Study of the Secondary Benefits of the ZEV Mandate

A.F. Burke
K.S. Kurani
Institute of Transportation Studies
University of California-Davis
Davis, California 95616

E.J. Kenney
WestStart-CALSTART
Pasadena, California

August 2000

Prepared for the
California Air Resources Board
Research Division
Contract 99-328

Disclaimer

The statements and conclusions in this report are those of the Contractor and not necessarily those of the California Air Resources Board. Mention of commercial products, their source or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products.

Table of Contents

Figures

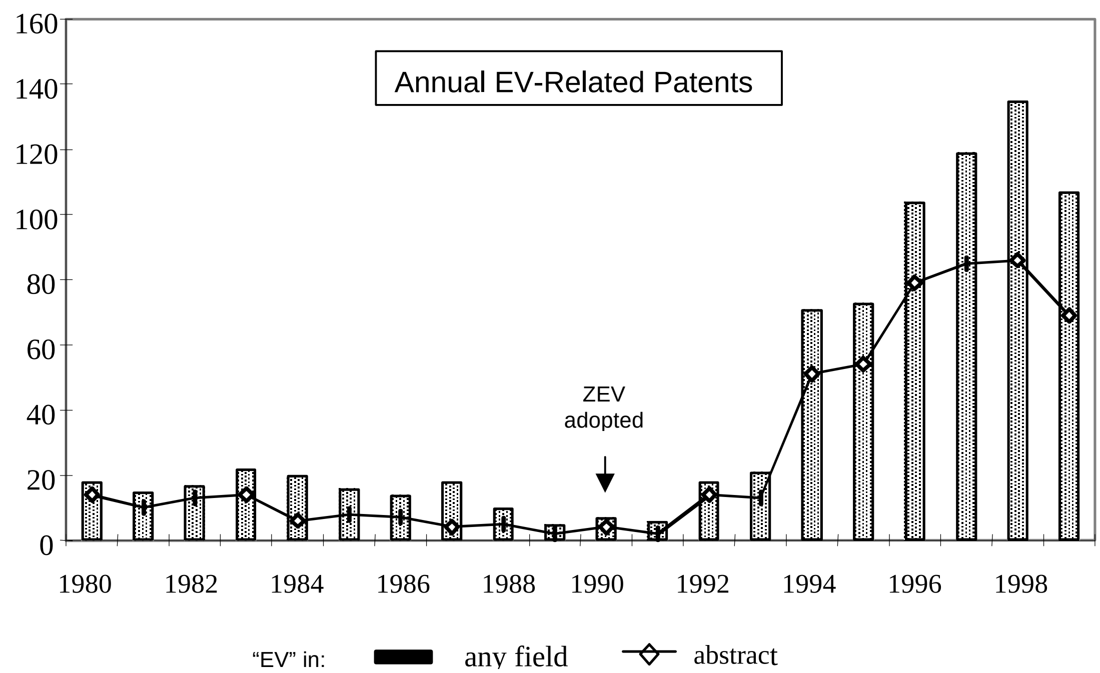
Tables

Executive Summary

The secondary benefits of the ZEV Program have been discussed in this report in terms of nine categories – (1) patents, (2) government/industry consortia, (3) new economic activity in California, (4) advanced vehicle development, (5) vehicle emissions outside California, (6) low-speed electric vehicle transportation, (7) electric utilities,(8) non-EV applications of advanced batteries, and (9) industrial and automotive applications of improved electric drives. The most important of the benefits in each category are highlighted in the following sections.

Patents

The U.S. patent database was searched for "electric vehicle". There was a sharp upturn beginning in 1992 in the annual number of patents that included that phrase in just the abstract or in any search field. Recently, the annual number of EV-related patents has been many times the typical number before the adoption of the ZEV Program. It seems clear that the ZEV Program has had a large effect on EV patent activity.



Government Programs and Industrial Consortia

There were government programs (primarily at the Department of Energy) concerned with the development of batteries and electric and hybrid vehicles before the ZEV Program. These programs were joint projects with industry, but they were poorly funded and not a high priority for either government or industry. The funding levels for the government/industry EV-related programs increased from $18 million in 1990 soon after the establishment of the ZEV Program to $100 million in 2000. In addition, a number of industrial consortia (USABC, ALABC, PNGV, etc) were formed, in most cases in conjunction with the federal government, to develop battery and vehicle technology for electric and hybrid vehicles. These consortia were well funded (about $2 billion spent) and resulted in a greatly quickened pace of technology development. This was especially true for advanced batteries. In addition, the formation of these consortia resulted in a much higher degree of cooperation between the government and automotive industry than had occurred in the past.

EV-Related Economic Activity in California

A survey of companies in California engaged in EV-related businesses was conducted by CALSTART to determine the impact of the ZEV Program on economic activity in California. The survey questionnaire was sent to 134 companies selected from the CALSTART database of clean transportation companies. Information regarding their past, present, and projected business activity was received from twenty-two (22) respondents, which included small, medium, and large companies involved with all phases of EV-related activities. These twenty-two replies were used to estimate the EV-related economic activity in California in terms of employment, sales revenue, R&D expenditures, and new investment requirements. Each company was asked what fraction of their economic activity occurred within California, and that information was used to calculate the total EV-related economic activity in California.

From the 22 responses, CALSTART has estimated that in 1999, the 134 companies had 3500 employees with 767 of the jobs directly due to the Program. The annual sales revenue in California of the 134 companies is estimated at $400 million. The 22 respondent companies said that they expected to spend about $25 million on R&D in 2000. About $10 million of the R&D will be in California, of which about $6 million will be directly due to the Program. Because the analysis is based on a small set of responses to a limited survey, these numbers should not be viewed as a complete or definitive statement of the economic effects of the ZEV Program.

Survey recipients were asked about the importance of the ZEV Program fto their business' success. 80% of the respondents said that the Program was very or somewhat important for the period 1990-1999, and 90% said the Program will continue to be very important or somewhat important to the growth of their businesses.

Advanced Vehicle Technologies

Since 1990, there has been great progress in the development of ultra-clean vehicle technologies that are presently being proposed by the auto industry as alternatives to EVs in terms of achieving near-zero emissions from cars and buses. These alternatives include ICE/gasoline passenger cars meeting SULEV standard or even ZLEV emission levels, hybrid-electric cars meeting the SULEV standard with 20-50% better fuel economy than conventional ICE cars, hybrid-electric transit buses with emissions approaching those of natural gas fueled buses, and fuel cell cars and buses using direct hydrogen or a methanol/reformer for fueling. All of these technical options for achieving ultra-clean emissions have been developed since the ZEV Program was adopted and in all likelihood they would not have been developed in the decade of the

1990's without the ZEV Program. The air quality and economic impacts of these advanced vehicle technology developments are likely to be great.

Vehicle Emissions Outside California

The 1990 Clean Air Act Amendments established the Ozone Transport Commission and defined the Ozone Transport Region (OTC) in the Northeast states stretching from Virginia to Maine. The states in the OTC region had the option of adopting the California LEV program, which includes the ZEV Program. When the OTC commission attempted to adopt the ZEV Program, the auto companies went to court to block that action, and a long period of negotiations involving EPA followed. The National Low Emissions Vehicle (NLEV) program, which sets lower vehicle emissions standards nationwide in 2001 than would have otherwise been the case, resulted from the negotiations with the OTC states. New York, Massachusetts, Vermont, and Maine did not accept the NLEV program and those states continue to require the ZEV Program. There is little doubt that the possibility that the Northeast states could adopt the California LEV program and in particular, the ZEV Program, was instrumental in the auto companies agreeing to accept the NLEV program. Further, in order to meet the lower emissions standards requiring advanced catalytic after-treatment, the auto companies supported clean gasoline standards. Thus the effect of the ZEV Program on emissions and fuel standards has been nationwide. The implementation of the program in the four northeastern states will magnify the economic effects of California's program.

Low-Speed Electric Transportation

The ZEV Program is concerned with the development and marketing of full-function electric cars that can be operated safely on the arterials and freeways of California. Much work has also been done over the last ten years to improve and develop low-speed electric transportation vehicles, such as electric bikes and scooters, neighborhood electric vehicles, and "city" EVs. These vehicles are used for short trips by one or two people. The maximum speed of these vehicles is 20-40 mph or less. Some of the companies that originally intended to develop electric vehicles for the ZEV Program shifted their interest to the development of low-speed vehicles as those markets seemed to be more easily entered. As a result, there are now about thirty (30) companies in the United States and around the world that are engaged in the design and production of vehicles of this type. Worldwide there are over 600,000 of the low-speed electric vehicles sold annually and these products will ultimately benefit from the recent advances in battery and electric drive technology. The near- and mid-term economic value of these markets could exceed that of the larger electric vehicles.

The low-speed electric vehicles most closely related to the ZEV Program are the "city" EVs developed by Nissan, Toyota, Honda, and Ford (Th!nk) as those vehicles utilize driveline and battery components similar to those in the larger full-function EVs. The role of the city EVs in meeting the ZEV Program is yet to be determined, but it seems clear that they are in all cases companion products to the larger EVs of the various auto companies.

Electric Utilities

The importance of electrical energy storage to the utilities and their customers is becoming more and more important in the business climate of deregulation and the present increased interest in "Green Power". Many of the potential utility applications require large batteries and/or ultracapacitors in contrast to consumer electronic applications that require small energy storage devices. The utility applications also require high power electronics. Hence, the utilities have shown much interest in the use of the advanced energy storage units and the associated interface electronics that have been developed for EVs.

Energy storage is used by the utilities for load leveling and power quality enhancement both to alleviate short interruptions of service and to maintain strict voltage and frequency standards. The utilities now use lead acid batteries for energy storage because of their relatively low cost. In the future, they could use one of the advanced battery types developed for EVs either as new batteries or as used batteries after their performance is no longer satisfactory for the EV application. The potential market for batteries and ultracapacitors in utility applications is very large. Utilities can adopt these technologies when their reliability has been proven and their costs become practical.

Industrial and Consumer Applications of Advanced Batteries

The present study has identified a number of non-EV related applications of battery technologies that have been developed or improved as part of the R&D effort to provide the batteries needed to meet the ZEV Program. The EV battery development programs of the US Advanced Battery Consortium focused primarily on the development of large Ampere-hour, high-power cells and modules of prismatic (slab-shaped) design. These advanced batteries are suitable for industrial and utility applications for which the smaller cells already sold in high volume for consumer electronics are not appropriate. In addition, the related development of very high power pulse batteries and ultracapacitors for hybrid vehicles has yielded products for auto as well as industrial and consumer markets. The potential non-EV related markets for these advanced energy storage devices is very large, at least one billion dollars annually.

Significant improvements in sealed lead acid battery technology have resulted from the R&D performed by the Advanced Lead-Acid Battery Consortium in an effort to develop batteries suitable for use in EVs. Irrespective of their success as an EV battery, the improvements in the lead acid batteries will enhance their competitive position relative to advanced batteries in both conventional automotive and industrial applications. The improved performance and cycle life of lead acid batteries will make them more difficult to displace as the battery of choice as the auto industry moves to 36-42V systems and electric utilities install more energy storage for load leveling and power quality enhancement.

EV batteries require much more sophisticated testing, monitoring, and charging hardware and software than was previously available. The required equipment was developed and marketed in the 1990's in support of the battery industry and these technologies will be available for future battery development and application.

1.0 Introduction and Background

1.1 Introduction

This report is divided into essentially two parts. The first main part (Section 2) discusses the approach taken in performing the study. Section 2 includes a definition of what is meant by a secondary benefit and the criteria used to justify the relevance of the benefit to the ZEV Program. It also discusses the categories of benefits considered and why the changes attributed to the ZEV Program are benefits to California or the United States in general. In some cases, the cited effects of the Program are economic; in others they are technological. The second large section of the report (Section 3) contains a discussion of nine categories of benefits in terms of their relationship to the ZEV Program and what impacts they have had up to the year 2000 and are likely to have in the future to the societies and economies of California, the United States, and the world. In some instances, the benefits are only now becoming apparent and in other cases the benefits are clearly identifiable and their impact to date has been determined. In the final section of the report (Section 4-Summary/Conclusions), the secondary benefits are reviewed in general, and the special circumstances of the 1990s that resulted in the important and far-reaching secondary benefits are identified and discussed.

1.1 Background

The California Air Resources Board put in place in September 1990 the LEV-I vehicle emission standards which included the requirement that 2% of new vehicle sales in California in 1998 be zero emission vehicles (ZEVs), 5% in 2001, and 10% in 2003. These requirements for sales of electric vehicles are often referred to as the ZEV Program. In 1990, ZEVs meant electric vehicles (EVs) as that was the only technology available that had zero exhaust and fuel related emissions. Except for the GM Impact and several electric vehicles being developed as part of the United States Department of Energy (DOE) Electric/Hybrid Program, electric vehicles in 1990 utilized relatively low technology and had performance (range and acceleration) clearly unacceptable to the car purchasing public. The reaction of the auto industry to the ZEV Program was that electric vehicles were impractical and not marketable and that even if they were possible, the technology would take many years to develop. Nonetheless, the presence of the ZEV Program initiated in both industry and government a great deal of R&D directed to the development of batteries and other components for electric vehicles as well as the improvement of the emissions from gasoline engine-powered vehicles as a means of greatly reducing the difference in emissions between conventional and electric vehicles. After a few years, the auto industry also started the development of hybrid-electric vehicles as an alternative to the pure battery-powered electric vehicles, which were still thought to be impractical by the auto industry except in small niche markets. A summary of the advances in electric vehicle technology for the time period from 1990 to 1995 is given in Reference 1, which was prepared by researchers at the Institute for Tranportation Studies at UC Davis. The present report can be considered an update and extension of that report to consider a wider range of benefits of the ZEV Program.

As will be discussed in later sections of this report, it was the R&D done by the auto industry and related industries to show that there were alternative means of meeting the emission reduction objectives of the ZEV Program that in large part has resulted in the secondary benefits of the Program described in this report. In addition, as it became clear in the mid-1990's that markets for electric vehicles were going to develop slower than many developers of EV related components had expected, they began to seek other markets for their products that were more immediate and less sensitive to the relatively high cost of the new technologies. This situation has also contributed to the extensive secondary benefits of the ZEV Program. Another factor in the development of secondary benefits was the almost immediate interest of the military in the development of military vehicles that incorporated high power electric drive systems and the related concept of the development of technology that had application in both the civilian and military sectors. Factors such as the globalization of the auto industry and deregulation of the electric utility industry in the United States have also contributed to the wide range of secondary benefits from the ZEV Program. Globalization made available to US companies both technology and potential markets that would not have been available otherwise. Deregulation of the electric utility industry is expected to increase the markets for the advanced energy storage technology being developed for electric vehicles (Reference 2).

2.0 Approach

2.1 Definition of a Secondary Benefit

The primary benefits of the ZEV Program are the consequences of activities initiated in response to the Program that directly result in the development and commercialization of road-worthy electric vehicles by the auto industry to achieve a nominal 10 percent of sales in 2003. Favorable consequences of the Program that are not directly related to its successful implementation in California are considered to be secondary benefits of the Program. The secondary benefits include the economic benefits to California of the primary ZEV program and new and improved technologies/products attributable to the Program in both industries related and unrelated to transportation. The new technologies include advanced emission-control technologies that will promote improvements in the air quality in California by means other than electric vehicles and provide improved consumer and industrial products. The secondary benefits also include new economic activities related to the Program that take place in the whole United States and in other countries of the world. The economic activities include that of private companies as well as that of state and federal governments. Hence the scope of the secondary benefits as defined in this report is far reaching and for that reason some of the benefits may be somewhat debatable in the eyes of some observers.

2.2 Criteria of Relevance to the ZEV Program

As discussed in the previous section, secondary benefits of the ZEV Program have been defined as favorable consequences of the Program not directly related to the development and marketing of EVs. Identifying an activity as a benefit of the Program means that it would not have occurred in the time period that it occurred or to the extent that it occurred if the ZEV Program had not been in place. Such a determination is to some extent subjective so that it is necessary to have criteria on which to base an assertion that a specific activity resulted from the Program. Key criteria for relevance are the time (calendar dates) when an activity occurred or when there were significant changes in the level of that activity. For example, one can look at the number of patents filed related to electric vehicle technology or the size of the budgets of various government departments related to EVs for years before and after the Program and determine if large changes are evident. If large changes did occur, then one can conclude that those changes were a result of (relevant to) the Program. Similarly, if a new or significantly improved product was offered for sale in the period after the Program was established and that product utilized technology developed primarily for use in EVs, it can be concluded that the development of that product was a secondary benefit of the Program. In some instances, the development of a technology could have been started in support of the Program and later evaluation of the technology could indicate it is better suited for another application, as in the case of ultracapacitors or flywheels. Particular technologies can result in both primary and secondary benefits as in the case of some of the advanced batteries.

Another criterion of relevance is concerned with the reasons that particular technologies were developed and how those reasons are related to the Program. Consider the development of ultra-clean emission technologies for gasoline engine vehicles. Such technologies are customarily developed to meet specific emission standards, such as ULEV. In the case of emission technologies developed in response to the ZEV Program, CARB stated in 1990 that the effective emission levels for EVs, including the power plant emissions, in the LA basin were 0.004 gm/mi HC and .02 gm/mi NOx. It was thus concluded by the auto industry that if a conventional ICE car could be developed to achieve these emissions, then the rationale for the need for EVs to improve air quality would be significantly eroded. The result was the development of emission control technology to meet the proposed SULEV standard and thus its relevance to the ZEV Program. In Section 3, these types of criteria will be used to argue the relevance of the various activities to the ZEV Program.

2.3 Selection of Categories

In discussing the secondary benefits, it is convenient to divide the various benefits into a number of broad categories (see Table 2-1). The categories consist of related activities that result from particular types of technology development, their application to specified industries, or result from particular government and/or industrial decisions. Benefits from each of the categories are significant and would not have occurred without the ZEV Program.

TABLE 2-1: CATEGORIES OF SECONDARY BENEFITS OF THE ZEV PROGRAM

1. Increased Patent Activity related to electric vehicle
2. Growth of government programs and formation of government/industry consortia to support EV development
3. New economic activity in California and world-wide related to EV
4. Advanced vehicle developments:
-- Ultra-clean ICE-powered passenger cars
-- Hybrid-electric light duty vehicles
-- Hybrid-electric transit buses
-- Fuel cell-powered cars and buses
-- Light-weight materials
5. New stricter emission and fuel standards in California and in other States
6. Development of low-speed electric transportation:
-- City and Neighborhood EVs
-- Electric bikes and scooters
-- Establishment of new companies
7. Electric utilities use of advanced energy storage technologies
8. Industrial and consumer applications of EV advanced battery technologies:
-- Large prismatic nickel metal hydride and lithium batteries
-- Electrochemical capacitors (ultracapacitors)
-- Pulse power batteries
-- Improved lead-acid batteries
-- Zinc-air batteries
-- Zinc-bromine batteries
-- Battery test equipment and monitoring systems
9. Industrial and automotive applications of improved electric drive systems:
-- Automotive auxiliary systems
-- Industrial electric drive systems

2.4 Measures of the Impacts

For each category, an attempt is made to measure the impacts of the activities in as quantitative a manner as possible. The measures are basically of two general types – product performance and economic. For some activities, the impact is given in terms of both types of measures. The economic measures for products are the number of companies involved, their sales ($), employment, and investment in R&D and capital equipment. For government programs and consortia formed, the measures are the number of companies involved and the magnitude ($) of their budgets. It is of particular interest to see how these economic measures have changed over the period (1990-2000) in which the ZEV Program has been in effect. The performance of new and/or improved products is given in terms of familiar parameters such as fuel economy and emissions for vehicles, and energy and power density for batteries and other energy storage devices. Instances where these improvements in performance have resulted in new applications of a technology and/or higher sales will also be noted. Reductions in cost and thus enhanced marketability resulting from development as EV components are also cited. A final type of measure of the impact of the ZEV Program is opportunity for federal and state regulatory agencies to set emissions and fuel quality standards that would have been impossible or unacceptable to the auto and petroleum/fuel industries without the Program.

3. Discussion of the Benefits by Category

3.1 Patents

3.1.1 Scope of Activity

The goals of this part of the study were to: (1) identify changes in the number of patents related to electric vehicles that were issued over the time period from 1980 to the present; (2) assess whether changes in total patent activity are contemporaneous with the ZEV program; and (3) explore whether applications other than electric vehicles are systematically related to the timing of the ZEV program, other changes to the LEV program (specifically, LEV-II), or the total number of patents. Some of the work reported here is taken from Kurani and Turrentine (Reference 3).

Additional data searches were made for this report. In particular, an effort was made to identify secondary applications of inventions that received EV-related patents. This line of inquiry proved largely unproductive—and thus the last goal stated in the previous paragraph could not be achieved. The patents themselves rarely contain mention of other applications. Further, any number of patents may be for inventions that are applied to EVs, but do not mention EVs specifically. An example of the latter is GM’s patent for a light-weight magnesium seat frame. This seat frame was patented by GM, and GM claims it is one of 23 patents that came out of their Impact development program (www.gmev.com). That patent, however, was not found by the search for EV-related patents.

3.1.2 Criteria for Relevance to the ZEV Program

The primary criterion for determining the relevance of the ZEV program is whether changes in patent activity are contemporaneous with the establishment of, or changes to, the ZEV program.

Cases of corroborating statements from patent holders that specific patents were related to the development of vehicles to meet the ZEV Program or to fulfill an MOA obligation were not found. The only public statement regarding patents by an automotive-OEM subject to the ZEV Program or an MOA came from General Motors. The following statement is found on GM’s web site:

> “In all, 23 new patents were granted [for the EV1], most of which can be used in other GM cars. For instance, the EV1 seat cushion frame is magnesium, and that component is 60% lighter than if it were made of steel. Sunfires and Cavaliers now use this Duoflex magnesium seat. Other GM cars use the adhesive developed to keep the electric car’s chassis parts together.” (www.gmev.com)

GM and Ford may legitimately claim that some of their EV-related patents are not traceable to the ZEV Program. The GM program was started before the ZEV program, but it was significantly expanded after the Program was put in place. The Ford EV program was started under contract to DOE and was expanded after the Program.

3.1.2 Measures of Patent Activity

The basic measure of patent activity is the annual number of patents related to EVs that were issued by the U.S. Patent and Trademark Office (USPTO) between the year 1980 and the present. The USPTO data base was searched through its on-line search facility. Whether a patent is related to EVs was determined by reviewing abstracts of all patents found by searching for the occurrence of the search phrase in any field of the patent. USPTO guidelines recommend searching only the abstract to limit searches to the "most relevant patents." However, as the purpose of this project is to identify secondary impacts of the ZEV program, it is desirable that all mentions of electric vehicles be reviewed.

To establish whether changes in total patent activity are contemporaneous with the ZEV program, counts of patents per year were plotted. To establish whether changes in other, non-EV applications mentioned in EV-related patents are contemporaneous with the establishment of, or changes to, the ZEV program and LEV program, patents were reviewed for mention of non-EV applications. This exercise proved unproductive. Specific mentions of non-EV applications in patents were rare. Further, total patents per year were counted so that changes in EV-related patents can be compared to overall change in all patent activity. European and Japanese patent data bases were not searched, but they would be expected to contain a large number of patents related to EVs.

3.1.4 Changes in EV-related U.S. Patents since 1980

The discussion below will document there was a sharp upturn in EV-related patent activity early in the 1990s. During the period of 1980 through 1991, the average number of EV-related U.S. patents granted was declining on average by about 1 patent per year. For reference, 20 EV-related patents were granted in 1980. During the period from 1992 to 1998 the annual number of EV-related patents granted increased by about 20 per year.

This upturn is not matched by a similar upturn in all patent activity. All patents show a steady and statistically constant growth throughout the time period 1980 to 1998. Clearly, events of 1990 markedly increased EV-related patent activity.

3.1.5 EV-related Patent Activity Compared to All Patent activity

Not all patents represent ideas or products that are successful in the market. However, taken as a whole, the rate at which patents are filed and granted in a particular area is an index of inventive and entrepreneurial activity. In this section, we identify changes in the number of patents related to electric vehicles that were issued over the time period from 1980 to the present and assess whether changes in total patent activity are contemporaneous with the ZEV program. In cases where corroborating statements can be found, for example, claims by automakers that their electric vehicle research programs have produced patents, these are included.

1980 was a convenient year to start tracking patents related to EVs. (The USPTO on-line data base can be searched as far back as 1976.) During the early 1980s, the federal Department of Energy supported a number of EV and hybrid EV related research programs. The DOE was established late in the 1970s. By starting our patent count in 1980, we insure those federally funded programs had been in place long enough to begin producing patentable inventions. We also ensure that some time has passed to allow for the patent process itself. 1999 is the last complete year for which data on EV-related patents are available; 1998 is the last year for which there is a count of total patents.

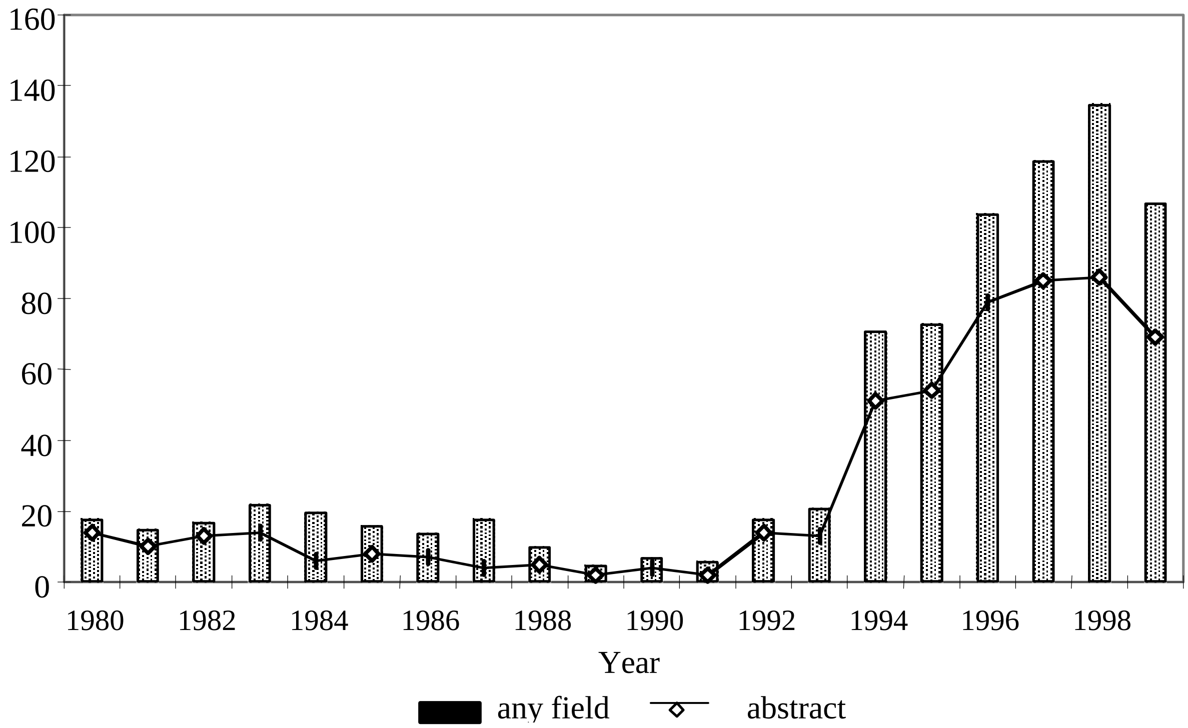
Patents were searched for the phrase “electric vehicle*.” The star character is a wildcard, allowing the search to return patents containing “electric vehicle,” “electric vehicles,” or “electric vehicle’s” in one search pass. Further, the search was run twice--once to search all data fields of the patent for the occurrence of the search phrase, and once again to search only the patents’ abstracts. Patent abstracts were reviewed to insure the patent was indeed related to the subject matter at hand. A few patents were rejected--one related to toy electric vehicles and some related to electrically actuated or powered devices for vehicles, i.e., the phrase “electric vehicle” was not an adjective (electric) modifying a noun (vehicle), but in fact two adjectives modifying a subsequent noun. As an example, a patent for an “electric vehicle coupling device” was not a means to connect electric vehicles, but an electrically powered device for coupling railway cars together. The results of the search are illustrated in Figures 3.1-1 and -2.

