6 MARKETABILITY

6.1 SUMMARY

In the coming decade, electric vehicles will probably offer sufficient range and performance for most urban travel by personal vehicles. Near-term hybrid vehicles will probably be adequate not only for most urban travel, but for most long-distance trips as well. From limited survey data on vehicle use, it appears that electric cars with a 100-mile range could electrify about 80 percent of the annual travel distance of the average US automobile. Hybrids with a 60-mile useful electric range could probably electrify an equal amount, because they could be used on long trips which electric vehicle owners would make entirely by an alternate ICE vehicle.

Nevertheless, market penetrations for electric and hybrid vehicles are generally expected to be modest. Projections produced by several independently-developed econometric models indicate market shares in the mid-1990s of 1-10 percent, despite major advances in technology and the advent of mass-produced EHVs in auto showrooms. The projections, however, are generally based on assumptions that real prices for gasoline and electricity remain little changed. Under these conditions, the reduction of operating costs offered by EHVs is insufficient to offset their higher initial prices and limited capabilities, at least for the great majority of motorists.

The key uncertainty in such projections is the future price and availability of gasoline in future years. Though EHV technology improvements are unlikely to suffice for substantial market penetration, future EHVs could capture far more than 10 percent of the market if interruptions in the supply of motor fuel recur, or if motor fuel prices rise rapidly in relation to electricity prices and the overall price level. As of late 1980, however, such price trends were not clearly established.

The US Government is seeking to enhance the competitive position of electric cars by subsidizing research, development, and demonstration (RD&D) of new technology and by supporting fledgling EHV manufacturers. Even if the RD&D is successful, however, major additional governmental incentives would probably be necessary to obtain an EHV market share exceeding a few percent, unless gasoline becomes relatively scarce and expensive in relation to electricity. Projections of EHV market share versus relative gasoline price are not available.

6.2 VEHICLE USE

Personal automobiles have brought Americans unparalleled mobility, and with it the ability to choose among a wide variety of residential settings and job opportunities, and to participate in a broad spectrum of social, educational, recreational, religious, and cultural activities. With good reason, the American motorist seeks to preserve this mobility even as resources of petroleum dwindle. To examine his willingness to purchase an electric vehicle, then, it is necessary to begin with the kinds of conventional vehicles in use, the travel they provide, and the extent to which this travel might be curtailed by vehicles with limited capabilities.

6.2.1 Types of Vehicles

There are about 146 million light-duty vehicles--passenger cars, light trucks, and vans--in the United States. The days of rapid growth of this light-duty vehicle fleet appear over (Table 6.1); one estimate places the average annual increase at only 0.6 percent per year. Years ago, growth was rapid as more and more families were able to afford automobiles. Now there are nearly,as many light-duty vehicles available as there are Americans of driving age.

Passenger cars are expected to constitute roughly 80 percent of light-duty vehicles in the future, as at present. Ninety-one percent of passenger cars are personal vehicles, while the remainder are operated in fleets. In 1979, 56 percent of new passenger cars were domestic subcompacts and compacts, or else imported. Twenty-four percent were intermediates, and only 20 percent were standard or luxury models.[2] The future percentage mix of four-, five-, and six-passenger cars will probably move even further towards the smaller vehicles, as it has tended to do over the past decade. This trend tends to favor EHVs, which are more expensive to buy than comparable conventional cars and thus are more likely to be beyond the average family budget unless small.

The trend toward smaller passenger cars has in part been offset by increased personal use of trucks.[3] In the decade 1968-1977, truck sales grew at 6.1 percent per year, versus 3.6 percent per year for passenger cars. This growth was interrupted by motor fuel shortages and price increases largely due to reductions in Iranian production during late 1978 and early 1979; whether it will resume is uncertain. Demand for personal trucks shifted industry output towards the light-duty versus heavy-duty trucks; by 1980, 90 percent of all new trucks were under 10,000 pounds gross weight, versus 77 percent ten years earlier. About 60 percent of all light trucks are in personal use. Most light trucks are pickups, and most of those standard rather than compact in size. Vans account for something under 20 percent of all light trucks, while utility vehicles and other light truck designs account for about 10 percent.

6.2.2 Urban Use of Personal Vehicles

In urban travel, distances are usually shorter than in travel outside and between urban areas. For this reason, it is generally expected that electric cars with limited ranges will be used primarily in

TABLE 6.1

PROJECTED SIZE AND COMPOSITION
US LIGHT-DUTY VEHICLE FLEET

Year	Total Vehicles, millions	Passenger Cars, millions	Light Trucks, millions	Light Trucks, percent
1980	146.1	117.5	28.6	19.6
1985	154.5	122.3	32.2	20.8
1990	161.8	128.0	33.8	20.9
2000	167.6	132.1	35.5	21.2
2010	175.2	136.9	38.3	21.9

Source: Projection of Light Truck Population to Year 2025, ORNL/Sub-78/14285/1, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Assumptions:

- Moderate population growth (US Bureau of the Census, "Series II")
- Moderate economic growth (1 percent per year growth in per capita disposable income)
- Maximum car/population ratio of 0.53 in 1980-1990 (versus 0.50 in 1975), declining to 0.51 in 2000 and 0.50 in 2025
- Termination of the current growth trend in number of light trucks per capita in 1985

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urban travel. About three-fourths of the personal cars in the United States are based in urban areas, and about one-third of urban-based cars are second or third cars at multi-car households.[4] These cars are driven much less than the average and might easily be electrified because another car at the household could be used for long distance travel or carrying large loads. The short distances in urban travel are also suitable for electrification by hybrid cars, which must use petroleum fuels only in long-distance travel.

Though average urban travel is undemanding, roughly 20-25 miles per day, most urban cars are driven much longer distances at least occasionally. The critical questions then for EHVs are these: How much of the time would a given electric range suffice for typical EV drivers? What fraction of the total distance driven could hybrids travel on electric power from utilities?

