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The First Annual Report to Congress on the
Implementation of

PUBLIC LAW 94-413

THE ELECTRIC & HYBRID VEHICLE RESEARCH, DEVELOPMENT & DEMONSTRATION ACT OF 1976

U.S. Department of Energy

Assistant Secretary for Conservation & Solar Applications
Division of Transportation Energy Conservation

December 1977

**electric
& hybrid
vehicle
program**

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PREFACE

This is the first annual report on the progress of implementing the Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976 (Public Law 94-413). It is intended to fulfill the reporting requirements of Section 14, and in part, is based on work currently in progress and continuing toward completion. Much of the information presented may therefore be subject to updating and refinement. A general discussion of accomplishments, project status and plans is provided in the Executive Summary, while technical details are contained in the main body of the report.

The material which follows is presented to apprise Congress of:

- Results of the first year's work in implementing

all of P.L. 94-413's requirements.

- DOE's approach to the management, administration and coordination of projects for improving a young electric and hybrid vehicle technology, and assisting an immature industry toward competitive status.
- Notable but perhaps tentative results of studies, evaluations and assessments.

This report is also intended to serve as a communication link between the Electric and Hybrid Vehicle Project and all of the interests involved in making the Project a success.

Specific requirements of P.L. 94-413 which are addressed in this report include:

1. General description of actions taken and progress achieved. . . . All Chapters and the Executive Summary
2. Section 4, Duties of the Administrator. All Chapters
3. Section 6, Research and Development Chapters 2, 3 and 4
4. Section 7, Demonstrations Chapter 6
5. Section 9, Encouragement and Protection of Small Business Chapter 5
6. Section 10, Loan Guarantees Chapter 5
7. Section 11, Use of EHV's by Federal Agencies Chapter 7
8. Section 13, Studies Chapter 4
9. Section 14, Annual Report:
 - Projections and Estimates of Progress Chapter 8
 - Foreign Components Chapter 6
 - Recommendations Chapter 9 and Executive Summary

Acknowledgements for major contributions to this report are extended to the many industry contractors performing various research, development, evaluation and study efforts; the DOE Division of Energy Storage Systems; NASA Lewis Research Center; NASA Jet Propulsion Laboratory; Lawrence Livermore Laborato-

ry; Lawrence Berkeley Laboratory; The Department of Transportation; Purdue University's Institute for Interdisciplinary Engineering Studies; and Mueller Associates, Inc., for assisting the DOE Office of Electric and Hybrid Vehicle Systems in the preparation of this report.

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EXECUTIVE SUMMARY

Introduction

On September 17, 1976, the U.S. Congress stated its strong desire to reduce our nation's dependence on foreign petroleum by the introduction of electric and hybrid vehicles, and expressed this by enacting Public Law 94-413, the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976. The Act further echoes Congress' intent to foster the EHV* development and implementation processes through Government involvement.

Public Law 94-413 provided for research designed to advance EHV technology, and established a rigorous schedule for in-use demonstrations. It also authorized ERDA to provide loan guarantee and planning grant incentives to encourage small business participation.

Highlights

Several key events bearing significantly on the program status have occurred since the Act's passage:

- October 1976 - - - An initial operating budget of \$5 million was provided to implement the Act's requirements.
- March 1977 - - - - A public meeting was held in Washington, D.C. to announce ERDA's plans for implementing the requirements of the Act.
- June 1977 - - - - ERDA was granted the authority to reprogram an additional \$16.7 million for the Project.
- July 1977 - - - - Congress restricted the Project's FY 1978 appropriation to \$30 million and held oversight hearings to review the status of the Project.

During this first year, ERDA has taken necessary actions to implement the requirements of Public Law 94-413 and to accomplish its objectives. These are summarized in Table 1.

Current Status

The responsibility for implementing Public Law 94-413 was assigned by ERDA's Administrator to the Office of Electric and Hybrid Vehicle Systems in the Division of Transportation Energy Conservation, with the Division Director as Project Manager. Three Branches within this Office handle individual programs by functional arrangement:

1. Demonstrations and incentives;
2. Vehicle systems R&D and state-of-the-art assessments, and;
3. Technology development, special studies and performance standards.

These three branches direct various supporting activities provided by DOE laboratories, private contractors, and other Government agencies. Within this last category, major R&D support is being provided by NASA's Lewis Research Center (propulsion systems), the Jet Propulsion Laboratory (vehicle system development) and the Department of Transportation (specific mandated studies). Battery and other energy storage technology development is handled by the DOE Division of Energy Storage Systems.

Coordination and consultation is undertaken on a continuing basis with all involved Federal agencies, the industry sector, scientific organizations, and other interested groups. This function will intensify as the Electric and Hybrid Vehicle R, D&D project becomes more formalized and program plans mature.

Work is currently underway to finalize a plan which will define a general framework for conducting the Project, establish objectives consistent with Public Law 94-413's longer-range goals, outline implementation strategies, and present management controls. This plan will be a positive asset in more formally structuring the individual programs and in adding stability to the implementation process.

Problems Encountered

During the course of this first year's activities, several problems have been encountered and potential risks to success identified. Essentially all immediate requirements of the Act were fulfilled, but R&D program activities were somewhat delayed due to the late receipt of operating funds, and the lack of a specific appropriation for the loan guaranty program is delaying its implementation.

*A list of acronyms follows Chapter 9.

The availability of only limited capability vehicles for early demonstrations is a problem which has been judged a potential risk to the success of the demonstration program since consumer acceptance of these vehicles is difficult to predict. Specific incentives in the Act may actually impede ultimate commercialization. For example, the loan guaranty level may be too low to significantly assist small businesses, and the total demonstration vehicle quantities may not create a sufficient market to attract responsible manufacturers. A similar situation pervaded and led to the unsuccessful outcome of the Federal Clean Car Incentive Program/Low Emission Vehicle Program (sponsored by the EPA in 1970).^{*} Additionally, the Project may impede acceptance of electric and hybrid vehicles by creating the impression with prospective users, manufacturers and policy makers (through potential reliability problems, inadequate service facilities, or use of inappropriate market segments) that a potentially viable concept is unsound.

Plans for the Coming Year

DOE has initiated all required actions under P.L. 94-413 and kept pace with the early requirements for state-of-the-art testing, special study reports and vehicle standards development. The funding appropriated by Congress will provide for the acquisition of no more than 200 demonstration vehicles in FY 1978 unless sacrifices are made in carrying out the vehicle and battery research. DOE believes that this research will be critical to the "advanced" vehicle demonstrations.

During FY 1978, DOE expects to actively continue support of all implementation actions required by P.L. 94-413. Notable expectations are summarized in Table II.

DOE is also seeking appropriate methods of implementing several of the more prominent opportunities for improving the demonstration program's success by:

- Designing the demonstration to focus on the development of market data to provide a more reliable basis for commercial investment decisions.
- Concentrating first efforts on commercial and special-purpose vehicle fleet markets since these markets have the potential for significant petroleum savings and environ-

mental pollution relief, and are better matched to the use of near-term EHV technology than the general passenger car market.

- Sheltering demonstration users and service facility investments so that early reliability and other development problems will not mask the potential benefits of electric and hybrid vehicles.

Recommendations

Based on the experience gained during this past year and the results of the Opportunity/Risk Assessment, DOE has proposed a number of changes to Public Law 94-413. These changes are designed to enhance the capability for satisfying both the letter and intent of the Law, and are pursuant to the requirements of Section 14. Accordingly, DOE recommends that Public Law 94-413 be amended as follows.*

- Revise the Act's restrictive demonstration vehicle acquisition requirements to allow flexibility in the timing and quantities of vehicle procurement. The demonstrations should be paced by the identification of market opportunities and advancements in vehicle technology.
- Expand the existing provisions for loan guarantee interest assistance to include assistance on the principal.
- Establish in the Treasury Department a specified electric and hybrid vehicle development fund free of fiscal year limitations. This would assure and instill confidence in potential lenders regarding the support of the Government-sponsored Project.
- Empower the DOE Secretary to borrow money as required to meet Government obligations in the event of a default on loan guarantees. This would provide an increased measure of confidence from lending institutions, and strengthen the "full faith and credit" posture of the guaranty program.

Prognosis

Public Law 94-413 brought new resources, focus and emphasis to DOE's predecessor program for ad-

*Many of these recommendations have been incorporated into Title VII of the ERDA Authorization Act.

TABLE I. HIGHLIGHTS OF ACCOMPLISHMENTS

Act Section	Requirements	Accomplishments
SECTION 4 Duties of the Administrator	<ul style="list-style-type: none"> Establish EHV Project. Enter into agreements with other Agencies. 	<ul style="list-style-type: none"> EHV Project Office was established within ERDA-TEC in January, 1977. Agreements have been formalized with DOT, DOD and NASA.
SECTION 5 Coordination with Other Agencies	<ul style="list-style-type: none"> Coordinate and consult with other Agencies. 	<ul style="list-style-type: none"> Coordination has been effected with all involved Agencies, particularly with regard to activities under Sections 5, 6, 7, 9, 11 and 13.
SECTION 6 Research and Development	Conduct R&D in: <ul style="list-style-type: none"> Energy storage. Vehicle control systems including regenerative braking. Urban design and traffic management. Vehicle design. 	<ul style="list-style-type: none"> In addition to private sector and ERDA laboratory assistance, major R&D support is provided by the NASA Lewis Research Center, the Jet Propulsion Laboratory, and DOT. Through competitive procurements, two advanced technology electric vehicle concepts are proceeding toward design and fabrication.
SECTION 7 Demonstrations	<ul style="list-style-type: none"> Characterize state-of-the-art. Promulgate performance standards. Acquire vehicles and conduct demonstrations. 	<ul style="list-style-type: none"> State-of-the-art testing of vehicle range, acceleration, maximum speed, and other important measurements of performance has been conducted. Performance standards will be published for comment in December. Competitive selection of the demonstration planning contractor has been completed and detailed planning of demonstrations is underway.
SECTION 8 Contracts	<ul style="list-style-type: none"> Contract to carry out purposes of the Act. Consult with other Agencies and non-government organizations. 	<ul style="list-style-type: none"> Contracts and agreements have been effected with all organizations who are supporting the Project. Coordination and consultation is undertaken on a continuing basis with all involved Federal agencies, the industry sector, scientific organizations, and other interested groups. Work is currently underway to finalize a plan which will define a general framework for conducting the Project, establish objectives consistent with P.L. 94-413's longer-range goals, outline implementation strategies, and present management controls.
SECTION 9 Encouragement and Protection of Small Businesses	<ul style="list-style-type: none"> Provide opportunities for small businesses. Make planning grants available. 	<ul style="list-style-type: none"> Procurement was initiated to assist existing small business electric vehicle manufacturers in upgrading their products. Procedures for implementing the Planning Grant Program are being prepared.
SECTION 10 Loan Guarantees	<ul style="list-style-type: none"> Guarantee loans for R&D, equipment, and production expenses. 	<ul style="list-style-type: none"> Loan guarantee regulations have been developed and the administrative procedures for accepting loan applications have been established. Implementation is dependent upon a specific appropriation.
SECTION 11 Use of EHV's by Federal Agencies	<ul style="list-style-type: none"> Have Government agencies study EHV for their applications 	<ul style="list-style-type: none"> Other Federal agencies have been contracted to discuss their use of electric and hybrid vehicles. Specific plans for introducing EHV's in their fleets are being considered by USDA, DOD and GSA.
SECTION 13 Studies	Perform studies of: <ul style="list-style-type: none"> Institutional constraints. Materials and pollution effects. Promotional incentives. Safety standards. Regenerative braking. 	<ul style="list-style-type: none"> EHV Project staff has completed these six major studies. These are being forwarded to the Congress under separate cover.
SECTION 14 Annual Report	<ul style="list-style-type: none"> Report progress. Desireability of foreign components. Recommendations. 	<ul style="list-style-type: none"> Annual Report to Congress is completed. Assessment of foreign component desireability is contained in the Annual Report. A comprehensive Opportunity/Risk Assessment specifically designed to identify risks which may jeopardize achievement of Project goals, highlight opportunities that will improve the Project and increase its success potential, has been completed. Recommendations from this assessment have been reported.

vancing the technology of electric vehicle systems. In the twelve months since the passage of P.L. 94-413, DOE has been planning a balanced program of research, development, and demonstrations to meet the requirements and goals of the Act.

As a result of these activities, DOE has gained a much greater appreciation of the potential that electric and hybrid vehicles offer as an option for reducing petroleum consumption in the highway

transportation sector. Thus, DOE is convinced that the Act's overall objectives of stimulating the development of electric and hybrid vehicles and their introduction into the transportation system are both appropriate and achievable. DOE is just as convinced that the successful implementation of these objectives must be approached with careful planning and thoughtful consideration of the markets to be served.

**TABLE II,
Notable Actions For FY 1978**

Act Section	Expected Accomplishments
SECTION 6	<ul style="list-style-type: none"> • Test and evaluation of state-of-the-art propulsion system components will be completed.
Research and Development	<ul style="list-style-type: none"> • Conceptual study of improved electric and hybrid vehicle propulsion system components will be completed. • Fabrication and laboratory testing of power systems and vehicle structures for near-term passenger, integrated test vehicles (electric) will be completed. • Hybrid vehicle preliminary design and trade-off analyses will be initiated. • Development of advanced lead-acid batteries will be initiated. • In-vehicle prototypes of nickel-zinc and nickel-iron batteries will be built.
SECTION 7	<ul style="list-style-type: none"> • Contracts will be awarded for demonstration site operators.
Demonstrations	<ul style="list-style-type: none"> • Planning for the first demonstration will be completed. • Vehicles for the first demonstration will be acquired. • The first state-of-the-art report covering testing of domestic and foreign vehicles and comprehensive technology assessment will be disseminated. • Performance standards will be promulgated for the first demonstration vehicle acquisition.
SECTION 8	<ul style="list-style-type: none"> • Coordination and consultation with Federal agencies, contractors and other organizations will intensify as the project becomes more formalized and program plans mature.
Contracts	<ul style="list-style-type: none"> • A formal Project plan will be completed. This plan will be a positive asset in more formally structuring the individual programs and in adding stability to the implementation process.
SECTION 9	<ul style="list-style-type: none"> • Up to 10 improved state-of-the-art electric/hybrid vehicles will be delivered and testing initiated.
Encouragement and Protection of Small Business	
SECTION 11	<ul style="list-style-type: none"> • A joint study effort concerning EHV agricultural and rural applications with the Department of Agriculture will be initiated.
Use of EHV's by Federal Agencies	
SECTION 13	<ul style="list-style-type: none"> • All studies will be updated and expanded to incorporate the latest developments and to more comprehensively address study topics.
Studies	
SECTION 14	<ul style="list-style-type: none"> • Recommendations resulting from the Opportunity/Risk assessment are expected to be incorporated into operating strategies.
Annual Report	

CHAPTER 1 INTRODUCTION

Public Law 94-413 brought new resources, focus and emphasis to DOE's predecessor program for advancing the technology of electric vehicle systems. Through the Law's enactment, Congress expressed its interest and desire to:

- Foster and support research and development in electric and hybrid vehicle systems and their component technology through R&D programs and the demonstration of advanced vehicles.
- Accelerate the commercialization of electric and hybrid vehicles by demonstrating their economic and technical practicality, by providing an incentive program, and by using them in Federal agencies.
- Encourage small businesses to participate in electric and hybrid vehicle research, development, and demonstration projects.
- Identify potential market segments, foster innovative marketing approaches, study the long-term demand, and promote consumer acceptance of electric and hybrid vehicles.
- Identify and help remove institutional, legal and economic barriers to electric and hybrid vehicle acceptance.
- Ascertain those long-term changes in the energy and transportation systems required to facilitate electric and hybrid vehicle use.

The Act required DOE to establish the Electric and Hybrid Vehicle R,D&D Project (EHVP) as an organizational entity, and in addition to the vehicle R&D requirement, specified that a two-part demonstration be conducted. It also specified that certain studies be performed and established provisions for financial incentives.

Prior to Public Law 94-413, the intent of DOE's EHV research and development was to make available advanced technology in the decade between 1985 and 1995. The Act will assist in making this advanced technology available at an earlier date, but the primary impact will be to provide needed support to enhance the development of both the vehicle manufacturing and service industries. The overall effect of the Act will be a shortening of the timescale that would normally be required to introduce a new technology, and an earlier penetration of the markets that electric and hybrid vehicles can serve.

To implement the Act's requirements, DOE established the EHVP within its Division of Transportation Energy Conservation. Three Branches and another DOE Division (Energy Storage Systems) carry out individual activities according to the program functions described in Figure 1-1. Details of the Project's administration and organization are more fully discussed in Chapter 7; progress achieved in each of these activities is presented in the remaining chapters.

FIGURE 1-1

Management and Organization Structure

CHAPTER 2 VEHICLE TECHNOLOGY

Vehicle technology activities are structured under three major program areas:

1. *Electric and Hybrid Vehicle Systems R&D:* Development of integrated test vehicles and systems analysis.
2. *Advanced Technology:* Propulsion subsystems R&D, energy storage/propulsion subsystem interfacing, vehicle supporting technology, and advanced concepts.
3. *Test and Evaluation:* State-of-the-art assessments, safety tests, product improvement evaluations (through purchase of existing vehicles), and related supporting activities.

The elements of these program areas satisfy the requirements of P.L. 94-413 which direct the ERDA Administrator to initiate and provide for the conduct of research and development in areas related to electric and hybrid vehicles, including (a) "vehicle control systems and overall design for energy conservation, including the use of regenerative braking" and (b) "vehicle design which emphasizes durability, length

of practical lifetime, ease of repair, and interchangeability and replaceability of parts."

In initiating these activities, it was recognized that many improvements will be necessary to ensure consumer acceptance of electric and hybrid vehicles. Commercial feasibility can be enhanced with improvements in cost (both in purchase and maintenance), vehicle performance, range between battery recharges, energy efficiency, reliability, and safety. Tradeoff considerations for these improvements are represented in Figure 2-1.

It was also recognized that many of these areas for improvement can be reduced or eliminated by significantly upgrading electric and hybrid technology. The greatest potential improvements in electric vehicle technology can be made in batteries. Also, major improvements can be made in traction motors, motor controls, regenerative braking, battery chargers, power delivery transmissions, vehicle weight, and overall vehicle optimization.

Before discussing the specifics of Vehicle Technology activities, it is appropriate to highlight the mechanism by which the results of this project are passed on to industry. A major objective of the Electric and Hybrid Vehicle Project and P.L. 94-413 is to transfer the knowledge of technological improvements to private industry. Such knowledge encompasses design, manufacturing, economic, operating, environmental, and other data required to aid in the development, growth and improved market penetration of the EHV industry.

The target audiences for the transfer of this information include potential industrial manufacturers; suppliers of vehicles, vehicle components, and vehicle operating support equipment and facilities; electric utility industries; potential large-scale users; and energy and environmental organizations.

