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The enclosed report, *The California Air Resources Board...And the "Elsewhere Emissions Vehicle"* was prepared by Thomas G. Burns, a member of PIRINC's newly created Board of Visitors. The Board of Visitors allows PIRINC to draw on leading energy experts to help assess research priorities and, on occasion, to contribute their own analyses of key energy issues.

In early September, despite strong technical evidence as to its infeasibility, the California Air Resources Board voted unanimously to maintain the basic mandate requiring automakers to market thousands of zero emissions vehicles (ZEVs) beginning in 2003. The Board did, however, express concern about several issues including: the current lack of ZEV availability, market demand, and cost and incentives. The CARB staff was directed to review the regulation and propose modifications to address these issues. The recently released staff report and proposed amendments to the ZEV program has again demonstrated that, assuming the recommendations are adopted, after looking at the facts, the regulators are willing to step back from imposing unenforceable mandates on the California motorist.

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The California Air Resources Board... And the "Elsewhere Emissions Vehicle"

EXECUTIVE SUMMARY

In early September, despite strong technical evidence as to its infeasibility, the California Air Resources Board voted unanimously to maintain the basic mandate requiring automakers to market thousands of zero emissions vehicles (ZEVs) beginning in 2003. The Board did, however, express concern about several issues including: the current lack of ZEV availability, market demand, and cost and incentives. The CARB staff was directed to review the regulation and propose modifications to address these issues. The recently released staff report and proposed amendments to the ZEV program has again demonstrated that, assuming the recommendations are adopted, after looking at the facts, the regulators are willing to step back from imposing unenforceable mandates on the California motorist.

Based on their ongoing review of the current state of the art, CARB staff now proposes to modify the mandate requiring that 10% of all vehicles offered for sale by major manufacturers in 2003 be zero emission vehicles (ZEVs). Staff recommends that the Board, at its next meeting in January, adjust the mandate to permit the inclusion of 2% electric vehicles (pure ZEVs), 2% hybrid electric, and 6% super ultra low emissions vehicles (SULEVs). However, this new target would still require sale of at least 4,650 pure ZEVs in 2003, more than twice as many as are currently on the road in California, although well below the 22,000 estimate under the unmodified mandate. While near-term requirements would be relaxed significantly, the staff is recommending that long-term ZEV targets be raised gradually beginning in 2008.

This will be the third revision of the original 1990 mandate requiring auto manufacturers, beginning in 1998, to make increasing numbers of ZEVs available for sale, rising to 10% in 2003 and perhaps higher thereafter. Although the original mandate did not specify that these would all be electric vehicles, it was widely recognized that the only way to achieve zero tailpipe emissions was to use an electric drive train.

The first revision to the original goal occurred in 1996. In order to promote electric vehicle development, CARB signed a memorandum of agreement with the auto industry to the effect that putting 2300 electric vehicles on the road by 2000 would satisfy the ZEV mandate for the years prior to 2003. The second revision occurred in 1998 when CARB agreed that the 2003 mandate could be met by 4% pure ZEVs and 6% vehicles qualifying for partial ZEV credit.

The ZEV Mandate Program was designed to be technology forcing—and it undoubtedly worked, even if not in the way that CARB and the electric vehicle community envisioned. Faced with the threat of having to sell 10% electric vehicles at huge discounts, the auto industry almost certainly invested more money and energy in developing new engine and emissions technologies than they would have otherwise. However, rather than following CARB's desired path to electric vehicles, the auto industry worked hard to develop technologies that would meet the overarching goals of the program in ways that were more cost effective and more likely to meet consumer needs and to be commercially successful.

However, meeting even these new mandated goals will be difficult and expensive, even though state law now provides $18 million over the next three years for subsidies of up to $9000 per ZEV. There is still considerable potential to disrupt the California automobile market, and if other states join in, the national market. Fuel suppliers should be cautious about projecting future trends in California motor fuel consumption. In addition to steadily improving fuel economy, there is still a considerable potential for limited use electric vehicles to take a growing share of the personal transportation market.

