Passenger Vehicle Replacement Tire Efficiency Study

October 31, 2013

Contract number 13451

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Acknowledgements:

The authors would like to acknowledge the review or other assistance provided by Alex Chase, Stan Cowen, Aaron Katzenstein, Mark Loutzenhiser, Nic Lutsey, Dipankar Sarkar, and the retailers listed in Appendix C. Any errors are the responsibility of the authors.

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1 Introduction

Air quality improvements and greenhouse reductions are important priorities for California air quality agencies including the South Coast Air Quality Management District (SCAQMD). Passenger vehicle low rolling resistance replacement tires (herein referred to as "fuel efficient tires") provide significant opportunities for reducing air pollutants and carbon dioxide while saving consumers fuel and money. Fuel efficient tires are technically feasible and common for new vehicles (due to environmental regulations) but face significant market barriers in the replacement market. This is because manufacturers face a modest cost increase, tire retailers lack a significant incentive to stock and promote fuel efficient tires, and consumers have limited resources to identify these tires.

The purpose of this report is to evaluate various program design options to overcome market barriers and to increase the fuel efficient passenger vehicle replacement tire stock in the SCAQMD. The report presents information on fuel efficient replacement tire technologies and describes potential fuel efficiency, air pollution, and carbon dioxide emission benefits. The report finds that these benefits greatly exceed costs with a 7:1 benefit to cost ratio under one potential scenario, and a rapid payback period. The report also describes market readiness and potential incentive program design options aimed at consumers and/or retailers combined with improved consumer education. Finally, the report provides implementation recommendations.

2 Fuel Efficient Tires

This section describes passenger vehicle low rolling resistance tire technology and metrics, as well as the potential for efficiency improvements in the replacement market.

2.1 Low Rolling Resistance Materials and Metrics

Rolling resistance occurs when tires deform during rotation. The portion of the tire that is deformed is subjected to compression, bending, and shearing forces. Energy is used during these repeated deformations to overcome the viscosity of the rubber and is then dissipated as heat as the tire returns to its original shape (Tonachel 2004). Increased tire deformation increases the amount of energy needed to overcome the viscosity of the rubber. Additional rolling resistance occurs through friction with the road. Rolling resistance can be reduced through improved tires, such as the material described below as well as maintaining proper inflation.

Rolling resistance can be expressed as rolling resistance force (RRF) for a given tire load. RRF can be directly measured through laboratory procedures such as ISO 28580. Rolling resistance can also be expressed as a dimensionless rolling resistance coefficient (RRC), which is calculated based on the measured RRF divided by tire load during the test (the test load should be based on the typical on-road load). Lower values for RRC and RRF correspond to more fuel efficient tires. Metrics are further discussed in the program design section of this report.

A primary mechanism for lower rolling resistance is increased use of silica, especially in combination with natural rubber as shown in Figure 2.1 (Pike 2011). Natural rubber has good rolling resistance properties but lags synthetic rubber on traction, which can be overcome with the increased use of silica. Silica does not inherently disperse well in natural rubber and several technologies have been developed to improve silica dispersion to achieve further rolling resistance benefits (Nakaseko 2013; TARRC 2013). Manufacturers could, in theory, improve rolling resistance by trading-off traction and/or durability. Section 5 discusses program implementation recommendations that encourage lower rolling resistance without backsliding in other areas.

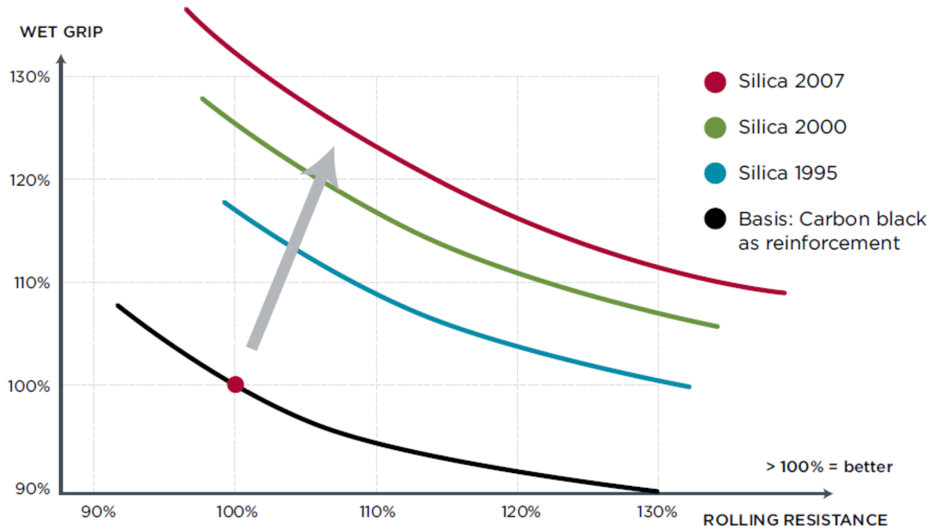

Figure 2.1 Use of Silica to Decrease Rolling Resistance

Source: EPEC Impact Assessment Study 2008

2.2 Estimated Fuel Savings

Improving per vehicle replacement tire rolling resistance by 20% or more is technically feasible. According to the National Research Council, there is a significant gap between the Original Equipment Manufacturer (OEM) and replacement vehicle market (NRC 2006). Eliminating the gap will improve the replacement market for low rolling resistance tires by approximately 16-18%, as shown by the first two bars in Figure 2.2 below. Data for replacement tires came from the Rubber Manufacturers Association based on laboratory testing and data for current OEM vehicle tires was reported to US EPA based on calculations from measurements at test tracks. In addition, the U.S. Environmental Protection Agency (EPA) estimates that by 2015 most new vehicles will be sold with tires 10% better than current OEM levels,[1] also shown in Figure 2.2. While a 25% or greater improvement is technically feasible for most passenger vehicles in the replacement market, we assume a value of 20% for two reasons. First, the use of specialty tires (e.g., off-road tires) may be challenging to address through an incentive program. Second, our comparisons use laboratory data on one hand and test track data on the other and we have not found data confirming that the

[1] Vehicle OEMs have an incentive for low rolling resistance tires under U.S. EPA and National Highway Traffic Safety Administration (NHTSA) new vehicle greenhouse gas (GHG) and fuel economy regulations and labeling, which are absent for the replacement tire market. The Rubber Manufacturers Association (RMA) estimated that the average of California Energy Commission (CEC) and other non-sales weighted data was RRC 0.010 (RMA April 8, 2009). RMA's consultant report excluded a number of tests for winter tires, deep tread tires and metric-LT tires (Environ 2009). RMA has presented data weighted by tire size while the OEM vehicle tire rolling resistance data is not sales weighted. Lutsey (2012) calculated mean rolling resistance for model year 2011 new vehicles at 0.0082 based on "coast-down" test data reported to US EPA. Coast-down tests are conducted on test tracks to measure deceleration from a coasting vehicle and then calculate rolling resistance and other factors. CEC replacement tire data were based on ISO 28580 laboratory testing (Tuvell 2009), while RMA data were based on SAE J1269. The National Research Council (NRC 2006) found comparable differences in the range of OEM and replacement market tire RRC (p. 54), without determining mean values for the two markets.

two methods correlate precisely. ISO 28580 lab testing of OEM tires would help confirm whether OEM RRC data is directly comparable to replacement tire lab testing.

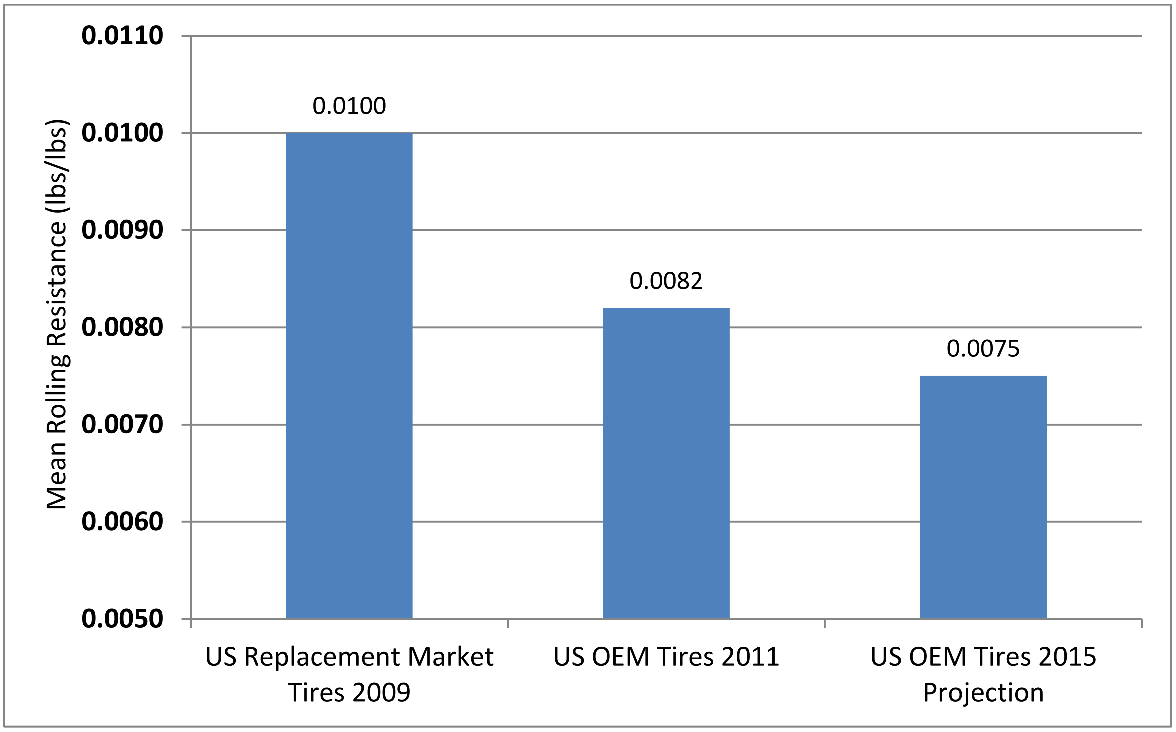

Figure 2.2 Replacement Market Passenger Vehicle Tire Rolling Resistance Coefficient (RRC) Compared to OEM Median RRC

