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Prepared By:
TIAX LLC
Cupertino, California
Subcontractor:
Ecos Consulting
Portland, Oregon

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Prepared For:
Bernard Treanton and Bill Blackburn,
Project Managers

Ken Koyama,
Program Manager

Susan Brown,
Manager
Transportation Technology Office

Scott W. Matthews,
Deputy Director
Transportation Energy Division

Steve Larson,
Executive Director

Authors Include:
Chris Calwell, Senior Project Manager
My Ton, Research Director
Deborah Gordon, Policy Analyst
Travis Reeder, Data Analyst
Marissa Olson and Suzanne Foster,
Researchers

Contributors Include:
Bill Blackburn
Kenneth Koyama
Kenneth Ridgley
Bernard G. Treanton

Disclaimer

Acronyms Used in This Report

ADVISOR	Advanced vehicle simulator
BCWR	Base course wear rate
BCWRn	True base course wear rate
CARB	California Air Resources Board
CEC	California Energy Commission
CIWMB	California Integrated Waste Management Board
CMT	Course monitor tire
CAFE	Corporate Average Fuel Economy
CSAF	Course severity adjustment factor
FI	Fuel efficiency index (graded from 5 TO 150)
GAF	Grade adjustment factor
ISO	International Standards Organization
LI	Load index
LRR	Low rolling resistance
Mc	Wear rate of candidate tire
Mcmt	Wear rate of course monitor
M	Wear rate (in units of mil/mile)
NHTSA	National Highway Traffic Safety Administration
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
OE	Original equipment
OEM	Original equipment manufacturer
PM miles	Projected mileage
PTT	Peak tire traction
RG	Relative grade (compared to CMT)
RMA	Rubber Manufacturers Association
RRC	Rolling resistance coefficient
SAE	Society of Automotive Engineers
SCC	Standard control coefficient
SMERF	Standard mean equivalent rolling force
SRTT	Standard reference test tire
TPMS	Tire pressure monitoring system
US DOT	US Department of Transportation
US EPA	US Environmental Protection Agency
UTQGS	Uniform Tire Quality Grading System
Yi	Average tread depth at end of life
Yo	Average tread depth
ZEV	Zero emission vehicle

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Executive Summary

California's SB 1170 legislation authorizes the California Energy Commission (CEC) to investigate opportunities for increasing usage of low rolling resistance (LRR) tires in the State. The legislation includes provisions requiring the purchase of LRR tires for State fleet vehicles and assessing various strategies to encourage their purchase by consumers, including information programs, labeling, incentives, and standards. The CEC must report its findings regarding these topics to the Governor and Legislature by January 31, 2003.

This report finds that the opportunity for cost-effective energy savings in California from LRR tires is substantial – about 300 million gallons of gasoline per year resulting from a 3% average improvement in the fuel efficiency of light duty vehicles currently operating on replacement tires. These savings can be achieved at an incremental cost projected to be less than the value of fuel saved. Specifically, over 10 years and two sets of tires, a typical California driver is estimated to save from $87 to $260 on fuel at an incremental cost of only $9 to $22, if they choose LRR replacement tires. While consumers may pay this higher incremental price upfront for low RR tires (compared to conventional tires), they will recover these costs over time through lower gasoline bills. We project a payback period for investing in LRR replacement tires of about one year.

Fuel savings can also be achieved without substantial tradeoffs in other aspects of tire performance, including traction, tread wear, price, and overall consumer satisfaction. While we cannot state definitively that all LRR tires are as safe as standard tires, the evidence to date does not suggest that improving rolling resistance comes with any automatic or significant safety penalty. Variations in tire design among models tend to be far greater than the variations that result from changes in rolling resistance, suggesting that the most innovative manufacturers continue to find new tire formulations and designs that improve multiple aspects of tire performance simultaneously.

Likewise, the evidence suggests no strong correlations between tire rolling resistance and longevity, so efforts to encourage greater fuel efficiency can operate hand-in-hand with the State's ongoing efforts to minimize tire waste. In fact, markets for reusing and recycling tires have been growing steadily and should continue, regardless of any additional activities undertaken by the State to encourage reductions in tire rolling resistance.

Our assessment of the merits of encouraging low rolling resistance tires relative to encouraging proper tire inflation is similar. Both policies are worth pursuing for their own sake and both offer a means of reducing fuel consumption. However, consumers that purchase LRR tires will enjoy the fuel-saving benefits of that technology for another 30,000 to 50,000 miles of driving, with no other action or behavioral modification required. By contrast, proper tire inflation can yield smaller (though still useful) fuel savings benefits, but requires regular attention by the vehicle operator to maintain its effect. The State faces no difficult choice between the two measures, but should instead pursue both, recognizing that substantial private sector and federal government resources are already being devoted to encouraging proper tire inflation.

This report urges the State of California require the use of the SAE J2452 tire testing methodology for reporting rolling resistance values for tires. This test method yields results that are more predictive of "real-world" performance than other test methods, and is already in widespread use by the major manufacturers of tires and automobiles. State action can accelerate its usage by smaller manufacturers and independent test laboratories, providing the data upon which all other promotional strategies depend.

Ecos Consulting initially requested rolling resistance data directly from the tire manufacturers and received small amounts of data from a few companies. Such information is routinely collected for original equipment (OE) tires when they are specified for use on new vehicles, and exists for some replacement tires as well. Before larger quantities of data could be obtained from the manufacturers, the Rubber Manufacturers Association (RMA) refused a general rolling resistance data request from the CEC, halting the data collection process. This made determinations of potential benefits and performance tradeoffs significantly more challenging.

However, RMA, in its 12/18/02 comments to the CEC, committed to work cooperatively with the CEC to develop an appropriate test protocol and provide industry expertise to support the collection of LRR tire and fuel economy data. Such a collaborative effort between the State and the tire industry could help the State meet the requirements of SB 1170, if it hastens rolling resistance data collection and subsequent changes to the tire procurement process.

The Legislature should consider moving rapidly to require tire manufacturers to disclose the rolling resistance of all light duty vehicle tires offered for sale in the State, measured according to SAE J2452. Such a provision would require manufacturers to test their tires at an independent laboratory competitively selected by the State. Unless manufacturers could come up with an acceptable alternative approach to test the tires themselves and calibrate their test equipment appropriately to ensure comparable results (a process routinely followed by vehicle manufacturers). Round robin testing or a formal challenge process might be useful complements to any process involving self-testing by manufacturers. *All other policy steps discussed below depend on that information for successful execution.*

The CEC should post the resulting rolling resistance information on its website for all tire models sold in the State as it becomes available. Furthermore, the CEC should construct additional Internet content allowing consumers to compare the likely fuel economy impacts of particular tire models on particular vehicles, employing the ADVISOR modeling process developed by the National Renewable Energy Laboratory.

Once consistently measured data on tire rolling resistance are readily available, the State should move quickly to modify its procurement process for replacement tires to include consideration of rolling resistance. This may require revisions to the procurement model currently used by the federal government and many states, but the changes California undertakes could make it easier for those other government entities to follow suit. In addition, greater demand for LRR tires for State vehicles can only help to increase their availability in the distribution channels that serve corporate fleets and the consumer marketplace.

We encourage the Legislature to fund additional assessments of the potential designs and impacts of consumer labeling programs for tire efficiency. Beyond providing information via the Internet, there may be substantial benefits associated with providing clear information to consumers in retail stores regarding the fuel efficiency impacts of their tire choices.

Incentive programs involving fees and rebates warrant similar exploration, though they would logically follow efforts to gather rolling resistance data and label tires accordingly. Mandatory standards may also serve as a valuable backstop to other market transformation efforts, ensuring some progress with rolling resistance improvements if the other market mechanisms fail to achieve significant progress within the coming years.

More on-road assessments of the performance and fuel economy impacts of LRR tires are also warranted. The State may wish to utilize its own fleet vehicles as a test population, gathering data to assess the likely impacts of a broader consumer-focused outreach effort. Some independent laboratories are also equipped to validate laboratory measurements of rolling resistance with instrumented vehicles driving on "real world" road surfaces, so it may prove useful to fund additional studies of that nature.

Finally, in order to realize the full potential of fuel savings from LRR tires, it may also be useful to conduct focus groups regarding consumers' tire preferences. Not all consumers are likely to be receptive to new advertising or labeling messages about tire rolling resistance, but thorough market research can highlight how such preferences interact with other consumer interests in tire warranties, traction capabilities, appearance, brand, etc. Those consumers most interested in reducing fuel costs, either because of the resulting environmental or economic benefits, are likely to be the "early adopters" that initiate transformation of this vital market.

1. Introduction

1.1 Overview of California's SB 1170

This report was produced as a result of Senate Bill 1170 (Chapter 912, Statutes of 2001). This measure requires the California Energy Commission to develop and adopt recommendations for a California State Fuel-Efficient Tire Program for consideration by the Legislature and Governor no later than January 31, 2003.

SB 1170's key provisions include:

- Fuel-efficiency specifications for government fleet vehicles and replacement tires
- Proposals regarding ways to reduce petroleum consumption "to the maximum extent practicable and cost-effective."
- Reductions in the energy consumption of the state vehicle fleet by at least 10% by January 1, 2005

SB 1170 urges consideration of a number of policy options, including product labeling, a centralized website, printed materials available in retail stores, financial incentives, and mandatory standards. In fact, SB 1170 specifically required CEC to make recommendations by January 31, 2003 in the following areas:

- Test procedure for measuring rolling resistance
- Database of tire models and their efficiency
- Consumer tire fuel efficiency rating system
- Other consumer education approaches
- A study regarding safety implications of more widespread low rolling resistance tire use
- Mandatory standards for tire efficiency in California
- Incentive programs to encourage the purchase of more fuel-efficient tires

The State of California currently accounts for about 23 million light-duty vehicles of the 220 million total vehicles registered in the US.[1] Because these 23 million vehicles together consume about 12% of the annual national transportation fuel budget, measures that can reduce overall vehicle fuel consumption in California can have profound implications for both the State and the nation.[2] Californians also purchase about 28 million replacement tires per year, which represents a major opportunity to affect the State's fuel consumption. With SB 1170, action could begin at the State level in California that would strongly influence the national after-market for tires.[3]

The main purpose of this report is to examine the available information on the potential to save fuel from increasing the use of low rolling resistance (LRR) replacement tires. Such analysis

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[1] California Energy Commission, *Task 2: Base Case Forecast of California Transportation Energy Demand – Staff Final Report* #600-01-019F; as derived from CALCARS Energy Demand Model, December 2001.

[2] *Statistical Abstract of the United States*. US Bureau of the Census, Washington DC, 2001.

[3] There are approximately 202 million replacement tires sold in the U.S. each year for passenger cars, and another 35 million replacement tires sold for light trucks, according to tirebusiness.com. The current US tire market consists of at least 28 tire brands and more than 700 models of tires, available in a variety of sizes. California's share of national tire sales is likely to be roughly proportionate to its share of the nation's registered vehicles – about 12%. That translates into about 28 million replacement tires sold in California per year.

includes an assessment of how rolling resistance interacts with other aspects of tire performance. It also includes preliminary discussions of potential cost effectiveness, comparing the likely incremental cost of LRR tires to their estimated fuel savings. Fuel savings estimates, in turn, account for any expected changes in tire lifetime, which could shorten or lengthen the period of time over which fuel would be saved. The report concludes with a wide-ranging review of possible policy options to encourage the use of more efficient tires in the State.

1.2 Background on Tire Rolling Resistance

According to the National Academy of Sciences (NAS), about 80 to 88% of the energy contained in a vehicle's gasoline tank is wasted in thermal, frictional, and standby losses in the engine and exhaust system. This leaves only about 12 to 20% of the potential energy actually converted to vehicle motion.[4] Even after the engine successfully converts chemical fuel energy to rotational energy at the drive axle, additional losses occur between the wheel rims and tires, and between the tires and the road. These losses are collectively known as rolling resistance. Recognizing that new vehicles often employ tires with lower rolling resistance than replacement tires, the NAS nevertheless identified additional opportunities to improve average new vehicle fuel economy by 1.0 to 1.5% with further reductions in rolling resistance at an incremental retail cost of $14 to $56 per car.[5]

Once a vehicle is purchased, there are few opportunities available to the operator to improve its fuel efficiency. A handful of after-market technologies, including lubrication oils and replacement tires, offer promising opportunities for making the vehicle itself inherently more efficient. Other strategies, including maintaining proper tire inflation pressure, keeping tires aligned, and driving more efficiently, can yield valuable fuel savings, but rely heavily on the behavior of the vehicle operator, making them difficult to sustain over time.

Tread design, composition, cross-section geometry, and inflation pressure can create significant variations in the rolling resistance of various tire models. This rolling resistance can present a varying load to the vehicle's engine, causing meaningful differences in fuel consumption when the same vehicle is driven with different tires. Auto manufacturers are aware of this phenomenon and have largely moved to incorporate fuel-efficient tires in new vehicles. Between 1980 and 1994, the tire industry reduced the rolling resistance of the tires it produces for original equipment manufacturing (OEM) purposes by approximately 48% (Figure 1). Additional improvements have likely continued thereafter.

While these improvements in rolling resistance have helped auto manufacturers meet their Corporate Average Fuel Economy (CAFE) requirements; consumers currently do not have such information available to help them select replacement tires for optimal fuel economy once their OEM tires have worn out. Though the industry asserts that OEM tires are often available for special order by customers wishing to continue using the same models as replacements,[6] there is no evidence that many customers are willing to go to such effort to obtain them or have the information needed to justify such a purchase.

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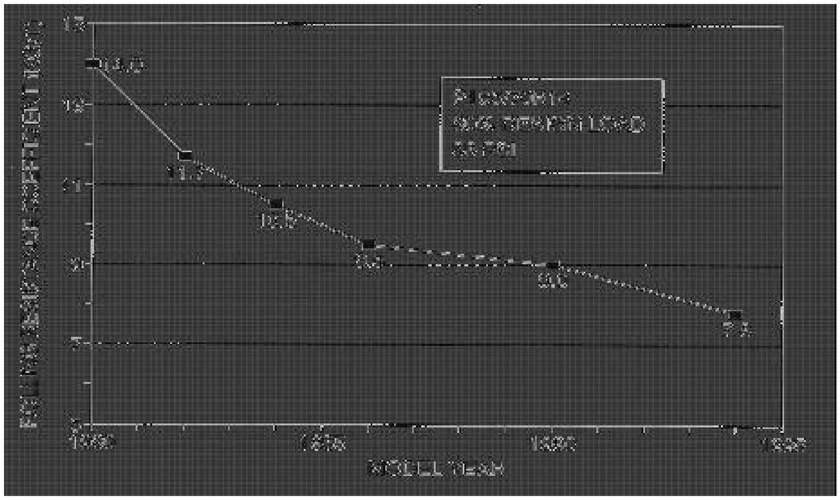
[4] National Research Council, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFÉ) Standards*, 2002, pp. 3-2 and 3-4.

[5] National Research Council, pp. 3-14 and 3-20. Note that these energy savings and incremental cost estimates compare existing OE tires with future alternatives, rather than comparing today's typical replacement tires to LRR alternatives. OE tires, have already made substantial improvements in rolling resistance, would likely be more expensive to improve than replacement tires.

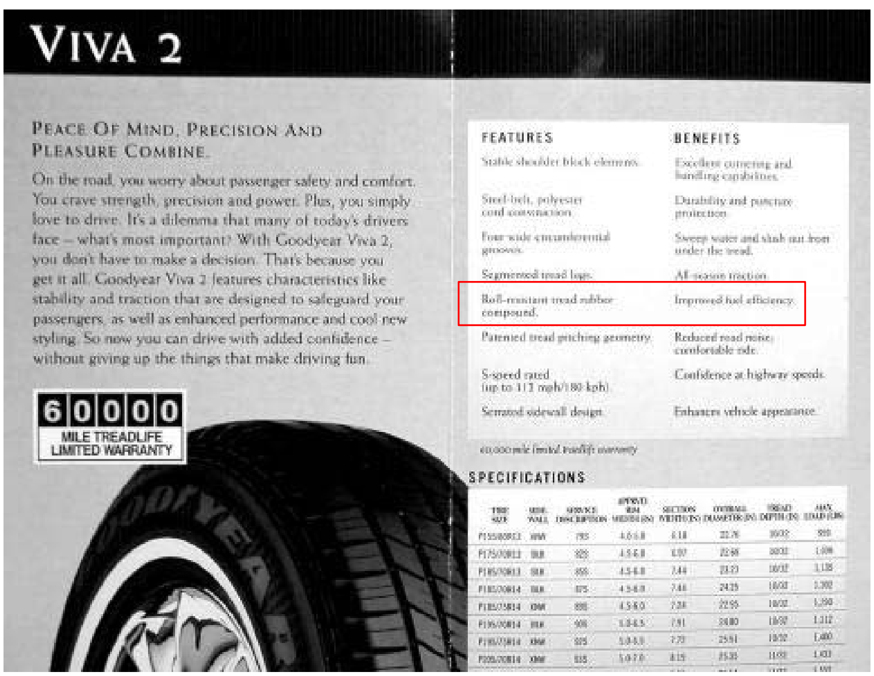
[6] Tracey Norberg, comment letter to the California Energy Commission from the Rubber Manufacturers Association, November 4, 2002, p. 10.

Figure 1 – Average OEM Tire Rolling Resistance Over Time[7]



The more likely scenario is that customers replace tires on fairly short notice as needed, either in response to an individual tire failure or to take advantage of an advertised sale. This limits the range of likely replacement tires to those models readily available in stock. Information is not routinely available from tire dealerships regarding the relative rolling resistance performance of various tire models or the likely impacts individual tires would have on vehicle fuel economy.

