Driven into a Corner

To Clean the Air, California Can Steer Old Cars and New Cars in Better Directions

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California has made steady progress in reducing automobile pollution in the past three decades. The progress is due, in large part, to the increasingly stringent federal and state regulatory standards that have been imposed on the average exhaust emissions of new vehicles. The regulatory standards have engendered tremendous advances in the design of internal combustion engines.

Nonetheless, California and particularly the Los Angeles area still have a long way to go to meet federal clean air standards. Today, the state can choose among several options to move closer toward that goal. We believe that the state should adopt the programs that are most likely to achieve the goal at the least cost to society. In this regard, however, the state is veering off course. The problem is evident on two fronts, one pertaining to old cars that pollute heavily and one pertaining to new cars that emit absolutely no fuel or exhaust emissions.

A promising program to scrap old vehicles, which tend to have especially high pollution rates per vehicle, has been stalled. Old vehicles tend to spew high amounts of emissions for two reasons: The vehicles were subject to less-stringent emissions standards when they were built, and their emission control equipment has deteriorated over time. Scrapping these vehicles would be a relatively low-cost way to clean the air and should remain a state priority.

Meanwhile, the state has aggressively pursued an ambitious program that mandates automakers to manufacture cars that produce no emissions at all. This program is the first step toward the California Air Resources Board's (CARB's) long-term goal of reducing emissions from the state's vehicle fleet to zero. Although the program is appealing in the abstract—who wouldn't want zero-emission vehicles?—we believe it is unwise in practice, considering the alternatives that are still available. The program may help to clean the air—but only at tremendous cost. Meanwhile, the program could divert resources from less costly ways to clean up the air.

California air quality managers are now moving in the wrong directions regarding both programs. The state has failed to secure the money to take older cars off the road. Meanwhile, the state has mandated that zero-emission cars be put on the road, but doing so will involve very high costs to automakers and consumers. California, instead, should jump-start the first program and ease up on the requirements of the second.

Old Vehicles: Scrap 'Em

In 1994, California promised the federal Environmental Protection Agency that it would implement a Voluntary Accelerated Vehicle Retirement (VAVR) program that would remove some cars and light-duty trucks 15 years old or older from the road. The plan was to buy and scrap 75,000 of the vehicles each year from 2001 through 2010.

Geographically, the program applies to the South Coast Air Basin, which includes all of Orange County and the urbanized portions of Los Angeles, Riverside, and San Bernardino Counties. The annual scrapping target amounts to about 5 percent of the vehicles in the South Coast that are 15 years old or older and 2 percent of such vehicles in California as a whole.

The strategy is sensible, because older vehicles are some of the chief culprits in producing ozone,

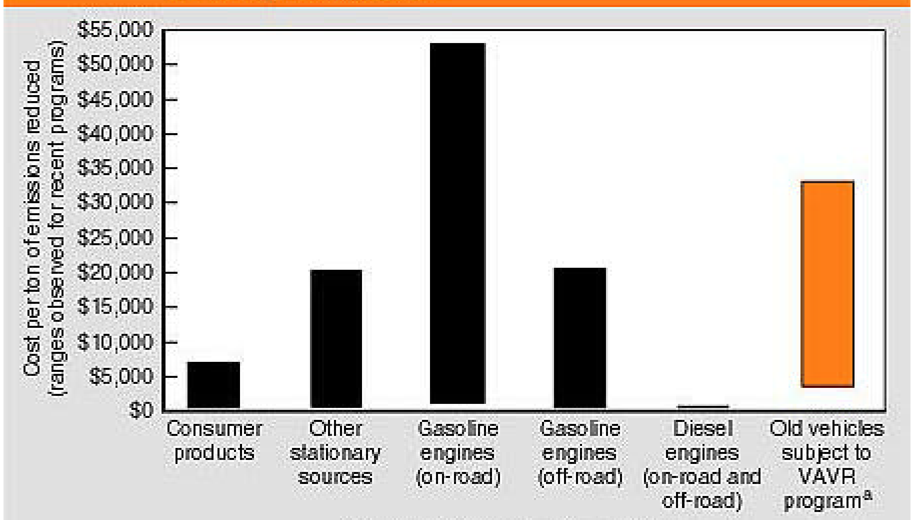
one of the pollutants subject to federal air quality regulations. Ozone forms when automobile emissions—non-methane organic gases (NMOG) and oxides of nitrogen (NOx)—react chemically with sunlight. In 1998, older vehicles accounted for just 11 percent of the miles driven by cars and light-duty trucks in the South Coast Air Basin but 39 percent of their ozone-forming emissions. In fact, the older vehicles accounted for 18 percent of the ozone-forming emissions from all sources, including industrial sources.