Sources: RMA 2009, Lutsey 2012, Energy Solutions Calculation

We also estimate that a 4% per vehicle improvement in fuel economy can be achieved based on a 20% reduction in passenger vehicle replacement tire rolling resistance. This correlation between fuel economy and rolling resistance is based largely on a U.S. EPA estimate that a 20% improvement in rolling resistance will result in a 3.9% CO_2 improvement for new passenger vehicles (U.S. EPA 2012, Table 1.2-26). We raised this number slightly based on the expectation that rolling resistance will have a higher influence on fuel efficiency for existing vehicles without low rolling resistance tires. This estimate is consistent with studies indicating a 2-3% reduction or 1-3% reduction in fuel consumption for a 10% improvement in tire rolling resistance (Durft 2011; NRC 2010).[2] In addition, a European Union study found that a 1-5% improvement in fuel consumption is possible depending on the reduced level of rolling resistance achieved (Commission of the European Communities 2008b, p.42) and the California Energy Commission (CEC) estimated that improving rolling resistance by 10% can improve fuel efficiency by up to 2% (Tuvell 2009).

Market penetration of low rolling resistance tires will also depend on program design (incentive/consumer education, regulation, or both) and scope. Our 4% estimate for improvement is not intended to reflect a target for a fleet-wide voluntary incentive program. Potential benchmarks and market share for a stand-alone voluntary incentive program are discussed in later Sections.

[2] For additional information see also Commission of the European Communities 2008a, p. 7. Rolling resistance in the South Coast air basin may have a larger influence on fuel economy than nationally due to congested freeways, lower speeds, and thus, reduced aerodynamic losses.

3 Benefits and Costs

This section presents criteria pollutant and GHG emission reductions calculations and methodology for passenger vehicle fuel efficient replacement tires. This section also monetizes these benefits and fuel savings, estimates potential costs and shows a very favorable benefit/cost ratio.

3.1 Air Quality and Greenhouse Emissions Modeling

3.1.1 Scenario Modeled

We analyzed a theoretical one-year program with full replacement market participation to show the near term technical potential of low rolling resistance tires. Benefits could potentially scale up with longer program implementation or scale down with lower participation rates. Key characteristics of this scenario include:

- We selected a 4% fuel savings target per participating vehicle as an ambitious yet realistic target (as discussed in Section 2).
- We included passenger vehicles in model years 2010 and earlier (MY 2010)[3] based on the assumption that relatively few newer cars would need replacement tires (due to accidents, damage or high driving patterns).
- We assumed that the theoretical full participation rate in 2014 would be 1.76 million vehicles and 7.04 million replacement tires. This rate is based on EMFAC2011 output results for MY 2010 and earlier vehicles as well as an assumption that these tires would be replaced on average about every 3.5 years (based on their average mileage rates and an assumed 40,000 miles tire life from U.S. EPA 2012, Table 5.2-3). While this level of deployment is not realistic for a voluntary incentive program, modeling the technical potential is helpful for assessing benefits and costs of scaled-down deployment levels.
- We calculated lifetime benefits by multiplying annual benefits by a factor of slightly greater than 3.5 years to represent expected persistency (again based on estimated tire life and annual VMT).[4]

3.1.2 Emissions Calculation Methodology

We established the baseline passenger vehicle emissions inventory of CO_2, nitrogen oxides (NOx), reactive organic gases (ROG), carbon monoxide (CO) and fine particulates (PM) based on CARB's EMFAC2011 passenger vehicle emissions model (with default values for vehicle population, activity factors, and inspection and maintenance programs). Emission sources that would be decreased by lower rolling resistance tires that reduce engine load are listed in Table 3.1 EMFAC2011 modeled baseline data is shown in Appendix B.

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[3] EMFAC2011 modeling includes categories LDA, LDT1 and LDT2.

[4] This approach may understate lifetime emission benefits due to the greater calendar year longevity of replacement tires on the oldest and highest emitting vehicles. For instance, a vehicle that is 15 years old may have emission rates several times higher than a MY2010 vehicle. An older vehicle with annual VMT of 10,000 miles may have a tire longevity of 4 years rather than just over 3.5 years (U.S. EPA and NHTSA 2012, Tables 4-3 and 4-4). Conversely some emission reductions may occur in other air district(s) due to vehicle mobility.

Fuel savings and emission reductions from Table 3.1 sources will generally scale linearly with reductions in fuel consumption.[5] For more detail, see U.S. EPA calculation methods for mobile industrial internal combustion engine emissions.[6] In the modeling scenario, total lifetime vehicle emissions would drop by more than 1500 tons of ozone precursors and 8900 tons of total criteria pollutants primarily from vehicle tailpipes, along with reductions of over 1.2 million U.S. tons of CO_2, as shown in Table 3.3 and Table 3.4. We expect that similar results could be achieved on an annual basis if the entire stock of replacement tires were fuel efficient.

Table 3.1 Emission sources reported by EMFAC2011

Emissions sources affected by engine load	Emission sources not affected by engine load
▪ All tailpipe emissions ▪ Running fraction of evaporative organics	▪ All start and idle tailpipe emissions ▪ Diurnal, hot soak, and resting fraction of evaporative emissions ▪ Brake and tire wear fraction of particulates

We also calculated upstream emission reductions in SCAQMD criteria pollutants and global GHG emissions due to reduced fuel usage. Upstream emission sources such as petroleum production, shipping, refining and marketing were included. Since crude oil is a global market, potential criteria pollutant reductions from decreased crude oil production were not included in the analysis. We also omitted potential refinery criteria pollutant reductions due to uncertainty about the extent to which in-base reductions would occur.

The inventory includes all upstream GHG emissions regardless of geographic location due to the global impact of GHG. This approach is consistent with the approach of the U.S. Interagency Working Group (IWG) on the Social Cost of Carbon. Upstream GHG emissions would be reduced by almost 400,000 U.S. tons based on emission factors from the CARB Low Carbon Fuel Standard (CARB 2008, Table 2).

The gasoline marketing hydrocarbon baseline emissions inventory is based on CARB's California Emissions Forecasting System (CEFS)[7] but with several adjustments (i.e. NOx, sulfur oxides or SOx, carbon monoxide or CO, and PM emissions are relatively small and are not addressed for this source.) The CEFS hydrocarbon marketing macro-category covers a variety of activities and was broken down into sub-categories. We totaled the sub-categories associated with gasoline marketing (see Table 3.2) as an initial refinement, while excluding others such as diesel fuel distribution. We excluded unspecified hydrocarbons, about 2 percent of the total petroleum marketing emissions, as a conservative assumption and calculated values for 2014 by interpolating forecasts for 2010 and 2015.

We then adjusted the total gasoline marketing baseline to account for the fraction of gasoline throughput attributed to passenger vehicles compared to overall sources of gasoline demand. We multiplied the gasoline marketing activities listed in Table 3.2 by 72% to estimate the fraction attributable to on-road

[5] For a specific engine operating at a specific load, a change in load may increase or decrease the efficiency of the engine for converting fuel to mechanical output. The shift in engine load under consideration for this report would be relatively small on a per vehicle basis and is not expected to change the average efficiency of converting fuel to mechanical output.

[6] See U.S. AP AP-42 section 3.3, Gasoline and Diesel Industrial Engines. We do not propose to use the specific values in AP-42, which have not been updated recently, but rather apply the general principle of load-based emission factors to this study. Engine emissions modeling, which is beyond the scope of this project, may provide more specific data for specific vehicles and engines.

[7] This database is available at: http://www.arb.ca.gov/app/emsinv/fcemssumcat2006.php.

activities in 2014,[8] based on EMFAC2011 and CARB's off-road model. Upstream reactive organic gas (ROG) emissions would be 223 tons lower under the modeled scenario, as shown in Tables 3.3 and 3.4.

Table 3.2 Gasoline marketing subcategories included in baseline emissions

BARGE LOADING
BULK PLANTS/TERMINALS – Gasoline storage breathing loses and working loses
CARGO TANKS - Pressure, vapor hose and produce hose fugitive
FIXED ROOF TANKS – Breathing loses and working loses
FLOATING ROOF TANKS – Working loses
FUEL DISPENSING TANKS - Breathing loses and working loses
TANKER LOADING
TANK CARS AND TRUCKS – Working loses
VEHICLE REFUELING – Vapor Displacement Losses and Spillage
OTHER

3.2 Emissions Valuation Methodology and Results

We calculated the value of both GHG and criteria pollutant reductions by multiplying the total tons by a per ton value. For GHG, the U.S. IWG on the Social Cost of Carbon has developed a range of potential costs based on avoided damage costs, such as economic, human health and ecological impacts, as explained in Appendix A. We used values of $34 per metric ton under Option A and $108 per metric ton under Option B to present examples of avoided GHG damage cost estimates. Avoided GHG costs for a hypothetical one year full participation program total $53.9 million to $173.5 million as shown below in Tables 3.3 and 3.4.

Similarly, we monetized criteria pollutant emission reductions using an Option A and Option B because the value of certain criteria pollutant reduction benefits can be estimated in different ways (though there is less variability than for the two GHG options). The Carl Moyer emission reduction incentive program includes cost per ton thresholds for transportation ozone precursor and fine particulate emissions. These thresholds were used to monetize expected tailpipe criteria pollutant emission reductions resulting from fuel efficient tires under both Option A and Option B (SCAQMD 2013 and CARB 2011).[9] Other emissions (stationary source petroleum marketing ROG, vehicle CO and SOx) were monetized using SCAQMD Best Available Control Technology (BACT) cost per ton benchmarks for stationary sources (SCAQMD 2006). In Option A, the lower (average) BACT benchmarks were used while in Option B the upper (incremental) benchmarks were used. For instance, the ROG BACT benchmark of $20,200 per ton is used for Option A and $60,600 per ton is used for Option B.