As illustrated in Figure 3.1-1 below, between 1980 and 1991, EV-related patent activity started low and then declined. From 1980 to 1987, typically 15 to 20 patents were issued per year. The annual number of patents then fell, such that in 1991, the year the ZEV Program was first announced, only six patents related to EVs were issued. There was a small increase in the number of patents in 1992 and 1993. There was a pronounced increase in 1994. From that time through 1998, the number of patents continued to grow. There was a sharp downturn in 1999; but one year does not make a trend, and only time will tell whether this measure of EV-related activity will continue to decline.

The basic measure of total patent activity passes the test of whether or not an upturn in EV-related inventive activity was contemporaneous with the announcement of the ZEV program. In fact, it is interesting to note that despite a strong federally funded R&D program in electric and hybrid electric vehicles during the early 1980s, patent activity was low. During the 1990s, the ZEV program affected overall efforts to patent inventions related to EVs in a way that federal research dollars did not in the 1980s.

Is the simple fact that increased EV-related patent activity was contemporaneous with the announcement of the ZEV program proof the program caused these increases? No. Conceivably, something about the patent system or the world at large changed in the early 1990s such that all patent activity increased. However, Figure 3.1-2 shows that this was not the case. The table shows numbers of EV-related patents and total patents, each indexed to the year 1980. That is, in each year, the chart shows the number of each patent type issued in that year divided by the number of like patents in 1980.

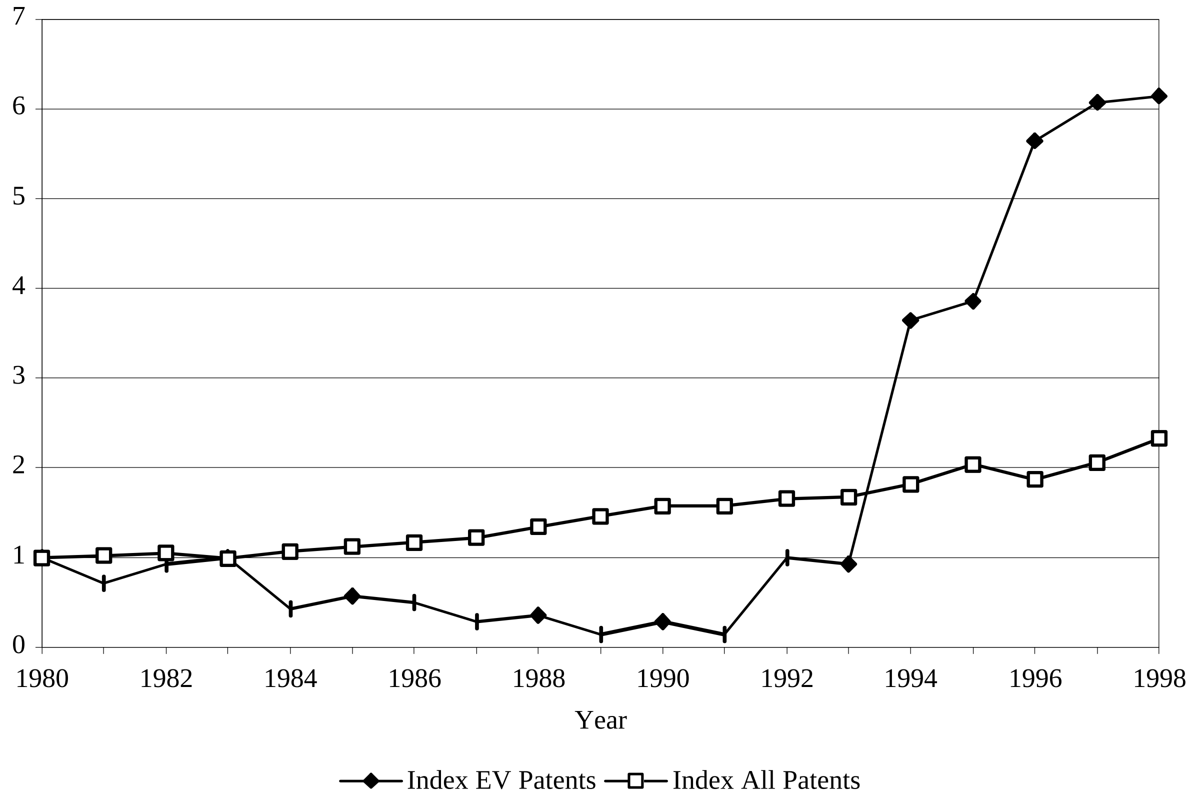
FIGURE 3.1-1: ANNUAL NUMBER OF EV-RELATED UNITED STATES PATENTS GRANTED FROM 1980 TO 1999.



During the years of low and declining patent activity related to EVs (1980 to 1991), all patent activity in general is increasing. In fact, all patent activity increased slowly and steadily throughout the period from 1980 to 1998, such that by 1998 the number of patents had increased by a factor of 2.3. In the time period 1991 to 1996, the rate of patent activity related to EVs increases faster than all patent activity. By 1991, EV-related patent activity had dropped to only 0.14 times that in 1980; by 1998, over 6 times as many EV-related patents were granted every year as had been in 1980.

These observations suggest, and statistical analyses of these data confirm, that increases in the number of EV related patents are not correlated with increases in overall patent activity. (Details of the statistical analysis are contained in Appendix 1.) We are therefore more inclined to attribute the upturn in EV-related patent activity to the fact that after 1990 all automobile manufacturers had to develop EV technology to meet the ZEV Program.

FIGURE 3.1-2: ANNUAL NUMBER OF EV-RELATED AND ALL UNITED STATES PATENTS GRANTED FROM 1980 TO 1998. INDEXED TO 1980.



Our patent search was conservative and we undoubtedly under-counted EV-related patents, as we counted only those patents which mention electric vehicles in their texts. That is, there may be any number of inventions that could be and have been applied to EVs, that did not mention this application in the patent itself. For example, we did not include many battery patents. The reason is that many battery patents do not limit the use of the battery to electric vehicles. Many materials related patents, especially those having to do with developing lightweight vehicle frames and bodies are not included here. Certainly though, such advances are important to, if not specific to, EVs. We do not report here on such broadly applied patents because it is beyond the scope of the present study. Further, the data presented here in are for US patents only and do not account for Japanese or European patents.

3.2 Government Programs and Industrial Consortia

3.2.1 Government Programs

Scope of Activity

The government programs of primary interest are those in the United States Departments of Energy and Transportation related to electric and hybrid vehicle development and demonstration. Some states, including California, have state and air quality management district programs concerned with electric vehicles, but in many cases, a significant fraction of the funding for the state programs comes through a federal program. The United States has had an Electric and Hybrid Vehicle Development and Demonstration Program (EHVDD) since 1976. It was started during the Oil Crisis of the mid-1970's to foster cooperative research and development by the government, industry, and universities to reduce the dependency of the United States on imported oil. Most of the R&D on batteries and electric vehicles that was in progress in the United States in 1990 was funded under the DOE EHVDD program. The exception was the "Impact" program, privately funded by General Motors, which in fact demonstrated that available technology could be utilized to design and fabricate EVs that many thought would be attractive to the car buying public. The DOE EHVDD program had been getting smaller in the 1980's as the concerns of the oil crisis were fading from memory. The establishment in California of the ZEV Program greatly increased the interest of DOE and the auto industry in battery-powered vehicles resulting in a large expansion of federal government programs related to electric vehicles.

The activities in this category include battery and electric driveline component development and the design, fabrication, and testing of electric vehicles to demonstrate advances in technology. These programs were performed in industry as well as at the DOE National Laboratories and universities. Before the ZEV Program, the projects making up the DOE EHVDD program were treated as research projects of relatively low priority by the auto industry and little urgency for rapid progress was felt by most of the participants. This changed radically after the Program and lead to the formation of the various government/industry consortia discussed later in this section of the report.

Measures of the Impact

The primary measures of the impact of the ZEV Program on the government programs directly and indirectly were the scope of those programs and their budgets. After the formation of the various government/industry consortia, much of the technology activity supported by DOE was integrated into the consortia programs and it became difficult to separate out the DOE programs and budgets from those of the consortia. The formation of the consortia would not have been possible without the federal (DOE) funding and they would not have been able to begin work at a high level of knowledge and development without the prior DOE EHVDD programs. Companies and labs in California, as well as the rest of the United States, benefited as the federal programs were expanded after the Program.

Criteria for Relevance to the ZEV Program

As noted above, the DOE EHVDD program formed the foundation for much of the government and industrial R&D done in response to the ZEV Program. When the government/industry consortia were formed, the people on the government side were previously involved with the EHVDD programs and the link to their activities after the ZEV Program was very direct. The large interest by industry in attaining government support for their work on batteries and electric vehicles was a primary factor in the expansion of the EHVDD programs after 1990. The federal government clearly felt the responsibility to assist the US auto industry in meeting the ZEV Program, especially with the strong presence of the Japanese manufacturers in the California market.

Budgets for Government Programs

As noted previously, it is somewhat difficult to separate the government programs and their budgets from those of the consortia formed and supported in part with government funding. In this section, only government funding will be considered and the total funding including industry contributions will be considered in the next section that focuses on consortia. In this section, we are interested in the funding from the federal budget to support R&D programs related to electric and hybrid vehicles and component technologies used in those vehicles. One way of tracking the DOE Electric and Hybrid Vehicles Program is through the Annual Reports to Congress that the DOE must prepare each year by law. These reports are available for 1977 – 1997 (see Reference 4).

Funds for these programs are primarily in the Department of Energy and Department of Transportation budgets. Tracking the magnitude of these budgets for years before and after the ZEV Program is an indicator of the influence of the Program on the level of the federal government's programs on electric and hybrid vehicle technology (References 5, 6). The relevant DOE budgets for 1985 –1992 are shown graphically in Fig. 3.2-1 for the early years after the Program and in Table 3.2-1 for 1999-2001.

TABLE 3.2-1: DOE AND PNGV BUDGET INFORMATION

Item	Year	Requested
DOE-Transportation	2001	$251 million
PNGV	2001	$255 million
DOE-USABC	2001	$9.7 million (65% cost share required)
DOE- Hybrid vehicles	2001	$47.8 million
DOE-Fuel cells	2001	$41.5 million
DOE-Clean cities	2001	$10 million

Source: www.evaa.org

		Expended
DOE Battery Program	1999	$22 million
EV batteries		$6 million
HEV batteries		$13 million
Exploratory Research		$3 million

Source: Sutula, R.A., from Proc. of 15th & 16th Electric Vehicle Symposia (DOE)

Fig. 3.2-1

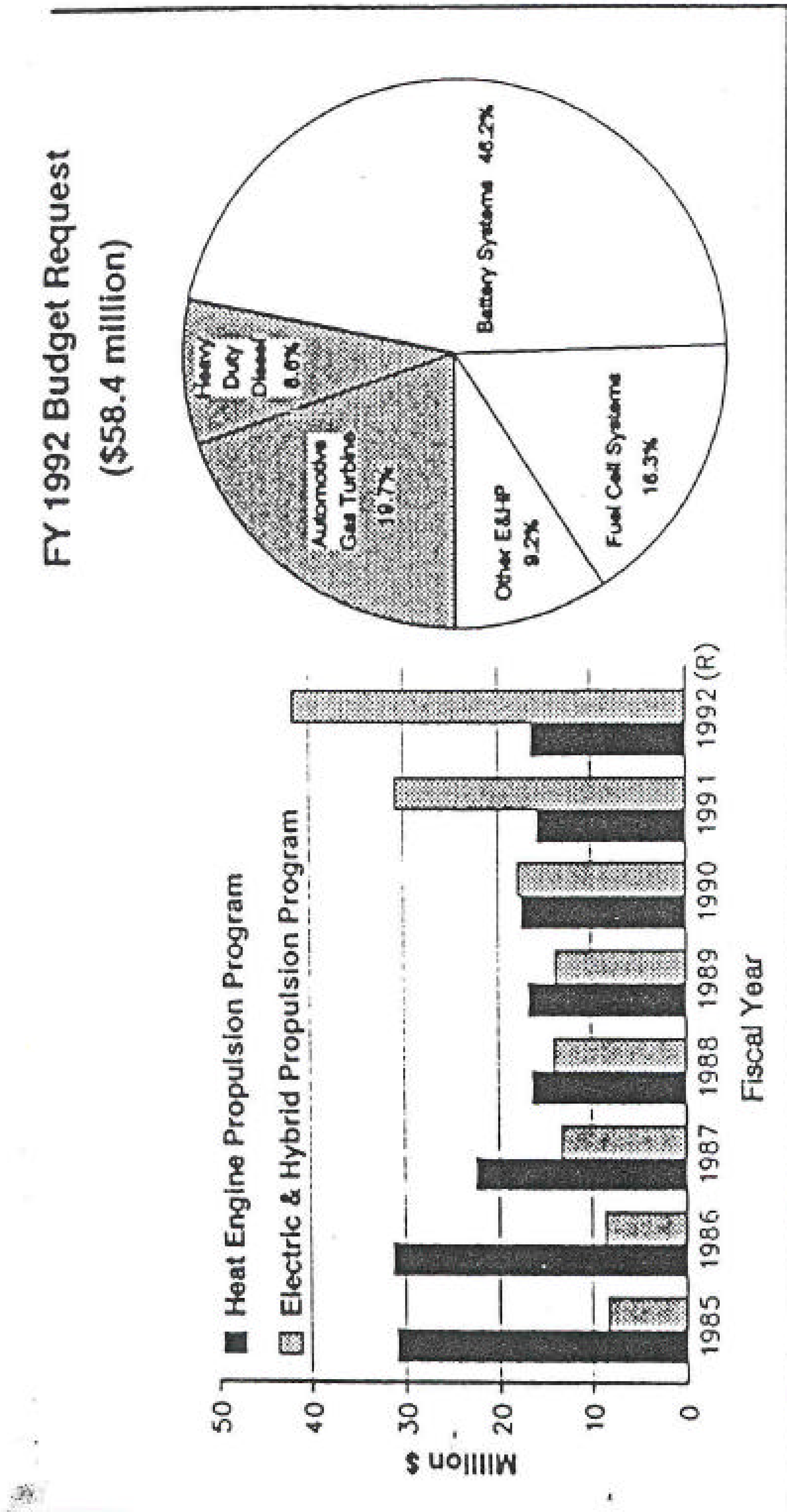


Figure 3: DOE Office of Propulsion Systems Budget History

Source: Brogan & Venkateswaran (1991).

The change in emphasis from heat engine propulsion programs to electric and hybrid propulsion programs at DOE is clearly shown in Figure 3.2-1 taken from Reference 5. The effect on the dollar value of the change in DOE's emphasis to electric powered vehicles on R&D/infrastructure programs in California is shown in Table 3.2-2 taken from Reference 7. Note that in the time period 1995-2000, work on electric and hybrid vehicle R&D averaged about $16 million per year representing about 65% of the federal funding for R&D/infrastructure programs in California.

California has two DOE National Laboratories – Lawrence Livermore National Lab and Lawrence Berkeley National Lab – that have been heavily involved with research for electric and hybrid vehicles. The large expansion of such research in DOE and industry benefited those laboratories and the University of California campuses with which they are associated.

TABLE 3.2-2: CALIFORNIA SHARE OF THE FEDERAL R&D/INFRASTRUCTURE PROGRAMS RELATING TO AFVS

Program Description	1995	1996	1997	1998	1999	2000	Cumulative (1995-2000)	Long-Term (2001-2010)
EPA - R&D	$2,060,000	$2,122,000	$2,186,000	$2,252,000	$2,320,000	$2,390,000	$13,330,000	$28,224,000
DOE AF Utilization	$6,295,000	$6,669,000	$6,869,000	$7,075,000	$7,287,000	$7,506,000	$41,701,000	$88,632,000
DOE Electric & Hybrid R&D	$10,783,000	$15,527,000	$15.993,000	$16,473,000	$16,967,000	$17,476,000	$93,219,000	$206,348,000
DOD ARPA/TRP	$1,292,000	$667,000	$667,000	$0	$0	$0	$2,626,000	$0
DOD ATTI	$600,000	$600,000	$0	$0	$0	$0	$1,200,000	$0
TOTAL	$20,830,000	$25,385,000	$25,715,000	$25,800,000	$26,574,000	$27,372,000	$152,076,000	$323,204,000

Source: reference 7

3.2.2 Government/Industry Consortia

Scope of Activity

Since the ZEV Program was put in place, a number of government/industry and industry consortia were formed that were concerned with developing technology needed to successfully meet the Program. These technologies included various types of traction batteries, high power electric drivelines, fuel cells, and demonstration vehicles. The government/industry consortia were formed to perform R&D in areas in which the cost of the R&D was high and the risk of failure was such that no one company wanted to finance it alone. In the government/industry consortia, the R&D was financed with a combination of government and industry funds with the industry cost share usually being about 50%. In some cases, the consortia consisted only of industry partners that desired to share the cost of the R&D that would benefit all the partners. A list of the various consortia formed after the Program is given in Table 3.2-3 along with the technologies and goals of each of the consortia. Note that the formation of consortia to work on technologies related to the ZEV Program occurred also in Japan and Europe.

Measures of the Impact

The impact of the consortia on the development of ZEV Program- related technologies can be measured both in economic terms and in terms of the progress made in developing the new and improved technologies needed to commercialize electric vehicles. The economic impact can be stated in terms of the number of companies involved in each of the consortium and the scope and budget of their programs. The budgets will include both the dollars from the industrial partners and the government funding where appropriate. The primary reason that the consortia were formed was to shorten the time period needed to develop the technologies needed to meet the Program. Hence a measure of the impact of the consortia is their contribution to the development of the new technologies for EVs, particularly the batteries. For some of the consortia, the improvements in the technologies yielded products for markets other than electric vehicles resulting in secondary benefits of the ZEV Program. In this regard, it is important to project the possible continuing impact of government/industry consortia in the future, especially in the United States where such consortia are not common.

Relevance of the Consortia to the ZEV Program

The primary factors in showing the relevance of the consortia to the ZEV Program are the types of activity in which they are engaged and the timing of their formation. The activities of the various consortia and the time of their formation are given in Table 3.2-3. In the case of the battery consortia (USABC and ALABC), there is no doubt that they were formed in response to the Program as development of advanced batteries for EVs was felt to be the key requirement for meeting the Program. The programs of all the consortia listed in the table are concerned with electric drivelines and electric and hybrid vehicles in one way or another and all were formed after the ZEV Program. Hence it seems reasonable to assert that the ZEV Program was a strong factor in their formation and that the consortia would not have been as productive as they have been without the ZEV Program. For example, the Partnership for a New Generation Vehicle (PNGV) consortium, which has a goal of developing a family car with a fuel economy of 80mpg, has utilized electric driveline components and battery technology in all their designs. Similarly, the DARPA Regional Advanced Vehicle Consortia that have had a number of large military and transit vehicle projects have involved many of the same companies and technologies (advanced batteries, improved electric drivelines) that are critical to the success of the ZEV Program.

There have also been Electric Vehicle Associations and Battery Development consortia formed in Japan and Europe. All of the consortia have contributed significantly to the rapid development of electric vehicle and battery technology that has occurred over the last ten years.

Scope and Budgets of the Consortia

The various consortia are described in Table 3.2-3 in terms of the type of companies and agencies that are members of each of them and their budgets. The dollar values given are the total annual budgets including funds contributed by the government and the industrial companies. It is difficult to determine with confidence the budgets of

TABLE 3.2-3: EV-RELATED CONSORTIA AND THEIR BUDGETS

Consortium, Date of Founding	Main Activity	Members	Budget in Period million $	Period
USABC, 1991	Advanced battery development	U.S. auto companies, battery developers, DOE, National Labs	230 250	1991-1995 1995 - 2000
ALABC, 1992	Improved lead acid batteries	55 lead-acid battery companies	46	1992-2002
PNGV, 1993	Improved fuel economy (3X) of passenger cars	US auto companies and government agencies	950	1997-2000
ARPA, 1993	Heavy-duty hybrid vehicles and energy storage technology	Military agencies, small businesses developing vehicles and energy storage technology, heavy vehicle developers	100	1993-1996
California Fuel Cell Project, 1999	Demonstration of fuel-cell-powered vehicles	Auto companies, fuel cell suppliers, energy companies, federal and California agencies	----	----

the consortia because most of the contracts let by the consortia are multi-year contracts and they are cost shared to varying fractions by industry. For this reason, budget figures given in the literature often refer to dollars spent over a period of years. Also it is not always clear whether the budget numbers refer to total dollars spent or only to the government funds provided. These ambiquities are present in the budget numbers given in Table 3.2-3. Nevertheless the budget numbers given in the table indicate that large sums of money, about two (2) billion dollars have been spent in R&D activity related to the ZEV Program by the consortia in the United States. Large sums of money have also been spent by consortia in Europe and Japan, but it is difficult to determine how much from literature available in the United States.

Each of the consortia has focused on particular aspects of EV technology or type of vehicle development, a shown in Table 3.2-3. The work on advanced batteries by the USABC has resulted in the development of nickel metal hydride and lithium batteries with high energy and power density suitable for use in electric and hybrid vehicles. In less than ten years, these batteries have been developed to the point that they are being tested in high performance electric vehicles. In 1991, only small numbers of very small cells of these battery types were being produced for consumer applications and the application of those battery chemistries in large EV batteries seemed many years away. It seems unlikely that this rapid progress would have occurred without the USABC. Work on the improvement of the performance of lead acid batteries had been funded by DOE during 1980's, but progress was relatively slow especially for valve regulated batteries. The pace of progress increased significantly with the formation of the ALABC with contributions from many companies. Sealed lead-acid batteries are now available with energy densities of 35-40 Wh/kg and cycle life approaching 500 cycles. While this higher energy density may still be marginal for EV applications, it makes lead acid batteries even more attractive for other applications such as automotive SLI, fork lifts, and UPS. The remarkable progress made in batteries in the last ten years has been primarily a result of the ZEV Program and battery consortia.

After the USABC, the Partnership in a New Generation Vehicle program (PNGV) seemed like a logical next step in which the US government and the auto companies could work together to greatly increase (up to 3X) the fuel economy of passenger cars. This was particularly appropriate in that from the start of the PNGV program it was envisioned that the vehicles designed and built would incorporate hybrid-electric drivelines, including some type of energy storage, probably batteries. The connection between the ZEV Program and the PNGV program became even stronger in 1996 when CARB introduced the concept of Partial ZEV Credits (PZEV) to permit the auto companies to use hybrid vehicles to satisfy part of their 10% ZEV requirement in 2003. Much of the new technology being developed by the auto companies for electric vehicles is applicable to the PNGV prototype vehicles. This includes electric motors and power electronics, batteries, and light-weight materials. Especially in the case of energy storage, the work being done for EVs is very closely related to the high fuel economy vehicle designs, which incorporate regenerative braking as a key element in reducing fuel usage.

The DARPA consortia were established in 1993 by the Congress in response to the end of the Cold War as means to develop technology transfer projects for civilian/military cooperation with the idea of converting some military contractors to civilian technology development. The program was called the ARPA Electric and Hybrid Vehicle Technology Program. It was recognized that with the ZEV Program, one of the most attractive areas for the utilization of defense contractors and high tech military technology companies were the development of emerging electric and hybrid vehicle technologies. ARPA consortia were setup on a regional basis in the Northeast, South, Midwest, Southern California (CALSTART), Northern California (SMUD), and Hawaii. Each of these consortia developed a program primarily involving companies in their geographical region. Especially in the first few years, many of the projects funded by the consortia had some components of special interest to the military as dual-use technologies. The tendency of the ARPA consortia was to support the development of large vehicles, like transit buses and heavy-duty trucks, and advanced energy storage technologies such as advanced batteries, ultracapacitors, and flywheels. The new heavy-duty vehicle technologies developed on the ARPA projects can be taken as a secondary benefit of the ZEV Program because the development of those technologies would not have been initiated without the parallel work being done on components for light-duty vehicles required by the ZEV Program.

3.3 Survey of New Economic Activity in California

A limited study of new economic activity in California as a result of the ZEV Program was done by CALSTART under a subcontract from UC Davis. CALSTART is an advanced clean transportation technology consortium. Since 1992, CALSTART has monitored advanced clean transportation technology companies in California, working closely and side-by-side on numerous demonstration and commercialization projects. Many of these companies are involved with EV-related technologies. For this reason, CALSTART was uniquely positioned to analyze EV-related economic activity in California.

However, the economic analysis that was feasible in this project is simply a survey of 134 companies known to CALSTART to provide certain products and services directly related to EV technologies. Only 22 responses were received. Therefore, the numbers derived in the analysis, while interesting and instructive, should not be viewed as a complete statement of the economic effects of the ZEV program.

3.3.1 Companies Surveyed

The list of companies to survey was developed as follows: (1) CALSTART first considered its Participant Program comprised of over 200 advanced clean transportation technology companies. CALSTART's working relationship with these organizations enabled it to develop a list of the companies most likely affected by the ZEV Program. This list numbered 60 California companies. (2) Over the course of 8 years, CALSTART has developed ties with an additional 400 companies that are not participants in the CALSTART program, but are involved in the industry. CALSTART maintains relationships with these organizations and identified 65 of these as California candidates potentially affected by the ZEV Program. (3) CALSTART enlisted the expertise of its in-house personnel in expanding these lists to include potential candidates. A review of over 1100 potential companies generated an additional 9 companies. The total number of organizations contacted numbered 134. (See Table AP3-1 in Appendix 3).