Under the VAVR program, state-licensed auto dismantlers would purchase older vehicles and destroy them. All VAVR transactions between car owners and dismantlers would be voluntary. The state would pay the dismantlers for every vehicle scrapped. Estimates indicate that the state would have to pay between $500 and $1,500 per vehicle to scrap 75,000 vehicles each year. The total amount of money needed to scrap the vehicles would be roughly $100 million per year for 10 years—or $1 billion over the decade. Unfortunately, the state has not found the money to implement the program.

CARB has nonetheless issued regulations for the program, and local air quality management districts are allowing auto dismantlers to use the program to earn "transferable credits." Under this arrangement, the dismantlers can sell emission reduction credits generated by each scrapped vehicle directly to other businesses. The most common customers for the credits today are companies that buy the credits to offset rideshare requirements. But only about 5,000 cars per year are now scrapped statewide through such programs.

The fate of the VAVR program is very much in doubt. In fact, the program has recently been eliminated from the state strategy to meet federal clean air standards. Our analysis, however, shows that the program is a cost-effective means of achieving federal ozone standards. We conclude that the cost per ton of emissions reduced by the VAVR program would range from $3,700 to $33,300. This range compares favorably with the costs of many other components of California's air-quality strategy that have already been implemented (see Figure 1).

Figure 1—Voluntary Accelerated Vehicle Retirement (VAVR) Would Be Cost-Effective Compared to Recently Adopted Regulations on Other Sources of Ozone-Forming Emissions



[a]The VAVR bar shows the range of the *estimated* cost per ton of emissions reduced.

SOURCES: *Driving Emissions to Zero*, 2002; *Fighting Air Pollution in Southern California by Scrapping Old Vehicles*, 2001.

Even more important for policy purposes, the VAVR program is likely to be even more cost-effective compared with other still available options for further reducing emissions of ozone precursors. Future options are likely to be less cost-effective than current programs and, thus, less cost-effective than a VAVR program. New technologies and additional creative thinking may provide California with attractive new options for reducing emissions further, but the programs that have already been implemented are by and large the most cost-effective ones that are politically acceptable.

In sum, the VAVR program is an attractive way to promote air quality in the South Coast Air Basin. If the program is not implemented, less cost-effective ones—or even ineffective ones—may be used instead in the continuing struggle to move California toward compliance with federal air quality standards.

Degrees of Zero

One program that may very well not be cost-effective is California's Zero Emission Vehicle (ZEV) program. Adopted by CARB in 1990, the ZEV program requires auto manufacturers to sell at least 4,000 cars, minivans, light trucks, and sport utility vehicles in the state in 2003 that emit zero pollution. The mandated number of emission-free vehicles rises gradually to about 30,000 in 2015.

The ZEV program requires manufacturers to meet their fleet-average emission requirements in part with a specific kind of technology: a zero-emission vehicle. Such a technological mandate would make sense if zero-emission vehicles were necessary to meet air quality standards or if there were no way to meet air quality standards less expensively. We found, however, that neither is the case. Even though California will require a vehicle fleet with very low emissions to meet federal air quality standards, the state will not necessarily require a fleet with zero emissions. We also found that the cost of moving from very low to zero emissions could be extremely high.

We compared the costs and air quality benefits of various types of vehicles that manufacturers can use to satisfy ZEV program requirements. The costs include vehicle production costs as well as indirect costs, such as corporate overhead, warranty cost, and cost of capital. Over the long run, such costs are generally passed along to consumers. The various types of vehicles include the following:

- *Zero-emission vehicles (ZEVs).* ZEVs include battery-powered electric vehicles. They rely on either nickel-metal-hydride batteries, lead acid batteries, or lithium ion batteries. The electric vehicles come in three classes: full-function electric vehicles, which are similar in size to many vehicles on the road today; "city" electric vehicles, which are much smaller than typical passenger cars and have limited speed and acceleration; and "neighborhood" electric vehicles, which resemble golf carts and are not freeway capable. We limited our analysis to nickel-metal-hydride and lead acid batteries, because lithium ion technology continues to have important shortcomings. We also did not consider neighborhood electric vehicles because many policymakers, including CARB, feel that it is unlikely that these vehicles will displace many of the miles traveled by the types of vehicles currently on the road. ZEVs also include direct hydrogen fuel-cell vehicles, which can be fueled with either hydrogen gas, liquid hydrogen, or hydrogen embedded in metal. We analyzed the hydrogen gas option, which currently appears to be the most practical one.

