APPENDIX

ASSUMPTIONS FOR PROJECTING WEIGHT AND PERFORMANCE OF ELECTRIC AND HYBRID VEHICLES

Weight of an electric vehicle was estimated based on these assumptions:

1. propulsion weight must be proportional to vehicle test weight (i.e., the curb weight plus payload during acceleration tests) .

2. Structure and chassis weight must be proportional to gross vehicle weight (i.e., curb weight plus the maximum allowed payload).

3. Battery weight must be some arbitrary fraction of weight.

4. Upper body weight is given for a specified payload.

5. Vehicle curb weight is the sum of propulsion weight, structures and chassis weight, and upper body weight.

Table A.1 shows the combination of these assumptions into a parametric weight model, The key parameter here is battery fraction f , the fraction of vehicle test weight devoted to battery. Use of the model requires estimates for payload weight, upper body weight, the propulsion fraction a (the fraction of test weight devoted to the electric drive train), and the structure fraction b (the fraction of gross vehicle weight devoted to structure and chassis) . These estimates are summarized in Table A.2.

The propulsion weight fraction a in Table A.2 is based on an overall requirement for capability to accelerate from O to 40 mph in 10 seconds. As discussed in Chapter 2, this suffices for safe entry into freeway traffic and requires an electric drive train output of about 28 hp per ton of vehicle test weight. This horsepower requirement, combined with the drive train weights and efficiencies of Table A.3, yields the propulsion weight parameters in Table A.2 for passenger cars. For light trucks, which historically employ transmissions and axles weighing more per horsepower of capacity, propulsion weight parameters in Table A.2 are correspondingly higher.

Range and energy use of electric vehicles were estimated using the ELVEC computer simulation. ELVEC was constructed in 1976 by General Research Corporation to support projections fo electric vehicle capabilities for a DOE study, and was subsequently expanded to support analyses for DOE of electric and hybrid vehicle performance standards. After a survey of over a hundred competing models and simulations, the

TABLE A.1

PARAMETRIC REPRESENTATION OF ELECTRIC VEHICLE WEIGHT

Symbol	Definition	Formula
$W_{PL, max}$	Maximum design payload	--
W_{UB}	Upper body weight	--
W_G	Gross vehicle weight	$W_G = W_C + W_{PL, max}$
W_C	Curb weight	See below
W_T	Test weight	$W_T = W_C + 300$ lb
W_S	Structure and chassis weight	$W_S = a \cdot W_G$
W_P	Propulsion weight	$W_P = b \cdot W_T$
W_B	Battery weight	$W_B = f \cdot W_T$

$$W_C = W_{UB} + W_S + W_P + W_B = \frac{W_{UB} + aW_{PL,max} + 300(b + f)}{1 - (a + b + f)}$$

Source: W. Hamilton, Electric Automobiles, McGraw-Hill Book Company, New York, 1980

TABLE A.2

WEIGHT PARAMETERS FOR ELECTRIC VEHICLES

Vehicles with Near-Term Batteries	Maximum Payload, lb	Upper Body Weight, lb	Structural Weight Fraction, a	Propulsion Weight Fraction, b
4-Passenger Car	900	833	0.247	0.101
5-Passenger Car	1200	957	0.243	0.101
6-Passenger Car	1650	1226	0.237	0.101
Compact Pickup	1190	882	0.241	0.109
Compact Van	1190	996	0.241	0.109
Vehicles with Advanced Batteries				
4-Passenger Cars	900	719	0.239	0.083
5-Passenger Cars	1200	826	0.237	0.083
6-Passenger Cars	1650	1056	0.232	0.083
Compact Pickup	1190	761	0.2363	0.091
Compact Van	1190	860	0.2363	0.091

Source: General Research Corporation

Cal Tech Jet Propulsion Laboratory (JPL) chose ELVEC in 1978 for continued development. JPL now maintains ELVEC for general use on a nationwide computer time-share system.

ELVEC used as inputs vehicle and battery weights from the model of Table Al, propulsion efficiencies from Table A.3, and the road load parameters shown in Table A.4. It was run to determine range and energy use of electric vehicles with the batteries and battery fractions in Table A.5. Battery performance was described in Sec. 2.2; ELVEC outputs were summarized in Sees. 2.5 and 2.6.

TABLE A.3

SPECIFIC WEIGHTS AND EFFICIENCIES OF PROPULSION COMPONENTS

Technology	Component	Specific Weight, lb/hp	Average Efficiency, percent	
			City	Highway
Near-Term	Improved DC traction motor with transistor controller	6.25	82.5	87.5
Advanced	Brushless variable-reluctance "disc" motor with 3-phase semiconductor controller	4.93	85.0	90.0
Near-Term and Advanced	4-speed transmission, clutch, axle	0.93	94.0	96.0

Source: W. Hamilton, Electric Automobiles, McGraw-Hill Book Company, New York, 1980.

