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Service Report

The Impacts of Increased Diesel Penetration in the Transportation Sector

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For Further Information

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Preface

This study was requested by Thomas J. Gross, Deputy Assistant Secretary for Transportation Technologies, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy. The Energy Information Administration (EIA) was requested to analyze the impacts on petroleum prices of increased demand for diesel fuel stemming from an increase in the penetration of diesel-fueled engines in the light-duty vehicle fleet. Three cases were requested, each of which was defined in terms of diesel technology increasing its penetration of new light duty vehicle LDV sales to 10, 20, and 30 percent, respectively, by the year 2010. By assumption, those sales reduced sales shares of new gasoline-powered vehicles, maintaining or increasing the sales of alternate fuel vehicles. In subsequent discussions with staff of the Office of Transportation Technologies (OTT), the analysis was extended to include the impacts on refinery profitability, and to add a case which showed the impacts of reducing the sulfur content of diesel fuel for LDVs.

This report presents the methodology and results of the analysis, based on the assumptions provided by OTT. The National Energy Modeling System (NEMS), EIA's mid-term energy forecasting model, was used for analysis of the cases. The version of NEMS developed for the *Annual Energy Outlook 1998 (AEO98)* was modified to incorporate the requested assumptions. The analysis in this report compares the case results for prices, demand, and profits to the reference case published in the AEO98.

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Executive Summary

This study was undertaken at the request of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Office of Transportation Technologies (OTT). OTT requested that EIA examine the impacts on supply and prices of assumed increased penetration of diesel fuel in the U.S. transportation sector. Specifically, OTT requested that EIA examine cases in which diesel technology penetrated new U.S. light duty vehicle (LDV) sales at rates of 10, 20, and 30 percent by 2010. In addition, it was requested that EIA analyze a 30-percent penetration case in which the diesel fuel required would have a sulfur content of 50 parts per million (ppm) compared to the current specification of 500 ppm, in order to examine some of the impacts of requiring a much lower-sulfur diesel fuel. In each of these cases, OTT requested that EIA assume that the diesel technology to be used is 50 percent more efficient than that of conventional gasoline-powered internal combustion engines, based on the best currently available technology. The primary reason for the request was to assist in the measurement of costs and benefits of OTT's programs, as required by the Government and Performance Results Act of 1993, the National Performance Review's Performance Agreements with the President, and Executive Order 12862 on setting Customer Service Standards.

Results

The primary results for each of the four cases are compared with the reference case in Table ES1. The reference case for this study is that appearing in the *Annual Energy Outlook 1998*.

Diesel consumption in the transportation sector is as high as 4.54 million barrels per day (mmbd) in 2020 with 30 percent sales of diesel-fueled LDVs, compared to 2.99 mmbd in the reference case. Conversely, motor gasoline consumption is lower in the 30-percent case (8.02 mmbd compared to 10.24 mmbd in the reference case), as consumers switch from gasoline to diesel fuel as a result of the increased penetration of diesel-fueled LDVs. Alternative-fuel vehicles (AFV) also are slightly higher than in the reference case, reaching about 0.47 million barrels per day oil equivalent (mmbdoe) in each of the three diesel penetration cases by 2020, about 0.06 mmbdoe above the reference case level. This is primarily due to further inroads of AFVs (especially those fueled by ethanol, methanol, and electricity) in the light-duty truck fleet, as the share of gasoline-powered trucks is reduced by assumption. In the low-sulfur diesel case, motor gasoline use is slightly higher, and diesel fuel consumption slightly lower, than in the 30-percent case in 2020. Because the price of diesel fuel with the more stringent sulfur specification is higher, there is less incentive for consumers to switch away from gasoline in this case. AFVs are also slightly lower than in the 30-percent case, since there is a smaller non-gasoline market in which to compete.

Because total demand is lower for the diesel penetration cases, net imports of crude oil and petroleum products are also lower. The United States would continue to be dependent upon imports for more than half of its petroleum supply under these cases, but the dependence would be less than in the reference case. In the 30-percent case by 2020, total net imports are 0.70

mmbd lower than in the reference case, a savings of more than 4 percent. Because a larger share of imports is expected to come from finished products by 2020, most of the reduction in imports (0.59 mmbd) is due to lower product imports, primarily motor gasoline. Crude imports in the 30-percent case are only 0.11 mmbd below the reference case. In the low-sulfur diesel case, because prices for diesel fuel are higher, there is correspondingly less incentive to shift out of motor gasoline. As a result, net imports of product are higher (0.08 mmbd) than in the 30-percent penetration case, only partially offset by slightly lower (0.04 mmbd) net crude imports. In this case, domestic refineries would be expected to supply most of the low-sulfur diesel fuel, requiring continuing imports of crude oil.

Prices for motor gasoline, diesel fuel, and crude oil are all lower in 2020 in each of the diesel penetration cases as compared with the reference case, with the exception of diesel prices in the low-sulfur diesel case. For motor gasoline, both the cost of the feedstock (crude oil) as well as the incremental processing costs associated with motor gasoline production, would be lower as a result of the lower percentage of motor gasoline produced by refineries. Diesel fuel prices also respond to the lower crude oil prices, but the difference from the reference case is not as great because the cost of processing rises as more diesel fuel must be produced. Motor gasoline prices in the 30-percent case are about 10 cents per gallon (in real 1996 terms) below the reference case by 2020, while diesel fuel prices are only about 1.5 cents per gallon lower. Crude oil prices, assumed to be set in world oil markets, are about 87 cents per barrel, or about 2 cents per gallon, lower in the 30-percent case compared to the base case. Thus, while the refiner margin for motor gasoline would be as much as 8 cents per gallon lower in the 30-percent case than in the reference case, diesel fuel margins are expected to remain relatively flat compared to the reference case, reflecting the lower cost of converting refineries to produce more distillate fuel compared to the cost of upgrading equipment to produce a higher yield of motor gasoline.

Both economic output and carbon emissions are expected to show small changes as a result of higher diesel penetration. Gross domestic product (GDP) shows a slightly higher level in each of the diesel penetration cases in 2020 compared with the reference case. This reflects the benefit to the economy of lower energy prices, particularly those for gasoline. It should be noted, however, that this study does not take into account all of the effects that might arise from a higher level of diesel demand, such as the impacts on suppliers of equipment to refineries, the feedback effects due to trade, or the tax revenue consequences of lower petroleum prices. It is not clear whether the ultimate impact would be negative or positive for the economy; however, the first-order impacts of lower petroleum prices would be beneficial. Carbon emissions are lower in the diesel penetration cases by as much as 20 million metric tons in 2020 compared with the reference case, as the higher assumed efficiency of diesel-fueled LDVs reduces overall petroleum demand.

Table ES1. Summary Results from Reference and Four Diesel Penetration Cases (million barrels per day, except where noted)

	1996	2020 Reference Case	2020 10-percent Case	2020 20-percent Case	2020 30-percent Case	2020 Low-Sulfur Case[1]
Transportation Demand						
Motor Gasoline	7.73	10.24	9.51	8.78	8.02	8.22
Diesel Fuel	2.10	2.99	3.45	3.98	4.54	4.42
Alternative Fuels[2] (million barrels per day distillate equivalent)	0.02	0.41	0.47	0.47	0.47	0.42
Net Imports						
Crude Oil	7.40	11.65	11.83	11.62	11.54	11.50
Refined Petroleum Products	1.10	4.33	3.92	3.87	3.74	3.82
Production						
Motor Gasoline	7.65	9.34	8.97	8.57	7.93	8.12
Distillate[3]	3.32	3.79	4.21	4.48	4.99	5.07
Prices						
Motor Gasoline (1996 cents per gallon)	122.5	126.8	124.1	122.2	116.7	117.4
Transportation Diesel Fuel (1996 cents per gallon)	123.5	118.2	117.1	117.3	116.7	120.5
Crude Oil (1996 dollars per barrel)	20.64	22.32	21.97	21.72	21.45	21.63
Gross Domestic Product (billion chain-weighted 1992 dollars)	6928	10900	10903	10904	10908	10906
Carbon Emissions (million metric tons)	1463	1956	1949	1943	1936	1938

Sources: 1996: Transportation demand, net imports, production, and crude oil prices: Energy Information Administration (EIA), *Monthly Energy Review* (DOE/EIA-0035(98/04)); motor gasoline and diesel fuel prices, gross domestic product, and carbon emissions: *Annual Energy Outlook 1998* (DOE/EIA-0383(98), December 1997). **Projections**: EIA, AEO98 National Energy Modeling System runs AEO98B.D100197A, PCT10.D122997B, PCT20.D122997B, PCT30.D122997B, and P3S51DV.D020698A.

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[1] Assumes 30 percent diesel penetration.

[2] Includes alcohol fuels, compressed natural gas, electricity, and liquefied petroleum gas.

[3] Includes diesel and all other distillate products, such as residential heating oil.

Profitability of the refining industry could be affected by increased diesel penetration. Because the margins for motor gasoline are lower than those in the reference case, and the margins for diesel fuel are about the same, revenues are lower in these cases than they are in the reference case. However, because the processing of distillate products is less expensive than that of motor gasoline, there is less need to make costly investments than there would be in the more gasoline-intensive reference case. In all cases, refinery profits are higher by 2020 than in recent history, primarily because it is assumed that refiners would need approximately a 15-percent return on their investment to invest in expensive new upgrades for refineries, compared to a recent return of less than 10 percent. While there is a likelihood that refinery profits would suffer somewhat with a large reduction in motor gasoline production, the impact would probably not be severe in the 10- and 20-percent cases. Under the 30-percent case, it is possible that revenues would be reduced enough to cause some pressure to raise prices or reduce other costs in order to maintain the same level of viability as in the reference case. Under those circumstances, the prices shown in this analysis for the high-penetration case could be somewhat understated for diesel fuel.

The Impacts of Increased Diesel Penetration in the Transportation Sector

Introduction

The Office of Transportation Technologies (OTT), Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy (DOE), requested that the Energy Information Administration (EIA) analyze the impacts on petroleum prices, demand, and refinery operations of an increased demand for diesel fuel stemming from greater penetration of diesel-fueled engines in the light-duty vehicle (LDV) fleet of the U.S. transportation sector, compared with the Annual Energy Outlook 1998 reference case. This request was made as part of EE's "Quality Metrics" initiative, which is designed to collect a wide range of data and information required for the Government and Performance Results Act of 1993, the National Performance Review's Performance Agreements with the President, and Executive Order 12862 on setting Customer Service Standards. OTT also wanted the impacts to respond to inquiries from the White House, Congress, and other entities of DOE.

The specific cases that OTT requested EIA to analyze were as follows:

(1) Advanced diesel technology begins penetrating the market in 2003,[1] increasing to 10 percent of new LDV sales by 2010, and constant thereafter.

(2) Advanced diesel technology begins penetrating the market in 2003, increasing to 20 percent of new LDV sales by 2010, and constant thereafter.

(3) Advanced diesel technology begins penetrating the market in 2003, increasing to 30 percent of new LDV sales by 2010, and constant thereafter.

OTT also requested that the advanced diesel cases include a direct injection diesel technology with 50 percent higher fuel efficiency than an equivalent conventional gasoline engine. According to the Fuel Economy Guide,[2] current turbo direct injection diesel technology achieves approximately 63 percent higher fuel economy than a gasoline engine in the Volkswagen Jetta model, indicating that such high efficiency diesel engines are already commercially available.

[1]Although the original OTT request was to assume that penetration begins in 2000, during discussions with OTT staff it was decided to delay the onset of additional penetration until 2003, due to the short lead time.

[2]U.S. Department of Energy, Model Year 1998 Fuel Economy Guide, DOE/EE-0136, U.S. Government Printing Office, October 1997, (Washington D.C.)

By comparison, in the *Annual Energy Outlook 1998* (AEO98) reference case, the reference case for this report, penetration of diesel engines in 2010 is only about 0.3 percent of new sales of LDVs. Thus the requested cases represent a significant increase in the penetration of diesels in the LDV fleet beginning in 2003.

Methodology

This analysis was conducted using EIA's National Energy Modeling System (NEMS). NEMS is an integrated model that represents the supply, conversion, and end-use demand sectors in domestic energy markets. It also contains macroeconomic and international modules to incorporate the effects of economic factors and world oil markets. By balancing energy supply and demand, NEMS projects production, imports, consumption, and prices of energy through 2020. The transportation and industrial demand modules, the Petroleum Market Module, and the macroeconomic and international oil modules of NEMS were used in the preparation of this report.[3] The demand modules represent the consumption of energy to meet end-use sector requirements based on underlying factors governing the demand for energy, such as prices, gross domestic product (GDP), demographic factors, and the costs and performance characteristics of energy-consuming equipment (including automobiles). The demand modules provide regional results at the Census Division level. The PMM represents the conversion of crude oil to petroleum products and their distribution to end-use sectors, based on the costs and technical characteristics of refinery operations, the costs of distribution, and the demand for products, subject to refineries' engineering constraints. The PMM is a three-region model, consisting of the East Coast, the central United States (including the Gulf Coast), and California. The PMM provides prices of all petroleum products to the demand modules. Both the macroeconomic and international modules were also run for this analysis in order to incorporate feedback effects of increased diesel fuel penetration to economic growth and world oil prices. In addition, the industrial demand model was also run to determine the change in the mix of industrial fuel demand as a result of changing prices for distillate fuel.

In order to analyze the impacts of increased diesel fuel penetration, the following cases were developed:

Reference Case. The Reference Case in this report is the same as that prepared for the AEO98. The results in this case are based on the expected continuation of existing laws, regulations, and policies. This case serves as the comparison case for analyzing the impacts of increased diesel penetration beginning in 2003.

10-Percent Case. This case assumes that all aspects of the reference case are in effect, with the

[3] The remaining NEMS modules were not included because of expectations that results from those modules would not differ significantly from the reference case as a result of increased diesel penetration.

exception that penetration of new sales of LDVs by diesel-fueled engines are forced to 10 percent of all sales by 2010 (ramping up from reference case values starting in 2003). In particular, the availability of imports of refined petroleum products, the configuration of refineries, and the quality of diesel fuel produced by domestic refiners are all assumed to remain the same. Light-duty vehicle sales are set to achieve the assumed diesel penetration levels, and AFV sales are held the same as the AEO98 reference case level (8 percent by 2020). Because the purpose of these model runs was to assess the impacts of various levels of diesel vehicle sales penetration, diesel vehicle attributes were not altered, with the exception of increasing the diesel fuel economy level to 50 percent above comparable conventional gasoline fuel economy levels, as requested by OTT.

20-, 30-Percent Cases. Each of these cases was exactly the same as above, except that diesel-fueled sales of LDVs were ramped to 20 and 30 percent, respectively, by 2010. Again, all other aspects of the transportation and refinery model assumptions were unchanged, with the exception of the fuel economy level for diesel.

Low-Sulfur Diesel Case. In this case, all of the assumptions of the 30-Percent case were combined with the assumption that the maximum sulfur content for diesel fuel for LDVs would be 50 parts per million (ppm), compared to 500 ppm in the other cases. This case was run to show the impact of requiring a low-sulfur diesel fuel to enable the use of catalytic converters to reduce emissions of oxides of nitrogen that would result from higher diesel fuel demand. Additionally, product imports for 50 ppm diesel were not made available, while imports of 500 ppm diesel and other distillate were made available at the same price and volume as in the 30 percent case. Imported ultra-low sulfur diesel was not incorporated because there is currently no reliable data upon which to make any assumptions concerning the price at which the imported product would be available. Therefore, the prices for ultra-low sulfur diesel reflect the marginal cost at the average U.S. refiner absent any international ultra-low sulfur diesel supply effect.

Transportation Fuel Consumption

Total transportation sector fuel consumption is lower with increasing penetration levels of diesel vehicle sales across the cases. Table 1 indicates that total transportation fuel consumption is as much as 0.34 million barrels per day oil equivalent (mmbdoe)[4] lower for the 30 percent diesel sales share case by 2020 compared with the reference case, with smaller differences for the 10 and 20 percent cases. Gasoline consumption is as much as 2.0 mmbdoe lower than the reference case by 2020 (Figures 1A and 1B). Gasoline consumption is displaced with distillate fuel use,

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[4]Quantities in the text have been converted from quadrillion Btu, as shown in the tables, to million barrels per day oil equivalent, using the conversion factor 5.8 million Btu/barrel.