- *Partial zero-emission vehicles (PZEVs).* Although awkwardly named, these vehicles are extremely clean gasoline-powered vehicles that produce almost negligible

AP/WIDE WORLD PHOTOS/DAMIAN DOVARGANES

If the battery lasts, great. California Assemblywoman Gloria Negrete McLeod sits on her new hybrid car outside her Montclair office on April 26. The Toyota Prius, which has both a gasoline engine and an electric motor, averages 48

amounts of emissions. CARB allows manufacturers to satisfy part of their ZEV requirements with PZEVs. Five conventional gasoline-powered PZEVs can substitute for one ZEV. Large-volume manufacturers can satisfy up to 60 percent of ZEV program requirements with PZEVs. However, PZEVs are yet to be sold, and it will be many years before their on-road emissions can be verified.

miles per gallon of gas.

- *Gasoline hybrid electric vehicles (GHEVs) that meet PZEV standards.* GHEVs integrate a gasoline engine with an electric motor. The advantage of a GHEV is that it combines a smaller (and thus easier to clean) gasoline engine with a smaller (and thus cheaper) electric battery. There is no loss of power, because the battery compensates for the lower power output of the smaller engine, and the vehicle can travel as far or farther than standard vehicles between refills. Compared to other PZEVs, GHEVs generate the same amount of exhaust emissions (from the tailpipe) and evaporative emissions (from the rest of the vehicle). But GHEVs also generate fewer "indirect" emissions associated with petroleum extraction, refining, and distribution because of their higher gas mileage. Manufacturers can use GHEVs to fulfill an additional 20 percent of their ZEV requirement above the 60 percent that can be met with other kinds of PZEVs. Thus, ZEVs could conceivably fulfill as little as 20 percent of the ZEV requirement.

In comparing the various types of vehicles, we restricted our attention to the cost of eliminating an additional ton of the ozone-forming emissions of NMOG and NOx. As a point of reference, we looked at the cost-effectiveness of today's vehicles that meet the toughest emissions standards outside the ZEV program. These vehicles are known as super ultra low emission vehicles, or SULEVs. They produce very little exhaust emissions and must also meet stringent evaporative emission standards. We first estimated the marginal cost per additional ton of emissions reduced by advancing just one technological step, from the SULEV to the PZEV.

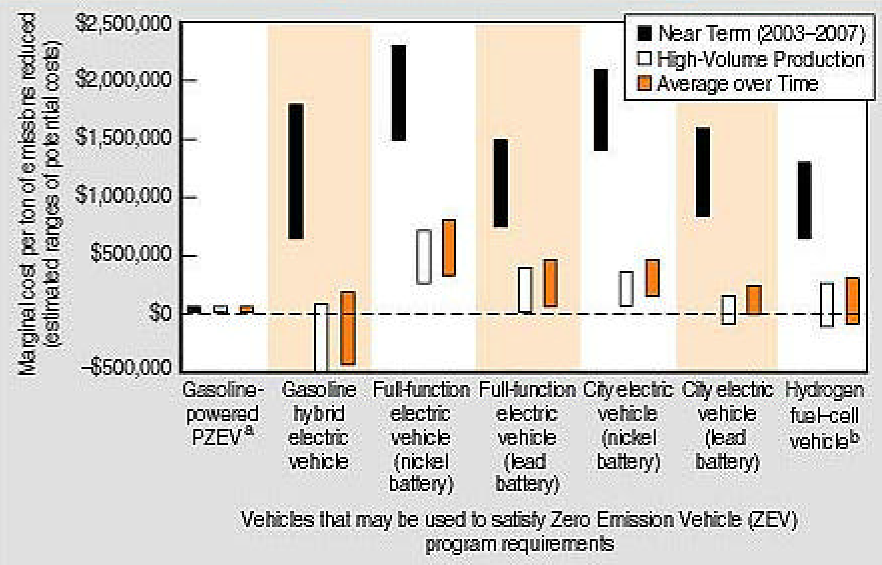
We then calculated the cost per additional ton of emissions reduced by moving one technological step further, either incrementally from PZEVs toward GHEVs or directly all the way from PZEVs to the various kinds of ZEVs. In each of these cases, the basis of comparison was the PZEV, not the SULEV, because we assumed that manufacturers would first produce the maximum allowable number of relatively inexpensive PZEVs.

In every case, we estimated three ranges of cost-effectiveness: one for the near term (the first four years of production, representing initial investment costs), one for the longer term (high-volume production, representing economies of scale and also manufacturing improvements), and one for the average over time. We do not expect that manufacturing costs over the next decade will fall appreciably below our estimates absent significant and unanticipated technological advances.

