Appendix A-3

ALTERATIONS TO NEMS FOR TRANSPORTATION SECTOR POLICIES

The NEMS Transportation Sector Model comprises two FORTRAN programs. The TRANF program includes subroutines handling light duty highway vehicles, non-highway modes and miscellaneous uses of transportation fuels. The TRANFRT program represents heavy truck energy demand. Most data input is handled via two spreadsheets: (1) TRNINPUT.WK1 contains most of the input data for the TRANF program, and (2) CFFUEL.WK1 contains all of the input data for the TRANFRT model. Much of the data required by the Alternative Fuel Vehicle Model is contained within the TRANF code. Thus, to change prices, fuel economy, acceleration performance, etc. of alternative fuel vehicles requires changing and recompiling TRANF. Changes were also made to other parts of the TRANF code dealing with the AFV Model, as explained below. In the course of constructing the Moderate and Advanced Scenarios changes were made to all four components except TRANFRT.

In order to represent policies for promoting cellulosic ethanol as a blending stock for gasoline, it was necessary to make changes to portions of the refinery model code. Changes were made to the REFINE.F and to the REFETH.F files.

A-3.1 CHANGES TO REFINERY MODEL

To represent policies promoting the production of cellulosic ethanol for use in blending with gasoline, the CHGETHN subroutine located in the REFINE.F file, and the CELLETH subroutine in the REFETH.F file were modified.

To reflect loan subsidies or guarantees for ethanol plant construction, three lines of code in the CELLETH subroutine which add risk premiums to the cost of capital for cellulosic ethanol plants by means of the variable CAPRSK were nullified by setting CAPRSK=1.0 for all years.

In the AEO99 Reference Case, it is assumed that the cost of producing cellulosic ethanol will decline exponentially to 20% below current levels by the year 2020. The rate of decline was increased to achieve a 50% reduction by 2020 in the moderate and advanced cases, to simulate greater success in R&D. This was accomplished by changing the value of the variable PCTRD from 0.01057 to 0.03406.

Finally, in the AEO99 Reference Case the expansion of cellulosic ethanol capacity is limited to 250 million gallons per year from 2005 to 2020. This is accomplished by a factor in the equation for WQETOH which is set to 5. This means that the maximum amount of cellulosic ethanol that could be produced in 2020 is 3.75 billion gallons. The maximum annual expansion factor was changed to 650 million gallons capacity per year by setting the factor formerly equal to 5 to 13, so that total capacity could reach almost 10 billion gallons by 2020. To be consistent, the value of the variable M was set to 13 in all cases.

A-3.2 CHANGES TO TRANF.FORT

TRANF contains most of the code for the Transportation Sector model and numerous changes were made to represent the suites of policies comprising the moderate and advanced scenarios.

A-3.2.1 Subroutine TPRI

For the advanced scenario only, a Pay-at-the-Pump (PATP) variabilization policy was simulated by adding a surcharge to all motor fuels. Since there is no net increase in expenditures on transportation, and since there is no convenient way to represent the reduction in insurance costs within the NEMS model, it is appropriate that this surcharge be recognized only within the Transportation Sector model and not be transmitted to any other modules.

The design of the PATP fee used here is quite simple. For the year 2003 to 2012, a surcharge of $2.00 per million BTU in 1987$ ($2.70/MMBtu in 1997 $, or $0.34 per gallon of gasoline equivalent energy) is added to the price of all motor fuels. From 2013 on the surcharge is increased in one large step to $3.00/MMBtu in 1987$ ($4.06/MMBtu in 1997$ or $0.51 per gallon of gasoline equivalent energy) to roughly correct for the increasing efficiency of the light-duty vehicle fleet.

Modification of the code was made in the subroutine TPRI, which is intended for implementing an ad valorem tax on motor fuels. Five lines of code that initialize a variable called TAX to 1.0 were commented out. Then six lines were added to set the value of tax to 0 through 2002, at 2.0 from 2003 to 2012, and to 3.0 from 2013 to 2020. Finally the sixteen lines of code in which TAX was multiplied times the price (in 1987 $) of each fuel were changed so that it is added, as described above.

A-3.2.2 Changes to the Fuel Cell Subroutines and Related Data

Three subroutines, FCMCALC, FCHCALC, and FCGCALC, predict the cost and energy efficiency of methanol, hydrogen and gasoline fuel cell vehicles respectively. In each of these subroutines, two equations predict the variable, FUELCELL, which is the incremental cost of a fuel cell vehicle. In addition, the subroutines make use of a variable, FUELCELL$COST, which is input data representing the cost of each type of fuel cell stack in dollars per kilowatt. In the NEMS AEO99 version this variable is set to 9999 through 2004. In 2005 it is set to 650 for methanol, 450 for hydrogen and 750 for gasoline; it then declines to one-tenth those values by 2020.

The two equations predicting the incremental cost of the fuel cell vehicle were replaced by a single equation whose parameters were taken from a recent analysis of future fuel cell costs by Directed Technologies (1998). The equation is comprised of five components:

1. Fuel cell stack cost
2. Electric motor cost
3. Reformer cost
4. Hydrogen tank cost
5. Internal combustion engine/transmission credit

The cost equations are identical for each fuel cell type, except for a coefficient representing the kilowatts required per ton of vehicle weight. This variable, which is represented in the equation below by A, takes on the values 58 for methanol, 53 for hydrogen, and 60 for gasoline. The new fuel cell cost equation is as follows:

```
FUELCELL(ICL,IGP,YEAR,IFT) = 1.75*(FUELCELL$COST(YEAR,IFT)*
&  ((1073 + 21.97*A*WEIGHT(ICL,IGP,YEAR,1)/2200)        ! Stack Cost
&  + 260 + 8.26*A*WEIGHT(ICL,IGP,YEAR,1)/2200           !Motor Cost
&  + 100 + 10*A*WEIGHT(ICL,IGP,YEAR,1)/2200)            ! Reformer Cost
&  + 15.3*A*WEIGHT(ICL,IGP,YEAR,1)/2200                 ! Hydrogen Tank
&  - 600 — 20*75*WEIGHT(ICL,IGP,YEAR,1)/2200)           ! ICE Credit
```

Note that the line labeled Hydrogen Tank is included only for the hydrogen fuel cell vehicle. In the case of the hydrogen vehicle that line replaces the line labeled Reformer Cost , which is not used.

