industry loses jobs while most other industries gain jobs. Advanced transportation technologies create jobs, in large part, because they induce spending in areas with larger multipliers than areas where spending would have occurred. The mining industry loses jobs because the reduced spending on oil affects the mining industry more than other industries. Job impacts attributable to the individual technologies fostered by OTT are indicated in Exhibit 4-9.

Exhibit 4-8: Employment Impacts by Sector of Economy (Jobs)

Jobs by Industry	2000	2010	2020
Farm, forestry, and fishery products	22	-623	11,672
Mining	-282	-29,853	-72,028
Construction	4	-687	-2,278
Durable goods	484	119,754	196,074
Non-durable goods	99	18,630	40,612
Transportation and public utilities	84	12,167	24,092
Wholesale trade	107	22,808	41,344
Retail trade	102	-10,934	2,051
Finance, insurance, & real estate	2	-13,875	-13,717
Service	301	-20,165	19,487
Private households	5	-1,990	-1,536
Total	928	95,232	245,772

Exhibit 4-9: Employment Impacts by Technology (Jobs)

Technology	2000	2010	2020
Alternative Fuel Vehicles	302	11,829	15,654
Biofuels	0	9,407	32,799
Electric Vehicle R&D	0	-477	6,743
Fuel Cell R&D	0	500	18,868
Heavy Truck R&D	626	7,614	17,285
Hybrid Vehicle R&D	0	23,180	64,209
Light Engine--car	0	9,111	14,148
Light Engine--truck	0	22,965	42,470
SIDI	0	8,314	21,283
Lightweight Materials R&D	0	2,789	12,313
	928	95,232	245,772

The increase in GDP is shown in Exhibit 4-10. Like the increase in jobs, the increase in GDP was calculated by applying the multipliers discussed above and in Appendix C. While the impact on GDP appears to be large, compared to the baseline, it represents an effect of less than one percent (1%). In addition to the internal OTT projects discussed above, the effects of the Partnership for a New Generation Vehicle (PNGV) Program were measured with the same model. PNGV is a partnership of eleven government agencies and the United States Council for Automotive Research, a cooperative research effort between Daimler-Chrysler, Ford Motor Co. and General Motors Corp. The goal of PNGV is to develop a commercially-viable 80 MPG five passenger car. The effect of PNGV ("3 times" conventional fuel economy difference) on jobs and GDP for automobiles and all light vehicles for the years 2010 and 2020 are shown in Exhibit 4-11.

Exhibit 4-10: GDP Increase (Millions of Dollars)

Technology	2000	2010	2020
Alternative Fuel Vehicles	$0	$826	$2,747
Biofuels	$43	$1,118	$1,373
Electric Vehicle R&D	$0	$2,342	$2,374
Fuel Cell R&D	$0	$2,402	$13,079
Heavy Truck R&D	$27	($116)	$(294)
Hybrid Vehicle R&D	$0	$10,258	$13,231
Light Engine--car	$0	$2,467	$2,225
Light Engine--truck	$0	$3,529	$3,550
SIDI	$0	$2,742	$2,336
Lightweight Materials R&D	$0	$234	$1,033
	$70	$25,805	$41,653

Exhibit 4-11: Economic Impacts of PNGV Scenarios

	2010	2020
Automobiles Only		
3x intro 2008, all other attributes the same		
Jobs	10,104	149,974
GDP (million $)	-281	-4,165
All Light Vehicles (automobiles & light trucks)		
3x intro 2008, all other attributes the same		
Jobs	18,955	294,836
GDP (million $)	-526	-8,188

4.2.2 Vehicle Infrastructure Capital Requirements

This section describes the methodology for estimating vehicle infrastructure capital requirements. The basic methodology, rationale for production volume cost estimates, and capital constraints of auto manufacturers are addressed.

A rough estimate of capital investment necessary to produce advanced light vehicles was made. The methodology consists of three (3) steps:

1. Estimate vehicles sold per technology by year;
2. Estimate production facility costs on a volume basis by technology;
3. Apply the production facility cost factor to vehicle sales that exceed the sales in the previous year for each technology.

Step 1 is based on the vehicle choice model results--the vehicle choice model provides sales estimates by technology per year. Step 2 is from empirical data and is discussed in more detail below. Step 3 is a simple way to estimate the incremental costs. In general, it is anticipated that a minimum of 300,000 vehicle sales per year are required in order for the production of an advanced technology or alternative fuel vehicle to be sustained.

<u>Production Facility Costs</u>

To estimate production facility costs, some recent estimates to develop new car lines were reviewed. Examples used include (Refs. 16-22):

- Saturn production plant costs of $4.5 billion to produce 500,000 vehicles per year.
- Ford Contour costs to retool nine assembly plants for new model costing $6 billion to produce 700,000 per year.
- Various estimates of engine and transmission plants indicating costs of about $300 million to build facilities with production outputs of 100,000 engines/transmissions per year.
- A Congressional Research Service report estimating changeover costs (for producing more efficient vehicles and engine) of $1.5 billion to $3.0 billion per car line (250,000 to 300,000 vehicles per year).

Based on the above information, the following production infrastructure costs by type of vehicle were estimated:

- CIDI and SIDI: $300 million per 100,000 vehicles. This cost is based primarily on cost to build a new engine plant. It is assumed that these technologies would be options for an existing production line.
- CNG Vehicles: $700 million per 100,000 vehicles. This cost is based on engine costs plus supporting fuel systems costs such as different on-board tanks and fuel supply systems. It is assumed that CNG vehicles would be adapted from existing car lines.
- Electric, hybrid, and fuel cell vehicles: $2 billion per 100,000 vehicles. This cost is based on new assembly plant, engine, battery, motor, and supporting technology plant costs. It is assumed that these vehicles would be totally new car lines.

Exhibit 4-12 shows capital infrastructure costs associated with producing advanced automotive technologies. It shows that expenditures are greatest in 2006 at almost $750 million, primarily due to production of hybrid vehicles. This table is reproduced from Appendix A, Table A-32.

Exhibit 4-12: Capital Infrastructure Costs
(Millions of 1996 Dollars)

Year	CIDI	CNG	Electric	Hybrid	Fuel Cell	Total
2000	$0	$15	$5	$73	$0	**$94**
2001	$0	$48	$20	$260	$0	**$328**
2002	$5	$44	$24	$291	$0	**$365**
2003	$76	$30	$0	$7	$0	**$113**
2004	$181	$15	$13	$243	$0	**$452**
2005	$190	$27	$28	$423	$0	**$667**
2006	$234	$25	$34	$446	$0	**$739**
2007	$115	$21	$46	$398	$23	**$605**
2008	$48	$23	$55	$467	$91	**$684**
2009	$6	$25	$64	$448	$122	**$666**
2010	$16	$21	$68	$414	$135	**$654**
2011	$18	$0	$5	$196	$137	**$356**
2012	$10	$0	$4	$215	$146	**$376**
2013	$0	$0	$4	$130	$144	**$279**
2014	$10	$1	$10	$110	$199	**$330**
2015	$0	$0	$0	$0	$244	**$244**
2016	$0	$0	$1	$0	$304	**$305**
2017	$0	$0	$0	$0	$272	**$272**
2018	$3	$0	$0	$0	$194	**$197**
2019	$3	$0	$0	$0	$166	**$169**
2020	$2	$0	$0	$0	$166	**$168**

Capital Constraints of Auto Manufacturers

Exhibit 4-13 shows aggregate capital expenditures by the motor vehicle industry in the U.S. and expenditures by the major domestic manufacturers globally in billions of dollars for 1991 to 1997. The U.S. expenditures column includes expenditures by the major domestic manufacturers, transplants and parts suppliers. These figures give an indication of how constrained industry would be if they incurred capital infrastructure investment costs referred to in Exhibit 4-12.

Our analysis indicates that in most years, the capital spending on production facilities would be less than $2 billion per year, which is substantially less than what the major domestic manufacturers have been spending on capital infrastructure. However, this may mean that other improvements may be deferred.

Exhibit 4-13: Aggregate Capital Expenditures
(billions of U.S. dollars)

YEAR	GM	Ford	Chrysler	TOTAL Big 3
1997	$10.1	$7.9	$5.0	**$23.0**
1996	$9.9	$8.2	$4.6	**$22.7**
1995	$9.0	$8.9	$3.7	**$21.6**
1994	$5.8	$8.7	$4.0	**$18.5**
1993	$5.6	$7.2	$3.2	**$16.0**
1992	$5.8	$6.3	$2.5	**$14.6**
1991	$6.6	$6.5	$2.5	**$15.6**

4.2.3 Life-Cycle Cost Effects

In the last release of this report (QM 2000), this section contained a general discussion of the ANL spreadsheet models for projecting hybrid electric and battery electric vehicle capital and operating costs, the result of work by Vyas et al., (Ref 23); Cuenca and Gains, 1997 (Ref. 24); and Cuenca, 1995 (Ref. 25 and 1996 (Ref. 26).

As part of the continuing OTT Impacts Assessment, a more detailed description of the HEVCOST model is presented below. This work is independent but supportive of the Quality Metrics cost estimates and may be used to adjust the HEV QM cost and performance estimates in the future. The final HEV cost estimates generated by the model are strongly dependent upon the assumptions of performance and weight as well as battery technology and hybrid operating mode (series of parallel) assumed. The numbers shown below are the default assumptions and results used in the model. The cost estimates generated by this model using the default assumptions are generally somewhat higher than the cost estimates currently used in the QM analysis. The model will be used in the future to refine the QM HEV cost estimates as deemed appropriate.

The model assumes that production volumes increase with time (25,000 – 250,000 vehicles/year) and substantial reduction in electric components costs during the first 10 years of production. The cost model does not apply to low-volume production where such items as batteries and inverters are manufactured through a largely manual process. The cost during the introductory phase is not estimated, as the objective is to consider the long-term viability of the technology.

The costs shown here are for assumed production volumes and dates for one manufacturer:

- 25,000 in 2005,
- 50,000-100,000 in 2010,
- 150,000-250,000 in 2015, and
- over 250,000 in 2020.

The years may be changed by the analyst. The model allows such a change. The model includes separate estimates for the effects of number of years since introduction and volume produced.

The basic assumption of the cost model is that an HEV's body and chassis would remain the same as the current CV's. The costs of individual vehicle systems and common components cost shares for subcompact and midsize cars and minivan. The common component cost share is seventy-five percent (75%) for the subcompact, seventy-two percent (72%) for the midsize, and seventy-eight percent (78%) for the minivan. The model first estimates the cost of common components by applying the appropriate cost share factor to the CV price. The model then adds the costs of an aluminum body, Auxiliary Power Unit (APU), generator, inverter and power electronics, motor, transmission/gear drive, battery pack, system control, and other components (such as HVAC and electrical brakes) as described below.

Most of the components data represent original equipment manufacturer (OEM) factory gate. The final price to the consumer is computed through factors applied to these factory gate costs to include overhead, R&D and engineering, warranty, transportation, advertising and dealer support, and profit. A conventional component is subjected to a factor of 2 (i.e. 100% increase) while an outsourced electric drive component is subjected to a factor of 1.5 (i.e. 50% increase) to account for the indirect costs. The battery pack is also assumed to be outsourced and is subjected to a factor of 1.15 to account only for OEM warranty and profit. All the electric drive components: inverter and power electronics, motor, and generator are considered as outsourced within the model. Two cost items, aluminum body and diesel premium, are presently reported as additional price increments paid by the consumer. These two items are not subject to any factors.

The methodology employed here for estimating vehicle purchase price, through application of "post factory gate" factors, provides approximate values. The vehicle manufacturers allocate their indirect costs several different ways. The method of determining the suggested retail price also differs among manufacturers.

<u>Components Manufactured by OEM</u>

APU**:** The APU system includes engine, emissions and electronic controls, cooling system, exhaust system with catalyst, fuel storage with evaporative emissions control, and equipment necessary to use the motor for starting the engine. This list excludes such engine accessories as alternator and starter systems. The APU system cost equation has a fixed component and a variable component based on kW rating. The equation was developed from cost information on two engine systems developed by ANL. A subcompact engine system with 75 kW power would cost $2,435 and a 93 kW midsize engine system would cost $2,950. Exhibit 4-14 shows the baseline cost data and fixed and variable terms used by the cost model. The validity of this cost equation was confirmed by applying it to a conventional midsize car that accelerates from zero to 60 mph in 10 seconds. The resulting powertrain cost share of the total vehicle cost was twenty-eight percent (28%), consistent with ANL's estimate for the mid-ninety's midsize vehicle.

Exhibit 4-14. Derivation of APU Cost Equation for the HEV Cost Model

Item	OEM Cost ($ except as noted)		Allocation of Variable Cost	
	Engine #1	Engine #2	% Share	$

Engine	1,300	1,630	54.3	15.0
Emissions & Electronic Control	240	280	9.7	2.7
Engine Cooling System	150	190	6.3	1.7
Exhaust System (w/ catalyst)	300	340	11.9	3.3
Fuel Storage & Evaporative Emissions Control	90	105	3.6	1.0
Engine Accessories*	355	405	14.2	3.9
Total	2,435	2,950		
Power (kW)	74.6	93.3		
Cost Equation				
Variable Cost ($/kW) for CV	27.6			
Variable Cost ($/kW) for HEV	23.7			
Fixed Cost ($/Engine)	375			

* Not included in the HEV model. The variable cost of $23.7 per kW is used in the model.

Both fixed and variable costs are assumed to rise five percent (5%) every 5 years. The results are seen in Exhibit 4-15. The cost increases are associated with assumed improvements in engine technology. The power and mass computing procedure within the cost model assumes steady increases in specific power of the engine due to these improvements.

Exhibit 4-15. Fixed and Variable Costs from HEV Cost Model

	2010	2015	2020
Fixed Costs	$393.8	$413.4	$434.1
Variable Costs (per kW)	$24.9	$29.1	$27.4

Transmission and Gear Drive: The model assumes a transmission and a gear drive for the parallel configuration and only a gear drive for the series configuration. Each cost function for transmission and gear drive has a minimum cost value (up to a threshold value of power) and a variable component if power exceeds the threshold value. Exhibit 4-16 lists the fixed and variable components and the associated threshold power.

The variable component is zero for an APU that has a 50 kW or lower rating. For a larger APU (i.e. power greater than 50 kW), the variable cost is $5.20 per kW in 2005 and $5 per kW thereafter. The motor of an HEV is connected to a gear drive whose fixed cost for a 50 kW or smaller motor is $90 in 2005 and $85 thereafter. For motors that have more than 50 kW of power, the additional cost would be $1.8 per kW in 2005 and $1.7 thereafter. A version of the cost model assumes a parallel HEV configuration in which the transmission handles both APU and motor (after gear drive) power. This change became necessary to be compatible with the current version of the National Renewable Energy Laboratory's advanced vehicle simulation (ADVISOR) model.

Exhibit 4-16. Transmission and Gear Drive Cost Components

Item	2005	2010	2015	2020
Parallel HEV				
APU Transmission: Fixed Cost ($)	336	330	330	330
APU Power Threshold for Fixed Cost (kW)	50	50	50	50
Variable Cost per kW over Threshold ($/kW)	5.20	5.00	5.00	5.00
Parallel or Series HEV				
Motor Gear Drive: Fixed Cost ($)	90	85	85	85
Motor Power Threshold for Fixed Cost (kW)	50	50	50	50
Variable Cost per kW over Threshold ($/kW)	1.80	1.70	1.70	1.70

System Control: See Exhibit 4-17.

Exhibit 4-17. System Control Costs

	2005	2010	2015	2020
System Control	$210	$202	$192	$172

Other Costs: The other costs include the combined additional cost of the braking system, HVAC, and the chassis electric system. This cost to OEM is seen below.

Exhibit 4-18. Other Costs

	2005	2010	2015	2020
Other Costs	$260	$250	$242	$236

<u>Outsourced Electric Drive Components</u>

The fixed and variable costs for the electric drive components are shown in Exhibit 4-19.

Inverter and Power Electronics: The cost function has a fixed and a variable term. The fixed term is $500 in 2005, $425 in 2010, $385 in 2015, and $350 in 2020. The variable term, dollar per kW, is 24 in 2005, 19 in 2010, 15 in 2015, and 13 in 2020. Since this component is unique to electric drive, we assumed continuous reduction in both fixed and variable costs.

Motor/Generator: The values for the permanent magnet motor and generator are computed from the Prius cost information from Ref. 25. The motor is assumed to be more mature with less potential for cost reduction. The values for the induction motor were estimated by ANL. During a presentation of the model at DOE/OTT, some members of the OAAT (Office of Advanced Automotive Technology) staff indicated that they would like to include the switched reluctance motor. However, we do not have good cost information on that motor.

Exhibit 4-19. Electric Drive Fixed and Variable Costs

Type	2005	2010	2015	2020
Inverter & Power Electronics				

Fixed Cost	500	425	385	350
Variable Cost ($/kW)	24	19	15	13
Motor/Generator				
Fixed Cost	200	200	200	200
Variable Cost ($/kW) for				
Permanent Magnet	17.0	13.7	11.7	11.0
Induction	11.0	10.5	9.8	9.0

Outsourced Battery Pack

The nickel metal hydride battery is the only battery type available in the present setup of the cost model. The data on the batteries in Toyota's RAV-4 electric vehicle and Prius hybrid electric vehicle show that the nickel metal hydride battery can be produced to optimize either its specific power (W/kg) or its specific energy (Wh/kg). The characteristics of both the RAV-4 type (high specific energy) and Prius type (high specific power) batteries have been extrapolated. Also included in the model were five assumed "mid level" batteries with characteristics that are in between the "high specific energy" and "high specific power" batteries. Their specific power and specific energy were estimated through linear interpolation between the "high specific power" and "high specific energy" batteries. A cost equation was developed to estimate battery cost. The equation format was adapted from a report on nickel metal hydride battery costs by Tim Lipman of University of California at Davis. The costs of these batteries are shown in Exhibit 4-20. These costs are subjected to an admittedly low factor of 1.15 within the cost model.

The component sizing model, depending on the acceleration and grade climbing requirements, determines the size of the battery pack. The "high specific power" battery would be the battery of choice for most, so called power-assist type, HEVs. If some all-electric travel capability (also called dual-mode capability) were desired, one of the "mid level" batteries or the "high specific energy" battery would be preferred. However, the analysis of HEVs with all-electric acceleration capability of zero to 60 mph in 12-16 seconds has shown that the "high specific energy" battery would not be the least cost means of meeting the performance minima even though it would provide all-electric range above the minimum.

Exhibit 4-20. Nickel Metal Hydride Battery Costs Used in the Cost Model

Battery Type	Battery Cost $/kWh				Battery Specific Power W/kg			
	2005	2010	2015	2020	2005	2010	2015	2020
High Specific Energy	532	430	398	366	177	184	194	203
Mid Level 1	588	475	439	404	231	240	252	265
Mid Level 2	646	522	483	444	282	296	311	326
Mid Level 3	710	574	531	488	338	352	370	388
Mid Level 4	778	625	575	526	392	408	429	450
Mid Level 5	865	698	646	594	446	464	488	511
High Specific Power	961	776	718	660	500	520	545	575

The cost values in Exhibit 4-20 are well above, and the specific power values well below, the PNGV targets. Dr. Linda Gaines provided us with a copy of the PNGV battery performance and cost targets from a presentation by Dr. Helen Cost of DaimlerChrysler. The cost target for the power-assist HEV battery is $300. The battery's physical attributes that relate to the performance targets are 0.3 kWh energy, 25-30 kW power, and 40 kg mass. The implied specific power and specific energy values are 7.5 Wh and 625-750 W per kg. The cost is $1,000 per kWh or $10-12 per kW. The specific energy values for the 7 batteries in Table 4 range from 43 to 77 Wh/kg. The range of per kW cost is $58-83, much higher than the PNGV target. A 25 kW high specific power battery pack (from Exhibit 4-20) will have 2.15 kWh of energy at a cost of $2,066 in 2005 and 2.18 kWh energy at $1,439 in 2020. The (PNGV) specific power target of 625-750 W/kg is achievable. Both Panasonic and GM-Ovonic have claimed a laboratory level value of 1,000 W/kg. However, the cost and specific energy targets would be very difficult to achieve. According to researchers at the University of California at Davis, the cost target of $1,000/kWh could be achieved under high-volume, highly automated production. But because the battery pack is likely to have 1-1.5 kWh energy content, the total cost ($1,000-1,500) would be much higher than the PNGV target of $300.

Costs Charged Directly to the Consumer

Two cost items, cost of aluminum body and diesel engine premium, are added directly to the vehicle price. These cost items are not subjected to any factors.

Aluminum Body: The cost of an aluminum body for a midsize vehicle is $3,600 in 2010, $1,700 in 2015, and $1,200 in 2020. We assumed that mass produced aluminum body vehicles would not be available in 2005. The cost numbers are from an ANL study of lightweight materials by Stodolsky, et al. The study assumed that low-cost wrought aluminum and cost effective manufacturing techniques would be developed by the year 2010. Also, techniques to recycle wrought aluminum for reuse would be developed by the time the initially produced aluminum vehicles are scrapped. The future cost reductions are due to higher volumes, experience, and availability of low-cost recycled material.

Diesel Premium: A premium is added to the final cost (to consumer) of the gasoline engine system if the HEV is to be equipped with a diesel engine. The cost of the gasoline engine system is computed first by using the earlier described cost equation, a factor of 2 is applied, and the diesel premium is added to the resulting cost. The premium for a midsize vehicle is $900 in 2005, $800 in 2010, $700 in 2015, and $600 in 2020.

Tabular Summary

Many of the costs presented below (see Exhibit 4-21) are variable costs related to the kW (power) or kWh (energy) rating of the hybrid vehicle in question. These costs are determined "from the ground-up" by the model while the QM HEV costs presented in Section 2 are determined based on consensus. However, these estimates do provide support for the QM estimates and are used periodically to adjust them as appropriate.

Exhibit 4-21. Summary of the Component Costs Used in the ANL HEV Cost Model†

Item	2005	2010	2015	2020
I Manufactured Within				
APU – Fixed Cost ($)	375.0	393.8	413.4	434.1
- Variable Cost ($/kW)	23.7	24.9	26.1	27.4
Parallel HEV: APU Transmission– Fixed Cost ($)	286.0	270.0	270.0	270.0
- Threshold Power§ (kW)	50	50	50	50
- Variable Cost ($/kW over Threshold)	5.1	5.0	5.0	5.0
Series and Parallel: Motor Gear Drive– Fixed Cost ($)	90.0	85.0	85.0	85.0
- Threshold Power (kW)	50	50	50	50
- Variable Cost ($/kW over Threshold)	1.8	1.7	1.7	1.7
System Control ($)	210.0	202.0	192.0	172.0
Other Costs ($)	260.0	250.0	242.0	236.0
II Outsourced				
Inverter – Fixed Cost ($)	500.0	425.0	385.0	350.0
- Variable Cost ($/kW)	24.0	19.0	15.0	13.0
Motor/Generator – Fixed Cost ($)	200.0	200.0	200.0	200.0
- Variable Cost ($/kW): Permanent Magnet	17.0	13.7	11.7	11.0
: Induction	11.0	10.5	9.8	9.0
III Nickel Metal Hydride Battery				
High Specific Energy Battery ($/kWh)	532	430	398	366
Mid Level 1 Battery ($/kWh)	588	475	439	404
Mid Level 2 Battery ($/kWh)	646	522	483	444
Mid Level 3 Battery ($/kWh)	710	574	531	488
Mid Level 4 Battery ($/kWh)	778	625	575	526
Mid Level 5 Battery ($/kWh)	865	698	646	594
High Specific Power Battery ($/kWh)	961	776	718	660
IV Charged Directly to Consumer (for midsize car)				
Aluminum Body ($)	N/A	3,600	1,700	1,200
Diesel Premium ($)	900	800	700	600

† Applicable to subcompact, midsize, and minivan except as noted.

§ A version of the cost model applies these values to combined APU and motor power.

4.2.4 Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model

GREET was developed to be used as an analytic tool for evaluating emissions of criteria pollutants and greenhouse gases, energy use, and petroleum consumption of various vehicle technologies on a full fuel-cycle basis (Ref. 27). For a given transportation fuel, a fuel cycle covers the processes from energy feedstock (or primary energy) production to on-vehicle combustion of fuel. In particular, the following stages are included in a fuel cycle:

- Energy feedstock production;
- Feedstock transportation and storage;
- Fuel (or energy product) production;
- Fuel transportation, storage, and distribution; and
- Vehicular fuel combustion.

The GREET model consists of three elements:

- Light vehicles (current version 1.5)
- Light vehicle materials (current version 2.4), and
- Heavy vehicles (current version 3.4).

Exhibit 4-22 lists the Carbon Coefficients for the different fuels. These coefficients are used in the Appendix A Table A-21, "Total Carbon Emissions Reductions" to calculate the reduction in carbon emissions each year to 2020 due to the market penetration of the advanced vehicle technologies.

Exhibit 4-22: Carbon Coefficients

Fuel	Coefficient, MMT/Quad
Gasoline	19.41
Diesel	19.95
CNG	14.47
LPG	17.16
Ethanol	0.5823
Electric Utilities	22.32

DOE/EIA-0573, Emissions of Greenhouse Gases in the United States, Table 6, P. 15

GREET includes sixteen (16) fuel cycles. Among them, four (4) are petroleum-based cycles: petroleum to conventional gasoline, petroleum to RFG; petroleum to diesel; and petroleum to LPG. Seven (7) cycles are natural gas (NG)-based: NG to CNG; NG to liquefied natural gas (LNG); NG to LPG; NG to methanol; NG to dimethyl ether; NG to hydrogen; and NG to Fischer Tropsch diesel. Three (3) cycles are ethanol production cycles: corn to ethanol; woody biomass to ethanol; and herbaceous biomass to ethanol. The remaining two (2) cycles are soybean to biodiesel, and solar energy to hydrogen.

GREET was developed for estimating emissions and energy use of light and heavy vehicles (i.e., passenger cars, light, medium, and heavy trucks, and buses). The advanced and conventional technologies included are: electric vehicles; hybrid vehicles; fuel cell vehicles operating on hydrogen, ethanol or methanol; CNG vehicles; LPG vehicles; and internal combustion engine vehicles fueled with RFG, low-sulfur diesel, M85, M100, E85, or E100. Fuel cycle grams per mile emissions and Btu per mile energy use are calculated for each vehicle type.

GREET calculates the energy consumption of a fuel cycle by taking into account the amount of energy consumed in each of the stages involved in the fuel cycle. In addition, by considering petroleum consumption in each fuel-cycle stage, the model calculates petroleum use by different vehicle types using different fuels.

Calculation of emissions for a particular stage are estimated in grams per million Btu of fuel throughput from the stage. The calculation of emissions takes into account combustion of process fuels, leakage of fuels, fuel evaporation, and other emission sources.

Outputs resulting from GREET include the following:

- Grams per mile emissions for HC, CO NO_x, PM_{10}, and SO_x;
- Grams per mile emissions for CO_2, CH_4, and N_2O;
- Global warming potential weighted greenhouse gas emissions;
- Btu per mile fuel-cycle energy consumption; and
- Btu per mile fuel-cycle petroleum consumption.

Currently, the GREET model has been linked with the IMPACTT model so that IMPACTT output is now directly and automatically used by GREET. Also, Version 1.5 of GREET has been released by the author but has not yet been integrated into the OTT QM/PAM tools.

4.2.5 Costs of Various Pollutants

The criteria pollutant emissions reduction values were calculated using an EPA estimate developed in 1990 which sets the costs of environmental controls at \$360/ton for CO, \$3660/ton for HC and \$3300/ton for NO_x (Ref. 28). Costs in Reference 29 were modified to reflect 1996 dollars.

Various CO_2 control cost estimates are indicated in Exhibit 4-23. Control costs are used instead of damage costs due to the great difficulty of calculating damage costs. These costs represent the "value" of reducing CO_2 emissions.
For the QM 2001 evaluations, a low-end value of **\$15/metric ton (tonne) of CO_2** reduction was utilized. This **equates to \$55/metric ton of carbon reduced**. Note that the QM benefit values (carbon reduction) relate to fuel economy/conservation effects only.

