Chapter 21

ROCKY MOUNTIAN INSTITUTE LIGHT-VEHICLE STOCK AND FLOW POLICY MODEL OVERVIEW

The RMI light vehicle stock-and-flow model estimates the effects of the following light-vehicle policies on efficient-vehicle market penetration.

Feebates

Previous studies have shown that greater than 90 percent of the efficiency improvement from feebates results from manufacturers response to the feebate (product-mix), as opposed to consumer response (sales-mix).[i] As a simplification and conservatism, we assume light-vehicle supply equals demand and explicitly ignore the sales-mix response. Our model takes feedback from previous years' sales to compute the next year's feebate pivot point, which in turn affects consumer choice through a Benefit to Cost calculation to the manufacturer. This calculation compares the fuel savings and rebates to the consumer with the incremental cost of the *Conventional Wisdom* or *State of the Art* technology to the manufacturer. Technological progress is modeled through the gradual introduction of *State of the Art* technologies. The model then estimates the effect of efficient-vehicle market penetration on vehicle stock dynamics through 2025 (including fuel use, vehicle stock efficiency, and consumer surplus) based on EIA's *Annual Energy Outlook 2004* projected sales mix and vehicle miles traveled (VMT).

Low-income vehicle scrappage program with replacement

This policy applies only to *Conventional Wisdom* vehicles. We model one million vehicle sales (above EIA's baseline projection) beginning in 2010, with a five year phase-in period in which the number of vehicles introduced through this program increases at a linear rate. For simplification we ignore the effect of removing inefficient vehicles from the stock and focus instead on the much larger efficiency increase brought about by new efficient-vehicle purchase.

Platinum carrot competition and government vehicle purchases

State of the Art with technology procurement assumes 3-year shortening of the time it takes to capture 010% of the market as a result of secured market demand from three policies (government procurement, golden carrot, and platinum carrot). Thus, we model the guaranteed loans to directly increase the *State of the Art* retooling rate by pushing the retooling end date from 2030 to 2024.

Secured debt financing to the manufacturer

We recognize the strained balance sheets of auto manufacturers,. Our model therefore assumes secured debt financing to enable the manufacturers to finance the retooling effort.

Assumptions

-5%/y discount rate to the consumer, fuel savings valued over 3 years.
-14-year vehicle life.
-Retooling: first *State of the Art* vehicle by 2010, 20 years to 90*%; Conventional Wisdom* much earlier and steeper slope (because they incremental technologies currently in the marketplace).
-No technology improvement for *Conventional Wisdom* or *State of the Art* vehicles while EIA light vehicles improve per baseline (and include 1 million hybrids by 2025).
-Non-changing incremental costs for *Conventional Wisdom* and *State of the Art.*
-Per Davis (1995) and Greene (2004) 90%+ of improvement from feebates is due to manufacturer (product-mix) improvement, while the remaining 10% is due to consumer (sales-mix). For this reason we conservatively ignore the consumer response.
-Manufacturer response is modeled by Benefit to Cost ratio that compares consumer's valuation of the technologies with consumers incremental technology cost (see *Technical Annex,* Ch. 5, table 5-10 for more information).
-We assume EIA baseline for new light-vehicle sales volume, distribution of sales between cars and light trucks, and VMT.
-Technological improvement will go entirely towards decreasing fuel consumption, not increasing performance (except for the performance increase implicit in the EIA projection). EIA projected vehicles and *Conventional Wisdom*/*State of the Art* technologies assumed to be the same except for efficiency and price (consumers value of performance increase = 0 in all cases).
-When introduced into the marketplace, *State of the Art* vehicles are purchased by buyers who otherwise would have purchased *Conventional Wisdom* vehicles in the absence of *State of the Art* technologies.
-Consumers will respond in the same way through the model to *State of the Art* vehicles as they do to *Conventional Wisdom* vehicles.
-Indifferent manufacturers will adopt technologies 50% of the time.

Introduction

Consumers only consider the first three years of fuel savings in their automobile purchase decision, and fuel efficiency ranks low on the list of considerations for new car buyers.We examine a feebate system to solve this market failure by giving a rebate for a portion of the previously undervalued fuel savings. Each feebate policy has a pivot point, or fuel intensity (in gallons per mile) above which car buyers pay a fee and below which car buyers receive a rebate. Both the fee and the rebate are based on the difference between the new car’s fuel intensity and the pivot point. Feebates work by increasing market capture of existing efficient vehicles and, by changing the pivot point yearly, work to incentivize manufacturers towards continued automobile efficiency. Unlike efficiency standards, feebates are fully transparent to buyers and are continuous rather than step functions, removing the incentives for gaming the policy. Unlike fuel taxes, feebates provide a direct and undiscounted price signal at the time and place of buying the car and unlike any other policy instrument, feebates reward continuous improvement.