A key difference between the Directed Technologies study cost estimates and the equation above is the 1.75 overhead factor we apply to the net change in vehicle costs.

The variable FUELCELL$COST no longer represents fuel cell stack costs in dollars per kilowatt. Instead it is an index of cost that represents the decline in fuel cell system costs with time. When FUELCELL$COST = 1.0, then the cost of fuel cell vehicles corresponds to the cost estimates derived from the Directed Technologies study. This variable is still set to 9999 through 2004, however, beginning in 2005 it takes on the value 2.0 and declines thereafter at a rate described by the following equation:

$$FUELCELL\$COST(I,IFT) = 2.0e^{-ke^{-at}}$$

This equation implies that cost decline exponentially with time, but that the rate of decline is itself declining exponentially. The rate of decrease in costs begins at a rate of (k*100)% per year, but this rate declines by (a*100)% per year. This is intended to simulate a period of rapid learning immediately following introduction of the new technology that slows as the technology becomes mature. In the Advanced Scenario, the parameters of the cost index equation are set to k = -0.15 and a = -0.05. As a result, FUELCELL$COST decreases from 2.0 in 2005 to 1.12 by 2010, 0.81 in 2015 and 0.69 in 2020. In the Moderate scenario the following parameters are used in the cost index equation: k = -0.11, a = -0.05. The data for FUELCELL$COST were changed in the Block Data section of TRANF to reflect the new definitions of this variable.

A-3.2.3 Block Data

Much of the basic input data for the Alternative Fuel Vehicle Module is contained within the FORTRAN code of TRANF, in a BLOCK DATA segment. Key variables describing alternative fuel vehicles in BLOCK DATA include:

1. Performance differences,
2. Range differences,
3. Fuel economy differences,
4. Weight differences,
5. Low and high production volume price differences,
6. Time trajectories for the cost of key technologies such as batteries and fuel cells,
7. Applicabilities of AFV technologies to vehicle classes.

Modifications were made to some data in all of these categories in the process of creating the Moderate and Advanced scenarios. The specific changes are highlighted in Table A-3.1. The changes are described in general in the sections describing policy implementation in the respective scenarios.

A-3.2.4 AFV Model Equations

The AFV Module subroutine TALT1 determines the share of, (1) conventional gasoline, (2) alternative fuel, and (3) TDI Diesel vehicles. It contains a variable labeled CALIB, which is set equal to 1 for conventional gasoline vehicles and 0 for the other two categories. CALIB is then added to weighted sum of attributes for each vehicle type before predicting the shares of each technology. The effect of this is to significantly increase the share of gasoline vehicles versus the other two types. In the scenarios, CALIB was set to zero for all three-vehicle types.

In the TALT1 subroutine, several variables describe vehicle range: (1) RNG1 = vehicle range in miles, (2) DR2501 is a dummy variable equal to one if the vehicle s range is >250 miles, and zero otherwise, (3) DR2001 is another discontinuous variable which is set equal to one if the vehicle s range is greater than 200 miles, and (4) RGT2501 is the excess of range over 250 miles, in miles. In the AEO99 version, several of these variables were set equal to 0 for gasoline and diesel vehicles: (1) for the TDI diesel, DR2001 prior to 2003, DR2001 and RNG1 after 2003; and (2) RNG1, DR2001, and RGT2501 for all years. We restored these variables to all equations. However, since we set the coefficients of all but the range variable RNG1 equal to zero in TRNINPUT.WK1, most of these changes had no effect.

In subroutine TATTRIB, we discovered and confirmed with Duc Lee of EIA that two lines of code were missing. These lines resent an index variable to technologies 14 and 15, which are unused and TDI Diesel , respectively. Although we don t know what effect the failure to reset these indices had on the AEO99 case, both ORNL and EIA agreed that it was appropriate to add these lines to the code.

A-3.3 CHANGES TO TRNINPUT.WK1

Numerous changes were made to this basic data input file to describe new technologies, advance the introduction of technologies already included in the AEO99 and modify parameters describing consumer acceptance of technologies. In general, these changes are described in the sections dealing with the implementation of the policy scenarios. Details are provided below and copies of the spreadsheets themselves are available on request.

Three adjustments were made to update the AEO99 technology data. First, the cost of gasoline direct injection engines was reduced to \$200 for 4-cylinder and \$300 for 6-cylinder versions in accordance with the most recent data available on market prices for these technologies. Second the fuel economy benefit was adjusted downward to 12% from 17%, to reflect the most recent estimates of fuel economy benefits obtainable in the U.S., given tier II U.S. emissions standards. Third, the cost of a gasoline hybrid vehicle was reduced. In order to scale the cost of hybrid vehicles by vehicle class, the cost is specified in proportion to vehicle weight. The AEO99 specifies a cost of \$75*(0.05) per pound of vehicle weight. For a 3,000 lb. vehicle this implies a retail price increase of \$11,250. In the moderate case we reduced this to \$30*(0.05)/lb., which implies a mark-up of \$4,500 for a 3,000 lb. vehicle, more in line with the recent evidence concerning Toyota s Prius hybrid.

A-3.3.1 Technology Introduction

In both cases, policies are implemented to accelerate the introduction of new technologies. These include increased investments in R&D, golden carrot awards for technological achievements in energy efficiency and pollution reduction, and voluntary and mandatory fuel economy standards. The impacts of these policies were simulated by reducing the time to market introduction by 30% in the moderate case and 40% in the advanced scenario. However, no introduction times prior to 2003 were changed because of the lead time required for government to implement policies and for manufacturers to alter product plans. In general, introduction times for light trucks lag those of passenger cars by several years. In the advanced scenario, light truck technology introduction dates were set equal to those of passenger cars.

The formula used to advance technology introduction dates in the Moderate case was,

New Date = ((Old Date) - 1999)*0.7 + 1999

Dates were rounded to the nearest year later than 2003. For the advanced case, the formula was,

New Date = ((Old Date - 1999)*0.6 + 1999

In addition, technology introduction dates for light trucks were set equal to those of passenger cars in the advanced scenario.