A survey form was developed consisting of a series of questions to determine the number of new companies established since 1990, and/or new divisions of companies established in this industry, sales revenues, employment figures and new investments needed. Finally, each company was asked to make a determination as to the importance of the ZEV Program on past and future business. The survey form sent to each company is given Appendix 3 as Table AP3-2.

Of the 60 CALSTART participant companies targeted with the selection method described above, 17 companies responded to the survey. Of the 65 industry organizations targeted, 4 responded, and of the 9 additional companies targeted, there was one response. A total of 22 complete survey responses were received and recorded. As the survey requested actual sales revenue and projected revenue information, research and development information, and investment information, it was anticipated there would be some reluctance to provide this information. Telephonic follow-up confirmed this problem to some degree.

Each business was categorized as "small," "medium" or "large" based on the number of employees and their sales revenue. Of the respondents, twelve (12) companies were categorized as small businesses, 2 medium-sized businesses, and 8 large businesses. The non-responding remainder of 112 companies were categorized by employment data in CALSTART's files as 55 small businesses, 20 medium-sized businesses, and 34 large businesses. There were insufficient data for three companies of the 112 to judge their size, so a basis of 109 companies was used. The Table 3.3-1 summarizes the size characteristics of the respondents and the complete database surveyed.

Table 3.3-1: Size Characteristics of Respondent and Non-Respondent Companies

Company Size	Respondents	Non-Respondents
Small	12	55
Medium	2	20
Large	8	34

The percentages in each size class are shown in Table 3.3-2 for the respondents and the overall population.

Table 3.3-2: Correction Factors to Account for the Size Difference Between the Respondent and 134 Companies

	A	B	
Company Size	% of Respondents	% of 134 Companies*	Ratio, B:A **
Small	54.5	51.1	.94
Medium	9.1	16.8	1.85
Large	36.4	32.1	.88

* fraction of all (131) companies in Table 3.3-1 (assumed to apply to 134 companies)

** used in considering how to scale-up (extrapolate) the survey data from the 22 respondents to the 134-company database.

CALSTART's role as manager of small business incubators and virtual incubators probably accounts for the higher rate of small business response. CALSTART also works with utilities and OEM's, and some of those companies account for the larger organization numbers.

3.3.2 Survey Results

Questions (1-3) - Company Activities

The companies surveyed were asked to indicate in which specific EV-related product, technology or service they were involved (Survey Question 1A). This open-ended question generated the following list of business activities. Each specific activity represents that of one respondent unless otherwise noted.

List of Business Activities of Respondents

APU Supplier
Battery Manufacturer
Bus Development and Manufacturing (2)
Consulting/Grant Management/Market Research
Drive System, System Integration, Vehicle Integration
Electric Bicycle Conversion Pack Manufacturer
Electric Vehicle Design/Distribution
Engine Manufacturer
Engineering Services
EV & HEV Accessories
EV Infrastructure
EV Publications
EV Sales and Service
Hybrid Electric Vehicle Manufacturer
Light Rail
Lightweight EV's
Market Research
Safety Disconnect & Auxiliary Power Relays for Drive Systems
Utility
Fuel Cell R&D

In Question 1B, companies were asked their product or service emphasis, a multiple-choice question. The respondents categorized their products as shown in Table 3.3-3. Most companies chose multiple categories, and a total of 54 answers were recorded.

Table 3.3-3: Product Categories of the Respondent Companies (by type and percentage)

Category	Responses	% of total
EV Components	10	18.5
EV's	9	16.7
HEV Components	9	16.7
EV Infrastructure	8	14.8
HEV's	7	13.0
Fuel Cells	7	13.0
Fuel Provider	4	7.4
TOTAL	54	100

While there were seven categories from which to choose and most companies chose more than one category, nine companies selected one category and six selected just two categories. The diversity of the activities of the respondents is indicated in Table 3.3-4.

Table 3.3-4: Diversity of Products of the Respondent Companies

# of Categories Selected	# of Companies Selecting	Overall %
1	9	40.9
2	6	27.3
3	3	13.6
4	0	0
5	1	4.6
6	2	9.1
7	1	4.6
Totals	22	100%

Question 2 was concerned with the year in which the company or EV division was established. Seven (7) companies or divisions were established before 1990. Those established in the 1990's totaled 15. The year of establishment in terms of business activity are shown in the Table 3.3-5.

Table 3.3-5: Activities of the Respondent Companies

Business Activity	In 7 co.s founded before 1990	In 15 co.s founded after 1990
EV Infrastructure	1	7
HEV's	1	6
Fuel Provider	1	3
EV's	3	6
EV Components	4	6
Fuel Cells	3	4
HEV Components	4	5
TOTALS	17	37

Twice as many companies or EV divisions were established after 1990 as compared to prior to 1990. The post-1989 companies tend to be involved in more business categories than their earlier counterparts. 50% of the large businesses and 75% of the small businesses surveyed were established after 1989.

When asked (Question 3) if the organization was established because of the ZEV Program, 7 answered "yes" and 15 answered "no". However, seven of the 15 "no's" were the companies founded before the ZEV adoption. Among those founded after the ZEV program, almost half attributed their founding to the Program.

Questions (4-5) – Employment

Survey Question 4 addressed California employment data for the companies. The survey was designed to determine the number of California employees initially employed in each company or EV related division when established. A total of 134 employees from the 22 companies resulted. In other words, each company or division only had an average of 6-7 employees when established.

It is of interest to track the number of employees in this industry from 1990 and see how the number of employees changed. This is shown in the Table 3.3-8. The survey recognized that some organizations also operate outside the state of California. Companies and divisions were asked to determine whether the ZEV Program accounted for employment outside California and to specify those numbers. Only California employment figures were targeted in the ZEV-related aspect of the question.

Table 3.3-8: Employment in Respondent Companies in Various Time Periods (1990-2004)

Period	Total Employees	Total California Employees	Total CA Employees Attributed to Program
1990 – 1992	1025	223	24
1993 – 1995	1467	473	237
1996 – 1998	1549	428	123
1999 – 2000	1994	574	126
2001 – 2004	2416	850	273

The data in Table 3.3-8 represents only 22 of the 134 identified EV-related companies operating in the state of California. It is of interest to estimate the employment for the entire group of 134 organizations. To scale up the employment numbers that would have been generated had all 134 organizations responded to the survey, one can take the data from the respondents in each company size group and apply the ratio for that size group (in Table 3.3-2) and then multiply the result by the ratio of total companies in the data base to the number of respondents (134/22 = 6.09). Addition of the numbers of employees for the three size (small, medium, and large) companies results in the total EV-related employment in California for each of the time periods. Estimations of the total employment of the 134 companies was also done using the employment responses for the companies in each size group directly and applying the ratio of the companies in the 134 company database and the respondents of that size group. The two methods of extrapolating the respondent sample to the total 134 companies yielded employment numbers in agreement to better than 10%.

Since the list of companies surveyed and the survey itself were taken in June 2000 and thus did not reflect the size distribution of companies in existence in the early years of the Program, extrapolated employment figures are given in Table 3.3-9 starting in the 1996-1998 time-period.

Table 3.3-9: Employment in EV-related Companies in California for Various Time-periods

Period	Total Employment	Total CA Employment	Total Attributed to Program
1996 – 1998	9440	2613	749
1999 – 2000	12145	3496	767
2001 – 2004	14715	5177	1662

The numbers in Table 3.3-9 are an estimate of employment for 134 companies identified as involved in California's EV-related industry. The total California employment numbers indicate an employment of 4000-5000 in 2000-2004.

Questions (6) - Sales Revenue

Sales revenues data were requested from the respondents for three separate time periods in Survey Question 6. The question asked respondents for total sales for 1990 – 1999 and for the year 2000. Projected sales for the three-year period 2001–2004 were also requested. The survey sample produced one company that did not respond to this question. Additionally, one company was deleted from the totals as the company revenues and employee numbers indicated significant sales outside the state.

Table 3.3-10: Sales Revenues for the Respondent Companies in Various Time-Periods (nearest 10,000)

Period	Total Sales Revenue in California
1990-1999*	$187,680,000
2000	$65,000,000
2001-2004**	$248,880,000

*denotes 10 years **denotes 4 years

Using the same method as used for employee projections, estimates were made of the total sales revenue in California that would be generated by the 134 companies whom were sent questionnaires. Total sales revenues are given for small, medium and large companies in the Table 3.3-11.

Table 3.3-11: California Sales Revenues

Period	CA total sales ($) for Respondents	Estimated sales ($) for 134 Companies
Small Companies		
1990 – 1999	84,660,000	*
2000	14,230,000	86,670,000
2001 – 2004	142,210,000	870,730,000
Medium companies		
1990 – 1999	27,000,000	*
2000	3,150,000	19,190,000
2001 – 2004	42,500,000	258,900,000
Large Companies		
1990 – 1999	76,020,000	*
2000	47,620,000	290,100,000
2001 – 2004	63,420,000	386,300,000
Total		
1990 - 1999	187,680,000	*
2000	65,000,000	395,900,000
2001-2004	248,880,000	1,515,900,000

* Not all 134 existed; number of companies varied

From the Table 3.3-11, it is seen that for the year 2000, the total California sales revenues of the 134 businesses are estimated to be about $395 million and that for the period 2001-2004, the sales revenues are projected to be about $1.5 billion or about $375 million per year.

Question (7) – R&D Expenditures

Survey respondents were asked in Survey Question 7 to report their annual R&D expenditures for the past 10 years, for the year 2000, and projected for 2001-2004. The results of the survey for R&D expenditures are given in Tables 3.3-12.

Table 3.3-12: Annual R&D Expenditures by the Respondent Companies

Period	**No. companies**	**Total Expenditures** ($/yr)	**Total CA Expenditures** ($/yr)	**Amount in CA due to Program**	**Average per Company** (program)
1990 – 1999	varied	$13,380,500	$11,380,500	$8,766,000	n/a
2000	22	$24,557,500	$10,457,500	$5,854,000	$266,000
2001 – 2004	22	$18,738,000	$12,738,000	$4,163,000	$189,000

Question (8-9) – Non-EV related markets

While most of the companies concentrated primarily on EV-related markets, survey questions 8 and 9 sought to determine whether their products or services had found markets outside the EV industry. Of the 20 respondents answering this question, one-half indicated their products found markets in non-EV-related areas. Those that indicated markets existed outside the traditional EV-related markets were asked to disclose the product or service, their customers and sales in those areas. The results of this part of survey are given in Table 3.3-13.

Table 3.3-13: Non-EV Products for the Respondent Companies

Product - service	Market - customers	Sales since 1990
Electric Bikes	Retail Bicycle Sales	$200,000
Power Plant/Engine	Water Pumps & electric Generator set	$0
Off Road EV's	Fork Lift users	$100,000
Relays	Power Management	$500,000
Non Electric Bikes	Recreational/Commute	$250,000
Kick Powered Scooter	Recreational	new product
Generators	Stationary Power	new product
Computer Simulation Tools	Vehicle and Component Management	$4,000,000
Electric Motors	Electric Utilities	$50,000
Fast Charger / EV Forklift	Industrial	$3,000,000

Total sales in other markets were about $8 million over the past 10 year period. California sales accounted $2.4 million, about 30% of the total.

Question (10) – New investment requirements

Survey question 10 asked the respondents to estimate the investment ($) required to pursue the EV market and any secondary markets for their products. The investment requirements are shown in Table 3.3-14.

Table 3.3-14: Investment Requirements for the Respondent Companies

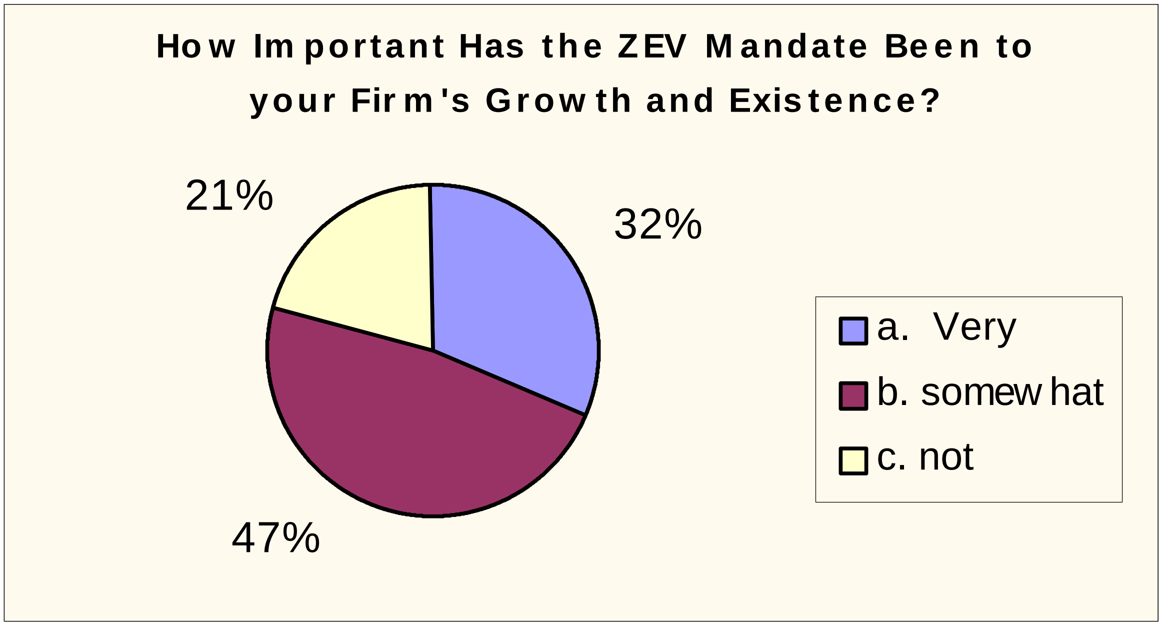
Period	Total Investment Needed	Average per Company
2000 - 2001	$51,025,000	$2,319,000
2002 - 2003	$74,600,000	$3,391,000
2004 - 2005	$205,200,000	$9,327,000
2006 - 2007	$375,300,000	$17,059,000

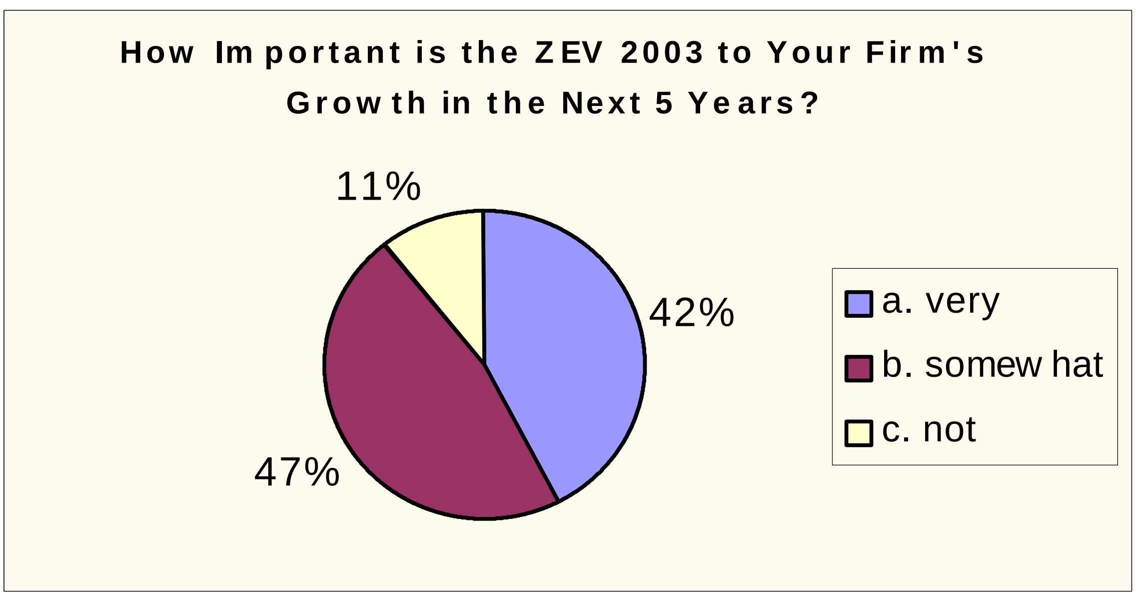
Most of these organizations are beyond the seed financing and start-up stages. Typically first-stage financing provides capital for companies which have progressed beyond the prototype phase, usually to initiate commercial manufacturing and sales. This stage requires from $250,000 to $2 million. Second stage financing typically requires $1 million to $5 million for expansion of the existing market and production capabilities.[1] These figures appear consistent with the types of organizations responding to the survey.

When asked how important the ZEV Program has been to the existence and growth of their companies in the 1990's, only 21% of the respondents indicated it has not been important. (See Figure 3.3-1.) Additionally, when asked how important maintaining the ZEV Program will be to the growth of their companies, only 11% indicated it was not important.

[1] Source: California Research Bureau, California State Library *Business Capital Needs in California: Designing a Program*

Figure 3.3-1


How Important Has the ZEV Mandate Been to your Firm's Growth and Existence?
21%
32%
47%
a. Very
b. somewhat
c. not


How Important is the ZEV 2003 to Your Firm's Growth in the Next 5 Years?
11%
42%
47%
a. very
b. somewhat
c. not

3.4 Advanced Vehicle Technologies

3.4.1 Scope of the Activity

The auto companies around the world have been very active since 1990 in the development of vehicle technologies that will result in vehicle emissions approaching those of electric vehicles as means to reduce the air quality advantages of EVs. These technologies include ultra-clean ICE /gasoline passenger cars, hybrid-electric light-duty vehicles, hybrid-electric transit buses, and fuel cell powered vehicles. All of these vehicles have exhaust emissions very low compared to standards for ICE vehicles.

3.4.2 Relevance to the ZEV Program

All of the advanced vehicle developments to be discussed in this section of the report can be viewed as potential alternative approaches for achieving the pollution reductions expected from battery-powered vehicles. Most of these alternative possibilities were not considered to be likely candidates in 1990. All of these technologies were known in 1990, but their rapid development to the present level was not foreseen at that time. In all cases, these advanced vehicles represent a less radical change than battery-powered vehicles for both the purchasers/users and the manufacturers of the vehicles. For this reason, the auto companies are more confident they can market the advanced vehicles than the battery powered vehicles and thus have been willing to invest large sums of their money in their development in some cases with little or no government funding. There seems little doubt that the ZEV Program was the primary motivating force in the development of these advanced vehicles in the relatively short time period that it occurred. Fortunately the development of the hybrid-electric and fuel cell vehicles benefited greatly from much of the component development that was taking place concurrently for electric vehicles.

3.4.3 Advanced Vehicle Technologies

Ultra-clean ICE/gasoline passenger cars

All the auto companies have had development programs to reduce exhaust emissions from passenger cars to meet the ULEV emission standard, which was the most stringent set by CARB as part of the 1990 LEV-I regulations. Nearly all the auto companies have now certified cars meeting the ULEV standard (.04 gm/mi HC, 1.7 gm/mi CO, .05 gm/mi NOx). A more stringent emission standard, SULEV (.01 gm/mi HC, 1.0 gm/mi CO, .02 gm/mi NOx), was set by CARB in 1998 Several auto manufacturers have now certified ICE/gasoline vehicles meeting the SULEV standard. These include Nissan with the Sentra, Honda with the Accord, and Toyota with the hybrid-electric Prius.

Honda has had a program (Reference 8) for several years to develop a prototype vehicle with exhaust emissions less than what it terms “ZLEV” emissions: 0.004 gm/mi HC, .17 gm/mi CO, .02 gm/mi NOx. As indicated in Figure 3.4-1 (taken from Reference 9), Honda has succeeded in meeting the ZLEV levels in an Accord 4-door sedan vehicle. Hence it is reasonable to conclude that passenger cars meeting such low emission levels can be developed by the auto companies in the relatively near future. The remarkable progress made in reducing the emissions from light-duty vehicles is shown graphically in Figure 3.4-2 taken from Reference 9.

FIGURE 3.4-1

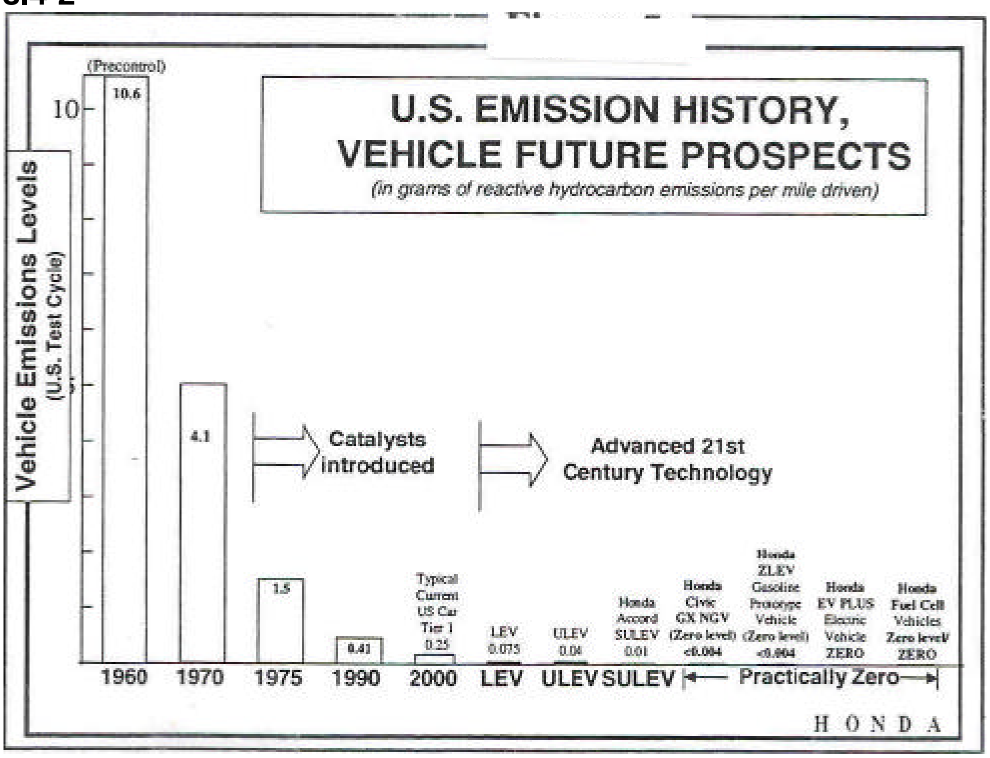
ZLEV EMISSIONS CHART

ZLEV Internal Test Data (LA 4 Mode)
(100 K Aged Catalysts) (g/mile)

	ULEV Standard	SULEV Standard	ZLEV Vehicle Target & Tested Result
CO	1.7	1.0	< 0.17
NMOG	0.04	0.01	< 0.004
NOx	0.2	0.02	< 0.02

HONDA

FIGURE 3.4-2



Hybrid-Electric Passenger Cars

There was very little work done on hybrid-electric vehicles after the oil crisis of the 1970's eased and development did not start again until the early 1990's. The work on hybrid vehicles was restarted as means of extending the range of electric vehicles being developed in response to the ZEV Program. At that time, the primary emphasis was on the potential low emissions of hybrid vehicles. It was for that reason that CARB introduced the concept of the partial ZEV credits when they refined the ZEV Program requirements in 1998 With the formation of the PNGV consortium, the focus of hybrid vehicle development was shifted to increased fuel economy and emission reduction was considered solely as a constraint. However, the PNGV projects (References 10) benefited greatly from the development of improved electric driveline components and high power advanced batteries that were taking place concurrently due to the ZEV Program. The rapid progress on hybrid vehicles from 1995-2000 would not have been possible if the needed electric drive systems were not available.

Almost all the auto companies around the world now have hybrid-electric vehicle development programs with the intent of marketing hybrid vehicles in the near-term. In fact, Honda (Insight) and Toyota (Prius) are currently marketing hybrid passenger cars in Japan and the United States. It is expected that many other hybrid vehicle products will follow over the next several years. It is likely that hybrid versions of sport utility vehicles (SUV) will be available soon as a means of improving the fuel economy of that type of vehicle. It is also likely that the introduction of hybrid-electric vehicles meeting the SULEV emission standards will be favored by the auto industry as a means of meeting the 2003 ZEV Program requirements.

Since the marketing of hybrid-electric passenger cars has already started and several auto companies have announced products to be introduced by 2003, it is apparent that the economic impact of vehicles having electric drive systems will be very large. Total car sales will likely be unaffected, but new companies/suppliers will be providing components that previously were not part of the car. Hence the economic impact of vehicles utilizing electric driveline components will be large in the near future. These new vehicles will have significantly improved fuel economy, as well as very low emissions, so they will reduce CO_2 emissions and oil imports.

Hybrid-Electric Transit Buses

Reducing emissions from diesel engine powered transit buses has become a high priority for CARB and many transit agencies in the world. One approach to accomplishing this is to utilize hybrid-electric drivelines in the buses. Development of these hybrid drivelines and vehicles utilizing them have been an important part of the regional DARPA/FTA consortia that were started in the early-mid 1990s to incorporate emerging electric driveline technology in heavy duty military/civilian vehicles. Most of that technology was being developed in response to the ZEV Program. The ARPA consortia are still functioning in year 2000 and are leaders in the development and demonstration of hybrid heavy-duty vehicles. The heavy-duty vehicle development is closely coupled to the work on batteries, motors, and electronics being done on light duty EVs and HEVs.

The development and demonstration of hybrid-electric transit buses has progressed to the stage that the New York City Transit Authority has recently ordered one hundred (100) hybrid buses from Orrin Bus Co. to be delivered in 2001. These hybrid buses utilize a large electric motor, lead acid batteries, and a diesel engine generator for on-board electricity generation. Recent emissions tests (Reference 11) of various transit buses, including the Orrin hybrid-electric bus, indicate that the particulate emissions of the diesel hybrid bus using very low sulfur fuel can be comparable to those of CNG fueled buses. New York City is planning to purchase a total of five hundred (500) hybrid buses before 2004. Hence it appears that there has been a successful transfer of the electric driveline technology developed in response to the ZEV Program to transit bus products.

The long-term economic value of the hybrid electric bus technology will depend on the decisions made outside of New York City concerning the use of diesel engine-generators in urban areas needing to reduce particulate emissions. In California, for example, CNG and fuel cell buses are strongly preferred, because they are inherently very much cleaner. The diesel engine hybrid buses are fuel-efficient and require much less investment in infrastructure. If diesel engine hybrid buses become viewed as a first step to fuel cell transit buses (both require a high power electric driveline), then in the near-term there could be a large market for the existing diesel engine hybrid buses and the economic impact of this technology could be reasonably large as each bus costs at least $300K.