RECENT DEVELOPMENTS

The California Air Resources Board (CARB) held its biennial review of the Zero Emission Vehicle (ZEV) Program in early September, deciding to make no immediate change in the mandate requiring manufacturers to offer 10% ZEVs (including 4% pure ZEVs, i.e., about 22,000 electric, and 6% hybrids) for sale in 2003. CARB directed Staff to develop implementing regulations, and to specify exactly which vehicles qualify for the program and how much credit should be given for vehicles partially meeting the requirements.

The Staff Report that formed the basis for the biennial review in September identified the successes and failures of the program in its first ten years. Data presented in the report indicate that the ZEV Program is 200 to 1200 times more expensive per ton than other CARB regulations to control ozone precursors. Only by making admittedly "optimistic, but nonetheless plausible" assumptions about the long-term cost and performance of future ZEVs in high-volume production was the staff able to suggest that the mandate might actually confer benefits in excess of costs to the environment and economy of California.

In an effort to move the program forward, the Board scheduled a workshop in mid-November followed by a Board Meeting in early December. One of the goals of this process was to develop guidelines to implement a new state law (signed on September 30th) that provides a total of $18 million in grants to reduce the incremental cost of new ZEVs over the next three years. This program begins in 2001 and offers up to $9000 ($3000 per year for three years) to about 2000 purchasers of new or upgraded ZEVs. A key issue yet to be resolved is exactly what vehicles will qualify for the subsidy.

In view of the emerging realities and the looming 2003 deadline, CARB staff in December recommended modifications to the guidelines that would increase the ability of manufacturers to meet the mandate in the early years by building vehicles that can qualify for partial ZEV (PZEV) credit. The September Staff Report stated, "Development of vehicles able to meet the PZEV requirements is an engineering challenge, in particular given the relatively large number of vehicles that must be produced. Staff is concerned that leaving the PZEV option intact in its present form would preclude most manufacturers from fully using this option." The new proposal, which will be decided in January, would require only 2% electrics, 2% hybrids and fuel cells and allow 6% of new vehicles in 2003 to make use of super ultra low emissions technology on gasoline engines.

Electric vehicle proponents, who were successful in maintaining support for the mandate in the September meeting, are wary of making any changes to the program. Auto companies and their customers recognize the need to adjust the program to make it practical and effective, but are

unsure that this change will be sufficient. CARB and Staff now appear to be trying to navigate these difficult waters safely.

BACKGROUND

California, particularly Southern California, has traditionally had a real problem with local air quality that is increasingly shared with other large metropolitan areas. In spite of unprecedented reductions in stationary and mobile source emissions that have led to steady improvements in air quality, the South Coast Air Basin seems unlikely to attain the desired levels specified in existing regulations. It is the basin's geography, high concentration of people, and large number of stationary and natural emissions sources that make it exceedingly difficult to meet current air quality standards.

California's population continues to increase, and resumed economic growth in the last few years has led to ever larger numbers of cars on the road and more vehicle miles traveled (VMT). Internal combustion engine technology has come to the rescue and is responsible for the continued reductions in total mobile source emissions despite the growth in VMT. Improved fuel injection and emissions control systems have, in combination with tailor-made fuel formulations, allowed auto manufacturers to provide the kind of vehicles desired by California motorists while still reducing per vehicle, per mile, and total air emissions.

Progress, however, has not come without significant costs. Cars and light trucks generally cost somewhat more in California than in the rest of the country. The specially reformulated gasoline blends sold in California cost in the range of 10-12 cents a gallon more than the national averages. Californians complain a bit about higher prices, but have been generally willing to pay them in return for the air quality improvements they bring.

Since the early 1990s, the California Air Resources Board, a division of the California EPA, has sought to shift some of the remaining local mobile source emissions out of California, or at least out of the South Coast Air Basin. This effort goes under the banner of the Zero Emission Vehicle Program and was the subject of a biennial review in early September in Sacramento.