DOE has devised the following methods to facilitate the transfer of technological information to the private sector:

- Invitations to potential manufacturers for technical consultations, technical conferences and seminars, and actual participation in the development and testing of vehicles;
- Dissemination of reports on projects,

Figure 2-1
Examples of Trade-off Considerations

progress, testing, demonstrations, etc. to potential manufacturers;

- Presentations, exhibits, films, etc. to technical and trade associations, potential manufacturers, etc;
- Advertisement and publication of technological progress in trade journals and other periodicals;
- Prompt professional response to all inquiries and indications of interest.

One of the most effective means of transferring technological information to the private sector and of achieving an interaction between the private sector and government agencies involved in EHV-related activities is a strong and capable EHV industry association, much like the current Motor Vehicle Manufacturers Association (MVMA). DOE will encourage the formation of such an organization.

Technology transfer is an ongoing activity and as the total EHV RD&D Project moves forward, potential manufacturers and users will be more precisely defined.

I. Vehicle Systems Research and Development

A structured approach is needed in order to achieve the Act's requirements for vehicle systems R&D. Such an approach includes a thorough analysis of vehicle subsystems and component compatibility to support total vehicle development, and serves as the focal point for establishing early mission requirements. Figure 2-2 conceptually describes this systems analysis approach to achieving vehicle R&D goals.

FIGURE 2-2
The Systems Analysis Process to Achieve Vehicle Systems R&D Goals

Systems R&D activities are generally divided according to vehicle application (either electric or hybrid); project management responsibility for these activities has been assigned to NASA's Jet Propulsion Laboratory (JPL) through an interagency agreement. The remainder of this chapter's section is devoted to a description of progress achieved in each of these application areas.

Electric Vehicles

In FY 1976 under the Non-Nuclear Energy R&D Act, ERDA initiated a near-term Electric Vehicle Program which has now been expanded to include total vehicle systems analysis and development. This program is aimed at:

- Advancing electric vehicle technology.
- Demonstrating that EV's can be practical, energy efficient, safe, and affordable.
- Developing validated vehicle designs that can be viable candidates for the later demonstrations.
- Providing analytical and test methodologies/tools to assist the development of electric vehicle technology.

In addition to addressing the advancement of electric power systems technology, the program addresses all of the requirements that must be considered if the viability of the EV concept is to be established. These requirements include functional utility, energy efficiency, consumer acceptance, cost, and safety.

Specific vehicle designs are being developed and will be tested in order to confirm that the necessary performance levels and characteristics are mutually compatible, and that the vehicle designs are technologically and economically achievable. Of special significance is the fact that, even though the near-term nature of these activities dictates the use of lead-acid batteries, the advancements expected to be incorporated into these vehicles could lead to widespread acceptance of electric urban cars in a few years, instead of the decade or more when more powerful, high temperature batteries are expected to be available.

To date, preliminary trade-off analyses and preliminary designs have been completed by three firms. Detailed design development and integrated

test vehicle fabrication have been initiated by General Electric Co. and the Garrett Corporation. In keeping with the policy of P.L. 94-413 to accelerate the development of electric and hybrid vehicle technologies, these vehicles will be completed and ready for testing by May 1979. This schedule will result in the availability of these designs and technology developments for possible consideration within the second phase of the demonstration required by P.L. 94-413. Design drawings and the technology which they describe will be public information and, as such, will be available to any business interested in using them to build demonstration vehicles.

Performance objectives for these vehicles are listed in Table 2-1.

TABLE 2-1
Near-Term Electric
Vehicle Objectives

Min. Passenger Capacity	4 Adults
Max. Curb Weight	Open
Min. Urban Range-Kilometers (miles)	121 (75)
Max. Initial Cost (1975 dollars)	5,000
Min. Life-Kilometers (miles)	161,000 (100,000)
Max. Life Cycle Cost-1975 \$/km (\$/mile)	0.09 (0.15)
Max. Electric Recharge Energy in Urban Driving-KWh/km (KWh/mile)	0.32 (0.5)
Max. Recharge Time-Hours	6
Safety Features	Meet Federal Motor Vehicle Safety Standards
Min. Unserved Park Duration-Days	7
Min. Ambient Temperature Range-°C (°F)	-29 to + 52 (-20 to +125)
Min. Top Speed-km/hr (mi./hr.)	97 (60)
Min. Acceleration-Seconds for 0-48 km/hr (0-30 mph)	9
Min. Merging Time-Seconds for 40-89 km/hr (25-55 mph)	18

Major merits of the GE and Garrett design approaches are as follows:

For the GE approach:

- Transistor control of separately excited motor with field control
- Regenerative braking
- Integrated power conditioning unit and charger
- Microprocessor
- Integrated circuits and power modules
- Body with low drag coefficient

For the Garrett approach:

- New drivetrain approach for EV's
- Composite flywheel

Figure 2—3

Figure 2-4

- Regenerative braking
- Composite vehicle body and structural members

Final detailed designs of the GE and Garrett vehicles have not been completed; however, based on the work that has been completed to date, the appearance of these vehicles is expected to approximate the representations shown in Figures 2-3 and 2-4.

When received by the Government, the vehicles will be tested and evaluated, then used in projects to take advantage of any upgraded or improved components that may have become available by that time. Subsequent testing will include durability and reliability tests.

The results of this near-term Electric Vehicle Program should enhance the image (and then the commercial prospects) of the electric vehicle and provide an effective rebuttal to negative criticisms of the EV stimulated by unsuccessful EV designs.

Similar activities are planned for an Advanced EV Program which will result in the delivery of several integrated test vehicles at the end of FY 1983.

Hybrid Vehicles

The development of hybrid vehicles has lagged behind that of EV's. With the exception of a few experimental vehicles, no hybrid vehicles are in general use today, and none have been offered for commercial sale in this country. Consequently, the Hybrid Vehicle System R&D task area is only beginning, with the definition of near-term vehicle performance specifications and development of preliminary designs scheduled for completion by the fourth quarter of FY 1979. Near-term vehicles based on these designs are scheduled for delivery by the first quarter of FY 1982, and several advanced vehicles for about four years later.

II. Advanced Technology

Propulsion Systems Research and Development*

Through an interagency agreement, DOE has

* Report of NASA Lewis Research Center EHV Activities (Letter Report), Schwartz, H. J., NASA Lewis Research Center, June 15, 1977.

assigned the primary project management responsibility for electric and hybrid vehicle propulsion system R&D to NASA's Lewis Research Center (LeRC), in Cleveland, Ohio. The Electric and Hybrid Vehicle Systems Project Office requested LeRC to prepare a long-range plan for carrying out the necessary propulsion system R&D which will satisfy DOE established milestones and objectives. A draft of this plan has been submitted and is undergoing review at this time.

LeRC has been supporting DOE to a limited extent for the past year. In the propulsion R&D area this support has consisted of some in-house component testing and two study contracts to examine the current state-of-the-art of electric vehicle propulsion systems. In addition to examining the state-of-the-art, these studies have also identified areas for improving currently available propulsion system components.

The general objective of the propulsion system R&D effort is to accelerate the technological advancement of the following components:

- Motors, controllers, chargers and other related power system components;
- Transmissions and other mechanical components; and,
- Regenerative braking (which will be explored for automotive applications over and above its use in EHV's).

These advancements are being designed to improve overall vehicle efficiency, reliability and drivability and to reduce overall life-cycle cost.

The immediate emphasis of the activity that is being initiated by NASA-LeRC is on improving the current technology to the greatest extent possible, while simultaneously initiating longer range developments that have the potential for providing significant improvements in vehicle performance and cost characteristics of vehicles that might be available in the early to mid-1980's.

The following approach describes the timeframe to achieve these technological advancements:

1. For Near-Term Improved Systems: NASA-LeRC will address present industry-developed powertrain components and systems. They will also provide government support to industry to help accelerate performance improvement, with specific emphasis on better matching the capabilities of these components with their in-

tended EHV use. The primary objective is to develop and demonstrate a 20% to 50% improvement in powertrain performance over current state-of-the-art hardware.

2. For Advanced Systems: NASA-LeRC will undertake more ambitious advanced system concept studies and developments which, in turn, will result in aggressive, higher risk, significantly advanced component and system technology development programs. The goal of this effort is to assist industry in developing the technologies necessary to permit a 100% improvement in powertrain performance.

As of September 1977, accomplishments have been related primarily to near-term system activities and are summarized below:

- Two six-month parallel study contracts were awarded in December 1976. From these and the results of other DOE contracts, state-of-the-art propulsion system concepts will be identified that represent the best available current technology, and recommendations will be made concerning the direction of improved component and system technology. The contractors performing this task are Booz-Allen & Hamilton, Inc. and Rohr Industries, Inc.
- A number of preliminary design approaches have been compared and a specification has been developed for the design and construction of a road load simulator which will be used to test and evaluate state-of-the-art powertrain systems.
- Tests are conducted to determine the performance of motors and Silicon Controlled Rectifier or transistorized chopper controllers.
- A breadboard version of an experimental, two-motor differential drive system has been built for a preliminary engineering assessment.

Vehicle Supporting Technology

Certain special vehicle supporting technologies need to be developed concurrently with the propulsion system R&D activities. These include accessories and auxiliaries, such as improved occupant heating and cooling systems; the selection of light

weight, high strength materials; the optimization of drag and rolling resistance; and specialized instrumentation.

Current efforts have been aimed at achieving improvements that will result in better vehicle range and performance by overall mass reduction, optimizing rolling resistance and aerodynamic resistance and optimization of the vehicle configuration.

These vehicle supporting technology activities are being conducted by JPL under a DOE-NASA agreement. This work will be closely coordinated with the propulsion system R&D activities managed by NASA-LeRC. It is DOE's intention that the major R&D activities at both LeRC and JPL be contracted to industry, universities and other appropriate groups which can convert these technological advancements into marketable products.

JPL is also in the process of conducting an overall assessment of the various hybrid vehicle options in order to provide DOE with some reasonable technical rationale for selecting specific R&D actions required for these systems. This assessment encompasses:

- A study of potential hybrid configurations including:
 - fuel cells (chemical refueling),
 - batteries (electrical refueling),
 - recharge storage forms (mechanical, pneumatic and thermal);
- A study of the hybrid system modeling;
- An evaluation of the most promising hybrid system candidates;
- An evaluation of the role which hybrid vehicles can fulfill for both passenger and commercial applications; and,
- Recommendations for programs to develop the most promising hybrid systems.

JPL's assessments include an evaluation of both near-term and mid-term applications, but concentrate on the adaptability of near-term concepts. Los Alamos Scientific Laboratories and the Brookhaven National Laboratories are providing support to JPL in the area of fuel cell characterization for vehicle applications.

Propulsion System/Energy Storage Interface

It is becoming widely recognized that the performance of energy storage devices may be heavily influenced by their interaction with the remainder of the powertrain system design. Thus, this interaction may significantly affect the total vehicle system design, especially since the energy storage device represents a major expense.

The objective of this effort is to evaluate the interaction of the propulsion system with one of its major components, the energy storage device. For the electric vehicle, this device is the battery and perhaps some other power storage device such as a flywheel. The hybrid may use a battery and flywheel in conjunction with a heat engine or some other energy source.

Currently, the effect on battery performance of typical silicon controlled rectifier or transistorized chopper motor-controllers is being evaluated by NASA-

LeRC. Additionally, a special pulse charger is being used to evaluate the efficiency and feasibility of very high rate charging equipment. Argonne National Laboratory (ANL) will also evaluate and characterize potential charging interface problems associated with new batteries developments.

A joint effort sponsored by DOE and UMTA (DOT) is addressing the effects of load leveling (via flywheels) on storage batteries. Laboratory testing for this activity is being provided by the US Army MERADCOM. Initial research and testing will concentrate on the lead-acid battery/flywheel load leveling system through a simulated driving cycle in order to determine the effects on battery efficiency, recharge capacity and storage life.

Advanced Concepts

The Advanced Concepts activity is aimed at investigating new long-range technology concepts and performing R&D on concepts which appear

FIGURE 2-5
Roadway-Power System for Electric Vehicles

feasible and attractive but beyond the timeframe of P.L. 94-413. At present, the Lawrence Berkeley Laboratory (LBL) is conducting a study* to examine the feasibility of providing electric energy to vehicles through an inductive coupling technique (Figure 2-5) whereby the vehicle has the option of receiving its energy from a conduit buried in the roadway.

This propulsion system has two modes of operation. In one mode, the vehicle is powered by a stored energy device, such as a battery or flywheel. This mode is used for travel at moderate speeds and relatively short range on streets or for passing or lane-changing on freeways. The second mode uses energy from a conduit installed in the center of freeway or expressway lanes. In this operating mode, the vehicle can travel at high speeds for long distances. Since the energy is magnetically (inductively) coupled to the vehicle, physical contact between the power source and vehicle is not necessary and electrical conductors are not exposed to accidental contact.

A decision to develop a prototype system will be made in the second quarter of FY 1980, and if warranted, tests will be scheduled for completion in mid-FY 1983.

Also under the program area of advanced concepts is the development of a vehicle test bed for evaluating and characterizing potential vehicle/battery interface problems associated with the advanced lithium/metal sulfide high temperature battery system. The initiation of this activity is dependent upon the first full scale prototype battery test results. A similar test bed vehicle is being developed for the advanced sodium/sulfur high temperature battery system.

III. Vehicle Test and Evaluation

In support of various R&D and demonstration activities, vehicle tests and evaluations were conducted and will continue on a periodic basis. In addition to developing data which characterize the state-of-the-art of electric and hybrid vehicles, evaluation

tests to determine improvements will also be conducted. Acceptance testing on upgraded vehicles as well as "product improved" vehicles (described later in this chapter) will add to the data collected.

The Department of Transportation will have the responsibility for safety testing of vehicles when such data and information are appropriate. Vehicles from the R&D program, from "product improvement" purchases, or acquired for the demonstrations are possible candidates for testing. Two vehicles were safety tested in 1977, the EVA Metro Sedan and the Sebring-Vanguard Citicar. Data from these vehicle tests are presented in following sections of this report and in a report to the Congress and the Administrator of the ERDA from the Secretary of Transportation.

State-of-the-Art Assessment

A State-of-the-Art Assessment was initiated in FY 1976 with the testing of five vehicles and expanded in FY 1977 to satisfy the state-of-the-art assessment requirements stated in P.L. 94-413. This assessment also includes the collection and analysis of vehicle data available from other Government agencies and from many foreign countries. Current assessments include:

- Performance data on twenty-two electric vehicles and two hybrid vehicles.
- User data from about sixty buses of sixteen different types and more than eight hundred delivery vans/passenger cars representing vehicles from eight different manufacturers.

NASA-LeRC (with additional assistance provided by the US Army MERADCOM and the Jet Propulsion Laboratory) was chosen as the lead laboratory for the vehicle test and evaluation efforts. The Jet Propulsion Laboratory was assigned the responsibility for in-use data collection. Results of the first year's assessments will be published in December 1977 with updates published annually.

The State-of-the-Art Assessment included data from three sources:

1. Controlled tests of a representative sample of commercially-available and experimental vehicles;
2. The available literature from vehicle designers

* "Investigation of the Feasibility of a Dual Mode Electric Transportation System," Bolger, J.G., and Kirsten, F.A., Lawrence Berkeley Laboratory, May, 1977.

and manufacturers;

3. Experiences of users, both fleet operators and individual vehicle owners.

Results from each data source are described in the following paragraphs:

1. Controlled Vehicle Testing

Since the purpose of the study was to characterize present electric and hybrid vehicles and not to represent any particular vehicle technology, vehicles selected for test and evaluation were picked to provide a representation of the current state of the art. However, the number of vehicles selected was limited by the funding available and the time available to complete this initial phase of the work. Therefore, selection was based on: (1) ready availability of a vehicle; and (2) its technical representation and the apparent maturity of its construction. A summary of the types and origins of all twenty-four (24) vehicles tested is shown in Table 2-2. Because the emphasis of producers has been on electric vehicles rather than on hybrid vehicles, testing was concentrated on the electric vehicles. Only a few hybrid vehicles have been built, and development efforts have been minimal, but two that satisfied the selection criteria were tested to provide some preliminary insight as to their characteristics. No buses were tested in this assessment.

2. Other Information

Additional data were collected from the literature and from vehicle designers and manufacturers. Data from designers and manufacturers were solicited by means of notices placed in the *Commerce Business Daily* and *Electric Vehicle News* (Figure 2-6).

The material obtained from these sources provided data on 121 vehicles as summarized in Table 2-3. Approximately 35 additional vehicles have been omitted from the summary because very little information was available about them and/or they were early experimental vehicles.

Information tabulated for each vehicle includes manufacturer, dimensions, weight, type and size of battery, electric motor, controller, transmission, engine (for hybrids), and performance.

TABLE 2-3
Summary of Vehicles Reported in the Literature

	Origin		Total
	Domestic	Foreign	
Personal Vehicles	53	13	66
Commercial Vehicles, Excluding Buses	15	26	41
Buses	2	12	14
Total	70	51	

TABLE 2-2
Summary of Vehicles Tested

	Number of Vehicles Tested			
	Electric		Hybrid	
	Personal	Commercial	Personal	Commercial
NUMBER TESTED	10	12	1	1
ORIGIN:				
U.S. MANUFACTURE	9	6	1	0
FOREIGN MANUFACTURE	1(a)	5	0	1
PURPOSE-BUILT(b)	3	3	0	1
CONVERSIONS(c)	7	8	1	1

(a) Sold in United States

(b) Designed and built as electric vehicles

(c) Conversions of heat engine vehicles to electric and hybrid vehicles

ERDA Wants Electric and Hybrid Vehicle Data

A State-of-the-Art Assessment of Electric and Hybrid Vehicles is Now Being Conducted by the Energy Research and Development Administration (ERDA). Data is Being Collected on All Existing Electric and Hybrid Vehicles, Both Production and Experimental. Physical Descriptions of Vehicles and Their Propulsion Systems, and Vehicle Performance Data are Being Sought. ERDA is Being Supported by the National Aeronautics and Space Administration with NASA's Lewis Research Center as the Responsible Center Assisted by the Jet Propulsion Laboratory.

Public Law 94-413, the Electric and Hybrid Research, Development and Demonstration Act of 1976, Dated September 17, 1976, Required that "Within Twelve Months After the Date of this Act, the Administrator (of ERDA) Shall Develop Data Characterizing the Present State-of-the-Art with Respect to Electric and Hybrid Vehicles. The Data So Developed Shall Serve as Baseline Data to Be Utilized in Order (1) to Compare Improvements in Electric and Hybrid Vehicle Technologies; (2) to Assist in Establishing the Performance Standards Under Subsection (b) (1); and (3) to Otherwise Assist in Carrying Out the Purposes of this Section."

