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HYBRID VEHICLE POTENTIAL ASSESSMENT

Volume 6: Cost Analysis

By
K. S. Hardy

MASTER

September 30, 1979

Work Performed Under Contract No. EM-78-I-01-4209

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

U. S. DEPARTMENT OF ENERGY

Division of Transportation Energy Conservation

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ELECTRIC AND HYBRID VEHICLE SYSTEM
RESEARCH AND DEVELOPMENT PROJECT
HYBRID VEHICLE POTENTIAL ASSESSMENT
VOLUME VI. COST ANALYSIS

September 30, 1979

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PREFACE

In 1976, Congress passed the Electric and Hybrid Vehicle (EHV) Research, Development, and Demonstration Act of 1976, Public Law 94-413, later amended by Public Law 95-238. The Department of Energy is conducting an EHV development program in compliance with that Law. The EHV System Research and Development Project, one element of this Program, is being conducted by the Jet Propulsion Laboratory (JPL) of the California Institute of Technology through an agreement with the National Aeronautics and Space Administration. This report presents the results of the investigations conducted under the Hybrid Vehicle Potential Assessment Task which is a part of the EHV Systems R&D Project.

Early results of this study were used as the technical basis for the Near Term Hybrid Vehicle Development Program now being carried out by the JPL Electric and Hybrid Vehicle System Research and Development Project.

This report is in ten volumes. Volume I contains an overview of the study and the major findings. Volumes II through X are of technical supplementary reports that describe the details of the study and present the most important data generated by the study elements.

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Volumes Comprising the Hybrid Vehicle Potential Assessment

Report No.	Subject	Author(s)
5030-345, Vol. I	Summary	F. T. Surber et al.
5030-345, Vol. II	Mission Analysis	F. T. Surber G. K. Deshpande
5030-345, Vol. III	Parallel Systems	S. P. DeGrey
5030-345, Vol. IV	Series Systems	Z. Popinski
5030-345, Vol. V	Flywheel Systems	S. G. Liddle
5030-345, Vol. VI	Cost Analysis	K. S. Hardy
5030-345, Vol. VII	Hybrid Vehicle Review	K. O. Leschly
5030-345, Vol. VIII	Scenario Generation	K. O. Leschly
5030-345, Vol. IX	Power Train Summary, Component Descriptions, HYVEC Vehicle Simulator	S. G. Liddle S. P. DeGrey
5030-345, Vol. X	Electric and Hybrid Vehicle Cost Handbook	R. C. Heft S. C. Heller

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I. INTRODUCTION AND CONCLUSIONS

The purpose of the cost analysis is to determine the economic feasibility of a variety of hybrid vehicles with respect to conventional vehicles specifically designed for the same duty cycle defined by the mission analysis (Refer to Supplementary Report 1). This study evaluates several different hybrid configurations including parallel, parallel-flywheel, and series vehicles. The basic difference between these vehicles is the capability of the parallel vehicles to transmit power mechanically from the heat engine to the drive train. The reader should refer to Supplementary Reports 2, 3, and 4 for the detailed powertrain analysis. The vehicles within the same mission have been designed with the same minimum performance requirements as well as the same passenger and payload capability.

This study also investigates the ramifications of incorporating examples of "advanced" batteries, these being the "advanced" lead-acid, nickel-zinc, and sodium sulfur. Vehicles were specifically designed with these batteries and for the driving cycles specified by the mission (various combinations of the EPA Urban and Highway Cycles, N.Y. City Cycle, and the Aerospace Van Cycle). Simulated operation on the missions yielded the fuel consumption (petroleum and/or electricity) over the driving cycles.

A computer program was developed to apply the annual travel patterns defined by the mission analysis to each basic vehicle design which resulted from the powertrain analysis. This program produced annual average kilometers per liter (KPL), kilowatt-hours per mile, vehicle kilometers travelled (VKT), and the necessary vehicle specifications which were compatible with the input format for the EHV Cost Handbook.¹ Another function of the travel pattern program was to determine the battery life based on the particular driving pattern. This required an estimate of the battery cycle life, that is the total number of full discharge-recharge cycles which could be expected in its life. Due to the fact that the batteries are still under development and the cycle lifetime remains far below the ultimate design goals, the cycle lives

1. EHV Cost Handbook/Interim. JPL Document No. 5030-182

have been treated parametrically. Cycle lives of 500 and 1000 were chosen to represent basically current technology and the design goals for the 1985-1990 time period. A third cycle life of 2000 was chosen to show the effects on cost if this admittedly optimistic cycle life was achieved. Since this study deals basically with battery cost per kWh per cycle, this would amount to halving the cost of the 1000 cycle life battery.

With this in mind the role of the travel pattern program is to provide vehicle specifications for the EHV Cost Handbook while iterating over battery cycle life and annual vehicle kilometers traveled (the missions were defined with several travel patterns to show the effect of VKT).

The EHV Cost Handbook was then used to translate the technical aspects and energy consumption of these vehicles into cost data. Based on the common design criteria and cost estimating relationships, a comparative cost analysis was performed using discounted life cycle cost. This resulted in a break-even gas price (BEGP) for each of the vehicles, that is the necessary price of gasoline in 1978 dollars to make the life cycle cost of the hybrid vehicle equal that of the conventional vehicle designed for the same mission. In most cases the BEGP was found to be higher than the expected price of gasoline in 1985 and the subsidy necessary to make the hybrid vehicles economically competitive was also calculated. The flow diagram of Figure 1 outlines the costing procedure used in this analysis.

A. CONCLUSIONS

1. In the event that gasoline prices reach \$2.50 to \$3.00 per gallon (1978 dollars), hybrid vehicles in many applications (representing a large percentage of the fleet) will become economically competitive with conventional vehicles without subsidization. (Refer to Section IV-A, Figure 6)

2. In some commercial applications it appears that hybrid vehicles will be economically competitive somewhat earlier, when the gasoline price ranges from \$1.20 to \$1.50 per gallon (1978 dollars). (Refer to Section V-A, Mission VII-2)

Figure 1. Cost Analysis Flow Diagram

3. The cost per kWh per cycle of the advanced batteries is much more important economically than the specific energy. (Refer to Section IV-A, Figure 6)

a. The "exotic" batteries (Ni-Zn, Na-S, Li-S, etc.) cannot help the economic situation unless the cycle life can be dramatically increased or the costs dramatically decreased from those currently projected.

4. The series hybrid vehicles were found to be more expensive in comparison to the parallel or parallel-flywheel hybrids when designed as passenger vehicles. (Refer to Section IV-A, Figure 13)

5. Hybrid Vehicles designed for private use could become economically competitive (on a life cycle cost basis) and displace up to 50% of the fuel normally used on that mission if subsidies of \$500 to \$2000 were supplied to the owner/operator. (Refer to Section IV-A, Figure 8)

II. COSTING METHODOLOGY

A. VEHICLE DESIGN

The most basic assumptions inherent to the comparative cost analysis concern the vehicle design. The vehicles have been designed with identical minimum performance requirements as well as passenger and payload capability. The technical aspects of all vehicles within the same mission are also identical (i.e., frontal area, drag coefficient, rolling resistance coefficients, baseline carriage weight, etc.).

The hybrid vehicles were designed with several "primary electric" ranges to show the effect of fuel displacement on overall costs. For the vehicle design, this was defined as that range where the electrical propulsion system could no longer supply most of the power necessary for the driving cycle. The limiting factor for primary electric range is the battery pack size. The battery pack sizing depends on the power capability of the batteries as well as energy storage capacity and the vehicle control strategy. Due to the vehicle control strategy, which is largely a function of the power capability, the batteries are not always discharged to the same depth of discharge. For instance, in the cases of parallel or series vehicles the primary electric range was defined as that point where the battery was discharged to approximately 80 percent DOD (C/3 rate). For the flywheel vehicles the definition used by the vehicle designer was a bit more complex due to the combination of flywheel and battery. In this case, the primary electric was that point where the battery and flywheel could not supply power to load level the heat engine. In an effort to be conservative in terms of battery life, the primary electric range for all vehicle types was defined as that distance where the battery reached an 80 percent DOD (C/3 rate).

B. TRAVEL PATTERN PROGRAM

The travel pattern program was designed to transform energy consumption which is supplied at given intervals (powertrain analysis) into an annual average kilometers per liter and kilowatt-hours per mile by applying a particular trip length distribution. By using this same distribution the lives of the batteries were calculated under the following assumptions:

- 1) Batteries have a total limited number of deep cycles in a lifetime (i.e., a battery regularly discharged 40% lasts twice as long as one regularly discharge to an 80% DOD). Cycle lives of 500, 1000, and 2000 were used for all vehicles.
- 2) The battery charge state at the primary electric range is equivalent to an 80% DOD at the C/3 rate.
- 3) The battery life is based on the daily trip length distribution (if the vehicle is operated over the same driving cycle continuously, the battery will be discharged to only half the DOD when driven 25 km as when driven 50 km).

The travel pattern program also has the role of iterating battery lives (based on 500, 100, and 2000 cycle lives) and travel patterns (VKT) for each vehicle. This program then outputs the vehicle specifications, liters of fuel consumed per year, annual vehicle kilometers travelled, and battery life in a form compatible with the EHV Cost Handbook program.

C. EHV COST HANDBOOK

The purpose of the EHV Cost Handbook is to provide a consistent set of cost estimating relationships (CER's) for determining the manufacturing, acquisition, operating, and life cycle costs for electric and hybrid vehicles. Furthermore, the cost data is presented for major component and sub-assembly costs so that conventional vehicles as well can be costed under the same basic assumptions. However, since no consistency exists among the various sources of the handbook in the definitions of manufacturing cost, the assumptions used, or the level of effort expended, the range of estimates is very large. For this reason the handbook should be used in a comparative, not absolute manner. Manufacturing cost is defined here as plant cost composed of both factory fixed and variable cost (i.e., direct and indirect labor and materials, special tooling, expendable tooling, factory overhead, etc.). Manufacturing cost does not include any corporate level cost such as G&A, R&D, return on investment, cost of sales, etc.

The cost handbook can be a very effective tool if the vehicle under consideration has been designed in enough detail for the major components to be characterized in terms of their key cost parameters (chassis weight, heat engine power rating, etc.). The use profile of the vehicle must also be specified, such as 10,000 kilometers per year for a life of 10 years. With this information, the cost handbook is capable of generating the four costs mentioned previously. However, there are a number of assumptions inherent to each of these costs and they are presented in the following sections.

1) Manufacturing Cost

- a. All vehicles used in the comparative cost analysis were assumed to be constructed using the same methods and level of technology.
- b. Vehicle R&D is complete and the unit is in a preproduction prototype form.
- c. Production quantities are 300,000 or more units per year.
- d. Production facilities are operating near their planning volumes.
- e. Costs are calculated in 1976 dollars, then adjusted to 1978 dollars using a factor of 1.11.
- f. Because the cost of batteries has a strong influence on the total cost of electric and hybrid vehicles the assumptions used in the EHV Cost Handbook for the batteries employed in this study are listed below. These costs are subjective averages of estimates of the eventual manufacturing cost for batteries in mass production. Battery cost per kilowatt-hour is based on the energy density at the c/3 discharge rate.

Advanced Lead-Acid	- \$40/kWh	(44 wh/kg)
Sodium-Sulfur	- \$50/kWh	(120 wh/kg)
Nickel-Zinc	- \$60/kWh	(77 wh/kg)

2) Acquisition Cost

- a. Though the "sticker price" of conventional vehicles has been found to range from 1.7 to 2.4 times the manufacturing cost, an average multiplier of 2.0 for all vehicles has been used in this study with an aftermarket mark-up of 2.3 (i.e. replacement batteries).

3) Operating Cost

- a. Because the vehicles have been defined as mission-specific vehicles, the annual VKT was assumed to remain constant over the lifetime of the vehicle.
- b. Vehicle life is approximately 100,000 miles or 15 years, whichever comes first. Vehicles of the same mission and travel pattern have the same lifetime.
- c. Gasoline costs \$1.05 per gallon in the first year and increases by \$.05 per year (1978 dollars). This corresponds to the gasoline price scenario A starting in 1985.² Electricity costs \$.042 per kWh.