Close to Zero Is Better Than Zero

Figure 2 shows our results. The most encouraging conclusion is that PZEVs are a fairly economical way to reduce ozone-forming emissions. Since PZEVs are conventional gasoline-powered vehicles, they require only incremental improvements on an existing and proven technology, rather than an entirely new technology. We found that reducing emissions from SULEV to PZEV levels will cost between $18,000 and $71,000 per ton of emissions. The lower end of this range is less than the cost per ton of other regulations that have recently been adopted. The upper end of the range exceeds the costs of recent regulations, but it is plausible that policies with costs this high will need to be implemented for federal air quality standards to be met.

Figure 2—Partial Zero-Emission Vehicles (PZEVs) Are a Cost-Effective Way to Reduce Ozone-Forming Emissions



[a] All cost-effectiveness estimates assume that manufacturers first produce the maximum allowable number of gasoline-powered PZEVs.

[b] The "near term" for the hydrogen fuel-cell vehicle is 2006–2010.

SOURCE: *Driving Emissions to Zero*, 2002.

We are not confident that it would be cost-effective to advance beyond the standard PZEV to a GHEV. This depends largely on whether GHEV batteries will last for the entire lives of the vehicles. If the hybrids' maintenance costs (including battery replacement) are comparable to those of a typical PZEV, then GHEVs will be attractive. The GHEV's life-cycle cost may even be less expensive than that of the typical PZEV in high-volume production, as indicated by the negative costs (or savings) that appear within our ranges of estimates in Figure 2. But if GHEV batteries need replacing, the average cost over time may be as high as $180,000 per ton of additional emissions reduced—more than twice the cost of moving from SULEVs to PZEVs.

The news gets worse. None of the exclusively battery-powered electric vehicles appears to be an economical way to reduce the emissions from PZEV levels to zero. Even after a decade of intensive research and development involving costs exceeding $500 million, battery-powered vehicles still face two formidable roadblocks: the high cost of batteries and the limited amounts of energy they can store. The limited energy storage restricts driving ranges between charges to less than 100 miles for most full-function electric vehicles. The vehicles are extremely expensive to manufacture and show little long-term commercial promise. It makes no sense to continue investing in this technology.


AP/WIDE WORLD PHOTOS/JULIE JACOBSON

Solving a chicken-and-egg problem? Yasuo Takagi examines the hydrogen dispenser at a new hydrogen fueling station on Oct. 30 in Richmond, Calif. The station will allow automotive companies affiliated with the California Fuel Cell Partnership in West Sacramento to extend the test-drive range of their hydrogen-powered vehicles.

Figure 2 shows that the cost could be lower for electric vehicles with lead acid batteries, but the size and weight of these batteries make it difficult to produce vehicles with broad appeal. In addition, the cost per ton of their emissions reduced may also just as likely turn out to be very high. The figure shows potentially lower costs for city electric vehicles. But these vehicles, which typically have a range of 50 to 60 miles, are very different from vehicles on the road in California today and may also have limited commercial appeal.

Direct hydrogen fuel-cell vehicles show much more promise than battery-powered electric vehicles, but a great deal of uncertainty remains. If fuel-cell-system costs fall sufficiently, then these vehicles could become an attractive part of California's strategy for meeting ozone standards. Beyond questions of cost, fuel-cell vehicles also face a chicken-and-egg problem regarding infrastructure. A sparse infrastructure of hydrogen filling stations limits the attractiveness of the vehicles, while small numbers of vehicles limit the number of commercially viable fueling stations. It is too early to tell whether fuel-cell vehicles will become an economical way to reduce emissions from PZEV levels to zero.

Keep Your Eyes on the Ball

Based on our analyses of the VAVR and ZEV programs, we make six recommendations to California policymakers:

1. *Revive the VAVR program.* Resources should be found to fund this attractive program.

2. *Abandon the goal of reducing emissions from the state's vehicle fleet to zero.* The emissions do not have to be zero to meet federal air quality standards. Since the ZEV program was adopted in 1990, tremendous progress has been made in reducing emissions from internal combustion engines. ZEVs are now unnecessary. Rather than striving for zero emissions from some sources, the state should pursue the most cost-effective strategies for reducing emissions from all sources.

3. *Require passenger cars and smaller light-duty trucks to meet PZEV emissions standards.* CARB could gradually reduce the average allowable exhaust emissions from these vehicles to PZEV levels.

CARB should also factor indirect emissions (from fuel extraction, processing, and distribution) into the fleet-average requirement. This inclusion would ensure that gasoline hybrid vehicles, which could become an attractive way to reduce ozone-forming emissions, would be appropriately encouraged.