Figure 1A. Transportation Fuel Consumption, 2010

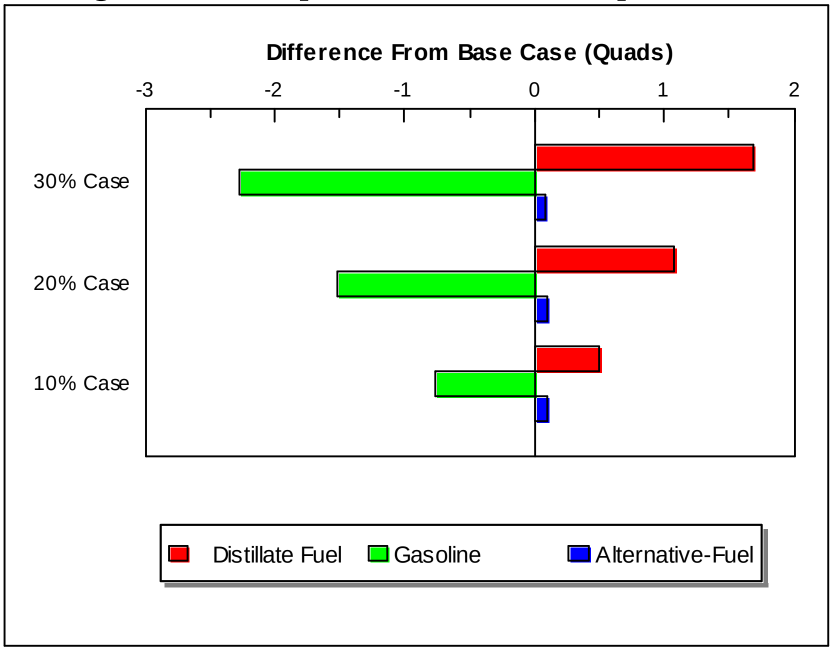
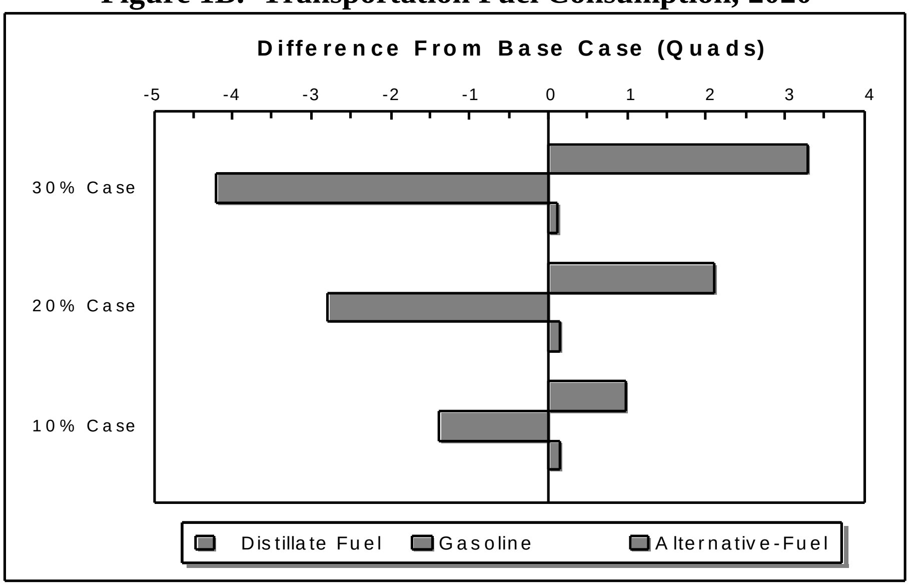


Figure 1B. Transportation Fuel Consumption, 2020



which is 1.55 mmbdoe higher than the reference case in 2020 in the 30 percent case. Additional displacement of gasoline consumption results from slightly higher alternative-fuel consumption of about 0.06 mmbdoe in 2020 in the 30-percent case (Table 1). Total petroleum use in the transportation sector is as much as 0.43 mmbdoe lower by 2020 at 30 percent penetration levels

Table 1. **Energy Consumption by Source and Related Statistics**
(Quadrillion Btu per Year, Unless Otherwise Noted)

Source	2000				2010				2015				2020			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Transportation																
Distillate Fuel	5.14	5.14	5.14	5.14	6.02	6.52	7.10	7.70	6.19	7.00	7.93	8.91	6.31	7.29	8.41	9.59
Jet Fuel	3.83	3.84	3.84	3.84	5.23	5.23	5.23	5.24	5.79	5.79	5.80	5.80	6.28	6.29	6.29	6.30
Motor Gasoline	15.96	15.96	15.96	15.96	18.22	17.46	16.70	15.95	18.84	17.65	16.48	15.26	19.38	18.00	16.60	15.16
Residual Fuel................	0.94	0.94	0.94	0.94	1.27	1.27	1.27	1.27	1.42	1.42	1.42	1.42	1.56	1.56	1.56	1.56
Liquefied Petroleum Gas......	0.04	0.04	0.04	0.04	0.16	0.17	0.17	0.17	0.20	0.23	0.22	0.22	0.24	0.26	0.26	0.25
Other Petroleum	0.31	0.31	0.31	0.31	0.35	0.35	0.35	0.35	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.38
Petroleum Subtotal.........	26.22	26.22	26.22	26.22	31.25	31.01	30.83	30.68	32.80	32.45	32.22	31.98	34.14	33.77	33.49	33.24
Pipeline Fuel Natural Gas....	0.80	0.80	0.80	0.80	0.95	0.95	0.95	0.95	0.99	0.99	0.99	0.99	1.03	1.03	1.03	1.03
Compressed Natural Gas.......	0.05	0.05	0.05	0.05	0.24	0.25	0.24	0.24	0.30	0.31	0.30	0.30	0.34	0.35	0.34	0.34
Renewables (E85)	0.00	0.00	0.00	0.00	0.09	0.12	0.12	0.11	0.13	0.18	0.18	0.17	0.16	0.20	0.21	0.20
Methanol	0.00	0.00	0.00	0.00	0.08	0.11	0.11	0.11	0.13	0.17	0.17	0.17	0.15	0.20	0.20	0.20
Liquid Hydrogen.............	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electricity.................	0.06	0.06	0.06	0.06	0.16	0.18	0.18	0.18	0.19	0.22	0.22	0.22	0.22	0.25	0.25	0.25
Delivered Energy..........	27.14	27.15	27.15	27.15	32.77	32.62	32.43	32.27	34.54	34.32	34.08	33.82	36.04	35.81	35.53	35.25
Electricity Related Losses...	0.14	0.14	0.14	0.14	0.32	0.36	0.36	0.36	0.37	0.42	0.42	0.43	0.41	0.46	0.47	0.47
Total.....................	27.28	27.29	27.29	27.29	33.09	32.98	32.79	32.64	34.91	34.74	34.51	34.25	36.45	36.27	35.99	35.72
Energy Use & Related Statistics																
Delivered Energy Use.........	74.88	74.89	74.89	74.89	85.19	84.98	84.72	84.45	88.50	88.18	87.81	87.45	90.95	90.62	90.24	89.79
Total Energy Use.............	99.8	99.8	99.8	99.8	112.2	111.9	111.7	111.4	115.7	115.4	115.0	114.7	118.5	118.2	117.9	117.4
Population (millions).........	275.6	275.6	275.6	275.6	298.9	298.9	298.9	298.9	311.2	311.2	311.2	311.2	323.5	323.5	323.5	323.5
US GDP (billion 1992 dollars).	7653	7653	7653	7653	9431	9433	9434	9437	10211	10213	10216	10218	10900	10903	10904	10908
Tot. Carbon Emis.(mill m. ton)	1577	1577	1577	1577	1803	1799	1795	1791	1888	1882	1876	1870	1956	1949	1943	1936

AEO98 Reference Case (1), 10-percent Diesel Penetration case (2), 20-percent Diesel Penetration Case (3), and 30-percent Diesel Penetration Case (4).

Source: Energy Information Administration, AEO98 National Energy Modeling System runs AEO98B.D100197A, PCT10.D122997B, PCT20.D122997B, AND PCT30.D122998B.

for diesel, compared with reference case levels. The difference between total petroleum demand and total transportation demand is due to the increase in AFV consumption, together with the increase in the associated losses for electricity-related consumption.

Total transportation consumption is lower than in the reference case because of the higher efficiency of diesel-fueled engines. In the reference case, the overall efficiency of the LDV fleet is approximately 20.7 miles per gallon (mpg) in 2010, rising to 21.2 mpg by 2020. In the diesel penetration cases, because of the assumption that diesel engines are 50 percent more efficient than conventional gasoline engines, the 2020 fleet efficiency rises to as high as 23.0 mpg in the 30-percent penetration case. New gasoline-powered cars average 29.0 mpg in 2020 in the 30-percent case, with new diesel-powered cars averaging 44.1 mpg. For light-duty trucks, the corresponding efficiencies are 20.5 mpg for gasoline-powered engines, and 30.3 for diesel-fueled new trucks.

The mix of fuel consumption in 2020 results in a reduction in gasoline's share of total transportation fuel, from 54 percent in the reference case, to as low as 43 percent in the 30-percent penetration case. At the same time, the use of distillate fuel in transportation is higher, with the share going from 18 percent in the reference case to as high as 27 percent in the 30-percent penetration case by 2020. Although petroleum consumption is lower in all cases, petroleum as a percent of total transportation sector fuel use remains relatively unchanged at approximately 94 percent in 2020.

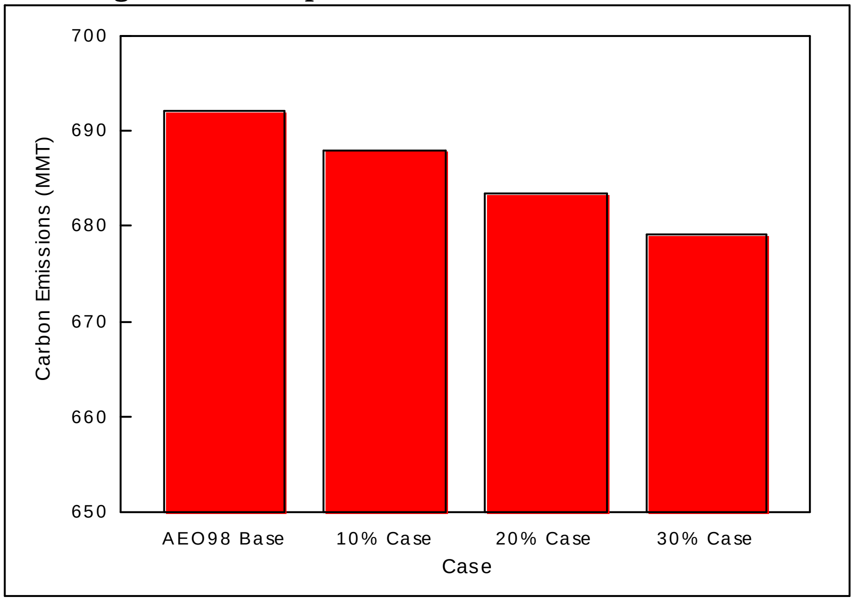
Carbon Emissions

Transportation sector carbon emissions (Figure 2) are slightly lower across the cases, by as much as 13 million metric tons (mmt) compared with the reference case by 2020, in the 30-percent penetration case. This represents less than 2 percent of the sector's reference case emissions. Refinery fuel consumption (included in the industrial sector) is also up to 0.227 mmbdoe lower in 2020 compared with the reference case, resulting in total carbon reductions--including those in the transportation sector--of as much as 20 mmt in 2020. Refinery fuel consumption falls because of the reduced still gas consumption needed to meet the revised slate of petroleum product demands.

Macroeconomic Feedback

Table 1 includes the macroeconomic impacts due to the assumptions of increased diesel fuel penetration. In general, there is a net economic benefit due to the increased penetration of diesel-fueled LDVs, because world oil prices and other petroleum prices are slightly lower as a result of the decreased overall demand for petroleum products. Real GDP is less than 0.1 percent higher than the reference case ($8.5 billion in real 1992 dollars) in the 30 percent case by 2020. Real disposable personal income (DPI) also changes very little compared with the reference case in 2020, with an additional $11.3 billion (0.14 percent of DPI) in the 30 percent case. It should be

Figure 2. Transportation Carbon Emissions, 2020



noted, however, that this study does not take into account all of the effects that might arise from a higher level of diesel demand, such as the impacts on suppliers of equipment to refineries, the feedback effects due to trade, or the tax revenue consequences of lower petroleum prices. It is not clear whether the ultimate impact would be negative or positive for the economy; however, the first-order impacts of lower petroleum prices would be beneficial.

Vehicle Sales

Total vehicle sales in 2020 are slightly higher due to the higher DPI levels. Approximately 105,000 additional units are sold in the 30 percent case. Gasoline vehicle sales (Table 2) in 2020 are lower as a result of the displacement by diesel vehicles. In the 10 percent case gasoline vehicle sales are almost 1.5 million units lower than in the reference case, or approximately 720,000 cars and 763,000 light trucks by 2020. More drastic reductions in gasoline vehicle sales occur in the 20 and 30 percent cases with reductions of over 3.0 million units (1.57 million cars and 1.47 million light trucks) and almost 4.6 million units (2.41 million cars and 2.17 million light trucks), in the two cases respectively. The loss in gasoline vehicle sales is more than offset by the increase in diesel light-duty vehicle sales. Almost 4.6 million (2.52 million cars and 2.05 million light trucks) more diesel vehicles are sold in the 30 percent diesel case, compared with the reference case.

Table 2. Light-Duty Vehicle Sales by Technology Type (Thousands)

Technology Type	2000				2010				2015				2020			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
New Car Sales																
Conventional Vehicles																
Gasoline ICE Vehicles........	6833	6835	6835	6835	6538	5853	5054	4246	6777	6071	5240	4399	6912	6192	5344	4501
Distillate (diesel) ICE......	46.2	52.5	52.5	52.5	16.9	739.6	1557	2399	17.8	778.9	1620	2489	18.3	792.8	1659	2539
Total Conventional............	6879	6887	6887	6887	6555	6593	6611	6645	6795	6849	6860	6888	6930	6985	7003	7041
Total Alternative Fuel Vehicles	119.3	119.4	119.4	119.4	813.7	789.0	776.0	752.8	845.5	809.3	800.0	774.7	859.3	822.4	806.7	775.0
Percent Alternative Car Sales..	1.71	1.70	1.70	1.70	11.04	10.69	10.50	10.18	11.07	10.57	10.44	10.11	11.03	10.53	10.33	9.92
Total New Car Sales...........	6998	7007	7007	7007	7369	7382	7387	7398	7640	7659	7660	7663	7789	7807	7810	7816
New Light-Truck Sales																
Conventional Vehicles																
Gasoline ICE Vehicles........	5550	5549	5549	5549	6131	5394	4722	4036	6259	5510	4830	4124	6389	5626	4924	4223
Distillate (diesel) ICE......	24.3	40.4	40.4	40.4	21.1	592.9	1274	1988	22.0	615.4	1304	2031	22.7	626.5	1339	2074
Total Conventional............	5574	5590	5590	5590	6152	5987	5996	6024	6281	6125	6134	6155	6411	6252	6263	6297
Total Alternative Fuel Vehicles	85.5	87.6	87.6	87.6	301.1	512.0	508.0	494.3	301.9	514.4	513.6	499.3	303.1	521.8	516.6	497.6
Percent Alternative L.T. Sales..	1.51	1.54	1.54	1.54	4.67	7.88	7.81	7.58	4.59	7.75	7.73	7.50	4.51	7.70	7.62	7.32
Total New Truck Sales..........	5660	5677	5677	5677	6453	6499	6504	6518	6583	6639	6648	6654	6714	6774	6779	6794
Percent Total Alternative Sales.	1.62	1.63	1.63	1.63	8.07	9.37	9.24	8.96	8.07	9.26	9.18	8.90	8.01	9.22	9.07	8.71
Total Vehicle Sales............	12658	12684	12684	12684	13822	13881	13891	13916	14223	14298	14308	14317	14504	14581	14589	14610

AEO98 Reference Case (1), 10-percent Diesel Penetration case (2), 20-percent Diesel Penetration Case (3), and 30-percent Diesel Penetration Case (4).

Source: Energy Information Administration, AEO98 National Energy Modeling System runs AEO98B.D100197A, PCT10.D122997B, PCT20.D122997B, AND PCT30.D122998B.

Fuel Economy

Diesel fuel efficiencies are assumed to be 50 percent higher than gasoline vehicles in all years (Table 3). When combined with the additional diesel vehicle sales, new car fuel economy in as much as 4.26 mpg higher in 2020 in the 30-percent case, compared with the reference case. New light truck fuel economy is 3.11 mpg above the reference case by 2020 in the 30-percent case. However, because of the slow turnover of the entire stock of vehicles, the improvement in the fleet is much less dramatic. By 2020, average fleet car economy is 1.72 mpg above the reference case in the 30-percent penetration case, with the corresponding truck fleet economy 1.73 mpg higher.

Why Fuel Consumption is Higher than Expected: "Shortfall" Effects

"Shortfall" refers to the fact that the total reduction in consumption as a result of the increased penetration of new diesel-fired vehicles, together with the improved efficiency of those engines, is not as great as would be expected[5] from a first-order calculation of the impacts. Even assuming reference case VMT and other factors, the factors discussed below mitigate the reduction. Although new car mpg and new light truck mpg are higher than in the reference case, these new fuel economy improvements from higher diesel sales penetration levels do not result in identically equivalent improvements in light-duty vehicle "on the road" stock mpg. Several factors that result in this "shortfall" effect can be traced back to lower gasoline prices, higher DPI, and slow turnover of the vehicle stock. In addition, because VMT is a function of the cost per mile of driving, higher efficiencies and lower fuel prices increase VMT in the diesel penetration cases, further mitigating the benefits of the high-efficiency diesel engines. Each of these factors is discussed in turn.