Figure 2 – Sample Tire Brochure from Goodyear (Fuel Efficiency Claim Highlighted)



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7 Clarence Hermann, Michelin Tire Corporation, *Statement Before the National Highway Traffic Safety Administration Regarding the Proposed Rule to Modify the Uniform Tire Quality Grading Standards,* July 28, 1995, Figure 1.

A few tire models (see example in Figure 2) bear names or advertising messages implying "green" performance or greater fuel efficiency, but such claims are not based on independently validated or consistently comparable measurement protocols. This effectively eliminates rolling resistance as a purchase criterion in the replacement tire market today, without action by government and industry to provide such information.

2. Approach

In order to support the CEC in its implementation of SB 1170 provisions, Ecos Consulting staff carried out a number of tasks, briefly summarized below.

2.1 Assess test procedures

Tire rolling resistance is defined as the energy a tire consumes per unit distance of travel. As a tire rolls under load, it deforms (because rubber is a viscoelastic material). A fraction of that energy is stored elastically, but the remainder is dissipated as heat. This conversion of absorbed energy to heat, along with friction in the tire "contact patch" and between the tire and its rim, creates what is known as hysteretic losses. These losses, as well as aerodynamic drag and internal friction, are irrecoverable energy, and combine to create the total drag force on a moving vehicle.

Rolling resistance is measured on a specialized dynamometer, which is instrumented to allow the accurate measurement of the tire forces needed under various load and inflation pressure conditions. The rolling resistance of a free rolling tire can be considered as a force that opposes vehicle motion. The standard metric units of rolling resistance force are joules per meter (J/m) or simply newtons (N). The comparable English units are pounds.

Given the wide range of load conditions observed across the array of vehicles that can accommodate a particular tire, rolling resistance force is often divided by the vertical load force (the weight of the car divided across four individual tires) to create a dimensionless measure of tire efficiency, known as the rolling resistance coefficient (RRC). These numbers can be expressed as simple fractional values between 0 and 1, with lower values corresponding to higher efficiencies. A metric variant, kilograms/metric ton, is also effectively dimensionless, but multiplies by a factor of 1,000 to account for the ratio of kilograms to metric tons.

At present, there are two established methodologies developed by the Society of Automotive Engineers (SAE) for assessing light-duty vehicle's (passenger cars and light trucks) tire rolling resistance, one endorsed by the International Standards Organization (ISO), two more in development by the U.S. Environmental Protection Agency, and others in use by industry informally:

> **SAE J1269** tests a tire at a single, fixed speed of about 50 miles per hour. This method is the most widely used both by tire manufacturers and independent laboratories. The results are readily comparable with each other, but not highly predictive of actual on-road performance across a wide range of speeds.
>
> **SAE J2452** tests a tire at five different discrete, fixed speeds. This method is designed to replicate the range of speeds found in EPA's Supplemental Federal Test Procedure (SFTP) for vehicle fuel economy, but does not attempt to measure rolling resistance

during acceleration and deceleration. As a result, it is somewhat more predictive of "real world" rolling resistance than SAE J1269. This method is now used by a number of tire manufacturers and automakers, but not yet by the major independent testing laboratories.

ISO 8767 appears to be largely similar to J1269 and was employed by the German government in its recent laboratory tests of tire rolling resistance. The German "Blue Angel" labeling program has established rolling resistance and noise criteria for recognizing tires in the marketplace, which are based where appropriate on ISO 8767 measurements.

The US EPA has explored two other tire-testing methods in order to capture more "real world" conditions (such as the impact on rolling resistance of cold tires, acceleration, braking, etc.). One is known as a "coast-down" test and assesses the amount of time a vehicle with a particular set of tires can coast before dropping to a certain speed. Ecos has obtained the results of EPA's initial coast-down testing and is assessing those data. EPA's other approach is an attempt to replicate the entire SFTP during a tire test, which would capture the effects of acceleration and deceleration, but may be costly to perform and difficult to replicate.

Manufacturers utilize other approaches as well, including testing various tires on pairs of identical vehicles that are driven on standardized test tracks. Fuel consumption is carefully compared for both vehicles over a course of known length to determine the impact of changes in tire type on fuel efficiency.

Ecos Consulting evaluated all of the above approaches, and recommended an approach to be used by the CEC for making the most appropriate comparisons. A summary of these recommendations appears in the Findings and Results section of this report.

2.2 Develop tire database

Ecos Consulting gathered available data from tire manufacturers and conducted market research to determine which tire manufacturers and models represent the largest share of sales in the US and California. We expanded this database by adding information provided by the National Highway Traffic Safety Administration (NHTSA) regarding the federal Uniform Tire Quality Grading System – (UTQGS). These include measures of tires' tread wear, traction, temperature resistance, and speed ratings.

We requested rolling resistance data from tire manufacturers individually and collectively through their trade association (the Rubber Manufacturers Association). A few manufacturers provided a handful of data points, but the industry as a whole (acting through RMA) refused to provide this information when it was requested by the CEC. This greatly compounded the difficulty of making meaningful comparisons between tire rolling resistance and other aspects of tire performance.

We supplemented the database with other readily available public data sources regarding tire price, performance, efficiency, and customer satisfaction. *Consumer Reports* has conducted such evaluations of about 100 tire models, which were converted to numeric values for inclusion in the database. The consumer website TireRack.com has likewise gathered and published customer feedback on 10 different aspects of tire performance and product satisfaction after more than a billion miles of collective use by customers, inclusion of those findings were pertinent.

Lastly, we examined data obtained through a parallel effort Ecos Consulting is conducting with Green Seal on behalf of the Energy Foundation to test tires for rolling resistance and recommend efficient models to government and private sector fleet buyers. Ecos selected 43 initial tire models representing a variety of manufacturers, tire types, sizes, and performance characteristics for J1269 rolling resistance testing by an independent laboratory. Additional tire testing is ongoing.

2.3 Fuel economy/rolling resistance correlations

Ecos worked with Ken Kelly of the National Renewable Energy Laboratory (NREL) to make estimates of the likely fuel economy impacts from changes in tire rolling resistance. NREL has developed a sophisticated mathematical model called ADVISOR to compute the fuel energy required in various vehicles on a range of different test cycles when driven on different tires. ADVISOR works from J2452 rolling resistance data and a library of known vehicles and test cycles to quickly model a range of scenarios that would be very costly to test physically. ADVISOR also assessed the range of likely fuel efficiency impacts from various changes to tire rolling resistance and inflation pressure for particular vehicles, making possible comparisons of the likely incremental fuel savings from each measure.

2.4 Assess rolling resistance impacts on other aspects of tire performance

The CEC convened a public workshop on September 19, 2002 to facilitate discussion of initial findings and solicit input from tire manufacturers and other interested parties. Three manufacturers and the RMA provided specific input regarding interactions and potential tradeoffs between tire rolling resistance and other aspects of tire performance like traction, tread wear, and cost. An additional presentation from the Umweltbundesamt (German Environmental Protection Agency) highlighted findings from ongoing testing in Germany regarding tire rolling resistance, noise levels, and traction. Ecos Consulting, CEC staff, EPA, NREL, and the Nevada Automotive Test Center conducted presentations as well.

RMA provided additional information in a comment letter after the workshop, which was considered along with a variety of materials presented on similar topics by a diverse array of participants in NHTSA proceedings in 1994 and 1995 regarding proposed federal labeling of tire rolling resistance. Ecos weighed this information with the information contained in the database described above, to assess interactions between rolling resistance and other aspects of tire performance. Our recommendations regarding those interactions are found in section 4 below.

A second stakeholder workshop was held on December 4, 2002. Feedback provided at that meeting and in subsequent written comments has also been considered in this revised draft report, within the limits of time available to full analyze all input.

2.5 Policy options

SB 1170 urged consideration of a number of policy options, including product labeling, a centralized website, printed materials available in retail stores, financial incentives, and mandatory standards. Ecos analyzed the merits of each approach, considered other approaches that have been tried internationally, and made recommendations regarding the most promising options for implementation in California. These options are included in Section 4 of this report.

3. Findings and Results

3.1 Recommended Test Methodology

After extensive evaluation of methodologies and discussions with tire industry experts, we recommend that the CEC employ test method SAE J2452 in meeting the requirements of SB1170. A full discussion of the technical merits, test methodologies, and details is included in a separate report to the CEC. A brief summary of the recommendations on test methods follows below.

There are three main advantages to using SAE J2452. First, three tire manufacturers comprising 85% of the original equipment manufacturers and over 50% of the replacement tire market conduct J2452 testing currently. For these tire manufacturers, much of the data needed to meet California's needs would already be in hand, especially as original equipment (OE) tires are more readily made available to the replacement marketplace. It is possible that other manufacturers already conduct the more advanced test as well, either on their own equipment or by renting time on competitors' test equipment.

Second, at least three auto manufacturers are requesting J2452 data so they may accurately calculate how OE tires will affect their vehicle fuel efficiency. So the automakers themselves lend tremendous validity to the J2452 testing process, ensuring that the connection between tire efficiency and vehicle efficiency is an explicit one. Over time, this will likely lead to greater capabilities in the independent testing labs for this test procedure as well.

Third, J2452 represents a more complete, sophisticated level of testing and a more complete picture of tire rolling resistance than the J1269 and ISO 8767 procedures. The data are at least more representative of real world results, allowing reasonable predictions of how a tire will react under complex driving patterns without the expense of on-road testing. The procedure was designed by tire manufacturers and automakers to meet the EPA's road load and speed dependent fuel consumption tests and is endorsed by the Society of Automotive Engineers.

Michelin noted that slight variations have been observed in the actual J2452 data reported by manufacturers, which it attributes to small variability in the precision of testing equipment and the manner in which it is used. As a result, says Michelin's Mike Wischhusen, automakers will commonly send individual tire samples around to the tire makers for measurement, and then develop adjustment factors to account for those variations.[8] Such a process might also be needed in California over the long term to ensure that the reported values are fairly and accurately characterized, though true-up could also be handled through the use of a single independent testing laboratory or a formal challenge process among manufacturers.

The need for such adjustments and an ongoing monitoring process is not unique to tire testing, but is found in virtually all programs in which products compete on measured efficiency performance. If the observed variations in J2452 measurement are found to be small (a few percent or less), we believe the CEC could proceed with manufacturer-reported data initially, and implement the adjustments and true-up process later, as needed, rather than delaying implementation of SB1170 until all aspects of testing are finalized and perfected.

[8] Personal communication, Mike Wischhusen, Michelin Government Affairs, September 2002.

The State could also accelerate J2452 testing by investing in the necessary infrastructure at a competitively selected independent laboratory. The test equipment cost is about $200,000, with a laboratory facing significant additional startup costs to create a dedicated facility, train staff, and calibrate equipment. Lead times of nine months to a year may be likely, and per-tire testing costs could be $300 to $500 if a lab needed to invest its own capital to create a test facility. A guaranteed, large-volume testing contract or co-funding of the startup costs could significantly reduce that amount.[9]

3.2 Fuel Economy/Rolling Resistance Correlations

With assistance from NREL, we used ADVISOR to examine the effects of vehicle speed and driving conditions. The results from these simulations confirmed that tire rolling resistance has different effects under different driving conditions and vehicle speeds. For example, tire rolling resistance has more of an effect in highway driving conditions than at a constant speed of 50 mph, but less of an effect in urban driving conditions. The highway fuel economy test yielded a return ratio of 1:5.3, or more than a 2% fuel economy change for every 10% change in rolling resistance. The urban fuel economy test yielded a return ratio of 1:9.6, or about a 1% fuel economy change for every 10% change in rolling resistance.

Our initial findings, summarized in a separate report to the CEC, indicated that even with the progress made in the past two decades by the tire industry, variations in rolling resistance still have a significant effect on vehicle fuel consumption. This effect varies with vehicle speed and conditions, with fuel economy improvements most noticeable in highway (extra urban) cycle driving. These results correlate well with tests that have been conducted elsewhere. For example, the German Umweltbundesamt has found through its extensive tire testing efforts for its own energy-efficient tire labeling program, that a 30% reduction in a tire's rolling resistance can reduce a vehicle's fuel consumption from 2% to 6%, depending on driving conditions and other factors.[10]

Low tire inflation pressure, as well as heavy vehicle load, can also affect vehicle fuel economy. Lower tire pressure or a heavy load results in more tire distortion and greater energy absorbed by the tire as well as increased contact and rim friction, thus reducing vehicle fuel efficiency. According to the Rubber Manufacturers' Association, when a tire is under-inflated by 1 pound per square inch (psi), the tire's rolling resistance is increased by approximately 1.1 percent. This ratio between rolling resistance and fuel economy is dynamic and is dependent on several other factors, including vehicle type and load, road and environmental conditions, etc. However, RMA stated that a typical range for light duty (passenger and light truck) vehicles would be 5% to 8% deterioration in rolling resistance performance, which equates to a roughly 1% reduction in fuel efficiency.[11]

Using ADVISOR, we compared fuel economy effects from changes in tire inflation pressure with variations in rolling resistance for a typical vehicle like a Ford Focus. The results from these tests indicated that under highway driving conditions, the potential to improve vehicle fuel economy from reducing rolling resistance is greater than the savings potential from just keeping the tires properly inflated. For example in Figure 3 below, going from the tire with the highest rolling resistance to the tire with the lowest rolling resistance within this test group can improve

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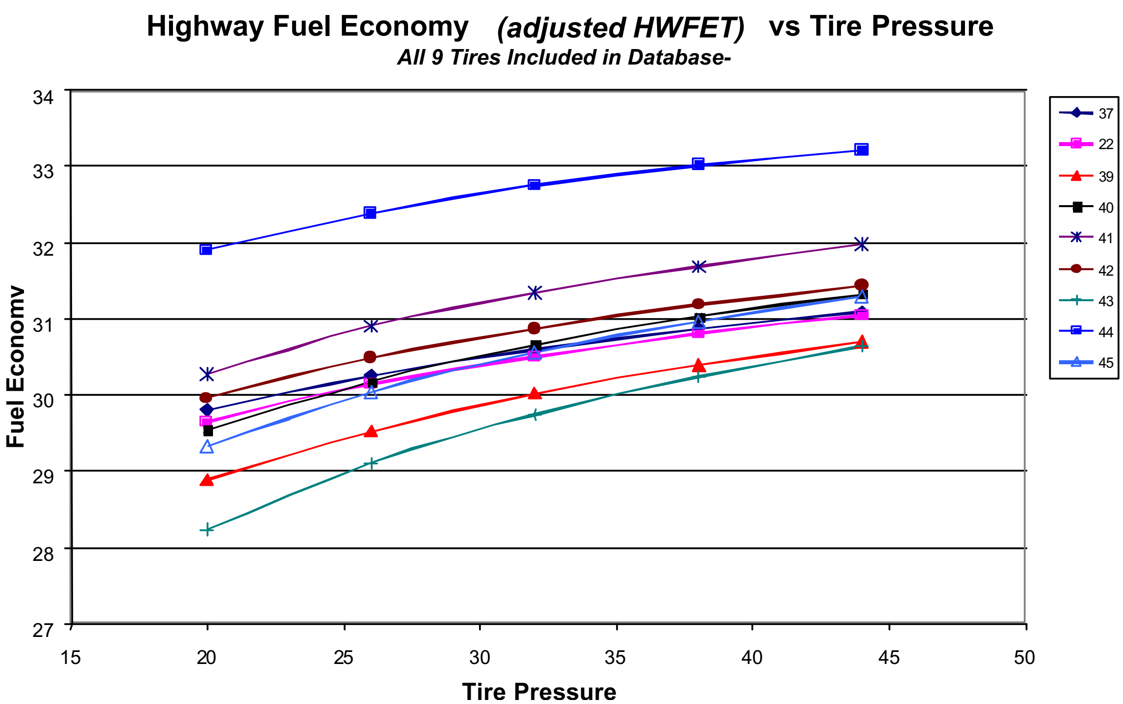
[9] Estimates derived from Ecos conversations with independent testing laboratories, December 2002.
[10] *Fuel Savings Potential From Low Rolling-Resistance Tires*. Presentation by Axel Friedrich of the Umweltbundesamt at the September 2002 CEC Tires Workshop in Sacramento, CA. Note that the "Extra Urban Driving" environment is more representative of the US's highway driving environment, as autobahn driving conditions can reach over 100 miles per hour.
[11] Communication from Tracey Norberg of the RMA to Kenneth Koyama of the CEC, November 4, 2002.

highway mileage by about 3.9 mpg, or about 12%, even at 25 psi, which is typically lower than the recommended tire pressure. On the other hand, going from 20 psi (low inflation) to 45 psi (maximum recommended inflation) yielded about a 1.5 to 2.0 mpg difference in the fuel economy expected from each set of tires. The range of pressures examined is wider than would typically be seen in consumer use, with 45 psi corresponding to an uncomfortable ride on many tire models available today.

Figure 3 - Highway fuel economy & tire pressure (each curve represents a different tire model #)



We arrived at four overall conclusions from the above investigations:

- There are strong reasons to encourage vehicle operators to maintain proper tire inflation pressure. It will not only lead to fuel economy benefits, but may also contribute to longer tire life and improved overall safety.[12] However, the effect is short-lived without constant diligence by the vehicle operator.
- The potential fuel economy benefits of low rolling resistance tire design are even greater in magnitude than proper inflation, and are worth pursuing on their own merits.
- The potential for fuel savings from proper tire inflation can be more immediate, but the savings from the widespread use of LRR tires will be more sustained and should yield greater savings in the long-term.
- These two public policy objectives are not mutually exclusive in any way. The greatest fuel economy benefits could be achieved by pursuing both. Indeed, given the existing industry and national government focus on proper tire inflation, the State of California

[12] Communication from Tracey Norberg of the RMA to Kenneth Koyama of the CEC, November 4, 2002.

might make the greatest *incremental* contribution to additional fuel economy savings by focusing on LRR tire design, and ways to encourage it in the marketplace.

