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Are Cars Still A Problem?

Real-World Emission Reductions from Passenger Vehicles Over the Past 30 Years

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Executive Summary

Recently, auto and oil industry groups have claimed that modern cars emit 96 percent less pollution than 1960s-era cars built before emissions were regulated. However, these claims are misleading. In fact, thirty years of motor-vehicle pollution control regulations have resulted in far fewer reductions from the entire US passenger vehicle fleet than the lowering of emission standards would imply for the following reasons:

- A significant gap exists between emission standards and what cars emit in the real world. The primary sources of these excess real-world emissions are malfunctioning emission control equipment; and aggressive driving behavior and air conditioning operation that are not captured in the regulatory test cycle (i.e., "off-cycle" emissions).
- Total miles driven by all passenger vehicles in the US (cars and light trucks) increased 2.7 times between 1965 and 1995, offsetting substantial amounts of the pollution reductions achieved on a per vehicle basis.
- The market share of light trucks (pickup trucks, minivans, and sport utilities) increased from 15 percent to 40 percent between 1970 and 1995. In most cases, these light trucks have less stringent emission standards than passenger cars, especially for nitrogen oxides. In addition, miles driven by light trucks have increased at a much faster rate than cars: 5.9 times for light trucks versus 2.2 times for cars.

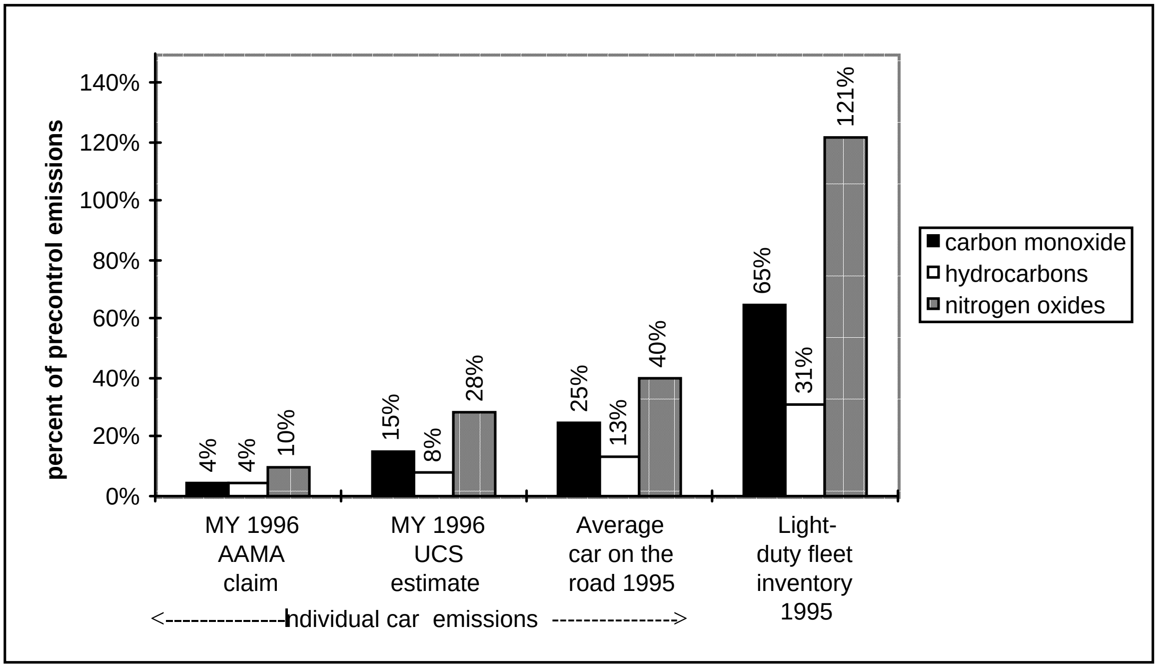
Summary of Our Key Findings

- The claim that an individual modern car is 96 percent cleaner for carbon monoxide and hydrocarbons and 90 percent cleaner for nitrogen oxides than its 1960s, precontrol-era counterpart is overstated. Over its lifetime, the average emission rate for a car is much higher than its emission standard. A modern car will likely emit 4 times more carbon monoxide, 2 times more hydrocarbons, and 3 times more nitrogen oxides (Figure ES-1).
- For the entire US passenger vehicle fleet, emissions reductions have been considerably more modest or non-existent. While emissions of hydrocarbons have been reduced by about two-thirds, emissions of carbon monoxide have been reduced by only one-third, and emissions of nitrogen oxides emissions have actually *increased* by over one-fifth over the past 30 years (Figure ES-2).
- The light truck fleet's share of US passenger vehicle emissions has increased by 1.7 times for carbon monoxide, 2.3 times for hydrocarbons, and 1.3 times for nitrogen oxides over the past 30 years. For the combined inventory of smog-forming pollutants (hydrocarbons and nitrogen oxides), the light truck fleet's share has doubled.
- The passenger vehicle fleet is still the largest single source of carbon monoxide and smog-forming pollutants nationwide. For hydrocarbons and nitrogen oxides separately, it is the second largest source, and its shares of these inventories have not changed appreciably since 1970.