1) "On the Road" Fuel Efficiency Effects

The net effect of the "shortfall" phenomena results in "on the road" stock mpg that is higher than the reference case, but not as high as new vehicle efficiencies. On the road stock efficiencies are only as much as 1.77 mpg higher for the 30-percent penetration case by 2020, compared to the reference case. This represents less than half of the corresponding new vehicle fuel economy improvement by 2020.

[5]"Expected" fuel savings were calculated as follows: Reference case LDV fuel consumption in the transportation sector in 2020 is 19.20 quads. If there were a full 30 percent penetration in the LDV stock (as opposed to LDV sales) by diesel vehicles in 2020, they would represent 30 percent of that consumption, or 5.76 quads. Since by assumption diesel engines are 50 percent more efficient than gasoline engines (or 1.5 times as efficient), consumption would be only two-thirds (the inverse of 1.5) the consumption in the reference case, or 3.84 quads. The difference between the reference case and diesel-adjusted consumption is therefore 1.92 quads, which represents "expected" savings in Table 10.

Table 3. Light-Duty Vehicle MPG by Technology Type (MPG Gasoline Equivalents)

Technology Type	2000					2010					2015					2020			
	(1)	**(2)**	**(3)**	**(4)**		**(1)**	**(2)**	**(3)**	**(4)**		**(1)**	**(2)**	**(3)**	**(4)**		**(1)**	**(2)**	**(3)**	**(4)**
Conventional Vehicles																			
Gasoline ICE Vehicles..........	27.93	27.93	27.93	27.93		29.63	29.51	29.38	29.03		29.84	29.72	29.33	28.95		30.1	29.93	29.64	29.04
Distillate (diesel) ICE........	29.93	42.83	42.83	42.83		30.12	43.43	43.89	44.03		30.25	43.70	43.80	43.95		30.39	43.88	44.22	44.08
Average New Car MPG............	27.95	28.03	28.03	28.03		30.25	31.47	33.13	34.92		30.46	31.72	33.10	34.87		30.73	31.93	33.47	34.99
Light-Duty Trucks																			
Conventional Vehicles																			
Gasoline ICE Vehicles..........	19.25	19.25	19.25	19.25		20.00	19.95	19.93	19.78		20.43	20.38	20.21	20.06		21.00	20.91	20.82	20.54
Distillate (diesel) ICE........	19.98	29.21	29.21	29.21		20.59	28.66	29.04	29.20		21.07	29.32	29.48	29.62		21.66	30.07	30.35	30.31
Average New Truck MPG...........	19.26	19.32	19.32	19.32		20.06	21.01	22.10	23.29		20.49	21.48	22.42	23.62		21.06	22.03	23.10	24.17
Fleet Average Stock Car MPG	22.62	22.64	22.64	22.64		23.57	23.89	24.26	24.63		24.20	24.64	25.14	25.67		24.71	25.24	25.81	26.43
Fleet Average Stock Truck MPG ..	16.05	16.07	16.07	16.07		15.69	16.09	16.52	16.97		15.94	16.47	17.02	17.64		16.29	16.85	17.39	18.02
Fleet Aver. Stock Vehicle MPG ..	20.31	20.33	20.33	20.33		20.33	20.70	21.12	21.54		20.74	21.24	21.78	22.38		21.19	21.74	22.32	22.97

AEO98 Reference Case (1), 10-percent Diesel Penetration case (2), 20-percent Diesel Penetration Case (3), and 30-percent Diesel Penetration Case (4).

Source: Energy Information Administration, AEO98 National Energy Modeling System runs AEO98B.D100197A, PCT10.D122997B, PCT20.D122997B, AND PCT30.D122998B.

Within each of the three diesel cases (Table 4), new car and new light truck efficiency is "degradated" to reach the "on the road" new efficiency, which is lower than the rated efficiency by approximately 16 percent for cars and 21 percent for light trucks. These efficiency losses reflect the "degradation factor", which accounts for the difference between EPA rated new fuel economy and actual "on the road" efficiency.[6] Degradation factor components consist of elements such as the ratio of city to highway travel, road congestion, and average highway speed.

Table 4. On the Road MPG Losses For Three Diesel Cases, 2020

	New Sales (thousand)	New Sales Shares (percent)	New Vehicle MPG	"On the Road" New Vehicle MPG	"On the Road" Stock MPG
Reference Case					
Cars	7,789	53.71	30.73	25.79	24.71
Light Trucks	6,714	46.29	21.06	16.65	16.29
Combined	14,504	100.00	25.36	20.56	21.19
10% Case					
Cars	7,807	53.54	31.93	26.80	25.24
Light Trucks	6,774	46.46	22.03	17.36	16.85
Combined	14,581	100.00	26.38	21.39	21.74
20% Case					
Cars	7,810	53.53	33.47	28.14	25.81
Light Trucks	6,779	46.47	23.10	18.23	17.39
Combined	14,589	100.00	27.70	22.46	22.32
30% Case					
Cars	7,816	53.50	34.99	29.40	26.43
Light Trucks	6,794	46.50	24.17	19.09	18.02
Combined	14,610	100.00	28.98	23.50	22.97

a) Stock Turnover Effects

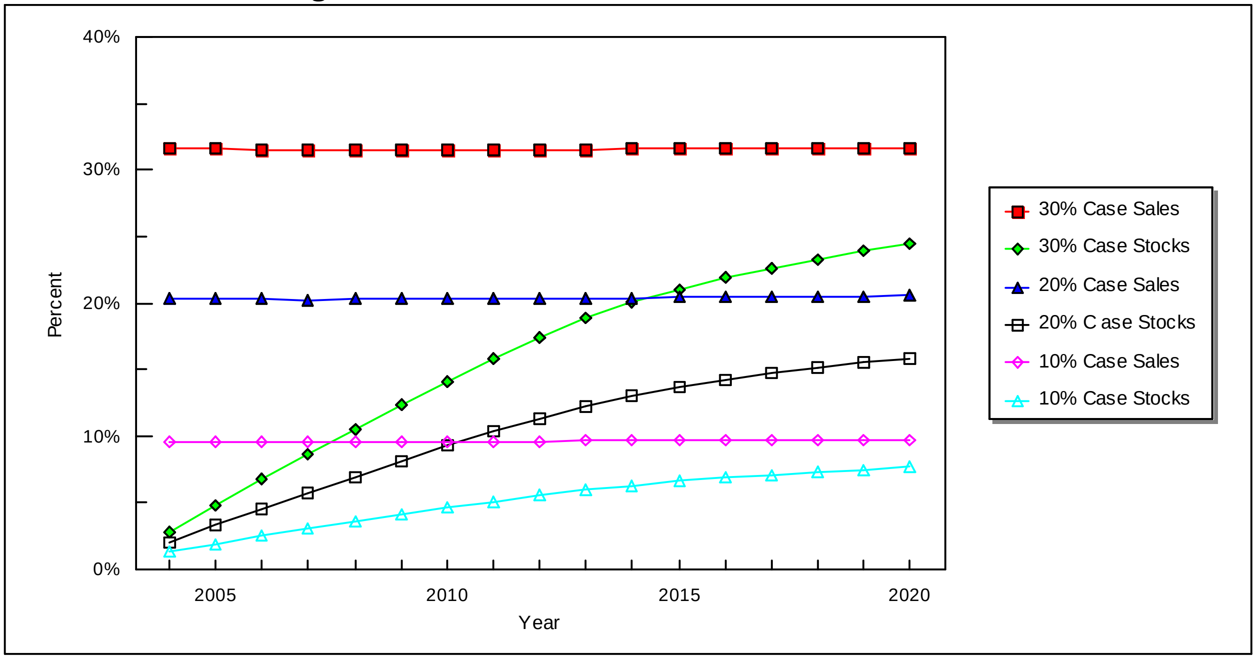
An important factor in the "shortfall" effect of stock efficiency relative to new vehicle fuel efficiencies is the slow turnover in the vehicle stock. To illustrate this phenomenon, Table 4 displays harmonically sales weighted average efficiencies for combined new light-duty vehicles for each of the three diesel cases. Comparisons between the combined "on the road" new mpg and "on the road" stock mpg can be attributed to the slow turnover in the stock, because older vehicles have a lower efficiency than that assumed for new vehicles. Table 4 shows the new fuel efficiencies for 2020 only, but prior to 2020 the new vehicle fuel efficiencies are lower (because gasoline-powered engine efficiencies are lower than diesel-powered, and because new cars improve in efficiency every model year), and these vehicles leave the stock very slowly. Even after 10 years, 75 percent of all cars, and 81 percent of all light trucks purchased in a given year are still on the road.[7] Although the assumptions for the runs included reaching diesel sales

[6] Decision Analysis Corporation of Virginia, *Fuel Efficiency Degradation Factors*, prepared for the Energy Information Administration, Final Report, Subtask 1, August 3, 1992.

[7] U.S. Department of Energy, prepared by Oak Ridge National Laboratory, Transportation Energy Databook: Edition #17, ORNL-6919, pg. 3-9 and 3-10, August 1997, (Oak Ridge, Tennessee).

"on the road" stock mpg can be attributed to the slow turnover in the stock, because older vehicles have a lower efficiency than that assumed for new vehicles. Table 4 shows the new fuel efficiencies for 2020 only, but prior to 2020 the new vehicle fuel efficiencies are lower (because gasoline-powered engine efficiencies are lower than diesel-powered, and because new cars

Figure 3. Diesel Vehicle Sales & Stocks, 2004-2020



improve in efficiency every model year), and these vehicles leave the stock very slowly. Even after 10 years, 75 percent of all cars, and 81 percent of all light trucks purchased in a given year are still on the road.[7] Although the assumptions for the runs included reaching diesel sales penetration levels of 10, 20, and 30 percent of total light-duty vehicle sales by 2010, these same levels are not attained in the vehicle stock. As shown in Table 5 and Figure 3, by 2020 diesel vehicle stocks are as much as 24 percent of total vehicle stock in the 30-percent case, compared with less than 0.5 percent in the reference case.

b) Horsepower (HP)/Performance Effects

With rising income levels from the positive macroeconomic feedback effects and falling gasoline prices, horsepower (HP) or performance demanded is above the reference case in all three cases (Table 6). Consumers choose higher HP within each size class for both cars and light trucks. Automobile HP is up to 11.12 HP higher than the reference case across the cases by 2020.

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[7]U.S. Department of Energy, prepared by Oak Ridge National Laboratory, Transportation Energy Databook: Edition #17, ORNL-6919, pg. 3-9 and 3-10, August 1997, (Oak Ridge, Tennessee).

Table 5. Light-Duty Vehicle Stock by Technology Type (Millions)

Technology Type	2000				2010				2015				2020			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Light-Duty Car Stock																
Conventional Vehicles																
Gasoline ICE Vehicles..........	132.0	132.0	132.0	132.0	136.7	132.2	127	121.6	139.7	132.5	124.1	115.6	142.9	133.6	122.7	111.7
Distillate (diesel) ICE........	1.04	1.08	1.08	1.08	0.85	5.61	10.95	16.47	0.75	8.38	16.91	25.76	0.68	10.6	21.69	33.17
Total Conventional.............	133	133.1	133.1	133.1	137.6	137.8	137.9	138.1	140.5	140.9	141.1	141.3	143.6	144.2	144.4	144.8
Total Alternatives.............	0.4	0.41	0.41	0.41	5.96	5.84	5.78	5.64	8.97	8.71	8.6	8.36	11.37	11	10.82	10.49
Total Car Stock.................	133.4	133.5	133.5	133.5	143.5	143.7	143.7	143.7	149.4	149.6	149.7	149.7	155	155.2	155.3	155.3
Light-Duty Truck Stock																
Conventional Vehicles																
Gasoline ICE Vehicles..........	50.68	50.67	50.67	50.67	63.81	58.95	54.51	49.92	67.4	59.74	52.77	45.53	69.82	61.35	53.64	45.66
Distillate (diesel) ICE........	0.19	0.27	0.27	0.27	0.25	4.06	8.52	13.23	0.24	6.22	13.27	20.73	0.25	6.91	14.73	23
Total Conventional.............	50.87	50.94	50.94	50.94	64.06	63.01	63.03	63.14	67.64	65.96	66.04	66.27	70.07	68.26	68.38	68.65
Total Alternatives.............	0.32	0.33	0.33	0.33	2.43	3.79	3.78	3.69	3.20	5.37	5.35	5.20	3.41	5.84	5.79	5.61
Total Truck Stock..............	51.19	51.27	51.27	51.27	66.48	66.8	66.81	66.84	70.85	71.33	71.39	71.47	73.48	74.09	74.16	74.27
Total Vehicle Stock............	184.6	184.7	184.7	184.7	210	210.5	210.5	210.5	220.3	221.0	221.0	221.2	228.5	229.3	229.4	229.6

AEO98 Reference Case (1), 10-percent Diesel Penetration case (2), 20-percent Diesel Penetration Case (3), and 30-percent Diesel Penetration Case (4).

Source: Energy Information Administration, AEO98 National Energy Modeling System runs AEO98B.D100197A, PCT10.D122997B, PCT20.D122997B, AND PCT30.D122998B.

Table 6. Summary of New Light-Duty Vehicle Size Class Attributes

Class Attributes	2000				2010				2015				2020			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Personal Vehicles																
New Fuel Efficiency EPA Rated																
Average New Car.............	28.55	28.55	28.55	28.55	30.46	30.49	30.55	30.43	30.76	30.81	30.60	30.46	31.11	31.11	31.04	30.67
Average New Car On-Road MPG..	24.45	24.45	24.45	24.45	25.61	25.64	25.69	25.58	25.85	25.89	25.73	25.60	26.15	26.16	26.09	25.77
Average New Light Truck......	19.47	19.47	19.47	19.47	20.21	20.22	20.27	20.21	20.64	20.66	20.56	20.48	21.22	21.20	21.18	20.97
Average New LT On-Road MPG...	15.67	15.67	15.67	15.67	15.95	15.96	16.00	15.95	16.29	16.31	16.23	16.16	16.74	16.73	16.71	16.54
Degradation Factors ..																
Cars.........................	0.856	0.856	0.856	0.856	0.841	0.841	0.841	0.841	0.840	0.840	0.841	0.841	0.840	0.841	0.841	0.840
Light Trucks................	0.805	0.805	0.805	0.805	0.789	0.789	0.789	0.789	0.789	0.789	0.789	0.789	0.789	0.789	0.789	0.789
Fleet Vehicles																
New Fuel Efficiency EPA Rated																
Cars.........................	26.25	26.25	26.25	26.25	27.61	27.48	27.43	27.27	27.62	27.50	27.24	27.08	27.69	27.51	27.34	27.02
Light Trucks................	18.77	18.71	18.71	18.71	19.56	19.41	19.37	19.27	19.98	19.82	19.65	19.54	20.53	20.33	20.23	20.00
Average On Road MPG																
Cars.........................	22.19	22.19	22.19	22.19	23.17	23.08	23.04	22.95	23.28	23.16	22.99	22.86	23.29	23.14	22.95	22.78
Light Trucks................	15.24	15.22	15.22	15.22	15.32	15.22	15.19	15.14	15.63	15.50	15.40	15.31	16.04	15.88	15.77	15.65
New Vehicle Sales Shares (%)																
Conventional Cars																
Minicompact.................	0.004	0.000	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Subcompact..................	0.107	0.107	0.107	0.107	0.104	0.103	0.103	0.102	0.102	0.102	0.101	0.100	0.101	0.100	0.100	0.099
Compact.....................	0.448	0.448	0.448	0.448	0.459	0.457	0.456	0.452	0.462	0.460	0.454	0.450	0.464	0.460	0.458	0.449
Mid-Size....................	0.295	0.295	0.295	0.295	0.285	0.286	0.287	0.290	0.282	0.284	0.289	0.292	0.280	0.283	0.285	0.292
Large.......................	0.137	0.137	0.137	0.137	0.139	0.140	0.140	0.142	0.140	0.141	0.144	0.145	0.141	0.143	0.144	0.147
Two Seater..................	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
Conventional Light Trucks																
Small Pickup................	0.072	0.072	0.072	0.072	0.069	0.070	0.070	0.071	0.069	0.069	0.070	0.071	0.068	0.069	0.069	0.071
Small Van...................	0.232	0.232	0.232	0.232	0.239	0.238	0.237	0.235	0.241	0.239	0.235	0.233	0.242	0.239	0.237	0.232
Small Utility...............	0.312	0.312	0.312	0.312	0.324	0.325	0.325	0.327	0.329	0.330	0.332	0.334	0.333	0.335	0.336	0.338
Large Pickup................	0.291	0.291	0.291	0.291	0.272	0.272	0.273	0.273	0.266	0.266	0.267	0.267	0.261	0.262	0.262	0.262
Large Van...................	0.032	0.032	0.032	0.032	0.030	0.030	0.030	0.030	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
Large Utility...............	0.062	0.062	0.062	0.062	0.065	0.065	0.065	0.065	0.066	0.066	0.066	0.066	0.067	0.067	0.067	0.067
New Vehicle Average Horse Power																
Average New Car...............	180.8	180.9	180.9	180.9	233.8	235.5	236.4	239.1	257.4	259.3	263.9	266.6	275.2	278.1	280.4	286.4
Average New Light Truck........	205.2	205.3	205.3	205.3	262.8	264.4	265.3	268.0	292.0	293.9	298.4	301.0	312.9	315.9	318.1	323.9

AEO98 Reference Case (1), 10-percent Diesel Penetration case (2), 20-percent Diesel Penetration Case (3), and 30-percent Diesel Penetration Case (4).