We based the model on literature describing the adoption rate for individual fuel-efficient technologies to model the adoption of our suite of *Conventional Wisdom* and *State of the Art* technologies.

Methodology
We consider feebates on two distinct classes of vehicles (cars and light trucks) and over two technology portfolios (*Conventional Wisdom* and *State of the Art*). *Conventional Wisdom* and *State of the Art* are portfolios of technologies available to the consumer in 2025. At a respective 31 mpg and 74 mpg (EPA adjusted), they represent the upper end of the new car efficiency distribution (see below).

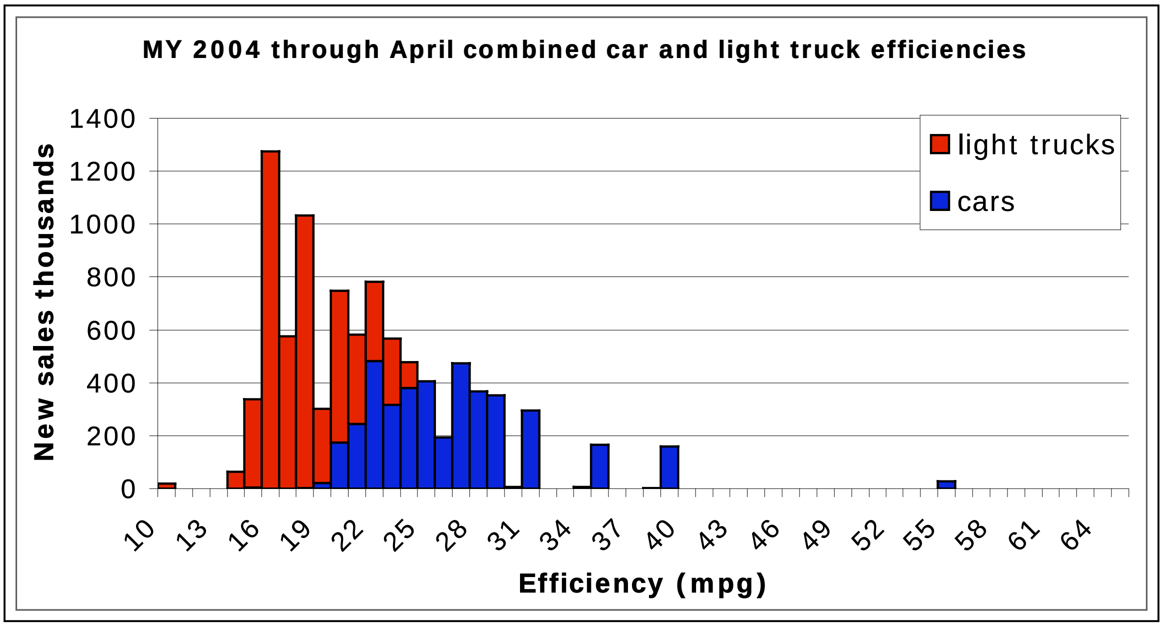

Figure 21-1: MY 2004 cars include 657 models with a median fuel economy of 23 mpg, a maximum of 63mpg, and a standard deviation of 5.45. MY 2004 light trucks include 488 models with a median fuel economy of 18 mpg, a maximum of 26 mpg, and a standard deviation of 2.99.[ii]

In keeping with our assumption that consumer's utility function will not change, we design a separate pivot point for cars and light trucks so as to not encourage shifting between vehicle classes. We calculate the pivot point for the feebate in Equation 21-1 as the difference between the average car and the *Conventional Wisdom* or *State of the Art* car efficiency in gpm (gallons per mile), weighted by their respective populations for the previous year.