Organizations or Individuals with Material to Offer Should Send it to NASA at the Address Below:

Mr. Richard M. Schuh
Mail Stop 500-210
NASA Lewis Research Center
Electric and Hybrid Vehicle Project Office
21000 Brookpark Road
Cleveland, OH 44135

Data Should Reach NASA by June 15, 1977.
For Additional Information, Call (216) 433-4000, Extension 6726

TABLE 2-4
Responses to Domestic Use Survey

Vehicle	Number	User/Sponsor	Primary Applications (s)
Personal Vehicles			
Citicar	207	Respondents to mail survey of owners	Commuting, shopping and errands
	1	John Hoke, U.S. Park Service	Commuting, business
Elcar	11	Respondents to mail survey	Pleasure, commuting
	6	Fermi National Accelerator Lab	Inter-facility trans.
	3	Downtown Parking Assoc., Stockton, CA	
	2	Erwin Ulbrich, Creative Automobile Research	Security Patrol Demonstration
EVA Sedan	7	Government of Manitoba, Department of Public Works	Local business trips
	3	ERDA	Local business trips
Mars II	8	Pennsylvania Power and Light	Demonstration, messenger service
EVE Islander	25	Sea Pines Plantation	Public rental
Electra King	0	Manufacturer ^(a)	
Commercial Vehicles			
DJ-5E	352	U.S. Postal Service	Mail delivery
	10	Bell Telephone/AT&T	Customer service
Harbilt	31	U.S. Postal Service	Mail delivery
Batronic Minivan	107	Utility Companies/EVC ^b	Customer service
	5	3 U.S. and 2 Canadian Utilities	Customer service
Otis P-500	2	NASA-Lewis Research Center	Inter-facility mail service
	1	Hydro Quebec	Customer service
CDA Van	1	Water Department, Birmingham, Mich./Cooper/Development Association	Customer service

(a) Contact was made only with the manufacturer, no actual users were surveyed.

(b) These are utility companies participating in the Electric Work Vehicle Purchase Program sponsored by the Electric Vehicle Council.

3. User Experience Survey and Information

Information taken from daily operators of electric vehicles is invaluable. To obtain data of this type, NASA-JPL surveyed domestic fleet operators and individual owners of nearly 800 vehicles. Also, domestic and foreign electric and hybrid bus operators were interviewed by the Trans Systems Corporation under contract to the Department of Transportation. Other foreign experience was obtained from the literature and some personal contacts.

These data not only permitted a comparison of performance results obtained on the test track and user experience in the field, but also provided information on operating costs, maintenance requirements, and a measure of vehicle reliability and durability which was not otherwise available from short duration track tests. User experience is also the best source of information on public acceptance of electric and hybrid vehicles as a form of transportation, since the user's acceptance or rejection is based on his actual experience with the vehicle.

In all, usable information was collected on 697 of an estimated 1,830 American-built vehicles of all types which are currently operating in the United States and Canada. Detailed information also was obtained on the operation of 44 electric and hybrid buses in 4 foreign countries through site visits and interviews.

Additional data on several hundred other vehicles in operation abroad were collected from the literature. Responses to domestic use surveys are summarized in Table 2-4.

Product Improvement Vehicle Purchase

To stimulate the early production of electric vehicles incorporating improved, off-the-shelf technology and to encourage small business involvement in the Electric and Hybrid Program, DOE has requested proposals from firms qualifying as small businesses to deliver vehicles which incorporate technological advances in performance, reliability and marketability. These vehicles will be tested and evaluated by DOE. In some cases, these vehicles are expected to provide a bridge between present vehicles and the production of improved vehicles which could be available for the first demonstrations. DOE's intent is to purchase a minimum of 10 electric and/or hybrid vehicles, two each from five or more different manufacturers. Contractor selection is expected to be completed by December 1977, with vehicle deliveries scheduled for eight months thereafter. If the test results warrant it, additional vehicles may be purchased.

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Chapter 3

Energy Storage Systems Technology

P.L. 94-413 stresses at least three fundamental areas which the battery R&D program must address. First, the rigorous schedule set forth for the demonstrations places severe demands on the performance of electric vehicle research and development activities, particularly for the development of improved near-term batteries which are to be available for manufacturers of demonstration vehicles. Secondly, the Act requires activity in the area of hybrid vehicles and, therefore, will require consideration of battery designs which can be used in conjunction with other power/storage devices. Finally, the schedule dictates accelerated activities in the development of manufacturing technologies for battery systems.

Activities within the scope of energy storage R&D include the planning and monitoring of government, industrial and institutional research on energy storage systems having near-term and long-term application in the propulsion of electric and hybrid vehicles (buses, vans, light delivery trucks and passenger automobiles). This work is being conducted by industry, DOE national laboratories and other Government agencies.

I. Batteries

Batteries, because of their unique operating and physical characteristics, are particularly well-suited as efficient electrical energy storage devices for electric vehicles. Battery cycle life, performance and cost constitute the major criteria for potential use in electric vehicles. Lead-acid, iron-nickel oxide and zinc-nickel oxide systems are near-term electric vehicle battery candidates which can potentially meet the latter demonstration vehicle delivery schedule. Improved technologies for these systems will be developed and implemented under the impetus of P.L. 94-413.

As part of its activities, DOE will pursue the development of more advanced batteries requiring longer range programs. Significant technological

progress (Table 3-1) has been made over the last two years in the following advanced battery systems: the ambient-temperature zinc-chlorine hydrate system, the high-temperature lithium-iron sulfide system, and the sodium-sulfur system. These advanced batteries approach the goals of contemplated applications in terms of cell capacity, performance and efficiency, but the demonstrated cycle life still falls short of the goals. At the present rate of progress, the advanced battery systems are not expected to reach the stage of major testing of full-size batteries sooner than five years. Therefore, the lead-acid battery system will most likely be the power source for both statutory vehicle demonstrations, with some possibility for the iron-nickel oxide and the zinc-nickel oxide systems.

DOE's Electrochemical Systems Program has the responsibility for battery RD&D and has designated Argonne National Laboratory (ANL) as the lead institution for such activities. As shown in Table 3-2, R&D is being conducted on seven battery concepts for electric and hybrid vehicle applications. Table 3-3 lists current battery contractors and their respective projects.

Table 3-4 shows characteristics and relative performance goals near-term batteries and the time-frame in which these goals are expected to be achieved. In addition to meeting specific battery R&D goals, this research area is also concerned with the development of manufacturing technologies for battery systems, the identification of promising methods of achieving low manufacturing costs, preliminary system engineering designs, and the development of a standardized method of battery costing.

II. Flywheels and Other Energy Storage Systems

Considerable attention has been given to flywheels for energy storage. State-of-the-art specific energy values for flywheels are about the same as

TABLE 3-1
Status of Major Advanced Batteries

Battery System	Status		Major Achievements	Approach
	Battery Size Watt-Hours	Life (Cycles)		
Zinc-Chlorine	25	> 750	Demonstrated High Electrochemical Efficiency. Eliminated Chlorine Compressor.	Optimization of Temperature, Electrolyte Flow and Composition. Optimization of Operating Variables.
	1400	> 200		
	20,000	Test		
	100,000	Initiated Under Construction		
Lithium-Iron sulfide	100-300	> 500	Improved Capacity and Active Material Utilization. Option for Low Cost Separators.	Optimization of Electrode Structures and Additives. Paper, Felt,
	1000	Test		
	25,000	Initiated Under Construction		
Sodium-Sulfur (ceramic)	30	1000	Improved Life. Improved Utilization of Sulfur. Improved Seal Between Alpha and Beta Aluminum. Low-Cost Positive Current Collector.	Improved Solid Electrolyte, Current Distribution and Purities. Control of Current Collector Structure. Development of Stable, Physically Compatible, & Low Melting Glasses. Use of Carbon Materials.
	150	250		
	300	Under Construction		
Sodium-sulfur (glass)	10	220	Improved Cycle Life. Use of Metal Cell Case.	Purity Control in Sodium. Improved Assembly Techniques.
	80	Under Construction		

TABLE 3-2
Potential Electric Vehicle Batteries

Batteries			Current				Projected			
Systems	Electrolytes	Temp. °C	Watt-Hours/ Kilogram	Watts/ Kilogram (Peak)	Life (Cycles)	Cost \$/KWH	Watt-Hours/ Kilogram	Watts/ Kilogram (Peak)	Life (Cycles)	Cost \$/KWH
Near-Term (1-2 yr)										
Lead-Acid (SOA)	Sulfuric Acid	Room Ambient	30	50	700	50	50	150	>1000	50
Nickel-Iron	Potassium Hydroxide	Room Ambient	44	130	1500	120	60	150	>1000	120
Intermediate Term (3-5 yr)										
Lead-Acid (Advanced)	Sulfuric Acid	Room Ambient	—	—	—	—	50	150	>1000	60
Nickel-Zinc	Potassium Hydroxide	Room Ambient	70	110	200	800	90	150	>1000	50
Long-Term (5 yr)										
Zinc/Iron-Air	Potassium Hydroxide	Room Ambient	80-120	40	150	2000	90	80	>1000	60
Zinc-Chlorine	Zinc Chlorine	Room Ambient	66	60	100	2000	130	150	>1000	50
Lithium-Metal Sulfide	Lithium/ Potassium Chloride	400-450	100	120	250	2000	150	300	>1000	40
Sodium-Sulfur	Beta-Alumina	300-350	90	100	200	2000	170	200	>1000	40

TABLE 3-3
Battery Project Contractors

Program	Lead Institution	Battery Projects	Contractors/Sub-Contractors
Near-Term Ambient Temperature Batteries	Argonne National Laboratory	Lead-Acid	<ul style="list-style-type: none"> • Eltra (C&D, Prestolite) • ESB • Globe Union • Gould
		Nickel-Iron	<ul style="list-style-type: none"> • Eagle-Picher/Swedish National Development Co.
		Nickel-Zinc	<ul style="list-style-type: none"> • Westinghouse • Eagle-Picher • Energy-Research Corp. • Gould • Yardney Electric Company
		National Battery Test Laboratory	<ul style="list-style-type: none"> • Argonne National Laboratory (ANL)
Advanced Batteries	DOE/Div of Energy Storage Systems	Zinc-Chlorine	<ul style="list-style-type: none"> • Energy Development Associates
		Lithium-Iron Sulfide	<ul style="list-style-type: none"> • ANL/Gould • Eagle-Picher • Catalyst Research • Atomics International
		Sodium-Sulfur (Ceramic)	<ul style="list-style-type: none"> • Ford/University of Utah
		Sodium-Sulfur (Glass)	<ul style="list-style-type: none"> • Dow Chemical

TABLE 3-4
Development Goals for Near Term Electric Vehicle Batteries*

Calendar Year	Present	Lead-Acid 1978	1980	Present	Nickel/Iron 1978	1980	Present	Nickel/Zinc 1978	1980
Specific Energy (watt-hours/kilogram)	30	40	50	44	50	60	70	70	90
Specific Power (watts/kilogram)									
Sustaining	15	20	25	20	40	50	20	40	50
Peak	50	100	150	130	150	200	130	150	200
Energy Efficiency (%)	65	>60	>60	70	70	70	>60	>60	60
Cycle Life	700	800	1000	1500	1500	2000	200	500	700
Initial Installed Cost (\$/kilowatt-hour)									
for less than 10,000 batteries	100	80-100	80-100		100-120	100-120		100-120	100-120
for more than 10,000 batteries	50	50	40	120	70-80	50-60		70-80	50-60

* Batteries Duty Cycle: 2-4 hr Discharge, 70-80% Depth of Discharge 1-6 hr. Charge

the lead-acid battery, although specific costs (dollars per unit energy) for flywheels are expected to be somewhat higher.

The addition of a flywheel system to an electric vehicle improves vehicle performance and range by using flywheel energy during peak load requirements, thus increasing battery life through reduced discharge rate at peak load.

Flywheels can also provide regenerative braking energy wherever the battery type precludes high charge rates to the battery itself. Table 3-5 illustrates the status of flywheel technology and performance projections for transportation applications.

TABLE 3-5
Flywheel Technology
and Projections

Element	Current (1976)	Near-Term (1980)	Advanced (1985)
Isotropic Material Rotor			
Energy Density (watt-hours/kg)	6.6-31		11-33
Composite-Rotor Energy Density (watt- hours/kg)	22-44 *	66-88	132-155
Ball Spin Bearings			
Life (years)	3-5		3-5
Losses (% of Rated Power	2-4		1-2
Hybrid Bearings			
Life (years)			5-7
Losses (% of Rated Power			1-2
Motor/Generator Efficiency (Percent)	60-94		88-97
Overall Efficiency (Percent)	55-70	70-75	75-80

*Laboratory/Demonstrations

No domestically produced flywheel systems will be available in commercial quantities in 1978. However, through concerted effort by contractors

and national laboratories, some flywheel technology may become available by 1980.

The immediate objective is to produce a flywheel module for electric vehicles that will:

- Extend range by 20% ,
- Improve acceleration by 50% ,
- Increase battery life by 33% ,
- Have capability of 50 mph on 5% grade,
- Cost less than \$500,
- Be safe,
- Be suitable for production,
- Be operable without added driver effort,
- Require little maintenance.

Demonstration of regenerative flywheels in subway cars by DOT in recent years showed that energy savings of 30-35% were possible. This demonstration along with other demonstrations and studies by Rockwell International, the Garrett Corporation, LLL and others, gave an indication of the need to increase the efficiency of flywheels and reduce their costs.

Garrett is developing a module to recover braking energy and improve operating performance of an electric postal jeep under a jointly supported contract from DOE and USPS.

GE is fabricating and testing for DOE a hermetically sealed flywheel module with improved storage capacity. The fiber composite flywheel and related power input-output devices will be tested under simulated road conditions in the laboratory.

Sandia Laboratories, LLL and Union Carbide are contributing to component technology development by providing materials data to fiber composite flywheel designers and by testing different rotor failure modes. These organizations are also investigating advanced bearings, seals and input-output devices.

In a planned technology demonstration program for the next three years, selected contractors will design, manufacture and test advanced energy storage modules which include flywheels or other mechanical storage devices. These efforts are geared to the second generation electric vehicles and advanced hybrid vehicles.

The hydropneumatic accumulator has been suggested for storing energy in hybrid vehicles. However, such a system requires a formidable structure and is therefore subject to a weight penalty. The

energy density determined in a current study by LLL for commercially available systems is at best one-tenth that of present technology batteries or flywheel energy storage systems.

Other alternative energy storage systems, including thermal storage and fuel cells, are being studied and evaluated by LLL for their potential applications.

But these systems are not available commercially, and they do not offer enough performance potential to merit serious consideration for automotive use at present. Important new developments in alternative energy storage systems are unlikely, and none is likely to be available in time for any of the demonstrations.

CHAPTER 4 SPECIAL STUDIES AND PERFORMANCE STANDARDS

I. Studies Required by Section 13 of P.L. 94-413

Section 13 of P.L. 94-413 outlines five specific areas to be studied:

- (1) *Institutional Factors* which may bias the transportation system toward vehicles of particular characteristics.
- (2) *Long-Range Material Demands and Pollution Effects* stemming from the use of electric and hybrid vehicles.
- (3) *Promotional Incentives* for broader utilization and consumer acceptance of electric and hybrid vehicles.
- (4) *Safety Standards and Regulations* for electric and hybrid vehicles.
- (5) *Regenerative Braking* system effectiveness and feasibility for electric and other automobiles.

While detailed reports on studies identified in (1), (4) and (5) above are being submitted to Congress under separate cover, a brief summary of each is included in this chapter along with the summary results of studies (2) and (3).

Institutional Factors Study*

The study of institutional factors was conducted by the Department of Transportation, Transportation Systems Center (DOT-TSC) in Cambridge, Massachusetts as a result of an interagency agreement between DOE and DOT.

DOT-TSC's approach to this study was to review the various institutional areas specified in P.L. 94-413 (tax, regulatory, traffic, urban design, rural electrical, and other factors), then identify the institutional factors that might be sources of bias. These are shown in Figure 4-1 where the factors identified are listed in

terms of bias source and areas of potential bias impact.

For this study an institutional factor was defined as a policy, practice, regulation, or infrastructure element that influences vehicle production, ownership or use. Bias was determined by comparing the effect of an institutional factor on electric or hybrid vehicles with its effect on comparable, conventional internal combustion engine-equipped vehicles (ICEV). If the comparison revealed an inclination favoring one type of vehicle over the other (in terms of production, ownership or use), then a bias existed. Some 60 factors were identified, characterized and evaluated.

Based on the findings of the DOT-TSC Study, the following conclusions were reached.

- Of the 60 factors analyzed, 28 cause bias against electric and hybrid vehicles, 14 cause no bias, 14 cause bias in favor of EHV's and 4 can be interpreted as a source of bias either for or against EHV's, depending on the assumptions made.
- Thirteen bias producing factors are considered to have the potential for major impact. These factors are:
 - safety laws and standards
 - sales taxes
 - property taxes
 - speed laws
 - highway design (grade characteristics)
 - electricity infrastructure
 - Federal research, development and demonstration policy
 - automotive industry structure and practices
 - oil prices and oil supply shortfalls
 - capital availability and markets
 - insurance laws and availability
 - consumer financing
 - Rural Electrification Act
- Performance and cost characteristics of near-term and intermediate technology EHV's are the basis for many of the biases identified. Any

* "Institutional Factors in Transportation Systems and Their Potential for Bias Toward Vehicles of Particular Characteristics," Rosenberg, N., et al., DOT Transportation Systems Center, August, 1977.

FIGURE 4-1
Matrix of Institutional
Factors Considered in
The DOT-TSC Study

Source Potential Bias*							
Area of Impact	Taxes and Regulations	Traffic Control	Urban Design	Electricity Supply	Federal Policies and Programs	Automotive Industry Structure & Practice	Miscellaneous Institutional Factors
1. Vehicle Pro- duction and Distribution	<ul style="list-style-type: none"> • Federal Motor Vehicle Safety Standards • Federal Motor Carrier Safety Regulations • Air Pollution Control Laws • Federal Noise Standards • State Noise Control 				<ul style="list-style-type: none"> • Automotive Research 	<ul style="list-style-type: none"> • Economies of Scale • Capital Requirements • In-Place Infrastructure • Research & Innovation • Pricing 	<ul style="list-style-type: none"> • OPEC • International Energy Program • Material Cartels • Capital Availability
2. Vehicle Pur- chase and Ownership	<ul style="list-style-type: none"> • Registration Fees/Laws • Sales Taxes • Property Taxes • Insurance Laws • Income Tax Deductions • Customs and Tariffs • Rural Electrification Act 		<ul style="list-style-type: none"> • Urban Density • Parking and Charging Facilities 	<ul style="list-style-type: none"> • Utility Capital • Utility Regulations 	<ul style="list-style-type: none"> • Fleet Procurement Programs • Energy Research 		<ul style="list-style-type: none"> • Insurance Availability • Financing Availability • OPEC • International Energy Programs
3-A. Vehicle Operation Fuel	<ul style="list-style-type: none"> • Motor Fuel Taxes • Emergency Petroleum Allocation • Utility Tax • Energy Policy and Conservation Act 			<ul style="list-style-type: none"> • Utility Rate's • Electricity Distribution Infrastructure 			
3-B. Maintenance	<ul style="list-style-type: none"> • Lubricating Tax • Tire & Tube Tax • Pollution Control Laws 			<ul style="list-style-type: none"> • Battery Exchange 			
3-C. Operating conditions	<ul style="list-style-type: none"> • Minimum Speed Laws 	<ul style="list-style-type: none"> • Highway Traffic Speed • Highway Access Ramps • Traffic Light Timing • Preferential Traffic Lanes • Tolls and Congestion Pricing • Vehicles Segregation Policy 		<ul style="list-style-type: none"> • Intermodal Planning • Access Policy • Covered Automobile Facilities 			

* Potential sources can lead to positive or negative biases or to no biases.

vehicle with similar performance and cost characteristics, irrespective of the propulsion system, would be subject to the same biases.