4) Life Cycle Cost

- a. In the case of private use vehicles (Missions I-III) the vehicle purchase price was financed at 10% for a period of 5 years (with a 20% down payment).
- b. Battery replacements were financed at 10% for 2 years.

- c. In calculating the present value of life cycle costs a 2% discount rate was assumed for private use vehicles (Missions I-III) while 15% was used for commercial vehicles (Missions IV-VII). 2% represents the time value of money for an individual and 15% is the sum of opportunity cost and the time value of money for commercial enterprises. Costs were discounted as if they were paid at the end of each year.
- d. Though the majority of vehicles in the U.S. private vehicle fleet are not one owner vehicles no effort was made to inject any loss or gain due to resale of these vehicles.
- e. No special charges affecting tax, license, or insurance were assumed for the hybrid vehicles.

With these assumptions the program outputs all aspects of cost of a particular vehicle including manufacturing costs, maintenance, repair, etc., as can be seen in the example of Figure 2. With the cost information for the conventional vehicles built into the program, comparative cost analysis was possible for vehicles of the same mission. The basis of the comparative cost analysis was the discounted life cycle cost of each vehicle. The present value of the life cycle cost was used in determining the break-even gas price (BEGP) which is the necessary initial price of gasoline given the assumed (\$.05 per gallon annual increase) to make the life cycle cost of the hybrid or electric vehicle equivalent to that of the conventional comparison vehicle. The scenario A gasoline price increase of \$.05 per gallon per year was chosen to show the economic comparison which would be consistent with the assumptions for market penetration³. However, in those cases where BEGP cost breakdowns are presented the component due to the gasoline price increase is presented as a separate component which can be ignored, resulting in the BEGP under the assumption of a constant \$1.05 per gallon (1978 dollars). The component of BEGP due to gas price increase was small in all cases and did not change the conclusions. Equivalent life cycle costs imply:

3. See Chapter 6, Hybrid Vehicle Impacts, Summary Report

P2L6A4 2
 VIO VMT RGE BL CL BTP MPG KWHPM
 PAR 9114. 50. 2.6 500. L 49.1 .1954

ACQUISITION COST

CHASSIS	.00 LBS	2340.00 LBS	\$ 1888.00
ENGINE(HEAT)	.00 LBS	88.00 HP	\$ 476.79
TRANSMISSION	.00 LBS	101.00 HP	\$ 147.73
MOTOR/GENERATOR	.00 LBS	6.00 HP	\$ 34.08
CONTROLLER	.00 LBS	10.00 KW	\$ 155.09
FLYWHEEL(BY ENERGY)	.00 LBS	.00 KWH	\$.00
CHARGER	.00 LBS	10.00 KW	\$ 20.00
BATTERY	354.00 LBS	10.00 KWH	\$ 400.00
SUBTOTAL PROPULSION	154.00 LBS		\$ 1333.69
VEHICLE ASSEMBLY	.00 LBS	3541.00 LBS	\$ 211.62
TOTAL MANUFACTURING	354.00 LBS		\$ 3433.30
STICKER PRICE	\$ 6866.61		

YEAR	0	1	2	3	4	5	6	7	8	9	10	11
MILE DEP. COSTS		9114.	9114.	9114.	9114.	9114.	9114.	9114.	9114.	9114.	9114.	9114.
MILES EACH YEAR		9114.	9114.	9114.	9114.	9114.	9114.	9114.	9114.	9114.	9114.	9114.

MAINTENANCE												
ENGINE		57.	57.	57.	57.	57.	57.	57.	57.	57.	57.	57.
CHASSIS		32.	32.	32.	32.	32.	32.	32.	32.	32.	32.	32.
ELECTRIC		7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.
BATTERY		13.	13.	13.	13.	13.	13.	13.	13.	13.	13.	13.
TOTAL MAINT.		108.	108.	108.	108.	108.	108.	108.	108.	108.	108.	108.
REPAIR												
ENGINE		90.	90.	90.	90.	90.	90.	90.	90.	90.	90.	90.
CHASSIS		87.	87.	87.	87.	87.	87.	87.	87.	87.	87.	87.
ELECTRIC		9.	9.	9.	9.	9.	9.	9.	9.	9.	9.	9.
ACCES		0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TRANS.		17.	17.	17.	17.	17.	17.	17.	17.	17.	17.	17.
SUBTOTAL		202.	202.	202.	202.	202.	202.	202.	202.	202.	202.	202.
REP. MAIN. FACT.		.00	.05	.21	.36	.51	.66	.81	.97	1.00	.61	.00
ADJ. REPAIR COST		0.	11.	42.	72.	103.	134.	164.	195.	202.	123.	0.
FUELS												
GASOLINE		195.	195.	195.	195.	195.	195.	195.	195.	195.	195.	195.
ELECTRIC		75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.
TOTAL FUELS		270.	270.	270.	270.	270.	270.	270.	270.	270.	270.	270.
TOTAL MILE DEP.		378.	389.	419.	450.	481.	511.	542.	573.	580.	500.	378.
TAX/LICENSE	30.00	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	0.
INSURANCE	193.67	194.	194.	194.	194.	116.	116.	116.	116.	116.	116.	0.
TOTAL YEAR DEP	223.67	224.	224.	224.	224.	146.	146.	146.	146.	146.	146.	0.
BATTERY REPLACEMNT	.00	0.	0.	1029.	0.	0.	1029.	0.	1029.	0.	0.	0.
TOTAL OPERATING		401.	412.	472.	674.	627.	1686.	688.	1748.	726.	647.	378.
TOTAL OPERATING COST		= 10281.61										
AVERAGE PER YEAR		= 934.69										
		OPERATING COST PER MILE = .1026										

LIFE CYCLE COSTS

YEAR	0	1	2	3	4	5	6	7	8	9	10	11
PURCHASE PRICE	1373.32											
FINANCING		1449.	1449.	1449.	1449.	1449.	0.	0.	0.	0.	0.	0.
GASOLINE		195.	195.	195.	195.	195.	195.	195.	195.	195.	195.	195.
ELECTRICITY		75.	75.	75.	75.	75.	75.	75.	75.	75.	75.	75.
REPAIR		0.	11.	42.	72.	103.	134.	164.	195.	202.	123.	0.
MAINTENANCE		108.	108.	108.	108.	108.	108.	108.	108.	108.	108.	108.
BATTERY REPLACEMNT		0.	0.	1029.	0.	0.	1029.	0.	1029.	0.	0.	0.
LICENSE, TAX, INS.	223.67	224.	224.	224.	224.	146.	146.	146.	146.	146.	146.	0.
CHASSIS SALVAGE		0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	-487.
BATTERY SALVAGE		0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	1596.99	2050.	2041.	3121.	2123.	2076.	1686.	688.	1748.	726.	647.	-309.
DISCOUNT FACTOR	1.00	.98	.96	.94	.92	.90	.89	.87	.85	.83	.82	.80
PRESENT VALUE	1596.99	2009.	1980.	2937.	1958.	1877.	1494.	598.	1487.	605.	528.	-247.

PRESENT VALUE OF LIFE CYCLE COST \$ 16821.96

PRESENT VALUE OF LIFE CYCLE PER MILE \$.17

P2L6A4 2
 VIO VMT RGE BL CL BTP MPG KWHPM
 PAR 9114. 50. 2.6 500. L 49.1 .1954

TLCC	GASCST	ELECST	TLI	REPMAT	LIFE
16822.	1904.	730.	1829.	1959.	11
TOTAL	ACR	TLCCR	BEGP	SUBSIDY	8FD
2043.	.26	1.34	4.27	4084.	.38

Figure 2. Example Output of EHV Cost Program

Life Cycle Cost w/o Gas (A) + (Gas per Year (A) x Gas Cost)

= Life Cycle Cost w/o Gas (B) + (Gas per Year (B) x Gas Cost)

$$\text{where Gas Cost} = \sum_{i=1}^L f_i (\text{BEGP} + .05 (i))$$

$\sum$ = Life of the Vehicle

f_i = Yearly Discount Factor = $(1 + \text{DR})^{-i}$

DR = Discount Rate

Solving for the BEGP implies:

BEGP (A) = $\frac{(\text{Life Cycle Cost (A)} - \text{Life Cycle Cost (B)}) \text{ w/o Gas}}{(\text{Gas per Year (B)} - \text{Gas per Year (A)}) \times \sum_{i=1}^L f_i}$

$$- \frac{\sum_{i=1}^L f_i (.05) (i)}{\sum_{i=1}^L f_i}$$

If this price is higher than the 1985 gasoline price of \$1.05 per gallon⁴ (1978 dollars), the program calculates the present value of the subsidy (amount which must be taken off the present value life cycle cost of the hybrid) needed to achieve a \$1.05 BEGP. This subsidy is directly proportional to the amount of gas saved and the difference in the BEGP and \$1.05 as outlined in the following equations:

4. Supplementary Report #7, Scenario Generation

$$\$1.05 = \frac{(\text{Life Cycle Cost (A)} - \text{Subsidy} - \text{Life Cycle Cost (B)}) \text{ w/o Gas}}{(\text{Gas per year (B)} - \text{Gas per Year (A)}) \sum_{i=1}^L f_i}$$

$$- \frac{\sum_{i=1}^L f_i (.05) (i)}{\sum_{i=1}^L f_i}$$

Solving for the necessary subsidy in terms of the actual BEGP yields:

$$\text{subsidy} = (\text{BEGP (A)} - \$1.05) \times (\text{Gas Saved per Year}) \times \sum_{i=1}^L f_i$$

For instance, a vehicle with a BEGP of \$2.50 would require the subsidy to pay \$1.45 to save each gallon of gas that sells for \$1.05. On the other hand, if the BEGP was \$1.50 the cost of saving the gallon would be only \$.45. In essence, the difference in the BEGP and the actual gas price is the discounted present value of what the nation must be willing to pay to replace a gallon of gasoline with electricity if the particular vehicle/mission set being studied is used to obtain the displacement.

III. COST TRADE-OFFS

The hybrid or electric vehicle must be able to save the consumer a substantial amount of fuel, hence operating cost, to offset the larger initial cost and subsequent increases in tax, license, and insurance. To save fuel costs the operator must trade electrical energy for thermochemical energy. To make this trade the vehicle design must incorporate a propulsion system to trade electrical power for power available previously from the heat engine. The following comparisons show the trade-off in terms of cost to the consumer.

A. BATTERY AND ELECTRICITY COSTS VS. GASOLINE COST

This trade-off is the major factor in determining the economic feasibility of hybrid or electric vehicles, but the following discussion will show that this trade-off is only favorable in a limited number of circumstances. Since the trade-off in costs is a function of the cycle life of the battery and the heat engine efficiency over the driving cycle, the relationships are presented parametrically. The relationships are also a function of the costs of the battery, electricity, and gasoline plus the efficiency of the hybrid or electric vehicle over the driving cycle. These costs were held constant at the estimates used in the cost study and a representative conversion efficiency for an electric propulsion system has been chosen. The exercise has been carried out for those batteries used in the cost study and the assumptions concerning the batteries and the other cost parameters are listed below.

- 1) The purchase prices for the batteries are as follows:

Advanced Lead-Acid	- \$80/kWh
Sodium-Sulfur	- \$100/kWh
Nickel-Zinc	- \$120/kWh

- 2) The costs for fuel are as follows:

Electricity	- \$.042/kWh
Gasoline	- \$1.05/gallon

- 3) The electric propulsion system has an assumed conversion efficiency of 60% (wallplug to wheels).