<u>Fuel Cells and Fuel Cell-Powered Buses and Cars</u>

DOE had a small effort on PEM (proton exchange membrane) fuel cells before the ZEV Program was in place. That effort was directed toward assessing the feasibility of fuel cells for use in light-duty vehicles. The first fuel cell development effort at DOE was in connection with the Georgetown Transit Bus program which started in 1989 as a joint program with FTA (Reference 14). This effort was concerned with a phosphoric acid fuel cell system. Large DOE funding for PEM fuel cell development started in about 1992 just before the start of the PNGV program and preceded the large auto industry interest in and support of PEM fuel cell development. Initial interest in fuel cells for cars was due to their near-zero emissions and later in their potentially high efficiency. The advent of electric cars greatly simplified the development of fuel cell powered cars as both required high power electric motors and electronics and likely batteries for load leveling the fuel cell. The rapid interest in and increase in resources for the development of fuel cells for transportation coincided with ZEV Program and the auto industry's strong desire to develop a zero emission alternative to battery powered electric vehicles.

Fuel cells are being developed for both transportation and stationary applications. The largest funding is devoted to transportation applications, but it is possible that the first markets will be in stationary applications (distributed power generation). Most of the auto companies around the world have programs to assemble prototype fuel cell powered cars and there are several programs to integrate a fuel cell into a transit bus (References 12, 13). A number of these vehicles will be demonstrated and tested as part of the California Fuel Cell Project Project (Reference 14). At the present time, there are many strong efforts to commercialize fuel cells and there seems to be little doubt that they will be marketed as soon as the their economics are viable.

The economic value of the fuel cell technology is projected to be very large (many billions of dollars) by most observers. In fact, some say that fuel cells will replace internal combustion engines in the relatively near future (within twenty years) even using gasoline and a reformer as the fuel – the main question being when this transition will take place. The ZEV Program and the international competition to find means of meeting it has undoubtedly hastened and made much easier this projected transition from engines to fuel cells.

Light Weight Materials

One phase of the PNGV program is involved with research and development of the use of light-weight materials, primarily aluminum and plastic composites, in vehicle design as a means of reducing vehicle weight and thus increase fuel economy. Similar work has also been done on various EV projects as a means of reducing the energy consumption (Wh/mi) of the electric vehicle and thus increase its range. Vehicle design and manufacture with light-weight materials were certainly not done only in connection with electric vehicles, but R&D done in this area as part of EV projects clearly has made an important contribution to the progress made over the last ten years. In addition, the claims (References 30) made by electric vehicle proponents that the use of light-weight materials in vehicles could be cost effective and lead to large increases in vehicle range was a factor in the significant funding of such R&D by the federal government and the auto industry.

Most electric vehicles designed and built from the ground-up utilize aluminum and/or carbon composites in the chassis and aluminum and/or plastic-composite materials in the body to reduce weight. A good example of a prototype EV that used composite materials is the Solectria Sunrise that achieved a range of 373 miles using nickel metal hydride batteries (Reference 29). A number of the DARPA consortia projects were involved with the development of manufacturing processes for electric vehicle chassis and body components.

3.5 Vehicle Emission Standards Outside California

3.5.1 Scope of the Activity

California's ZEV program exists within the context of California's Low Emissions Vehicle program (of which the ZEV program is simply one facet), federal policies and laws regarding emissions and energy, and the policies and laws of other states. In general, federal law mediates state laws in the area of air quality, and largely supercedes any state jurisdiction in the area of automotive emissions. Thus, the federal 1990 Clean Air Act Amendments (CAAA) re-confirmed California's power to set its own vehicle emissions standards—power first conferred by the federal Air Quality Act of 1967. The 1990 CAAA also confirmed that states other than California had two options—to adopt either the federal standards or California's.

The 1990 CAAA also established the Ozone Transport Commission (OTC) and defined the states and portions thereof that would become the Ozone Transport Region (OTR). In general, the OTR is made up of the Northeast states, stretching from Virginia and the District of Columbia, north to Maine. The effort by states within the OTR—in particular New York and Massachusetts—to adopt California's LEV program (including the ZEV program) led directly to the National Low Emission Vehicle (NLEV) Program.

The states of Massachusetts, New York, Vermont, and Maine have adopted California's LEV program, including the ZEV program, but others like Connecticut and New Hampshire have opted to become part of the NLEV program. However, NLEV will cause cleaner ICE cars and trucks to be sold nationwide sooner than EPA would have otherwise required them to be sold. In addition, most of the states in the OTR have demonstration programs involving EVs and some financial incentives in place to encourage individuals and fleets to purchase or lease EVs. These programs outside of California are certainly secondary benefits of the ZEV Program and have contributed significantly to the progress made in developing and testing EVs since 1990.

The federal 1992 Energy Policy Act is also related to ZEV developments, primarily through the incentive and promotional programs for electric vehicles that are defined in the Act, and related activities of the federal Department of Energy. These policies and programs can be considered as either secondary benefits or simply supporting policies and programs. In either case, they have favorably influenced the development of EVs.

This section focuses on the activities of the OTC and the NLEV Program, as well as the LEV programs (and ZEV programs) of Maine, Massachusetts, New York, and Vermont.

3.5.2 Relevance to the ZEV Program

In general, we have assessed the relevance of the ZEV program based on plausible causality implied by the time order of events, and direct attribution where possible. The subject matter of this section is an area in which direct attribution is clear. While the OTC was defined in the 1990 CAAA prior to the announcement of California's ZEV program, subsequent actions by the OTC, the federal Environmental Protection Agency (EPA), and other partners from the environmental community and automobile industry have clearly attributed the NLEV program to efforts by OTC member states to adopt California's LEV program, including the ZEV Program.

3.5.3 The Ozone Transport Commission

The history of the OTC and the initial steps leading to the NLEV program are summarized in the Regulatory Impact Analysis of the NLEV Program issued on December 2, 1997.

> "The Clean Air Act as amended in 1990 (Act) established, under section 184, the Ozone Transport Region (OTR) made up of the states of Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, the District of Columbia, and the portion of Virginia within the Consolidated Metropolitan Statistical Area that includes the District of Columbia.

> Congress established the OTR in recognition of the fact that the transport of ozone and ozone precursors throughout the region may render the Northeast states' attainment strategies interdependent.
>
> "As part of the statutory requirements in section 184, the Administrator established the Northeast Ozone Transport Commission (OTC) for the OTR. The OTC consists of the Governor of each state or their designees, the Administrator or the Administrator's designee, the Regional Administrator for the EPA regional offices affected or the Administrator's designee, and an air pollution control official representing each state. The OTC can develop recommendations for additional control measures to be applied within all or part of the OTR if the OTC determines that such measures are necessary to bring any area in the OTR into attainment for ozone by the applicable dates in the Act. (USEPA, 1997a)

The need for this regional approach to ozone is based on meteorology and political geography. Ozone and its precursors, NMOG and NOx, are easily and commonly transported over long distances. Thus precursor emissions and ozone from one part of the northeastern U.S. are transported to other parts. In particular, the prevailing southwest to northeast summer winds create increased difficulty for states further north and east to meet their obligations to satisfy the National Ambient Air Quality Standards—in part because ozone created in another political jurisdiction is blown into their state within a matter of hours. Recognizing that independent actions by states would not be sufficient for the region as a whole to attain the NAAQS for ozone, Congress established the Ozone Transport Commission to address the region-wide transport of ozone and its precursors.

Based on a petition to the OTC by three of member states—Maryland, Massachusetts, and Maine—one of the OTC's first actions was to recommend to the USEPA that it require the OTR states to adopt California's LEV program.

> "The OTC, under authority granted by section 184(c)(1) of the Act and after notice and opportunity for public comment, developed a recommendation that EPA program a low emission vehicle program, based on the California Low Emission Vehicle program (Cal LEV), throughout the OTR. The OTC voted 9-4 in favor of this recommendation with New Hampshire, Virginia, Delaware, and New Jersey dissenting. On February 10, 1994, this recommendation was submitted to the EPA for consideration." (USEPA, 1997a)

3.5.4 The National Low Emission Vehicle Program

EPA described in its first Notice of Public Rulemaking (NPRM) regarding the National Low Emission Vehicle Program that the NLEV Program was based on the efforts of some OTR member states to adopt California's LEV program:

> "This NPRM is another step in an on-going process to achieve cleaner air in the OTR. The OTR States submitted a petition in February, 1993, requesting EPA to require all states in the OTR to adopt the more stringent California motor vehicle program.

> “The OTC States and environmentalists provided the opportunity for this cooperative effort by pushing for adoption of the California LEV program throughout the Ozone Transport Region (OTR).…
>
> “National LEV benefits the environment by reducing air pollution nationwide. This program is designed to address air pollution problems and will produce public health and environmental benefits both inside and outside the OTR. This should assist states outside the OTR that were considering adopting the California program in meeting their obligations under the Clean Air Act (CAA).…
>
> “Thus, EPA is proposing that National LEV would relieve the OTR States of their regulatory obligation to adopt and implement a state motor vehicle program. This obligation arose when the OTR States had requested that EPA require all the OTR States to adopt the more stringent California Low Emission Vehicle (LEV) program, and EPA granted the request in December, 1994, based on the finding that the region needed the emission reductions to achieve and maintain the ozone National Ambient Air Quality Standards (NAAQS).” (EPA, 40 CFR Parts 51, 85 and 86)

The NLEV program was formally announced in an issuance of a finding by the EPA Director on February 12, 1998.

> “Today EPA is finding the National LEV program in effect. Nine northeastern states and 23 manufacturers have opted into this voluntary clean car program and the opt-ins have met the criteria set forth by EPA in its National LEV regulations. This means light-duty vehicles and light light-duty trucks cleaner than those available today will be produced and sold starting later this year.
>
> “Today EPA is taking the final step necessary for the National Low Emission Vehicle program to come into effect. The National LEV program is a voluntary clean car program which will reduce smog and other pollution from new motor vehicles. On December 16, 1997, EPA finalized the regulations for the National Low Emission Vehicle (National LEV) program. 63 FR 926 (January 7, 1998). Because it is a voluntary program, it could only come into effect if agreed upon by the northeastern states and the auto manufacturers. EPA has now received notifications from all the auto manufacturers and the relevant states lawfully opting into the program. As a result, starting in the northeastern states in model year 1999 and nationally in model year 2001, new cars and light light-duty trucks will meet tailpipe standards that are more stringent than EPA can program prior to model year 2004. Now that the program is agreed upon, these standards will be enforceable in the same manner as any other federal new motor vehicle program. (EPA 40 CFR Part 86)

The member states of the OTR that volunteered to take part in the NLEV are: Connecticut, Delaware, District of Columbia, Maryland, New Hampshire, New Jersey, Pennsylvania, Rhode Island, and Virginia. Notable by their absence are New York, Massachusetts, Maine, and Vermont. These states adopted the California LEV program. Twenty-three automobile manufacturers also volunteered to take part. These companies were: American Honda Motor Company, Inc., American Suzuki Motor Corporation, BMW of North America, Inc., Chrysler Corporation, Fiat Auto U.S.A., Inc., Ford Motor Company, General Motors Corporation, Hyundai Motor America, Isuzu Motors America, Inc., Jaguar Motors Ltd., Kia Motors America, Inc., Land Rover North America, Inc., Mazda (North America) Inc., Mercedes-Benz of North America, Mitsubishi Motor Sales of America, Inc., Nissan North America, Inc., Porsche Cars of North America, Inc., Rolls-Royce Motor Cars Inc., Saab Cars USA, Inc., Subaru of America, Inc., Toyota Motor Sales, U.S.A., Inc., Volkswagen of America, Inc., and Volvo North America Corporation,

The NLEV Program is apparently so "popular" with some of the automotive manufacturers that they would like to take credit for initiating the process. A synopsis of the keynote speech to the 1999 Environmental Vehicle Conference by Lawrence Burns, General Motors' vice president of Research and Development appears on the EV World web site. This synopsis implies that Burns stated GM initiated NLEV. (The synopsis is available at http://evworld.com/conferences/env99/env99_lburns.html). (An editorial comment by the EV World site operator provides one example of the counter-point that NLEV "is also largely responsible for killing ZEV programs in most of the northeastern states of the U.S." (ibid.)) This position by the automobile manufacturers is based on their "Fed LEV" proposal. At the close of 1993, Chrysler, Ford, and General Motors—acting through what was then the American Automobile Manufacturers Association—proposed "Fed LEV." (Electric Vehicle Progress, January 1, 1994) Their idea was to propose a national slate of tighter motor vehicle emissions regulations that would 1) be a uniform 49-state standard, 2) incorporate flexibility in emissions standards by defining multiple categories while holding the manufacturers to a sales fleet average emissions standard, but 3) would eliminate the ZEV vehicle classification.

However, Fed LEV was widely perceived as a reaction by the domestic automobile industry to events already well under way at OTC. Maine, Maryland, and Massachusetts had already petitioned the OTC Board to adopt California's standards in October of 1993 (ibid.).

In the end, NLEV does contain several key elements of Fed LEV. It does exclude ZEVs. It does provide flexibility by defining several classifications of emissions levels. It does program the average emissions level of new vehicle sales. It does establish a uniform 49-state standard. On the other hand, it allows EPA to implement stricter emissions limits, sooner than EPA would have otherwise been able. And it did so two years earlier, 1999 rather than 2001, as originally proposed in Fed LEV.

3.5.6 Benefits of the NLEV Program

Throughout the process of negotiating NLEV, EPA has published a series of reports on the expected effects of the program. These reports have covered health and environmental benefits, regulatory effects on the states, and effects on the automotive industry. These reports can be found on the federal EPA web site at: http://www.epa.gov/OMSWWW/lev-nlev.htm. The last of these reports was prepared in

1997 prior to the final proposed NLEV Program being sent to the states in the OTR and the automotive industry for their final review and decision. The conclusions of these reports are summarized in a Regulatory Announcement by EPA in December 1997. The emissions reductions benefits are characterized as both cleaner vehicles (less emissions per mile of travel) and reduced total emissions of NO_x and NMOG.

> "National LEV vehicles will be 70 percent cleaner than today's models. The National LEV program will result in substantial reductions in non-methane organic gases (NMOG) and oxides of nitrogen (NOx), which contribute to unhealthy levels of smog in many areas across the country. Emission reduction estimates are based on a start date of MY1999 in the Northeast and MY 2001 nationwide:
>
> - NOx will be reduced by 496 tons per day in 2007.
> - NMOG will be reduced by 311 tons per day in 2007.
>
> "The National LEV program will also result in reductions in toxic air pollutants such as benzene, formaldehyde, acetaldehyde, and 1,3 butadiene. Benzene is classified as a human carcinogen, while the others are considered probable carcinogens." (USEPA, 1997b)

These results are based on the technical studies conducted to analyze whether or not NLEV would produce equivalent or better emissions reductions over the policy time frame. The report by E,H, Pechan & Associates details the analysis of three scenarios.

> "(1) a national LEV program in all States except California and (2) the continuation of the Federal Motor Vehicle Emission Control Program with Tier 1 exhaust emission standards in all States except California and those States in the Northeast Ozone Transport Region (OTR) where a California Low Emission Vehicle (LEV) program has been adopted. A sensitivity analysis is also presented that examines the emissions for a scenario where all Northeast OTR States adopt the CAL-LEV program." (E.H. Pechan & Associates, 1997)

Further,

> "In all scenarios, a Tier 2 exhaust emission standard is assumed (equivalent to the LEV standard) in all States that are not modeled with the CAL-LEV program. The national LEV program to come into effect starts with special provisions in the OTR beginning with the 1999 model year. In States outside the OTR, the national LEV program starts with model year 2001 light-duty vehicles (LDVs)." (ibid.)

It should also be noted that none of the scenarios include ZEVs. NLEV does not recognize or require ZEVs, and the analysis of NLEVs health and environmental benefits assumes that those OTR states who did not volunteer to take part in NLEV would not require ZEVs as part of their LEV programs.

The study findings were as follows:

> "By 2007, when most areas must attain the ozone standard, national NMOG and NOx emissions are estimated to be 3 percent lower compared with those from the current program (Tier 1 followed by Tier 2 plus California LEV). By 2015, a national LEV program is expected to reduce highway vehicle nonmethane organic gas (NMOG) emissions nationally by 1.4 percent, and oxides of nitrogen (NO_x) emissions by 2 percent, when compared with a scenario where the northeast State-adopted CAL-LEV programs continue indefinitely with a Tier 2 program starting in all other States in 2005.
>
> "The national LEV program provides benefits beyond the reductions achieved in criteria pollutants; reductions in NMOG associated motor vehicle-emitted air toxic compounds such as benzene, formaldehyde, acetaldehyde, and 1,3-butadiene are also achieved. Reductions in NO_x and NMOG are also estimated to reduce secondary particulate formation, which would be expected to provide regional reductions in PM_{10} and fine particle levels. Improved visibility through reduced nitrogen dioxide (NO_2) concentrations and secondary particulate nitrate formation is also expected.
>
> "The approximate national cost difference between the two cases is $965 million annually. The cost difference per vehicle in each case is approximately $95.
>
> "Within the Ozone Transport Commission (OTC) States, NMOG and NO_x emissions with a national LEV program are about 4 percent lower compared with the current program. In the OTR, the benefits of the national LEV program are achieved at about $21 less per vehicle. At expected 2005 sales levels within the Northeast OTR, this would result in a cost savings of $56 million per year." (ibid.)

The effects of the NLEV program on the automobile industry and consumers are summarized in the EPA Regulatory Announcement as follows.

> "This voluntary program provides auto manufacturers flexibility in meeting the associated standards as well as the opportunity to harmonize their production lines and build vehicles more efficiently.
>
> "EPA currently estimates that National LEV vehicles will cost an additional $95 above the price of vehicles available today, but it is expected that, due to factors such as economies of scale and historical trends related to emission control costs, the actual per vehicle cost will be even lower. This incremental cost is less than 0.5 percent of the price of an average new car." (USEPA, 1997b)

As regards the regulatory effects on states, this Regulatory Announcement did not resolve the issue of individual states adopting a ZEV program. That issue was left to be resolved outside the NLEV process.

Clearly, any advances in ZEV technology and plausible reductions in emissions beyond the year 2015 that could be attributed to ZEVs in Massachusetts, New York (and any other states in the OTR that might have adopted California's LEV program) represent forgone benefits.

3.5.7 ZEV Programs in other States

The four OTC member states that have adopted Cal LEV are Maine, Massachusetts, New York, and Vermont. As of now, all four of these states have requirements that auto companies offer ZEVs for sale within those states starting in 2003.

Massachusetts LEV program is stated in General Laws of Massachusetts Chapter 111 Section 142J and 142K (http://www.state.ma.us/legis/laws/mgl/111-142K.htm). Vermont's LEV program is defined in its Air Pollution Control Regulations, Chapter 5, Subchapter 11. Legislation in New York is currently in a public comment period. At issue is language that would make New York's ZEV program identical to California's. The public comment period on this change is open until August 30, 2000. The specific language is as follows:

> Proposed Revisions of PART 218 EMISSION STANDARDS FOR MOTOR VEHICLES AND MOTOR VEHICLE ENGINES
>
> §218-4.1 ZEV percentages.
>
> Commencing in model-year 2003, each manufacturer's sales fleet of passenger cars and light-duty trucks from 0-3750 lbs. LVW, produced and delivered for sale in New York, must, at minimum, contain at least 10 percent ZEV's subject to the same requirements set forth in California Code of Regulations, Title 13, section 1962 (see Table 1 section 200.9 of this Title) using New York specific vehicle numbers. (http://www.dec.state.ny.us/website/dar/bms/p218.htm)

The actual implementation of these states' "Cal LEV" programs are on slightly different schedules. The following explanatory language is from a federal EPA Frequently Asked Questions list.

> "There are a variety of certification options available to manufacturers in the 1999 and later model year. See the attached table for a tabular layout of state-by-state requirements and options for the 1999-2001 model years. The following two certification options, which are not new and will be processed as they always have been, will be available options in 1999 and later model years:
>
> - Federal Tier 1 certificate. Vehicles covered by a federal Tier 1 certificate can be sold in any state, except California and states that have adopted the California emissions control program under section 177 of the Act.
> - California-only certificate. Vehicles covered by a California-only certificate meeting Tier 1, TLEV, LEV, ULEV, or ZEV emission standards can be sold in California, states that have adopted the California emissions control program under section 177 of the Act

(New York and Massachusetts in model year 1999, plus Vermont in the 2000 model year, plus Maine in the 2001 model year), and contiguous states (as defined by EPA's Cross Border Sales policy for the 1999 model year). (Available at: http://www.epa.gov/OMSWWW/lev-nlev.htm)

The total effect of the ZEV sales requirements in these four states is to almost double the total number of ZEVs that must be offered in California in 2003. For the past several years, California has accounted for about ten percent of annual, national, new passenger car and truck sales. The states of Maine, Massachusetts, New York, and Vermont combined have accounted for seven to eight percent of sales.

References for 3.5

Web sites cited throughout this section.

Segments of the CFR cited throughout. All are available at this page of the federal EPA web site: http://www.epa.gov/OMSWWW/lev-nlev.htm

Electric Vehicle Progress (1994) "Big 3 Fed LEV Standards: A Modest Proposal?" Alexander Research & Communications, Inc. v.16. n.1. January 1.

E.H. Pechan & Associates, Inc. (1997) Analysis of Costs and Benefits of a National Low Emission Vehicle Program. EPA Contract No. 68-D4-0102; Work Assignment 4-4; Technical Directive #3 Pechan Report No. 97.11.002/446.006. December. (Available at: http://www.epa.gov/OMSWWW/lev-nlev.htm)

United States Environmental Protection Agency (1997a) Regulatory Impact Analysis" National Low-Emission Vehicle Program. December. (Available at: http://www.epa.gov/OMSWWW/lev-nlev.htm)

United States Environmental Protection Agency (1997b) Regulatory Announcement: Final Rule for the National Low Emission Vehicle Program. Air and Radiation: Office of Mobile Sources. EPA420-F-97-047. December. (Available at: http://www.epa.gov/OMSWWW/lev-nlev.htm)

3.6 Low-Speed Electric Transportation

3.6.1 Scope of Activity

The goals of the work in this category are to identify companies, products, and markets for low-speed electric transportation vehicles in the U.S. and internationally. Travel modes considered here include electric bikes, scooters, neighborhood electric vehicles ("low-speed vehicles"), "city" EVs, and three-wheeled electric motorcycles. All these vehicles (with the exception of city EVs) fit within the definition of "neighborhood electric vehicles" offered by researchers at UC Davis and others (see for example, Kurani *et al*, 1995). We identify the formation of new companies and new agreements between companies to manufacture and market low speed vehicles, trends in sales of vehicles, and present a few case studies of specific companies.

The technological evolution in EV technology during the 1980s and 1990s facilitated the extension of the capabilities of EVs from small, low-speed, short-range curiosities into practical and attractive vehicles. However, continued increases in motorization of personal mobility around the world affords opportunities for new, clean, and inexpensive travel modes that have little historical precedent in the so-called "developed" economies. Such vehicles have historically been extremely limited in their on-road application, especially in the U.S. Interest in such low-speed vehicles as electric-assist bicycles has attracted the attention of such technology and automobile industry personalities as Paul Macready, Richard Currie, and Lee Iaccoca. If for no other reason than the long histories of innovation that these people represent, low speed electric travel modes are worth some scrutiny.

As an introduction to each low-speed travel mode, we provide their regulatory definitions. Many of these definitions did not exist prior to 1991. It appears that of the modes discussed here, only golf carts were defined in the California Vehicle Code prior to 1991. Many definitions still are not consistent from state to state (or from country to country). The promulgation of a federal definition for "low speed vehicles" and efforts to similarly promulgate a federal definition for "low speed electric bicycles" are two activities that have come out of the need for regulatory frameworks for new, primarily electric, travel modes. A complete list of the relevant definitions contained in the California Vehicle Code for the types of vehicles discussed here is provided in Appendix 2.

A summary of the products and manufacturers who have, or may, provide a variety of small and/or low-speed electric transportation modes to markets in the U.S. is provided in Table 3.6-1. More detailed specifications are provided in the following sections.

TABLE 3.6-1: TYPES OF LOW SPEED ELECTRIC TRAVEL MODES AND SOME ACTUAL OR POTENTIAL SUPPLIERS TO THE U.S. MARKET.

Electric bicycles and add-on motor kits for bicycles	BIKIT; Charger Bicycles, LLC; Condor Industry; Currie Technologies; Electric Transportation Company; EV Global Motors; EV Rider Electric Bicycles; Giant Bicycles; Honda Motor Co., Ltd.; DaimlerChrysler; Merida; Montague; Bicycles Corporation USA; USA-Bikes.com; TH!NK; Yamaha; and ZAPWORLD.COM
Electric scooters and motorcycles	Badsey Industrial Group Inc.; Celco Profil; Denali Cycles; Electric Motorbike, Inc.; EV Rider Inc.; Huffy Bikes; Pedal Power, LLC.; Power Assisted Products; REVI; ZAPWORLD.COM
Neighborhood electric vehicles	Honda; Global Electric Motor Cars; TH!NK; ZAPWORLD.COM
City EVs	TH!NK; Nissan; Toyota; Honda
Three-wheel electric motorcycles	Clean-Energy; Neighborhood Electric Vehicle Company; Transit Innovations; Corbin Motors

3.6.2 Measures

We identify companies and company divisions selling low-speed modes formed since 1991. Where possible, we trace the activities of any predecessor companies before 1991. The primary measures are the existence of low-speed vehicles, changes in economic activity—sales, units sold, employment—related to those vehicles, and any links to policies or technology improvements that can be linked to the ZEV Program.

3.6.3 Criteria for Relevance to the ZEV Program

Economic activity around low speed modes must:

1. be contemporaneous with the ZEV program; and if possible
2. be given direct attribution to the ZEV program for new or increased activity.

3.6.4 Electric Bicycles and Scooters

Electric bicycles are currently classified as motorized vehicles by the U.S. Department of Transportation. The U.S. Electric Bicycle and Scooter Association is promoting a bill (HR2592) in Congress to define and regulate "low speed electric bicycles." The bill was introduced by Congressman James Rogan of California. The bill would amend the Consumer Product Safety Act (15 USC 2051) to stipulate how low speed electric bicycles are to be regulated and to define low speed electric vehicles. The definition is found in the proposed new section 38 (b):

> For the purpose of this section, the term low speed electric bicycle means a two or three wheeled vehicle with fully operable pedals and an electric motor of less than 750 watts (1 hp) whose maximum speed on a paved level surface when powered solely by such a motor while ridden by an operator who weighs 170 lbs. is less than 20 mph.