- Limits on current and intermediate technology are a major source of bias against EHV's. These limits lead to biases in such areas as safety standards, sales and property taxes, speed laws and highway design. Major improvements in technology and cost factors would lead to diminution (or elimination) of these biases.
- There is a serious lack of reliable experiential information available to institutions about EHV's and their applications. EHV's are essentially new products with the associated uncertainties and risks that automatically elicit caution from established manufacturers, insurers and financial institutions.
- Introduction of EHV's to any large extent will have a significant negative impact on Federal and state revenues derived from automotive transportation.

The preliminary findings of DOE's Opportunity/Risk Assessment (which is discussed more fully in Chapter 8) in general substantiate and further complement those of DOT-TSC. Bias against electric and hybrid vehicle use exists because of sales taxes, safety regulations, speed laws, and highway access ramp design. These biases also exist because of the performance, design, and cost limitations inherent in current EHV technology in comparison with ICEV technology. For example, EHV sales taxes are higher than ICEV sales taxes because of higher acquisition prices for EHV's. Safety regulations will penalize EHV's more heavily than ICEV's because they lead to a greater total weight increase for EHV's than for ICEV's. The accident rate for EHV's is higher than for ICEV's because of such factors as existing highway access ramp grades, power limitations of EHV's and current speed limits which enable ICEV's to travel at a faster speed than EHV's.

Bias against EHV use also exists in the unavailability of capital for electric vehicle manufacturers, in restrictive insurance and financing practices, and in the unwillingness of existing firms to market EHV's. Since the EHV is an unknown, new product, there is virtually no reliable information based on experience with EHV's and their applications as compared to today's ICEV. Until some of the uncer-

tainties and risks are resolved, key economic institutions in the private sector (insurance companies, banks and other lending institutions) will be cautious.

Bias against EHV use also exists because current EHV technology does not allow the EHV, especially the passenger auto, to be cost competitive with the ICEV. EHV's appear to offer cost savings in some fraction of the automobile market, but quantification of this market segment and of the potential cost savings is difficult because of the scarcity of market application data.

Long Range Material Demands and Pollution Effects Study*

The long range material demands and pollution effects are being continually assessed by the General Research Corporation (GRC) under contract to DOE. This work is divided into four topics:

1. Materials and Resources for Electric Cars;
2. Impacts on Energy and Air Quality of Future Electric Cars;
3. Lubricant Disposal Impacts of Electric Cars;
4. Noise Impacts of Electric Cars.

The status of each is treated in the paragraphs that follow.

1. Materials and Resources for Electric Cars

Production of large numbers of electric automobiles will have significant impact on U.S. markets for battery materials. Materials used elsewhere in electric cars

* "Materials and Resources for Battery-Electric Cars," Hamilton, W., General Research Corporation, August 12, 1977.

"Impacts on Energy and Air Quality of Future Electric Cars," (report in progress), Collins, M.M., and Carriere, W.M., General Research Corporation, June, 1977.

"Lubricant Disposal Impacts of Electric Cars," (report in progress), Johnson, M.F., General Research Corporation, June, 1977.

"Noise Impacts of Electric Cars," (report in progress), Johnson, M.F., and Hamilton, W., General Research Corporation, August, 1977.

are either the same as in conventional cars or else in abundant supply.

The study of battery materials and resources first describes several representative electric cars which might be produced in the future. It then estimates the quantities of battery materials required for these cars, but which may be scarce and/or necessary to import. Next, it summarizes projected demand and supply of these materials in the absence of electric cars. Finally, it presents relative materials requirements for manufacturing a million electric cars annually and for equipping a fleet of ten million electric cars.

Table 4-1 presents brief descriptions of several electric cars which represent possibilities for manufacture and use in the United States within the next fifteen years. All the cars are small, carry four passengers, offer sufficient speed and acceleration for operation on freeways, but are intended primarily for urban use.

A variety of other battery prospects may become available in the future: nickel-iron, iron-air, zinc-air, zinc-chlorine, and sodium-sulfur, to name some leading possibilities. In general, they either use the same material or more abundantly available

TABLE 4-1
Representative Electric Cars

Urban Range, km	Level of Technology	Battery Type	Curb Weight, kg	Battery Weight, Percent of Curb Weight
75	Current	Lead-Acid	2,220	41
100	Improved	Lead-Acid	1,370	30
150	Improved	Lead-Acid	1,770	38
150	Improved	Nickel-Zinc	1,280	27
300	Optimistic	Lithium-Alum./ Iron Sulfide	1,310	31
450	Optimistic	Lithium-Alum./ Iron Sulfide	1,500	40

TABLE 4-2
**Materials Required For
Representative Cars**

Car Range, km	Battery Type	Nominal Battery Capacity kWh	Material Required per Car, kg							
			Lead	Antimony	Nickel	Zinc	Cobalt	Lithium	Molybdenum	Yttrium
75	Lead-Acid	24.7	540	12						
100	Lead-Acid	19.0	227	4.1						
150	Lead-Acid	31.0	370	6.7						
150	Nickel-Zinc	26.7			88	117	1.5			
300	Lithium-Aluminum/ Iron Sulfide	46.5					4.7	19.5	14.0	2.6
450	Lithium-Aluminum/ Iron Sulfide	69.0					6.9	29.0	20.7	3.8

materials than those of the batteries in the Table.

For the cars in Table 4-1, battery materials which may be scarce and/or necessary to import and their total requirements are indicated in Table 4-2. The table shows the nominal capacity of each battery type in Table 4-1 (assuming discharge in two hours and including the insulating enclosure required by the high-temperature lithium battery).

Table 4-3 shows actual and projected US and world demand for key battery materials. It provides a baseline to which additional materials demanded for electric cars may be compared.

Table 4-4 shows estimates of US and world reserves and resources of materials. These are important in considering whether production can be

TABLE 4-3
Demand for Materials in the Absence of Electric Cars

Material	Annual Demand, Millions of Kilograms					
	1974		1985		2000	
	US	World	US	World	US	World
Lead	845	3,077	1,089	4,681	1,388	6,867
Antimony	18	70	28	96	44	128
Nickel	199	704	236	971	349	1,442
Zinc	1,328	5,806	1,923	8,020	2,767	11,203
Cobalt	10.4	31.3	12.2	37.6	19.5	62.1
Lithium	4.5	7.3	6.4	11.8	12.7	26.3
Molybdenum	34.5	90.7	46.3	139	87.5	266

TABLE 4-4
Reserves and Resources of Materials

Material	1974 Reserves, Millions of kg		Identified Reserves, Millions of kg	
	US	World	US	World
Lead	53,500	150,000	108,000	300,000
Antimony	91	4,161	118	5,060
Nickel	---	54,000	13,600	112,000
Zinc	45,000	236,000	118,000	1,500,000
Cobalt	---	2,450	764	4,280
Lithium	297	675	840	1,910
Molybdenum	2,700	5,900	16,000	29,000
Yttrium	3.2	35	41	176

reasonably expanded to provide for the added demands of electric cars.

Table 4-5 shows the increased demand for key battery materials which would result from the manufacture of one million electric cars per year. At this rate of production, electric cars would account for a little less than ten percent of new cars sold in the US. The table shows significant demand increases for every material under consideration except zinc.

Except in the case of lithium, the increases in US demand are under 40%. These increases would not, of course, appear overnight, since it would take years to increase electric car production from the present inconsequential level to the million-per-year level assumed. In the case of lithium, present demand is relatively low. Consequently, the percentage increase due to electric cars using lithium batteries appears rather large. But, because the actual amount of lithium required will still be relatively small

and because most of today's lithium is supplied in chemicals rather than as a pure metal, the increased demand for lithium for electric cars can probably be met without major problems.

Once a fleet of electric cars is in operation, materials for replacement batteries will come primarily from recycling. At present, about 90% of lead and antimony in conventional automobile starting-lighting-ignition batteries is reclaimed. Higher percentages may be extracted for electric propulsion batteries, which cannot be readily discarded and are therefore more likely to be returned for reprocessing. As materials grow scarce and expensive, increasingly efficient recovery processes will be devised. With a typical battery lifetime of over five years and with a 95% recovery of used materials, requirements for new material to make up losses in recycling for a fleet of ten million cars would be less than the requirements in Table 4-5 for manufacturing a million new cars per year.

TABLE 4-5
Increased Demand for Materials
from Manufacturing One
Million Electric Cars Per Year

Car Range, km	Battery Material	Percent Increase in Demand for Materials			
		US	1985 World	US	2000 World
100	Lead	21	5	16	3
	Antimony	15	4	9	3
150	Lead	34	8	27	5
	Antimony	24	7	15	5
150	Nickel	37	9	25	6
	Zinc	6	1		1
	Cobalt	12	4	8	2
300	Cobalt	39	13	24	8
	Lithium	305	165	153	74
	Molybdenum	30	10	16	5

2. Impacts on Energy and Air Quality of Future Electric Cars

This section presents the initial results of the air pollution analysis and the early findings of the energy impact analysis. The two are interrelated because to determine air pollutant emissions which would result from electric car use it is necessary to project the fuels and generating stations which would be utilized to recharge electric cars.

Future work in this ongoing national impact assessment will refine the emissions and energy use projections offered here and develop a broader parametric description of the energy and air pollution impacts of electric car use.

Replacing conventional cars with electric cars will reduce vehicular pollutant emissions in proportion to the number of cars replaced. The percent of total emissions in a region attributable to conventional automobiles serves as a useful upper bound against which to measure the potential impact of electric cars. Electric cars, of course, can do no more than eliminate this percentage of pollution, which in most cases is surprisingly small. For this report GRC estimated this upper bound, using baseline air pollution emission projections from REPS (Regional Emission Projection System), a computer model developed by EPA. REPS combines exogenous regional economic forecasts from the Department of Commerce projections with point and area source emissions inventories for 243 Air Quality Control Regions (AQCR) from the Environmental Protection Agency's National Emissions Data System (NEDS). It projects air pollution emission levels for five major air pollutants on an annual basis.

Using this computer model, GRC assembled baseline air pollution projections for 1976 and 1990 for twenty-one of the twenty-four AQCR's which contain urbanized areas over a million in population. All twenty-four AQCR's are shown in Figure 4-2; only twenty-one were analyzed because REPS did not provide complete projections for three regions (Chicago, Detroit and Minneapolis-St. Paul).

Overall results are summarized in Table 4-6 by means of population-weighted averages for all of the twenty-one AQCR's. This table shows that the importance of conventional autos in air pollution is expected to decline rapidly.

Automobile emission calculations are based on EPA's Federal Test Procedure (FTP) mean emission

TABLE 4-6
Percent Emissions from Conventional Autos (Population-weighted averages for 21 AQCR's)

Year	Particulates	SO _x	NO _x	HC	CO
1976	16.05%	0.85%	30.08%	43.73%	71.05%
1990	12.03%	0	10.69%	23.10%	21.24%

factors adjusted to reflect average vehicle speed for each of four road classes: limited, rural, suburban, and urban. These emission factors reflect statutory CO, HC and NO_x exhaust emission standards. The percent HC emissions shown in Table 4-6 also includes total gasoline evaporation emissions as part of auto emissions, and the percent particulate emissions includes emissions from tires, which are estimated to account for 40% of auto-related emissions for 1976 and 80% for the year 1990.

In order to estimate the impact of electric cars on electricity demand in 1990, it was assumed that most electric cars would be used as second cars and would be kept at single family houses with off-street parking, where overnight recharge could be most easily arranged.

Once the electric car population was selected, it was a rather simple task to estimate the increase in electricity demand caused by electric cars. Allowing for an eight percent loss in electricity transmission, it was determined that electric cars will require generation of approximately 0.52 kilowatt hours of electricity per mile driven.

The increased demand on each utility was used to calculate the fuel quantities which would be used by each utility to satisfy the recharge demand. With these data and daily recharge requirement figures, the increase in demand on utilities serving the urban areas and the fuels that would be used to satisfy the demand were estimated. A typical hourly load curve shown in Figure 4-3 illustrates the necessary parameters for a typical utility on a typical day. The figure shows that for this particular utility and day, the recharge requirement will be satisfied using base-load and intermediate-load oil capacity and that recharging will occur during the early morning hours.

For those electric utility systems serving the ur-

banized areas with populations over one million, the 1990 projection showed that electric cars will increase total electricity demand by only a few percent. Under the assumption that, in 1990, 14% of all urban area cars would be electric, electric car recharge would produce an average 1.7% increase in total electricity demand. Over 42% of the increased demand would be supplied from coal, 34% from oil, and much of the remainder (20%) from nuclear fuel.

While reducing the baseline air pollution from conventional automobiles, electric cars will increase the emissions from power plants. To evaluate this increase, GRC again focused on the year 1990 and the AQCR's containing urbanized areas with popula-

tions over one million. Using the baseline projections for total electric power generated within each AQCR, GRC estimated the resultant percent increase in coal, oil and gas fuel usage for plants in each AQCR. By comparing increased power plant emissions to total AQCR emissions, GRC estimated percentage increases in emissions by each AQCR and by each pollutant. Electric car recharge would affect only particulate, SO_x and NO_x emissions, since emissions by power plants of hydrocarbons and carbon monoxide are negligible. The weighted average increases in total emissions (due to battery recharging) for 1990 are shown below (assuming 14% electric car population):

FIGURE 4-2

The Twenty-Four Air Quality Control Regions in the United States Containing the Urbanized Areas with the Largest Population

Year	Particulates	NO _x	SO _x
1990	0.41%	1.11%	2.10%

Considering the nation as a whole, it is estimated that HC and CO pollution would be reduced by approximately 3%, SO_x increased by approximately 2%, and particulate and NO_x essentially unchanged in 1990. This figure takes into account both the decrease in auto emission pollutants brought about by the expanded use of electric cars (estimated at 14% by 1990) and the relatively small increase in utility plant pollutants caused in generating the additional electricity needed to recharge EV batteries.

FIGURE 4-3
Typical Hourly Load Profile

3. Lubricant Disposal Impacts of Electric Cars

As part of the analysis of nationwide electric car implementation, a number of possible environmental

impacts were considered, including automotive lubricant disposal impacts.

In 1972 approximately 8 billion liters of lubricating oil were sold in the US. The Environmental Protection Agency estimates that 50% of this oil was consumed in use, discarded with filter cartridges or lost through leakage, leaving an estimated 4 billion liters of waste lubricating oils for which environmentally acceptable disposal was needed. Approximately 2 billion liters of waste oil obtained from automotive crankcases and 1.5 billion liters of aviation and industrial waste oil composed the largest part of the waste oils generated.

Three primary areas of waste oil contamination by unrecovered oil are landfill dispersal, storm drain flow and sanitary sewer flow. Additionally, significant amounts of waste oil may be introduced from road oiling and consequent runoff onto adjacent land and water areas. It is estimated that 618 million liters of undesirably disposed of waste oil could be eliminated (at a maximum) if all US privately owned automobiles were replaced with electric cars.

Environmental ramifications implicit in disposal methods cited above include damage to fresh water and marine organisms at critical points in their life cycles, which in turn, imposes undesirable disruption of food chains in the afflicted ecology.

In addition to reductions in environmental damage, certain other benefits will be realized because EV's do not need crankcase oil. For one, since millions of gallons of waste oil would be potentially eliminated from river systems, storm drains and waterways, costs typically incurred by cleanup operations would be proportionally reduced. Potential health benefits may be realized through diminished contamination of aquifers, and aquatic, agrarian and recreational environments. Many of these benefits are obviously highly subjective and difficult to quantify. Nonetheless, it should be apparent that environmental damage will be lessened by the extensive use of electric cars.

Finally, in terms of maximum petroleum conservation, approximately 2 billion liters less virgin lubricating oil would be required (90% of demand) if all US privately owned automobiles were replaced with electric cars. This represents approximately 59% of all automotive lube demand, 28% of all lube demand, 1% of automotive petroleum demand, and 0.25% of US petroleum demand.

4. Noise Impacts of Electric Cars

The importance of noise pollution and its control have been recognized in recent years in legislation at all levels of government. In particular, the Federal Noise Control Act of 1972 established as a national policy the control of noise emissions that are detrimental to the human environment. The Act, which notes that "... the major sources of noise include transportation vehicles and equipment," is the current basis for regulation of noise emissions from transportation vehicles.

Current urban traffic noise, regulatory goals for the future and resultant changes in noise impacts were recently investigated by the Interagency Task Force on Motor Vehicle Goals Beyond 1980. The Task Force report is the basis for the discussions of community noise and baseline traffic noise (in the absence of electric vehicles) which follow.

The customary measure of community noise is the A-weighted sound level, which ordinarily varies considerably with time. The A-weighting emphasizes sounds in the middle frequencies to which the human ear is most responsive. In quiet areas at quiet times of day, A-weighted sound levels may be as low as 30-40 dB(A), while in very noisy areas they may approach or exceed 100 dB(A).

Noise may be defined as unwanted sound, and when excessive, it interferes with many human activities. An important source of annoyance with noise arises in its interference with communication. At a 65 dB(A) noise level, for example, relaxed conversation is fully intelligible to a listener only within one foot of the speaker, while a raised voice enables easy communication only to a distance of about six feet. An outdoor noise level of 75 dB(A) is typically reduced to 65 dB(A) indoors. Several studies of airport and other community noise have shown that this noise level produces community annoyance that leads to complaints and vigorous community action.

Noise from current automobiles emanates from five sources:

- Exhaust
- Cooling fan
- Engine
- Air intake
- Tires

For most automobiles, exhaust noise predominates at cruise speeds under 56 kilometers per hour (35 mph). At higher speeds tire noise becomes equally significant. During accelera-

tion, exhaust and other engine-related noises increase drastically.

Electric cars do not have an engine, cooling fan, air intake device, or exhaust system. Instead, they have an electric motor and controller, which are typically much quieter than the engine-related components of ICE automobiles. There is, however, a scarcity of quantitative experimental data that indicate the quietness of electric cars.

In the "Intercollegiate Clean Air Car Race" held in 1970, noise levels were measured for several electric automobiles. The quietest electric car, designed from the ground up for electric propulsion, produced passby cruise noise of 58 dB(A) at 48 kilometers per hour (30 mph) when measured at about a 15 meter (50 feet) sideline distance.

In another study, the noise level from an electric car developed at Cornell University was compared to measured noise from 35 other experimental cars with internal combustion engines. The electric car was 12 db quieter than the average of the internal combustion vehicles (64 dB versus 76.3 dB, for 48 kilometer per hour cruise at 7.5 meter sideline distance). Since the Cornell measurements were not A-weighted, however, this level is not directly comparable to the 58 dB(A) figure above. The 12 dB differential relative to conventional cars, however, clearly suggests that electric cars are advantageous.

In view of the above, the cruise noise of the electric car in urban driving is expected to be about 58 dB(A), due primarily to tire noise. During acceleration, the noise of the electric car will increase to about 61 dB(A). This is in line with recent Japanese measurements comparing light ICEV's with EV's, and with current findings on tire noise.

