REPORT BY THE

Comptroller General

OF THE UNITED STATES

Electric Vehicles: Limited Range And High Costs Hamper Commercialization

Although electric vehicles have been improved over the past few years, their limited range and high costs continue to make them noncompetitive with conventional vehicles. Widespread electric vehicle commercialization depends on production by the major automakers and ultimately on the availability of an advanced battery. U.S. automakers are not ready to produce electric vehicles because they believe the vehicles cannot currently compete in the automotive marketplace.

Federal efforts to commercialize electric vehicles have not been successful, and GAO agrees in large measure with the Department of Energy to discontinue program funding. GAO believes, however, that the one area where the Congress should consider the desirability of funding is advanced battery research and development. Continued Federal support of work in this area is essential for electric vehicles to become a widely commercialized transportation option.

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MARCH 19, 1982

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COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON D.C. 20548

B-206511

The Honorable Richard L. Ottinger
Chairman, Subcommittee on Energy
Conservation and Power
Committee on Energy and Commerce
House of Representatives

Dear Mr. Chairman:

As requested in your letter of July 17, 1981, this report discusses the current state of electric vehicle development, the readiness and capability of the major automakers to develop and commercialize electric vehicles, and the success of Federal efforts to advance their commercial readiness.

At your request we did not obtain agency comments. We are sending copies of this report to the Director, Office of Management and Budget; the Secretary of Energy; and other interested Committees of the Congress. Copies will also be made available to others upon request.

Sincerely yours,

Milton J. Socolar

Acting Comptroller General
of the United States

REPORT BY THE COMPTROLLER
GENERAL OF THE UNITED STATES

ELECTRIC VEHICLES: LIMITED RANGE AND HIGH COSTS HAMPER COMMERCIALIZATION

D I G E S T

Electric vehicles can potentially provide the Nation with a transportation alternative that is not dependent on oil for its fuel source. Recognizing the value of such an alternative in reducing oil consumption and consequently oil imports, the Congress enacted the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976. The objective of that act was to expedite electric vehicle commercialization through a program of research and development, large-scale demonstrations, and financial incentives to developers and producers.

In April 1979, the General Accounting Office (GAO) reported on the program and concluded that electric vehicles available at that time cost too much and delivered too little performance for widespread commercialization to be likely in the near-term. (See p. 4.)

In response to a request from the Chairman, Subcommittee on Energy Conservation and Power, House Committee on Energy and Commerce, GAO followed up on its prior report and evaluated the

- --current state of electric vehicle development,
- --readiness and capability of the major automakers to develop and commercialize the vehicles including the impact of Government initiatives on the automakers, and
- --success of Federal efforts to advance their commercial readiness. (See p. 5.)

CURRENT STATE OF DEVELOPMENT

GAO found that currently available electric vehicles are improved over those of a few years ago, but still have little potential for widespread commercialization. While performance, appearance, and quality have been advanced, limited range and high costs continue to make them

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noncompetitive with comparably sized conventional vehicles. In addition, industrial, infrastructure, and marketing barriers remain to be overcome. For the vehicles to be ultimately competitive with conventional vehicles, long-term, advanced batteries will have to be developed. To develop such batteries, the Department of Energy (DOE) provided over $10 million in fiscal years 1981 and 1982. (See p. 8.)

READINESS OF MAJOR AUTOMAKERS TO DEVELOP AND COMMERCIALIZE ELECTRIC VEHICLES

If electric vehicles are ever to be widely commercialized, the major automakers will have to be actively involved with the process. GAO found that the manufacturers are willing and able to mass produce and commercialize the vehicles but only when they are convinced the technology is developed sufficiently to enable the vehicles to compete in the automotive marketplace. In this connection, none of the automakers has begun the investment and procurement cycle that would be necessary to bring a mass produced electric vehicle to market. Only General Motors Corporation has made a public announcement that it intends to market them in the future. The other companies have conducted varying levels of developmental activities but at this time they believe the vehicles are not close to being ready for commercialization.

Without an industry perception that electric vehicles could be marketed in large numbers, Government efforts to encourage automakers to begin production have had, and will most likely continue to have, little impact. In particular, the incentive offered in the Chrysler Corporation Loan Guarantee Act of 1980 which enabled automakers to include electric vehicles in their corporate average fuel economy computations has little value to the automakers. All expect to meet the established mileage standards without including electric vehicles in their computations. (See p. 15.)

FEDERAL EFFORTS IN ADVANCING ELECTRIC VEHICLE COMMERCIALIZATION

While the Federal program has succeeded in raising consumers' awareness of electric vehicles,

directly aided some manufacturers, and helped produce technological improvements, the program has made only marginal progress toward achieving the primary objective of the Electric and Hybrid Vehicle Act--expediting commercialization. The program, which has received over $180 million through fiscal year 1982, sought to stimulate a growing market and build a healthy, self-sustaining industry. From each of these standpoints, the program has not been very successful. No discernible commercialization momentum has been created. (See p. 22.)

Given the overwhelming nature of the barriers to be overcome, achieving the objective of expediting electric vehicle commercialization would have been extremely difficult even if the Federal program created by the Electric and Hybrid Vehicle Act had been flawlessly implemented. In fact, without a more advanced battery and the commitment of at least one of the major U.S. automakers to build and market the vehicles, there is little likelihood that any Federal program could have accomplished the objective. Nonetheless, there have been problems with each of DOE's three main program activities--research and development, demonstrations, and financial incentives--which made program success less likely.

--The demonstration program activity failed to meet many of its objectives and was particularly deficient in disseminating demonstration results to the industry and the research and development community.

--Much of the research and development activity was devoted to developing prototype vehicles that have not fully met cost and development goals and, at least in some cases, have had questionable practical value.

--Neither recipient of a loan guarantee issued as part of the financial incentives activity has met its sales and production milestones and it is not clear whether the guarantees will substantially enhance the recipients' long-term future. (See p. 27.)

CONCLUSIONS

The Federal electric vehicle program has had little success in expediting the widespread commercialization of electric vehicles. As

was the case when the program began, widespread electric vehicle commercialization remains dependent on advances in battery technology and the entry of the major automakers into electric vehicle production and marketing.

The administration's budget proposal for fiscal year 1983 calls for terminating the program and discontinuing future funding related to specific advanced battery research and development. GAO believes the administration's budget proposal is, for the most part, appropriate. GAO finds little basis to argue against the curtailment of the demonstration and loan guarantee activities and reductions in the research and development activity. However, research and development on advanced batteries needs to be continued if electric vehicles are ever to become a general purpose transportation option. Advanced batteries are needed to provide electric vehicles with performance comparable to conventional vehicles and hence remove a major barrier to widespread commercialization by the major automakers. (See p. 34.)

MATTER FOR CONSIDERATION OF THE CONGRESS

Based on information in this report, the Congress should consider the desirability of funding for advanced battery research and development in DOE's fiscal year 1983 budget. If electric vehicles are ever to become the widely commercialized transportation option envisioned by the act, an advanced battery is needed. The Federal Government's failure to continue to support advanced battery developmental efforts could therefore jeopardize the electric vehicle's future and risk forfeiting the $180 million Federal investment that has already been made. (See p. 36.)

AGENCY COMMENTS

As requested, GAO did not obtain official DOE comments on this report.

Contents

ABBREVIATIONS

DOE	Department of Energy
EV	Electric Vehicle
GAO	General Accounting Office
GM	General Motors Corporation
NHTSA	National Highway Traffic Safety Administration
R&D	Research and Development

CHAPTER 1

INTRODUCTION

The Nation's reliance on imported oil for its energy needs has been recognized as a serious drain on the economy and a significant threat to national security. In 1981, the United States relied on imports to meet over 35 percent of its oil needs at a cost of about $77 billion. Unlike other sectors of the economy where coal and other fuels are being used to meet most energy requirements, the transportation sector remains almost totally reliant on oil and, accordingly, most dependent on a continuing flow of oil imports. Currently, more than one-half of the Nation's total oil consumption (over 8 million barrels a day) occurs in the transportation sector. Gasoline accounts for about 80 percent of that total. To reduce this consumption and import dependency, the Federal Government has examined a number of alternative fuels and methods of transportation. One such alternative is the electric vehicle (EV).

Although similar in basic design to conventional vehicles, EVs are powered by electric energy stored in batteries. The electric energy is used to drive an electric motor which moves the vehicle. EVs are generally considered to be quieter and pollute less than conventional vehicles. Also, EVs provide the opportunity for oil savings because about 85 percent of the Nation's electricity is produced from fuels other than oil, such as coal and nuclear energy. However, with current technology, EV performance is limited by the amount of electricity that can be stored in the batteries and converted through the propulsion system.

The EV is not a new concept. In the early 1900s there were more EVs than gasoline-powered cars on the road. With the availability of inexpensive gasoline, and the faster speed and improved range provided by internal combustion engines, however, EVs almost disappeared by the late 1920s.

