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Reducing Automobile Emissions in Southern California: The Dance of Public Policies and Technological Fixes

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REDUCING AUTOMOBILE EMISSIONS IN SOUTHERN CALIFORNIA: THE DANCE OF PUBLIC POLICIES AND TECHNOLOGICAL FIXES

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For many years I have taught at a small liberal arts college in Southern California. When first-year students arrived at the college in the early 1970s, they settled into the usual things that occupy freshmen. A few weeks would go by, and then they would make a remarkable discovery: tall mountains would appear to the north as autumn weather dissipated the heavy blanket of smog that had obscured them. Today, the air is not perfectly clear in September, but students are aware of the mountains from the day they move into the dormitories. The region's partial victory over smog illustrates the successful use of technological fixes for a problem that was itself caused by technology. But it also shows that technological fixes have to be complemented by appropriate policies if they are to be successful. Moreover, these policies have to resonate with the political environment if they are to have a chance of success. This essay does not attempt to provide a comprehensive review of the war against smog. Rather, it presents a brief description of technologies used to reduce the emissions of cars and light trucks, followed by a summation of the government polices that have motivated the development and use of these technologies. These provide a background for the final section of the essay, which notes some of the circumstances under which technological advances can be stimulated by appropriate public policies.

HOW CARS MAKE SMOG

In the 1940s, residents of Southern California began to notice an atmospheric condition that obscured their vision, irritated their eyes, and hindered their breathing. It was dubbed "smog," an etymological mixture of "smoke" and "fog," although its actual constitution was far more complicated.

A major contributor to air pollution in Southern California was the exhaust from cars and trucks, a fact vehemently denied by the automobile industry until it was irrefutably proven by Arie Haagen-Smit at the California Institute of Technology in the early 1950s. Today, cars and light trucks account for about 60 percent of smog-creating emissions in the region, so any successful effort to reduce air pollution has to take full account of the emissions produced by the region's large vehicle population.

Motor vehicle emissions are converted to smog through a series of chemical reactions that occur in the presence of sunlight.[1] Uncontrolled vehicles produce the constituents of smog in a number of ways: through the venting of vaporized gasoline, the emission of gases from the engine's crankcase, and most important through the combustion process that converts gasoline into the power that propels them. When a charge of air and vaporized fuel is compressed and then ignited in an engine's combustion chamber, not all of the fuel is completely combusted; some unburned hydrocarbons are emitted. At the same time, high temperatures and pressures within the combustion chamber convert atmospheric nitrogen into various oxides of nitrogen (NOx for short). The exhaust gases are then released into the atmosphere, where the ultraviolet portion of sunlight breaks down NO_2, one of the oxides of nitrogen, into NO. The liberated oxygen atoms then combine with atmospheric oxygen (O_2) to produce one of the major constituents of photochemical smog: ozone (O_3), a major irritant to the respiratory system. At the same time, other oxides of nitrogen are converted into a variety of compounds, notably the peroxyacyl nitrates that contribute to the eye-burning effects of smog. Residual NO_2 adds to the general nastiness by obscuring vision with a brown haze.

Combustion of gasoline in an engine also produces carbon monoxide (CO), carbon dioxide (CO_2), water vapor, sulfur dioxide, and particulates. Strictly speaking, these are not constituents of photochemical smog. They are still a significant problem, however. Recent years have seen a growing concern about the emission of CO_2 into the atmosphere because it may contribute to a "greenhouse effect" and consequent global warming. Solid proof of this phenomenon remains elusive, but the increasing likelihood that today's cars and trucks are contributing to global warming may necessitate the eventual supplantation of fossil-fuel burning internal-combustion engines by other sources of power; no matter how clean it is in other respects, an internal-combustion engine powered by a carbon-based fuel will always produce CO_2.