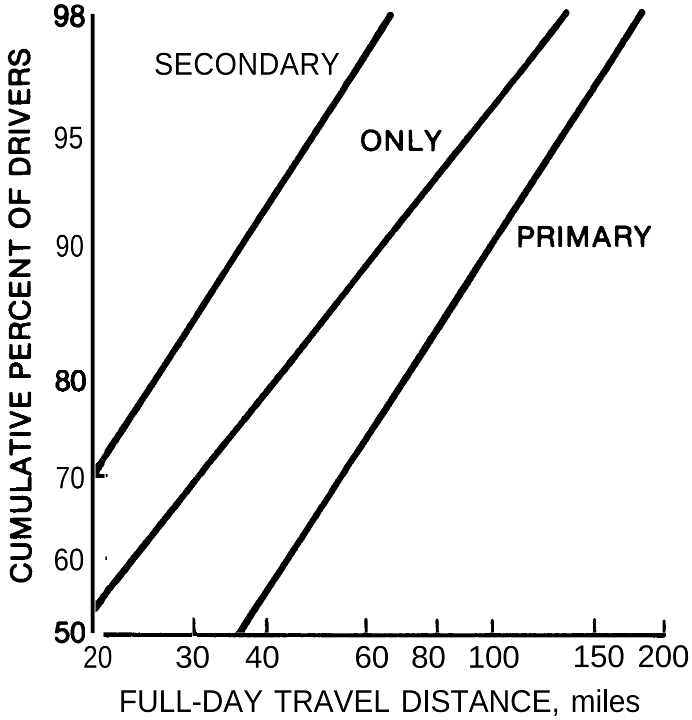
The most useful answers to these questions are based on typical full-day driving, i.e., driving required between overnight recharges. At present, facilities are unavailable for recharges during the day away from home, and it is not clear that they will ever be widely dispersed. Detailed information on full-day travel in two large US cities is available.[4] The data from Los Angeles, a reasonable example which was specifically analyzed for EHV applications, shows:

- At households with only one driver on the survey day, 95 percent of the drivers reported driving less than 93 miles.
- At households with more than one driver, 95 percent of the secondary drivers reported less than 47 miles, while 95 percent of the primary drivers reported less than 137 miles.

The primary driver at each multi-driver household is that driver reporting the greatest total driving distance on the survey day. The secondary drivers were all other drivers reporting driving at these households. These three groups of drivers, only, primary, and secondary drivers, are approximately equal in size. The distances traveled by the vehicles they drove are very close to the distances traveled by the drivers because very few drivers shared a single vehicle on the survey day.

These data give a good picture of travel by many drivers on a single day. They are based on a very large sample, all the drivers at around 30,000 households. It is uncertain, however, what they imply for a single driver during many consecutive days. There is little information to show whether the drivers reporting little total travel on a given day are unlikely to travel long distances on any day, or whether all drivers in a class are equally likely to travel a long distance in a day. The latter has been generally assumed for electric vehicle analyses. Thus it is assumed that an electric car with a range of 93 miles would suffice for 95 percent of the urban travel days of drivers at households with only one driver.

A large increase in range is necessary to make electric cars capable of all driving on 98 percent rather than 95 percent of driving days (3 extra days out of each hundred). For only drivers, the necessary range increase would be 45 percent (from 93 to 135 miles) (Fig. 6.1).



SOURCE: LOS ANGELES ORIGIN-DESTINATION SURVEY, 1967

Primary driver: the driver reporting more travel than any other driver at a multi-driver household

Secondary driver: any driver other than the primary driver at a multi-driver household

Only driver: the only driver reporting travel at a single-driver household

Figure 6.1 Distributions of Full-Day Urban Driving Distance Reported by Major Categories of Drivers

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Because the increase is large it would add substantially to the expense of the electric car; and for only 3 days out of every hundred, the extra expense may not be justified. It appears, for example, that renting an ICE car for long travel days becomes cheaper when electric car range is somewhere between the 95th and 98th percentile requirement of only drivers.[4]

The survey data discussed above is 13 years old and comes from a city long regarded as exceptionally dependent on automobiles. Better data will not become available until a new national survey of similar overall size made during 1977 is completely analyzed. Meanwhile, the Los Angeles results remain useful and probably relevant. There is little reason to expect that there have been large changes in personal vehicle use since 1977: freeway networks changed little in the 1970s, and the average travel per passenger car in the United States in 1978, the most recent year for which data is available, was little more than in 1968 (10,046 versus 9,507 miles). The probable decline in average travel per passenger car since the summer of 1979 has probably brought average travel per vehicle in 1980 even closer to that of the Los Angeles survey. Annual travel per passenger car is among the most stable of national travel statistics: over the 50 years from 1930 to 1980 it has moved within a 6 or 7 percent range around 9,500 miles (excepting only the years of gasoline rationing during World War II). Average travel per automobile in the Los Angeles area, furthermore, is not atypical; in fact, both the survey discussed here and annual estimates reported by the Department of Transportation for California suggest average annual vehicle use in Los Angeles is a little less than the national average.

Survey data from Washington D.C. taken in 1968 shows daily travel distances somewhat below those of Los Angeles. For secondary drivers, the 95th percentile travel distance reported on the survey day was 25 percent less than in Los Angeles, while for primary drivers it was nearly 50 percent less (Table 6.2). Somewhat less travel is to be expected because the Washington area is much smaller physically than the Los Angeles area, so maximum distances of single urban trips are more limited. Furthermore, the central focus of the Washington area is much greater and there was much less freeway available per car, making long trips slower and more difficult. Even so, there remain reasons to question the lesser travel indicated by the Washington survey.[4] In any case, both the Washington and Los Angeles data indicate that to meet the needs of 95th percentile drivers, cars must seat 3 to 4 persons, and that in Los Angeles freeway capability is required. It may still be that substantial percentages of cars could be limited in size and performance to two passengers and slow speeds; but the data suggests that such "urban" cars would be unsatisfactory for the great majority of drivers unless patterns of vehicular use change substantially.

An electric car with 100-mile range would suffice for the travel of households with only drivers on 96 percent of urban travel days, according to the Los Angeles data (Fig. 6.1). The 100-mile range would also have sufficed for 96 percent of all drivers taken together in Los Angeles. This does not imply, however, that the 100-mile electric cars could accomplish 96 percent of the total urban travel of all drivers. Instead, a safer estimate would be 80 percent of all miles driven (Fig. 6.2). Drivers who travel over 100 miles in a day account for a disproportionate fraction of the total distance traveled. If none of them could use an electric car for any portion of their full-day travel, and

TABLE 6.2

NOMINAL REQUIREMENTS FOR PERSONAL URBAN ELECTRIC CARS

(to satisfy 95th percentile requirements)

	Range, miles	Capacity, persons
Secondary Car	35-47*+	3-4
Only Car	53-93	3-4
Primary Car	68-137	4

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

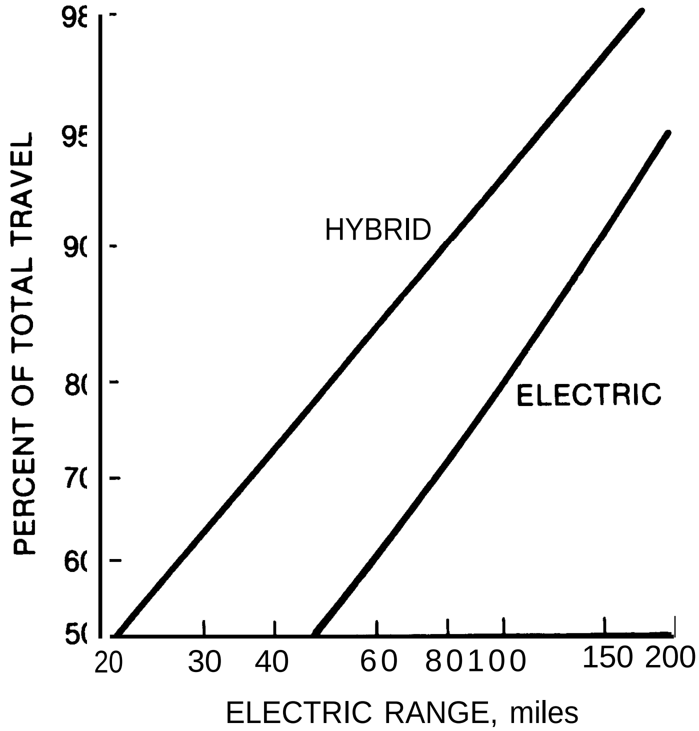
*-Based on Washington, D.C., data from 1968

