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Cafe Credits For Alternative Fuel Vehicles

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Under the Alternative Motor Fuels Act of 1988 (AMFA), alternative fuel vehicles are given favorable treatment in calculations of their fuel efficiency for the purposes of complying with corporate average fuel efficiency (CAFE) standards. Established by the Energy Policy and Conservation Act of 1975, CAFE standards establish the minimum sales-weighted average fuel economy that each automobile manufacturer's new cars must meet. There is a separate standard for automobiles and light duty trucks.[1] If a manufacturer does not meet the standard it is liable for a civil penalty of $5.50 for each 0.10 mpg its fleet average falls below the standard, multiplied by the number of vehicles sold in a given model year and reduced by the number of credits available to the manufacturer (Federal Register 62(23):5170). Formally, the civil penalty is calculated as follows.

$$\text{Penalty} = 10 \cdot \$5.50 \cdot (\text{Standard} - \text{CAFE}) \cdot \text{Vehicles Sold} - \text{Credits}$$

Credits are earned when a manufacture more than attains the standard in any model year and may be banked or borrowed for 3 years on a rolling basis.[2]

According the AMFA (including revisions contained in EPACT) a gallon of alternative fuel used in a dedicated alternative fuel vehicle shall be considered to contain 15% of a gallon of gasoline (on an equivalent fuel basis). Vehicle fuel economy is to be measured in terms of gallons of *gasoline* per mile, not gallons of motor fuel per mile.. Thus for the purposes of the CAFE standards, the fuel efficiency of dedicated AFV is measured as: $MPG_{CAFE-ded} = \frac{MPG_{measured}}{0.15}$ (AMFA, Sec 513). As with conventional vehicles, measured MPG is the weighted harmonic average of the MPG of city and highway driving, where the weights are 0.55 and 0.45, respectively. For dual-fueled (or multi-fueled) vehicles the AMFA assumes that the gasoline and the alternative fuel are each used half of the time. The MPG calculation is, therefore, the harmonic average of the

[1]Imported and domestic vehicles fleets are counted separately.

[2]The actual determination of a vehicle manufacturer's liability for civil penalties is determined by the National Highway Traffic Safety Administration (NHTSA) who keeps track of the borrowed and banked CAFE credits.

fuel efficiency using both fuels (AMFA, Section 513 (b)).[3]

$$MPG_{CAFE-flex} = \frac{1}{\frac{0.5(gasoline)}{MPG_{measured}} + \frac{0.5(alternative\ fuel)}{\frac{MPG_{measured}}{0.15}}}$$

In determining fuel efficiency, gallons are measured in terms of gasoline equivalent gallons. For gaseous fuels the equivalent measurements are defined by NHTSA. These equivalents are shown in the Table below.

Table Gallon Equivalents for Gaseous Fuels per 100 Standard Cubic Feet

Fuel	Gasoline Gallon Equivalent
CNG	0.823
LNG	0.823
LPG (grade HD-5)	0.726
Hydrogen	0.259
Hythane (Hy5)	0.741

Source: Federal Register, April 2, 1996 (Volume 61, Number 64)

To incorporate alternative vehicles into an automobile manufacturer's fleetwide CAFE rating, the law requires a harmonic average of the MPGs of each vehicle type's MPG weighted by the sales share. The harmonic average yields the following formula:

$$CAFE = \frac{1}{\sum_f \frac{S_f}{MPG_f}}.$$

where S_f is the share of vehicles using fuel-technology type *f*, i.e., $S_f = \frac{V_f}{\sum_f V_f}$, and V_f is the number of vehicles using fuel-technology type *f* sold in a particular model year.

Given the their favorable treatment for CAFE compliance purposes, AFVs are potentially quite valuable to automobile manufacturers. In past years, the sales-weighted fuel economies of all (domestic and imported) automobiles and light trucks have, *on average*, met the CAFE standards (Davis 1997, Table 3.40).[4]

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[3]The fuel economy credit for FFVs applies only for model years 1993-2004 (AMFA, Sec. 513f(1)).

[4]Davis, Stacy C., Transportation Energy Databook, Edition 17, ORNL-6919, Center for Transportation Analysis, Oak Ridge National Laboratory, August 1997.

Individual manufacturers, however, have not been able to meet the standards and have paid tens of millions of dollars in fines, as shown in the table below.

Table: CAFE Fines Collected (Thousands)		
Model Year	Current Dollars	1990 constant dollars
1983	58	76
1984	5,958	7,496
1985	15,565	18,908
1986	29,872	35,603
1987	31,261	35,945
1988	44,519	49,181
1989	47,381	49,946
1990	48,449	48,449
1991	42,243	40,511
1992	38,287	35,645
1993	28,688	25,693
1994	31,474	27,760
1995	39,985	34,267
Sources: Davis (1997, Table 3.41)		

Even if a vehicle manufacturer meets the CAFE standards, selling AFVs may still be worthwhile. This is because the sale of additional high-MPG AFVs allows manufacturers to shift their sales mix to incorporate more low-MPG vehicles, which can have higher profit margins. This of course requires the CAFE standard to be binding, or close to binding.