Source: Energy Information Administration, AEO98 National Energy Modeling System runs AEO98B.D100197A, PCT10.D122997B, PCT20.D122997B, AND PCT30.D122998B.

Similarly, light truck horsepower exceeds the reference case by as much as 11.0 HP for the 30-percent case in 2020. This reflects consumers' desire for more performance-oriented vehicles when purchasing power increases, either because the costs of the vehicles are reduced, or there is more disposable income available. Since efficiency is inversely related to HP, this effect causes lower efficiency relative to the reference case.

c) Size Class Consumer Purchase Shifting Effects

Higher income levels and lower gasoline prices also lead to consumer purchase shifts away from small vehicles and toward larger vehicles (Table 6). By 2020 consumers have shifted away from purchasing compacts and instead purchase more mid-size and large size cars. Less purchase shifting across size classes occurs within light trucks, where consumers purchase more small sport utility vehicles rather than small vans.

To summarize the above two effects, both performance and size class shifts cause new car and new light truck fuel economy to be lower than would be the case without these effects. All new car and light truck fuel efficiencies in 2020 are actually lower relative to reference case efficiency, by approximately 0.1 to 0.94 mpg (Table 3). Table 7 also illustrates the effects of performance and size class shifts on new fuel efficiencies for gasoline and diesel vehicles. Given the reference case new fuel economy levels for cars and light trucks in 2020, and combining this with the assumption in all three cases that diesel vehicles are 50 percent higher in new vehicle fuel economy, we show an expected diesel efficiency both with and without shifts in purchases to larger, higher performance vehicles. In each case, the actual new fuel efficiency for diesel

Table 7. New Fuel Economy Losses Due to Rising HP and Size Class Shifts, 2020

	Sales Share (percent)	MPG Without Shifts	MPG With Shifts
10% Case			
New Car			
Gasoline	90.00	30.10	29.93
Diesel	10.00	45.15	43.88
Combined	100.00	31.14	30.91
New Light Truck			
Gasoline	90.00	21.00	20.91
Diesel	10.00	31.50	30.07
Combined	100.00	21.72	21.57
20% Case			
New Car			
Gasoline	80.00	30.10	29.64
Diesel	20.00	45.15	44.22
Combined	100.00	32.25	31.73
New Light Truck			
Gasoline	80.00	21.00	20.82
Diesel	20.00	31.50	30.35
Combined	100.00	22.50	22.22
30% Case			
New Car			
Gasoline	70.00	30.10	29.04
Diesel	30.00	45.15	44.08
Combined	100.00	33.44	32.35
New Light Truck			
Gasoline	70.00	21.00	20.54
Diesel	30.00	31.50	30.31
Combined	100.00	23.33	22.74

vehicles is lower than the expected efficiency. A portion of the difference can be attributed to a lower actual efficiency for both gasoline and diesel (as a result of the increase in HP and size class shifting effects).

d) AFV Sales Effects

Although almost all new vehicle fuel efficiencies in the diesel penetration cases are lower than the reference case, due to rising HP, AFV fuel efficiencies are not as adversely affected as gasoline and diesel vehicles, because AFVs are inherently more efficient than vehicles powered by traditional fuels. The net result is a relative advantage in both fuel efficiency and vehicle range (a function of fuel efficiency, holding the fuel tank size constant), translating into higher AFV sales. AFV sales in 2020 are 182,000, 161,000, and 110,000 vehicles higher than the reference case total of 1.16 million vehicles, in the 10-, 20-, and 30-percent diesel penetration cases, respectively. Fuel efficiency gains cannot offset the rising HP effects across the cases, however, because AFV fuel prices are relatively equal across the diesel cases while income levels continue to spur HP demands. Therefore, AFV sales are lower the higher the diesel penetration (beyond the 10-percent penetration level), as the advantages of the fuel price effects on higher fuel efficiency are overcome by the countervailing force of the rise in HP. The total "shortfall" effect from higher AFV sales results in rising alternative-fuel consumption of as much as 0.709 mmbdoe in 2020 in the 10- and 20-percent cases compared with the reference case (Table 8).

2) VMT Effects

VMT rises slightly across the cases and is higher relative to the reference case with higher diesel penetration levels, because of the macroeconomic feedback effects of higher income levels and

Table 8. Light-Duty Vehicle Energy Consumption by Technology Type and Fuel Type (Trillion Btu)

Technology type	2000					2010					2015					2020			
	(1)	(2)	(3)	(4)		(1)	(2)	(3)	(4)		(1)	(2)	(3)	(4)		(1)	(2)	(3)	(4)
Light-Duty Consum. by Tech. Type																			
Conventional Vehicles ..																			
Gasoline ICE Vehicles..........	14855	14854	14854	14854		16992	16213	15455	14702		17519	16294	15130	13921		17935	16494	15109	13688
Distillate (diesel) ICE........	88.26	81.67	81.67	81.67		86.40	582.2	1160	1761		79.74	879.6	1810	2782		75.94	1047	2170	3347
Alternative-Fuel Vehicles																			
Total Alcohol..................	9.31	9.44	9.44	9.44		218.8	290.9	291.2	281		329.2	439.8	443.3	427.4		393	512.1	514.5	495.8
Total Natural Gas Technology...	73.4	75.93	75.93	75.93		373.2	397.8	389.2	381.7		479.4	517.7	503.3	489.3		553.6	598.6	579	560.8
Total Electricity.............	3.29	3.73	3.73	3.73		89.2	109.4	110.1	110.7		118.7	145.9	147.4	148.3		143.4	171.6	173.4	174.9
Total Turbine..................	0.0	0.0	0.0	0.0		0.01	0.01	0.01	0.01		0.2	0.42	0.41	0.39		0.82	1.77	1.75	1.67
Light-Duty Consum.by Fuel Type..																			
Motor Gasoline.................	14866	14865	14865	14865		17061	16302	15542	14784		17645	16458	15288	14068		18160	16775	15378	13938
Distillate (diesel)............	88.26	81.67	81.67	81.67		86.40	582.2	1160	1761		79.74	879.6	1810	2782		75.94	1047	2170	3347
Methanol.......................	4.29	4.41	4.41	4.41		83.28	113.7	113.5	109.1		127	173.8	174.6	167.2		154.4	204.9	204.7	195.1
Ethanol........................	3.34	3.33	3.33	3.33		88.12	115.8	116.1	112.3		132.2	175.9	177.5	172		156.8	205.0	206.6	200.7
Compressed Natural Gas.........	45.82	47.5	47.5	47.5		214.3	221.2	217.9	215.6		262.1	269.4	264.0	259.6		295.1	302.8	295.4	289.5
Liquid Petroleum Gas...........	27.5	28.34	28.34	28.34		139.5	152.3	150.2	148.1		182.3	204.1	200.7	196.7		212.6	239.2	234.3	229.0
Electricity....................	3.29	3.73	3.73	3.73		89.2	109.4	110.1	110.7		118.7	145.9	147.4	148.3		143.4	171.6	173.4	174.9

AEO98 Reference Case (1), 10-percent Diesel Penetration case (2), 20-percent Diesel Penetration Case (3), and 30-percent Diesel Penetration Case (4).

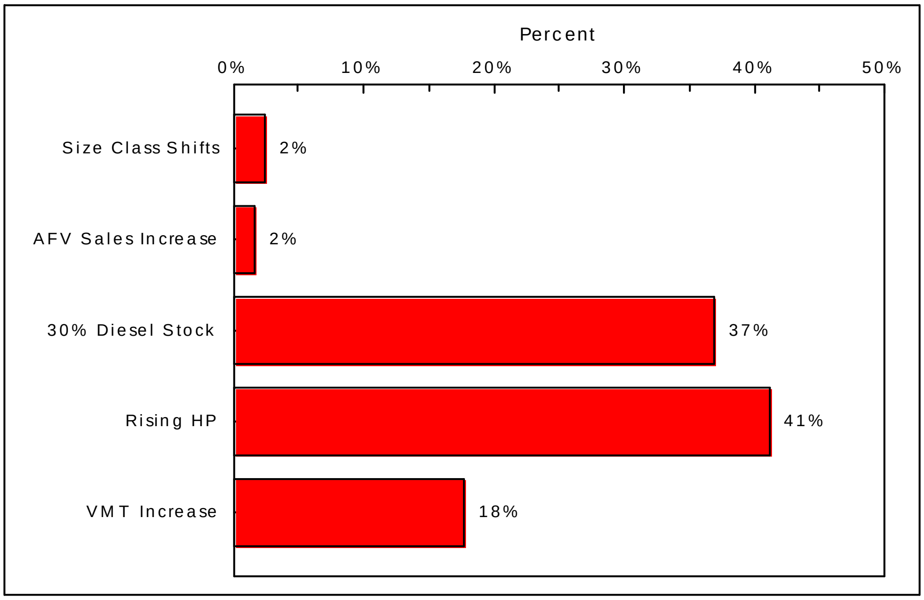
Source: Energy Information Administration, AEO98 National Energy Modeling System runs AEO98B.D100197A, PCT10.D122997B, PCT20.D122997B, AND PCT30.D122998B.

lower gasoline prices. Lower gasoline prices reduce the cost of driving, which increases VMT. By 2020 (Table 9) total VMT is higher by up to 25.53 billion miles (0.78 percent of total VMT) in the high penetration case, compared with the reference case.

Quantification and Distribution of "Shortfall" Effects

In order to provide an estimate of the quantitative effects of each "shortfall" phenomenon, a partial derivative methodology was used. Sequential runs of the model were made, changing one "shortfall" variable at a time. For example, one run was made in which VMT was held at reference case levels, with all other assumptions consistent with the 30-percent penetration case.

Figure 4. Energy Savings "Shortfall" Effects by Factor for 30 Percent Case, 2020



In this run, total consumption of diesel fuel was .065 mmbdoe (138 trillion Btu) lower than in the 30-percent case. This represents the "shortfall" effect due to increasing VMT. The net effect of each of the variables upon fuel consumption was then calculated relative to the reference case in the year 2020, and compared to "expected" savings of 1920 trillion Btu. The results are shown in Table 10 and Figure 4. This methodology is only an approximation, in that it ignores the effects of combining variables, and it assumes that there are no cross product effects. Since the individual contributions do not sum to the total "shortfall" they have been normalized in Table 10 on a proportional basis.

The largest "shortfall" effect, 41 percent, was attributed to the rise in horsepower that occurred in response to the lower gasoline price and the secondary macro-economic feedback effect of slightly higher income. Slow turnover in the stock, which effectively yielded only a 24 percent diesel stock penetration despite a 30 percent diesel sales penetration by 2020, contributed 37

Table 9. Transportation Sector Key Indicators and Delivered Energy Consumption

Key Indicators and Consumption	2000				2010				2015				2020			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Key Indicators																
Level of Travel (billions)																
Light-Duty Veh.<8500 lbs.(VMT).	2454	2454	2454	2454	2892	2897	2901	2908	3077	3083	3092	3099	3242	3250	3257	3268
Commercial Light Trucks(VMT) ..	72	72	72	72	87	87	87	88	93	93	93	93	98	98	98	98
Freight Trucks >10000 lbs.(VMT)	188	189	189	189	232	232	233	233	243	243	243	243	250	251	251	251
Air (seat miles demanded)......	1230	1231	1231	1231	1855	1857	1857	1859	2139	2142	2144	2146	2416	2419	2420	2424
Rail (ton miles traveled)......	1334	1335	1335	1335	1533	1533	1533	1534	1584	1585	1585	1585	1623	1624	1624	1625
Marine (ton miles traveled)....	815	815	815	815	923	922	922	922	949	949	949	949	967	968	968	968
Energy Efficiency Indicators																
New Car MPG	28.0	28.0	28.0	28.0	30.2	31.5	33.1	34.9	30.5	31.7	33.1	34.9	30.7	31.9	33.5	35.0
New Light Truck MPG	19.3	19.3	19.3	19.3	20.1	21	22.1	23.3	20.5	21.5	22.4	23.6	21.1	22	23.1	24.2
Light-Duty Fleet MPG	20.3	20.3	20.3	20.3	20.3	20.7	21.1	21.5	20.7	21.2	21.8	22.4	21.2	21.7	22.3	23
New Comm. Light Truck (MPG)	18.9	18.9	18.9	18.9	19.6	19.6	19.7	19.6	20	20	19.9	19.9	20.6	20.6	20.5	20.3
Stock Comm. Light Truck(MPG) ...	14.7	14.7	14.7	14.7	15	15	15	15	15.2	15.2	15.2	15.2	15.4	15.4	15.4	15.4
Aircraft Eff.(seat miles/gallon)	52.1	52.1	52.1	52.1	55.7	55.7	55.7	55.7	57.4	57.4	57.4	57.4	59	59	59	59
Freight Truck Efficiency MPG....	5.7	5.7	5.7	5.7	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.1	6.1	6.1	6.1
Rail Eff.(ton miles/thous. Btu).	2.8	2.8	2.8	2.8	2.9	2.9	2.9	2.9	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Domestic Shipping Efficiency																
(ton miles per thousand Btu...	2.7	2.7	2.7	2.7	2.9	2.9	2.9	2.9	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Energy Use by Mode(quad. Btu/yr)																
Light-Duty Vehicles............	15.04	15.03	15.03	15.03	17.76	17.6	17.41	17.24	18.55	18.31	18.06	17.79	19.2	18.95	18.66	18.37
Commercial Light Trucks	0.62	0.62	0.62	0.62	0.73	0.73	0.73	0.73	0.76	0.76	0.77	0.77	0.79	0.79	0.8	0.8
Freight Trucks	4.54	4.54	4.54	4.54	5.32	5.33	5.33	5.33	5.47	5.48	5.48	5.48	5.58	5.59	5.59	5.59
Air............................	3.87	3.88	3.88	3.88	5.27	5.28	5.28	5.29	5.84	5.85	5.86	5.86	6.35	6.35	6.35	6.37
Rail...........................	0.57	0.57	0.57	0.57	0.62	0.62	0.62	0.62	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.64
Marine.........................	1.51	1.51	1.51	1.51	1.91	1.91	1.91	1.91	2.09	2.09	2.09	2.09	2.25	2.25	2.25	2.26
Pipeline Fuel..................	0.8	0.8	0.8	0.8	0.95	0.95	0.95	0.95	0.99	0.99	0.99	0.99	1.03	1.03	1.03	1.03
Other	0.27	0.27	0.27	0.27	0.31	0.31	0.31	0.31	0.32	0.32	0.32	0.32	0.33	0.33	0.33	0.33
Total.........................	27.14	27.15	27.15	27.15	32.77	32.62	32.43	32.27	34.54	34.32	34.08	33.82	36.04	35.81	35.53	35.25

AEO98 Reference Case (1), 10-percent Diesel Penetration case (2), 20-percent Diesel Penetration Case (3), and 30-percent Diesel Penetration Case (4).

Source: Energy Information Administration, AEO98 National Energy Modeling System runs AEO98B.D100197A, PCT10.D122997B, PCT20.D122997B, AND PCT30.D122998B.

percent of the total “shortfall” effect. VMT “shortfall” effects, which amounted to 18 percent of the total shortfalls, occurred from the decline in gasoline prices making the cost of driving per mile decline resulting in more driving.

The last column in Table 10 reflects a scenario in which manufacturers hold HP and size class shifts at base case levels. Figure 2 carbon levels for the 30 percent diesel case would decline by an additional 6.7 mmt carbon, bringing the total carbon savings to 19.7 mmt of carbon from the trnsportation sector, and 27 mmt from all sectors.