+Based on Los Angeles data from 1967

always substituted ICE cars instead, then the 100-mile electric car could electrify about 80 percent of urban travel. If part of these long-distance travel requirements could have been met by electric cars, then the percentage could be as high as 96 percent. It seems unlikely, however, that a driver would take trips such that the full range of the electric car could be entirely used before the switch to an ICE car for the remainder of the day's travel.

The driver of a hybrid car, however, can conveniently utilize the entire electric range of the car before switching to ICE propulsion. Thus a hybrid with 100-mile useful electric range could electrify 96 percent of urban travel, and hybrids with shorter electric ranges could still electrify as much urban travel as the 100-mile electric car (Fig. 6.2).

Electrification has so far been discussed only for average cars (or only cars at one-car households). If used as secondary cars, the 100-mile electric car could electrify almost all urban travel by secondary drivers, but this would amount to less total travel mileage per car then electrifying 80 percent of annual travel by the average car. The reason is that secondary cars travel perhaps 6,000 miles per year,



SOURCE: LOS ANGELES ORIGIN-DESTINATION SURVEY, 1967

Assumptions: Hybrid vehicles electrify the first M miles of full-day travel by all drivers, where M is the useful electric range of the hybrids. Electric vehicles electrify only the full-day travel reported by drivers who traveled less than the maximum electric range of the vehicles.

Figure 6.2 Potential Electrification of Urban Driving by Electric and Hybrid Cars

compared with 10,000 miles per year for the average car. Because usage of secondary cars is undemanding, electric cars are often advocated for second-car application. On the other hand, second cars today are ordinarily relatively old and inexpensive cars which were not purchased new. Electric cars may be entirely too high-priced for this application, given limited consumer budgets for transportation. It seems more likely that with the advent of EHVs, patterns of use will change, at least at multi-car households where different assignments of trips among household vehicles are possible. In the future, travel may be reassigned to maximize electrification of household vehicle-miles. The ICE car could become the second car; it would be used when the other (electric) car was already busy, as at present, but unlike today's secondary cars it would also be used for long trips because they could not be accomplished by the electric car. Because such changes in usage seem likely, it is most appropriate here to focus on electrification of average car travel rather than secondary car travel.

The percentage of urban travel by the average car which could be electrified by an electric car of 100-mile range probably lies somewhere between the extremes just described (80-96 percent). If the actual percentage were halfway between these extremes, it would be about 85 percent for the 100-mile electric car, about the same as the electrification of urban travel by a hybrid with a useful electric range of some 60 miles.

6.2.3 Overall Use of Personal Vehicles

The addition of long-distance trips, beyond the urban area, to urban travel gives overall travel by personal vehicles. It appears that long-distance trips account for roughly 10 to 15 percent of the total distance travelled by personal vehicles. A large minority of households with personal vehicles, 38 percent, reported no such trips in an entire year (Table 6.3). Households making such trips, however, reported an average of five for the year, with an average distance of 620 miles. Furthermore, 43 percent of the total long-distance travel mileage was in trips of over 1,000 miles and 25 percent was in trips over 2,000 miles.

Long-distance travel is important for electric vehicles because it represents an important component of total personal vehicle travel which they could not accomplish. It would require use of an ICE vehicle--either one rented or available at the household. Hybrids, on the other hand, could accomplish at least the first part of a long trip on stored electric energy. A hybrid with a 60-mile useful electric range would accomplish about 10 percent of total long-trip distance on electric power, assuming no recharges after leaving home. With a 180-mile electric range, the hybrid would accomplish nearer 30 percent of the total long-distance travel on electricity.

Combining long-distance and urban travel electrification gives overall electrification potential for hybrid and electric cars. The biggest uncertainty arises in urban travel. Multi-vehicle households have considerable latitude in how both hybrid and electric vehicles can be affected greatly by the manner in which vehicles are assigned to trips in multi-vehicle households, as well as by the length and number of trips on long-distance travel days.

If the 100-mile electric car or the 60-mile hybrid could each electrify about 85 percent of the urban travel by the average car, then the addition of long-distance travel would reduce total electrification to about 77-78 percent. This would probably be increased in both cases by trip reassignment among household cars to minimize gasoline use.

TABLE 6.3

LONG TRIPS (over 100 miles one-way) BY CAR AND LIGHT TRUCK, 1972

Fraction of US households with car or truck reporting one or more long trips	62 percent
Average number of trips per household reporting long trips	5.0
Average round-trip distance	620 miles

Round-Trip Length, miles	Percent of Trips	Percent of Total Distance
200-400	49	22
400-600	22	17
600-800	10	11
800-1000	5	7
1000-2000	8	18
over 000	4	25
outside US	2	

Source: 1972 Census of Transportation, National Travel Survey, Travel During 1972, TC72-N3, US Government Printing Office, Washington, 1973.

Accordingly, a reasonable estimate of electrification for use in this report appears to be 80 percent of average annual vehicle miles traveled, both for the electric car with 100-mile maximum range and the hybrid with a useful electric range of 60 miles.

6.2.4 Non-Personal Vehicles

Light trucks in various non-personal uses have often been singled out as promising candidates for electrification. In such stop-start missions as mail delivery, utility meter reading, and coin telephone servicing, electric vehicles first promise to be cost-effective in the United States.

The only major use today of on-road electric vehicles in the world is commercial, for milk delivery in England. Vehicles are specially built for this purpose, whether they use diesel or electric propulsion, so the electric vehicles compete on equal terms rather than with mass-produced conventional vehicles. In this application, the low speeds, frequent lengthy stops, and short ranges required are easily managed by the electric vehicles, but tend to result in high fuel use and maintenance for comparable diesel vehicles. As a result, the electric vehicles have proven cheaper overall.[5] Conditions for milk delivery in the United States, however, are different and ill-suited to electric vehicles.