The analysis simply compares the cost of the useable energy stored in a vehicle by summing the cost of electricity per kilowatt-hour and the cost of purchasing a battery per kilowatt-hour per cycle with the cost of gasoline per kilowatt-hour. This analysis makes no assumption regarding which vehicle is more efficient to operate (i.e., road load). The basic equations are simply stated as follows:

$$\frac{\text{ELECTRICITY COST PER KWH}}{\text{ELECTRICAL CONVERSION EFF.}} + \frac{\text{BATTERY COST PER KWH}}{\text{CYCLE LIFE OF BATTERY}} = \text{COST OF ELECTRICAL ENERGY USED PER KWH}$$

$$\frac{\text{GASOLINE COST PER KWH}}{\text{THERMOCHEMICAL CONVERSION EFF.}} = \text{COST OF THERMOCHEMICAL ENERGY USED PER KWH}$$

$$\text{ENERGY COST RATIO (ECR)} = \frac{\text{ELECTRICAL ENERGY COST}}{\text{THERMOCHEMICAL ENERGY COST}}$$

Using the assumptions enumerated and plotting the energy cost ratio (ECR) versus heat engine thermal efficiency yields an interesting conclusion. This implies that the tradeoff of electrical energy useage versus thermochemical is only attractive in situations where the average thermal efficiency of the heat engine falls below 19% in the case of a 1000 cycle life lead-acid battery (see Figure 3). It is obvious from this presentation that the advanced batteries cannot help this situation unless their cycle life is dramatically increased or the cost per kilowatt-hour is dramatically decreased. Since this cost trade-off is based on cost per kWh per cycle, the energy cost ratio plotted for 2000 cycle life batteries is equivalent to calculating the ECR with the cost of the 1000 cycle life batteries cut in half (corresponding to the 1980 DOE goal of \$40/kWh for Pb-Ac batteries⁵). The acceptable trade-off point is shifted to a thermal efficiency of 26 percent which is well above the efficiency of most engines operated in the conventional manner.

5. The Second Annual Report to Congress on the Implementation of Public Law 94-413, The Electric and Hybrid Research, Development, and Demonstration Act of 1976, Final Draft, October 1978.

Figure 3. Cost Ratio of Energy Delivery to Vehicle Wheels

B. ELECTRIC MOTOR AND CONTROLLER VS. HEAT ENGINE

In many cases this trade-off has been conceived as motor versus heat engine, but a necessary part of the propulsion system is the electric motor controller. In this case the controller costs are based on having an electronic solid state armature and field controller. Figure 4 illustrates how deceptive leaving controller costs off can be, assuming the cost data provided by the EHV Cost Handbook. This would imply quite an attractive trade-off in favor of the electric motor, yet when the controller cost is added, there is a limited chance for an economic advantage.

However, if the controller cost could be reduced by one-half (i.e., perhaps by using battery switching and a sophisticated field control in conjunction with the mechanical transmission), the cost trade-off would take the form of the dotted line in the figure.

But electric motors are not chosen as a result of this type of analysis, rather the sizing is determined from performance requirements. This trade-off has been presented to relate the cost penalty incurred in the vehicle designs of this study.

To sum up the discussion of electric versus heat engine propulsion systems, it has been found that the results are favorable under a limited number of circumstances. The energy trade-off indicates that the heat engine to be replaced must average a low thermal efficiency over the driving cycle (i.e., 19% for a 1000 cycle life lead-acid battery, \$80/kWh).

The power trade-off leads to the conclusion that there is a very slim chance of savings in the cost of power producers unless the costs of the controllers are decreased substantially. Perhaps a reduction in sophistication would be preferred to the high cost. It is not apparent at this time that the sophistication in control is saving energy or cost in the operation of these vehicles.

Figure 4. Power Cost Ratio

IV. COST FUNCTIONS

The hybrid vehicles investigated have one dominant factor in common, the higher initial cost when compared to conventional vehicles designed for the same task. To be cost competitive, these alternative vehicles must save fuel costs over their lifetime to make up for this difference and those unique costs incurred such as battery replacement and electrical propulsion system maintenance. To test the capability of these vehicles to compete economically in this manner, the break-even gas price (BEGP) has been used as the basis of comparison. The BEGP dictates an economic comparison with an internal combustion engine (ICE) vehicle which has been specifically designed for the same mission. The following sections detail the results of analyzing the conventional vehicles with the costing methodology previously described as well as the economic comparisons for the seven missions.

A. PRIVATE USE VEHICLES (MISSIONS I-III)⁶

1) Conventional Vehicles

The ICE vehicles specifically designed for each mission were found to be very fuel efficient based on current standards as well as having reasonable purchase prices as can be seen in Table 1 which presents the first three mission vehicles. This fuel efficiency is critical to the analysis because the BEGP is inversely proportional to the amount of fuel the contending vehicle can save over its lifetime. In short, these ICE vehicles are very hard to beat in economic terms as the following sections will attest.

2) Hybrid Vehicles

a. Life Cycle Cost vs. Fuel Displacement

Several vehicles have been designed to perform the same mission with different types of batteries and different energy storage capabilities to show the effect of primary electric range

6. Supplementary Report No. 1, Mission Analysis

Table 1

Conventional Vehicles - Missions I, II & III

Discounted Present Value Costs (1978 \$)					Annual		Vehicle life (Years)
Mission	Mfg	Acquisiton	Operating	Life Cycle	Mileage (km)	Fuel Mileage MPG (KPL)	
I-1	1892	3784	7030	10814	12858	43.7 (18.6)	13
-2			6564	10348	18692	43.8 (18.6)	9
3			6413	10197	24495	43.9 (18.7)	7
II-1	2970	5940	7992	13932	9026	30.1 (12.8)	15
-2			8568	14508	14664	30.3 (12.9)	11
-3			8542	14482	21456	30.6 (13.0)	8
III-1	3499	6998	10464	17462	10627	24.5 (10.4)	15
-2			9889	16887	16264	24.5 (10.4)	10
-3			9299	16297	23057	24.7 (10.5)	7

on life cycle cost. The cost analysis showed no major differences between the first three missions or the travel patterns within those missions and Mission II-1 was chosen as an example of the private use vehicles (with the exception of the series hybrid vehicle cost analysis - see Section h).

Total life cycle cost increased with fuel displacement as can be seen in Figure 5 which presents the conventional vehicle as well as the parallel and parallel-flywheel hybrids designed for this mission. It is quite evident from this figure that the increase was due primarily to an increase in purchase price and related costs (financing, tax, license, and insurance). These costs obviously overshadowed the fuel cost savings of the hybrid systems. (See appendix for detailed cost breakdown). The following section presents the necessary gas price (BEGP) to make the trade-off comparable economically.

b. BEGP vs. Fuel Displacement

The BEGP results as shown in Figure 6 are somewhat unexpected in that there is not a very strong dependence on fuel displacement (battery pack size). This would imply that once the gasoline price reaches a certain level that it is possible to displace large amounts of fuel with the hybrid vehicle. The fact that the BEGP does not fall below certain plateaus warrants investigation and this was done for an example group of hybrid vehicles to support the approximate \$2.50 level (1000 cycle life batteries) which is prevalent throughout the private use vehicle analysis. Figure 7 presents the comparative cost breakdown of the hybrid and conventional vehicles. The effect of purchasing batteries and electricity is quite obvious in that these unique costs add up to \$1.65 of the \$2.55 BEGP (lowest BEGP vehicle). The other components of the purchase price unique to the hybrid (motor, charger, controller) account for another \$.51, primarily due to controller cost. The balance of the BEGP can be seen in the added chassis cost due to weight propagation and the added costs of interest, tax, license, and insurance due to the higher purchase price.

Figure 5. Mission II-1 Life Cycle Cost
 Pb-Ac Batteries - 1000 Cycle Life
 15 Year Vehicle Life

Figure 6. Mission II-1 Break-Even Gas Price

Figure 7. Mission II-1 Comparative BEGP
 Cost Breakdown
 Pb-Ac Batteries - 1000 Cycle Life

It should be pointed out that the curve representing the vehicles with 2000 cycle life lead-acid batteries is exactly the same result as if the vehicles were evaluated with 1000 cycle life batteries at half the cost (\$40/kWh). This corresponds precisely to the 1980 DOE goal referenced previously, yet the BEGP drops to only \$2.00 per gallon.

Another somewhat unexpected result is the relatively small effect of the specific energy of the advanced batteries on the BEGP if batteries of the same cycle life are compared. Though the specific energy (C/3 rate) of the nickel-zinc batteries (77 WH/kg) is 75 percent higher than the advanced lead-acid (44 WH/kg), the nickel-zinc BEGP is actually higher in this case. The difference is even more dramatic with sodium-sulfur batteries (120 WH/kg) with a specific energy approximately three times lead-acid, yet the BEGP is at the same level. However, the effect of the specific energy differences are evident in the slopes of the curves of Figure 6. The lead-acid battery dictates much more structural support as the battery pack size increases than the other batteries of this study. This weight propagation incurs direct costs as well as increasing maintenance costs, etc.

The increasing slope of the lead-acid BEGP curves was not only a product of specific energy, but another battery characteristic important to hybrid vehicles, specific power. The vehicle with lead-acid batteries requires a larger battery pack (kWh) for the same power capability.

The graph of BEGP as a function of fuel displacement leads to an interesting conclusion with respect to advanced battery development which supports the cost trade-offs discussed previously. The BEGP is much more strongly dependent on cycle life and cost per kWh than specific energy. The specific battery cost requirements for the vehicles of this mission are presented in Section h.

c. Subsidy vs. Fuel Displacement

The battery need not be forced to carry the total economic burden if the life cycle cost of the hybrid vehicle could be reduced by subsidizing a portion of the initial cost. The present value of the subsidy necessary for the Mission II-1 vehicles to have a BEGP of \$1.05 has been calculated and is shown graphically in Figure 8 as a function of fuel displacement. The results are interesting in that subsidizing the owner/operator in some manner, perhaps with an interest-free loan on the purchase price could result in the displacement of 25-40% of the fuel use on this mission, though the actual cost to the government would not be insignificant.

d. Acquisition Cost Ratio vs. Fuel Displacement

The dominant economic factor concerning the hybrid and electric vehicles is the higher initial cost. Since the private individual does not buy a vehicle based on life cycle cost at the present time, this could be a very important factor in sales. The purchase prices of the Mission II vehicles range from 1.1 to 1.75 times the cost of the conventional Mission II vehicle and the ratios are shown in Figure 9. The shape of the curve resembles that of the BEGP because a substantial part of the BEGP is due to this purchase price differential as shown previously. It is quite evident from this curve that the different battery types make very little difference in the purchase price of vehicles designed for this specific mission. The savings in weight propagation by using batteries with higher specific energy was offset by the higher cost per kWh.

e. MPG vs. Acquisition Cost Ratio

Another factor which will affect the sales of this type of vehicle is the expected fuel efficiency or MPG. These vehicles are capable of very high MPG as shown in Figure 10. For instance, an automobile costing 50 percent more than its conventional counterpart would get up to 3 times the mileage in this case.

Figure 8. Mission II-1 Subsidy

Figure 9. Mission II Acquisition Cost Ratio

Figure 10. Mission II Mileage

f. Battery Life

The battery life is a function of the cycle life of the battery and the mission travel pattern of the vehicle. This factor is very important to the economic analysis since battery costs are one of the main "drivers" in BEGP. As can be seen in the example of Figure 11, a 2000 cycle life battery is adequate for the life of the vehicle. This is true for most of the private use vehicles as the table in the appendix shows.

g. Battery Cost Requirements

The battery cost requirements necessary to develop economically competitive hybrid vehicles (on a life cycle cost basis) were derived from the BEGP results which were presented earlier. The obvious conclusion was that reductions in battery cost alone would not be enough to make these vehicles economically competitive with their conventional ICE counterpart without subsidization. This is born out by the graphic presentation of Figure 12 which shows that even free lead-acid batteries would not result in equivalent vehicle life cycle cost until the gasoline price reaches approximately \$1.50 per gallon.

h. Series Hybrid Vehicles

Series hybrid vehicles for private use were designed only for Mission I, hence direct comparison to the Mission II-1 vehicles discussed previously could not be made. However, the parallel and parallel-flywheel hybrids were also designed for Mission I and the comparison is presented in this section. The series hybrid vehicles resulted in much higher BEGP's primarily due to the larger motor/controller costs as well as the added generator costs, although the series design was capable of operating without a transmission. Figure 13 reflects these cost differences and illustrates the problem of substituting costly vehicle components for relatively inexpensive gasoline.

Figure 11. Mission II-1 Battery Life

Figure 12. Lead-Acid Battery Purchase Price Requirements for Equivalent Vehicle Life Cycle Cost

Figure 13. Mission I-1 Comparative BEGP Cost Breakdown - 1000 Cycle Life Batteries

B. COMMERCIAL VEHICLES (MISSIONS IV-VII)

The commercial vehicles considered in this study cover a wide range of applications (i.e., taxis, vacation rental vehicles, variable route delivery vans, fixed route delivery vans) hence the resulting vehicle designs and fuel efficiencies vary tremendously. For these reasons the commercial hybrid vehicles designed for each mission are presented separately.