INDICATIONS OF IMPROVED AIR QUALITY

Although no technology for the control of CO_2 exists, substantial progress has been made in the reduction of other emissions, and the skies over Southern California are much cleaner as a result. This accomplishment has been significant, for Southern California is the ideal location for the production of photochemical smog: it has a huge car population, valleys that trap stagnant air, and a frequent inversion layer that prevents emissions from dissipating into the upper atmosphere. For many years it seemed as though the region would be perpetually blighted, but technological advances have produced a noticeable improvement in air quality through a reduction of vehicular emissions and other measures. By the 1990s, tailpipe emissions of carbon monoxide and hydrocarbons had been reduced by 96 percent compared to cars built in the 1960s, while oxides of nitrogen have been reduced by 76 percent. The impressive progress that has been made in reducing air pollution can be seen in the dramatic reduction of one index of smog severity, the con-

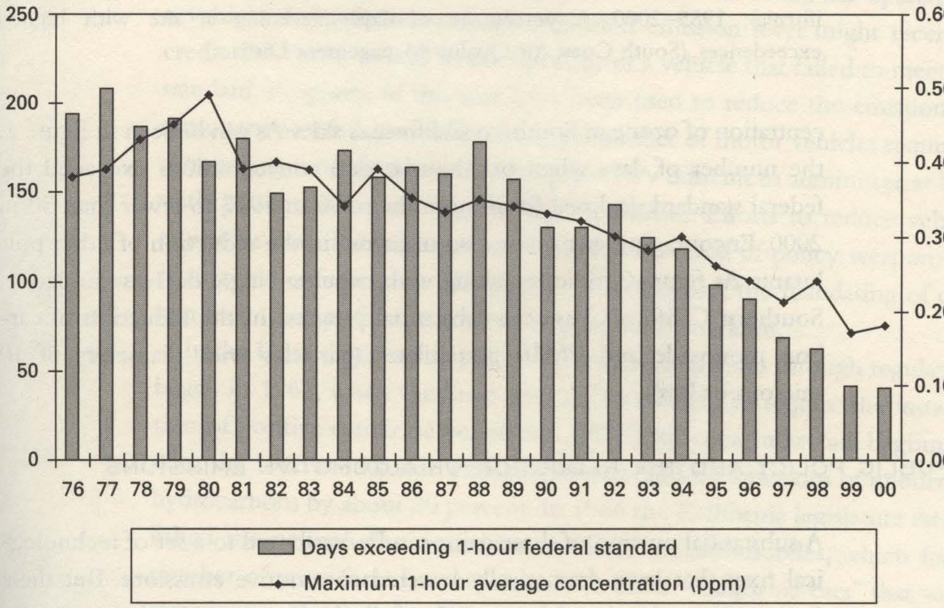

FIGURE 1

Ozone air quality trends, South Coast Air Basin (California), 1976–2000. Left vertical axis: days exceeding 1-hour federal standard. Right vertical axis: maximum 1-hour average concentration (ppm). (South Coast Air Quality Management District)

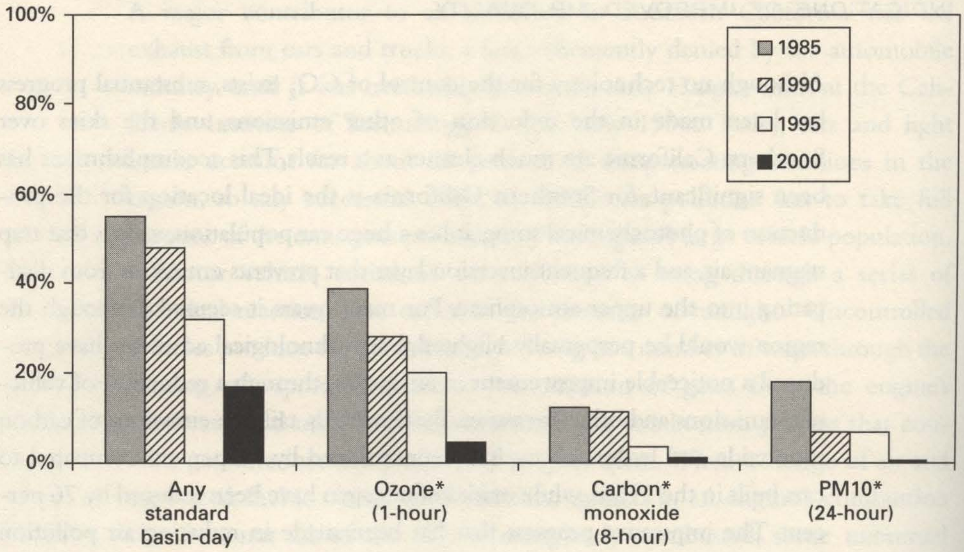

FIGURE 2

Percentage of days exceeding federal health standards, South Coast Air Basin (California), 1985–2000. *: percentage of days exceeding at site with highest exceedences. (South Coast Air Quality Management District)

centration of ozone in Southern California's skies. As can be seen in figure 1, the number of days when one-hour ozone concentrations exceeded the federal standard declined from more than 200 in 1977 to fewer than 50 in 2000. Encouraging gains have also occurred in the reduction of other pollutants. As figure 2 indicates, along with experiencing a decrease in ozone, Southern California has seen substantial progress in the reduction of carbon monoxide and PM10 particulates (particles with diameters of 10 microns or less).