In the past decade, as concern over oil availability increased, interest in EVs reemerged, and on September 17, 1976, the Congress passed the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976 (P.L. 94-413)--hereafter referred to as the Electric and Hybrid Vehicle Act. The act's objective was to save oil and reduce oil imports by expediting the introduction of EVs' into the Nation's vehicle fleet. This objective is to be achieved not only by improving vehicle technology but also by demonstrating EVs' commercial feasibility. Accordingly, the act mandated a program consisting of in part

--research and development (R&D);

--demonstration of up to 7,500 vehicles in the private and public sectors;

--financial incentives, consisting of loan guarantees to EV producers and developers and grants to small businesses; and

--studies on the best means to promote EV commercialization and the effects of such commercialization on the Nation.

The act was amended by the Department of Energy Act of 1978--Civilian Applications (P.L. 95-238, Feb. 25, 1978). The amendments in part (1) extended the demonstration program activity 2 years and revised the demonstration schedule to provide for fewer EVs in the early program years, (2) increased the total number of vehicles to be demonstrated from 7,500 to 10,000, and (3) established an Electric and Hybrid Vehicle Development Fund in the U.S. Treasury to carry out the loan guarantee activity.

Two additional laws have since been enacted affecting Federal EV activities. The Treasury, Postal Service, and General Government Appropriation Act, 1980 (P.L. 96-74, Sept. 29, 1979) exempted EVs purchased for demonstration purposes by Federal agencies from Federal motor vehicle purchase price limits which at the time were set at $3,400 for passenger cars and $3,800 for station wagons. Because EV costs far exceeded these limits, this exemption enabled Federal agencies to purchase EVs they otherwise would not have been able to purchase. The Chrysler Corporation Loan Guarantee Act of 1979 (P.L. 96-185, Jan. 7, 1980) authorized U.S. automakers to include EVs in their corporate average fuel economy computations. This provision was intended to be an inducement to automakers to begin producing EVs by making it easier for the automakers to meet the fleet mileage requirements mandated by the Energy Policy and Conservation Act (P.L. 94-163, Dec. 22, 1975). 1/

FEDERAL PROGRAM

The Department of Energy (DOE) has had primary responsibility for implementing the program mandated by the Electric and Hybrid Vehicle Act. Through fiscal year 1981, DOE--and its predecessor agency the Energy Research and Development Administration--had spent about $162 million on the program. In fiscal year 1982, DOE's EV program was substantially reduced in scope. Fiscal year 1982 program funding was reduced to $18.8 million from about $33 million in the preceding year. According to budget documents and DOE officials this reduction was made in accordance with the administration's philosophy of supporting long-term, high-risk R&D with high potential payoff, and relying primarily on the private

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1/Including EVs in an automaker's total fleet fuel economy average could help bring up the average because, under a formula developed by DOE, EVs would be counted as having an equivalent fuel economy of perhaps 100 miles per gallon or higher depending on the EV's individual characteristics.

sector to carry out commercialization activities. Fiscal year 1982 funding is being devoted primarily to supporting R&D and managing commercialization activities--such as conducting EV demonstrations and providing financial incentives to EV producers--undertaken with previous years' funding. None of these funds are being used to initiate new demonstrations or provide additional financial incentives. The administration has proposed discontinuing the entire EV program in fiscal year 1983, although a small amount of R&D related to EV technology will be continued as part of a newly created multi-purpose conservation R&D activity.

EV program funding for fiscal years 1976 through 1982 has been allocated as follows:

EV PROGRAM FUNDING

Program Activity	Fiscal year 1976 thru 1979	1980	1981	1982	Total
	(millions)				
R&D	$63.8	$24.0	$24.5	$16.2	$128.5
Demonstrations (note a)	17.5	10.9	7.0	2.0	37.4
Financial incentives (Loan guarantees and small business grants)	3.1	1.5	--	--	4.6
Other (Program management, studies, etc.)	6.9	1.6	1.4	.6	10.5
Total	$91.3	$38.0	$32.9	$18.8	$181.0

a/Includes funds for vehicle testing and improvement related to the demonstration activity.

The R&D activity has consisted primarily of work aimed at developing near-term EV battery technology and producing improved EV prototypes. DOE's EV R&D budget has also funded efforts to improve EV components such as motors and electrical current controllers, develop hybrid vehicle 1/ technology and produce a hybrid vehicle prototype, and explore advanced EV concepts such as

1/Hybrid vehicles combine an electric propulsion system with a secondary power source, such as a small gasoline engine. The secondary power source is used to recharge batteries or provide supplemental power.

electrified roadways. In addition, as part of its overall energy storage program DOE has conducted work on more advanced batteries that could have applicability for EVs.

DOE's demonstration activity was aimed at building an EV market and developing a self-sustaining EV industry. As part of this activity, DOE's demonstration site operators in private industry, State and local governments, and Federal agencies have contracted for about 1,100 EVs for the purpose of demonstrating EV performance capabilities. In addition, DOE is supporting the establishment of a network of 50 car dealers to put another 1,250 EVs on the road.

The financial incentives program activity was intended to encourage and assist EV developers, particularly small businesses, in their efforts to develop and produce EVs. In conducting this activity, DOE has issued two loan guarantees totalling $5.5 million 1/ to two EV manufacturers and awarded 27 grants totalling about $200,000 to small businesses to help them develop proposals for improving EV technology.

In addition to DOE's EV program, other Federal agencies and organizations have conducted EV activities. For example, the U.S. Postal Service has purchased over 700 specially adapted jeeps and vans to assist in mail delivery functions and has made a tentative commitment to purchase over 3,000 additional EVs. The Postal Service has also conducted EV testing to help determine performance capabilities and design improvements needed in its future EVs. In addition, the National Park Service has been using EVs since 1973. The Park Service is using EVs to carry out off-road as well as some on-road duties at some parks and recreational facilities which were previously carried out by conventional vehicles. The Tennessee Valley Authority, in conjunction with the Electric Power Research Institute, 2/ is presently testing and evaluating EVs at its EV Test Facility in Chattanooga, Tennessee. Finally, the National Highway Transportation Safety Administration (NHTSA) in the Department of Transportation, is conducting safety testing on commercially available EVs.

1/DOE has a loan guarantee ceiling of $16 million. With $5.5 million in loan guarantees outstanding, DOE has authority to issue up to $10.5 million in additional loan guarantees with available funding. Loan guarantees are limited to $3 million each by the Electric and Hybrid Vehicle Act.

2/The Electric Power Research Institute is funded by nearly 600 utilities nationwide to develop and administer a coordinated national electric power R&D program. In 1981, the Institute had a research budget of about $218 million, about $2 million of which was related to EVs.

PRIOR REPORT ON EVs

We previously examined and reported on EVs and the effectiveness of DOE's EV program. In a report entitled, "The Congress Needs to Redirect the Federal Electric Vehicle Program" (EMD-79-6, Apr. 9, 1979), we stated that EVs had the potential to reduce oil consumption and air pollution and that the EV concept was worth pursuing. We pointed out, however, that EVs available at that time had little commercial potential because they cost more than, and performed poorly compared to conventional vehicles and had questionable safety characteristics. Accordingly, the report concluded that large-scale EV demonstrations and loan guarantees to EV producers mandated in the act were premature and offered little realistic hope of bringing about widespread EV commercialization.

In this context, the report recommended, in part, that DOE

--redirect battery R&D funding away from near-term batteries and toward batteries capable of bringing about widespread EV commercialization,

--postpone private sector demonstrations until EV technology was improved, and

--delay issuance of loan guarantees until EVs were shown to be commercially viable.

In recognition of the undeveloped nature of EV technology, DOE with congressional concurrence, reduced the number of vehicles to be included in its demonstration program activity beginning with the third year of the demonstration schedule.

OBJECTIVES, SCOPE, AND METHODOLOGY

We conducted our review of the development and commercialization of EVs in response to a July 17, 1981, request by the Chairman, Subcommittee on Energy Conservation and Power, House Committee on Energy and Commerce. The Chairman requested that we follow-up on our prior EV report. He specifically asked us to

--determine the current state of EV technology,

--measure the readiness and capability of the major U.S. automakers to increase their efforts in developing and commercializing EVs,

--assess the possible impact on EV development of the legislation enabling automakers to include EVs in their corporate average fuel economy computations, and

--assess the success of Federal and other efforts conducted to develop and commercialize EVs.

Our basic approach in responding to the Chairman's request was to obtain data and supporting opinions from private and Government organizations most involved with developing, testing, using, and commercializing EVs. We acquired data and interviewed representatives from

--each of the major U.S. automakers;

--current EV manufacturers which together accounted for about 80 percent of recent EV production;

--several major battery manufacturers that have been involved in DOE's near-term battery R&D efforts;

--EV fleet operators in each of the four sectors included in DOE's demonstrations (private firms, State and local governments, Federal Government, and universities);

--DOE, NHTSA, Tennessee Valley Authority, U.S. Postal Service, and the National Park Service;

--Government research laboratories responsible for managing each segment of DOE's R&D program activity; namely Argonne National Laboratory, Lawrence Livermore Laboratory, and the National Aeronautics and Space Administration's Lewis Research Center and Jet Propulsion Laboratory;

--Booz Allen and Hamilton Inc., the DOE contractor responsible for managing the private sector vehicle demonstrations;

--the Electric Power Research Institute and the Electric Vehicle Council; 1/ and

--the lending institutions involved with DOE's loan guarantees.

A listing of the organizations contacted during our review is attached as an appendix to this report.