As the definition and regulation of electric bicycles are not consistent from state to state, this bill would also amend the Consumer Product Safety Act to insure that this federal action and definition would supersede any more stringent state regulations and definitions.

In California, motorized bicycles and mopeds are defined in the California Vehicle Code (CVC) section 406. The definitions are as follows.

> (a) A "motorized bicycle" or "moped" is any two-wheeled or three-wheeled device having fully operative pedals for propulsion by human power, or having no pedals if powered solely by electrical energy, and an automatic transmission and a motor which produces less than 2 gross brake horsepower and is capable of propelling the device at a maximum speed of not more than 30 miles per hour on level ground.
>
> (b) A "motorized bicycle" is also a device that has fully operative pedals for propulsion by human power and has an electric motor that meets all of the following requirements:
>
> (1) Has a power output of not more than 1,000 watts.
>
> (2) Is incapable of propelling the device at a speed of more than 20 miles per hour on ground level.

(3) Is incapable of further increasing the speed of the device when human power is used to propel the motorized bicycle faster than 20 miles per hour.

The California definition for motorized bicycles or mopeds with fully operative pedals (part b) appears to be less restrictive than the proposed definition for low speed bicycles in HR2592 in that California allows a more powerful motor (1.0kW vs. 0.75kW), but limits the top speed to the same 20 mph.

One possible source of disagreement between the California definition and the proposed federal definition is the very specific conditions under which HR2592 establishes the top speed limit. Implicit in the phrasing of HR2592 is the possibility that a rider weighing less than 170 lbs. could be propelled to a speed greater than 20mph on a paved level surface. The language in CVC section 406, part (b) clearly indicates that a motorized bicycle with fully operative pedals cannot provide any motorized propulsion at speeds greater than 20 mph a level paved surface, independent of the weight of the rider and independent of whether the rider is pedaling or not.

Another class of two-wheeled vehicles is defined in CVC section 407.5.

(a) A “motorized scooter” is any two-wheeled device that has handlebars, is designed to be stood or sat upon by the operator, and is powered by an electric motor that is capable of propelling the device with or without human propulsion. For purposes of this section, a motorcycle, as defined in Section 400, a motor-driven cycle, as defined in Section 405, a motorized bicycle or moped, as defined in Section 406, or a toy, as defined in Section 108550 of the Health and Safety Code, is not a motorized scooter.
(b) A device meeting the definition in subdivision (a) that is powered by a source other than electrical power is also a motorized scooter.

Specifications for a variety of electric bicycles are shown in Table 3.6.2. This table is not intended to be comprehensive, but to be descriptive of the types of bicycles that are available.

Electric motors can be added to a bicycle as aftermarket kits, and electric bicycles may be purchased either with such kits pre-installed or as integrated designs. A variety of operating schemes are used, determined primarily by national or state regulations. In Europe, the most common type of electric bike requires the operator to pedal in order for the electric motor to also run. Vehicle definitions in Europe would classify an electric bike with a motor that could run without the operator pedaling as a motor vehicle. This would subject the buyer to much higher taxes and registration fees. In contrast, it is more common for electric bikes in the US to have an electric motor that can run even if the rider does not pedal. Electric bicycle definitions and regulations in the US afford no particular advantage to one type or the other.

Another distinction is how the power from an electric motor is applied. A hub motor is contained within a wheel hub and supplies power directly at the axle of the wheel. Another system uses a roller on the end of a shaft that extends out the motor. This roller is pressed against the outer edge of the tire, and power is transferred by the friction between the roller and the tire. A third system supplies power by means of a secondary chain or belt. In this design, there is a gear on both ends of the rear wheel axle. The rider powers the bike through the pedals connected by chain or belt to the gear on one side. The electric motor supplies power through a belt or chain to the gear on the other end of the axle. Finally, a fourth system applies power at the axle of the pedals, not the driven wheel.

Two of the companies represented in Table 3.6-2 were started by former automotive executives: Currie Technologies (Richard Currie) and EV Global Motors (Lee Iacocca). Both these men retired from the automotive industry during the 1990s, and both have offered public statements indicating a belief that low-speed electric vehicles represent a pathway to introduce the public to electric travel modes.

TABLE 3.6-2: EXAMPLES OF ELECTRIC BICYCLES AND SCOOTERS

Manufacturer and Model	Drive Type	Top Speed[1], miles per hour	Range[2], miles	Sample Price, $US
Scooters				
Badsey Industrial Group, Zip	rear belt drive	15	15	
EV Rider City Bug/Huffy Buzz	rear belt drive	12 to 14	13 to 15	$600
ZAPWORLD.COM Zappy	rear belt drive	13	8	599
Bicycles				
Currie Technologies, Inc., Pro-drive	rear chain drive	18	20	899
Elebike Co. Ltd.	front hub motor	16	20	
Electric Transportation Co., Traveler Express	rear friction drive	13 to 14	10	
Electrobike Jazz				749
EV Global Motors Co., Standard	rear hub motor	15	20	995
EV Rider, LX		15	15	999
Giant, LaFree		20	20	899
Honda, Racoon[3]		15	17	
Montague, Folding	rear chain drive	18	18 to 20	
TH!NK fun		12	20	1,000
ZAPWORLD.COM, ElectriCruizer DX (SX)	rear friction drive	18 (13)	8 (15)	825

Sources: Manufacturer or distributor web sites.

1. For bicycles, this is the top speed with electric power assist. All bikes can reach higher speeds by pedaling only.
2. Test conditions for range are rarely specified. Descriptions of range typically imply travel across smooth, level pavement, and in the case of bicycles, with the rider pedaling to provide some of the motive power.
3. The TH!!NK fun is supposed to be available for purchase in July 2000. The Honda Racoon is not available in the U.S.

3.6.4 Mopeds and Motorcycles

According to CVC section 406, part (a), a motorized bicycle or moped powered solely by a motor may have a motor of up to 2.0 brake horsepower, and may have a top speed of up to 30mph.

The distinction between mopeds and motorcycles is something of a matter of size, speed, and style. CVC section 400, parts (a) and (c) define motorcycles as follows.

(a) A "motorcycle" is any motor vehicle having a seat or saddle for the use of the rider, designed to travel on not more than three wheels in contact with the ground, and weighing less than 1,500 pounds.

…

(c) A motor vehicle that is electrically powered, has a maximum speed of 45 miles per hour, and weighs less than 2,500 pounds, is a motorcycle if the vehicle otherwise comes within the definition of subdivision (a).

Stylistically, mopeds are often designed so that the rider can sit with his or her legs together, whereas the rider straddles a motorcycle. Mopeds have small wheels; motorcycles have larger wheels. Though both the moped and motorcycle definitions include three-wheeled vehicles, as a particular class of mopeds and motorcycles, there are a few examples of electric three-wheeled mopeds or motorcycles. Because these vehicles represent a qualitatively different product—affording occupants complete enclosure and having more substantial cargo capacity—we treat them separately from motorcycles and scooters. Further, because they are mopeds or motorcycles, they do not meet the same safety requirements as do either four-wheel neighborhood and city EVs, which are defined next. Specifications for some electric mopeds and motorcycles available in the U.S. are shown in Table 3.6-3.

TABLE 3.6-3: SOME ELECTRIC MOPEDS AND MOTORCYCLES AVAILABLE IN THE US

	Driving Range, miles (conditions)	Top Speed, miles per hour	Acceleration, sec. (speed interval, mph)	Motor	Battery
Mopeds					
ZAPWORLD.COM Electricycle	20	25	6 (0 to 18)	24v dc	2x 24v, 38Ah
Motorcycles					
Denali HSR	10 (constant 30mph)	30	~4 (0 to 30)	1kW (1.3 HP continuous, 9.9 kW peak)	36 volt, 16.7 amp-hour (0.6 kWh) Hawker Genesis lead/acid
Denali Moto Pro	10 (constant 30mph)	30	~4 (0 to 30)	1kW (1.3 HP continuous, 9.9 kW peak)	36 volt, 16.7 amp-hour (0.6 kWh) Hawker Genesis lead/acid
EMB LECTRA	15 to 50 (not specified)	40		24v dc brushless	Optima D750S (x4) Valve-regulated lead-acid

Sources: Manufacturer or distributor web sites.

3.6.5 Low-Speed Vehicles

We adopt the convention that "neighborhood" vehicles meet the National Highway Traffic Safety Administration Low-Speed Vehicle (LSV) definition. To permit the manufacture and sale of small, 4-wheeled motor vehicles with top speeds of 20 to 25 miles per hour, NHTSA reclassified these small passenger-carrying vehicles. Instead of being classified as "passenger cars," they are now being classified as "low-speed vehicles." Since conventional golf cars, as presently manufactured, have a top speed of less than 20 miles per hour, they are not included in the LSV classification (63 FR 33913, June 17, 1998). Low-speed vehicles are subject to a new Federal Motor Vehicle Safety Standard No. 500 (49 CFR 571.500). The standard requires low-speed vehicles to be equipped with headlamps, stop lamps, turn signal lamps, tail lamps, reflex reflectors, parking brakes, rearview mirrors, windshields, seat belts, and vehicle identification numbers (ibid). California adopted a new section of its vehicle code defining low speed vehicles. The new definition became effective on January 1, 2000. It is congruent with the federal definition.

"Low-speed vehicles" meet NHTSA's new Low Speed Vehicle definition. That definition includes a specification for electric drive. Brief descriptions of LSVs are shown in Table 3.6-4.

TABLE 3.6-4: LOW-SPEED VEHICLES

	Seats	Driving Range, miles (conditions)	Top Speed, miles/hr	Acceleration, seconds (speed interval)	Safety Certification	Sample Price, $US[4]
Global Electric Motors (GEM) Neighborhood EV[1]	2 or 4	30 (not specified)	25		FMVSS 500, LSV	7,795 (2 seats) 9,995 (4 seats)[5]
Bombardier NV[2]	2	30 (not specified)	25	6 (0 to 20mph)	FMVSS 500, LSV	6,199
TH!NK Neighbor[3]	2 or 4	30 (not specified)	25		FMVSS 500, LSV	6,000 (est.)

1. http://www.electric-bikes.com/lev.html
2. http://www.bombardiernv.com
3. http://www.thinkmobility.com
4. Price does not include tax, license, delivery, or any applicable EV purchase incentives.
5. Prices from ZAPWORLD.COM web site.

With the possible exception of Ford's new TH!NK Neighbor, the LSV that started with the best financial support was Bombardier's Neighborhood Vehicle (NV). Bombardier, Inc. is a large Canadian firm with a long history of manufacturing in both transportation and aerospace. They are the manufacturers of Learjet®, Canadair® regional jet aircraft, SKI-DOO® snowmobiles, and SEA-DOO® watercraft, among other products. For the fiscal year ending January 31, 1996, Bombardier Inc.'s Motorized Consumer Products Group had $1.6 billion in sales (www.bombardiernv.com). Despite this pedigree, as of now Bombardier has ceased any plans for production and distribution of the NV. We do not know if this is a temporary or permanent decision.

Development of their Neighborhood Vehicle can be dated back to at least 1994, and Bombardier announced it would proceed with manufacturing the NV in 1996. Bombardier's involvement in low speed vehicles has had profound effect on the development of the whole market idea in North America. The rulemaking by NHTSA to create the LSV classification was initiated in response to a request by Bombardier, Inc., that the agency make regulatory changes to permit the introduction of a new class of 4-wheeled, passenger-carrying vehicle that is small, relatively slow-moving, and low-cost. Though this information is not posted on their web site, Bombardier has for now halted production and distribution of the NV. Using their on-line search facility for dealers, none were located in either Canada or the U.S.

The TH!NK Neighbor is built on an aluminum space frame; body panels are formed out of thermoplastic. Thus its links to the TH!NK City are clear, as the original PIVCO City Bee (a direct precedent of the City) was built of similar materials. In contrast to the City, the Neighbor will use lead-acid batteries (not nickel-cadmium). While the pack voltage is reported to be 72V, neither the Ah rating of the modules or the total energy storage of the pack is reported in public sources. The motor is rated at 5kW peak.

There are currently no TH!NK Neighbors (nor any other TH!NK vehicles) to purchase (or lease). It is possible to place orders for the TH!NK bikes and the Neighbor on the TH!NK web site. Long scheduled for release in November 2000, the TH!NK web site now indicates the sales of the Neighbor will begin in January 2001 (www.thinkmobility.com). Detailed specifications for the vehicle are also available at the web site. It is thought the Neighbor will be manufactured for Ford by TDM Inc. in Kansas.

Global Electric Motor Cars (GEM) was originally started in 1992. Its headquarters and manufacturing facilities are now located in Fargo, North Dakota. The design of the GEM vehicle is based on a neighborhood electric vehicle originally designed and built by Trans2—a firm that is no longer in business. There are two and four seat models, as well as a new micro-truck. The vehicle shape is reminiscent of golf cars, largely because of the general size and configuration of the vehicle. Suspension and steering are improved over golf cars to provide safer driving, in addition to the other safety features required to meet the LSV definition. The basic vehicle has no doors, but a soft enclosure is available to provide protection from weather.

We believe the GEM products are the only LSVs currently available for purchase in the U.S. The company reports it has built between 5,000 and 6,000 vehicles since it began production in April 1998. Production capacity is stated to be 500 vehicles per month (personal communication, T. Clevenger). On their web site they report that many vehicles are sold for use on golf courses, in amusement parks, and in retirement communities (www.gemcar.com). The vehicle has a two position speed control that allows the top speed to be limited to 12 to 15mph for driving on golf courses. They also report that a cruise ship operator in Florida has purchased 50 of the four-seat models, and placed a standing order for another 150. Sales of the four-seat model has exceeded company expectations. They had originally expected the four-seat model to comprise 25 percent of sales. The actual figure is about 50 percent.

Their dealer locator lists 89 dealerships selling the GEM Neighborhood Electric Vehicle in the U.S. Only one of these is located in California (in Huntington Beach). In addition, there are 10 dealerships outside the U.S. The vehicles are also distributed through ZAPWORLD.COM, and may be ordered from that web site (zapworld.com).

3.6.6 City EVs

"City EVs" are distinguished from neighborhood EVs (LSVs) by speed and safety certification. City EVs are capable of freeway speeds, but typically do not have large enough battery packs to facilitate long-distance freeway cruising. Examples include the TH!NK City, which has a reported top speed of 56mph and the Honda City Pal which has a reported top speed of 68mph. While it is not yet clear whether any of the City EVs described in this report meet the full range of Federal Motor Vehicle Safety Standards that apply to light-duty passenger vehicles, we believe it is likely they will ultimately be required to meet those standards.

Specifications for a variety of city electric vehicles are shown in Table 3.6-5. Of these vehicles, only the Toyota e•com and Nissan Hypermini have been brought to the U.S. in small numbers for on-road tests. For example, the e•com is part of a larger, community design and information technology demonstration project at U.C. Irvine. The Toyota, Nissan, and Honda vehicles are in a number of demonstrations and applications in Japan.

The TH!NK City is being sold in Norway. It is currently manufactured near Oslo by TH!NK Nordic AS, an enterprise of Ford Motor Co. PIVCO, the predecessor to TH!NK, had been manufacturing and marketing its City Bee vehicle in Norway prior to its reorganization as PIVCO/TH!NK and its eventual purchase by Ford.

Production of the current model of the City started in November 1999. The vehicle is powered by a liquid-cooled three-phase AC induction motor. Energy is stored in a liquid-cooled nickel-cadmium battery pack. The motor produces a maximum of 27kW of power. The battery stores 11.5kWh of energy. Charging is accomplished via an on-board 220V charger capable of operating at 10A or 16A (giving a nominal charger rating of 2kW or 3.2kW). This charger can recharge a fully drained battery in 10 hours, or provide an 80 percent charge in between four and six hours.

In a press release dated December 1, 1999, TH!NK has announced plans to bring as many as 100 City's to the Presidio in San Francisco in "mid-2000." The vehicles would be used as part of the new Presidio Trust's mission to develop and promote sustainable development. These 100 vehicles are part of a total of an announced 700 City's that TH!NK will bring to North America over the next two years. On January 20, 2000, Ford of Canada announced that 50 City's would be brought to Canada for demonstration purposes. We believe that many of these demonstration vehicles will be from the current

"European" specification vehicles currently being sold in Norway (and either now, or soon to be, throughout Scandinavia). TH!NK has said it is developing a North American version of the vehicle. We speculate that differences between the European and U.S. versions likely will be in the details of meeting different safety certifications.

TABLE 3.6-5: CITY ELECTRIC VEHICLES

	Seats	Driving Range, miles (conditions)[2]	Top Speed, miles per hour	Acceleration, seconds (speed interval)	Safety Certification
1996 PIVCO City Bee, pre-production[1]	2	90 miles (@constant 30mph)	68	18 (0-30 mph)	1996 U.S.FMVSS (excluding passive restraints)
TH!NK City	2	53 (ECE)	56	7 (0-30 mph)	ECE
Toyota E-com	2	62 (10.15)	62		
Nissan Hypermini	2	70 (10.15)	62		
Honda City Pal	2	80 (10.15)	68		

1. PIVCO/TH!NK was purchased by Ford. The City Bee vehicle is shown here simply as a point of comparison, as it is the forerunner of the TH!NK City, which Ford says will be available in the U.S.
2. ECE is a European Commission test cycle. The 10.15 is a Japanese test cycle for urban driving.
Sources include company promotional literature, press releases, and web sites, as well as EVAA (1999).

According to specifications on the Toyota web site (www.toyota.com), the Toyota e•com is powered by a 19kW permanent magnet motor. Energy is stored in a pack of nickel metal hydride batteries. Total pack voltage is 288V; total energy stored is about 8kWh. Charging is by means of an on-board conductive charger capable charging from either 110 or 220V.

The Nissan Hypermini shares many technologies with the Alta EV. The Hypermini is powered by a 24kW permanent magnet synchronous motor. Nissan uses lithium-ion batteries in their Hypermini, as they do in their Altra. In contrast to the City and the e•com, Nissan chose to use inductive charging for the Hypermini. It is the Generation III small paddle charger.

Honda has brought the City Pal to North America, but only for automobile shows. The vehicle is being used in Honda's Intelligent Community Vehicle System (ICVS) in Tochigi, Japan. Along with the City Pal, a wide variety of small EVs from Honda are being demonstrated there. These include the Racoon bicycle, Mon Pal, and the Step Deck. None of these are available in the U.S.

3.6.7 Three-Wheel Motorcycles

We treat three-wheel motorcycles in a separate category from two-wheel motorcycles for two reasons. First, all the vehicles described here are fully enclosed, thus provide a much greater degree of protection from the elements for the occupant and any cargo than do the two-wheel motorcycles. Second, because they are motorcycles, they do not meet the same safety requirements as do LSVs or the four-wheel city EVs described in the previous section.

Four examples of three-wheel, fully-enclosed, electric motorcycles are described in Table 3.6-6. The Neighborhood Electric Vehicle Co. Gizmo and Corbin Motor's Sparrow are available for purchase. The Clean Energy City-el is marketed only in Europe. Transit Innovations is located in Virginia, but only a mock-up of their P32 has been built.

The City-el vehicle is manufactured and marketed in Europe. Several hundred have been sold over a period of years. A small number of City-el vehicles were brought to the U.S. in the early 1990s for trials, and a few were sold, primarily in the Sacramento/Davis area. None have been imported for a few years, and we know of no plans to renew importing the vehicle. The vehicle is a three-wheel design, thus falls under the definition of motorcycles. It is a clamshell design. The top and bottom are hinged together at the front of the vehicle. It seats one person, and has room for the equivalent of three to four bags of groceries behind the driver.

The Neighborhood Electric Vehicle Company is located in Eugene, Oregon. They manufacture the three-wheel electric motorcycle Gizmo. The Neighborhood Electric Vehicle Company was formed in 1995 to develop and produce a three wheeled, single passenger neighborhood electric vehicle. The first Gizmo prototype was completed in July of 1996. Subsequently, ten Gizmos were placed with a variety of users for long term trials. Based on that experience, several design and performance modifications were made. Notable among these changes, the top speed was raised from 30mph to 40mph, and ancillary changes were also made to the suspension and brakes (www.nevco.com).

Corbin-Motors is a subsidiary of Corbin-Pacific. Corbin-Pacific has been business for many years, but it is a manufacturer of motorcycle components and accessories. Corbin-Motors began work on the Sparrow in 1996. It represents their first EV effort. Unlike other vehicles listed here, the Sparrow has a top speed high enough to make freeway driving realistic under many conditions. The vehicle is constructed to exceed the safety standards applicable to motorcycles—it fully encloses the driver in a hard shell, it has a three-point harness, it protects the driver from wind and rain. The vehicle is being built in Corbin-Pacific's motorcycle components factory in Hollister, CA.

After several months of delay, the first Sparrows were delivered in September 1999. In January 2000, the company announced it had delivered 50 Sparrows and had orders for 500 more. At the time it was seeking financial backing to achieve its ambitious goals: to build another production facility in Daytona Beach, FL, and to bring 2,500 Sparrows to market by the end of the year 2000. In addition to the Florida facility, Corbin-Motors wants to move out of shared factory space with Corbin-Pacific, and into its own new facility in Hollister. In their current facility and with their current number of employees (about 50), Corbin-Motors is limited to producing only a few vehicles per month.

TABLE 3.6-6: THREE-WHEEL ELECTRIC MOTORCYCLES

	Seats	Driving Range, miles (conditions)	Top Speed, miles per hour	Acceleration, seconds (speed interval)	Safety Certification	Sample price, $US
Clean Energy City-el[1]	1	20 to 25 (not specified)	30 to 35		motorcycle	na
Neighborhood Electric Vehicle Co. Gizmo[2]	1	25 (city driving, cycle not specified)	40		motorcycle	
Corbin-Pacific Sparrow[3]	1	60 (@constant 60 mph)	70	15 (0 to 60mph)	motorcycle	13,900
Transit Innovations[4]	2	100 (not specified)	79	9 (0 to 60mph)	motorcycle	na

1. Electric Vehicle Association of the Americas (1999).
2. http://www.electric-bikes.com/lev.html
3. http://www.corbinmotors.com/sparrowu.htm
4. http://www.p32fun.com/index.html

Corbin-Pacific has been granted two U.S. patents (#5,960,901 and #5,791,307) for one invention and one design related to the development of their Sparrow and Merlin vehicles. They have seven more patents pending based on additional inventions for their Sparrow and Merlin vehicles. Note though that the Merlin will be powered by an internal combustion engine and one of the patents granted is for its IC engine. (Information on Corbin Motors and the Sparrow was largely taken from the company web site: www.corbinmotors.com).

3.6.8 Miscellaneous Low Speed Electric Vehicles

A few vehicles defy even the extensive list of categories above; others are in established categories that clearly pre-date the ZEV Program. In the first group are a few aid-to-walking vehicles (Garrison and Clarke, 1977), and other forms of human-electric hybrid vehicles. Many aid-to-walking vehicles can be classified as scooters. These tend to be three-wheel, walking-speed vehicles. One distinctly different design is Honda's Mon Pal. This is a one-seat, very small, four-wheel vehicle. It is less than a meter wide, and less than 1 1/2 meters long. It has a sun-shade over the driver. Its top speed is 4mph. The Mon Pal is not available in the U.S.

Another vehicle that defies categorization is the Twike. This is a human-electric hybrid vehicle. It is a three-wheel, fully enclosed design. It seats two people. Unlike the three-wheeled motorcycles discussed in the previous section, the Twike is designed for the rider and driver to provide some propulsion through pedaling. The manufacture claims a top speed of 53mph, and a range of 25 to 50 miles. A few of the Twike have been imported to the U.S. An electric bicycle store in Seattle, WA, says that it has sold a few of them.

In the group of vehicles whose definitions pre-date the ZEV Program perhaps the most important are golf carts. Golf carts are used in many resort settings and retirement communities to provide transportation services, in lieu of or in addition to, recreational services. In January 1993, the City of Palm Desert, California implemented a golf cart demonstration project. Until 1992 in California, golf carts were only allowed on public streets that had speed limits of 25 mph or less and that were within 1.5 miles of a golf course. The California Attorney General issued an opinion in 1992 stating golf carts could drive on any street with a speed limit of 25 mph or lower regardless of proximity to a golf course, but could neither drive on, nor cross, any streets with a posted speed limit higher than 25 mph.

Because of the Attorney General's opinion and opposition from the California Highway Patrol (CHP) and the California State Department of Transportation (Caltrans), an act of the California State Legislature (Assembly Bill 1229, circa 1992) was required to authorize the Palm Desert demonstration project and to define the limits under which golf carts would be allowed to travel on public streets in Palm Desert.

The bill was clear in its intent to expand the use of golf carts to general purpose, local travel. To achieve this end, the bill created Chapter 5 of Division 2.5, Sections 1930-1941 of the Streets and Highway Code, CVC Section 21115.5 and amended CVC Section 21716. In addition to these changes to these Codes, AB1229 stipulated the city's responsibilities to plan and develop golf cart specific infrastructure, golf cart safety standards and operating limits. The bill included this specific definition of a golf cart:

> "'Golf cart' means an electric motor vehicle having not less than three wheels in contact with the ground and an unladen weight less than 1,300 pounds which is designed to be and is operated at not more than 15 miles per hour and is designed to carry golf equipment and not more than two persons, including the driver."

Because the project is intended to explore the potential of small, low speed vehicles to improve air quality, only electric golf carts can be approved for use, not gasoline-powered carts.

Other communities have experimented with golf cart transportation. Notably, some of these experiments have taken place in non-golf towns e.g., Davis, CA had a short-lived experiment in 1995. Golf and retirement communities such as the number of new Sun City developments continue to be cited as locations where electric golf cars could provide substantial transportation services. UC Davis studied two such communities in the early 1900s and found that many households had replaced a full size ICEV with a golf cart (Kurani *et al*, 1995).

3.6.9 Case Studies

ZAPWORLD.COM

ZAPWORLD.COM was started in 1994 as ZAP® (an acronym for Zero Air Pollution) by Gary Starr, a long-time electric vehicle entrepreneur and inventor. Recently, ZAPWORLD.COM has been moving strongly into electric low speed transportation. Of the manufacturers and suppliers listed above, they are the only one currently positioned to provide a wide variety of low-speed modes—bikes, scooters and motorcycles, and LSVs. According to information from the web site (zapworld.com), total sales have climbed from $650k in 1995, to $3.8 million in 1998, then nearly doubling to $6.4m in 1999. Part of the increase in sales is due to an aggressive acquisition campaign. ZAPWORLD.COM recently purchased emPower, a scooter maker from Massachusetts. In early 2000 they announced they had entered into negotiations to acquire Global Electric MotorCars LLC, the LSV manufacturer. By April 17, that deal was off. ZAPWORLD.COM's stance as technical innovators is evidenced by the five patents they hold.