[8] LDA, LDT1 and LDT2 fuel consumption was modeled at 14,022,000 gallons per day for the South Coast AQMD. The total was modeled as 19,421,000 gallons per day. A small adjustment was made to account for off-road vehicle usage from CARBs off-road model based on the assumption that all fuel usage for off-road vehicles up to 250 hp is gasoline and that all fuel usage for larger engines is diesel. This fraction was not adjusted for aviation gasoline usage. CARB's off-road emissions database is available at: http://www.arb.ca.gov/msei/categories.htm#offroad_motor_vehicles.

[9] The Carl Moyer program focuses largely on trucks and buses within the transport sector which are assumed to have similar locational impacts as passenger vehicles.

For Option A, total monetized benefits of all pollutants are $24.9 million annually and $88.2 million lifetime in 2013 dollars. For Option B, benefits are $62.9 million annually and $222.5 million for lifetime, as shown below in Table 3.3 and Table 3.4.

Table 3.3 Option A - Monetized Air Pollution Reduction Benefits for Hypothetical One Year SCAQMD Program[10]

	Lifetime Benefit (Tons)	OPTION A Dollar ($) per U.S. ton	One year benefit	Lifetime (3.54 years) Benefit
ROG Tailpipe and Running Evaporative	612	$17,460	$3,019,000	$10,687,000
NO_x Tailpipe	715	$17,460	$3,531,000	$12,500,000
SO_x Tailpipe	13	$10,100	$37,000	$131,000
CO Tailpipe	7,278	$400	$823,000	$2,913,000
PM Tailpipe	10	$349,200	$986,000	$3,490,000
ROG Distribution	223	$20,200	$1,278,000	$4,524,000
Criteria Subtotal	***8,900***		***$9,674,000***	***$34,245,000***
CO_2 Tailpipe	1,207,000	$34	$11,446,000	$40,519,000
CO_2 Upstream	400,000	$34	$3,793,000	$13,427,000
CO_2 Subtotal	***1,607,000***	***$34***	***$15,239,000***	***$53,946,000***
GRAND TOTAL			**$24,913,000**	**$88,191,000**

Table 3.4 Option B - Monetized Air Pollution Reduction Benefits for Hypothetical One Year SCAQMD Program

	Lifetime Benefit (tons)	OPTION B Dollars ($) per U.S. ton	One year benefit	Lifetime (3.54 years) benefit
ROG Tailpipe and Running Evaporative	612	$17,460	$3,019,000	$10,687,000
NO_x Tailpipe	715	$17,460	$3,531,000	$12,500,000
SO_x Tailpipe	13	$30,300	$110,000	$389,000
CO Tailpipe	7,278	$1,150	$2,365,000	$8,372,000
PM Tailpipe	10	$349,200	$986,000	$3,490,000
ROG Distribution	223	$60,600	$3,835,000	$13,576,000
Criteria Subtotal	***8,900***		***$13,846,000***	***$49,014,000***
CO_2 Tailpipe	1,207,000	$108	$36,813,000	$130,318,000
CO_2 Upstream	400,000	$108	$12,199,000	$43,184,000
CO_2 Subtotal	***1,607,000***	***$108***	***$49,012,000***	***$173,502,000***
GRAND TOTAL			**$62,858,000**	**$222,516,000**

[10] Totals may not exactly match the sum of each individual item due to rounding.

3.3 Cost Estimates

We estimate an incremental cost of $5 to $7.50 per tire ($20 to $30 per vehicle) for a 20% improvement in rolling resistance in the replacement market including retail mark-ups. This estimate is based primarily on U.S. EPA and NHTSA data. U.S. EPA estimates that OEM vehicle tires can improve rolling resistance by 10% at a cost of $7/vehicle (U.S. EPA TSD 3-210), which appears to exclude transportation, marketing, and retail price mark-up.[11] This cost converts to a retail price estimate of about $10/vehicle assuming a 1.45 retailer mark-up ratio (DOE 2013, ch. 6).[12] Improvements to bridge the gap between OEM and replacement tire RRC are expected have a similar cost or less than for improvements beyond current OEM levels. This is because an incremental reduction from a higher replacement market RRC baseline may be easier to make than from current OEM RRC levels. Thus, retail costs should be no greater than $20 per vehicle to achieve a 20% improvement in replacement market rolling resistance, based on U.S. EPA cost data for new vehicles.

Other estimates overlap this value but are less precise. NHTSA estimated a consumer cost of $3 per tire (from a range of $2 to $4) to improve rolling resistance by 10% in the replacement market (NHTSA 2009, p. 93). Rubber Manufacturers Association (RMA) member surveys "generally confirm NHTSA's estimates regarding the cost per tire to improve rolling resistance without sacrificing traction or treadwear" (RMA 2009, p.15) while providing a less specific estimated efficiency benefit of 5-10%.[13] Scaling up from the NHTSA estimate would give a cost of about $24 per vehicle to improve rolling resistance by 20%, though additional incremental improvements could come at a somewhat higher cost. The National Research Council (NRC 2010) provides an estimate of $8 to $20 per vehicle in the OEM context. We selected an upper end of potential retail costs at $30 per vehicle based on the potential for cost uncertainties.

Thus, reducing tire rolling resistance of 20% (or greater) should cost $20 to $30 per vehicle or less absent market barriers. Payback periods would be very short as noted below. (Section 4 contains information on current market conditions.)

3.4 Benefits/Cost Evaluation

Total benefits would greatly exceed program costs across a broad range of potential scenarios based on the air quality benefits described earlier and fuel savings at $3.68/gallon exclusive of taxes.[14]

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[11] U.S. EPA applied a ratio of 1.26 for direct and indirect costs to estimate that $5/vehicle direct manufacturing costs would result in a cost of $7/tire including indirect costs (IC). We infer that because U.S. EPA used the IC ration (1.26) corresponding to U.S. EPA's general 1.26 ration for IC exclusive of transportation and marketing (including mark-up) that the $7/tire estimate similarly excludes transportation, marketing, and mark-up. While these costs are estimated for MY 2017-2025 in the context of the 2017-2025 GHG regulation, they are also close to the prior April 2010 "Final Rulemaking to Establish Light Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards" cost estimates of $6 per vehicle for MY2012-2016 in $2007 (see Section 3.4.2.4.3).

[12] We use U.S. DOE's 1.45 electronic and home appliance stores retailer mark-up ratio as a proxy for retail mark-ups on incremental manufacturing costs for low rolling resistance replacement market tires. This ratio may not be precise because: 1) mark-ups may not scale fully with increases in cost for a better quality tire; 2) individual products are not disaggregated and may have different mark-ups; and 3) some types of tire retailers may have a different ratio. Based on several retailer interviews described later, retailer mark-ups are likely no higher than this level.

[13] We assume that this estimate is the retail cost.

[14] We selected fuel costs of as of September 9, 2013, as reported by U.S. Energy Information Agency and CEC. We based fuel savings baselines on the same EMFAC2011 modeling run described in the air quality section and shown in Appendix B along with a hypothetical program achieving an overall 4% improvement in fuel economy in 2014 for all vehicles in the passenger vehicle replacement tire market.

Table 3.5 Potential benefits and costs from a hypothetical program

Potential Participation Rate	*Program Costs at $20/ Vehicle*	*Program Costs at $50/ Vehicle*	*Air Quality Benefits-Option A*	*Air Quality Benefits-Option B*	*Fuel savings at $3.69 /gal*
10%	$3,520,000	$8,801,000	$8,819,100	$22,251,600	$50,011,000
20%	$7,041,000	$17,602,000	$17,638,200	$44,503,200	$100,021,000

Table 3.5 shows the potential benefits and costs of a hypothetical one year program with 10% penetration at a cost of $12.50/tire ($50/vehicle), or about $9 million total (this example is not intended to predict actual participation rates). This hypothetical program would achieve net lifetime benefits of $50-$64 million at a benefit/cost ratio of about 7:1. A $50/vehicle program cost would roughly match the low valuation of total air quality benefits ("Option A") even without considering fuel savings. A $20/vehicle program cost would roughly correspond with the expected criteria pollutant benefits ($3.4 million for 10% implementation for instance, based on Table 3.4).

Figure 3.1 illustrates how benefits would greatly exceed costs under an even wider range of scenarios. Higher incentive levels, such as $80/vehicle, would still have a very positive net benefit/cost ratio. This higher incentive level could also increase total net benefits by achieving greater participation rates, i.e. moving further right on the horizontal axis, including potentially shifting some consumers between market segments as discussed later.

Fuel savings alone are many times greater than costs in each scenario shown in Figure 3.1, resulting in short payback periods. (The potential for free ridership is relatively low due to low current adoption rates, and may be mitigated by additional benefits such as future repeat purchases of low rolling resistance tires without an incentive.)