PUBLIC POLICY AND THE REDUCTION OF AUTOMOTIVE EMISSIONS

A substantial portion of these gains can be attributed to a set of technological fixes that have dramatically lowered automotive emissions. But these fixes were implemented because the federal government and the government of California made clean air a major policy objective.[2] Government initiatives were essential for addressing the problem of poor air quality because individual efforts will never produce cleaner skies. Air pollution is the classic example of a "negative externality," that is, a market transaction's negative effects on parties not involved in the transaction. When an individual buys a car, he or she gains the benefits of car ownership; the seller benefits from the money earned through the sale of the car. But that is not the end of the matter; another car is now on the road, and its emissions contribute to the poor air quality that affects everyone in the region. Although they both suffer from poor air quality, the buyer and the seller of the car have no stake in addressing the problem by themselves. A vehicle equipped with pollution-control technology costs more, yet it provides no additional benefit to its purchaser. Even a buyer with a yearning for better air quality will not pay extra for a car or truck with reduced emissions, as an improvement made to a single vehicle results in an infinitesimal gain in air quality. Air pollution can be successfully addressed only when all or most vehicles have cleaner exhausts, and this requires a collective effort of some sort.

One possible way of producing a collective effort is to levy a pollution tax, perhaps coupling it with the establishment of a market for pollution credits.[3] People could drive dirty vehicles, but they would have to pay a tax tied to the amount of pollution they produce. Conversely, the operator of a vehicle that falls below some stipulated emission level might receive a credit that could be sold to the operator of a vehicle that failed to meet the standard. Programs of this sort have been used to reduce the emissions of stationary power sources, but the large number of motor vehicles requiring monitoring would make such a program very difficult to administer, at least with present information-gathering capabilities. Efforts to reduce vehicle emissions have instead been based on another kind of policy weapon, the setting and enforcement of emissions standards and the mandating of certain technologies for the achievement of these standards.

In the United States, the process of limiting emissions through regulation began in 1961, when the State of California began to require the installation of positive crankcase ventilation (PCV) valves on new cars beginning with the 1963 model year. That simple step reduced emissions of unburned hydrocarbons by about 20 percent. In 1966 the California legislature established the nation's first emissions standards for automobiles, which for a number of years forced manufacturers to build "California cars" that were cleaner than those destined for the other 49 states.

The first piece of federal regulation to directly target automotive emissions, the Motor Vehicle Air Pollution and Control Act of 1965, simply allowed the Secretary of Health, Education, and Welfare to set emissions standards, but later in the same year Congress passed legislation that required that Secretary do so. Beginning with the 1968 model year, federal standards set hydrocarbon emissions at no more than 275 parts per million (ppm) and put the acceptable level of carbon monoxide at 1.5 percent of total emissions. By the 1970 model year these were required to drop to 180 ppm and 1.0 percent, respectively. The federal Clean Air Act, passed in 1970, mandated a 90 percent reduction in emissions of nitrogen oxide by 1976. New standards for hydrocarbons and carbon monoxide were even more ambitious; amendments to the act passed in 1977 required a 96 percent reduction of these pollutants.

Another set of amendments passed in 1990 gave the automobile industry its current emissions standards, which are now defined in terms of pollutants per mile rather than as percentages of total emissions. Beginning with the 1994 model year, carbon monoxide was to be limited to 3.4 grams per mile, hydrocarbons to 0.25 gram per mile, and NOx to 0.4 gram per mile. There was also a requirement that emissions controls perform acceptably for 100,000 miles. Regions currently not in compliance with current air-quality standards were obliged to meet them according to a specific schedule or face a possible loss of federal highway construction and maintenance funds.