Exhibit 4-23: Range of Costs to Control CO_2 Emissions

Study	Year	Reported Value ($/MMTCE)		$1996 Value ($/MMTCE)	Notes
Costs of Tree Planting Used as a Reasonable First Approximation					
Buchanan (Bonneville Power Adm.)	1988	Low High	$17.08 $47.44	$22 $61	
Dudek and LeBlanc (EDF)	1990	Low High	$53 $58	$63 $69	
Chernick and Caverhill	1989	Low High	$80 $120	$99 $149	
Carbon Tax Required to Meet Stated Levels					
EMF 12 (1990 levels)	1992	Low High	$15 $150	$17 $165	Summary of 10 models
EMF 12 (10% below 1990 levels)	1992	Low High	$35 $200	$39 $220	Summary of 10 models
EMF 12 (20% below 1990 levels)	1992	Low High	$50 $330	$55 $363	Summary of 10 models
AFL-CIO (1990 levels)	1997		$100	$100	Congressional testimony
David Montgomery (Charles R. Assoc.)	1997	Low High	$150 $200	$150 $200	Congressional testimony
DOE/EIA (7% below 1990 levels)	1998		$348	$348	"Carbon price" for 2010
DOE/EIA (3% below 1990 levels)	1998		$294	$294	"Carbon price" for 2010
DOE/EIA (1990 levels)	1998		$250	$250	"Carbon price" for 2010
DOE/EIA (9% over 1990 levels)	1998		$163	$163	"Carbon price" for 2010
DOE/EIA (14% over 1990 levels)	1998		$134	$134	"Carbon price" for 2010
DOE/EIA (24% over 1990 levels)	1998		$67	$67	"Carbon price" for 2010
Cost of Emission Allowances under a Trading System					
Clinton Administration (domestic only)	1998		$200	$196	The Oil Daily, 8/4/98
Clinton Administration (global trading)	1998		$14	$13.72	The Oil Daily, 8/4/98
Cecil Roberts(UMWA)	1998 1998		$100 $200	$98 $196	Assumes global trading; JI; etc. No global trading
Optimal Tax (taking into account projected damage)					
Peck and Tiesberg	1992	Low High	$8 $210	$9 $231	Lower value is for 1990 Higher value is for 2200
Maddison	1993		$16.84	$18	Tax for 2000
Nordhaus	1993		$5.24	$6	
Williams	1995		$0	$0	
Damage Estimates for Marginal Emissions					
Fankhauser and Pearce	1993	Low High	$5 $25	$5 $27	
Hope and Maul	1996	Low High	$5 $29	$5 $29	Mean value of initial scenario Mean value for scenario w/ highest cost
Proposed Externality Values					
California	1990		$29	$35	Proposed value for resource planning
Massachusetts	1990		$92	$109	Proposed value for resource planning
New York	1990		$5	$6	Proposed value for resource planning
Nevada	1990		$61	$73	Proposed value for resource planning
EPA (*Renewable Electricity Generation*)	1992	Low High	$50 $150	$55 $165	Values used for modelling purposes
Miscellaneous					
Ledbetter and Ross (ACEEE)	1990		$176	$209	Based on gas tax needed to raise CAFE to 44 mpg

4.2.6 Aggregate Environmental and Economic Benefits Estimates

The OTT Program Analysis Methodology includes estimating reductions in carbon emissions from the commercial utilization of OTT-sponsored technologies. Exhibit 4-24 details carbon emission reductions estimated by technology. By 2020, the OTT program impact will reduce carbon emissions by more than seven percent (7%).

Exhibit 4-24: Carbon Emissions Reductions

Technology	Carbon Reductions Million Metric Tons Equivalent (MMTCE)		
	Year 2000	Year 2010	Year 2020
Vehicle Technologies R&D	**0.173**	**14.087**	**34.180**
Hybrid Systems R&D	0.018	4.785	12.118
Fuel Cell R&D	0.000	0.263	4.194
Advanced Combustion R&D	0.000	7.188	13.316
SIDI	*0.000*	*1.646*	*3.863*
Car CIDI	*0.000*	*2.758*	*4.440*
Light Truck CIDI	*0.000*	*2.784*	*5.013*
Electric Vehicle R&D	0.000	0.219	0.828
Household EV	*0.000*	*0.118*	*0.384*
EPAct ZEV Mandates	*0.000*	*0.101*	*0.444*
Heavy Vehicle Systems R&D	0.155	1.632	3.724
Class 3-6	*0.000*	*0.009*	*0.035*
Class 7&8	*0.149*	*1.617*	*3.688*
Class 7&8 CNG	*0.006*	*0.006*	*0.001*
Rail	*0.000*	*0.000*	*0.000*
Materials Technologies	**0.001**	**0.179**	**0.851**
Propulsion System Materials	0.000	0.000	0.000
Light Vehicle Materials	0.001	0.179	0.851
Electric Vehicle	*0.000*	*0.011*	*0.037*
Hybrid Vehicle	*0.001*	*0.139*	*0.353*
Fuel Cell Vehicle	*0.000*	*0.029*	*0.461*
Technology Deployment	**0.293**	**1.832**	**2.251**
Household CNG	0.009	0.904	1.340
EPAct Fleet	0.284	0.928	0.911
Fuels Development	**0.001**	**3.426**	**12.837**
Blends and Extenders	0.000	2.762	10.663
Flex-Fuel	0.001	0.664	2.174
Dedicated Conventional	0.000	0.000	0.000
Fuel Cell	0.000	0.000	0.000
Total	**0.468**	**19.524**	**50.119**
Baseline (AEO 99 - Transportation)	515.8	626.3	697.3
Percent Reduction	**0.09%**	**3.12%**	**7.19%**

Emissions reductions for NO_x, CO, and HC also are evaluated. Total emissions reductions and values for NO_x, CO and HC are found in Tables A23 – A28 in Appendix A.

4.3 Benefit/Cost Analysis and Accomplishments

Exhibit 4-25 provides a summary of all costs and benefits associated with OTT's QM 2001 estimates in cumulative terms. The benefits-cost table summarizes the benefits and costs of OTT's technologies. Costs include DOE Budgets, incremental vehicle costs to consumers, industry investment, and the induced increase in natural gas prices. The benefits consist of energy cost savings, oil security benefits, gasoline, distillate, and residual price decreases due to reduced demand, the value of reducing CO_2, CO, HCs, and NO_x, and the increase in GDP.

Costs

The budget cost is the estimated OTT budget through 2013.

The incremental costs are the additional costs incurred by consumers by choosing an advanced technology over a conventional technology. It is the difference between the advanced technology cost and the conventional cost. Industry investment represents the additional cost that would be incurred by the automotive industry in the infrastructure necessary to produce the alternative vehicles. This cost is in addition to projected investment levels that would be anticipated with conventional technology.

Benefits

Energy cost savings are the reduced energy costs of operating advanced vehicles compared to the cost of conventional vehicles; it is the difference between the operating costs of conventional vehicles and advanced vehicles.

The benefits of energy security were conservatively estimated at $5 per barrel based on a number of estimates presented in Exhibit 4-4.

Some increase in natural gas prices can be expected to occur due to the increase in demand from alternative fuel vehicles. However, it was assumed that the aggregate effect of a reduction in world and domestic oil prices due to conservation and substitution from the advanced technologies would offset the aggregate effect of a natural gas price rise.

The value of reducing CO_2, CO, HCs, and NO_x was estimated by multiplying the tons of the pollutant reduced by OTT technologies by the value of reducing the pollutant. To determine the value of reducing the pollutants, OTT used estimates from EPA for a National Energy Strategy exercise. For CO_2, OTT used an estimate based on a number of studies presented in Exhibit 4-23.

The increase in GDP was estimated by the Economic Spreadsheet Model discussed in Section 4.2.1.

Benefit/Cost Ratios

Benefit/cost ratios are shown at the bottom of Exhibit 4-25. Note that these are cumulative values both down and across the table. For instance, the benefit/cost ratio for Energy + Environment in Year 2015 includes all energy and environmental benefits and all OTT budget costs accrued from 2000 through 2015 inclusive. Also note that all non-OTT economic costs are considered as negative benefits (dis-benefits) so that they appear in the (benefit) numerators of the benefit/cost calculations rather than in the (cost) denominators. The overall benefit/cost ratios for the OTT budget by Year 2020 are in the range of 58:1 to 117:1, depending upon which benefits are counted, indicating the powerful influence of OTT programs on the transportation sector.

More results of the QM 2001 analysis can be found in the Appendix A.

Exhibit 4-25: Benefit-Cost Table From the Societal Perspective (Million $, 1997)

Item	2005	2010	2015	2020
OTT Budget Costs	$1,250	$2,500	$3,250	$3,250
Energy (Table A-1a)				
Net Energy Savings	$5,353	$34,007	$97,301	$188,732
Benefit/Cost - Energy	**4.28**	**13.60**	**29.94**	**58.07**
Environment (Tables A-22, 24, 26, 28)				
Carbon ($55 per tonne C)	$675	$4,203	$12,499	$24,873
NOX ($3,300 per tonne)	$81	$239	($152)	($425)
CO ($360 per tonne)	$179	$2,076	$7,714	$16,540
HC ($3,660 per tonne)	$718	$3,866	$11,294	$21,540
Total - Net Environmental Benefits	$1,652	$10,385	$31,355	$62,528
Benefit/Cost - Environment	**1.32**	**4.15**	**9.65**	**19.24**
Economy (Tables A-31, 32)				
Incremental Costs	($24,795)	($100,534)	($217,777)	($361,219)
Capital Investment	($2,019)	($5,367)	($6,952)	($8,063)
GDP Benefits	$39,018	$135,819	$284,199	$472,654
Total - Net Economic Benefits	$12,204	$29,918	$59,470	$103,372
Benefit/Cost - Economy	**9.76**	**11.97**	**18.30**	**31.81**
Security (Table A-14)				
Oil Security ($5/bbl)	$183	$2,008	$6,388	$12,958
Military Costs ($5/bbl)	$183	$2,008	$6,388	$12,958
Total - Net Security Benefits	$365	$4,015	$12,775	$25,915
Benefit/Cost - Security	**0.29**	**1.61**	**3.93**	**7.97**
Total Benefits	**$ 19,574**	**$ 78,325**	**$ 200,901**	**$ 380,547**
Cumulative Benefit/Cost Ratio: Energy	**4.28**	**13.6**	**29.9**	**58.1**
Cumulative Benefit/Cost Ratio: Energy + Environment	**5.60**	**17.8**	**39.6**	**77.3**
Cumulative Benefit/Cost Ratio: Energy + Environment + Economy	**15.4**	**29.7**	**57.9**	**109**
Cumulative Benefit/Cost Ratio: Energy + Environment + Economy + Security	**15.7**	**31.3**	**61.8**	**117**

Three principal changes were made in the Quality Metrics calculations compared to the preceding year. These modifications contributed to the changes in oil savings and other program benefits:

1. The EIA AEO 99 base case fuel prices were similar to the base case in AEO 98. The somewhat lower petroleum prices influenced benefits estimates.

2. Changes in the technology input assumptions. For example, the SIDI engine option was added to all light vehicle classes. Two vehicle classes (SUV and Minivan) were separated this year, whereas they were combined before.

3. Also, the oil savings for the Technology Utilization planning unit are based on the level of natural gas use in light vehicles. These vehicles have a much lower market penetration in this year's projection than in prior years.

Analytical improvements planned for future QM and OTT Impacts Assessments include the following:

- Update of heavy vehicle analyses based on the results available from the 1997 Vehicle Inventory and Use Survey (VIUS).
- Review heavy vehicle fuel economy assumptions based on current VIUS and other sources of recent market trends.
- Expand the use of GREET results to include total fuel cycle analysis comparisons (OTT Impacts).
- Update light vehicle technology baselines to the most recent year for which conventional technology vehicle characterizations are available.
- Extend the Quality Metrics results to the year 2030.

Section 5.0: References

5.0 References

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Section 6.0: Supporting Information

6.0 Supporting Information

6.1 Glossary

1. APU – Auxiliary Power Unit: APU's are smaller prime movers typically mounted within a vehicle to provide power to auxiliary equipment. An example would be to power a refrigeration system on a refrigerated truck. APU's are often more efficient than using the main power unit to provide power to auxiliary systems.
2. CIDI – Compression Ignition/Direct Injection: Diesel engines produce combustion via high pressure compression of the air/fuel mixture, rather than with a spark as in conventional automobile engines. Direct Injection (DI) diesel engines inject the fuel directly into the main combustion chamber rather than indirectly into a smaller pre-chamber. This tends to be more difficult to control, but yields a higher efficiency than the indirect injection technique.
3. CNG: Compressed Natural Gas: When used as a transportation fuel, natural gas is stored on-board either as a compressed gas or a cryogenic liquid form. Most CNG systems store compressed natural gas at pressures up to 3,000 to 3,500 psig. At 3,000 psig, one gallon of compressed natural gas contains about 27,500 BTU, about 30% of the energy density of liquefied natural gas.
4. CV – Conventional Vehicle: In this case, this usually applies to a conventional automobile, powered with a spark ignition engine burning gasoline.
5. EE/RE – Office Energy Efficiency and Renewable Energy at DOE
6. EIA – Energy Information Agency
7. EPAct – Environmental Policy Act
8. ESM – Economic Spreadsheet Model
9. ETOH: An acronym abbreviation for ethanol or ethyl alcohol. Ethanol can be used in its "pure" form (95% + ethanol) or as blended with various petroleum-based hydrocarbon fuels.
10. FCV-Fuel Cell (Powered) Vehicle: A vehicle obtaining motive power from an on-board fuel cell.
11. FFV - Flex Fuel Vehicle: A vehicle designed to operate within a range of different fuels or fuel mixtures. For instance, one vehicle may be designed to burn pure ethanol or mixtures if ethanol and gasoline within specific limits. Emissions effects often control the permitted ranges of FFV's.
12. FLEX FUEL-see FFV
13. GREET – Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model
14. GPRA – Government Performance Results Act: The basis of the Quality Metrics Program.
15. GVW – Gross Vehicle Weight: This is the maximum total weight (vehicle + passengers + cargo) that is permitted by the manufacturers.
16. HEV – Hybrid Electric Vehicle: A Vehicle that utilizes two or more power systems for motive power-typically a combination internal combustion engine and a battery/motor. These systems may be interconnected in parallel (both providing motive power) or series (the internal combustion engine feeding the batteries and the batteries feeding the electric motor).
17. HDDV -Heavy Duty Diesel Vehicle: A generic term applied to large diesel-powered trucks.
18. HVMP – Heavy Vehicle Market Penetration Model
19. IMPACTT – Integrated Market Penetration and Anticipated Cost of Transportation Technologies Model
20. LV – Light Vehicle: An automobile or light truck under 6500 LB GVW.

21. LNG – Liquefied Natural Gas: Natural gas can be converted into liquid form for on-board storage if it is cooled to approximately -258°F. at atmospheric pressure.
22. LPG – Liquid Propane Gas: LP gas is typically a mixture of propane and butane.
23. MMB/DOE-Millions of Barrels per day of Oil Equivalent: An energy measure expressed in cure oil production rate at 5.8 million BTU per barrel.
24. MMTONS – Million Metric Tons: Commonly used as a measure of carbon emissions generation.
25. NG – Natural Gas: A naturally-occurring mixture of light hydrocarbons (mostly methane with some ethane and higher carbon gases) as well as other trace gases (hydrogen, carbon dioxide, nitrogen). When gathered into pipelines, natural gas is made more uniform by mixing propane and other gases with it.
26. OAAT – Office of Advanced Automotive Technologies
27. OEM – Original Equipment Manufacturer
28. OFD – Office of Fuels Development
29. OTT – Office of Transportation Technologies in the DOE Office of Energy Efficiency and Renewable Energy
30. PNGV – Partnership for a New Generation Vehicle Program
31. QUADS: A measure of energy quantity. One Quad is equal to 10^{15} (a million-billion) BTU's. One Quad of petroleum is equal to 181 million barrels of crude petroleum or 8 billion gallons of gasoline. The US consumes about 100 Quads of energy annually.
32. RIMS II – Regional Input-Output Modeling System
33. RFG – Reformulated Gasoline: Gasoline that has been refined in such a way to reduce emissions more than conventional gasoline-typically lower in sulfur and with better control of the volatile sub-fraction.
34. SIDI – Spark ignition direct injection or stratified charge direct injection
35. TIUS – Truck Inventory and Use Survey
36. VMT – Vehicle Miles Traveled: This term usually applies to the sum of the miles traveled by each vehicle within a selected group. It is a measure of overall transportation service.
37. VSCC – Vehicle Size/Consumer Choice Model
38. ZEV – Zero Emissions Vehicle

6.2 Energy Conversion Factors

All energy values and conversion factors units used in this report are based on the values and conversion factors used in the Transportation Energy Data Book, Version 18 which is available on-line at: ***http//www-cta.ornl.gov/data/tedb.htm.*** Unless otherwise indicated, gross energy values have been used.

Appendix A: Quality Metrics 2001 Results

TABLE A-1   QM 2001 SUMMARY

PLANNING UNIT	Primary Energy Displaced (quads) 2000	2005	2010	2015	2020	Primary Oil Displaced (quads) 2000	2005	2010	2015	2020
Vehicle Technologies R&D	**0.007**	**0.152**	**0.740**	**1.350**	**1.768**	**0.011**	**0.156**	**0.851**	**1.517**	**1.977**
Hybrid Systems R&D	0.000	0.045	0.246	0.498	0.624	0.000	0.001	0.246	0.498	0.624
Fuel Cell R&D	0.000	0.000	0.014	0.082	0.220	0.000	0.000	0.014	0.082	0.220
Advanced Combustion R&D	0.000	0.064	0.394	0.639	0.727	0.000	0.064	0.394	0.639	0.727
SIDI	*0.000*	*0.006*	*0.085*	*0.164*	*0.199*	*0.000*	*0.006*	*0.085*	*0.164*	*0.199*
Car CIDI	*0.000*	*0.028*	*0.163*	*0.248*	*0.264*	*0.000*	*0.028*	*0.163*	*0.248*	*0.264*
Light Truck CIDI	*0.000*	*0.031*	*0.147*	*0.227*	*0.264*	*0.000*	*0.031*	*0.147*	*0.227*	*0.264*
Electric Vehicles R&D	0.000	0.001	0.004	0.009	0.010	0.002	0.047	0.114	0.175	0.219
Household EV	*0.000*	*0.001*	*0.004*	*0.009*	*0.010*	*0.000*	*0.007*	*0.031*	*0.059*	*0.071*
EPAct/ZEV Mandates	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.002*	*0.040*	*0.083*	*0.116*	*0.147*
Heavy Vehicle Systems R&D	0.007	0.042	0.082	0.123	0.187	0.009	0.044	0.083	0.124	0.187
Class 3-6	*0.000*	*0.000*	*0.000*	*0.001*	*0.002*	*0.000*	*0.000*	*0.000*	*0.001*	*0.002*
Class 7&8	*0.007*	*0.042*	*0.081*	*0.122*	*0.185*	*0.007*	*0.042*	*0.081*	*0.122*	*0.185*
Class 7&8 CNG	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.001*	*0.002*	*0.001*	*0.000*	*0.000*
Rail	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
Materials Technologies	**0.000**	**0.001**	**0.009**	**0.024**	**0.043**	**0.000**	**0.002**	**0.012**	**0.029**	**0.049**
Propulsion System Materials	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Light Vehicle Materials	0.000	0.001	0.009	0.024	0.043	0.000	0.002	0.012	0.029	0.049
Household EV	*0.000*	*0.000*	*0.000*	*0.001*	*0.001*	*0.000*	*0.001*	*0.003*	*0.006*	*0.007*
Hybrid Vehicle	*0.000*	*0.001*	*0.007*	*0.014*	*0.018*	*0.000*	*0.001*	*0.007*	*0.014*	*0.018*
Fuel Cell Vehicle	*0.000*	*0.000*	*0.002*	*0.009*	*0.024*	*0.000*	*0.000*	*0.002*	*0.009*	*0.024*
Technology Deployment	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.070**	**0.278**	**0.414**	**0.484**	**0.498**
Household CNG	0.000	0.000	0.000	0.000	0.000	0.002	0.073	0.183	0.254	0.271
EPAct Fleet	0.000	0.000	0.000	0.000	0.000	0.068	0.204	0.231	0.229	0.227
Fuels Development	**0.000**	**0.023**	**0.182**	**0.429**	**0.682**	**0.000**	**0.023**	**0.182**	**0.429**	**0.682**
Blends and Extenders	0.000	0.019	0.147	0.326	0.566	0.000	0.019	0.147	0.326	0.566
Flex-Fuel	0.000	0.004	0.035	0.103	0.115	0.000	0.004	0.035	0.103	0.115
Dedicated Conventional	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	**0.008**	**0.177**	**0.932**	**1.804**	**2.493**	**0.081**	**0.459**	**1.459**	**2.460**	**3.206**

Note:
1) Advanced Materials - metrics shown for Light Vehicle Materials are derived from percentages of total metrics estimated for Electric, Hybrid and Fuel Cell vehicles
Electric: 8.8% of total
Hybrid: 2.8% of total
Fuel Cell 9.9% of total
2) EPAct/ZEV Mandate EVs are not included in Materials Technologies Planning Unit

TABLE A-1a   QM 2001 SUMMARY

PLANNING UNIT	Energy Cost Savings (billions of 1997 $'s) 2000	2005	2010	2015	2020	Carbon Reductions (million metric tons) 2000	2005	2010	2015	2020
Vehicle Technologies R&D	**0.055**	**1.299**	**7.516**	**14.107**	**18.564**	**0.174**	**2.914**	**14.087**	**25.942**	**34.178**
Hybrid Systems R&D	0.008	0.442	2.564	5.191	6.492	0.018	0.871	4.785	9.660	12.117
Fuel Cell R&D	0.000	0.000	0.143	0.850	2.288	0.000	0.000	0.263	1.554	4.194
Advanced Combustion R&D	0.000	0.634	4.100	6.668	7.559	0.000	1.161	7.188	11.696	13.316
SIDI	*0.000*	*0.058*	*0.882*	*1.711*	*2.070*	*0.000*	*0.115*	*1.646*	*3.184*	*3.863*
Car CIDI	*0.000*	*0.158*	*0.969*	*1.430*	*1.403*	*0.000*	*0.461*	*2.758*	*4.194*	*4.440*
Light Truck CIDI	*0.000*	*0.417*	*2.249*	*3.526*	*4.086*	*0.000*	*0.585*	*2.784*	*4.318*	*5.013*
Electric Vehicles R&D	-0.011	-0.137	0.007	0.341	0.633	0.000	0.033	0.218	0.567	0.828
Household EV	*0.001*	*0.040*	*0.208*	*0.415*	*0.511*	*0.000*	*0.020*	*0.118*	*0.287*	*0.384*
EPAct/ZEV Mandates	*-0.011*	*-0.177*	*-0.201*	*-0.073*	*0.122*	*0.000*	*0.012*	*0.101*	*0.280*	*0.444*
Heavy Vehicle Systems R&D	0.058	0.360	0.701	1.057	1.591	0.156	0.849	1.633	2.465	3.723
Class 3-6	*0.000*	*0.003*	*0.004*	*0.010*	*0.015*	*0.000*	*0.006*	*0.009*	*0.023*	*0.035*
Class 7&8	*0.057*	*0.354*	*0.695*	*1.047*	*1.577*	*0.149*	*0.831*	*1.617*	*2.441*	*3.688*
Class 7&8 CNG	*0.001*	*0.004*	*0.002*	*0.000*	*0.000*	*0.006*	*0.011*	*0.006*	*0.002*	*0.001*
Rail	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
Materials Technologies	**0.000**	**0.017**	**0.111**	**0.285**	**0.490**	**0.001**	**0.027**	**0.180**	**0.480**	**0.851**
Propulsion System Materials	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Light Vehicle Materials	0.000	0.017	0.111	0.285	0.490	0.001	0.027	0.180	0.480	0.851
Household EV	*0.000*	*0.004*	*0.020*	*0.040*	*0.049*	*0.000*	*0.002*	*0.011*	*0.028*	*0.037*
Hybrid Vehicle	*0.000*	*0.013*	*0.075*	*0.151*	*0.189*	*0.001*	*0.025*	*0.139*	*0.281*	*0.353*
Fuel Cell Vehicle	*0.000*	*0.000*	*0.016*	*0.093*	*0.251*	*0.000*	*0.000*	*0.029*	*0.171*	*0.461*
Technology Deployment	**0.026**	**0.394**	**0.784**	**0.977**	**0.959**	**0.293**	**1.204**	**1.832**	**2.177**	**2.251**
Household CNG	0.004	0.230	0.591	0.794	0.822	0.009	0.363	0.904	1.257	1.340
EPAct Fleet	0.021	0.164	0.192	0.183	0.137	0.284	0.842	0.928	0.920	0.911
Fuels Development	**0.000**	**-0.006**	**0.006**	**0.119**	**0.139**	**0.001**	**0.438**	**3.426**	**8.086**	**12.837**
Blends and Extenders	0.000	0.000	0.000	0.000	0.000	0.000	0.365	2.762	6.144	10.663
Flex-Fuel	0.000	-0.006	0.006	0.119	0.139	0.001	0.072	0.664	1.942	2.174
Dedicated Conventional	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	**0.081**	**1.704**	**8.415**	**15.488**	**20.152**	**0.468**	**4.583**	**19.524**	**36.685**	**50.117**

Note:

1) Advanced Materials - metrics shown for Light Vehicle Materials are derived from percentages of total metrics estimated for Electric, Hybrid and Fuel Cell vehicles
   Electric: 8.8% of total
   Hybrid: 2.8% of total
   Fuel Cell 9.9% of total

2) EPAct/ZEV Mandate EVs are not included in Materials Technologies Planning Unit

TABLE A-1b QM 2001 SUMMARY

	Primary Energy Displaced (mbpd)					Primary Oil Displaced (mbpd)				
PLANNING UNIT	**2000**	**2005**	**2010**	**2015**	**2020**	**2000**	**2005**	**2010**	**2015**	**2020**
Vehicle Technologies R&D	**0.004**	**0.072**	**0.350**	**0.638**	**0.835**	**0.005**	**0.094**	**0.402**	**0.717**	**0.934**
Hybrid Systems R&D	0.000	0.021	0.116	0.235	0.295	0.000	0.021	0.116	0.235	0.295
Fuel Cell R&D	0.000	0.000	0.007	0.039	0.104	0.000	0.000	0.007	0.039	0.104
Advanced Combustion R&D	0.000	0.030	0.186	0.302	0.343	0.000	0.030	0.186	0.302	0.343
SIDI	*0.000*	*0.003*	*0.040*	*0.077*	*0.094*	*0.000*	*0.003*	*0.040*	*0.077*	*0.094*
Car CIDI	*0.000*	*0.013*	*0.077*	*0.117*	*0.125*	*0.000*	*0.013*	*0.077*	*0.117*	*0.125*
Light Truck CIDI	*0.000*	*0.015*	*0.069*	*0.107*	*0.125*	*0.000*	*0.015*	*0.069*	*0.107*	*0.125*
Electric Vehicles R&D	0.000	0.000	0.002	0.004	0.005	0.001	0.022	0.054	0.083	0.103
Household EV	*0.000*	*0.000*	*0.002*	*0.004*	*0.005*	*0.000*	*0.003*	*0.014*	*0.028*	*0.034*
EPAct/ZEV Mandates	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.001*	*0.019*	*0.039*	*0.055*	*0.070*
Heavy Vehicle Systems R&D	0.004	0.020	0.039	0.058	0.088	0.004	0.021	0.039	0.058	0.088
Class 3-6	*0.000*	*0.000*	*0.000*	*0.001*	*0.001*	*0.000*	*0.000*	*0.000*	*0.001*	*0.001*
Class 7&8	*0.004*	*0.020*	*0.038*	*0.058*	*0.087*	*0.004*	*0.020*	*0.038*	*0.058*	*0.087*
Class 7&8 CNG	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.001*	*0.001*	*0.001*	*0.000*	*0.000*
Rail	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
Materials Technologies	**0.000**	**0.001**	**0.004**	**0.011**	**0.020**	**0.000**	**0.001**	**0.006**	**0.014**	**0.023**
Propulsion System Materials	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Light Vehicle Materials	0.000	0.001	0.004	0.011	0.020	0.000	0.001	0.006	0.014	0.023
Electric Vehicle	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.001*	*0.003*	*0.003*
Hybrid Vehicle	*0.000*	*0.001*	*0.003*	*0.007*	*0.009*	*0.000*	*0.001*	*0.003*	*0.007*	*0.009*
Fuel Cell Vehicle	*0.000*	*0.000*	*0.001*	*0.004*	*0.011*	*0.000*	*0.000*	*0.001*	*0.004*	*0.011*
Technology Deployment	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.033**	**0.131**	**0.196**	**0.228**	**0.235**
Household CNG	0.000	0.000	0.000	0.000	0.000	0.001	0.035	0.086	0.120	0.128
EPAct Fleet	0.000	0.000	0.000	0.000	0.000	0.032	0.097	0.109	0.108	0.107
Fuels Development	**0.000**	**0.011**	**0.086**	**0.203**	**0.322**	**0.000**	**0.011**	**0.086**	**0.203**	**0.322**
Blends and Extenders	0.000	0.009	0.069	0.154	0.268	0.000	0.009	0.069	0.154	0.268
Flex-Fuel	0.000	0.002	0.017	0.049	0.055	0.000	0.002	0.017	0.049	0.055
Dedicated Conventional	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	**0.004**	**0.084**	**0.440**	**0.852**	**1.178**	**0.038**	**0.238**	**0.689**	**1.162**	**1.514**

Note:

1) Advanced Materials - metrics shown for Light Vehicle Materials are derived from percentages of total metrics estimated for Electric, Hybrid and Fuel Cell vehicles

Electric: 8.8% of total

Hybrid: 2.8% of total

Fuel Cell 9.9% of total

2) EPAct/ZEV Mandate EVs are not included in Materials Technologies Planning Unit