Total non-personal use accounts for about 40 percent of all light trucks. Unfortunately, relatively few non-personal trucks are now in the utility services--meter reading, coin telephone servicing--which appear most favorable for electric vehicles, and little change is expected here in the future (Table 6.4). Overall, the total number of utility vehicles which are amenable to electrification may be on the order of 100,000. Postal delivery vehicles (not included in Table 6.4) number a little over 100,000; their stop-start mission makes them amenable to electrification. Taken together, however, utility and postal vehicles which could reasonably be electrified constitute only 2 to 3 percent of non-personal light trucks.

Except in these applications, range requirements for light trucks are quite demanding. Range requirements for personal electric light trucks probably equal those of personal electric urban automobiles. Range requirements for fleet light trucks, based on a survey of fleet operators, are even greater.[6] It appears that electric light trucks with 100-mile range would satisfy the range requirements of under 10 percent of fleet trucks, though this is inconclusive because of the low response rate in the fleet operator survey.

The fleet operator survey also disclosed that requirements for passenger cars operated in commercial fleets are generally demanding as well, not just in terms of range, but also speed and passenger capacity.

TABLE 6.4

APPLICATIONS OF NON-PERSONAL LIGHT TRUCKS

Major Use	Percent 1975	Percent 1995
Agriculture	40	26
Services	18	28
Construction	15	14
Wholesale and Retail Trade	14	17
Utilities	5	6
Manufacturing	3	4
For Hire	1	1
Forestry and Lumber	1	1
Other	3	3

Source: Projection of Light Truck Population to Year 2025, ORNL/Sub-78/14285/l, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

This is corroborated by independent investigations of the willingness of fleet operators to use electrics and EHVs, as discussed below.

6.3 MARKET PENETRATION ESTIMATES

Estimates of market penetration for EHVs are generally unsatisfying because they are based on inadequate and incomplete data. They lend some substance to the obvious inference that cars which cost more and do less are unlikely to capture a large market share. They do not establish, however, whether the market share which will be captured is large enough, 2 or 3 percent, to support mass production and the associated vehicle prices assumed in the estimates. Furthermore, most existing estimates are based on little change in the price and availability of gasoline relative to the mid-1970s.

- SRI International estimated for the Department of Energy that some 3.5 percent of the US light vehicle fleet in 2000 might be electric.[7] The estimate was based largely on supply considerations, i.e., the times required to develop improved technology, demonstrate effectiveness, develop commercial designs, tool up for production, and replace vehicles in the existing fleet. The SRI scenario made generally optimistic assumptions about the process by which decisions to produce are made, including full success for the DOE EHV research, development, and demonstration program by 1985.

- Arthur D. Little, Incorporated, made projections of EHV market penetration for DOE with and without additional government incentives beyond the RD&D program.[8] The ADL projection was based on consumer panel surveys, plus the optimistic assumption that electric vehicles would be mass-produced with effective nickel-zinc batteries in 1983. For personal vehicle sales in 1983, market penetration for electrics was estimated at 0.4 percent, and for hybrids a little under 2 percent. For non-personal vehicles, market potential was investigated through interviews with fleet operators which revealed no “sizeable market” in 1983.

- Cambridge Systematic, Incorporated, estimated market penetration for the Department of Energy using an econometric model of auto choice decisions modified for EHVs.[9] Penetrations of zero to 2.2 percent of sales in the year 2000 were estimated for the "most likely" case, which included an advanced 150-mile electric car with high-temperature battery. In the “optimistic” case, an advanced hybrid tripled market penetration.

- Mathtech, Incorporated, projected electric vehicle penetration into the US vehicle fleet for the Electric Power Research Institute.[10] With an econometric model modified to account explicitly for limited range, plus optimistic assumptions about technology, 9 percent of vehicles were projected to be electric in the year 2000. The technological assumptions were optimistic, however, and the actual effect of range limitation on market penetration was negligible in the Mathtech model.

In short, projections to date suggest that 1 to 10 percent of the US vehicle fleet may be EHVs in 2000. All the projections assume, explicitly or implicitly, conditions more or less like those prevailing in 1980. Only the ADL projections, the most conservative of those noted, utilized any direct information about consumer valuation of operating range and rapid refueling capability.

The ADL Analysis is unique because it obtained explicit information from consumers about the relative values they attached to range, purchase price, and other attributes of electric and hybrid cars. One hundred ninety-three auto owners served on panels of consumers who examined both their own actual driving behavior and the probable characteristics of future electric, hybrid, and conventional vehicles. Thus they understood to some extent the implications of the choices they were asked to make among 16 hypothetical electric, hybrid, and conventional vehicles with various capabilities, limitations, and costs. It would be more satisfactory, of course, to infer consumer preferences from actual purchases in the marketplace. But today's auto market does not include electric and hybrid vehicles, or other vehicles with similar limitations, on any significant scale.

Because of its unique value, the ADL preference data is being reanalyzed by Charles River Associates for the Electric Power Research Institute. Results presented to date are especially useful because they make explicit the tradeoffs which consumers make between driving range, acceleration, seating capacity, price, and annual fuel costs (for electricity or gasoline) . These tradeoffs are critical to effective design of electric vehicles as well as to their probable market penetration. The findings show that the average consumer surveyed would pay:

- **$2,100 to $3,700** more to avoid 7-hour refueling (or recharge) times (depending on whether vehicle range between refueling were 200 or 50 miles)
- **$6,500 more to** increase range from so to 200 miles
- $3,900 more to increase maximum speed from 45 mph to 65 mph
- **$2,000 more** to obtain average rather than low acceleration
- $3,500 more for four seats rather than two
- **$2.16** more initially to save $1 annually thereafter in operating costs.

Clearly, the average consumer in the ADL panels values the range and the quick refueling capability of the conventional car very highly, and values speed, acceleration, and capacity sufficiently that in the absence of data to the contrary, it is hard to foresee a major role for a limited-performance two-passenger urban automobile in the future. Such vehicles would, of course, cost less to buy and to operate. It is precisely the costs of purchase and operation, however, which the ADL consumer panels addressed as they expressed preferences among the variety of options described to them. Their concern with range, performance, and capacity are especially noteworthy because all panelists came from two-car households in urban areas with mild climates, and none commuted long distances. Furthermore, they were asked to indicate their preferences among the hypothetical electric, hybrid and conventional cars as a replacement for their second car, rather than for some more demanding application.

