7 BENEFITS AND COSTS, MONETARY AND NON-MONETARY

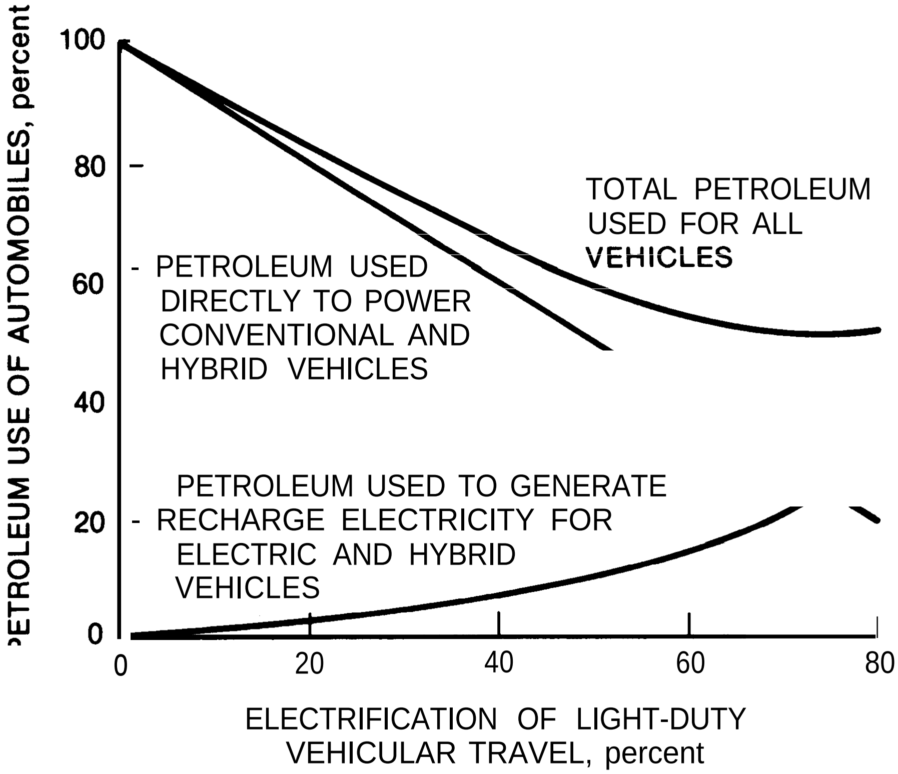
7.1 SUMMARY

No one knows with any degree of certainty how many EHVs will be sold in the 1985-2010 time frame. It is clear, however, that EHVs can provide various benefits to the nation and the user, given a willingness to accept the associated costs. Though any attempt to estimate benefits and costs must rely on an arbitrary assumption of EHV sales, it is clear that at any sales level, EHVs can save petroleum. It is also clear that EHVs initially will be more expensive than comparable conventional vehicles, and that electric vehicles will provide the user with substantially less mobility.

The benefits and costs of EHVs can generally be divided into five major categories: energy, the environment, the economy, resources, and transportation. In terms of energy, the primary benefits of using EHVs would be a reduction of petroleum consumption and a lessening of US dependence on foreign oil. For example, in the year 2010, electrification of 20 percent of light-duty vehicle travel would reduce automotive petroleum consumption by nearly 18 percent (Fig. 7. 1). Furthermore, if EHVs were utilized first in selected regions, up to 70 percent of all light-duty vehicular travel could be electrified without using any petroleum to generate recharge electricity. This would result in automotive petroleum savings of about 65 percent. In this case, most of the electricity would be derived from coal and nuclear power plants during otherwise idle off-peak periods. With market penetrations of less than 20 percent, savings would be proportionately smaller.

The primary environmental impacts from the use of EHVs would be an improvement in national air quality and a reduction in urban traffic noise. Since EHVs do not produce emissions like conventional internal combustion engines (when operating in the electric mode), the contribution of automobiles to air pollution would be reduced. However, the generation of recharge electricity through the use of fossil fuels would result in increased sulfur-oxide emissions which would partially offset this improvement. To mitigate this problem, the use of EHVs could be encouraged in those areas where electric generation is least dependent on fossil fuels. Because they are inherently quieter than conventional vehicles, the use of EHVs could also be expected to result in desirable reductions in traffic noise, the major noise problem in urban areas.