A comparison of passby noise levels for conventional ICE cars and electric cars is shown below. Note that composite noise level for the future electric car is 58.7 dB(A) which is a reduction of 6.3 dB(A).

	Urban Cruise	Urban Acceleration	Composite
Conventional Car			
Current	60 dB(A)	72 dB(A)	65 dB(A)
Future	58	68	62
Electric Car	58	61	59

from the current composite of 65 dB(A) for conventional automobiles.

Desirable reductions in the future impacts of traffic noise are likely with widespread use of electric cars. Relative to existing conditions, however, a comparable reduction in urban cruise noise will probably be achieved through quieting of conventional cars.

The noise impact reduction which might ensue if all future conventional cars were replaced with electric cars is about 10% of the present total impact. This is a relatively modest percentage; on the other hand, nearly 100 million people are presently impacted by urban traffic noise, so in practical terms the contribution of electric cars might be substantial.

Promotional Incentives Study*

Through an interagency agreement, the study of incentives to promote broader utilization and consumer acceptance of EHV technologies is being conducted jointly by DOE and DOT with overall responsibility assigned to DOT-TSC. This first year's efforts have resulted in:

1. The identification and description of all feasible incentives to promote electric and hybrid vehicles;
2. An evaluation of incentives by means of interviews with prospective users and related market research techniques;
3. An evaluation of incentives by means of econometric analysis.

DOT-TSC was the major contributor to the first item. Arthur D. Little (ADL) and MATHTECH, Inc. performed studies and analyses leading to the second and third results, respectively.

* "Federal Incentive Programs for Electric and Hybrid Vehicles," Staff Study, Pollard, J.K., DOT-TSC, July, 1977.

"Incentives and Acceptance of Electric, Hybrid and Other Alternative Vehicles," prepared by Arthur D. Little, Inc., Cambridge, Mass. and submitted to DOT-TSC, Interim Report for the Period May-July 1977.

"An Analysis of Federal Incentives to Stimulate Consumer Acceptance of Electric Vehicles," prepared by MATHTECH, Inc., Princeton, N.J., and submitted to DOT-TSC, August 1, 1977.

1. Identification and Description of Feasible Incentives

The approach which DOT-TSC used was to investigate four broad classes of considerations which influence user acceptance of EHV's and which are amenable to Government incentives:

1. Physical characteristics of EHV's such as capacity, range, comfort, performance, etc., generally considered relative to the characteristics of internal combustion engine-powered vehicles in the same application.
2. Economic characteristics of EHV's, with attention focused chiefly upon purchase, fuel and maintenance costs, again considered relative to similar ICEV's.
3. Regulatory factors (if any) which may favor or constrain the application of EHV's.
4. Institutional factors (particularly the current absence of support services) which constitute a deterrent to the use of EHV's.

With regard to the first class, physical characteristics, technology improvements were identified as a major area where Federal incentives would prove beneficial. In fact, success in advancing technology will undoubtedly enhance the effects of any incentives applied to the other three areas of consideration.

The needed economic incentives which surfaced within the second class resulted from the generally higher total user cost of EHV's compared to ICEV's. This increased cost is, in part, indicative of EHV technology and the low volume and high capital costs which characterize EHV manufacturers. Until such time as improved technology lowers this part of the cost factor, outright subsidies will be necessary to make EHV's commercially competitive in most applications. The low production volume part of the cost issue should be helped by the institution of financial incentives contained with P.L. 94-413 to expand EHV manufacturing and thus capturing substantial economics of scale.

Two principal types of incentives have been identified in the third class, regulatory factors. The first type concerns the prospect for substantial discounts offered by electric utility companies on electricity used for overnight recharging of EHV batteries. The second type of incentive involves vehicle use regulations. Potential incentives which might apply to the promotion of EHV's include:

- Restricting or banning ICEV's in areas of high pollution;
- Establishing speed and acceleration limits on all newly produced ICEV's similar to those of EHV's; and
- Establishment of priority highway lanes for EHV's.

The actual implementation of such regulatory incentives must be regarded as problematic, however, because of extreme public hostility to major restrictions on the use of conventional cars and on the grounds of cost where special EHV facilities are required.

Under the fourth class of incentive considerations, institutional factors, one could entertain an almost unlimited number of influences which could favor, or disfavor, the EHV. However, two principal types of institutional factors appear amenable to change by Government programs. The first of these is public ignorance about, or misconception of, EHV's. This problem is already recognized and will be addressed in a public information campaign now being planned by DOE. The second major institutional problem is the lack of a system of supporting services for EHV's. Distribution and retailing, financing, insurance, repair parts and service, recharging away from home, and resale of used cars are all areas where problems need to be overcome through the application of an effective incentives strategy.

2. Incentives Evaluation Via User Interviews

In performing this investigation, ADL investigated three fleet uses: passenger cars, light trucks and vans, and mass transit. In short, their survey findings indicate that a large market for EHV's is not likely by 1983, unless price or availability of petroleum-based fuel changes radically. The present adaptations to ICEV technology and infrastructure constitute formidable barriers to EHV acceptance. More detailed results are presented in the following paragraphs.

There are no perceived relevant advantages to EHV's; those that are purported are either not believed or are considered irrelevant to the purchase decision process under present conditions.

Less maintenance, purported to be an advantage, is not credible for two reasons: (1) those who have had experience with EHV's have had increased maintenance problems and believe even 1983 technology

will have "bugs" to be ironed out; (2) there are no hard data to prove the lower maintenance claims.

The longer life built into the life cycle cost figures is also discounted for two reasons: (1) no EHV's have been in continuous duty cycle operation for the stated lifetimes to prove the contention; (2) body rot, not engine life, is the key to much present turnover in ICEV's—particularly those with Diesels.

Quiet running is not a major consideration in the purchase decision process. It has, in fact, proved hazardous in the very environments where EV's are most advantageous—multistop urban routes—because pedestrians do not watch for vehicles approaching curbs; they listen for them. Pollution-free performance is also not usually a major factor in the purchase decision process.

Lower costs, a distinct advantage for the purchase process, are achieved only by some form of subsidy; there is no guarantee that the subsidy will go on for the life of the vehicle.

Even with a guaranteed subsidy or an actual (unsubsidized) lower cost, however, EHV's require many changes in driving patterns and provide less in the way of vehicle performance, so the price/value relationship is difficult to determine.

At the present time, most conventional fleets are largely nondedicated, i.e., vehicles are rotated among missions. Rotation is considered to be a good business practice because it allows a fleet to age more evenly (a positive factor when body deterioration is a major enemy of vehicle longevity). EV's must be dedicated to missions which are amenable to their performance limits. This is far less true of HV's.

Nondedicated vehicles mean common denominator vehicles which can serve a multitude of functions. Common denominator vehicles tend to be larger and more powerful. ICEV's offer a wider variety of common denominator vehicles (e.g., station wagons) than the EHV's that have been considered, and ICEV's tend to give maximum performance under the simultaneous strains of load, acceleration, and auxiliary power drains from air conditioning and the like.

Drivers, in many firms, are entitled to take their vehicles home at night. The driver gets an "extra," which is not considered as income. In return, requirements for company lot or garage space is reduced. This presents two problems with EHV's: (1) daily missions may use up most of the available range, thus preventing the driver from taking the vehicle home; (2)

if a driver were able to take the EHV home, night-time charging would have to be done at the driver's home (causing reimbursement problems), or the driver would have to stop at the company for an exchange of batteries.

Cost incentives fail to elicit much response, primarily because subsidies, which provide a means of lowering manufacturing and retail costs, do not overcome other economic liabilities, such as the expense of adopting a new vehicular system or the lowered value of EHV's because of poorer performance.

Leasing, as an incentive, helps address some of the infrastructure and new technology concerns (e.g., obsolescence). But leasing may again mean, for many companies, either (1) having two systems (owned ICEV's for tax advantages; leased EHV's for infrastructure advantages) and the hidden costs of doing so (e.g., maintenance facilities and personnel only partially utilized); or (2) adapting the entire system to suit EHV's. Company-provided infrastructure support would present the same problems.

Incentives involving performance improvements had little effect, partly because of skepticism, but more frequently because even the improved performance of EHV's fell noticeably short of ICEV performance. The shortfalls were in areas that fleet managers consider critical to the mission or that are inextricably bound to prevailing practices which managers and drivers do not wish to abandon.

The EHV service system is not now compatible, nor is it likely to be by 1983, with that of present vehicles. Hence, for a company to utilize EHV's, it would have to sustain two transportation systems rather than one unless it could totally convert to EHV's, a rather inconceivable feat. The Diesels, which can offer many of the same advantages claimed for EHV's in terms of longer life, lower maintenance, and better performance under urban multistop conditions (and Diesels have more proof for their claims), can more readily be accommodated within the present automotive system and infrastructure.

Many of the respondents interviewed expressed incredulity about the performance data of EHV's. EHV's have no proven track record with regard to longevity, etc. Since second generation vehicles are only in the prototype stage in the U.S., the respondents expressed substantial doubts that these vehicles can live up to performance claims.

EHV performance was unacceptable to most re-

spondents interviewed; however, two factors must be taken into account in considering their judgment: (1) the fact that their skepticism made them discount performance claims; (2) the fact that performance equivalent to that of ICEV's can only be achieved through less convenient means—e.g., by having to change batteries in midroute. Some performance factors clearly meant that EHV's were incapable of certain missions (e.g., long urban or highway missions where vehicles do not return to home base). Other factors clearly make EHV's less preferable than ICEV's (e.g., lack of air conditioning).

3. Econometric Analysis of Incentives

To complete the incentives study, MATHTECH employed their Electric Vehicle Demand Model, along with cost and performance projections (provided by DOT-TSC) of both electric and internal combustion engine passenger vehicles, to project vehicle demand. A baseline projection which assumed no Federal incentive programs was compared to a series of projections based on various possible incentives:

1. \$300 Subsidy: This incentive, a \$300 subsidy to purchasers of electric vehicles, is being considered in current Congressional energy hearings.
2. \$1,000 Subsidy for Electric Vehicle Purchases.
3. \$3,000 Subsidy for Electric Vehicle Purchases.
4. Off-Peak Pricing: This would reduce the cost of electricity during off-peak hours, the normal recharging hours for EHV batteries. Specifically, it was assumed that electricity would be available during the 9:00 p.m. - 6:00 a.m. period at the following rates (1975 dollars):
1977-1985, 4.34 cents/kwh
1986-1990, 4.40 cents/kwh
1991-2000, 4.44 cents/kwh
5. Fifty Cent Gasoline Tax: This involves a gasoline tax along the lines proposed by President Carter, beginning at five cents per gallon in 1978 and rising in annual five-cent increments to fifty cents.
6. A Ten Cent Gasoline Tax: This involves a milder gasoline tax, set at a flat rate of ten cents per gallon in all years.
7. Improvement in Electric Vehicle Technology: This projects technological developments

which will double the maximum daily range of EHV's at no increase in cost.

8. One-third Operating Subsidy: For this policy it was assumed that the Government provided a subsidy of one-third of the initial purchase price and the cost of maintenance, tires and insurance. That is, all components except electricity and "miscellaneous" expenditures were subsidized. This subsidy is intended to simulate a program in which drivers rent their vehicles at favorable rates.
9. First Combination Experiment: This combines the fifty cent gasoline tax and the doubling of

the electric vehicle range.

10. Second Combination Experiment: This combines the fifty cent gas tax with the one-third operating subsidy.

The computer demand model was used to analyze the impact of the above listed incentive policies selected by DOT-TSC. Table 4-8 provides a brief description of the incentive policies, as well as the projections of electric vehicle sales, on-the-road stock and kilometers traveled by electric vehicles under each of these policies. For comparison, the projections are given for the baseline case (assuming no incentive programs) as well.

TABLE 4-7
Analysis of Incentives to Stimulate
The Demand for Electric Vehicles

Policy	1990 Vehicle Sales		1990 On-The-Road Stock		1990 Distance Driven	
	Number	% Increase	Number	% Increase	(millions of Km) Increase	% Increase
Baseline	23,000	—	167,000	—	2,269	—
1. \$300 Subsidy to EV Purchasers	32,000	39	231,000	38	3,458	52
2. \$1,000 Subsidy to EV Purchasers	67,000	191	491,000	194	7,340	223
3. \$3,000 Subsidy to EV Purchasers	554,000	2,308	4,142,000	2,379	61,663	2,617
4. Off-Peak Electricity Prices of Night Time Battery Recharging	31,000	35	226,000	35	3,393	49
5. 50 cents Gas Tax, Im- posed in Annual Increments of 5 cents Beginning in 1978	69,000	200	457,000	174	7,037	210
6. 10 cents Gas Tax, Imposed Immediately	28,000	22	209,000	25	3,127	38
7. Doubling of Range of Vehicle (at no cost)	70,000	204	543,000	225	8,016	253
8. Operating Subsidy, Equal to One-Third of Initial and (with minor exceptions) All Operating Costs	279,000	1,113	2,300,000	1,099	29,974	1,221
9. Combination of 5. and 7.	210,000	813	1,447,000	766	22,223	879
10. Combination of 5. and 8.	809,000	3,417	5,331,000	3,092	82,085	3,515

As can be seen, the various policies have markedly different impacts. Fortunately, there is a simple basis for explaining why this is so: To a first approximation, the logic of the computer model is such that the demand for electric vehicles is a function only of the difference between the capitalized cost per kilometer for electric vehicles and the capitalized cost per kilometer for subcompact ICEV's. Each of the ten policies affects this difference. Some policies, like the \$300 subsidy, lower the capitalized cost per kilometer for electric vehicles; in other cases, like the gas taxes, the policies raise the capitalized cost per kilometer for ICEV's; in still other cases (the combination policies), both ICEV and electric vehicle costs are affected.

All the policies considered in this analysis in fact operate to change one or both of these prices—either by making electric passenger vehicles less expensive, ICEV's more expensive, or a combination of both.

As can be seen from the table, it is clear that a substantial decrease in the capitalized cost per kilometer is needed if electrical vehicle sales are to be significant in practical terms. For example, the \$3,000 purchase subsidy, which has one of the largest impacts, reduces the initial cost of the vehicle by about two-thirds. However, it is possible that other policies not considered here might have a considerable impact on costs without requiring large subsidies to purchasers. For example, improvements in electric vehicle technology (e.g., increased battery cycle life) can have significant cost impacts, with a resulting major increase in EHV use. In short, the range of policies considered by the Federal Government might usefully be increased from those given in the table. In summary:

- Given the assumptions about ICEV and electric vehicle characteristics provided by DOT-TSC, and the fact that potential EHV users are primarily concerned with cost, the demand for electric or hybrid vehicles is likely to be negligible without significant cost improvements, either through direct subsidy or through improved technology.
- Thus, given two subsidy plans with equal impact on cost, policy analysts should concentrate on analyzing attributes such as ease of administration.

Safety Standards and Regulations Study*

P.L. 94-413 specifies that a study of safety standards and regulations relative to EHV's be conducted by the Secretary of Transportation. The Secretary has assigned this task to the National Highway Traffic Safety Administration (NHTSA).

Areas which affect safety standards and regulations of EHV use are categorized as chemical problems, electrical dangers, crashworthiness, the electric vehicle as a member of the traffic stream, and the applicability of current or future motor vehicle safety standards.

Chemical problems which may result primarily from batteries include leaks, acid burns, and the possibility of explosion during charging operations. Electric dangers may arise because of the use of relatively lethal voltages (greater than 100 volts) in some vehicles. Crash-worthiness may be considered with respect to the power system (battery spills as a result of crashes, electrical danger as a result of crashes, etc.) and with respect to interior safety of occupants.

On July 14, 1977, NHTSA held a public hearing for the purpose of soliciting competent testimony on the applicability of safety standards to EHV's. The hearing was well attended; twenty-two speakers supplied relevant testimony, and their consensus was that NHTSA should develop and apply an appropriate class of safety standards to EHV's since any motor vehicle should exhibit a minimum level of safety compatible with that exhibited by other vehicles when operated in the same highway environment. Where current standards are not directly relevant to electric or hybrid vehicles (as in the case of fuel system integrity), exemptions should be allowed.

* "Comments on Public Hearing, Application of Federal Motor Vehicle Safety Standards (FMVSS's) to Electric and Hybrid Vehicles (EHV's), National Highway Traffic Safety Administration (NHTSA), Washington, D.C.," July 14, 1977, Eastman, S.E., The Economic Sciences Corp., July 19, 1977.

"Applicability of Federal Motor Vehicle Safety Standards and Regulations to Electric and Hybrid Vehicles," DOT-NHTSA, September, 1977.

Based on the findings of this public hearing and the results of NHTSA's safety evaluation, NHTSA has determined that nearly all existing Federal Motor Vehicle Safety Standards should be applicable to EHV's. Furthermore, NHTSA is recommending to DOE the adoption of the following safety specifications for all demonstrations:

1. Electrical isolation of the propulsion batteries from the vehicle chassis and/or electrical-conducting components, adequate to prevent shorting during a 48 kilometer per hour (30 mph) frontal barrier crash.
2. Ground fault interruption on transformerless, on-board chargers.
3. A battery charger receptacle lock.
4. An interlock to disconnect charging power if the battery compartment is opened.
5. An interlock to prevent driving the vehicle while still connected to the charging power source.
6. Propulsion system fuses and/or circuit breakers.
7. Warning light and or a buzzer for motor overheating.
8. A standard to limit electrolyte spillage.
9. Positive ventilation within the battery compartment to maintain the concentration of hydrogen below 4 percent by volume during charging, regenerative braking or in the event of cell reversals during discharging.
10. Explosion-proof battery caps.
11. Spark arrestors and insulated connectors.
12. Sufficiently strong mounts to prevent batteries from intruding into the passenger compartment during frontal, rear and side collisions and during a dynamic rollover test.

NHTSA is also proposing that:

- Separate circuits to prevent loss of power to auxiliary electrical systems like lights and flashers be provided, along with an audible backup warning signal.
- A mechanism be established for detailed investigation of accidents involving electric and hybrid vehicles.
- For 1982 and beyond, a standard permitting no spillage of electrolyte (particularly for high-temperature batteries like the lithium-metal sulfide type) be adopted.
- A standard for containment of flywheel

systems (in the event of severe crashes and the control of gyroscopic forces on vehicle handling) be adopted.

Depending upon the experience with the demonstrations, NHTSA intends to develop all of the above recommended specifications into Federal Motor Vehicle Safety Standards which will be applicable to all future electric and hybrid vehicles.

Regenerative Braking Study*

The study of the effectiveness and feasibility of regenerative braking systems was conducted by the Lawrence Livermore Laboratory and is related to a study that LLL has been performing for the DOE on "Analysis of the Effect of Energy Storage Power Systems on National Transportation." The remainder of this section is devoted to a summary of LLL's report and findings.

The recovery of a vehicle's kinetic energy during periods of deceleration, i.e., when descending an incline or coming to a stop, has long been considered by many as a worthwhile method of increasing vehicle efficiency. This method of energy recovery is called regenerative braking because in addition to recovering kinetic energy by charging an on-board storage device for later reuse, the load imposed by the charging causes the vehicle to decelerate or brake.