Table A-2 GRPA: Advanced Vehicle Technologies

Year	Primary Energy Savings (trillion btu)	Electric Use (billion kWhr)	Nat. Gas. Use (billion cft)	Petrol Displaced (mbpd)	Energy Cost Savings (billion $)	Non-Energy Costs (billion $)	CO (MMTons)	Carbon (MMTCe)	SO2 (MMTons)	(1) NOx (MMTons)	Particulates (MMTons)	VOC's (MMTons)	HC's (MMTons)
2000	9.71	0.01	0.000	1.946	-0.003	0.036	0.002	0.1736		0.002			0.001
2001	20.25	0.06	0.000	3.951	0.034	0.154	0.006	0.3730		0.005			0.003
2002	34.66	0.14	0.000	6.708	0.110	0.276	0.014	0.6515		0.010			0.377
2003	55.05	0.23	0.000	12.515	0.169	0.679	0.033	1.0426		0.016			2.248
2004	92.19	0.33	0.000	21.074	0.421	1.144	0.068	1.7427		0.014			8.314
2005	154.44	0.48	0.000	33.878	0.939	1.677	0.142	2.9136		0.020			19.056
2006	243.99	0.68	0.000	51.273	1.782	2.236	0.260	4.6001		0.026			35.831
2007	350.95	0.95	0.000	71.581	2.837	2.722	0.414	6.6212		0.033			56.468
2008	471.63	1.29	0.000	94.379	4.089	2.858	0.602	8.9134		0.039			80.090
2009	602.31	1.72	0.000	119.112	5.366	2.726	0.824	11.4104		0.046			106.850
2010	741.79	2.23	0.000	145.490	6.814	2.787	1.081	14.0870		0.053			137.627
2011	877.78	2.71	0.000	171.101	8.228	2.546	1.371	16.7131		0.059			172.932
2012	1009.10	3.16	0.000	195.640	9.534	2.334	1.685	19.2563		0.064			211.651
2013	1131.59	3.58	0.000	218.588	10.886	1.971	2.010	21.6400		0.068			251.628
2014	1248.27	3.97	0.000	240.521	11.927	1.727	2.339	23.9216		0.072			291.509
2015	1350.83	4.28	0.000	259.844	13.050	1.407	2.655	25.9419		0.075			328.581
2016	1447.24	4.56	0.000	278.034	14.049	1.194	2.957	27.8306		0.078			362.731
2017	1537.36	4.79	0.000	295.054	14.831	0.987	3.241	29.6031		0.082			393.171
2018	1620.81	4.96	0.000	310.780	15.674	0.794	3.502	31.2505		0.086			419.472
2019	1697.26	5.10	0.000	325.204	16.261	0.613	3.739	32.7668		0.090			441.478
2020	1768.12	5.19	0.000	338.546	16.972	0.443	3.954	34.1780		0.095			459.378
Cumulative Total From Year 2000 to Year													
2005	366.31	1.25	0.00	80.07	1.67	3.97	0.27	6.90	0.00	0.07	0.00	0.00	30.00
2010	2776.97	8.11	0.00	561.90	22.56	17.29	3.45	52.53	0.00	0.26	0.00	0.00	446.86
2015	8394.55	25.81	0.00	1647.60	76.18	27.28	13.51	160.00	0.00	0.60	0.00	0.00	1703.17
2020	16465.33	50.40	0.00	3195.21	153.97	31.31	30.90	315.63	0.00	1.03	0.00	0.00	3779.40

(1) Assumes diesel meets emission standards

Table A-2a GRPA: Advanced Automotive Technologies

Year	Primary Energy Savings (trillion btu)	Electric Use (billion kWhr)	Nat. Gas. Use (billion cft)	Petrol Displaced (mbpd)	Energy Cost Savings (billion $)	Non-Energy Costs (billion $)	CO (MMTons)	Carbon (MMTCe)	SO2 (MMTons)	(1) NOx (MMTons)	Particulates (MMTons)	VOC's (MMTons)	HC's (MMTons)
2000	0.92	0.01	0.00	0.430	-0.003	0.036	0.000	0.0180		0.000			0.000
2001	5.05	0.06	0.00	1.329	0.034	0.146	0.003	0.0982		0.002			0.002
2002	12.48	0.14	0.00	2.883	0.104	0.218	0.007	0.2424		0.004			0.375
2003	20.21	0.23	0.00	6.508	0.091	0.226	0.014	0.3885		0.008			2.245
2004	39.90	0.33	0.00	12.058	0.206	0.353	0.027	0.7502		0.003			8.309
2005	79.36	0.48	0.00	20.932	0.522	0.803	0.067	1.4795		0.004			19.049
2006	141.04	0.68	0.00	33.524	1.067	1.182	0.134	2.6273		0.006			35.820
2007	214.69	0.95	0.00	48.088	1.741	1.445	0.220	4.0050		0.009			56.453
2008	302.89	1.29	0.00	65.286	2.557	1.602	0.327	5.6692		0.013			80.070
2009	402.61	1.72	0.00	84.682	3.527	1.552	0.455	7.5671		0.017			106.825
2010	512.44	2.23	0.00	105.946	4.565	1.669	0.605	9.6702		0.022			137.596
2011	620.17	2.71	0.00	126.685	5.651	1.463	0.777	11.7472		0.028			172.895
2012	724.90	3.16	0.00	146.641	6.682	1.275	0.966	13.7742		0.033			211.607
2013	823.93	3.58	0.00	165.542	7.702	1.033	1.164	15.7023		0.038			251.577
2014	918.45	3.97	0.00	183.656	8.616	0.849	1.368	17.5526		0.044			291.452
2015	999.74	4.28	0.00	199.311	9.523	0.583	1.566	19.1586		0.049			328.517
2016	1075.66	4.56	0.00	213.969	10.337	0.418	1.758	20.6472		0.055			362.662
2017	1146.03	4.79	0.00	227.583	11.061	0.258	1.943	22.0329		0.061			393.097
2018	1209.95	4.96	0.00	239.943	11.781	0.104	2.118	23.2969		0.067			419.393
2019	1266.79	5.10	0.00	250.986	12.267	-0.045	2.283	24.4271		0.073			441.395
2020	1317.61	5.19	0.00	260.872	12.887	-0.186	2.435	25.4428		0.080			459.291
Cumulative Total From Year 2000 to Year													
2005	157.92	1.25	0.00	44.14	0.95	1.78	0.12	2.98	0.00	0.02	0.00	0.00	29.98
2010	1731.60	8.11	0.00	381.67	14.41	9.23	1.86	32.52	0.00	0.09	0.00	0.00	446.74
2015	5818.79	25.81	0.00	1203.50	52.59	14.43	7.70	110.45	0.00	0.28	0.00	0.00	1702.79
2020	11834.84	50.40	0.00	2396.85	110.92	14.98	18.24	226.30	0.00	0.62	0.00	0.00	3778.63

(1) Assumes diesel meets emission standards

Table A-2b GRPA: Heavy Vehicle Technologies

Year	Primary Energy Savings (trillion btu)	Electric Use (billion kWhr)	Nat. Gas. Use (billion cft)	Petrol Displaced (mb)	Energy Costs (billion $)	Non-Energy Costs (billion $)	CO (MMTons)	Carbon (MMTCe)	SO2 (MMTons)	(1) NOx (MMTons)	Particulates (MMTons)	VOC's (MMTons)	HC's (MMTons)
2000	8.79	0.00	0.000	1.515	0.000	0.000	0.002	0.1556		0.002			0.000
2001	15.21	0.00	0.000	2.622	0.000	0.008	0.003	0.2748		0.003			0.001
2002	22.18	0.00	0.000	3.825	0.006	0.058	0.008	0.4091		0.006			0.002
2003	34.84	0.00	0.000	6.007	0.077	0.453	0.019	0.6541		0.009			0.003
2004	52.29	0.00	0.000	9.016	0.215	0.791	0.041	0.9925		0.012			0.005
2005	75.08	0.00	0.000	12.945	0.417	0.875	0.075	1.4340		0.016			0.008
2006	102.94	0.00	0.000	17.749	0.714	1.054	0.125	1.9728		0.020			0.011
2007	136.26	0.00	0.000	23.492	1.097	1.276	0.194	2.6162		0.023			0.015
2008	168.74	0.00	0.000	29.092	1.531	1.256	0.275	3.2442		0.027			0.020
2009	199.70	0.00	0.000	34.430	1.840	1.173	0.370	3.8434		0.029			0.025
2010	229.35	0.00	0.000	39.543	2.249	1.118	0.476	4.4168		0.031			0.031
2011	257.61	0.00	0.000	44.416	2.577	1.084	0.593	4.9659		0.031			0.038
2012	284.20	0.00	0.000	48.999	2.852	1.059	0.719	5.4820		0.031			0.044
2013	307.66	0.00	0.000	53.045	3.183	0.938	0.846	5.9377		0.030			0.051
2014	329.82	0.00	0.000	56.865	3.311	0.878	0.970	6.3690		0.028			0.057
2015	351.09	0.00	0.000	60.533	3.526	0.824	1.089	6.7833		0.025			0.064
2016	371.57	0.00	0.000	64.064	3.712	0.776	1.199	7.1834		0.023			0.069
2017	391.33	0.00	0.000	67.471	3.770	0.729	1.297	7.5703		0.021			0.075
2018	410.85	0.00	0.000	70.837	3.893	0.690	1.383	7.9535		0.018			0.079
2019	430.47	0.00	0.000	74.219	3.994	0.658	1.457	8.3397		0.017			0.083
2020	450.50	0.00	0.000	77.673	4.086	0.628	1.519	8.7352		0.015			0.087
Cumulative Total From Year 2000 to Year													
2005	208.39	0.00	0.00	35.93	0.72	2.18	0.15	3.92	0.00	0.05	0.00	0.00	0.02
2010	1045.37	0.00	0.00	180.24	8.15	8.06	1.59	20.01	0.00	0.18	0.00	0.00	0.12
2015	2575.75	0.00	0.00	444.10	23.60	12.84	5.81	49.55	0.00	0.32	0.00	0.00	0.38
2020	4630.49	0.00	0.00	798.36	43.05	16.33	12.66	89.33	0.00	0.42	0.00	0.00	0.77

Table A-3 GRPA: Materials Technologies

Year	Primary Energy Savings (trillion btu)	Electric Use (billion kWhr)	Nat. Gas. Use (billion cft)	Petrol Displaced (mb)	Energy Costs (billion $)	Non-Energy Costs (billion $)	CO (MMTons)	Carbon (MMTCe)	SO2 (MMTons)	(1) NOx (MMTons)	Particulates (MMTons)	VOC's (MMTons)	HC's (MMTons)
2000	0.03	0.00	0.00	0.031	0.000	0.020	0.000	0.0005		0.000			0.000
2001	0.15	0.01	0.00	0.071	0.002	0.085	0.000	0.0030		0.000			0.000
2002	0.38	0.01	0.00	0.137	0.004	0.144	0.000	0.0075		0.000			0.000
2003	0.60	0.02	0.00	0.396	0.007	0.131	0.001	0.0117		0.000			0.000
2004	0.90	0.03	0.00	0.654	0.011	0.157	0.001	0.0175		0.000			0.000
2005	1.40	0.05	0.00	0.941	0.017	0.183	0.001	0.0273		0.000			0.000
2006	2.15	0.07	0.00	1.258	0.026	0.232	0.001	0.0420		0.000			0.000
2007	3.18	0.09	0.00	1.616	0.039	0.307	0.002	0.0624		0.000			0.000
2008	4.67	0.12	0.00	2.066	0.057	0.415	0.003	0.0918		0.000			0.000
2009	6.66	0.17	0.00	2.621	0.081	0.520	0.004	0.1309		0.001			0.000
2010	9.12	0.22	0.00	3.270	0.111	0.611	0.006	0.1796		0.001			0.001
2011	11.80	0.26	0.00	3.942	0.142	0.681	0.008	0.2327		0.001			0.001
2012	14.69	0.31	0.00	4.623	0.175	0.750	0.011	0.2899		0.001			0.001
2013	17.71	0.35	0.00	5.319	0.212	0.826	0.015	0.3497		0.001			0.002
2014	20.93	0.38	0.00	6.049	0.245	0.908	0.019	0.4136		0.002			0.002
2015	24.28	0.41	0.00	6.785	0.285	0.971	0.025	0.4798		0.002			0.002
2016	27.93	0.44	0.00	7.566	0.326	1.085	0.031	0.5511		0.002			0.003
2017	31.79	0.46	0.00	8.375	0.366	1.177	0.039	0.6264		0.003			0.004
2018	35.70	0.48	0.00	9.178	0.409	1.231	0.048	0.7023		0.003			0.005
2019	39.55	0.49	0.00	9.962	0.448	1.284	0.058	0.7771		0.004			0.005
2020	43.35	0.50	0.00	10.727	0.490	1.339	0.068	0.8508		0.005			0.006
Cumulative Total From Year 2000 to Year													
2005	3.47	0.12	0.00	2.2	0.04	0.72	0.00	0.07	0.00	0.00	0.00	0.00	0.00
2010	29.24	0.78	0.00	13.1	0.35	2.81	0.02	0.57	0.00	0.00	0.00	0.00	0.00
2015	118.64	2.49	0.00	39.8	1.41	6.94	0.10	2.34	0.00	0.01	0.00	0.00	0.01
2020	296.96	4.86	0.00	85.6	3.45	13.06	0.34	5.85	0.00	0.03	0.00	0.00	0.03

Table A-4 GRPA: Technology Deployment

Year	Primary Energy Savings (trillion btu)	Electric Use (billion kWhr)	Nat. Gas. Use (billion cft)	Petrol Displaced (mb)	Energy Cost Savings (billion $)	Non-Energy Costs (billion $)	CO (MMTons)	Carbon (MMTCe)	SO2 (MMTons)	NOx (MMTons)	Particulates (MMTons)	VOC's (MMTons)	HC's (MMTons)
2000	0.00	0.00	61.89	12.106	0.03	0.018	0.001	0.2933		0.000			0.001
2001	0.00	0.00	95.46	18.674	0.09	0.109	0.005	0.4648		0.000			0.008
2002	0.00	0.00	132.75	25.969	0.16	0.159	0.012	0.6550		0.000			0.018
2003	0.00	0.00	171.75	33.597	0.25	0.134	0.022	0.8496		0.000			0.032
2004	0.00	0.00	209.74	41.028	0.33	0.188	0.030	1.0341		0.000			0.045
2005	0.00	0.00	244.86	47.900	0.39	0.635	0.041	1.2044		0.000			0.059
2006	0.00	0.00	274.75	53.747	0.46	1.037	0.053	1.3490		0.000			0.078
2007	0.00	0.00	299.22	58.534	0.53	1.329	0.069	1.4722		0.000			0.100
2008	0.00	0.00	322.15	63.019	0.66	1.526	0.086	1.5940		0.000			0.125
2009	0.00	0.00	343.89	67.271	0.70	1.537	0.104	1.7137		0.000			0.151
2010	0.00	0.00	365.17	71.434	0.78	1.736	0.123	1.8318		0.000			0.177
2011	0.00	0.00	383.05	74.932	0.84	1.626	0.140	1.9320		0.000			0.202
2012	0.00	0.00	397.99	77.855	0.87	1.546	0.157	2.0163		0.000			0.224
2013	0.00	0.00	409.55	80.115	0.95	1.421	0.173	2.0821		0.000			0.244
2014	0.00	0.00	419.14	81.992	0.92	1.358	0.188	2.1371		0.000			0.263
2015	0.00	0.00	426.28	83.389	0.98	1.209	0.202	2.1774		0.000			0.279
2016	0.00	0.00	431.45	84.400	0.99	1.165	0.213	2.2069		0.000			0.294
2017	0.00	0.00	435.28	85.150	0.96	1.131	0.224	2.2285		0.000			0.308
2018	0.00	0.00	437.91	85.663	0.97	1.105	0.232	2.2434		0.000			0.319
2019	0.00	0.00	439.14	85.904	0.94	1.093	0.237	2.2507		0.000			0.326
2020	0.00	0.00	438.97	85.871	0.96	1.096	0.240	2.2506		0.000			0.330
Cumulative Total From Year 2000 to Year													
2005	0.00	0.00	916.45	179.27	1.24	1.24	0.11	4.50	0.00	0.00	0.00	0.00	0.16
2010	0.00	0.00	2521.64	493.28	4.38	8.41	0.55	12.46	0.00	0.00	0.00	0.00	0.79
2015	0.00	0.00	4557.65	891.56	8.94	15.57	1.41	22.81	0.00	0.00	0.00	0.00	2.01
2020	0.00	0.00	6740.40	1318.55	13.75	21.16	2.55	33.99	0.00	0.00	0.00	0.00	3.58

Table A-5 GRPA: Fuels Development

Year	Primary Energy Savings (trillion btu)	Electric Use (billion kWhr)	Nat. Gas. Use (billion cft)	Petrol Displaced (mb)	Energy Costs (billion $)	Non-Energy Costs (billion $)	CO (MMTons)	Carbon (MMTCe)	SO2 (MMTons)	NOx (MMTons)	Particulates (MMTons)	VOC's (MMTons)	HC's (MMTons)
2000	0.05	0.00	0.00	0.008	0.000	0.000	0.000	0.0009		0.000			0.000
2001	0.49	0.00	0.00	0.084	-0.001	-0.001	0.000	0.0092		0.000			0.000
2002	2.15	0.00	0.00	0.370	-0.001	-0.002	0.000	0.0404		0.000			0.000
2003	4.96	0.00	0.00	0.855	-0.003	-0.005	0.000	0.0933		0.000			0.000
2004	11.59	0.00	0.00	1.998	-0.005	-0.050	0.057	0.2181		0.003			0.002
2005	23.24	0.00	0.00	4.006	-0.006	-0.100	0.114	0.4375		0.006			0.004
2006	42.34	0.00	0.00	7.300	-0.008	-0.167	0.185	0.7971		0.009			0.007
2007	68.04	0.00	0.00	11.730	-0.009	-0.251	0.267	1.2809		0.013			0.011
2008	101.02	0.00	0.00	17.417	-0.007	-0.343	0.350	1.9019		0.018			0.015
2009	140.95	0.00	0.00	24.301	-0.004	-0.462	0.457	2.6537		0.023			0.020
2010	181.97	0.00	0.00	31.375	0.006	-0.594	0.576	3.4261		0.030			0.027
2011	233.42	0.00	0.00	40.244	0.016	-0.739	0.696	4.3947		0.036			0.035
2012	283.26	0.00	0.00	48.837	0.027	-0.880	0.813	5.3331		0.043			0.042
2013	331.93	0.00	0.00	57.229	0.056	-1.017	0.923	6.2495		0.049			0.049
2014	381.85	0.00	0.00	65.836	0.068	-1.440	1.253	7.1894		0.058			0.110
2015	429.47	0.00	0.00	74.047	0.119	-1.566	1.353	8.0860		0.064			0.115
2016	479.55	0.00	0.00	82.680	0.130	-1.365	1.167	9.0287		0.062			0.067
2017	530.03	0.00	0.00	91.385	0.128	-1.458	1.219	9.9793		0.065			0.070
2018	580.25	0.00	0.00	100.044	0.139	-1.541	1.258	10.9249		0.067			0.072
2019	631.79	0.00	0.00	108.929	0.125	-1.611	1.282	11.8952		0.069			0.073
2020	681.83	0.00	0.00	117.557	0.139	-1.680	1.303	12.8373		0.070			0.075
Cumulative Total From Year 2000 to Year													
2005	42.46	0.00	0.00	7.32	-0.02	-0.16	0.17	0.80	0.00	0.01	0.00	0.00	0.01
2010	576.77	0.00	0.00	99.44	-0.04	-1.97	2.01	10.86	0.00	0.10	0.00	0.00	0.09
2015	2236.70	0.00	0.00	385.64	0.25	-7.62	7.04	42.11	0.00	0.35	0.00	0.00	0.44
2020	5140.15	0.00	0.00	886.23	0.91	-15.27	13.27	96.78	0.00	0.68	0.00	0.00	0.80

TABLE A-6 OTT QM 2001 Planning Unit Estimates

Total Fossil Energy Savings Estimates
(Quadrillion Btu/Year)

Planning Unit	2000	2010	2020
Vehicle Technologies R&D	0.01	0.85	1.98
Materials Technologies	0.00	0.01	0.05
Technology Deployment	0.07	0.41	0.50
Fuels Development	0.00	0.18	0.68
TOTAL	0.08	1.46	3.21

Total Energy Savings Estimates
(Quadrillion Btu/Year)

Planning Unit	2000	2010	2020
Vehicle Technologies R&D	0.01	0.74	1.77
Materials Technologies	0.00	0.01	0.04
Technology Deployment	0.00	0.00	0.00
Fuels Development	0.00	0.18	0.68
TOTAL	0.01	0.93	2.49

Total Energy Cost Savings Estimates
(Billion 1997 $/Year)

Planning Unit	2000	2010	2020
Vehicle Technologies R&D	0.05	7.52	18.56
Materials Technologies	0.00	0.11	0.49
Technology Deployment	0.03	0.78	0.96
Fuels Development	0.00	0.01	0.14
TOTAL	0.08	8.42	20.15

Total Carbon Equivalent Emissions Savings
(Million Metric Tons of Carbon/Year)

Planning Unit	2000	2010	2020
Vehicle Technologies R&D	0.17	14.09	34.18
Materials Technologies	0.00	0.18	0.85
Technology Deployment	0.29	1.83	2.25
Fuels Development	0.00	3.43	12.84
TOTAL	0.47	19.52	50.12

TABLE A-7 The Transportation Petroleum Gap

Million Barrels per Day
(AEO'99)

Year	Trans Petroleum Use	Domestic Petro Production	Imported Oil	Petroleum "Gap"	QM '01 Crude Oil Displaced	Displaced Substitution	Displaced Efficiency
1970	7.230	9.637	3.27				
1971	7.514	9.463	3.81				
1972	8.007	9.441	4.64				
1973	8.423	9.208	6.13				
1974	8.219	8.774	5.98				
1975	8.321	8.375	5.91	0.00			
1976	8.742	8.132	7.18	0.61			
1977	9.089	8.245	8.62	0.84			
1978	9.467	8.707	8.06	0.76			
1979	9.365	8.552	8.00	0.81			
1980	8.979	8.597	6.38	0.38			
1981	8.886	8.572	5.37	0.31			
1982	8.702	8.649	4.27	0.05			
1983	8.783	8.688	4.29	0.10			
1984	9.078	8.879	4.67	0.20			
1985	9.214	8.971	4.23	0.24			
1986	9.575	8.680	5.45	0.90			
1987	9.859	8.349	5.92	1.51			
1988	10.218	8.140	6.62	2.08			
1989	10.330	7.613	7.24	2.72			
1990	10.303	7.356	7.22	2.95			
1991	10.263	7.417	6.72	2.85			
1992	10.303	7.191	7.07	3.11			
1993	10.440	6.847	7.75	3.59			
1994	10.638	6.662	8.15	3.98			
1995	11.508	6.562	8.92	4.95			
1996	11.682	6.467	9.55	5.22			
1997	11.385	6.448	9.28	4.94			
1998	11.626	6.410	9.41	5.22			
1999	11.857	6.325	9.52	5.53			
2000	12.339	6.292	10.77	6.05	0.039	0.035	0.004
2001	12.608	6.207	11.09	6.40	0.062	0.054	0.009
2002	12.854	6.047	11.45	6.81	0.091	0.075	0.016
2003	13.100	5.948	11.70	7.15	0.130	0.105	0.025
2004	13.331	5.867	11.97	7.46	0.177	0.135	0.043
2005	13.591	5.815	12.25	7.78	0.238	0.165	0.073
2006	13.851	5.792	12.53	8.06	0.311	0.196	0.115
2007	14.101	5.735	12.83	8.37	0.393	0.227	0.166
2008	14.342	5.683	13.16	8.66	0.485	0.260	0.224
2009	14.574	5.636	13.46	8.94	0.584	0.297	0.287
2010	14.800	5.588	13.78	9.21	0.689	0.335	0.354
2011	14.956	5.546	13.98	9.41	0.795	0.375	0.420
2012	15.112	5.508	14.18	9.60	0.896	0.413	0.483
2013	15.259	5.456	14.38	9.80	0.990	0.447	0.543
2014	15.429	5.400	14.59	10.03	1.081	0.481	0.599
2015	15.603	5.338	14.85	10.27	1.162	0.512	0.649
2016	15.755	5.272	15.05	10.48	1.240	0.544	0.697
2017	15.915	5.211	15.29	10.70	1.315	0.574	0.741
2018	16.080	5.149	15.53	10.93	1.385	0.603	0.782
2019	16.236	5.059	15.77	11.18	1.452	0.632	0.820
2020	16.383	4.965	16.04	11.42	1.514	0.659	0.856

Petroleum - Domestic Production and Imports pre-1973; Annual Energy Review 1991, DOE/EIA-0384(91), Table 52 Petroleum Overview, 1949 - 1991, pg. 119. 1973 - 1994; Monthly Energy Review, DOE/EIA-0035(96/01), Table 3.1b Petroleum Overview: Imports, Exports, and Net Imports, pg. 43. 1997 - 2020; Annual Energy Outlook 1999, DOE/EIA-0383(99), NEMS model run AEO99B.D100198a, Table 1.

Transportation Energy Use pre-1973; Annual Energy Review 1991, DOE/EIA-0384(91), Table 5 Energy Consumption by Sector, 1949-1991, pg. 15. 1973 - 1994; Monthly Energy Review, DOE/EIA-0035(96/01), Table 2.5 Transportation Energy Consumption, pg. 31. 1997 - 2020; Annual Energy Outlook 1999, NEMS model run AEO99B.D100198a, Table 2.