We supplemented the information obtained during our interviews with analyses of DOE budget documents, progress reports, operating plans, and contract records; pertinent legislation; EV and battery specifications provided by EV and battery manufacturers; and a variety of studies published by DOE and other

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1/The Electric Vehicle Council is an international trade association created in 1967 to promote the acceptance of EVs and advance EV technology.

organizations addressing EV performance and potential. We also observed several currently available EVs, and compared their driveability and performance with those EVs observed during our prior review.

In conducting our review, we also obtained information on hybrid vehicles. However, since hybrid vehicles are not nearly as developed as EVs and are farther from commercial readiness, we concentrated our efforts on EVs.

Our review was performed in accordance with GAO's current "Standards for Audit of Governmental Organizations, Programs, Activities, and Functions."

CHAPTER 2

WHAT IS THE CURRENT STATE OF EV DEVELOPMENT?

While EV technology and quality have unquestionably improved in recent years, EVs are still far from a point where widespread commercialization is likely. EVs have improved performance capabilities, better appearance, higher quality, and are saleable in a limited number of applications, but they still have such limited range and high cost that they remain noncompetitive with comparably sized conventional vehicles. Beyond these technological and cost barriers, EVs must also overcome imposing industrial, infrastructure, and marketing barriers before large numbers begin appearing on the Nation's roadways.

RECENT IMPROVEMENTS IN EV TECHNOLOGY

In the past few years, commercially available EV technology has made gradual although not revolutionary improvements. Based on the findings of recent studies, changes in the performance standards used by DOE in conducting its demonstration program activity, and opinions expressed by demonstration site operators, improvements are evident in several aspects of vehicle performance capabilities including range, acceleration, and speed. Advances have also been made in the more subjective measurements of appearance, quality, and overall level of refinement.

With respect to range, DOE's latest EV state-of-the-art report indicates that under controlled testing conditions state-of-the-art EVs are capable of achieving ranges between 30 and 70 miles before the vehicle's batteries need recharging. 1/ This is higher than ranges achieved by EVs during testing conducted for DOE between 1973 and 1978 which indicated EVs available at that time had range capabilities between 20 and 57 miles. The report also shows advances in acceleration and speed. With respect to acceleration, most state-of-the-art EVs tested accelerate from 0 to 30 miles per hour in an average of about 12 seconds compared to an average of about 15 seconds for vehicles tested during the 1973 to 1978 time period. Finally, concerning speed, current state-of-the-art EVs are capable of achieving top speeds on level ground of between 45 and 68 miles per hour, compared to between 31 and 56 miles per hour for vehicles tested during the earlier time period. This improved performance is, however, still not comparable to conventional vehicles which have much longer ranges, and with the exception of some diesel cars, better acceleration capabilities.

1/"State of the Art of Electric and Hybrid Vehicles," prepared for DOE by The Aerospace Corporation, May 1981.

The performance improvements made in EVs are also shown in the changes DOE made in the minimum EV performance standards promulgated as part of its demonstration program activity. Because of the increase in vehicle performance capabilities, DOE was able to make more stringent the requirements EVs had to meet before they qualified for purchase under the demonstration program. The revisions to the standards between 1978 and 1980 are set forth in the table below.

Performance category	1978 Standard	1980 Standard
Range (in miles)		
Personal use	31	34
Commercial use	31	37
Top Speed (in miles per hour)		
Personal use	50	50
Commercial use	43	47
Acceleration (from 0 to 30 miles per hour)		
Personal use	15 seconds	13.5 seconds
Commercial use	15 seconds	14 seconds

While vehicle performance capabilities are somewhat improved, several demonstration site operators and EV manufacturers we spoke with believed greater improvements have been made in less quantifiable areas. They told us that, in general, today's EVs are much more refined than they were several years ago. Specifically, they pointed to better appearance, increased reliability, and better quality. Based on our own observations, we concur with the assessment that today's EVs are better products than those available several years ago.

MAJOR TECHNICAL AND COST BARRIERS STILL IMPEDE WIDESPREAD EV COMMERCIALIZATION

While improvements have been made in recent years, the typical EV available today continues to be a converted conventional vehicle with limited performance capabilities, unresolved safety issues, and high costs. Major advances in battery and related technology are needed to make EVs more competitive with conventional vehicles and thereby provide the opportunities for significant oil savings as envisioned in the Electric and Hybrid Vehicle Act.

Performance capabilities limited

Limited range is a critical technical weakness of EVs. According to DOE's May 1981 state-of-the-art report cited earlier, EVs can achieve ranges of between 30 and 70 miles between battery

charges. These results, however, were obtained on test tracks under more controlled conditions than those normally encountered during regular day-to-day driving. Many EV fleet operators we spoke with, in fact, told us the practical operating limit for their EVs was about 30 miles, and a November 1981 report issued by the Electric Power Research Institute states that the maximum range that can be consistently achieved by available EVs is 30 to 40 miles. In any event, today's EVs are significantly far away from achieving a range capability necessary for widespread commercialization. Furthermore, once the EVs range limit has been achieved, the batteries must be recharged for a period of between 8 and 10 hours. Conventional vehicles, on the other hand, are refueled in a period of minutes.

Most EV performance limitations hinge on the need for a better battery. The only battery type available in commercial quantities for EVs today is the lead-acid battery, which is similar in chemical composition to those used during the past 50 years or more in conventional cars. Improvements have been made in these batteries in recent years. However, there is widespread agreement that lead-acid batteries cannot provide the power necessary to enable EVs to be widely commercialized. For widespread commercialization to be possible, other battery candidates with more energy storage capabilities and, more importantly, longer life, will probably have to be developed. DOE and battery companies have been developing a number of near-term candidates such as nickel-zinc, nickel-iron, and zinc-chlorine, but to date the performance of these batteries outside the laboratory has not been proven and none are being produced on a commercial scale. Furthermore, the ability of these batteries to be produced commercially at a reasonable cost has not been established. For EVs to achieve widespread commercialization, it may be that more advanced batteries will be needed. DOE has funded work on several such batteries, including aluminum-air, lithium-metal-sulfide, and sodium-sulfide, as part of its overall energy storage R&D program.

Safety issues not fully resolved

Unresolved safety questions also stand as a potential technical obstacle to widespread EV commercialization. Although there is nothing in EV technology that makes EVs inherently unsafe and the safety experience to date has been encouraging, testing performed by NHTSA indicates that safety performance problems could surface in the future. As part of its own independent efforts as well as through an interagency agreement with DOE, NHTSA has tested or is currently testing over 20 EVs

for compliance with Federal Motor Vehicle Safety Standards 1/ as well as for research purposes. Of the EVs tested, none passed the standard for windshield defrosting and many failed one or more of the standards related to the 30 miles per hour crash test. In addition, testing related to battery safety showed that during the 30 miles per hour crash test, six EVs had battery acid spills into the occupant compartment.

DOE officials told us that with the exception of the windshield defrosting standard, EVs included in its demonstration program activity pass all standards. They further stated that the safety problems noted in previous NHTSA tests have, for the most part, been corrected. Several of the vehicles that failed to meet crash-related standards are no longer being produced and others have undergone design improvements to make them more crashworthy. The DOE officials also believed the defrosting standard--which requires that the vehicle be capable of defrosting 80 percent of the windshield area in 40 minutes while the vehicle is in a 0^0F room--was overly demanding and that failure to meet the standard did not indicate a real safety weakness. The officials conceded, however, that safety problems remain a concern on some EVs and that EV safety continues to be an issue meriting close attention.

NHTSA has not strenuously pursued the EV safety issue. Although NHTSA testing has shown that many EVs failed to meet standards, NHTSA has not made a formal legal ruling of non-compliance with Federal safety standards on any EV. Under existing procedures, EV manufacturers can self-certify compliance with safety standards and can continue to sell their EVs even if NHTSA testing indicates failure to comply, unless NHTSA takes legal action. A NHTSA official told us NHTSA has not pursued the issue more vigorously because so few EVs are on the road and because forcing EV manufacturers to demonstrate strict compliance with all standards could impose severe financial hardship. EV safety issues cannot remain unresolved indefinitely, however. Assured EV safety performance will be essential to any future widespread EV marketing.

EV costs not competitive

In addition to providing inferior performance compared to conventional vehicles, costs for EVs available today are also not competitive with conventional vehicles from either an initial cost or operating cost basis. Generally, EVs still cost about twice as much as their conventional counterparts. Most EV passenger cars, light vans, and light pick-up trucks we examined had a base price tag between $12,000 and $20,000 compared to between $6,000 and $10,000 for the comparable conventional version. Some of the price differential between EVs and conventional vehicles can be

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1/Currently, there are 50 Federal Motor Vehicle Safety Standards. These standards do not specifically address unique aspects of EV safety such as electrical shock or battery acid spills.

attributed to the fact that EVs today are generally produced by converting conventional vehicles in small numbers. In this process, the EV manufacturer must purchase a conventional vehicle, remove the engine and other associated components and replace those components with batteries and other electrical drive components. The manufacturer then attempts to sell the removed conventional components but normally is not able to fully recover its initial outlay. The Ford Motor Company is considering selling Ford Escort bodies and frames to EV manufacturers without engines and related components. According to EV manufacturers, such an action could help reduce initial costs for Escort conversions by $1,000 or more. While these savings are significant, EVs will still cost far more than their conventional counterparts.