Conclusion

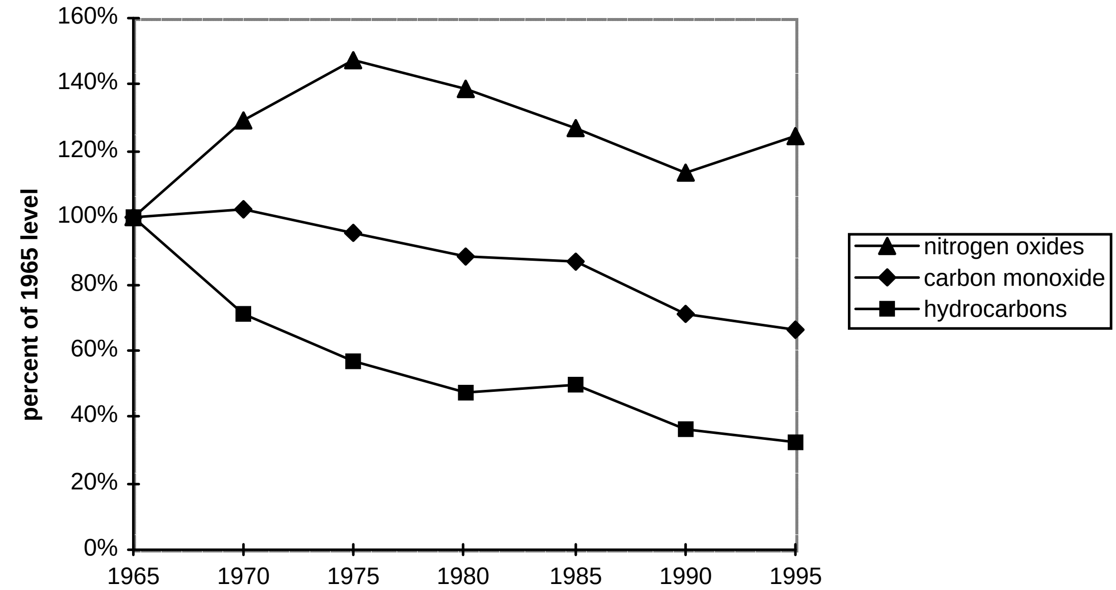
With half of all Americans living in areas that violate national clean air standards, clearly emissions from the passenger vehicle fleet must be reduced. The main strategies that state and federal governments must adopt to reduce pollution from cars and trucks are: lower emission standards to treat light trucks and cars equally; implement well-run inspection and maintenance programs; increase regulatory focus on emission control system durability and off-cycle emissions; and most importantly, promote the introduction of truly advanced, intrinsically-clean vehicle technologies that have lifetime, real-world zero or near-zero emissions.

Figure ES-1. Are Cars Still a Problem? Summary of Real-World Progress in Reducing Emissions over the Past 30 Years



Sources: AAMA claim from *Motor Vehicle 1996 Facts and Figures*, American Automobile Manufacturers Association for a Tier 1 car. All others, UCS estimates based on data from the US Environmental Protection Agency and the US Department of Transportation.
Note: "Light-duty fleet inventory" (or "passenger vehicle fleet") includes the effect of a 2.7 times increase in total miles driven over this period, the 1995 on-road fleet being composed of mostly Tier 0 vehicles rather than Tier 1 cars, and the increased number of light trucks.

Figure ES-2. National Emission Inventories for the Passenger Vehicle Fleet for the Period 1965 to 1995 (includes cars, pickup trucks, minivans and sport utility vehicles)



Sources: 1965 inventory is UCS estimate. All other years from *National Air Pollution Trends, 1900-1995,* US Environmental Protection Agency.

Are Cars Still A Problem?
Real-World Emission Reductions from Passenger Vehicles Over the Past 30 Years

Recent claims state that modern cars emit 96 percent less pollution than 1960s-era cars built before emissions were regulated.[1] Although impressive strides have been made in reducing emissions, actual reductions from individual cars are considerably more modest due to a significant gap between emission standards and what cars emit in the real world. Furthermore, the claim does not account for the tremendous growth in the light truck fleet (pickup trucks, minivans, and sport utility vehicles). Light trucks are increasingly being used as replacements for cars and, in most cases, have less stringent emission standards. Finally, comparing emissions on an individual vehicle basis ignores that since 1965, total miles driven by cars and light trucks almost tripled, offsetting substantial amounts of the emission benefits achieved on a per vehicle basis.

To answer the question "are cars still a problem?," we examine real-world emission reductions for the three primary motor vehicle pollutants (carbon monoxide, hydrocarbons, and nitrogen oxides) on an individual vehicle basis. In order to account the impact of the shift to light trucks and increased travel, we also estimate the change in total emissions from the entire passenger vehicle fleet.[2] Overall, we find that 30 years of motor-vehicle pollution control regulations have resulted in far less reductions from the entire passenger vehicle fleet than the lowering of emission standards would imply. With half of all Americans living in areas that violate national clean air standards,[3] clearly cars and light trucks are still a major contributor to our air pollution problem and more must be done to reduce their actual emissions.

Estimates of Real-World Emissions from Cars and Light Trucks

Emissions Estimates from Individual 1960s, Precontrol Cars

This paper adopts the American Automobile Manufacturers Associations' (AAMA's) estimates of precontrol tailpipe emissions for cars of 84, 10.6, and 4.1 grams per mile of carbon monoxide, hydrocarbons from the tailpipe, and nitrogen oxides, respectively (Table 1).[4] These values are generally consistent with output from our runs of the US Environmental Protection Agency's (EPA's) own model, MOBILE5a, and with results by other researchers. MOBILE5a estimates for the 1965 fleet values that are slightly higher for carbon monoxide (94.8 versus 84 grams per mile), but somewhat lower for tailpipe

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[1] See for example, "Electric cars: still a bumpy ride" Mobil advertisement, *New York Times*, 12/5/96; and "The pollution from the one car on the left was worse than from the twenty-five on the right combined." Boston Alliance for Clean Air Progress, *Boston Globe*.
[2] In this paper, we use the term "passenger vehicle" to include cars and light trucks.
[3] Based on the recently adopted NAAQS standards for ozone and PM2.5.
[4] American Automobile Manufacturers Association, *Motor Vehicle 1996 Facts and Figures*, Detroit, Michigan, 1996.

hydrocarbons (8.3 versus 10.6 grams per mile) and nitrogen oxides (3.2 versus 4.1 grams per mile). Calvert et al. [5] adopts AAMA's values in their paper, and Harley et al.[6] re-estimates almost identical values for carbon monoxide and nitrogen oxides based on a review of data reported in previous studies. They adopt a slightly higher tailpipe hydrocarbon emission estimate based on data reported in Pierson et al.. [7] In general, all these estimates appear to be based on limited data of actual measurements.

Table 1. Estimates of Precontrol and Modern Car Emission Rates
grams per mile

Pollutant	Precontrol[(1)]	Average of 1995 On-Road Fleet[(2)]	Lifetime Average for a Model Year 1996 Tier 1 Car: Emission Standards	Real-World Tailpipe Emissions[(3)]	Ratio of Real-World to Standards
carbon monoxide	84	20.64	3.4	12.5	3.7
hydrocarbons, total	19.7	2.49	na	1.31	na
tailpipe	10.6	1.60	0.25[(4)]	0.81	2.8
evaporative[(5)]	9.1	0.89	2 grams/test	0.5	na
nitrogen oxides	4.1	1.63	0.4	1.15	2.9

1. For evaporative hydrocarbons, UCS estimate. All others, American Automobile Manufacturers Association, *Motor Vehicle 1996 Facts & Figure*s, 1996.
2. National emission factors from Bureau of Transportation Statistics, *Transportation and Air Quality, Selected Facts and Figure,* US Department of Transportation, Federal Highway Administration, 1996.
3. Average over 100,000 lifetime. UCS estimates based on Ross et al., "Real World Emissions from Conventional Passenger Cars," forthcoming article for *Journal of Air and Waste Management*, 1997, and personal communication with Prof. Marc Ross, June 25, 1997.
4. Measured as non-methane hydrocarbons (NMHC). We convert from the 0.25 g/mile standard to total hydrocarbons by dividing by 0.85, yielding 0.29 of total hydrocarbons.
5. Precontrol evaporative emissions includes engine crankcase emissions.