Table 10. “Shortfall” Effects for Light Duty Vehicle Consumption for 30 Percent Penetration Case, 2020

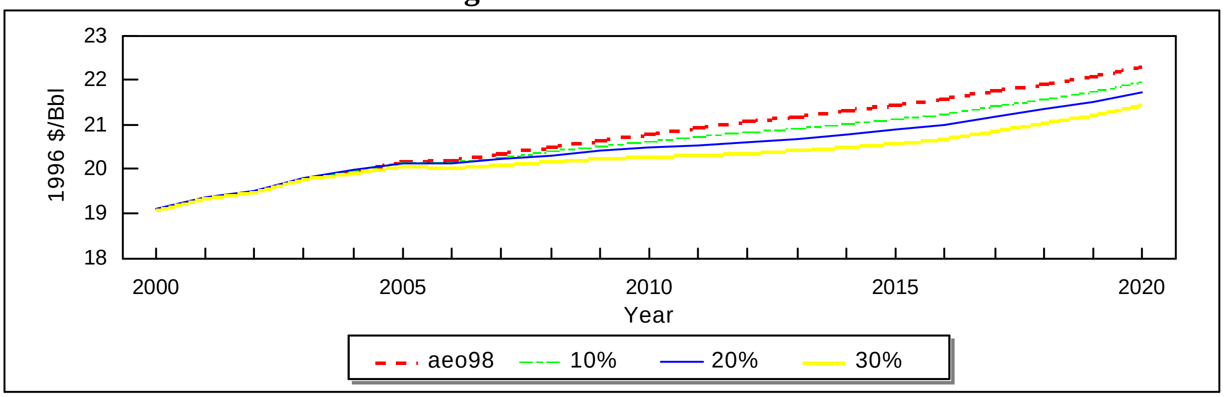
	Shortfall (percent)	Shortfall (trillion BTU)	Shortfall w/o Size and HP Shifts
Size Class Shifts	2	27	0
AFV Sales Increase	2	18	18
30% Diesel Stock	37	406	406
Rising HP	41	452	0
VMT Increase	18	194	194
Total Shortfall	100	1097	618
“Actual” Fuel Savings		823	1302
“Expected” Fuel Savings		1920	1920

Refinery Operations

Petroleum Prices

Crude and average petroleum product prices are lower in all three cases compared to the reference case, with the largest decrement in gasoline. By the year 2020 gasoline prices are 10.1 cents[8] per gallon lower in the 30 percent case relative to the AEO98 (Table 11). Jet fuel price decrements are not as large as those of gasoline, with a price 5.7 cents per gallon lower by 2020 in the 30 percent case compared to the reference case. Diesel and residential distillate prices are slightly lower, with a decrement of 1.5 cents per gallon for transportation diesel in the 30 percent case by the year 2020. (Total distillate prices are higher because of greater consumption of higher-priced diesel fuel.) Overall average petroleum product prices are as much as 7.2 cents per gallon lower in the 30 percent case compared with the AEO98 case, or by as much as 5.1 cents per gallon net of the drop in world oil prices (WOP). The latter comparison shows the reduction in price due to changes in the refinery yield, over and above changes in the price of crude oil attributed to increased diesel penetration.

Figure 5. World Oil Price



The lower U.S. petroleum product demands in the three cases result in a lower WOP, with a decrement in 2020 compared to the AEO98 reference case of as much as $0.87 per barrel in the 30 percent case (Figure 5).

[8]All prices in this report are in real (inflation - adjusted) 1996 dollars.

Table 11. Petroleum Product Prices (1996 Cents per Gallon, Unless Otherwise Noted)

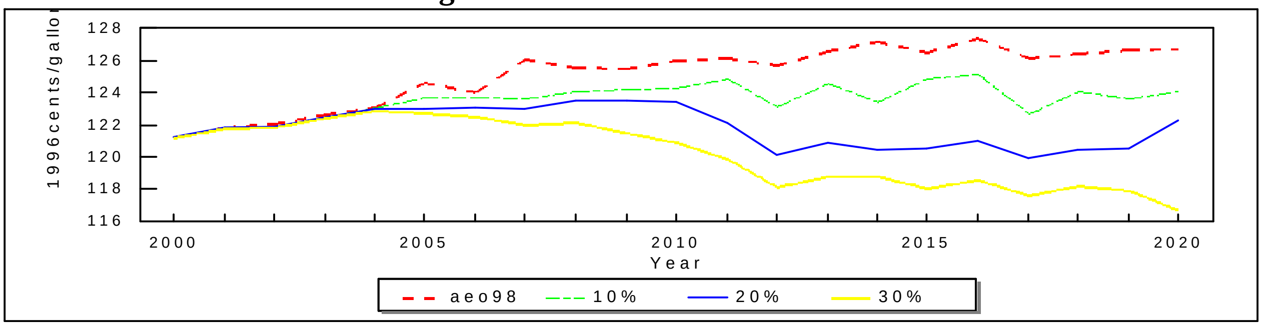
Sector and Fuel	2000				2010				2015				2020			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
World Oil Price ($/bbl)........	19.11	19.09	19.09	19.09	20.81	20.62	20.47	20.3	21.48	21.13	20.87	20.6	22.32	21.97	21.72	21.45
Delivered Sector Product Prices																
Residential																
Distillate Fuel.............	99.2	99.2	99.2	99.2	104.8	104.5	104.6	103.9	106.0	105.4	104.9	104.3	107.0	106.2	106.1	105.6
Liquefied Petroleum Gas......	99.8	100.2	100.2	100.2	107.5	107.2	106.9	105.3	107.3	106.3	105.4	104.9	108.5	106.8	105.7	104.2
Commercial																
Distillate Fuel.............	72.5	72.5	72.5	72.5	78.3	78.0	78.1	77.5	79.7	79.4	78.8	78.1	81.3	80.6	80.2	79.6
Residual Fuel................	44.5	44.4	44.4	44.4	47.3	46.8	46.5	45.4	49.2	48.4	47.7	47.0	50.9	49.9	49.3	48.6
Residual Fuel($/bbl).........	18.68	18.65	18.65	18.65	19.85	19.68	19.52	19.06	20.65	20.34	20.05	19.72	21.36	20.97	20.72	20.39
Industrial																
Distillate Fuel.............	72.7	72.7	72.7	72.7	79.6	79.4	79.2	78.9	81.5	81.5	81.0	80.1	84.2	83.6	82.9	82.2
Liquefied Petroleum Gas......	51.6	52.1	52.1	52.1	58.4	57.9	57.6	55.9	57.3	56.4	55.8	55.1	58.8	57.5	55.8	54.4
Residual Fuel................	40.4	40.2	40.2	40.2	45.2	45.0	44.7	44.2	47.2	47.1	46.0	44.2	50.1	48.8	47.9	46.3
Residual Fuel($/bbl).........	16.98	16.88	16.88	16.88	18.97	18.9	18.77	18.47	19.8	19.77	19.3	18.57	21.04	20.51	20.13	19.44
Transportation																
Diesel Fuel (Distillate)	118.4	118.4	118.4	118.4	119.4	119.3	119.3	119	119.3	118.4	117.9	118	118.2	117.1	117.3	116.7
Jet Fuel	69.1	69.3	69.3	69.3	79	77.5	76.9	75.4	81.7	79.7	78.1	76.9	84.6	82.3	82.1	78.9
Motor Gasoline	121.2	121.2	121.2	121.2	126	124.3	123.5	120.9	126.6	124.9	120.5	118.1	126.8	124.1	122.2	116.7
Residual Fuel................	39.1	39.0	39.0	39.0	46.0	45.3	45.0	44.6	47.0	46.1	45.4	43.9	49.7	47.8	47.7	46.4
Residual Fuel($/bbl).........	16.41	16.37	16.37	16.37	19.32	19.04	18.9	18.72	19.75	19.36	19.07	18.45	20.88	20.08	20.05	19.49
Electric Generators ..																
Distillate Fuel.............	67.1	67.0	67.0	67.0	73.9	73.8	73.7	73.5	75.9	75.6	75.2	74.6	78.2	77.2	77.1	76.2
Residual Fuel................	44.2	44.0	44.0	44.0	51.9	51.4	51.1	50.5	53.9	53.1	52.4	51.2	56.4	54.8	54.8	53.7
Residual Fuel($/bbl).........	18.55	18.48	18.48	18.48	21.78	21.6	21.47	21.22	22.64	22.31	22.00	21.52	23.7	23.03	23.01	22.55
Refined Petroleum Prod.Prices..																
Distillate Fuel	106.1	106.1	106.1	106.1	109.2	109.7	110.2	110.4	109.7	109.8	110.1	110.6	109.6	109.4	110.2	110.3
Jet Fuel	69.1	69.3	69.3	69.3	79.0	77.5	76.9	75.4	81.7	79.7	78.1	76.9	84.6	82.3	82.1	78.9
Liquefied Petroleum Gas......	61.5	62.0	62.0	62.0	69.8	69.5	69.2	67.5	69.4	68.9	68.1	67.4	71.1	70.1	68.5	67
Motor Gasoline	121.0	121.0	121.0	121.0	125.9	124.1	123.3	120.7	126.4	124.7	120.4	117.9	126.7	123.9	122.1	116.5
Residual Fuel................	40.9	40.8	40.8	40.8	46.7	46.2	45.9	45.3	48.0	47.2	46.4	45.0	50.5	48.8	48.6	47.3
Residual Fuel($/bbl).........	17.19	17.13	17.13	17.13	19.63	19.41	19.27	19.04	20.15	19.83	19.51	18.91	21.23	20.51	20.41	19.85
Average......................	99.8	99.8	99.8	99.8	104.9	103.5	102.8	101.0	105.4	103.6	101.0	99.5	106.0	103.5	102.2	98.8

AEO98 Reference Case (1), 10-percent Diesel Penetration case (2), 20-percent Diesel Penetration Case (3), and 30-percent Diesel Penetration Case (4).

Source: Energy Information Administration, AEO98 National Energy Modeling System runs AEO98B.D100197A, PCT10.D122997B, PCT20.D122997B, AND PCT30.D122998B.

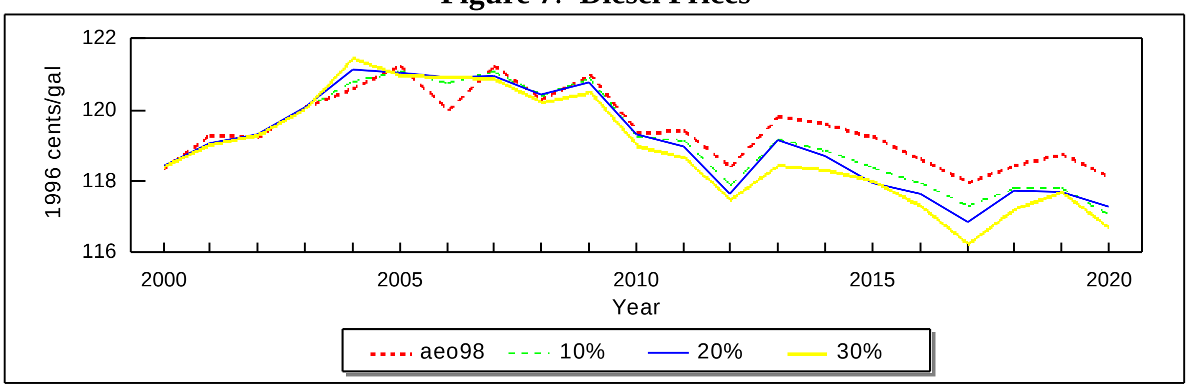
The three cases result in lower prices for gasoline, with a price decrement of as much as 10.1 cents per gallon (8 percent) by 2020 for the 30 percent case compared with the AEO98 reference case (Figure 6). Subtracting the decrement in the WOP between cases results in the net gasoline

Figure 6. Motor Gasoline Prices



price being slightly higher, with a decrement of about 8.0 cents per gallon in the 30 percent case as compared to AEO98. Net gasoline prices are used to highlight refinery industry effects of shifting product demand excluding the WOP effects. Gasoline prices are lower in all cases compared to the reference case, because investments to meet increasing demand for gasoline are not required in the higher diesel penetration cases. Additionally, the decrement in total petroleum product demand with a resulting lower WOP reduces the average of all petroleum product prices. While most individual product prices are lower, the average price of distillate to all sectors is higher because of the increasing share of the higher-priced transportation diesel. Transportation diesel prices are slightly lower in the three cases in 2020, compared with the reference case. For the 10, 20, and 30 percent cases, diesel prices are lower relative to the AEO98 by 1.1, 0.9, and 1.5 cents per gallon, respectively (Figure 7). However, most of the lower

Figure 7. Diesel Prices

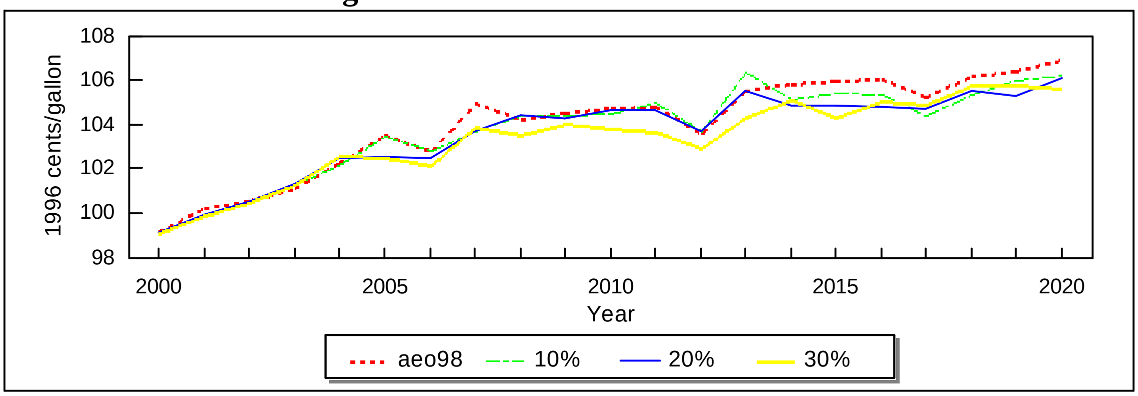


diesel price is due to a lower WOP. Total petroleum demand is lower, resulting in a lower crude oil price. Net of the WOP, the diesel price is lower in the 10 percent case (by 0.3 cents per gallon), and higher in the 20- and 30-percent cases (by about 0.5 cents per gallon in both cases). Diesel prices remain essentially flat while demand is higher because producing diesel requires fewer investments than producing gasoline, and because overall refinery production is lower, reducing the marginal cost of production.

Jet fuel prices are lower in 2020 by as much as 5.7 cents per gallon (6.7 percent) relative to the AEO98 in the 30 percent case. Jet fuel prices are lower because refiners have available relatively more feedstocks for lighter products because of lower demand for gasoline and higher demand for the heavier diesel fuels, reducing the marginal cost of producing jet fuel.

Higher consumption of diesel fuel has a smaller effect on residential heating oil prices. In the 30-percent case, heating oil prices are lower by 1.4 cents per gallon in 2020 (Figure 8). However, net of the lower WOP, heating oil prices are higher by 0.7 cents per gallon for the high-diesel penetration case. Prices for heating oil and diesel fuel--which are nearly identical products in terms of refinery specifications--are slightly higher because the increased demand for diesel fuel can be produced with small increases in refinery investment.

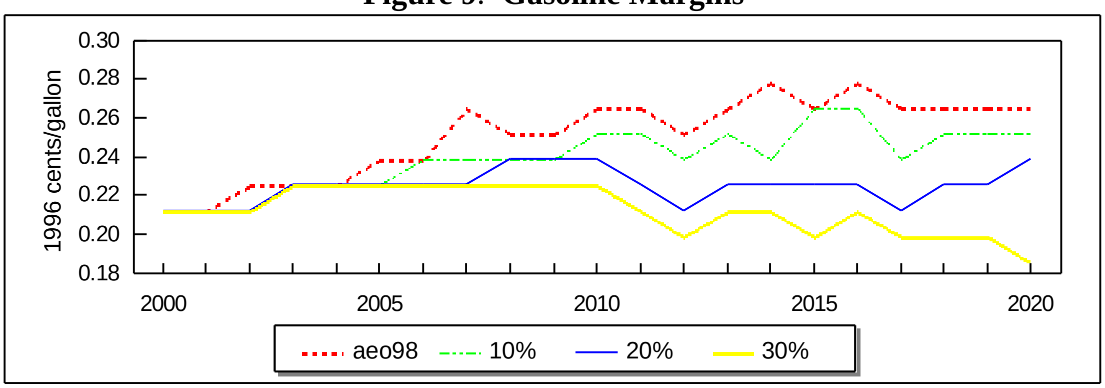
Figure 8. Residential Distillate Prices



Refined Product Margins

The refined product margins (refinery gate price minus the world oil price) for the light products follow the same trend as the consumer prices. Product margins diminish for gasoline (Figure 9), while margins for distillate and diesel remain approximately the same compared with the AEO98.

Figure 9. Gasoline Margins



Product Imports

Net product imports are lower in each of the three cases compared with the AEO98 reference case. The shift in demand from gasoline to diesel has a direct effect on offsetting refined product imports. Net product imports are as much as 590,000 barrels per calendar day lower in 2020 in the 30-percent case relative to the AEO98 (Figure 10 and Table 12). This result reflects the lower demand for gasoline, the greater energy content per gallon of diesel fuel, and the fact that refiners are able to meet a portion of the increased diesel demand because of the reduction in production of motor gasoline. Imports for gasoline, distillate, and diesel are displayed in Figures 11, 12, and 13. As the figures show, while gasoline imports are lower in all cases, imports of diesel and other distillate fuels are moderately higher to meet the increased consumption. However, the combined result is lower imports for all products.

