NYSERDA--94-18

REFORMULATED GASOLINE STUDY

Executive Summary

New York State Energy Research and Development Authority

The New York State Energy Research and Development Authority (Energy Authority) is a public benefit corporation created in 1975 by the New York State Legislature. A 13-member board governs the Energy Authority. By law, the Commissioner of the State Energy Office, Francis J. Murray, Jr., serves as Chair and Chief Executive Officer. F. William Valentino is President and Chief Operating Officer.

The Energy Authority's primary mission is to carry out a broad program of energy research, development and demonstration projects designed to develop and apply efficient technologies to help ensure that New York has secure and economical future supplies of energy, while protecting environmental values and promoting economic growth.

The Energy Authority derives its basic research revenues from an assessment levied on the intrastate sales of New York State's investor-owned electric and gas utilities. Additional research dollars come from limited corporate funds and a voluntary annual contribution by the New York Power Authority.

In its research program, the Energy Authority stresses consultation and collaboration with other organizations, including utilities, universities, industries, private engineering and scientific research firms, local governments, and State and Federal agencies. These efforts stretch the Authority's limited research funds and ensure the involvement of those who can use the results of the research.

The Energy Authority also has responsibility for:

- Managing the 3,300-acre Western New York Nuclear Service Center at West Valley 35 miles south of Buffalo, the site of a former commercial nuclear fuel reprocessing plant and a low-level radioactive waste disposal area. These responsibilities include:
    - Participating in the West Valley Demonstration Project, a joint Federal/State effort to solidify the high-level radioactive wastes left over from the reprocessing operation and to clean up the facilities used.
    - Maintaining the portion of the site not being used in the Demonstration Project, including the shut-down low-level radioactive waste disposal area.
- Issuing tax-exempt bonds to finance facilities for electric and gas utilities and energy projects for private companies.
- Constructing and operating facilities for disposal of low-level radioactive wastes produced in New York State, once the disposal method and site decisions have been made by the State Low-Level Radioactive Waste Siting Commission and approvals have been issued by State regulatory authorities.
- Managing a 365-acre portion of a Superfund clean-up site in Malta, 20 miles north of Albany. Part of the site was once owned by the Federal government. Portions of it have been used by the Federal government and its contractors since the 1940s for activities that have included rocket engine and fuel testing, weapons testing, and space research.

For more information, contact the Media Relations and Outreach unit, The Energy Authority, 2 Empire State Plaza, Suite 1901, Albany, New York 12223-1253, (518) 465-6251, ext. 272.

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Executive Summary

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DISCLAIMER

FOREWORD

by the New York State Energy Research and Development Authority

The New York State Clean Air Compliance Act directed the New York State Energy Research and Development Authority (the Energy Authority) to retain an independent contractor to evaluate issues associated with the use of reformulated gasoline (RFG) in New York State. The study was to consider the impact of RFG on "the availability and distribution of motor fuels in the state, the costs to customers and to the economy of the state, and the air quality benefits..." Further, the study was to include an analysis of California RFG specifications and "any other specifications for gasoline which the Commissioner of Environmental Conservation recommends for inclusion in the study."

The Energy Authority, following its standard practice, established a Technical Evaluation Panel (TEP) to help develop a detailed Statement of Work that would be used in a competitive Request for Proposals (RFP). The TEP members, listed on page 27, include representatives from New York State agencies, the oil industry, academia, and other relevant parties. Following a review of the proposals submitted in response to the RFP, the TEP selected a team of contractors led by Turner, Mason & Company (TM&C) of Dallas, Texas. DRI/McGraw-Hill of Washington, DC and Sierra Research of Sacramento, California were subcontractors to TM&C and performed economic impact and air quality analyses, respectively. TM&C was responsible for analyzing fuel production and distribution and for combining the results of the various analyses into a final report.

Throughout this project, the Energy Authority, assisted by the TEP, reviewed and commented on draft results provided by TM&C and its subcontractors. This process produced consensus on many issues as well as an appreciation of the complexities surrounding the use of RFG. The issues that eluded consensus among reviewers included:

1. Method of calculating tailpipe emissions. Estimates of the impact of gasoline specifications on tailpipe emissions are subject to many caveats, primarily because the vehicle population is diverse and changing. Some reviewers suggest that the U.S. Environmental Protection Agency's (U.S. EPA's) current air quality model, MOBILE5a, understates the emissions benefits of CARB 2 (California RFG) versus EPA II (Federal RFG), particularly in newer vehicles. Debate centers on the data used to calibrate the emissions model and the test procedures used to measure tailpipe emissions. In this study, Sierra Research was directed to use U.S. EPA's MOBILE5a model to benchmark the findings against current U.S. EPA procedures.

2. Economic benefits of clean air. The economic impact analysis does not quantify the benefits of improved air quality. Conventional economic analysis tools are limited in this respect.

Quantifying RFG benefits is problematic due to the difficulty in estimating tailpipe emissions for different types of RFG, uncertainties about how and to what extent these emissions produce impacts on human health and the environment, and the inherent difficulty of placing a dollar value on these impacts. Although improved tools are needed to estimate RFG benefits, the present report can be used to compare, in accordance with U.S. EPA procedures, the cost-effectiveness ($/ton of emissions reduction) of competing strategies for reducing emissions of criteria pollutants.

3. RFG production and distribution scenarios. Some reviewers feel that oil companies could reduce RFG costs from the levels estimated in this study by forming production and distribution consortia and by optimizing interregional and international product transfers. However, another opinion is that analysts sometimes rely too heavily on computer-optimized fuel supply schemes that ignore significant constraints, not the least of which are antitrust laws. In this study, East Coast refineries are assumed to shoulder the entire burden of supplying New York State's RFG, a conservative perspective consistent with TM&C's extensive oil industry experience.

4. Amount of time needed to implement mandates. Opinions differ about how fast the refining industry can react to a change in mandated fuel specifications; some reviewers feel that TM&C's assumed four-year lead time is too long. Shortening this lead time is probably unrealistic in view of regulatory and physical constraints, and, considering the study's 1998-2012 timeframe, would have little effect on study findings.

NOTICE

ABSTRACT

The feasibility of adopting alternative standards for reformulated gasoline (RFG) in New York State has been studied for the New York State Energy Research and Development Authority (the Energy Authority). In addition to Federal RFG (EPA I and EPA II), California Air Resources Board RFG (CARB 2) and a modified Federal low sulfur RFG (LS-EPA II) were investigated. The effects of these alternative RFGs on petroleum refinery gasoline production costs, gasoline distribution costs, New York State air quality and the New York State economy were considered.

New York has already adopted the California low emission vehicle (LEV) and other emission control programs that will affect vehicles and maintenance. From 1998 to 2012 without the introduction of any type of RFG, these programs are estimated to reduce New York State mobile source summer emissions by 341 tons per day (or 40%) of non-methane hydrocarbons (NMHC) and by 292 tons per day (or 28%) of nitrogen oxides (NO_x), and to reduce winter emissions of carbon monoxide (CO) by 3,072 tons per day (or 39%). By 2012, the planned imposition of Federal RFG will produce further reductions (percent of 1998 levels) of 10%, 4% and 11%, respectively, for NMHC, NO_X and CO. If New York State goes beyond EPA II and adopts CARB 2 specifications, further reductions achieved in 2012 are estimated to be very small, equaling 2% or less of 1998 levels of NMHC and NO_x emissions, while CO emissions would actually <u>increase</u> by about 2%. When compared to EPA II over the same time frame, LS-EPA II would produce negligible (less than 1%) reductions in each of the above emissions categories.

The cost of CARB 2 gasoline would be high relative to EPA II. New York motorists could expect to pay about 30¢ per gallon (in 1992 dollars) more at the pump for CARB 2 gasoline than for conventional gasoline (about 18¢ per gallon more than for EPA II). NMHC and NO_x emissions reductions achieved with EPA II cost less than the EPA standards of $5,000 per incremental ton. CARB 2 emissions reductions are much more expensive at over $100,000 per incremental ton.

Adopting CARB 2 RFG would have a deleterious effect on the New York economy. Approximately 23,300 jobs would be lost in the year 2000 compared to continued use of conventional gasoline (14,300 more than for EPA II). Higher pump prices and poorer fuel economy for CARB 2 RFG would cause New York drivers to travel 3 billion (or 2.2%) fewer miles in 2004 than they would if they could continue to use conventional gasoline (1.8 billion, or 1.3% fewer miles than with EPA II).

Key Words: Reformulated gasoline; emissions; air quality; refining; RFG; CARB; New York State economy

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INTRODUCTION

BACKGROUND

The Federal Clean Air Act Amendments of 1990 (FCAAA) contained provisions intended to reduce mobile source emissions, requiring vehicle manufacturers to meet new Federal emission standards and allowing states with air pollution problems to require the use of reformulated gasoline (RFG) that meets new Federal standards. In addition, states required to develop plans for improving their air quality can elect to require that motor vehicles and/or gasoline sold in their state meet the more stringent standards set by California. Because of unique, severe air pollution problems, California has set vehicle and fuel standards much more stringent than the Federal standards. It has become an issue of debate whether or not states which adopt the California vehicle emission standards must also adopt the California gasoline standards.

The State of New York has adopted the California low emission vehicle (LEV) standards, but not the California gasoline standards. The motor vehicle manufacturers have filed a lawsuit contending that the State of New York must adopt either the California standards for both vehicles and gasoline or adopt neither. This lawsuit is currently proceeding through the judicial process. If the State of New York is required to mandate the sale of gasoline that meets California standards, it will significantly affect the costs of fuel, the air emissions, the cost-effectiveness of air emissions reductions and the economy of the State.

Accordingly, the New York State Clean Air Compliance Act of 1993 directed the New York State Energy Research and Development Authority (the Energy Authority) to contract for a study of the feasibility and impacts of adopting California gasoline specifications for New York State. The goals of this project were to determine the effect that adoption of alternative RFG specifications would have on the availability and distribution of motor fuels in the State, the effect on costs to customers and the State economy and the effect on air quality. This report summarizes the results of the study conducted by Turner, Mason & Company (TM&C) with assistance from DRI/McGraw-Hill (DRI) on effects on the economy and Sierra Research, Inc. (Sierra) on the impacts on air quality.

ALTERNATE GASOLINES

Baseline CG

The logical starting point for studying alternative forms of gasoline is conventional gasoline (CG) of the type that would have been produced absent the FCAAA. While it is impossible to know exactly what the quality of this gasoline is, it can be inferred from historic gasoline properties, as well as the capability of the refineries that produce it and the requirements of the cars that use it. Similarly, the future New York economy and air quality can be inferred from history when CG has been used. We have estimated the future quality of CG in this study and used it for the baseline projection of fuel costs, air quality and the New York economy.

RFG Types

The FCAAA requires that RFG be available in severe ozone non-attainment areas starting in late 1994, thus giving refiners approximately four years to make the refinery modifications needed to meet new gasoline specifications. Federal RFG is defined by the U.S. Environmental Protection Agency (EPA), which is using the so-called Simple Model for controlling RFG properties (SM) in 1995-97. A Phase I Complex Model will be used in 1998-99 to reduce volatile organic compounds (VOC) and toxics, while allowing no increase in nitrogen oxide (NO_x) emissions, and the resulting RFG is dubbed EPA I. All three of these emissions will be further reduced in 2000 and later by means of the Phase II Complex Model and more stringent VOC and NO_x limits, thus creating EPA II RFG. Properties for an average of 65% regular grade gasoline and 35% premium grade gasoline are shown in Table 1.

Table 1. Summer Gasoline Specifications and Properties

	Baseline	RFG			
	CG	EPA I	EPA II	LS-EPA II	CARB 2
Octane, (R+M)/2	89.3#	89.3#	89.3#	89.3#	89.3#
Aromatics, Vol. %	31.9	26.2	27.6	27.0	22.0*
Oxygen, Wt. %	0.4	2.1#	2.1#	2.1#	2.0#
Olefins, Vol. %	15.8	12.5	11.6	13.1	4.0*
Benzene, Vol. %	1.69	0.95*	0.95*	0.95*	0.80*
Sulfur, wppm	449	240	124	75*	30*
RVP, psi	8.2*	8.0	6.7	6.8	6.6*
Distillation, °F					
50%	210	197	203	204	199*
90%	351	341	344	342	290*
% Reduction[(1)]					
VOC	7.0	15.7#	27.6#	27.6#	29.5
NO_x	(6.8)	1.7#	6.8#	8.2	14.9
TAP	(4.9)	24.3	26.6	27.7	34.5

* At maximum specification.
# At minimum specification.
(1) From statutory, based on EPA Phase II complex model for comparability.