ZAPWORLD.COM's headquarters are in Sebastopol, CA and its activity has a direct impact on local employment and the local tax base in Sonoma County. In a press release from July 1998, the company described itself as developing, manufacturing, marketing, and distributing "a full line of competitively priced electric vehicles to over 45 countries worldwide through distributors, dealers, joint ventures, its web site…and franchise stores."

ZAPWORLD.COM is the clear U.S. market leader. Through product development and corporate acquisition, they have positioned themselves to offer low speed electric vehicles ranging from standing scooters, to electric bicycles, mopeds, motorcycles, and low speed vehicles—everything but City EVs. Various sources, including Jamerson (2000) and the ZAPWORLD.COM web site claim they have sold 30,000 units in the US since 1994. A breakdown of this by vehicle type and year is not available.

TH!NK

In the late 1990s, PIVCO was reorganized as PIVCO/TH!NK. The Ford Motor Company then acquired a controlling interest, and the moniker was shortened to TH!NK. Now, TH!NK Mobility, LLC, is a limited liability corporation that is wholly owned by Ford Motor Company. Its focus is on battery-powered electric vehicles. It is one of the two groups that make up the TH!NK Group, an enterprise of Ford Motor Company. TH!NK Technologies (fuel cell electric vehicles) is the other group. It is dedicated to developing and marketing environmentally friendly solutions for personal mobility.

On May 8, 2000 during the 6th Annual Clean Cities Conference in San Diego, TH!NK Group senior executives at Ford announced that the TH!NK Group would move from Dearborn, MI to southern California. In addition to the TH!NK Neighbor, City, Traveler, and Fun projects, its new San Diego area headquarters will include engineering and research on fuel cell-powered and other advanced technology vehicles.

Ford Motor Company has positioned itself to provide small, low-speed electric transportation. While the new TH!NK division will have design facilities based in California, the TH!NK City is currently manufactured in Norway, the Neighbor will reportedly be manufactured for Ford by TDM, Inc. in Kansas, and if Ford is following the established pattern in the electric bicycle industry, its bikes will be manufactured in Asia.

EV Global Motors Co.

In June 1997, former Chrysler Corp. Chairman Lee Iacocca announced he'd formed a new company to build and market electric bicycles and scooters. "The time has come," Iacocca said of his new company, EV Global Motors Co., and the opportunities represented by "light electric transportation." He also suggested that unlike the United States, Asia could easily bypass the gasoline-powered-vehicles stage and go directly to electric vehicles. Just two months later, Iacocca stated he expects the U.S. market for electric bikes to be one million bikes annually. He offered this prediction at a meeting of shareholders of Unique Mobility, an electric vehicle drive-system supplier in which he owns a 12 percent share. His personal evangelism is revealed in his reasons for starting EV Global Motors. "I've spent 50 years in the auto industry, putting one and sometimes two cars in a lot of garages. Now we need to replace one of those cars with an electric car. It may take a while to get the right battery, but I believe it will happen. In the meantime, we'll start with bicycles and scooters to lead the electric revolution." He said there are already 100 million bikes in the U.S.; 10 million new ones are sold annually. Ten percent of these could be electric bikes, he said.

This enthusiastic market appraisal was followed in February 1998 with a statement from Iacocca that his goal was to sell 50 thousand electric bicycles per year, beginning late in the summer of 1998. Earlier that same week, Iacocca announced a partnership between EV Global Motors and the parent company of nickel-metal hydride (NiMH) battery-maker Ovonic Battery Co. The use of NiMH batteries would allow EV Global Motors to cut the weight of their battery for electric bikes nearly in half, while keeping miles per battery charge constant at 20 miles. Iacocca also announced that EV Global Motors Co. plans to offer electric scooters and small, four-wheel neighborhood vehicles. These ambitious sales goals have not been met as yet.

3.6.10 Advances in Low-Speed EV Technology

Technology advances in traction batteries for EVs have not as yet made their way to electric bicycles, but they are evident in City EVs. The current specifications for City EVs include Ni-Cd, NiMH, Li-Ion, and lead-acid batteries. While NiMH and Ni-Cd batteries are used for high-end, after market bicycle light systems, other small consumer electronic devices, and EVs, they are not found as traction batteries for vehicles smaller than City EVs in the U.S. Jamerson (2000) reports that Ni-CD batteries are used in some electric bicycles in Europe and that a nickel-zinc battery may be used soon on electric bicycles in China and electric scooters in Taiwan.

A "starved electrolyte," "gel-cell," or "recombinant" lead-acid battery is used on virtually every vehicle up to LSVs. These batteries are sealed, and do not require maintenance. They are heavy (due to their low specific energy), but they are also inexpensive. Jamerson's (2000) survey of vehicles reveals that most electric bicycles and scooters store between 0.2 and 0.4kWh—or one-100th the energy stored in typical automotive applications. Matsushita and Hawker are among the larger battery suppliers (ibid.). Based on wor*k to develop a valve-regulated bipolar lead-acid, Bipolar Power International is developing a valve-regulated grid-type battery for application to electric bicycles. It is expected that this battery will increase the specific energy of lead-acid traction batteries typically used in electric bicycles and scooters from about 30Wh/kg to 37Wh/kg. This would represent a 23 percent decrease in the weight of a battery required to achieve a given distance.

Jamerson (ibid.) also indicates a number of Asian battery manufacturers are developing small NiMH batteries that could have applications in electric bicycles and scooters. The problem is these small cells still have very high prices. Holding battery weight constant (at 7.5kg), Jamerson presents results indicating that while substituting a NiMH battery for a sealed gel-cell lead-acid battery would increase range from 15km to 30km, this doubling of range would cost 10 times as much—$225 compared to $22.

For the most part electric bikes, scooters, and motor cycles still use simple, inexpensive, brush DC motors. Brushless dc designs are seeing wider application because of their lower maintenance requirements and higher efficiency, and at least one multi-phase AC motor is being offered. Kollmorgen manufactures a brushless DC motor that is used by Currie Technologies and EV Global Motors. The Kollmorgen brushless DC motor is 90 percent efficient, a figure they say makes their brushless motors twice as efficient as older, brush motors (www.kollmorgen.com/kol2000/ic/bicycle.html). Jamerson (2000) reports that Rabbit Tool U.S.A. has developed a compact 3-phase AC induction motor/generator. They have matched this motor with NiMH batteries and a controller with integral DC-AC inverter. The motor is 95 percent efficient in both the motor (propulsion) and generator (regenerative braking) operating modes. Their battery prices correspond to those Jamerson reports—still their web site (www.rabbittool.com) offers complete bikes and kits that are cost competitive with other products. The kit price is $500; bikes are about $1,000 depending on the size battery ordered.

Unique Mobility of Golden, Co also manufactures electric drive systems for bicycles. Jamerson reports they have a new brushless dc motor with integrated controller in large scale production. The price is expected to be about $250.

Lightweight Platforms

There appears to have been extensive development of lightweight vehicle platforms for LSVs and City EVs. In particular, aluminum is substituted for steel in LSVs and City EVs. The TH!NK City is built around a space frame of both steel (lower half) and aluminum (upper half). The body panels are plastic. Their Neighbor is built around an aluminum space frame. Toyota’s e•com and Nissan’s Hypermini are built around a wholly aluminum space frame. Both also use plastics for body parts.

3.6.11 Summary of economic activity

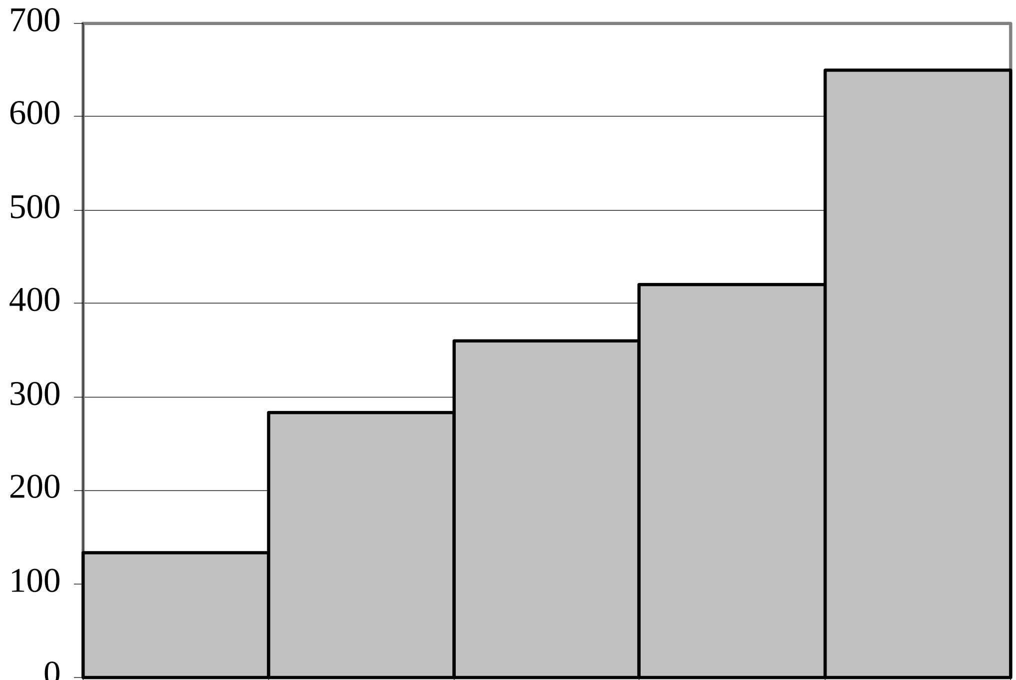
There is scant evidence that allows detailed measures of economic activity related to on-road low speed modes. The Electric Battery Bicycle Company produces an annual report on the electric bicycles and scooters; we draw heavily on this source (Jamerson, 2000). The economic activity related to three-wheel, electric motorcycles and low speed vehicles is not collected as yet in any industry reports. A market study by International Competitive Assessments did evaluate markets for low speed modes, but included off-road modes. (A summary of the study can be found on the EV World web site:

http://www.evworld.com/interviews2/smetzger.html.) We know the overall economic activity for on-road low speed modes is small based on the known limited number of suppliers and vehicles. The economic impact of non-automotive electric travel modes appears to still be largely measured in terms of potential, not actual, effects.

Many firms have stepped into the market electric-assist bicycles and other small and/or low-speed electric transportation modes. And while our attention is focused on markets in California, little of the economic activity to date is located in California, and much of the expected future growth of markets is in Asia. The developing industries of low speed bicycles and electric mopeds, scooters, and motorcycles have attracted significant amounts of economic activity to California, but the vast majority of the economic impact to date appears to be in Asia. The list of companies with California addresses that market, or plan to market, electric bikes or electric motor kits for bicycles includes: Chronos, Currie Technologies, Electric Bike Systems Inc., Electric Motorbike Inc., Electric Transportation Company, Electro Bike, EV Global Motors Company, i-Bike Corporation, TH!NK, ZAPWORLD.COM, and ZVO Inc. However, virtually all their products—bikes and kits—are manufactured in Asia. The dominance of Asia in manufacturing electric bicycles and kits mirrors the situation for all bicycles—the manufacturing centers, measured by numbers of bicycles, are in Taiwan, China, and India.

The total economic impact to date of low speed vehicles—electrically propelled, four-wheeled vehicles with top speeds between 20 and 25mph—is likewise limited. Ford has announced that its TH!NK headquarters will be located in southern California. This will certainly focus attention on low speed modes in California, but at least for now, the TH!NK City is being manufactured in Norway, Ford has announced that the TH!NK Neighbor will be manufactured by TDM in Kansas. Corbin-Motors, who is currently limited to producing less than 10 vehicles per month is likely the largest producer of LSVs or three-wheel electric motorcycles in the California.

FIGURE 3.6-1: WORLDWIDE SALES OF ELECTRIC BIKES AND SCOOTERS, X 1,000.

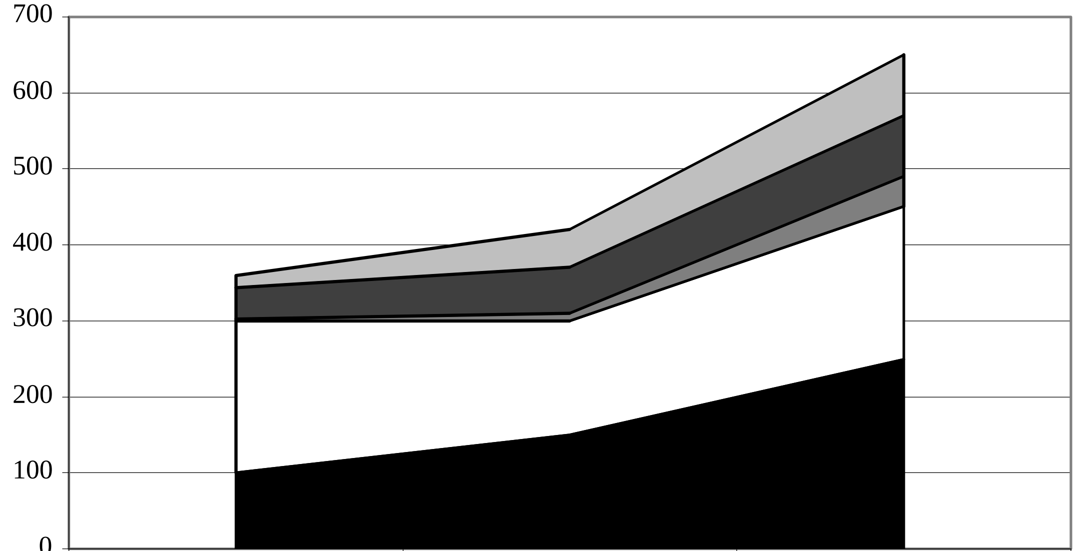


	1996	1997	1998	1999	2000
Worldwide (est.)	133	283	360	420	650

Estimates of world-wide sales of electric bikes and scooters for the interval 1995 through 2000 are illustrated in Figure 3.6-1. Data are from Jamerson (2000). Electric bikes and scooter sales are rising. They are still small compared to total bicycle sales, but the fact they are increasing is counter to trends in the sales of all bicycles. Jamerson states that bicycle manufacturing peaked in 1995 at 107 million units, then declined to 79 million units in 1998. Thus while electric bike and scooter sales accounted for 0.1 percent of bicycle sales in 1996, it rose to 0.45 percent in 1998. These are very small percentages, but when the total market is 80 to 100 million units, small percentages can represent significant market niches.

Jamerson's estimates of sales of electric bikes and scooters by country or region are shown in Figure 3.6-2. The data indicate that electric bike and scooter sales, in addition to manufacturing, are concentrated in Asia, but that for the short time-period the data cover, there is a trend toward an increased proportion of sales to Europe and the United States. In 1998, 83 percent of electric bike and scooter sales were to China and Japan. In 1999 this dropped to 73 percent, and based on estimates for 2000, the percentage of world sales that are to China and Japan will decline to 69 percent. The proportion of bikes to scooters is very different from country to country. In the US, scooters—especially the style ridden while standing—account for 30 to 40 percent of "electric bike and scooter" sales; in Taiwan and Italy, it is the riding style scooter that predominates (Jamerson, 2000).

FIGURE 3.6-2: ESTIMATED ELECTRIC BICYCLE AND SCOOTER SALES BY , X1,000



	1998	1999	2000 (est.)
United States	16	50	80
Europe	42	60	80
Taiwan	2	10	40
Japan	200	150	200
China	100	150	250

Another electric bicycle industry analyst, Edward Benjamin, is cited in a Los Angeles Times article from February 23, 2000 as saying there were 1,500 electric bicycles sold nationwide in the U.S. in 1995 and 30,000 in 1999. His estimate for the year 2000 was 120,000 electric bicycles.

The study by International Competitive Assessments concludes that the off-road application of low speed modes could dwarf the on-road market. Their study addressed only LSVs and does not include bicycles, scooters, motorcycles, or city EVs. ICA states that about one-half of the estimated 220,000 off-road low speed vehicles in 1999 were electrically powered. The current inventory of low-speed EVs is estimated to be between 750,000 and 800,000 vehicles. Current (1999) sales of both gasoline and electric golf carts and utility vehicles is estimated to be $1 billion dollars.

Market Segments

The 80 million members of the baby boom generation are being counted by purveyors of low speed modes, from riding scooters, to electric bicycles, to LSVs, as their first market. As this generation ages they will represent a large cohort of people who on average have higher incomes, better health, and longer life expectancies than any prior generation. The same Los Angeles Times article cited above describes Currie Technologies plans to aggressively market their electric bicycles to people in their 40s and 50s. Quoting from the article, these are "…two age groups that were instrumental in popularizing mountain bikes in the 80s and 90s and now may need a little zip in their pedals as the get older." (Gregory, 2000). TotalEV, a large electric vehicle wholesaler, reports that ZAPWORLD.COM's sales tracking statistics show even scooter markets appear to have started among older buyers. Reportedly, 75% of Zappy scooter buyers in 1998 were between 30 and 60 years old, and the majority of these were aged 40 to 49.

Police departments around the country are purchasing a number of electric bicycles. On November 11, 1999, CALSTART and six electric bicycle manufacturers hosted A conference for various Ventura County, CA law enforcement agencies. The six companies were Currie Technologies, Elebike, Electric Transportation Company, EV Global Motors, Giant, and ZAPWORLD.COM.

An EVAA press release of April 13, 2000 states that in particular, ZAPWORLD.COM and Currie Technologies, Inc. are marketing electric bicycle motor systems and bikes. As it has in other areas, ZAPWORLD.COM has moved aggressively into this market segment. They claimed their electric bicycles were already in use by over 200 law enforcement agencies nationwide, when they announced they had negotiated with Smith and Wesson to include their electric motor system for bicycles as an option on Smith and Wesson's police bicycles. Each company agreed to an exclusive two-year arrangement in which Smith & Wesson will provide bicycles for use with the patented ZAPWORLD.COM's electric motor system. Smith & Wesson, which already has over 500 agencies using its bikes on a daily basis, will offer the ZAP system as an option for each model Smith & Wesson bicycle. During the summer of 1999, over 100 Smith & Wesson bicycles with ZAP motors were deployed to a dozen departments in Los Angeles. Funded by air quality grants and the Los Angeles Department of Water and Power, the project is the largest of its kind and has proven to be very successful.

Resort communities and retirement communities are also cited as ideal applications for many of these low speed modes.

Finally, commuters are the obvious targets for one-seat vehicles. Statements from Corbin Motors and the Neighborhood Electric Vehicle Co. attempt to build a case for such vehicles based on aggregate travel statistics regarding the number of trips for which there is only one occupant per vehicle. This must be recognized as a new possible market segment, not an existing one. Kurani *et al* (1995) have cautioned against over-estimation of markets for one and two seat vehicles. Virtually ever manufacturer of these low-speed modes has cited statistics about the proportion of trips taken, and proportion of miles driven, in automobiles in which the driver is the only occupant. This approach ignores the linkages between trips. Household roles in particular lead to drivers providing chauffeur services to children—simply dropping off a child at school on the way to work can eliminate the possibility of a driver using a one seat vehicle. In a small sample (n = 15) of households from Davis and Sacramento, CA who kept diaries for one week, 18 percent of all trips were "serve passenger" trips, and in only two households were there no serve passenger trips over the course of their diary week (ibid.). In short, it isn't the most favorable trip patterns that define the limits on markets for low-speed vehicles, it is the least favorable limits—and the least favorable limit is not always speed or range.

3.6.12 Summary of Relevance of ZEV Program

Virtually all activity—research, development, production, and marketing—related to all these low-speed modes began subsequent to the announcement of the ZEV Program. Every company discussed here was either started, or announced a new or revived program in low-speed electric transportation products, subsequent to the ZEV program.

Although the direct effect of the program is different from vehicle to vehicle and company to company, Jamerson credits the beginning of the electric bicycle industry to the introduction by Yamaha of its Power Assist System (PAS) in Japan in 1993. Electric bicycles then made their way to the U.S., where other firms began to market them. The activity of Richard Currie and Lee Iacocca came out of their experiences with electric automobiles (with GM and Chrysler respectively) believing in electric mobility, but believing it should start with electric bicycles. The GEM web site states it was started by former automotive engineers. The principals of Trans2 also came out of the automobile industry.

New regulations regarding vehicle definitions for low-speed EVs and electric bicycles are intended to make definitions consistent and resolve policy questions. The LSV definition and subsequent ruling by CARB have resolved some (but not all) ambiguities regarding small, slow EVs regarding their ZEV status.

References for 3.6

Electric Vehicle Association of the Americas (1999) EVs for Work and Play. EVAA: Washington, DC.

Garrison, W.L. and J.F. Clarke (1977) Studies of the Neighborhood Car Concept. University of California, Berkeley: College of Engineering Report 78-4.

Gregory, Stephen (2000) Swear off smog/traffic/parking hassles: embrace Ebikes. Los Angeles Times. Home Edition. p.G-1. The Times Mirror Company. February 23.

Jamerson, F. (2000) Electric Bikes Worldwide 2000: Electric Transportation for the Millennium. Electric Battery Bicycle Company: Petoskey, MI.

Kurani, K.S., D. Sperling, T. Lipman, D. Stanger, T. Turrentine, and A. Stein (1995) Household Markets for Neighborhood Electric Vehicles in California. Institute of Transportation Studies, University of California: Davis, CA. Report UCD-ITS-RR-95-6.

Other sources include the websites of manufacturers that are referenced throughout the text of the report, published specifications contained in promotional and descriptive literature, and personal interviews.

3.7 Electric Utilities

3.7.1 Technology and Relationship to the ZEV Program

The technologies being developed for EVs that are most applicable to electric utility systems are energy storage and power electronics. Energy storage technologies include batteries of various types, ultracapacitors, and flywheels. The charging and discharging of these energy storage units requires interface electronics that can handle high power in a precisely controlled manner. The importance of electrical energy storage to utilities and their customers is becoming more and more important in the business climate of deregulation and the present increased interest in "Green Power" such as wind and solar that by their nature are intermittent and diurnal (References 2,15). Many of the potential utility applications require large devices in contrast to consumer electronic applications that require small energy storage devices. Hence the size and scale of the energy storage devices/units being developed for EVs are suitable in many cases for use with utilities with little or no modification.

3.7.2 Examples of Utility Application of EV Technology

There are a number of potential applications of EV technology in electric utility systems. Utilities and their customers presently use batteries for both small and large scale energy storage to load level power demand, provide power during periods of service interruption, and enhance the quality of the power being provided by the utility during periods of high system demand. In most cases in these applications, lead-acid batteries (Reference 16) are being used primarily because of easy availability and relatively low cost. In recent years, most of the lead acid batteries used were of the valve regulated design as flooded batteries require high maintenance (watering). In utility applications, the batteries spend most of their time on float at near fixed voltage so they are always in a high state of readiness should they be needed.

There has been some discussion (Reference 17) concerning the possibility that utility energy storage could be a secondary market for EV batteries after their performance has degraded so that they are no longer useable in electric vehicles. This typically would be the case when their power and/or energy storage capacity has degraded about 25%. The use of EV batteries in this way would both provide a secondary market for the batteries and also permit the use by the utility systems of batteries having higher energy and power density and longer life than the lead-acid batteries currently being used. This would make the advanced batteries being developed for EVs more cost effective in both the EV and utility applications.

Another example of a utility application of technology being developed for EVs is that of ultracapacitors for short period load leveling and power quality enhancement. Maxwell Technologies in San Diego, California has been very active in marketing their large 2.3V, 2700 F devices for use in 56V units to be used by utilities. Some field testing of the units in large banks has already taken place (Reference 18). Ultracapacitors are attractive for this application because of their high power density (>1 kW/L) and their long, no maintenance life. The present main deterrent to the use of ultracapacitors in place of batteries for this application is the high price of the capacitors, but it is expected that the price will be greatly reduced in high volume production.

3.8 Industrial and Consumer Applications of Advanced Batteries

A number of industrial and consumer applications of advanced batteries are discussed in the following sections. In each case, the development of the batteries, related devices, or battery-related service was started for application to EVs, but subsequent development of that battery/device/service or a competing technology indicated that it was more suitable for an application other than electric vehicles. In some cases, the economic value of the alternative market is very large and equally attractive as the EV market.

3.8.1 Large Prismatic Nickel Metal Hydride and Lithium Batteries

Technology and Its Relationship to the ZEV Program

When the development of nickel metal hydride and lithium batteries for electric vehicles was started by the USABC, most of the cells being designed and built were small and spiral wound in construction. It was clear from the outset that large batteries of about 100 Ampere-hour/cell would be required for the vehicle applications. Hence the battery developers for vehicles concentrated on large cells. In addition, prismatic (slab-like in shape consisting of flat plate electrodes) cells are more easily packaged into modules and packs and utilize volume more efficiently. Hence most of the advanced battery development done by the USABC concentrated on large, prismatic cells. There seems little doubt that the ZEV Program greatly accelerated the development of this type of advanced batteries.

Application of This Technology to Products Other than EVs

The large batteries developed for electric vehicles can be used in any application that requires large energy storage (at least several kWh) and relatively high power (a fraction of a kW to hundreds of kW). These applications include many industrial drive, utility load leveling, and telecommunication systems as well as small consumer systems such as electric lawn mowers and wheel chairs. As discussed later, these applications include electrical systems for conventional ICE cars that are expected to utilize 42V in the near future.

Estimated Economic Value of the Markets for This Technology

The automotive and industrial markets for large batteries is almost totally dominated by lead-acid batteries at the present time. The automotive market is the largest being about $5 billion with the replacement market for SLI batteries being the major share (about $4 billion). The industrial battery market is split between stationary and motive applications. In 1999, the industrial market for batteries was about $1.1 billion with stationary applications being 59% of the total. Fork-lifts represent the major part of the motive battery market. These markets are discussed in detail in References (19, 20).

Sealed lead-acid batteries account for nearly all the market for the automotive market and 82% of the industrial market. The fast growing segment of the industrial battery market is UPS and communications, which sold $174 million and$310 million, respectively, in 1999. Whether or not the advanced batteries make major inroads into the motive power and industrial markets for large batteries would seem to depend on cost because in terms of performance and life they have significant advantages over sealed lead-acid batteries. With the expansion of the battery markets for communications, it would appear that those markets would be ideal for the advanced batteries. The development of the large batteries (>25 Ah) for electric vehicles could result in those advanced batteries being used in many applications.