In 1990 the state of California went one step further. The California Air Resources Board (CARB) decreed that by 1998 2 percent of new cars sold had to be zero-emissions vehicles (ZEVs), with the ratio rising to 5 percent in 2000 and 10 percent in 2003. Faced with intense opposition from manufacturers and the absence of a receptive market, in 1996 CARB rescinded the 1998 and 2000 mandates while retaining the one for 2003. The program was further modified in early 2001, when CARB enacted a complicated schedule that granted manufacturers extra credits for such things as the early introduction of ZEVs and the sale of ZEVs with ranges beyond 50 miles, as well as an award of half a ZEV credit for "partial zero emission vehicles" such as gasoline-electric hybrids. The program also stipulated that the ZEV requirements would increase after 2008, rising to 16 percent of the light vehicle fleet by 2018.[4]

Whether these standards will be met is an open question. The only zero-emissions vehicles available for at least the next decade are battery-powered electrics. The high cost and limited range of these vehicles makes their widespread usage problematic, and up to now the few electrics that have been put on the market have met with a tepid consumer response at best.

Hybrid vehicles have enjoyed greater acceptance, but they will not be a significant part of the vehicle fleet for many years to come.[5] At a considerable distance over the commercial horizon are vehicles powered by fuel cells that, theoretically at least, emit nothing but water vapor.[6] Although prototype fuel-cell vehicles are currently being tested by a number of manufacturers, they are not likely to be a commercial reality until well into the second decade of the twenty-first century, if even then.

TECHNOLOGIES FOR CLEANER AIR

With alternatives to the internal-combustion engine many years away from practical application, the motor vehicle industry has had to develop a number of technologies to reduce the tailpipe emissions produced by conventional engines. The centerpiece of these efforts has been the catalytic converter. California was the first place to require its use, mandating that all 1975 model cars be so equipped. A catalytic converter has an internal structure made of tiny ceramic pellets or a ceramic honeycomb that gives the interior of the converter a surface area the size of a football field. The converter's internal surfaces are coated with metals that catalyze chemical reactions: palladium, rhodium, and platinum. The first catalytic converters supported only an oxidation process that turned unburned hydrocarbons and carbon monoxide into water vapor and carbon dioxide. Within a few years cars began to be equipped with three-way catalytic converters that, in addition to the first two functions, support a reduction process that turns oxides of nitrogen into free nitrogen and oxygen.

A car produces the most emissions when a cold engine is started, as catalytic converters work effectively only at operating temperatures of 250–300°C (480–570°F). Tests conducted by the Environmental Protection Agency have shown that in the course of a 10-mile trip made by a catalytic converter-equipped car 80 percent of hydrocarbon emissions occur during a warm-up period of 2½ minutes.[7] To counter this problem, it is likely that the next generation of catalytic converters will be kept at operating temperature by the car's electrical system.

Catalytic converters require just the right amount of oxygen admitted into an engine's combustion chamber. If there is too little, the unburned hydrocarbons and carbon monoxide are not oxidized; if there is too much, the NOx will not be reduced to free oxygen and nitrogen. Consequently, today's cars are equipped with oxygen sensors, fuel injection, and computerized engine management systems that keep the fuel-air ratio within precise limits. The reduction of automotive emissions also has required the use of other technologies such as exhaust gas recirculation (EGR) devices and vapor recovery systems for the vehicle's fuel tank. Finally, since catalytic converters are quickly destroyed by lead, that additive (which was used to allow engines to have higher compression ratios) has been removed from gasoline, which has had the additional benefit of reducing the presence of a highly toxic element. Today's engines are vastly more complicated and sophisticated than the ones found under the hoods of the cars of a few decades ago. Given the demands for cleaner air, the continued use of the internal-combustion engine, a nineteenth-century invention, now requires a host of technologies developed in the late twentieth century.

KEEPING CARS CLEAN

Emissions-control devices have made a major contribution to cleaner air, but their effectiveness depends on their working properly. As was noted above, federal law requires that anti-pollution devices have to maintain their effectiveness for 100,000 miles. But this mandate is of value only if there is some way to ensure that the vehicle population remains in compliance. Although emissions standards are set by the federal government, the enforcement of these standards is the responsibility of individual states. The federal government, however, is able to retain some control over the process by threatening to withhold highway funds from states deemed to have inadequate testing procedures.