Figure 10. Net Petroleum Product Imports

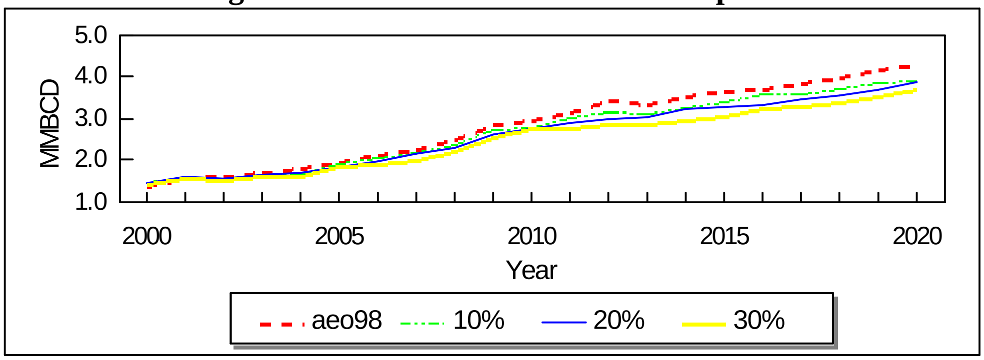


Figure 11. Gross Imports of Motor Gasoline

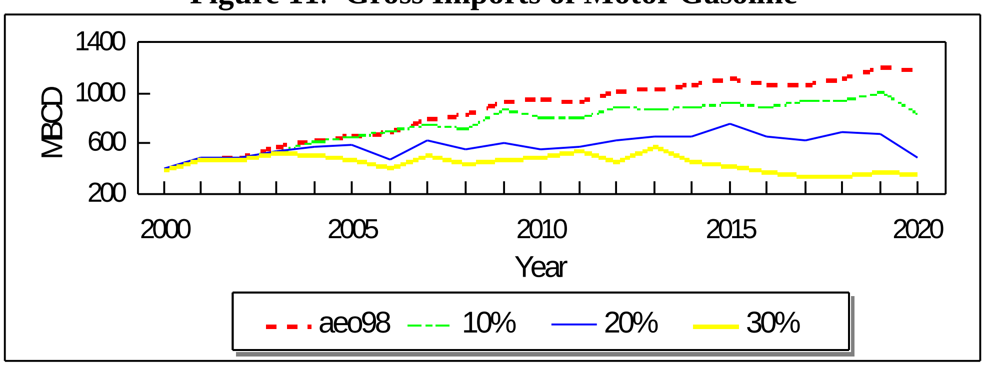


Figure 12. Gross Imports of All Other Distillate

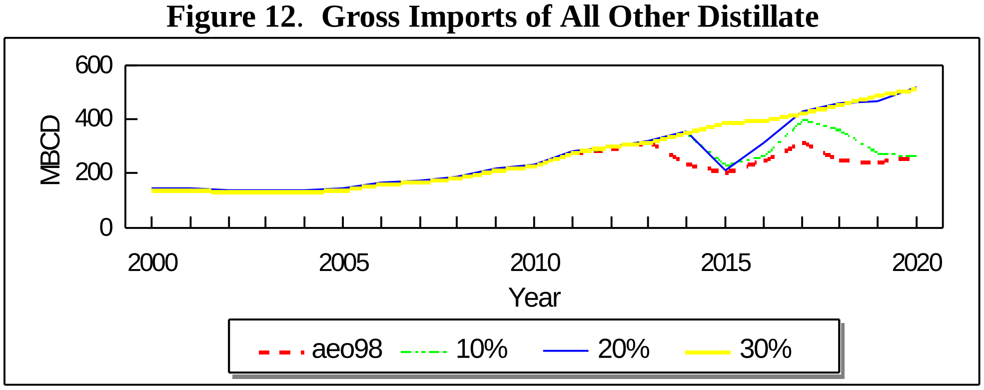


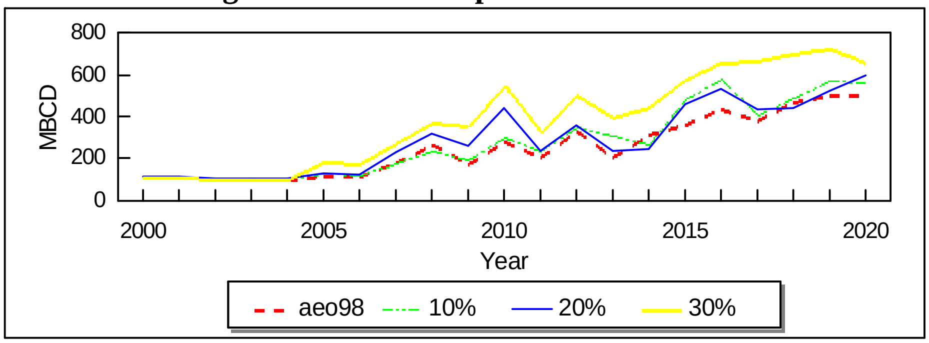
Table 12. Petroleum Supply and Disposition Balance (Million Barrels per Day, Unless Otherwise Noted)

Supply and Disposition	2000				2010				2015				2020			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Crude Oil																
Domestic Crude Production ...	6.17	6.17	6.17	6.17	5.57	5.57	5.57	5.57	5.24	5.24	5.24	5.24	4.92	4.92	4.92	4.92
Alaska....................	1.13	1.13	1.13	1.13	0.75	0.75	0.75	0.75	0.6	0.6	0.6	0.6	0.48	0.48	0.48	0.48
Lower 48 States...........	5.04	5.04	5.04	5.04	4.82	4.82	4.82	4.82	4.64	4.64	4.64	4.64	4.44	4.44	4.44	4.44
Net Imports.................	8.75	8.75	8.75	8.75	10.67	10.7	10.66	10.63	11.22	11.22	11.19	11.15	11.65	11.83	11.62	11.54
Other Crude Supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Crude Supply............	14.92	14.92	14.92	14.92	16.24	16.27	16.23	16.2	16.46	16.46	16.43	16.39	16.58	16.76	16.55	16.46
Natural Gas Plant Liquids......	1.87	1.87	1.87	1.87	2.24	2.24	2.24	2.24	2.35	2.35	2.35	2.35	2.47	2.47	2.47	2.47
Other Inputs	0.32	0.32	0.32	0.32	0.25	0.22	0.22	0.22	0.22	0.21	0.21	0.21	0.2	0.2	0.2	0.2
Refinery Processing Gain	0.86	0.86	0.86	0.86	0.89	0.87	0.85	0.84	0.87	0.85	0.81	0.81	0.82	0.81	0.79	0.76
Net Product Imports	1.42	1.49	1.49	1.49	3.00	2.82	2.74	2.80	3.70	3.41	3.25	3.08	4.33	3.92	3.87	3.74
Total Primary Supply	19.39	19.46	19.46	19.46	22.63	22.43	22.27	22.29	23.6	23.28	23.05	22.84	24.4	24.15	23.87	23.62
Refined Petrol. Products Supp.																
Motor Gasoline	8.52	8.52	8.52	8.52	9.75	9.36	8.96	8.56	10.1	9.48	8.86	8.22	10.39	9.66	8.93	8.17
Jet Fuel	1.85	1.85	1.85	1.85	2.53	2.53	2.53	2.53	2.8	2.8	2.8	2.8	3.03	3.04	3.04	3.04
Distillate Fuel	3.61	3.61	3.61	3.61	4.09	4.33	4.6	4.89	4.19	4.57	5.01	5.46	4.25	4.71	5.24	5.8
Residual Fuel................	0.81	0.81	0.81	0.81	0.88	0.89	0.89	0.89	0.93	0.93	0.94	0.94	0.99	0.99	0.99	0.99
Other	4.82	4.82	4.82	4.82	5.45	5.44	5.41	5.37	5.64	5.63	5.57	5.54	5.72	5.71	5.66	5.57
Total.....................	19.62	19.62	19.62	19.62	22.7	22.55	22.38	22.24	23.65	23.4	23.17	22.96	24.39	24.11	23.86	23.57
Refined Petrol. Products Supp.																
Residential and Commercial...	1.11	1.11	1.11	1.11	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.08	1.08	1.08	1.08
Industrial	5.02	5.02	5.02	5.02	5.65	5.64	5.6	5.57	5.82	5.78	5.73	5.71	5.89	5.86	5.81	5.73
Transportation..............	13.26	13.26	13.26	13.26	15.81	15.66	15.53	15.42	16.6	16.38	16.2	16.02	17.27	17.03	16.82	16.62
Electric Generators	0.24	0.24	0.24	0.24	0.16	0.16	0.16	0.16	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Total.....................	19.62	19.62	19.62	19.62	22.7	22.55	22.38	22.24	23.65	23.4	23.17	22.96	24.39	24.11	23.86	23.57
Discrepancy	-0.23	-0.16	-0.16	-0.16	-0.08	-0.12	-0.11	0.05	-0.05	-0.12	-0.11	-0.12	0.01	0.04	0.02	0.05
World Oil Price (1996 $/bbl)...	19.11	19.09	19.09	19.09	20.81	20.62	20.47	20.3	21.48	21.13	20.87	20.6	22.32	21.97	21.72	21.45
Imp. Share of Product Supplied.	0.52	0.52	0.52	0.52	0.6	0.6	0.6	0.6	0.63	0.63	0.62	0.62	0.66	0.65	0.65	0.65
Net Expenditures for Imp. Crude																
& Petr.Prod.(billion 96$ /year)	71.35	71.63	71.63	71.63	106.4	103.6	101.3	100.6	120.2	115.3	111.8	108	133.5	128.6	124	120.3
Domestic Refinery Distill. Cap.	15.9	16.0	16.0	16.0	17.1	17.2	17.1	17.1	17.4	17.4	17.4	17.3	17.5	17.7	17.5	17.4
Capacity Utilization Rate (%)..	94.1	93.6	93.6	93.6	95.2	95.2	95.2	95.2	95.2	95.1	95.1	95.2	95.2	95.2	95.1	95.2

AEO98 Reference Case (1), 10-percent Diesel Penetration case (2), 20-percent Diesel Penetration Case (3), and 30-percent Diesel Penetration Case (4).

Source: Energy Information Administration, AEO98 National Energy Modeling System runs AEO98B.D100197A, PCT10.D122997B, PCT20.D122997B, AND PCT30.D122998B.

Figure 13. Gross Imports of Diesel Fuel



Refinery Investment

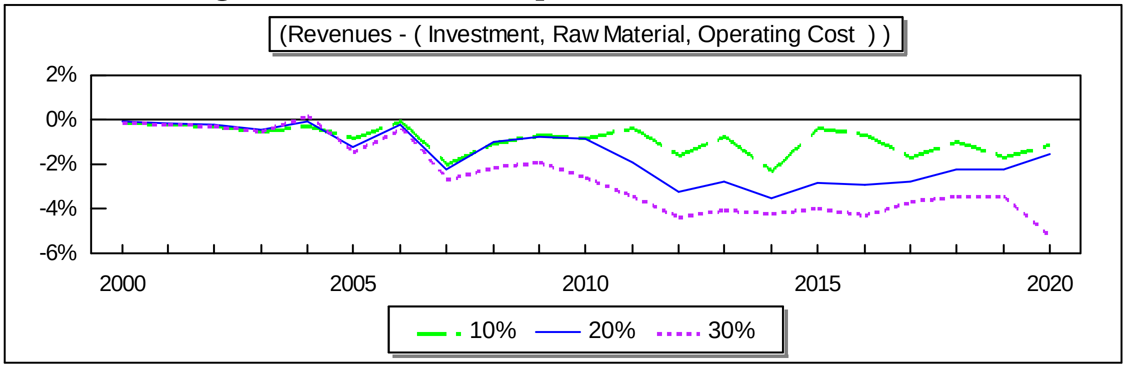
Compared to AEO98, refinery capacity investment is lower in the three cases due to lower gasoline and total product demand (Figure 14). Lower demand for gasoline results in less need for downstream capacity to upgrade heavier intermediate streams or enhance the properties of lighter intermediate streams required to meet gasoline blending specifications. The production of on-road

Figure 14. Cumulative Capacity Expansion Investment Relative to AEO98

low-sulfur diesel requires refiners to catalytic-hydrotreat distillate streams to remove sulfur, increase production of low-sulfur distillate streams from the catalytic hydrocracking units, or use low-sulfur distillate streams normally used in the production of kerosene and jet fuel. Light duty vehicle (LDV) on-road diesel fuel quality specifications are assumed to remain the same as in AEO98. Thus, the only downstream capacity additions over those required in the AEO98 to meet the higher diesel demand is distillate desulfurization, with capacity additions doubling in the 30 percent case by 2020, compared to the reference case. Catalytic hydrocracking capacity is actually less in the 10, 20, and 30 percent cases because of the reduced demand for gasoline. Figure 14 displays the percent differences in cumulative refinery capacity investment to year 2020 in the 10, 20, and 30 percent cases as compared to the AEO98. The 30 percent case requires 61 percent less cumulative investment than in AEO98 by 2020.

Total revenues by 2020 from the sale of petroleum products are as much as 9.9 percent lower in the

Figure 15. Net Revenues per Barrel Relative to AEO98



30 percent case, while revenues minus the differential in WOP are 8.0 percent lower than in the AEO98 reference case. Revenues per barrel of product are 2.4, 3.6, and 6.8 percent lower, respectively, compared to AEO98 (Figure 15). Factoring in investment costs and operating and raw material costs results in net revenues per barrel of product produced 1.1, 1.5, and 5.1 percent lower than AEO98 in the 10, 20, and 30 percent cases respectively. This decreasing revenue per barrel of product supplied is attributed to displacement of the refiners' most valuable product (motor gasoline) by a less economically attractive alternative, diesel. While refinery investment in the three cases is lower than in the AEO98, the additional revenue losses due to lower product prices erode profits. Reductions in total product supplied due to the LDV diesel efficiency gains compounds the reduction in total revenues even further.

Refined product margins reported by EIA's Financial Reporting System (FRS) were \$0.41, \$0.49, and \$0.87 (in 1996 dollars) per barrel for 1992, 1995, and 1996 respectively. While the Petroleum Market Module (PMM) values of net revenues per barrel cannot be directly compared with FRS refined product margins per barrel because of differences in accounting revenues, investments, and depreciation, the FRS refined product margins indicate refining profitability is marginal. Combining this fact with the lower net revenues yielded by the three cases presented, it is clear that refiners would have to continue to reduce operating costs to maintain financial viability under the diesel penetration cases analyzed.

The PMM maximizes profit in a given year with that year's set of assumptions (WOP, product specifications, product demand, costs of imports, etc.) Additionally, the PMM maximizes profitability in any given year while maintaining constant per barrel operating costs and refinery technology. Also, the PMM accounts for some of the costs associated with supplying petroleum products by assuming constant end-user markups to account for distribution and marketing costs. Because operating, distribution and marketing costs, as well as refinery technology costs, are held constant, there is no guarantee that absolute refining profitability will be maintained across the cases. However, the comparison across cases gives a broad indication of the refinery profitability situation with respect to changes in the penetration of diesel fuel.

Sulfur Specification Case

A fourth case was generated to determine the effects of requiring an ultra-low sulfur diesel for light duty diesel vehicles for the 30 percent case. If policies to encourage higher penetration levels of diesel-fueled vehicles are instituted, lower sulfur specifications may be required for on-road light duty vehicle (LDV) diesel fuel to reduce emissions and prolong the life of diesel catalytic converters. In this case, it was assumed that the sulfur specification for diesel was reduced to 50 ppm from 500 ppm for all diesel demanded by LDVs. It is technically possible for refiners to produce 50 ppm diesel, though only a small amount is produced in the United States. It was also assumed that diesel with 500 ppm sulfur would continue to be produced to satisfy demand from other diesel vehicles besides LDVs.

Demand for transportation diesels as a percent of total transportation diesel demand in the reduced sulfur case is summarized below.