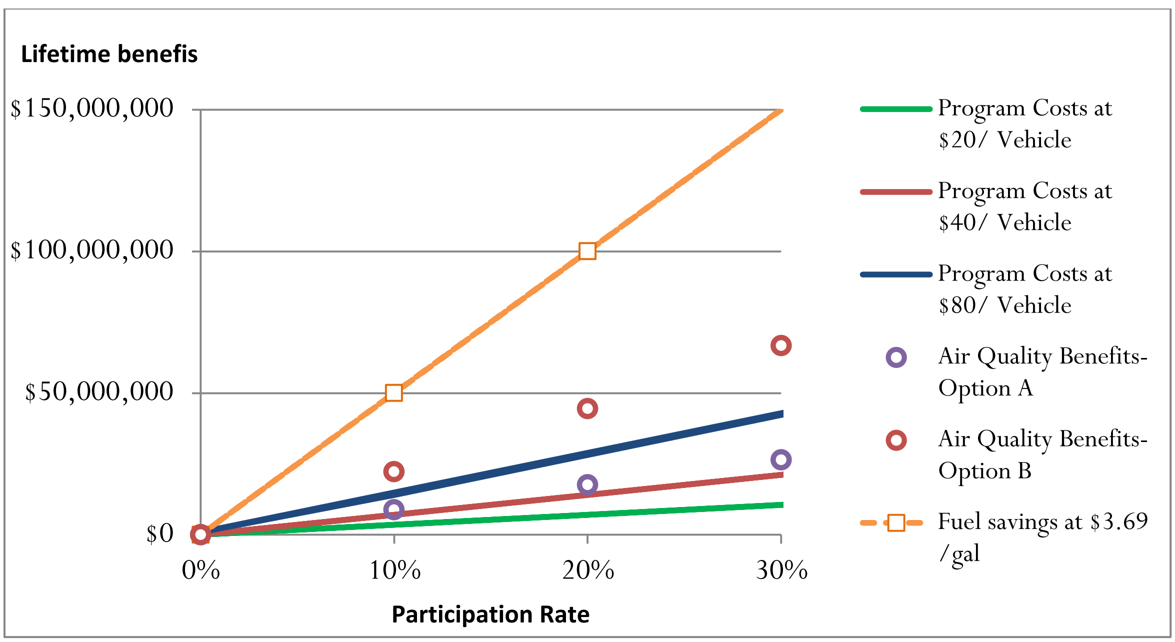

Figure 3.1 Calculated Program Benefits and Costs for Different Scenarios

4 Additional Market Readiness Considerations

This section addresses market readiness considerations including marketing, retailer engagement, and the regulatory landscape.

4.1 Current Marketing

Several major manufacturers market one or more lines of tires based on fuel economy statements. For instance, Goodyear claims a 4% fuel economy improvement for Assurance Fuel Max and Assurance CS Fuel Max tires, as compared to a Goodyear product with unspecified rolling resistance.[15] Michelin claims "a level of energy efficiency among the highest in the market" without specifying a level of fuel efficiency or rolling resistance.[16] Bridgestone brands several tire lines as fuel efficient "Ecopia" tires and calculates fuel savings based on 36% lower rolling resistance than a competing brand with unspecified rolling resistance.[17] Manufacturers state that tire materials, structure, and/or tread contribute to fuel savings. These marketing claims indicate some consumer interest in fuel efficient tires and we expect that a rebate program combined with consistent, independently verified information would increase that interest as discussed below.

Retailer interviews indicate that fuel efficient tires may sell at mid-range and premium prices (see Appendix C for additional details). In addition, we informally surveyed prices on TireRack.com for six tires sized for several top selling vehicles.[18] The least expensive tire marketed as a low rolling resistance product costs $11, $14, $14, $15, $25 and $34 more than the least expensive tire for these six sizes. Since these costs are higher than manufacturing costs, fuel economy (as claimed by manufacturers) may be bundled with other tire attributes and/or priced based on marketing strategies in addition to manufacturing cost.

4.2 Retailer Engagement

Bricks and mortar retailers and their sales staff can play a key role in any incentive and education program for several reasons. First, these retailers account for almost all tire sales, as shown in Figure 4.1. Second, consumers often do not conduct research in advance when purchasing tires and they infrequently ask for low rolling resistance tires on their own accord. Therefore, retailer staff can play an important role by providing customer education and marketing fuel efficient tires. Several retailers believe that an incentive program could represent an opportunity to do both. Information on fuel efficient tires provided by SCAQMD could help facilitate the educational process. Third, retailer stocking decisions are also likely to play an

Store Type	Market Share
Independent tire dealers	61%
Mass merchandisers	14%
Warehouse clubs	9%
Tire company stores	8%
Auto dealerships	7%
Misc. outlets	3%
Total	100%

Figure 4.1 Passenger Vehicle Tire Retail Sales

Source: Modern Tire Dealer 2013; note that sum of individual values do not equal 100% due to rounding

[15] http://www.goodyear.com/en-US/tires/category/fuel-efficient
[16] http://www.michelinman.com/tire-selector/category/luxury-performance-touring/energy-saver/tire-details#image_gallery
[17] http://www.bridgestonetire.com/fuel-calculator
[18] One tire size each was surveyed for the model year 2011 Toyota Camry (215 60R16), Nissan Altima (215 60R16), Honda Accord (225/50R17) and two each for the Toyota Corolla (195 65R15 and 205 55R16) and Chevy Silverado (265 70R17 and 275 55R20).

important part in the success of a potential incentive program since consumers value convenience. Ordering tires on demand rather than having them on hand will require customers to wait for delivery, though the waiting period is relatively short with same day or next day delivery. Most retailers have some low rolling resistance tires in stock as well as some flexibility in ordering alternative models. Ideally, an incentive program will increase availability of fuel efficient tires in a wider diversity of market segments.

Additional background on consumer decision-making and the retailer interviews that helped inform this research is available in Appendix C.

4.3 Regulatory Landscape

The current regulatory landscape provides precedents indicating that the market is ready for domestic policy(s) including the South Coast Air Quality Basin. Current policies in the European Union, South Korea, and Japan cover about 490 million tires annually, roughly half of all passenger vehicle tires sold globally (as shown in Figure 4.2) (European Commission Enterprise and Industry, Energy Solutions estimate for South Korea, JATMA). The European Union system contains two tiers of standards and requires labeling new and replacement tires for rolling resistance, wet grip and noise (Figure 4.3) and includes a basic fuel-savings calculator. The South Korean policy is modeled on the European Union system. The Japanese system is limited to labeling of replacement tires (for more details see Pike 2011), but Japan has also adopted a Green Purchasing policy based on RRC of 0.009. These policies not only create a broad precedent for action in California and the U.S. but also raise the question of whether low quality tire products pushed out of these markets could be shuffled to the California and U.S. replacement market if domestic policies are not adopted.

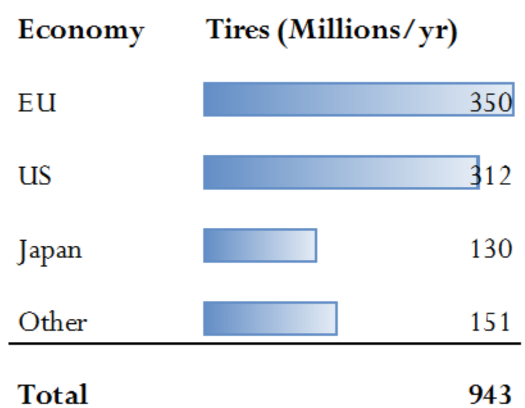

Figure 4.2 Global Passenger Tire Market (millions of tires per year)

Sources: Analysis of data from Rubber News; and Michelin Factbook "Passenger Car and Light Truck 2009".

Tire type	Phase-in Period		Rolling resistance coefficient kg/tonne (dimensionless)		Noise & Wet Grip
	EU Phase 1	EU Phase 2	Phase 1	Phase 2	
C1	Nov 2012-Nov 2014	Nov 2016-Nov 2018	12.0 (0.0120)	10.5 (0.0105)	70-74 dB(A) noise; wet grip index > 1.1 (except snow tires)
C2	Nov 2012-Nov 2014	Nov 2016-Nov 2018	10.5 (0.0105)	9.0 (0.0090)	72-75 dB(A) noise; wet grip pending test method
C3	Nov 2012-Nov 2016	Nov 2016-Nov 2020	8.0 (0.0080)	6.5 (0.0065)	
Tires for passenger and goods vehicles under 3.5 metric tons are categorized as C1. Tires for buses and commercial vehicles are categorized as C2 if they are designed for a maximum load of 1450 kg per tire and a specific speed category; and categorized as C3 if designed for a higher load or different speed category. Rolling resistance is measured according to ISO 28580.					

Figure 4.3 European Union Regulatory System

Several domestic efforts to promote low rolling resistance may be helpful as well. First, California has adopted a "Smartway" program for trucks, setting a precedent for promoting low rolling resistance tires (though not directly regulating the passenger vehicle market), as well as passenger vehicle tire inflation as noted in the text box below. In addition, AB844 (2003) requires the adoption of California passenger vehicle replacement market rolling resistance standards based on achieving fuel efficiency levels comparable to new OEM vehicle tires. A SCAQMD incentive program could move towards achieving this goal either standing alone or implemented along with broader state-wide action. (We note that Ventura County APCD has taken action at the local level by funding a rebate program for up to 1,000 sets of low rolling resistance tires.) In addition, the NHTSA-approved ISO 28580 rolling resistance test method could be leveraged by a potential South Coast AQMD incentive program. (NHTSA intends to re-propose a rating regulation in 2014 and has approved a test method in the meantime.) Thus, implementation of a SCAQMD incentive program could demonstrate the benefits of fuel efficient replacement tires and also influence broader domestic efforts to catch up with international programs.

The U.S., and more recently the European Union, have also established regulations requiring on-vehicle indicators of tire under-inflation. In addition, California has established a "check and inflate" requirement for service shops. Proper tire inflation represents another opportunity to improve tire efficiency and safety as well as durability (Lutsey 2006). For a tire inflated to pressures between 24 and 36 psi, each drop of 1 psi leads to a 1.4% increase in its rolling resistance. The impact is even greater for pressure changes below 24 psi (National Research Council 2006, p. 46).

4.4 Potential Participation Rates

Retailer interviews did not provide enough information to predict a specific consumer participation rate for an initial pilot program. The rebate level, product availability, and retailer marketing efforts are likely to be key considerations to overcome consumers' lack of information and prioritization for fuel efficiency. Additional research on sales volumes and fuel efficient tire availability in different market segments may help indicate potential participation rates for an incentive of a given level. (Ideally, a robust program will encourage retailers to stock fuel efficient tires in a diversity of budget segments and tires sizes.)