1) Conventional Vehicles

Since the cost analysis is on a comparative basis the conventional reference vehicles that have been specifically designed for these missions are detailed in Table 2. The variation in cost and fuel economy is quite evident and can be easily explained. The relatively low fuel mileage of the Mission IV taxi when compared to the Mission V rental vehicle is a result of the much larger percentage of urban driving. Similarly, the Mission VII fixed route delivery van performs at a much lower fuel efficiency than the van which operates over the variable route (Mission VI) because of the larger percentage of idle time and largely transient heat engine operation (Mission VII is 70% Aerospace Van Cycle).

2) Mission IV Taxi

a. Life Cycle Cost vs. Fuel Displacement

As in the case of the private use vehicles, the total life cycle cost for hybrids performing the taxi mission increases with fuel displacement as shown in Figure 14. The vehicles could not make up for the difference in purchase price with the fuel cost savings obtained at \$1.05 per gallon. However, it appears that type type of vehicle could displace 25-30 % of the fuel with a life cycle cost equivalent to the conventional vehicle.

Table 2

Conventional Vehicles - Missions IV, V, VI & VII

Mission	Discounted Present Value Costs (1978 \$)				Annual		Vehicle Life (years)
	Manufacturing	Acquisition	Operating	Life Cycle	Mileage (km)	Fuel Mileage mpg(KPL)	
IV	3503	7006	5747	12753	48352	19.6 (8.3)	3
V	3519	7038	4665	11703	48428	27.2 (11.6)	3
VI-1	4528	9056	4502	13558	8652	16.7 (7.1)	15
-2			6117	15173	16315	17.0 (7.2)	10
VII-1	4654	9308	8111	17419	11300	9.1 (3.9)	14
-2			10103	19411	22061	8.9 (3.8)	7

Figure 14. Mission IV Life Cycle Cost
Pb-Ac Batteries - 1000 Cycle Life
3 Year Vehicle Life

b. BEGP vs. Fuel Displacement

The hybrid system was found to be very capable of saving fuel when operated in situations where the internal combustion engine of the conventional engine must operate largely in the transient mode, hence at a low thermal efficiency. This is illustrated by the BEGP of the hybrid taxis shown in Figure 15. On the basis of cost competitiveness, it appears that the hybrid taxi could displace 25-30% of the fuel consumed in that mission when the gas price reaches \$1.25. The fact that the price level approached \$1.00 is quite encouraging and can be explained with the help of the comparative cost breakdown of Figure 16. In contrast to the previous cost breakdowns of the example private use vehicles, this taxi succeeded in reducing the operating cost by an amount almost equal to the difference in purchase price of the vehicles. The main factor is the fuel intensive nature of the mission which results in the reduction of fuel costs (gasoline and electricity) of 38 percent for the hybrid vs. the ICE taxi amounting to a discounted present value of \$1510.

c. Subsidy vs. Fuel Displacement

Because the BEGP came very close to the expected gas price in 1985 the necessary subsidy to reach \$1.05 was relatively small for hybrid designs capable of displacing 40% or greater of the fuel consumed by ICE taxis as can be seen in Figure 17. It appears that the hybrid taxi could displace 25-30% of the fuel normally used on this mission without added cost to the operator or subsidization.

d. Acquisition Cost Ratio vs. Fuel Displacement

The purchaser must be willing to pay a higher purchase price for these vehicles according to the amount of fuel displaced as shown in Figure 18. In this case, a price differential of 24 percent will save 38 percent of the fuel while an additional 65 percent displaces 58 percent of the fuel.

Figure 15. Mission IV Break-Even Gas Price

Figure 16. Mission IV Comparative BEGP Cost Breakdown
 Pb-Ac Batteries - 1000 Cycle Life

Figure 17. Mission IV-1 Subsidy

Figure 18. Mission IV Acquisition Cost Ratio
Pb-Ac Batteries

e. MPG vs. Acquisition Cost Ratio

Although this relationship is not apt to be as impressive to the commercial buyer who purchases based on life cycle cost, the MPG is impressive for vehicles constantly operating in urban traffic conditions. Figure 19 shows the possible MPG with parallel hybrid system compared to the MPG of the conventional vehicle.

f. Battery Life

The concept of battery life in a vehicle operated as a taxi is not as straightforward as in the other vehicles of this study. The taxi in this study was treated as if it was operating on the first shift where the driving would be predominantly urban. The taxi operating at night would operate on a different cycle, presumably less stringent. If one battery pack was designed to operate over the entire day, the size would be excessive and the cost would drive the system out of competition. This problem could be solved by the purchase of two interchangeable battery packs, but they would undergo entirely different duty cycles. Costs associated with the necessary infrastructure for this type of operation have not been considered and for this reason the study deals only with taxi operation over the first shift with an annual VKT of 48352 kilometers.

Table 3 summarizes the battery lives for the vehicles designed for several primary electric ranges which operate over the same travel pattern. In this case a 1000 cycle life battery would very closely match the expected life of the vehicle operated as a taxi on the daytime shift.

g. Battery Cost Requirements

The battery cost requirements for the hybrid vehicles operated on the taxi mission are more encouraging than those presented for the private use vehicles. Figure 20 presents the possibility of the hybrid taxi becoming economically competitive with the ICE taxi

Figure 19. Mission IV Mileage

Table 3

Battery Life - Mission IV

Primary Electric Range (km)	Battery Cycle Life	Battery Life (Years)	Vehicle Life (Years)
50	500	1.4	3
	1000	2.8	
	2000	5.6	
75	500	1.4	3
	1000	2.9	
	2000	5.8	
100	500	1.5	3
	1000	3.0	
	2000	5.9

Figure 20. Lead-Acid Battery Purchase Price Requirements for Equivalent Vehicle Life Cycle Cost

and displacing perhaps 30-35% of the fuel normally used on this mission if the DOE cost goal for lead-acid batteries was met (\$.04 per kWh per cycle) and if gasoline costs \$1.00 per gallon. With the battery costs of the EHV Cost Handbook (\$.08 per kWh per cycle) it appears that an economically competitive hybrid taxi could displace approximately 25-30% with gasoline costing \$1.00 per gallon.

3) Mission V - Vacation Rental Vehicle

The reference vehicle operated very efficiently over this driving cycle, achieving an annual average of 27.2 mpg. The hybrid vehicle does not save very much fuel when operated over mainly highway cycles simply because the added weight of the system becomes a burden and the hybrid system capabilities are not utilized effectively. For these reasons the BEGP was found to be greater than \$4.00 per gallon (see appendix for details). Therefore, this is not considered an attractive mission for hybrid vehicles.

4) Mission VI - Variable Route Delivery Van

Much like the vacation rental vehicle the conventional vehicle designed for this mission operated relatively efficiently over this cycle (16.7 mpg). The combination of fuel efficiency and the 15 percent discount rate priced the hybrid vehicles out of contention with BEGP's well over \$5.00 per gallon. To illustrate the detrimental effect of the 15 percent discount rate the BEGP of one example delivery van was calculated with a discount rate of zero percent. The result was a drop in the BEGP from \$6.71 per gallon to \$3.44 per gallon, hence the assumption of a discount rate has a major effect on the outcome.

5) Mission VII - Fixed Route Delivery Van

The hybrid fixed route vans produced very interesting results which will be detailed in the following sections. The results were found to be somewhat better than those vehicles which were designed for private use, even with the 15 percent commercial discount rate.

There are several reasons why these results occurred and these should be stated explicitly to guard against erroneous conclusions. The major factor is the fuel efficiency of the conventional vehicle designed for the same mission which only gets 9 MPG. Another important assumption made with these vehicles was that the parallel hybrid system could utilize its unique capabilities in such a way that the heat engine need only be turned on when it is necessary (i.e., power could be drawn from the electrical system to get the engine to speed before ignition, etc.). Since the Mission VII driving cycles were predominantly van cycles, there were a considerable number of stops and decelerations. Because idle fuel flow has a strong effect on the fuel efficiency, this was a source of a large savings in fuel which the conventional vehicle could not achieve.

a. Life Cycle Cost vs. Fuel Displacement

This mission was similar to the other missions in that the total life cycle cost is an increasing function with fuel displacement though there was a slight minimum at a fuel displacement of 60 percent. Figure 21 illustrates this minimum and the dramatic shift from fuel costs to initial costs. The purchase price and related costs (i.e. tax, license, and insurance) had much the same trend as in the other mission vehicles presented previously and the difference in life cycle cost was produced largely by the energy conversion efficiency of the propulsion systems. Again the differences between the parallel and parallel-flywheel hybrid systems were minimal.

b. BEGP vs. Fuel Displacement

The graph of BEGP for Mission VII-1 is shown in Figure 22. This implies the optimum hybrid van design was capable of displacing 60 percent of the fuel normally used on this mission at about \$1.60 (1000 cycle life lead-acid battery). To support this BEGP a cost breakdown and comparison with the other vehicles designed for this mission is shown in Figure 23. There are several

Figure 21. Mission VII-1 Life Cycle Cost
 Pb-Ac Batteries - 1000 Cycle Life
 14 Year Vehicle Life

Figure 22. Mission VII-1 Break-Even Gas Price
Pb-Ac Batteries - 1000 Cycle Life

Figure 23. Mission VII-1 Comparative BEGP Cost Breakdown
 Pb-Ac Batteries - 1000 Cycle Life

obvious differences in this and the cost breakdowns presented for the other vehicles of this study which combine for the lower BEGP. The first is the relatively small contribution of purchase price difference (\$1.03) to the \$1.60 BEGP. Another difference is the volume of gas saved over the lifetime of the vehicle (6475 gallons) due to the annual fuel mileage of almost 23 MPG. The effect of higher VKT is shown in Mission VII-2 (see appendix) which lowers the BEGP to \$1.20 (Pb-Ac, 1000 cycle life).

c. Subsidy vs. Fuel Displacement

The required subsidy to reach BEGP's of \$1.05, \$1.30, and \$1.80 are shown in Figure 24. The effect of the optimum design is shown by the dip in subsidy at 50 to 60 percent fuel displacement.

d. Acquisition Cost Ratio vs. Fuel Displacement

The purchaser must be willing to pay a higher purchase price for the hybrid vehicle (added batteries, motor, etc.) in order to save fuel while in operation. The relationship of acquisition cost to fuel displacement is shown in Figure 25. In this case the optimum hybrid (in terms of lowest BEGP) costs about 30 percent more than the conventional vehicle and saves about 60 percent of the fuel.

e. MPG vs. Acquisition Cost Ratio

The graph of this relationship (Figure 26) shows the dramatic increases in MPG which could be expected for parallel hybrid vehicle designs of this type. Though this should not influence the commercial purchaser to a great extent, this stresses the highly nonlinear relationship of MPG to purchase price.

Figure 24. Mission VII-1 Subsidy
Pb-Ac Batteries - 1000 Cycle Life

Figure 25. Mission VII Acquisition Cost Ratio

Figure 26. Mission VII Fuel Mileage

f. Battery Life

The expected battery lives for Mission VII hybrid vehicles are summarized in Table 4. The battery does not last the lifetime unless the cycle life is greater than 2000 and only then when operated at 100 km per day for a lifetime of 7 years.

g. Battery Cost Requirements

The relatively low BEGP's of the Mission VII hybrid vehicles produced the most lenient battery cost requirements for economic competitive life cycle cost. The cost requirements shown in Figure 27 imply that these hybrid fixed route delivery vans could be economically competitive in a situation where the gasoline price was \$1.25 per gallon and lead-acid batteries were sold at \$.04 per kWh per cycle (DOE goal). If batteries were sold at twice that price (corresponding to the EHV Cost Handbook assumption) the gasoline price would have to be \$1.60 per gallon to be competitive without subsidization.