TABLE A-8 Light Vehicle Market Penetration

Year	Conventional	CIDI	Alcohol Flex	SIDI	CNG	Electric	Hybrid	Fuel Cell
2000	92.77%	0.0%	6.78%	0.00%	0.16%	0.02%	0.27%	0.00%
2001	86.96%	0.0%	11.00%	0.00%	0.68%	0.09%	1.26%	0.00%
2002	84.15%	0.1%	11.94%	0.00%	1.18%	0.19%	2.40%	0.00%
2003	83.80%	2.1%	9.97%	0.00%	1.51%	0.19%	2.44%	0.00%
2004	78.60%	6.7%	8.83%	0.61%	1.67%	0.24%	3.36%	0.00%
2005	70.23%	11.4%	6.91%	4.32%	1.94%	0.34%	4.90%	0.00%
2006	59.19%	17.0%	6.74%	7.86%	2.18%	0.47%	6.51%	0.00%
2007	51.90%	19.7%	6.38%	11.04%	2.38%	0.63%	7.89%	0.09%
2008	45.77%	20.6%	6.15%	14.18%	2.58%	0.82%	9.48%	0.42%
2009	40.10%	20.5%	6.11%	17.60%	2.81%	1.04%	10.98%	0.85%
2010	35.30%	20.5%	6.06%	20.24%	2.97%	1.27%	12.27%	1.32%
2011	33.90%	21.0%	5.98%	19.99%	2.97%	1.29%	13.00%	1.81%
2012	32.51%	21.3%	5.93%	19.81%	2.95%	1.31%	13.80%	2.33%
2013	32.55%	21.1%	5.72%	19.26%	2.87%	1.33%	14.31%	2.85%
2014	31.66%	21.1%	5.72%	19.24%	2.84%	1.35%	14.55%	3.52%
2015	33.86%	19.8%	5.72%	18.47%	2.70%	1.25%	13.91%	4.33%
2016	32.76%	19.8%	5.70%	18.46%	2.70%	1.26%	13.89%	5.40%
2017	31.82%	19.9%	5.69%	18.47%	2.68%	1.24%	13.88%	6.37%
2018	31.15%	19.9%	5.67%	18.46%	2.68%	1.22%	13.86%	7.05%
2019	30.59%	20.0%	5.64%	18.45%	2.67%	1.19%	13.83%	7.64%
2020	30.01%	20.1%	5.63%	18.44%	2.66%	1.17%	13.81%	8.22%

Ref. VSCC Model

TABLE A-9 Conventional and Advanced Technology Market Penetration Within Light Vehicle Size Class

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2020
Conventional	92.8%	87.0%	84.2%	83.8%	78.6%	70.2%	59.2%	51.9%	45.8%	40.1%	35.3%	33.9%	32.5%	32.6%	31.7%	33.9%	30.0%
Flex Alcohol	6.8%	11.0%	11.9%	10.0%	8.8%	6.9%	6.7%	6.4%	6.1%	6.1%	6.1%	6.0%	5.9%	5.7%	5.7%	5.7%	5.6%
SIDI	0.0%	0.0%	0.0%	0.0%	0.6%	4.3%	7.9%	11.0%	14.2%	17.6%	20.2%	20.0%	19.8%	19.3%	19.2%	18.5%	18.4%
Advanced Diesel	0.0%	0.0%	0.1%	2.1%	6.7%	11.4%	17.0%	19.7%	20.6%	20.5%	20.5%	21.0%	21.3%	21.1%	21.1%	19.8%	20.1%
CNG Dedicated	0.2%	0.7%	1.2%	1.5%	1.7%	1.9%	2.2%	2.4%	2.6%	2.8%	3.0%	3.0%	3.0%	2.9%	2.8%	2.7%	2.7%
Electric	0.0%	0.1%	0.2%	0.2%	0.2%	0.3%	0.5%	0.6%	0.8%	1.0%	1.3%	1.3%	1.3%	1.3%	1.3%	1.2%	1.2%
Hybrid	0.3%	1.3%	2.4%	2.4%	3.4%	4.9%	6.5%	7.9%	9.5%	11.0%	12.3%	13.0%	13.8%	14.3%	14.5%	13.9%	13.8%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.4%	0.9%	1.3%	1.8%	2.3%	2.9%	3.5%	4.3%	8.2%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
SIZE CLASS SHARES																	
Small Car	31.5%	31.2%	30.9%	30.6%	30.3%	30.0%	29.7%	29.4%	29.0%	28.7%	28.4%	28.0%	27.7%	27.3%	27.0%	26.6%	25.0%
Large Car	25.1%	25.1%	25.1%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%
Minivan	11.2%	11.3%	11.3%	11.4%	11.4%	11.5%	11.5%	11.5%	11.5%	11.5%	11.5%	11.5%	11.5%	11.5%	11.5%	11.5%	11.5%
SUV	12.5%	12.8%	13.1%	13.4%	13.7%	14.0%	14.4%	14.7%	15.1%	15.4%	15.8%	16.1%	16.5%	16.8%	17.2%	17.5%	19.0%
Cargo Truck	19.7%	19.7%	19.6%	19.6%	19.5%	19.5%	19.5%	19.4%	19.4%	19.3%	19.3%	19.3%	19.3%	19.4%	19.4%	19.4%	19.5%
SMALL CAR																	
Conventional	98.8%	94.5%	89.7%	89.5%	77.5%	60.5%	44.9%	38.8%	32.5%	26.5%	21.7%	21.5%	21.3%	21.2%	21.2%	32.6%	24.8%
Flex Alcohol	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SIDI	0.0%	0.0%	0.0%	0.0%	0.6%	4.0%	7.3%	10.5%	13.7%	16.8%	19.3%	19.0%	18.7%	18.5%	18.4%	15.5%	15.1%
Advanced Diesel	0.0%	0.0%	0.0%	1.2%	11.6%	21.6%	31.1%	31.3%	31.4%	31.4%	31.6%	32.6%	33.3%	33.8%	34.1%	29.2%	30.4%
CNG Dedicated	0.3%	1.2%	2.0%	1.6%	1.6%	1.9%	2.2%	2.5%	2.9%	3.2%	3.4%	3.3%	3.3%	3.2%	3.2%	2.7%	2.7%
Electric	0.1%	0.3%	0.6%	0.6%	0.7%	1.0%	1.3%	1.7%	2.1%	2.7%	3.2%	3.1%	3.0%	3.0%	2.9%	2.4%	2.3%
Hybrid	0.9%	4.0%	7.8%	7.1%	8.0%	11.0%	13.1%	15.2%	17.3%	19.4%	20.9%	20.6%	20.4%	20.2%	20.2%	17.1%	16.9%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	7.9%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
LARGE CAR																	
Conventional	84.9%	78.0%	77.7%	83.2%	84.3%	80.0%	70.1%	64.1%	54.2%	47.7%	41.7%	38.3%	34.8%	31.7%	30.2%	28.6%	26.1%
Flex Alcohol	15.0%	21.3%	21.1%	14.6%	10.6%	9.0%	8.6%	7.4%	7.2%	7.1%	6.9%	6.8%	6.6%	6.6%	6.5%	6.5%	6.2%
SIDI	0.0%	0.0%	0.0%	0.0%	0.8%	4.2%	7.6%	9.6%	12.4%	15.3%	17.6%	17.3%	17.1%	17.0%	17.1%	17.0%	17.0%
Advanced Diesel	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	4.6%	7.7%	10.9%	10.9%	10.9%	11.1%	11.2%	11.3%	11.3%	11.3%	11.4%
CNG Dedicated	0.2%	0.7%	1.3%	1.3%	1.3%	1.4%	1.6%	1.6%	1.8%	2.0%	2.1%	2.1%	2.0%	2.0%	2.0%	2.0%	1.9%
Electric	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.4%	0.6%	0.8%	0.9%	1.1%	1.3%	1.4%	1.6%	1.6%
Hybrid	0.0%	0.0%	0.0%	0.9%	3.1%	5.0%	7.4%	9.0%	11.6%	13.7%	15.8%	17.7%	19.7%	21.2%	21.3%	21.3%	21.7%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	1.5%	2.8%	4.3%	5.8%	7.5%	8.9%	10.3%	11.7%	14.1%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
MINIVAN																	
Conventional	97.6%	96.6%	96.7%	95.8%	86.8%	78.3%	65.4%	53.2%	49.0%	44.8%	41.2%	39.9%	38.8%	42.0%	40.4%	39.1%	35.8%
Flex Alcohol	2.4%	3.4%	3.1%	3.0%	11.1%	7.4%	7.3%	7.2%	7.0%	7.0%	6.8%	6.7%	6.5%	6.0%	5.9%	5.9%	5.5%
SIDI	0.0%	0.0%	0.0%	0.0%	0.7%	3.3%	6.1%	9.0%	11.8%	14.8%	16.9%	16.6%	16.4%	15.1%	15.0%	14.9%	14.6%
Advanced Diesel	0.0%	0.0%	0.0%	0.0%	0.2%	9.5%	18.3%	26.3%	26.6%	26.6%	26.8%	27.4%	27.8%	26.2%	26.3%	26.5%	27.2%
CNG Dedicated	0.0%	0.0%	0.3%	1.2%	1.2%	1.2%	1.6%	1.9%	2.2%	2.6%	2.9%	3.2%	3.4%	3.1%	3.1%	3.1%	3.0%
Electric	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hybrid	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	1.3%	2.3%	3.3%	4.3%	5.3%	6.2%	7.1%	7.5%	8.4%	9.0%	8.9%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.9%	1.6%	5.0%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
SUV																	
Conventional	91.4%	83.6%	77.9%	78.4%	82.8%	73.9%	63.7%	53.0%	47.1%	42.1%	37.9%	37.1%	36.2%	40.3%	39.4%	38.7%	35.0%
Flex Alcohol	8.6%	16.4%	21.9%	19.1%	12.4%	11.4%	10.9%	10.5%	10.2%	10.2%	10.1%	9.9%	9.8%	8.9%	8.9%	8.9%	8.6%
SIDI	0.0%	0.0%	0.0%	0.0%	0.9%	5.3%	9.4%	13.4%	17.2%	21.4%	24.7%	24.5%	24.3%	22.3%	22.3%	22.3%	22.3%
Advanced Diesel	0.0%	0.0%	0.0%	0.0%	0.1%	3.8%	9.7%	16.0%	17.6%	17.5%	17.6%	18.0%	18.2%	17.0%	17.0%	17.0%	17.1%
CNG Dedicated	0.0%	0.0%	0.2%	2.1%	2.7%	3.5%	3.4%	3.3%	3.2%	3.2%	3.2%	3.1%	3.1%	2.8%	2.8%	2.8%	2.7%
Electric	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.3%	0.3%	0.5%	0.6%	0.7%	0.7%	0.8%	0.8%	0.8%	0.8%
Hybrid	0.0%	0.0%	0.0%	0.4%	1.1%	2.0%	2.8%	3.6%	4.3%	5.2%	6.0%	6.7%	7.7%	7.7%	7.8%	7.9%	8.0%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	1.0%	1.7%	5.6%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
PICK-UP AND LARGE VAN																	
Conventional	91.3%	83.0%	80.6%	72.3%	65.3%	65.3%	59.9%	54.6%	51.9%	46.2%	41.4%	40.1%	38.8%	37.4%	36.0%	34.9%	33.5%
Flex Alcohol	8.5%	16.2%	17.6%	17.4%	16.4%	11.3%	11.2%	11.1%	10.3%	10.3%	10.2%	10.0%	9.9%	9.8%	9.7%	9.7%	9.3%
SIDI	0.0%	0.0%	0.0%	0.0%	0.1%	4.9%	9.0%	13.1%	16.3%	20.3%	23.5%	23.2%	23.1%	23.0%	23.0%	23.0%	23.0%
Advanced Diesel	0.0%	0.0%	0.7%	8.7%	16.1%	16.2%	16.3%	16.3%	15.5%	15.4%	15.5%	15.9%	16.1%	16.3%	16.3%	16.3%	16.5%
CNG Dedicated	0.2%	0.8%	1.0%	1.5%	1.8%	2.0%	2.3%	2.7%	2.9%	3.2%	3.4%	3.4%	3.3%	3.3%	3.3%	3.3%	3.3%
Electric	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.3%	0.3%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
Hybrid	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	1.1%	1.9%	2.6%	3.5%	4.3%	5.2%	6.0%	6.9%	7.7%	8.4%	8.4%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.7%	1.3%	1.8%	2.4%	3.0%	3.5%	4.1%	5.6%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Ref. VSCC Model

TABLE A-10 Conventional and Advanced Technology Market Penetration in the Light Vehicle Sector

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2020
SMALL CAR																	
Conventional	31.1%	29.5%	27.7%	27.4%	23.5%	18.2%	13.3%	11.4%	9.5%	7.6%	6.2%	6.0%	5.9%	5.8%	5.7%	8.7%	6.2%
Flex Alcohol	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SIDI	0.0%	0.0%	0.0%	0.0%	0.2%	1.2%	2.2%	3.1%	4.0%	4.8%	5.5%	5.3%	5.2%	5.1%	5.0%	4.1%	3.8%
Advanced Diesel	0.0%	0.0%	0.0%	0.4%	3.5%	6.5%	9.2%	9.2%	9.1%	9.0%	9.0%	9.1%	9.2%	9.2%	9.2%	7.8%	7.6%
CNG Dedicated	0.1%	0.4%	0.6%	0.5%	0.5%	0.6%	0.7%	0.7%	0.8%	0.9%	1.0%	0.9%	0.9%	0.9%	0.9%	0.7%	0.7%
Electric	0.0%	0.1%	0.2%	0.2%	0.2%	0.3%	0.4%	0.5%	0.6%	0.8%	0.9%	0.9%	0.8%	0.8%	0.8%	0.6%	0.6%
Hybrid	0.3%	1.3%	2.4%	2.2%	2.4%	3.3%	3.9%	4.5%	5.0%	5.6%	5.9%	5.8%	5.6%	5.5%	5.4%	4.5%	4.2%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	2.0%
LARGE CAR																	
Conventional	21.3%	19.6%	19.5%	20.8%	21.1%	20.0%	17.5%	16.0%	13.5%	11.9%	10.4%	9.6%	8.7%	7.9%	7.5%	7.2%	6.5%
Flex Alcohol	3.8%	5.3%	5.3%	3.7%	2.7%	2.2%	2.2%	1.9%	1.8%	1.8%	1.7%	1.7%	1.7%	1.6%	1.6%	1.6%	1.5%
SIDI	0.0%	0.0%	0.0%	0.0%	0.2%	1.1%	1.9%	2.4%	3.1%	3.8%	4.4%	4.3%	4.3%	4.3%	4.3%	4.3%	4.2%
Advanced Diesel	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	1.2%	1.9%	2.7%	2.7%	2.7%	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%
CNG Dedicated	0.0%	0.2%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Electric	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%	0.3%	0.4%	0.4%	0.4%
Hybrid	0.0%	0.0%	0.0%	0.2%	0.8%	1.2%	1.9%	2.3%	2.9%	3.4%	3.9%	4.4%	4.9%	5.3%	5.3%	5.3%	5.4%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.4%	0.7%	1.1%	1.5%	1.9%	2.2%	2.6%	2.9%	3.5%
MINIVAN																	
Conventional	11.0%	10.9%	11.0%	10.9%	9.9%	9.0%	7.5%	6.1%	5.6%	5.2%	4.7%	4.6%	4.5%	4.8%	4.6%	4.5%	4.1%
Flex Alcohol	0.3%	0.4%	0.3%	0.3%	1.3%	0.9%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.7%	0.7%	0.7%	0.6%
SIDI	0.0%	0.0%	0.0%	0.0%	0.1%	0.4%	0.7%	1.0%	1.4%	1.7%	1.9%	1.9%	1.9%	1.7%	1.7%	1.7%	1.7%
Advanced Diesel	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%	2.1%	3.0%	3.1%	3.1%	3.1%	3.2%	3.2%	3.0%	3.0%	3.0%	3.1%
CNG Dedicated	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.2%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	0.4%	0.4%	0.3%
Electric	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hybrid	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.3%	0.4%	0.5%	0.6%	0.7%	0.8%	0.9%	1.0%	1.0%	1.0%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.6%
SUV																	
Conventional	11.4%	10.7%	10.2%	10.5%	11.3%	10.3%	9.1%	7.8%	7.1%	6.5%	6.0%	6.0%	6.0%	6.8%	6.8%	6.8%	6.6%
Flex Alcohol	1.1%	2.1%	2.9%	2.6%	1.7%	1.6%	1.6%	1.5%	1.5%	1.6%	1.6%	1.6%	1.6%	1.5%	1.5%	1.6%	1.6%
SIDI	0.0%	0.0%	0.0%	0.0%	0.1%	0.7%	1.3%	2.0%	2.6%	3.3%	3.9%	3.9%	4.0%	3.8%	3.8%	3.9%	4.2%
Advanced Diesel	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	1.4%	2.4%	2.6%	2.7%	2.8%	2.9%	3.0%	2.9%	2.9%	3.0%	3.3%
CNG Dedicated	0.0%	0.0%	0.0%	0.3%	0.4%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Electric	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Hybrid	0.0%	0.0%	0.0%	0.0%	0.2%	0.3%	0.4%	0.5%	0.7%	0.8%	0.9%	1.1%	1.3%	1.3%	1.3%	1.4%	1.5%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.3%	1.1%
PICK-UP AND LARGE VAN																	
Conventional	18.0%	16.3%	15.8%	14.2%	12.8%	12.7%	11.7%	10.6%	10.0%	8.9%	8.0%	7.7%	7.5%	7.2%	7.0%	6.8%	6.5%
Flex Alcohol	1.7%	3.2%	3.4%	3.4%	3.2%	2.2%	2.2%	2.2%	2.0%	2.0%	2.0%	1.9%	1.9%	1.9%	1.9%	1.9%	1.8%
SIDI	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	1.8%	2.6%	3.2%	3.9%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%
Advanced Diesel	0.0%	0.0%	0.1%	1.7%	3.1%	3.2%	3.2%	3.2%	3.0%	3.0%	3.0%	3.1%	3.1%	3.2%	3.2%	3.2%	3.2%
CNG Dedicated	0.0%	0.1%	0.2%	0.3%	0.4%	0.4%	0.5%	0.5%	0.6%	0.6%	0.7%	0.7%	0.6%	0.6%	0.6%	0.6%	0.6%
Electric	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Hybrid	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.4%	0.5%	0.7%	0.8%	1.0%	1.2%	1.3%	1.5%	1.6%	1.6%
Fuel Cell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.4%	0.5%	0.6%	0.7%	0.8%	1.1%

Ref. VSCC Model

TABLE A-11 Annual New Light Vehicle Sales
(millions)

Year	Conventional	Advanced Diesel	Alcohol Flex	SIDI	CNG	Electric	Hybrid	Fuel Cell	AEO'99 Total
2000	12.60	0.00	0.92	0.00	0.02	0.00	0.04	0.00	13.58
2001	11.51	0.00	1.46	0.00	0.09	0.01	0.17	0.00	13.24
2002	10.95	0.02	1.55	0.00	0.15	0.02	0.31	0.00	13.02
2003	10.85	0.27	1.29	0.00	0.20	0.02	0.32	0.00	12.95
2004	10.25	0.87	1.15	0.08	0.22	0.03	0.44	0.00	13.04
2005	9.30	1.50	0.92	0.57	0.26	0.05	0.65	0.00	13.24
2006	7.93	2.28	0.90	1.05	0.29	0.06	0.87	0.00	13.39
2007	7.04	2.67	0.87	1.50	0.32	0.09	1.07	0.01	13.57
2008	6.30	2.83	0.85	1.95	0.35	0.11	1.30	0.06	13.76
2009	5.59	2.85	0.85	2.45	0.39	0.15	1.53	0.12	13.92
2010	5.00	2.90	0.86	2.86	0.42	0.18	1.74	0.19	14.14
2011	4.78	2.96	0.84	2.82	0.42	0.18	1.83	0.25	14.10
2012	4.57	3.00	0.83	2.78	0.42	0.18	1.94	0.33	14.06
2013	4.57	2.96	0.80	2.70	0.40	0.19	2.01	0.40	14.02
2014	4.49	2.99	0.81	2.73	0.40	0.19	2.06	0.50	14.17
2015	4.86	2.84	0.82	2.65	0.39	0.18	2.00	0.62	14.36
2016	4.69	2.84	0.82	2.64	0.39	0.18	1.99	0.77	14.31
2017	4.54	2.83	0.81	2.64	0.38	0.18	1.98	0.91	14.27
2018	4.44	2.84	0.81	2.63	0.38	0.17	1.98	1.01	14.27
2019	4.36	2.85	0.81	2.63	0.38	0.17	1.97	1.09	14.27
2020	4.28	2.86	0.80	2.63	0.38	0.17	1.97	1.17	14.26

Does not include sales of alternative fuel vehicles estimated in the AEO'99 Reference Case

TABLE A-12 Percent of Total Light Vehicles in Use by Year

Year	Conventional	Advanced Diesel	Alcohol Flex	SIDI	CNG	Electric	Hybrid	Fuel Cell	Total Vehicles (million)
2000	99.3%	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	205.41
2001	98.5%	0.0%	1.3%	0.0%	0.1%	0.0%	0.1%	0.0%	206.67
2002	97.5%	0.0%	2.1%	0.0%	0.1%	0.0%	0.2%	0.0%	207.25
2003	96.5%	0.1%	2.7%	0.0%	0.2%	0.0%	0.4%	0.0%	207.39
2004	95.2%	0.6%	3.2%	0.0%	0.3%	0.0%	0.6%	0.0%	207.41
2005	93.4%	1.3%	3.6%	0.3%	0.4%	0.1%	0.9%	0.0%	207.32
2006	90.8%	2.4%	4.0%	0.8%	0.6%	0.1%	1.3%	0.0%	207.25
2007	87.8%	3.7%	4.3%	1.5%	0.7%	0.1%	1.8%	0.0%	206.95
2008	84.4%	5.0%	4.5%	2.5%	0.9%	0.2%	2.4%	0.0%	206.52
2009	80.6%	6.4%	4.7%	3.7%	1.1%	0.3%	3.2%	0.1%	205.99
2010	76.6%	7.7%	4.9%	5.1%	1.3%	0.3%	3.9%	0.2%	205.53
2011	72.6%	9.0%	5.0%	6.4%	1.4%	0.4%	4.8%	0.3%	205.09
2012	68.7%	10.3%	5.1%	7.7%	1.6%	0.5%	5.6%	0.5%	204.76
2013	65.1%	11.4%	5.1%	9.0%	1.7%	0.6%	6.4%	0.7%	204.67
2014	61.6%	12.5%	5.1%	10.1%	1.8%	0.7%	7.2%	0.9%	204.75
2015	58.6%	13.4%	5.1%	11.2%	1.9%	0.7%	7.9%	1.2%	205.02
2016	55.8%	14.1%	5.1%	12.1%	2.0%	0.8%	8.5%	1.6%	205.27
2017	53.3%	14.7%	5.0%	12.9%	2.1%	0.9%	9.1%	2.0%	205.59
2018	51.2%	15.2%	4.9%	13.6%	2.1%	0.9%	9.6%	2.4%	205.98
2019	49.4%	15.6%	4.8%	14.2%	2.2%	0.9%	10.0%	2.9%	206.71
2020	47.9%	15.9%	4.7%	14.7%	2.2%	1.0%	10.3%	3.4%	207.33

Does not include sales of alternative fuel vehicles estimated in the AEO'99 Reference Case

TABLE A-13 Number of Light Vehicles in Use by Year
(millions)

Year	Conventional	CIDI	Alcohol Flex	SIDI	CNG	Electric	Hybrid	Fuel Cell
2000	204.07	0.00	1.28	0.00	0.02	0.00	0.04	0.00
2001	203.61	0.00	2.73	0.00	0.11	0.02	0.20	0.00
2002	202.14	0.02	4.27	0.00	0.27	0.04	0.52	0.00
2003	200.21	0.29	5.53	0.00	0.46	0.06	0.83	0.00
2004	197.51	1.16	6.63	0.08	0.68	0.10	1.27	0.00
2005	193.59	2.66	7.44	0.65	0.93	0.14	1.90	0.00
2006	188.26	4.93	8.19	1.70	1.21	0.20	2.76	0.00
2007	181.74	7.58	8.82	3.20	1.52	0.29	3.80	0.01
2008	174.31	10.35	9.35	5.15	1.85	0.40	5.05	0.07
2009	166.11	13.10	9.78	7.58	2.21	0.54	6.49	0.19
2010	157.42	15.82	10.12	10.41	2.57	0.71	8.10	0.37
2011	148.90	18.50	10.35	13.17	2.92	0.88	9.76	0.63
2012	140.68	21.08	10.48	15.84	3.24	1.05	11.45	0.95
2013	133.20	23.43	10.51	18.33	3.52	1.21	13.12	1.35
2014	126.18	25.62	10.49	20.72	3.77	1.38	14.75	1.84
2015	120.10	27.42	10.49	22.86	3.98	1.52	16.20	2.45
2016	114.58	28.98	10.38	24.81	4.15	1.65	17.52	3.19
2017	109.66	30.30	10.26	26.54	4.30	1.77	18.70	4.06
2018	105.43	31.39	10.10	28.06	4.42	1.87	19.73	5.01
2019	102.13	32.28	9.91	29.34	4.50	1.95	20.60	6.01
2020	99.28	32.97	9.74	30.41	4.55	2.01	21.32	7.05

Does not include sales of alternative fuel vehicles estimated in the AEO'99 Reference Case

TABLE A-14 Summation of Gasoline Displaced by Light Vehicles

	Advanced Diesel			Flex Fuel			(1) ETOH	SIDI		
Year	Gasoline Potential (bill. gals)	Diesel Used (bill. gals)	Gasoline Displaced mmb/d	Gasoline Potential (bill. gals)	ETOH Used (bill. gals)	Gasoline Displaced mmb/d	MEOH Used mmb/d	Gasoline Potential (bill. gals)	Gasoline Used (bill. gals)	Gasoline Displaced mmb/d
2000	0.00	0.00	0.000	0.98	0.00	0.000	0.000	0.00	0.00	0.000
2001	0.00	0.00	0.000	2.04	0.00	0.000	0.000	0.00	0.00	0.000
2002	0.01	0.01	0.000	3.10	0.01	0.000	0.000	0.00	0.00	0.000
2003	0.21	0.14	0.003	3.90	0.01	0.000	0.000	0.00	0.00	0.000
2004	0.85	0.56	0.012	4.54	0.03	0.001	0.001	0.06	0.05	0.000
2005	1.91	1.26	0.028	4.95	0.05	0.002	0.002	0.47	0.38	0.003
2006	3.48	2.29	0.050	5.29	0.09	0.003	0.003	1.22	0.98	0.007
2007	5.23	3.45	0.076	5.54	0.15	0.005	0.005	2.25	1.80	0.013
2008	6.98	4.60	0.101	5.71	0.25	0.009	0.009	3.53	2.82	0.021
2009	8.60	5.67	0.124	5.82	0.32	0.012	0.012	5.08	4.07	0.030
2010	10.12	6.67	0.146	5.88	0.47	0.017	0.017	6.82	5.45	0.040
2011	11.53	7.60	0.167	5.89	0.58	0.021	0.021	8.41	6.72	0.049
2012	12.81	8.44	0.185	5.84	0.68	0.024	0.024	9.85	7.88	0.058
2013	13.89	9.16	0.201	5.75	0.92	0.033	0.033	11.10	8.88	0.065
2014	14.84	9.78	0.214	5.65	1.01	0.036	0.036	12.24	9.79	0.072
2015	15.54	10.24	0.224	5.53	1.36	0.049	0.049	13.19	10.55	0.077
2016	16.09	10.61	0.233	5.48	1.44	0.051	0.051	14.00	11.20	0.082
2017	16.52	10.89	0.239	5.34	1.47	0.053	0.053	14.67	11.74	0.086
2018	16.85	11.10	0.243	5.23	1.53	0.055	0.055	15.23	12.18	0.089
2019	17.09	11.26	0.247	5.11	1.45	0.052	0.052	15.67	12.53	0.092
2020	17.25	11.37	0.249	5.02	1.53	0.055	0.055	16.00	12.80	0.094
Cumulative Total From Year 2000 to Year										
2005	3.0	2.0	0.0	19.5	0.1	0.0	0.0	0.5	0.4	0.0
2010	37.4	24.6	0.5	47.8	1.4	0.0	0.0	19.4	15.5	0.1
2015	106.0	69.9	1.5	76.4	5.9	0.2	0.2	74.2	59.4	0.4
2020	189.8	125.1	2.7	102.6	13.3	0.5	0.5	149.8	119.8	0.9

Gasoline Potential: amount of gasoline used by conventional vehicle, had it not been displaced by new technology.
(1) mmb/d equivalent energy use - conversion of quads to mmb/d.

TABLE A-14a Summation of Gasoline Displaced by Light Vehicles

	Electric		(1)		**Fuel Cell**		(1)	
Year	Gasoline Potential (bill. gals)	Electricity Used bill. kWhr	Electricity Used mmb/d	Gasoline Displaced mmb/d	Gasoline Potential (bill. gals)	Gasoline Used (bill. gals)	ETOH Used mmb/d	Gasoline Displaced mmb/d
2000	0.00	0.01	0.000	0.000	0.00	0.00	0.000	0.000
2001	0.01	0.06	0.000	0.000	0.00	0.00	0.000	0.000
2002	0.02	0.16	0.001	0.001	0.00	0.00	0.000	0.000
2003	0.03	0.25	0.001	0.002	0.00	0.00	0.000	0.000
2004	0.04	0.36	0.002	0.002	0.00	0.00	0.000	0.000
2005	0.06	0.52	0.003	0.003	0.00	0.00	0.000	0.000
2006	0.09	0.74	0.004	0.005	0.00	0.00	0.000	0.000
2007	0.12	1.04	0.006	0.007	0.01	0.00	0.000	0.000
2008	0.17	1.41	0.008	0.009	0.05	0.02	0.000	0.001
2009	0.22	1.88	0.010	0.012	0.13	0.06	0.000	0.004
2010	0.29	2.44	0.014	0.016	0.25	0.12	0.000	0.007
2011	0.35	2.97	0.017	0.019	0.42	0.20	0.000	0.012
2012	0.41	3.47	0.019	0.023	0.62	0.29	0.000	0.018
2013	0.47	3.92	0.022	0.025	0.86	0.41	0.000	0.024
2014	0.52	4.35	0.024	0.028	1.14	0.55	0.000	0.033
2015	0.56	4.70	0.026	0.031	1.50	0.71	0.000	0.043
2016	0.60	5.00	0.028	0.032	1.93	0.92	0.000	0.055
2017	0.63	5.25	0.029	0.034	2.42	1.15	0.000	0.069
2018	0.65	5.44	0.030	0.035	2.95	1.40	0.000	0.084
2019	0.67	5.59	0.031	0.036	3.49	1.66	0.000	0.100
2020	0.68	5.69	0.032	0.037	4.04	1.93	0.000	0.115
Cumulative Total From Year 2000 to Year								
2005	0.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0
2010	1.1	8.9	0.0	0.1	0.4	0.2	0.0	0.0
2015	3.4	28.3	0.2	0.2	5.0	2.4	0.0	0.1
2020	6.6	55.3	0.3	0.4	19.8	9.4	0.0	0.6

Gasoline Potential: amount of gasoline used by conventional vehicle, had it not been displaced by new technology.
(1) mmb/d equivalent energy use - conversion of quads to mmb/d.