The California Air Resources Board (CARB) has taken a more stringent approach to gasoline specifications. Their Phase 2 RFG program (CARB 2), to be effective in the spring of 1996, requires severe reductions in benzene, olefins, sulfur, aromatics, RVP and T90 and strict limits on oxygen.

Sulfur content is a fuel property that has attracted attention because of its potential for interfering with LEV catalyst performance. Accordingly, the New York State Department of Environmental Conservation (DEC) proposed to study an alternative to EPA II, called LS-EPA II, with a sulfur specification that is lower than that of EPA II, while retaining the other requirements of EPA II. This fuel was also required to have control on vapor pressure, but this limit would be already achieved under EPA II.

SCENARIOS

In response to the FCAAA and EPA regulations, the refining industry has been gearing up to produce Federal SM RFG in 1995, EPA I in 1998 and EPA II in 2000. Assuming fast track legislation and regulation in New York and adjacent states, expedited permitting, ready financing and construction, alternative RFGs to EPA II could be available in 2000. It takes at least four years lead time to make alternative RFGs, starting with enactment of legislation. This timing has been reflected in the scenario descriptions.

Figure 1. Four-State Area

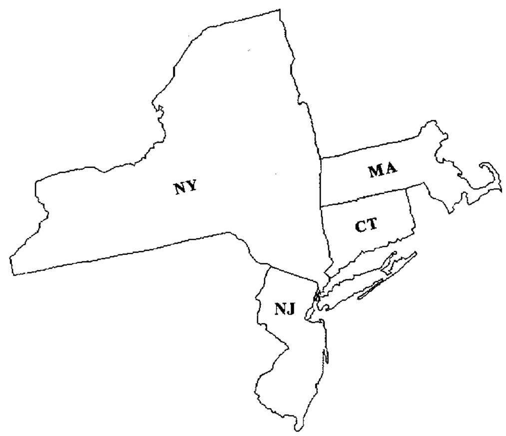
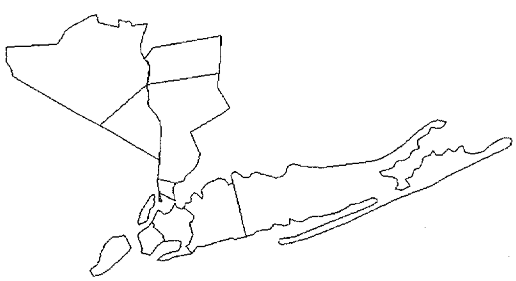


Figure 2.
New York City Metropolitan Area*



* New York City plus Orange, Rockland, Putnam, Westchester, Nassau and Suffolk counties.

The baseline for this study was all CG from 1998 to 2012. Four alternative RFG scenarios were evaluated. In Scenario 1, it is envisioned that EPA I in 1998 and EPA II in 2000+ would replace CG in New York and three adjacent states – New Jersey, Massachusetts and Connecticut, as shown in Figure 1. Scenario 2 would require that CARB 2 be supplied in 2000 and later to the New York State portion of the New York City Standard Metropolitan Statistical Area (NYC-SMSA), shown in Figure 2. Surrounding areas would require EPA II as in Scenario 1.

In Scenario 3, CARB 2 gasoline would be required in 2000 and later in New York State and the previously identified three adjacent states. For Scenario 4, LS-EPA II would be required in this four-state area in 2000 and later.

MAJOR CONCLUSIONS

HIGHLIGHTS

- Most of the projected reductions in New York State mobile source air emissions will result from vehicle programs such as LEV and inspection and maintenance (I/M), regardless of whether any RFG is used. Even if CG is used, by 2012 summer reductions in non-methane hydrocarbons (NMHC) will grow to 341 tons per day (or 40%) versus the 1998 baseline with CG. Similarly, summer reductions in NO_x will increase to 292 tons per day (or 28%) in 2012. Winter reductions in carbon monoxide (CO) will reach 3,072 tons per day (or 39%).

- Beyond the impact of improved vehicles and improved maintenance, use of EPA II in 2012 will further reduce NMHC summer emissions by 82 tons per day (or 10%) versus the 1998 CG baseline. Summer NO_x emissions will drop 37 tons per day (or 4%), and CO winter emissions will decline by 823 tons per day (or 11%).

- The imposition of more stringent RFG specifications, such as LS-EPA II or CARB 2, will do little to further reduce emissions. LS-EPA II would not reduce NMHC compared to EPA II. CARB 2 would eliminate 8 more NMHC tons per summer day (or 1%). LS-EPA II would decrease NO_x emissions about 3 tons per summer day (or less than 1%) and CO emissions by 7 tons per winter day (or less than 1%), compared to EPA II. CARB 2 would reduce NO_x by 25 tons per summer day (or 2%) and would increase CO by 149 tons per winter day (or 2%), relative to EPA II.

- Summer gasoline pump prices, including refining and distribution costs, fuel economy penalty and sales tax (in 1992 dollars), will increase by about 12¢ per gallon for EPA II gasoline over CG. LS-EPA II and CARB 2 would increase prices by about 17¢ and 30¢ per gallon, respectively, or by an additional 5¢ and 18¢ per gallon, respectively, over EPA II. This assumes that the incremental cost to manufacture and distribute these fuels will be recovered, without markup, in the price to the consumer.

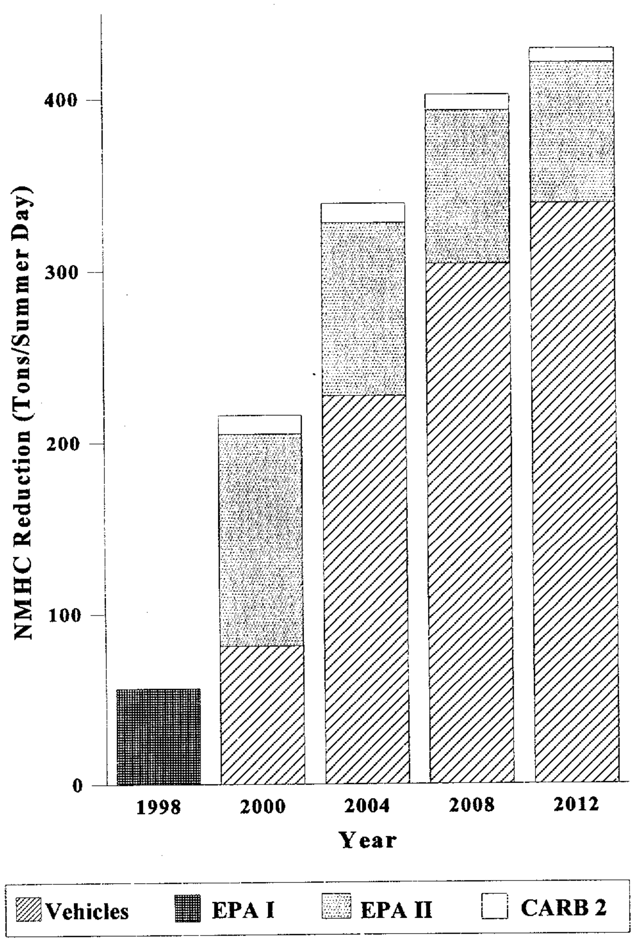
- Costs for implementing EPA II emission reductions over EPA I are lower than EPA's benchmark of $5,000 per ton ($2.50 per pound), as expected. More severe alternate RFGs, like LS-EPA II or CARB 2, cost over ten times more than EPA's benchmark per ton of emissions reduction.

- Shifting from EPA I to EPA II will reduce NMHC at a cost of $2,000 per ton ($1 per pound) after $5,000 per ton credit for NO_x reduction. The proposed LS-EPA II NMHC reduction would cost $830,000 per ton ($415 per pound). CARB 2 NMHC reductions would cost $150,000 per ton ($75 per pound).

- After taking $5,000 per ton credit for NMHC reductions, NO_x reduction costs are a negative $6,000 per ton (negative $3 per pound) for changing from EPA I to EPA II. For LS-EPA II, the costs rise to $140,000 per ton ($70 per pound). CARB 2 NO_x emissions reductions cost $65,000 per ton ($32 per pound).

- Mandating CARB 2 gasoline would result in the loss of about 23,300 jobs (0.3% of the work force) in New York in 2000 relative to the use of CG (14,300 relative to the use of EPA II).

Figure 3.
New York State Mobile Source NMHC Reduction
(compared to 1998 vehicles operating on CG)



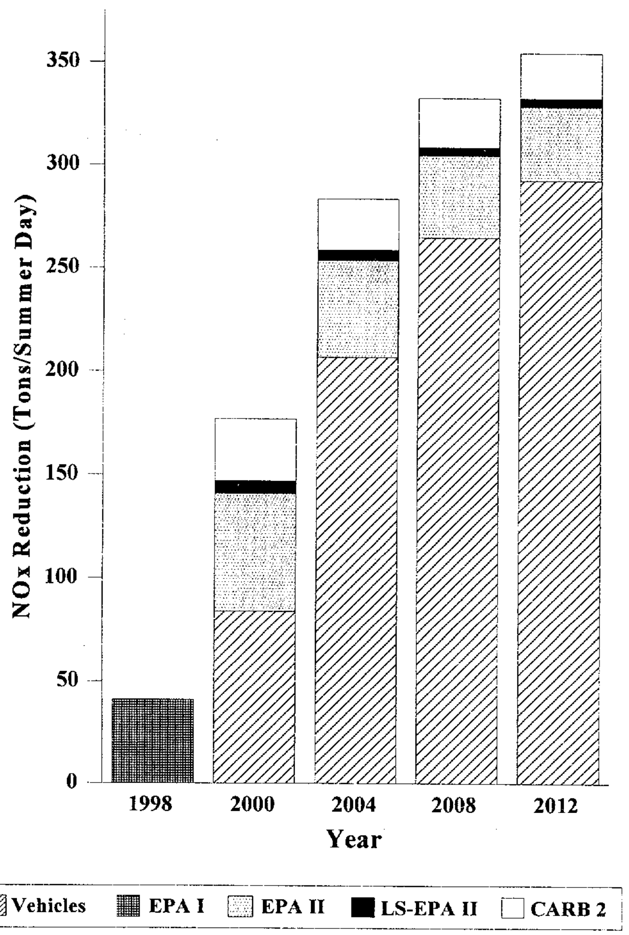
EMISSIONS REDUCTIONS

Figure 3 shows reductions in summertime NMHC (a measure closely related to VOC) that can be achieved over more than a decade with car- and gasoline-related controls. Most of the reductions come from the LEV program and other vehicle controls that New York already has adopted. Another sizable reduction will come as a result of the planned Federal RFG program. Only modest further improvements could be achieved with more stringent controls on RFG. Adoption of a low sulfur version of Federal RFG would result in no improvement in NMHC compared to Federal RFG, as refiners would take advantage of the flexibility of the EPA complex formulas. Adoption of very stringent California

RFG specifications would result in only small improvements in emissions.

The NO_x emissions picture is similar to the NMHC outlook. Large improvements in NO_x emissions are achieved with the adopted LEV program with secondary benefits from the Federal RFG program, as shown in Figure 4. A further reduction of the sulfur specification relative to the EPA formulas would result in a small improvement in NO_x. The very severe California RFG specifications also would improve NO_x a small amount. The latter steps have more impact on NO_x than on NMHC emissions.