Although initial EV costs are higher, EV costs over the vehicle's lifetime could be equal to or less than conventional vehicles because electrical energy costs per mile will be less than gasoline costs. Based on results from DOE's demonstration program, however, total operating costs (fuel and maintenance) are currently proving to be higher for EVs than comparable conventional vehicles. Electricity costs per mile are less than gasoline costs but high maintenance costs are more than offsetting any savings. For example, private sector site operators participating in DOE's demonstration are reporting total EV operating costs of between 45 and 66 cents a mile compared to 12 cents a mile for comparable conventional vehicles. The majority of the EV operating costs were maintenance costs involving, in particular, the need to replace batteries and to conduct routine but time-consuming battery servicing.

Short battery life is a serious problem with major impact on current EV costs. Private sector site operators participating in DOE's demonstration activity are reporting an average useful battery life of only between 110 and 200 cycles. This means that the EV batteries can be substantially discharged and recharged a maximum of only up to 200 times. If, for example, an EV was driven each day for 50 weeks, substantially discharging the batteries each day, a complete set of batteries, costing between $1,000 and $1,300, would likely have to be replaced in less than a year.

DOE officials believe the high costs and battery life problems experienced to date are common to an infant industry such as the EV industry and will likely not be present in a mass produced EV. They accordingly do not believe the high costs of today's EVs will necessarily be a valid predictor of costs for a future mass-produced EV.

OTHER BARRIERS IMPEDING WIDESPREAD COMMERCIALIZATION

In addition to technical and cost barriers, EVs must overcome imposing industry, infrastructure, and marketing barriers

before widespread EV commercialization can be achieved. The EV industry today is comprised of a few small manufacturers who primarily convert conventional vehicles in small numbers and hence do not have the ability to achieve the scale economies necessary to bring costs down. Relatedly, these small manufacturers do not have the resources necessary to establish the sales, service, and battery charging infrastructure needed to support large numbers of EVs. Finally, available market surveys indicate that EVs may face a significant level of consumer resistance because they are a product with which potential consumers are not familiar.

Industry barriers

The existing EV industry is made up of a few small producers who, for the most part, convert conventional vehicles in small quantities on either unautomated assembly lines or with no assembly line at all. An industry survey conducted by the Electric Vehicle Council in July 1981 demonstrates the limited scale of operation which currently characterizes the EV industry. This survey showed that total industry production during the period July 1980 to July 1981 was about 1,500 vehicles. Of this, only 4 companies out of a total of 12 companies responding to the survey produced more than 100 vehicles and 1 of these companies is now out of the EV business. Only 3 other companies produced as many as 50 EVs during that 1-year period.

By producing EVs in such small numbers, none of the existing manufacturers are able to make bulk component purchase orders and otherwise obtain the economies of scale necessary to lower costs and make their products more attractive to larger numbers of customers. In the automobile industry, scale economies are not normally believed achievable until production levels are above 100,000 to 200,000 vehicles a year. In the context of the current EV industry, several EV manufacturers we spoke with said they need to produce and sell about 2,000 EVs a year to begin lowering production costs. The highest level of production reported by an EV manufacturer in the 1-year period covered by the Electric Vehicle Council survey was only 500 vehicles.

Infrastructure barriers

Operating at such minimal production levels, the industry is also not able to establish a sales and service infrastructure necessary to support large numbers of EVs. Although a number of EV manufacturers are beginning to work out arrangements with individual car dealers, we are not aware of any that has yet been able to establish a network for selling large numbers of its EVs or for providing service and repairs to those EVs after the sales. Almost all of the site operators in DOE's demonstration program are experienced operators of vehicle fleets and, as such, have maintenance staffs and facilities available. If larger numbers of EVs are to be sold to individual buyers who do not have the service facilities possessed by fleet operators, it will be essential that a well-developed service infrastructure be in place.

Another infrastructure barrier is the lack of convenient recharging facilities for a large segment of potential EV buyers. With limited range, an important target for individual EV passenger car sales will be residents of urban areas in close proximity to central cities. It is in these areas that a large number of residents live in apartments or other multi-family dwellings and hence may not have convenient access to electrical outlets necessary to recharge their EVs. Without such recharging capability, access to a large number of potential EV buyers could be lost.

Marketing barriers

Concerning EV marketing, the high initial cost and limited performance capabilities of EVs stand as the major barriers to dramatically increasing EV sales, particularly to individuals. Marketing data for passenger EVs are limited. The data that are available from research conducted by J.D. Power and Associates, 1/ Syracuse University, and others, however, suggest that passenger EVs will likely require much improved ranges and will have to be priced more comparably with conventional vehicles if they are to be marketable in large numbers. Even then, however, the marketing challenge will be formidable.

Consumer acceptance of new technologies normally lags behind the development of the technologies themselves. Accordingly, large-scale marketing of an unfamiliar, high-cost product with uncertain resale value such as EVs will be difficult and will require extensive marketing efforts. The marketing task will be especially difficult because, in making vehicle purchase decisions, consumers generally attach very high value to characteristics where EVs are weak, namely range, performance, and initial price.

The marketing problem will be further compounded by the fact that EVs will likely be competing in the commuter car market with small, efficient, conventional vehicles getting 50 or more miles per gallon of fuel that are projected to be available in large numbers by 1985. Perhaps more importantly, these vehicles will employ engine technology familiar to consumers. Sharp increases in the price of fuel also may not be sufficient to lead consumers to reject familiar conventional vehicles and purchase EVs in large numbers. In Europe, for example, gasoline prices average nearly $3 a gallon and yet, for a variety of reasons, very few EVs are on the road. The return of long gasoline lines might, on the other hand, dramatically improve EV marketability.

1/J.D. Power and Associates has conducted attitudinal surveys of the American car buying public for over a decade.

CHAPTER 3

HOW READY, WILLING, AND ABLE ARE MAJOR AUTOMAKERS TO DEVELOP AND COMMERCIALIZE EVs?

The active involvement of the large U.S. automakers will be necessary for EVs to achieve widespread commercialization. In this context, the attitudes of the automakers toward EVs are crucial.

We found that the major U.S. automakers are willing and able to mass produce and commercialize EVs but will be ready only when they are convinced that EV technology has been developed sufficiently to enable EVs to successfully compete in the marketplace. To date, the automakers are not convinced that this condition has been met and, accordingly, no manufacturer has committed the major financial investments that would be necessary to bring a mass-produced EV to market. Without an industry perception that EVs can be marketed in large numbers, amending the Federal corporate average fuel economy regulations to encourage automakers to begin EV production has had, and will most likely continue to have, little impact on the automakers' decisions to develop and market EVs.

As recent auto industry experience has shown, foreign automakers are capable of identifying and capturing segments of the U.S. auto market not identified by U.S. manufacturers. Concerning EVs, however, there is little imminent danger that large auto manufacturers in either Europe or Japan will be able to seize a U.S. EV market in at least the near future. Although information is not plentiful, indications are that foreign EV technology is no more advanced than U.S. technology. Like U.S. automakers, foreign automakers do not now have an EV that would have much appeal to a significant portion of the U.S. car-buying public.

AUTOMAKERS NOT YET READY TO COMMIT TO LARGE-SCALE EV PRODUCTION

Although the U.S. auto industry is able to and ultimately willing to build and market EVs, the major automakers are convinced that the current state-of-the-art does not support a widespread EV market. Accordingly, the industry has been understandably reluctant to commit to the long and expensive process of building production capacity and lining up component suppliers necessary to put EV production on line. Although no automaker has begun making such an investment, each has conducted EV R&D activities in the past, and two automakers have continuing efforts underway.

While differing somewhat on the specific parameters that would define a widely marketable EV, the automakers are unanimous that there is not a widespread market for state-of-the-art EVs and that technological advances must be made to make a widely marketable EV possible. The major automakers have established general targets which they believe represent the minimum performance levels that must be met before EVs will have mass market appeal. These targets vary in many respects but, for the most part, are higher than those achieved by currently available EVs. The targets are set forth in the following table.

Automaker opinions on EV minimum performance targets

Performance category	Range of opinion (note a)
Vehicle range (in miles)	60 to 100
Top speed (in miles per hour)	55 to 65
Acceleration (in seconds)	
0 to 30 miles per hour	b/ 8
0 to 50 miles per hour	b/17
Battery pack life (in miles)	30,000 to 40,000

a/Two automakers did not provide specific targets in these areas but expressed a general view that performance would have to be significantly improved over current technology.

b/Only one automaker provided a target in this category.

While varying somewhat in their performance targets, the automakers were unanimous that from a cost standpoint, EVs would have to be competitive with comparable conventional vehicles to be widely marketable. The automakers do not believe today's EVs, which cost twice as much as conventional vehicles, are marketable in large numbers and that ways must be found to bring costs down if widespread EV marketing is to be achieved. In addition, the auto company representatives we spoke with said it would be important that any EV they produced be safe and--to maintain consumer credibility--reliable.

Industry cautious toward making large financial commitment

Until EV performance and cost targets are met and there is reasonable certainty of marketability, the automakers are understandably reluctant to commit themselves to EV production. The investments necessary to make EVs in large numbers would be massive. In addition, industry caution to introduce a radically different product such as EVs is probably made even more pronounced by the bleak financial picture currently being faced by the industry.