The results from the ADVISOR simulations are important for another reason: continued federal inaction regarding fuel economy standards has sharply limited policy options for improving fuel economy. LRR tires offer opportunities for individual states and corporate fleets to make meaningful increases in fuel efficiency in the near term, regardless of action by the federal government. These savings opportunities are likely greatest in older vehicles, for which few alternative gasoline-saving options are available. Studies conducted by the German Umweltbundesamt show that a further improvement in rolling resistance of 50% or more in the next 4 to 5 years is possible.[13]

Given the ADVISOR simulation results and the German findings, a savings potential of approximately 3% seems reasonable from LRR replacement tires (with total fleet changeover). This 3% acknowledges that savings of up to 6% are possible on some driving cycles and with some tire combinations, but that many vehicles are operating on new (OEM) tires at any given time, and that very low rolling resistance designs are not suited to some vehicle types and operating conditions. Achieving a 3% reduction in the state's light duty motor vehicle gasoline usage would yield annual savings of more than 300 million gallons of gasoline, worth more than $470 million annually at current retail prices, or approximately $1.4 billion over the three year lifetime of a typical set of replacement tires.

Table 1 - Estimated Fuel Savings for California

Percent Fuel Savings from LRR Tires	Estimated Annual Fuel Savings (Gallons)	Estimated Annual Consumer Savings
1.5% savings	153,623,500	$235,043,955
3.0% savings	307,247,000	$470,087,910
4.5% savings	460,870,500	$705,131,865

Source: Ecos Consulting, 2002

Table 1 provides a range of estimated fuel savings from the California light-duty fleet. The calculations used an average annual vehicle miles traveled (VMT) of 12,500 miles per vehicle. Each vehicle averages 21.2 miles per gallon. We assumed that only the 17 million light-duty vehicles older than 3 years would require replacement tires.[14]

3.3 Fuel Cost Savings and Cost Effectiveness of Low Rolling Resistance Tires

We calculated fuel cost savings for low rolling resistance tires on a typical vehicle in use in California (See Table 2). It is assumed that this typical vehicle is driven about 38,000 miles over the first three years of its lifetime[15], after which, the original tires tend to be replaced. The first set of replacement tires typically lasts about 50,000 miles, needing replacement when the vehicle is around seven years old. The second set of replacement tires is then purchased (either by the original vehicle owner or a second owner) and lasts until the vehicle is ten years old.

[13] Axel Friedrich, *Fuel Savings Potential From Low Rolling-Resistance Tires*, presentation on behalf of the Umweltbundesamt at the CEC Tires Workshop, September 2002.
[14] The calculations were based on the number of light-duty vehicles older than 2000 model year (about 17.3 million vehicles), and used an average price of $1.533 per gallon of gasoline.
[15] Transportation Energy Data Book, Oak Ridge National Laboratory, October 2000, Table 6.6, for estimates of annual miles driven by vehicle age. http://www.osti.gov/gpo/servlets/purl/769291-1oGlz8/webviewable/769291.pdf (downloaded 12/19/02).

Although any given vehicle may remain on the road for many more years, on average, the annual mileage drops to under 9,000 miles as it ages beyond 10 years,[16] reducing the fuel savings potential. The average fuel economy of a California vehicle is assumed to be 21.2 miles per gallon.[17] These utilization rates amount to a fuel consumption of 4,370 gallons per vehicle, in years 3-10, when the vehicle is equipped with its first two sets of replacement tires. At an average gasoline price of $1.533 per gallon[18], the net present value of the vehicle's fuel cost (when it is equipped with replacement tires) is $5,770.[19]

Table 2 - Estimated NPV of Fuel Costs on an Average California Vehicle

Year	Tires Used	Avg. Miles Driven/Yr[1]	Cum. Miles per Tire Set	F.E. MPG[2]	Gallons Consumed	2001$ Gasoline[2]	Proj. Fuel Cost (2001$)	NPV of $1 @ 5% Paid in Future	NPV[3] Fuel Cost
0-1	OEM	15,600	0	21.2	736	$1.53			
1-2	OEM	11,200		21.2	528	$1.53			
2-3	OEM	11,300	38,100	21.2	533	$1.53			
3-4	1st replacement	11,600	0	21.2	547	$1.53	$839	1	$839
4-5	1st replacement	12,400		21.2	585	$1.53	$897	0.95	$852
5-6	1st replacement	12,700		21.2	599	$1.53	$918	0.907	$833
6-7	1st replacement	12,900	49,600	21.2	608	$1.53	$933	0.864	$806
7-8	2nd replacement	13,800	0	21.2	651	$1.53	$998	0.823	$821
8-9	2nd replacement	14,800		21.2	698	$1.53	$1,070	0.784	$839
9-10	2nd replacement	14,500	43,100	21.2	684	$1.53	$1,049	0.746	$782
Averages (years 3-10)			**46,000**			**$1.53**			
Replacement Miles		**92,700**					**$6,700**		**$5,770**
Total Lifetime Miles		**130,800**							

Source: Ecos Consulting, December 20, 2002.

Notes:

1. Transportation Energy Databook, Edition 22, 1999, Table 6.6; See http://www.osti.gov/gpo/servlets/purl/769291-1oGlz8/webviewable/769291.pdf, downloaded 12/20/02.
2. F.E. = fuel economy; California average in-use vehicle fuel economy assumed at 21.2 mpg and gasoline price of $1.533/gallon. Data provided by personal communication with Bill Blackburn, California Energy Commission, November 12, 2002.
3. Assumes 5% discount rate; Based on personal communication with Ken Koyama, California Energy Commission, December 19, 2002.

Consumers are given many product choices when they replace their vehicles' tires. If LRR tires are used as replacement tires they are estimated to save 1.5 to 4.5% of their lifetime fuel consumption. Selecting LRR tires during the first two tire replacements on their vehicles is projected to save consumers from $87 to $260 in fuel. Based on testimony from tire manufacturers, there is expected to be a small incremental cost increase for manufacturing LRR tires, at least in the short term. Public comments to NHTSA in 1995 claimed that incremental costs of low rolling resistance replacement tires ranged from less than $1 to no more than $2.50.[20] In 2001 dollars, this estimated incremental cost equates to $5 to $12 per set of tires.

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[16] Transportation Energy Data Book, October 2000.

[17] CEC, *Task 2: Base Case Forecast of California Transportation Energy Demand – Staff Final Report* #600-01-019F; as derived from CALCARS Energy Demand Model, December 2001.

[18] California's 2001 gasoline price was held constant over ten years based on the Energy Information Administration's projection that nationwide gasoline prices will not increase over the next 20 years. See www.eia.doe.gov/oiaf/archive/aeo01/pdf/aeo_base.pdf, downloaded December 18, 2002.

[19] For purposes of calculating net present value the discount rate is assumed to be 5 percent in 2001 dollars based on information provided by Ken Koyama, California Energy Commission, December 19, 2002.

[20] Statement of Clarence Hermann, Michelin Tire Corporation, before the National Highway Traffic Safety Administration Regarding the Proposed Rule to Modify The Uniform Tire Quality Grading Standards, July, 28, 1995, p. 8. Other parties to the 1995 NHTSA

Table 3 presents a comparison of the cost savings from LRR tires to the estimated incremental cost to purchase these tires. Accordingly, if a California driver selects fuel-efficient tires each of the two times her tires are replaced, she is expected to save from $87-$260 in fuel costs at an incremental price ranging from $9 to $22 (two sets of tires). These figures indicate that the payback period of LRR tires is about one year. It is important to note that, even if the incremental cost is doubled or tripled, it is expected to be cost effective for California consumers to switch to LRR tires.

Table 3 – Estimated Cost Effectiveness of LRR Replacement Tires on In-Use Vehicles

Year	**Tires Used**	**Cumulative Miles per Tire Set**	**$ Saved on Fuel Low RR Tires**			**Incremental Cost Set of low RR Tires**	
			NPV @ 1.5% FE	NPV @ 3% FE	NPV @ 4.5% FE	Low Est.	High Est.
0-1	OEM	0					
1-2	OEM						
2-3	OEM	38,100					
3-4	1st replacement	0				$5	$12
4-5	1st replacement						
5-6	1st replacement						
6-7	1st replacement	49,600	$50	$100	$150		
7-8	2nd replacement	0				$4	$10
8-9	2nd replacement						
9-10	2nd replacement	43,100	$37	$73	$110		
Total for 2 Sets of Replacement Tires			**$87**	**$173**	**$260**	**$9**	**$22**

Source: Ecos Consulting calculations, December 20, 2002.

Assumptions:
1. Two sets of fuel-efficient replacement tires on in-use vehicles that are from 4-10 years old.
2. Fuel economy of California in-use vehicles averages 21.2 mpg.
3. All figures in 2001 dollars.

3.4 Tire Rolling Resistance and Solid Waste Issues

On a national basis, the stockpile of discarded tires is declining, having fallen from roughly 1 billion tires in 1990 to about 308 million in 2001. Of the 281 million waste tires generated in the U.S. in 2001, about 218 million were reused according to the RMA. In addition, about 85% of the stockpiled tires are concentrated in nine states: Texas, New York, Michigan, Alabama, Ohio, Colorado, Connecticut, Pennsylvania, and West Virginia. Markets for reused, recovered, and recycled tires are growing steadily throughout the country, leading to the following applications for waste tires:[21]

- Ground into pieces for use in playground surfaces, horse arena flooring, running tracks, soil amendments, and horticultural applications
- Shredded for use in road embankments and landfill construction projects

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proceeding asserted higher incremental costs ranging up to $22 per tire, but chose tires that differed in far more ways than simply rolling resistance. Our limited analysis so far suggests no obvious, substantial price premium for LRR tires – see Figure 7.

[21] Vera Fedchenko, "Scrap tire markets grow as piles decline," *Tire Business*, September 30, 2002, p. 14.

- Combusted in cement kilns to provide higher fuel value and lower emissions than coal, with iron supplementation for the cement manufacturing process
- Pyrolysis to produce no. 3 grade oil, scrap steel, and tire-grade carbon black
- Formed into “hail proof” roofing shingles
- Thermally combusted to power greenhouses and manufacturing facilities

The number of waste tires generated in the State of California each year is roughly equal to its population size. In view of the continued increase in the population of California, the California Integrated Waste Management Board (CIWMB), the public body responsible for dealing with waste tires in California, faces an escalating challenge. The CIWMB is looking to address this issue through various options, including investigating the possibility of extend the average tire-life mileage. Representatives of the CIWMB attended the CEC’s tire workshops.

The CIWMB’s main concern with the CEC’s efforts to increase fuel savings through the promotion of LRR tires is to insure that this effort does not result in increased volume of annually discarded tires in California. CIWMB data show that in 2001, 33.3 million waste tires were generated in the State of California, and an additional 1.7 million waste tires were imported into the state. Between 1990 and 2001, the total number of waste tires (generated and imported) processed in the State of California increased from 27 million to 35 million, a 29.6% increase. Thus, CIWMB faces an increasingly challenging task in view of this rising volume, and has identified extending average tire-life mileage as one possible strategy.

A report commissioned by CIWMB[22] identified a number of factors that can combine to reduce average tire-life mileage (41,000 miles in 2001 for light-duty tires) including:

- Poor tire and vehicle maintenance.
- Increased use of performance tires at the high end and the availability of discount tires at the low end.
- Original equipment tires that are designed to optimize vehicle performance and reduce fuel consumption, sometimes at the expense of tire wear.
- Pavement designs that for the most part neglect to include tire wear as a design criteria.

This CIWMB report further suggested strategies for CIWMB to help consumers reduce their tire wear, including education on proper tire inflation, rotation, and vehicle alignment. Other strategies suggested for consideration by the CIWMB range from increasing the light-duty tire retreading rates to government mandates for extended tire wear warranties.

As our report discusses below, every tire represents a balance between a wide assortment of desired performance characteristics. In general, the tires sold with new vehicles place relatively more emphasis on low rolling resistance and traction performance than on longevity. By contrast, replacement tires in general will often place greater emphasis on low price and longevity than on low rolling resistance.

However, the data do not at this time indicate that low rolling resistance is only obtainable by sacrificing longevity. Changes in tire compounds often permit improvements in both aspects of tire performance.[23] Indeed, in the most recent issue of *Tire Technology International* 2002,

[22] Integrated Waste Management Board, *Waste Tire Management Program: 2000 Annual Report*, July 2001.
[23] *External Literature References Referring to the Absence of Tradeoffs from Improvements in Rolling Resistance*, citations and abstracts provided by Michelin in comments to NHTSA, May 24, 1995, Docket No. 94-30.

numerous articles were devoted to the topic of simultaneous improvements in rolling resistance and other aspects of tire performance. Four article titles and subtitles are illustrative:

- "An Enduring Product – There has been much concern in recent years about the environmental impact of discarded old tires. One way to reduce pollution and waste is to improve the durability and service life of tire treads by means of reinforcing fillers. Synthetic silicas [the same compounds added to reduce rolling resistance] are a promising alternative to traditional carbon fillers." – M.A. Ansarifar & R Nijawan, Loughborough University, pp. 12-14.

- "Tire Tread Applications of Polyisoprene Techniques – Polyisoprene with a high 3,4 content is particularly effective in enhancing the wet grip of high-performance tires. It is therefore possible, by adjusting the levels of carbon black and cis-butadiene rubber, to enhance wear and rolling resistance properties while retaining superior wet grip." – J. Stander, M.J. van der Merwe & J. van Noordwyk, Isogrip, pp. 46-48.

- "High-Performance Preciptiated Silica for Winter Tire Tread – The introduction of new solution polymer systems, together with highly dispersable silica and coupling agents have helped to improve the compromise between rolling resistance, wet traction and wear resistance." – Ph. Cochet, Rhodia Silica Systems, pp. 64-66.

- "Increase Tire Life and Fuel Economy with Improved Polymers – Over the last 10 years, the low rolling resistance and grip performance of OE tires has continued to improve to meet the more stringent targets of the vehicle manufacturers. This has only been possible because of the continual development of tread polymers." – J. Trimbach, R. Engehausen, A.J.M. Sumner, Bayer AG, pp. 130-132.

Thus, we find that the State should be able to pursue both the goal of improving fuel economy from LRR tires and the goal of reducing tire waste, without the fear that these are mutually exclusive objectives. Indeed, efforts to find additional markets for reusing and recycling tires to reduce solid waste and air pollution are worth pursuing on their own merits, as are efforts to increase sales of LRR tires to save fuel and reduce greenhouse gas emissions.

3.5 Industry Input

At the Tires Workshop held on September 19, 2002, CEC and Ecos Consulting presented the goals of SB1170 to industry association representatives as well as representatives from individual manufacturers. The CEC and Ecos Consulting requested additional information regarding rolling resistance testing methodologies as well as rolling resistance data from industry at this meeting. Discussions during the Workshop also included sources and availability of data, issues associated with available test methods, and the industry's concerns over making such data available to the CEC.

In a follow-up document, the Rubber Manufacturer Association (RMA) provided the CEC with technical information about the complexities of tire technology, the tradeoffs inherent in tire design, rolling resistance considerations, and the contribution of tires to the fuel economy equation. RMA also outlined some initial policy recommendations to the CEC.

The industry's primary concern lies with a tire manufacturer's ultimate responsibility for a tire's performance and suitability for its intended use. RMA pointed out that when the cause or potential cause of any serious tire performance concern is related to tire materials or construction, tire manufacturers' responsibilities include recalling the tires to protect the public. Therefore, any change in materials or construction is likely to impact one or more tire-performance factors. A spider chart (Figure 4) below, illustrates the interdependence of tire performance factors that manufacturers have to balance in tire design.

Figure 4

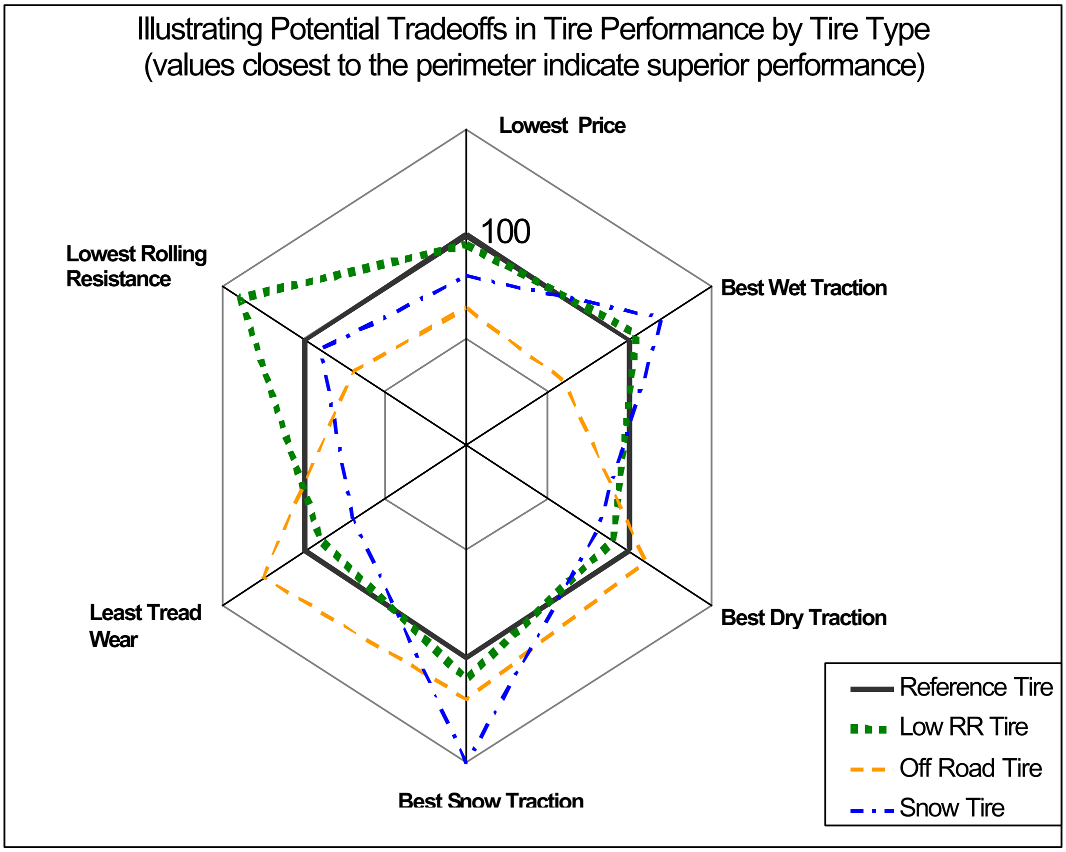

Figure 4 is similar to those shown at the workshop by RMA and Bridgestone/Firestone, illustrating hypothetical examples of how particular tire types might emphasize one aspect of tire performance more heavily than others to meet specific design objectives. Other examples furnished by RMA in written comments illustrate other types of potential tradeoffs among other types of tires, but were compiled "based on comprehensive tire industry expertise and experience and reflect overall trends in the tire industry" rather than from quantitative test data on multiple tire models. As more test data are gathered by the CEC, it may be possible in the future to compare the actual performance of a set of LRR tires against the actual performance of a set of typical replacement tires to further hone the relationships illustrated in this spider chart.