Figure 4.
New York State Mobile Source NO_X Reduction
(compared to 1998 vehicles operating on CG)



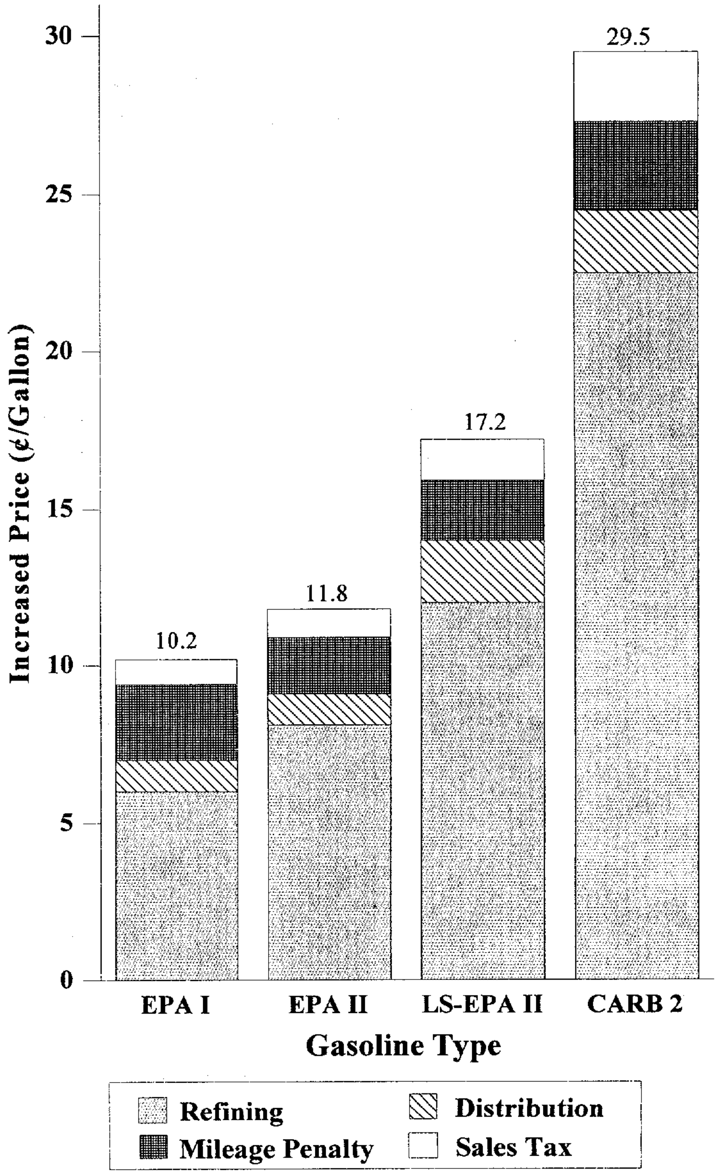
As Figures 3 and 4 show, the incremental emission reductions associated with the use of either CARB 2 or LS-EPA II are small relative to the emission reductions that will be realized from the planned LEV program and EPA II.

PRICE INCREASES

For the four-state area (New York, New Jersey, Connecticut and Massachusetts), the added or incremental cost of alternate RFGs over CG in the summer in the year 2000 and later, in cents per gallon, is as follows (Figure 5):

- EPA I = 10.2¢;
- EPA II = 11.8¢;
- LS-EPA II = 17.2¢; and
- CARB 2 = 29.5¢.

Figure 5.
Summer Gasoline Price Increase Over CG

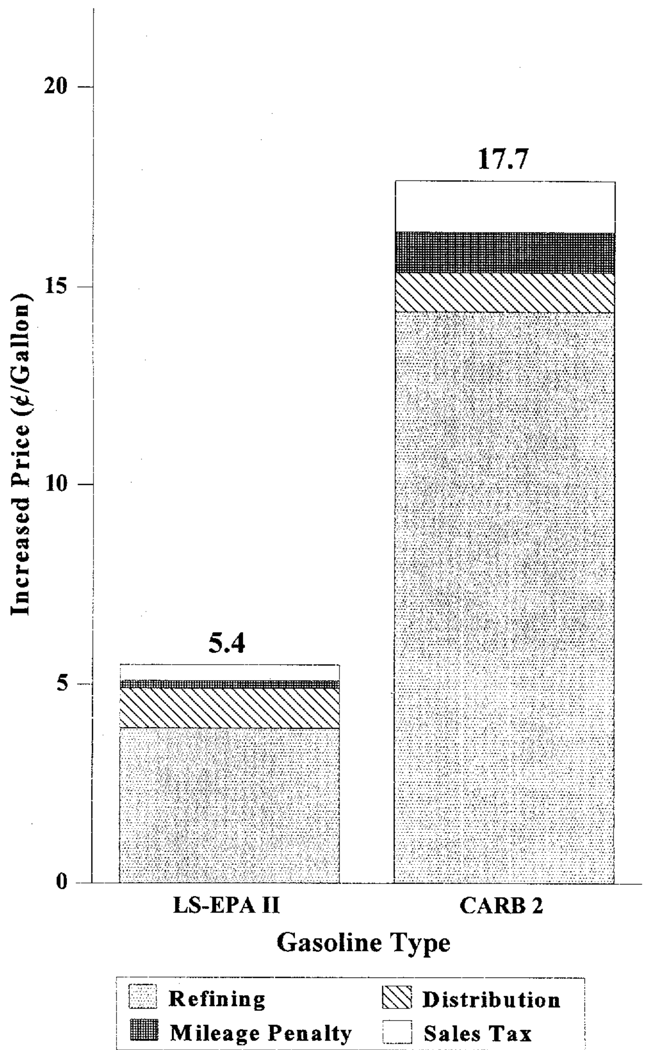


These results show that unit RFG costs increase from EPA II to CARB 2. The changes in effective pump price are stated in 1992 dollars and include increased refining cost, increased distribution costs, mileage or fuel economy penalty and sales tax. The mileage or fuel economy penalty (of lower miles per gallon) stems from the increased oxygenates required in RFGs and the corresponding reduction in energy content of RFGs, as compared to CG. The price increases are deemed equivalent to calculated cost increases with full cost pass-through and no increased markup in distribution and marketing.

The price increases for alternate RFGs over EPA II in the summer in the year 2000 and later, in cents per gallon, are shown in Figure 6 and as follows:

- LS-EPA II = 5.4¢; and
- CARB 2 = 17.7¢.

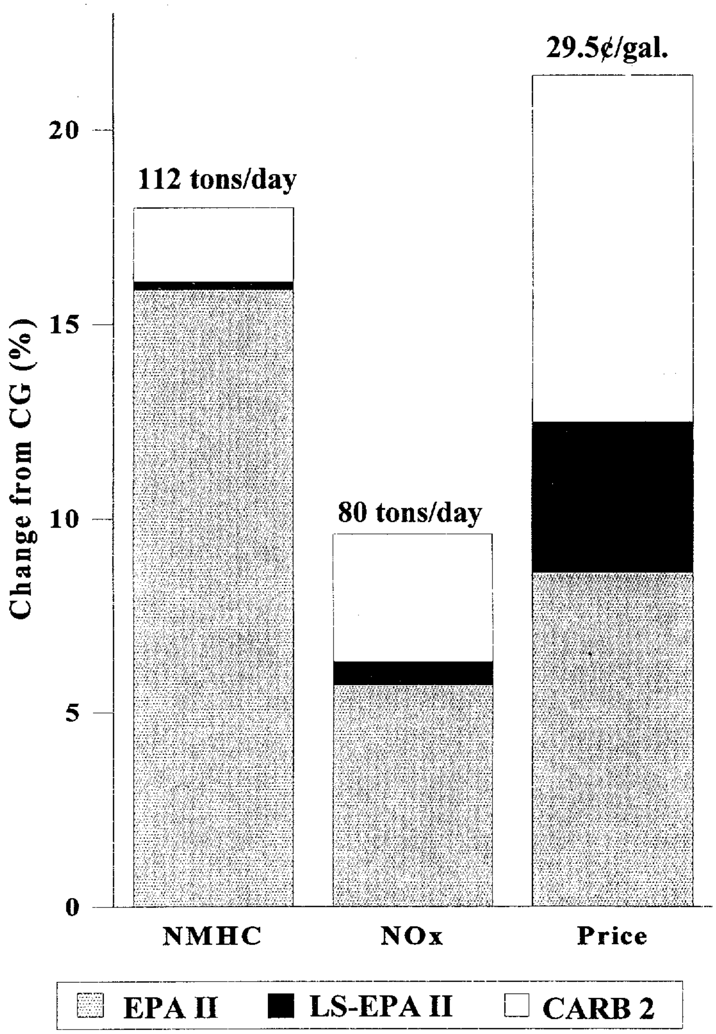
Figure 6.
Summer Gasoline Price Increase Over EPA II



PRICE INCREASES VERSUS EMISSIONS REDUCTIONS

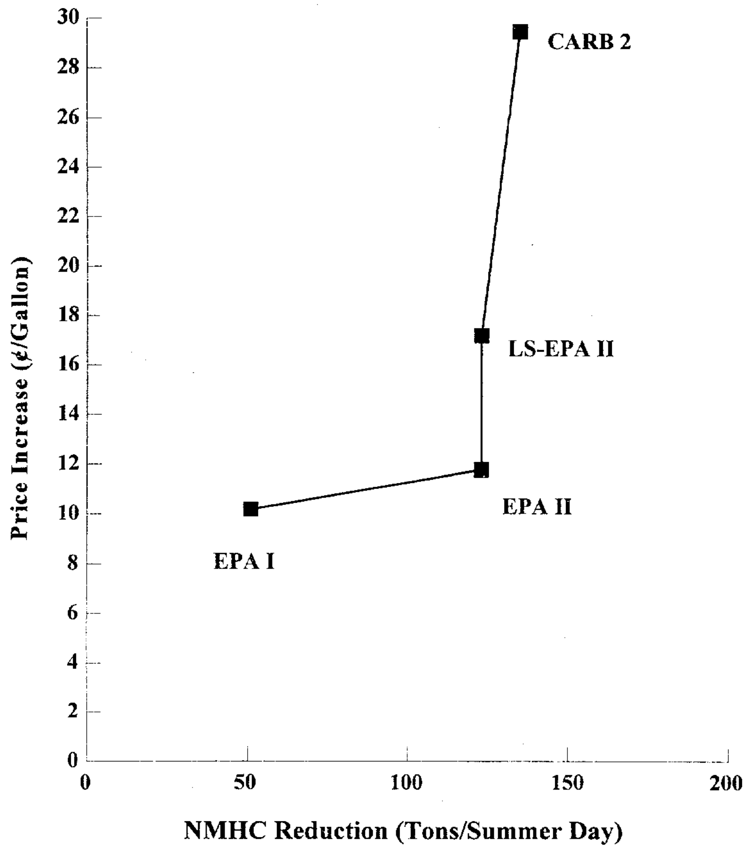
Figure 7 shows the relationship between price increases and NMHC reductions in New York State for various types of RFG in 2004 during the summer ozone season. Note that prices increase significantly for more severe reformulations than EPA II. In contrast, only small emissions reductions are achieved by more severe reformulations than EPA II.

Figure 7.
Decreased Emissions Versus Increased Price
(2004 Summer)



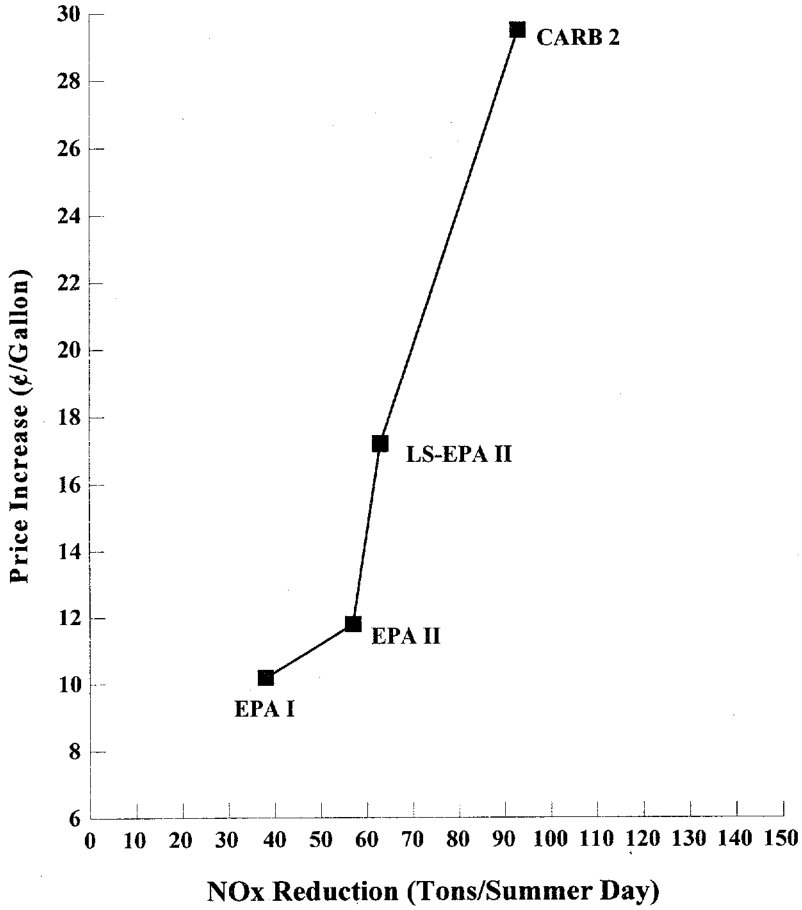
These contrasting factors lead to a sharp break in the RFG costs-versus-emissions reduction curve. The curve is a classic "hockey stick", as shown in Figure 8. In moving from EPA I to EPA II, there is a dramatic reduction in NMHC with only a slight increase in pump price. From EPA II to LS-EPA II, there is a large increase in price with no improvement in NMHC. Then from LS-EPA II to CARB 2, there is a very large increase in price for a small decrease in NMHC. This indicates that CARB 2 has a much higher cost to the motorist with very little added benefit compared to EPA II.