CARB's original goal was to mandate production of automobiles that would not emit criteria air pollutants at the point of operation. This approach led energy analyst Dr. Lee Schipper to coin the name, "elsewhere emissions vehicles."[1] CARB's intent was to develop vehicles that would be perfect substitutes for conventional vehicles powered by internal combustion engines. Because the only vehicle that can achieve zero tailpipe emissions is the electric vehicle, it became the "gold standard" against which all other options were compared.

The program has undergone a series of adjustments since it was originally conceived in 1990. It has always been seen as a "technology forcing" program that mandates certain levels of performance and then awaits the response of the industry. To its credit, CARB recognized early on that the needed technologies simply could not be developed in time to meet its original goals

[1] These days, with imported electricity limited, power generation from within the South Coast Air Basin has surged, indicating that the "emissions elsewhere" feature cannot be taken for granted.

(ZEVs to account for 2% of all vehicles sold in California in 1998, rising to 5% by 2001 and 10% by 2003).

Recognizing this reality, CARB signed a memorandum of agreement with the auto industry in 1996 to sustain progress and get at least some electric cars on the road. The near-term production goals were adjusted accordingly. The memorandum of agreement was successful, at least to some extent. There are now 2300 electric vehicles on the road, up from less than 1000 in 1993, meeting the manufacturers' obligations. Furthermore, the current crop of electric vehicles is far superior in reliability and performance to earlier models.

The issue addressed by the current biennial review was whether the 2003 goal (10% of new cars sold in California by the major manufacturers, or 4% if full allowances for vehicles granted partial ZEV credits are taken) can be achieved in the time remaining. Without the recently proposed modifications, this would mean that at least 22,000 electric vehicles would have to be offered for sale in 2003. The well-attended public hearings that were part of the biennial review process appeared to result in relatively little communication among the interested parties and almost no search for consensus on a way forward. Supporters of electric vehicles believe so strongly in the correctness of their position that they are willing to overlook any and all data suggesting that there may be any weakness in their case. They see industry as negative and unwilling to take the measures necessary to develop and promote a product that has obvious, multiple, long-term benefits.

On the other hand, the auto industry believes that it has already spent far more resources on this matter than can be justified, either by the possible environmental benefits or by the potential market. They have exhaustively examined the technical and market realities and cannot envision any significant breakthroughs. The expected rate of continuous, incremental improvement will not lead to a marketable vehicle, either by the mandated 2003 deadline or anytime soon thereafter.

The CARB studies admittedly make optimistic assumptions about the expected performance levels of new technologies—both for drive trains and for power sources—and the costs of attaining them. The CARB approach has been to subsidize the initial development and introduction of new technologies, in the hope that subsequent large-scale manufacturing will drive down costs and allow ZEVs to compete on their own merits.

In the past decade, substantial progress has been made in conventional electric vehicle technology as well as in the potentially more significant hybrid power trains now being developed. Nonetheless, the on-road performance of today's battery-electric vehicles, along with those likely to be available for at least the next 5-10 years, falls far short of that expected by the motoring public. Both CARB and the industry seem to agree that battery limitations will make it impossible to make an electric vehicle that is equivalent in range, carrying capacity, and cost to the conventional 5-passenger car that is standard in today's market.

VEHICLE TECHNOLOGY

Electric vehicles are clearly feasible today. A wide variety of models of trucks, vans, and cars are among the 2300 vehicles on the road today in California. (Notably absent from the

population of purpose-built electric cars resulting from the memorandum of agreement is the model with the largest market—a typical, 5-passenger sedan.) Reported consumer satisfaction with vehicle reliability is high and early operating problems seem to have been overcome. Consumers, however, consistently report that they desire increased range, faster recharging, more recharging stations, and, most importantly, lower costs.

The Staff Report admits that the program has been a success in every respect but cost. Auto manufacturers point out that they simply cannot make an equivalent electric vehicle at anything approaching the cost of a conventional one. The proof of this statement lies in the fact that no serious competitor to the existing auto companies has emerged to take advantage of what is described by EV enthusiasts as a vibrant, growing market with a large unsatisfied demand. If there really were such a market, wouldn't someone be trying to capture it?