Distance from the center of the chart indicates greatest performance with respect to a particular objective, so a tire that is maximized for price would be less expensive than a tire with a cost falling closer to the center of the diagram. Likewise, a tire maximized for dry traction would perform better than a tire not maximized in that area.

As illustrated by the above chart, any given change by the tire manufacturer can make each of the other tire factors better or worse by large or small amounts. The reference tire achieves nominal performance of 100 on all design aspects, while the hypothetical low rolling resistance tire achieves major improvements in rolling resistance and minor improvements in wet traction and snow traction at the cost of a slightly higher price and slight reductions in dry traction and longevity. The off road and snow tires demonstrate different types of tradeoffs, consistent with their design objectives. Note in particular that performance tradeoffs may be more significant when price is held constant than when tire price is allowed to increase as more advanced materials are incorporated into tire design.

Because tire manufacturers continuously develop new tires, their new products may yield environmental benefits other than fuel savings. Goodyear in particular has made claims of improved rolling resistance and other environmental benefits associated with the use of corn starch in its GT3 “BioTred” models. An improvement in tread wear can lead to a reduction in the amounts of scrap tires generated annually. RMA stated in its letter that one of the most significant contributions by the tires industry to reducing the impact of tires on the environment is the radial tire, which almost doubled tire life from the bias tire.

RMA also expressed concerns over NHTSA’s recently promulgated final regulation mandating tire pressure monitoring systems (TPMS), which will require automobile manufacturers to provide TPMS on new vehicles. The systems mandated by the regulation would warn drivers if their tires are either 25 or 30 percent underinflated, depending on the type of TPMS installed on a particular vehicle. While it may seem that this new regulation will lessen the number of under-inflated tires on the road, RMA believes that the opposite may occur.

RMA noted that recommendations for proper tire inflation pressure on specific vehicles are set by automobile manufacturers. In some cases, drops in tire pressure could cause tires on particular vehicles to operate outside of their recommended design parameters before they reach an inflation pressure that would trigger the TPMS. The tire industry is concerned that the TMPS will give drivers a false sense of security about tire inflation pressure and will inhibit drivers from regularly checking tire inflation pressure. In short, drivers may rely on TPMS to warn them when a tire has reached a dangerously under inflated state, when in actuality an unsafe condition may have already occurred.

RMA stated that proper tire inflation pressure can play a crucial role in achieving lower rolling resistance and good vehicle fuel economy. RMA is currently committed to a multi-year education campaign to increase public awareness about proper tire maintenance. The campaign “Be Tire Smart – Do your PART” focuses on four important tire maintenance activities – Pressure, Alignment, Rotation and Tread. Originally designed to promote tire safety, the RMA campaign also promotes concepts that would achieve environmental benefits.

RMA pointed out that the key benefits of the campaign include the fact that it can be implemented immediately, and it does not require consumers to buy new tires. Consequently, RMA believes that greater public awareness about proper tire maintenance has the potential to have a far greater impact on fuel economy, and recommended that the CEC consider developing a comprehensive plan to educate Californians about tire care and maintenance.

As discussed in the previous section (section 3.2), a campaign to promote proper tire inflation has the potential to complement CEC's efforts to promote fuel conservation through low rolling resistance tires. Since properly inflated tires have lower rolling resistance, modest fuel savings can be achieved with this campaign. On the other hand, tires with low rolling resistance are inherently more fuel-efficient, and properly inflated low rolling resistance tires benefit from both strategies.

3.6 Interactions Between Rolling Resistance and Other Tire Performance Characteristics

With the recent availability of independent test laboratory data regarding rolling resistance, it is now possible to make initial comparisons among tire models and provide initial correlations between rolling resistance and other tire characteristics. We specifically examined traction, tread wear, tire prices, and overall customer satisfaction in the context of rolling resistance. Of the 43 models submitted for rolling resistance testing under SAE J1269, most had other publicly available data with which to correlate, from the sources identified in section 2.2 above (see Appendix B for details regarding methodology for converting published data to quantitative rankings).

Figure 5 - Traction vs. Rolling Resistance

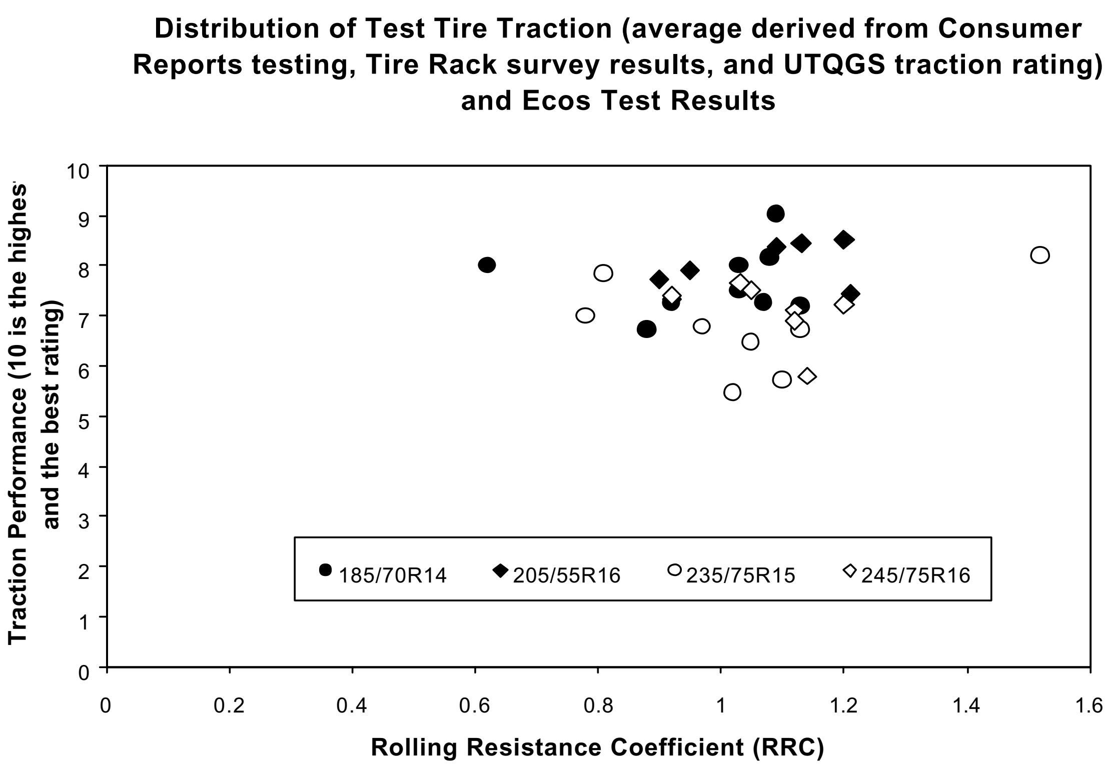

Figure 5 illustrates the distribution of traction scores achieved by the various tires Ecos Consulting has submitted for testing. The most fuel-efficient tire tested had a rolling resistance coefficient of 0.62 – about 60% less than the least fuel-efficient tire tested. The outlying data points are perhaps less instructive than the mass of data in the middle of the chart. Note that the majority of the tires achieved a rolling resistance coefficient between 0.9 and 1.2, with widely dispersed traction scores and no clear trend that would indicate a strong correlation between rolling resistance and traction.

Figure 6 - Tread Wear vs. Rolling Resistance

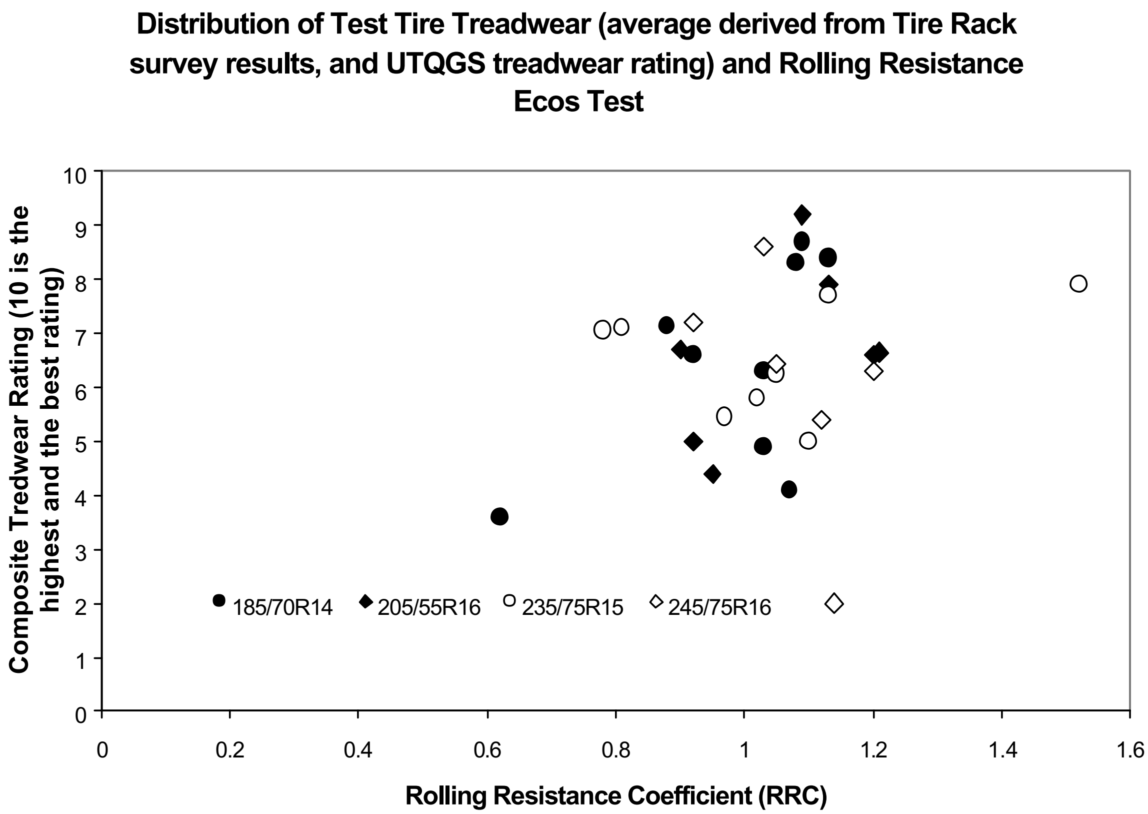

Figure 6 plots the same tire rolling resistance coefficients against composite ratings of tread wear. Again, the outlying data points are less interesting than the bulk of the data falling between an RRC of 0.9 and 1.2. Note a wide range of tread wear ratings both by tire size and by RRC. The tire that has been highly optimized for low rolling resistance exhibits a low tread wear rating, but the next three highest scoring tires all deliver above average tread wear performance. This comparison shows that there is no significant relationships between tire tread wear rating and its rolling resistance characteristics.

While there is some evidence that OEM tires can frequently have shorter lifetimes than replacement tires, this is more likely due to the fact that tires are not covered by car manufacturer warranties (and therefore bring with them little incentive for longevity) than due to some unavoidable aspect of LRR design. If, for example, one straightforward means of reducing rolling resistance is to produce a lighter weight, thinner tire, it is also the case that other means of doing so are available, and rely in large part on material *substitution* instead.

Even if it were the case that low rolling resistance tires exhibited on average shorter lifetimes than typical tires, it is important to remember that the energy consumed over the lifetime of a tire greatly exceeds the energy required to manufacture it. Pirelli found, for example, that about 94.6% of the energy consumption for which a tire is responsible occurs during its use, compared to 1.1% in the production process and 4.3% in the raw material production process.[24] Thus, even if there were lifetime tradeoffs, the energy benefits would, on net, likely be positive.

Figure 7 – Tire Price vs. Rolling Resistance

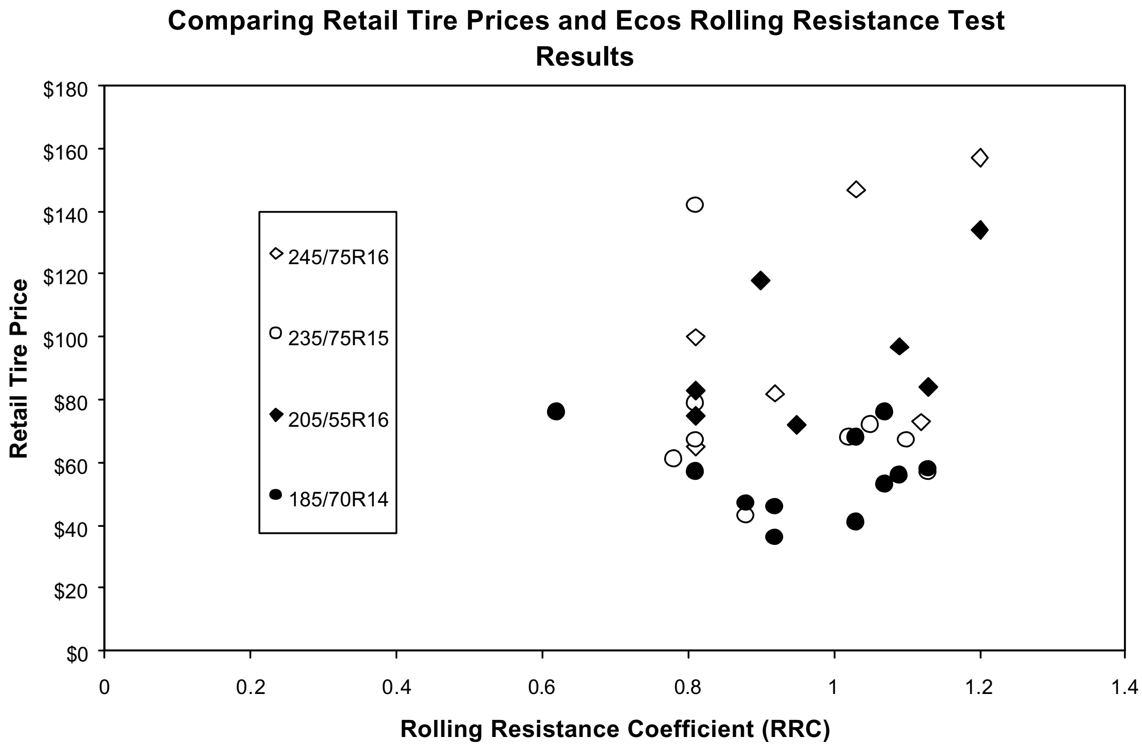

Figure 7 also shows an exceptionally wide range of price data, both across the four sizes in which tires were tested and within each size. Note that larger tire sizes tend to be more expensive, but that LRR tires were, if anything, somewhat less expensive than high rolling resistance models. The most expensive tire in the test group also has the highest rolling resistance, while the tires with the lowest rolling resistance in the test group are generally close to the average price for the group.

A final useful benchmark is to correlate tire rolling resistance with overall consumer satisfaction or desirability of a particular model, at least as subjectively evaluated by Consumer Reports and Tire Rack.com customers.

[24] See "The results of Life Cycle Assessment" under "Production and Quantitative Data" at www.pirelli.com.