We note that fleet customers are a significant complementary opportunity to boost implementation rates. Fleet customers are likely to have a greater awareness of transportation fuel costs and receive a greater cumulative benefit from an incentive program.

5 Incentive Program Design Options

This section describes incentive program design options for fuel efficient tires. This section begins with key aspects of potential program structure and benchmarks for fuel efficiency, safety (measured as traction), and durability. This section also addresses potential participation rates, and verification procedures.

5.1 Incentive Program Structure

We researched the following potential incentive program design structures based on retailer interviews and supplemental research:

- Electronic retailer submittal versus paper mail-in rebates;
- "Midstream" retailer rebates versus "downstream" consumer rebates as explained below; and

- Considerations for setting incentive levels.

The majority of retailers we interviewed prefer electronic "Point-of-Sale" or POS incentives over mail-in rebates. "POS incentive" means incentives processed based on POS records without any additional paper copies of forms and receipts. POS rebates can be submitted based on electronic records and processed automatically after verification, reducing implementation costs and providing consumer convenience. Appendix D lists one example (the Business and Consumer Electronics program). Further, retailers reported that manufacturer incentives offered as mail-in rebates are often dismissed by customers because the rebate occurs later. Therefore, mail-in rebates have a poor follow-through rate unless retailers help customers complete the rebate application.[19]

Retailers have mixed opinions about whether an incentive would be most effective as a direct customer rebate (defined as a "downstream" rebate) or as an incentive to retailers (defined as a "midstream" incentive).[20] A downstream customer incentive program is easy for sales staff to market, is familiar to retailers, and can be displayed on products and receipts as a marketing strategy. On the other hand, a midstream retailer incentive program provides the retailer with more flexibility and options for promoting fuel efficient tires. For example, a midstream program would allow a retailer to decide whether or not to pass the incentive through to the customer, to run promotions and educate consumers, to train and incentivize sales staff, and/or make adjustments to stocking practices. Programs can also be designed to include both "downstream" and "midstream" elements. For example, many of the "midstream" incentive programs sponsored by energy utilities require some element of consumer education.

Midstream programs can often be more cost-effective than downstream programs because retailers compare the incentive amount to their profit margin per tire, as opposed to the selling price. For instance, if retailer's hypothetical net profit after expenses for a $600 set of tire is 10% or $60, then a $20/vehicle incentive could boost net profit for a given model by 33%. Thus, the incentive level (e.g., $/tire) can often be lower compared to a downstream program while achieving equal or greater results.

Retailer interviews provided some guidance in determining potential incentive levels, though they did not pin-point a specific level:

- A defined customer rebate below $40-$50 per set of tires is unlikely to capture consumers' attention, and thus would be ineffective even if fuel efficiency benchmarks were set at a level that could be met with inexpensive incremental production costs. If funding constraints limit potential incentive levels to below $40-$50, we would recommend only considering a midstream approach.

- Incentives should be targeted to customers in the mid-range and premium tire segments unless the incentive is large enough (probably more than $40 per vehicle) to influence budget consumers seeking the least expensive tire.

[19] One retailer participant reported a negative experience with electronic processing (i.e. a manufacturer failed to respond to an electronic rebate application), but also expressed a personal preference as a consumer for electronic processing over paper forms. The retailer also expressed a willingness to "give it another try" and use an electronic system that is proven to be effective. Well-designed and implemented on-line systems will achieve efficient processing and create a positive experience for retailer participants.

[20] "Downstream" and "midstream" terminology is used frequently to describe utility incentive programs. An "upstream" incentive program could also be designed to provide an incentive to a distributor or manufacturer.

5.2 Fuel Efficient Tire Benchmarks

We recommend using RRC rather than RRF as the benchmark for a SCAQMD tire program. RRC is a convenient metric across tire sizes and is potentially easier to communicate to retailers and consumers than RRF. The RRC metric may be somewhat favorable for larger tires. For instance, larger P265 tires tested for the CEC had a 10% lower average rolling resistance than smaller P195 size tires.[21] On the other hand, installing a low rolling resistance tire on a light truck or sport-utility vehicles should deliver comparable air quality benefits for a given percentage reduction in rolling resistance due to higher baseline emissions. This recommendation is specific to a potential SCAQMD incentive program and does not address metrics for other potential purposes such as regulations or providing an on-line fuel savings calculator.

We recommend initially establishing a two-tiered system. For example, the benchmark for the first tier could be less strict than the calculated median OEM tire rolling resistance (0.0082 RRC) to increase availability of qualifying products. We recommend considering a value such as 0.0085 RRC, which represents a 15% improvement over the average replacement tire product and possibly other alternatives. The benchmark for the stricter tier could be slightly stricter than the calculated median OEM tire rolling resistance to create a stretch goal and encourage further improvement. It could potentially also encourage consumers to consider switching market segments if the rebate is large enough. We recommend considering a value such as 0.080 RRC and possibly other alternatives. The two-tiered system may work best with a mid-stream incentive, as educating retailers about this more complicated system would likely be easier than educating individual consumers. (We recommend considering only a mid-stream program if incentive level(s) fall below $40-$50 per vehicle including under a two tiered system.)

5.3 Benchmarks for Safety/Traction and Durability

5.3.1 Safety/Traction

Safety is another important tire attribute that can be addressed by a potential SCAQMD incentive program. Safety is often evaluated based on traction, even though traction is not an all-encompassing metric. Manufacturers could in some cases attempt to trade-off traction for rolling resistance but can also use improved technology to improve rolling resistance without sacrificing traction. The goal is a tire that allows deflection to the extent required to maintain tire contact when hitting bumps in the road while minimizing deformation and decreasing rolling resistance on smooth roads (Michelin 2005; Tyres On-line 2010).

The only national traction rating system at this time relies on manufacturer traction ratings and is based on skidding frictional forces on wet pavement and concrete at 40 mpg (TireRack.com 2013). Manufacturers rate most tires "A" for traction, including low rolling resistance tires tested by the CEC (Pike 2011), and a SCAQMD incentive program could establish the "A" rating as a minimum benchmark. NHTSA is currently considering, but has not yet finalized, a new rating system that could be considered as an alternative method of benchmarking traction in the future.

[21] We recommend selecting either RRC or RRF as a metric for tire policies based on the intended purpose. RRC is a convenient metric across tire sizes and is potentially easier to communicate to retailers and consumers. The European Union, South Korea and Japan use the RRC metric, though no similar domestic precedent has been established. On the other hand, RRF provides a more relevant metric for a consumer wishing to quantify potential fuel savings between specific tires. The RRC for a given tire may not scale precisely with load.

5.3.2 Durability

Durability is also an important tire attribute. Manufacturers could in some cases attempt trade-offs between durability (such as treadwear) and rolling resistance, though we have not found evidence that this would occur.[22] Evaluation of CEC test data for 125 models of tires shows neither a visible correlation between rolling resistance and manufacturer-stated treadwear nor any strong correlation with new tire tread depth (Pike 2011; Energy Solutions 2013). The National Research Council (2006, p.92) and a report commissioned for the European Commission (Smokers et al. 2006, p.120) did not find a strong, adverse correlation between rated tire wear and fuel efficiency. (We note that our cost estimates in other sections are intended to reflect tires without reduced traction.)

We recommend considering a minimum warranty requirement for an incentive program as a backstop against possible trade-offs of durability for lower rolling resistance.[23] While warranties are not a precise indication of durability, a minimum warranty would at least partially mitigate the possibility of back-sliding since manufacturers would be liable for replacement costs under the warranty if they were to produce a lower quality tire.

5.4 Verification Procedures

Product eligibility and sales records verification are important procedures for ensuring that program benefits are achieved. For the first procedure, we recommend collecting test data on rolling resistance and any other characteristics that are needed to determine which tire models would be eligible for a potential incentive program. As noted in Appendix D, the Cool Roof Rating Council (CRRC) is an example of lab accreditation procedures for rating energy efficient products based on ISO standards and similar procedures that could be explored for tires. CRRC verifies testing results data from manufacturers while also conducting random verification testing of rated products. We recommend using the ISO 28580 testing methods approved by NHTSA and other governments internationally as the test method for manufacturer-supplied tire rolling resistance data and independent confirmatory testing.[24] The Multi-State Appliance Standards Collaborative is another example. This program's website features a detailed product database that includes energy consumption ratings and other product attributes that can be used to determine whether products meet energy efficiency standards.

For the second procedure, we recommend electronic processing systems to verify sales records. The Business and Consumer Electronics (BCE) program represents one example. The BCE system provides retailer incentives using a highly efficient paperless online incentive processing system and has processed 4.5

[22] While the possibility of limited decreases in tire durability is difficult to rule out, any potential increase in waste generation that could result should be considered along with the potential for reduced waste production at refineries due to fuel savings. California refineries reported an annual production of 71,371,000 pounds of toxic waste in 2011 (Lee 2013).

[23] For instance, U.S. EPA has estimated a tire life of 40,000 miles for tires on new vehicles. Most tires included in a Consumer Reports presentation had warranties of 50,000 miles or more (Petersen 2012). Manufacturer rated treadwear is not recommended because it is a poor a proxy for durability (Petersen 2012, and TireRack.com 2013) and manufacturers do not face consequences for inaccurate ratings.

[24] There are thousands of tire models on the market, but a much smaller number that are marketed as low rolling resistance tires (manufacturer benchmarks for marketing claims may differ from program eligibility benchmarks). Lab testing fees are likely to range from $200-$300 per tire, and multiple tires, such as three per model, may be appropriate to account for variations between individual tires. Such testing may also be desirable to assess the rolling resistance of tires supplied for the most fuel efficient new vehicles, as well as the best-selling new vehicles. Assuming NHTSA adopts a transparent and reliable rating system, a transition to the NHTSA rating system may be viable.

million high efficiency television incentive applications for California, the Northwest, and Nevada. Please see Appendix D for additional details about these examples.