Unlike carbon monoxide and nitrogen oxides, the tailpipe is not the only source of hydrocarbon emissions from a car. Hydrocarbons are also released through evaporation, and in precontrol cars, hydrocarbons were also released directly from the engine crankcase. Evaporative emission standards have been in place since the 1975 model year, and crankcase emissions have been essentially eliminated. Unfortunately, these non-tailpipe emissions from precontrol cars are especially uncertain.[8] Black[9] reports that crankcase and evaporative emissions each contribute about the same (very roughly 20

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[5] J.G. Calvert, J.B. Heywood, R.F. Sawyer, and J.H. Seinfeld, "Achieving Acceptable Air Quality: Some Reflections on Controlling Vehicle Emissions," *Science*, vol. 260, July 2, 1993.
[6] Robert Harley, Robert Sawyer, and Jana Milford, "Updated Photochemical modeling for California's South Coast Air Basin: Comparison of Chemical Mechanisms and Motor Vehicle Emission Inventories," *Environmental Science & Technology*, 31, in press, 1997.
[7] William Pierson, Alan Gertler, and Ronald Bradow, "Comparison of the SCAQS Tunnel Study with Other On-Road Vehicle Emissions Data," *J. Air Waste Manage. Assoc.*, volume 40, no. 11, November 1990.
[8] Pierson et al. 1990.
[9] F. M. Black, "Control of Motor Vehicle emissions – the U.S. Experience," *Critical Reviews in Environmental Control*, 21, 373-410. 1991.

percent each) to the total emissions. Calvert et al.[10] report crankcase emissions of 4.1 g/mile for precontrol cars. MOBILE5a estimates 4.93 grams per mile of "running" and "resting" evaporative losses and 7.15 grams per mile of crankcase emissions. However, while MOBILE5a estimates a higher crankcase emission rate than Calvert et al., it also estimates a lower tailpipe emissions factor for hydrocarbons than AAMA. We adopt MOBILE5a's evaporative emission estimate and Calvert et al.'s crankcase emission estimate. The result of 19.7 grams per mile of tailpipe, evaporative, and crankcase hydrocarbon emissions is about the same as MOBILE5a's result of 20.88 grams per mile.

Estimates of the 1965 Passenger Vehicle Fleet Emissions Inventory

We develop our own estimates for a 1965, passenger vehicle fleet national emissions inventory (Table 2). We choose 1965 as our base year because the first emissions standards began with model year 1966 in California, followed by federal standards starting with model year 1968. We choose to include light trucks (pickup trucks, minivans, and sport utility vehicles) in our fleet emission estimate since the market share of these vehicles have experienced tremendous growth in the last 30 years (from 15 percent of passenger vehicle sales in 1970 to 40 percent in 1994)[11] and are being used mostly as replacements for cars.

We use two methods to estimate a precontrol, 1965 emissions inventory: 1) an original estimate based on our precontrol emissions estimates and published US Department of Transportation (DOT) data on vehicle miles driven; and 2) an estimate based on interpolation of published EPA data. To develop our original, precontrol emissions inventory for 1965, we simply multiply the precontrol emission rates for cars (Table 1) and light trucks (see appendix, Table A1) by their total vehicle miles traveled in 1965. We adjust estimates of vehicle miles traveled published by the US Department of Transportation[12] to match the appropriate categories (Table 3). For light truck emission rates, we adopt AAMA's estimates of precontrol tailpipe emissions of 102, 8.0, and 3.6 grams per mile of carbon monoxide, hydrocarbons from the tailpipe, and nitrogen oxides (Table A1). AAMA cites EPA baseline data as the source of this estimate, and it roughly matches with MOBILE5a output. For evaporative and crankcase emissions from light trucks, we use the same estimate as for cars.

For our other estimate, we generate simple estimates based on published EPA data on the 1960 and 1970 inventories (EPA does not appear to publish a 1965 national emissions inventory). EPA prepares its inventory by combining output from its emission inventory model, MOBILE5a, and data from the Federal Highway Administration on total vehicle miles traveled. Since the 1960 inventory is not broken down beyond the category of

[10] Calvert et al. 1993.
[11] Stacy Davis and David McFarlin, *Transportation Energy Data Book: Edition 16*, prepared for Office of Transportation Technologies, U.S. Department of Energy, prepared by Oak Ridge National Laboratory, Oak Ridge, Tennessee, July 1996.
[12] US Department of Transportation, *National Transportation Statistics 1997*, Federal Highway Administration, US Department of Transportation, Bureau of Transportation Statistics, Washington, D.C., December 1996.

"highway vehicles," we apportion emissions to the car and light truck category in the same shares as the 1970 inventory. Then, we simply linearly interpolate between 1960 and 1970 to obtain a 1965 inventory.

As shown in Table 2 we find the two methods to be roughly consistent for carbon monoxide, but our original estimates to be significantly lower for car hydrocarbons and significantly higher for light truck nitrogen oxides. In general, we believe that our estimates of precontrol emission rates are more reliable than MOBILE5a's estimates. However, to ensure that we do not underestimate emissions progress (and as a consequence, bias our analysis against AAMA's claims), we always adopt the higher of the two estimates.

Table 2. Two Estimates of the 1965 Passenger Vehicle Emissions Inventory
thousands of short tons

	Original Estimate(1)	Estimate Derived from EPA Data(2)	Adopted in this Study(3)
Cars			
carbon monoxide	56,800	65,400	65,400
total hydrocarbons	8,400	14,600	14,600
nitrogen oxides	3,300	3,200	3,300
Light Trucks			
carbon monoxide	14,700	13,000	14,700
total hydrocarbons	2,500	2,100	2,500
nitrogen oxides	1,000	500	1,000
Total			
carbon monoxide	71,500	78,400	80,100
total hydrocarbons	10.900	16,700	17,100
nitrogen oxides	4,300	4,200	4,300

1. Based on our estimates of precontrol emissions estimates (Tables 1 and A1) and vehicle miles driven (Table 3).
2. Based on interpolation of published EPA data of the national emissions inventory.
3. We always adopt the higher value, even though we believe our estimates of precontrol emission rates are more reliable than MOBILE5a's estimates. Hence, if anything, our estimates should overstate emissions progress.