Figure 8 – Overall Tire Satisfaction vs. Rolling Resistance

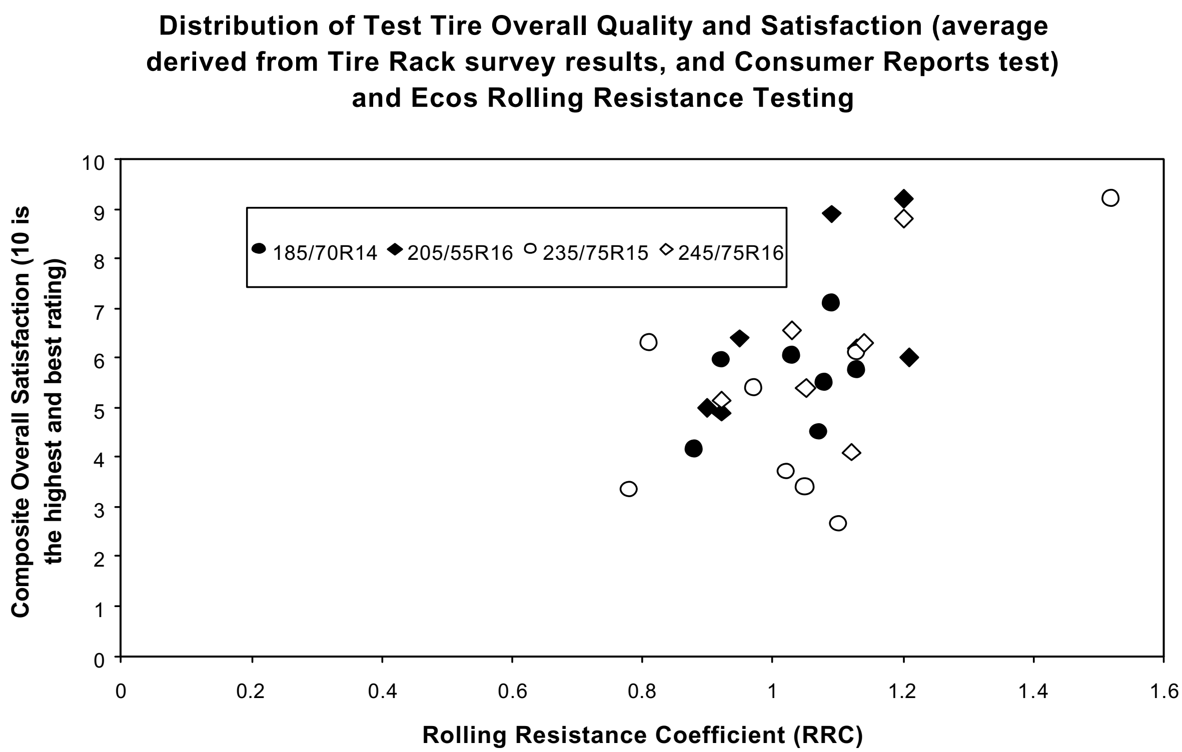

Figure 8 compares consumer satisfaction against tire rolling resistance data. As can be seen in this chart, the rolling resistance of a tire does not significantly affect the satisfaction level of consumers. There are a small number of tires with high rolling resistance in the sample that also registered very high with consumers, as well as a number of tires with low rolling resistance that scored well. As with the other charts, the mass of data clustered in the middle is more instructive than the extremes.

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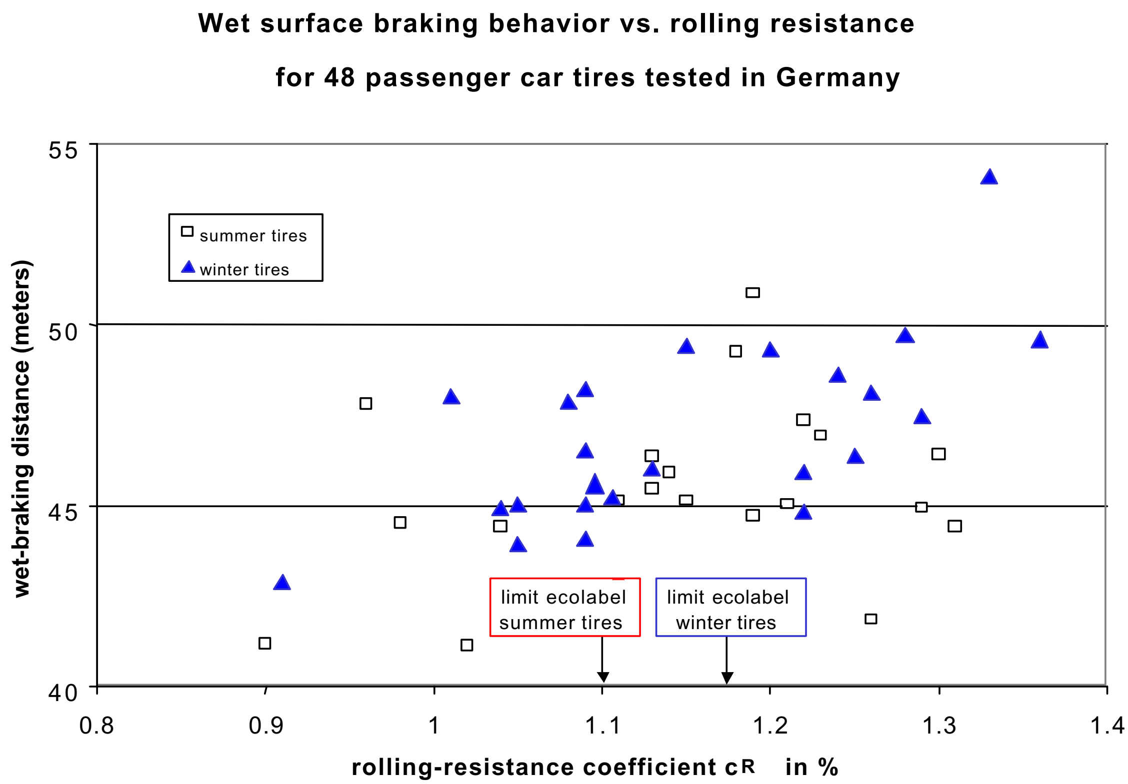
Figure 9 – German Findings Regarding Rolling Resistance and Wet Braking Distance



Finally, we include for consideration correlations already developed by the German government between measured rolling resistance and various aspects of tire performance.

Note in Figure 9 the range of braking distances observed for the 48 summer and winter tires tested. Tires that passed their rolling resistance criteria tended to achieve similar braking distances (shorter is better) to ones that did not. The Germans established separately allowed rolling resistance maximums for both summer and winter tires, confident from the data below that this would not impede the ability of consumers to purchase tires that would stop quickly in wet road conditions.

Figure 10 - Tire Efficiency and Noise Criteria Used in the German Labeling Program

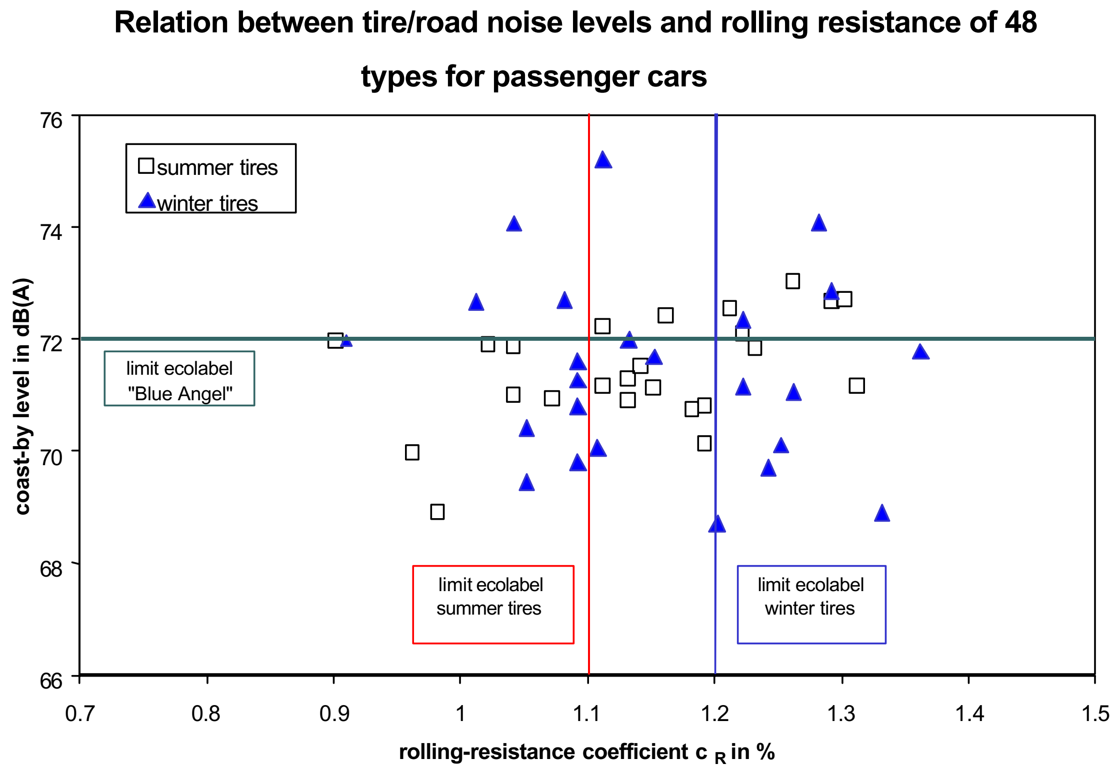


Figure 10 compares measured relationships between tire rolling resistance and noise. Again, in this case, the Germans found that they were able to achieve the desired reductions in road noise without limiting substantially their ability to also encourage greater sales of low rolling resistance tires. Note that tires with a rolling resistance less than (to the left of) the two cutoff lines marked were eligible for the Blue Angel label, if they also fell below the noise threshold.
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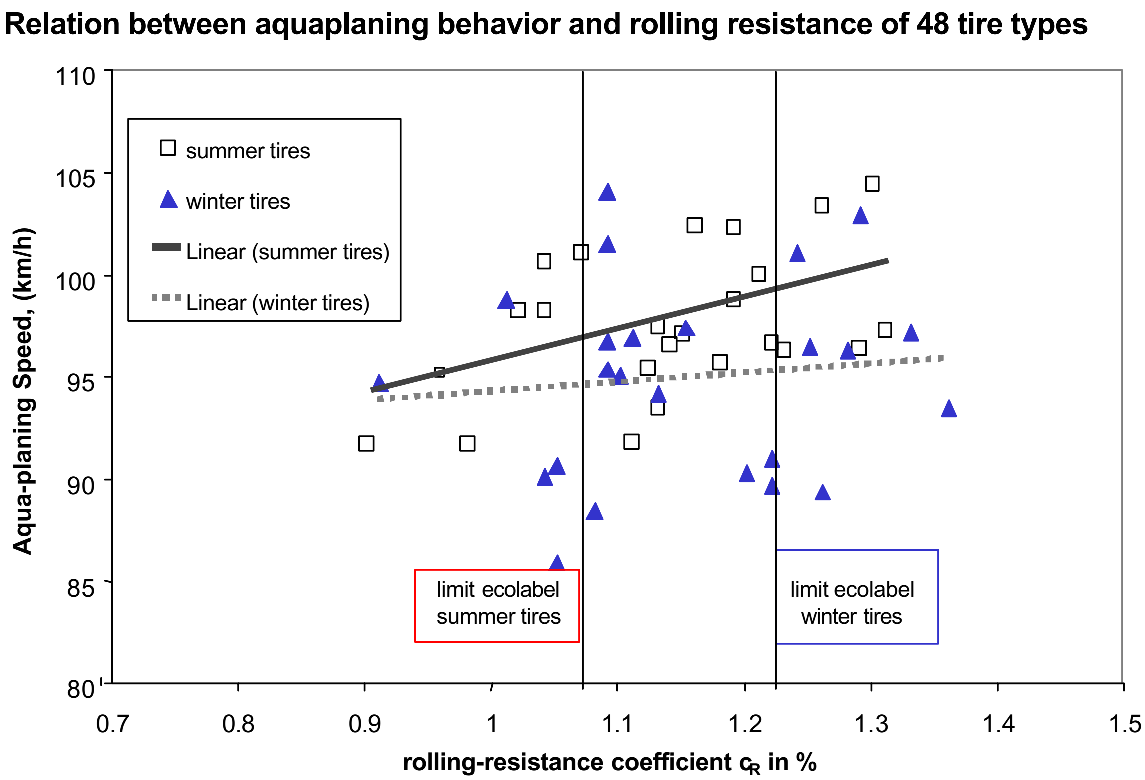
Figure 11 – German Findings Regarding Rolling Resistance and Aquaplaning on Passenger Cars



Finally, we examine in Figure 11 German findings comparing rolling resistance to the speed at which tires began to aquaplane in testing. In this case, higher speeds indicate superior performance. As the linear regression lines on the chart indicate, LRR tires tended to perform slightly worse than standard tires with regard to aquaplaning, but differences in design still accounted for much greater variations in aquaplaning than differences in rolling resistance.

4. Policy Options

Tire manufacturers consider many factors when designing new tires or making modifications to existing products. These considerations include, product safety, performance, manufacturing considerations, government regulations, and environmental benefits.[25] High-efficiency tires exist that produce fuel savings in excess of their incremental cost, yet these tires are not widely manufactured for, and marketed to, the U.S. replacement tire market.[26]

Other factors – brand recognition, price, traction, longevity, and speed ratings – have long taken precedence over low rolling resistance in the replacement tire market. Energy efficiency is not a specific design priority for most replacement tires in part because no means of systematically and quantitatively highlighting those benefits to consumers has yet been created, either by industry or government. Herein lies a market failure that SB 1170 is trying to address and that this section explores.

It is helpful to begin such a process by considering the differences between original equipment (OE) tires and replacement models. By contrast to the situation described above, OE tires are frequently marketed to automakers on the basis of their rolling resistance. Automakers provide explicit rolling resistance design parameters to their tire suppliers, using improved tire technology as a key strategy for achieving particular CAFE levels per model and, in turn, across the range of new vehicles they sell.[27] They specify one or more standardized test methods for measuring rolling resistance, conduct round robin testing of reference tires to adjust for lab-specific variations in reported results, and often specify the use of a particular independent laboratory for final data submissions. All of these actions together stimulate continued innovation by tire manufacturers in reducing rolling resistance.

California policymakers are just becoming aware of the need to hasten the wide-scale commercial availability of fuel-efficient tires. SB 1170 urges consideration of a number of policy options to reduce gasoline consumption by increasing the utilization of more fuel-efficient tires by state-owned vehicles and by Californians. Numerous policy options merit consideration to correct this situation, including consumer outreach, incentive programs, and mandatory standards. Successful implementation of a future tire efficiency program in California could increase the likelihood of creating a new market for fuel-efficient tires and the potential for other states to follow suit.

There are several reasons why tire markets fail to promote fuel efficiency. The U.S. tire industry does not utilize a consistent means of measuring tire rolling resistance. Consequently, consumers do not have a basis for verifying the accuracy of particular fuel efficiency claims. Many consumers never realize that the type of tires they purchase has an impact on their gasoline use. Even those who fundamentally understand the relationship between rolling resistance and fuel economy are unable to make an informed purchase decision without reliable data comparing the relative rolling resistance of different tire models. Further, low gasoline

[25] Rubber Manufacturers Association (RMA) correspondence to CEC dated November 4, 2002.
[26] NAS report on fuel economy, 2001 and Ecos calculations in Section 3.3 of this Report.
[27] See, for example, Appendix 2-1 in the rolling resistance comments provided by Michelin to NHTSA in 1995: "Rolling Resistance Coefficient for Twenty -Five 1995 Vehicles with Volumes Delivered and Forecasted by Michelin." The RRC specifications in kg/T range from 6.9 to 11.4, with a simple average of 9.2 and a sales -weighted average of 8.4. By contrast, the 37 replacement tires listed in Figure 2 of Hermann's 7/28/95 comment letter to NHTSA exhibited a range of RRCs from 8.7 to 13.4, with an average (not sales-weighted) of 11.2. This implies an average difference in rolling resistance between OE and replacement tires in 1995 of roughly 22 to 33%.

prices have not motivated most consumers to demand rolling resistance tires in order to save fuel.

The policies examined in this chapter are intended less to compel a reduction in gasoline consumption and more to foster a competitive marketplace that enables customers to save gasoline more cheaply than it can be purchased. In the specific context of tires, that means establishing the guidelines and "rules" within which an open competition can begin to provide the long lasting, high performance, safe, environmentally benign, and highly fuel-efficient replacement tires at the lowest price.

After examining materials presented during federal investigations of tire rolling resistance in 1994-95 and a recent public workshops hosted by the CEC, we believe there are three key dynamics in the current tire marketplace that must be understood to craft sensible public policies:

1. Having recently experienced an unusually high level of federal government scrutiny (leading to regulations in the Tread Act) as a result of the tire-related safety problems associated with the Ford Explorer and its tires, the tire industry is especially sensitive at present to new regulatory proposals. The State of California clearly shares the federal government's interest in promoting and encouraging safety. Its efforts to promote greater tire fuel efficiency, like NHTSAs in 1994-95, have met with opposition from the tire industry.

2. Manufacturers possess different degrees of technology and expertise regarding the development of low rolling resistance capability, so vary in their level of interest in government efforts to promote low rolling resistance.

3. Most tire manufacturers already compete to provide low rolling resistance capabilities along with other aspects of tire performance in the OEM models they sell to new vehicle manufacturers. As a result, the aim of California policy should be to build the kind of marketplace conditions in the replacement tire market that would stimulate an equally vigorous competitive response by manufacturers in that market. Even if such an outcome were to be opposed by the trade association representing the industry as a whole (RMA), it may still provide competitive advantages and new market opportunities to individual manufacturers with the greatest capabilities and desire to deliver these improved products.