The 1990 amendments to the Clean Air Act required that testing procedures had to simulate actual driving conditions. The place where the procedure was performed was left up to the individual states. The federal government has favored a network of facilities that do nothing but testing, but this has been strongly resisted by owners of gas stations and repair shops who perform emissions testing as an adjunct to their other services. The problem with this arrangement is that the presence of a large number of facilities makes it difficult to inspect the equipment and personnel performing the tests. There is also an inherent conflict of interest when enterprises are in the business of making repairs in addition to conducting emissions tests.

It is likely that the main value of smog inspection systems is that they allow the detection of the relatively small number of cars and trucks that are responsible for a disproportionate share of vehicular emissions. A study conducted by the National Research Council reported in 1991 that 50 percent of the ozone-forming emissions from mobile sources come from fewer than 10 percent of the vehicles in operation. Getting these "gross polluters" into compliance (or off the road, if this is not possible) may be the most cost-effective way of reducing automotive emissions.[8]

The issue of cost effectiveness must be faced squarely in any serious discussion of emissions control.[9] Government-mandated technological fixes have added hundreds of dollars to the cost of a car, while the costs of California's inspection program and required repairs come to about $500 million annually. In return, Southern California has benefited from cleaner air, but the region is still not in compliance with federal standards, and more drastic (and expensive) measures may be required in the years to come. We are well past the point where the installation of simple devices like PCV valves, and even complex ones like catalytic converters can effect substantial improvements. It is likely that diminishing returns have set in with regard to the benefits obtained from anti-pollution expenditures.

At the same time, there is no easy consensus in regard to additional expenses that should be borne in pursuit of cleaner skies. There is some evidence that air pollution in Southern California is associated with higher risks of bronchitis and asthma,[10] but it can always be argued that all good things, such as the personal mobility afforded by the automobile, will have some unfortunate consequences. Greater precision can be brought to the issue by conducting cost-benefit analyses that attempt to put a monetary value on the illnesses engendered by air pollution, but carrying out a precise epidemiological study would be a very difficult task, given the many factors involved in ill health, as well as the continual movement of people into and out of Southern California. And there is simply no way to put a dollar value on the ability to see the mountains or to play a game of tennis without feeling that one's lungs are being reamed out.

The complexities of cost-benefit analysis aside, there can be no question that the skies over Southern California are much better than they were before the effort to build cleaner cars was launched. Reduced levels of air pollution show that some problems can be successfully addressed through the application of one or more technological fixes. Smog pollution has been effectively addressed through the development of new technologies because it is a problem with a definite point of origin. A large portion of the emissions that cause smog can be traced to a single set of sources—cars and light trucks. Its unambiguous origins make smog a categorically different problem than, say, violent crime, which is the result of a vast number of things ranging from poor family environments to chronic unemployment to violent media programming. When the source of a problem can be definitively identified, a crucial step has been taken toward the development and application of successful remedial technologies.

The next step in the solution of a problem may be the pursuit of a technological fix through the invention of new devices like catalytic converters. But these devices will remain bottled up in research laboratories unless decisions are made to put them to use. This is an inherently political process, one in which priorities are set and resources are allocated. Technology can fix things only when we can collectively agree on what needs fixing and how much we are willing to pay for it. When such agreement exists, there is at least a reasonable chance that effective policies will emerge from the political arena. For decades, smog in Southern California was a problem that was never far from public consciousness, especially since much of the appeal of the region lay in its benevolent climate and the outdoors-oriented lifestyle that it fostered. Consequently, policies oriented toward the reduction of air pollution emerged in a receptive political environment where smog was producing universal discomfort. Everyone living in Southern California was affected by air pollution, irrespective of their social class, race, ethnicity, gender, age, or political affiliation. The reduction of air pollution has been an issue that has galvanized the citizenry as a whole, an issue that elected and appointed officials cannot easily disregard.

Political efforts to alleviate smog also benefited from the fact that, in contrast with what has happened in regard to other sources of health problems (cigarettes come to mind), there has been no organized group with a vested interest in the perpetuation of the problem. To be sure, car manufacturers and others implicated in the production of smog were at times unenthusiastic and even hostile to efforts to clean up the emissions generated by their products. Quite naturally, they feared that the cost of emissions equipment would raise the price of the vehicles to the point where sales and profits would be harmed. In fact, nothing of the sort has happened. The cost of vehicles has gone up as the negative externalities have been internalized, but cars appear to be relatively price inelastic, so higher prices have not significantly limited sales, and consumers have absorbed the costs of emissions-control equipment. Another cost of cleaner air that has been sloughed off onto the consumer has been the time and money expended in passing an emissions test every 2 years in order to renew a car or truck's registration. California's vehicle inspection system has not always been a model of either efficiency or consistency, but there has been no widespread revolt against it. Again, we see that elements of a technological fix are more likely to be implemented when they have at least tacit political support.