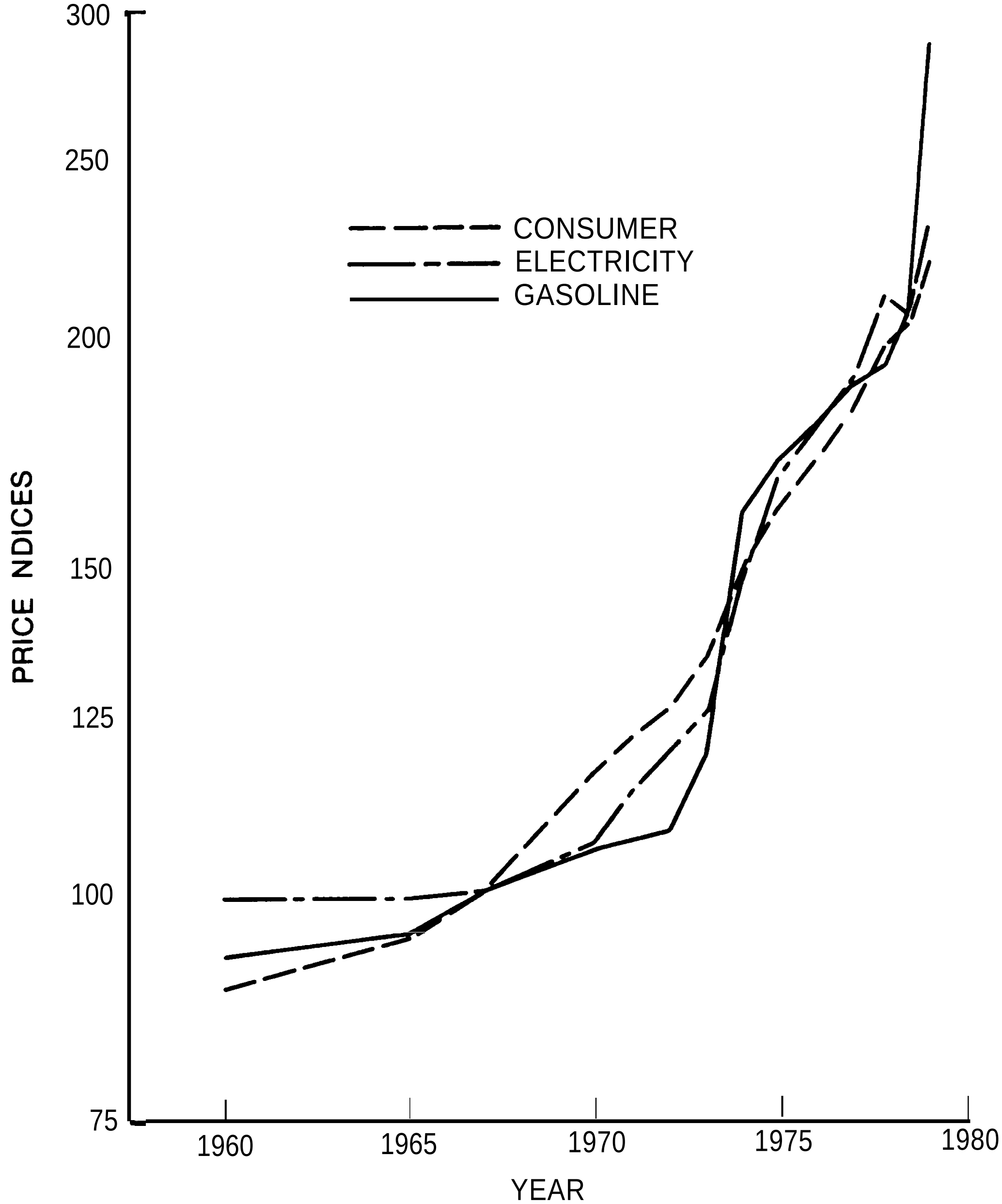
Given the valuations of performance and capability from the ADL Data, summarized above, electric cars can be designed (for a given technology) to offer the best overall combination of range, price, and annual cost for the average motorist. This leads to ranges of 85-90 miles for cars with near-term batteries having the capabilities and costs projected in Fig. 3.10, and 125-150 miles for cars with advanced batteries.

6.4 COST AND AVAILABILITY OF FUEL

The ultimate market potential of EHVs depends greatly upon the relative price and availability of petroleum fuels and electricity. To the extent that gasoline and diesel fuels become more expensive or less available relative to electricity, motorist would have an incentive to switch from conventional vehicles to EHVs.

Since the OPEC oil embargo of 1974, the US has faced unstable energy supplies and much higher prices. Supply disruptions in 1979 focused public concern clearly on the energy issue. The problem has been that over the last decade, petroleum consumption has continued to rise in the United States, but domestic production has remained relatively constant. As a result, it has become necessary to rely on foreign imports to satisfy an increasing share of our demand (48 percent in 1979). Recent disruptions in foreign supply have clearly demonstrated our vulnerability. To some extent, motorists may purchase EHVs as a hedge against further disruptions, even though petroleum fuels may remain as available as they have been in 1980, and no more costly.

The price indices for gasoline, electricity, and all consumer goods have risen at roughly the same rate during the period 1960-1979 (Fig. 6.3). Gasoline prices generally lagged behind electricity prices through 1973, but, as a result of the 1973-1974 OPEC oil embargo, they jumped ahead of electricity prices and the consumer price index. During the following years, gasoline prices fell in relative terms until the Iranian crisis of 1979 led to another abrupt increase. During 1980, gasoline prices have risen much more slowly than electricity prices, which appear to be "catching up" as they did in 1975-1978. At the typical 1980 prices used in this report ($1.25 per gallon, 6 cents per kilowatt-hour average, and 3 cents per kilowatt-hour for off-peak recharging), gasoline has risen about 30 percent relative to average residential electricity since 1967. If this differential increases, EHVs could become important factors in the auto market, in personal transportation, and in the conservation of petroleum.



Source: <u>Statistical Abstract of the United States</u>, US Department of Commerce, Bureau of the Census, 1979