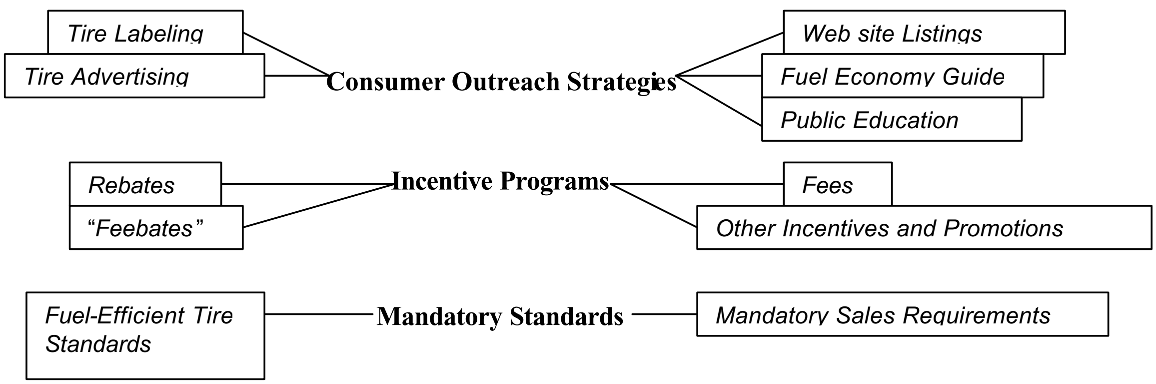
The greatest single barrier at present to establishing a thriving, competitive marketplace for LRR replacement tires is the absence of readily available, consistently measured data on rolling resistance. Missing information is a common market barrier that has hampered sales of efficient products in a wide array of other consumer product types, including cars themselves, lighting, ceiling fans, appliances, homes, office equipment, consumer electronics, etc. In each case, manufacturers would occasionally make an energy efficiency claim about an individual product that could not be readily compared to other such claims or independently validated by a neutral third party, leading consumers to give it very little credence. Coupled with cheap energy prices, consumers have little motivation to clamor for better information and products.

But the subsequent establishment of federal or state regulations, voluntary labeling programs, or other third party information programs employing a common test procedure and efficiency specification have historically broken the logjam. Such efforts lead to widespread measurement of efficiency and dissemination of that information to an increasingly interested marketplace of buyers, who in turn began purchasing the more efficient products and steadily improving the average efficiency of products sold.

While manufacturers might elect to pursue such a process on their own, the effect of an external impetus has been to push the process toward a clearly defined objective, on an accelerated timetable, and with some independent credibility imbued to the resulting data. Thus, California's efforts to establish a common test method for measuring tire rolling resistance, minimize the variations associated with multiple labs conducting such tests, and disseminate the findings in a consistent, readily understood fashion can only help to better equip consumers to make informed purchase decisions.

In this section, the policy approaches specified in SB 1170 are detailed and evaluated (See Figure 12). These policies are not mutually exclusive and may be most effective when used in combination.

Figure 12 - Policies Outlined in SB 1170



SB 1170 specifically required CEC to make recommendations by 1/31/02 on the following policy areas:

- Consumer tire fuel efficiency rating system
- Other consumer education approaches
- Mandatory standards for tire efficiency in California
- Incentive programs to encourage the purchase of more fuel-efficient tires

4.1 Consumer Tire Fuel-Efficiency Rating System

4.1.1 Tire Labeling

Labeling products themselves is an effective way of educating consumers at the point of purchase. Given that California would be initiating a program covering only a portion of the country, it would initially make more sense to label showroom models of tires with dealer-applied stickers than require manufacturers to modify their molds to imprint that information in all tires they sell nationally. These labels can be used to alert consumers about the energy trade-offs between different models of comparable products. They also simplify complex computations for consumers relating to lifetime energy savings, making it more manageable for individuals to assess the benefits and costs of purchasing a more fuel efficient tire model.

One approach could be something akin to *EnergyGuide* labels. The US DOT has experience using *EnergyGuide* stickers on new appliance in showrooms for three decades.[28] The U.S. government established a mandatory compliance program in the 1970s requiring that certain types of new appliances bear a label to help consumers compare the energy efficiency among similar products. In 1980, the Federal Trade Commission's Appliance Labeling Rule became effective, and requires that *EnergyGuide* labels be placed on all new refrigerators, freezers, water heaters, dishwashers, clothes washers, room air conditioners, heat pumps, furnaces, and boilers.[29] Although these labels do not convey which appliance is the most efficient, they do tell the annual energy consumption and operating cost for each appliance so consumers can compare them side-by-side.

EnergyGuide labels show the estimated yearly electricity consumption to operate the product along with a scale for comparison among similar products. The comparison scale shows the least and most energy used by comparable models. The labeled model is represented by an arrow pointing to its relative position on that scale. This allows consumers to compare the labeled model with other similar models. The consumption figure printed on *EnergyGuide* labels, in kilowatt-hours (kWh), is based on average usage assumptions and consumers' actual energy consumption may vary depending on their appliance usage. It may be possible for the *EnergyGuide* Label to be at least partially adapted for tires.[30]

Figure 13 – Various Energy Efficiency Labels in Use Around the World[31]

[28] US Department of Energy, Office of Codes and Standards, Energy Efficient Appliances, http://www.eren.doe.gov/buildings/consumer_information/energyguide.html (Information retrieved on October 29, 2002).
[29] EnergyGuide labels are not currently required on kitchen ranges, microwave ovens, clothes dryers, on-demand water heaters, portable space heaters, and lights.
[30] In order to convey meaningful information on a sticker or label, the CEC may have to take into account the UTQGS, which is the federal tire quality grading system (treadwear, traction, and temperature tolerance), and how this system relates to fuel efficiency.
[31] International Energy Agency, *Energy Labels and Standards*, 2000, p. 17.

After extensive market research by the International Energy Agency, the American Council for an Energy Efficient Economy, and other organizations around the world, it has become clear that other forms of efficiency labeling offer distinct advantages over the current *EnergyGuide* label.[32] The California Energy Commission's Appliance Energy Group found that consumers got confused about the number posted on the Energy Guide labels.[33] Evidently, consumers assumed that the higher the number the better the product. But, in fact, the higher the number, the more energy it uses.

Other approaches, like the US EPA/DOE Energy Star label and Europe's Group for Efficient Appliances (GEA) label, can simply help consumers select a product whose efficiency is better than average. Unfortunately, these binary labels lack context. With some products, such as computer monitors, Energy Star currently recognizes perhaps 80 to 90% of the available models. For other end uses, the label may only appear on the most efficient 15 to 25% of available products. So the comparison shopper hopefully learns that an Energy Star-labeled product is likely to be at least somewhat more energy efficient than a typical product, but often has no information about the efficiency of products without an Energy Star.

IEA research suggests that simple, comparative labels employing one to six stars or a range of letter grades (like the Australian and European Union examples shown in Figure 13) are the most effective of all. They provide useful comparative information without the complexity or confusing visual content of the *EnergyGuide* label. They succeed not just by clearly identifying the most efficient products, but also by calling attention to the least efficient products. Faced with the prospect of having some of their products bear one star in Australia or a "G" rating in Europe, manufacturers worked very hard to improve the design of those products.

4.1.2 Printed Fuel Economy Guide Booklets Featuring Efficient Tire Options

The US Department of Energy and US Environmental Protection Agency have a 25-year track record publishing annual *Fuel Economy Guides* that provide relatively technical, yet accessible, information on new vehicle fuel economy.[34] The Guide is available online and, by request, in automobile showrooms. In its introduction, the *Fuel Economy Guide* discusses "Tips for Improving Fuel Economy." This could include a new section on explaining the benefits associated with purchasing fuel efficient replacement tires and referencing the CEC's web site for this program.

Moreover, either as a new booklet or a supplement to the existing Fuel Economy Guide, the CEC (possibly in conjunction with the US DOE and US EPA) could produce a booklet that focuses solely on fuel-efficient tires, providing fuel efficiency data on all replacement tires in the market. If this proves too unwieldy, given that each tire has its unique operating characteristics when paired with an individual car/SUV make and model, this new booklet could publish the best-in-class tire options for each vehicle make and model. This booklet could be updated and published annually, as a companion to the *Fuel Economy Guide*. These Fuel Economy Tire Guide booklets could be distributed through a wide array of outlets, including new auto dealers (as part of new car maintenance guide booklets); used automotive dealers; gasoline service stations; tire retailers; Bureau of Automotive Repair (possibly as part of Smog Check programs);

[32] International Energy Agency, *Energy Labels and Standards*, 2000, pp. 87-115.
[33] Communication with Scott Mathews, Division Chief, California Energy Commission Energy Efficiency Division, December 13, 2002.
[34] US Department of Energy and US Environmental Protection Agency, "Fuel Economy Guide," Annual Releases, www.fueleconomy.gov (Information retrieved on October 29, 2002).

Department of Motor Vehicles; High-school driver education courses; and private driver education schools.

4.2 Consumer Outreach and Public Education

SB 1170 specifies that the Energy Commission develops recommendations for state policymakers that include a "consumer-friendly system to disseminate tire fuel-efficiency information as broadly as possible." The components of such a consumer information and education system include information disseminated in three formats: (1) web site listings, (2) pamphlet guide books that are widely distributed, and (3) labels on tires. Each of these consumer outreach options is discussed below.

4.2.1. Web site Listings

The Internet has emerged as a very powerful tool for providing comparative product information to consumers. This consumer outreach mode is geared toward individuals who already possess enough information and computer literacy to enable further inquiry. This is an *active* means of educating oneself and obtaining more in-depth information. In other words, the onus is on the consumer to access the Internet through a computer and search for information, programs, and ideas relating to their query.

Web sites are not all equally effective. Studies evaluating web site effectiveness have identified ten criteria that determine the success of the web as an information tool. These include: (1) first impressions; (2) ease of navigation; (3) content; (4) attractors; (5) findability; (6) making contact; (7) browser compatibility; (8) knowledge of users; (9) user satisfaction; and (10) other useful information. Appendix B provides a checklist of criteria helpful in evaluating web site effectiveness. These criteria will help in designing a future web site for CEC's tire program.

Attracting and educating online customers ("surfers") is a fundamental part of having an effective web site. An estimated 47 percent of all web site referrals come from direct navigation (typing the URL directly into the navigation bar).[35] Therefore, the site's URL should be strategically selected, viewed as an outreach tool, and printed on all relevant CEC literature.

Straightforward information will be needed on this web site to set the stage for consumers and ultimately provide them with better tire options. As such, a successful tire web site created by the CEC should aim to convey the following:

- Magnitude of the state's petroleum dependence and the ways it impacts the state's economy
- Links between fuel efficiency, tire rolling resistance, California's energy resources and economics
- Consumer benefits (financial and environmental) when choosing more fuel efficient replacement tires, stated quantitatively and explained visually.
- Aggregate information of statewide benefits if consumers collectively use fuel efficient tires

The most promising means of quantifying these benefits would be to work with NREL to adapt or reference its ADVISOR model to make real-time calculations. The model possesses the ability to calculate the rolling force required on a particular test cycle with a particular vehicle

[35] Management Centre International Limited, "Search Engines and Directories," based on a survey by StatMarketRatings on April 3, 2000, www.mcil.co.uk/7-search-engine-directories.htm

using particular tires. Thus it would be possible for a web site to estimate impacts for the purchase decision a particular customer faces, rather than simply provide ranges of likely benefits or average impacts. These estimates could be verified and revised over time, as new data become available on the real-world impacts of using low rolling resistance tires under particular road surface, weather, and traffic conditions.

The CEC has the choice of including information on its Efficient Tire Program on its existing web site or designing a new devoted linked web site for efficient tires. Currently the new CEC web site, www.consumerenergycenter.org, provides consumer tips on residential, transportation, and renewable energy choices. This web site is broad and has recently added information on high-efficiency cars and the state rebates available for hybrid and high-efficiency vehicles. This URL location may be the best option, as long as the breadth and size of the web site do not pose limitations.

It will also be important to link the CEC efficient tire web site, along with its ability for consumers to perform tire computations, to numerous other existing web sites (U.S. and international) dealing with facets of this issue. The first priority is to investigate links with existing governmental agencies working on any aspects of this issue. Linkages will enhance the CEC web site "findability" and overall effectiveness. A few relevant web sites that are good candidates for linkages are presented below.

- Green Seal Web site (www.greenseal.org): Green Seal is an independent, non-profit organization that identifies and promotes products and services that cause less toxic pollution and waste, conserve resources and habitats, and minimize global warming and ozone depletion. It was initiated in the US 13 years ago, patterned after similar ecolabeling programs in Germany and Canada. Green Seal's goal is to direct consumers to environmentally responsible products and services. Green Seal works with manufacturers, industry sectors, purchasing groups, and governments to "green" the production and purchasing chain. Among the tools Green Seal uses are: product certification, purchasing guidance (product recommendations), evaluations of products and purchasing, and policy recommendations. Thus, purchasers may use Green Seal's assistance in a variety of forms – certified or recommended products, manuals on best practices and product criteria, environmental specifications and standards for products, and evaluations of specific cases or situations. Green Seal is already planning to publish a printed guide regarding low rolling resistance tires, but would benefit greatly from linking that information to more specific, continually updated online content.

- Retail Tire Web sites: Many retailers either provide printed materials or on-line comparisons to allow customers to select tires across a range of desired criteria. Online retailers like discounttiredirect.com, onlinetires.com, tirerack.com, and etires.com represent particularly promising linking opportunities. They often cater to those interested in researching particular aspects of tire performance and comparing prices across a range of brands. In some cases, they gather additional survey data from their customers and conduct test track comparisons of their own. These web sites could greatly expand the reach of state data by providing relevant information to those most interested in making a tire purchase at the time it is most useful to them.

- Consumer Reports (www.consumerreports.org): This publication has conducted numerous comparisons of tire performance characteristics, which in some cases has included coast down testing as a proxy for rolling resistance. It might find systematically measured laboratory data more useful and be willing to link to such information or republish it within its online and printed product comparisons.

- Other web links to relevant sites (retail, manufacturer, government – federal and state, and advocacy groups): There are numerous existing private and public sector web site links that could help achieve the information dissemination goals of SB 1170.

Table 4 – Potential Tire Information Sources for Linking to CEC Tires Content

Market Sector	Organization	Web Address (URL)
Industry	Rubber Manufacturers Association	www.rma.org
	Michelin	www.michelin.com
	Honda	www.honda.com
	Toyota	www.toyota.com
	Ford Motor Company	www.ford.com/en/ourCompany environmentalInitiatives/envirodrive.htm
	Online Tire retailers	discounttiredirect.com, onlinetires.com, tirerack.com, etires.com
	Page Wise Auto Repair	www.essortment.com/in/Automotive.Repair
	Various other Tire/Auto Businesses	www.google.com for URLs of other firms
Federal Government	US EPA	www.epa.gov
	US DOE	www.fueleconomy.gov ; www.energy.gov ; www.energystar.gov
	National Renewable Energy Laboratory	www.nrel.gov
	National Highway Traffic Safety Admin.	www.nhtsa.dot.gov/cars
	Federal Trade Commission	http://www.ftc.gov/bcp/conline/pubs/alerts/fuelalrt.pdf
State Government	California	CA Air Resources Board: www.arb.ca.gov Cal EPA: www.calepa.ca.gov CA Integrated Waste Management Board: www.ciwmb.ca.gov CA Dept. of Motor Vehicles: www.dmv.ca.gov CA Dept of Transportation: www.dot.ca.gov CA Department of Consumer Affairs: http://www.dca.ca.gov/assist_guid_eng_0701.pdf
	Florida	www.fsec.ucf.edu/pubs/EnergyNotes/en-19.htm
	Ohio	www.epa.state.oh.us/opp/consumer/carp2.html
	Maryland	www.mde.state.md.us/was/recycle/factsheets/recycautoproducts.htm
	Iowa	http://www.energy.iastate.edu/newupdated/pressrelease/CarTips.htm
	New York	www.nyserda.org
International Government	Canada	Natural Resources Canada, Office of Energy Efficiency: www.oee.nrcan.gc.ca
Non Profit Organizations	Natural Resources Defense Council	www.nrdc.org
	Consumers Union	www.consumerreports.org
	Energy Foundation	www.ef.org
	ED & ACEEE	www.greenadviser.org/focus.cfm?focus=1
	Union of Concerned Scientists	www.ucsusa.org
	Public Citizen	www.citizen.org
	MPG Plus	www.mpgplus.org/importance/importance.html
	Frugality Network	www.frugalitynetwork.com/automobiles.html

Source: All URLs downloaded on 10/28/02.

Examples of these sites are listed in Table 4, above.[36] Other pertinent online information sources are thought to exist and new websites are likely to result from California's future fuel efficient tire program. If organizations are willing to provide information on fuel efficient tires and allow links to the CEC tires web site, additional consumers could obtain information about fuel and cash savings before they purchase replacement tires.

4.2.2. Tire Advertising

Tires are highly advertised commodities – primarily by manufacturers seeking to establish brand prominence, and secondarily by retailers and installers promoting sale prices and service opportunities. A typical car can require replacement tires two or more times over its 120,000 mile lifetime due to wear and tear and damage.

Advertising in print, radio, and TV media can be a more passive means of consumer outreach than the Internet, but is certainly larger in scale and more familiar to many buyers. Energy efficiency messages are largely absent from such outreach currently, but could be included in targeted ways, as opportunities become available. Advertisers of energy efficient appliances, for example, routinely promote the opportunity to upgrade or replace an existing product as a means of saving energy. In the case of tires, replacement before the existing product has failed provides opportunities to improve safety and handling as well.

As soon as this information is made available by the CEC in their Efficient Tire Program, this information should be advertised widely by a host of methods. These can include: (1) promoting CEC tire web site at tire retail outfits using banners, written materials with tire sales, and other advertising materials; (2) placing placards on showroom floors alerting consumers about efficient tires and their benefits; and (3) conducting public service announcements in the media on efficient tires and their energy reduction and consumers' cost savings.

The manufacturers and retailers of the most fuel-efficient tires may have an incentive to advertise these new product offerings. However, the CEC may need to supplement their advertising with consumer outreach suggested above.