To achieve large-scale EV production, the auto industry will have to make a major commitment of resources, both in terms of money and time. An estimate made by one auto industry analyst (Arthur D. Little, Inc.) holds that the costs for facilities to produce 200,000 to 300,000 EVs a year--a production level generally desired by the automakers--would be between $0.5 billion and $1.0 billion. In addition, the analyst reported that once the decision to begin EV production is made it will likely take 5 to 7 years to construct the facilities, line up component suppliers, and otherwise prepare for production.

The industry would move cautiously toward investing such resources in an unconventional product such as EVs even in the best of times. It is well known, however, that these are not the best of times for the U.S. auto industry. None of the major U.S. automakers reported a profit in 1980 and only one reported a profit in 1981. Combined losses reported by domestic automakers in 1980 exceeded $4 billion and were over $1 billion in 1981. Moreover, domestic car sales for the U.S. automakers continue to slide. The 1981 domestic car sales of 6.2 million cars, a 20-year low, followed 1980 sales which were not much better (only 6.6 million cars). Further characterizing the industry's slide in the last few years has been the large-scale attrition in automobile dealerships nationwide. In the last 2 years, the domestic automakers' sales network has lost over 2,400 outlets representing more than 10 percent of the entire retail sales network.

Industry R&D activities are continuing

While no major U.S. automaker has made the financial commitment necessary to begin mass producing EVs, all of them have conducted EV related activities. Two companies have discontinued their efforts. Of the two other companies which are continuing with their programs, General Motors (GM) has announced its intention to produce EVs in the future but has not yet translated this intention into a finalized production commitment. Because of the proprietary nature of the data, the automakers were not willing to share with us the specific types and amounts of resources they had spent or are spending on EV R&D. However, they did provide general information on past and current EV activities within their companies. The activities of each company are discussed below.

General Motors Corporation

GM is the only U.S. automaker to publicly announce its intention to market EVs in the future. In 1979, following years of R&D, the company announced that it had achieved a breakthrough with its nickel-zinc battery system and, accordingly, that it intended to build and market a two-passenger EV by the mid-1980s. GM representatives told us that, from a technological standpoint, the company is on target for having a car available for

introduction in the 1986 time frame. However, GM has not yet begun the lengthy process of developing an EV production capacity nor has it begun lining up EV component suppliers. Moreover, representatives told us they were not irreversibly committed to producing EVs and could still delay or even back away from GM's announced plans until it is assured that the technology is developed and the marketplace conditions are right.

In the meantime, GM has invested millions of dollars in EV developmental efforts in support of its announced marketing plans. In January 1980, it established an electric car "project center" made up of experts from various corporate divisions and departments to develop an electric car concept, design, and prototype; perform prototype testing; and then determine the market potential. Handbuilt prototypes powered by nickel-zinc batteries are now being tested on dynomometers and on the road. A company representative told us that the company's prototypes have logged about 100,000 miles in dynomometer and road testing.

GM also has separate tentative plans to market an electric van by the mid-1980 time frame. The company's Truck and Coach Division participated in DOE's demonstration program by supplying 35 electric vans (converted conventional vans) and monitoring the operating results. It is also working through the Argonne National Laboratory to test nickel-iron batteries currently planned for use in its van. GM is continuing its electric van developmental efforts and is working towards a possible mid-1980s debut.

Ford Motor Company

Ford has also been active in EV R&D for a number of years. Ford has concentrated its efforts on monitoring battery R&D and, with DOE's support, conducted sodium-sulfide battery development in accordance with its belief that significantly advanced batteries are needed to provide the performance necessary for a competitive EV. The company has also worked on advanced EV components and constructed several test vehicles which it has road tested using various component configurations. In addition, Ford is considering selling "gliders"--vehicle bodies and frames without engines or other drive train components--to small EV manufacturers. This involvement with the EV industry provides the company with some generalized EV experience that could be used in any subsequent EV production by the company.

Chrysler Corporation

Chrysler's main involvement with EVs occurred in conjunction with DOE's efforts to develop a prototype EV. In this effort, the company was responsible for vehicle styling, body design and fabrication, suspension, braking, and vehicle testing on one of DOE's EV prototype designs. Chrysler's involvement with this effort provided it with considerable experience that would be useful if the company decided to produce EVs in the future. Since

concluding this effort in 1979, the company has no longer been involved in EV development. A company representative told us the company plans to wait on the sidelines until a production battery meeting its performance objectives is available, market conditions are right, costs are competitive with conventional vehicles, and the sales volume appears promising enough that a profit can be made.

American Motors Corporation

American Motors Corporation's involvement with EVs has occurred through its subsidiary, AM General. In 1975, the U.S. Postal Service awarded AM General a contract to produce 350 EVs for its local mail delivery fleet. In producing these vehicles, the company used off-the-shelf technology to convert its conventional jeep to an electrically powered jeep. Off this same production run, the company also produced 20 more vehicles for testing by the American Telephone and Telegraph Corporation. Since producing these EVs, AM General has not been actively pursuing EV development primarily because of the lack of a viable EV market.

FEDERAL FUEL ECONOMY STANDARD INCENTIVE HAS LITTLE IMPACT ON AUTOMAKER COMMITMENT DECISIONS

The primary Federal incentive aimed at encouraging the major automakers to produce and sell EVs was the amendment to the Federal corporate average fuel economy regulations which enabled automakers to include any EVs produced in their overall model year computations. For several reasons, this incentive was of little significance to the automakers.

The Energy Policy and Conservation Act established minimum average mileage requirements for the cars produced by each automobile manufacturer, including importers, in a given model year. The mileage requirements mandated by the act were

Model year	Mileage requirement (in miles per gallon)
1978	18.0
1979	19.0
1980	20.0
1985	27.5

The act also allowed the Secretary of Transportation to set interim standards for model years 1981 through 1984. The Secretary took action by setting interim standards at 22 miles per gallon for model year 1981, 24 miles per gallon for model year 1982, 26 miles per gallon for model year 1983, and 27 miles per gallon for

model year 1984. As an incentive to the automakers to begin producing and selling EVs, the Chrysler Corporation Loan Guarantee Act of 1979 contained a provision which authorized automakers to include any EVs produced (counted as having a high miles-per-gallon equivalent) in their computations, and thereby make it easier to meet the mileage standards.

Automaker representatives told us, however, this incentive will have little or no impact on their decisionmaking regarding EVs. None of the automakers have any plans to produce any EVs through model year 1985, when they will have to meet the final mileage requirement of 27.5 miles per gallon. Further, the automakers are confident their companies will meet or surpass the standards through 1985 without including EVs.

FOREIGN EV TECHNOLOGY NOT AN IMMINENT THREAT TO U.S. MARKET

As demonstrated in recent years, foreign automakers are capable of identifying and capturing car market segments not identified by domestic automakers. While foreign automakers and governments are working to develop EV technology, it appears that none has established a leadership position. Although we did not perform a detailed assessment of foreign EV technology, based on the comments of U.S. automaker representatives and other industry observers, it appears there is little imminent danger that any foreign automaker will be able to introduce EVs in the U.S. market in the near future. As in the United States, the lack of an effective battery is apparently preventing a large-scale EV breakthrough in both Japan and Europe.

Status of EV development in Japan

EV technology in Japan appears to remain at much the same level as in the United States with the lack of a sufficiently advanced battery being the most important technical barrier to commercialization. Few EVs (about 450) are on Japanese roadways. These EVs are two to three times as expensive as conventional vehicles and have low performance levels. To make EVs more practical, the Japanese private sector, in conjunction with the Japanese government, has conducted, and is actively pursuing, EV R&D. A performance battery now under development may make a practical EV possible, but as yet the future of EVs in Japan remains uncertain. DOE officials are concerned that Japan could be on the threshold of an EV breakthrough. However, U.S. auto industry representatives, as well as other industry observers, do not believe Japanese EV technology is at a point where large-scale EV imports are a significant near-term threat. There was some concern expressed, however, that Japan could capitalize on breakthroughs originating in the United States or elsewhere and develop an EV having widespread marketability in this country. Relatedly, DOE officials pointed out that Japan's electricity is produced in large measure from imported fuel sources. Accordingly, they

believe any future Japanese EV production would likely be for the export market.

Status of EV development in Europe

EV development in Europe is also not at a more advanced level than in the United States. Little progress has been made in the development of a competitive EV passenger car. Existing vehicles have limited range and high costs. Furthermore, European automakers have not expressed much interest in building EVs. The situation is somewhat better with commercial type EVs, where developmental attention has been concentrated, but here too, large-scale commercialization remains a distant objective.

Most of the European nations' ongoing EV R&D programs are relatively small-scale. Much of the R&D is concentrated on batteries and other components. Several countries are also conducting small-scale demonstrations usually involving 100 EVs or less; large-scale R&D programs are not currently planned. Instead, the major European EV organization--the European Electric Road Vehicle Association--is proposing to document current EV deficiencies and lay out appropriate R&D initiatives to pursue solutions. Although R&D is continuing, there does not appear to be a serious threat that European automakers will begin exporting EVs in large numbers to the United States in the near future.

CHAPTER 4

HOW SUCCESSFUL HAVE FEDERAL EFFORTS BEEN IN ADVANCING EV COMMERCIALIZATION?