Figure 8.
Gasoline Price Increase Versus NMHC Reduction
(2000 summer)



A similar relationship has been developed for NO_x reductions in New York State compared to corresponding gasoline price increases. Again, the change from EPA I to EPA II shows a reduction in NO_x at a slight increase in gasoline price (Figure 9). From EPA II to LS-EPA II, there is a sharp increase in price with a small decrease in NO_x emissions. CARB 2 shows a reduction in NO_x emissions but still at a greatly increased cost to the motorist.

Figure 9.
Gasoline Price Increase Versus NO_X Reduction
(2000 summer)

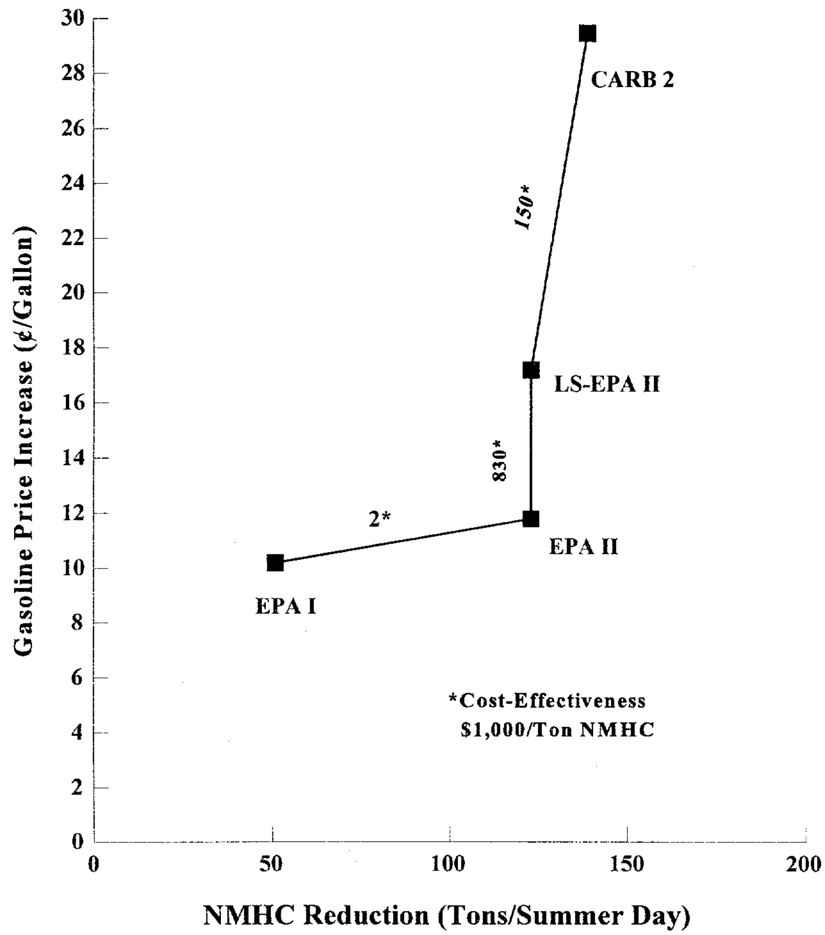


The figures further show that EPA has been successful at specifying Federal RFG to get the maximum emissions reduction for the least cost – the biggest bang for the buck!

COST-EFFECTIVENESS

Cost-effectiveness is a measure of the cost-versus-benefits relationship shown in the preceding figures. It is defined as the change in cost between two options divided by the change in emissions between these same two options. It is the slope, or steepness, of the costs increase-versus-emissions reduction curve. Moving from left to right along the curve, relatively flat sections are considered to have good cost-effectiveness; in other words, it is economic to adopt policies that move the gasoline refining industry from the first point to the second point if the line between them is relatively flat. Conversely, if the slope is steep, the move is much less desirable from the standpoint of cost-effectiveness. When is a line too steep to justify a move? EPA uses a figure of $5,000 per ton as a benchmark. An emissions reduction option that costs more than this benchmark is deemed to have poor cost-effectiveness. When plotted on the costs-versus-reduction curve, LS-EPA II and CARB 2 options would be seen as reachable only by going up relatively steep slopes; hence, they would both have poor cost-effectiveness.

Figure 10.
Cost-Effectiveness of NMHC Reduction
(2000 summer)

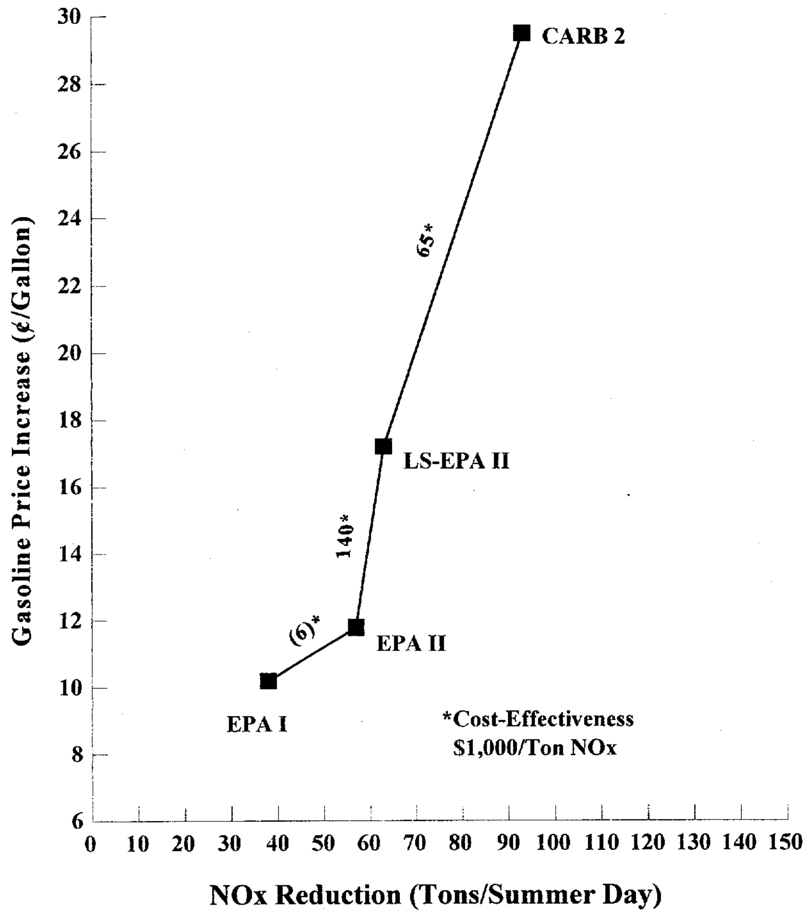


The cost-effectiveness between the various RFGs is presented on Figure 10. Because both NMHC and NO_x respond to changes in gasoline properties, it is helpful to take credit for NO_x reductions when calculating the cost-effectiveness of NMHC reductions. The credit used by EPA for this type of calculation is EPA's guideline of $5,000 per ton. After this credit, the cost-effectiveness of EPA II compared to EPA I is an attractive $2,000 per incremental ton of NMHC. From EPA II to LS-EPA II, the cost-effectiveness is over

$830,000 per ton of NMHC removed from New York air. From LS-EPA II to CARB 2, the cost-effectiveness is $150,000 per ton of NMHC reduction. Both of these steps are much more expensive than the EPA guidelines; they have high costs and low emissions benefits.

Figure 11 shows the cost-effectiveness for NO_x. In calculating the cost-effectiveness for NO_x, credit is taken for NMHC reductions at $5,000 per ton of NMHC. This is greater than the total cost encountered from EPA I to EPA II, so that NO_x cost-effectiveness turns out to be a negative $6,000 per ton of NO_x. From EPA II to LS-EPA II, the cost-effectiveness is $140,000 per ton of NO_x removed, and from LS-EPA II to CARB 2, the cost is $65,000 per ton of NO_x removed.

Figure 11.
NO_X Reduction Cost-Effectiveness
(2000 summer)

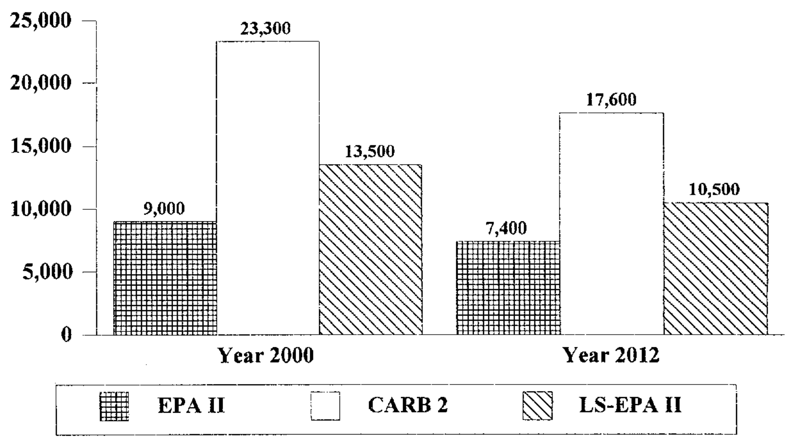


These hockey stick-shaped curves clearly identify EPA II as a lower cost, more effective RFG option than CARB 2 or LS-EPA II. This finding confirms that EPA achieved their goal of setting RFG specifications that successfully balance incremental costs and emissions benefits. The obvious conclusion to this study is that CARB 2 gasoline in New York would be extremely costly and would provide little environmental benefit. It would be like paying the significant increased cost for a new high-performance car over a new low-performance car and then finding that it has only very slightly better performance than the much cheaper low-performance car.

JOB LOSSES

Implementation of CARB 2 gasoline would result in the loss of about 23,300 jobs (or about 0.3% of the work force) in New York State in the year 2000 relative to the CG baseline (about 14,300 relative to EPA II). As the economy adjusted to the higher cost of CARB 2 gasoline, job losses would mitigate to about 17,600 in 2012 (about 10,200 relative to EPA II). These employment losses are depicted in Figure 12.

Figure 12.
Employment Losses for RFG Relative to Conventional Gasoline



Increasing gasoline prices will reduce driving and gasoline demand. The higher price and poorer fuel economy of CARB 2 gasoline will cause New York drivers to travel about 3.0 billion miles, or 2.2%, less in 2004 than they would with more moderate priced CG (about 1.8 billion miles, or 1.3%, less relative to EPA II). As motorists select more fuel-efficient cars to offset the higher price of gasoline, the CARB 2 mileage reduction will drop to about 2.5 billion miles, or 1.8%, by 2012 (about 1.4 billion miles, or 1.0%, relative to EPA II).

FINDINGS AND DISCUSSION

AIR QUALITY IMPACTS

In September 1990, CARB adopted its Low-Emission Vehicles and Clean Fuels Program, which includes, among other features, stringent mass emission standards for vehicular emissions of NMHC*, CO and NO_x for three classes of vehicles - transitional low-emission vehicles (TLEVs), LEVs and ultra-low emission vehicles (ULEVs).