A-3.3.2 Changes in Horsepower and Weight

Two changes were made to the TRNINPUT spreadsheet to slow down future increases in horsepower and weight in response to a shift in emphasis towards cleaner vehicles. First, the technology list contains an item labeled Increased Size/WT which represents the historical trend of increasing weight for both passenger cars and light trucks. Between 1992 and 1998, the average weight of a new passenger car increased by 6% and that of a light truck by 8%. The AEO99 version of this variable allows for a gradual, continued increase in weight to a total of 20% for passenger cars and 30% for light trucks. These would produce 13.3% and 20% reductions in MPG, respectively. In the moderate case, the total increase in weight for both passenger cars and light trucks was limited to 10%, for a 6.7% reduction in MPG. In the Advanced case, the increase was capped at the 1998 values of 6% and 8%, for cars and trucks, respectively.

The NEMS model contains an equation to predict the change in vehicle performance (measured by the ratio of horsepower to weight) over time, as a function of income, fuel prices, vehicle prices and fuel economy. In the NEMS AEO99 Reference Case, the average horsepower of passenger cars and light trucks increases 48% and 43%, respectively, from 1999 to 2020. For each vehicle class, a multiplier is specified in the TRNINPUT.WK1 file to express the relative importance of performance to vehicles in that class. The multiplier scales the projected typical increase to obtain the percent increase for vehicles in the class. Values in the AEO99 Reference Case were reset for the Moderate Scenario as follows. All were set to 1.0 except for domestic and imported sports and luxury cars, which were set to 2.0. For the Advanced Scenario, these factors were reduced to reflect a greater emphasis by manufacturers and consumers on environment and therefore a reduction of the *rate of increase* of vehicle performance. All vehicle classes were set to 0.5 except for domestic and imported sports and luxury cars, which were set to 1.0.

A-3.3.3 Market Shares

Base year and maximum potential market shares must be specified for each technology. In the Moderate Scenario two changes were made to the AEO99 market shares. First, values were added for the two new materials substitution technologies. For applicable vehicle classes, the base penetration was set at 0 and the maximum at 100. Second, the maximum potential market penetrations for gasoline direct injection (GDI) engines were increased, In the Moderate Scenario, the maximum potential market penetrations of GDI engines were doubled versus the AEO99 Reference Case. For example, the maximum penetrations of 15% for 4-cylinder GDI and 15% for 6-cylinder GDI in the AEO99 case were increased to 30% and 30% in both the Moderate and Advanced Scenarios. In the Advanced Scenario, the maximum market share of the gasoline hybrid was increased from 50% to 66%.

A-3.3.4 Light-Duty Vehicle Fuel Economy Technologies

Only two new technologies were added to the AEO99 version of TRNINPUT.WK1:

1. Materials substitution VI representing a 25% weight reduction versus baseline vehicles at a cost of $1.25/lb, available in the year 2007 for passenger cars, 2009 for light trucks.
2. Materials Substitution VII, a 30% weight reduction at $1.50/lb, available in 2010 for cars, 2012 for light trucks.

Numerous modifications were made to the characteristics of technologies already present.

For these two technologies, the technology notes matrix was modified to require that Materials Substitution VI supersedes Materials Substitutions V, IV, III, II, and I, and that Materials Substitution VII supersedes VI, as well as all of the others.

A-3.3.5 Valuation of Fuel Economy Technology

The Transportation Sector Model estimates the value to the consumer of increased fuel economy as the discounted present value of future fuel savings. In the AEO99, the fuel savings are counted for only the first four years and are discounted at a real annual rate of 8%. This assumption was retained for the Moderate Scenario. In the Advanced Scenario it was assumed that fuel savings are discounted over a 12 year vehicle life at a real annual rate of 15%. The higher discount rate reflects the fact that money invested in vehicle fuel economy technology can be expected to depreciate at approximately the same rate as the value of the vehicle (about 10% per year). Still the second method of discounting assigns a much higher value to future fuel savings, about 45% greater.

A-3.3.6 CEF Study Changes to AFV Model Coefficients

The NEMS Transportation Sector Alternative Fuels and Vehicles Module relies for calibration on estimates of consumers valuation of various vehicle attributes that have been derived from stated preference surveys conducted in California, and for the United States as a whole. The estimates derived from these surveys have been supplemented by several adjustments apparently made in order to insure that AFV module s estimates corresponded more closely with historical AFV market shares. These changes included adding a calibration constant to increase the share of conventional gasoline vehicles, and zeroing out certain variables describing range from the calculations for certain AFV types. While stated preference surveys can be very valuable in eliciting consumers preferences for new commodities for which there is no historical record of revealed preference, they suffer from several well-known shortcomings. Most significant among these are the tendency for respondents to underestimate their true sensitivity to market prices, and the inability of respondents to consistently make trade-offs among a large number of attributes. The former leads to much lower price elasticities than obtained using revealed preference data. The latter leads to inconsistent valuation of attributes. Since neither of these properties is acceptable in a model used for policy analysis or technology forecasting, the CEF study employed an alternative approach.

The CEF study has made extensive changes to the NEMS AFV model coefficients in order to make them more consistent with the assumptions of the Fuel Economy Module, to impose logical consistency among the parameters of the MNL model itself. Our approach is to deduce coefficient values using basic economic principles whenever that is possible, and to use consensus values from the econometric literature when it is not. Whereas in NEMS, some vehicle choice parameters vary by vehicle size class and vehicle type (passenger car versus light truck), the CEF study takes a simplified approach, using one set of parameters for all vehicle types. As noted below, some parameters would be expected to vary with vehicle characteristics while others would not. Correctly implementing these variations would have required changes to the NEMS model that are beyond the scope of our study. We believe that the simplified approach will still produce reasonable estimates.