Conceptually, the benefit of producing a larger share of AFVs, $B(S_a)$, is equal to the sum of avoided penalties and increased profits from changes in the sales mix. In other words,

$$B(S_a,S_c) = -P(S_a,S_c) + \pi(S_c,S_a)$$

where - P(Sa) are the avoided penalties and $\pi(S_c,S_a)$ is the manufacturers profit function whose arguments are the shares of conventional and alternative fuel vehicles.[5] Knowing how vehicle manufacturers' profits change from shifts in sales mixes requires detailed privately held information which cannot be easily obtained.

[5]In addition to these two components there are also costs to corporate image from public shame at failing to attain the CAFE standard.

For the model year 1995, domestic manufacturers had CAFE ratings below the standard for light-duty trucks (see Davis 1997, Table 3.40).[6] This does not mean that domestic manufacturers necessarily paid fines for these vehicles since they are allowed to borrow and bank CAFE credits for 3 years. It does show, however, that the CAFE standard is, on average, binding for domestic LDV manufactures. Combining the observed ratings (using a harmonic sales weighted average for cars and light-duty trucks) yields a combined domestic CAFE rating equal to 23.82, this compares to a combined CAFE standard of 23.92. We can use this average data as an approximation for the value of avoided fines that could be made possible by incorporating AFVs into the sales mix of domestic manufacturers. Using the 1995 (harmonic) average fuel efficiency for domestic cars and trucks as the base, the fuel efficiency of alternative vehicles can be calculated. These fuel efficiencies are shown in the table below.

Table: Fuel Economy of Vehicles for CAFE Compliance

Fuel and Vehicle System	Fuel Economy (miles/GEG)
Gasoline Dedicated	32.82
Alcohol Dedicated	158.80
Alcohol Dual	41.43
LPG Dedicated	158.80
LPG Dual	41.43
CNG Dedicated	158.80
CNG Dual	41.43
Electricity Dedicated*	154.0

*Based on the EV1

Ignoring the banking and borrowing of credits, the change in benefits from a reduction in penalties is given by

$$\frac{\partial B(S_a,S_c)}{\partial S_a} = -\$55\sum_a \left(\frac{\partial CAFE(S_a,S_c)}{\partial S_a}\right), \qquad \forall\ a. \tag{1}$$

As can be seen, the level of the CAFE standard does not affect the marginal value of an increase in the CAFE rating. The level of the CAFE standard, does however, determine how many AFVs need to added to the conventional fleet in order to raise the sales-weighted fuel efficiency such that no penalties are imposed. This share of AFVs is, of course, dependent on which AFVs are added since they have different fuel efficiencies.

Incorporating these fuels and vehicles into the average CAFE rating shows that the CAFE standard is binding up until (approximately) 1% of dual-fuel or 0.5% of dedicated vehicles are added to the current sales fleet sales mix. The marginal value of an additional vehicle, up until these percentages are reached, ranges from about $557 - $1,120, respectively.[7] The estimated total penalty using this average data is about $71 million

[6]Manufacturers of imported vehicles do not, on average, face binding CAFE standards. Some imported manufacturers, especially those selling high-performance vehicles, fail to meet the CAFE standard and pay fines.

[7]The marginal value is determined using a discrete approximation to the above formula. Interestingly, the marginal values are fairly constant over the range in which the CAFE standard is binding.

dollars, while the actual assessed penalties over the ten-year period 1986-1995 average $43 million. We, therefore, adjust our estimated marginal values down by multiplying by 0.61 (≈ 43/71). This yields per-vehicle marginal values of $343 - $686 for dual and dedicated vehicles (respectively) up until AFVs make up 1% - 0.5% (respectively) of new vehicle sales in each year.

As a policy case, we asked the question, what would happen if the automobile and LDT CAFE standards were raised from 27.5 to 28.5 MPG and 20.7 to 21.7 MPG, respectively? That is, what would happen to the number and value of CAFE credits and to the penetration of AFVs into the market place if the CAFE standard were raised 1 MPG? Naturally, vehicle manufacturers could use available technologies on gasoline vehicles to meet the new higher standard. Alternatively, if they chose to meet it only using AFVs, then using the same assumptions described above, we find that the marginal value of CAFE credits to be $600 - $1200. The CAFE standards will no longer be binding (and the credits will lose their value) when the AFV sales reach either 5.5% for dedicated vehicles or 11% for dual fueled vehicles, or some combination in-between[8]

[8]It is not too surprisingly that the marginal value of credits does not change significantly when the CAFE standard is raised. As is seen in equation (1), the marginal value of a CAFE credit is determined by the level of the fine, not the degree of non-compliance.