In November 1991, CARB adopted CARB 2 specifications, which reduced the RVP, benzene, aromatic, olefin, sulfur, oxygen content and distillation properties of all gasoline sold in California, beginning in March 1996. According to CARB, use of this fuel will result in significant reductions in mass emissions of NMHC and NO_x, as well as in the ozone-forming potential of those NMHC emissions. In California, the CARB 2 gasoline program is primarily intended to reduce emissions from the existing vehicle fleet. Because CARB regulations allow CARB 2 gasoline to be used in the emissions certification of all TLEVs, LEVs and ULEVs, auto manufacturers can take the benefits of CARB 2 gasoline into account when designing emission control systems to meet the LEV program standards for New York and other states. As a result, the emissions of LEV program vehicles may be slightly higher in New York if they are not operated on a fuel with comparable or better emissions performance.

The State of New York has adopted the California LEV program, without the California clean fuels provisions, pursuant to Section 177 of the Federal Clean Air Act. Instead of mandating the use of CARB 2 gasoline, New York has indicated that it will require the sale of gasoline meeting the specifications adopted by the EPA for Federal RFGs. This decision has created a considerable amount of controversy between the State of New York and automobile manufacturers regarding the implementation of the California LEV program. The main issue in this controversy has been whether the State is required by the Federal Clean Air Act to mandate the use of CARB 2 gasoline throughout the state if it wishes to implement the California LEV program. The primary argument from the automakers' point of view is that since LEV program vehicles will be certified on CARB 2 gasoline, any state that adopts and enforces the LEV program emissions standards without requiring CARB 2 gasoline will force them to manufacture a "third vehicle" that is different than the Federal or California cars. A counter argument is that LEV manufacturers who produce vehicles for California must recognize that these vehicles must operate satisfactorily, and not produce problems to the owner, when driven outside of California where they are likely to be fueled with CG and possibly Federal RFG. Achieving such LEV design for California should then resolve any "third vehicle" problem when these cars are sold in other states.

From the State's perspective and from the perspective of air quality, the two most important questions

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*Actually non-methane organic gases (NMOG), which is closely related to NMHC and VOC. See Glossary.

associated with the use of CARB 2 or LS-EPA II gasoline in New York, in lieu of EPA II, are:

1. What incremental emissions reductions would be realized from the use of CARB 2 or LS-EPA II in on-road vehicles, non-road vehicles and engines which operate on gasoline? and

2. What incremental emissions increases would result from the use of fuels other than CARB 2 gasoline in vehicles certified to the various CARB LEV program standards?

The first question is addressed in Figures 13, 14 and 15, which show the statewide mobile source emissions inventories of NMHC, NO_x and CO, respectively, for New York over the period 1998-2012. The line labeled baseline represents the emission inventory for the state if planned emission control strategies, such as the California LEV program, are implemented but no RFG of any type (including oxygenated winter fuels) is required and CG continues to be used. The baseline also assumes, based on direction received from the DEC, that Stage II refueling vapor control would be implemented statewide and that a "maximum" inspection and maintenance (I/M) program would be in place in all areas where enhanced I/M programs are currently planned.

Figure 13.
New York State Mobile Source NMHC Inventory
(tons/summer day)

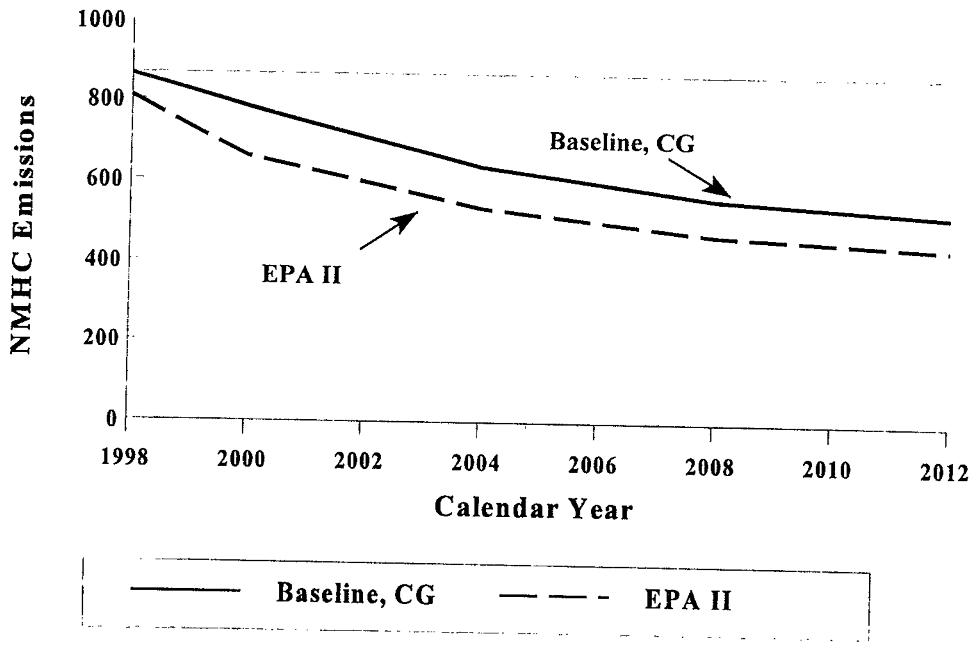


Figure 14.
New York State Mobile Source NO_x Inventory
(tons/summer day)

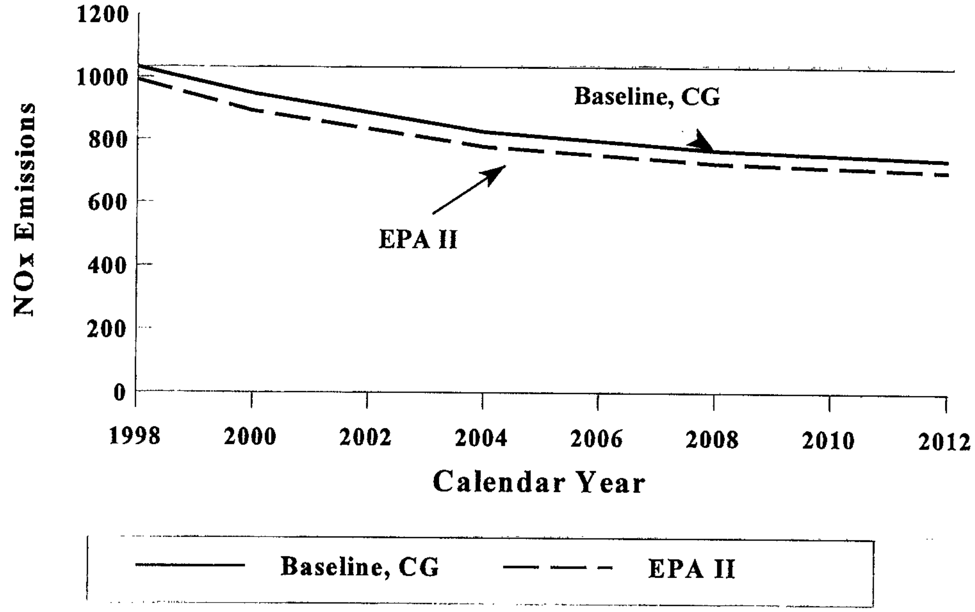
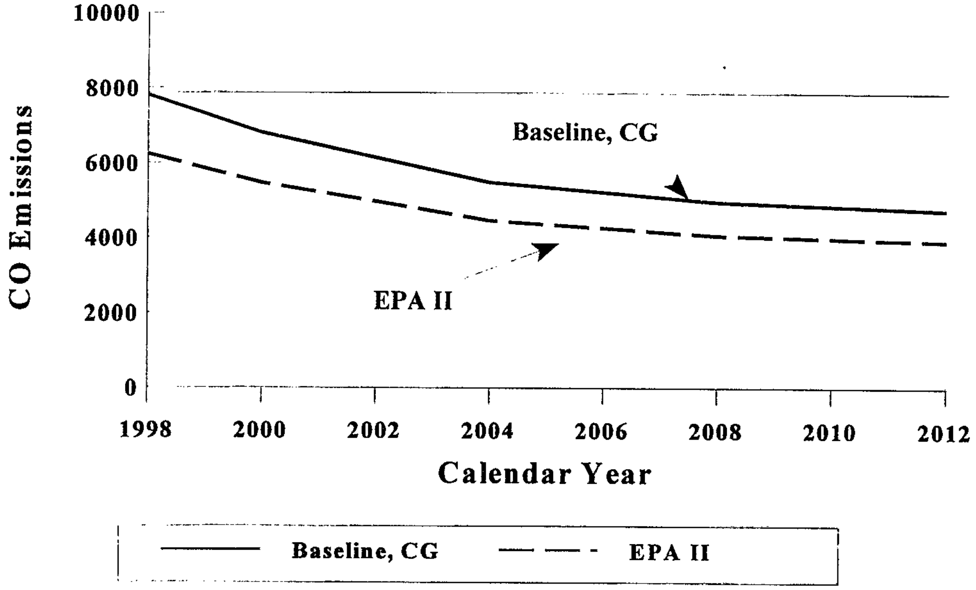


Figure 15.
New York State Mobile Source CO Inventory
(tons/winter day)



The line labeled EPA II in Figures 13, 14 and 15 represents the emissions inventory, assuming that the Federal RFG program is implemented. Separate CARB 2 lines have not been drawn because the estimated impact of CARB 2 is so similar to EPA II that, unless plotted on a much larger scale, the lines would virtually overlap. The figures show that the emission reductions that will result over time from control measures contained in the baseline will far exceed those realized from the use of EPA II.

The emission reductions, in terms of tons of pollutant emissions eliminated per day associated with the use of the different RFGs, are given in Table 2. The largest reductions in NMHC and NO_x emissions (both of which are precursors to ambient ozone) would occur with the statewide use of CARB 2 gasoline. This would reduce emissions of those pollutants by a maximum of 135 tons per day and 93 tons per day, respectively, in the year 2000, dropping to 90 and 62 tons per day, respectively, in 2012. However, the incremental emission reductions associated with CARB 2 relative to EPA II would be only 12 and 36 tons per day for NMHC and NO_x, respectively, in 2000 and would fall to 8 and 25 tons per day in 2012. In 2012, these reductions would represent about 1% and 3% of the 1998 baseline inventory of NMHC and NO_x emissions from vehicular sources. CARB 2 would increase CO emissions, compared to EPA II.

Table 2. Reductions in Criteria Pollutants Versus Baseline

(NMHC, NO_x - tons/summer day; CO - tons/winter day)

	Calendar Year				
RFG	1998†	2000	2004	2008	2012
EPA II					
NMHC	56	123	101	89	82
NO_x	41	57	47	40	37
CO	1,575	1,350	1,029	881	823
LS-EPA II					
NMHC	56	123	102	89	82
NO_x	41	63	52	45	40
CO	1,575	1,367	1,044	892	830
CARB 2*					
NMHC	56	131	108	94	87
NO_x	41	72	60	50	45
CO	1,575	1,244	962	825	768
CARB 2					
NMHC	56	135	112	98	90
NO_x	41	93	80	68	62
CO	1,575	1,107	858	728	674

† All EPA I in 1998.
* In NYC-SMSA, EPA I and EPA II elsewhere.

Table 3 shows the estimated incremental increase in exhaust emissions (compared to CARB 2 RFG) associated with the use of EPA I and EPA II RFGs, as well as LS-EPA II. These are presented in terms of grams of pollutant emitted per mile of travel for vehicles certified to CARB's LEV program. These estimates are based on the assumption that the vehicle emissions are equivalent to the standards to which they were certified (shown in parenthesis in the table). As the data in the table indicate, the use of Federal RFGs in LEV program vehicles is projected to result in increases of generally less than 5% in exhaust emissions of NMHC and less than 10% in exhaust emissions of NO_x.

Table 3. Increase in Exhaust Emissions from LEV Program Vehicles Operated on Federal RFGs*

(g/mile relative to operation on CARB 2 gasoline)

	TLEVs		LEVs		ULEVs	
	NMHC (0.125)**	NO_x (0.40)	NMHC (0.075)	NO_x (0.20)	NMHC (0.040)	NO_x (0.20)
RFG						
EPA I	0.009	0.06	0.005	0.03	0.003	0.03
EPA II	0.005	0.04	0.003	0.02	0.002	0.02
LS-EPA II	0.002	0.03	0.002	0.02	0.001	0.02

* Assumes that vehicles meet applicable emission standards at 50,000 miles on CARB 2.