The formulation of the NEMS AFV model is well suited to the deductive estimation of coefficients. The NEMS AFV model uses an approximation to a nested multinomial (MNL) logit model to predict market shares of conventional and alternative fuel vehicles. Shares of alternative fuel vehicles are estimated based on a measure of the expected utility, U_j , of each vehicle type, j. Utility is represented by a weighted sum of relevant vehicle attributes, x_{ij} . The weights, a_i , are the marginal utilities of each attribute. One of the attributes is the retail price, P_j , of the vehicle type. The weight for price is therefore the marginal utility of $1 of cost, present value, or the negative of $1 of income. Thus, if we can deduce the marginal, present value, V_i , of a 1-unit change in variable i, we can calculate its coefficient, a_i , by multiplying by the coefficient of vehicle price, a_P .

$$a_i = -V_i a_P \quad (1)$$

Equation (1) is used extensively below in translating deduced values for attributes into MNL model coefficients.

Price Elasticity. The most important coefficient in a vehicle choice model is the coefficient of purchase price. In effect, the price coefficient serves as a scaling factor for all other variables in the model. In a multinomial logit model, the price elasticity of market share, , is not constant, but depends on the current market share, s, and on the price level, P as follows: = bP(1-s). Thus, price elasticity will approach a maximum as s nears 0 and approach 0 as s nears 1. For this reason, price elasticities of different models should be compared at constant price and market share. The NEMS AFV model price coefficients range from -0.000041 for mid-size cars to -0.000113 for small vans, with most coefficients in the vicinity of -0.00007. At an average vehicle price of $15,000 and a market share of 50%, the price elasticity would be about -0.5. This is lower even than the overall price elasticity of demand for automobiles, which is generally agreed to be approximately -1.0 (e.g., Kleit, 1990; McCarthy, 1996).

In theory, the demand for types of vehicles should be much more price elastic than the demand for vehicles as a whole. Empirical evidence supports economic theory on this point. Greene (1986) estimated a price elasticity of -10 for the choice between gasoline and diesel engine options on the same carline at a 50% market share. A survey of a dozen econometric studies of vehicle choice produced a consensus price elasticity estimate of -2.8 at 50% market share (Greene, 1994). Lave and Train s (1979) seminal study of automobile choice implies a price elasticity of -3 at 50% share. Recent studies have confirmed that choices among makes and models of cars are highly price elastic. Bordley (1993) concluded that while price elasticities of demand for car classes (e.g., compact, midsize, luxury) ranged from -1.7 to -3.4, average elasticities for carlines within segments ranged from -2.4 to -4.7. Berry, Levinsohn and Pakes (1995) estimated price elasticities of 1990 carlines ranging from -3.1 to -6.7.

A key question is whether choice among alternative fuel vehicles is more or less elastic than choice among carlines. Greene s (1986) revealed preference study suggests that when the choice is between gasoline and diesel engines for an otherwise identical carline, the choice is more elastic, about -10. Greene s (1998) stated preference study of the value of fuel availability implied a price elasticity of about -50 for vehicles described as identical except for the ability of an engine to use a different fuel. This would seem to be an upper bound on elasticity. On the other hand, the choice between very different AFVs, such as a flex-fuel gasoline-alcohol vehicle and a battery-electric vehicle, should be less price elastic because of significant other design differences between the vehicles. This point implies that the current nesting of the AFV choices in NEMS is inappropriate, because it groups choices of very different price sensitivity, whereas in theory it should group vehicles with similar price sensitivity in the same nest. Restructuring the AFV model, however, is beyond the scope of the CEF study. Thus, the question is, on average, what price elasticity is most appropriate in the context of the NEMS AFV model as it is currently structured?

It seems clear that the current price sensitivity is far too small, perhaps by an order of magnitude. A price coefficient of -0.0005 implies and elasticity of -3.75 at $15,000 and 50% market share. This is smaller than the elasticities suggested by Greene s analyses, but those analyses compared otherwise nearly identical vehicles. It is more in line with the estimates for choices among carlines. Given the current structure of the NEMS AFV model, some choices (e.g., between an FFV and a conventional gasoline vehicle) might be similar to choices among engine options for a given carline, while others might be more similar to choices across carlines (e.g., the choice between a fuel cell hybrid and a direct-injection diesel). There is no clear answer. We choose the value of -0.0005 for the CEF study because it seems much more consistent with the majority of the literature on this subject and with the types of choices being made, in general.

The Value of Range. If one assumes that the value of increased range is the value of avoided refueling time, then the proper representation of range and an estimate of its coefficient can be readily deduced. Range, R, is defined as the typical (not maximum) distance a vehicle travels between refuelings. If the typical driver uses 80% of a tank full before refueling, then range is tank size (S, in gallons), times 0.8, times average miles per gallon, MPG (R = (0.8 § S) § MPG).

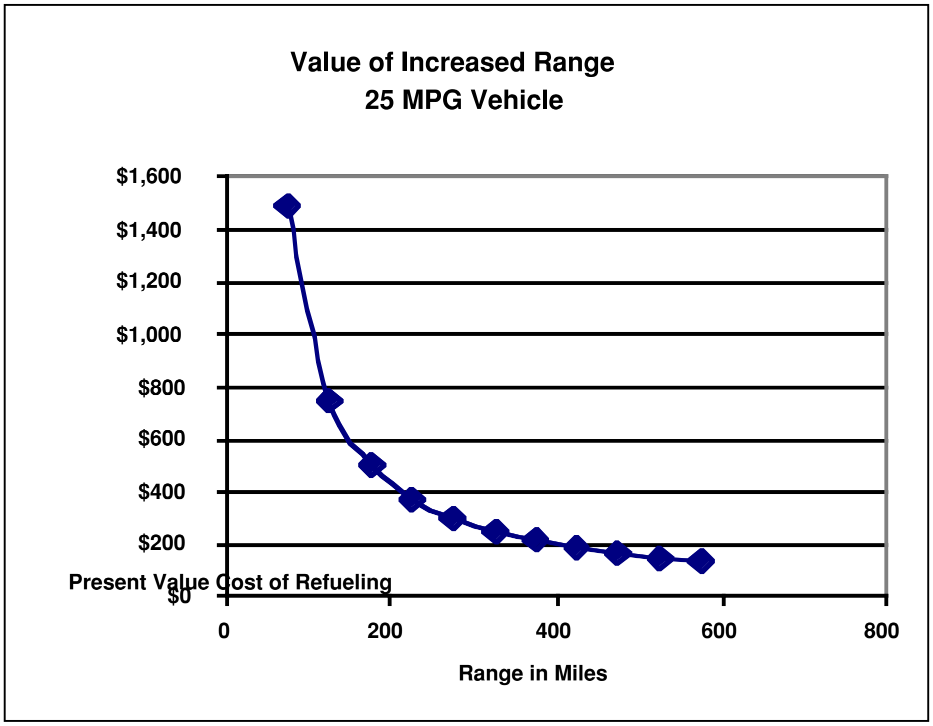
Total refueling cost per year, is equal to the miles driven per year, M, divided by range (which gives the number of refuelings), multiplied by the time required per refueling, T (in hours), and by the value of time, w (in $/hour). The present value of refueling cost will be the discounted sum of costs over the vehicle s lifetime. However, if we assume that range is constant over a vehicle s life, then the value of range is equal to a constant divided by R.