Table 3. Total Vehicle Miles Traveled, 1965 and 1995
billions of miles

Category	1965(1)	1995(2)	Ratio
Passenger Car & Taxi	707	1,541	2.2
Other 2-axle, 4-Tire Vehicles	116	687	5.9
Total	823	2,228	2.7

1. UCS estimates based on data in US Department of Transportation 1996. Since the 1965 data for cars & taxi includes motorcycles and "other 2-axle, 4-tire vehicles" includes "other single-unit 2-axle, 6-tire or more trucks", we adjusted the categories to eliminate these other categories.
2. US Department of Transportation, 1996.

Estimates of Real-World Emissions from Modern Cars

Comparing precontrol emission levels to emission *standards* is inaccurate when characterizing progress in reducing air pollution from cars. Regulators and researchers have long recognized that emissions in the real world are much higher than regulatory standard levels.[13] The primary sources of these excess real-world emissions are failed or malfunctioning emission control equipment; and aggressive driving behavior and air conditioning operation that are not captured in the regulatory test cycle (i.e., "off-cycle" emissions). Furthermore, the focus on *tailpipe* emissions alone ignores evaporative emissions of hydrocarbons from cars, and emissions upstream of the car from refueling, refining, and distributing gasoline. Although we do not estimate reductions in upstream sources, emissions from these sources are significant, accounting for about 7 percent of the total emissions of hydrocarbons and almost 20 percent of nitrogen oxide emissions from a modern car (Table 4).

Table 4. Real-World Emission Estimates, Model Year 1996
Average over 100,000 lifetime

Pollutant-> Source	carbon monoxide	hydrocarbons	nitrogen oxides
1) Hot moderate driving	2.9	0.22	0.26
3) Off-cycle	2.8	0.05	0.24
4) Degradation	1.8	0.14	0.3
5) Malfunction	5	0.4	0.35
subtotal, tailpipe emissions	**12.5**	**0.81**	**1.15**
6) Evaporation	0.0	**0.5**	0.0
7) Upstream	0.063	0.098	0.315
TOTAL	12.56	1.408	1.465

Source: UCS estimates based on Ross et al., "Real World Emissions from Convention Passenger Cars," forthcoming article for *Journal of Air and Waste Management*, 1997. We modified Ross et al.'s estimates based on personal communication with Prof. Marc Ross, June 25, 1997.

For a Tier 1, 1996 model year car, our estimates of lifetime average, real-world tailpipe emissions are based on a recent analysis by Ross et al..[14] They are summarized in Table 1 and shown in more detail in Table 4. Ross et al. estimate real-world emissions for model years 1993 (Tier 0), 2000 (Tier 1), and 2010 (Tier 2) vehicles. We adopt their estimate for a model year 2000 car certified to Tier 1 standards for all of their emission categories except for "evaporative" and "off-cycle" emissions. By model year 2000, they estimate that evaporative emissions will be reduced by new requirements for on-board canisters that absorb vapors from gas tanks, and off-cycle emissions will be reduced somewhat due to a new EPA test cycle procedure. However, since these procedures do not apply to

[13] National Research Council, *Rethinking the Ozone Problem in Urban and Regional Pollution,* National Academy Press, San Francisco, 1991; Calvert et al., "Achieving Acceptable Air Quality: Some Reflections on Controlling Vehicle Emissions," *Science*, vol. 260, July 2, 1993; and Ross et al, *Real World Emissions from Model Year 1993, 2000, and 2010 Cars*, Energy Foundation, San Francisco, 1995.

[14] Marc Ross, Rob Goodwin, Rick Watkins, Tom Wenzel, and Michael Q. Wang, "Real World Emissions from Conventional Passenger Cars," forthcoming article for *Journal of Air and Waste Management*, 1997.

model year 1996 vehicles, we use their model year 1993 estimates for evaporative and off-cycle emissions. Their results are generally consistent with output from MOBILE5a, but provide a more detailed breakdown on the sources of emissions. These values may be somewhat underestimated because they are averaged over a nominal 100,000 mile vehicle lifetime. The average lifetime of vehicles in use has increased from 10.7 years for a 1970 model year car to 13.7 years for a 1990 model year car,[15] about equivalent to a 150,000 mile lifetime. We do not estimate real-world emissions of 1996 model year light trucks. For light trucks under 3,750 lb. loaded vehicle weight (LVW) which must meet the same emission standards as cars, we expect these lighter trucks to have roughly the same real-world emissions as their car counterparts.

The last column in Table 1 illustrates the gap between emission standards and real-world emissions. It demonstrates the inaccuracy of using emission standards to measure actual progress in motor vehicle control. For a 1996 model year car, the real-world carbon monoxide emission levels are almost 4 times higher than the standard levels (Table 1). For hydrocarbon and nitrogen oxides tailpipe emissions, the real-world emission levels are about 3 times higher than the standard levels.[16]

For the on-road passenger vehicle fleet, we use official EPA estimates of emission rates (Table 1) and the emission inventory for 1995 (Table 7). The majority of the cars on the road in 1995 were certified to Tier 0 emission standards that are less stringent than Tier 1 standards.

Real-World Emission Reductions over the Past 30 Years

Emission Reduction Claims by AAMA

The most detailed source of the "96 percent cleaner" claim is the AAMA's annual publication *Motor Vehicle Facts and Figures.*[17] In their various advertisement campaigns to fight new vehicle regulations and clean air standards, other organizations have likely adopted AAMA's claims.

According to AAMA, emission levels for cars built since the 1980s are 96 percent lower for both carbon monoxide and hydrocarbons tailpipe emissions compared to 1960s, precontrol cars.[18] For nitrogen oxides tailpipe emissions, AAMA claims that emission levels of cars built in the 1980s are 76 percent lower than precontrol cars and that emission levels of cars built since the mid-1990s are 90 percent lower than precontrol cars. If these claims were true, the lifetime emissions of an average new car today would

[15] Davis and McFarlin 1996.
[16] Note that this comparison does not imply that regulators underestimate the *current* emission inventory for passenger vehicles by this amount. Ross et al.'s (1995) results are generally consistent with MOBILE5a. However, it is less clear how accurately the models predict the impact of current and upcoming vehicle regulations, technologies, and inspection and maintenance programs on future emission inventories.
[17] AAMA 1996.
[18] The first federal standards limited carbon monoxide and hydrocarbons from model year 1968 cars sold in the US. California led the way by instituting standards beginning in the 1966 model year.

be just 4 or 10 percent of what a precontrol car emitted over its lifetime (Table 5 and Figure 2).