3.8.2 Electrochemical Capacitors (Uultracapacitors)

Technology and its Relationship to the ZEV Program

Ultracapacitors are electrical energy storage devices with much higher power density and longer cycle life, but much lower energy density, than batteries. When the ZEV Program was first put in place in 1990, the batteries available at that time had much lower power capability than was needed to design electric vehicles with acceptable acceleration capability. It was envisioned that ultracapacitors would be combined with batteries to provide the needed power and the batteries would provide the energy needed to meet the range requirement for the vehicles. DOE started a development program in 1992 to meet the need for ultracapacitors for EVs. As the power capability of EV batteries improved, the focus of the vehicle applications of ultracapacitors shifted to hybrid-electric vehicles. As happened for EVs, the power capability of batteries for hybrid vehicles greatly improved and the auto industry presently prefers to use pulse batteries rather than ultracapacitors in their hybrid electric vehicles. Development of ultracapacitors around the world has continued and presently much of the development is directed toward consumer electronics applications, such as cell phones and pagers, and electrical utility applications. The initial development of high power ultracapacitors, however, was started as a means of load leveling batteries in electric vehicles and there is little doubt the present significant activity in their development is due to the ZEV Program.

Application of the Technology for Products other than EVs

Ultracapacitors can be used in any system in which the peak electrical power demand is much larger (by a factor greater than three) than the average power demand and the capability for very rapid recharge is important. In these applications, it is usually not necessary to store very much energy and the low energy density of the capacitors is not a big disadvantage. This was the case for electric vehicles. There have been many studies (References 21, 22) identifying applications of ultracapacitors in industrial, automotive auxiliary, electric utility, and consumer electronics systems. In these applications, ultracapacitors could replace batteries based on their performance characteristics. This has not occurred as yet because of the present high cost of ultracapacitors. The present problem is not one of performance, but of cost.

Estimated Economic Value of the Markets for This Technology

Many estimates have been made of the potential markets for ultracapacitors. The largest projected market is that of hybrid-electric vehicles (cars and transit buses), but there are many other attractive markets. A recent study of markets for ultracapacitors indicated a total available market in 2003 of $637 million and in 2006 of $2.3 billion (see Reference 23). The primary question is not the availability of markets, but the likelihood that the cost of ultracapacitors will be reduced in the next 5-10 years such that they are affordable in those applications.

3.8.3 Pulse Power Batteries

Technology and Its Relationship to the ZEV Program

Pulse power batteries are batteries designed to have very high power density in both charge and discharge. In nearly all cases these batteries are derived from EV batteries using the same battery chemistry. Hence they benefited directly from battery development performed to meet the ZEV Program. Presently there are nickel-metal-hydride, lithium-ion, and lithium-polymer type pulse batteries. Much of the pulse power battery development has been done in support of the PNGV program under the direction of the USABC.

Application of the Technology to Products other than EVs

In general, pulse power batteries can be utilized in most applications in which ultracapacitors could be used. At present the pulse batteries are a lower cost alternative to ultracapacitors in those applications. These include hybrid-electric vehicles (passenger cars and transit buses) and consumer electronics, such as cell phones, particularly GSM (Global System Mobile) phones. As with ultracapacitors, pulse batteries will be used in more applications as the price of the advanced batteries is reduced with higher production volumes.

Estimated Economic Value of the Markets for this Technology

The markets for batteries are very large with shipment of hundreds of millions of cells each year primarily due to the rapid growth of sales in consumer electronics. Most of the batteries for consumer electronics were developed outside of the battery development programs related to the ZEV Program, but many improvements achieved in the vehicle related battery development are now being utilized in batteries for consumer-use products. As the power performance demanded in consumer electronics increases, there will be increasing markets for the pulse power batteries developed as spin-offs from the EV battery developments. This is currently happening in the GSM mobile phone product. The economic value of the advanced battery markets (nickel cadmium, nickel metal hydride, and lithium ion) for consumer products is very large being over $5 billion in 1999 (Reference 24).

3.8.4 Improved Lead-Acid Batteries

Technology and Its Relationship to the ZEV Program

When the ZEV Program was put in place, it was the position of the auto industry that the energy density of lead–acid batteries was too low to be used in electric vehicles. Hence the development of advanced lead-acid batteries was excluded from consideration by the United States Advanced Battery Consortium (USABC). As a result, the lead-acid battery developers of the world formed the Advanced Lead-acid Battery Consortium (ALABC) in 1993. The ALABC concentrated on improving the energy density and cycle life of sealed valve regulated lead-acid batteries and showing that lead-acid batteries could be fast charged in 15-20 minutes without adversely effecting cycle life. The result of ALABC work has been to improve the energy density of commercially available lead-acid modules from 25 to 35 Wh/kg. Prototype lead acid cells having an energy density of 40-45 Wh/kg are being tested in the laboratory by several companies. Cycle life has been improved to 500-1000 deep discharge cycles and fast charging has been demonstrated in electric vehicles. These improvements in lead-acid battery performance far exceeded that which had occurred in the previous decade of R&D on EV lead-acid batteries supported by DOE.

Application of the Technology for Products Other than EVs

The improved lead-acid batteries will find application in any product that presently uses that type of battery and in other products that use NiCd primarily because of the higher energy density of the NiCd batteries. The relatively low cost of lead-acid batteries gives them an inherent advantage when their energy density is sufficiently high for their consideration in a specific application. With the auto industry seriously considering going to 42V electrical systems in the relatively near future, it could be critical that improvements in lead-acid batteries have been made at the time that the auto industry is reconsidering their choice of a battery technology for the high voltage systems.

Estimated Economic Value of Markets for This Technology

The economic value of the markets for lead-acid batteries is very large (References 19, 20) with the markets for batteries in new cars and the replacement of batteries in in-use cars being the largest component. Lead-acid batteries are also used in golf carts and fork lifts and other industrial vehicle as well as wheel chairs. All these markets will benefit from the improvements in lead-acid batteries that have resulted from the activities of the ALABC. In addition lead-acid batteries can be competitive in other applications for which their energy density was previously too low. This could result in the use of rechargeable batteries for applications for which only primary batteries (not recharged/reused) were previously used. This could alter the battery market significantly and shift sales to lead-acid batteries.

3.8.5 Zinc-Air Batteries

Technology and Its Relationship to the ZEV Program

One of the battery chemistries considered in the early 1990s for use in EVs was zinc-air because of its potentially high energy density. Considerable work was done to develop electrically rechargeable Zn-air batteries for EV applications. Most of this work was done after the ZEV Program was put in place. An important part of that work was done in California by DEMI in Santa Barbara (References 25, 26). DEMI tested several electric vehicles using their batteries, but the technology was not accepted by the auto industry via the USABC and eventually the work at DEMI on developing the battery system for EVs was stopped. The rights to the technology were sold to AER Energy Resources, a company in Georgia intent on developing the Zn-air technology for consumer markets. AER has concentrated on the development of disposable (primary) batteries for various consumer electronics applications.

Application of This Technology to Products Other than EVs

As noted above disposable zinc-air batteries are being developed for consumer applications like camcorders, cellular phones, lap-top computers, handheld PCs, portable audio devices including hearing aids, and lighting products. The advantage of the zinc-air battery is lower cost and higher energy density. One of the major problems with zinc-air is that it will self-discharge as long as there is a source of air available. A diffusion air management system is one of the new components for the technology being developed by

AER. The zinc-air system shows good promise for consumer applications, especially as a disposable battery.

Estimated Economic Value of the Markets for This Technology

As for other battery products, there is a very large market with hundreds of millions of dollars of sales. AER is presently a struggling, private start-up company with losses and no profits to date, but with a business plan projecting profitability in the future. Zinc-air batteries are currently marketed for hearing aids and computers.

3.8.6 Zinc-Bromine Batteries

Technology and Its Relationship to the ZEV Program

Zinc-bromine is another one of the battery chemistries that were being developed for EV applications and that were not accepted by the auto industry for inclusion in the USABC battery development program. Work on developing zinc-bromine batteries for EV applications was continued on private funds for several years with the hope of convincing the USABC that it was a viable candidate for EVs, because of its potential low cost. One of the companies involved with this development was Powercell in Boston, Mass. Powercell purchased the zinc-bromine technology from S.E.A in Austria, whom had previously licensed the technology from the original developer, Exxon. Eventually, Powercell stopped developments for EVs and is now concentrating on the battery for use in utility and industrial applications where load leveling of the power demand with ultracapacitors could be attractive. Powercell currently manufactures the batteries in Austria, but the systems are assembled in Livermore, California for shipment to customers elsewhere in the United States and abroad. The power electronics for management of the battery system are also designed and manufactured in Livermore.

Estimated Economic Value of the Markets for This Technology

This technology is best suited for the industrial and utility stationary battery markets that are presently dominated by lead-acid batteries. As discussed previously in Section 3.8.4, these are sizable markets which are expected to grow in future years.

3.8.7 Battery Test Equipment and Monitoring Systems

Technology and Its Relationship to the ZEV Program

When battery development and testing for EVs started, equipment for testing and monitoring battery packs was not available. This was especially true of equipment for testing cells or packs at high power (kW not W). With the high level of battery development and testing resulting from the ZEV Program, several new companies and/or divisions of existing companies were formed to develop and market test equipment for batteries. Very sophisticated, high power, programmable test equipment is now available. One of the leading companies in the development and sale of battery test systems is Aerovironment located in Monrovia, California. Aerovironment has developed and marketed equipment for battery testing and monitoring and battery charging (Reference 27). Other companies have developed equipment also.

Application of the Technology to Products Other than EVs

The battery equipment developed for testing EV batteries is applicable for testing and monitoring batteries for all application. The entire field of battery testing and monitoring has benefited greatly from the work done directly related to EV batteries. The level of sophistication needed to evaluate cells and modules for EV applications was much greater than was previously practiced in the battery industry. This has resulted in the general upgrading of the testing practices in the industry in the last 5-10 years. This technology is presently used for small batteries for phones and small consumer appliances.

Estimated Economic Value of the Market for This Technology

Compared to the battery markets, the markets for test and monitoring equipment are not large, but they represent large opportunities for new business for companies designing and manufacturing equipment for the battery industry.

3.9 Industrial and Automotive Applications of Improved Electric Drive

System and Accessory Components

Development of the electric drive systems for electric cars was very challenging in that the systems had to operate efficiently and reliably over a wide range of speed and power. The systems also operated over a fairly wide range of voltage as the battery voltage changed during both charge and discharge. In additional, accessory components were developed for the electric vehicles to provide power steering and braking, climate control, and other vehicle functions with the energy provided by the traction battery. Most of this work is directly related to more conventional automotive and industrial applications and opportunities in these areas are important secondary benefits of the ZEV Program. During the process of developing electric vehicle systems, the auto companies in particular became familiar with the advantages of driving the vehicle accessories with electricity rather than with belts or hydraulic fluid.

3.9.1 Automotive Auxiliary Systems

The auxiliary systems of primary interest in this discussion of the use of components developed for electric vehicles in conventional ICE cars and trucks are those that require relatively high power, not the low power accessories like the radio and lights. The high power auxiliaries include the power steering, power brakes, and climate control. At the present time, these auxiliaries are belt driven from the engine which runs continuously in an ICE vehicle. The 12V battery is recharged from the alternator which is also belt driven from the engine. Hydraulic fluid needed for the automatic transmission or the brakes is provided by a hydraulic pump belt driven from the engine. The water pump for cooling the engine or heating the interior of the car is also belt driven. Any of the belt driven auxiliaries must operate at a RPM proportional to the engine RPM which results in the auxiliary systems performing at much less than their optimum efficiency. In addition, it requires that the auxiliary components must be sized to satisfy the system requirements at engine idle RPM which means they are over-sized when operating at high engine RPMs.

Vehicle designers are well aware of these deficiencies in the present auxiliary systems and also are aware that these deficiencies can be eliminated by using electric motor driven auxiliaries. This has been done by necessity in electric vehicles in which all the auxiliaries are driven using energy from the traction battery. In principle, each of the auxiliaries could be driven by a separate electric motor with its control electronics in a manner to optimize its efficiency. The motors can be powered at the full voltage of the electric driveline (300-400V) or at 12V with the 12V battery being recharged with a DC/DC converter from the main traction battery. The auto industry is beginning to think in terms of electrically driven auxiliaries for conventional vehicles as a result of their experience with them for electric vehicles. For example, the Honda S2000 has an electrically driven power steering system and most of the hybrid vehicles being developed will utilize primarily electrically driven auxiliaries even though the vehicles have the possibility of them being engine driven at least part of the time. The size and efficiency advantages of electrically driven auxiliaries at high voltage are significant with components developed for EVs. This is particularly true in the case of the climate control system, which operates over a wide range of load depending on the cooling requirements.

A recent development in the automotive field that could result in the use of considerable technology from electric vehicles is the likelihood that the electrical system voltage in conventional vehicles will be significantly increased from 12V to as high as 42V with an increase in maximum system power capability. This would require a redesign of the vehicle electric system, including new batteries, which would provide an opportunity to use electric components developed for EVs.

The introduction of electrically driven auxiliaries in conventional ICE vehicles would represent both a secondary benefit of the EV Program and an enlarged market for EV component suppliers as they move to mass production/marketing of their products and subsequent reductions in cost. The present high level of development activity on electric-hybrid vehicles by the auto industry worldwide would seem to make inevitable the use of electrically driven auxiliaries in many mass marketed vehicles in the near future. The economic value of these markets is very large (billions of dollars) in that they are driven by the auto sales.

3.9.2 Industrial Electric Drive Systems

At the outset of efforts to develop electric drive systems for electric vehicles, most of the components used were DC motors/choppers from fork lift trucks and AC induction motors/power electronics available from transit and industrial applications. With the advent of the ZEV Program and the resultant large efforts to develop motors and power electronics for electric vehicles, the advanced motors and electronics developed for EVs are now being used in both transit and industrial applications. The electric vehicle application required variable power electric drivelines in which the motor had to operate over a wide range of RPM and both the motor and power electronics had to packaged in as small a volume as possible. The result of this requirement was the development of high efficiency, microprocessor controlled power electronics and motor systems that are attractive for use in transit and industrial applications.

Hence the electric drive system developments for electric vehicles have resulted in improvements in the electric driveline technology for other applications. These mutually beneficial advances in technology will continue as long as the auto industry perceives a need for continuing advances and cost reductions in electric drivelines for electric and hybrid vehicles. At the present time, as part of the PNGV program, a co-operative program on power electronics and electric machines involving the auto industry, private companies, and national laboratories has been established to enable dramatic increases in component integration and flexibility while improving reliability and ruggedness and achieving significant reductions in cost, volume, and weight of the electronics/motor systems. This program is managed by DOE (Reference 28) and is a good example of the kind of government and industry programs involving the auto industry that did not occur before the ZEV Program.

4. Summary/Conclusions

The secondary benefits of the ZEV Program have been studied in terms of activity in nine (9) categories – (1) patents, (2) government/industry consortia, (3) new economic activity in California, (4) advanced vehicle development, (5) vehicle and fuel emission standards outside California, (6) low-speed electric vehicle transportation, (7) electric utilities, (8) non-EV applications of advanced battery technology, and (9) industrial and automotive applications of improved electric drives. It was found that the ZEV Program resulted in important and far-reaching secondary benefits in all the categories.

There are a number of factors related to this result. First, the federal government already had in place R&D programs to develop batteries and electric vehicles with industry, and formation of the consortia in support of the ZEV Program was facilitated by those prior relationships. Second, public interest in improving air quality was high worldwide and the electric vehicle was viewed by the public as an attractive means of reducing/eliminating the emissions from passenger cars. Third, the auto companies were skeptical from the outset concerning the practicality of EVs, but recognized that the public was demanding cars with drastically lower emissions and possibly reduced energy consumption. Hence their strong motivation to develop other ultra-clean technical alternatives to the electric car. Fourth, the 1990s were the decade of consumer electronics and important advances in new battery types, microprocessors, and computers. Fifth, the end of the cold war resulted in the need for the DOE National Laboratories and many military/aerospace companies to focus on a new advanced technology that had civilian applications. This resulted in strong partnerships between industry and the National Laboratories in areas related to EV development.

All of the above factors combined to create a set of circumstances that lead to well-funded programs and great advances in EV technology as well as technology for ultra-clean vehicles using engines and fuel cells. In addition, industrial and utility applications of the EV-related technologies , especially energy storage and microprocessor controlled power electronics, resulted in substantial funding and markets for those key components for electric vehicles. It was apparent during the study that many of the secondary benefits are "potential" benefits because the economics of the EV-related technologies are still uncertain as is the case for the primary benefit of the ZEV Program - the mass marketing of electric vehicles. The most likely secondary benefits in the United States to be realized in the near-term are ultra-clean (SULEV) vehicles using IC engines and hybrid-electric vehicles having significantly improved fuel economy.

The CALSTART survey of companies in California engaged in EV-related businesses over the last ten years indicated clearly the high potential for economic growth for those companies due to the ZEV Program even though California is not presently a center for automotive manufacturing and assembly. Some of that growth will be sustainable without the mass marketing of EVs, but much of it is dependent on the EV market.

5. References

1. Turrentine, T. and Kurani, K.S., Advances in Electric Vehicle Technology from 1990 to 1995: The Role of California's Zero Emission Vehicle Program, EPRI Report TR-106274, February 1996
2. O'Connor, P.R. and Jacobson, E.B., The Value of Storage: Today Gas, Tomorrow Electricity? , Public Utilities Fortnightly, September 15, 1996
3. Kurani, K.S. and Turrentine, T., Progress in Electric Vehicle Technology and Electric Vehicles from 1990 to 2000: The role of California's Zero Emission Vehicle Program, Report to the California Electric Transportation Coalition, Sacramento, California, July 2000
4. Electric and Hybrid Vehicles Program: Annual Report to Congress – 1977-1997, United States Department of Energy, Office of Transportation Technologies
5. Greene, D.L. and Santini, D.J., Transportation and Global Climate Change, Chapter 7, 1993
6. Electric Vehicle Association of the Americas (EVAA), website, June 2000
7. Macomber, S.K., Williams, L.L., Gianolini, K.A., and Ashby, H.A., Institutional Support Programs for Alternative Fuels and Alternative Fuel Vehicles in California, Sierra Research, Inc., Report to the Western States Petroleum Association, April 1995
8. Kishi, N., Kikuchi, S., Suzuki, N., and Tadayoshi, H., Aiming to Reduce Exhaust Emissions to the Zero Level, Honda, SAE Paper, 1998
9. Proceedings of the Conference, Ultra-Clean Vehicles: Technology Advances, Relative Marketability, and Policy Implications, University of California-Davis, Institute of Transportation Studies, December 1999
10. Review of the Research Program of the Partnership for a New Generation of Vehicles, prepared by the National Research Council, Annual Reports published in 1994 through 1999.
11. Hybrid-Electric Drive Heavy-Duty Vehicle Testing Project, Final Emissions Report, published by the Northeast Advanced Vehicle Consortium, February 15, 2000
12. Wimmer, R., Fuel Cell Bus Testing and Development at Georgetown University, Proceedings of the 32nd Intersociety Energy Conversion Engineering Conference, Paper 97156, August 1997
13. Greenhill, C., Fuel Cell Engines for Cars and Buses, Dbb Fuel Cell Engines, presentation at the Ultra-Clean Vehicles Conference, University of California – Davis, December 1999
14. Press Release April 20, 1999 on the California Fuel Cell Project, Sacramento, California
15. Zweibel, K., Harnessing Solar Power: The Photovoltaics Challenge ,Chapter 15, Plenum Press, 1990
16. Brochure from the AC Battery Company, East Troy, Wisconsin, on the PQ2000 Power Quality System using lead acid batteries for energy storage reference for the secondary market for used EV batteries
17. Farahmandi, C.J. and Spee, R., Application of Electrochemical Capacitors in a 100 kW, 650V Ride-Through System, Proceedings of the 8th International Seminar on Double-Layer Capacitors and Similar Energy Storage Devices, Deerfield Beach, Florida, December 1998

18. Cullen, R., U.S. Industrial Battery Forecast 2000-2004, The Battery Man Magazine, June 2000
19. Anstey, B., Battery Shipment Review and Five Year Forecast, The Battery Man Magazine, July 1999
20. DeGaynor, J. and Johnston, R., Double-Layer Capacitors for Automotive Applications, Proceedings of the 4th International Seminar on Double-Layer Capacitors and Similar Energy Storage Devices, Deerfield Beach, Florida, December 1994
21. Miller, J.R., Engineering Battery-Capacitor Combinations in High Power Applications: Diesel Engine Starting, Proceedings of the 9th International Seminar on Double-Layer Capacitors and Similar Energy Storage Devices, Deerfield Beach, Florida, December 1999
22. Nickerson, J., Beyond the Technology; Focusing of Market Demand, Proceedings of the 9th International Seminar on Double-Layer Capacitors and Similar Energy Storage Devices, Deerfield Beach, Florida, December 1999
23. Takeshita, H., Rechargeable Battery Applications and Market, Proceedings of the 16th International Seminar & Exhibit on Primary and Secondary Batteries, Fort Lauderdale, Florida, March 1999
24. Cheiky, M.C., Danczyk, L.G., and Wehrey, M.C., Rechargeable Zinc-Air Batteries for Electric Vehicle Applications, SAE Paper 901516, August 1990
25. Cheiky, M.C. and Danczyk, L.G., Zinc-Air Powered Electric Vehicle Systems Integration Issues, SAE Paper 910249, February 1991
26. Brochure from AeroVironment , Inc. for the ABC-150 Battery Test System
27. 1999 Annual Report for the Power Electronics and Electric Machines Program, United States Department of Energy, Office of Advanced Automotive Technologies, March 2000
28. Electric Vehicles: An Industry Prospectus, Markets, Technologies, and Strategies, Chapter 8; Vehicle Catalog, 1996
29. Moore, T.C. and Lovins, A.B., Vehicle Design Strategies to Meet and Exceed PNGV Goals, SAE Paper 951906, August 1995

Appendix 1: Analytical and Statistical Details of Patent Study

Analytical and Statistical Details

We are interested in the hypothesis that the year 1990—when CARB announced the ZEV program—represented a change of "eras" in EV-related research and development activity. We expect that after 1990, EV-related research and development activity greatly increased.

As discussed in the body of this report, plots of the number of EV-related patents give a qualitative indication that the ZEV program did signal a shift in inventive activity directed toward EVs. Between 1980 and 1991, there were few EV-related patents issued per year—in fact, the number of patens starts low (around 15 to 20), and then declines (4 to 6) between 1989 and 1991. Twelve patents were assigned to the federal DOE during this time period. After 1991, the number of EV-related patents climbs rapidly. By 1996, over 100 EV-related patents per year were being issued.

However, it is not enough to simply show that the annual number of EV-related patents increased after 1991. We must show that this increase is not due to any other factors that may have caused all patent activity to increase after 1991. A variety of factors may have caused the number of all patents to increase in the same time period. Changes in international agreements might have caused more foreigners to apply for U.S. patents; the advent of the rapid expansion of the World Wide Web in the early 1990s might have affected patents. The plots of all U.S. "utility" patents does show that increasing numbers of all patents were issued throughout the study period.

For statistical analysis, the two-tail null hypothesis is formulated as "no change," that is there was no difference in the number of EV-related patents issued per year before and after 1991. If $P\text{-}EV_{-1991}$ is the measure of EV-related patent activity during and before 1991, and $P\text{-}EV_{+1991}$ is the measure after 1991, then

1. H_{10} two -tail: $P\text{-}EV_{-1991} = P\text{-}EV_{+1991}$

We can conduct even stronger, one-tail tests since the entire analysis is driven by the idea that the ZEV increased EV-related patent activity. We form the alternative one-tail hypothesis

2. H_{1A} one -tail: $P\text{-}EV_{-1991} < P\text{-}EV_{+1991}$

Further, if $P\text{-}All_{-1991}$ is the measure of all patent activity during the period 1980 through 1991, and if $P\text{-}All_{+1991}$ is the measure after 1991, then we are interested in the null hypotheses that all patent activity was unchanged after 1991:

3. H_{20}: $P\text{-}All_{-1991} = P\text{-}All_{+1991}$

Finally, if H_{20} is rejected, we are interested in whether the change in EV-related patent activity from before to after 1991 was the same as the change in all patent activity:

4. H_{2A}: (P-EV_{-1991} - P-EV_{+1991}) = (P-All_{-1991} - P-All_{+1991})

The specific measure of P that we test two is the slope of linear regression line fit to data in each of the two eras. This is equivalent to measuring 1) whether or not a linear model fits the number of patents from year to year, and if so, 2) whether or not the slopes are equal in the two eras and for the two types of patents. The analysis is shown below.

To summarize the analysis that follows, we conclude that one equation does not provide a satisfactory fit to the whole time series of data. The best fit is accomplished by fitting separate equations to two distinct eras. While we show the analysis for a dividing year of 1991, we note that similar substantive results are reached if we use 1992. During the 1980 to 1991 era, the number of EV-related patents issued per year is generally declining. After 1991, the number of patents increases each year. Further, That is, we reject H_{10} and accept H_{1A}. In addition, we show that a single equation does provide a robust fit to the data for all patents, that is, we do not reject H_{20}, and therefore do not accept H_{2A}.

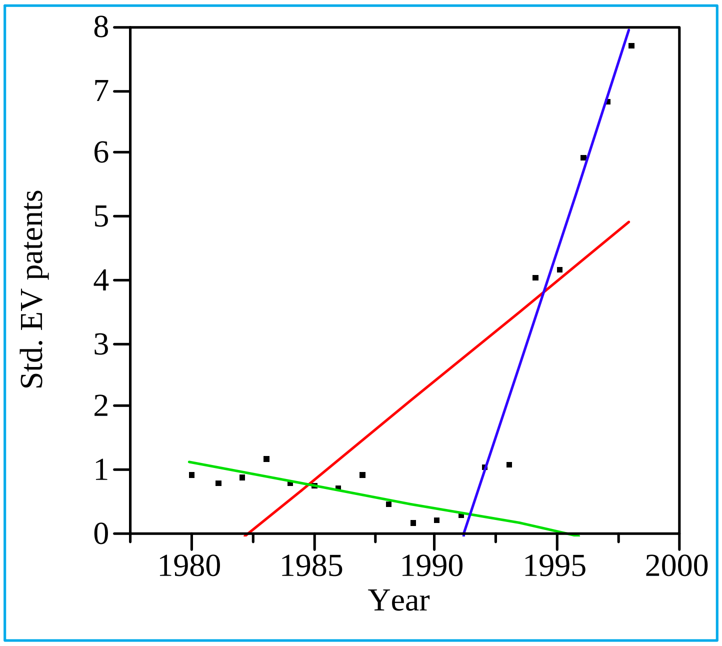
EV-related patents

Figure A1 shows the data points of the annual number of EV patents granted per year and three lines fit by linear regression. The data have been standardized to the year 1980. This only affects the scale of the coefficients. The red line is an equation fit to all years. The green line is the fit to years 1980 through 1991. The blue line is the fit to the years 1992 to 1998.