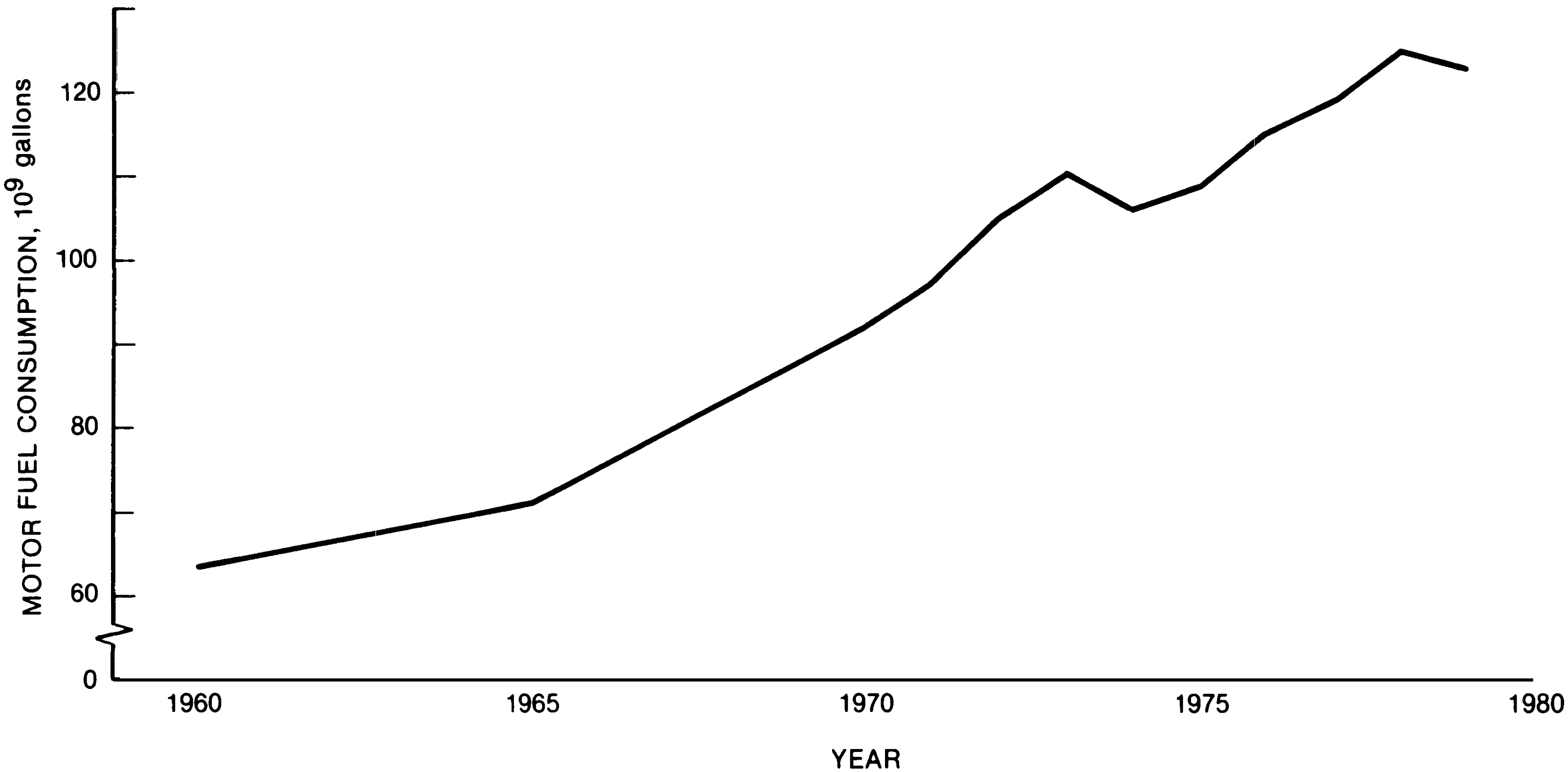
Figure **6.3** Gasoline, Electricity, and Consumer Price Indices, 1960 Through 1979 (average)

Experience during the 1973-1974 OPEC oil embargo and the 1979 disruptions in supply indicates that long lines at service stations--and concern about the unavailability of fuel--may affect motorists more than the price increases accompanying them. Quarterly figures for gasoline prices and sales support this clearly. In fact, the rapid response of the public, in terms of demand, is clearly evident in analyzing annual consumption of all motor fuels, including diesel, since 1960 (Fig. 6.4). Each major crisis was immediately followed by a sharp decrease in consumption. However, in 1973-1974, this sharp decrease was followed by a resumption of normal growth after only about two years. Whether this will happen again as a result of the 1979 crisis is unclear.

Future prices and availability of gasoline and diesel are difficult to predict because they are dependent upon many imponderable, largely government actions, both foreign and domestic. The cutoff of Iranian production, future OPEC price and supply decisions, and the ability of Saudi Arabia and Kuwait to continue stepped-up production to make up for other shortfalls are typical of situations that could have great influence in the future.

The price and availability of electricity is also influenced by increased prices for foreign oil, as well as by increased costs of capital for construction and public resistance to development of new nuclear power plants. Although an average price of 6 cents per kilowatt-hour is used in this report to represent the national average, it is important to note that prices vary greatly from region to region and company to company. This variation is on the order of 8: 1.

One means of minimizing the impact of EHVs on the electric utility industry is to make use of existing underutilized capacity, rather than constructing new power plants. This can best be done if recharging is accomplished during off-peak periods. Establishment of low off-peak electricity prices would help to encourage recharging during these periods, particularly if the difference between the peak and off-peak rates were great. As an example, a recent report regarding peak and off-peak pricing for five electric utilities in California[12] estimated that the off-peak price of electricity would range between 2 and 4 cents per kilowatt-hour, even though the utilities' peak rates varied between 4 and 14 cents per kilowatt-hour. The specific estimates for Pacific Gas and Electric (serving the San Francisco area) were 14.0 cents per kilowatt-hour at the peak rate, and 2.4 cents per kilowatt-hour for the off-peak rate. For averge driving, this would result in an additional $50 per month if on-peak rather than off-peak recharging were used. Not all electric utilities will have this large a differential in peak and off-peak prices. As a result, off-peak pricing may be more effective in some areas of the country than in others.



Source: US Federal Highway Administration, Highway Statistics, 1960-1979 (excludes Alaska and Hawaii)

Figure 6.4 National Motor Fuel Consumption, 1960-1979

6.5 INCENTIVES

The EHV industry is currently in the embryonic stage of development. As a result, it faces stiff competition from the fully-developed conventional automobile industry. Not only are the capital costs required to penetrate the automotive market great, but so are the associated risks. Nevertheless, the potential benefits to the country of an expanded EHV industry are also great. Consequently, the Federal Government has undertaken to play a major role in supporting the development of the EHV industry.

In 1976, the Congress passed the Electric and Hybrid Vehicle Research, Development, and Demonstration (EHV RD&D) Act (Public Law 94-413). Since that time, the Department of Energy has supported an extensive program whose objectives are to improve the capabilities of and expand the market for EHVs. The total budget initially authorized for this program was $160 million through September 1981. Additional funds have been appropriated since that time, particularly in the area of advanced battery research and development. The recent inclusion of EHVs in the calculation of Corporate Average Fuel Economy (CAFE), resulting from an amendment to the Chrysler Corporation Loan Guarantee Act of 1979 (PL 96-185), represents a further Federal effort to encourage their development.

Other means that could be employed to increase the acceptance and use of EHVs include subsidies and tax credits for both producers and purchasers of vehicles, tax credits for electricity used to recharge vehicles, markets for EHVs guaranteed by the Federal Government, and vehicle sharing schemes whereby limited use of a larger conventional vehicle is guaranteed as part of the purchase of an EHV. Possible disincentives for conventional vehicle use, which would improve the relative position of EHVs, would be to increase automotive fuel taxes or vehicle purchase taxes. Gasoline rationing could tend to encourage the purchase of fuel-efficient conventional vehicles rather than EHVs if it is simply used to allocate a limited supply of gasoline without price increases. Rationing accompanied by a ‘white market” in ration coupons would encourage EHV sales by allowing increases in the effective price of gasoline.