Equation 21-1:
#*Conventional Wisdom* x (GPMcw – PIVOT) = #AV x (PIVOT – GPMav)

Rearranging Equation 21-1 implies:
PIVOT = [#*Conventional Wisdom* x GPMcw + #AV x GPMav] / (#*Conventional Wisdom* + #AV)

To keep the policy revenue neutral, and to create incentives to manufacturers for installing new efficient technologies, we adjust the pivot point yearly based on previous year's sales data and projected fleet efficiencies. To calculate the 2005 market share, we use the seed values below for *Conventional Wisdom* and *State of the Art* light vehicle sales in 2004:

Table 21-1: Estimated values for 2004 vehicle sales

	car	light truck
Conventional Wisdom	100,000	10,000
State of the Art	0	0

The resulting rebate, or fee, is calculated at a variable rate per 0.01 gpm delta from the pivot point (equation 21-2). As market penetration increases (mainly as a result of increasing retooling rates for *State of the Art* vehicles), more cars will adopt fuel-efficient technologies and will receive rebates, while fewer inefficient cars will be sold to pay the complementary fees. Extremely efficient vehicles would receive a much larger rebate and vehicles near the pivot point would receive a near zero rebate. The same would also be true on the fee side, for a example a 2004 *Toyota 4Runner* would pay a fee of $429 in 2005 while the average fee would be $2, and the same *Toyota 4Runner* would pay $2,004 if it were sold in 2025, when the average fee would be $865. This moving pivot point is an important instrument in feebates, beginning with small fees and large rebates when volumes of efficient vehicles are small and increasing towards efficient technologies.

Equation 21-2:
$FEEBATE = RATE x [(GPMx - PIVOT) / 0.01]

Feebates can either be paid to the consumer or to the manufacturer. In theory, both destinations would have the same effect to increase consumer choice for efficient vehicles. We have learned from rebates to efficient appliances that the most value can be captured from a program if incentives are applied throughout the value chain. However, feebates given solely to the manufacturer would leave open the possibility of rebates not being passed directly to the consumer (a lack of transparency). We recommend feebates be given to the consumer at the point of purchase, to increase transparency and prevent distillation of the rebate by the manufacturer. We imagine a feebate program that is described directly on the sticker price, possibly in combination with EPA's fuel efficiency labeling program.[iii]

We recognize that 90 percent of the increased efficiency that results from a feebate program comes from a manufacturer's reaction to the increased market incentive for efficient technologies. In reality, due to economic inefficiencies and indirect market signals, we suggest feebates to effect the consumer decision directly and rely on manufacturers to respond to the increased consumer demand for efficient technologies. For these two reasons, we use the convention outlined in Davis et al. 1995 to calculate the Benefit to Cost ratio for the manufacturer's adopting efficiency technologies (we consider the entire *Conventional Wisdom* or *State of the Art* portfolio to be one efficiency technology, as opposed to studying the effects of an individual technology as done in Davis et al.).[iv]

Equation 21-3:
B/C = (PVFUELSAVE + Val$PERF + $FEEBATE)/TECHCOST

We define PVFUELSAVE as the discounted fuel savings (at a 5%/year real discount rate) difference between a new *Conventional Wisdom* or *State of the Art* vehicle and the average car or light truck projected by EIA for sale in that year. We only account for the first three years of fuel savings using NRC's suggestion that consumers may only account for this amount of savings when purchasing a new car.[v] Although it is important to note this number is highly sensitive to perceived future fuel prices, rates of return on investments in efficient technologies, and beliefs on the effect of fuel-efficient technologies on used vehicle value. As the *Conventional Wisdom* or *State of the Art* efficiencies remain constant while the EIA baseline projections increase, the PVFUELSAVE decreases over time.

Val$PERF is the consumer's value of the performance change as a result of the fuel-efficient technology. As we assume the *Conventional Wisdom* and *State of the Art* vehicles to be equivalent to the average new vehicle projected by EIA except for the increase in efficiency, we set Val$PERF to 0 for all calculations. $FEEBATE is the change in feebate brought about by the introduction of *Conventional Wisdom or State of the Art* technologies, as outlined in Equation 21-2. TECHCOST is the incremental cost of the fuel saving technologies to the manufacture. We use the incremental technology costs given in tables 5-4 and 5-10 of *Technical Annex,* Ch. 5:

Table 21-2: Incremental technology costs for *Conventional Wisdom* and *State of the Art* vehicles

	car	light truck
Conventional Wisdom	$806	$667
State of the Art	$2167	$2805

We further adopt the methodology outlined in Davis et. al 1995 to calculate market penetration, M, of *Conventional Wisdom* and *State of the Art* vehicles that results from the feebate policy.