TABLE A-14b Summation of Gasoline Displaced by Light Vehicles

	Hybrid			CNG			Summary		
Year	Gasoline Potential (bill. gals)	Gasoline Used (bill. gals)	Gasoline Displaced mmb/d	Gasoline Potential (bill. gals)	CNG Used mill. cu.ft.	(1) CNG Used mmb/d	Total Gasoline Displaced mmb/d	Total Alt. Fuel Used mmb/d	Efficiency mmb/d
2000	0.03	0.02	0.000	0.02	1862	0.001	0.001	0.001	0.000
2001	0.15	0.11	0.002	0.08	9440	0.005	0.007	0.005	0.002
2002	0.38	0.27	0.006	0.20	21840	0.011	0.018	0.012	0.006
2003	0.60	0.43	0.009	0.33	36985	0.018	0.033	0.020	0.013
2004	0.89	0.64	0.014	0.48	52995	0.026	0.056	0.029	0.027
2005	1.32	0.92	0.022	0.64	71194	0.035	0.092	0.039	0.053
2006	1.89	1.27	0.034	0.82	91085	0.044	0.144	0.052	0.092
2007	2.55	1.65	0.049	1.01	111884	0.054	0.205	0.066	0.139
2008	3.34	2.07	0.069	1.20	133373	0.065	0.275	0.082	0.193
2009	4.21	2.51	0.093	1.40	155514	0.076	0.350	0.098	0.252
2010	5.15	2.95	0.120	1.60	177537	0.086	0.432	0.117	0.316
2011	6.08	3.38	0.147	1.77	196997	0.096	0.511	0.133	0.377
2012	6.98	3.80	0.173	1.92	213729	0.104	0.585	0.148	0.437
2013	7.84	4.20	0.199	2.05	227210	0.111	0.658	0.165	0.493
2014	8.64	4.56	0.222	2.15	238595	0.116	0.722	0.177	0.545
2015	9.30	4.86	0.242	2.22	246821	0.120	0.786	0.195	0.591
2016	9.86	5.11	0.259	2.28	253148	0.123	0.836	0.203	0.633
2017	10.34	5.32	0.274	2.32	257762	0.126	0.880	0.207	0.673
2018	10.74	5.49	0.286	2.35	260901	0.127	0.920	0.212	0.708
2019	11.05	5.63	0.296	2.36	262552	0.128	0.950	0.211	0.739
2020	11.29	5.73	0.303	2.37	263101	0.128	0.982	0.214	0.767
Cumulative Total From Year 2000 to Year									
2005	3.4	2.4	0.1	1.7	194317	0.1	0.2	0.1	0.1
2010	20.5	12.8	0.4	7.8	863708	0.4	1.6	0.5	1.1
2015	59.3	33.6	1.4	17.9	1987060	1.0	4.9	1.3	3.5
2020	112.6	60.9	2.8	29.6	3284523	1.6	9.4	2.4	7.1

Gasoline Potential: amount of gasoline used by conventional vehicle, had it not been displaced by new technology.
(1) mmb/d equivalent energy use - conversion of quads to mmb/d.

TABLE A-15 Light Truck Class 1&2 Advanced Diesel

Year	New Sales Percent	New Sales Units (million)	Stock Percent	Stock Units (million)	Gasoline Potential (bill. gals)	Diesel Used (bill. gals)	Gasoline Displaced mmb/d	Energy Cost Reduction (billion $)	Carbon Reduction (mmt)	Carbon Value (mm$)	Criteria Emissions Reductions NOX (MMT)	CO (MMT)	HC (MMT)	Value NOX (mm$)	CO (mm$)	HC (mm$)
2000	0.0%	0.000	0.0%	0.00	0.00	0.00	0.000	0.000	0.000	0.0	0.000	0.000	0.000	0.0	0.0	0.0
2001	0.0%	0.000	0.0%	0.00	0.00	0.00	0.000	0.000	0.000	0.0	0.000	0.000	0.000	0.0	0.0	0.0
2002	0.1%	0.018	0.0%	0.02	0.01	0.01	0.000	0.006	0.009	0.5	0.000	0.002	0.000	-0.1	0.6	0.4
2003	1.7%	0.221	0.1%	0.24	0.18	0.12	0.003	0.077	0.114	6.2	0.000	0.010	0.001	-0.7	3.6	1.9
2004	3.2%	0.415	0.3%	0.65	0.48	0.31	0.008	0.215	0.304	16.7	-0.001	0.027	0.001	-2.4	9.9	4.9
2005	4.8%	0.631	0.6%	1.28	0.92	0.60	0.015	0.417	0.585	32.2	-0.002	0.057	0.003	-5.6	20.3	9.5
2006	6.7%	0.891	1.0%	2.17	1.52	1.00	0.024	0.714	0.972	53.5	-0.003	0.101	0.004	-11.0	36.2	16.2
2007	8.6%	1.162	1.6%	3.32	2.29	1.51	0.036	1.097	1.459	80.2	-0.006	0.162	0.007	-19.2	58.5	25.3
2008	8.7%	1.197	2.2%	4.49	3.02	1.99	0.048	1.531	1.928	106.0	-0.009	0.237	0.010	-30.8	85.2	35.7
2009	8.7%	1.216	2.7%	5.65	3.71	2.44	0.059	1.840	2.367	130.2	-0.014	0.323	0.013	-45.8	116.4	47.4
2010	8.8%	1.251	3.3%	6.82	4.36	2.87	0.069	2.249	2.784	153.1	-0.019	0.422	0.017	-64.2	152.0	60.8
2011	9.1%	1.287	3.9%	7.98	4.98	3.28	0.079	2.577	3.176	174.7	-0.026	0.532	0.021	-85.7	191.5	75.9
2012	9.3%	1.311	4.4%	9.10	5.54	3.65	0.088	2.852	3.534	194.4	-0.033	0.650	0.025	-110.0	234.2	92.5
2013	9.0%	1.264	4.9%	10.10	6.00	3.95	0.095	3.183	3.827	210.5	-0.041	0.770	0.030	-135.7	277.2	109.3
2014	9.1%	1.288	5.4%	11.03	6.40	4.22	0.102	3.311	4.087	224.8	-0.049	0.888	0.034	-161.7	319.8	126.3
2015	9.2%	1.317	5.8%	11.90	6.76	4.46	0.107	3.526	4.318	237.5	-0.057	1.002	0.039	-186.8	360.5	142.7
2016	9.3%	1.326	6.2%	12.68	7.07	4.66	0.112	3.712	4.513	248.2	-0.064	1.106	0.043	-210.5	398.2	158.0
2017	9.3%	1.332	6.5%	13.35	7.32	4.83	0.116	3.770	4.675	257.1	-0.070	1.200	0.047	-232.1	432.2	171.9
2018	9.4%	1.344	6.8%	13.94	7.53	4.96	0.120	3.893	4.809	264.5	-0.076	1.283	0.050	-251.0	462.0	184.2
2019	9.5%	1.357	7.0%	14.45	7.71	5.08	0.122	3.994	4.921	270.6	-0.081	1.354	0.053	-267.3	487.4	194.6
2020	9.6%	1.368	7.2%	14.88	7.85	5.17	0.125	4.086	5.013	275.7	-0.085	1.414	0.056	-281.1	509.2	203.8
Cumulative Total From Year 2000 to Year																
2005					1.58	1.04	0.03	0.72	1.01	55.64	0.00	0.10	0.00	-8.77	34.41	16.63
2010					16.48	10.86	0.26	8.15	10.52	578.69	-0.05	1.34	0.06	-179.72	482.62	202.00
2015					46.16	30.42	0.73	23.60	29.46	1620.55	-0.26	5.18	0.20	-859.70	1865.88	748.58
2020					83.64	55.12	1.33	43.05	53.39	2936.71	-0.64	11.54	0.45	-2101.72	4154.85	1661.01

Carbon value/tonne = $55
NOx value/tonne = $3,300
CO value/tonne = $360
HC value/tonne = 3,660

TABLE A-16 Projected Biofuels Demand

Year	FFV Percent ETOH	FFV ETOH (mill. gals)	Total Direct Fuel Use Biomass ETOH (million gals)	Total Direct Fuel Use Biomass ETOH (mbpde)	Blends and Extenders (million gals)	Blends and Extenders (mbpde)	Program Goal (million gals)
2000	0.0%	0.60	0.6	0.000	0.0	0.000	0.0
2001	0.1%	2.25	2.3	0.000	3.7	0.000	6.0
2002	0.1%	5.84	5.8	0.000	20.2	0.001	26.0
2003	0.2%	13.38	13.4	0.000	46.6	0.002	60.0
2004	0.4%	28.98	29.0	0.001	111.0	0.004	140.0
2005	0.7%	50.65	50.7	0.002	229.3	0.009	280.0
2006	1.1%	90.76	90.8	0.003	419.2	0.017	510.0
2007	1.8%	150.25	150.2	0.005	669.8	0.027	820.0
2008	2.9%	246.59	246.6	0.009	973.4	0.039	1220.0
2009	3.7%	322.88	322.9	0.012	1377.1	0.055	1700.0
2010	5.2%	465.79	465.8	0.017	1734.2	0.069	2200.0
2011	6.5%	579.11	579.1	0.021	2240.9	0.090	2820.0
2012	7.7%	682.65	682.7	0.024	2737.3	0.109	3420.0
2013	10.5%	916.70	916.7	0.033	3103.3	0.124	4020.0
2014	11.8%	1011.13	1011.1	0.036	3608.9	0.144	4620.0
2015	16.2%	1362.84	1362.8	0.049	3857.2	0.154	5220.0
2016	17.4%	1440.14	1440.1	0.051	4379.9	0.175	5820.0
2017	18.2%	1470.84	1470.8	0.053	4949.2	0.198	6420.0
2018	19.4%	1531.75	1531.7	0.055	5488.3	0.219	7020.0
2019	18.7%	1445.25	1445.3	0.052	6174.7	0.247	7620.0
2020	20.1%	1526.04	1526.0	0.055	6694.0	0.268	8220.0
Cumulative Total From Year 2000 to Year							
2005		101.7	101.7	0.00	411	0.02	512
2010		1378.0	1378.0	0.05	5585	0.22	6962
2015		5930.4	5930.4	0.21	21132	0.84	27062
2020		13344.4	13344.4	0.48	48818	1.95	62162

Dedicated Alcohol Vehicle assumes E-85 fuel mix, this is taken into account in the calculation of total ethanol used.
The percent of total fuel consumed that is ethanol by flex fuel vehicles is shown in column 2.

TABLE A-17 EPACT Light Vehicle Fleet Alternative Fuel Use Estimates

	Quads					Carbon Reduction - Million Metric Tons					Energy Cost Savings - Billion 1997 $				
	Total	Total	Total	Total											
Year	CNG	LPG	ETOH	MEOH	TOTAL	CNG	LPG	ETOH	MEOH	TOTAL	CNG	LPG	ETOH	MEOH	TOTAL
2000	0.044	0.022	0.0003	0.003	0.068	0.217	0.049	0.006	0.012	0.284	0.096	-0.065	-0.001	-0.007	0.021
2001	0.065	0.029	0.0005	0.004	0.099	0.323	0.065	0.010	0.019	0.417	0.160	-0.086	-0.002	-0.011	0.062
2002	0.086	0.037	0.0007	0.005	0.128	0.423	0.082	0.013	0.026	0.544	0.225	-0.111	-0.002	-0.013	0.099
2003	0.103	0.046	0.0008	0.006	0.157	0.510	0.104	0.016	0.031	0.661	0.293	-0.139	-0.002	-0.015	0.137
2004	0.118	0.058	0.0010	0.007	0.183	0.580	0.129	0.018	0.036	0.764	0.361	-0.177	-0.002	-0.015	0.166
2005	0.127	0.068	0.0011	0.008	0.204	0.629	0.153	0.020	0.040	0.842	0.399	-0.217	-0.002	-0.016	0.164
2006	0.132	0.077	0.0011	0.008	0.218	0.651	0.172	0.021	0.041	0.885	0.420	-0.245	-0.001	-0.016	0.158
2007	0.133	0.082	0.0011	0.008	0.224	0.656	0.184	0.021	0.042	0.902	0.429	-0.253	-0.001	-0.015	0.160
2008	0.134	0.084	0.0011	0.008	0.228	0.662	0.190	0.021	0.042	0.915	0.443	-0.225	0.000	-0.014	0.204
2009	0.135	0.085	0.0011	0.009	0.230	0.666	0.192	0.021	0.042	0.922	0.434	-0.230	0.000	-0.016	0.187
2010	0.136	0.086	0.0011	0.009	0.231	0.671	0.193	0.021	0.042	0.928	0.439	-0.228	0.000	-0.019	0.192
2011	0.136	0.086	0.0011	0.009	0.231	0.672	0.193	0.021	0.042	0.929	0.437	-0.224	0.000	-0.023	0.191
2012	0.136	0.086	0.0011	0.009	0.231	0.672	0.192	0.021	0.042	0.928	0.430	-0.225	0.001	-0.028	0.178
2013	0.136	0.085	0.0011	0.009	0.230	0.670	0.191	0.021	0.042	0.925	0.438	-0.220	0.001	-0.026	0.194
2014	0.135	0.085	0.0011	0.009	0.230	0.668	0.191	0.021	0.042	0.922	0.416	-0.233	0.001	-0.027	0.157
2015	0.135	0.085	0.0011	0.009	0.229	0.667	0.190	0.021	0.042	0.920	0.421	-0.216	0.001	-0.023	0.183
2016	0.135	0.084	0.0011	0.008	0.228	0.665	0.190	0.021	0.042	0.917	0.420	-0.219	0.001	-0.031	0.171
2017	0.134	0.084	0.0011	0.008	0.228	0.663	0.190	0.021	0.042	0.916	0.408	-0.233	0.001	-0.026	0.150
2018	0.134	0.084	0.0011	0.008	0.228	0.663	0.189	0.021	0.042	0.915	0.411	-0.232	0.001	-0.036	0.144
2019	0.134	0.084	0.0011	0.008	0.228	0.662	0.189	0.021	0.041	0.913	0.402	-0.236	0.001	-0.037	0.131
2020	0.134	0.084	0.0011	0.008	0.227	0.660	0.188	0.021	0.041	0.911	0.405	-0.234	0.001	-0.035	0.137
Cumulative Total From Year 2000 to Year															
2005	0.543	0.259	0.004	0.033	0.839	2.683	0.582	0.082	0.164	3.511	1.533	-0.794	-0.0113	-0.077	0.650
2010	1.212	0.673	0.010	0.076	1.970	5.989	1.513	0.187	0.373	8.062	3.699	-1.974	-0.0140	-0.158	1.552
2015	1.695	1.011	0.014	0.107	2.827	8.374	2.275	0.265	0.527	11.441	5.360	-2.830	-0.0044	-0.253	2.272
2020	2.561	1.518	0.021	0.160	4.261	12.650	3.416	0.398	0.792	17.257	7.887	-4.247	-0.0033	-0.448	3.188

Ref. AEO'99

TABLE A-18 ZEV and EPACT Light Duty Electric Vehicle Fuel Use Estimates

	Trillion Btu			Quads			Carbon Reduction Million Metric Tons			Energy Cost Savings Billion 1996 $		
Year	EPACT	ZEV	Total	EPACT	ZEV	Total	EPACT	ZEV	Total	EPACT	ZEV	Total
2000	0.90	0.70	1.60	0.0009	0.0007	0.0016	0.0000	0.0000	0.0000	-0.006	-0.005	-0.01
2001	1.28	0.92	2.20	0.0013	0.0009	0.0022	0.0001	0.0001	0.0002	-0.008	-0.006	-0.01
2002	1.64	1.15	2.79	0.0016	0.0012	0.0028	0.0002	0.0001	0.0004	-0.010	-0.007	-0.02
2003	1.94	14.34	16.28	0.0019	0.0143	0.0163	0.0004	0.0027	0.0031	-0.011	-0.080	-0.09
2004	2.12	26.55	28.67	0.0021	0.0266	0.0287	0.0005	0.0066	0.0072	-0.010	-0.130	-0.14
2005	2.21	37.73	39.94	0.0022	0.0377	0.0399	0.0007	0.0117	0.0124	-0.010	-0.167	-0.18
2006	2.17	47.64	49.81	0.0022	0.0476	0.0498	0.0011	0.0233	0.0244	-0.009	-0.187	-0.20
2007	2.03	56.19	58.22	0.0020	0.0562	0.0582	0.0014	0.0376	0.0390	-0.007	-0.194	-0.20
2008	1.91	64.53	66.44	0.0019	0.0645	0.0664	0.0016	0.0549	0.0565	-0.006	-0.188	-0.19
2009	1.80	73.12	74.92	0.0018	0.0731	0.0749	0.0019	0.0753	0.0772	-0.005	-0.198	-0.20
2010	1.73	81.40	83.13	0.0017	0.0814	0.0831	0.0021	0.0985	0.1006	-0.004	-0.197	-0.20
2011	1.70	88.96	90.66	0.0017	0.0890	0.0907	0.0025	0.1290	0.1315	-0.003	-0.166	-0.17
2012	1.70	95.25	96.95	0.0017	0.0953	0.0970	0.0029	0.1610	0.1638	-0.003	-0.153	-0.16
2013	1.72	101.48	103.20	0.0017	0.1015	0.1032	0.0033	0.1959	0.1992	-0.002	-0.119	-0.12
2014	1.72	107.98	109.70	0.0017	0.1080	0.1097	0.0037	0.2343	0.2380	-0.002	-0.112	-0.11
2015	1.74	114.36	116.10	0.0017	0.1144	0.1161	0.0042	0.2756	0.2798	-0.001	-0.072	-0.07
2016	1.75	120.75	122.50	0.0018	0.1208	0.1225	0.0044	0.3055	0.3099	-0.001	-0.036	-0.04
2017	1.77	127.23	129.00	0.0018	0.1272	0.1290	0.0047	0.3372	0.3419	0.000	-0.012	-0.01
2018	1.78	133.42	135.20	0.0018	0.1334	0.1352	0.0049	0.3696	0.3745	0.000	0.031	0.03
2019	1.79	139.61	141.40	0.0018	0.1396	0.1414	0.0052	0.4035	0.4086	0.001	0.062	0.06
2020	1.80	145.60	147.40	0.0018	0.1456	0.1474	0.0054	0.4383	0.4437	0.001	0.120	0.12
Cumulative Total From Year 2000 to Year												
2005	10.09	81.39	91.48	0.01	0.08	0.09	0.00	0.02	0.02	-0.06	-0.4	-0.5
2010	19.73	404.27	424.00	0.02	0.40	0.42	0.01	0.31	0.32	-0.09	-1.4	-1.4
2015	28.31	912.30	940.61	0.03	0.91	0.94	0.03	1.31	1.33	-0.10	-2.0	-2.1
2020	37.20	1578.91	1616.11	0.04	1.58	1.62	0.05	3.16	3.21	-0.09	-1.8	-1.9

Ref. AEO'99

TABLE A-19 Light Vehicle Energy Cost Savings

Year	Advanced Diesel	Flex Fuel	SIDI	Electric	Fuel Cell	Hybrid	CNG	Total
2000	0.000	0.000	0.000	0.001	0.000	0.008	0.004	0.013
2001	0.000	-0.001	0.000	0.004	0.000	0.045	0.024	0.073
2002	0.004	-0.001	0.000	0.012	0.000	0.115	0.059	0.188
2003	0.062	-0.003	0.000	0.019	0.000	0.186	0.108	0.372
2004	0.251	-0.005	0.007	0.029	0.000	0.285	0.168	0.736
2005	0.575	-0.006	0.058	0.044	0.000	0.455	0.230	1.356
2006	1.070	-0.008	0.153	0.065	0.000	0.716	0.300	2.294
2007	1.633	-0.009	0.285	0.093	0.005	1.062	0.373	3.441
2008	2.211	-0.007	0.455	0.131	0.031	1.511	0.455	4.787
2009	2.717	-0.004	0.653	0.174	0.081	2.025	0.516	6.162
2010	3.218	0.006	0.882	0.228	0.159	2.638	0.591	7.723
2011	3.672	0.016	1.089	0.282	0.262	3.235	0.652	9.207
2012	4.067	0.027	1.272	0.329	0.388	3.810	0.696	10.588
2013	4.450	0.056	1.446	0.379	0.542	4.402	0.757	12.031
2014	4.703	0.068	1.578	0.415	0.717	4.873	0.758	13.112
2015	4.956	0.119	1.711	0.455	0.944	5.342	0.794	14.320
2016	5.149	0.130	1.821	0.488	1.219	5.735	0.814	15.357
2017	5.257	0.128	1.899	0.510	1.521	6.023	0.808	16.146
2018	5.376	0.139	1.976	0.533	1.856	6.311	0.823	17.014
2019	5.415	0.125	2.019	0.545	2.182	6.485	0.812	17.583
2020	5.489	0.139	2.070	0.561	2.540	6.682	0.822	18.301
Cumulative Total From Year 2000 to Year								
2005	0.89	-0.02	0.07	0.11	0.00	1.09	0.59	2.74
2010	11.74	-0.04	2.49	0.80	0.28	9.05	2.83	27.14
2015	33.59	0.25	9.59	2.66	3.13	30.71	6.48	86.40
2020	60.27	0.91	19.37	5.30	12.45	61.94	10.56	170.80

Billions of 1996 $'s
See Transportation Energy Prices for Fuel Prices

TABLE A-20 Transportation Energy Prices

	1997 Dollars per Million Btu						**1997 Dollars per 125,000 Btu**					
Year	Gasoline	Diesel	LPG	CNG	Electricity	Ethanol	Gasoline	Diesel	LPG	CNG	Electricity	Ethanol
2000	8.67	7.56	11.70	6.49	15.81	12.80	1.08	1.05	1.46	0.81	1.98	1.60
2001	8.92	7.71	11.90	6.48	15.57	12.54	1.12	1.07	1.49	0.81	1.95	1.57
2002	9.13	7.86	12.15	6.50	15.32	12.29	1.14	1.09	1.52	0.81	1.92	1.54
2003	9.40	8.09	12.40	6.56	15.43	12.03	1.18	1.12	1.55	0.82	1.93	1.50
2004	9.69	8.30	12.77	6.62	15.24	11.78	1.21	1.15	1.60	0.83	1.91	1.47
2005	9.85	8.49	13.04	6.72	15.10	11.52	1.23	1.18	1.63	0.84	1.89	1.44
2006	10.05	8.61	13.24	6.86	14.98	11.26	1.26	1.19	1.66	0.86	1.87	1.41
2007	10.20	8.70	13.29	6.97	14.85	11.01	1.28	1.21	1.66	0.87	1.86	1.38
2008	10.36	8.62	13.02	7.05	14.65	10.75	1.30	1.20	1.63	0.88	1.83	1.34
2009	10.33	8.70	13.03	7.11	14.59	10.50	1.29	1.21	1.63	0.89	1.82	1.31
2010	10.40	8.58	13.06	7.17	14.55	10.24	1.30	1.19	1.63	0.90	1.82	1.28
2011	10.41	8.57	13.02	7.20	14.18	10.05	1.30	1.19	1.63	0.90	1.77	1.26
2012	10.38	8.56	13.01	7.22	14.06	9.86	1.30	1.19	1.63	0.90	1.76	1.23
2013	10.47	8.51	13.05	7.24	13.91	9.66	1.31	1.18	1.63	0.91	1.74	1.21
2014	10.36	8.51	13.11	7.28	13.81	9.47	1.30	1.18	1.64	0.91	1.73	1.18
2015	10.43	8.56	12.99	7.31	13.67	9.28	1.30	1.19	1.62	0.91	1.71	1.16
2016	10.46	8.56	13.06	7.34	13.55	9.26	1.31	1.19	1.63	0.92	1.69	1.16
2017	10.40	8.59	13.17	7.36	13.44	9.25	1.30	1.19	1.65	0.92	1.68	1.16
2018	10.43	8.61	13.19	7.37	13.33	9.23	1.30	1.19	1.65	0.92	1.67	1.15
2019	10.36	8.50	13.17	7.36	13.20	9.22	1.30	1.18	1.65	0.92	1.65	1.15
2020	10.40	8.53	13.20	7.37	13.04	9.20	1.30	1.18	1.65	0.92	1.63	1.15

DOE/EIA-0383(99), Annual Energy Outlook 1999, Reference Case Forecast Table A3. Energy Prices by Sector and Source
Prices Include Federal and State taxes and exclude county and local taxes.
Ethanol: Programs goals as stated in FY 2001 Budget.

TABLE A-21 Total Carbon Emission Reductions

Million Metric Tons per Year

Year	Advanced Diesel Car CIDI	Advanced Diesel LT CIDI	Flex Fuel	SIDI	Electric	Fuel Cell	Hybrid	CNG	EPAct LDV Fleets	ZEV Mandates	Heavy Duty	Blends	Total Reduction	Total Carbon Emissions
2000	0.000	0.000	0.001	0.000	0.000	0.000	0.018	0.009	0.284	0.000	0.156	0.000	0.468	515.8
2001	0.000	0.000	0.003	0.000	0.002	0.000	0.099	0.048	0.417	0.000	0.275	0.006	0.850	527.6
2002	-0.001	0.009	0.008	0.000	0.006	0.000	0.244	0.111	0.544	0.000	0.400	0.032	1.354	538.5
2003	0.004	0.114	0.019	0.000	0.010	0.000	0.383	0.188	0.661	0.003	0.541	0.074	1.997	550.1
2004	0.160	0.304	0.041	0.014	0.015	0.000	0.571	0.270	0.764	0.007	0.689	0.177	3.012	560.8
2005	0.461	0.585	0.072	0.115	0.022	0.000	0.897	0.363	0.842	0.012	0.849	0.365	4.583	572.8
2006	0.935	0.972	0.129	0.295	0.033	0.000	1.382	0.464	0.885	0.024	1.001	0.668	6.788	584.2
2007	1.408	1.459	0.214	0.542	0.048	0.010	2.020	0.570	0.902	0.039	1.157	1.067	9.437	595.1
2008	1.895	1.928	0.351	0.853	0.069	0.056	2.832	0.679	0.915	0.056	1.316	1.551	12.501	605.9
2009	2.343	2.367	0.460	1.227	0.096	0.150	3.805	0.792	0.922	0.077	1.476	2.194	15.909	616.1
2010	2.758	2.784	0.664	1.646	0.129	0.291	4.924	0.904	0.928	0.101	1.633	2.762	19.524	626.3
2011	3.142	3.176	0.825	2.030	0.166	0.479	6.032	1.003	0.929	0.131	1.790	3.570	23.272	633.5
2012	3.484	3.534	0.973	2.378	0.203	0.712	7.124	1.089	0.928	0.164	1.948	4.360	26.896	640.4
2013	3.785	3.827	1.306	2.681	0.241	0.986	8.160	1.157	0.925	0.199	2.110	4.943	30.321	647.0
2014	4.044	4.087	1.441	2.956	0.279	1.319	9.130	1.215	0.922	0.238	2.282	5.749	33.662	654.7
2015	4.194	4.318	1.942	3.184	0.315	1.725	9.941	1.257	0.920	0.280	2.465	6.144	36.685	662.3
2016	4.304	4.513	2.052	3.380	0.342	2.221	10.642	1.289	0.917	0.310	2.670	6.977	39.617	669.0
2017	4.378	4.675	2.096	3.544	0.366	2.789	11.241	1.313	0.916	0.342	2.895	7.884	42.437	676.8
2018	4.422	4.809	2.182	3.677	0.388	3.392	11.745	1.329	0.915	0.375	3.144	8.742	45.121	684.1
2019	4.441	4.921	2.059	3.783	0.406	4.016	12.150	1.337	0.913	0.409	3.419	9.836	47.690	690.8
2020	4.440	5.013	2.174	3.863	0.421	4.655	12.470	1.340	0.911	0.444	3.723	10.663	50.117	697.3
Cumulative Total From Year 2000 to Year														
2005	0.62	1.01	0.14	0.13	0.06	0.00	2.21	0.99	3.51	0.02	2.91	0.65	12.27	
2010	9.96	10.52	1.96	4.69	0.43	0.51	17.18	4.40	8.06	0.32	9.49	8.90	76.42	
2015	28.61	29.46	8.45	17.92	1.63	5.73	57.56	10.12	12.69	1.33	20.09	33.66	227.26	
2020	50.60	53.39	19.01	36.17	3.56	22.80	115.81	16.73	17.26	3.21	35.94	77.76	452.24	

Carbon Coefficients: DOE/EIA-0573, Emissions of Greenhouse Gases In the United States, Table 6. pg. 15.

Gasoline = 19.41 CNG = 14.47 = 4.94 Ethanol = 0.5823

Diesel = 19.95 LPG = 17.16 = 2.25 Electric Utilities = 22.32 (NREL, QM)

Ethanol Reduction = 97% of Gasoline Carbon Coefficient: 19.41 x 0.97 = 18.8277

Total Carbon Emissions: Annual Energy Outlook 1999, DOE/EIA-0383(99), Table A19 Carbon Emissions by End-Use Sector and Source, pg. 136.