6.5.1 Present Incentives

The stated goal of the EHV R&D program approved by Congress in 1976 is to assure the availability and broad market acceptance of vehicles that depend primarily on externally generated electricity for propulsion energy in order to minimize dependence on imported oil[13] while maintaining continued flexibility in the transportation sector.

The program initially consisted of three major elements: Demonstrations, Incentives, and Research and Development. A fourth major element, Product Engineering, was subsequently added. The purpose of the Demonstration program element is to show that EHVs can perform functions presently accomplished by petroleum-fueled vehicles, to develop the market for EHVs, to develop the support systems necessary to maintain the vehicles in practical operations, and to provide a cash flow to manufacturers. The purpose of the Incentives program element is to remove barriers and facilitate the development and subsequent use of EHVs, primarily through business loan guarantees, small business planning grants, and special studies on barriers to using EHVs. The purpose of the Product Engineering program element is to accelerate the commercialization of EHVs by facilitating the transfer of improved technology into the marketplace, thereby bridging the gap between the Research and Development and the Demonstration elements of the program. The purpose of the Research and Development program element is to advance EHV technologies to the point where they are more acceptable, have improved utility, and are available at lower cost. A complete discussion of each of these program elements is presented in the most recent report to Congress on the EHV program.[14]

In order to help achieve the goal of the EHV RD&D program, the following five major projects have been established:

- Market Demonstration. The purpose of this project is to identify, test, and prove EHV market sectors; to develop the necessary support infrastructure; and to provide cash flow to manufacturers.

- Vehicle Evaluation and Improvement. The purpose of this project is to develop improved vehicles through optimization of off-the-shelf technology and to aid the rapid commercial availability of improved vehicles.

- Electric Vehicle Commercialization. The purpose of this project is to induce mass production by 1986 of cost-competitive electric vehicles that will be acceptable to a broad segment of the market.

- Hybrid Vehicle Commercialization. The purpose of this project is to induce mass production by 1988 of cost-competitive hybrid vehicles with a range capability comparable to internal combustion engine vehicles.

- Advanced Vehicle Development. The purpose of this project is to develop by the early 1990s a general-purpose electric or hybrid vehicle system, completely competitive with internal combusion engine vehicles, which does not use any petroleum for operation.

The rationale for these projects is to provide a balance between ‘market pull" and "technology push," to enhance the demand for EHVs, and to improve their capability simultaneously. Together they represent an attempt to support the newly-developing EHV industry until it becomes self -sufficient.

At present, the industry consists of numerous small companies which are involved in all aspects of EHV design, development, and production, and several large established firms, such as General Motors and General Electric, which are preparing to produce and market EHVs or their associated components. With the probable large-scale entry of the conventional automobile industry into the EHV marketplace, many small companies which were integrally involved in the early development of the EHV industry are attempting to 'link up" with these major producers.

Although almost no Federal funding of EHV development was available before 1976, the program has since received additional emphasis each year (Table 6.5). Total funding for FY 1976-1980 was over $130 million, 60 percent of which was allocated for FY 1979 and 19800 The budget emphasis for FY 1980 concentrates on market demonstration projects and research and development, particularly in the area of electric vehicle commercialization. Nearly 70 percent of the present budget is directed at these two major efforts.

Since batteries are one of the major cost components of EHVs, and since they are the limiting factor in EHV range, significant additional funding has been allocated to improve technology in this area. The Department of Energy supported advanced battery research and development even before the EHV RD&D Act of 1976. However, the level of effort has been increased since that time such that FY 1980 funding is $41 million (Table 6.6). Although the zinc-chlorine, lithium-aluminum metal sulfide, and sodium-sulfur battery programs are currently receiving the greatest emphasis, other batteries which also show some promise are being funded, but to a lesser extent. Increased funding for the most promising battery R&D projects will most likely be required to achieve the technological advances necessary to make EHVs cost-competitive and to provide sufficient range.

Another recent incentive for EV production by the major automobile manufacturers is the inclusion of EVs in the computation of Corporate Average Fuel Economy (CAFE). This incentive was initiated **as a** result of an amendment to the Chrysler Corporation Loan Guarantee Act of 1979 (PL 96-185). EV fuel economies as high as 185 miles per gallon have been proposed for use in the CAFE computation.[15] Even at much lower fuel EV economy estimates, the differential between fuel economy for conventional vehicles and EVs appear large enough to provide a significant improvement in CAFE if sufficient EVs are manufactured and sold. Market demand for fuel efficient automobiles is already such, however, that the major manufacturers are expected to exceed the current standards through 1985. In this case, EVs are not needed to meet the standards.

TABLE 6.5

DOE EHV PROGRAM AND PROJECT FUNDING

Programs	FY 1976-1978, millions of dollars	FY 1979, millions of dollars
Demonstrations	5.5	12.1
Incentives	0.9	2.5
Product Engineering	10.9	6.9
Research and Development	35.5	16.0
	52.8	37.5

Projects	FY 1980, millions of dollars
Market Demonstration	12.0
Vehicle Evaluation and Improvement	2.5
Electric Vehicle Commercialization	17.0
Hybrid Vehicle Commercialization	7.5
Advanced Vehicle Development	3.5
	42.5

Source: 3rd Annual Report to Congress for FY 1979, Electric and Hybrid Program, US Department of Energy, January 1980; and Mort Cohen, Aerospace Corporation, Washington, D.C., private communication, June 1980.

[1] Includes near-term battery development and technology demonstrations.

TABLE 6.6

DOE BATTERY R&D FUNDING

Battery System	Millions of Dollars FY 1975	FY 1980
Improved Lead-Acid	2.3	2.7
Nickel-Iron	0.5	1.5
Nickel-Zinc	1.3	2.3
Metal-Air	2.2	1.7
Zinc-Chlorine	0.5	4.1
Lithium-Aluminum Metal Sulfide	5.0	6.5
Sodium-Sulfur	3.2	6.0
	15.0	24.8[1]

Source: F. George, Electromechanical Power Sources for Electric Highway Vehicles, Arthur D. Little, Inc. Report C-74692, June 1972; N. P. Yao, Argonne National Laboratory, private communication; and Kurt Klunder, US Department of Energy, private communication.

[1]The total budget for advanced battery research and development is $41 million. The additional $16.2 million is to be used for test facilities, special studies, support, and exploratory work on other batteries.

6.5.2 Possible Future Incentives

Various incentives that could be implemented to stimulate the transition from conventional vehicles to EHVs are described below.

Subsidies and Tax Credits. These are the most common general incentives that have been used by the Federal Government to stimulate new technology. They are primarily used to offset the economic disadvantages of a particular technology when the overall benefits to the nation can be better served. However, they do interfere with the normal workings of the marketplace. Consequently, special care must be taken to ensure that the resulting benefits warrant this interference.