Equation 21-4:
M = Mmax X Pmax X [1/(1+e^-2(B/C-1)]

M_{max} is defined as the maximum market share of the technology. We assume M_{max} to be 100 percent, as our *Conventional Wisdom* and *State of the Art* technology portfolios include numerous technologies that can be substituted for each other to achieve a full market share.

P_{max} is defined as the retooling percentage that allows manufacturers to introduce new technologies in their products. It includes both the engineering and manufacturing improvements needed to bring new technologies to market. The retooling rate assumes government financial support (i.e., removes financial constraint of the automotive industry). Since *Conventional Wisdom* technologies are currently available to consumers, we use a logistic function that is modeled after the introduction of incremental technology adoption in the marketplace. Our P_{max} function reaches 50 percent market share by 2013 and achieves 99 percent by 2025.

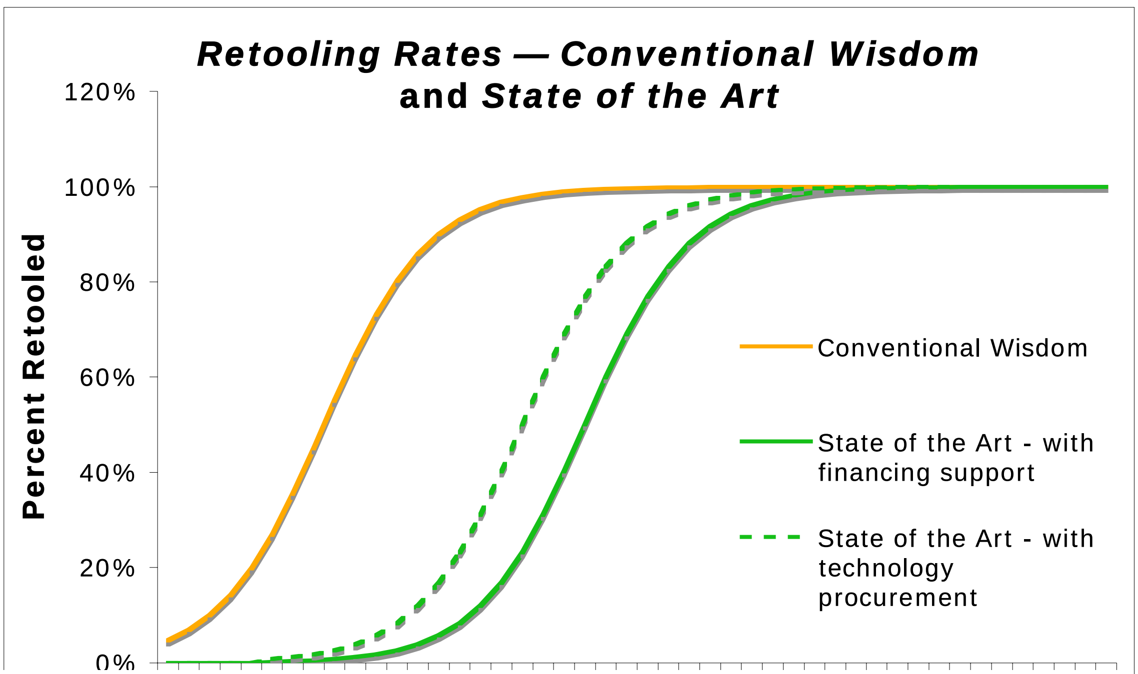

Figure 21-2: Retooling rates for *Conventional Wisdom* and *State of the Art* vehicles with and without technology procurement.

For the *State of the Art* technologies, we opt against describing the P_{max} function on historical data due to the dramatically different manufacturing requirements compared to an equivalent volume average vehicle plant. We base the P_{max} function for *State of the Art* technologies on our approximate judgment of the capital and operational constraints of the automobile industry. The S-curve begins in 2010, reaches 50 percent by 2025, and plants are fully retooled by 2035.

From equation 21-3 we see that if M_{max} and P_{max} are both 100 percent, and the Benefit to Cost ratio is 1, we would see about half the manufacturers adopting *the Conventional Wisdom* and *State of the Art* technologies, as they would be indifferent towards installing the technology. The resulting market share percentage from Equation 21-4 is used to calculate the number of *Conventional Wisdom* or *State of the Art* vehicles in the next year.