Table 4

Battery Life - Mission VII

Mission	Primary Electric Range(km)	Battery Cycle Life	Battery Life (Years)	Vehicle Life (Years)
VII-1	50	500	2.3	14
		1000	4.6	
		2000	9.2	
	75	500	3.3	14
		1000	6.6	
		2000	13.3	
	100	500	4.4	14
		1000	8.8	
		2000	17.7	
VII-2	50	500	2.1	7
		1000	4.2	
		2000	8.3	
	75	500	2.1	7
		1000	4.2	
		2000	8.3	
	100	500	2.3	7
		1000	4.6	
		2000	9.2

Figure 27. Lead-Acid Battery Purchase Price Requirements for Equivalent Vehicle Life Cycle Cost

APPENDIX A

BREAK-EVEN GASOLINE PRICE AS A FUNCTION OF FUEL DISPLACEMENT
(PARAMETRIC WITH BATTERY CYCLE LIFE)

Figure A-1. Break-Even Gasoline Price as a Function
Fuel Displacement, Mission I-1

Figure A-2. Break-Even Gasoline Price as a Function Fuel Displacement, Mission I-2

Figure A-3. Break-Even Gasoline Price as a Function Fuel Displacement, Mission I-3

Figure A-4. Break-Even Gasoline Price as a Function Fuel Displacement, Mission II-1

Figure A-5. Break-Even Gasoline Price as a Function Fuel Displacement, Mission II-2

Figure A-6. Break-Even Gasoline Price as a Function
Fuel Displacement, Mission II-3

Figure A-7. Break-Even Gasoline Price as a Function
Fuel Displacement, Mission III-1

Figure A-8. Break-Even Gasoline Price as a Function Fuel Displacement, Mission III-2

Figure A-9. Break-Even Gasoline Price as a Function Fuel Displacement, Mission III-3

Figure A-10. Break-Even Gasoline Price as a Function Fuel Displacement, Mission IV

Figure A-11. Break-Even Gasoline Price as a Function Fuel Displacement, Mission V

Figure A-12. Break-Even Gasoline Price as a Function Fuel Displacement, Mission VI-1

Figure A-13. Break-Even Gasoline Price as a Function Fuel Displacement, Mission VI-2

Figure A-14. Break-Even Gasoline Price as a Function Fuel Displacement, Mission VII-1

Figure A-15. Break-Even Gasoline Price as a Function Fuel Displacement, Mission VII-2

APPENDIX B

BREAK-EVEN GASOLINE PRICE AS A FUNCTION OF SUBSIDY
(PARAMETRIC WITH BATTERY CYCLE LIFE)

Table B-1. Break-Even Gasoline Price as a Function of Subsidy, Mission I-1

MISSION		ICE-FE (MPG)		WKT (KID)		LIFE (YEARS)			
I-1		43.7		12858		13			
VEHICLE TYPE		ELECTRIC		PARALLEL		PAR-FLYWHEEL		SERIES	
BATTERY TYPE	CYCLE LIFE	SUBSIDY (1973\$)	RANGE MPG	50	75	100	50	75	100
PB-AC	500	0		72.1	145.0	290.7		182.2	
				34	70	85		76	
				4.38	4.58	4.99		3.57	
				3.77	4.24	4.71		3.26	
				3.16	3.89	4.43		2.94	
				2.55	3.55	4.14		2.67	
				1.94	3.21	3.86		2.31	
				2726	5124	6958		3983	
				2.87	3.03	3.42		2.50	
				2.26	2.69	3.13		2.19	
				1.65	2.34	2.85		1.87	
				1.03	2.00	2.57		1.55	
				.42	1.66	2.28		1.24	
				1483	2878	4178		2295	
				2.12	2.25	2.62		1.96	
				1.51	1.91	2.34		1.65	
PB-AC	500	0		.90	1.56	2.05		1.33	
				.24	1.22	1.77		1.01	
				-.33	.87	1.49		.70	
				874	1744	2770		1444	
PB-AC	500	0							
PB-AC	500	0							
PB-AC	500	0							
PB-AC	500	0							
PB-AC	500	0							
PB-AC	500	0							
PB-AC	500	0							
PB-AC	500	0							
PB-AC	500	0							
PB-AC	500	0							

Table B-2. Break-Even Gasoline Price as a Function of Subsidy, Mission I-2

MISSION I-2				ICE-FE (¢PG)	43.8	WKT (KTD)	18692	LIFE (YEARS)	9				
VEHICLE TYPE				ELECTRIC	PARALLEL			PAR-FLYWHEEL			SERIES		
BATTERY TYPE	CYCLE LIFE	SUBSIDY (1978\$)	RANGE (MPG)		50	75	100	50	75	100	50	75	100
PB-AC	500	0	250		71.1	146.3	307.7			168.2			72.8
					38	70	86			74			40
					440	4.57	492			3.65			8.54
					3.79	4.24	4.65			3.33			7.96
					3.19	3.91	4.38			3.02			7.38
					2.54	3.58	4.11			2.71			6.81
					1.99	3.25	3.84			2.40			6.23
					2184	5342	7193			4162			6478
					2.89	3.02	3.37			2.55			6.50
					2.29	2.69	3.10			2.23			5.92
					1.69	2.36	2.83			1.92			5.34
					1.09	2.03	2.56			1.61			4.77
					.78	1.70	2.29			1.30			4.19
					1530	2989	4304			2397			4714
					2.14	2.24	2.56			1.99			5.47
					1.53	1.91	2.29			1.68			4.89
					.93	1.58	2.02			1.37			4.31
					.33	1.25	1.75			1.05			3.74
					-27	.92	1.48			.74			3.16
					21.05 Subsidy				903	1802	2800		1507
HI-ZN	500	0	250										93.8
													53
													5.72
													8.24
													7.86
													7.42
													6.99
													8863
													5.67
													5.23
													4.80
													4.37
													3.94
													5334
													4.13
													3.69
													3.26
													2.83
													2.39
					21.05 Subsidy								
HA-S	500	0	250										107.2
													59
													5.96
													5.57
													5.18
													4.79
													4.40
													6248
													3.86
													3.47
													3.08
													2.69
													2.30
													3403
													2.80
													2.41
													2.02
													1.63
													1.24
					21.05 Subsidy								

Table B-3. Break-Even Gasoline Price as a Function of Subsidy, Mission I-3

MISSION		I-3		ICE-FE (1PG)		43.9		WGT (KID)		24495		LIFE (YEARS)		7	
VEHICLE TYPE		ELECTRIC		PARALLEL		PAR-FLY-WHEEL		SERIES							
BATTERY TYPE	CYCLE LIFE	SUBSIDY (1973\$)	RANGE (PG)	50	75	100	50	75	100	50	75	100	50	75	100
PB-AC	500	0	1PG	63.7	128.9	291.4				113.2				66.1	
			2FD	31	66	85			61			33			
				463	4.72	4.87			4.23			1.86			
				500	3.91	4.38	4.61			3.87			9.19		
				1000	3.19	4.04	4.35			3.50			8.52		
				1500	2.47	3.70	4.08			3.14			7.86		
				2000	1.75	3.36	3.82			2.77			7.19		
				\$1.05 Subsidy	2484	5418	7277			4365			6608		
				1000	0	3.11	3.12	3.35			2.94			7.49	
				500	2.34	2.78	3.08			2.58			6.83		
	1000	0		1.67	2.44	2.82			2.21			6.16			
				.95	2.10	2.56			1.85			5.50			
				.24	1.76	2.30			1.48			4.83			
				\$1.05 Subsidy	1434	3054	4374			2593			4835		
				2000	2.35	2.32	2.54			2.24			6.31		
				500	1.63	1.98	2.28			1.93			5.65		
				1000	.92	1.64	2.02			1.57			4.98		
				1500	.20	1.30	1.75			1.20			4.32		
				2000	-.52	.96	1.49			.84			3.65		
				\$1.05 Subsidy	906	1874	2838			1707			3950		
	1500	0	1PG										90.3		
			2FD										51		
				500									8.75		
				1000									8.32		
				1500									7.83		
				2000									7.45		
				\$1.05 Subsidy									7.01		
				1000	0								88.61		
				500									5.67		
				1000									5.24		
	2000	0										4.80			
												4.37			
				\$1.05 Subsidy								3.93			
				2000								5317			
				500								4.13			
				1000								3.70			
				1500								3.26			
				2000								2.83			
				\$1.05 Subsidy								2.39			
				1000								3546			
	2500	0	1PG										102.2		
			2FD										57		
				500									57		
				1000									57		
				1500									57		
				2000									57		
				\$1.05 Subsidy									57		
				1000	0								57		
				500									57		
				1000									57		
	3000	0										57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
				1000	0							57			
				500								57			
				1000								57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
	3500	0										57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
				1000	0							57			
				500								57			
				1000								57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
	4000	0										57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
				1000	0							57			
				500								57			
				1000								57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
	4500	0										57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
				1000	0							57			
				500								57			
				1000								57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
	5000	0										57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
				1000	0							57			
				500								57			
				1000								57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
	5500	0										57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
				1000	0							57			
				500								57			
				1000								57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
	6000	0										57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
				1000	0							57			
				500								57			
				1000								57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
	6500	0										57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
				1000	0							57			
				500								57			
				1000								57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
	7000	0										57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
				1000	0							57			
				500								57			
				1000								57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
	7500	0										57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
				1000	0							57			
				500								57			
				1000								57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
	8000	0										57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
				1000	0							57			
				500								57			
				1000								57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
	8500	0										57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
				1000	0							57			
				500								57			
				1000								57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
	9000	0										57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
				1000	0							57			
				500								57			
				1000								57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
	9500	0										57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
				1000	0							57			
				500								57			
				1000								57			
				1500								57			
				2000								57			
				\$1.05 Subsidy								57			
	10000	0										57			
				1500								57			
				2000								57			
				\$1.05 Subsidy											

Table B-4. Break-Even Gasoline Price as a Function of Subsidy, Mission II-1

MISSION II-1				ICE-FE (1PG)	30.1	WKT (KD)	9026	LIFE (YEARS)	15					
VEHICLE TYPE				ELECTRIC	PARALLEL			PAR-FLYWHEEL			SERIES			
BATTERY TYPE	CYCLE LIFE	SUBSIDY (1978\$)	RANGE (MPG)		50	75	100	50	75	100	50	75	100	
PB-AC	500	0	1PG		38.4	102.4	183.4		110.9					
			2FD		21	71	84		73					
					3.62	4.74	5.14		4.09					
					2.65	4.44	4.89		3.80					
					1.67	4.15	4.64		3.52					
					.70	3.85	4.39		3.23					
					-.28	3.55	4.14		2.94					
					\$1.05 Subsidy		1320	6231	8185		5296			
					1000	0	2.53	3.23	3.58		3.03			
					500		1.55	2.93	3.33		2.75			
					1000		.58	2.64	3.08		2.46			
					1500		-.40	2.34	2.83		2.17			
					2000		-1.37	2.05	2.58		1.88			
					\$1.05 Subsidy		758	3682	5054		3455			
					2000	0	1.98	2.49	2.85		2.51			
					500		1.01	2.19	2.60		2.23			
					1000		.03	1.90	2.35		1.94			
					1500		-.94	1.60	2.10		1.65			
					2000		-1.92	1.30	1.85		1.37			
					\$1.05 Subsidy		477	2430	3343		2551			
11-ZN	500	0	1PG		40.1	82.4	183.1							
			2FD		25	63	84							
					5.02	5.46	5.73							
					4.18	5.13	5.48							
					3.34	4.80	5.23							
					2.50	4.47	4.98							
					1.66	4.14	4.73							
					\$1.05 Subsidy		2366	6693	9347					
					1000	0	3.13	3.36	3.55					
					500		2.29	3.03	3.30					
					1000		1.45	2.70	3.05					
					1500		.61	2.37	2.80					
					2000		-.23	2.04	2.55					
					\$1.05 Subsidy		1240	3506	4999					
					2000	0	2.19	2.33	2.54					
					500		1.35	2.00	2.29					
					1000		.51	1.67	2.04					
					1500		-.33	1.34	1.79					
					2000		-1.17	1.01	1.53					
					\$1.05 Subsidy		679	1942	2969					
1A-S	500	0	1PG		48.0	85.2								
			2FD		37	65								
					4.78	4.69								
					4.22	4.37								
					3.66	4.04								
					3.10	3.72								
					2.54	3.39								
					\$1.05 Subsidy		3323	5626						
					1000	0	2.99	2.91						
					500		2.43	2.58						
					1000		1.87	2.26						
					1500		1.31	1.94						
					2000		.75	1.61						
					\$1.05 Subsidy		1730	2872						
					2000	0	2.11	2.08						
					500		1.55	1.75						
					1000		.99	1.43						
					1500		.43	1.11						
					2000		-.13	.78						
					\$1.05 Subsidy		948	1586						