The following is the initial list of new vehicle models eligible for the newly enacted ZEV Incentive Program showing the large incremental costs for electric vehicles. All of these vehicles would qualify for the full $9000 credit paid over the three years covered in the legislation. With only one exception, however, the subsidy would offset less than half of the incremental cost of the electric vehicles.

Make and Model	Incremental Cost
Chrysler EPIC EV NiMH van	$17,905
Ford Ranger EV Pb-A truck	$23,265
General Motors EV1 Pb-A coupe	$11,925
General Motors EV1 NiMH coupe	$21,925
General Motors S-10 Pb-A truck	$18,067
General Motors S-10 NiMH truck	$30,577
Toyota RAV 4 NiMH sports utility	$21,395
Solectria Force Pb-A	$18,935

BATTERY TECHNOLOGY

Battery packs have also improved, but not as fast as expected when the program was first established in 1990. Expected battery life now ranges between 25,000 and 40,000 miles, meaning that the battery pack will have to be replaced 2-4 times over the expected life of the vehicle. What has not changed significantly is the cost of the battery pack. This remains the single largest hurdle for the electric vehicle.

The Board commissioned a Battery Technical Advisory Panel to focus on advanced batteries. The results were not auspicious for the future of electric vehicles. Lead-acid batteries remain the cheapest and, therefore, the most common source of power for these vehicles, although these batteries continue to be handicapped by short lives and low specific energy which leads to extremely heavy packs and limited range.

Although nickel-metal hydride (NiMH) batteries also have a limited driving range, they have demonstrated the ability to meet power and durability requirements, but at an unacceptably high cost (two to three times that of lead-acid batteries). Another candidate, at least from a reliability and safety standpoint, is the lithium-ion battery. This battery system has not been tested

extensively on the road, however, and appears unlikely to match the NiMH battery in either durability or cost at its present rate of development.

The Panel concluded that, although incremental improvements in battery life, storage capacity, and reliability will continue to be made, major breakthroughs are unlikely. Costs will come down somewhat with large volume production, but materials costs (not manufacturing costs) already dominate, suggesting that the potential for significant additional cost reductions as the result of economies of scale is limited.

Because the Panel apparently took their mandate to perform a "technical" review of battery technology seriously, they were willing to examine alternative approaches to the full ZEV mandate favored in the past by CARB. They concluded, "All major carmakers are now actively pursuing other advanced-technology vehicles—such as hybrid and mini EVs—to achieve emission reductions. Like conventional EVs, HEVs and mini-EVs depend on improved batteries for their technical and cost feasibility. However, they require only a fraction of an EV's battery capacity—between 5% and 50%, depending on HEV technology and application. Battery cost is thus substantially reduced, and thereby one of the largest barriers to the commercial viability of these new automotive products."

Why aren't batteries experiencing the same rate of technical improvements enjoyed by other electrical and electronic products?

Battery technology has been around for a long time, helping to launch the age of electricity in the 1860s, when the first successful storage batteries were developed. The potential materials for electricity storage and recovery are well known (to anyone who didn't doze off gazing at the Periodic Table of Elements on the walls of their high school chemistry class!) Electricity storage has always been the Holy Grail of power companies, who are in business that inherently faces significant differences between periods of low, average, and peak demand for their product.

As a result, the electricity industry has spent significant effort and money over the past 120 years to try to solve the storage problem at reasonable costs. Thomas Edison, who believed strongly in direct current electricity, recognized early on that the economics of direct current would be greatly enhanced by the availability of low cost storage (rechargeable storage batteries are users and suppliers of direct current electricity). Edison devoted his considerable abilities to improving battery technology in the 1880s, receiving, among many others, patents for the first alkaline storage cells.

About the same time, George Westinghouse advocated the use of alternating current generators and motors to take advantage of some of his designs. The absence of low cost electricity storage systems meant that direct current systems were unable to offer any advantage over the alternating current approach. Westinghouse won out, and alternating current prevails today.