4.3. Other Consumer Education Approaches

Beyond influencing tire purchase decisions, education can also influence motorists to maintain tire pressure at recommended levels. Existing tire pressure education efforts are already underway with the support of manufacturers and the federal government, so the opportunity for the state to have additional impact is unclear.

There is also preliminary evidence that all-season tires may not perform as efficiently or effectively as differently designed tires for summer and winter driving. If the German data now being collected reveal significant benefits in terms of rolling resistance, performance, and traction, the CEC may wish to promote seasonal tire switching through consumer education. Before all-season tires were introduced into the market several decades ago, switching tires each season was a more common motorist practice. Today such switching is less common, especially in more temperate California areas. The cost-effectiveness of this option merits further examination. The cost of owning two different sets of tires (and potentially two different

[36] These entities are included because they are good examples of existing tire of fuel efficiency information. The many missing organizations that sell or regulate tires merit further examination for linkage with CEC's future Efficient Tire web site.

sets of rims), labor to change tires twice a year, and the storage space to keep the off-season tires would have to be weighed against the consumers' resulting fuel savings.

4.4. Mandatory Standards

SB 1170 specifies that recommendations be developed for a mandatory rolling resistance standard for all aftermarket tires sold in California. If a market for low rolling resistance tires is not created based on energy and fuel cost savings alone, and informational policies do not deliver desired results, mandatory standards may be a more feasible way to reduce gasoline consumption from LRR tires. Standards could be useful if it turns out that the information on LRR tires is either not forthcoming, highly complex, or too small of a component of the larger vehicle system (similar to the electronic ballasts used to power fluorescent light fixtures).

4.4.1. Fuel-Efficient Tire Standards

There is a precedent for efficiency standards in California. Energy efficiency standards for appliances and other equipment have been one of the major policies used by governments, first in California thirty years ago, then in other states, and finally at the federal level, to reduce energy use and consumer energy bills. Appliance and equipment efficiency standards, for example, set minimum efficiency requirements for newly manufactured appliances and other energy-consuming products. The standards prohibit the production, import, or sale of products less efficient than the minimum requirements. Rolling resistance standards could be viewed as an extension of this idea to another sector – automotive tires. If the CEC is found to lack the statutory authority currently to pursue mandatory standards for tires, clear legislative guidance would need to be adopted and passed to convey this authority.

Specifically, a rolling resistance or fuel efficiency rating could be required for all replacement tires sold in the State that prohibits the production, import, or sale of less-efficient tires. Such a standard presents the simplest design that is most easily enforced. Another option is an average standard, like Corporate Average Fuel Economy Standards (CAFE) which would allow for a wide variety of fuel-efficiency tires (high and low) to be sold, but sets an average efficiency for each manufacturer to meet. This standard requires ongoing computations, verifications, and penalties to achieve its goal. It may also be rather complicated, since a particular tire's rolling resistance can only be translated into a particular fuel savings impact by knowing which vehicle it will be used with. Average standards are more complex overall, but permit more product differentiation to sell tires that do not all maximize energy efficiency. This mandate design may be necessary if it is found out that there are trade-offs between tire fuel efficiency and other tire characteristics. As such, by not forcing all tires to meet a minimum efficiency level, tires with different attributes could be available on the market while average efficiency goals were met.

4.4.2. Mandatory Sales Requirements

Another way to approach standards is to set known deadlines for introduction of these new tires at particular sales levels, with standards triggered by a failure to meet those deadlines. For example, such a standard could require 25 percent of all tires sold at a future date to be 40 percent more efficient than today's average tire. The Zero-Emission Vehicle Standards (ZEV) were initially constructed as this type of mandate and have succeeded in spurring advanced vehicle technologies that may never have made it to market without such a mandatory marketing requirement. This approach can help advance tire technology in the absence of detailed efficiency data upfront. Marketing goals can be set that require tire makers to voluntarily provide accurate data, and if sales requirements are not met, then penalties, prohibitions, or product standards could kick in.

4.5. Incentive Programs

SB 1170 specifies that the California Energy Commission develops recommendations for state policymakers that include "consumer incentive programs to offer a rebate to purchasers of replacement tires that are more fuel efficient than the average replacement tire." The various forms of such incentive program are detailed below. Four options are discussed: (1) rebates, (2) fees, (3) "feebates", and (4) other promotional incentive programs.

Energy-efficient product rebates have a long history in California of spurring energy-efficiency markets and reducing demand in the electricity sector. Public utilities offer rebates for a host of highly efficient products, ranging from insulation to windows to residential lighting products.[37] More recently, in light of California's electricity crisis, the state has provided appliance rebates as well.[38,39] The pricing and design of these rebates have been tested on the California market.

System benefit charges (SBC's) are collected from utility bills in California and many other states to fund the cost of such rebate programs. No comparable mechanism exists within the transportation sector at present, though policies have been proposed in the past in which gasoline taxes, vehicle registration fees, and other sources of car-related revenue could be earmarked for investment in demand reduction programs. In the case of the "feebates" option discussed below, the incentives would be self-financing.

The incentive level selected depends on the price differential between efficient and inefficient tires, the price elasticity of demand for tires (in the short and long run), and the energy-saving goals established by policymakers. If incentive levels are set too low, the are unlikely to have an effect and if they are set too high, they are likely to meet with public and/or political resistance.

4.5.1. Rebates

When the price of a good is reduced, more consumers demand it. Whether it is a $0.50 coupon on a $3.50 box of breakfast cereal, a $50 rebate on a $350 dishwasher, or a $1,500 rebate on a $20,000 car, financial incentives can have the effect of increasing demand for a product. Rebates are commonly set in the range of 5-15 percent of the product's cost, though they have been much higher in particular instances where utilities were interested in capturing energy savings rapidly.[40]

To predict consumer behavior, economists use well-defined techniques evaluating the sensitivity of consumers to changes in price. The most commonly used measure of consumers' sensitivity to price is known as the "price elasticity of demand." This is simply the proportionate change in demand given a change in price. For example, if a one-percent drop in price of a product produces a one-percent increase in demand for the product, the price elasticity of demand is said to be one. Hundreds of studies have been done over the years calculating long

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[37] California Public Utilities Commission, "Statewide Programs," http://www.cpuc.ca.gov/static/industry/electric/energy+efficiency/statewide.htm , downloaded on October 30, 2002.

[38] "State to Offer Appliance Rebates," In Business Journal, May 7, 2002, http://sanjose.bizjournals.com/sanjose/stories/2002/05/06/daily26.html , downloaded on October 30, 2002.

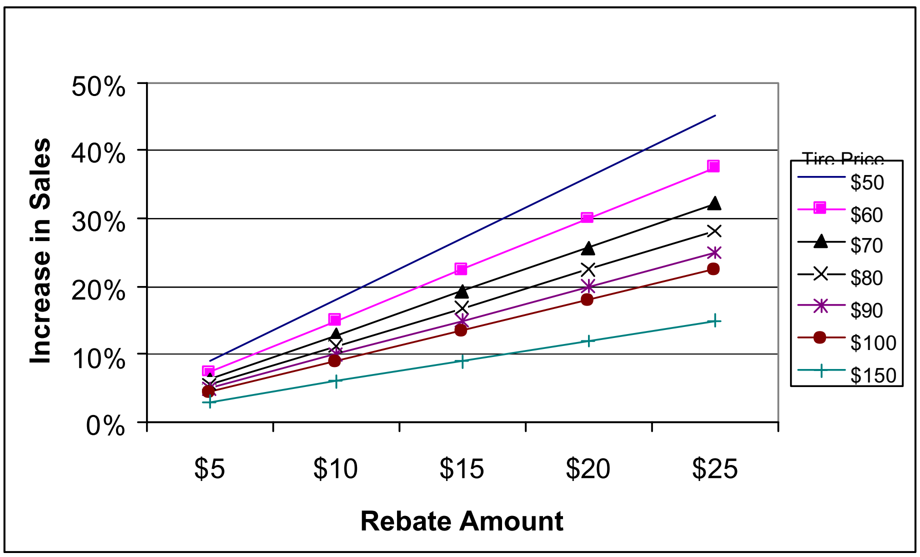
[39] California Energy Efficiency and Demand Reduction Program, http://www.energy.ca.gov/peakload/AB29x-SB5x_program_summary.html, downloaded October 30, 2002.

[40] Estimate made by Ecos based on experience implementing lighting and appliance efficiency programs.

run and short run price elasticities of demand. Accordingly, the estimated price elasticities of demand for automobile tires are 0.9 in the short-run and 1.2 in the long run.[41] These estimates are used to provide guidance on rebate levels.

Rebates cannot be modeled in the absence of complete data on energy performance, cost, and sales data on every tire in the market. However, sensitivity estimates are provided below to initiate a future dialogue on designing incentives to induce the sale of more energy-efficient tires. Figure 14 indicates the projected increase in sales for a variety of rebate levels, given the price of a specific tire. For example, if a $15 rebate were offered on a tire that costs $70, a 20 percent increase in sales would be anticipated. It is expected that rebates will achieve greater gains on lower-priced tires and on tires that are driven more miles over their lifetime.

Figure 14 - Projected Impacts of Rebates on Tire Sales



Source: Ecos Consulting calculations, November 7, 2002.

There are several different ways to structure an efficient tire rebate program.

- *Flat rebates for all fuel-efficient tires*: The simplest rebate to design and implement is a uniform rebate for all fuel-efficient tires above a given efficiency cut-off. This rebate makes the most sense if the majority of fuel-efficient tires are clustered around a single point. One downside of this rebate program design is that it will not spur innovation on high-efficiency tires that are well above average.

- *Variable rebates based on individual tire efficiency ratings*: Given the variety of tires on the market and their relative efficiency ratings, policymakers may want to construct a more targeted policy that rewards consumers more for purchasing the most efficient tires. These variable rebates could be based on a tire efficiency rating or as a relative measure compared to conventional tires. For example, if a tire were 10, 20 or 30 percent more efficient than the average tire, it would get a proportionately higher rebate.

[41] Mackinac Center for Public Policy, "Price Elasticity of Demand," November 13, 1997, www.mackinac.org/1247, downloaded October 24, 2002.

This policy design will tend to spur innovation in the efficient tire market by rewarding the most efficient tires with the largest rebates. Initial measurements of fuel-efficient tires estimate that there may be significant variations – as much as 3 mpg on particular car models – between the most and least efficient tires tested to date.[42]

- *Rebates can be set to cover the average price differential between less efficient and more efficient replacement tires*: As an alternative to using elasticity calculations to determine rebates, the average price differential between conventional and fuel-efficient tires could be used. This would mean that consumers would pay no more for efficient tires at the time of purchase and would recoup additional cost savings in the form of lower gasoline bills over the lifetime of their tires. Studies have found that consumers either do not have enough information to calculate the cost of conserved energy or apply a high discount to long-term savings. These factors make consumers resistant to pay more up-front for efficient products when they have to wait to recoup savings over time.

- *Funds to finance rebates can come from manufacturers, retailers, government agencies, and/or state budget*: Rebates require funds to finance them. Funds can come from the private or public sector. Tire manufacturers and retailers do, from time to time, offer rebates on their products. They also put them on sale temporarily below their market price to attract demand. Whether the industry chooses to offer rebates on efficient tires is entirely up to these businesses and may not achieve the energy saving goals set by the state for efficient tires. Depending on how prescriptive the state wants to be in terms of enhancing demand for these new products, it may not want to depend on the private sector alone to provide incentives. Policies that require the private sector to provide rebates are uncommon. However, private sector rebates could be triggered if other measures fail to create a market for LRR tires. Alternatively, the public sector could fund efficiency rebates, given their predominantly social goal. Funds could come from separate fees (discussed below) or general revenues.

4.5.2. Fees

Charging fees is one common way of addressing societal problems according to the "polluter pays principle." Fees can be used to fund rebates and provide funds for additional research on fuel-efficient tires (i.e., continued testing or verification of the efficiencies of new tire products). The Tire Recycling Fee currently in effect in California is collected from customers who purchase new tires from California retailers. Fee revenues are used by the California Integrated Waste Management Board for programs that provide alternatives to the landfill disposal of used tires. Sellers of new tires collect the fee from their customers for each new tire they sell. The current fee rate is $1.00 per tire.[43] The retailer pays the Board of Equalization, who deposits the fees in the California Tire Recycling Fee Management Fund (Three cents of the per-tire fee can be retained by tire retailers as reimbursement for their costs of collecting the fee.).

The Tire Recycling Fee could be expanded to include a new "Tire Efficiency Fee." Accordingly, policymakers could increase the fee already being collected at the point of sale of new tires. This would not require any additional implementation costs. The Board of Equalization could split these fees collected into two funds – the existing California Tire Recycling Fee Management Fund and a new "California Tire Efficiency Rebate Fund."

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[42] Based on Ken Kelly, National Renewable Energy Laboratory, Advisor Model and Ecos Consulting calculations, October 2002.

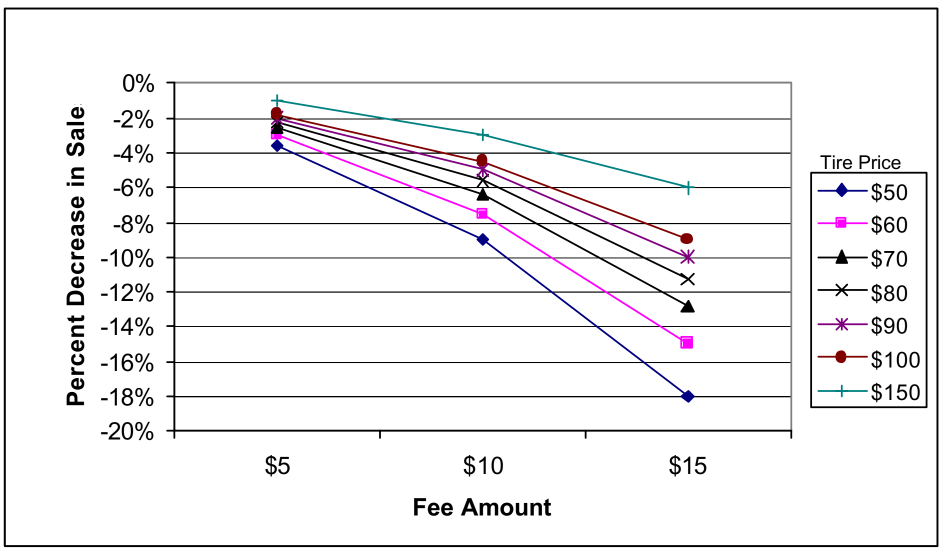
[43] State Board of Equalization, "Tire Recycling Fee," Publication 91 LDA, January 2001.

Depending on the materials used and other factors, LRR tires may or may not affect the recyclability of tires. If low rolling resistance tires reduced the societal cost of reclaiming and recycling tires, some of the available funding for solid waste issues could potentially be used to encourage the sale of the most efficient products. Alternately, the two issues could be linked to supplement funding as described above, if low rolling resistance tires somehow compound the challenge of waste management.

As depicted in Figure 15, fees, if set high enough, can affect the sales volume of a given tire. For example, a $15 fee on a $60 tire is projected to cut demand by 15 percent. This may be a desirable policy in the case of individual tires that perform extremely poorly in energy terms), but have other performance specifications that merit keeping them on the market (high-traction, off-road tires, for example).

Fees, however, do not have to be set at high levels to be effective. If the fee is nominal, (i.e., only $1-$2, as is currently the case with the California Tire Recycling Fee Management Fund), the result will be revenue raising rather than demand reducing. These revenues can prove worthwhile in funding rebates or transitioning into a *feebate* program as described below.

Figure 15 - Projected Fee Impacts on Tire Sales



Source: Ecos Consulting calculations, November 7, 2002.

4.5.3. Feebates

"Feebates" are a combined program of fees that directly fund rebates. Unlike the system of fees described above, feebates are packaged together in a self-financing manner and are implemented and advertised as a single program. One of the selling points of feebates is that they can be more effective because those consumers purchasing fuel-efficient tires would not only get a rebate, they avoid paying a fee. As such, consumers can be highly motivated to change their purchase decisions.

Specifically, an efficient tire "feebate" program would assess a fee on tires with below-average efficiency and use the revenue to provide rebates on tires with above-average efficiency. Fees and rebates can either be flat or variable, depending on the spread in efficiency performance and the tolerance for policy complexity.

- *Fixed fee on all below-average tires / Fixed rebate on all above-average tires*: The simplest feebate design is a fixed system whereby the average tire efficiency is calculated and set as the "balance point." Then all below-average tires are assessed a uniform fee and these go to fund all above-average tires. The fee and rebate amounts would be determined up front and adjusted periodically to balance the account so that fee revenues equal rebate spending.

- *Variable fees and rebates on tires depend on their percentage below or above the average in terms of fuel efficiency*: A more complex, but refined feebate design is to vary feebates with actual levels of energy savings and waste. The formula can use the external prices of gasoline (i.e., environmental costs, energy security costs, etc.) as a means of determining the cost per efficiency gained or lost. Such a system will have to be adjusted using sophisticated computations over time to maintain fiscal balance.

Extensive data on the energy performance, cost, and sales volumes of individual tires are needed to model a feebate policy. However, the sensitivity analysis presented in Table 5 shows that, given the large estimated volume of 235 million replacement tires sold in the current market, a small fee placed on all tires could provide enough revenue to fund a meaningful rebate to a significant fraction of the fuel-efficient tire market. For example, if all cars were assessed a $1 fee and SUVs were assessed a $2 fee, then as much as 11 percent of the market could be awarded with a $10 rebate on efficient tires. According to elasticity calculations, a $10 rebate is projected to increase sales of efficient tires in the range of 5-18 percent.[44] The higher the fee, the higher the rebate and the larger fraction of the market could receive this incentive.