Although the Federal EV program had some important accomplishments, it has made only marginal progress toward achieving the Electric and Hybrid Vehicle Act's primary objective--expediting EV commercialization. The program has succeeded in raising consumer awareness of EVs, been instrumental in keeping several small EV manufacturers afloat, and has helped produce some important improvements in EV technology. However, in the final analysis, the program has not established momentum leading ultimately to widespread EV commercialization. As was the case when the program began, widespread EV commercialization today remains dependent on advances in battery technology and decisions by the major automakers. Given that battery shortcomings and other barriers are yet to be overcome, achieving expedited EV commercialization would have been difficult even with optimum program implementation. However, we found several problems with DOE's program which reduced the chances of program success.

PROGRAM ACCOMPLISHMENTS

Over the past 6 years, DOE's $180 million EV program has produced some important accomplishments. On an overall basis, we believe the most significant accomplishments have been increasing consumer awareness of EVs and providing EVs with a degree of respectability as a serious transportation option. In addition, each of DOE's three primary EV program elements generated specific accomplishments. The R&D program has helped produce significant advances in battery technology. The demonstration program has provided the basis for the existing industry to improve the performance and quality of currently available EVs. Finally, the two loan guarantees issued have helped two manufacturers remain in business and expand their operations.

Battery technology has been advanced

Since the inception of DOE's R&D program, measurable technical progress has been made in battery technology. Advances have been made in near-term battery technology as well as advanced battery concepts. DOE has concentrated its near-term battery development efforts on three battery types; (1) improved lead-acid, (2) nickel-zinc, and (3) nickel-iron. The following table compares the performance levels achieved by each battery type in battery tests conducted by Argonne National Laboratory in 1981 with those levels achieved by commercially available lead-acid batteries available in 1977 and demonstrates the advances that have been achieved.

Near-Term Battery Performance Improvements

Description	Performance		
	Energy storage (watt hours/ kilogram)	Power output (watts/ kilogram)	Cycle life (cycles)
Lead-acid batteries commercially available in 1977	30	95	200
Batteries developed under DOE's R&D program			
Improved lead-acid	41	104	488 a/
Nickel-zinc	68	131	179
Nickel-iron	48	103	746 a/

a/Testing still underway; battery failure point not yet reached.

Most of the credit for the battery technology advances made over previously available lead-acid batteries belongs to the DOE program. It should be recognized, however, that these improvements are based on fragmentary data and have been demonstrated in the laboratory, not in actual commercial operation. Some versions of improved lead-acid batteries are slowly finding their way into the marketplace but nickel-zinc and nickel-iron batteries are not being produced on a commercial-scale and are not available other than in small quantities.

Important accomplishments have also been achieved in advanced battery concepts to which DOE has devoted about $12 million in fiscal year 1981 funding and about $11 million in fiscal year 1982 funding. Because advanced batteries are projected for use in a number of energy storage applications, work with these batteries has been funded as part of DOE's overall energy storage program, 1/ not as part of the EV program. Nevertheless, developments here could have significant impact on the future of EVs. For example, one of these concepts--the aluminum-air battery--is potentially one of the most promising advanced battery candidates for EV application. While the practicality of the aluminum-air battery has not been demonstrated and private sector interest in the concept is limited at present, testing has indicated that these batteries could provide EVs with good power capability and

1/For fiscal year 1983, DOE has proposed closing out its overall energy storage program and conducting any remaining battery-related R&D as part of a multi-purpose energy conservation R&D program.

ranges of 250 miles or more. Moreover, these batteries have the potential for rapid refueling by adding water and replacing aluminum plates in the battery. DOE's R&D efforts have advanced this battery from the most basic conceptual stage to the point where laboratory, bench-scale cells have been produced and successfully operated.

Other longer term battery candidates such as lithium-metal-sulfide, sodium-sulfide, and zinc-bromine have also been advanced through DOE's efforts. Like the aluminum-air battery, these batteries have vastly superior performance potential compared to the near-term batteries that have been developed as part of DOE's program, but these advanced batteries are at a much earlier stage of development than near-term batteries.

Because these concepts are long-term in nature, they are not an attractive investment for battery companies, which are oriented to achieving profits in the short run. Federal funds have been essential to advanced battery development in the past and will likely continue to be essential in the future.

Demonstrations have contributed to practical improvements in available EVs

DOE's demonstration program activity has been perhaps the primary motivator behind the practical improvements made in EVs. Demonstration program sales have constituted the majority of sales for a number of EV manufacturers. The income from these sales provided the cash flow these manufacturers needed to expand production and finance product improvements that otherwise could probably not have been accomplished. Furthermore, the specification demands and performance requirements set forth by the demonstration program site operators provided market pressures on the EV manufacturers to make vehicle design improvements. Finally, the demonstration sales also stimulated component suppliers to introduce improved products.

Loan guarantees provided specific help to two EV manufacturers

In addition to the generalized sales stimulus provided by the demonstration activity, DOE loan guarantees have provided specific help to two EV manufacturers. In July 1980, DOE authorized a loan guarantee of $2.5 million to Electric Vehicle Associates, Inc. (Cleveland, Ohio), and in September 1980 it authorized a $3 million loan guarantee to Jet Industries, Inc. (Austin, Texas). Together, these two companies produced nearly 80 percent of the EVs delivered to site operators under DOE's demonstration program as of November 1981. Moreover, according to the EV industry survey conducted in July 1981 by the Electric Vehicle Council, these two companies possess about 40 percent of the EV

industry's total manufacturing capacity. Clearly, these two companies have been integral members of the existing EV industry. Representatives of both loan guarantee recipients and DOE officials managing the loan guarantee activity told us the Federal loan guarantees helped improve the financial situation for each company, at least in the short run.

FUNDAMENTAL PROGRAM OBJECTIVE NOT ACHIEVED

While some important accomplishments have been achieved, the Federal EV program has made negligible progress toward reaching its fundamental objective--expediting EV commercialization. To achieve this objective, the program sought to stimulate a growing EV market and build a self-sustaining EV industry. From each of these standpoints, the program has not been very successful. No discernible momentum toward widespread EV commercialization has been created. As was the case when the program was initiated, widespread commercialization remains dependent on the development of improved batteries and independent decisions by the major automakers to begin producing and marketing EVs.

EV market not well stimulated

DOE's EV program has not succeeded in stimulating a large and growing market for EVs. During the early years of its program, DOE established a sales level of 100,000 electric and hybrid vehicles a year by 1988 as a program goal. At this sales level, demonstration program officials believed a self-sustaining industry would be in place, and Government incentives would no longer be necessary. In building to that objective, DOE's strategy was to increase vehicle sales over time. For example, DOE's goal was 4,000 electric and hybrid vehicle sales in 1981, 13,000 in 1983, and 35,000 in 1985. Based on the experience to date, it is unlikely that these goals will be reached. Hybrid vehicles are not available and indications are that DOE's program has not persuaded significant numbers of potential EV buyers to move from a "wait and see" attitude to actual EV purchases.

Based on information obtained from the Electric Vehicle Council, total EV sales in 1981 were probably no more than 1,500, or less than half of DOE's 1981 sales goal of 4,000. Moreover, an important portion of these sales was heavily subsidized as part of DOE's demonstration program activity. As the demonstration activity comes to a conclusion and EVs have to begin competing in the marketplace without large Federal subsidies, increasing EV sales beyond existing levels--much less to DOE's future target levels--will be difficult.

In this context, there are signs that problems could lie ahead. According to the Electric Vehicle Council, EV orders on hand as of July 1981 were down 73 percent from July 1980 levels. Comments we received from DOE demonstration site operators in the

private and public sectors were no more encouraging. None of the site operators we spoke with had immediate plans for placing new EV orders without a DOE subsidy. In general, they said they were waiting to see more performance results from their existing EVs before making any commitments. Several also told us EV costs have to become more competitive with conventional vehicles before they will seriously consider purchasing many EVs with their own funds.

Even the electric utility industry, which could be considered a high-potential target for future EV sales, remains largely uncommitted. A survey of the largest 170 utility companies published by the Electric Power Research Institute in October 1981 showed these utilities were seriously considering purchasing only about 200 EVs over the next 2 years. 1/ The survey reported that utility involvement with EVs is not increasing much beyond purchases made with heavy DOE subsidies. The survey also reported that most of the electric utility experience with EVs has been unsatisfactory and that utilities were reluctant to make commitments to EV purchases until the technology was improved.

Healthy, self-sustaining industry capable of large-scale EV production not established

Another goal of DOE's program where little progress has been made concerned the establishment of a self-sustaining EV industry capable of large-scale EV production. No major automaker has been induced to make a financial commitment to produce EVs in large numbers. EV production remains the domain of a limited number of small, fragile companies. Several of these companies may be able to capture a small market niche and continue EV production in the future, but is is unlikely any of the existing manufacturers will be able to mass produce EVs in the future. Relatedly, several of the companies have been heavily dependent on subsidized sales from DOE's demonstration activity. As subsidized sales come to an end, these companies will face difficulty until they can establish a functioning open-market sales network.