THE FUTURE OF SMOG IN SOUTHERN CALIFORNIA

As with most things, efforts to reduce vehicular emissions are subject to diminishing returns. Thanks to the improvements noted above, cars and light trucks are much cleaner than they were 20 years ago. Even so, the region still has the worst air in the United States. In 1989 the regional agency responsible for smog reduction, the South Coast Air Quality Management District, released an Air Quality Management Plan that would have required massive changes in ensuing years, such as having 40 percent of all passenger vehicles powered by methanol or electricity, while at the same time reducing the number of vehicle-miles traveled to the 1985 level. Loud protests accompanied the plan, which subsequently went through a number of revisions that diluted its proposed mandates. Yet if reducing smog in 1989 was problematic, it is even more so today and will be into the future. The population of California now numbers nearly 33 million. The state has nearly 17 million cars and light trucks, more than one for every two inhabitants.[11] According to recent projections, California will have up to 45 million people by 2020, and a large percentage of that increased population will be located in Southern California. Under these circumstances, just holding the line on air pollution will be difficult; making the skies cleaner will pose Herculean technical and political problems. Engineers, politicians, bureaucrats, and the citizenry will encounter many challenges down the road—or should I say the freeway?

NOTES

1. On the chemistry of smog formation, see Robert Jennings Heinsohn and Robert Lynn Kabel, *Sources and Control of Air Pollution* (Prentice-Hall, 1999), 281–313.

2. For a review of federal laws and regulations regarding air pollution, see Gary C. Bryner, *Blue Skies, Green Politics: The Clean Air Act of 1990 and Its Implementation* (CQ, 1993, 1995). For a brief history of efforts by the local and state governments in California, see Jeffrey Fawcett, *The Political Economy of Smog in Southern California* (Garland, 1990), 78–91.

3. Bryner, 256, 257.

4. California Air Resources Board, "Zero-Emission Vehicle Program Changes," accessed June 10, 2002 at http://www.arb.ca.gov/msprog/zevprog/factsheets/zevchanges.pdf.

5. Today's hybrid vehicles run cleaner because they consume less fuel than conventionally powered cars of equivalent performance. Future hybrids employing engines running at constant speed have the potential to be even cleaner because it is easier to control the emissions of engines that are not continually speeding up and slowing down. For a discussion of hybrid vehicles, see Victor Wouk, "Hybrid Electric Vehicles," *Scientific American* 277 (1997), no. 4, 70–74.

6. A. John Appleby, "The Electrochemical Engine for Vehicles," *Scientific American*, 281 (1999), no. 1, 74–79.

7. I. Gottberg, J. E. Rydquist, O. Backlund, S. Wallman, W. Maus, R. Bruck, and H. Swars, New Potential Exhaust after Treatment Technologies for Clean Air Legislation. SAE Technical Paper 10840, 1991, 3.

8. Lamont C. Hempel et al., Going After Gross Polluters: Remote Sensing of On-Road Vehicle Emissions. Center for Politics and Policy, Claremont Graduate School, 1992.

9. RAND Corporation, Rx for Urban Smog: Find and Fix Those 'Clunker' Cars. Accessed June 10, 2002 at http://www.rand.org/publications/randreview/issues/RRR.fall94.calif/smog.html. For an evaluation of the costs and benefits of pollution reduction, see J. Clarence Davies and Jan Mazurek, *Pollution Control in the United States: Evaluating the System* (Resources for the Future, 1998), 123–150 and 278–280.

10. James M. Lents and William J. Kelly, "Clearing the Air in Los Angeles," *Scientific American* 269 (1993), no. 4, 38.

11. State of California, Department of Finance, Table J-3, "Transportation and Public Utilities," accessed June 2002 at http://www.dof.ca.gov/html/FS_DATA/STAT-ABS/sec_J.htm.