6 Conclusions and Summary of Recommendations

6.1 Conclusions

Based on our analysis, a fuel efficient passenger vehicle replacement tire incentive program can achieve significant fuel savings and environmental benefits. Key findings include the following:

- Deployment of fuel efficient replacement tires can reduce fuel consumption by 4% on average per passenger vehicle. Hypothetical full deployment over one year (not including early replacement) would achieve a lifetime benefit of 8,800 tons per year of criteria pollutant reductions, 1,500 tons per year of ozone precursor reductions, and 1.6 million tons of CO_2 reductions. A hypothetical demonstration program with an incentive of $50/vehicle and 10% deployment could achieve net benefits of $50-$64 million at a cost of about $9 million and about a 7:1 benefit to cost ratio. Payback periods would be very short.

- Fuel efficiency does not inherently conflict with other desirable characteristics such as durability and traction, and there is no evidence that trade-offs between these attributes are currently occurring. Minimum warranty and traction requirements based on currently available information are one option to mitigate any potential for backsliding. In the future, new NHTSA rating systems may offer another option.

- Fuel efficient products are not currently available for all passenger vehicle replacement market segments (e.g., the budget segment, and to some extent, the mid-range segment), despite modest manufacturing costs. These limitations may be due to bundling fuel efficient characteristics with other features and/or market positioning. Thus, an incentive program should be targeted to shifts within market segments, and eventually increasing product availability, unless incentive levels are large enough to potentially shift consumers between market segments.

- Retailer participation will play a major role in the level of success of a potential incentive program. Retail sales staff could use an incentive to lower upfront retail costs and to educate consumers about fuel efficient tires and/or improve product availability. Retailers generally view the electronic processing systems as an effective implementation option.

- Both retail and fleet consumers can benefit from an incentive and education program.

- A two-tiered incentive based on RRC may be most effective such as 0.0085 and 0.0080 RRC or alternative values.

- A SCAQMD incentive program can capture momentum from international policies and potentially catalyze additional domestic programs.

6.2 Summary of Implementation Recommendations

We recommend the following steps to guide incentive program implementation:

1. Test tires under ISO 28580 for top-selling OEM passenger vehicle tires. This data will help verify the comparability of ISO 28580 results with rolling resistance calculations from test track coast-

down testing reported to the U.S. EPA. We recommend also correlating test data with OEM sales data to provide a sales-weighted average RRC.

2. Develop a list of qualifying products that meet program benchmarks based on rolling resistance, along with data for any other requirements such as warranty and traction. Some products could qualify based on agency-sponsored testing and manufacturers could also opt to qualify additional low rolling resistance products by submitting the appropriate data.
3. Determine incentive levels and structure based on available funding levels and further retailer engagement.
4. Evaluate potential designs for an on-line processing and verification system that contains a list of qualifying products and validates and processes rebate applications.
5. Support a national customer information and labeling program based on verified data and state-level efforts to promote low rolling resistance tires. These additional efforts would complement a SCAQMD program while covering a broader geographic scale. For the time being, SCAQMD should consider the creation of outreach materials to help educate consumers about the benefits of fuel efficient tires.

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Appendix A: Greenhouse Gas Valuation Discussion

(*From "IOU CASE Report: Dimming Fluorescent Lamp Ballasts" submitted to the California Energy Commission July 29, 2013.*)

The climate impacts of pollution from fossil fuel combustion and other human activities, including the greenhouse gas effect, present a major risk to global economies, public health and the environment. While there are uncertainties of the exact magnitude given the interconnectedness of ecological systems, at least three methods exist for estimating the societal costs of greenhouse gases: 1) the Damage Cost Approach 2) the Abatement Cost Approach and 3) the Regulated Carbon Market Approach. See below for more details regarding each approach.

A.1 Damage Cost Approach

In 2007, the U.S. Court of Appeals for the Ninth Circuit ruled that the NHTSA was required to assign a dollar value to benefits from abated carbon dioxide emissions. The court stated that while there are a wide range of estimates of monetary values, the price of carbon dioxide abatement is indisputably non-zero. In 2009, to meet the necessity of a consistent value for use by government agencies, the Obama Administration established the Interagency Working Group (IWG) on the Social Cost of Carbon to establish official estimates (Johnson and Hope).

The IWG primarily uses estimates of avoided damages from climate change which are valued at a price per ton of carbon dioxide, a method known as the damage cost approach.

A.1.1 Interagency Working Group Estimates

The IWG Social Cost of Carbon estimates, based on the damage cost approach, were calculated using three climate economic models called integrated assessment models which include the Dynamic Integrated Climate Economy (DICE), Policy Analysis of the Greenhouse Effect (PAGE), and Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) models. These models incorporate projections of future emissions translated into atmospheric concentration levels which are then translated into temperature changes and human welfare and ecosystem impacts with inherent economic values. As part of the Federal rulemaking process, DOE publishes estimated monetary benefits using Interagency Working Group SCC values for each Trial Standard Level considered in their analyses, calculated as a net present value of benefits received by society from emission reductions and avoided damages over the lifetime of the product. The recent U.S. DOE Final Rulemaking for microwave ovens contains a SCC section that presents the Interagency Working Group's most recent SCC values over a range of discount rates (DOE 2013) as shown in Table A.1. The two values of dollar per metric ton (converted to U.S. tons) used in this report were taken from the two highlighted columns, and converted to 2013 dollars.

Table A.1 Social Cost of CO_2 2010 – 2050 (in 2007 dollars per metric ton of CO_2)

Discount Rate	5.0%	3.0%	2.5%	3.0%
Year	Avg	Avg	Avg	95th
2010	11	33	52	90
2015	12	38	58	109
2020	12	43	65	129
2025	14	48	70	144
2030	16	52	76	159
2035	19	57	81	176
2040	21	62	87	192
2045	24	66	92	206
2050	27	71	98	221

Source: Interagency Working Group 2013

The IWG decision to implement a global estimate of the SCC rather than a domestic value reflects the reality of environmental damages which are expected to occur worldwide. Excluding global damages is inconsistent with U.S. regulatory policy aimed at incorporating international issues related to resource use, humanitarian interests, and national security. As such, a regional SCC value specific to the Western U.S. or California specifically should be similarly inclusive of global damages. Various studies state that certain values may be understated due to the asymmetrical risk of catastrophic damage if climate change impacts are above median predictions, and some estimates indicate that the upper end of possible damage costs could be substantially higher than indicated by the IWG (Ackerman and Stanton 2012, Horii and Williams 2013).

A.2 Abatement Cost Approach

Abating CO_2 emissions can impose costs associated with more efficient technologies and processes, and policy-makers could also compare strategies by estimating the annualized costs of reducing one ton of CO_2 net of savings and co-benefits. The cost of abatement approach could reflect established GHG reduction policies and establish values for CO_2 reductions relative to electricity de-carbonization and other measures. (While recognizing the potential usefulness of this method, this report utilizes the IWG SCC approach and we note that the value lies within the range of abatement costs discussed further below.)

The cost abatement approach utilizes market information regarding emission abatement technologies and processes and presents a wide-range of values for the price per ton of carbon dioxide. California Air Resources Board data of the cost-effectiveness of energy efficiency measures and emission regulations would provide one source of potential data for an analysis under this method. To meet the AB 32 target, ARB has established the "Cost of a Bundle of Strategies Approach" which includes a range of cost-effective strategies and regulations (CARB 2008b). The results of this approach within the framework of the Climate Action Team Macroeconomic Analysis are provided for California, Arizona, New Mexico, the United States, and a global total identified in that same report, as shown in Table A.2 below.

Table A.2 Cost-effectiveness Range for the CAT Macroeconomic Analysis

Exhibit 3: Cost-effectiveness Range for the CAT Macroeconomic Analysis, Selected States, United States, Global -

State	Cost-effectiveness Range $/ ton CO_2eq	Tons Reduced MMtCO_2e/yr	Percent of BAU
California 2020 (CAT[1], CEC[2])	- 528 to 615	132	22
Arizona[3] 2020	- 90 to 65	69	47
New Mexico[4] 2020	- 120 to105	35	34
United States (2030)[5]	-93 to 91	3,000	31
Global Total (2030)	-225 to 91	26,000	45

Source:
1. Climate Action Team Updated Macroeconomic Analysis of Climate Strategies, Presented in the March 2006 Climate Action Team Report, September 2007.
2. California Energy Commission, *Emission Reduction Opportunities for Non-CO2 Greenhouse Gases in California*, July 2005, ICF ($/MTC$0_2$eq).
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Source: CARB 2008b

An Energy and Environmental Economics (E3) study defines the cost abatement approach more specifically as electricity de-carbonization and is based on annual emissions targets consistent with existing California climate policy. Long-term costs are determined by large-scale factors such as electricity grid stability, technological advancements, and alternative fuel prices. Near-term costs per ton of avoided carbon could be $200 per ton (Horii and Williams 2013), thus as noted earlier the value used in this report may be conservative.

A.3 Regulated Carbon Market Approach

Emissions allowance markets provide a third potential method for valuing carbon dioxide. Examples include the European Union Emissions Trading System (EU ETS) and the California AB32 cap and trade system as described below. Allowances serve as permits authorizing emissions and are traded through the cap-and-trade market between actors whose economic demands dictate the sale or purchase of permits. In theory, allowance prices could serve as a proxy for the cost of abatement. However, this report does not rely on the prices of cap-and-trade allowances due to the vulnerability of the carbon allowance market to external fluctuations, the influence of regulatory decisions affecting scarcity or over-allocations, and thus uncertainty of current trading value as a long-term proxy for damages or abatement costs.