The higher prices of EHVs would substantially impact motorists. Aside from this, however, the widespread use of EHVs would have little economic impact in the United States. Only about 3 percent of US jobs would be affected by a complete switch to EHVs. Even if such a transition were completed in only two or three decades, the annual changes would be very small. Total employment in manufacturing, selling, and servicing automobiles would be increased. The overall net change in



Source: Recharge Capacity Projection System (RECAPS), General Research Corporation

Assumptions: The RECAPS model schedules the use of nuclear, coal, and hydroelectric facilities before oil and gas facilities, and base-load facilities before intermediate and peaking facilities to minimize operating costs. Recharging is controlled to maximize the use of off-peak power available during late night and early morning hours when demand is lowest. The model makes use of capacity and demand projections developed by the electric utility companies in 1979. Energy required was assumed to be 0.5 kilowatt-hours per mile at the charging outlet This value reflects a mix of cars and light-duty trucks to electrify 20 percent of light-duty vehicular travel in 1980, 1990, 2000, and 2010 (Table 6.1). Vehicles were assumed to be distributed uniformly across the United States based on population. They were also assumed to travel an average of 10,000 miles per year. Electrical distribution system efficiency was assumed to be 90 percent.

Figure 7.1 Petroleum Use with Electric and Hybrid Vehicles in 2010 employment and payrolls would be insignificant, amounting to about a one-percent increase even in the extreme case of a complete shift to EHVs. Though some battery materials might be imported, their costs would be offset by savings on imported petroleum.

The widespread use of EHVs would considerably increase the demand for materials used in batteries. However, electrifying 20 percent of the personal cars in the United States by 2010 would probably create no serious shortages of materials. In the absence of interruptions of imports, the increase in the demand for battery materials caused by the production of EHVs is unlikely to precipitate price increases for these materials in the long run, except for lithium, cobalt, and nickel. Even then, increases are not expected to exceed 20 percent if suppliers are given sufficient lead time (perhaps ten years) to plan an orderly expansion of exploration activities and production facilities. Although the identified reserves of battery materials are no more abundant than those of petroleum for meeting world demand through 2010, new discoveries are likely to increase the identified reserves of battery materials as demand increases. Uncertainties are greatest for lithium, partly because it may also be in great demand for use in fusion power plants. However, alternative future batteries based on such abundant materials as sodium, sulfur, and chlorine could effectively eliminate problems of inadequate resources.

Owners of EHVs would have the advantage of a vehicle which does not depend on petroleum as a primary fuel. They would also have the convenience of at-home recharging. Their vehicles would operate more quietly and might be more reliable and maintainable than conventional vehicles. The primary disadvantage to the hybrid vehicle owner primarily would be higher purchase price, particularly in the near term. Overall life-cycle costs (at 1980 gasoline and electricity prices) would be higher in the near term, but might become 8 to 11 percent lower than those of conventional vehicles if advanced EHVs become available. Owners of electric vehicles would not only pay more, but would also be limited to ranges of less than 100-150 miles between recharges.

There are major uncertainties surrounding the future of EHVs. They include the extent to which expected improvements in battery technology can be realized, the actual level of market penetration that EHVs can achieve, the future growth and utilization of the electric utility industry, and the extent to which improvements in conventional vehicles reduce the potential advantages of EHVs.

7.2 ENERGY

The use of EHVs to electrify 20 percent of light-duty vehicular travel would result in a significant reduction in petroleum consumption. In the year 2010, automobile petroleum use would be cut by 16 to 20 percent, saving approximately 600,000 barrels of crude oil per day, or 4 percent of projected future national petroleum consumption. Even greater petroleum savings could be achieved if EHVs were selectively implemented in those regions which would use little or no petroleum to generate recharge energy. However, the national use of coal and nuclear fuels would be increased correspondingly as electric utilities generated recharge electricity during otherwise idle off-peak periods.

The fuel economy of future conventional vehicles and the fleet size determine vehicular petroleum consumption without EHVs. Fuel economy assumptions used in this report for passenger and light trucks range from 14.3 miles per gallon in 1980 to about 40 miles per gallon in 2010 (Table 7.1). Based on these assumptions, energy required from petroleum used directly as fuel in conventional automobiles would be approximately 14 quadrillion BTUS (quads) in 1980, 10 quads in 1990, 7.5 quads in 2000, and 6 quads in 2010 (equivalent to 6.6, 4.7, 3.5, and 2.8 million barrels of oil per day) . As these figures show, increases in fuel economy in the 1980-2010 time frame might reduce petroleum consumption of automobiles by more than 50 percent, even without the use of EHVs.