The point of this discussion is that, with almost 150 years of R&D effort behind us, major new breakthroughs in storage battery technology are extremely unlikely. Contrast this with the rate of progress in the electronics industry, an industry whose basis (the transistor) was first demonstrated only 50 years ago.

In batteries, incremental progress is the best that can be hoped for at this point.

WHAT IS THE POTENTIAL AIR QUALITY BENEFIT FOR CALIFORNIA?

The original ZEV mandate was expected to result in the reduction of significant volumes of smog precursors by shifting away from the combustion of gasoline in internal combustion engines. What is good news for Californians—current cars already emit 97% less and 2010 cars will emit 99+% less smog precursors than earlier models—is, unfortunately, bad news for the ZEV mandate.

In 1990, it was projected that ZEVs would reduce smog precursors by 14 tons per day at a cost of $1350 per vehicle. Today, the CARB staff estimates that each ZEV will reduce these emissions by only 23.8 pounds over a 10-year life (117,000 miles). This means that the statewide 2003 emissions reductions will be about 1 ton per day, but at an average incremental cost of $22,000 per vehicle. This amounts to an astronomical cost of $1.8 million per ton of emissions reduced. (So far, the maximum cost of any CARB emissions reduction program has been $11,040 per ton.) This cost per ton (relative to an evolving conventional motor vehicle) is not likely to change much in the future in the absence of the chimerical battery breakthrough that is hoped for but not predicted.

The ZEV program is not an air quality program. The benefits out through 2020 are far too small to be detected in any projections. The costs cannot be justified on any economically rational basis. Therefore, other rationales are being sought including full fuel cycle greenhouse gas emissions, energy supply diversification, environmental justice issues, California jobs, and groundwater pollution from the existing fuel supply system.

WHAT IS THE IMPACT OF CURRENT ELECTRICITY SUPPLY PROBLEMS ON THE ZEV PROGRAM?

The ZEV Program continues to assume that battery recharging would be done with off-peak power, generated in existing hydroelectric and gas-fired plants at low marginal costs. This is in spite of the well-documented desire of drivers of electric vehicles to have widely available recharging stations to increase range as well as the effects of existing programs to provide low-cost (free) recharging at workplaces and mass transit parking lots, both of which lead to on-peak electricity demand. Because of the small number of electric vehicles projected in the near future, it is certainly true that total electricity demand (like air quality) would not be significantly affected for many years. However, unlike the cost per ton of air emissions reduction, which is likely to remain relatively flat in the future, the impact on the peak electricity demand pattern will definitely grow with increasing numbers of electric vehicles on the road.[2]

How To Make A Battery From A Lemon

With thanks to:
http://www.miamisci.org/af/sln/frankenstein/fruity/html

The referenced website describes a junior high science project that demonstrates how you can light a small holiday bulb by connecting its lead wires to a small zinc screw and a small copper screw that are placed about 5 cm apart in a lemon.

One suggested use for the partially depleted battery packs that are no longer suitable for EVs is load leveling to permit electricity consumers to balance their load in the event that the utility grid is no longer able to provide that service. The Staff Report claims that this would extend the useful life of the expensive battery packs at low cost.

This might be another way to turn a "lemon" into a "battery."

WHO ARE THE INTERESTED PARTIES IN THE OUTCOME OF THE ZEV DEBATE?

The main participants in the ZEV mandate process so far have been the appointed air quality regulatory

[2] Increases in peak demands are most likely to be met by increased fossil fuel power generation within the South Coast Air Basin.

agencies, the environmental NGOs, the vocal but small group of electric vehicle enthusiasts, builders and suppliers, and the automobile industry.

Elected officials who might be considered to be ultimately responsible have so far been able to support the concept at low cost because of the extended (after the next several elections) time horizon of the program. This position is becoming more difficult to maintain as the potential size of the required subsidies grows and starts to compete with other requirements for scarce State resources.

To date, because of the press of other issues and the recognition that the near term impact on fuel demand will be quite small, the petroleum industry has observed the process closely but not taken a visible, active role in the debate.