** Values in parentheses are CARB 50,000-mile standards for each vehicle type.

GASOLINE REFINING

Refinery Investment Requirements

The production of RFGs will require additional refinery processing equipment at the eleven "high conversion" refineries in PADD I, the region comprising the East Coast. These eleven refineries are located in Delaware, New Jersey, Pennsylvania and Virginia and produce about 670,000 barrels per day of gasoline, equivalent to 80% of the supply for the four states included in the study (New York, New Jersey, Massachusetts and Connecticut). For the purposes of this study, the PADD I refineries are considered to be the primary source of RFG for this area, and they will have to invest the amounts shown in Table 4 to make the alternative RFGs.

Table 4. Refinery Investment

(billions of 1992 dollars)

Fuel	
EPA I	0.5
EPA II	1.0
LS-EPA II	1.8
CARB 2	3.1

Production of CARB 2 gasoline only for the NYC-SMSA would require investment in PADD I refineries of about $2 billion.

All of these RFGs contain oxygen. This is assumed to be supplied in the form of methyl tertiary butyl ether (MTBE). Some MTBE is produced in local East Coast refineries, but much more would probably be imported from marginal suppliers in the Middle East. This expensive, low energy raw material adds to the cost of RFG. In addition, all RFGs require varying levels of reduced sulfur content. This requires more expensive hydrogen processing of high sulfur gasoline components or of feeds to gasoline-producing process units. Finally, CARB 2 gasoline also requires removal of high boiling parts of gasoline. Due to Federal RFG limits and CG anti-dumping regulations, this heavy gasoline must be exported at a loss.

Fuel Economy

All RFGs require the addition of oxygen compounds (partially oxidized hydrocarbons), and CARB 2 gasoline also requires removal of high-boiling, high-energy-content portions of the fuel. These factors reduce the amount of combustible energy remaining in each gallon of fuel. This in turn reduces fuel economy and will force New York motorists to buy more fuel to travel the same total vehicle miles. The increased fuel demand will range from 1.5% to 2.7% and increase motorists' costs by the equivalent of about 2¢ to 3.5¢ per gallon. These costs are included in the Table 5 prices.

Price of Gasoline

Compared to CG, RFGs all require more severe refinery processing, major refinery equipment investments and more expensive raw materials. As a result, these RFGs will cost more to produce than CG. Due to the addition of oxygenates, fuel economy will be lower. These alternate fuels will require segregation from other types of gasoline, which will increase distribution costs. RFG pump price increases over CG, including fuel economy penalty, higher distribution costs and sales taxes, are shown in Table 5. The cost increases are assumed to be passed on as pump price increases without markup.

Table 5. Pump Price Increases Over CG

(¢/gallon)

Fuels	Summer	Winter	Average
EPA I	10.2	7.9	9.1
EPA II	11.8	9.2	10.5
LS-EPA II	17.2	14.5	15.9
CARB 2	29.5	22.4	26.0

The NYC-SMSA would be more sharply affected if it alone is required to use CARB 2. In this case, pump prices for metropolitan area motorists would rise by about 33.2¢ per gallon in the summer and 25.6¢ per gallon in the winter.

Table 6. 2000 Summer Increased Price Versus Emissions Reduction

	EPA I	EPA II	LS-EPA II	CARB 2
Price Increase(1), ¢/Gallon				
Gasoline Production Cost	6.0	8.1	12.0	22.5
Fuel Economy Penalty	2.4	1.8	1.9	2.8
Distribution Cost	1.0	1.0	2.0	2.0
Sales Tax	0.8	0.9	1.3	2.2
Total Price Increase	10.2	11.8	17.2	29.5
Emission Reduction(1), Tons/Day				
NMHC	51	123	123	135
NO_x	38	57	63	93

(1) Over CG baseline.

For discussion purposes, some results from the fuel production, fuel distribution and air quality sections of this report are summarized in Table 6. Based on these results, it is possible to develop cost-effectiveness estimates for the reduction of emissions. It is beyond the scope of this study to compare the cost-effectiveness of the emission control strategies studied here with all of the alternatives available to New York State. Nevertheless, these cost-effectiveness figures can be put in perspective by comparing them with guidelines used by EPA.

The NMHC cost-effectiveness results have been shown in Figure 10. In moving from EPA I to EPA II, the cost-effectiveness curve for NMHC is relatively flat – a significant emission reduction is obtained for only a modest increase in gasoline cost. From EPA II to LS-EPA II, there is almost no improvement in NMHC emissions, but the cost of gasoline increases by about 5¢ per gallon. (Refiners will take advantage of the flexibility of the EPA Complex Formulas to maintain about the same level of NMHC emissions at lower sulfur while minimizing costs by slightly increasing RVP, aromatics, olefins and T90.) Imposition of very stringent CARB 2 gasoline would raise costs by about 12¢ per gallon over LS-EPA II gasoline, while achieving only a slight improvement in NMHC. Hence, EPA II is the optimum RFG for NMHC reduction from a cost-effectiveness viewpoint.

Similar results for NO_x were shown in Figure 11. Again EPA II appears to be the most cost-effective way of reducing emissions, while the LS-EPA II and CARB 2 options are very expensive considering the small incremental emissions benefit.

Incremental cost-effectiveness in terms of thousands of dollars per ton of reduction are shown on both figures. Since both NMHC and NO_x are reduced simultaneously, it is helpful to take credit for one when calculating the costs for the other. The EPA estimate of \$5,000 per ton for alternate means of reducing either NMHC or NO_x has been used in these calculations. As shown on the figures, NMHC can be reduced for \$2,000 per ton, and NO_x can be reduced for a negative \$6,000 per ton when going from EPA I to EPA II. These are well below the \$5,000 per ton EPA guidelines for other emissions control strategies. From EPA II to LS-EPA II, the cost-effectiveness fails to satisfy EPA guidelines. NMHC reductions cost \$830,000 per ton, and NO_x reductions cost \$140,000 per ton. From LS-EPA II to CARB 2, the costs are \$150,000 and \$65,000 per ton for NMHC and NO_x, respectively, which (although lower than the prior step) are also much more costly than EPA guidelines. Not shown on the charts are the costs for going from EPA II to CARB 2 in a single step. After credit for the other pollutant, NMHC reduction costs \$220,000 per ton, and NO_x reduction costs \$75,000 per ton for this single step.

Alternative RFG cost-effectiveness above EPA II fails by at least an order of magnitude to meet EPA guidelines. Therefore, more stringent RFG requirements like LS-EPA II were not imposed by EPA as it selected cost-effective RFG standards based on its own guidelines. EPA studied more stringent specifications and decided to stop at EPA II.

GASOLINE DISTRIBUTION

Both metropolitan New York City and upstate New York are currently supplied with gasoline by a well established, low-cost distribution system, primarily by transfers from New Jersey and secondarily by imports. Some 230 MBPCD (thousands of barrels per calendar day) of gasoline is produced by New Jersey refineries, about the same as New Jersey demand. Over 50% of the historic gasoline supply to the central and north Atlantic states is produced at refineries in Delaware, New Jersey, Pennsylvania and Virginia. These are the price-setter refineries for gasoline sold in the region. About 30% of the gasoline supply comes from the U.S. Gulf Coast – mostly by way of the Colonial Pipeline. The remainder, less than 20%, is currently imported.

Although New Jersey refinery production is about the same as demand, three of the top New York gasoline marketers (Exxon, Amoco and Shell) move gasoline up the Colonial Pipeline from Gulf Coast refineries to New Jersey. Hence, part of the gasoline produced in New Jersey is transferred north and northeast. Further, some gasoline flowing through New Jersey is made in the Philadelphia area. Some Pennsylvania gasoline production helps meet both Pennsylvania demand and pipeline transfers from eastern to central states (primarily from Pennsylvania to Ohio).

Imports currently supply about 270 MBPCD into the general middle Atlantic area, including New York. A key factor in the future supply patterns for the scenarios of this study will be the probable lack of availability of imported alternative RFGs (RFGs other than EPA I and EPA II). Foreign refiners are unlikely to make the investment to supply CARB 2 or other non-Federal RFGs to localized markets. Assuming Federal RFG is used, importing companies with long-term relationships, particularly those dealing with Canadian, Virgin Islands or Venezuelan entities, will experience much less disruption than those now bringing in occasional gasoline cargoes from a variety of countries. In the four-state area, Massachusetts is potentially more vulnerable to increased transportation and distribution costs due to its present high level of direct imports.

Also critical will be the ability of terminals, particularly those in northern New Jersey, to handle receipt and shipment of alternative RFG in addition to the planned extra products - normal (Federal) RFG and recent very low-sulfur diesel - on top of conventional light products (gasolines and distillates, mainly) historically carried. Introducing the alternative RFGs of this study would add another six to 12 new products, which must be kept segregated. The segregated batches will be smaller, and terminals will lose capacity as existing large tanks will be used for the smaller parcels. Some physical changes may be required, such as installing additional lines, pumps and valves, plus even building new tanks. Terminals now having less flexibility will be at an even greater competitive disadvantage in the future; this would particularly impact the smaller terminals.

Operationally, there may well be cost penalties for pipeline and marine movements, as well as for terminals. Much will depend on the flexibility/rigorousness of the relevant potential new regulations and how they are interpreted and enforced. Also important is the size of the total market for which alternative RFG will be prescribed.

Distribution of RFG is estimated to cost more than that for CG, primarily due to loss of capacity associated with increased segregation, smaller batches, more record-keeping, greater interface losses and different supply sources. This study estimates the increased cost of distribution of the various gasolines, as shown in Table 7.

Table 7. Gasoline Distribution Costs

(¢/gallon increase over CG)

Type of Gasoline	Increased Costs
CG	0
EPA I and EPA II	1
OG and RFG-OG	2
LS-EPA II or CARB 2	2
CARB 2 in NYC-SMSA Only	3

Given the complexity of the distribution discussed above, the estimated distribution costs of alternative RFG are only approximate, and extending these estimates to different geographic areas requires even greater approximations.

For the NYC-SMSA alone, increases of about 3¢ per gallon in distribution costs are estimated in Table 7. Extension of alternative RFG to Connecticut probably would have a similar, or only slightly greater, cost. In both instances, the availability of suitable imports would not be a major factor. For Massachusetts, on the other hand, both additional volume and greater current supply by imports suggest that the increases in transportation and distribution costs might escalate another 20 to 30%.

Requiring alternative RFG in upstate, as well as downstate, New York will affect refineries and terminals in the Philadelphia area, as well as those in northern New Jersey. If Connecticut and Massachusetts are not included, then the impact on supply cost is not expected to be appreciable for RFG for upstate New York. However, if those two states are included, then the added transportation and distribution costs for upstate New York might increase by another 20% to 30%.

Finally, if alternative RFG were required for New Jersey as well, the cumulative effect could be somewhat more significant. Much of the base cost occurs in the New Jersey terminals, which serve much of the four-state area, as well as adjacent areas. Any increased costs would depend on both major and incremental sources of the alternative RFG and also on the capacity and flexibility of the terminals. Costs overall might go up if products were displaced from current means of transportation (mainly the Colonial Pipeline) to other, more expensive means. In all of this, the present advantages and disadvantages of size and efficiency among competing companies will be considerably amplified. This may well result in concentration via attrition or mergers of the less competitive companies.

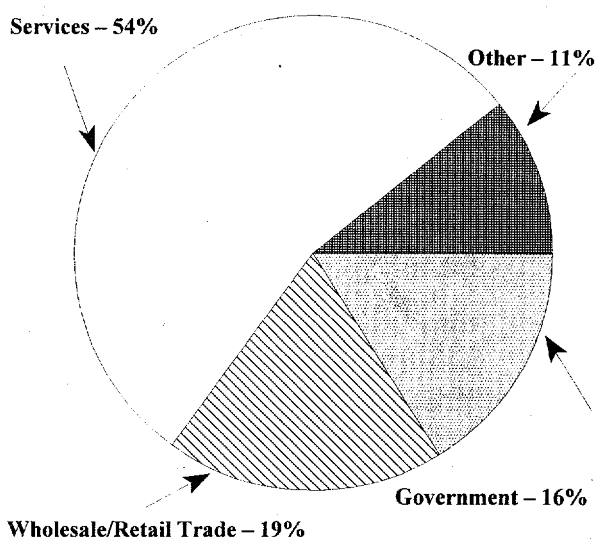
IMPACTS ON NEW YORK ECONOMY

The additional cost of producing each type of RFG was included in the effective unit pump price of gasoline. For each alternative RFG pump price, the quantity of gasoline purchased was recalculated to reflect the effect of higher prices on consumption, using DRI econometrics models. As the gasoline unit price increased, the quantity consumed decreased. However, at higher unit prices, the dollar expenditure on gasoline increased. As consumers are forced to spend more money on gasoline, they have less discretionary income available to purchase other goods and services. Since a significant part of an individual's discretionary income is spent on the purchase of goods and services from local businesses, those sectors of the State economy that serve local consumers will decline most. This decline is characterized as reduced levels of employment and lower wages.