Commercialization momentum not advancing

Despite the over $180 million dollars and years of effort invested by the Federal Government in EV developmental efforts, it cannot be said that a momentum leading to widespread EV commercialization has been established. There are few indications that EVs are substantially more attractive to large bodies of consumers than they were prior to the program. In addition to

1/Electric Power Research Institute, "The Demand for Electric Automobiles," October 1981.

the need for much improved battery technology, widespread EV commercialization remains dependent on factors largely outside the control of the Federal EV program, such as independent decisions by the major U.S. automakers or a long fuel supply interruption which would make the EV alternative more appealing. In this sense, little has changed from when the program began.

In discussing this issue, DOE program officials told us that the program has changed over time and that widespread commercialization was no longer being pursued as a program objective. They said the program as initially set forth in the Electric and Hybrid Vehicle Act--including demonstration of up to 10,000 vehicles--had never been fully implemented. Moreover, as a result of recent policy changes, commercialization activities such as a planned project to induce automakers to mass produce EVs by providing direct cost-sharing support of the automaker's developmental and commercialization activities had been dropped. They believed it was important to keep these program and policy changes in mind when assessing the program's performance.

PROBLEMS IN DOE'S PROGRAM CONTRIBUTED TO LIMITED PROGRAM SUCCESS

Achieving the objective of widespread EV commercialization in the short time frame envisioned by the Electric and Hybrid Vehicle Act would have been extremely difficult even if the Federal EV program set forth in the act had been fully and flawlessly implemented. Without a more advanced battery and the involvement of at least one of the major U.S. automakers in building and marketing EVs, the likelihood that any Federal program could have accomplished the task is slim. Nonetheless, each of DOE's three main program activities has had problems which have made program success less likely. The problems experienced in the demonstration, R&D, and financial incentives activities are discussed separately below.

Demonstration difficulties

DOE's demonstration program had eight general objectives, many of which have not been fully achieved. The demonstration was to

--identify and test markets in which electric and hybrid vehicles can perform as substitutes for conventional vehicles;

--develop the market for EVs;

--provide the basis for market expansion as vehicle performance improved;

--encourage production at levels allowing economies of scale and lower unit prices;

--develop and establish a post-sales support infrastructure;

--provide market feedback data to manufacturers, R&D groups, and other interested groups for focusing product improvement efforts;

--define and resolve "real world" problems in the marketplace; and

--introduce new technology through cost-sharing demonstrations with site operators.

As discussed previously, a growing EV market has not been developed, EV industry production levels are still below those necessary to lower prices, and an EV support infrastructure has not been established.

In the EV community, however, the most common criticism of the demonstration has been the failure to effectively disseminate demonstration results. Despite the fact that providing feedback data and resolving practical operating problems were two of the demonstration's objectives, numerous representatives of the Government R&D laboratories, EV manufacturers, automakers, and other EV organizations we spoke with complained that they had not obtained much data from the demonstration which would aid them in their respective activities. Two EV manufacturers were especially disappointed that the demonstration had failed to identify practical operating problems they needed to solve to facilitate sales outside the demonstration.

Perhaps nowhere has the dissemination problem been more acute than within the DOE program itself. Poor information interchange has for some time characterized the situation between the demonstration and R&D program activities. Cross-fertilization which could have aided both efforts has generally not occurred. Representatives outside DOE complained that obvious conflict between officials in the two program activities has been occurring for some time and that this conflict hampered cooperation and overall program effectiveness.

Demonstration program officials did not dispute the claim that little data from the demonstration had been disseminated. The officials told us the objective of their effort was never to aid the R&D community in its efforts to develop improved EVs. Instead, they said their objective was to help fledgling producers develop into a viable industry by providing the necessary vehicle sales. They believed, therefore, that disseminating limited and adverse data from the demonstration would not serve that objective.

Another commonly voiced criticism of the demonstration concerned the legislative mandate itself more than DOE's implementation. Representatives from some of the major U.S. automakers and

demonstration site operators, and a Government R&D laboratory believed the Federal demonstration was needlessly large. They told us demonstrating such large numbers of EVs with the limitations of existing technology was of little value in selling EVs as a concept to potential EV buyers. Some feared that limited performance and high costs associated with available EVs might lead to generalized disappointment with EVs and damage future marketability. Such a result may, in fact, have occurred in the electric utility industry where experience with EVs has made many utilities wary of additional EV purchases.

In discussing this issue, DOE program officials told us that when assessing the demonstration it was important to recognize that the demonstration size and schedule had, with congressional concurrence, been modified several times in recognition of the undeveloped state of EV technology.

R&D problems

The R&D program activity has also not been problem free. Our principal area of concern with DOE's R&D activity deals with DOE's efforts to develop prototype electric and hybrid vehicles. In this connection, DOE spent about $16 million to develop and produce two alternative EV prototypes and is currently spending an additional $9 million to build a hybrid vehicle prototype. Neither of the completed EV prototypes fully met DOE's costs and developmental goals. Moreover, there is room for questioning, at least in some respects, the practical value of the efforts. Neither EV prototype had any measurable impact on commercially available EVs and only one has made a contribution to developmental activities being conducted by the automakers. Since U.S. automakers for the most part see little future in hybrid vehicles, there are indications that the hybrid prototype may have less practical value.

The development of two alternative EV prototypes was the most visible aspect of DOE's EV R&D program. The major objective of these efforts was to develop the performance potential and economic viability of an advanced EV that could be put into production in the 1980s. Among 24 specific developmental goals, the vehicles were to have a minimum urban range of 75 miles, top speed of 60 miles per hour, acceleration from zero to 30 miles per hour in 9 seconds, and be producible for $5,000 in 1975 dollars.

While the vehicles' met the majority of their developmental goals, several important goals were not reached. For example, as discussed previously, limited range is a crucial technical barrier to EV commercialization. In Government testing, the first prototype design achieved a range of only 45 miles, or 30 miles less than the developmental goal. DOE program officials believe this result understated the vehicle's true capabilities because the conditions under which the testing was conducted were more stringent than would exist in normal driving. Nonetheless, they conceded that the vehicle fell short of its goal. In addition, the

vehicle could not meet its production cost goal of $5,000 in 1975 dollars. The second prototype design was deemed by DOE to have little near-term production potential and, accordingly, was moved from the near-term portion of DOE's program to the long-term advanced vehicle stage.

In addition, DOE's EV prototypes experienced significant cost overruns. Initially, the two prototypes were to cost $12 million. Final costs for the two designs were $16 million, or a 33 percent cost increase.

In some respects, the practical value of the prototype development efforts can be questioned as well. Neither completed EV prototype had much value to the existing industry. The current EV manufacturers with whom we spoke believed the prototypes' design improvements were either superficial, unaffordable, or not commercially available. From the standpoint of the major automakers, the prototypes were partially beneficial. Representatives from Ford and GM, the only U.S. automakers with ongoing EV activities, told us that one design contributed at least in general terms to their EV developmental efforts but that the other had yielded little of value.

A similar effort to develop a hybrid vehicle prototype is in progress. As discussed in chapter 1, hybrid vehicles are much farther behind EVs in terms of technological development and commercial readiness. In addition, the major U.S. automakers generally believe hybrid vehicles have low commercialization potential because they are likely to be more complex and expensive than either conventional vehicles or EVs. Consequently, it is likely that DOE efforts to develop a hybrid vehicle prototype will have less practical value than the EV prototypes.

In discussing the prototype development efforts, DOE R&D program managers expressed the view that the efforts achieved their main objective--demonstrating to the auto industry that EVs were advanced beyond the curiosity stage and that a viable EV could be produced with available technology. They further stated that the EV prototype development efforts should not be assessed separately. In this connection, they believed that since one design was viewed as beneficial by the auto industry, it was not necessary for the other design to achieve an appreciable impact. Finally, concerning the hybrid prototype, the officials recognized the U.S. auto industry's negative assessment of the technology but hoped the prototype would persuade the industry that hybrid vehicles are more practical than they currently believe. The officials also pointed out that while U.S. automakers are generally negative to the hybrid concept, several foreign automakers have expressed considerable interest in DOE's work.

Another criticism voiced concerning the R&D program is that there has been minimum technology transfer to the existing industry. The existing small manufacturers we spoke with generally contended that the R&D program did not yield practical advances

that they could incorporate into their vehicles at reasonable cost. Consequently, they said few R&D improvements found their way into the marketplace. In discussions on this issue, DOE program officials told us that the program was never aimed at assisting the existing manufacturers and, therefore, comments from these manufacturers about the program were not germane. They said the advances made in the R&D laboratories would likely not be available to, or affordable by, small-scale manufacturers and that they had accordingly concentrated program attention on the major automakers and component suppliers.

Problems with financial incentives

The financial incentives program activity is composed of two main activities--loan guarantees and planning grants. Neither has been very effective. To date, DOE has issued loan guarantees to two EV manufacturers; $3 million to Jet Industries, Inc., and $2.5 million to Electric Vehicle Associates, Inc. According to the terms of the loan guarantees, DOE authorized the lending institutions involved to disburse loan funds in accordance with established disbursement schedules. As part of these schedules, the manufacturers are required to meet certain sales and production milestones. With the exception of one milestone, neither loan guarantee recipient has met its milestones. Moreover, neither recipient has substantially closed the gap between milestones and actual performance during the course of the loan to date. In the case of Jet Industries, the gap has widened. The performance of the loan guarantee recipients in comparison with established milestones is set forth in the following table.