Table B-5. Break-Even Gasoline Price as a Function of Subsidy, Mission II-2

MISSION II-2				ICE-FE (CPG)	30.3	WKT (KID)			14664	LIFE (YEARS)			11
VEHICLE TYPE		SUBSIDY (1978\$)	RANGE (MPG)	ELECTRIC	PARALLEL			PAR-FLYWHEEL			SERIES		
BATTERY TYPE	CYCLE LIFE				50	75	100	50	75	100	50	75	100
PB-AC	500	0	REF		38.0	96.9	170.9		95.6				
					20	69	82		68				
					3.34	4.58	4.94		3.96				
					2.50	4.34	4.73		3.71				
					1.67	4.09	4.53		3.46				
					.83	3.84	4.32		3.21				
					-.01	3.59	4.11		2.97				
					1367	7153	9425		5854				
					2.31	3.06	3.36		2.85				
					1.47	2.81	3.15		2.60				
					.63	2.56	2.94		2.35				
					-.21	2.32	2.74		2.11				
					-1.05	2.07	2.53		1.86				
					751	4064	5588		3624				
					1.80	2.30	2.58		2.30				
					.96	2.05	2.37		2.05				
					.12	1.80	2.16		1.80				
					-.72	1.56	1.96		1.55				
					-1.56	1.31	1.75		1.30				
					447	2523	3702		2511				
					39.9	79.3	173.2						
					24	62	83						
II-21	500	0	REF		4.52	5.33	5.56						
					3.86	5.05	5.35						
					3.15	4.78	5.15						
					2.45	4.50	4.94						
					1.74	4.23	4.74						
					2488	7789	10955						
					2.83	3.21	3.36						
					2.12	2.93	3.16						
					1.41	2.66	2.95						
					.71	2.38	2.75						
					0.0	2.11	2.54						
					1258	3929	5625						
					1.97	2.15	2.29						
					1.26	1.88	2.08						
					.56	1.60	1.88						
					-.15	1.33	1.67						
					-.86	1.05	1.46						
					650	2003	3006						
						476	83.2						
						36	64						
II-S	500	0	REF			4.66	4.59						
						4.19	4.32						
						3.73	4.05						
						3.26	3.79						
						2.79	3.52						
						3863	6627						
						2.86	2.79						
						2.39	2.52						
						1.92	2.25						
						1.45	1.98						
						.99	1.72						
						1933	3251						
						1.96	1.90						
						1.49	1.63						
						1.02	1.37						
						.55	1.10						
						.09	.83						
						970	1592						

Table B-6. Break-Even Gasoline Price as a Function of Subsidy, Mission II-3

MISSION II-3				ICE-FE (1PG)	30.6	WKT (KTD)	21456	LIFE (YEARS)	8							
VEHICLE TYPE				ELECTRIC	PARALLEL			PAR-FLYWHEEL			SERIES					
BATTERY TYPE	CYCLE LIFE	SUBSIDY (1973\$)	RANGE 1PG 2FD		50	75	100	50	75	100	50	75	100			
PB-AC	500	0			37.5	86.6	148.2		80.2							
				18	65	79		62								
				3.46	4.28	4.93		3.86								
				2.61	4.04	4.73		3.60								
				1.76	3.80	4.53		3.35								
				.91	3.55	4.34		3.10								
				.06	3.31	4.14		2.84								
				1417	6673	9831		5542								
				2.38	3.08	3.33		2.95								
				1.53	2.84	3.13		2.70								
				.68	2.60	2.94		2.44								
				-.17	2.36	2.74		2.19								
				-1.02	2.11	2.54		1.94								
				784	4197	5784		3754								
				1.84	2.31	2.55		2.37								
				.99	2.07	2.35		2.12								
				.15	1.83	2.15		1.86								
				-.70	1.58	1.95		1.61								
				-1.55	1.34	1.76		1.36								
				71.05 Subsidy				467	2605	3791		2605				
				1000	0			39.4	73.5	153.9						
				500				22	58	80						
HIL-ZI	500	0			4.63	4.87	5.51									
				3.94	4.60	5.31										
				3.24	4.33	5.12										
				2.54	4.06	4.92										
				1.84	3.79	4.73										
				71.05 Subsidy				2367	7112	11409						
				1000	0			2.87	3.20	3.31						
				500				2.17	2.94	3.12						
				1000				1.47	2.67	2.92						
				1500				.79	2.40	2.73						
				2000				.07	2.13	2.53						
				71.05 Subsidy				1301	4017	5788						
				2000	0			1.98	2.14	2.23						
				500				1.28	1.87	2.04						
				1000				.59	1.60	1.84						
				1500				-.11	1.33	1.64						
				2000				-.81	1.06	1.45						
				71.05 Subsidy				668	2027	3021						
									46.6	79.0						
									34	61						
			H-S	500	0			4.27	4.60							
							3.81	4.34								
	3.36	4.08														
	2.90	3.83														
	2.45	3.57														
	71.05 Subsidy							3531	6939							
	1000	0						2.86	2.78							
	500							2.40	2.52							
	1000							1.95	2.27							
	1500							1.49	2.01							
	2000							1.03	1.75							
	71.05 Subsidy							1783	3379							
	2000	0						1.95	1.88							
	500							1.50	1.63							
	1000							1.04	1.37							
	1500							.58	1.11							
	2000							.13	.86							
	71.05 Subsidy							488	1627							

Table B-7. Break-Even Gasoline Price as a Function of Subsidy, Mission III-1

MISSION III-1				ICE-FE (CPG)	24.5	WKT (K1)	106.27	LIFE (YEARS)	15			
VEHICLE TYPE			ELECTRIC	PARALLEL			PAR-FLYWHEEL			SERIES		
BATTERY TYPE	CYCLE LIFE	SUBSIDY (1973\$)	RANGE MPG	50	75	100	50	75	100	50	75	100
PB-AC	500	0	MPG	41.8	72.4	124.1	70.1	78.2	98.3			
				41	66	80	65	69	75			
				3.43	3.83	4.46	3.10	3.37	3.44			
				3.68	3.61	4.28	2.88	3.16	3.24			
				2.73	3.59	4.10	2.66	2.95	3.05			
				2.38	3.17	3.92	2.44	2.74	2.86			
				2.03	2.95	3.74	2.21	2.53	2.67			
				3.15	6.365	9.487	4.626	5.519	6.208			
				2.20	2.62	3.03	2.23	2.50	2.50			
				1.85	2.40	2.85	2.01	2.29	2.31			
				1.51	2.18	2.67	1.79	2.08	2.12			
				1.16	1.97	2.49	1.57	1.87	1.92			
		\$1.05 Subsidy	MPG	.81	1.75	2.31	1.35	1.66	1.73			
				16.55	36.01	53.17	26.71	34.45	37.75			
				1.59	1.95	2.35	1.80	2.02	2.06			
				1.24	1.74	2.17	1.58	1.81	1.86			
				.90	1.52	1.99	1.36	1.60	1.67			
				.55	1.30	1.81	1.14	1.39	1.48			
				.20	1.08	1.64	.92	1.18	1.29			
				7.78	20.76	36.28	16.97	23.02	26.17			
								87.4				
								72				
								3.64				
				MI-ZI	500	0	MPG					3.44
								3.24				
								3.04				
								2.84				
								6.463				
								2.39				
								2.19				
								1.99				
								1.79				
								1.54				
								33.53				
								1.71				
		\$1.05 Subsidy	MPG					1.51				
								1.31				
								1.10				
								.90				
								16.37				
								87.2				
								72				
								3.73				
								3.53				
								3.33				
								3.13				
								2.93				
		\$1.05 Subsidy	MPG					66.88				
								2.42				
								2.22				
								2.01				
								1.81				
								1.61				
								34.03				
								1.69				
								1.49				
								1.29				
								1.09				
								.89				
		\$1.05 Subsidy	MPG					15.94				

Table B-8. Break-Even Gasoline Price as a Function of Subsidy, Mission III-2

MISSION <u>III-2</u>				ICE-FE (1PG)	24.5	WKT (KID)	16274	LIFE (YEARS)			10			
VEHICLE TYPE		ELECTRIC		PARALLEL			PAR-FLYWHEEL			SERIES				
BATTERY TYPE	CYCLE LIFE	SUBSIDY (1973\$)	RANGE 1PG 2ED	50	75	100	50	75	100	50	75	100		
PB-AC	500	0		41.5	72.8	128.5	66.0	74.5	96.7					
				41	66	81	63	67	75					
				3.41	3.73	4.39	3.12	3.33	3.40					
				3.08	3.52	4.22	2.90	3.13	3.22					
				2.75	3.32	4.05	2.69	2.93	3.04					
				2.42	3.12	3.89	2.48	2.73	2.86					
				2.09	2.91	3.72	2.26	2.53	2.68					
				\$1.05 Subsidy	3584	6582	10011	4822	5676	6505				
				1000	0	2.20	2.58	2.96	2.24	2.48	2.45			
				500	1.87	2.38	2.79	2.03	2.28	2.27				
				1000	1.54	2.17	2.62	1.81	2.08	2.09				
				1500	1.21	1.97	2.46	1.60	1.85	1.91				
				2000	.88	1.77	2.24	1.38	1.68	1.73				
				\$1.05 Subsidy	1739	3765	5721	2773	3563	3876				
				2000	0	1.60	1.92	2.26	1.80	1.99	1.99			
				500	1.27	1.71	2.10	1.59	1.79	1.81				
				1000	.94	1.51	1.93	1.38	1.59	1.63				
				1500	.61	1.31	1.76	1.16	1.39	1.45				
				2000	.28	1.10	1.60	.95	1.19	1.27				
					\$1.05 Subsidy		827	2131	3642	1759	2337	2601		
II-ZI	500	0	1PG 2ED					83.4						
								71						
								3.59						
								3.40						
								3.21						
								3.02						
								2.83						
								6648						
								2.38						
								2.19						
								2.00						
								1.81						
								1.61						
								3478						
								1.68						
								1.49						
								1.29						
								1.10						
								.91						
								1640						
II-S	500	0	1PG 2ED					83.0						
								70						
								3.68						
								3.49						
								3.30						
								3.11						
								2.92						
								6880						
								2.40						
								2.21						
								2.02						
								1.83						
								1.64						
								3534						
								1.66						
								1.47						
								1.28						
								1.09						
								.89						
								1594						

Table B-9. Break-Even Gasoline Price as a Function of Subsidy, Mission III-3

MISSION <u>III-3</u>				ICE-FE (MPG) <u>24.7</u>	WKT (K'D) <u>23057</u>			LIFE (YEARS) <u>7</u>		
VEHICLE TYPE				ELECTRIC	PARALLEL			PAR-FLYWHEEL		
BATTERY TYPE	CYCLE LIFE	SUBSIDY (1973\$)	RANGE (MPG)		50	75	100	50	75	100
PB-AC	500	0	250		40.3	68.3	119.8	58.8	66.1	85.0
					34	64	79	58	63	71
					345	342	442	326	340	354
					3.10	3.71	4.25	3.03	3.38	3.35
					2.76	3.50	4.09	2.80	3.17	3.16
					2.41	3.29	3.42	2.57	2.96	2.98
					2.07	3.08	3.75	2.37	2.74	2.79
					3474	6863	10036	4797	5974	6621
					2.25	2.63	2.98	2.37	2.61	2.55
					1.90	2.42	2.81	2.14	2.40	2.36
					1.56	2.21	2.64	1.91	2.19	2.17
					1.21	2.01	2.48	1.68	1.97	1.99
					.89	1.80	2.31	1.45	1.76	1.80
					1732	3786	5745	2862	3666	3491
					1.65	1.96	2.28	1.92	2.10	2.07
					1.30	1.75	2.11	1.69	1.89	1.88
					.95	1.54	1.95	1.46	1.67	1.70
					.61	1.33	1.78	1.23	1.46	1.51
					.26	1.13	1.61	1.00	1.25	1.32
					862	2180	3665	1895	2462	2716
									73.4	
									67	
11-24	500	0	250						3.85	
									3.65	
									3.45	
									3.25	
									3.05	
									6978	
									2.46	
									2.26	
									2.06	
									1.86	
									1.66	
									3517	
									1.74	
									1.54	
									1.33	
									1.13	
									.93	
									17.1	
									73.6	
									66	
12-S	500	0	250						3.45	
									3.75	
									3.55	
									3.35	
									3.15	
									7220	
									2.48	
									2.28	
									2.08	
									1.88	
									1.68	
									3566	
									1.72	
									1.52	
									1.31	
									1.11	
									.91	
									1659	