Energy recovery, of course, increases the vehicle's efficiency, while the regenerative braking system saves wear and tear on the normal service braking system. This has been particularly effective for railroad systems. Regenerative braking systems have also been proposed and, in some cases, installed in electric vehicles to increase range; yet it is still not clear which design approaches (of the myriad available for these systems) are best.

Regenerative braking has a 90-year history, and the basic technology is available in a number of forms. No technical breakthroughs are needed to apply these principles. However, there is a lack of knowledge about the effects of regenerative braking upon battery life and battery energy storage characteristics. There is a general belief that they are positive and beneficial

*"Determination of the Effectiveness and Feasibility of Regenerative Braking Systems on Electric and Other Automobiles," Vol. I and II, (interim progress report), Davis, D.D., et al., Lawrence Livermore Laboratory, July 11, 1977.

effects, but information is needed to support future design efforts.

Regenerative braking will not replace the normal service brakes of the vehicle. Service brakes will still be needed for hand braking and for bringing the vehicle to a final stop. Regenerative braking, however, can salvage a very significant amount of energy, because most stops involve only moderate decelerations and because very little of the recoverable energy remains in the final low-speed portion of the deceleration.

For vehicles which do not already have the basic elements needed for regenerative braking (such as the standard auto powered by an IC engine), the economic incentive for adding regenerative braking is marginal at best and does not seem to be warranted. This is particularly true for privately-owned autos, but there may be greater incentive to use regenerative braking in city buses, taxis or delivery vehicles which encounter stop-and-go driving missions.

Most EHV's already have the basic elements needed for regenerative braking. Regenerative braking can be added for only a slight additional cost, mostly in the controls. For such vehicles, regenerative braking is clearly justifiable from an economic viewpoint.

Range extension (for range-limited electric vehicles) is a valuable attribute of regenerative braking. It is difficult to assign a dollar value to range extension, but the values would be at least equivalent to the lifetime costs of the extra batteries which would otherwise be needed to provide the range extension.

The energy savings achievable through regenerative braking are very strongly influenced by the characteristics of the driving schedule (driving cycle). There is a strong correlation of braking energy with the frequency of stops. Since many variables affect the practical result, there are no single, well-defined values for energy savings or range extension.

Energy savings (in urban stop-and-go driving) of 15-25% would be a major benefit of regenerative braking systems. This corresponds to an increase in range of 18-33%. Regenerative systems utilizing mechanical energy storage devices such as flywheels will generally provide a higher level of recovery than systems that use electrical storage. Accordingly, regenerative braking appears justifiable for stop-and-go urban vehicles, and those operated in hilly terrain.

Regenerative braking should be a valuable asset for electric and hybrid vehicles to be acquired for the

later demonstrations. Demonstration vehicle specifications and standards should be written in a way that will utilize the beneficial gains which regenerative braking can provide. However, since many design options exist, the specifications should not constrain the vehicle designer by specifically requiring that regenerative braking be incorporated.

A review of patents did not bring to light any blocking patents now in force. Most of the technology is in the public domain. There remains an incentive for invention mainly in the area of improved control technology and in the reduction of manufacturing costs.

II. Vehicle Performance Standards*

As required by Section 7 of P.L. 94-413, rules establishing performance standards for electric and hybrid vehicles to be acquired for demonstrations will be posted by December 17, 1977, and will be revised periodically until September, 1980. Contracts have been awarded to the General Research Corporation and Arthur D. Little, Inc., to examine the available electric and hybrid vehicle technologies and establish reasonable standards for the acquisition of these vehicles. Any differences in the standards developed by these two contractors are to be adjudicated by a committee established under the auspices of the Society of Automotive Engineers (SAE). This committee is composed of representatives from small business, universities, consumer interests, and the automotive industry. DOE will exercise final judgement on the standards that are ultimately promulgated.

To date, both contractors have completed their background data collection and analysis and have submitted final reports which contain their recommended standards. Factors that have been considered include: performance, emissions, safety, roadability, passenger comfort, maintainability, operating range, rechargeability, payload capacity, and operability in extremes of weather conditions. The

*"Minimum Performance Standards for Electric and Hybrid Vehicles," (Letter Report), Underhill, B.B., Arthur D. Little, Inc., July 18, 1977.

"State-of-the-Art Assessment of Electric and Hybrid Vehicles," NASA Lewis Research Center, September, 1977.

"Electric and Hybrid Vehicle Performance and Design Goal Determination Study," Brennand, J., General Research Corp., May 26, 1977.

SAE has reviewed the recommendations of the two contractors and has submitted a report to DOE with their findings and recommendations.

In performing the studies which have culminated in vehicle standards, agricultural applications were found to require a more in-depth analysis. As a result, ERDA has held discussions with the USDA and it is expected that an agreement (between DOE and USDA) will be reached wherein a separate study will be initiated of agricultural missions which EHV's could fulfill. This study will begin in early FY 1978, will identify and assess EHV applications specific to agriculture, and will delineate the required technologies to fit these applications.

III. Environmental Assessments

The National Environmental Policy Act (NEPA) of 1969 requires the preparation of Environmental Impact Statements for major Federal actions significantly affecting the environment. The environmental impact statement process has three steps. These steps, in chronological order, are: (a) environmental impact assessment (EIA), (b) negative declaration or draft environmental impact statement (DEIS), and (c) final environmental impact statement (EIS).

The EIA process identifies all environmental impacts (as they affect the ecosystem, resources, physical environment, health, safety, and socio-economic areas) resulting directly or indirectly from the action. It must also assess the severity of the impacts and estimate the time and amount of research necessary to characterize the impacts. The EIA is the forerunner of the DEIS and identifies problems that must be solved before the DEIS can be written. Before the EIS becomes final, the DEIS is revised based on the results of public review and hearings.

The Electric and Hybrid Vehicle R, D&D Project requires two EIS processes because the scope and timing of the assessments for the demonstration activities do not coincide with DOE's requirement for a comprehensive electric and hybrid vehicle programmatic assessment. An EIA is scheduled for FY 1978 to precede the first demonstration. A determination of the need for an EIS will be made, based upon this EIA. The programmatic EIA is scheduled to be completed during late FY 1978, and will be amended as required to reflect improvements in technology and changes in the demonstration scope.

Development of the electric and hybrid vehicle programmatic EIA will include substantial

involvement of the public, Government agencies and industry. Workshops will be held with the public, regional transportation planners, transportation system operators, and local governmental officials in order to develop a thorough perspective on the impacts. It is expected that these workshops will result in a broader appreciation of the environmental issues, and will allow R, D&D decision processes to incorporate the proper and necessary consideration of environmental impacts.

An Environmental Development Plan (EDP) is the basic DOE document for planning, budgeting, managing, and reviewing the environmental activities for all DOE energy technologies. It outlines the requirements for the above-mentioned processes.

A pilot EDP for the Electric and Hybrid Vehicle R, D&D Project was completed in August 1977. The full programmatic EDP for the Electric and Hybrid Vehicle R, D&D Project is underway and scheduled for completion by October, 1977.

IV. Other Related Studies

The need for additional related studies will depend on the results of state-of-the-art vehicle testing, early demonstrations and current study efforts. They will most likely be long range studies directed toward assisting the emergence of a self-sufficient electric and hybrid vehicle industry, but they are also likely to affect the planning for later vehicle demonstrations. Examples of such areas are:

- Electric and hybrid vehicle use relative to other forms of available transportation;
- Vehicle life-cycle costs as a function of depreciation period, operating expense, maintenance, etc.;
- The impact of specific financial incentives.

It has not yet been determined which types of electric and hybrid vehicles would be useful for agricultural applications and still meet the stated intent of P.L. 94-413. Certainly, applications requiring high power levels such as heavy tillage are not feasible with existing or projected battery technology. At the other end of the spectrum, there are small vehicles which can be steered by the driver's knees, leaving his hands free for other chores, such as gathering eggs. Such vehicles are already developed, yet their potential impact on energy consumption is virtually immeasurable. An evaluation of EHV applications to agriculture will be undertaken in the joint effort study previously described in Section II of this chapter.

CHAPTER 5

FINANCIAL INCENTIVES

I. Incentive Requirements

In addition to the market support provided to the emerging electric and hybrid vehicle industry, P.L. 94-413 authorizes two specific forms of financial incentives. The two incentives are encouragement and protection of small business and loan guarantees. Further, the Act authorizes studies and research on incentives to promote broader utilization and consumer acceptance of electric and hybrid vehicle technology. Specifically, P.L. 94-413 authorizes the following actions regarding small business concerns:

- Reserve a reasonable portion of funds for research, development or demonstration contracts for small business concerns;
- Include in all contracts the terms, conditions and payment schedules as may assist in meeting the needs of small business and avoid terms, conditions or penalties that would tend to prevent their participation;
- Make planning grants available to qualified small business concerns that require assistance in developing, submitting and entering into such contracts.

Factors that were considered in this assessment include the industry product profile, the mix of projects to be funded in R&D, demonstration and study areas, and target levels for small business participation in DOE-wide programs that deal with energy conservation.

II. Loan Guarantees

Public Law 94-413 sets forth in some detail the guidelines for the loan guarantee authorities, leaving only a limited area for discretionary action by DOE in the implementation of the program. The purposes of the loan guaranty program are to assure that qualified small business concerns are not excluded from participation in the EHV project due to lack of adequate capital and to encourage early commercial production. A brief outline of the significant provisions of the act is as follows:

1. Under Section 10, loan guarantees are available to qualified small business and other qualified borrowers to encourage commercial vehicle production. Guaranteed principal and interest of loans are to

be available, as set forth in the proposed regulation, for:

- Capital equipment construction related to research, development and production (first priority);
 - Initial operating expenses of development and production (first priority also);
 - Prototype development of vehicles and parts (second priority);
 - Research and development (third priority).
2. Up to 90% of the cost of the loan activity may be financed and loans are to be guaranteed only if:
 - The Secretary determines the interest rate is reasonable;
 - The term does not exceed 15 years;
 - The amount of the loan together with other capital enables the borrower to carry out the activity;
 - There is a reasonable assurance of repayment;
 - There are no other reasonable means of financing available.
 3. Additional provisions are that:
 - Each loan guarantee is not to exceed three million dollars, unless raised by the DOE Secretary to meet the purpose of the Act, and Congress is notified;
 - The aggregate guarantee is not to exceed 60 million dollars;
 - The qualified borrower must have presented satisfactory evidence of interest in the electric and hybrid vehicle project and be capable of performing research or completing development and production of vehicles or components.
 4. DOE will pay interest charges if:
 - The borrower is unable to meet the charges and cost to the Government is less than the cost of default; and it is in the public interest to permit the borrower to continue the project.
 - The charges are no greater than the interest charges to the borrower.
 5. Upon default, the Attorney General shall recover from the defaulting borrower's assets or from other surety included in the terms of the guarantee.

6. The loan guarantee authority expires five years from the date of enactment (September 17, 1981) and loan applicants must be U.S. Citizens or Nationals.

In planning the implementation of the Loan Guaranty Program, care has been taken not to exclude those organizations which could be assisted in becoming healthy participants in the commercial Electric and Hybrid Vehicle Industry. On the other hand, the criteria were designed to permit adequate screening of applicants and to identify those who see the Federal funds as an opportunity to cut their risk in promoting a small, short-term venture for the sole purpose of the demonstration acquisitions. Loan guarantee acceptance criteria were designed to provide reasonable financial help for the serious entrepreneur for expanding or developing an existing capability, while, at the same time, these criteria are restrictive enough to protect the program from any irresponsible participants.

The Electric and Hybrid Vehicle R, D&D Project Loan Guaranty Program is not a high-volume, risk-spreading program like FHA or VHA Housing Guarantees where the Government as a matter of social policy wants to ensure availability of credit to classes that might otherwise be shut out of loan markets. Such programs are generally of long duration, and defaults can be predicted. The Electric and Hybrid Vehicle R, D&D Project, on the other hand, involves "accelerated" research and relatively short lead times for vehicle production. Accordingly, the focus is on individual firms, and the incentives program has established the means to identify those who are both genuinely interested and capable (i.e., those who are "qualified borrowers").

Pursuant to Section 10 of P.L. 94-413, loan guaranty regulations were published for comment on April 22, 1977. The comment period closed May 23, 1977, with only seven respondents. In order to develop a continued working relationship with the lending community and understand the community's position relative to participation in the loan guarantee process, DOE initiated an out-reach program to contact the prime lenders throughout the country. Forty-one executive level officers in selected financial institutions in six cities were visited at the senior officer and vice president levels. The synthesis of these discussions has been taken into consideration in drafting final regulations. Publication of final regulations has been

delayed because of a provision in Public Law 95-91, the Department of Energy Organization Act, which requires that the comment period on the proposed regulations published in April, 1977, be extended for an additional thirty days. Before final regulations become effective, DOE intends to conduct a public awareness program to assure that the lending communities and electric and hybrid vehicles industry, including the small business community, have every reasonable opportunity to learn of the regulations and procedures. Initiation of the Loan Guaranty Program will require a specific Congressional appropriation in FY 1978.

III. Planning Grants

Most of the entrepreneurial firms which might participate in the EHV market are small businesses with limited financial resources. While DOE is directed, in Section 9 of the Act, to set aside funds for contracts with these small businesses to carry out research, development and demonstration activities, these firms may lack the financial resources needed to develop and submit proposals which will enable them to enter into such contracts. The provision of planning grants will overcome this barrier to small business participation.

The DOE Secretary has great latitude under P.L. 94-413 in determining the scope and extent of the planning grant activities. The statute instructs that such grants be made available for "developing, submitting and entering into research, development or demonstration contracts." It does not tie the grants to the preparation of competitively solicited proposals.

By definition, planning grants may only be used to cover costs normally incurred in developing, preparing and submitting a proposal to DOE. They cannot be used to pay for research, development, design, testing, or other end-product oriented efforts.

For implementing the planning grant program, DOE has taken a straightforward approach by designing the program so that its provisions and requirements can be easily understood by small business concerns. To achieve the maximum possible dissemination of planning grant program information, DOE will issue semi-annual announcements through October, 1981, the date which coincides with the end of the loan guaranty program.

No upper limit for planning grants has been established, and those requesting grants will be ad-

vised that an excessive request for grant funds will penalize an otherwise acceptable grant request. In questioning the small business community it was learned that their estimate for cost of preparing proposals was in the range of \$8,000 to \$12,000. DOE encourages those who cannot show a financial need or for other reasons do not qualify for a grant to submit an unsolicited proposal or respond to requests for proposals on their own initiative. In establishing provisions for planning grants, DOE has made it clear that there is no guarantee that all who request a grant will be successful and no guarantee that any proposals resulting from such a grant will be accepted.

To date, DOE has completed a detailed study of similar Federal grant programs for potential guidance in establishing the EHV planning grant program. Background discussions have been held with more than 35 small businesses and individuals interested in applying for a grant in order to solicit their input for the planning process. Agreements have been reached with the Small Business Administration (SBA) for applying the appropriate SBA-established definitions of a "small business" to the grant program. For purposes of planning grant eligibility, a small business is a firm, including its affiliates, that is independently owned and operated and is not dominant in the field of operation in which it proposes to bid on Government contracts. If the firm is a manufacturer or regular dealer planning to submit proposals in its own name, it must agree to furnish end items manufactured or produced in the United States, its possessions, or Puerto Rico by small business firms. Also, at least 50% of the value of all components and materials

to be used in any item for which a grant request is submitted must be of domestic origin.

In terms of additional progress, a Planning Grant Program Announcement is being developed and will be issued as soon as funds are available. Procedures for administering the grant program are being developed and soon will be ready for implementation.

IV. Studies and Research

Public Law 94-413 authorizes studies and research on incentives to promote broader utilization and consumer acceptance of electric and hybrid technologies. Certain appropriate studies are now being considered independent of other activities in the demonstration or research programs. Examples of the areas of studies currently under consideration are:

- Sales and use patterns where electric and hybrid vehicles have been marketed;
- Reasonable targets for the electric and hybrid vehicle share of the future automotive market.
- Identification of constraining factors that could prevent achievement of such targets;
- Review of existing financial incentives that promote or retard market growth;
- Determination of a means for subjugating market growth barriers by adequate assistance and identification of barriers most susceptible to financial impact.

These studies will be undertaken to complement the promotional incentive programs as their suitability, need and appropriateness are established.

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CHAPTER 6 DEMONSTRATIONS

I. Demonstration Requirements

Public Law 94-413 specifies that demonstration projects be conducted to determine the economic and technological practicality of electric and hybrid vehicles for personal and commercial use in urban areas, and for agricultural and personal use in rural areas. Specifically, Section 7 of P.L. 94-413 authorizes the following actions:

Schedule	Action
Within 12 months	Characterize current state-of-the-art through vehicle tests.
Within 15 months	Promulgate performance standards for both personal and commercial use; report to Congress.
Within 21 months	Contract for Phase I Demonstration vehicles.
Within 39 months	Deliver last of Phase I vehicles; conduct demonstration.
Within 48 months	Amend performance standards.
Within 54 months	Contract for Phase II Demonstration vehicles.
Within 72 months	Deliver last of Phase II vehicles; conduct demonstration.

The above demonstration program will be conducted in consonance with and supported by the various research and development activities outlined in Chapters 2 and 3.

II. Implementation Plans

DOE has established an overall approach toward the vehicle demonstration program which will maximize the value of the demonstration while minimizing the risk of obtaining inaccurate results or an unfavorable public reaction stemming from factors other than the characteristics of the vehicles. Some of the expected outputs from the demonstrations are:

1. Identification of suitable roles for electric and hy-

brid vehicles in the nation's transportation system.

2. Development of consumer awareness of electric and hybrid vehicles' characteristics.
3. Establishment of an operating cost, performance and reliability data base for in-service operation.
4. Provision of user feedback to serve as input to subsequent planning of the R&D activities.
5. Development of insights into maintenance, service and support requirements.
6. Development of a data base which will allow more precise impact and market assessments.
7. Stimulation of industry capability for the production of quality vehicles.

Only by adopting a "user orientation" toward the demonstrations can DOE expect to obtain an accurate assessment of electric and hybrid vehicles. The achievement of specified demonstration goals requires that the selection of test sites, screening and selection of participants (users), definition of support requirements, data evaluation, and communication of information to the public be set within a framework which as closely as possible resembles the commercial world.

The primary organizational components of the demonstrations as currently envisioned are: (1) a demonstration planning/management support contractor; (2) demonstration site operating contractors; (3) vehicle manufacturers/suppliers; and (4) industrial, commercial, Federal, and State fleet operators and individuals who may become vehicle users.

Implementation of the demonstration project will be largely conducted by contractors chosen from among those industries ultimately responsible for the commercial success of electric and/or hybrid vehicles. The Government's role will be to oversee operations and verify that schedules are adhered to and goals achieved.

The first responsibility which DOE has addressed is the initial planning and organization of the demonstration. There are many variables to be considered, such as: the location of the demonstration; the number of vehicles per site; the type of vehicles per site; the operators of the site data collection system; the users of demonstration vehicles; the types of missions; the

legal and financial arrangements between the site operator, user, manufacturer and the Government; the manner of vehicle disposal; the test data requirements; the time and procedures for gathering test data; the R&D program interface with the demonstration project; and the manner in which both will be conveyed to the industry and public. All of these factors are being carefully considered for their impact on a successful demonstration program. Their treatment for each demonstration phase will likely be different depending on the nature of demonstration progress.