Recipient and milestone number	Vehicle Sales		Vehicle Production	
	Milestone	Actual	Milestone	Actual
	(in vehicle units)			
Electric Vehicle Associates				
1	40	7	45	14
2	45	38	45	38
3	80	14	90	14
4	33	33	55	33
5	70	48	55	33
Total	268	140	290	132
Jet Industries				
1	212	127	212	169
2	223	129	223	134
3	261	62	261	91
4	264	87	264	153
5	350	22	350	30
Total	1,310	427	1,310	577

Although the loan guarantees certainly provided a short-term boost to both recipients' finances, we believe there is reason to question whether the guarantees will substantially enhance the recipients' long-term future. DOE officials told us that they do not believe either loan will default. Both recipients were heavily dependent on the demonstration program activity for vehicle sales. Without these sales in the future, generating sufficient EV sales to repay the loans could be difficult. In the meantime, the recipients are making substantial interest payments. Electric Vehicle Associates, for example, paid interest rates on its loan as high as 22 percent in fiscal year 1981. In total, it paid about $400,000 in interest during the year, or about $3,000 for each car sold. Jet Industries paid over $200,000 interest on its loan during the same period. Finally, the value of the loan guarantee to enhance the long-term security of the two recipients is not clear because of the manner in which the loan funds were used. The funds were used primarily for short-term purposes such as paying off old debts and purchasing inventory, and not for capital equipment. DOE currently is evaluating two additional loan guarantee applications.

The other effort conducted as part of the financial incentives program activity is planning grants. Planning grants were authorized in the Electric and Hybrid Vehicle Act as a means of providing funds to small businesses to assist in obtaining Government contracts. Before discontinuing its efforts to award planning grants, DOE issued 27 grants totalling about $200,000.

None of the grantees received follow-on contracts because DOE deemed the proposals submitted to be unworthy of future funding. The planning grant process therefore had little value as a means of aiding small businesses in the R&D area. DOE currently has no plans for issuing additional planning grants.

CHAPTER 5

CONCLUSIONS AND MATTER FOR CONSIDERATION OF THE CONGRESS

CONCLUSIONS

While EV technology has undoubtedly improved over the past few years, EVs are still far from being widely commercialized. EVs have such limited range and high costs that they are not close to being competitive with comparable conventional vehicles. As was the case when we issued our EV report 3 years ago, successful EV commercialization remains dependent on the development of improved batteries and the active efforts of at least one major automaker.

The major automakers are willing and have the capability to mass produce EVs, but will not be ready to do so until EV technology is improved enough to enable them to produce EVs that meet performance and cost conditions they believe are demanded by the market. These conditions have not been met and until they are, Federal incentives and Federal EV program activities will have little impact on the automakers' decisions to produce and market EVs.

While the Federal EV program has had some important accomplishments such as increasing consumer awareness of EVs, it has made only marginal progress toward achieving the program's primary objective of expedited EV commercialization. No sustaining momentum which can be seen as leading ultimately to widespread EV commercialization has been created. Given the state of battery development and the embryonic nature of the EV industry, it is hardly likely that any Federal program could have achieved widespread EV commercialization in the short time frame envisioned by the Electric and Hybrid Vehicle Act.

Nonetheless, there have been problems in DOE's three main program activities--demonstrations, R&D, and financial incentives--which made program success less likely. Such problems include (1) inadequate dissemination of demonstration results, (2) cost increases and performance shortfalls in the EV prototype development efforts, and (3) the unclear contribution of DOE's two loan guarantees to enhancing the recipient's long-term future.

The administration has begun phasing out the Federal EV program in accordance with its commercialization philosophy. The administration's philosophy holds that (1) principal reliance for commercializing energy technologies should be placed on the private sector and (2) Government programs should concentrate on long-term, high-risk R&D, with high potential payoff. Because EV technology is for the most part near-term in nature, the administration reduced fiscal year 1982 program funding to less than

$19 million compared to the nearly $33 million appropriated in fiscal year 1981. These funds are being devoted primarily to R&D. The administration has proposed that the program be discontinued altogether in fiscal year 1983.

We believe the administration's budget proposals are appropriate for the most part. EVs have been shown to be technically feasible and to have a market, albeit a small market in a limited number of applications. To expand that market to a level where appreciable quantities of oil can be saved will require the active participation of the major auto companies and the development of a much improved battery. It is clear that a continued Federal program will have little influence on automaker decisionmaking regarding EVs unless the automakers are convinced that EVs are capable of capturing a large market. To this end, therefore, it is difficult to argue against curtailment of the demonstration and financial incentives activities and certain reductions in the R&D activity. One area where it makes sense to continue funding concerns R&D related to advanced batteries. The reductions made and proposed for each of the three main elements in DOE's program are assessed below.

Concerning the demonstration program activity, funding to initiate new demonstration sites was eliminated in the fiscal year 1982 budget. Through DOE's demonstration, site operators have contracted for over 1,000 EVs and with funds available from prior year appropriations DOE is supporting the establishment of a network of 50 car dealers to sell another 1,250 EVs. Until EVs with more advanced batteries become available, providing additional funds for demonstrating EVs with current performance limitations would seem to contribute little to promote widespread EV commercialization. Accordingly, we find little basis to argue against the elimination of the demonstration program activity.

The fiscal year 1982 budget also contained no additional funds for loan guarantees. With prior year budgets, a loan guarantee fund with a ceiling of $16 million was established. To date, loan guarantees of $5.5 million have been issued leaving about $10.5 million available for additional guarantees. Awarding additional loan guarantees could undoubtedly help the financial condition of an additional few EV manufacturers, at least in the short run. However, it is unlikely that any manufacturer needing a loan guarantee that is limited to $3 million will play a major role in widespread EV commercialization. In awarding additional loan guarantees, the Government therefore would be assuming risk with little hope that the loan guarantees would contribute significantly to expediting widespread EV commercialization. Accordingly, there seems to be little justification for authorizing more loan guarantees.

Finally, concerning the R&D program activity, funds were reduced somewhat in fiscal year 1982 and have been reduced further in fiscal year 1983. We agree that some cuts in the EV R&D

budget are justified. For example, funding devoted to hybrid vehicle prototype development could most likely be discontinued without serious long-term consequences for EV commercialization. Hybrid vehicles are in general viewed by the U.S. auto industry as having low commercialization potential. Hybrids will almost certainly be more complex and more expensive than either conventional vehicles or EVs because they combine two power systems in one vehicle. Additional funding for building and testing a hybrid vehicle prototype with such questionable value seems unwarranted.

While many elements of DOE's program can be discontinued, work on advanced batteries such as aluminum-air, lithium-metal-sulfide, and sodium-sulfide may be essential if EVs are to ever become a widely commercialized transportation option. For both fiscal years 1981 and 1982, DOE provided over $10 million for specific advanced battery R&D, however, for fiscal year 1983 DOE is proposing to close out these efforts and discontinue future funding.

Our work clearly indicates the desirability to maintain funding for advanced battery R&D. These batteries have the potential for providing EVs with vastly improved performance capabilities and thereby remove one of the major barriers to widespread EV commercialization by the major automakers. It is unlikely that battery companies will perform extensive advanced battery R&D without Federal funding. To date, Federal funding has been essential to advanced battery development.

MATTER FOR CONSIDERATION OF THE CONGRESS

Based on information in this report, the Congress should consider the desirability of funding for advanced battery R&D in DOE's fiscal year 1983 budget. If EVs are ever to become the widely commercialized transportation option envisioned by the act, an advanced battery is needed. Without continued Federal funding of advanced batteries, however, it is unlikely that the necessary development efforts will be conducted because the private sector will almost certainly not pick up funding for these batteries. The Federal Government's failure to continue to support advanced battery developmental efforts could therefore jeopardize the future of EVs and risk forfeiting the $180 million Federal investment in EVs that has already been made.

ORGANIZATIONS CONTACTED DURING REVIEW

Major U.S. Automakers

General Motors Corporation
Ford Motor Company
Chrysler Corporation
American Motors Corporation

Electric Vehicle Manufacturers

Jet Industries, Inc.
Electric Vehicle Associates, Inc.
Commuter Vehicles, Inc.
Lectra Motors, Inc.
South Coast Technology, Inc.
Marathon Vehicles, Inc.
H-M Vehicles, Inc.

Battery Manufacturers

Gould, Inc.
Johnson Controls, Inc.
Gulf and Western Industries, Inc.

Electric Vehicle Fleet Operators Participating in DOE's Demonstration

American Telephone and Telegraph Corporation
General Telephone and Electronics
Northrup Corp.
Detroit Edison
City of Austin, Texas
City of San Jose, California
DOE-Nevada Operations Office
Lawrence Livermore Laboratory
National Park Service - Department of the Interior
University of Maryland

Federal Agencies and R&D Laboratories Involved with EV Development

DOE
Tennessee Valley Authority
NHTSA
U.S. Postal Service
National Park Service - Department of the Interior
Argonne National Laboratory
Lawrence Livermore Laboratory
National Aeronautics and Space Administration's Lewis Research Center and Jet Propulsion Laboratory

Other Organizations

Booz Allen and Hamilton, Inc.
Electric Power Research Institute
Electric Vehicle Council
Ameritrust Company
Federal Financing Bank

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