WHAT DO "MANDATES" ACTUALLY DO?

If it is effective, a "mandate" forces some desired change in behavior. In this case, the ZEV mandate is attempting to force the development of new technologies and to require consumers to accept them in order to achieve improvements in ambient air quality. Any effective mandate incurs additional costs—after all, if the desired change were cost neutral (or as some believe, cost reducing), consumers would presumably embrace the change, perhaps after some initial education about the economics and the advantages of the alternative.

In order to offset these additional costs, subsidies are required. These are cheap at the outset, because production volume is low. It is not unheard of that manufacturers don't try to recoup all of their initial costs as a market is being developed, because they believe that later, high volume production will be profitable enough to justify the outlays incurred during the development period. (It appears that many .com companies are exhibiting this behavior at the moment.)

On the other hand, truly innovative technologies seem able to find markets among so-called Early Adopters who are willing to pay premium prices (for not yet fully developed products) just to have the latest and greatest. In fact, all of the major technical innovations of the late 20th Century have followed this pattern—think computers, video equipment, stereo systems, compact discs, etc. In this type of rapidly evolving market, premium prices can be realized, even though the purchaser knows full well that the useful life of the product will be short. (For example, most 2-5 year old computers—that originally cost much more that their equivalent replacements do today—are already headed for the recycling bin.)

DO SUBSIDIES WORK?

Not all new technologies are successful in finding a market or in replacing old ones. Technical sophistication is nice, but it is not enough for commercial success. A new technology must be seen as either better or cheaper—preferably both—than the one it is trying to replace in order to achieve a significant market. If it isn't, it won't succeed.

An example recently in the news has been the supersonic aircraft, the Concorde. This technically sophisticated plane was significantly faster, but it was certainly not cheaper or more comfortable than the alternative wide-body aircraft it was competing against. Without

significant government investment in the design and construction phases, this aircraft would have never gotten off the ground. Commercially, by charging premium prices (generally paid by someone other than the passenger), the Concorde was ultimately able to more than cover its very much higher operating costs per seat mile, but it never was able to attain the commercial success that would have made it the dominant technology.

Although the Concorde's current problems appear completely unrelated to the fundamental airworthiness of the aircraft, it now seems as if the UK and French governments will take this opportunity to cut their losses on this project.

ALTERNATIVE APPROACHES

As the 2003 deadline approaches, CARB has both reaffirmed its commitment to the ZEV but opened the door to more flexible approaches. These eventually should go beyond the immediate modifications proposed by the CARB staff in December.

As suggested in the battery report, CARB should begin to recognize the market realities by emphasizing niche markets for electric vehicles, including fleets, City Cars, and shared vehicles. This seems to be a more promising approach. Research done years ago by Dr. Dan Sperling of the University of California Davis suggested that the vast majority of California auto trips *actually made by motorists* could be made comfortably with a conventional battery-powered vehicle.

At the time, the problem identified by Dr. Sperling was that there was no market for such a vehicle. It could not replace an existing family vehicle because it would not have the versatility expected by consumers. Therefore, at least initially, it would have to be an additional car for the average family. This means an additional investment, the need for another parking space, and the installation of some means of overnight recharging. This remains the situation today.

In these findings, however, is a potential opportunity for the CARB ZEV program. It lies in a redirection of the efforts toward vehicles that appear to have real air quality benefits and a viable market. With proper positioning, the HEV, mini-EV, minivan-EV, or the City-EV could satisfy a significant share of the personal transportation market. These vehicles would not be a replacement for a conventional automobile, however. At the same time, such a vehicle, after proving itself on the road, could gradually substitute for the third or even the second car in the typical family's fleet.

In order for this to happen, however, there will have to be a recognition that the full, freeway capable ZEV—the so-called "gold standard" of electric vehicle enthusiasts—is not achievable before 2003, if ever. Supporters of the electric vehicle will have to avoid falling into the trap of letting the best be the enemy of the good. If this shift in emphasis occurs, the longer-term impact on the transportation fuel market could be significant