TABLE A-22 Value of Carbon Emission Reductions

(million 1997 $)

Year	Advanced Diesel Car CIDI	Advanced Diesel LT CIDI	Flex Fuel	SIDI	Electric	Fuel Cell	Hybrid	CNG	EPAct LDV Fleets	ZEV Mandates	Heavy Duty	Blends	Total Reduction
2000	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.5	15.6	0.0	8.6	0.0	25.8
2001	0.0	0.0	0.2	0.0	0.1	0.0	5.4	2.6	22.9	0.0	15.1	0.3	46.7
2002	-0.1	0.5	0.5	0.0	0.3	0.0	13.4	6.1	29.9	0.0	22.0	1.8	74.5
2003	0.2	6.2	1.0	0.0	0.6	0.0	21.1	10.4	36.4	0.2	29.7	4.1	109.8
2004	8.8	16.7	2.3	0.8	0.8	0.0	31.4	14.8	42.0	0.4	37.9	9.7	165.7
2005	25.3	32.2	4.0	6.3	1.2	0.0	49.3	19.9	46.3	0.7	46.7	20.1	252.1
2006	51.4	53.5	7.1	16.2	1.8	0.0	76.0	25.5	48.7	1.3	55.0	36.7	373.4
2007	77.4	80.2	11.8	29.8	2.7	0.5	111.1	31.3	49.6	2.1	63.6	58.7	519.0
2008	104.2	106.0	19.3	46.9	3.8	3.1	155.7	37.4	50.3	3.1	72.4	85.3	687.6
2009	128.9	130.2	25.3	67.5	5.3	8.2	209.3	43.6	50.7	4.2	81.2	120.7	875.0
2010	151.7	153.1	36.5	90.5	7.1	16.0	270.8	49.7	51.0	5.5	89.8	151.9	1073.8
2011	172.8	174.7	45.4	111.6	9.1	26.4	331.8	55.2	51.1	7.2	98.4	196.3	1280.0
2012	191.6	194.4	53.5	130.8	11.2	39.2	391.8	59.9	51.0	9.0	107.1	239.8	1479.3
2013	208.2	210.5	71.8	147.4	13.2	54.2	448.8	63.7	50.9	11.0	116.1	271.9	1667.7
2014	222.4	224.8	79.2	162.6	15.4	72.6	502.1	66.8	50.7	13.1	125.5	316.2	1851.4
2015	230.7	237.5	106.8	175.1	17.3	94.9	546.8	69.1	50.6	15.4	135.6	337.9	2017.7
2016	236.7	248.2	112.9	185.9	18.8	122.1	585.3	70.9	50.5	17.0	146.9	383.7	2179.0
2017	240.8	257.1	115.3	194.9	20.1	153.4	618.2	72.2	50.4	18.8	159.3	433.6	2334.1
2018	243.2	264.5	120.0	202.3	21.3	186.6	646.0	73.1	50.3	20.6	172.9	480.8	2481.7
2019	244.3	270.6	113.3	208.1	22.3	220.9	668.2	73.6	50.2	22.5	188.0	541.0	2622.9
2020	244.2	275.7	119.6	212.5	23.2	256.0	685.8	73.7	50.1	24.4	204.7	586.5	2756.4
Cumulative Total From Year 2000 to Year													
2005	34.3	55.6	8.0	7.1	3.1	0.0	121.7	54.4	193.1	1.3	160.0	36.0	674.6
2010	548.0	578.7	108.0	258.0	23.7	27.9	944.6	242.0	443.4	17.6	522.1	489.3	4203.3
2015	1573.6	1620.5	464.7	985.6	89.9	315.1	3165.9	556.7	697.7	73.3	1104.8	1851.4	12499.3
2020	2782.9	2936.7	1045.7	1989.2	195.7	1254.1	6369.5	920.1	949.1	176.6	1976.6	4277.0	24873.4

$55/ton

TABLE A-23 Light Vehicle NOx Emission Reductions

Million Metric Tons per Year

Year	Advanced Diesel	Flex Fuel	SIDI	Electric	Fuel Cell	Hybrid	CNG	Total
2000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0003
2001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0017	0.0000	0.0017
2002	0.0000	0.0000	0.0000	0.0002	0.0000	0.0044	0.0000	0.0045
2003	-0.0003	0.0000	0.0000	0.0004	0.0000	0.0075	-0.0001	0.0075
2004	-0.0011	0.0027	0.0001	0.0005	0.0000	0.0020	-0.0001	0.0041
2005	-0.0031	0.0055	0.0004	0.0007	0.0000	0.0030	-0.0001	0.0065
2006	-0.0068	0.0091	0.0011	0.0010	0.0000	0.0044	-0.0001	0.0086
2007	-0.0125	0.0134	0.0021	0.0014	0.0000	0.0059	-0.0002	0.0102
2008	-0.0204	0.0176	0.0033	0.0020	0.0001	0.0078	-0.0002	0.0103
2009	-0.0308	0.0233	0.0048	0.0026	0.0004	0.0099	-0.0002	0.0101
2010	-0.0438	0.0296	0.0066	0.0034	0.0008	0.0123	-0.0002	0.0088
2011	-0.0591	0.0362	0.0081	0.0043	0.0014	0.0146	-0.0002	0.0053
2012	-0.0764	0.0426	0.0096	0.0052	0.0023	0.0170	-0.0001	0.0001
2013	-0.0947	0.0486	0.0109	0.0061	0.0035	0.0192	-0.0001	-0.0065
2014	-0.1132	0.0577	0.0121	0.0071	0.0051	0.0213	-0.0001	-0.0099
2015	-0.1310	0.0642	0.0131	0.0081	0.0073	0.0231	0.0000	-0.0153
2016	-0.1474	0.0621	0.0140	0.0090	0.0100	0.0247	0.0000	-0.0276
2017	-0.1620	0.0651	0.0147	0.0099	0.0134	0.0260	0.0000	-0.0328
2018	-0.1746	0.0674	0.0153	0.0107	0.0174	0.0271	0.0001	-0.0366
2019	-0.1851	0.0690	0.0158	0.0114	0.0220	0.0280	0.0001	-0.0388
2020	-0.1935	0.0702	0.0162	0.0120	0.0271	0.0288	0.0001	-0.0392
Cumulative Total From Year 2000 to Year								
2005	-0.0046	0.0083	0.0005	0.0019	0.0000	0.0189	-0.0003	0.0246
2010	-0.1190	0.1013	0.0185	0.0124	0.0012	0.0592	-0.0011	0.0725
2015	-0.5934	0.3505	0.0723	0.0432	0.0208	0.1544	-0.0017	0.0462
2020	-1.4561	0.6844	0.1484	0.0962	0.1107	0.2890	-0.0014	-0.1288

TABLE A-24 Value of Light Vehicle NOx Emission Reductions

(million 1997 $)

Year	Advanced Diesel	Flex Fuel	SIDI	Electric	Fuel Cell	Hybrid	CNG	Total
2000	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0
2001	0.0	0.0	0.0	0.2	0.0	5.5	-0.1	5.7
2002	-0.1	0.0	0.0	0.7	0.0	14.4	-0.1	14.9
2003	-0.9	0.0	0.0	1.2	0.0	24.7	-0.2	24.8
2004	-3.8	9.0	0.2	1.7	0.0	6.7	-0.3	13.5
2005	-10.3	18.2	1.5	2.4	0.0	10.0	-0.4	21.4
2006	-22.6	30.0	3.7	3.4	0.0	14.4	-0.5	28.5
2007	-41.3	44.1	6.9	4.7	0.1	19.6	-0.5	33.6
2008	-67.5	58.2	11.0	6.5	0.4	25.8	-0.5	33.8
2009	-101.8	76.9	16.0	8.7	1.2	32.8	-0.5	33.2
2010	-144.4	97.8	21.6	11.3	2.5	40.6	-0.5	28.9
2011	-195.1	119.4	26.9	14.2	4.6	48.3	-0.5	17.6
2012	-252.1	140.5	31.7	17.1	7.5	56.0	-0.5	0.2
2013	-312.6	160.3	36.0	20.2	11.5	63.4	-0.4	-21.6
2014	-373.6	190.5	39.9	23.4	16.9	70.4	-0.3	-32.7
2015	-432.1	211.8	43.3	26.6	24.0	76.3	-0.2	-50.4
2016	-486.4	205.1	46.1	29.7	33.1	81.4	0.0	-91.0
2017	-534.8	214.9	48.6	32.7	44.3	85.8	0.1	-108.4
2018	-576.3	222.4	50.6	35.4	57.5	89.5	0.2	-120.7
2019	-611.0	227.7	52.3	37.7	72.5	92.5	0.3	-128.0
2020	-638.7	231.6	53.6	39.6	89.5	94.9	0.3	-129.2
Cumulative Total From Year 2000 to Year								
2005	-15.1	27.3	1.6	6.3	0.0	62.3	-1.1	81.3
2010	-392.6	334.2	60.9	40.9	4.1	195.4	-3.7	239.3
2015	-1958.2	1156.8	238.7	142.5	68.5	509.6	-5.5	152.4
2020	-4805.3	2258.5	489.8	317.6	365.4	953.7	-4.6	-424.9

$3,300/ton

TABLE A-25 Light Vehicle CO Emission Reductions

Million Metric Tons per Year

Year	Advanced Diesel	Flex Fuel	SIDI	Electric	Fuel Cell	Hybrid	CNG	Total
2000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0003	0.0008	0.0013
2001	0.0000	0.0000	0.0000	0.0010	0.0000	0.0017	0.0046	0.0072
2002	0.0016	0.0001	0.0000	0.0027	0.0000	0.0044	0.0115	0.0203
2003	0.0118	0.0003	0.0000	0.0049	0.0000	0.0075	0.0217	0.0461
2004	0.0464	0.0569	0.0000	0.0069	0.0000	0.0020	0.0302	0.1424
2005	0.1114	0.1139	0.0001	0.0096	0.0000	0.0030	0.0408	0.2788
2006	0.2184	0.1846	0.0003	0.0132	0.0000	0.0044	0.0535	0.4743
2007	0.3592	0.2672	0.0005	0.0183	0.0004	0.0059	0.0687	0.7203
2008	0.5304	0.3499	0.0007	0.0249	0.0027	0.0078	0.0862	1.0026
2009	0.7302	0.4568	0.0011	0.0330	0.0078	0.0099	0.1043	1.3433
2010	0.9595	0.5756	0.0015	0.0429	0.0166	0.0123	0.1227	1.7311
2011	1.2171	0.6961	0.0018	0.0538	0.0298	0.0146	0.1405	2.1537
2012	1.4940	0.8127	0.0022	0.0657	0.0482	0.0170	0.1574	2.5971
2013	1.7761	0.9232	0.0024	0.0785	0.0729	0.0192	0.1733	3.0457
2014	2.0540	1.2534	0.0027	0.0923	0.1057	0.0213	0.1882	3.7176
2015	2.3111	1.3525	0.0029	0.1062	0.1484	0.0231	0.2016	4.1458
2016	2.5450	1.1666	0.0031	0.1202	0.2029	0.0247	0.2135	4.2760
2017	2.7509	1.2185	0.0033	0.1336	0.2693	0.0260	0.2237	4.6254
2018	2.9265	1.2579	0.0034	0.1460	0.3465	0.0271	0.2319	4.9395
2019	3.0719	1.2825	0.0036	0.1568	0.4339	0.0280	0.2373	5.2140
2020	3.1878	1.3031	0.0036	0.1657	0.5310	0.0288	0.2404	5.4603
Cumulative Total From Year 2000 to Year								
2005	0.17	0.17	0.00	0.03	0.00	0.02	0.11	0.50
2010	2.97	2.01	0.00	0.16	0.03	0.06	0.55	5.77
2015	11.82	7.04	0.02	0.55	0.43	0.15	1.41	21.43
2020	26.30	13.27	0.03	1.28	2.22	0.29	2.55	45.94

TABLE A-26 Value of Light Vehicle CO Emission Reductions

(million 1997 $)

Year	Advanced Diesel	Flex Fuel	SIDI	Electric	Fuel Cell	Hybrid	CNG	Total
2000	0.0	0.0	0.0	0.1	0.0	0.1	0.3	0.5
2001	0.0	0.0	0.0	0.4	0.0	0.6	1.6	2.6
2002	0.6	0.0	0.0	1.0	0.0	1.6	4.2	7.3
2003	4.3	0.1	0.0	1.8	0.0	2.7	7.8	16.6
2004	16.7	20.5	0.0	2.5	0.0	0.7	10.9	51.3
2005	40.1	41.0	0.0	3.5	0.0	1.1	14.7	100.4
2006	78.6	66.5	0.1	4.8	0.0	1.6	19.3	170.7
2007	129.3	96.2	0.2	6.6	0.2	2.1	24.7	259.3
2008	190.9	126.0	0.3	9.0	1.0	2.8	31.0	361.0
2009	262.9	164.5	0.4	11.9	2.8	3.6	37.6	483.6
2010	345.4	207.2	0.5	15.5	6.0	4.4	44.2	623.2
2011	438.1	250.6	0.7	19.4	10.7	5.3	50.6	775.3
2012	537.8	292.6	0.8	23.7	17.4	6.1	56.7	935.0
2013	639.4	332.3	0.9	28.3	26.2	6.9	62.4	1096.4
2014	739.4	451.2	1.0	33.2	38.1	7.7	67.8	1338.3
2015	832.0	486.9	1.1	38.2	53.4	8.3	72.6	1492.5
2016	916.2	420.0	1.1	43.3	73.0	8.9	76.9	1539.4
2017	990.3	438.7	1.2	48.1	96.9	9.4	80.5	1665.2
2018	1053.6	452.8	1.2	52.6	124.7	9.8	83.5	1778.2
2019	1105.9	461.7	1.3	56.4	156.2	10.1	85.4	1877.0
2020	1147.6	469.1	1.3	59.6	191.2	10.4	86.5	1965.7
Cumulative Total From Year 2000 to Year								
2005	61.6	61.6	0.0	9.1	0.0	6.8	39.5	178.6
2010	1068.8	721.9	1.5	56.8	9.9	21.3	196.2	2076.4
2015	4255.6	2535.5	5.8	199.5	155.7	55.6	506.2	7714.0
2020	9469.2	4777.8	12.0	459.6	797.8	104.0	919.0	16539.5

$360/ton

TABLE A-27 Light Vehicle HC Emission Reductions

Million Metric Tons per Year

Year	Advanced Diesel	Flex Fuel	SIDI	Electric	Fuel Cell	Hybrid	CNG	Total
2000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0014	0.0018
2001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0017	0.0075	0.0094
2002	0.0001	0.0000	0.0000	0.0002	0.0000	0.0045	0.0181	0.0230
2003	0.0006	0.0000	0.0000	0.0004	0.0000	0.0076	0.0322	0.0408
2004	0.0023	0.0022	0.0000	0.0005	0.0000	0.0006	0.0446	0.0503
2005	0.0052	0.0044	0.0001	0.0008	0.0000	0.0010	0.0594	0.0709
2006	0.0098	0.0073	0.0004	0.0011	0.0000	0.0014	0.0775	0.0975
2007	0.0154	0.0111	0.0007	0.0016	0.0001	0.0019	0.0996	0.1303
2008	0.0219	0.0148	0.0011	0.0023	0.0003	0.0025	0.1253	0.1681
2009	0.0292	0.0205	0.0015	0.0031	0.0008	0.0032	0.1514	0.2098
2010	0.0376	0.0275	0.0021	0.0041	0.0017	0.0039	0.1774	0.2543
2011	0.0472	0.0347	0.0026	0.0052	0.0029	0.0047	0.2016	0.2989
2012	0.0578	0.0418	0.0031	0.0064	0.0046	0.0054	0.2238	0.3428
2013	0.0687	0.0495	0.0035	0.0076	0.0068	0.0061	0.2438	0.3860
2014	0.0796	0.1100	0.0039	0.0089	0.0097	0.0068	0.2628	0.4817
2015	0.0898	0.1155	0.0042	0.0103	0.0135	0.0074	0.2795	0.5201
2016	0.0991	0.0665	0.0045	0.0118	0.0184	0.0079	0.2945	0.5025
2017	0.1074	0.0698	0.0047	0.0131	0.0243	0.0083	0.3078	0.5355
2018	0.1146	0.0724	0.0049	0.0144	0.0312	0.0086	0.3187	0.5649
2019	0.1206	0.0732	0.0050	0.0156	0.0390	0.0089	0.3259	0.5882
2020	0.1255	0.0746	0.0052	0.0166	0.0476	0.0092	0.3298	0.6084
Cumulative Total From Year 2000 to Year								
2005	0.008	0.007	0.000	0.002	0.000	0.016	0.163	0.196
2010	0.122	0.088	0.006	0.014	0.003	0.029	0.795	1.056
2015	0.465	0.439	0.023	0.053	0.040	0.059	2.006	3.086
2020	1.032	0.796	0.047	0.124	0.201	0.102	3.583	5.885

TABLE A-28 Value of Light Vehicle HC Emission Reductions

(million 1997 $)

Year	Advanced Diesel	Flex Fuel	SIDI	Electric	Fuel Cell	Hybrid	CNG	Total
2000	0.0	0.0	0.0	0.0	0.0	1.1	5.3	6.5
2001	0.0	0.0	0.0	0.3	0.0	6.4	27.6	34.3
2002	0.4	0.1	0.0	0.8	0.0	16.6	66.4	84.2
2003	2.2	0.1	0.0	1.4	0.0	27.8	117.9	149.4
2004	8.3	8.1	0.1	2.0	0.0	2.4	163.2	184.0
2005	19.0	16.2	0.5	2.9	0.0	3.5	217.4	259.6
2006	35.8	26.9	1.3	4.1	0.0	5.1	283.7	356.9
2007	56.5	40.5	2.5	6.0	0.2	6.9	364.4	476.8
2008	80.1	54.1	3.9	8.4	1.1	9.1	458.6	615.3
2009	106.8	74.9	5.6	11.4	3.1	11.6	554.2	767.8
2010	137.6	100.6	7.6	15.1	6.3	14.3	649.3	930.8
2011	172.9	127.0	9.5	19.1	10.8	17.0	737.8	1094.0
2012	211.6	153.2	11.2	23.3	16.8	19.8	818.9	1254.8
2013	251.6	181.1	12.7	27.8	24.7	22.4	892.5	1412.8
2014	291.5	402.7	14.1	32.7	35.4	24.8	961.9	1763.1
2015	328.5	422.7	15.3	37.8	49.3	26.9	1022.9	1903.4
2016	362.7	243.5	16.3	43.0	67.2	28.7	1077.8	1839.2
2017	393.1	255.6	17.2	48.1	89.1	30.3	1126.6	1959.9
2018	419.4	264.9	17.9	52.8	114.3	31.6	1166.5	2067.4
2019	441.4	267.9	18.5	57.1	142.6	32.7	1192.6	2152.7
2020	459.3	273.1	18.9	60.6	174.1	33.5	1207.2	2226.7
Cumulative Total From Year 2000 to Year								
2005	30.0	24.5	0.6	7.4	0.0	57.8	597.7	717.9
2010	446.7	321.5	21.5	52.5	10.7	104.8	2907.9	3865.6
2015	1702.8	1608.2	84.3	193.2	147.6	215.7	7341.8	11293.8
2020	3778.6	2913.2	173.0	454.9	734.8	372.6	13112.5	21539.6

$3,660/ton

TABLE A-29 Light Vehicle Purchase Price

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2020
Conventional	19.09	19.39	19.70	20.01	20.34	20.67	21.01	21.36	21.73	22.10	22.48	22.86	23.25	23.65	24.05	24.47	26.47
OTT Programs	19.45	19.90	20.34	20.70	21.17	21.68	22.26	22.80	23.34	23.88	24.42	24.94	25.46	25.98	26.52	27.01	29.58
SMALL CAR Purchase Price																	
Conventional	15.49	15.64	15.80	15.96	16.12	16.28	16.44	16.60	16.77	16.94	17.11	17.28	17.45	17.62	17.80	17.98	18.90
Advanced Diesel	N/A	N/A	N/A	17.07	17.25	17.42	17.59	17.77	17.94	18.11	18.28	18.45	18.62	18.79	18.97	19.15	20.07
Flex Alcohol	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SIDI	N/A	N/A	N/A	N/A	16.92	17.03	17.13	17.24	17.34	17.45	17.62	17.79	17.96	18.13	18.31	18.49	19.41
CNG Dedicated	16.65	16.81	16.98	17.15	17.32	17.50	17.67	17.85	18.03	18.21	18.39	18.57	18.76	18.95	19.14	19.33	20.31
Electric	41.81	39.64	37.46	35.28	33.10	30.92	29.87	28.82	27.77	26.71	25.66	25.83	26.00	26.17	26.35	26.53	27.45
Hybrid	26.33	25.03	23.70	22.34	20.95	19.53	19.73	19.92	20.12	20.32	20.53	20.73	20.94	21.15	21.36	21.57	22.68
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	23.37	24.57
AVERAGE	15.60	16.10	16.56	16.55	16.77	17.08	17.49	17.78	18.07	18.35	18.60	18.77	18.95	19.13	19.30	19.28	20.64
LARGE CAR Purchase Price																	
Conventional	23.93	24.34	24.75	25.17	25.61	26.05	26.50	26.96	27.43	27.91	28.40	28.89	29.40	29.92	30.45	30.99	33.58
Advanced Diesel	N/A	N/A	N/A	N/A	N/A	27.87	28.26	28.65	29.04	29.43	29.81	30.31	30.82	31.34	31.87	32.41	35.00
Flex Alcohol	23.93	24.34	24.75	25.17	25.61	26.05	26.50	26.96	27.43	27.91	28.40	28.89	29.40	29.92	30.45	30.99	33.58
SIDI	N/A	N/A	N/A	N/A	26.89	27.26	27.65	28.07	28.50	28.75	29.24	29.73	30.24	30.76	31.29	31.83	34.42
CNG Dedicated	26.44	26.54	26.65	26.75	26.86	26.96	27.41	27.87	28.34	28.82	29.31	29.80	30.31	30.83	31.36	31.90	34.49
Electric	N/A	N/A	N/A	N/A	N/A	N/A	N/A	48.41	46.47	44.53	42.59	43.09	43.60	44.12	44.65	45.19	47.78
Hybrid	N/A	N/A	N/A	35.24	34.77	34.31	33.84	33.38	32.91	33.40	33.89	34.38	34.89	35.41	35.94	36.48	39.07
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	40.43	39.99	39.55	39.11	38.66	38.22	38.74	39.27	39.81	42.40
AVERAGE	23.93	24.35	24.77	25.28	25.91	26.53	27.22	27.87	28.65	29.40	30.15	30.89	31.62	32.37	33.04	33.73	36.56
MINIVAN MARKET SHARES																	
Conventional	23.93	24.34	24.75	25.17	25.61	26.05	26.50	26.96	27.43	27.91	28.40	28.89	29.40	29.92	30.45	30.99	33.58
Advanced Diesel	N/A	N/A	N/A	N/A	27.53	27.99	28.46	28.93	29.40	29.86	30.35	30.84	31.35	31.87	32.40	32.94	35.53
Flex Alcohol	23.93	24.34	24.75	25.17	25.61	26.05	26.50	26.96	27.43	27.91	28.40	28.89	29.40	29.92	30.45	30.99	33.58
SIDI	N/A	N/A	N/A	N/A	26.89	27.26	27.63	28.00	28.37	28.75	29.24	29.73	30.24	30.76	31.29	31.83	34.42
CNG Dedicated	N/A	N/A	25.98	26.41	26.85	27.29	27.74	28.20	28.67	29.15	29.64	30.13	30.64	31.16	31.69	32.23	34.82
Electric	N/A	N/A	N/A	N/A	48.65	47.64	46.63	45.62	44.61	43.60	42.59	43.09	43.60	44.12	44.65	45.19	47.78
Hybrid	N/A	N/A	N/A	N/A	N/A	31.26	31.82	32.39	32.95	33.51	34.07	34.70	35.32	35.94	36.56	37.18	39.78
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	38.90	39.43	39.97	42.56
AVERAGE	23.93	24.34	24.75	25.18	25.63	26.31	27.02	27.72	28.27	28.83	29.40	29.96	30.54	31.07	31.72	32.37	35.26
SUV																	
Conventional	22.64	23.09	23.54	24.02	24.50	24.99	25.49	25.99	26.52	27.05	27.59	28.14	28.70	29.28	29.86	30.46	33.33
Advanced Diesel	N/A	N/A	N/A	N/A	26.34	26.86	27.38	27.90	28.42	28.95	29.48	30.03	30.59	31.17	31.75	32.35	35.22
Flex Alcohol	22.64	23.09	23.54	24.02	24.50	24.99	25.49	25.99	26.52	27.05	27.59	28.14	28.70	29.28	29.86	30.46	33.33
SIDI	N/A	N/A	N/A	N/A	25.72	26.15	26.58	27.01	27.44	27.86	28.40	28.95	29.51	30.09	30.67	31.27	34.14
CNG Dedicated	N/A	N/A	24.72	25.20	25.68	26.17	26.67	27.17	27.70	28.23	28.77	29.32	29.88	30.46	31.04	31.64	34.51
Electric	N/A	N/A	N/A	N/A	46.55	45.69	44.83	43.97	43.11	42.25	41.39	41.94	42.50	43.08	43.66	44.26	47.13
Hybrid	N/A	N/A	N/A	33.62	31.85	29.99	30.61	31.24	31.86	32.48	33.11	33.80	34.49	35.18	35.86	36.55	39.42
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	38.07	38.64	39.24	42.11
AVERAGE	22.64	23.09	23.55	24.08	24.63	25.28	25.99	26.71	27.34	27.95	28.57	29.19	29.83	30.39	31.06	31.74	34.95
PICK-UP AND LARGE VAN																	
Conventional	15.31	15.62	15.93	16.24	16.57	16.90	17.24	17.58	17.93	18.30	18.66	19.03	19.42	19.81	20.20	20.60	22.55
Advanced Diesel	N/A	N/A	17.52	17.78	18.04	18.30	18.55	18.81	19.16	19.53	19.89	20.26	20.65	21.04	21.43	21.83	23.78
Flex Alcohol	15.31	15.62	15.93	16.24	16.57	16.90	17.24	17.58	17.93	18.30	18.66	19.03	19.42	19.81	20.20	20.60	22.55
SIDI	N/A	N/A	N/A	N/A	17.40	17.69	17.98	18.27	18.56	18.85	19.21	19.58	19.97	20.36	20.75	21.15	23.10
CNG Dedicated	16.99	17.30	17.61	17.92	18.25	17.75	18.09	18.43	18.78	19.15	19.51	19.88	20.27	20.66	21.05	21.45	23.40
Electric	41.34	39.49	37.65	35.81	33.96	32.12	31.29	30.47	29.64	28.82	27.99	28.36	28.75	29.14	29.53	29.93	31.88
Hybrid	N/A	N/A	N/A	N/A	N/A	20.28	20.62	20.96	21.31	21.68	22.04	22.41	22.80	23.19	23.58	23.98	25.93
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	23.32	23.68	24.04	24.41	24.80	25.19	25.58	25.98	27.93
AVERAGE	15.32	15.64	15.97	16.42	16.87	17.22	17.61	17.99	18.38	18.82	19.26	19.70	20.14	20.59	21.04	21.50	23.52