Table B-10. Break-Even Gasoline Price as a Function of Subsidy, Mission IV

MISSION IV				ICE-FE (PG)	19.6	WKT (KID)	48352	LIFE (YEARS)	3						
VEHICLE TYPE		ELECTRIC		PARALLEL			PAR-FLYWHEEL			SERIES					
BATTERY TYPE	CYCLE LIFE	SUBSIDY (1973\$)	RANGE (MPG)	50	75	100	50	75	100	50	75	100			
PB-AC	500	0	MPG	31.3	37.2	46.9	26.3								
			MPG	38	47	58	26								
						2.06	2.92	4.03	4.94						
						1.63	2.62	3.79	4.39						
						1.30	2.32	3.54	3.83						
						.92	2.02	3.30	3.28						
						.54	1.72	3.05	2.72						
						1327	3110	6090	3501						
						1.53	2.13	2.93	4.17						
						1.15	1.83	2.69	3.62						
						.77	1.53	2.44	3.06						
						.39	1.23	2.20	2.50						
						.01	.93	1.96	1.95						
						632	1797	3851	2806						
						1.32	1.80	2.46	3.86						
						.94	1.50	2.22	3.30						
						.56	1.20	1.97	2.75						
						.18	.90	1.73	2.19						
						-.20	.60	1.48	1.63						
						\$1.05 Subsidy	350	1251	2889	2523					
NI-ZN	500	0	MPG												
			MPG												
			NA-S	500	0	MPG									
						MPG									

Table B-11. Break-Even Gasoline Price as a Function of Subsidy, Mission V

[illegible]

Table B-12. Break-Even Gasoline Price as a Function of Subsidy, Mission VI-1

MISSION		ICE-PE (PG)	16.7	WKT (MD)	8652	LIFE (YEARS)	15		
VEHICLE TYPE		ELECTRIC	PARALLEL		PAR-HYMEEL		SERIES		
BATTERY TYPE	CYCLE LIFE	SUBSIDY (1973\$)	RANGE MPG MPH	50	75	100	50	75	100
P3-AC	500	0	MPG MPH	26.4	63.7	137.6	54.8	183.2	
				3.7	7.4	8.8	6.9	9.1	
				8.40	7.51	8.38	5.57	7.12	
				1.67	7.15	8.08	5.19	6.83	
				6.94	6.79	7.77	4.81	6.54	
				6.21	6.43	7.47	4.73	6.24	
				5.49	6.07	7.17	4.04	5.95	
				5048	8961	12107	5908	10348	
				6.71	6.10	6.86	4.69	6.04	
				5.49	5.74	6.56	4.30	5.75	
				5.26	5.38	6.26	3.92	5.46	
				4.53	5.02	5.95	3.54	5.17	
				3.80	4.66	5.65	3.16	4.88	
				3471	7005	9600	4751	8554	
				5.41	5.53	6.40	4.26	5.12	
				5.18	5.17	6.10	3.88	5.42	
				4.45	4.81	5.80	3.50	5.13	
				3.72	4.45	5.49	3.11	4.84	
				3.00	4.09	5.19	2.73	4.55	
				#1.05 Subsidy	1000	0	MPG MPH	3337	6211
23.5	63.3	149.6	79.1					181.2	
2.9	7.4	8.9	7.9					9.1	
11.10	8.67	9.26	7.93					7.45	
10.18	8.31	8.96	7.59					7.16	
7.25	7.95	8.66	7.25					6.87	
8.33	7.58	8.36	6.92					6.57	
7.40	7.22	8.06	6.58					6.28	
5436	10539	13712	10197					10925	
8.35	6.61	7.14	6.00					5.95	
7.43	6.25	6.84	5.67					5.66	
6.50	5.89	6.54	5.33					5.37	
5.58	5.52	6.24	4.99					5.08	
4.65	5.16	5.44	4.66					4.78	
3948	7691	10166	7345					8371	
7.03	5.77	6.49	5.08					5.50	
6.11	5.41	6.19	4.75					5.21	
5.18	5.05	5.89	4.41					4.91	
4.26	4.69	5.59	4.07					4.62	
3.33	4.33	5.29	3.73					4.33	
#1.05 Subsidy	2000	0	MPG MPH	3236	6532	9087	5981	7594	
				24.4	52.0	99.6		155.7	
				31	68	83		89	
				10.01	8.26	7.81		7.02	
				9.16	7.87	7.49		6.72	
				8.32	7.47	7.17		6.42	
				7.48	7.08	6.85		6.13	
				6.63	6.69	6.53		5.83	
				5305	9195	10581		10020	
				7.89	6.40	5.77		5.58	
				7.04	6.01	5.45		5.28	
				6.20	5.62	5.13		4.98	
				5.35	5.23	4.81		4.68	
				4.51	4.84	4.49		4.38	
				4048	6830	7377		7546	
				7.02	5.84	4.79		5.14	
				6.18	5.45	4.47		4.34	
				5.34	5.06	4.15		4.54	
				4.49	4.66	3.83		4.24	
				3.65	4.27	3.51		3.95	
#1.05 Subsidy		0	MPG MPH	3537	6111	5845		6859	

Table B-13. Break-Even Gasoline Price as a Function of Subsidy, Mission VI-2

MISSION VI-2				ICE-FE (¢/PG)	17.0	WGT (KID)	16315	LIFE (YEARS)	10					
VEHICLE TYPE				ELECTRIC		PARALLEL		PAR-FLYWHEEL		SERIES				
BATTERY TYPE	CYCLE LIFE	SUBSIDY (1973\$)	RANGE (MPG)	50	75	100	50	75	100	50	75	100		
PB-AC	500	0		23.3	48.7	92.9	30.3		83.9					
				27	65	82	44		80					
					500		8.11	6.66	6.85	6.03		5.96		
					1000		7.49	6.41	6.65	5.65		5.75		
					1500		6.87	6.15	6.44	5.26		5.54		
					2000		6.25	5.89	6.24	4.88		5.33		
							5.63	5.63	6.03	4.50		5.12		
							5701	10898	14154	6502		11679		
					1000	0	6.28	5.03	5.33	4.90		4.80		
					500		5.66	4.77	5.12	4.51		4.59		
					1000		5.04	4.51	4.92	4.13		4.38		
					1500		4.42	4.25	4.71	3.75		4.17		
					2000		3.80	4.00	4.51	3.37		3.96		
							4223	1722	10430	5025		8935		
							5.40	4.28	4.64	4.35		4.28		
							4.78	4.02	4.43	3.97		4.07		
							4.16	3.77	4.23	3.54		3.86		
							3.54	3.51	4.02	3.20		3.65		
							2.92	3.25	3.82	2.82		3.44		
							3513	6272	8747	4314		7697		
PB-AC	500	0		21.7	50.3	107.0	38.6		81.9					
				22	66	84	56		79					
					500		10.59	7.68	7.53	7.73		6.36		
					1000		9.81	7.43	7.33	7.43		6.15		
					1500		9.03	7.18	7.14	7.14		5.93		
					2000		8.25	6.92	6.94	6.84		5.72		
							7.48	6.67	6.74	6.54		5.51		
							6130	13105	16284	11161		12557		
							7.63	5.34	5.83	5.55		4.75		
							6.85	5.09	5.23	5.25		4.54		
							6.08	4.83	5.03	4.95		4.33		
							5.30	4.58	4.84	4.66		4.12		
							4.52	4.33	4.64	4.36		3.91		
							4230	8477	11006	7520		8757		
							6.21	4.27	4.48	4.50		4.03		
							5.43	4.02	4.28	4.21		3.82		
							4.65	3.76	4.09	3.91		3.60		
							3.88	3.51	3.89	3.61		3.39		
							3.10	3.26	3.69	3.31		3.18		
							3316	6363	8624	5768		7042		
PB-AC	500	0		23.4	46.5	47.3			70.4					
				27	63	64			76					
					500		9.16	6.84	7.08		6.14			
					1000		8.35	6.57	6.82		5.92			
					1500		7.53	6.31	6.56		5.70			
					2000		6.72	6.05	6.30		5.48			
							6.00	5.78	6.03		5.26			
							6549	10957	11523		11547			
							6.65	4.98	4.94		4.55			
							6.04	4.71	4.68		4.33			
							5.42	4.45	4.42		4.11			
							4.81	4.19	4.16		3.89			
							4.19	3.92	3.89		3.67			
							4558	7438	7434		7741			
							5.51	4.14	3.91		3.83			
							4.89	3.88	3.65		3.61			
							4.28	3.61	3.39		3.39			
							3.66	3.35	3.13		3.17			
							3.05	3.08	2.86		2.95			
							3625	5850	5466		6313			
PB-AC	500	0		23.4	46.5	47.3			70.4					
				27	63	64			76					
					500		9.16	6.84	7.08		6.14			
					1000		8.35	6.57	6.82		5.92			
					1500		7.53	6.31	6.56		5.70			
					2000		6.72	6.05	6.30		5.48			
							6.00	5.78	6.03		5.26			
							6549	10957	11523		11547			
							6.65	4.98	4.94		4.55			
							6.04	4.71	4.68		4.33			
							5.42	4.45	4.42		4.11			
							4.81	4.19	4.16		3.89			
							4.19	3.92	3.89		3.67			
							4558	7438	7434		7741			
							5.51	4.14	3.91		3.83			
							4.89	3.88	3.65		3.61			
							4.28	3.61	3.39		3.39			
							3.66	3.35	3.13		3.17			
							3.05	3.08	2.86		2.95			
							3625	5850	5466		6313			

Table B-14. Break-Even Gasoline Price as a Function of Subsidy, Mission VII-1

MISSION VII-1			ICE-FE (MPG)		9.1		WKT (KID)		11300		LIFE (YEARS)		14			
VEHICLE TYPE			ELECTRIC		PARALLEL			PAR-FLYWHEEL			SERIES					
BATTERY TYPE	CYCLE LIFE	SUBSIDY (1973\$)	RANGE (MPG)		50	75	100	50	75	100	50	75	100			
PB-AC	500	0	MPG		29.8	60.1	78.8	196.3		—						
			MPG		69	85	88	95		100						
							2.54	3.41	4.85	4.22		5.61				
							2.38	3.28	4.72	4.10		5.50				
							2.21	3.15	4.59	3.98		5.39				
							2.05	3.01	4.47	3.86		5.27				
							1.89	2.88	4.34	3.74		5.16				
							\$1.05 Subsidy	4563	8641	14818	13330		20125			
							1000		1.81	2.54	3.85	3.06		4.56		
									500		1.64	2.41		3.72		2.95
									1000		1.48	2.27		3.59		2.83
									1500		1.32	2.14		3.46		2.71
									2000		1.15	2.01		3.33		2.59
									\$1.05 Subsidy	2320	5579	10899	8469		15467	
									2000		1.47	2.14		3.35		2.53
											500		1.31	2.01		3.26
											1000		1.14	1.87		3.13
											1500		.98	1.74		3.00
											2000		.82	1.61		2.87
											\$1.05 Subsidy	1284	4082	9104	6225	
VI-ZN	500	0	MPG													
			MPG													
							500									
							1000									
							1500									
							2000									
							\$1.05 Subsidy									
							1000									
									500							
									1000							
									1500							
									2000							
									\$1.05 Subsidy							
							2000									
									500							
									1000							
									1500							
									2000							
									\$1.05 Subsidy							
							2000									
VA-S	500	0	MPG													
			MPG													
							500									
							1000									
							1500									
							2000									
							\$1.05 Subsidy									
							1000									
									500							
									1000							
									1500							
									2000							
									\$1.05 Subsidy							
							2000									
									500							
									1000							
									1500							
									2000							
									\$1.05 Subsidy							
							2000									