Demand for Transportation Diesel 2005 - 2010
(percent)

	2005	2010	2015	2020
Low-Sulfur on-road Diesel	**74.5**	**64.0**	**57.5**	**54.8**
High-Sulfur off-road Diesel	**17.0**	**14.3**	**12.8**	**12.0**
Ultra-Low Sulfur on-road Diesel	**8.5**	**21.7**	**29.7**	**33.2**

Prices

The primary difference in prices is in the average price for transportation diesel, which is $1.21 per gallon in 2020 compared to $1.17 in the 30 percent case and $1.18 in the AEO98 (Table 13 and Figure 16). The price is higher due to the addition of an ultra-low sulfur diesel fuel (50 ppm), with an expected price of $1.27 per gallon in 2020. The price for low-sulfur diesel (500 ppm) is

Figure 16. Diesel Prices for Ultra-Low Sulfur Case

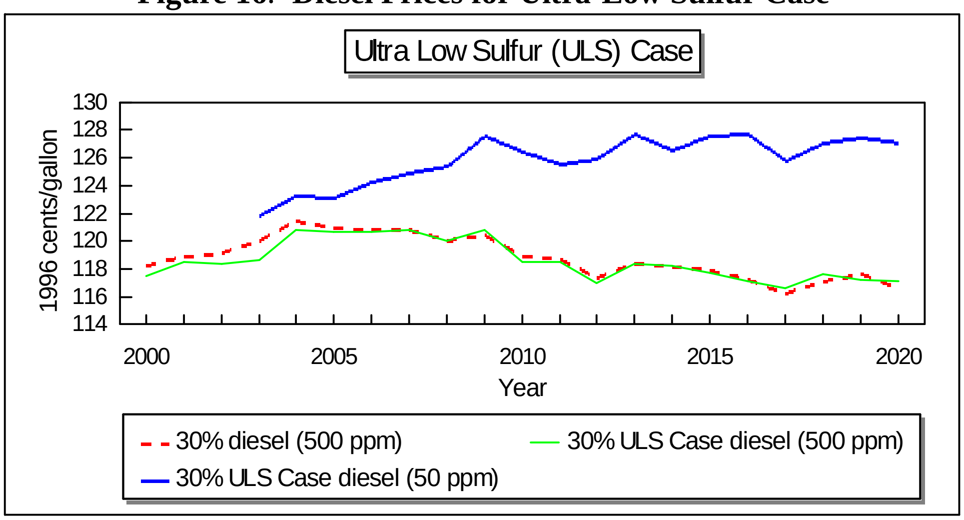


Table 13. Petroleum Product Prices for Ultra-Low Sulfur Case

(1996 Cents Per Gallon, Unless Otherwise Noted)

Sector and Fuel	2000				2010				2015				2020		
	(1)	(2)	(3)		(1)	(2)	(3)		(1)	(2)	(3)		(1)	(2)	(3)
World Oil Price ($/bbl)........	19.11	19.09	19.09		20.81	20.30	20.34		21.48	20.60	20.74		22.32	21.45	21.63
Delivered Sector Product Prices															
Residential															
Distillate Fuel.............	99.2	99.2	98.9		104.8	103.9	103.9		106.0	104.3	104.3		107.0	105.6	105.4
Liquefied Petroleum Gas......	99.8	100.2	99.7		107.5	105.3	106.3		107.3	104.9	106.1		108.5	104.2	106.7
Commercial															
Distillate Fuel.............	72.5	72.5	72.2		78.3	77.5	77.3		79.7	78.1	78.0		81.3	79.6	79.4
Residual Fuel................	44.5	44.4	44.4		47.3	45.4	46.1		49.2	47.0	47.4		50.9	48.6	49.1
Residual Fuel($/bbl).........	18.68	18.65	18.66		19.85	19.06	19.34		20.65	19.72	19.90		21.36	20.39	20.61
Industrial															
Distillate Fuel.............	72.7	72.7	72.4		79.6	78.9	78.4		81.5	80.1	79.9		84.2	82.2	81.9
Liquefied Petroleum Gas......	51.6	52.1	51.5		58.4	55.9	57.4		57.3	55.1	56.5		58.8	54.4	57.1
Residual Fuel................	40.4	40.2	40.2		45.2	44.0	43.8		47.2	44.2	45.2		50.1	46.3	47.3
Residual Fuel($/bbl).........	16.98	16.88	16.90		18.97	18.47	18.39		19.80	18.57	18.97		21.04	19.44	19.87
Transportation															
Diesel Fuel Average							120.3				120.7				120.5
Low Sulfur Diesel	118.4	118.4	117.4		119.4	119.0	118.5		119.3	118.0	117.8		118.2	116.7	117.1
Ultra Low Sulfur Diesel							126.5				127.8				127.2
Jet Fuel	69.1	69.3	68.1		79.0	75.4	77.7		81.7	76.9	78.5		84.6	78.9	81.1
Motor Gasoline	121.2	121.2	121.2		126.0	120.9	121.2		126.6	118.1	118.4		126.8	116.7	117.4
Residual Fuel................	39.1	39.0	39.2		46.0	44.6	43.8		47.0	43.9	45.0		49.7	46.4	47.6
Residual Fuel($/bbl).........	16.41	16.37	16.48		19.32	18.72	18.42		19.75	18.45	18.89		20.88	19.49	19.98
Electric Generators															
Distillate Fuel.............	67.1	67.0	66.7		73.9	73.5	72.7		75.9	74.6	74.1		78.2	76.2	76.1
Residual Fuel................	44.2	44.0	44.1		51.9	50.5	50.2		53.9	51.2	51.8		56.4	53.7	54.5
Residual Fuel($/bbl).........	18.55	18.48	18.51		21.78	21.22	21.09		22.64	21.52	21.76		23.70	22.55	22.89
Refined Petroleum Prod.Prices..															
Distillate Fuel	106.1	106.1	105.4		109.2	110.4	111.1		109.7	110.6	112.5		109.6	110.3	113.1
Jet Fuel	69.1	69.3	68.1		79.0	75.4	77.7		81.7	76.9	78.5		84.6	78.9	81.1
Liquefied Petroleum Gas......	61.5	62.0	61.4		69.8	67.5	68.8		69.4	67.4	68.6		71.1	67.0	69.5
Motor Gasoline	121.0	121.0	120.9		125.9	120.7	121.0		126.4	117.9	118.2		126.7	116.5	117.2
Residual Fuel................	40.9	40.8	41.0		46.7	45.3	44.8		48.0	45.0	45.9		50.5	47.3	48.3
Residual Fuel($/bbl).........	17.19	17.13	17.20		19.63	19.04	18.83		20.15	18.91	19.30		21.23	19.85	20.31
Average.....................	99.8	99.8	99.5		104.9	101.0	101.8		105.4	99.5	100.5		106.0	98.8	100.6

AEO98 Reference Case (1), 30-percent Diesel Penetration case (2), and 30-percent Ultra Low-Sulfur Diesel Penetration Case (3).

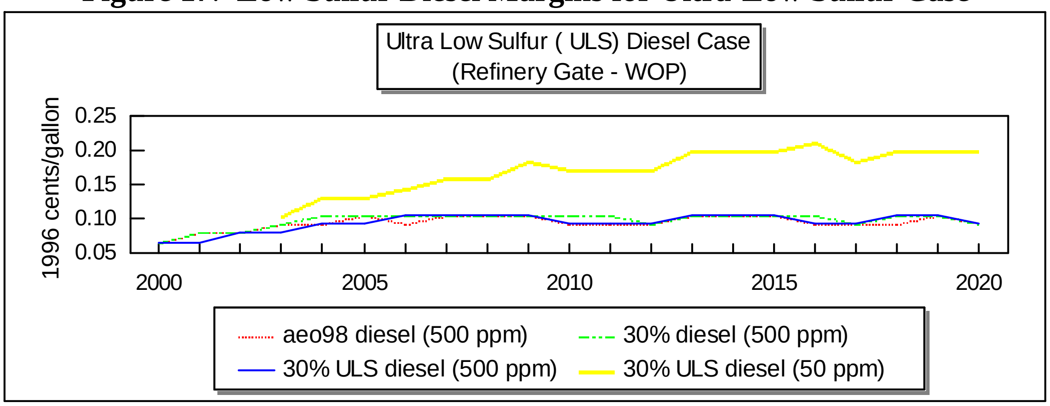
Source: Energy Information Administration, AEO98 National Energy Modeling System runs AEO98B.D100197A, PCT30.D122998B, AND P3S5LDV.D020698A.

$1.17 per gallon, the same price as in the 30 percent case if the WOP differential is removed. The prices for the other "light" products are slightly higher in the ultra-low sulfur case as compared to the 30 percent case when the prices are normalized to the same WOP. The price of jet fuel is 2.2 cents per gallon higher in the low sulfur case as compared to the 30 percent case. The price of gasoline is 0.7 cents per gallon higher than in the 30 percent case. The price of residential distillate is 0.2 cents per gallon lower than in the 30 percent case in year 2020. Jet fuel prices are affected by increased demand for ultra-low sulfur diesel because some of the low sulfur blending components that are used to make jet fuel are diverted to make ultra-low sulfur diesel. Additionally, these low sulfur components are produced by the relatively expensive additional hydrocracking capacity, which also applies upward pressure on the kerosene and diesel prices.

Refined Product Margins

`The product margins for most petroleum products in the ultra-low sulfur diesel case are similar to those of the 30 percent case, with the exception of the ultra-low sulfur diesel margins, which are about

Figure 17. Low Sulfur Diesel Margins for Ultra-Low Sulfur Case



twice those of low-sulfur diesel in the 30 percent case due to the added costs associated with removing the sulfur in the distillate streams (Figure 17). While the margins are higher for the product (ultra-low sulfur diesel) that is displacing the relatively high margin gasoline, there is still some revenue loss due to the MPG efficiency benefits of diesel, which reduces product demand.

Product Imports

Gasoline imports in the low-sulfur case are about the same as the 30 percent case by 2020. Imports of jet fuel are about 250,000 barrels per day higher by 2020, due to more of the light kerosene feeds going into the production of ultra-low sulfur diesel (Table 14). Distillate imports are about 100,000 barrels per day lower than the 30 percent case by 2020 because there are more medium to low-sulfur feeds available for distillate production that would have been used for low-sulfur diesel provided to the LDV market. Low-sulfur diesel imports are also down by about 165,000 barrels per day from the 30 percent case by year 2020 because part of the demand for

Table 14. Petroleum Supply and Disposition Balance for Ultra-Low Sulfur Case
(Million Barrels per Day, Unless Otherwise Noted)

Supply and Disposition	2000			2010			2015			2020		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Crude Oil												
Domestic Crude Production ...	6.17	6.17	6.17	5.57	5.57	5.57	5.24	5.24	5.24	4.92	4.92	4.92
Alaska....................	1.13	1.13	1.13	0.75	0.75	0.75	0.60	0.60	0.60	0.48	0.48	0.48
Lower 48 States...........	5.04	5.04	5.04	4.82	4.82	4.82	4.64	4.64	4.64	4.44	4.44	4.44
Net Imports.................	8.75	8.75	8.75	10.67	10.63	10.52	11.22	11.15	11.09	11.65	11.54	11.50
Other Crude Supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Crude Supply............	14.92	14.92	14.92	16.24	16.20	16.09	16.46	16.39	16.33	16.58	16.46	16.42
Natural Gas Plant Liquids......	1.87	1.87	1.87	2.24	2.24	2.24	2.35	2.35	2.35	2.47	2.47	2.47
Other Inputs	0.32	0.32	0.31	0.25	0.22	0.22	0.22	0.21	0.21	0.20	0.20	0.20
Refinery Processing Gain	0.86	0.86	0.86	0.89	0.84	0.85	0.87	0.81	0.83	0.82	0.76	0.75
Net Product Imports	1.42	1.49	1.49	3.00	2.80	2.92	3.70	3.08	3.29	4.33	3.74	3.82
Total Primary Supply	19.39	19.46	19.47	22.63	22.29	22.32	23.60	22.84	23.00	24.40	23.62	23.66
Refined Petrol. Products Supp.												
Motor Gasoline	8.52	8.52	8.52	9.75	8.56	8.66	10.10	8.22	8.38	10.39	8.17	8.37
Jet Fuel	1.85	1.85	1.85	2.53	2.53	2.53	2.80	2.80	2.80	3.03	3.04	3.04
Distillate Fuel	3.61	3.61	3.61	4.09	4.89	4.83	4.19	5.46	5.37	4.25	5.80	5.68
Residual Fuel...............	0.81	0.81	0.81	0.88	0.89	0.89	0.93	0.94	0.94	0.99	0.99	0.99
Other	4.82	4.82	4.82	5.45	5.37	5.37	5.64	5.54	5.57	5.72	5.57	5.57
Total.....................	19.62	19.62	19.62	22.70	22.24	22.27	23.65	22.96	23.05	24.39	23.57	23.65
Refined Petrol. Products Supp.												
Residential and Commercial...	1.11	1.11	1.11	1.09	1.09	1.09	1.09	1.09	1.09	1.08	1.08	1.08
Industrial	5.02	5.02	5.02	5.65	5.57	5.57	5.82	5.71	5.74	5.89	5.73	5.74
Transportation..............	13.26	13.26	13.26	15.81	15.42	15.45	16.60	16.02	16.07	17.27	16.62	16.69
Electric Generators	0.24	0.24	0.24	0.16	0.16	0.16	0.14	0.14	0.14	0.14	0.14	0.14
Total.....................	19.62	19.62	19.62	22.70	22.24	22.27	23.65	22.96	23.05	24.39	23.57	23.65
Discrepancy	-0.23	-0.16	-0.16	-0.08	0.05	0.05	-0.05	-0.12	-0.05	0.01	0.05	0.01
World Oil Price (1996 $/bbl)...	19.11	19.09	19.09	20.81	20.30	20.34	21.48	20.60	20.74	22.32	21.45	21.63
Imp. Share of Product Supplied.	0.52	0.52	0.52	0.60	0.60	0.60	0.63	0.62	0.62	0.66	0.65	0.65
Net Expenditures for Imp. Crude & Petr.Prod.(billion 96$ /year)	71.35	71.63	71.69	106.40	100.60	101.20	120.20	108.00	109.70	133.50	120.30	121.70
Domestic Refinery Distill. Cap.	15.9	16.0	16.0	17.1	17.1	17.0	17.4	17.3	17.2	17.5	17.4	17.3
Capacity Utilization Rate (%)..	94.1	93.6	93.5	95.2	95.2	95.0	95.2	95.2	95.1	95.2	95.2	95.2

AEO98 Reference Case (1), 30-percent Diesel Penetration case (2), and 30-percent Ultra Low-Sulfur Diesel Penetration Case (3).

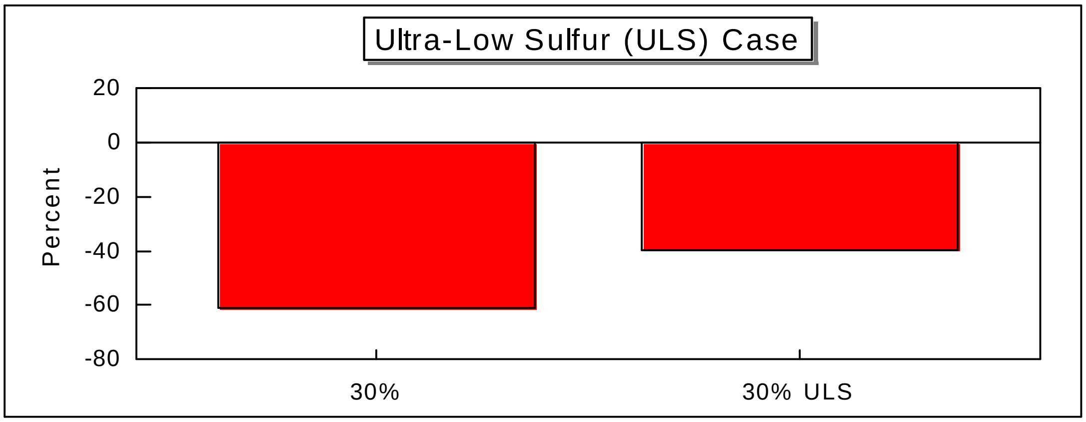
Source: Energy Information Administration, AEO98 National Energy Modeling System runs AEO98B.D100197A, PCT30.D122998B, AND P3S5LDV.D020698A.

low-sulfur diesel from the 30 percent case is now ultra-low sulfur diesel, which is not available as an import.

Refinery Investment

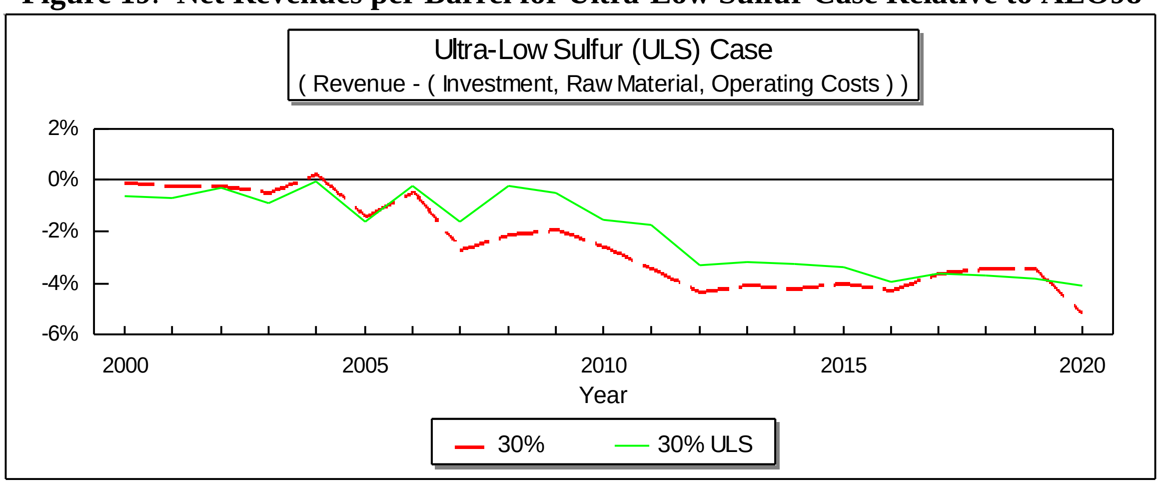
Refinery investment in the ultra-low sulfur diesel case reflects the need for very low-sulfur distillate streams required to meet the 50 ppm sulfur specification for the LDV diesel (Figure 18). Total cumulative investment in distillate desulfurization capacity is actually less in this case as

Figure 18. Cumulative Capacity Expansion Investment for Ultra-Low Sulfur Case Relative to AEO98



compared to the 30 percent case because distillate desulfurization capacity is replaced with investment in hydrocracking and hydrogen capacity to meet the more severe sulfur requirements of the ultra-low sulfur diesel. With this additional hydrocracking capacity cumulative investment is still considerably less (39 percent) than in the AEO98. Figure 19 displays the percent

Figure 19. Net Revenues per Barrel for Ultra-Low Sulfur Case Relative to AEO98



differences in cumulative refinery capacity investment to 2020 in the 30 percent and ultra-low sulfur diesel cases relative to the AEO98. Revenues per barrel of product decline by 5.1 percent compared to AEO98. Factoring in investment costs and operating and raw material costs results in net revenues per barrel of product produced 4.1 percent lower than AEO98.