Booz, Allen and Hamilton (BA&H) is the demonstration planning/management support contractor that is providing planning support for all activities required to conduct the demonstration and providing management support to monitor the progress of the demonstration activities through their entire term.

In assisting DOE's planning of the demonstrations, BA&H is tasked to recommend to DOE:

- A rationale for the nationwide distribution of site locations and site composition.
- The appropriate types of organizations to operate the demonstration sites.
- A rationale for the appropriate mix of demonstration users/drivers, their method of participation and the missions to be undertaken.
- The data elements to be provided by demonstration site operators, and the synthesis and frequency of data reporting.
- The complete vehicle logistics support package that will be needed by each site operator.
- The optimum method of vehicle selection.
- The optimum method of vehicle financing.
- Descriptions of various demonstration vehicle life cycles.

In addition, BA&H is conducting a survey of appropriate past vehicle demonstrations and potential demonstration opportunities; defining the role of the demonstration site operator; and developing a comprehensive plan for public information dissemination. A draft plan for the first demonstration phase is due to be completed by December, 1977. The schedule for currently planned demonstration activities is shown in Figure 6-1.

III. Informing the Public

One of the major elements of the demonstration program is to generate the widest beneficial publicity for electric and hybrid vehicles in order to increase their consumer acceptance and assure their ultimate commercialization. Public awareness was initiated through an ERDA sponsored public meeting held on March 1, 1977, at the Commerce Department Auditorium in Washington, D.C. A public awareness program which will operate in conjunction with the demonstration program has been planned. Implementation techniques and selected audiences for this publicity are described below.

Target Audiences

- Potential manufacturers/suppliers of vehicles, components, operating support equipment, and facilities. Included in this group is the electric utility industry which must be kept abreast of projected growth in demand for battery recharge energy which may lead to increased capacity, electric power generating stations. Potential manufacturers include present major and minor automotive manufacturers, present electric vehicle manufacturers, and new manufacturers.
- Federal and State Government departments, agencies, and offices. Such organizations are large volume buyers and users of automotive vehicles and are in an excellent position to demonstrate the practicality of electric vehicles by mandating purchase and use of these vehicles for Government operations.
- Fleet operators in the private sector (e.g., urban delivery, taxi service).
- Personal transportation users.
- Energy and environment conservationist organizations.

Implementation Techniques

- Visibility of demonstration vehicles in various parts of the country
- News releases
- Brochures
- Newsletters
- Speeches and articles

- Films
- Position papers
- Responses to inquiries
- Annual reports to Congress

- Multi-city seminars and demonstrations
- Displays at public meetings
- Guidelines for participants
- Consumer and industrial surveys.

FIGURE 6-1
Electric and Hybrid Vehicle Demonstration Schedule

IV. Desirability of Foreign Components

Although a detailed assessment of foreign technology is outside the scope of this report, an examination of foreign component and vehicle development activities as they may relate to the demonstrations is presented here. In addition, this section will address the restrictions imposed by law or regulation upon the importation or use of chassis or components and the extent to which these restrictions may impede the achievement of the Act's purposes.

In general, foreign component and vehicle system development programs are quite significant and in several cases precede similar efforts in this country by several years. The most significant foreign component and vehicle developments have appeared in Japan, Great Britain and West Germany. Other countries which have undertaken EHV development programs include the USSR, France, Italy, Sweden, and the Netherlands.

Japanese activity has included close cooperation among government and several major manufacturers and power companies since 1967. Several 70-passenger electric buses have been in trial operation in Japanese cities since 1975 and prototype versions of compact and lightweight electric cars, compact and lightweight electric delivery vans, and an electric route bus were demonstration tested on public roadways in 1976.

Electric vehicle development in Great Britain has been performed primarily by the private sector. Major manufacturers have been involved in only a limited way, but small commercial vehicles that appear viable have been produced. In addition, several larger commercial vehicles and buses are in service.

The West German development program is also a cooperative venture among government, industry and the utilities. Significant efforts are underway on components, systems and vehicles. Participating manufacturers include Volkswagen, Mercedes-Benz and MAN. Fleets of Mercedes and VW delivery vans of second-generation design are being tested, and electric buses are in demonstration revenue service in two German cities. Significant component and infrastructure system developments also have been made in Germany. These include battery-exchange techniques and systems to reduce labor in battery maintenance, vehicle diagnostic systems for im-

proved overall vehicle maintenance, and improvements in power system components.

Several recent reviews of EHV technology contain much information on foreign electric and hybrid automobiles, commercial vehicles and buses. The most recent study, "State-of-the-Art Assessment of Electric and Hybrid Vehicles," was prepared by the NASA-Lewis Research Center for the ERDA Project Office and was described in Chapter 2.

There has been considerable use of foreign chassis components by EHV developers in this country. The NASA-LeRC report lists 54 domestic manufacturers/builders of electric and hybrid passenger cars. Included in this total are 23 car builders who were identified as using foreign chassis components (see Table 6-1). Many conversions of heat engine vehicles to electric and hybrid vehicles have been based on foreign chassis because of their desirable characteristics, availability and ease of conversion. Until recently, foreign vehicles were generally smaller, roomier and, most important, lighter than their domestic counterparts and in some cases more amenable to conversion. For example, one reason that there are many conversion kits offered for the Volkswagen Beetle is the ease with which the engine and body can be removed. The ability to easily substitute a 200 lb. fiberglass body shell for a 500 lb. body is significant. Since the total vehicle system has been designed for a given vehicle weight and weight distribution, this would allow 300 lbs. of batteries to be added without significantly compromising the total vehicle design; however, the impact on safety must be determined.

Another consideration has been the availability of vehicles and components. At least one domestic manufacturer was unable to purchase a lightweight, domestic vehicle without an engine, but was able to obtain a foreign, safety-certified body and chassis when the manufacturer began production in 1974. The manufacturer has since obtained and converted a domestically produced vehicle.

Since the vehicles that would be acquired for the demonstrations could include converted ICE vehicles as well as vehicles designed and produced "from the ground up," the desirability of using foreign chassis and components is debatable. From the standpoint of acquiring vehicles with the best performance characteristics, it would be desirable to utilize foreign chassis and components where they offer advantages

TABLE 6-1
EHV Builders Using
Foreign Chassis

Braunlich-Roossle Co. Braun Electric - 2 pass.	General Motors Corporation Opel Kadett 4 pass.	Jausel, Virgil W. Renault	Sears, Roebuck Co. - XDH-1 2 pass.
Christianson, M.B. Renault R-10	Howes, Paul	Mallon, Richard G. Volkswagen Sedan 4 pass.	Steinfeld, Bob
Die Mesh Corp Electra Spider (Fiat 850) 2 pass.	Hughes, Max NSU Prinz	National Union Electric Henney Kilowatt (Renault Dauphine)	University of Colorado - Mars 2G Electric - 5 pass.
Electric Engineering Datsun 1200 - 4 pass.	Electric Fuel Propulsion Corp., Mars 2 - 5 pass.	Newell, John VW Fastback	Waterman Ind. CHW-886 4 pass.
Electric Engineering Kelmark, CT	Electric Passenger Cars, Inc., Hummingbird - 4 pass.	Paine, Donald Datsun 410 4 pass.	Westinghouse Electric Corp. Experimental Car 2 pass.
Electric Engineering Volkswagen Beetle 4 pass.	Electric Vehicle Assoc. Electric Luxury Sedan 4 pass.	Rippel, W.E. Ripp-Electric 4 pass.	

superior to their domestic counterparts. In some cases, this may not involve just small parts or components. It may be advantageous to acquire entire foreign vehicles which have been converted. On the other hand, P.L. 94-413, which requires that vehicles be manufactured in the United States and that purchase of components meet the standards of the Buy American Act, should help to stimulate both the domestic electric and hybrid vehicle market and industry, and also help them to remain viable after the demonstrations are completed.

Laws and regulations affecting both domestic production and the importation of vehicles, chassis and components include customs regulations and tariffs, the Clean Air Act, Federal Motor Vehicle Safety Standards, and the Buy American Act. Currently, any imported motor vehicle or motor vehicle engine must comply with the Clean Air Act and Federal Motor Vehicle Safety Standards. The Annotated Tariff Schedules

of the United States prescribe varying duties on imported motor vehicles and parts. These duties are in the range of 4 to 5% (approximately 8% on storage batteries and parts) with the exception of imports from Canada. Many imports from Canada are duty-free because of the integrated operations of the United States manufacturers in North America. However, such tariffs are not believed to impede the goals of P.L. 94-413 and are inherently represented in the cost of the product.

Of most importance is the Buy American Act. As noted earlier, P.L. 94-413 requires that vehicles purchased for the demonstrations meet the standards of the Buy American Act. This Act states that if the cost of the components thereof which are mined, produced or manufactured in the United States exceeds 50 percent of all of its components, the item would qualify as being domestic. This could prevent the inclusion of certain foreign electric and hybrid vehicle tech-

nologies which may be desirable for the demonstration program, however, it can also be viewed as an additional incentive for the domestic industry to improve its products to compete more effectively in domestic and world electric and hybrid vehicle markets beyond the time period of the demonstration program.

P.L. 94-413 explicitly states as a finding (Section 2 (a) (2)) that "the Nation's balance of payments is threatened by the need to import oil..." it would seem that an extension of this finding to include the manufacture of imported vehicles would be consistent with the general policy of the Act and with the desire of Congress to stimulate domestic industry and im-

prove the balance of payments. The policy expressed in the Solar Heating and Cooling Demonstration Act of 1974 (P.L. 93-409), which states, "early development and export ... of high technology products, can make a valuable contribution to our balance of trade ..." should also be applied to electric vehicles.

In order to expedite the process of developing and introducing reliable electric and hybrid vehicles, foreign technology should not be excluded because of the substantial benefit of transferring this technology to domestic industry. However, the underlying, long range strategy should be to give preference to domestic contractors in order to establish US preeminence in this field.

CHAPTER 7

ADMINISTRATION AND MANAGEMENT OF THE ACT'S REQUIREMENTS

I. The Electric and Hybrid Vehicle Research, Development and Demonstration Project

The basic ERDA Electric Vehicle R&D Program was initiated in Fiscal Year 1976 at a modest funding level. Prior to that year, electric vehicle work was managed by the Advanced Automotive Power Systems Division of the Environmental Protection Agency which later became a part of ERDA's Division of Transportation Energy Conservation. Under EPA direction, the scope of work included advanced battery development, advanced motor control studies and other studies related to design and hardware systems evaluation for electric and hybrid vehicles.

With the passage of P.L. 94-413, this basic program received added emphasis, was modified to enhance and broaden its R&D activities, and now includes provisions for implementing all of the incentive, demonstration and study requirements mandated by the Act. Accordingly, DOE's fulfillment of these requirements began with the establishment of the Electric and Hybrid Vehicle R,D&D Project as an organizational entity and the initiation of a comprehensive implementation plan.

In support of the Act's intent, the overall goal of DOE's Electric and Hybrid Vehicle R, D&D Project is to:

REDUCE U.S. CONSUMPTION OF PETROLEUM
AND DEPENDENCE UPON FOREIGN PETROLEUM
SOURCES BY PROVIDING THE TRANSPORTATION
SECTOR WITH ALTERNATIVES TO HEAT-ENGINE
POWERED VEHICLES WHICH DO NOT RELY ON
PETROLEUM AS A PRIMARY ENERGY SOURCE

The EHVP's tentative objectives are to:

1. Implement an electric and hybrid vehicle demonstration program in accordance with P.L. 94-413.
2. Provide financial and other incentives which will assist in the development by 1983, of a self-sustaining electric and hybrid vehicle industry capable of producing and maintaining limited perfor-

mance vehicles for transportation and agricultural applications.

3. Develop by 1985 the technology for mass-producible, four-passenger electric cars which utilize advanced powertrain components and batteries and provide significantly better performance.
4. Develop by 1985 the technology for mass-producible, light-duty commercial and agricultural vehicles utilizing advanced batteries and propulsion systems.
5. Develop by 1987 the technology for electric/heat-engine hybrid six-passenger cars and light/medium-duty commercial and agricultural vehicles.
6. Develop by 1990 the advancements in technology to extend greatly the range and payload capacity of electric vehicles and reduce their overall cost of ownership.
7. Reduce and/or neutralize the effects of barriers to electric and hybrid vehicle utilization.

These objectives will be finalized upon completion of the long range program plan.

DOE's strategy for achieving these objectives is described in four major pathways designed to:*

- I. Advance level of EHV technology.
- II. Stimulate the developing EHV industry toward self-sustainment.
- III. Identify barriers, biases and constraints to EHV utilization; develop incentives and implementation actions to overcome these deterrents.
- IV. Identify EHV market applications; demonstrate to various consumer factions the practicability of substituting EHV's where appropriate.

* "Electric and Hybrid Vehicle Program Plan," (In Preparation).

In addition, certain overview activities are being created to evaluate and provide perspectives concerning the entire Project. These include assessments of opportunities and risks, program reviews and an ongoing Project Evaluation System.

The first pathway will:

- Advance EHV technology's state-of-the-art.
- Demonstrate that electric and hybrid vehicles can be practical, energy efficient, safe, affordable, and provide adequate functional utility.
- Provide validated vehicle designs that are viable candidates for early implementation.
- Provide adequate analytical methodologies and tools to evaluate electric and hybrid vehicles, systems and components.

Activities under this pathway consist of broad-based vehicle systems R&D efforts supported by extensive testing and evaluation, the State-of-the-Art Assessment, and the effective implementation and transfer of technology developed through Federal support.

Pathway II will:

- Assist the timely development of a stable, self-sustaining EHV industry.
- Assure the availability of an infrastructure system capable of supporting expanding EHV utilization.
- Develop a market-sustained mode of technological progress within the EHV industry.

The means of achieving Pathway II is through Government-sponsored support and assistance. This support and assistance will take the form of financial and other incentives, providing small business planning grants and loan guarantees when and where needed, and developing market analysis information/techniques to assist industry's planning efforts.

The third pathway will:

- Identify barriers; institutional biases; legal, regulatory and implementation constraints which prohibit or hinder the increased utilization of electric and hybrid vehicles.
- Implement actions to overcome these deterrents.

The intent of this pathway is to define all actual or potential deterrents and the conceptual bases from which they have developed, recommend changes to alleviate existing deterrents, and develop appropriate incentives to facilitate EHV implementation. Recommendations to aid EHV implementation through new,

unique legislation, policy directives and/or other action routes will also be provided.

Pathway IV is designed to:

- Achieve maximum market penetration and the long-term acceptance of electric and hybrid vehicles as a major transportation medium.

Actions to be undertaken within this pathway include the demonstration activities mandated by P.L. 94-413 and the definition of EHV markets, performance requirements and areas where technical improvements are needed. Attention will be focused on:

- Providing assistance to industry for devising EHV market research techniques.
- Establishing ongoing communications links with appropriate government organizations (National, State, and local).
- Assisting consumers to reorient their transportation priorities toward the energy-saving aspects of electric and hybrid vehicles.

Work is underway to finalize the development of a long-range plan that will provide a general framework for the entire project. It is expected that the plan will be completed early in the coming year. The work breakdown structure that has been tentatively established to carry out this four-path strategy consists of the following Implementation Elements:

1. Implementation Element - Vehicle Technology

Task Area: Vehicle Systems R&D

- Electric Vehicles
- Hybrid Vehicles
- R&D Management; Systems Analysis and Support

Task Area: Advanced Technology

- Propulsion Systems
- Supporting Technology
- Propulsion System/ Energy Storage System Interface
- Advanced Concepts

Task Area: Test and Evaluation

- State-of-the-Art Assessment
- Safety Tests
- Product Improved Vehicles
- Vehicle Support

2. Implementation Element - Energy Storage Technology

Task Areas:

- Electrical Energy Storage Systems
- Mechanical Energy Storage Systems

FIGURE 7-1

Electric and Hybrid Vehicle R,D&D Project

3. Implementation Element-Studies and Performance Standards

Task Areas:

- Studies Mandated by P.L. 94-413
- Vehicle Performance Standards
- Environmental Studies
- Other Supporting Studies and Analyses

4. Implementation Element - Incentives

Task Areas:

- Loan Guarantees
- Planning Grants
- Incentive Studies and Support

5. Implementation Element - Demonstrations

Task Areas:

- Vehicle Acquisition
- Operational Support
- Demonstration Site Operations
- Public Information

6. Implementation Element - Program Support

Task Areas:

- Advisory/Evaluative (Opportunity/Risk Assessment)
- Technical Support
- Management Support

Figure 7-1 illustrates the current plans for the program.

II. Organizational Structure

In establishing the EHVP, ERDA assigned the responsibility for this project to the Division of Transportation Energy Conservation. Figure 7-2 illustrates the EHVP management and organization structure.

FIGURE 7-2
Management and Organization Structure

II. Use of EHV's by Federal Agencies

In accordance with Section 11 of P.L. 94-413, DOE requested the Federal agencies listed in Table 7-1 to provide an initial assessment of their EHV needs, and offered to coordinate their requirements with the DOE

program. In response to this request, each agency established a point of contact for coordinating all future efforts. Several agencies forwarded preliminary estimates of the transportation needs which EHV's might satisfy. The Department of Agriculture (through a Memorandum of Understanding) agreed to co-spon-

TABLE 7-1
Federal Agencies Contacted by ERDA

Interested Agencies with Large Fleets	Degree of Interest	Preliminary Estimate of of EHV Needs (No. per site)
U.S. Postal Service	High	20 (+)
Department of Defense	Moderate	20 (+)
General Services Administration	High	5 (-)
Department of the Interior	High	5 (-)
Department of Agriculture	*	*
Department of Justice	*	*
Department of Energy	High	10 (+)
Department of the Treasury	High	*
Tennessee Valley Authority	High	*
Other Interested Agencies with Federal Fleets		
Department of Transportation	High	*
Department of State	Low	5 (-)
Department of Commerce	Moderate	5 (-)
Department of Health, Education, and Welfare	Refer to GSA	
Department of Labor	Refer to GSA	
National Aeronautics and Space Administration	High	5
Panama Canal Company	High	*
Interested Agencies Supported by GSA		
Department of Housing and Urban Development	Refer to GSA	
Environmental Protection Agency	Moderate	2
Federal Energy Administration		

*Indicates an incomplete response.

sor a study to evaluate the role which EHV's could fulfill in agricultural applications.

The use of electric and hybrid vehicles by Federal agencies requires careful consideration of the agencies' needs and limitations, and assessment of fuel savings that can accrue through replacement of heat engine vehicles with EHV's. Accordingly, DOE is initially concentrating on those agencies that consume more than one million gallons of fuel annually or oper-

ate a fleet of at least 1000 vehicles. DOE is continuing to provide information and assistance to all agencies whose participation in R&D or vehicle demonstration programs will serve the purposes of:

- Satisfying the agency's transportation functions,
- Meeting the requirements of P.L. 94-413, and
- Establishing the practicability of EHV utilization.