Table 5 - Tire Feebate Sensitivity Analysis

Tire Market Data

Tire Market Volume	**Number Sold**
	(millions)
Car Tires	200
SUVs Tires	35
Estimated Totals	235

Projected Revenues from Fees (millions)

	$1car / $2SUV	$5 All Tires
Car Tires Fees	$200	$1,000
SUV Tires Fees	$70	$175
Total Estimated Fees	$270	$1,175

Sales Increase from Efficient Tire Rebates

Sensitivity Runs	$1car / $2SUV	$5 All Tires
Fraction of Market @ $25 Rebate	5%	20%
Fraction of Market @ $15 Rebate	8%	33%
Fraction of Market @ $10 Rebate	11%	50%

[44] Based on Ecos Consulting calculations, November 2002.

Source: Ecos Consulting calculations, November 7, 2002.

4.5.4. Other Incentives and Promotions

Incentives do not have to come in the form of a direct cash rebate or fee on tires. Creative incentives can include merchandise, services, and other promotional offerings. These each requires financing. However, with high-profile public outreach and advertising by the CEC and others, businesses may be persuaded to opt into these promotional programs, especially at a time of economic downturn to spur sales.

There is any number of promotional arrangements that could be advanced. A few examples include: (1) arrangement between auto dealers and tire manufacturers providing consumer incentives (i.e., free first set of efficient replacement tires) when purchasing a new car; (2) free oil changes from tire retailers when purchasing above-average fuel-efficient replacement tires; or (3) other promotional offerings to consumers identified by tire retailers and manufacturers.

4.6 Guidance on Selecting Policy Options

The market has not historically succeeded in promoting long term, sustained reductions in energy consumption in the absence of public policy. While the U.S. has used government mandates, such as CAFE standards, to reduce auto energy use, European countries have depended more on economic policies of high gasoline taxes. In both cases auto fuel economy would likely not be maintained without policy intervention. In the U.S., gasoline and diesel fuel are inexpensive enough to invite high energy consumption patterns that continue to trend upward. Brief interruptions of supply and intermittent price spikes only provoke short-lived changes in consumer behavior rather than sustained technological improvements. New products that reduce petroleum consumption tend to meet barriers in entering the marketplace in the absence of policies to usher them in.

This is certainly the case with fuel-efficient tires. In this report we have shown that low rolling resistance replacement tires are manifestly cost effective. Consumers could save $87 to $260 in fuel costs for an incremental cost of only $9 to $22. Nevertheless, LRR replacement tires are not widely produced by manufacturers, marketed by retailers, or purchased by consumers. If these consumer and societal gains in fuel savings are to be realized, public policies will be required to increase the use of LRR models.

Deciding which policies are the best options depends on many dynamic factors. In terms of designing an economically efficient program (whose benefits exceed its costs), the policy determination will depend, in part, on how large the incremental cost is between low rolling resistance tires and conventional tires (Table 6). We assume an incremental cost per tire in the range of $1 to $2.50.

As more data become available in response to SB 1170, actual incremental costs should become evident. Public policies used to promote fuel-efficient tires may have to change in response to these costs. If the incremental cost is zero, public education and outreach may still be necessary to create a new market niche if other obstacles exist. If the incremental cost is low, public outreach and smaller financial incentives are preferred options. Incremental costs in the middle range will take larger financial incentives and possibly advertising to spur a market. High incremental costs may take mandatory standards and significant marketing efforts to bring about a societally beneficial change. This degree of policy intervention may be justified especially if there are high external costs attributed to oil dependence or other energy concerns. Table 6 identifies preferred policy options given the cost associated with change.

Table 6 - Preferred Policy Options as a Function of Incremental Costs

Incremental Cost of Low RR Tires	Public Outreach and Education	Financial Incentives & Promotions	Advertising & Marketing	Mandatory Standards
Zero	✓			
Low	✓	✓		
Medium		✓	✓	
High			✓	✓

If it proves to be the case that LRR tires have low incremental costs, then heightened public outreach and education would be the first, best policy option to increase the use of these tires. However, this approach, if adopted, should be monitored to determine if a viable market is created for fuel-efficient replacement tires. If a high cost differential, the lack of reliable data, or other market failures continue to present barriers to wide-scale supply of these efficient tires, then more sophisticated public policies would be needed to create a market niche for these products. Such policy options to promote efficient tires, including incentives and regulations, should be examined more closely, once more data become available.

Each policy option has a different cost effectiveness. Table 7 provides guidance on the cost effectiveness of different policy options available to bring fuel-efficient tires to the market. Outreach can be moderately effective. Public outreach and education are moderately costly for the government and industry to prepare and disseminate. However, there is a low cost to the public in acquiring information, and the Internet has served to lower this cost even more. While it remains uncertain if public information can be highly effective in changing consumers' decisionmaking, there are certain to be market failures (resulting in wasted fuel) in the absence of information about fuel-efficient tires. To be sure, consumers will not opt to buy something that they do not even know exists.

Incentives are less effective when they are set at low levels. When greater monetary incentives are offered, these policies can be highly effective. The costs of incentives depend on what mechanism is used and the level at which they are set. Standards are a highly effective means of bringing about beneficial change, but they tend to carry high up-front costs for industry and a moderate cost to government to enforce. The costs of standards, however, are at least partially passed on to consumers in the form of higher prices for fuel-efficient tires. In the case of LRR tires, since their incremental cost is expected to be low, there may still be a significant net benefit if standards are put in place. The quantification of cost effectiveness of each option would take additional data and is recommended in the future as more complete cost and energy savings information is collected.

Table 7 - Projected Cost Effectiveness of Policies for Promoting Fuel-Efficient Tires

Policy Option	**Effectiveness**	**Level of Costs Borne By:**		
		Consumers	Industry	Government
Public Education & Outreach				
- Web site	Medium[a]	Low		Low
- Hard copy (label, stickers, etc.)	Medium[a]	Low	Medium[b]	Medium[b]
Incentives[g]				
- Rebates				
Smaller Dollars	Low			Medium
Larger Dollars	High			High
- Fees				
Smaller Dollars	Low	Low		Low[d]
Larger Dollars	High	High		Low[d]
- *Feebates*				
Smaller Dollars	Medium	Low[c]		Low[d]
Larger Dollars	High	Low[c]		Low[d]
- Other Promotional Incentives	Medium		High	
Standards	High	[e]	High[e]	Medium[f]

Notes:

a. Effectiveness of public outreach and education is uncertain if used alone (i.e., without incentives or standards); effectiveness is expected to be higher (and necessary) if packaged with incentives and/or standards.
b. Costs of labels, stickers, pamphlets, and other hard copy forms of outreach and public education could either be borne by industry, government, or both.
c. Costs to individual consumers depend on if consumer pays a fee or receives a rebate. Overall costs of feebates borne by consumers would be low when averaged over all consumers.
d. Administrative costs only.
e. Consumer costs could be medium or high. Industry costs to meet standards could be passed on to consumers, depending on the competitiveness of a future fuel efficient tire market.
f. Government costs for enforcement of standards and any follow-up testing.
g. Incentives have been assumed to be awarded/debited to consumers. However, they can also be borne by industry (manufacturers and/or retailers) themselves. Either way, the level of costs are expected to remain the same.

Beyond sheer economic efficiency, each policy option has trade-offs associated with its implementation. An initial look at the advantages and disadvantages associated with each policy option is presented below in Table 8. Barriers and weaknesses of each policy approach – outreach vs. incentives vs. standards – are also presented. Just because a policy is not ideal does not mean that it is unworthy of adoption. Clever policy designs can overcome weaknesses. And if advantages outweigh inherent disadvantages, then the policy can go a long way toward correcting market failures.

Table 8 - Advantages and Disadvantages of Policy Options for Promoting Fuel-Efficient Tires

Policy Options	**Advantages**	**Disadvantages**	**Barriers/Weaknesses**
Public Outreach & Education			1. Missing Data: Verifiable tire efficiency data needed on every tire sold 2. Public subject to information overload
- *Web site Listings*	1. Ability to supply missing information to consumers 2. Can be implemented in short-term (if information becomes readily available)	Consumers must have access to a computer & actively seek out information	
- *Fuel Economy Guide*	1. Clear, side-by-side comparison guide 2. Existing template available, just add information on tires.	Presumes consumer has knowledge to seek it out	
- *Tire Labeling*	Provides vital information at the time of sale	1. Accuracy vital 2. Retailers must support into system	
- *Tire Advertising*	1. Merges public and private interests 2. Near-term policy option, if private sector willing	Can be costly if designed to be effective	
- *Public Education*	1. Removes market barrier – absence of information 2. Education about saving money can be persuasive	Hard for public to decipher if detailed, technical, or at all complex	
Financial Incentives & Promotions			1. Missing Data: Detailed, accurate data needed to set prices 2. Funding needed (fees or general revenues)
- *Rebates*	1. Rewards positive action 2. Makes labeling more effective	Needs funding	
- *Fees*	1. Debits inferior products 2. Funds incentives 3. Creates awareness	Often unpopular	
- *"Feebates"*	1. Self-financing 2. Combining incentives with disincentives most effective	Increases complexity	
- *Other Promotions*	1. Can get creative 2. Can serve as public relations for stakeholders	Needs cooperation between different agents	
Mandatory Standards - *Fuel-Efficient Tire Standards*	1. Greatest chance of delivering results 2. Works well when specific data missing	1. Subject to gaming 2. Possibly less efficient than incentives	1. Greater political effort to adopt 2. Highest scrutiny for data accuracy
- *Sales Requirements*	1. Enhances marketing and sales of efficient tires 2. Works well when specific efficiency data is missing	1. Subject to gaming 2. Possibly less efficient than incentives	1. Could affect competition 2. Government must understand tire business

Appendix A

Criteria to Evaluate an Effective Web site*

CRITERIA
1. FIRST IMPRESSIONS
URL
Download time - size of home page
Look and feel – readability
Need to download software *
Home page on one screen (above the fold)
Unique Selling Point (USP) or Value Proposition
Ability to take action (Key action point – KAP)
Feeling of wanting more - depth of site
Contact details
Credential validation - certifications, associations etc.
Statement from management
Use of attractors
Are you made to register to get into site? *
Total score for Section 1
2. NAVIGATION
Ease of use
Site map
Return to Home Page from any page
Internal search engine
Internal links
Broken links
Text as well as graphic links (ALT tags)
Navigational links visible
Opens multiple windows
Total score for Section 2
3. CONTENT
Useful information
Degree of substantiated information
Level of interaction
Use of valuable graphics
Use of valuable animation
Use of valuable sound
Reviews, testimonials and certifications
Content in digestible quantity
Up-to-dateness
Available in multiple languages
Accessibility for the disabled
Terms and conditions
FAQ's
Availability of follow up discussion
Total score for Section 3
4. ATTRACTORS
Competitions
Special offers
Freebies
Breaking news
Ease of access by External links
Newsletter
Other (Specify)
Total score for Section 4

5. FINDABILITY
Intuitive URL
Designed for search engine performance
Intuitive keywords
Use of metatags
Use of frames
Advertising
On-line advertising
Off-line advertising
On-line recommend a friend
Partner and affiliate sites
Total score for Section 5
6. MAKING CONTACT
Email and other details visible
Response time to enquiries
Automatic email response
Personal email response
Use of online forms
Telephone contact number provided
Telephone call back offered
Total score for Section 6
7. BROWSER COMPATIBILITY
Internet Explorer (1-5)
Netscape Navigator (1-4)
Mac
Resizeability
Total score for Section 7
8. KNOWLEDGE OF USERS
Availability of utilization statistics

Adaptive web site
Offers based on buying history
Total score for Section 8
9. USER SATISFACTION
Robustness/reliability of the site
Clicks to completion
Acknowledge order/request
Order/request tracking online
Recognizing a pre-inclusion
Total score for Section 9
10. 10. OTHER USEFUL INFORMATION
Supplier terms and conditions
List of products bought by your company
Contact details for person in charge of suppliers
List of career opportunities
Contact details for HR department
Financial results
Up-to-date financial news
The company stock price performance
History of the company
Management and geographical structure of company
Mission statement
Up-to-date press coverage
Total score for Section 10
OVERALL TOTAL SCORE

Source: Trinity College Dublin, Management Centre International Limited, "10 Criteria to Evaluate a Web site," www.mcil.co.uk/7-10-criteria.htm. Note that not all criteria relevant to CEC; the entire criteria list has been included for a complete review of this resource guide.

Appendix B

Methodology for Assessing Tire Performance Data

Absent data from the manufacturers or their trade association, we evaluated Consumer Reports and EPA testing of tire rolling resistance, and the limited amounts of rolling resistance data provided to us initially by manufacturers, to aid in the selection of tires for testing. The goal was to assess tires with a wide range of likely rolling resistance performance. Budget and time limitations prevented us from testing more than 43 tire models initially, but they represent a wide variety of manufacturers, performance characteristics and prices.

While we would have preferred to test all models in a single size to ensure maximum comparability of data, the smallest number of sizes in which all of these tires were available was four. For this reason, the data are plotted individually by size and collectively across sizes, to permit comparison both ways. Industry research suggests that rolling resistance drops by approximately 5% for every 4% reduction in tire weight,[45] so it may be possible in future research to develop some approximate adjustment factors for the weight changes that result solely from differences in tire size.

Ecos Consulting assembled tire performance data from a wide variety of publicly available sources, including federal Uniform Tire Quality Grading System (UTQGS), Consumer Reports testing, and TireRack.com customer surveys. These are described in more detail below.

RMA asserted in its 12/18/02 comments to the CEC that evaluating multiple measures of traction, tread wear, or overall satisfaction together will yield information with less statistical validity than comparisons with individual metrics. We found the opposite – namely, that individual metrics often lack sufficient resolution or detail (particularly with small sample sizes) to highlight meaningful differences among tire models. By evaluating combined traction scores from three sources, for example, we were able to distinguish systematic differences among tire models from much smaller sources of apparent difference like measurement error, marketing adjustments, or low resolution in data reporting.

Cost

The tire costs are size specific retail prices taken directly from the Tire Rack website (tirerack.com). The prices tend to be lower than MSRP, but reflect actual prices paid by customers in November 2002.

Traction

The traction scale is an average of three traction sources: Consumer Reports testing, Tire Rack customer surveys, and UTQGS traction rating. Consumer Reports tests tires for several attributes. We averaged the results of tests that we considered indicators of overall traction and safety. The tests included in the average are: Snow Traction, Ice Braking with ABS, Wet Braking with ABS, Dry Braking, Cornering Stability, Emergency Handling, and Hydroplaning. Descriptions of these tests can be found in Consumer Reports magazine. Earlier tests performed with the ABS disabled were omitted because they were unavailable for most tires.

[45] See Figure 6 in J. Trimbach, R. Engehausen, and A.J.M Sumner, "Increase Tire Life and Fuel Economy with Improved Polymers," *Tire Technology International 2002*, pp. 130-132

Consumer Reports rates tires using a 5-point rating system. We multiplied results by two before the final averaging to match the 10-point scale used in the Tire Rack Survey.

Tire Rack publishes the results of customer satisfaction surveys on line, reflecting more than 1.03 billion miles and 6 years of collective driving on 576 different tire models by nearly 50,000 customers.[46] Customers are encouraged to participate in a voluntary survey assessing their experience with the tires after having used them extensively. We averaged the results of tests that we considered indicators of overall traction and safety. The tests included in the average for Tire Rack are: Dry Traction, Wet Traction, Hydroplaning Resistance, Snow Traction, Cornering Stability, and Steering Response. TR data is reported on a 10-point system.

Tires are rated for traction by the UTQGS system. Tires are rated as AA - Best, A - Better, B - Good, or C - Acceptable. All tires tested were either A or B. A tires were assigned a rating of 8 and B tires a rating of 7 on a 10-point scale. (AA tires could be given a score of 10 and C tires a score of 5). While it may seem desirable to have the point scale range from 0 to 10, this would imply greater differences in traction than we suspect the federal methodology actually conveys (since manufacturers often underrate the performance of some models to establish stronger marketing distinctions among models at different price points). Our compressed scale for UTQGS traction has the effect of according it proportionately less weight than the other two metrics for traction.

Finally, we averaged all three of these indicators of traction, now calibrated, to achieve the final traction rating reported in the chart.

Tread wear

The tread wear scale is an average of two tread wear sources: Tire Rack Customer Surveys and UTQGS tread wear rating. Tires are rated for tread wear by the UTQGS system. Tires we tested were rated between 160 and 560. These numbers were multiplied by 0.015 to calibrate them with the 10-point Tire Rack system.

Finally, we averaged these indicators of tread wear, now calibrated, to achieve the final tread wear rating reported in the chart. While we had hoped to include warranty periods as a criterion here, we encountered two major problems with that information. First, it was not readily available for all the tires we tested. Second, some tire warranties are provided by the manufacturer and others by the dealer, and the terms of each can vary, particularly with regard to what fraction of the tire's cost will be reimbursed at what point in a tire's lifetime. Few if any warranties are absolute (full replacement cost at any point up to the rated lifetime). As a result, warranty mileage data, when obtainable, often speak more to the manner in which a tire is marketed than to its expected lifetime.

Overall Satisfaction

The Overall Satisfaction Rating is an average of Consumer Reports' Overall Rating and Tire Rack's "Buy Again" criterion. Consumer Reports rates tires using a five point rating system, so we multiplied results by two before the final averaging to match the 10-point scale used in the Tire Rack Survey. Tire Rack publishes the results of customer satisfaction surveys on line. Customers are encouraged to participate in a voluntary survey assessing their experience with the tires. Tire Rack data are reported on a 10-point system.

[46] See www.tirerack.com/tires/surveyresults/index.jsp.