$$V_R = \sum_{l=1}^{L} \frac{wTM_l}{R(1+r)^l} = \frac{1}{R} \sum_{l=1}^{L} \frac{wTM_l}{(1+r)^l} = \frac{1}{R}K \qquad (2)$$

If the discounting were computed continuously by integration, the result would be the same. Also, even if the value of time and the amount of time for refueling were to change over time, the value (or cost) of refueling would still equal a constant divided by R, so long as R remains constant over time. The inverse relationship between range and total refueling cost is illustrated in Figure A-3.1, assuming a large passenger car with EPA-rated MPG of 25, a 15.5 gallon tank, 10 minutes per refueling and time valued at $10 per hour. A factor of 0.85 is used to estimate on-road MPG from the EPA rating.

The present value of range will be a function of both fuel economy and vehicle tank size. To compute a typical value, we use the average EPA MPG of a new passenger car sold in the U.S. in 1998, 28.7 MPG, and a tank size of 15.5 gallons. This gives a nominal range of 445 miles, but after discounting MPG by 15% for in-use fuel economy performance and discounting the tank size by 20% to account for maintaining a reserve at refueling, a more practical range of 302 miles is estimated. Several additional assumptions are required to compute the present value of refueling costs. In the Advanced Scenario, we assume a 12-year vehicle life, a discount rate of 8%, that a new car travels 15,640 miles, decreasing at an average rate of 6.7% per year over its life. This results in a total value for K (representing the value of a 1-unit change in 1/R) of $143,000. This would be, in theory, the value of increasing range from 1 mile to never having to refuel over the life of the car. Of course, half of that value would accrue in increasing range from 1 to 2 miles. The coefficient of range is equal to K times the coefficient of vehicle retail price. If we take the price coefficient to be b = -0.0005, then the coefficient of the inverse of range is -71.5.

Value of Home Refueling. The value of home refueling should be related to the cost of refueling, in general. To the extent that home refueling is faster or more convenient, it should reduce the overall cost of refueling. In other words, the value of home refueling is the value of not having to refuel conventionally, minus the cost of home refueling. A particularly simple approach is to assume that the time cost of home refueling is a certain fraction, f, of that of conventional, retail station refueling, and that h percent of refueling is done at home.



The value of home refueling is thus,

$$V_H = (1- \quad)h(-V_r) = (\quad -1)hV_r \qquad (3)$$

From equation (2) it is clear that the value of range, V_r , depends on the effective vehicle range, R. For a conventional gasoline vehicle with an effective range of about 300 miles, the present value of refueling costs given the discounting assumptions used above, is $473. For an battery electric vehicle with an effective range of 80 miles, the present value of refueling costs would be $1789, even assuming a 10 minute refueling time. Assuming longer refueling times would increase costs proportionately. Clearly, the value of home refueling will be far greater for an EV than for any other type of conventional or alternative fuel vehicle because of its much higher refueling costs.

Given assumptions for f and h, the value of home refueling can be calculated. Assuming that it would require two minutes to set up and disconnect home refueling for the EV, and that home refueling was possible 50% of the time, its value would be $715. Since the dummy variable coefficient equals the total value multiplied by the price coefficient, b, the dummy variable for EV home refueling would be 0.358. Since this dummy applies only to battery electric vehicles in the AFV module, this is the only coefficient needed.

Maintenance Cost. The AFV module represents maintenance costs by an exogenously specified annual dollar expenditure for each vehicle type. If consumers are economically rational, then they will respond equally to a dollar increase in the present value of maintenance costs and a dollar increase in the retail price of a vehicle. Thus, the coefficient for annual maintenance expenditures should equal the coefficient for retail price, multiplied by the ratio of the present value of maintenance costs to annual maintenance costs. If we assume that annual maintenance costs are constant over a vehicle s life, as the AFV module implicitly does, then the present value ratio will be the sum of the discounting factors over the vehicle s lifetime, L.

$$\frac{V_M}{M} = \frac{M \sum_{l=1}^{L} \frac{1}{(1+r)^l}}{M} = \sum_{l=1}^{L} \frac{1}{(1+r)^l} \qquad (4)$$

Given the discounting assumptions used above, equation (4) is equal to 5.491. Thus, the coefficient of maintenance cost should be -0.0005§5.491 = -0.275. Note that the value of this coefficient is not dependent on other vehicle attributes, but only on the discount rate and retail price coefficient.

Fuel Cost per Mile. Similar to maintenance costs, fuel costs can also be viewed as a stream of payments extending over the vehicle s lifetime. Its coefficient can therefore be derived from that of vehicle price by assuming that a dollar of discounted present value of future fuel costs would have the same effect as a dollar of vehicle price. The fuel cost coefficient can be related to the coefficient of vehicle price through a discounting of future fuel costs. However, the relationship between the fuel cost coefficient and the retail price coefficient is more complex and is dependent on the vehicle s fuel economy. It also depends on the consumer s expectation about the number of miles the vehicle will be driven in future years, m_t, and the future price of fuel, P_t. More precisely, the present value of future fuel costs is given by equation (5).

$$V_F = \sum_{l=1}^{L} \frac{M_l P_l}{MPG_l (1+r)^l} = \frac{-P_t}{MPG} \underset{\aleph}{\sqrt{\ }} \sum_{l=1}^{L} \frac{M_l}{(1+r)^l} \qquad (5)$$

If it can be assumed that MPG will remain roughly constant over a vehicle s lifetime and if consumers can be assumed to have static expectations about future fuel prices, then the value of fuel costs equals the current fuel cost per mile times discounted future vehicle miles of travel. Thus, the coefficient for fuel cost per mile is equal to discounted miles times the retail price coefficient, b. Using the same assumptions for vehicle usage and discounting as in equation (2), the number of discounted miles is equal to 58,875. Multiplying by b = -0.0005, and dividing by 100 to convert to cents gives fuel cost (in cents) per mile of -0.429. Note that the value of this coefficient does not depend on the current price of fuel, or on the fuel economy of the vehicle in question, since these are accounted for in the fuel cost per mile variable.