APPENDIX C

DETAILED BREAK-EVEN GASOLINE PRICE COST BREAKDOWNS

Table C-1. Detailed Break-Even Gasoline Price, Mission I-1

MISSION I-1		LIFE 13 (YEARS)					
% FD/Vehicle TYPE	Conventional	.39	PAR	.41	Series Pb-Ac	.53	Series Ni-Zn
COMPONENT	Cost	Δ Cost	BEGP	Δ Cost	BEGP	Δ Cost	BEGP
Chassis - Salvage	2005	92	.113	277	.322	163	.148
Engine	1095	—		163	.190	93	.089
Transmission	178	22	.027	-178	-.207	-178	-.162
Motor/Gen.		37	.045	945	1.099	775	.705
Controller		223	.274	834	.971	742	.675
Battery		444	.545	799	.930	1598	1.454
Charger		44	.054	44	.051	44	.040
Flywheel							
Vehicle Assembly	226	56	.069	207	.241	154	.140
Sticker - Salvage	3504	918	1.127	3091	3.597	3391	3.084

PRESENT VALUE OPERATING COSTS

Tax, Lic., & Ins.	1952	87	.107	298	.347	324	.295
Repair, Maint.	1755	119	.146	636	.740	419	.381
Batt. Repl. - Salvage		647	.794	1100	1.001	1475	1.342
Electricity		610	.749	381	.443	406	.369
Interest	736	193	.237	655	.762	713	.649
Subtotal BEGP			3.16		6.89		6.120
Gas Price Increase (negative component)			-.29		-.29		-.29
BEGP			2.87		6.60		5.83
Δ Gallons/Year			72		76		97

Table C-1. (contd)

MISSION I-1 (cont.) LIFE 13 (YEARS)

% FD/ Vehicle TYPE	Conventional		Series NA-5					
	Cost		Δ Cost	BEGP	Δ Cost	BEGP	Δ Cost	BEGP
COMPONENT								
Chassis - Salvage			129	.106				
Engine			25	.020				
Transmission			-178	-.146				
Motor/Gen			649	.531				
Controller			657	.538				
Battery			1221	1.000				
Charger			44	.036				
Flywheel								
Vehicle Assembly			109	.089				
Sticker - Salvage			2656	2.174				

PRESENT VALUE OPERATING COSTS

Tax, Lic., & Ins.			254	.208				
Repair, Maint.			228	.187				
Batt. Repl. - Salvage			1086	.889				
Electricity			385	.315				
Interest			559	.457				
Subtotal BEGP				4.230				
Gas Price Increase (negative component)				-.29				
BEGP				3.94				
Δ Gallons/Year				108				

Table C-2. Detailed Break-Even Gasoline Price, Mission II-1

MISSION II-1		LIFE 15 (YEARS)						
% FD/Vehicle TYPE	Conventional		.21 PAR		.73 FLY		.84 PAR	
	Cost		ΔCost	BEGP	ΔCost	BEGP	ΔCost	BEGP
Chassis - Salvage	3518		86	.168	245	.141	343	.172
Engine	1294		-5	-.009	-128	-.074	-5	-.003
Transmission	297		15	.029	43	.025	123	.063
Motor			24	.047	524	.301	263	.132
Controller			194	.379	1048	.602	686	.344
Battery			266	.520	1154	.663	2398	1.200
Charger			44	.086	44	.025	44	.022
Flywheel					202	.116		
Vehicle Assembly	391		37	.072	206	.118	293	.147
Sticker - Salvage	5500		661	1.292	3338	1.917	4145	2.076

PRESENT VALUE OPERATING COSTS

Tax, Lic., & Ins.	2376		70	.137	352	.202	437	.219
Repair, Maint.	1475		51	.100	143	.082	491	.246
Batt. Repl. - Salvage			257	.502	544	.313	534	.267
Electricity			323	.631	985	.508	1530	.766
Interest	1156		139	.271	701	.403	971	.436
Subtotal BEGP				2.933		3.425		4.010
Gas Price Increase (negative component)				-.38		-.38		-.35
BEGP				2.55		3.05		3.63
ΔGallons/Year				40		136		156

Table C-2. (contd)

MISSION II-1(cont.) LIFE 15 (YEARS)

% FD/ Vehicle Type	Conventional		.71 PAR					
	Cost		ΔCost	BEGP	ΔCost	BEGP	ΔCost	BEGP
COMPONENT								
Chassis - Salvage			246	.146				
Engine			-5	-.003				
Transmission			83	.049				
Motor			168	.099				
Controller			532	.315				
Battery			1578	.946				
Charger			44	.026				
Flywheel								
Vehicle Assembly			197	.117				
Sticker - Salvage			2863	1.695				

PRESENT VALUE OPERATING COSTS

Tax, Lic., & Ins.			302	.179				
Repair, Maint.			328	.194				
Batt. Repl. - Salvage			764	.452				
Electricity			1241	.734				
Interest			601	.356				
Subtotal BEGP				3.61				
Gas Price Increase (negative component)				-.38				
BEGP				3.23				
ΔGallons/Year				132				

Table C-3. Detailed Break-Even Gasoline Price, Mission IV

MISSION <u>IV</u>			LIFE <u>3</u> (YEARS)					
% FD/ Vehicle TYPE	Conventional		.38	PAR	.47	PAR	.58	PAR
COMPONENT	Cost		ΔCost	BEGP	ΔCost	BEGP	ΔCost	BEGP
Chassis - Salvage	4286		203	.154	281	.169	439	.215
Engine	1409		-15	-.011	-18	-.011	-15	-.007
Transmission	386		81	.024	65	.039	119	.058
Motor			89	.068	153	.093	276	.135
Controller			344	.261	498	.299	714	.349
Battery			799	.606	1510	.908	2575	1.260
Charger			44	.033	44	.026	44	.023
Flywheel								
Vehicle Assembly	498		105	.080	184	.111	315	.154
Sticker - Salvage	6579		1600	1.215	2719	1.634	4467	2.186

PRESENT VALUE OPERATING COSTS

Tax, Lic., & Ins.	636	45	.034	76	.046	125	.061
Repair, Maint.	1559	143	.108	266	.160	481	.235
Batt. Repl. - Salvage							
Electricity		421	.319	728	.438	1230	.602
Interest							
Subtotal BEGP			1.676		2.278		3.084
Gas Price Increase (negative component)			-.095		-.095		-.095
BEGP			1.58		2.18		2.99
Δ Gallons/Year			577		728		895

Table C-4. Detailed Break-Even Gasoline Price, Mission VII-1

MISSION <u>VII-1</u>		LIFE <u>14</u> (YEARS)						
COMPONENT	% FD/ Vehicle Type	Conventional	.37 PAR	.60 PAR	.69 PAR			
		Cost	ΔCost	BEGP	ΔCost	BEGP	ΔCost	BEGP
Chassis - Salvage		6553	500	.309	500	.189	600	.196
Engine		1444	40	.025	62	.023	87	.028
Transmission		417	130	.080	133	.050	163	.053
Motor			195	.120	155	.059	168	.055
Controller			581	.359	498	.188	532	.174
Battery			1154	.712	1154	.436	1598	.522
Charger			44	.027	44	.017	44	.014
Flywheel								
Vehicle Assembly		763	184	.114	182	.069	235	.077
Sticker - Salvage		9177	2828	1.746	2728	1.031	3427	1.190

PRESENT VALUE OPERATING COSTS

Tax, Lic., & Ins.	1492	157	.097	151	.057	190	.062
Repair, Maint.	938	189	.117	209	.079	284	.093
Batt. Repl. - Salvage		298	.184	1132	.428	1367	.446
Electricity		248	.153	886	.335	1255	.410
Interest							
Subtotal BEGP			2.297		1.930		2.201
Gas Price Increase (negative component)			-.27		-.27		-.27
BEGP			2.03		1.66		1.93
Δ Gallons/Year			283		463		535

Table C-4. (contd)

MISSION VIII-1 (cont.) LIFE 14 (YEARS)

% FD/Vehicle TYPE	Conventional		.85 PAR		.95 FLY		1.00 FLY	
	Cost		Δ Cost	BEGP	Δ Cost	BEGP	Δ Cost	BEGP
COMPONENT								
Chassis - Salvage			1000	.267	1022	.243	2020	.458
Engine			84	.022	56	.013	183	.042
Transmission			253	.068	301	.072	531	.120
Motor			372	.099	1129	.268	1616	.367
Controller			860	.230	1662	.395	2065	.468
Battery			3463	.926	3463	.823	7282	1.652
Charger			44	.012	44	.010	44	.010
Flywheel					202	.048	202	.046
Vehicle Assembly			468	.125	591	.140	1129	.256
Sticker - Salvage			6544	1.749	8470	2.012	15072	3.419

PRESENT VALUE OPERATING COSTS

Tax, Lic., & Ins.			364	.097	470	.112	837	.190
Repair, Maint.			495	.132	534	.127	1124	.255
Batt. Repl. - Salvage			1494	.399	2962	.704	1881	.427
Electricity			1815	.485	1818	.432	2644	.600
Interest								
Subtotal BEGP				2.862		3.387		4.871
Gas Price Increase (negative component)				-.27		-.27		-.27
BEGP				2.59		3.12		4.62
Δ Gallons/Year				653		735		770

APPENDIX D
BATTERY LIFE

Table D-1. Battery Life, All Missions vs Travel Pattern 1

MISSION		I		II		III		IV		V		VI		VII		
PER	BCL	BL	VL	BL	VL	BL	VL	BL	VL	BL	VL	BL	VL	BL	VL	
TRAVEL PATTERN - 1	50	500	2.6	13	3.4	15	3.7	15	1.4	3	1.5	3	3.4	15	2.3	14
		1000	5.2		7.9		7.4		2.8		3.0		6.9		4.6	
		2000	10.5		15.7		14.9		5.6		5.9		13.7		9.2	
	75	500	3.4	13	5.1	15	4.7	15	1.4	3	1.5	3	4.7	15	3.3	14
		1000	6.9		10.2		9.4		2.9		3.1		9.4		4.6	
		2000	13.8		20.3		18.9		5.8		6.2		18.8		13.3	
	100	500	4.3	13	6.3	15	5.7	15	1.5	3			6.0	15	4.4	14
		1000	8.6		12.5		11.4		3.0				12.0		8.8	
		2000	17.2		25.1		22.8		5.9				24.0		17.7	

PER - PRIMARY ELECTRIC RANGE (KM)

BCL - BATTERY CYCLE LIFE

BL - BATTERY LIFE (YEARS)

VL - VEHICLE LIFE (YEARS)

Table D-2. Battery Life, All Missions vs Travel Pattern 2

MISSION		I			II			III			IV			V			VI			VII		
TRAVEL PATTERN - 2	PER	BCL	BL	VL	BL	VL	BL	VL	BL	VL	BL	VL	BL	VL	BL	VL	BL	VL				
	50	500	19	9	2.6	11	2.5	10					2.3	10	2.1	7						
		1000	37		5.2		5.0						4.6		4.2							
		2000	7.5		10.4		10.0						9.3		8.3							
	75	500	2.4	9	3.2	11	3.1	10					2.8	10	2.1	7						
		1000	4.7		6.5		6.2						5.6		4.2							
		2000	9.4		12.9		12.3						11.2		8.3							
	100	500	2.9	9	3.9	11	3.7	10					3.4	10	2.3	7						
		1000	5.9		7.9		7.4						6.8		4.6							
		2000	11.7		15.7		14.8						13.6		9.2							

PER - PRIMARY ELECTRIC RANGE (KM)

BCL - BATTERY CYCLE LIFE

BL - BATTERY LIFE (YEARS)

VL - VEHICLE LIFE (YEARS)

Table D-3. Battery Life, All Missions vs Travel Pattern 3

MISSION		I			II			III			IV			V			VI			VII		
TRAVEL PATTERN - 3	PER	BCL	BL	VL	BL	VL	BL	VL	BL	VL	BL	VL	BL	VL	BL	VL						
	50	500	1.7	7	2.0	8	1.9	7														
		1000	3.5		3.9		3.8															
		2000	7.0		7.9		7.7															
	75	500	1.9	7	2.4	8	2.3	7														
		1000	3.8		4.7		4.6															
		2000	7.5		9.5		9.1															
	100	500	2.3	7	2.8	8	2.7	7														
		1000	4.5		5.6		5.3															
		2000	9.1		11.2		10.7															

PER - PRIMARY ELECTRIC RANGE (KM)

BCL - BATTERY CYCLE LIFE

BL - BATTERY LIFE (YEARS)

VL - VEHICLE LIFE (YEARS)