4. *Eliminate the ZEV requirement.* Manufacturers should not be required to produce ZEVs. Our analysis shows that ZEVs are at best a very risky bet on cost-effectiveness grounds, but there are several reasons—discussed presently—why ZEVs may appear attractive to policymakers. Overall, however, we do not believe these reasons tip the balance in favor of ZEVs.

One argument is that the ZEV program will spur technological development further than it otherwise would go. In particular, it is very difficult to know what would happen to fuel-cell research and development if the ZEV requirement were scrapped. However, by favoring particular technologies—in this case, battery-powered electric vehicles or direct hydrogen fuel-cell vehicles—the ZEV mandate could be pushing the wrong technology rather than spurring desirable technological development.

Another argument for the ZEV program is that it could insure against potential disappointments in the lifetime, in-use emissions of typical PZEVs. However, the ZEV mandate could be diverting the state away from better forms of insurance—such as research on how to reduce emissions from diesel vehicles, off-road equipment, and stationary sources. Strategies to achieve air quality standards at the least cost should explore the possibilities of reducing the considerable emissions from these sources before requiring ZEVs.

A third argument for the ZEV program is that it reduces carbon dioxide emissions (greenhouse gases) as well as ozone-forming emissions. In fact, the California legislature has recently directed CARB to develop regulations to reduce greenhouse gases. To reduce carbon dioxide emissions, however, it may be more cost-effective to increase overall gas mileage by raising the corporate average fuel-economy standard.

A fourth argument for the program is that it could reduce dependence on foreign oil. But to do so, it may make more sense to switch to alternative-fuel vehicles, such as those that run on compressed natural gas.

What concerns us most about the ZEV requirement is that it focuses on a very narrow set of technologies in its aim to reduce air pollution in California. The focus on zero-emission technologies seems particularly inappropriate given that ZEVs are not needed to meet air quality standards and that much lower-cost alternatives for reducing emissions appear to be available.

5. *If the state chooses not to eliminate the ZEV requirement, then either delay it or allow fewer numbers of fuel-cell vehicles to satisfy the requirement in the early years.* By delaying the program, CARB would allow time to evaluate the promise of fuel-cell vehicles, the only zero-emission technology that appears promising for the foreseeable future. If CARB does not want to delay the introduction of fuel-cell vehicles into the market, then CARB could increase the number of ZEV credits generated by each fuel-cell vehicle. A substantial increase would prevent a large number of battery-powered vehicles from being put on the road but would still allow CARB and the industry to gain a better understanding of the real-world potential of fuel-cell vehicles.

6. *Focus on emissions standards, not technology mandates.* CARB should set vehicle emissions standards and let the automakers determine how best to meet them, because automakers can be expected to meet the standards at least cost. CARB should continue to set very stringent fleet-average emissions standards for new vehicle fleets, but there is no need to set the standard for part of the fleet at zero or to require manufacturers to meet the average standard in part with ZEVs.

California has made remarkable progress in cleaning the air over the past 30 years. But much remains to be done. As for old vehicles, the state should accelerate their voluntary retirement. As for new vehicles, the state should continue to reduce their allowable emissions incrementally, but it should also allow the flexibility needed for different technologies to compete for roles in meeting air quality goals. It would also make sense for California to tighten the emissions standards on all new cars and light-duty trucks to the levels required for PZEVs and to reduce pollution from other vehicle and non-vehicle sources as well.

Related Reading

California's Ozone-Reduction Strategy for Light-Duty Vehicles: Direct Costs, Direct Emission Effects, and Market Responses, Lloyd Dixon, Steven Garber, RAND/MR-695-ICJ, 1996, 499 pp., ISBN 0-8330-2392-6, $13.00.

California's Ozone-Reduction Strategy for Light-Duty Vehicles: An Economic Assessment, Lloyd Dixon, Steven Garber, Mary Vaiana, RAND/MR-695/1-ICJ, 1996, 74 pp., ISBN 0-8330-2391-8, $15.00.

Driving Emissions to Zero: Are the Benefits of California's Zero Emission Vehicle Program Worth the Costs? Lloyd Dixon, Isaac Porche, Jonathan Kulick, RAND/MR-1578-RC/S&T, 2002, 163 pp., ISBN 0-8330-3212-7, $28.00.

Fighting Air Pollution in Southern California by Scrapping Old Vehicles, Lloyd Dixon, Steven Garber, RAND/MR-1256-PPIC/ICJ, 2001, 109 pp., ISBN 0-8330-2969-X, $15.00.

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