We calculate the retail fuel savings of the program as the difference between the cost of the program (incremental capital costs of the technologies) and the value to the consumer (discounted value of the fuel savings over the 14-year vehicle life). While we only consider the first three years of vehicle life in the Benefit to Cost calculation, when calculating consumer surplus to society we include the entire vehicle life, as consumers as a whole are indifferent towards who owns the vehicle but public goods accrue regardless of ownership. Because vehicles have a remaining life after 2025, this policy will save fuel beyond what is accounted for in this study.

Sanity-checking our light vehicle model:

Due to the significant differences in modeling environments between Greene et. al. (2004) and RMI (2004), we conclude that under conditions of using various NRC input variables, our simplified model computing MPG improvements from baseline that are 5%-25% within those predicted by Greene et. al. implies that our model is robust.

As our model only considers the manufacturer (product-mix) response and explicitly ignores the consumer (sales-mix) response, we expect to underestimate the feebate response by roughly 10%. We then note that major differences between Greene et. al.'s static pivot point and their snap-shot of one year approximately 10-15 years in the future gives opportunity only for approximate agreement. Nevertheless, sanity-checking with our dynamic model is useful and gives the expected (conservative) results vs. Greene et. al. In contrast with Greene et. al, we introduce dynamics into our model in that we have a continuously improving baseline (EIA 2005-2025), and a continuously increasing pivot-point to model the positive effect of feebates on technological progress. While not used for comparison with NRC vehicles, we employ a gradual introduction of SOA vehicles in modeling *our Conventional Wisdom* and *State of the Art Vehicles* to represent (dynamics in) technological progress.

As a sanity-check, we have therefore introduced NRCs vehicles to our dynamic model to see how closely their diffusion and resulting new-sales MPG agrees with Greene et. al.'s static model. We approximated the point-estimates of NRC vehicles from each of the curves by introducing these curves as single-point vehicles by inputting each curve's break-even vehicle under a given feebate rate. This break-even point (single MPG at a given incremental cost) was identified by the intersection of the marginal retail cost curve (i.e. cost faced by consumer) and the curve representing marginal present value to consumer, i.e. that curve describing the present value of the feebate and the three-year fuel savings (discounted at 6%, see Greene et. al., 2001). Depending on the feebate rate and NRC cost curve, we find that new-sales MPGs from RMIs model are between 5% above and 10% below the MPGs as predicted by Greene et. al. , as in the table below:

	Base Year (EIA *AEO*) N/A N/A		**Scenario 3** Feebate $500 Average Cost		**Scenario 6** Feebate $1000 Average Cost	
	MPG Greene	MPG RMI	MPG Greene	MPG RMI 2025	MPG Greene	MPG RMI 2025
CARS	28.2	28.5	31.8	32.5	35.2	34.3
LIGHT TRUCKS	20.7	20.8	26	25.7	29.2	27.4
AVERAGE	24.3	24.1	28.9	27.9	32.3	29.6
Percent change in GPM from baseline			Greene	RMI	Greene	RMI
CARS			11%	12%	20%	17%
LIGHT TRUCKS			20%	19%	29%	24%
AVERAGE			16%	14%	25%	19%

note: fuel economies are EPA laboratory as presented in EIA Annual Energy Outlook (Greene et. Al. based on AEO 2002, RMI on AEO 2004).

When the fundamental differences are accounted for, we are comfortable with concluding that our model applied in a dynamic setting gives results that broadly and to a sufficiently accurate degree agrees with other and more sophisticated modeler's outputs.

[i] W. Davis et. al., “Effects of Feebates on Vehicle Fuel Economy, Carbon Dioxide Emissions, and Consumer Surplus,” DOE/PO-0031, Office of Policy, U.S. Department of Energy, Washington DC, 1995. Also shown in D. Green et. al., “Feebates, Rebates, and

Gas-Guzzler Taxes: A Study of Incentives for Increased Fuel Economy," *En. Pol*. In Press, Oak Ridge, TN.

[ii] EPA Fuel Economy Guide, http://www.fueleconomy.gov/

[iii] EPA Fuel Economy Guide, http://www.fueleconomy.gov

[iv] W. Davis et. al., "Effects of Feebates on Vehicle Fuel Economy, Carbon Dioxide Emissions, and Consumer Surplus," DOE/PO-0031, Office of Policy, U.S .Department of Energy, Washington DC, 1995.

[v] NAS/NRC (National Academies of Science/National Research Council, "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards," National Academy Press, Washington, DC, 2002. http://books.nap.edu/books/0309076013/html