A.3.1 European Union Emissions Trading System

The EU ETS covers more than 11,000 power stations, industrial plants, and airlines in 31 countries. However, the market is constantly affected by over-supply following the 2008 global recession and has seen prices drop to dramatic lows in early 2013, resulting in the practice of "back-loading" (delaying issuances of permits) by the European parliament. At the end of June 2013, prices of permits dropped to $5.41 per ton, a price which is well below damage cost estimates and sub-optimal for encouraging innovative carbon dioxide emission abatement strategies.

A.3.2 California Cap & Trade

In comparison, California cap-and-trade allowance prices were reported to be at least $14 per ton in May 2013, with over 14.5 million total allowances sold for 2013 (CARB 2013). Cap-and-trade markets currently cover only subsets of emitting sectors of the industry covered by AB 32.

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Appendix B: EMFAC2011 Output File

(Highlighting added to indicate categories included in baseline emissions for emissions benefit calculations, abbreviations are copied directly from the output file.)

Title : South Coast AQMD Passenger Vehicle Baseline
Version : Emfac2011-LDV V2.50.58.094 Sp: Trip Assign Santa Clara County
Run Date : 2013/07/27 18:10:59
Scen Year : 2014 -- All model years in the range 1970 to 2010 selected
Season : Annual
Area : South Coast AQMD Average
I/M Stat : Enhanced Interim (2005)-Using I/M schedule for area 59 Los Angeles(SC)
Emissions : Tons Per Day

	LDA-TOT	**LDT1-TOT**	**LDT2-TOT**
Vehicles	4,243,120	543,456	1,444,520
VMT/1000	125865	16682	47475
Trips	26388500	3246470	8994700
Reactive Organic Gas Emissions			
Run Exh	8.7	2.87	3.77
Idle Exh	0	0	0
Start Ex	8.54	2.23	3.72
Total Ex	17.24	5.1	7.5
Diurnal	3.06	0.92	1.08
Hot Soak	6.44	1.55	2.29
Running	13.87	5.34	7.47
Resting	2.41	0.65	0.89
Total	43.02	13.56	19.21
Carbon Monoxide Emissions			
Run Exh	272.95	88.36	137.72
Idle Exh	0	0	0
Start Ex	101.76	27.98	48.24
Total Ex	374.72	116.34	185.96
Oxides of Nitrogen Emissions			
Run Exh	23.84	8.59	16.51
Idle Exh	0	0	0
Start Ex	7.05	1.61	4.78
Total Ex	30.89	10.2	21.3
Carbon Dioxide Emissions (000)			
Run Exh	49.67	7.51	25.56
Idle Exh	0	0	0
Start Ex	2.13	0.3	0.99
Total Ex	51.8	7.81	26.54

PM10 Emissions			
Run Exh	0.4	0.13	0.15
Idle Exh	0	0	0
Start Ex	0.1	0.02	0.03
Total Ex	0.5	0.15	0.18
SOx	0.52	0.08	0.27
Fuel Consumption (000 gallons)			
Gasoline	5571.02	852.41	2859.48
Diesel	11.31	0.64	0.58

Appendix C: Market Characterization

C.1 Introduction

This appendix provides additional background information on consumer decision-making and tire retailers as well as the process used to collect market characterization information. As part of this research, we conducted a limited literature review regarding consumer decision-making and consulted selected submittals for the CEC and NHTSA dockets for tire-related rulemaking procedures. We also interviewed several tire retailers to gain a better understanding of the replacement tire market and appreciate the participation of Big Brand Tires, Daniels Tire Service, Mountain View Tires and Sears Automotive Centers. Each interview was approximately thirty minutes and consisted of a series of questions that touched upon more general aspects of the market and the availability of fuel efficient tires described in this appendix. (We also asked questions more specifically related to potential incentive program design, which are addressed in the main report.) Although we did not ask retailers whether they would wish to participate in any potential pilot incentive program, several retailers volunteered to participate on their own initiative.

While we do not intend to provide exhaustive background research, this Appendix provides context in several areas potentially related to a fuel efficient tire incentive program, such as consumer purchasing behavior, product availability, and pricing. Overall, these interviews indicate that the market appears ripe for an effective fuel efficient tire incentive and education program.

C.2 Consumer Decision-Making

Consumer priorities are largely focused on tire price and availability (Petersen 2012) along with durability, tread life and stopping distance. A 2005 study conducted by the Rubber Manufacturers Association (RMA) indicated that tire life, traction and price were the most important factors in new tire purchase decisions, followed by weather handling. Fuel efficiency was listed as a fifth priority, although fuel prices have significantly increased since then.

While fuel efficiency has not been a top priority among consumers, there are opportunities to influence consumer decision-making in the retail environment. Yang and Carmon (2010) contend that many consumers are unable or unwilling to invest much time, effort, or attention in constructing their preferences, and thus, are forced to make decisions "on the fly." The difficulty in making a decision stems not only from the potentially wide selection of choices that are made available but also from the incomplete formation of preferences. This is particularly true when consumers are faced with several options among which to choose from (Yang & Carmon 2010). This general research appears to apply specifically to tires. For example, a Consumer Reports (Consumer Reports 2010) survey found that 56% of consumers did not conduct prior research when purchasing tires for their vehicles. Product labeling and product merchandising will likely affect which products are purchased, and strategic marketing will influence consumers to choose a particular tire, such as a fuel efficient tire, over another.

The retailers we interviewed confirmed that very few, if any, customers ask specifically for energy or fuel efficient tires. Half of the respondents felt it was due to a lack of education and marketing. Some volunteered that a rebate for low rolling resistance tires could be used as a sales point for retailers to educate customers about fuel efficient tires and to provide identification of fuel efficient offerings. One respondent volunteered that motivation of sales staff to sell particular models could have a strong influence on customer decision-making. Retailers were also asked which tire features typically attract customers. Price, durability (as indicated by warranty coverage), comfort, and online reviews were given as consumer priorities for tire purchasing decisions.

In addition, retailers indicated that tire sales increase at certain times of the year (generally late spring/early summer and fall). Manufacturer sales and promotions generally coincide with these popular tire-purchasing seasons. Most but not all retailers offer their own incentives, which can be timed to coincide with manufacturer rebates, while others only offer manufacturer rebates. Thus, peak seasons may be ideal for promotion of a fuel efficient tire incentive program.

C.3 Retail Store Characteristics and Supply Chain

Most tires are still purchased at physical stores, primarily tire stores that are not owned by a specific tire manufacturer. Other retail channels include department stores, warehouse clubs, automaker stores and tire manufacturer-owned stores as shown in Figure 4.1 (Petersen 2012). Online retail is a minor sales channel, though customers may consult Internet sources for tire-related information.

The retailers we interviewed reported that they have participated in rebate or incentive programs offered by manufacturers. Several respondents also volunteered to participate in a pilot incentive program through the SCAQMD, indicating significant potential interest. Retailers tended to feel that a defined customer incentive below $40-$50 would be ineffective. Some indicated that a lower level directed at retailers could influence retailers to stock and promote low rolling resistance tires.

In terms of product availability, retailers reported that most of the well-known tire brands market a line of tires as fuel efficient products. On the other hand, retailers that are affiliated with a specific manufacturer may have some constraints in cases where a very small percentage of the tire offerings from their main manufacturer affiliation are marketed as energy or fuel efficient. Respondents stated that these tires sell at either at a premium price or on-par with other offerings, though one noted that they may be sold at a sale or discounted price.

Retailers gave different answers with respect to product decisions (i.e. what tires are offered by a retailer) that could affect stocking decisions for fuel efficient tires. Some respondents stated that stocking decisions were based on local needs (at the regional or district-level or even at the store-level), whereas one retailer said that every location carried the same tire products. Retailers reported that changes in tire offerings were largely made company-wide, though it appears that retailers have enough flexibility to potentially boost their fuel efficient tire offerings in a region such as the SCAQMD jurisdiction even if they have a wider geographic footprint and typically make company-wide stocking decisions. Another possibility is that if local demand for fuel efficient tires increased sufficiently, company-wide stocking decisions could be revised.

Upstream product changes by the manufacturers would also influence product turnover and opportunities to introduce low rolling resistance tires. (In addition, retailers may not entirely control the decision to carry one brand or model over another). Thus, these retailers may stock a certain tire product that is available from the manufacturer for as little as a year, but more commonly for several years. In some cases, manufacturers are bound by commitments that ensure OEM tires are available in the replacement market for a minimum number of years. Thus, it appears that retailers would typically turnover a given model of tire every several years and stocking decisions may have a persistence of several years absent other over-riding considerations.

We also asked retailers about their distributor channels to determine their ability to supply fuel efficient tires upon customer request, i.e. tires that would qualify for an incentive program but were not routinely carried in stock. Respondents typically purchase stock directly from the manufacturer and then supplement with secondary suppliers. Most have their own warehouses where they keep back stock, while also requesting deliveries from a manufacturer's warehouse and/or a third party warehouse. When asked how quickly retailers could get tires that were not on-hand, all respondents stated they could usually get a tire delivered on the same day (except for orders later in the day). Options include shipments from secondary suppliers as well. Thus, retailers appear to have the flexibility to accommodate customers who are seeking products that qualify for the incentive but are not already in stock when they ask for them, and who are also willing to wait for delivery.

References:

Petersen, E. 2012. "TFECIP Public Workshop." Consumer Reports.

Rubber Manufacturers Association. 2005. "Poll Results: U.S. Drivers' Behaviors and Options Regarding Tire Characteristics in Tire Purchase Decision Making."

Yang, H. and Carmon, Z. 2010. "Consumer Decision Making."

Appendix D: Example Energy Efficient Product Rating & Verification Systems

D.1 Cool Roof Rating Council (CRRC)

Site: http://coolroofs.org/

The CRRC is a self-sustaining 501(c)(3) non-profit educational organization that maintains a third-party energy performance rating system for roofing products, and provides public information and resources regarding those ratings (see figure D.1). CRRC's ratings are used by code bodies such as the California Energy Commission to meet energy efficiency standards and by cities and utility companies to support voluntary cool roof incentive programs.