Testing of the hypothesis 1 and 2 from above is a matter of first establishing whether Equation 1 or the combination of Equations 2 and 3 are appropriate. If it is judged to be the latter, then we must compare the coefficients for the variable “Year” in Equations 2 and 3.

The Analysis of Variance table for Equation 1 tells us it is statistically better than assuming the mean value for all years is the best fit. The F-value is 20.302, and the probability of getting a larger value by chance alone is much less than one percent. The adjusted R-square value indicates that Equation 1 explains about 52 percent of the variation in the number of EV-related patents issued per year from 1980 through 1998. The coefficient for the variable “Year” is significantly different from zero at better than a 95 percent confidence level. The value of the coefficient indicates that on average the number of EV-related patents increased by 0.315 times as many such patents as were issued in 1980.

FIGURE A1: STD. EV PATENTS BY YEAR



Equation 1: All Years (red line)

Std. EV patents = -623.93 + 0.315 Year

Summary of Fit

RSquare	0.54426
RSquare Adj	0.517452
Root Mean Square Error	1.667802
Mean of Response	2.117647
Observations (or Sum Wgts)	19

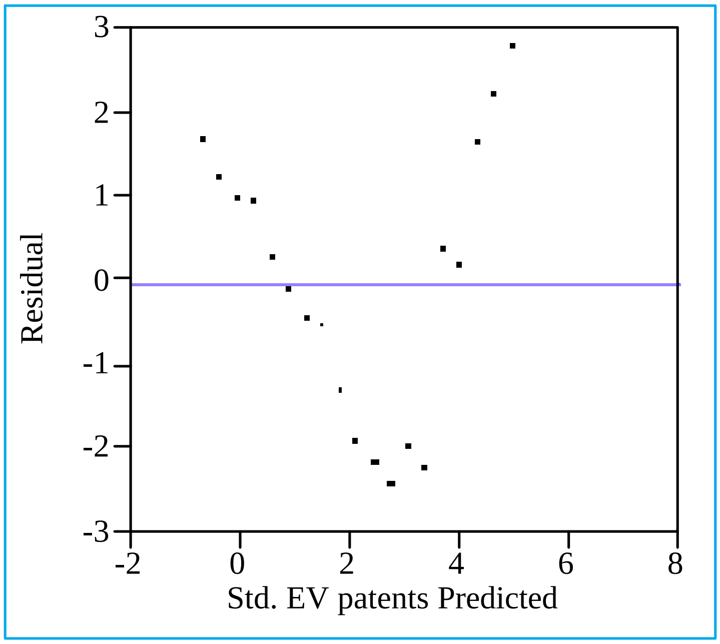
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	56.471	56.471	20.302
Error	17	47.287	2.782	**Prob>F**
C Total	18	103.758		0.0003

Parameter Estimates

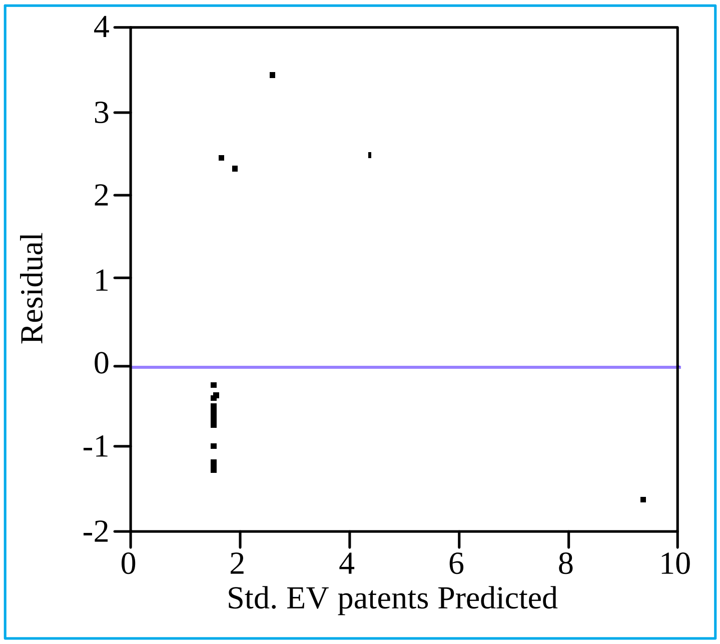
Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	-623.935	138.9452	-4.49	0.0003	-917.082	-330.788
Year	0.3147575	0.069857	4.51	0.0003	0.1673739	0.462141

FIGURE A2: RESIDUAL OF EQUATION 1 PLOTTED VERSUS PREDICTED STD. PATENTS.



However, the plot of the residuals (the difference between the predicted and actual values) in Figure A2 reveals (in fact, simply mirrors what is obvious in Figure A1) that Equation 1 violates one of the assumptions of linear regression. Specifically, the residuals show a regular relationship with the predicted values. The residuals consistently get smaller as the predicted value increases from 1 to 3, and then consistently decline as the predicted value increases. This can be re-scaled to show that the residuals have a consistent relationship with the explanatory variable Year. This specific pattern, especially since we are dealing with time series data, is most likely a representation of violation of the assumption of no *autocorrelation*—the error term associated with one observation (the number of patents in one year) cannot correlated with the error term of any other observation. If autocorrelation is present, then the estimate of the coefficient for Year is unbiased, but the significance tests are not accurate. In general, autocorrelation tends to overstate significance, leading us to accept a coefficient is different from zero, when in fact it is not.

FIGURE A3: RESIDUALS OF THE REGRESSION OF NUMBER OF EV-RELATED PATENTS PER YEAR ON $E^{\beta Year}$



One commonly suggested approach to treating autocorrelation is to transform the affected independent variable. Without showing the whole analysis, we do show the residuals plot for the analysis of the number of EV-related patents regressed on the year transformed as an exponential does little to solve the problem in this case. In this case, the equation overestimates patents (residuals are negative) in 14 of 18 years.

An alternative approach to the problem is to assume that 1991 divides the data into two distinct eras. We can then estimate one linear regression during each era, and compare the coefficients for the Year variable. If the coefficient for the era from 1980 through 1991 is statistically smaller than the coefficient for the era 1992 through 1998, then we accept hypothesis H_{1A}. The statistics for these two equations are shown below as Equation 2 and Equation 3.

Equation 2: 1980 to 1991 (green line)

Std. EV patents = 143.675 – 0.07199 Year

Summary of Fit

RSquare	0.663722
RSquare Adj	0.630094
Root Mean Square Error	0.193766
Mean of Response	0.745098
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.7410410	0.741041	19.7373
Error	10	0.3754527	0.037545	**Prob>F**
C Total	11	1.1164937		0.0012

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	143.67496	32.17215	4.47	0.0012	71.990485	215.35944
Year	-0.071987	0.016204	-4.44	0.0012	-0.108091	-0.035883

Equation 3: 1992 to 1998 (blue line)

Std. EV patents = -2363.5 + 1.18697 Year

Summary of Fit

RSquare	0.955649
RSquare Adj	0.946779
Root Mean Square Error	0.605115
Mean of Response	4.470588
Observations (or Sum Wgts)	7

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	39.449456	39.4495	107.7371
Error	5	1.830821	0.3662	**Prob>F**
C Total	6	41.280277		0.0001

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	-2363.544	228.1403	-10.36	0.0001	-2949.989	-1777.099
Year	1.1869748	0.114356	10.38	0.0001	0.8930177	1.4809319

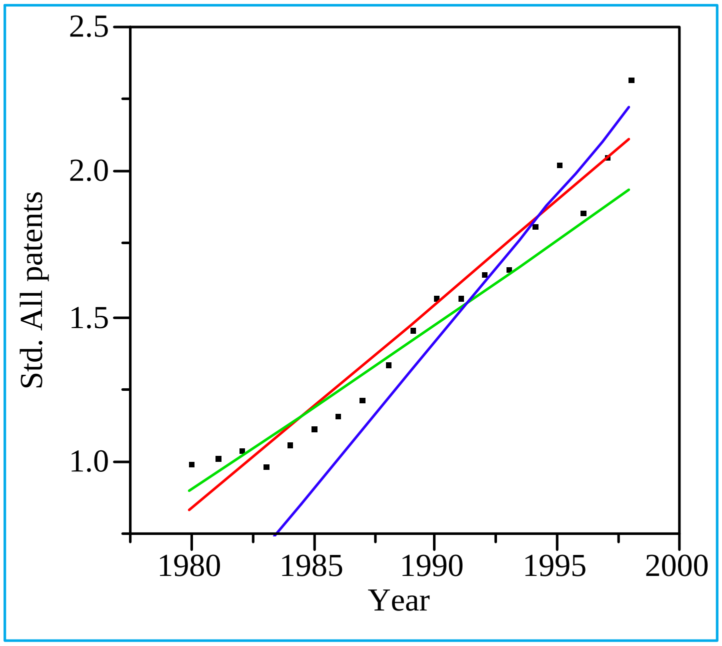
Per the same criteria discussed for Equation 1, both Equations 2 and 3 provide a statistically satisfactory fit to the data for its era. We then compare the coefficients for the explanatory variable Year. From Equation 2, the coefficient indicates that the number of EV-related patents declines on average by 0.07 times as many patents as were issued in 1980. We are confident at the 95 percent level that the value of the coefficient lies between -0.108 and -0.036. From Equation 3, the coefficient indicates that on average since 1992 the number of EV-related patents has increased by 1.19 times as many such patents as were issued in 1980. The 95 percent confidence interval ranges from 0.893 to 1.481.

Since confidence intervals from the two estimates do not overlap, we conclude they are different. Thus, we reject H_{10}. Since the coefficient from the time period from 1980 to 1991 is unambiguously less than zero, and the since the coefficient from the time period after 1991 is unambiguously greater than zero, we accept H_{1A}.

All Patents

The analysis of the number of all patents issued each year from 1980 to 1998 proceeds in a similar manner as that for EV-related patents above. In this case though, a single equation for the entire time period provides a good fit to the data, there are no obvious problems with autocorrelation, and even if we estimate two separate equations the coefficient for the explanatory variable Year are not significantly different at the 95 percent confidence interval. Therefore, we do not reject H_{20}. We conclude there is no change in 1991 in the rate of change of growth in the number of all patents per year. Before, during, and after 1991 all patents increased by 0.07 times as many patens as were issued in 1980.

FIGURE A4: STD. ALL PATENTS BY YEAR



Equation 4: All Patents from 1980 to 1998

Std. All patents = -140.46 + 0.07136 Year

Summary of Fit

RSquare	0.946199
RSquare Adj	0.943035
Root Mean Square Error	0.09853
Mean of Response	1.476961
Observations (or Sum Wgts)	19

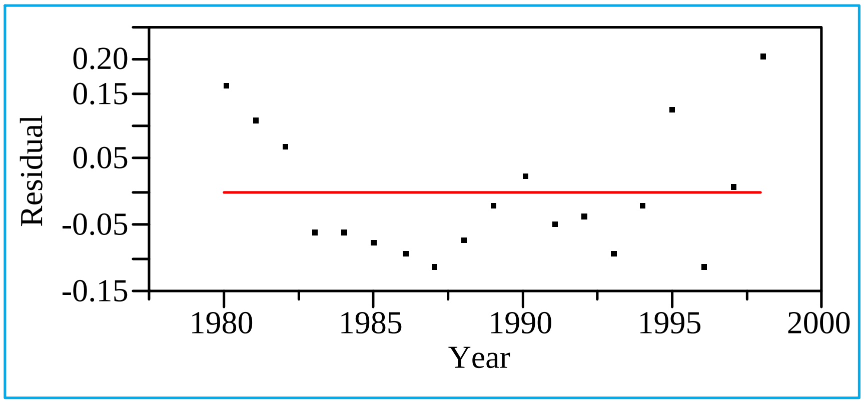
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	2.9025468	2.90255	298.9813
Error	17	0.1650381	0.00971	**Prob>F**
C Total	18	3.0675848		<.0001

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	-140.4572	8.208553	-17.11	<.0001	-157.7756	-123.1388
Year	0.0713596	0.004127	17.29	<.0001	0.0626525	0.0800666

FIGURE A5: RESIDUALS OF PREDICTED ALL YEARS VERSUS YEARS



Equation 5: All Patents from 1980 to 1991

Std. All patents = -113.29 + 0.05767 Year

Summary of Fit

RSquare	0.895574
RSquare Adj	0.885132
Root Mean Square Error	0.074473
Mean of Response	1.217422
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.47564888	0.475649	85.7619
Error	10	0.05546157	0.005546	**Prob>F**
C Total	11	0.53111044		<.0001

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	-113.293	12.36513	-9.16	<.0001	-140.8444	-85.74163
Year	0.0576734	0.006228	9.26	<.0001	0.0437971	0.0715496

Equation 6: All Patents from 1992 to 1998

Std. All patents = -200.44 + 0.10144 Year

Summary of Fit

RSquare	0.841305
RSquare Adj	0.809567
Root Mean Square Error	0.104254
Mean of Response	1.921884
Observations (or Sum Wgts)	7

Analysis of Variance

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**
Model	1	0.28810505	0.288105	26.5071
Error	5	0.05434493	0.010869	**Prob>F**
C Total	6	0.34244998		0.0036

Parameter Estimates

Term	**Estimate**	**Std Error**	**t Ratio**	**Prob>|t|**	**Lower 95%**	**Upper 95%**
Intercept	-200.4449	39.30598	-5.10	0.0038	-301.4827	-99.40717
Year	0.101437	0.019702	5.15	0.0036	0.0507915	0.1520825

Appendix 2: Vehicle Definitions from the California Vehicle Code

Bicycle

Section 231

A bicycle is a device upon which any person may ride, propelled exclusively by human power through a belt, chain, or gears, and having one or more wheels. Persons riding bicycles are subject to the provisions of this code specified in Sections 21200 and 21200.5.

Golf Cart

Section 345

A “golf cart” is a motor vehicle having not less than three wheels in contact with the ground, having an unladen weight less than 1,300 pounds, which is designed to be and is operated at not more than 15 miles per hour and designed to carry golf equipment and not more than two persons, including the driver.

Low Speed Vehicle

Section 385.5

A “low-speed vehicle” is a motor vehicle, other than a motor truck, having four wheels on the ground and an unladen weight of 1,800 pounds or less, that is capable of propelling itself at a minimum speed of 20 miles per hour and a maximum speed of 25 miles per hour, on a paved level surface. For the purposes of this section, a “low-speed vehicle” is not a golf cart, except when operated pursuant to Section 21115 or 21115.1.

Effective January 1, 2000.

Motorcycle

Section 400

(a) A “motorcycle” is any motor vehicle having a seat or saddle for the use of the rider, designed to travel on not more than three wheels in contact with the ground, and weighing less than 1,500 pounds.

(b) A motor vehicle that has four wheels in contact with the ground, two of which are a functional part of a sidecar, is a motorcycle if the vehicle otherwise comes within the definition of subdivision (a).

(c) A motor vehicle that is electrically powered, has a maximum speed of 45 miles per hour, and weighs less than 2,500 pounds, is a motorcycle if the vehicle otherwise comes within the definition of subdivision (a).

(d) A farm tractor is not a motorcycle.

(e) A three-wheeled motor vehicle that otherwise meets the requirements of subdivision (a), has a partially or completely enclosed seating area for the driver and passenger, is used by local public agencies for the enforcement of parking control provisions, and is operated at slow speeds on public streets, is not a motorcycle. However, a motor vehicle described in this subdivision shall comply with the applicable sections of this code imposing equipment installation requirements on motorcycles.

Motor-Driven Cycle

Section 405

A “motor-driven cycle” is any motorcycle with a motor that displaces less than 150 cubic centimeters. A motor-driven cycle does not include a motorized bicycle, as defined in Section 406.

Motorized Bicycle

Section 406

(a) A “motorized bicycle” or “moped” is any two-wheeled or three-wheeled device having fully operative pedals for propulsion by human power, or having no pedals if powered solely by electrical energy, and an automatic transmission and a motor which produces less than 2 gross brake horsepower and is capable of propelling the device at a maximum speed of not more than 30 miles per hour on level ground.

(b) A “motorized bicycle” is also a device that has fully operative pedals for propulsion by human power and has an electric motor that meets all of the following requirements:

(1) Has a power output of not more than 1,000 watts.

(2) Is incapable of propelling the device at a speed of more than 20 miles per hour on ground level.

(3) Is incapable of further increasing the speed of the device when human power is used to propel the motorized bicycle faster than 20 miles per hour.

(4) Every manufacturer of motorized bicycles, as defined in this subdivision, shall provide a disclosure to buyers that advises buyers that their existing insurance policies may not provide coverage for these bicycles and that they should contact their insurance company or insurance agent to determine if coverage is provided.

(c) The disclosure required under paragraph (4) of subdivision (b) shall meet both of the following requirements:

(1) The disclosure shall be printed in not less than 14-point boldface type on a single sheet of paper that contains no information other than the disclosure.

(2) The disclosure shall include the following language in capital letters:

“YOUR INSURANCE POLICIES MAY NOT PROVIDE COVERAGE FOR ACCIDENTS INVOLVING THE USE OF THIS BICYCLE. TO DETERMINE IF COVERAGE IS PROVIDED YOU SHOULD CONTACT YOUR INSURANCE COMPANY OR AGENT.”

Motorized Quadricycle and Motorized Tricycle

Section 407. A “motorized quadricycle” is a four-wheeled device, and a “motorized tricycle” is a three-wheeled device, designed to carry not more than two persons, including the driver, and having either an electric motor or a motor with an automatic transmission developing less than two gross brake horsepower and capable of propelling the device at a maximum speed of not more than 30 miles per hour on level ground. The device shall be utilized only by a person who by reason of physical disability is otherwise unable to move about as a pedestrian or by a senior citizen as defined in Section 13000.

Motorized Scooters: Manufacturer Disclosure

Section 407.5

(a) A “motorized scooter” is any two-wheeled device that has handlebars, is designed to be stood or sat upon by the operator, and is powered by an electric motor that is capable of propelling the device with or without human propulsion. For purposes of this section, a motorcycle, as defined in Section 400, a motor-driven cycle, as defined in Section 405, a motorized bicycle or moped, as defined in Section 406, or a toy, as defined in Section 108550 of the Health and Safety Code, is not a motorized scooter.

(b) A device meeting the definition in subdivision (a) that is powered by a source other than electrical power is also a motorized scooter.

(c) (1) Every manufacturer of motorized scooters shall provide a disclosure to buyers that advises buyers that their existing insurance policies may not provide coverage for these scooters and that they should contact their insurance company or insurance agent to determine if coverage is provided.

(2) The disclosure required under paragraph (1) shall meet both of the following requirements:

(A) The disclosure shall be printed in not less than 14-point boldface type on a single sheet of paper that contains no information other than the disclosure.

(B) The disclosure shall include the following language in capital letters:

“YOUR INSURANCE POLICIES MAY NOT PROVIDECOVERAGE FOR ACCIDENTS INVOLVING THE USE OF THIS SCOOTER. TO DETERMINE IF COVERAGE IS PROVIDED, YOU SHOULD CONTACT YOUR INSURANCE COMPANY OR AGENT.”

Appendix 3: Survey

Table AP3-1: Companies to which the Survey was sent

1. AC Propulsion
2. AC Transit
3. Adaptrans, Inc.
4. Advanced Controls Technology, Inc.
5. Advanced Projects Research, Inc.
6. AeroVironment
7. Alameda Power & Telecom
8. Allison Product Management
9. Alturdyne
10. American Honda Motor Company, Inc.
11. Amerigon
12. Analogy, Inc.
13. Anuvu Incorporated
14. APS Systems
15. Ashman Technologies
16. Badsey Industrial Group Inc.
17. Battery Powered Electric
18. Bay Area Air Quality Management District
19. Bay Area Rapid Transit
20. Bell Vehicles Company
21. BIKEable Communities
22. Bus Manufacturing USA, Inc.
23. California Alternative Propulsion Co.
24. California Bus Sales
25. CALSTART
26. Capstone Turbine
27. Charger Bicycles, LLC
28. Christie Electric Corp.
29. Clean Fuels, LLC
30. CM International
31. Coherent Power
32. Control Master Products
33. Coriolis Corporation
34. Currie Technologies
35. Cybertran
36. DaimlerChrysler Research and Technology
37. Delphi Automotive Systems
38. Derksen Design
39. DivTech
40. Doran Motor Company
41. Dreyco Energy Systems
42. EBUS, Inc.
43. Econotech U.S.A.
44. Edison EV

45. ElDorado National
46. Electric Auto Association
47. Electric Transportation Company
48. Electric Transportation Div. of Southern California Edison
49. Electric Vehicle Custom Conversions
50. Electric Vehicle Information Services (EVINFO)
51. Electric Vehicle Infrastructure, Inc
52. Electric Vehicles, Inc.
53. Enerpro, Inc.
54. Engine Corporation of America
55. Enginuity, L.C.C.
56. Enova Systems
57. EV Rental Cars, LLC
58. Eyeball Engineering
59. FAS Engineering
60. Ford Division
61. Fuel Cell Energy, Inc. (West)
62. General Motors ATV
63. GE-Supply
64. Gillig Corporation
65. Ginter-VAST Corporation
66. Glacier Bay
67. Gorilla Vehicles
68. Green Motorworks
69. Group IX Systems
70. Helios International
71. Honeywell/Allied Signal
72. Hybrid EV Company
73. I T S Bus, Inc
74. InnEVations
75. Intercraft, Inc.
76. Interesting Transportation, Inc.
77. International Rectifier Corporation
78. ISE Research
79. It's Electric
80. Jet Propulsion Lab
81. JHK & Associates
82. Jinriksha
83. Kassabian Motors
84. Kaylor Energy Products
85. Keystone Batteries
86. Kilovac, Division of CII Technologies
87. KTA Services, Inc.
88. Lawrence Livermore National Lab.
89. Light Engineering
90. Litton
91. Metallic Power, Inc.

92. Moller International
93. Motorola
94. Nelco Electric USA
95. ODU USA, Inc.
96. Pacific Gas & Electric
97. Pacific Information Design, Inc
98. Pavlics Engineering
99. Pentadyne Power Systems
100. Phasor Corporation
101. Planet Electric
102. PolyStor Corporation
103. Pro Electric Vehicles, Inc.
104. Procyon
105. PROE Power Systems
106. REBAC
107. Replica Roadsters
108. RLA Power & Electronics Group
109. Rockwell
110. Rod Millen Vehicles
111. Romac Supply Company
112. San Diego Electric Automobile Co.
113. San Diego Gas & Electric
114. Santa Barbara MTD
115. Santa Clara County Fleet Manager
116. Sao Paulo Group
117. Schock Power Conversion
118. Signal Processing Systems
119. Southern California Edison
120. Stuart Energy USA
121. Sulzer USA, Inc.
122. Taylor-Dunn
123. TechTran Consultants
124. Trinity Flywheel Power
125. Trojan Battery Company
126. Twenty First Century Electric Vehicles
127. U.S. Battery Co.
128. US Electricar
129. US Flywheel
130. VoltAge, Inc.
131. Voltek
132. Volvo
133. Yussa/Exide, Inc.
134. ZAPWorld, Inc.

www.calstart.org

Table AP3-2. Survey on the Economic Effect of the California ZEV Program

This is a survey being conducted by WestStart-CALSTART, the California-based advanced transportation technologies consortium, in conjunction with the University of California, Davis and with the support of the California Air Resources Board. We are gathering information about the economic benefits to California of the California Zero Emission Vehicle (ZEV) program in terms of new EV-related product and service companies established, the associated growth in jobs, sales, R&D expenditures, and new investment . Please complete the survey below and fax (805/987-6049) or e-mail (slong@calstart.org) to us by July 12th. **ALL NUMBERS WILL BE KEPT CONFIDENTIAL**. Any questions, please contact either Susan Long, Participant Services Director, 805/987-8009 or Erin Kenney, Director of Special Projects at 626/744-5603 or ekenney@calstart.org. Thank you for your time and assistance. We appreciate your input in this important survey.

Contact Name/ Position____

Company Name ____

Company Address ____

____

Company Headquarters Address (if different from above) ____________________

____

Phone____

Fax____

E-mail____

1) A. In what specific EV-related product/technology or service is your company involved?

____

____

____

B. Indicate your product or service emphasis

____EV components ______EV infrastructure ____EVs _____fuel cells ______HEVs
____hybrid electric components _____fuel provider

2) A. In what year was your company established?_____________________________

B. If your EV-related product/technology or service is a division of your company, what year was the division established? _________________

3) Was your company or EV-related division established as a result of/to help meet the requirements of the California ZEV program? ______Yes ______No

4) How many California employees were initially employed in your company or EV-related division when first established? ____________ **ALL NUMBERS ARE CONFIDENTIAL**

5) What is the average number of employees employed in your company or EV-related division in the following periods of time. How many are located in California? How many of these do you believe may be attributed to the existence of the CARB ZEV program? **ALL NUMBERS ARE CONFIDENTIAL**

Year	**Average # of employees**	**Average # of California employees**	**# which can be attributed to the ZEV program**
1990 – 1992			
1993 – 1995			
1996 – 1998			
1999 – 2000			
2001 – 2004 (projected)			

ANSWERS TO THE REMAINING QUESTIONS WILL BE HELD IN STRICTEST CONFIDENCE AND NOT ATTRIBUTED TO YOUR COMPANY.

6) A. What are total sales revenues of your company or EV-related division in the following periods, and what percentage of these revenues are derived from California markets?

Year	**Total sales revenues**	**% derived from California markets**
1990 - 1999	$	%
2000 (projected)	$	%
2001 – 2004 (projected)	$	%

7) Please state total R&D expenditures both within and outside the state of California, and an estimated amount you believe can be attributed to the existence of the CARB ZEV program for the following periods of time. (Note: Totals may be the same.)

Year	**Total Expenditures**	**Total expenditures in California**	**Amount that can be attributed to the program**
1990 – 1999	$	$	$
2000 (current)	$	$	$
2001 – 2004 (projected)	$	$	$

8) Are you involved in other non-EV-related products/technologies or services?
_________Yes ___________No

9) A. If the answer on the previous question (#8) is yes, what are these non-EV-related products/technologies or services and to whom (e.g. market) are they sold? Also please indicate sales in these non-EV-related areas.

Product/Service	Market/Customers	**Sales since 1990**
		$
		$
		$
		$

B. What percentage of your non-EV-related market/customers is in California? _______________%

C. What percentage of your non-EV-related sales is in California? __________________________%

10) Estimate the investment you believe is needed for your company/division to pursue the EV market and any secondary market or spin-off you are pursuing?

Year	**Investment Needed**
2000 - 2001	$
2002 – 2003	$
2004 - 2005	$
2006 – 2007	$