Based on the expected electricity and gasoline use for electric, hybrid, and comparably-constructed conventional cars, it is possible to determine the equivalent fuel economies for the simple case where all energy for vehicle operation is derived from either petroleum or coal (Table 7.2). In the case of petroleum, near-term electric and hybrid cars would provide from 6 to 20 percent less fuel economy than comparable conventional cars. However, advanced electrics and hybrids would provide a 4 to 18 percent improvement over conventional cars. In other words, if petroleum were the sole fuel used to power automobiles, only the advanced electric and hybrid cars would be more fuel-efficient than conventional vehicles, an advantage that could be eliminated if ICE vehicles attain fuel economy higher than assumed here.

In the case of coal, the equivalent fuel economies of electric and hybrid cars are quite high, largely because of the inefficiency of synthesizing gasoline from coal. In fact, both near-term and advanced EHVs would be more fuel-efficient than the assumed conventional vehicles. Near-term electrics and hybrids would provide the equivalent of a 33 to 75 percent increase in fuel economy, and advanced vehicles would provide an 80 to 105 percent advantage.

In practice, of course, neither coal nor oil alone would be used as energy sources for EHVs. Instead, electric utilities would use those fuels and facilities which are most cost-effective and available. In general, most recharge energy would come from a mix of coal, nuclear, and petroleum fuels which would vary from utility to utility, and from hour to hour during the day. If recharging occurred during otherwise idle, off-peak hours in 2010, for example, the use of oil in generating recharge electricity would drop to about 7 percent and coal would become

TABLE .1

FUEL ECONOMY OF FUTURE CARS AND LIGHT TRUCKS

Year	Assumed New Car Composite Fuel Economy, mpg	New Vehicle Urban Fuel Economy, mpg		Fleet Fuel Economy, mpg		Fleet Fuel Economy For Cars and ght Trucks, mpg
		Cars	Light Trucks	Cars	Light Trucks	
1980	21	18.3	13.9	14.8	12.6	14.3
1990	34	29.6	21.8	24.3	18.1	22.7
2000	45	39.2	26.1	35.0	22.3	31.2
2010	55	47.9	32.0	44.0	28.2	39.9

Source: General Research Corporation

Derivation: Assumptions were first made of new-car composite fuel economy for 1980-2000. These assumptions were based on the premise that new vehicles exceed CAFE standards in 1980 and will meet them in 1985. After 1985, composite fuel economy will improve at the rate of about 1 mpg per year. Urban new-car fuel economy was then derived by taking 87 percent of each composite mpg. Trucks were assumed to consume 50 percent more fuel than cars because of larger loads. Actual in-use fuel economy was assumed to be equal to urban fuel economy. Fleet averages assume a mix of old vehicles and new vehicles, thus resulting in fleet averages which are below the new-vehicle fuel economies. Assumed fleet sizes are given in Table 6.1.

TABLE 7.2

SUMMARY OF FUEL USE AND EQUIVALENT FUEL ECONOMY OF

ELECTRIC, HYBRID, AND CONVENTIONAL FOUR-PASSENGER SUBCOMPACT CARS

Vehicle	Basic Fuel Use: Electricity, kWh per mile	Basic Fuel Use: Gasoline, mpg	Equivalent Fuel Economy Resource Utilization, mpg[1]: Oil	Equivalent Fuel Economy Resource Utilization, mpg[1]: Coal
Electric				
Near-Term:				
Pb-acid	0.40	--	29.0	50.0
Ni-Fe	0.44	--	26.0	45.0
Ni-Zn	0.38	--	30.0	53.0
$Zn\text{-}Cl_2$	0.45	--	26.0	44.0
Advanced:				
$Zn\text{-}Cl_2$	0.31	--	37.0	64.0
Li-MS	0.30	--	38.0	67.0
Hybrid				
Near-Term:				
Pb-acid	0.38	31.0	31.0	53.0
Ni-Zn	0.37	34.0	33.0	58.0
Advanced:				
Li-MS	0.27	45.0	42.0	73.0
Conventional (ICE)[2]				
Near-Term	--	33.0	33.0	33.0
Advanced	--	35.6	35.6	35.6

Source: Tables 3.5, 3.7, 4.1, and 4.4 of this report.

Assumptions: See assumptions for each table listed above.

[1]Urban fuel economies are presented which are about 87 percent of composite fuel economy.

[2]Assumes that conventional vehicles are comparable to EHVs, i.e., same basic construction techniques and materials are used in all vehicles, with engine efficiencies of the 1980's.

the dominant fuel, providing nearly 65 percent of all recharge energy. Nuclear power would be used to satisfy approximately 25 percent of the load (Fig. 7.2).