Impacts on the State economy will be greatest if the entire State is required to use CARB 2. In the year 2000, job loss relative to the baseline CG case would be about 23,300 for CARB 2, whereas EPA II is estimated to lose 9,000 jobs and LS-EPA II about 13,500 jobs. CARB 2 restricted to NYC-SMSA would lose an estimated 17,900 jobs. Relative to EPA I and EPA II, the job losses would be about 14,300 for CARB 2, whereas LS-EPA II losses are 4,500 and CARB 2 in NYC-SMSA losses are 8,900. Real personal income (1992 dollars) losses relative to the baseline case exhibit a similar trend: EPA II, $450 million; CARB 2, $870 million; LS-EPA II, $570 million; and CARB 2 in NYC-SMSA, $710 million.

CARB 2 used over the entire four-state area produces the largest, most widespread gasoline price increase. Consequently, the impacts on the economy are the most severe. Since gasoline costs are less than 1% of all input costs in the manufacturing sector of the economy, even the most costly RFG produces minimal changes to the relative costs of production in the manufacturing sector.

Figure 16.
Employment Losses by Sector – CARB 2, Year 2012



Note: Total losses equal 17,600 jobs (relative to baseline).

Industries dependent upon local markets for their goods or services will bear a majority of the impact on the economy. Those sectors of the State economy which serve local residents will find their sales diminished. As shown in Figure 16, services and wholesale/retail trade combine for 73% of the job impact with CARB 2.

Employment impacts are most severe when the gasoline price increase is first imposed. With CARB 2, the employment losses relative to the baseline are 23,300 in the year 2000 (14,300 relative to EPA II) moderating to 17,600 by the year 2012 (10,200 relative to EPA II). The rapid increase in gasoline prices creates a stress on the economy, in which the local service-based sectors are the first to feel the effects of reduced household income expenditures. As employment in the services and trade sectors fall, the unemployment rate begins to edge up, initially lowering average wage rates. The lower wage rates improve the competitive position of the State, allowing the State to slow the incremental decline in employment and population. Eventually, the State moves back toward an equilibrium growth path, where employment and income are lower.

Increasing gasoline prices will reduce driving and gasoline demand, but not in proportion (Table 8). However, over time as consumers trade in their old vehicles for new ones, they are predicted to favor vehicles which deliver more miles per gallon of fuel. As a result, the cost of driving will begin to decrease due to the more efficient vehicle stock, and the difference in miles driven relative to the baseline will begin to abate after 2004. For EPA II versus the baseline, it is predicted that by 2012 gasoline consumption will be down by 24 million gallons per year and vehicle mileage will be down 1.1 billion miles per year.

Table 8. Miles Traveled and Fuel Demand Changes – CARB 2 Less Baseline

	1998	2000	2004	2008	2012
Gasoline, million gallons					
All Vehicles	62	(38)	(150)	(190)	(210)
Miles, millions					
All Vehicles	(1,040)	(2,500)	(3,020)	(2,760)	(2,480)

SUPPORTING INFORMATION

TECHNICAL EVALUATION PANEL

The Energy Authority defined the basic parameters of the study in accordance with the New York State Clean Air Compliance Act of 1993. Guidance was provided by a Technical Evaluation Panel (TEP) consisting of:

Joseph R. Wagner - New York State Energy Research and Development Authority
Charles Wesley - New York State Energy Office
James D. Hyde - New York State Department of Environmental Conservation
John J. Bartfai - New York State Bureau of Weights and Measures
Dean Simeroth - California Air Resources Board
Kenneth Hall - American Automobile Association
Richard G. Mallinson - University of Oklahoma
J. A. (Joe) Marcinek - Mobil Oil Corporation (for American Petroleum Institute)

The TEP also evaluated proposals and selected the team of consultants to perform the study.

CONSULTANTS

TM&C

Turner, Mason & Company provides engineering and management consulting services for the petroleum and petrochemical industries. The staff is made up of chemical engineers who have had significant experience with operating companies prior to joining the consulting practice. Founded in 1971, the firm serves a wide variety of clients, including most petroleum refining and marketing companies, petroleum industry associations and financial institutions, as well as chemical companies, government agencies, attorneys, utilities, individual and institutional investors, and various industry groups. TM&C has conducted almost all of the major refining-industry-funded refinery simulation modeling studies in the past nine years. Recent studies involving RFG have been conducted for Auto/Oil, the National Petroleum Council, the American Petroleum Institute, CARB and the Western States Petroleum Association, as well as numerous major and independent refining companies.

DRI

DRI/McGraw-Hill is a consulting and information firm that provides quantitative analysis through the use of large-scale macroeconomic models, extensive data banks and specialized computer facilities. The professional staff includes more than 500 economists, econometricians, engineers, industry experts and researchers. More than 1,000 client organizations are currently served from eleven DRI offices in the United States, Canada, Europe and Asia. DRI has been researching environmental issues in the U.S. and internationally since the 1970s. Clients have included both public sector agencies (including the EPA, DOE and DOC, as well as state agencies) and private sector companies (including oil companies, automotive companies and trade associations). Recent environmental modeling work includes analysis of RFG impacts in Illinois, Texas and Arizona.

Sierra

Sierra Research, Inc. is a consulting firm specializing in the field of air pollution control. The firm was founded in 1981 and has since grown to include all of the academic disciplines necessary to provide a complete range of air pollution engineering, modeling and analytical services. The staff includes individuals with training in the fields of automotive engineering, mechanical engineering, chemical engineering, civil engineering, atmospheric science, meteorology, biology and law. Sierra provides services to private industry, industry associations and government agencies. Private sector clients served by Sierra include numerous motor vehicle manufacturers, energy companies and operators of industrial facilities. For government agency clients, Sierra assists with the development and analysis of air pollution control programs and emissions data. Government clients have included the EPA, CARB, the U.S. Congressional Office of Technology Assessment and numerous state and local air pollution control agencies.

DATA SOURCES

The following were important sources of data used in this study:

- The New York State 1990 base year emissions inventory for on-road mobile sources published by the DEC and Radian Corporation in 1993.

- The Non-Road Engine and Vehicle Emissions Study, published by EPA in 1991.

- The Motor Vehicle-Related Air Toxics Study published by EPA in 1993.

- Various technical papers published as part of the Society of Automotive Engineers Technical Paper Series.

- Information on East Coast refinery raw materials, process configurations and product slates were obtained from the Federal Energy Information Agency.

- Petroleum raw material and product basic pricing data for the refinery simulation studies were obtained from *Platt's Oilgram* and projected to refinery gate prices by TM&C.

- National Petroleum Council (NPC), American Petroleum Institute (API) and Western States Petroleum Association (WSPA) reports were used to obtain information on approaches to making RFG and on the relative cost of making winter or summer RFG.

MAJOR ASSUMPTIONS

Both on-road and non-road emissions affected by gasoline quality were included in the initial inventories. Development of the on-road motor vehicle inventories prepared for this study followed a methodology similar to that employed by the DEC in preparing the 1990 base year inventory.

The major assumptions made in analyzing the impacts that different RFGs would have on mobile source emissions in New York State included the following assumptions that were specified by DEC and the New York State Energy Office, with concurrence by the Energy Authority:

- The California LEV program, including the ZEV mandate, would be implemented in New York State. All ZEVs are assumed to be electric vehicles (EVs) powered exclusively by batteries.

- A "maximum" I/M program, including I/M240 testing and functional evaporative system checks, would be in place in the NYC-SMSA, as well as upstate urban areas.

- Stage II refueling vapor recovery would be implemented statewide.

- Growth in the number of miles traveled by vehicles would increase over time, as projected by the New York State Energy Plan.

- Growth in the number and use of non-road engines and equipment would be constant over time.

- All gasoline-powered mobile and non-road sources operating in the State of New York would use the fuels considered in the study.

- Emissions from stationary sources were beyond the scope of this study; hence, power plant emissions due to incremental power generated due to EVs are not included. Also, any emissions from fossil fuel heaters on EVs are not included. Therefore, benefits from all scenarios are overstated. However, relative to each other, this had little impact since the California ZEV mandate is assumed in each scenario.

- The relative effect of RFG on emissions in vehicles certified to California LEV program standards would be the same as the effect of RFG on 1990 technology vehicles.

- The LS-EPA II will average 75 ppm sulfur (cap of 100 ppm). Vapor pressure maximum will be 6.9 psi (cap of 7.2 psi) but was actually controlled by the EPA II limits on VOC emissions.

The TM&C refinery model had been used recently to study various types of RFG in PADD I for the NPC. Adopting the NPC baseline scenario for this refining center while maintaining desired fuel and vehicle assumptions for New York State provided a firm foundation for this study. Confirmation of the major NPC assumptions, with some modifications, are as follows:

- RFG spillback from adjacent areas where Federal RFG is cheaper than the New York State-specified RFG will be 5% of demand.

- Motor gasoline demand level in New York State has a negligible impact on refinery cost differentials between scenarios. The cost differentials in 1992 dollars will remain essentially constant through the study time frame.

- Refinery netback pricing is based on New York harbor spot cargoes in 1992.

- Increased gasoline price to the consumer would reflect incremental manufacturing, distribution, sales tax and fuel economy cost for RFG.

- Constant 1992 dollars are used throughout the study.

- EPA's ethanol/ETBE mandate was not considered in this study. However, since all of the RFGs studied have similar oxygen requirements, results of this study are insensitive to whether or not the renewable oxygenate requirement exists.

- New York and adjacent states gasoline grade ratio was set at 65% unleaded regular and 35% unleaded premium to match recent history after correction for splitting midgrade into regular and premium.

- The baseline for this study is CG that would have been produced without the FCAAA.

- A 10% return on investment (ROI) was used to determine the capital charged for added facilities.

- Gasoline demand for equal vehicle miles traveled (VMT) is inversely proportional to the gasoline heat of combustion, as stated by EPA.

MODELS AND CALIBRATION

Air Emissions Models

Development of the on-road motor vehicle inventories prepared for this study followed a methodology similar to that employed by the DEC in preparing the 1990 base year inventory. That method couples emission factors in grams/mile (g/mi) with estimates of VMT for 33 regions in the state. The emission factors were generated with a modified version of EPA's MOBILE5a on-road emission factors model obtained from DEC, while the VMT and speed estimates were developed by the New York State

Department of Transportation. To generate the future-year (i.e., 1998, 2000, 2004, 2008 and 2012) inventories for this study, several modifications to the DEC version of the MOBILE5a emission factor model and the VMT estimates were made.

As noted previously, DEC's version of MOBILE5a (i.e., DECMOB5a) was used in this study. The DECMOB5a version of MOBILE5a has been modified by DEC to better represent motor vehicle control scenarios specific to the State of New York, particularly those related to inspection and maintenance (I/M) programs (e.g., the heavy-duty gasoline vehicle I/M credits were revised to include only vehicles up to 10,000 pounds gross vehicle weight, consistent with the actual requirements in New York). Also received from DEC were the input files for the 33 regions considered by DEC in developing the statewide inventory. These input files contained information regarding I/M scenarios, fleet mix, temperatures, speeds, operating mode fractions, etc. The speed and operating mode data were provided for up to 12 roadway types and four daily periods for each region. Emission factors for NMHC and NO_x were computed using DECMOB5a configured for summertime conditions, while CO factors were computed using the wintertime configuration.