As shown in Table A1 of the appendix, similar, but slightly less impressive, claims are made for light trucks. Light truck emission standards have lagged behind cars, both in terms of implementation (the first federal standards applied in 1975 versus 1968 for cars) and stringency. Currently, the lightest of the light trucks have the same emission standards, but those from 3,750 to 5,750 lb. loaded vehicle weight (LVW) have less stringent emission standards that are 1.75 percent times higher than cars in the case of nitrogen oxides. In addition, light trucks over 6,000 lb. gross vehicle weight (GVW) are a rapidly growing segment of the light truck market. These trucks are not listed in AAMA's annual publication *Motor Vehicle Facts and Figures*, but their emission standards are even less stringent with the nitrogen oxide standard being 2.75 higher than cars.

Careful interpretation of AAMA's claims reveals that they are only accounting for changes in tailpipe emission *standards* and not actual emissions of cars and light trucks in the real world. Furthermore, since precontrol cars by definition had no emission standards, they are comparing tailpipe standard levels to estimates of precontrol emission rates that are based on actual measurements. A more accurate characterization of AAMA's claim is that tailpipe emissions *standards* are 90 to 96 percent lower than their estimates of precontrol vehicle emissions *rates*.

Table 5. Reductions in Emissions Rates from Modern Cars Compared to Precontrol Cars

Pollutant	Precontrol versus	Precontrol versus Model Year 1996 Tier 1[1]	
	Average 1995 On-Road Car	AAMA claim[2]	Real-World
carbon monoxide	75%	96%	85%
hydrocarbons, total	87%	–	93%
tailpipe	85%	96%	92%
evaporative[3]	90%	–	95%
nitrogen oxides	60%	90%	72%

1. Tier 1 cars certified for sale in 49 states (except California) starting in model year 1994.
2. American Automobile Manufacturers Association, *Motor Vehicle 1996 Facts & Figure*s, 1996. Note that AAMA's claims for Tier 0 and Tier 1 car hydrocarbon reductions are identical (both 96%) despite the fact that Tier 1 cars have a 0.25 non-methane hydrocarbon standard. However, according to AAMA, a total hydrocarbon standard identical to the Tier 0 car standard (0.41 g/mile) also applies to Tier 1 cars.
3. Precontrol evaporative emissions includes engine crankcase emissions.

Progress in Emission Reductions from Individual Cars:
Precontrol Car versus 1996 Model Year Car

As shown in Table 5, when real-world estimates are used to estimate emission reductions on a per vehicle basis over the past 30 years, the results are considerably more modest. Rather than AAMA's claim of 96 percent for carbon monoxide and hydrocarbons, carbon monoxide emissions have actually been reduced by about 85 percent and total hydrocarbons have been reduced by about 93 percent. For nitrogen oxides, the real-world emission reduction is 72 percent rather than the 90 percent claimed by AAMA.

Table 6. Emissions Rates from New Cars as Percent of Precontrol Cars (i.e., "Residual" Emissions)

Pollutant	Precontrol versus Average of 1995 On-Road Fleet	Precontrol versus Model Year1996 Tier 1[1]		
		AAMA claim[2]	Real-World	Factor Over-statement
carbon monoxide	25%	4%	15%	3.8
total hydrocarbons	13%	–	7%	–
tailpipe	15%	4%	8%	2.0
evaporative[3]	11%	–	6%	–
nitrogen oxides	40%	10%	28%	2.8

1. Tier 1 cars certified for sale in 49 states (except California) starting in model year 1995.
2. See note 2, Table 2.
3. Precontrol evaporative emissions includes engine crankcase emissions.

In terms of fraction of precontrol emission levels, AAMA's claim that an individual modern car has only 4 or 10 percent of the emissions of a precontrol car is exaggerated by factors of about four, two, and three, for carbon monoxide, hydrocarbons, and nitrogen oxides, respectively (Table 6). These factors correspond to the ratio of real-world emissions to standards shown in Table 1 for carbon monoxide and nitrogen oxides (slight difference is due to rounding).

For hydrocarbons, AAMA bases its 96 percent lower emissions claim on the higher of the two standards that apply, 0.41 gram per mile *total* hydrocarbon rather than the 0.25 gram per mile non-methane hydrocarbon standard. We estimate a 0.25 gram per mile non-methane hydrocarbon standard to be equivalent to about 0.29 gram per mile of total hydrocarbons. Hence in Table 1, our ratio of real-world emissions to standards is based on the more stringent standard while the "factor overstatement" in Table 6 is based on AAMA's claim that uses 0.41 grams per mile.

Progress in Emission Reductions from Individual Cars: Precontrol Car versus Average On-Road Car in 1995

Since the average car on the road in 1995 was only about half as clean as a model year 1996 car, progress in emission reductions for the average passenger vehicle on the road today is considerably less than a model year 1996 car. As shown in Table 5, emissions have been reduced by 75, 87, and 60 percent for carbon monoxide, hydrocarbons, and nitrogen oxides. In terms of fraction of precontrol emission levels, Table 6 shows that the average on-road car in 1995 had about 25, 13, and 40 percent of carbon monoxide, hydrocarbons and nitrogen oxides, respectively, of the emissions of a precontrol car. Emission reductions for an average on-road light truck in 1995 is similar to cars except for nitrogen oxides which is somewhat lower, 55 percent rather than 40 percent of precontrol levels for cars (Table A1).