Direct subsidies to vehicle manufacturers and buyers could be used to encourage EHV production and purchase. A recent study by SRI International estimated that it could cost $7 to $12 billion by the year 2000 to equalize the initial purchase prices of conventional and electric vehicles.[7] This is based on an expected fleet size of 3.5 million electric vehicles with subsidies of $2000 to $3500 each. Tax credits for producers and purchasers could provide an incentive similar to those of subsidies, without extensive cash outlays by the government, but they would result in foregone tax revenues. A similar tax credit could also be applied to recharge electricity usage to reduce further the overall life-cycle costs of EHVs. The potential impacts of these measures have not yet been studied in detail.

Market Guarantees. Because of uncertainties in the marketplace regarding consumer acceptance of EHVs, manufacturers must be careful in initiating an extensive campaign to produce and market these types of vehicles. However, most experts feel that at least 20 percent of the light-duty vehicle market must be captured by 2010 in order to justify the cost of government incentives. In order to help provide a sound market, and to demonstrate government confidence in the utility of EHVs, it may be advantageous to guarantee the purchase of EHVs for government use. The Federal Government currently utilizes many conventional vehicles which could adequately be replaced by EHVs. However, this would involve at most only about one million passenger vehicles, and would represent less than six-tenths of one percent of the projected light-duty vehicle population in 1985.

Automotive Fuel Taxes. The appeal and marketability of EHVs might also be increased through the use of a disincentive such as higher gasoline taxes to discourage gasoline consumption. These taxes would make EHVs more attractive by reducing operating costs in comparison to conventional vehicles. However, they would result in various side effects which could require compensatory action by the Federal Government.

Fuel Rationinq. A measure closely related to higher fuel taxes is fuel rationing. Recent Administration and Congressional actions have formulated a stand-by gasoline rationing plan as a means of decreasing consumption if the foreign oil import situation becomes critical. Although rationing is generally considered a “last resort” response, the prospect of imposition could affect EHV purchases. During World War II, rationing stabilized the price of gasoline while reducing consumption; i.e., pump prices were fixed, available quantities of gasoline were reduced, and consumers were provided with non-transferable coupons. If this type of rationing were again implemented, it would not provide an advantage to EHV owners because the price of electricity would continue to rise, thus reducing the price differential between it and the stabilized gasoline price. In this case, consumers would be better off to purchase an inexpensive, fuel-efficient conventional automobile which would not have the range restrictions of an electric, Only if rationing were to result in a net increase in the effective price of gasoline, thus increasing the differential between gasoline and electricity, would it provide an incentive to purchase an EHV. In this case, coupons would be transferable, resulting in an effective gasoline price consisting of the cost of the gasoline itself and the cost of a coupon. These coupons would be purchased from individuals who chose to sell them rather than consume their allocated share of gasoline. As rationing became more and more stringent, a larger number of consumers would enter the market to purchase coupons, further increasing prices. The net effect would be similar to increased levels of gasoline taxation.

Vehicle-Sharing Schemes. Various vehicle-sharing schemes have been considered in recent years to help eliminate the disadvantages of electric vehicles with regard to long-distance travel. For example, electric vehicle dealers could guarantee buyers limited use of a larger conventional vehicle as part of the purchase agreement. These conventional vehicles could be owned by the dealers and be provided to purchasers of electric vehicles by appointment to use for vacations, weekend trips, transporting large loads, etc. It is not clear exactly how these schemes could best be employed, or whether they would remain desirable if hybrids enter the marketplace.

A study performed by Mathtech[16] in 1977 examined the effects of a variety of EHV incentives The study first defined a base case without incentives, and then measured the result of each potential incentive in relation to this base case (Table 6.7). The study estimated that less than 40,000 electric vehicles would be sold in 1995 without the use of incentives. Purchase price subsidies showed the greatest promise: a $3000 subsidy per vehicle was projected to boost estimated sales to over 850,000 in 1995. An operating subsidy of one-third of most life-cycle costs also showed great promise, boosting sales over the 450,000 mark. Although a gasoline tax of 50 cents per gallon could also increase EV sales, it would not be as effective as either of the first two incentives. The study found that the use of multiple incentives would provide the greatest increase in EHV purchases. In the case of a 50-cent per gallon gasoline tax and a one-third operating subsidy, electric vehicle sales in 1995 were projected to exceed 1,200,000.

Another[8] study of incentives was performed by Arthur D. Little, Incorporated. The study projected sales of various types of vehicles for 1983, including both electric and hybrid vehicles (Table 6.8). The study estimated that from two to seven times as many hybrids as electrics would be sold in 1983, depending upon the incentives used. The use of a $2000 subsidy and a special warranty was projected to result in sales of over 800,000 in 1983.

Current estimates by General Motors are on the order of 200,000 to 300,000 EHVs per year by the late 1980s, presumably with no incentives. These estimates differ substantially from the base cases for the Mathtech and A. D. Little studies.

TABLE 6.7

PROJECTION OF ANNUAL ELECTRIC VEHICLE SALES UNDER ALTERNATIVE POLICIES

	1985		1995	
Incentives	Number	Percent Increase	Number	Percent Increase
Base Case (no incentives)	20,300	--	36,900	--
$300 Purchase Subsidy	38,000	38	50,900	38
$1000 Purchase Subsidy	59,600	194	107,400	191
$3000 Purchase Subsidy	503,000	2378	867,800	2252
Off-Peak Electricity Pricing	27,100	33	49,900	35
50-cent Gas Tax	51,900	156	102,400	178
10-cent Gas Tax	25,300	25	45,500	23
Doubling of Range	55,900	175	114,200	209
Operating Subsidy of one-third of most life-cycle costs	240,100	108	465,500	1161
Combination of 50-cent Gas Tax and Doubling of Range	144,800	613	313,400	749
Combination of 50-cent Gas Tax and Operating Subsidy	601,700	2860	1,221,100	3209

Source: C. Upton and C. Agnew, An Analysis of Federal Incentives to Stimulate Consumer Acceptance of Electric Vehicles, Mathtech, September 1977.

TABLE 6.8

ESTIMATED SALES OF EHVs TO CONSUMERS IN 1983[1]

Incentive[2]	Vehicle Sales, thousands	
	Electric	Hybrid
Base Case (no incentives)	37	984
Special Warranty	73	514
Subsidy of $2000[3]	257	440
Subsidy and Warranty	477	807

Source: Anton S. Morton, Incentives and Acceptance of Electric, Hybrid and Other Alternative Vehicles, Arthur D. Little, Inc., November 1978.

[1] Assumes total new car sales of 10 million. Estimates total of 3.7 million sold to potential market for EHVs (multiple-car households which own at least one compact or subcompact car and live in warm or temperate climates.

[2] Gasoline at $1 per gallon.

[3] 1978 dollars

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