Multi-fuel Capability. The value of the ability to use more than one fuel is the most difficult value to deduce because it depends on so many unknown factors. The simplest economic value of multi-fuel capability would be the value of the option to buy the cheapest fuel at any given time. If the prices of fuels are not perfectly correlated, then having a choice among two or more fuels should enable the motorist to achieve a lower overall fuel cost. Greene (1994) simulated the value of this option using historical data on prices of petroleum fuels and natural gas, and obtained option values for M85, E85, CNG and LPG ranging from 0.1 cents to 2.6 cents per gallon. These values depend on the expected price differences among the fuels, the variability of prices and the correlations among prices over time. In general, the value increases the smaller the expected price differences, the larger the variability of prices, and the less correlated the prices are.

If we assume an option value of $0.02 per gallon (toward the high end of Greene s range), then the expected value per mile for a 28.7 MPG vehicle would be 0.07 cents per mile. Multiplying by the fuel cost per mile coefficient produces a dummy coefficient of 0.0299 for the multi-fuel option, a relatively small component and probably negligible. However, the value of a multi-fuel option will also strongly depend on the availability of alternative fuels. In effect, the cost of obtaining the alternative would be subtracted from the value. In no case would the value be negative, however, since purchasing a conventional fuel is still an option. Because the value of this dummy variable appears to be negligible, no correction is made for fuel availability.

Luggage Space. The value of luggage space is gleaned from other studies. Greene (1994) cited three studies that had reported values for luggage space ranging from $92 to $670 (1990 $) per cubic foot. Greene discounted these estimates, noting that Greene and Liu had found a range of estimates for interior volume of $32 to $192 per cubic foot. They argued that luggage space should be valued at less than passenger space and chose a value of $31. Donndelinger and Cooke (1997) take issue with Greene s reasoning, arguing that the marginal values of interior room and luggage room should be the same when competition between the two spaces is optimally balanced. They suggest a best estimate of $150 (1990 $). This argument assumes that the production functions for luggage space and interior volume are the same, because if the cost of producing luggage space differed from that of producing interior volume, then there is no reason why the marginal costs should be equal in the optimal design. Optimal design requires that the marginal cost of producing another unit of luggage space equal its marginal utility to the consumer, and the same for interior space. We think it is likely that the cost function for producing luggage space differs from that for interior space and suspect that the marginal utilities differ as well. However, given that the preponderance of the empirical evidence is much closer to Donndelinger and Cooke s estimate of $150, we will use their value, which translates into a coefficient of 0.05.

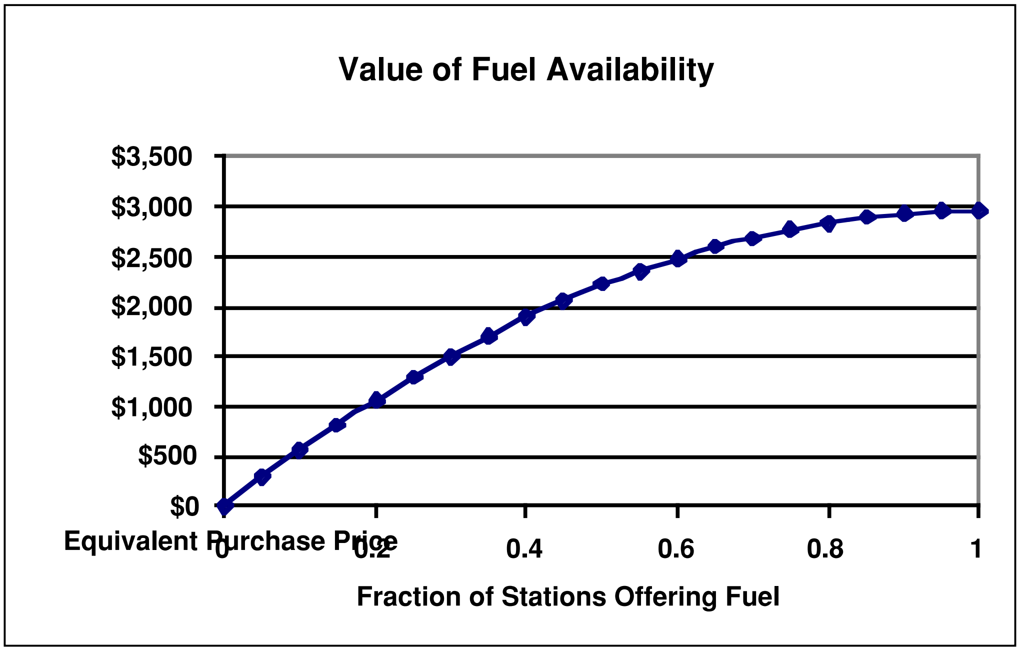
Acceleration Performance. Estimates for the value of performance based on consumer survey data vary even more widely than those for luggage space. Greene and Liu (1988) settled on a value of $450 (1990 $) per 10% increase in horsepower to weight ratio. Greene (1994) chose $25 per 1% increase, arguing that the marginal utility of performance should decrease with increasing performance. McConville and Cooke (1996) found that consumers valuation of performance seemed to correlate with the log of the acceleration force. Donndenlinger and Cooke (1997) report an estimate of $270 (1997$) for a 10% reduction in acceleration time from 0-60 mpg. This would be $225 in 1990 $. The NEMS model variable is 0-30 mph acceleration time, however, we assume an equivalent value for a 10 percent reduction. Given that a typical 0-30 mph acceleration time is about 3.5 seconds, $225-$250/0.35 seconds, gives a range of value of $643-$714 per second. We will use $700/second, which translates into a coefficient of -0.35.