Emission Reductions from the Entire Passenger Vehicle Fleet

A comparison of emissions on an individual vehicle basis is a misleading indicator of progress in meeting air quality goals. Over the last 30 years, vehicle ownership and miles driven per vehicle have both increased, resulting in a 2.7 times increase in total miles driven. Miles driven by light trucks with higher emission rates than cars, have increased at a much faster rate: 5.9 times for light trucks versus 2.2 times for cars (Table 3).[19] These trends have offset substantial amounts of the emission reductions achieved on a per vehicle basis. Regulatory efforts to reduce emissions from the passenger vehicle fleet have been only moderately successful for carbon monoxide and unsuccessful for nitrogen oxides (Table 7 and Figure 1). Comparing EPA's 1995 national emission inventory to our estimate of the 1965 precontrol inventory shows that the carbon monoxide and hydrocarbons emission inventories have been reduced by only 35 and 69 percent, respectively, between the years 1965 and 1995.[20]

Table 7. Passenger Vehicle National Emission Inventory, 1965 and 1995

	Emission Inventory		Change in
	1965[1]	1995[2]	Inventory
	thousand short tons		*percent*
Cars			
carbon monoxide	65,400	35,786	-45%
total hydrocarbons	14,600	3,584	-75%
nitrogen oxides	3,300	3,598	+9%
hydrocarbons + nitrogen oxides	17,900	7,182	-60%
Light Trucks			
carbon monoxide	14,700	16,292	+11%
total hydrocarbons	2,500	1,783	-29%
nitrogen oxides	1,000	1,624	+62%
hydrocarbons + nitrogen oxides	3,500	3,407	-3%
Total			
carbon monoxide	80,100	52,078	-35%

[19] In terms of average per annum growth rates, passenger vehicle miles driven grew at a rate of 5 percent, light trucks at 9 percent, and cars at 4 percent.

[20] As noted earlier, using a 1970 baseline shows similar, but slightly less dramatic, results. Emissions progress from the passenger vehicle fleet are 35, 55, and 4 percent reductions for carbon monoxide, hydrocarbons, and nitrogen oxides, respectively, using a 1970 baseline.

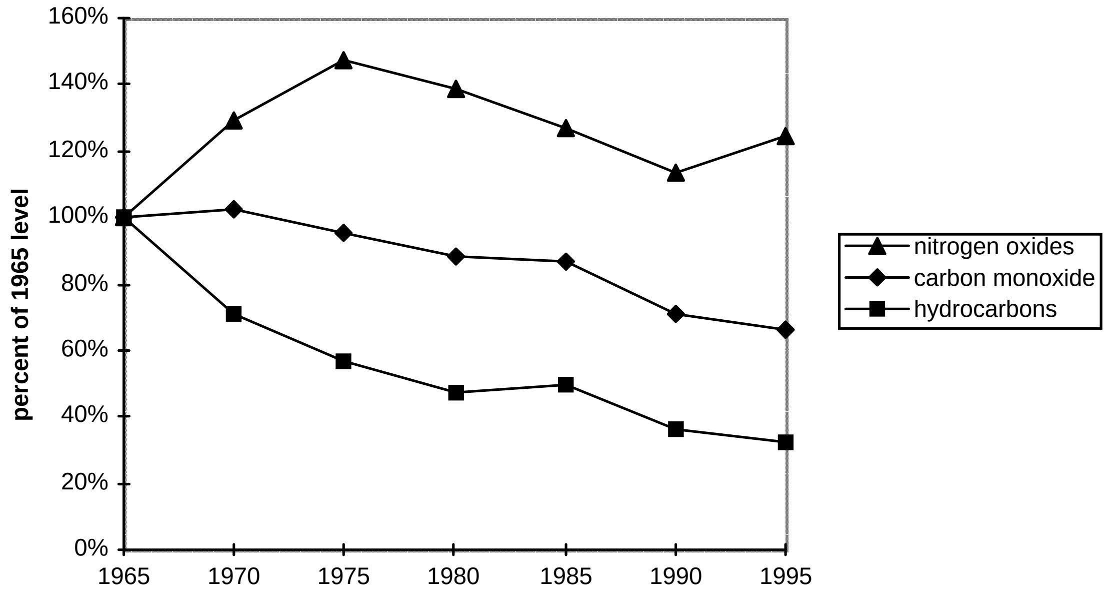
total hydrocarbons	17,100	5,367	-69%
nitrogen oxides	4,300	5,222	+21%
hydrocarbons + nitrogen oxides	21,400	10,589	-51%

1. UCS estimates based on data from the American Automobile Manufacturers Association and the Bureau of Transportation Statistics.
2. US Environmental Protection, *National Air Pollution Trends, 1990-1995*.

For nitrogen oxides, we estimate that the national emission inventory of nitrogen oxides has actually *increased* between 1965 and 1995 by over 20 percent,[21] with most of the the growth occurring between 1965 and 1975 (Figure 1). Besides the rise in overall miles driven, the increase can be attributed to two other factors. First, in its past strategy to reduce smog, EPA has emphasized reducing hydrocarbons rather than nitrogen oxides.[22] Consequently, EPA has not lowered nitrogen oxide emission standards as rapidly as hydrocarbons. In fact, EPA did not regulate the emissions of nitrogen oxides from cars until the 1973 model year, a full five model years after hydrocarbons and carbon monoxide were first controlled. As a result, the manufacturers' strategy to meet the first hydrocarbon and carbon monoxide standards actually resulted in a 50 percent increase in nitrogen oxide emissions (to about 6 grams per mile).[23] For the fleet, nitrogen oxide emissions peaked at a 40 percent increase over 1965 levels in 1975 and have been on the rise again since 1990 (Figure 1). Secondly, over the past 30 years, miles driven by light trucks have sharply increased, and most of these vehicles were subjected to less stringent emission regulations. As a result, the near halving of the nitrogen oxide emissions from individual on-road vehicles between 1965 and 1995 was more than offset by the 2.7 times increase in miles driven over this period.

[21] This is a conservative estimate. Using our original estimate (Table 2) yields a 40 percent increase.
[22] Calvert et al. 1993.
[23] Calvert et al. 1993.

Figure 1. National Emission Inventories for the Passenger Vehicle Fleet for the Period 1965 to 1995 *(includes cars, pickup trucks, minivans and sport utility vehicles)*



Sources: 1965 inventory is UCS estimate. All other years from *National Air Pollution Trends, 1900-1995,* US Environmental Protection Agency.

Policy Implications: Are Passenger Vehicles Still Part of the Problem?

To determine if passenger vehicles are still major contributors to our air pollution problem, we examine EPA's national emissions inventory.[24] We find that passenger vehicles are still the largest single source of carbon monoxide and the second largest single source of hydrocarbons and nitrogen oxides.[25] They account for 56, 23, and 24 percent of the 1995 national emissions inventory for carbon monoxide, hydrocarbons, and nitrogen oxides, respectively. Control programs have been the most successful for hydrocarbons where their contribution has been reduced from 39 percent in 1970 to 24 percent in 1995, yet passenger vehicles by themselves are still the second largest category contributing to the inventory. The passenger vehicle fleet's contributions to the carbon monoxide and nitrogen oxides inventories have not changed appreciably since 1970.