CHAPTER 8

PROJECTIONS AND ESTIMATES OF PROGRESS

I. The Impact and State of EHV Utilization

To provide the management insight it would need to carry out effectively the various EHV R, D&D activities, DOE undertook an assessment which described the state of EHV utilization as it exists today and projected these findings to determine the impact of increased utilization in the future. Included in the assessment were appraisals of:

- How EHV's would impact energy consumption and the environment.
- The state and needs of EHV technology.
- The state and needs of the EHV industry.
- EHV marketing requirements.
- Institutional and regulatory biases/barriers.
- The need for an adequate EHV supporting infrastructure.
- The significance of EHV costs toward consumer acceptance.

This experience complemented the results of those more intensive studies described in earlier chapters. Selected findings of major significance are presented in the following paragraphs.

Energy and the Environment

Substituting estimated feasible levels of electric and hybrid vehicles for petroleum-fueled automobiles and trucks would have the following impacts:

- Petroleum savings in the year 2000 of from 60,000 to 1.3 million barrels per day. Motor vehicle demand projections for the year 2000 range from 4 to 10 million barrels per day.
- Some potential relief from air and noise pollution in particular urban areas.
- Sufficient petroleum savings and environmental pollution relief from truck and commercial fleet substitution to justify strong concentration in this market segment.

Technology

The technology of electric and hybrid vehicles is such that:

- Present electric vehicles have limited range and performance, and generally higher life-cycle costs than existing petroleum-powered vehicles. No data are available for production hybrid vehicles.
- Improved range, performance and cost compared to existing electric and hybrid vehicles will require high levels of support for research, engineering and manufacturing development.
- Reliability problems can be expected for current technology vehicles; considerable time and resources will be required to improve the reliability to a level consistent with market expectations.
- The time required to develop prototype vehicles and limited production manufacturing facilities is three to five years; therefore, advanced vehicles with advanced energy storage systems are not likely to appear before the early to mid-1980's.

Industry

Industry characteristics used as a basis to determine the commercialization potential for electric and hybrid vehicles include:

- Present US manufacturers of electric passenger vehicles are primarily small or infant businesses with limited engineering development and production capabilities.
- Production facilities, technology and EHV mission characteristics all favor initial development of electric and hybrid vehicles for commercial fleet applications.
- Several established US firms manufacture electric vehicles for commercial, fleet or special purpose markets. These businesses, as well as other categories of US industries,

would probably have the production experience to penetrate additional EHV market segments, if provided with incentives and adequate time. Several foreign firms already have the potential to manufacture commercial and passenger electric and hybrid vehicles.

- The US automotive industry is showing renewed interest in electric and/or hybrid vehicles.
- Estimated Investments and lead times for electric or hybrid vehicle production lines vary from a minimum of \$10 million, and two to three years, for small production volumes of approximately 3,000 vehicles per year, to several hundred million dollars, and four to five years, for a 100,000 per year production rate.

Market

The status of the market and marketing data for electric and hybrid vehicles is that:

- Typical of an immature industry, production statistics are sparse and unreliable, and analytical market research experience is limited.
- Commercial vehicle market and production data are more representative of a mature industry than the data for passenger vehicles.
- Little in-depth research directly relevant to the unique characteristics of the electric/hybrid vehicle market has been reported by the traditional auto industry, despite its analytical marketing expertise. This is because industry market research has been based on the premise that all vehicles have essentially the same flexibility in terms of range and performance.
- Data on existing automobile and truck use patterns are limited and form an insufficient basis on which to make potential market projections.
- Full use-pattern data, even if it did exist, would not provide an adequate basis for market projections of electric and hybrid vehicle sales. Such data predominately define factors such as reliability, cost, items, marketing options, and image.
- Designing the demonstrations to focus on the development of market data could provide a basis for sales projections more valid

than the ones that currently exist.

- Electric and hybrid vehicles may represent two separate markets due to their different cost and use characteristics.

Institutional Factors

Institutional, regulatory and other barriers to electric and hybrid vehicle use include:

- State and local laws regarding vehicle registration, speed limits, safety, and tax rates.
- Insurance rates which would be uncertain until accident statistics provide a reliable basis for adjustment.
- Potential product liability suits against manufacturers and demonstration site operators, with small businesses particularly vulnerable.

Support Service Facilities

The existence of marketing, maintenance and recharging facilities for electric and hybrid vehicles is limited at present. Substantial investment and training would be required to provide facilities equivalent to those routinely expected for petroleum-fueled vehicles. Potential reliability problems with electric and hybrid vehicles and high consumer expectations for maintenance and vehicle availability combine to increase the investment and manpower levels which may be required in sales and service facilities.

Cost

The cost of electric vehicles, when compared to existing petroleum-fueled vehicles, depends on several factors. Those most important, given current technology, are battery cost, battery life and vehicle depreciation. Other factors such as gasoline prices, electricity rates and maintenance costs are relatively insignificant. In order for these operating expenses to be important in comparing petroleum-fueled and electric vehicle life-cycle costs, battery life and cost must be in the range of 1000 cycles and \$40 to \$50 per kilowatt-hour (the long-range DOE goals for high-volume production). (Current costs are in the range of \$100 per kilowatt-hour for lead-acid batteries).

II. Evaluating Progress

Specific progress which relates to the implementation of P.L. 94-413 has been addressed in the preceding chapters. Progress which relates to the achievement of goals and objectives is more difficult to assess on a subjective basis without having some means of measurement; therefore, DOE is establishing an ongoing evaluation activity to measure periodically:

- Progress in the improvement of vehicle operating range, acceleration, cruising speed, road handling and riding comfort, safety, reliability, versatility, and accessory options.
- Progress toward the comprehensive development of a viable EHV industry. This includes industry segments, such as components manufacture, sales and resales, maintenance and services' development; insurance; trade associations; technical journals; and user organizations.
- Progress toward the alleviation of barriers to EHV implementation.
- Progress toward the involvement of consumers, communities, state and local transportation officials, and private enterprise organizations as "partners" in the marketplace.
- The extent to which private enterprise assumes responsibility for EHV development and implementation.
- The increase in a favorable attitude toward the purchase of electric and hybrid vehicles.
- The impact of electric and hybrid vehicles on the environment, traffic systems and the demand for resources.

III. Opportunities and Risks*

To provide guidance on the implementation of P.L. 94-413, DOE undertook an assessment of opportunities and risks which could significantly influence

the achievement of the Act's goals. There are numerous implementation options which could be chosen to foster the increased utilization of electric and hybrid vehicles. While certain implementation directives were listed in the Act, such as the demonstration of a specified number of vehicles within a given time schedule and the guarantee of loans as incentives to small businesses, other decisions were left to DOE. This assessment was designed to analyze not only those opportunities and risks associated with the directives set forth in the Act, but also to provide guidance for DOE's implementation decisions.

An implementation option was defined as a potential source of action which may be taken to realize P.L. 94-413's goals. An opportunity was defined as an implementation option judged to have particular benefits in achieving the Act's goals, and a risk was an implementation option judged as a major constraint toward achieving the goals of the Act. Risk assessment concentrated primarily on the examination of directives specified within the Act and was, therefore, more of an analytical task. Opportunity assessment involved the synthesis and comparative analysis of alternative implementation options to judge those most likely to increase the probability of achieving the Act's goals.

A task force of experts from various institutions representing the broad range of disciplines necessary for the study analyzed available data from industry and government, and used appropriate methodologies to identify candidate opportunities and risks.

Opportunities to Enhance Success

In analyzing the strategies available to DOE, the following opportunities were judged to be particularly effective in achieving the goals of the Act:

- Develop adequate schedule and management flexibility to stimulate and demonstrate advanced vehicle developments.
- Stimulate research and development in a broad range of components and systems through cooperative government/industrial projects, and through direct and indirect incentives to industry.
- Concentrate on commercial and special purpose vehicle fleet markets in the demonstra-

*"Analysis of the Opportunities and Risks Associated with the Implementation of the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976," (Interim Report), Goodson, R.E., Institute for Interdisciplinary Engineering Studies, Purdue University, July, 1977.

tion of electric and hybrid vehicles, especially in the near term.

- Provide a continuing Federal Government market for electric and hybrid vehicle applications where range and performance are satisfactory.
- Identify potential institutional and regulatory incentives, and eliminate barriers to electric and hybrid vehicle acceptance. Develop a cooperative program with other Federal agencies, State and local governments, electric utilities, regulatory bodies, and insurance companies to remove such barriers and increase incentives.
- Shelter and protect buyer and service facility involvements in the demonstration and use of electric and hybrid vehicles so that reliability and other development problems will not mask potential benefits.

Risks

The following risks were judged as major constraints to achieving the goals of the Act:

- The rigid time schedule mandated in the Act for vehicle acquisition and demonstration is a pervasive constraint and sharply lowers the probability that the goals of the Act will be achieved.
- Several factors such as the tight demonstration schedule; the requirements for close coordination among the many participants that are involved with the Electric and Hybrid Vehicle Project; and inherent difficulties faced in aiding the commercialization process where the Government is not the primary market, combine to produce a high risk of management problems that could forestall the realization of the Act's goals.
- The stress on early and possibly premature demonstration, and lack of specific technology incentives in the Act result in a substantial risk that potentially attractive advanced technology may not be developed or integrated into demonstrated vehicles.

- The Electric and Hybrid Vehicle Project may actually impede acceptance of such vehicles by giving the image to prospective users, manufacturers and policy-makers—through reliability problems, inadequate service facilities, or application to inappropriate market segments—that a potentially viable concept is unsound and should not be commercialized.

IV. Issues and Problem Areas

DOE has initiated all actions required under P.L. 94-413 and is keeping pace with the early requirements for state-of-the-art testing, special study reports and the development of vehicle standards. The funding appropriated by Congress will provide for the acquisition of 200 demonstration vehicles in FY 1978, unless sacrifices are made in carrying out the vehicle and battery research. DOE believes that this will be critical to the "advanced" vehicle demonstrations.

A first demonstration step should comprise hundreds rather than thousands of vehicles in protected maintenance and service environments, and should include both U.S. and foreign vehicles. The introduction of some foreign vehicles into the first demonstration phase offers a low cost opportunity to benefit from extensive foreign technological development and actual operating experience. This phase, as well as later demonstration phases, should also allow some flexibility in the timing of vehicle acquisitions. Later phases or demonstration stages could gradually expand somewhat to include less sheltered environments. The last phase could include larger numbers of vehicles operating in relatively uncontrolled environments, thus proving the viability of electric and hybrid vehicles as practical, economical and energy-efficient transportation.

DOE remains confident that the goals and objectives of P.L. 94-413 can be achieved. However, the chances for success can be greatly improved by taking advantage of the best available worldwide technology, and by undertaking a careful, step-wise demonstration program with proper vehicle fleet control.

CHAPTER 9 RECOMMENDATIONS

Based on the experience gained during the first year and the results of the Opportunity/Risk Assessment, DOE has proposed a number of changes to P.L. 94-413 to enhance the capability for satisfying the letter and intent of the Law.

I. Proposed Changes to Legislation

- Revise the Act's restrictive demonstration vehicle acquisition requirements to allow flexibility in the timing and quantities of vehicle procurement. The demonstrations should be paced by the identification of market opportunities and advancements in vehicle technology.
- Expand the existing provisions for loan guaranty interest assistance to include assistance on the Principal.
- Establish in the Treasury Department a specified electric and hybrid vehicle development fund free of fiscal year limitations. This would assure and install confidence in potential lenders regarding the support of the Government-sponsored Project.
- Empower the DOE Secretary to borrow money as required to meet Government obligations in the event of a default on loan guarantees. This would provide an increased measure of confidence from lending institutions, and strengthen the "full faith and credit" posture of the guaranty program.
- Modify 31 USC 638a to exempt electric vehicles from the statutory purchase ceiling (per P.L. 95-81) of \$2700 for sedans and \$3100 for station wagons. This limitation currently applies to any vehicles purchased by Federal agencies.

II. Related Actions

The Opportunity/Risk Assessment provided a number of related actions that would increase the probability of success. These are currently under consideration for possible inclusion in various program activities and include such things as:

- Emphasizing commercial fleet applications in the early demonstrations.
- Emphasizing the utilization of electric and hybrid vehicles within the Federal Government.
- Planning with NHTSA and other regulatory agencies an appropriate transition path from the present safety, emissions, and damageability capabilities of electric vehicles to long term standards.
- Exploring with NHTSA possible ways to modify the automotive fuel economy provisions of the Energy Policy and Conservation Act of 1975 (Public Law 94-163) in order to allow inclusion of electric and hybrid vehicles in the computation of corporate average fuel economy (CAFE).
- Initiating an institutional and regulatory program specifically designed to remove barriers and provide incentives for the introduction and use of electric and hybrid vehicles.
- Focusing the demonstration on development of market data to provide a more reliable basis for commercial investment decisions.
- Increasing public awareness of the special characteristics and potential benefits of electric and hybrid vehicles.
- Serving as a catalyst and cost/risk sharer to link manufacturers, sales and service facilities, and users through innovative marketing and purchase approaches.
- Providing a mechanism to encourage or reward technological innovation on the part of vehicle manufacturers.

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List of Acronyms

AES — Assistant Administrator for Environment and Safety (ERDA)	LLL — Lawrence Livermore Laboratory
ADL — Arthur D. Little, Inc.	MERADCOM — Mobility Equipment Research and Development Command
ANL — Argonne National Laboratory	MVMA — Motor Vehicle Manufacturers Association
AQCR — Air Quality Control Region	NASA — National Aeronautics and Space Administration
BAH — Booz, Allen and Hamilton, Inc.	NEDS — National Emissions Data Systems
CAFE — Corporate Average Fuel Economy	NEPA — National Environmental Policy Act of 1969
DEIS — Draft Environmental Impact Statement	NHTSA — National Highway Traffic Safety Administration
DOC — Department of Commerce	OMB — Office of Management and Budget
DOD — Department of Defense	OPRA — Opportunity/Risk Assessment
DOE — Department of Energy	P.L. 94-413 — The Electric and Hybrid Vehicle R, D&D Act of 1976
DOT — Department of Transportation	PPBR — Program Planning, Budgeting and Review System
EDP — Environmental Development Plan	R, D&D — Research, Development and Demonstration
EHV — Electric and/or Hybrid Vehicle	R, D, T&E — Research, Development, Test and Evaluation
EHVP — Electric and Hybrid Vehicle R, D&D Project	RECAP — Recharge Capacity Model
EIS — Environmental Impact Statement	REPS — Regional Emission Projection System
EPA — Environmental Protection Agency	SAE — Society of Automotive Engineers
EPRI — Electric Power Research Institute	SBA — Small Business Administration
ERDA — Energy Research and Development Administration	SOA — State-of-the-Art
EV — Electric Vehicle	STOR — Division of Energy Storage Systems (ERDA)
FPC — Federal Power Commission	TEC — Division of Transportation Energy Conservation (ERDA)
FTP — Federal Test Procedure	TSC — Transportation Systems Center (DOT)
FY — Fiscal Year	UMTA — Urban Mass Transit Administration (DOT)
GE — General Electric Company	USDA — U.S. Department of Agriculture
GRC — General Research Corporation	USPS — United States Postal Service
GSA — General Services Administration	USSR — Union of Soviet Socialist Republics
HV — Hybrid Vehicle	
ICEV — Internal Combustion Engine Powered Vehicle	
JPL — Jet Propulsion Laboratory (NASA)	
LeRC — Lewis Research Center (NASA)	
LBL — Lawrence Berkeley Laboratory	

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APPENDIX A

List of EHV Contractors

Title	Contractor	Period of Performance	FY 77 Funding
Electric Vehicle Safety Testing	DOT	8/77-2/78	\$ 60,000
Near-Term Electric Vehicle Program - Phase II	Garrett AiResearch	4/77-4/79	\$2,790,000
Near-Term Electric Vehicle Program - Phase II	General Electric Company	4/77-4/79	\$3,050,000
Electric Vehicle Systems R&D Support	NASA-JPL	4/77-Open	\$ 900,000
State-of-the-Art Characterizations	NASA-LeRC	10/76-9/77	\$ 958,000
State-of-the-Art Characterizations	U.S. Army MERADCOM	5/77-5/79	\$ 132,000
Demonstration Planning/Management Support	Booz, Allen and Hamilton, Inc.	7/77-12/78	\$ 500,000
Loan Guaranty Analysis	Bradford National Corp.	7/77-9/78	\$ 90,000
Propulsion Systems R&D	NASA-LeRC	5/77-9/79	\$2,074,000
Evaluation of EHV Components	U.S. Army MERADCOM	5/77-9/79	\$ 456,000
Vehicle Supporting Technology Development	NASA-JPL	9/77-9/78	\$ 400,000
Stirling Engine/Hybrid Design Study	Mechanical Technology, Inc.	9/77-3/78	\$ 150,000
Institutional Factors and Their Effects of EHV	DOT-TSC	1/77-9/78	\$135,000
Institutional Factors and Their Effects on EHV	General Research Corp.	1/77-9/78	\$ 45,000

Title	Contractor	Period of Performance	FY 77 Funding
Federal Incentive Programs for EHV	DOT-TSC	1/77-9/78	\$150,000
Materials and Pollution Effects	General Research Corp.	1/77-9/78	\$132,000
Study of Regenerative Braking Systems	LLL	1/77-9/77	\$200,000
Hybrid Vehicle Assessment	NASA-JPL	1/77-9/78	\$150,000
Vehicle Systems Modeling and Simulation	NASA-JPL	1/77-9/78	\$200,000
Evaluation of EHV Performance Stds.	Society of Automotive Engineers	6/77-9/77	\$ 22,670
EHV Performance and Design Goal Study	General Research Corp.	6/76-8/77	\$ 50,000
Study for Determining EHV Performance Standards	Arthur D. Little, Inc.	10/76-10/77	\$120,000
In-Vehicle Testing of Lithium-Iron Sulfide Batteries	Argonne National Lab.	5/77-Open	\$230,000
Sodium-Sulfur Battery Evaluation	Ford Motor Co.	9/77-Open	\$307,000
Electric Transmission Study	Mechanical Technology, Inc.	8/76-10/77	\$ 28,000
Dual Mode Electric Transportation System	LBL	2/76-9/78	\$ 210,000
Fuel Cell System Characterization for Vehicles	Los Alamos Scientific Lab.	8/77-12/77	\$ 10,000
Fuel Cell System Characterization for Vehicles	Brookhaven National Lab.	8/77-12/77	\$ 10,000
Planning Grant Analysis	Don Sowle Associates	4/77-8/77	\$ 42,500
Opportunity/Risk Assessment	Purdue U.	1/77-12/77	\$ 490,000

Title	Contractor	Period of Performance	FY 77 Funding
Engineering/ Technical Support Services	Mueller Associates, Inc.	5/77-12/77	\$ 67,000
Hybrid Vehicle Technical Management Support	NASA-JPL	To be deter- mined	\$ 255,000
Program Management Support	LLL	3/77-Open	\$ 95,000
Analysis of Battery Applications for Transportation Systems	LLL	9/76-9/77	\$ 200,000
Vehicle Battery Development	Argonne National Lab	7/76-Open	\$5,600,000
Mechanical Energy Storage Systems for EHV Applications	LLL	9/77-9/78	\$1,360,000

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APPENDIX B

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