CRRC ratings are determined by tests conducted by ISO-accredited independent laboratories following CRRC-approved ASTM testing standards and submitted to the CRRC. To ensure that the ratings meet claimed energy efficiency levels, the CRRC audits a percentage of randomly selected products from its product directory each year. In addition, the CRRC Technical Committee conducts and reviews research to support ongoing CRRC Rating program improvements.

The CRRC is guided by a Board of Directors that includes representatives from the California Energy Commission, Lawrence Berkeley and Oak Ridge National Laboratories, as well as a range of roofing manufacturers and industry professionals. The CRRC rating program has been accredited as an American National Standards Institute (ANSI) standard. In addition, the program is also recognized by EPA as a Certification Body for roofing products under the ENERGY STAR program.

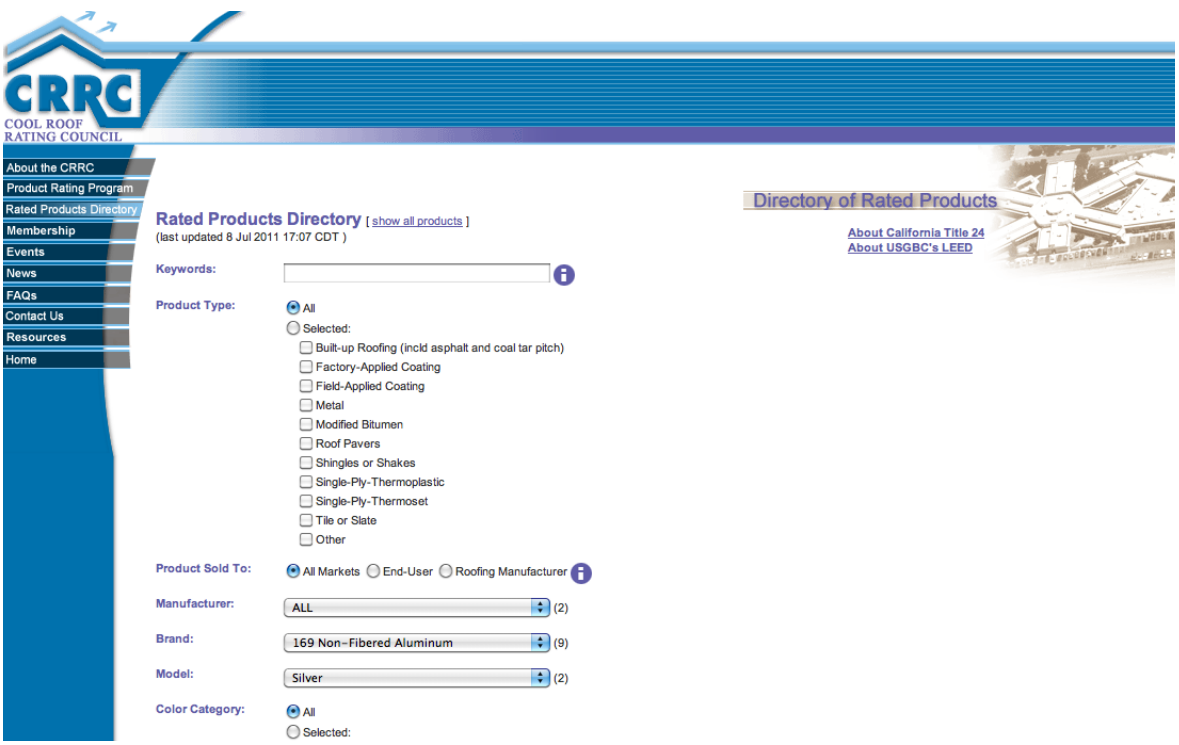

Figure D.1 Cool Roof Rating Council

D.2 Multi-State Appliance Standards Collaborative

Site: http://appliancestandards.org/

In 2006 several states joined together to form the Multi-State Appliance Standards Collaborative under the leadership of the Appliance Standards Awareness Project (ASAP). The Appliance Standards Awareness Project assists several states across the country to greatly reduce the cost of implementing their existing appliance standards programs. States that have participated in ASAP include California, Connecticut, Oregon, Rhode Island, and Washington. The website (see Figure D.2 below) features a detailed product level database including energy consumption ratings and other product attributes. Manufacturers or third party certifiers typically can certify products to the California Energy Commission by providing information including energy consumption data and use this technical certification in several other participating states. The California Energy Commission Certification forms for manufacturers, third party certifiers, and test laboratories can be downloaded at:
http://www.energy.ca.gov/appliances/forms/General_Instructions.pdf.

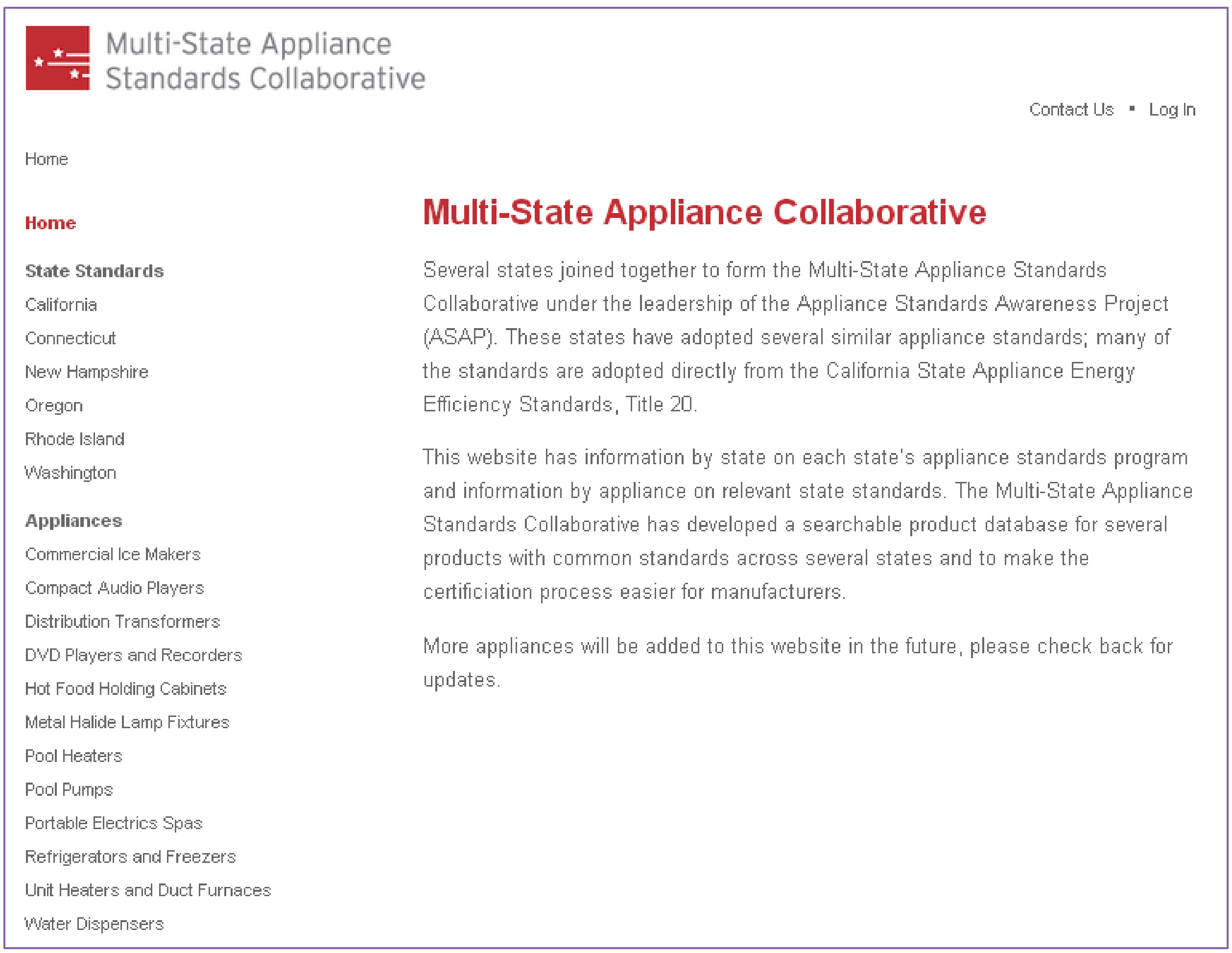

Figure D.2 Multi-State Appliance Standards Collaborative website

D.3 Business and Consumer Electronics Incentive Processing Website

Site: https://www.bceincentives.com/

The Business and Consumer Electronics (BCE) program provides retailer incentives for selling high efficiency televisions, using a highly efficient, paperless online incentive processing system. This system is used to provide incentives for California, the Northwest, and Nevada, which accounts for roughly 20% of the U.S. electronics market. To date, the system has processed 4.5 million applications and over $40 million of incentives since its inception in 2009. Retailers upload their sales data to bceincentives.com, which compares model sales data to the ENERGY STAR Qualifying Product Lists (QPLs) to verify model energy consumption and program qualification. Qualified models receive an incentive while non-qualifying models are rejected. Although the program currently only incentivizes TVs, the system has previously processed applications for a number of other products including desktop computers and monitors. In addition to validating energy consumption, the system has a rigorous sales validation process to ensure that the utilities are only paying for eligible sales within their territory, ensuring that they can claim energy savings for each incentive paid. In addition to providing incentives, the BCE partners actively participate in the ENERGY STAR specification process for a range of consumer electronics products. This includes providing written comments to ENERGY STAR regarding product test procedures, draft program qualifying levels, eligibility criteria, and other relevant topics.

Figure D.3 Business and Consumer Electronics Incentive Site