TABLE A-30 Total Consumer Investment - billion 1997$

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2020
SMALL CAR																	
Conventional	76.419	72.011	68.323	67.857	59.327	46.694	35.035	30.047	25.144	20.442	16.848	16.638	16.506	16.531	16.569	25.534	19.685
Advanced Diesel	0.000	0.000	0.000	1.007	9.488	17.872	25.986	25.930	25.995	25.916	26.168	26.937	27.505	28.134	28.361	24.328	25.628
Flex Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SIDI	0.000	0.000	0.000	0.000	0.502	3.199	5.904	8.453	10.924	13.396	15.384	15.120	14.909	14.870	14.820	12.507	12.303
CNG Dedicated	0.231	0.951	1.614	1.289	1.300	1.563	1.859	2.119	2.375	2.627	2.804	2.758	2.722	2.725	2.706	2.292	2.273
Electric	0.113	0.535	1.036	0.939	1.076	1.463	1.873	2.285	2.746	3.241	3.688	3.589	3.481	3.439	3.370	2.808	2.595
Hybrid	1.126	4.925	8.872	7.506	7.995	10.156	12.260	14.174	16.070	18.013	19.430	19.143	18.939	18.954	18.908	16.028	16.056
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.461	8.117
TOTAL	77.888	78.422	79.845	78.599	79.687	80.948	82.917	83.007	83.254	83.636	84.323	84.184	84.062	84.652	84.735	83.959	86.657
LARGE CAR																	
Conventional	80.805	74.360	75.170	81.363	84.647	82.324	74.217	68.642	58.954	52.782	47.271	44.226	40.975	38.470	37.412	36.268	36.750
Advanced Diesel	0.000	0.000	0.000	0.000	0.000	0.429	5.196	8.791	12.604	12.672	12.915	13.432	13.813	14.350	14.678	15.027	16.724
Flex Alcohol	14.254	20.266	20.382	14.303	10.651	9.236	9.116	7.951	7.804	7.809	7.841	7.813	7.813	7.948	8.072	8.201	8.709
SIDI	0.000	0.000	0.000	0.000	0.792	4.544	8.365	10.738	13.978	17.484	20.490	20.575	20.728	21.240	21.715	22.189	24.559
CNG Dedicated	0.161	0.714	1.311	1.364	1.369	1.503	1.774	1.802	2.024	2.268	2.457	2.456	2.460	2.516	2.550	2.598	2.814
Electric	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.366	0.664	0.986	1.336	1.630	1.918	2.245	2.557	2.886	3.178
Hybrid	0.000	0.000	0.000	1.229	4.184	6.752	10.046	11.970	15.168	18.168	21.324	24.375	27.536	30.405	31.084	31.825	35.576
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.554	2.443	4.471	6.670	8.972	11.448	13.920	16.420	19.041	25.163
TOTAL	95.220	95.340	96.863	98.259	101.643	104.787	108.714	110.813	113.639	116.640	120.305	123.479	126.691	131.095	134.488	138.034	153.473
MINIVAN																	
Conventional	41.549	41.392	42.313	42.642	39.864	37.043	31.844	26.242	24.521	22.814	21.460	21.199	21.002	23.391	23.029	22.797	23.192
Advanced Diesel	0.000	0.000	0.000	0.000	0.091	4.825	9.559	13.939	14.252	14.499	14.943	15.565	16.090	15.561	15.960	16.401	18.687
Flex Alcohol	1.027	1.461	1.341	1.344	5.089	3.510	3.555	3.543	3.525	3.546	3.569	3.540	3.539	3.327	3.373	3.419	3.568
SIDI	0.000	0.000	0.000	0.000	0.358	1.644	3.121	4.606	6.118	7.742	9.090	9.073	9.124	8.627	8.790	8.946	9.721
CNG Dedicated	0.000	0.000	0.121	0.538	0.591	0.592	0.790	0.981	1.173	1.371	1.581	1.767	1.908	1.810	1.834	1.870	2.039
Electric	0.000	0.000	0.000	0.000	0.003	0.003	0.003	0.004	0.004	0.005	0.006	0.006	0.006	0.005	0.005	0.005	0.005
Hybrid	0.000	0.000	0.000	0.000	0.000	0.174	0.772	1.378	1.990	2.636	3.309	3.954	4.632	5.008	5.731	6.296	6.808
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.151	0.664	1.191	4.069
TOTAL	42.577	42.854	43.776	44.524	45.996	47.791	49.644	50.692	51.584	52.614	53.958	55.105	56.300	57.880	59.386	60.926	68.090
SUV																	
Conventional	40.907	38.507	37.463	39.155	43.549	40.833	37.239	32.197	29.825	27.845	26.268	26.859	27.411	32.083	32.895	33.740	37.174
Advanced Diesel	0.000	0.000	0.000	0.000	0.073	2.232	6.073	10.461	11.917	12.364	13.019	13.922	14.700	14.409	15.029	15.714	19.226
Flex Alcohol	3.861	7.562	10.519	9.532	6.528	6.325	6.361	6.389	6.464	6.713	6.973	7.173	7.402	7.123	7.423	7.737	9.117
SIDI	0.000	0.000	0.000	0.000	0.477	3.054	5.718	8.435	11.295	14.603	17.666	18.261	18.922	18.284	19.118	19.968	24.322
CNG Dedicated	0.000	0.000	0.098	1.097	1.466	2.051	2.073	2.090	2.127	2.199	2.287	2.351	2.421	2.337	2.417	2.518	3.006
Electric	0.000	0.000	0.000	0.000	0.021	0.092	0.172	0.259	0.357	0.472	0.605	0.715	0.826	0.882	0.969	0.998	1.135
Hybrid	0.000	0.000	0.000	0.254	0.767	1.332	1.953	2.596	3.286	4.105	5.006	5.865	6.958	7.370	7.819	8.282	10.017
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.237	1.067	1.964	7.499
TOTAL	44.768	46.068	48.081	50.037	52.881	55.919	59.590	62.428	65.271	68.301	71.824	75.146	78.641	82.726	86.736	90.920	111.497
PICK-UP AND LARGE VAN																	
Conventional	43.663	39.791	39.312	35.682	33.168	33.979	32.123	29.626	28.595	25.965	23.812	23.572	23.324	23.233	22.975	22.836	24.729
Advanced Diesel	0.000	0.000	0.384	4.716	8.888	9.110	9.379	9.497	9.133	9.256	9.496	9.954	10.329	10.749	11.024	11.318	12.841
Flex Alcohol	4.068	7.761	8.566	8.594	8.344	5.908	6.012	6.021	5.707	5.764	5.842	5.880	5.945	6.074	6.193	6.320	6.895
SIDI	0.000	0.000	0.000	0.000	0.074	2.656	5.035	7.416	9.319	11.750	13.884	14.059	14.296	14.690	15.057	15.435	17.428
CNG Dedicated	0.093	0.404	0.554	0.806	1.030	1.075	1.309	1.528	1.658	1.878	2.056	2.076	2.103	2.160	2.201	2.253	2.517
Electric	0.010	0.049	0.074	0.116	0.161	0.154	0.194	0.234	0.264	0.308	0.348	0.349	0.349	0.354	0.356	0.360	0.380
Hybrid	0.000	0.000	0.000	0.000	0.000	0.152	0.687	1.244	1.730	2.320	2.953	3.578	4.240	4.982	5.744	6.361	7.108
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.119	0.526	0.951	1.384	1.836	2.331	2.842	3.385	5.121
TOTAL	47.834	48.004	48.890	49.914	51.666	53.033	54.739	55.567	56.525	57.767	59.341	60.850	62.423	64.573	66.392	68.268	77.017
TOTAL INVESTMENT	308.286	310.689	317.455	321.335	331.874	342.477	355.604	362.506	370.273	378.958	389.750	398.764	408.117	420.926	431.737	442.107	496.735

Total Consumer Investment - billion 1997 $

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2020
Advanced Auto	1.216	5.480	10.042	11.363	24.511	39.842	60.239	72.439	86.654	96.656	107.301	116.858	127.537	136.281	143.439	143.071	176.373
Materials	1.216	5.480	10.042	10.328	14.695	20.854	28.057	35.670	45.587	55.759	65.941	73.960	83.198	90.908	97.429	100.974	130.908
Tech Util	0.471	2.058	3.599	4.684	7.253	20.382	33.064	45.093	57.133	70.166	81.516	82.521	84.305	84.183	86.148	85.316	95.780
Biofuels	21.604	35.403	39.707	33.345	26.406	22.273	22.178	21.562	21.253	21.500	21.859	22.174	22.707	22.583	23.185	23.808	26.539
Heavy Duty	0.157	0.441	1.288	6.424	11.909	14.650	19.056	24.452	25.912	26.619	27.713	29.492	31.151	31.347	32.493	33.700	39.743
Total	15853787	15611598	15605203	15521876	15677932	15797644	15977657	15901829	15865459	15870487	15960229	15991185	16028013	16201181	16281923	16369182	16791278

TABLE A-31 Total Incremental Consumer Investment - billion 1997$

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2020
SMALL CAR																	
Conventional	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CIDI	0.000	0.000	0.000	0.068	0.644	1.218	1.762	1.801	1.809	1.775	1.773	1.815	1.855	1.870	1.870	1.590	1.604
Flex Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SIDI	0.000	0.000	0.000	0.000	0.025	0.146	0.246	0.328	0.383	0.414	0.471	0.461	0.454	0.447	0.441	0.369	0.347
CNG Dedicated	0.016	0.066	0.113	0.092	0.094	0.113	0.134	0.157	0.176	0.194	0.207	0.204	0.204	0.203	0.202	0.171	0.170
Electric	0.069	0.322	0.603	0.529	0.571	0.719	0.869	1.026	1.157	1.257	1.301	1.262	1.228	1.200	1.169	0.968	0.868
Hybrid	0.451	1.837	2.975	2.205	1.909	1.756	2.109	2.502	2.850	3.182	3.427	3.390	3.387	3.374	3.369	2.857	2.873
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.114	2.011
TOTAL	0.536	2.225	3.691	2.895	3.243	3.953	5.120	5.814	6.375	6.822	7.179	7.133	7.128	7.094	7.051	6.069	7.873
LARGE CAR																	
Conventional	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CIDI	0.000	0.000	0.000	0.000	0.000	0.029	0.334	0.551	0.745	0.692	0.651	0.669	0.683	0.694	0.699	0.704	0.729
Flex Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SIDI	0.000	0.000	0.000	0.000	0.039	0.209	0.360	0.451	0.562	0.540	0.623	0.618	0.618	0.619	0.623	0.626	0.643
CNG Dedicated	0.015	0.059	0.094	0.083	0.066	0.053	0.061	0.062	0.069	0.076	0.081	0.080	0.079	0.079	0.079	0.079	0.080
Electric	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.172	0.290	0.390	0.471	0.571	0.670	0.772	0.870	0.970	1.014
Hybrid	0.000	0.000	0.000	0.361	1.141	1.686	2.249	2.439	2.690	3.165	3.656	4.136	4.650	5.035	5.077	5.124	5.367
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.195	0.817	1.394	1.933	2.410	2.835	3.385	3.943	4.513	5.620
TOTAL	0.015	0.059	0.094	0.444	1.246	1.977	3.004	3.870	5.173	6.257	7.415	8.483	9.535	10.584	11.291	12.017	13.453
MINIVAN																	
Conventional	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CIDI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Flex Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SIDI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CNG Dedicated	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Electric	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hybrid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SUV																	
Conventional	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CIDI	0.000	0.000	0.000	0.000	0.005	0.161	0.433	0.757	0.852	0.857	0.883	0.931	0.975	0.933	0.956	0.982	1.107
Flex Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SIDI	0.000	0.000	0.000	0.000	0.024	0.141	0.242	0.335	0.403	0.451	0.533	0.543	0.557	0.526	0.540	0.553	0.619
CNG Dedicated	0.000	0.000	0.005	0.053	0.070	0.096	0.095	0.096	0.096	0.097	0.099	0.101	0.103	0.097	0.098	0.100	0.110
Electric	0.000	0.000	0.000	0.000	0.010	0.043	0.077	0.112	0.146	0.180	0.214	0.250	0.288	0.302	0.328	0.333	0.357
Hybrid	0.000	0.000	0.000	0.075	0.183	0.230	0.337	0.461	0.587	0.727	0.883	1.043	1.252	1.319	1.399	1.476	1.661
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.058	0.259	0.470	1.678
TOTAL	0.000	0.000	0.005	0.127	0.292	0.671	1.183	1.762	2.084	2.313	2.612	2.868	3.174	3.235	3.580	3.915	5.534
PICK-UP AND LARGE VAN																	
Conventional	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CIDI	0.000	0.000	0.035	0.418	0.747	0.719	0.685	0.658	0.624	0.618	0.621	0.642	0.660	0.671	0.676	0.682	0.713
Flex Alcohol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SIDI	0.000	0.000	0.000	0.000	0.004	0.122	0.213	0.295	0.333	0.363	0.421	0.420	0.423	0.424	0.427	0.429	0.446
CNG Dedicated	0.009	0.039	0.053	0.078	0.098	0.053	0.063	0.075	0.080	0.088	0.095	0.094	0.095	0.095	0.095	0.095	0.098
Electric	0.006	0.030	0.043	0.065	0.086	0.075	0.090	0.105	0.111	0.119	0.123	0.122	0.121	0.121	0.120	0.120	0.119
Hybrid	0.000	0.000	0.000	0.000	0.000	0.026	0.116	0.212	0.292	0.383	0.479	0.573	0.675	0.776	0.880	0.959	0.995
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.029	0.127	0.225	0.324	0.427	0.532	0.639	0.750	1.059
TOTAL	0.015	0.069	0.131	0.561	0.935	0.996	1.167	1.345	1.468	1.698	1.964	2.175	2.401	2.619	2.838	3.035	3.430
Advanced Auto	0.508	2.106	3.480	3.176	4.394	5.605	7.716	9.274	11.107	12.859	14.498	15.843	17.263	18.536	19.620	19.864	24.412
Materials	0.020	0.086	0.145	0.133	0.159	0.186	0.236	0.313	0.423	0.532	0.628	0.703	0.778	0.861	0.950	1.022	1.449
Tech Util	0.039	0.164	0.265	0.306	0.419	0.933	1.414	1.799	2.103	2.223	2.530	2.520	2.532	2.490	2.505	2.424	2.514
Biofuels	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Heavy Duty	0.015	0.038	0.107	0.535	0.917	1.060	1.312	1.623	1.695	1.707	1.748	1.811	1.883	1.852	1.879	1.906	2.025
TOTAL INC. INVEST.	0.582	2.393	3.997	4.150	5.889	7.784	10.678	13.009	15.328	17.321	19.403	20.878	22.456	23.739	24.954	25.216	30.401

TABLE A-32 Incremental Capital Expenditures for Advanced Vehicle Production

Million 1997$

Year	Advanced Diesel	CNG	Electric	Hybrid	Fuel Cell	Total
2000	0	15	5	73	0	$94
2001	0	48	20	260	0	$328
2002	5	44	24	291	0	$365
2003	76	30	0	7	0	$113
2004	181	15	13	243	0	$452
2005	190	27	28	423	0	$667
2006	234	25	34	446	0	$739
2007	115	21	46	398	23	$605
2008	48	22.6	55	467	91	$684
2009	6	25.5	64	448	122	$666
2010	16	20.5	68	414	135	$654
2011	18	0.0	5	196	137	$356
2012	10	0.0	4	215	146	$376
2013	0	0.0	4	130	144	$279
2014	10	0.5	10	110	199	$330
2015	0	0.0	0	0	244	$244
2016	0	0.0	1	0	304	$305
2017	0	0.0	0	0	272	$272
2018	3	0.0	0	0	194	$197
2019	3	0.0	0	0	166	$169
2020	2	0.0	0	0	166	$168
Cumulative Total From Year 2000 to Year						
2005	451	179	91	1298	0	2019
2010	871	294	359	3470	372	5367
2015	910	295	382	4122	1242	6952
2020	917	295	383	4122	2345	8063

Advanced Diesel: $300 million/100,000 vehicles
CNG: $700 million/100,000 vehicles
Electric, Hybrid, Fuel Cell: $2 billion/100,000 vehicles

TABLE A-33 New Light Vehicle Fuel Economy

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2020
Conventional	24.54	24.74	24.94	25.14	25.33	25.53	25.81	26.10	26.39	26.68	26.97	27.19	27.41	27.62	27.84	28.06	27.90
OTT Programs	24.60	25.01	25.47	25.80	26.47	27.38	28.12	29.30	30.52	31.56	32.60	32.67	33.27	33.72	34.25	34.47	35.05
SMALL CAR FUEL ECONOMY																	
Conventional	31.26	31.64	32.01	32.39	32.76	33.14	33.57	34.00	34.43	34.86	35.29	35.57	35.85	36.14	36.42	36.70	36.70
Advanced Diesel	N/A	N/A	N/A	43.72	44.23	44.74	45.32	45.90	46.48	47.06	47.64	48.02	48.40	48.78	49.16	49.55	49.55
Flex Alcohol	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SDI	N/A	N/A	N/A	N/A	40.96	41.43	41.96	42.50	43.04	43.58	44.11	44.47	44.82	45.17	45.52	45.88	45.88
CNG Dedicated	31.26	31.64	32.01	32.39	32.76	33.14	33.57	34.00	34.43	34.86	35.29	35.57	35.85	36.14	36.42	36.70	36.70
Electric	N/A	N/A	N/A	129.55	131.06	132.56	134.28	136.00	137.72	139.44	141.16	142.29	143.42	144.54	145.67	146.80	146.80
Hybrid	N/A	N/A	N/A	N/A	N/A	N/A	56.40	59.84	63.35	66.93	70.58	71.14	71.71	72.27	72.84	73.40	73.40
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	73.40	73.40
AVERAGE	31.55	33.06	34.92	35.13	37.09	40.48	39.88	41.49	43.26	45.17	46.97	47.34	47.70	48.07	48.42	46.60	48.91
LARGE CAR FUEL ECONOMY																	
Conventional	25.86	26.12	26.38	26.63	26.89	27.15	27.48	27.80	28.13	28.45	28.78	28.92	29.07	29.21	29.36	29.50	29.50
Advanced Diesel	N/A	N/A	N/A	N/A	N/A	36.65	37.09	37.53	37.97	38.41	38.85	39.05	39.24	39.44	39.63	39.83	39.83
Flex Alcohol	25.86	26.12	26.38	26.63	26.89	27.15	27.48	27.80	28.13	28.45	28.78	28.92	29.07	29.21	29.36	29.50	29.50
SDI	N/A	N/A	N/A	N/A	33.62	33.94	34.35	34.75	35.16	35.57	35.98	36.16	36.34	36.52	36.70	36.88	36.88
CNG Dedicated	25.86	26.12	26.38	26.63	26.89	27.15	27.48	27.80	28.13	28.45	28.78	28.92	29.07	29.21	29.36	29.50	29.50
Electric	N/A	N/A	N/A	N/A	N/A	N/A	109.90	111.21	112.51	113.82	115.12	115.70	116.27	116.85	117.42	118.00	118.00
Hybrid	N/A	N/A	N/A	39.95	43.03	46.16	49.46	52.82	56.26	56.91	57.56	57.85	58.14	58.42	58.71	59.00	59.00
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	58.38	59.63	60.89	62.16	63.05	63.95	64.27	64.58	64.90	64.90
AVERAGE	25.86	26.12	26.38	26.71	27.25	27.99	29.24	30.39	32.04	33.35	34.72	35.73	36.83	37.80	38.44	39.10	39.92
MINIVAN FUEL ECONOMY																	
Conventional	22.70	22.88	23.06	23.24	23.42	23.60	23.95	24.29	24.63	24.97	25.31	25.67	26.02	26.38	26.73	27.09	27.09
Advanced Diesel	N/A	N/A	N/A	N/A	33.96	34.23	34.72	35.22	35.71	36.21	36.71	37.22	37.74	38.25	38.76	39.28	39.28
Flex Alcohol	22.70	22.88	23.06	23.24	23.42	23.60	23.95	24.29	24.63	24.97	25.31	25.67	26.02	26.38	26.73	27.09	27.09
SDI	N/A	N/A	N/A	N/A	29.28	29.50	29.93	30.36	30.79	31.22	31.64	32.09	32.53	32.97	33.42	33.86	33.86
CNG Dedicated	N/A	N/A	23.06	23.24	23.42	23.60	23.95	24.29	24.63	24.97	25.31	25.67	26.02	26.38	26.73	27.09	27.09
Electric	N/A	N/A	N/A	N/A	93.69	94.41	95.78	97.15	98.52	99.89	101.26	102.68	104.10	105.52	106.94	108.36	108.36
Hybrid	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	37.73	40.08	42.47	44.91	47.41	47.41
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	55.40	56.14	56.89	56.89
AVERAGE	22.70	22.88	23.06	23.24	23.47	24.57	26.09	27.70	28.61	29.56	30.50	29.79	30.41	30.71	31.46	32.21	32.95
SUV FUEL ECONOMY																	
Conventional	21.10	21.27	21.44	21.60	21.77	21.94	22.26	22.58	22.89	23.21	23.53	23.86	24.19	24.52	24.85	25.18	25.18
Advanced Diesel	0.21	0.21	0.21	0.22	6.49	12.86	19.45	26.23	33.20	33.66	34.12	34.60	35.08	35.55	36.03	36.51	36.51
Flex Alcohol	21.10	21.27	21.44	21.60	21.77	21.94	22.26	22.58	22.89	23.21	23.53	23.86	24.19	24.52	24.85	25.18	25.18
SDI	N/A	N/A	N/A	N/A	27.22	27.43	27.82	28.22	28.62	29.02	29.41	29.83	30.24	30.65	31.06	31.48	31.48
CNG Dedicated	N/A	N/A	21.44	21.60	21.77	21.94	22.26	22.58	22.89	23.21	23.53	23.86	24.19	24.52	24.85	25.18	25.18
Electric	N/A	N/A	N/A	N/A	87.09	87.76	89.03	90.30	91.58	92.85	94.12	95.44	96.76	98.08	99.40	100.72	100.72
Hybrid	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	33.40	35.98	38.62	41.31	44.07	44.07
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	51.49	52.19	52.88	52.88
AVERAGE	21.10	21.27	21.44	21.68	21.99	22.05	23.04	24.71	26.46	27.38	28.30	27.40	27.99	28.26	28.88	29.49	30.22
PICK-UP AND LARGE VAN FUEL ECONOMY																	
Conventional	19.50	19.64	19.77	19.91	20.04	20.18	20.38	20.58	20.79	20.99	21.19	21.40	21.61	21.83	22.04	22.25	22.25
Advanced Diesel	N/A	N/A	26.69	26.88	27.06	27.24	27.52	27.79	28.06	28.33	28.61	28.89	29.18	29.47	29.75	30.04	30.04
Flex Alcohol	19.50	19.64	19.77	19.91	20.04	20.18	20.38	20.58	20.79	20.99	21.19	21.40	21.61	21.83	22.04	22.25	22.25
SDI	N/A	N/A	N/A	N/A	25.06	25.23	25.48	25.73	25.98	26.24	26.49	26.75	27.02	27.28	27.55	27.81	27.81
CNG Dedicated	19.50	19.64	19.77	19.91	20.04	20.18	20.38	20.58	20.79	20.99	21.19	21.40	21.61	21.83	22.04	22.25	22.25
Electric	48.75	49.09	49.43	49.77	50.11	50.45	50.96	51.46	51.97	52.47	52.98	53.51	54.04	54.57	55.10	55.63	55.63
Hybrid	N/A	N/A	N/A	N/A	N/A	25.02	26.56	28.12	29.70	31.31	32.95	34.63	36.33	38.06	39.82	41.61	40.27
Fuel Cell	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	43.65	44.07	44.50	44.94	45.39	45.83	46.28	46.73	46.73
AVERAGE	19.50	19.64	19.82	20.38	20.94	21.31	21.77	22.26	22.68	23.27	23.86	24.30	24.76	25.24	25.73	26.20	26.42

Table A-30 Summary Class 3 - 8 Energy and Emission Reductions

Year	Energy Reduction mmb/d	CNG Use mmb/d	Petroleum Reduction mmb/d	Emission Reductions (1000 tons) Carbon	NOx	CO	NMHC	Energy Cost Savings million 1997$	Incremental Vehicle Cost million 1997$
2000	0.004	0.001	0.004	0.156	1.554	1.666	0.442	0.000	53.330
2001	0.006	0.001	0.007	0.275	3.217	3.452	0.917	0.000	56.075
2002	0.009	0.001	0.010	0.400	5.583	5.996	1.595	0.000	58.477
2003	0.013	0.001	0.014	0.541	8.737	9.378	2.496	0.000	62.842
2004	0.016	0.001	0.017	0.689	12.679	13.563	3.620	0.000	67.286
2005	0.020	0.001	0.021	0.849	17.468	18.665	4.990	0.000	71.809
2006	0.023	0.001	0.024	1.001	22.956	24.657	6.603	0.000	77.476
2007	0.027	0.001	0.028	1.157	29.166	31.322	8.411	0.000	81.687
2008	0.031	0.001	0.032	1.316	35.985	38.630	10.410	0.000	87.371
2009	0.035	0.001	0.035	1.476	43.038	46.182	12.494	0.000	95.439
2010	0.039	0.001	0.039	1.633	50.252	53.889	14.645	0.000	99.643
2011	0.042	0.000	0.043	1.790	57.395	61.504	16.801	0.000	103.265
2012	0.046	0.000	0.046	1.948	64.260	68.800	18.902	0.000	108.269
2013	0.050	0.000	0.050	2.110	70.753	75.676	20.920	0.000	113.324
2014	0.054	0.000	0.054	2.282	76.739	82.004	22.814	0.000	118.981
2015	0.058	0.000	0.058	2.465	82.112	87.598	24.566	0.000	124.303
2016	0.063	0.000	0.063	2.670	86.857	92.461	26.170	0.000	132.248
2017	0.069	0.000	0.069	2.895	90.984	96.583	27.632	0.000	139.420
2018	0.074	0.000	0.075	3.144	94.557	100.000	28.976	0.000	147.029
2019	0.081	0.000	0.081	3.419	97.677	102.846	30.230	0.000	154.950
2020	0.088	0.000	0.088	3.723	100.477	105.010	31.463	0.000	162.243
Cumulative Total From Year 2000 to Year									
2005	0.067	0.006	0.073	2.909	49.239	52.719	14.060	0.000	369.819
2010	0.222	0.010	0.232	9.492	230.636	247.400	66.624	0.000	811.435
2015	0.473	0.011	0.484	20.087	581.895	622.981	170.627	0.000	1379.577
2020	0.848	0.012	0.860	35.939	1052.446	1119.881	315.097	0.000	2115.468

Table A-31 Market Penetration of Advanced Diesels and Alternative Fuels in Heavy Vehicles

	Class 7-8 Type 1		Class 7-8 Type 2		Class 7-8 Type 3		CLASS 7-8 Final		CLASS 3-6 Final	
Year	Advanced Diesel	CNG	Advanced Diesel	CNG	Advanced Diesel	CNG	Advanced Diesel	Alt. Fuel	Hybrid	CNG
2000	2.6%	0.2%	4.6%	0.3%	4.3%	0.1%	4.1%	0.2%	0.0%	0.0%
2001	2.8%	0.2%	5.0%	0.2%	4.6%	0.1%	4.4%	0.1%	0.1%	0.0%
2002	3.1%	0.1%	5.4%	0.1%	5.1%	0.0%	4.8%	0.1%	0.1%	0.0%
2003	3.4%	0.1%	6.0%	0.1%	5.5%	0.0%	5.3%	0.0%	0.2%	0.0%
2004	3.7%	0.0%	6.5%	0.0%	6.0%	0.0%	5.7%	0.0%	0.4%	0.0%
2005	4.0%	0.0%	7.0%	0.0%	6.6%	0.0%	6.2%	0.0%	0.5%	0.0%
2006	4.4%	0.0%	7.7%	0.0%	7.2%	0.0%	6.8%	0.0%	0.6%	0.0%
2007	4.6%	0.0%	8.2%	0.0%	7.7%	0.0%	7.3%	0.0%	0.9%	0.0%
2008	5.0%	0.0%	8.9%	0.0%	8.5%	0.0%	8.0%	0.0%	1.1%	0.0%
2009	5.3%	0.0%	9.8%	0.0%	9.4%	0.0%	8.8%	0.0%	1.5%	0.0%
2010	5.6%	0.0%	10.4%	0.0%	10.1%	0.0%	9.4%	0.0%	2.0%	0.0%
2011	6.0%	0.0%	11.0%	0.0%	10.8%	0.0%	10.0%	0.0%	2.0%	0.0%
2012	6.4%	0.0%	11.8%	0.0%	11.7%	0.0%	10.8%	0.0%	2.1%	0.0%
2013	7.0%	0.0%	12.7%	0.0%	12.6%	0.0%	11.6%	0.0%	2.1%	0.0%
2014	7.4%	0.0%	13.7%	0.0%	13.6%	0.0%	12.5%	0.0%	2.2%	0.0%
2015	8.0%	0.0%	15.0%	0.0%	14.8%	0.0%	13.7%	0.0%	2.2%	0.0%
2016	8.6%	0.0%	16.7%	0.0%	16.4%	0.0%	15.0%	0.0%	2.3%	0.0%
2017	9.4%	0.0%	18.1%	0.0%	18.0%	0.0%	16.4%	0.0%	2.4%	0.0%
2018	10.2%	0.0%	19.5%	0.0%	19.8%	0.0%	18.0%	0.0%	2.5%	0.0%
2019	11.1%	0.0%	21.1%	0.0%	21.8%	0.0%	19.7%	0.0%	2.6%	0.0%
2020	12.0%	0.0%	23.7%	0.0%	23.8%	0.0%	21.6%	0.0%	2.6%	0.0%

Table A-32 Heavy Vehicle (Class 3-8) Sales and Stocks of Advanced Diesel and Natural Gas Vehicles

	SALES				STOCKS				STOCKS (Percent of Total)			
	3-6		7&8		3-6		7&8		3-6		7&8	
Year	Adv. Diesel	CNG	Adv. Diesel	CNG	Adv. Diesel	CNG	Adv. Diesel	CNG	Adv. Diesel	CNG	Adv. Diesel	CNG
1995	0	0	0	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%
1996	0	0	0	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%
1997	0	0	0	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%
1998	0	0	0	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%
1999	0	0	4350	384	0	0	4350	384	0.0%	0.0%	0.1%	0.0%
2000	0	0	12209	499	0	0	16546	882	0.0%	0.0%	0.4%	0.0%
2001	0	0	13446	404	0	0	29933	1282	0.0%	0.0%	0.8%	0.0%
2002	0	0	14847	229	0	0	44653	1505	0.0%	0.0%	1.1%	0.0%
2003	177	0	16477	136	177	0	60897	1631	0.0%	0.0%	1.5%	0.0%
2004	388	0	18144	63	565	0	78655	1680	0.0%	0.0%	1.9%	0.0%
2005	438	0	20003	29	1001	0	98047	1689	0.1%	0.0%	2.3%	0.0%
2006	560	0	22201	10	1557	0	118966	1639	0.1%	0.0%	2.8%	0.0%
2007	785	0	23963	2	2334	0	140588	1563	0.2%	0.0%	3.2%	0.0%
2008	999	0	26303	0	3319	0	163938	1485	0.2%	0.0%	3.7%	0.0%
2009	1613	0	29174	0	4908	0	189406	1411	0.3%	0.0%	4.2%	0.0%
2010	1778	0	31436	0	6649	0	216238	1414	0.4%	0.0%	4.7%	0.0%
2011	1825	0	33784	0	8415	0	244314	1184	0.5%	0.0%	5.3%	0.0%
2012	1917	0	36751	0	10246	0	273993	1032	0.6%	0.0%	5.8%	0.0%
2013	2017	0	39955	0	12141	0	305399	985	0.8%	0.0%	6.4%	0.0%
2014	2391	0	43371	0	14365	0	338704	894	0.9%	0.0%	7.0%	0.0%
2015	2098	0	47623	0	16239	0	374619	818	1.0%	0.0%	7.7%	0.0%
2016	2209	0	52894	0	18158	0	414045	732	1.1%	0.0%	8.4%	0.0%
2017	2341	0	58276	0	20133	0	457065	651	1.2%	0.0%	9.1%	0.0%
2018	2483	0	64348	0	22162	0	504266	577	1.3%	0.0%	10.0%	0.0%
2019	2895	0	70891	0	24508	0	555976	505	1.5%	0.0%	10.9%	0.0%
2020	2603	0	78518	0	26458	0	613146	440	1.6%	0.0%	11.9%	0.0%