To improve the accuracy of the emissions estimates for older (pre-1986) vehicles, correction factors were developed after examining information from CARB and elsewhere. The CARB predictive model, which was adopted on June 9, 1994, was developed for use in certifying alternative CARB RFGs as being equivalent, in terms of emissions performance, to CARB 2. The model estimates the effect of alternative RFGs on exhaust emissions, using fuel property data, and compares those effects to the performance estimates for CARB 2. The CARB predictive model was used to predict RFG emissions effects in 1981-1985 vehicles. The effects of RFGs on emissions from pre-1981 vehicles were estimated using MOBILE5a, with a correction factor based on RFG oxygen content.

The FCAAA directed EPA to evaluate the contribution of non-road engines and vehicles to air pollution in non-attainment communities. The result of that directive was the *Non-road Engine and Vehicle Emission Study* (NEVES), published by EPA in November 1991. NEVES served as the basis for calculating the non-road inventories in this study.

The methodology used in NEVES to develop non-road equipment population and activity estimates relied on a "top-down" approach in which state-level equipment populations were allocated to individual counties on the basis of certain local statistics indicative of equipment use (e.g., number of households, employment in particular industries). However, aircraft, commercial marine and railroad emissions are not included in the non-road inventories because the RFGs considered in this study will not impact emissions from those sources. Annual hourly usage, horsepower and load factor estimates were then applied to the county-level equipment populations to generate equipment activity in terms of horsepower per hour per year.

Refining Industry Models

The TM&C refining industry linear program (LP) models have been designed to represent the group of conversion refineries in each PADD or geographical area. In earlier studies, TM&C used six refining industry LP models to represent all U.S. conversion refineries with one model for each PADD, except for PADD V (West Coast). Two models were used for PADD V – California refineries and outside of California refineries. A separate model was used for California because it has more stringent environmental limits and runs a unique high-nitrogen, heavy, naphthenic crude slate. This California model was also used to study alternatives for WSPA before CARB 2 was adopted. Thus, the California model provides essential background to this study of CARB 2 gasoline. TM&C uses the concept of an average refinery in each area to facilitate and simplify the analysis and results. The TM&C East Coast conversion refineries model has been used in this study.

The proprietary Turner, Mason Modeling System (TMMS) offers a high degree of flexibility in process options to reformulate gasoline to alternate potential specifications. More than 50 options are represented in the model to improve the following gasoline properties individually or in combination: sulfur, benzene, olefins, aromatics and T90. TMMS contains over 40 types of process units. It includes 13 units which were added in a 1989 API screening study to provide gasoline reformulation capability and uses up to 95 blendstocks in gasoline blending to meet potential reformulation specifications.

TM&C developed composite refining industry PADD models originally for refining industry studies conducted for the Federal Energy Agency and the Department of Energy in the 1970s. They were upgraded, modified and very extensively calibrated using an industry survey during TM&C's 1985-86 study of gasoline capability and cost for NPC. These models were then used in several multi-client subscription studies. In 1987, the models were calibrated for gasoline butane content versus RVP based on the results of an API survey in a vapor pressure reduction cost study for the API.

In 1989, TM&C's models were calibrated for benzene content plus T50 and T90 distillation temperatures from NIPER data in a gasoline reformulation screening study for API. In 1990, TM&C's models were further calibrated for gasoline blend and individual component reformulation properties of aromatics, olefins and sulfur for an Auto/Oil RFG capability and cost study. The National Petroleum Refiners Association (NPRA) survey of U.S. gasoline properties in the summer of 1989 provided the basis for this calibration. Sulfur level has been further calibrated in this study to meet actual 1989 refinery gasoline production as measured by the NPRA survey.

In the most recent NPC and API studies, TM&C added several versions of potential EPA complex models to TMMS. As the final modifications of the complex models were developed in December 1993, they were added to TMMS for this study. This feature allows TMMS to take advantage of the flexibilities in the complex models to consistently minimize the cost of EPA I, EPA II and LS-EPA II RFGs in this study.

Econometrics Models

Analysis of the impacts on the economy of the State of New York of the alternate RFGs required the use of three DRI models: New York On-Highway Transportation Model, New York Vehicle Sales Model and New York and Regional Economic Models. Summary descriptions of each are provided below.

The Transportation Sector of the DRI Energy Model was used in this study to estimate vehicle demand for motor fuels. With this model, DRI/McGraw-Hill tracked the stock, usage and fuel efficiency characteristics of cars.

The model structure is a vintage capital stock model, formulated algebraically rather than econometrically. For each vehicle category included in the study, the model endogenously forecasts the capital stock, miles traveled, fuel use and both new car and fleet-wide efficiency for gasoline and electric vehicles. The model incorporates dynamic adjustments to account for optional policies (RFG requirements and the California LEV program), acting through macroeconomic variables, as well as policies directly affecting technological characteristics of the vehicle stock.

DRI regularly projects sales and production, by manufacturer and by model, for all vehicles sold or produced in the U.S. The projections of segment mix are formed primarily by demographic forces and changes in the kind (i.e., size, price, function) of vehicles demanded. Estimates of shares are formed by historical performances and by future product plans and pricing and distribution strategies for individual manufacturers. DRI exercised this model to gauge the effects of alternate RFG requirements and the LEV program.

DRI used a fully integrated approach to forecasting economic activity at the national, regional and state levels. Its U.S. Quarterly Model determines the national economy's growth path; regions and states compete with each other for available growth. Regional economic models forecast over 50 concepts for each state and region. The principal indicator of sectoral economic activity is employment, which is forecasted for 20 manufacturing and ten nonmanufacturing industries. Wage rates and major components of personal income are modeled, as well as home-building activity, population, labor force and unemployment rates.

METHODOLOGY

The Energy Authority prescribed the basic parameters of the study in consultation with the DEC and the State Energy Office, as well as outside consultants. These parameters and guidelines were discussed and refined by TM&C, DRI, Sierra and members of the TEP at a study kickoff meeting in December 1993. Following this meeting, TM&C prepared a list of major assumptions to be used. Then TM&C calculated initial estimates of the increased cost of RFGs and their likely properties. These estimates were based on prior studies of RFGs for NPC, API and WSPA. TM&C proposed specifications for LS-EPA II.

Using these preliminary estimates of RFG quality, Sierra conducted initial runs on its air quality models. At the same time, DRI employed the cost estimates to make initial runs using its New York State and regional econometrics models. TM&C recalibrated its East Coast refineries model to more accurately predict the sulfur level of CG and RFG gasolines. Preliminary results were then presented to the Energy Authority.

TM&C ran summer cases on their East Coast refineries model to produce each type of gasoline. For Scenario 2, the refineries produced both CARB 2 gasoline for New York City and EPA II for their other markets. These model results determined the refinery investments required, the cost of manufacturing RFG compared to CG and the properties of RFG. TM&C determined the costs and quality of winter RFG from the summer results by comparison with previous winter results from studies for API, NPC and WSPA. TM&C also studied the supply and distribution problems and costs that would arise from the introduction of additional types of RFG.

Based on the final version of CG properties, Sierra ran its emission models to determine baseline New York State emission inventories from 1998 to 2012. Then the models were used to project emissions reductions with various types of RFG.

DRI determined its projections of New York State economic activity assuming that CG continued to be available. DRI's transportation model was used to feed information into its state economic model. The models were then used to project economic activity to 2012, as affected by the alternative RFG scenarios.

Report sections were written by TM&C on fuels production and distribution, by Sierra on air quality and by DRI on the effects of RFG on the New York economy. TM&C then combined the sections and edited them to make one draft report and a separate draft executive summary. These draft reports and the executive summary were reviewed and extensively commented on by the Energy Authority and its advisors. Then TM&C prepared the final report and executive summary.

GLOSSARY OF ABBREVIATIONS AND TERMS

REFORMULATED GASOLINE STUDY EXECUTIVE SUMMARY

Alternate fuels	Substitutes for gasoline
Alternative RFG	Any RFG that requires separate handling compared to Federal RFG
API	American Petroleum Institute
Auto/Oil	Auto/Oil Air Quality Improvement Research Program (three big U.S. auto companies and 14 major oil companies)
BPCD	Barrels per calendar day
CAAA	Clean Air Act Amendments of 1990
CARB	California Air Resources Board
CARB 2	RFG meeting CARB Phase 2 regulations
CF	Complex formula regulations
CG	Conventional gasoline
CO	Carbon monoxide
Conversion refinery	Refinery with catalytic or hydrocracking to increase gasoline production
DEC	New York State Department of Environmental Conservation
DOC	U.S. Department of Commerce
DOE	U.S. Department of Energy
Energy Authority	New York State Energy Research and Development Authority
EPA	U.S. Environmental Protection Agency
EPA I	RFG meeting EPA Phase I regulations in 1998-1999
EPA II	RFG meeting EPA Phase II regulations in 2000+
EPA SM	RFG meeting EPA simple model regulations in 1995-1997
ETBE	Ethyl tertiary butyl ether
EV or ZEV	Electric vehicle
FCAAA or CAAA	Federal Clean Air Act Amendments of 1990
Federal Phase II	RFG meeting EPA Phase II regulations in 2000+
Federal RFG	RFG meeting EPA I in 1998 and 1999 and EPA II in 2000+
gm or g	Grams
I/M	Inspection and maintenance – an emissions control program requiring periodic (i.e., annual or biennial) inspection and repair of in-use motor vehicles
LEV	Low emission vehicle – a vehicle certified according to CARB's low emission vehicles and clean fuels regulations with a certification standard of 0.075 gm/mi NMOG, 3.4 gm/mi CO and 0.2 gm/mi NO_x
LP	Linear program
LS-EPA II	EPA II RFG modified to meet low sulfur, controlled RVP specifications
MBPCD	Thousands of barrels per calendar day
MTBE	Methyl tertiary butyl ether

GLOSSARY OF ABBREVIATIONS AND TERMS

REFORMULATED GASOLINE STUDY EXECUTIVE SUMMARY

Netback pricing	Price at the refinery gate, defined as market price less distribution costs
NEVES	*Non-road Engine and Vehicle Emission Study* – a report by EPA that summarizes methodologies used to develop nonroad equipment emissions inventories
NIPER	National Institute for Petroleum and Energy Research
NMHC	Nonmethane hydrocarbons – a measurement of hydrocarbon emissions that includes all nonoxygenated organic compounds except methane
NMOG	Nonmethane organic gases – a measurement of hydrocarbon emissions that includes all organic compounds except methane
NO_x	Nitrogen oxides
NPC	National Petroleum Council
NPRA	National Petroleum Refiners Association
NYC-SMSA	New York State portion of the New York City Standard Metropolitan Statistical Area
OG	Oxygenated gasoline
Oxygenates	Liquid compounds that add oxygen to gasoline; examples include MTBE, ETBE, TAME and ethanol
PADD	Petroleum Administration for Defense District
PADD I	East Coast states plus West Virginia and Vermont
RFG	Reformulated gasoline
RFG-OG	Reformulated/oxygenated gasoline
RVP	Reid vapor pressure
SF or SM	Simple formula (model) regulations
SMSA	Standard Metropolitan Statistical Area
Spillback	Supply of more severe product specification area with less costly product from an adjacent area
TAME	Tertiary amyl methyl ether
TAP	Toxic air pollutants – a generic EPA term that includes the following toxic compounds: benzene, 1,3-butadiene, formaldehyde, acetaldehyde and particulate organic matter
TLEV	Transitional low emission vehicle – a vehicle certified according to CARB's low emission vehicles and clean fuels regulations with a certification standard of 0.125 gm/mi NMOG, 3.4 gm/mi CO and 0.4 gm/mi NO_x
TMMS	Turner, Mason Modeling System
T50	Temperature in °F at which 50% is distilled overhead
T90	Temperature in °F at which 90% is distilled overhead
ULEV	Ultra low emission vehicle – a vehicle certified according to CARB's low emission vehicles and clean fuels regulations with a certification standard of 0.04 gm/mi NMOG, 1.7 gm/mi CO and 0.2 gm/mi NO_x

GLOSSARY OF ABBREVIATIONS AND TERMS

REFORMULATED GASOLINE STUDY EXECUTIVE SUMMARY

VMT	Vehicle miles traveled
VOC	Volatile organic compounds - a measurement of hydrocarbon emissions that includes all organic compounds except methane and ethane
wppm	Weight parts per million
WSPA	Western States Petroleum Association
ZEV	Zero emission vehicles (assumed to be battery-powered electric vehicles)