Clearly, passenger vehicles are still a major contributor to our air pollution emissions and more must be done to reduce their emissions in the real world. As we have seen from the past 30 years, it has proven difficult to develop a regulatory scheme that works as well in the real world as it does on paper. Past control strategies that have primarily emphasized lowering the certification emission levels of gasoline vehicles have not resulted in

[24] US Environmental Protection Agency, *National Air Pollution Trends, 1900-1995,* Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. October 1996. EPA-454/R-96-007.

[25] Note that this assessment is based on EPA's source categories, except we separate out the passenger fleet from the "On-road Vehicles" category. When heavy and medium-duty trucks are included, the total on-road motor vehicle fleet is the largest single source of carbon monoxide and nitrogen oxides, and a very close second source of hydrocarbons.

commensurate reductions in the real world. By focusing on emission standards, regulators have inadvertently allowed automobile manufacturers to exploit loopholes in the regulations, such as "off-cycle" emissions and lower quality emission control systems.

Table 8. National Emissions Inventory for Non-miscellaneous Sources Over 5 Percent of the Total Inventory, 1970 and 1995

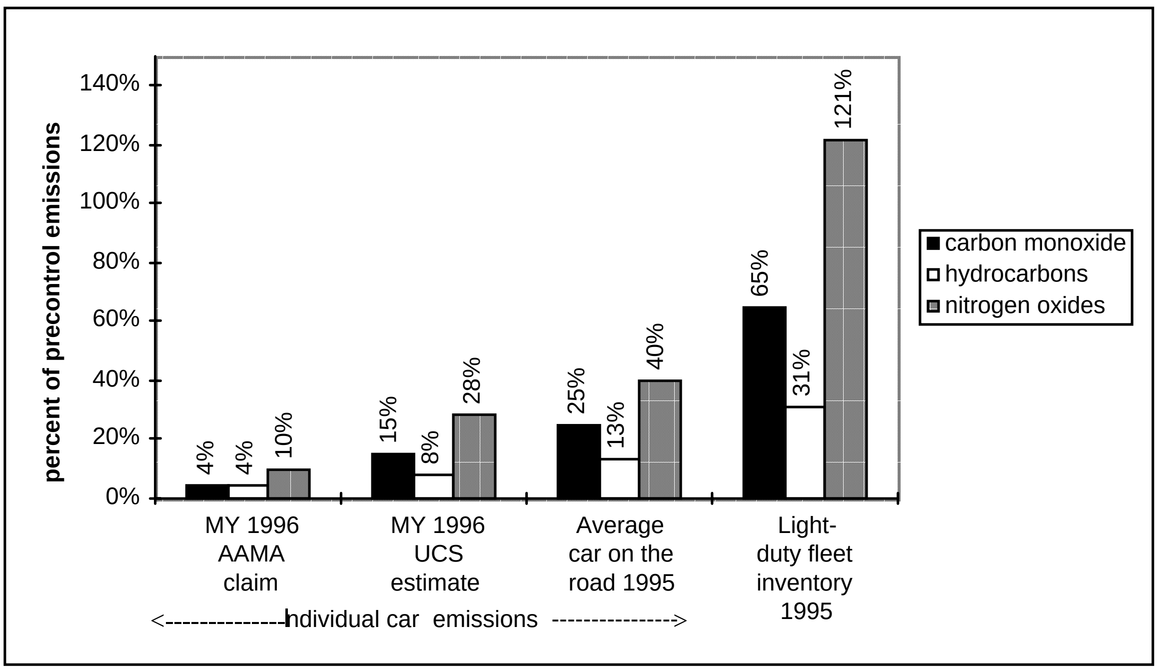
Pollutant	Source Category	1970	1995	1970	1995
		thousands of short tons		*percent*	
Carbon Monoxide	All On-road Mobile Sources[1]	88,034	58,624	69%	64%
	passenger vehicles only	***80,416***	***52,082***	***63%***	***57%***
	Non-road Mobile Sources	10,605	15,622	8%	17%
	All others	29,440	17,853	23%	19%
	Total	128,079	92,099		
Hydrocarbons	Solvent Utilization	7,174	6,394	23%	28%
(measured as volatile	All On-road Mobile Sources	12,972	6,104	42%	27%
organic compounds)	***passenger vehicles only***	***11,903***	***5,367***	***39%***	***23%***
	Waste Disposal & Recycling	1,984	2,411	6%	11%
	Non-road Mobile Sources	1,542	2,252	5%	10%
	Storage & Transport	1,954	1,803	6%	8%
	Chemical & Allied Prod.	1,341	1,617	4%	7%
	All others	3,679	2,284	12%	10%
	Total	30,646	22,865		
Nitrogen Oxides	All On-road Mobile Sources	7,390	7,605	36%	35%
	passenger vehicles only	***5,434***	***5,222***	***26%***	***24%***
	Electric Utilities	4,900	6,233	24%	29%
	Fuel Comb. Industrial	4,325	3,137	21%	14%
	Non-road Mobile Sources	1,628	2,996	8%	14%
	All others	2,382	1,808	12%	8%
	Total	20,625	21,779		
Hydrocarbons plus	All On-road Mobile Sources	20,362	13,709	40%	31%
Nitrogen Oxides	***passenger vehicles only***	***17,337***	***10,589***	***34%***	***24%***
	Solvent Utilization	7,174	6,397	14%	14%
	Electric Utilities	4,930	6,268	10%	14%
	Non-road Mobile Sources	3,170	5,248	6%	12%
	Fuel Comb. Industrial	4,475	3,272	9%	7%
	Total	51,271	44,644		

Source: US Environmental Protection Agency 1996.
1. "On-road Mobile Sources" includes cars, light trucks, medium trucks, heavy trucks, and motorcycles. "Passenger vehicles only" is a subset of "On-road Mobile Sources" that includes only gasoline cars and light trucks.

Current policies that address the realities of the current on-road passenger vehicle fleet must be maintained. While methods to identify and repair malfunctioning individual vehicles through inspection and maintenance programs have proven much more difficult to implement in practice, these efforts must not be abandoned. However, future inspection and maintenance programs that assigns the majority of the blame for in-use emissions to drivers are, in our opinion, bound to fall short of ambitious goals set by regulators due to a complex mixture of technical difficulties, consumer politics, and regulatory fallibility.