Table A-33 Heavy Vehicle (Class 3-8) Energy Use and Petroluem Reduction

	CLASS 3 - 6				CLASS 7&8						Total
	Energy Use (trills)		Energy Savings		Energy Use (trills)		Energy Savings		CNG Used		Petroleum
	Base Case	Technology	Trillion Btu		Base Case	Technology	Trillion Btu		Trillion Btu		Reduction
Year		Case		mmb/d		Case		mmb/d		mmb/d	mmb/d
2000	305.6	305.6	0.000	0.0000	3816.6	3809.2	7.47	0.0035	1.314	0.0006	0.0042
2001	304.7	304.7	0.000	0.0000	3902.3	3889.0	13.31	0.0063	1.900	0.0009	0.0072
2002	302.3	302.3	0.000	0.0000	3965.2	3945.6	19.52	0.0092	2.195	0.0010	0.0103
2003	303.0	303.0	0.053	0.0000	4065.2	4038.7	26.46	0.0125	2.351	0.0011	0.0136
2004	307.5	307.3	0.169	0.0001	4143.0	4109.3	33.76	0.0159	2.363	0.0011	0.0171
2005	307.4	307.1	0.301	0.0001	4231.7	4190.1	41.66	0.0197	2.307	0.0011	0.0209
2006	308.6	308.5	0.076	0.0000	4316.8	4267.2	49.56	0.0234	2.154	0.0010	0.0245
2007	308.6	308.5	0.139	0.0001	4377.0	4319.6	57.38	0.0271	1.940	0.0009	0.0281
2008	309.5	309.3	0.216	0.0001	4434.8	4369.5	65.34	0.0309	1.712	0.0008	0.0318
2009	314.2	313.9	0.340	0.0002	4470.6	4397.3	73.27	0.0346	1.479	0.0007	0.0355
2010	313.5	313.1	0.473	0.0002	4503.2	4422.1	81.05	0.0383	1.305	0.0006	0.0391
2011	313.7	313.1	0.606	0.0003	4535.1	4446.2	88.86	0.0420	0.979	0.0005	0.0427
2012	314.3	313.6	0.741	0.0003	4565.9	4469.2	96.71	0.0457	0.731	0.0003	0.0464
2013	315.4	314.6	0.877	0.0004	4595.3	4490.5	104.75	0.0495	0.584	0.0003	0.0502
2014	320.7	319.6	1.034	0.0005	4623.5	4510.2	113.22	0.0535	0.436	0.0002	0.0542
2015	320.7	319.5	1.158	0.0005	4651.7	4529.4	122.33	0.0578	0.336	0.0002	0.0585
2016	321.3	320.0	1.278	0.0006	4679.5	4547.0	132.50	0.0626	0.259	0.0001	0.0633
2017	322.6	321.2	1.396	0.0007	4707.8	4564.1	143.68	0.0679	0.207	0.0001	0.0686
2018	324.4	322.8	1.509	0.0007	4735.0	4579.0	156.05	0.0737	0.170	0.0001	0.0745
2019	329.9	328.3	1.639	0.0008	4761.2	4591.5	169.69	0.0802	0.139	0.0001	0.0810
2020	330.6	328.9	1.732	0.0008	4786.4	4601.6	184.83	0.0873	0.115	0.0001	0.0882
Cumulative Total From Year 2000 to Year											
2005	1831	1830	0.52	0.0002	24124	23982	142	0.067	12.43	0.0059	0.073
2010	3385	3383	1.77	0.0008	46226	45758	469	0.221	21.02	0.0099	0.232
2015	4970	4964	6.18	0.0029	69198	68203	995	0.470	24.09	0.0114	0.484
2020	6598	6585	13.74	0.0065	92868	91086	1781	0.842	24.98	0.0118	0.860

	ENERGY COST SAVINGS $/MILLION BTU		**MILLION BTU**		**ENERGY COST SAVINGS** million $		
Year	Diesel	CNG	cl 3-6	cl 7-8	cl 3-6	cl 7-8	CNG
2000	7.56	6.49	0	7473860	0.00	56.50	1.41
2001	7.71	6.48	0	13305028	0.00	102.58	2.34
2002	7.86	6.50	0	19522902	0.00	153.45	2.99
2003	8.09	6.56	52988.74	26456300	0.43	214.03	3.60
2004	8.30	6.62	169197	33763076	1.40	280.23	3.97
2005	8.49	6.72	301484.5	41660680	2.56	353.70	4.08
2006	8.61	6.86	75999.68	49556353	0.65	426.68	3.77
2007	8.70	6.97	138503.2	57382318	1.20	499.23	3.36
2008	8.62	7.05	216454.9	65341927	1.87	563.25	2.69
2009	8.70	7.11	339548.8	73268672	2.95	637.44	2.35
2010	8.58	7.17	472607	81050164	4.05	695.41	1.84
2011	8.57	7.20	605592.9	88858804	5.19	761.52	1.34
2012	8.56	7.22	740799	96707885	6.34	827.82	0.98
2013	8.51	7.24	877214.9	1.05E+08	7.47	891.46	0.74
2014	8.51	7.28	1033923	1.13E+08	8.80	963.51	0.54
2015	8.56	7.31	1157871	1.22E+08	9.91	1,047.12	0.42
2016	8.56	7.34	1278350	1.32E+08	10.94	1,134.17	0.32
2017	8.59	7.36	1395538	1.44E+08	11.99	1,234.21	0.25
2018	8.61	7.37	1509147	1.56E+08	12.99	1,343.59	0.21
2019	8.50	7.36	1638561	1.7E+08	13.93	1,442.38	0.16
2020	8.53	7.37	1732127	1.85E+08	14.78	1,576.57	0.13

Table A-34 Heavy Vehicle (Class 3-8) CO2 Emissions and Emission Reductions (1,000 tons)

	OPERATIONAL EMISSIONS			UPSTREAM EMISSIONS			TOTAL REDUCTION		
	Reduction			Reduction					
Year	CLS 3-6	CLS 7&8	Total	CLS 3-6	CLS 7&8	Total	CLS 3-6	CLS 7&8	Total
2000	0.0	902.9	902.9	0.0	117.4	117.4	0.0	1020.3	1020.3
2001	0.0	1903.2	1903.2	0.0	247.4	247.4	0.0	2150.6	2150.6
2002	0.0	3344.8	3344.8	0.0	434.8	434.8	0.0	3779.6	3779.6
2003	4.1	5289.5	5289.5	0.7	687.6	688.2	4.8	5977.0	5977.7
2004	13.1	7754.8	7757.4	2.1	1008.0	1010.1	15.2	8762.8	8767.5
2005	23.4	10806.8	10812.0	3.8	1404.8	1408.5	27.2	12211.6	12220.5
2006	5.2	14446.8	14461.1	1.8	1876.2	1878.0	7.0	16323.0	16339.1
2007	9.7	18590.8	18619.1	3.0	2410.2	2413.1	12.7	21001.0	21032.2
2008	15.4	23244.6	23292.7	4.4	3006.8	3011.2	19.8	26251.4	26303.9
2009	24.3	28191.7	28271.3	6.7	3637.5	3644.2	31.0	31829.2	31915.5
2010	33.9	33406.3	33520.8	9.2	4298.1	4307.3	43.1	37704.3	37828.1
2011	43.6	38753.9	38914.6	11.7	4970.1	4981.8	55.3	43723.9	43896.4
2012	53.4	44101.4	44323.2	14.2	5635.2	5649.4	67.6	49736.6	49972.5
2013	63.3	49350.3	49651.9	16.7	6279.8	6296.6	80.0	55630.2	55948.5
2014	74.6	54393.6	54812.7	19.7	6888.6	6908.3	94.3	61282.2	61720.9
2015	83.6	59144.1	59686.7	22.0	7448.6	7470.5	105.6	66592.7	67157.2
2016	92.4	63564.6	64262.3	24.2	7952.4	7976.6	116.6	71517.0	72238.9
2017	100.8	67625.8	68516.7	26.4	8393.5	8419.9	127.2	76019.2	76936.6
2018	109.1	71328.1	72455.0	28.5	8768.7	8797.2	137.6	80096.8	81252.2
2019	118.4	74693.4	76133.9	31.0	9077.3	9108.2	149.4	83770.6	85242.1
2020	125.2	77759.8	79503.6	32.7	9320.2	9352.9	157.9	87080.0	88856.5
Cumulative Total From Year 2000 to Year									
2005	41	30002	30010	7	3900	3906	47	33902	33916
2010	129	147882	148175	32	19129	19160	161	167011	167335
2015	448	393626	395564	116	50351	50467	564	443976	446031
2020	994	748597	756435	259	93863	94122	1252	842460	850557

Table A-35 Heavy Vehicle (Class 3-8) NOx Emissions and Emission Reductions (1,000 tons)

	OPERATIONAL EMISSIONS			UPSTREAM EMISSIONS			TOTAL REDUCTION		
	Reduction			Reduction					
Year	CLS 3-6	CLS 7&8	Total	CLS 3-6	CLS 7&8	Total	CLS 3-6	CLS 7&8	Total
2000	0.0	1.3	1.3	0.0	0.3	0.3	0.0	1.6	1.6
2001	0.0	2.7	2.7	0.0	0.6	0.6	0.0	3.2	3.2
2002	0.0	4.6	4.6	0.0	1.0	1.0	0.0	5.6	5.6
2003	0.0	7.2	7.2	0.0	1.5	1.5	0.0	8.7	8.7
2004	0.0	10.4	10.4	0.0	2.3	2.3	0.0	12.6	12.7
2005	0.1	14.3	14.3	0.0	3.1	3.2	0.1	17.4	17.5
2006	0.0	18.8	18.8	0.0	4.2	4.2	0.0	23.0	23.0
2007	0.0	23.8	23.8	0.0	5.3	5.4	0.0	29.2	29.2
2008	0.0	29.4	29.4	0.0	6.6	6.6	0.0	36.0	36.0
2009	0.0	35.1	35.1	0.0	8.0	8.0	0.0	43.0	43.0
2010	0.0	41.0	40.9	0.0	9.3	9.3	0.0	50.3	50.3
2011	0.0	46.7	46.7	0.0	10.7	10.7	0.0	57.4	57.4
2012	0.0	52.3	52.3	0.0	11.9	12.0	0.0	64.3	64.3
2013	0.0	57.6	57.6	0.0	13.1	13.1	0.0	70.8	70.8
2014	0.0	62.6	62.5	0.0	14.2	14.2	0.0	76.7	76.7
2015	0.0	67.1	67.1	0.0	15.0	15.0	0.0	82.1	82.1
2016	0.0	71.2	71.2	0.0	15.6	15.7	0.0	86.9	86.9
2017	0.0	74.9	74.9	0.0	16.0	16.1	0.0	91.0	91.0
2018	0.0	78.4	78.4	0.1	16.1	16.2	0.0	94.5	94.6
2019	0.0	81.7	81.7	0.1	15.9	16.0	0.0	97.7	97.7
2020	-0.1	85.1	85.0	0.1	15.4	15.5	0.0	100.5	100.5
Cumulative Total From Year 2000 to Year									
2005	0	40	41	0	9	9	0	49	49
2010	0	188	188	0	42	42	0	231	231
2015	0	475	475	0	107	107	0	582	582
2020	0	866	866	0	186	187	0	1052	1052

Table A-36 Heavy Vehicle (Class 3-8) CO Emissions and Emission Reductions (1,000 tons)

	OPERATIONAL EMISSIONS			UPSTREAM EMISSIONS			TOTAL REDUCTION		
	Reduction			Reduction					
Year	CLS 3-6	CLS 7&8	Total	CLS 3-6	CLS 7&8	Total	CLS 3-6	CLS 7&8	Total
2000	0.0	1.3	1.3	0.0	0.4	0.4	0.0	1.7	1.7
2001	0.0	2.7	2.7	0.0	0.8	0.8	0.0	3.5	3.5
2002	0.0	4.6	4.6	0.0	1.4	1.4	0.0	6.0	6.0
2003	0.0	7.2	7.2	0.0	2.2	2.2	0.0	9.4	9.4
2004	0.0	10.4	10.3	0.0	3.2	3.2	0.0	13.6	13.6
2005	-0.1	14.3	14.2	0.0	4.5	4.5	-0.1	18.7	18.7
2006	-0.1	18.8	18.7	0.0	6.0	6.0	-0.1	24.7	24.7
2007	-0.1	23.7	23.6	0.0	7.7	7.7	-0.1	31.4	31.3
2008	-0.1	29.1	29.0	0.0	9.6	9.6	-0.1	38.7	38.6
2009	-0.1	34.7	34.6	0.0	11.6	11.6	-0.1	46.2	46.2
2010	-0.1	40.2	40.2	0.1	13.7	13.7	0.0	53.9	53.9
2011	0.0	45.7	45.6	0.1	15.8	15.9	0.1	61.5	61.5
2012	0.0	50.8	50.8	0.1	17.9	18.0	0.2	68.6	68.8
2013	0.1	55.5	55.6	0.2	19.9	20.1	0.3	75.4	75.7
2014	0.3	59.6	60.0	0.2	21.8	22.0	0.5	81.5	82.0
2015	0.5	63.2	63.7	0.3	23.6	23.8	0.8	86.8	87.6
2016	0.8	66.2	67.0	0.4	25.1	25.5	1.1	91.3	92.5
2017	1.1	68.5	69.7	0.5	26.5	26.9	1.6	95.0	96.6
2018	1.5	70.3	71.8	0.6	27.6	28.2	2.1	97.9	100.0
2019	2.1	71.5	73.6	0.8	28.5	29.2	2.9	100.0	102.8
2020	2.6	72.3	75.0	0.9	29.1	30.0	3.5	101.5	105.0
Cumulative Total From Year 2000 to Year									
2005	0	40	40	0	12	12	0	53	53
2010	-1	187	186	0	61	61	0	248	247
2015	0	462	462	1	160	161	1	622	623
2020	9	811	819	4	297	301	13	1107	1120

Table A-37 Heavy Vehicle (Class 3-8) NMHC Emissions and Emission Reductions (1,000 tons)

	OPERATIONAL EMISSIONS			UPSTREAM EMISSIONS			TOTAL REDUCTION		
	Reduction			Reduction					
Year	CLS 3-6	CLS 7&8	Total	CLS 3-6	CLS 7&8	Total	CLS 3-6	CLS 7&8	Total
2000	0.0	0.3	0.3	0.0	0.1	0.1	0.0	0.4	0.4
2001	0.0	0.7	0.7	0.0	0.3	0.3	0.0	0.9	0.9
2002	0.0	1.2	1.2	0.0	0.4	0.4	0.0	1.6	1.6
2003	0.0	1.8	1.8	0.0	0.7	0.7	0.0	2.5	2.5
2004	0.0	2.6	2.6	0.0	1.0	1.0	0.0	3.6	3.6
2005	0.0	3.6	3.6	0.0	1.4	1.4	0.0	5.0	5.0
2006	0.0	4.7	4.7	0.0	1.9	1.9	0.0	6.6	6.6
2007	0.0	6.0	6.0	0.0	2.4	2.4	0.0	8.4	8.4
2008	0.0	7.4	7.4	0.0	3.1	3.0	0.0	10.4	10.4
2009	0.0	8.8	8.8	0.0	3.7	3.7	0.0	12.5	12.5
2010	0.0	10.3	10.3	0.0	4.4	4.3	0.0	14.7	14.6
2011	0.0	11.8	11.8	0.0	5.0	5.0	0.0	16.8	16.8
2012	0.0	13.3	13.2	0.0	5.7	5.7	-0.1	19.0	18.9
2013	0.0	14.7	14.6	0.0	6.3	6.3	-0.1	21.0	20.9
2014	0.0	16.0	15.9	-0.1	6.9	6.9	-0.1	22.9	22.8
2015	-0.1	17.2	17.2	-0.1	7.5	7.4	-0.1	24.7	24.6
2016	-0.1	18.4	18.3	-0.1	8.0	7.9	-0.2	26.3	26.2
2017	-0.1	19.5	19.4	-0.1	8.4	8.2	-0.2	27.9	27.6
2018	-0.1	20.6	20.4	-0.2	8.7	8.5	-0.3	29.3	29.0
2019	-0.2	21.6	21.5	-0.2	9.0	8.8	-0.4	30.6	30.2
2020	-0.2	22.8	22.6	-0.3	9.2	8.9	-0.5	31.9	31.5
Cumulative Total From Year 2000 to Year									
2005	0	10	10	0	4	4	0	14	14
2010	0	47	47	0	19	19	0	67	67
2015	0	120	120	0	51	51	0	171	171
2020	-1	223	222	-1	94	93	-2	317	315

Table A-38 Value of Heavy Vehicle Emission Reductions
Million 1997 $

	Carbon			**NOx**			**CO**			**NMHC**			
Year	CLS 3-6	CLS 7&8	Total	CLS 3-6	CLS 7&8	Total	CLS 3-6	CLS 7&8	Total	CLS 3-6	CLS 7&8	Total	**TOTAL**
2000	0.0	8.2	8.2	0.0	5.1	5.1	0.0	0.6	0.6	0.0	1.6	1.6	15.5
2001	0.0	14.6	14.6	0.0	10.6	10.6	0.0	1.2	1.2	0.0	3.4	3.4	29.8
2002	0.0	21.4	21.4	0.0	18.4	18.4	0.0	2.2	2.2	0.0	5.8	5.8	47.8
2003	0.1	29.0	29.1	0.0	28.8	28.8	0.0	3.4	3.4	0.0	9.1	9.1	70.4
2004	0.2	37.0	37.2	0.1	41.7	41.8	0.0	4.9	4.9	0.0	13.3	13.2	97.2
2005	0.3	45.7	46.0	0.2	57.4	57.6	0.0	6.7	6.7	0.0	18.3	18.3	128.7
2006	0.1	54.4	54.5	0.0	75.8	75.8	0.0	8.9	8.9	0.0	24.2	24.2	163.3
2007	0.2	63.0	63.1	0.0	96.3	96.2	0.0	11.3	11.3	0.0	30.8	30.8	201.4
2008	0.2	71.7	71.9	0.0	118.8	118.7	0.0	13.9	13.9	0.0	38.1	38.1	242.7
2009	0.4	80.4	80.8	0.0	142.1	142.0	0.0	16.6	16.6	-0.1	45.8	45.7	285.1
2010	0.5	88.9	89.5	0.0	165.9	165.8	0.0	19.4	19.4	-0.1	53.7	53.6	328.3
2011	0.7	97.5	98.2	0.0	189.4	189.4	0.0	22.1	22.1	-0.1	61.6	61.5	371.2
2012	0.8	106.1	106.9	0.0	212.1	212.1	0.1	24.7	24.8	-0.2	69.4	69.2	412.9
2013	1.0	114.9	115.9	0.0	233.5	233.5	0.1	27.1	27.2	-0.3	76.8	76.6	453.2
2014	1.1	124.2	125.4	0.0	253.2	253.2	0.2	29.3	29.5	-0.4	83.9	83.5	491.6
2015	1.3	134.2	135.5	0.0	271.0	271.0	0.3	31.2	31.5	-0.5	90.4	89.9	527.9
2016	1.4	145.4	146.8	0.0	286.6	286.6	0.4	32.9	33.3	-0.7	96.4	95.8	562.5
2017	1.5	157.7	159.2	0.0	300.2	300.2	0.6	34.2	34.8	-0.8	102.0	101.1	595.3
2018	1.7	171.2	172.9	0.0	312.0	312.0	0.8	35.2	36.0	-1.1	107.1	106.1	627.0
2019	1.8	186.2	188.0	0.0	322.3	322.3	1.0	36.0	37.0	-1.4	112.0	110.6	658.0
2020	1.9	202.8	204.7	0.0	331.5	331.6	1.3	36.5	37.8	-1.6	116.8	115.2	689.2
Cumulative Total From Year 2000 to Year													
2005	1	156	157	0	162	162	0	19	19	0	51	51	390
2010	2	514	516	0	761	761	0	89	89	0	244	244	1610
2015	7	1091	1098	0	1920	1920	1	224	224	-2	626	624	3867
2020	15	1955	1970	0	3473	3473	5	399	403	-7	1161	1153	6999

Carbon value/tonne = $55
NOx value/tonne = $3,300
CO value/tonne = $360
HC value/tonne = 3,660

Appendix B: Vehicle Size Consumer Choice Model Structure and Coefficients

VSCC Model Structure and Coefficients

The structure of the size class model is based on a three-dimensional matrix of i vehicle technology types and k attributes in each of t years. Each cell C_{ikt} of this matrix contains an attribute value (vehicle or fuel) multiplied by a corresponding coefficient reflecting the potential market share impact of the attribute k on vehicle i in year t. Using a logit function, the model estimates market share an as a function of a technology's attributes, the attributes of competing technologies, and external factors such as fuel prices. This can be expressed as:

$$S_{it} = P_{it} = \sum_{n=1}^{N} \frac{P_{itn}}{N} , \qquad P_{itn} = \frac{e^{V_{itn}}}{\sum_{i=1}^{I} e^{V_{itn}}} \qquad (1)$$

where: S_{it} *= market share of vehicle type i in year t*

P_{it} *= aggregate probability over population N of choosing type i in year t*

n = individual n from population N

P_{itn} *= probability of individual n choosing type i in year t*

V_{itn} *= a function of the k elements of the vector of attributes (A) and coefficients (B), generally linear in parameters, i.e.:*

$$V = B_1A_1 + B_2A_2 + ... + B_kA_k$$

and V is specific to vehicle i, year t, and individual n.

Vehicle Attribute Coefficients for the QM 2000 Analysis are listed in Exhibit B-1. The VSCC Model estimates the market share penetration of alternative-fuel light vehicles for twelve (12) individual technologies and five (5) vehicle size classes. The twelve vehicle technologies are described as follows: conventional vehicles with internal combustion engines (ICEs) operating on either gasoline or diesel; stratified direct injection engine vehicles operating on gasoline; ICE flex-fuel vehicles operating on a mixture of gasoline and alcohol fuels (ethanol or methanol); ICE dedicated alternative fuel vehicles operating on either alcohol (ethanol or methanol) or gaseous fuels (compressed natural gas or liquid propane gas); hybrid electric vehicles with combustion engines and electric motors operating on either gasoline, diesel, or compressed natural gas; and fuel cell vehicles operating on either gasoline, ethanol, or compressed natural gas. The five vehicle size classes include: small cars (compact and subcompacts, mini-compacts, and 2 seaters), large cars (midsize and large cars), minivans, sport utilities and cargo trucks (pickups and large vans). Dummy variables were developed to reflect expected consumer reluctance to purchase electric drivetrain vehicles in the light truck size classes. It is assumed that the utility consumer’s place on electric drivetrain light trucks is discounted to reflect a 50% reduction in the initial estimation of market penetration by the VSCC model. For sport utility, truck and large van sizes classes, it is assumed that all electric drivetrain vehicles are effected. For minivans, it is assumed that only battery powered electric vehicles will be effected.

Exhibit B-1: Vehicle Attribute Coefficients

Variables	Small Car		Large Car		Sport Utility		Truck & Van		Minivan	
	Coeff.	T-Stat.	Coeff.	T-Stat.	Coeff.	T-Stat.	Coeff.	T-Stat.	Coeff.	T-Stat.
Purchase Price (1,000's of $)	-0.0686	-5.220	-0.0411	-8.542	-0.0350	-3.669	-0.0723	-6.200	-0.1096	-6.287
Dedicated AFV Range (100's of miles)	0.4774	2.149	0.3154	2.336	0.3205	2.184	0.3205	0.000	0.5175	1.929
Maintenance Cost ($ per year)	-0.0004	-2.533	-0.0004	-2.533	-0.0004	-2.533	-0.0004	-2.533	-0.0004	-2.533
Acceleration (seconds)	-0.0646	-2.694	-0.0646	-2.694	-0.0646	-2.694	-0.0646	-2.694	-0.0646	-2.694
Top Speed (miles per hour)	0.0032	1.750	0.0032	1.750	0.0032	1.750	0.0032	1.750	0.0032	1.750
Luggage Space (% of conventional)	0.0035	2.576	0.0035	2.576	0.0035	2.576	0.0035	2.576	0.0035	2.576
Station Fuel Cost ($/mile)	-11.210	-2.824	-8.671	-3.148	-10.843	-4.321	-5.478	-2.597	-10.843	0.000
Home Refueling	0.1138	0.856	0.1138	0.856	0.1138	0.856	0.1138	0.856	0.1138	0.856
Multi-fuel Dummy	-0.5846	-4.170	-0.5846	-4.170	-0.5846	-4.170	-0.5846	-4.170	-0.5846	-4.170
Gasoline Capable Dummy	1.194	3.743	1.194	3.743	1.194	3.743	1.194	3.743	1.194	3.743
Gasoline Range Dummy > 250 miles	0.0034	0.021	0.0034	0.021	0.0034	0.021	0.0034	0.021	0.0034	0.021
Electric Vehicle Dummy					-1.630		-1.580		-1.500	
Hybrid Vehicle Dummy					-0.934		-0.887		0.000	
Fuel Cell Vehicle Dummy					-0.934		-0.887		0.000	
Constant Terms										
Gasoline Capable Range > 250 miles	Coeff.	T-Stat.								
Gasoline	-0.33869	-2.157								
Alcohol	-0.08145	0.239								
Dual Gaseous	-0.24143	0.181								
Hybrid	-0.37571	-0.557								
Fuel Availability										
Fuel Availability	2.76	0.000								
Fuel Availability^2	-1.43	0.000								

For each technology, the model considers a set of generic vehicle attributes representative of all vehicles within that technology and a set of fuel attributes corresponding to that technology. The vehicle attributes include:

- Vehicle purchase price in 1996 dollars;
- Vehicle efficiency (on-road) in equivalent miles per gallon of gasoline;
- Annual maintenance cost;
- Acceleration time (seconds from 0 to 30 mph);
- Top speed if lower than ninety (90) miles per hour;
- Range (defined as miles traveled before refueling is required); and
- Luggage space.

The fuel attributes include:

- Fuel price (estimated in dollars per gallon of gasoline equivalent); and
- Fuel availability (defined as the percent of stations offering the fuel for sale).

Consumer derived utilities for vehicle attributes described in the VSCC model were estimated from data collected in a 1995 national stated preference survey (Ref. B-1). The vehicle attribute coefficients and technology constant terms for each size class were derived from analyses using a discrete choice multinomial logit model.

Market penetration estimates for alternative fuel use in multi-fuel and bi-fuel vehicles are represented using a random utility, binomial logit model. This model expresses the value, U, of an option, i, as a function of its attributes and is expressed as:

$$U_{1j} = A_1 + BP_1 + Ce^{b\sigma} + \varepsilon_{1j} \qquad (2)$$

where: *U = total utility*
A = constant term
B = price coefficient
P = fuel price
C = fuel availability coefficient
b = exponential function
σ = fuel availability.
ε = random error that varies across individuals.

Coefficients used in Equation 2 are listed in Exhibit B-2.

Exhibit B-2: Coefficients Used in Fuel Choice Model for Equation 2

Item	Coefficient	Standard Error
Constant	-0.0503	0.10
Fuel Availability	-3.2651	0.12
Exponent	-5.35	N/A
Fuel Price	-9.1451	0.34

The VSCC model also endogenously estimates alternative fuel availability. This is accomplished through a feedback loop that considers alternative fuel and vehicle purchase. As vehicles capable of using alternative fuels are purchased, potential alternative fuel demand grows. Fuel suppliers are assumed to enter the market when the potential demand achieves a threshold level. In each forecast year the potential demand for each fuel is estimated and checked against available supply. If fuel demand is constrained by available supply, in the following year, additional refueling stations are assumed to open such that the new number of stations becomes sufficient based on last year's demand. As alternative fuel availability increases, the demand for vehicles using these fuels also increases, with respect to vehicle range and fuel price considerations.

The logit function used to estimate alternative fuel market penetration follows the model structure and equations described earlier. Coefficients used in the fuel choice model where developed from two nationwide surveys administered by CARAVAN® Opinion Research Corporation during 1996. Equation 2 coefficients were developed by David Greene at Oak Ridge National Laboratory (Ref. B-2).

In regard to attribute coefficient values for vehicles and fuels, it's important to note that a major limitation in estimating the potential household market penetration of alternative vehicle technologies is the lack of *revealed preference data*. Revealed preference data is gathered from actual consumer response in the market place. Currently, there are only a limited number of alternative-fuel technologies commercially available. Although purchase and use data are being collected on these vehicles, they are primarily owned by fleet operators, reflecting the desired attribute utilities of that market.

References for Appendix B

B-1. Thompkins, M. et al., "Determinants of Alternative Fuel Vehicle Choices in the Continental United States," 77th Annual Meeting of the Transportation Research Board, Washington D.C., January 1998.

B-2. Greene, David L. 1997. Survey Evidence on the Importance of Fuel Availability to Choice of Alternative Fuels and Vehicles, Published with permission of the author.