Appendix A: Petroleum Market Model Methodology

The model within the National Energy Modeling System (NEMS), which provides petroleum product prices and petroleum product supply and refinery activity is the Petroleum Market Model (PMM). The PMM simulates the operation of petroleum refineries in the United States,[9] including the supply and transportation of crude oil to refineries, the regional processing of these raw materials into petroleum products, the marketing of petroleum products to consumption regions, the production of natural gas liquids in gas processing plants, and domestic methanol production. The PMM projects petroleum product prices and sources of supply for meeting petroleum product demand. The sources of supply include crude oil, both domestic and imported; other inputs including alcohols and ethers; natural gas plant liquids production; petroleum product imports; and refinery processing gain. In addition, the PMM estimates domestic refinery capacity expansion and fuel consumption. Product prices are estimated at the Census division level and much of the refining activity information is at the Petroleum Administration for Defense (PAD) District level.

Within the PMM, the refinery sector is modeled by a linear programming representation. A linear programming model is developed for three refining regions. The model is comprised of three geographical regions, defined using the five Petroleum Administration for Defense (PAD) Districts. Individual refineries in PADD I are aggregated into one refinery representation for region 1. Region 2 is an aggregate of all refineries operating in PADD's II, III, and IV. PADD V refineries are represented by a single refinery in region 3. Each model region represents an aggregation of the individual refineries in the region. The PMM linear programming model also contains a transportation structure to move products from the refining regions to the Census division demand regions. Because a single demand region can be supplied by more than one refining region (if the transportation connections exist), changes in one refining region can affect operations in other refining regions. An optimal solution for the three representations together is found by minimizing the costs of meeting the demands. Revenues are derived from product sales, and costs are incurred from the purchase and processing of raw materials and the transportation of finished products to the market. The model chooses a set of petroleum industry activities (e.g. crude oils, processing units, etc.) to produce a product mix that maximizes the refinery's economic benefits. The activities are constrained by material balance requirements on the crude oil and intermediate streams, product specifications, processing and transportation capacities, and demand. Economic forces also govern the decision to import crude oil or refined products into the regions.

The PMM assumes the petroleum refining and marketing industry is competitive. The market will move toward lower-cost refiners who have access to crude oil and markets. The selection of

[9]The International Energy Model contains representation for foreign refinery operations via crude and petroleum product supply curves.

crude oils, refinery process utilization, and logistics will adjust to minimize the overall cost of supplying the market with petroleum products. Although the petroleum market responds to pressures, it rarely strays from the underlying refining costs and economics for long periods of time. If demand is unusually high in one region, the price will increase, driving down demand and providing economic incentives for bringing supplies in from other regions, thus restoring the supply-demand balance.

Each refining region is treated as a single firm. This restricts the ability to deal with issues such as rationalization of small refineries. Rationalization can only be dealt with on a desegregate basis. Capacity is allowed to expand, with some limitations, but the model does not distinguish between additions to existing refineries or the building of new facilities. Investment criteria are developed exogenously, although the decision to invest is endogenous. The model does not require foresight to be perfect, but uses the best available information concerning future prices, demands, and market conditions as the basis for investment decisions.

End-Use Product Prices

End-use petroleum product prices are based on marginal costs of production plus production-related fixed costs plus distribution costs and taxes. The marginal costs of production are determined by the model and represent variable costs of production including additional costs for meeting reformulated fuels provisions of the Clean Air Act Amendments of 1990 (CAAA90). Environmental costs associated with controlling pollution at refineries[10] are reflected as fixed costs. Assuming that refinery-related fixed costs are recovered in the prices of light products, fixed costs are allocated among the prices of liquefied petroleum gases, gasoline, distillate, kerosene, and jet fuel. These costs are based on average annual estimates and are assumed to remain constant over the forecast period.

The costs of distributing and marketing petroleum products are represented by adding fixed distribution costs to the marginal and refinery fixed costs of products. The distribution costs are applied at the Census division level and are assumed to be constant throughout the forecast and across cases. Distribution costs for each product, sector, and Census division represent average historical differences between end-use and wholesale prices. The costs for kerosene are the average difference between end-use prices of kerosene and wholesale distillate prices. End-use prices also include a variable which calibrates model results to historical levels. The calibration variable is specified by product and region.

State and Federal taxes are also added to transportation fuels to determine final end-use prices. Recent tax trend analysis indicated that State taxes increase at the rate of inflation, while Federal taxes do not. In the PMM, therefore, State taxes are held constant in real terms throughout the

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[10]Environmental cost estimates are based on National Petroleum Council, *U.S. Petroleum Refining - Meeting Requirements for Cleaner Fuels and Refineries,* Volume I (Washington, DC, August 1993).

forecast while Federal taxes are deflated at the rate of inflation.

Capacity Expansion Assumptions

PMM allows for capacity expansion of all processing units including distillation capacity, vacuum distillation, hydrotreating, coking, fluid catalytic cracking, hydrocracking, alkylation, and methyl tertiary butyl ether (MTBE) manufacture. Capacity expansion occurs by processing unit, starting from base year capacities established from historical data for each region.

Expansion is determined when the value received from the additional product sales exceeds the investment and operating costs of the new unit. The investment costs assume a 15-percent rate of return over a 15-year plant life. Expansion through 1997 is determined by adding to the existing capacities of units planned and under construction that are expected to begin operating during this time. Capacity expansion is done in 3-year increments. For example, after the model has reached a solution for forecast year 2000, the PMM looks ahead and determines the optimal capacities given the demands and prices existing in the 2003 forecast year. The PMM then allows 50 percent of that capacity to be built in forecast year 2001, 25 percent in 2002, and 25 percent in 2003. At the end of 2003, the cycle begins anew.

Appendix B: Transportation Sector Model Methodology[11]

The transportation demand module (TRAN) forecasts the consumption of transportation sector fuels by transportation mode, including the use of renewables and alternative fuels, subject to delivered prices of energy fuels and macroeconomic variables, including disposable personal income, gross domestic product, level of imports and exports, industrial output, new car and light truck sales, and population.

NEMS projections of future fuel prices influence the fuel efficiency, vehicle-miles traveled, and alternative-fuel vehicle (AFV) market penetration for the current fleet of vehicles. Alternative-fuel shares are projected on the basis of a multinomial logit vehicle attribute model, subject to State and Federal government mandates.

Fuel Economy Submodule

The Fuel Economy Submodule projects new light-duty vehicle fuel efficiency by 12 U.S. Environmental Protection Agency (EPA) vehicle size classes and 16 engine technologies (gasoline, diesel, and 14 AFV technologies) as a function of energy prices and income-related variables. There are 56 fuel-saving technologies which vary in cost and marginal fuel savings by size class. Technologies penetrate the market based on a cost-effectiveness algorithm which compares the technology cost to the discounted stream of fuel savings and the value of performance to the consumer. In general, higher fuel prices and/or lower income per capita lead to higher fuel efficiency estimates within each size class (i.e. lower performance/horsepower demanded), and a shift to a more fuel-efficient size class mix.

Regional Sales Submodule

Vehicle sales from the macroeconomic activity module are divided into car and light truck sales based on demographic analysis. The remainder of the submodule is a simple accounting mechanism that uses endogenous estimates of new car and light truck sales and the historical regional vehicle sales adjusted for regional population trends to produce estimates of regional sales, which are subsequently passed to the alternative-fuel vehicle and the light-duty vehicle stock submodules.

Alternative-Fuel Vehicle Submodule

The Alternative-Fuel Vehicle submodule projects the sales shares of alternative-fuel technologies as a function of time, technology attributes, costs, and fuel prices. Both conventional and new technology vehicles are considered. The alternative-fuel vehicle submodule receives regional new car and light truck sales by size class from the regional sales submodule.

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[11] Energy Information Administration, *The National Energy Modeling System: An Overview 1998*, DOE/EIA-0581(98) (Washington, DC, February 1998).

The forecast of vehicle sales by technology requires a three-stage nested decision process. The first stage consists of endogenously calculating the sales shares between conventional and total alternative-fuel vehicles on a regional level, based on the following factors: regional fuel operating costs per mile (fuel price divided by fuel efficiency), vehicle price, range, regional fuel availability, commercial and size-class availability, and regional regulatory constraints.

Once the level of total alternative-fuel vehicles per region has been calculated, the second stage estimates shares among the alternative-fuel vehicle technologies within each region, based on the same regional factors and methodology used in the prior step to calculate the shares of conventional and total alternative-fuel vehicle sales. The third stage subdivides electric vehicle sales into individual electric vehicle technologies. TRAN includes the following alternative-fuel technologies: methanol flex-fueled, methanol neat (85 percent methanol), ethanol flex-fueled, ethanol neat (85 percent ethanol), compressed natural gas (CNG), CNG Bi-Fuel, liquefied petroleum gas (LPG), LPG Bi-Fuel, electric, electric hybrid, gas turbine gasoline, gas turbine CNG, fuel cell methanol, and fuel cell hydrogen.

Light-Duty Vehicle Stock Submodule

The Light-Duty Vehicle Stock submodule specifies the inventory of light-duty vehicles from year to year. Separate car and light truck survival rates are applied to 10 vintages, and new vehicle sales are introduced into the vehicle stock through an accounting framework. The fleet of vehicles and their fuel efficiency characteristics are maintained through time as they are important to the translation of transportation services demand into fuel demand. Degradation factors are also applied to the new vehicle efficiencies to account for the differences between EPA estimated fuel economy and actual "on the road" fuel efficiencies. These degradation factors take into account over time increasing city to highway driving, rising congestion, and higher average highway speeds.

TRAN maintains a level of detail that includes ten vintage classifications and six passenger car and six light truck size classes corresponding to EPA interior volume classifications for all vehicles less than 8,500 pounds.

Vehicle-Miles Traveled (VMT) Submodule

This submodule projects travel demand for automobiles and light trucks. VMT per capita estimates are based on the fuel cost of driving per mile, per capita disposable personal income, an index that reflects the aging of the population, and an adjustment for female-to-male driving ratios. Total VMT is calculated by multiplying VMT per capita by the driving age population.

Light-Duty Vehicle Commercial Fleet Submodule

This submodule generates estimates of the sales and stock of cars and light trucks used in business, government, and utility fleets. It also estimates travel demand, fuel efficiency, and energy consumption for the fleet vehicles prior to their transition to the private sector at predetermined vintages.

Commercial Light Truck Submodule

The commercial light truck submodule estimates sales, stocks, fuel efficiencies, travel, and fuel demand for all trucks greater than 8,500 pounds and less than 10,000 pounds.

Air Travel Demand Submodule

This submodule estimates the demand for both passenger and freight air travel. Passenger travel is forecasted by domestic travel, which is disaggregated between business and personal travel, and international travel. Dedicated air freight travel is disaggregated between the total air freight demand and air freight carried in the lower hull of commercial passenger aircraft. In each of the market segments, the demand for air travel is estimated as a function of the cost of air travel (including fuel costs) and economic growth (GDP, disposable income, and merchandise exports).

Aircraft Fleet Efficiency Submodule

This submodule forecasts the total stock and the average fleet efficiency of narrow body and wide body aircraft required to meet the projected travel demand. The stock estimation is based on the growth of travel demand and a logistic function that calculates the survival of the older planes. The overall fleet efficiency is determined by the weighted average of the surviving aircraft efficiency (including retrofits) and the efficiencies of the newly acquired aircraft. The efficiency improvements of the new aircraft are determined by technology choice (ultra-high bypass, propfan, hybrid laminar flow, advanced aerodynamics, weight-reducing materials, or thermodynamics) which depends on the trigger fuel price and the time in which the technology has been commercially viable.

Freight Transport Submodule

This submodule translates NEMS estimates of industrial production into ton-miles traveled requirements for rail and ship travel, and into vehicle-miles traveled for trucks, then into fuel demand by mode of freight travel. The freight truck stock submodule is subdivided into medium and heavy-duty trucks. VMT freight estimates by truck size class and technology are based on matching freight needs, as measured by the growth in industrial output by Standard Industrial Classification (SIC) code, to VMT levels associated with truck stocks and new vehicles.

Rail and shipping ton-miles traveled are also estimated as a function of growth in industrial output. Freight truck fuel efficiency growth rates relative to fuel prices are tied to historical growth rates by size class and are also dependent on the maximum penetration, introduction year, fuel trigger price (based on cost-effectiveness) and fuel economy improvement of the technologies including alternative-fuel technologies. In the rail and shipping modes, energy efficiency estimates are structured to evaluate the potential of both technology trends and efficiency improvements related to energy prices.

Miscellaneous Energy Use Submodule

This submodule projects the use of energy in military operations, mass transit vehicles, recreational boats, and automotive lubricants, based on endogenous variables within NEMS (e.g., vehicle fuel efficiencies) and exogenous variables (e.g., the military budget).

Appendix C: Request for Service Report

Department of Energy
Washington, DC 20585

March 5, 1998

MEMORANDUM FOR: Mary Hutzler
Director, Office of Integrated Analysis and Forecasting
Energy information Administration

FROM: Thomas J. Gross
Deputy Assistant Secretary
for Transportation Technologies
Energy Efficiency and Renewable Energy

SUBJECT: Assumptions for Diesel Fuel Penetration Study

The purpose of this memorandum is to request an additional scenario for the analysis you are conducting for us on the impacts of increased penetration of diesel technology in the transportation sector. In addition to the three scenarios specified in my memorandum of November 19, 1997, we also request that you run a case in which advanced diesel technology begins penetrating the market in 2000, reaching 30 percent of light duty vehicle sales by 2010, and remaining constant thereafter, but with the sulfur content of diesel fuel reduced to 50 parts per million (ppm), This differs from the original three scenarios which assume a sulfur content of diesel fuel of 500 ppm. in discussions with your office, your staff has indicated that this case can be run with no changes to the basic modeling framework within the National Energy Modeling System. This case will be of considerable value to the study, since there are environmental issues associated with a high penetration of diesel-fueled vehicles.

Thank you for your cooperation. if you have any questions, please contact Phil Patterson on 6-9121.

Department of Energy
Washington, DC 20585

November 19, 1997

MEMORANDUM FOR: Mary Hutzler
Director of Integrated Analysis and Forecasting
Energy information-nation Administration

FROM: Thomas J. Gross
Deputy Assistant Secretary
for Transportation Technologies
Energy Efficiency and Renewable Energy

SUBJECT: Diesel Fuel Price Sensitivity Analysis

As you may be aware, the Office of Transportation Technologies (OTT) annually estimates and reports energy. and emission benefits of its research, development, and deployment programs as part of Energy Efficiency's "Quality Metrics" initiative. The Quality Metrics process is designed to collect a wide range of data and information required for the Government and Performance Results Act of 1993, the National Performance Review's Performance Agreements with the President, and Executive Order 12862 on setting Customer Service Standards. The information is also valuable in responding to requests of the White House, Congress, the Department, and Energy Efficiency and Renewable Energy.

During the reporting process, benefits estimates are reviewed both internally and externally. As OTT focuses more effort on the development of advanced high efficiency diesel engines for both light and heavy duty vehicles, our market penetration estimates of this technology also increase. As a result, reviewers have raised concerns regarding the impact of a substantial increase in the demand for diesel fuel on both refinery capacity and petroleum related fuel prices.

Therefore, OTT requests that EIA use NEMS to estimate the price impact on transportation fuels as the demand for diesel fuel increases under three different scenarios.

(1) Advanced diesel technology begins penetrating the market in 2000, increasing to 10 percent of light duty vehicle sales by the year 2010 and remaining constant thereafter.

(2) Advanced diesel technology begins penetrating the market in 2000, increasing to 20 percent of light duty vehicle sales by the year 2010 and remaining constant thereafter.

(3) Advanced diesel technology begins penetrating the market in 2000, increasing to 30 percent of light duty vehicle sales by the year 2010 and remaining constant thereafter.

For each scenario, we request that the results be compared with the AEO reference case annually through 2020. A delivery date of January 16, 1998, is requested.

We would like to schedule a meeting with you to further discuss this matter and address any recommendations you may have. Thank you for your attention, and I look forward to hearing from you.