TABLE A.4

ROAD LOAD PARAMETERS FOR REPRESENTATIVE FUTURE VEHICLES

Rolling Resistance Coefficient: Near-Term - 1.18%
Advanced - 1.08%

Aerodynamic Drag Parameters:

Vehicle	Drag Coefficient	Frontal Area, ft^2
4-passenger car	0.35	20
5-passenger car	0.35	23
6-passenger car	0.35	26
Compact pickup	0.45	20
Compact van	0.40	30

Source: General Research Corporation

TABLE A.5

BATTERY FRACTIONS AND WEIGHTS FOR 4-PASSENGER ELECTRIC CARS

<u>Near-Term Cars</u>:							
	Battery Fraction	0.2	0.24	0.28	0.32	0.36	
	Battery Weight, lbs	567	746	964	1235	1580	
<u>Advanced Cars</u>:							
Zinc-Chlorine	Battery Fraction	0.1	0.15	0.2	0.25	0.3	0.35
	Battery Weight, lbs	201	330	486	678	922	1240
Lithium-Metal Sulfide	Battery Fraction	0.05	0.075	0.1	0.15	0.2	0.25
	Battery Weight, lbs	93	144	201	330	486	678

Hybrid cars were also analyzed using ELVEC and the assumptions tabulated here, slightly modified to allow for the addition of a small internal-combustion engine to the basic electric drive train. The engine was sized to provide the power requirement at 55 mph cruise (shown in Fig. A.1), plus a 25 percent reserve to overcome modest head-winds and grades without use of electric Power, and to permit battery

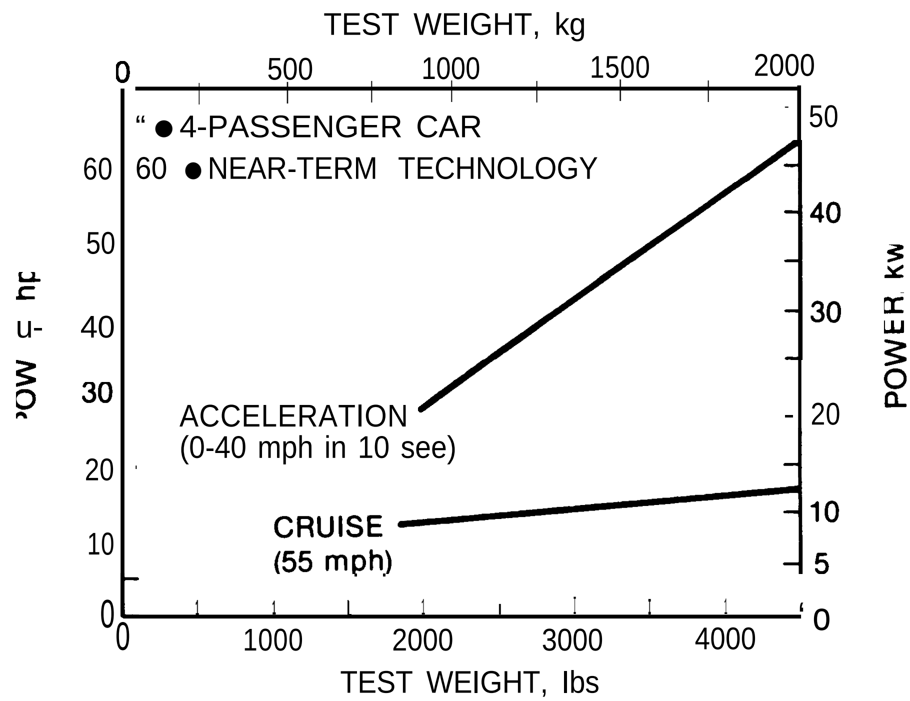

Figure A. 1 Power Requirements for Acceleration and Cruise Versus Test Weight

recharging during cruise to assure sufficient electric capability for occasional hills and bursts of acceleration. The near-term ICE was assumed to weigh 5 pounds per horsepower and to consume 0.6 pounds of gasoline per horsepower-hour. The fuel system was assumed to weigh 2 pounds per gallon of capacity, plus 6 pounds. For advanced ICE systems, these weights and the fuel consumption were reduced 10 percent. Hybrid vehicles were projected with the battery fractions and weights shown in Table A. 6.

TABLE A. 6

BATTERY FRACTIONS AND WEIGHTS FOR FOUR-PASSENGER HYBRID CARS

Near-Term

Battery Fraction	0.20	0.24	0.28	0.32
Battery Weight, lb	633	836	1086	1400

Advanced

Battery Fraction	0.10	0.12	0.15
Battery Weight, lb	221	275	364