Top Speed. There appear to be no estimates of the value of top speed other than that in the NEMS model equations and supporting studies. We therefore use the value of $44 per mile per hour implied by the NEMS model parameters for midsize vehicles. This translates into a coefficient of 0.022.

Fuel Availability. Lack of availability of fuel is probably the most salient feature of alternative fuel vehicles, at least until they achieve market success and develop a widespread fuel retailing network. There are few empirical studies of the value of fuel availability. Surveys of diesel vehicle owners suggested that at station densities of 10% to 20%, fuel availability went from a major concern to a minor one (Sperling and Kitamura, 1986; Sperling and Kurani, 1987). The California stated preference surveys on which the NEMS model coefficients are partially based, suggest very high values for fuel availability, in the tens of thousands of dollars per vehicle for full versus negligible fuel availability (Brownstone, 1995). A recent nationwide stated preference survey, focused exclusively on fuel availability and alternative fuel choice concluded that an increase from 1% to 100% availability was worth $1,000 to $3,500 to motorists, depending on the context of the choice and functional form used to represent value as a function of percent of stations offering the fuel (Greene, 1998). We use here a value of $3,000 for full versus 0% fuel availability, more consistent with Greene s recent study. This is implemented in NEMS as a quadratic function of the fraction of stations, s, offering the fuel, as shown in equation (6).

$$V_f = 3.0s - 1.5s^2 \tag{7}$$

This function has a maximum of 1.5 (with a dollar value of $3,000) at s = 1.0 and a value of zero at s = 0, as shown in Figure A-3.2.



Comparison of Original NEMS Model Coefficients and CEF Study Alternatives. The implied values of vehicle attributes for the NEMS AFV model coefficients and for the CEF alternatives are compared in Table A-3.2. Basic data on vehicle use, fuel economy and discount rates used in calculating the coefficients are shown in Table A-3.3. The NEMS coefficients apply to a compact automobile, but are not very different for other vehicle classes. In the 1999 NEMS AFV model, coefficients of price, fuel cost and range vary by vehicle class, while coefficients for other variables do not. The CEF coefficients do not vary by vehicle class. The CEF coefficients, however, do vary by scenario, because assumptions about discounting fuel economy and other future costs and benefits vary. In particular, the moderate scenario uses much higher discount rates and thus places lower values on fuel economy, maintenance costs, etc.

Some implied values are very different, while others are similar. Values for acceleration and maintenance costs are quite similar, and values for top speed are the same by assumption. The value of fuel economy is twice as large in the NEMS AFV model than for the CEF alternative. The CEF version puts three times as much emphasis on luggage space, but values fuel availability and home refueling far less. The implied value of fuel availability (100% v. 0%) is the difference between the linear and squared coefficients. This would be roughly $20,000 (or the full value of the vehicle) for the NEMS AFV coefficients, and $3,000 for the CEF alternative. The NEMS AFV model, however contains three other range variables which the CEF alternative zeroes out. The NEMS AFV model puts a very large negative value on the ability to use more than one fuel, while the CEF alternative gives it a small positive value. These imply, among other

Table A-3.2 Vehicle Choice Model Coefficients: Comparison of Original NEMS Transportation Sector AFV Model Values and CEF Study Values, Advanced Scenario

			Original NEMS Model Coefficients			CEF Modified Coefficients
Variable Description	**Name of Variable**	**Units**	**NEMS Coefficient**	**NEMS Value 1990 $**	**CEF Value 1990$**	**CEF Coefficient**
Vehicle Price	PSPR	1990 $	-0.000068	-$1.00	-$1.00	**-0.0005**
Fuel Cost	FLCOST	cents / mile	-0.1121	-$1,648.53	-$858.75	**-0.429**
Range (for only Evs in AFV)	VRNG	miles	0.00474	$69.71	-$143,125.76	**-71.56**
Top Speed	TPSD	mph	0.00304	$44.71	$44.00	**0.022**
Acceleration	ACCL	seconds 0-30mph	-0.062	-$911.76	-$700.00	**-0.35**
Range Ratio >250 miles	DR250	ratio	0.166	$2,441.18	$0.00	**0**
200 mi< Range Ratio <400mi	DR200	ratio	1.23	$18,088.24	$0.00	**0**
Multifuel Capability	MFUEL	dummy	-0.58	-$8,529.41	$2.99	**0.00150**
Home Refueling for Evs	HFUEL	dummy	0.186	$2,735.29	$189.26	**0.0946**
Maintenance Cost	MAINT	annual 1990 $	-0.0005	-$7.35	-$5.49	**-0.00275**
Luggage Space	LUGG	ratio to conv.	0.00335	$49.26	$150.00	**0.075**
Fuel Availability	BETAFA	fraction	2.96	$43,529.41	$6,000.00	**3**
Fuel Availability^2	BETAFA2	fraction^2	-1.63	-$23,970.59	-$3,000.00	**-1.5**
Range>250	RGT250	miles	-0.0059	-$86.76	$0.00	**0**

things, a large benefit of $18,000 for being in the conventional vehicle range of 200 to 400 miles, and a negative value for miles above 250. The implied values of the variable VRNG shown in table 1 are not comparable between the two formulations. In the NEMS AFV model VRNG applies only for battery electric vehicles. In the CEF alternative it applies to all vehicles, but appears as 1/range. Thus, the value of $140,000 is the value of a nearly infinite range versus a range of 1 mile. The value of 400 versus 80 miles of range, for example, would be 1% of that, or $1,400.

Table A-3.3 Basic Data for AFV Model Coefficient Calculations

Annual miles of use	Base MPG	Vehicle Lifetime	Fuel Price
15640	28.7	12	$ 1.15
Annual decrease in vehicle use.	In-use mpg factor	Discount Rate	Combined Rate
0.067	0.85	0.08	14.7%
Annual Fuel Cost	Total Fuel Cost	PV Fuel Cost	Check Calc.
$ 627	$ 7,520	$3,441	$ 3,441

A-3.3.7 Year of Availability

Several changes were made to the commercial availability assumptions for alternative fuel vehicles. These describe the year in which 50% of the demand for a type of AFV can be met by manufacturers. The year given is used as the midpoint of an S-shaped market penetration curve. Table A-3.4 compares the 50% year assumptions for the BAU, Moderate, Advanced scenarios and the Fuel Cell Success sensitivity case.