New regulatory initiatives should focus on incentivizing auto manufacturers to build more durable emission control systems for conventional gasoline vehicles. This can be done through increased regulatory and market attention to emission control system durability and "off-cycle" emissions. In addition, programs aimed at commercializing truly advanced, *intrinsically*-clean vehicles (i.e., battery electric vehicles, well-designed hybrid electric vehicles running on clean fuels, and hydrogen fuel cell vehicles) are the cornerstone of any serious plan for attainment and maintenance of clean air standards. These vehicles have the key attributes of zero or near-zero emissions both when certified and when subjected to real-world driving and maintenance conditions. Furthermore, these technologies will also reduce energy consumption and CO_2 emissions, the primary greenhouse gas. Integrated federal and state vehicle technology program goals are necessary to ensure that the "next generation vehicle" technologies will truly meet the air quality and carbon constraints of the 21st century.

Figure 2. Are Cars Still a Problem? Summary of Real-World Progress in Reducing Emissions over the Past 30 Years



Sources: AAMA claim from *Motor Vehicle 1996 Facts and Figures*, American Automobile Manufacturers Association for a Tier 1 car. All others, UCS estimates based on data from the US Environmental Protection Agency and the US Department of Transportation.
Note: "Light-duty fleet inventory" (or "passenger vehicle fleet") includes the effect of a 2.7 times increase in total miles driven over this period, the 1995 on-road fleet being composed of mostly Tier 0 vehicles rather than Tier 1 cars, and the increased number of light trucks.

Conclusions

Contrary to industry's claims that an individual modern car is 90 to 96 percent cleaner than its precontrol counterpart built in the 1960s, we find that in the real-world reductions are considerably lower (see Figure 2 for a graphical summary of our results). Our analysis uses estimates of what vehicles are actually emitting on the road instead of emissions standards. We estimate that a model year 1996 car has reduced carbon monoxide, tailpipe hydrocarbons, and nitrogen oxides reductions by about 85, 93, and 72 percent, respectively. In terms of fraction of precontrol emission levels, industry's claim that an individual modern car has only 4 or 10 percent of the emissions of its precontrol counterpart is exaggerated by factors of roughly four, two, and three for carbon monoxide, hydrocarbons, and nitrogen oxides, respectively.

The rising number of miles driven has offset, and will continue to offset, substantial amounts of the emission reductions achieved on a per vehicle basis. Over the past 30 years, the number of miles driven by the passenger vehicle fleet has increased by 2.7 times. In addition, miles driven by light trucks, that have higher emission rates than cars, have increased at a much faster rate: 5.9 times for light trucks versus 2.2 times for cars. As a result, the light truck fleet's share of smog-forming pollutants (hydrocarbons and nitrogen oxides combined) has doubled over the past 30 years. For the passenger vehicle fleet as a whole, the national emission inventories of carbon monoxide and nitrogen oxides have been reduced by only 35 and 69 percent, respectively, between 1965 and 1995. Somewhat surprisingly, we find that the emission inventory for nitrogen oxides has actually *increased* by over 20 percent between 1965 and 1995.

The passenger vehicle fleet is still the largest single source of carbon monoxide and smog-forming pollutants. It is the second largest source of hydrocarbons and nitrogen oxides separately. Furthermore, its contributions to the carbon monoxide and nitrogen oxides inventories have not changed appreciably since 1970. It is clear that more must be done to reduce emissions from cars and light trucks if regions are to meet clean air standards. The main strategies that state and federal governments must adopt to reduce pollution from cars and trucks are: lower emission standards to treat light trucks and cars equally; implement well-run inspection and maintenance programs; increase regulatory focus on emission control system durability and off-cycle emissions; and most importantly, promote the introduction of truly advanced, intrinsically-clean vehicle technologies that have lifetime, real-world zero or near-zero emissions.

APPENDIX: Further Details of Calculations

Table A1. Estimates of Precontrol and Modern Light Truck Emission Rates
grams per mile

Pollutant	Precontrol[1]	Average of 1995 On-Road Fleet[2]	MY 1996 Standards 0-3,750 lb. LVW	MY 1996 Standards 3,751-5,750 lb. LVW
carbon monoxide	102	27.58	3.4	4.4
hydrocarbons, total	17.1	3.39		
tailpipe	8.0	2.32	0.25[3]	0.32[3]
evaporative[4]	9.1	1.07		
nitrogen oxides	3.6	1.99	0.4	0.7

1. For evaporative hydrocarbons, UCS estimate. All others, American Automobile Manufacturers Association, *Motor Vehicle 1996 Facts & Figure*s, 1996.
2. National emission factors from Bureau of Transportation Statistics,*Transportation and Air Quality, Selected Facts and Figure,* US Department of Transportation, Federal Highway Administration, 1996.
3. Measured as non-methane hydrocarbons (NMHC). We convert from NMHC to total hydrocarbons by dividing by 0.85.
4. Precontrol evaporative emissions includes engine crankcase emissions.

Table A2. Reductions in Emissions Rates from Modern Light Trucks Compared to Precontrol Light Trucks

		AAMA claims[1]	
Pollutant	Precontrol versus Average of 1995 On-Road Fleet	MY 1996 0-3,750 lb. LVW	MY 1996 3,751-5,750 lb. LVW
carbon monoxide	73%	97%	96%
total hydrocarbons	79%	–	–
tailpipe	71%	97%	96%
evaporative[2]	87%	–	–
nitrogen oxides	45%	89%	81%

1. American Automobile Manufacturers Association, *Motor Vehicle 1996 Facts & Figure*s, 1996. Note that AAMA's claims for Tier 0 and Tier 1 car hydrocarbon reductions are identical (both 96%) despite the fact that Tier 1 cars have a 0.25 non-methane hydrocarbon standard. However, according to AAMA, a total hydrocarbon standard identical to the Tier 0 car standard (0.41 g/mile) also applies to Tier 1 cars.
2. Precontrol evaporative emissions includes engine crankcase emissions.

Table A3. Passenger Vehicle National Emission Inventory, 1965 and 1995

	Emission Inventory	
	1965[1]	1995[2]
	percent of inventory	
Cars		
carbon monoxide	82%	69%
total hydrocarbons	85%	67%
nitrogen oxides	77%	69%
hydrocarbons + nitrogen oxides	84%	68%
Light Trucks		
carbon monoxide	18%	31%
total hydrocarbons	15%	33%
nitrogen oxides	23%	31%
hydrocarbons + nitrogen oxides	16%	32%