Table A-3.4 Year of Availability Assumptions for Alternative Fuel Vehicles

	BAU Scenario	Moderate Scenario	Advanced Scenario	Fuel Cell Success Case
Gasoline ICE Vehicles	1960	1960	1960	1960
TDI Diesel ICE	2009	2010	2006	2006
Methanol-Flex Fuel ICE	1997	2003	2003	2003
Methanol ICE	2005	2010	2006	2006
Ethanol-Flex Fuel ICE	1997	2003	2003	2003
Ethanol ICE	2005	2010	2006	2006
Electric Vehicle	1997	2009	2009	2009
Electric-Diesel Hybrid	2005	2005	2005	2005
CNG ICE	1996	2010	2006	2006
CNG Bi-fuel	1998	2000	2000	2000
LPG ICE	2006	2010	2006	2006
LPG Bi-fuel	1998	2000	2000	2000
Fuel Cell Gasoline	2010	2010	2010	2005
Fuel Cell Methanol	2010	2010	2010	2005
Fuel Cell Hydrogen	2010	2010	2010	2005

A-3.3.8 Fuel Availability

The NEMS model input requires estimates of fuel availability for each of eight fuels by nine regions through 2020. The only change made to the AEO99 Reference Case in the Moderate Scenario was to decrease the availability of diesel fuel from 100% in 2020 to 50%. In the AEO99, diesel fuel availability is set to 1.0 (100%) throughout. In the Moderate Scenario it begins at 0.2 (20%) from 1990 to 2005. After 2005, diesel availability increases by 2 to 3 points per year to reach 50% by 2020. This assumption is uniform across regions. This change, which corresponds more closely to the current availability of diesel fuel, was considered to be necessitated by other changes in the AFV model coefficients described above.

In the advanced case, due to the much greater advances assumed to occur in fuel cell vehicle technology, availability of methanol and hydrogen were also increased to 50% in every region by the year 2020. Hydrogen fuel availability is 2% by 2005, increases to 20% by 2015 and 50% by 2020. Methanol availability increases from 2% in 2000 to 31% by 2010 and 50% by 2020. These assumptions are maintained across all regions. In the Fuel Cell Success sensitivity case, the availability of hydrogen fuel was increased gradually to reach 1.0 in the year 2020.

For reference, in the AEO99, the year 2020 availability of other alternative fuels varies across regions as follows:

1. Ethanol: from 10% to 98%
2. CNG: from 10% to 49%
3. LPG: from 10% to 49%
4. Electricity: 100%

A-3.3.9 Maintenance Costs

In the Fuel Cell Success sensitivity case, maintenance costs for methanol and gasoline fuel cell vehicles were set equal to those of conventional gasoline vehicles. Maintenance costs for hydrogen FCVs were set at 75% of conventional gasoline vehicles.

A-3.3.10 Luggage Space

In the Fuel Cell Success sensitivity case, luggage space for fuel cell vehicles was set equal to that for conventional gasoline vehicles.

A-3.4. TRUCK FREIGHT MODULE

No changes were made to the computer code of the Truck Freight Model.

A.3.5 CHANGES TO CFFFUEL.WK1

Technology inputs to the Freight Truck Module are contained in the spreadsheet CFFUEL.WK1. The AEO99 lists six new technologies introduced after the base year of the model, 1992. Of these, four have already been introduced, the last in 1997. This leaves two future technologies, the turbo-compound diesel introduced in 2010 and the Low-Emission 55" diesel engine (LE-55). The LE-55 diesel is listed, but not actually introduced in the AEO99 forecast, since its introduction year is set to 9999.

Several changes to the technology list were made in the Moderate Scenario. First, the LE-55 engine is introduced in 2010. Next, the turbo-compound engine is deleted and replaced by materials substitution to reduce vehicle empty weight, introduced in 2005. Trigger prices for the technologies were reduced to just below the lowest price in the AEO99 forecast, so that they will enter the market in the specified introduction year and penetrate according to the model s s-shaped curve. The prices for Diesel, gasoline, LPG and CNG, in 1987 dollars are $5, $6, $8, and $5 per million Btu, respectively. Parameters of the market penetration curves were not changed, the turbo-compound diesel curve was used for material substitution. The maximum market share for the LE-55 engine was set to 1.0 for both medium and heavy diesel trucks and 0 for all other fuel types and weight classes.

A few changes were made to the assumed percent fuel economy improvements for technologies. First, since Improved Tires and Lubricants supersedes Radial Tires , and since both have 5% efficiency gains, the net effect of introducing the improved technology would be zero. Hence, the improvement for Improved Tires and Lubricants is set to 10% so that there will be a net 5% benefit. The benefit of Electronic Transmission Controls was set to 5% for medium duty vehicles and 3% for heavy duty vehicles. Similarly, the impact of Advanced Drag Reduction was increased to reflect the fact that it supersedes Aerodynamic Features . It was increased to 7% for medium duty vehicles to give a net benefit of 2%, and to 18% for heavy vehicles to give a net benefit of 5%. Likewise, the LE-55" engine supersedes the Fuel Economy Engine . Its benefit is set at 26% for medium diesel trucks, for a net benefit of 19%, and at 34% for heavy diesel trucks for a net benefit of 21%.

In the Advanced Scenario, a hybrid truck technology is introduced in 2005. The hybrid truck is applicable to all fuel types and both truck sizes, but the maximum market shares are set at 0.25 for heavy diesel trucks, 1.0 for all types of gasoline trucks, and 0 otherwise. Time to 99% market penetration is set to 20 years, and a price variation parameter of 0.75 is chosen, the same as for the LE-55 engine. Fuel economy benefits for the hybrid are set at 25% for diesels and 45% for gasoline engines.

In addition, the LE-55 is advanced to 2005. The only change in fuel economy benefits is for the medium diesel application of the LE-55 engine, which is raised by 2%.

A-3.5.1 Air Travel Module

No changes were made to the computer code of the Air Travel Model.

A-3.5.2 Rail and Marine Module

No changes were made to the computer code of the Rail and Marine Models.

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