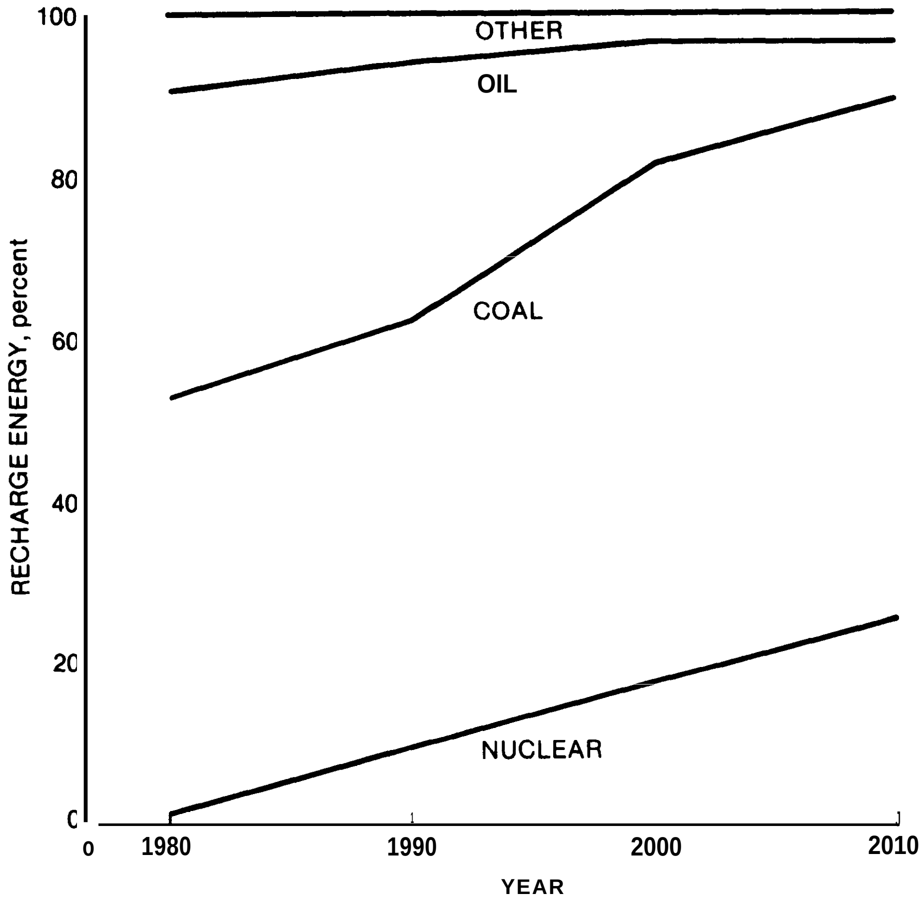
The fact that electrics do not use gasoline, hybrids use little gasoline, and electric recharge energy could be generated using little petroleum, provides the basis for estimating reduced petroleum consumption through the use of EHVs. If EHVs were used uniformly throughout the United States to electrify 20 percent of light-duty vehicular travel, petroleum used for automobiles would be reduced by 14 to 18 percent over the 1980-2010 time frame (Fig. 7.3).[1] However, if EHVs were selectively encouraged in those areas of the country where little or no petroleum would be required to generate recharge energy, a savings of up to 20 percent would result. The Mid-Atlantic, East Central, Southeast, Mid-America, and Mid-Continent regions would be best, but the Southwest and Texas regions also show some potential. The Northeast and West regions, due to their dominant use of oil-fired power plants, would be much less suitable on the whole. However, even in these areas, careful analysis of the particular fuel mixes used to generate power for selected cities could identify some with potential for saving petroleum. Other considerations such as air quality, terrain, weather, etc., would also enter into the selection of suitable areas for EHV use.

It would be possible to save even more petroleum if EHV market penetration were higher. At 80-percent electrification of light-duty vehicular travel, petroleum use by automobiles could be reduced by more than 70 percent in the year 2010. If EHVs were first utilized in selected regions, Up to 60 percent of light-duty vehicular travel could be electrified with virtually no use of petroleum for generating recharge energy by the year 2000, and up to 70 percent by the year 2010.

The impacts of 20-percent electrification of light-duty vehicular travel on overall national energy use would also be significant (Table 7.3): a reduction of 3.8 percent in 1990 or 2000 and 4.2 percent in 20100 Though these percentages are small, they represent significant absolute savings of petroleum, on 660,000 to 520,000 barrels per day. Although overall national energy use would increase between 1980 and 2010, and oil consumption would be reduced in the absence of EVHs because of other actions, EHV use would result in an even greater shift from petroleum to other sources of energy.

7*3 ENVIRONMENT

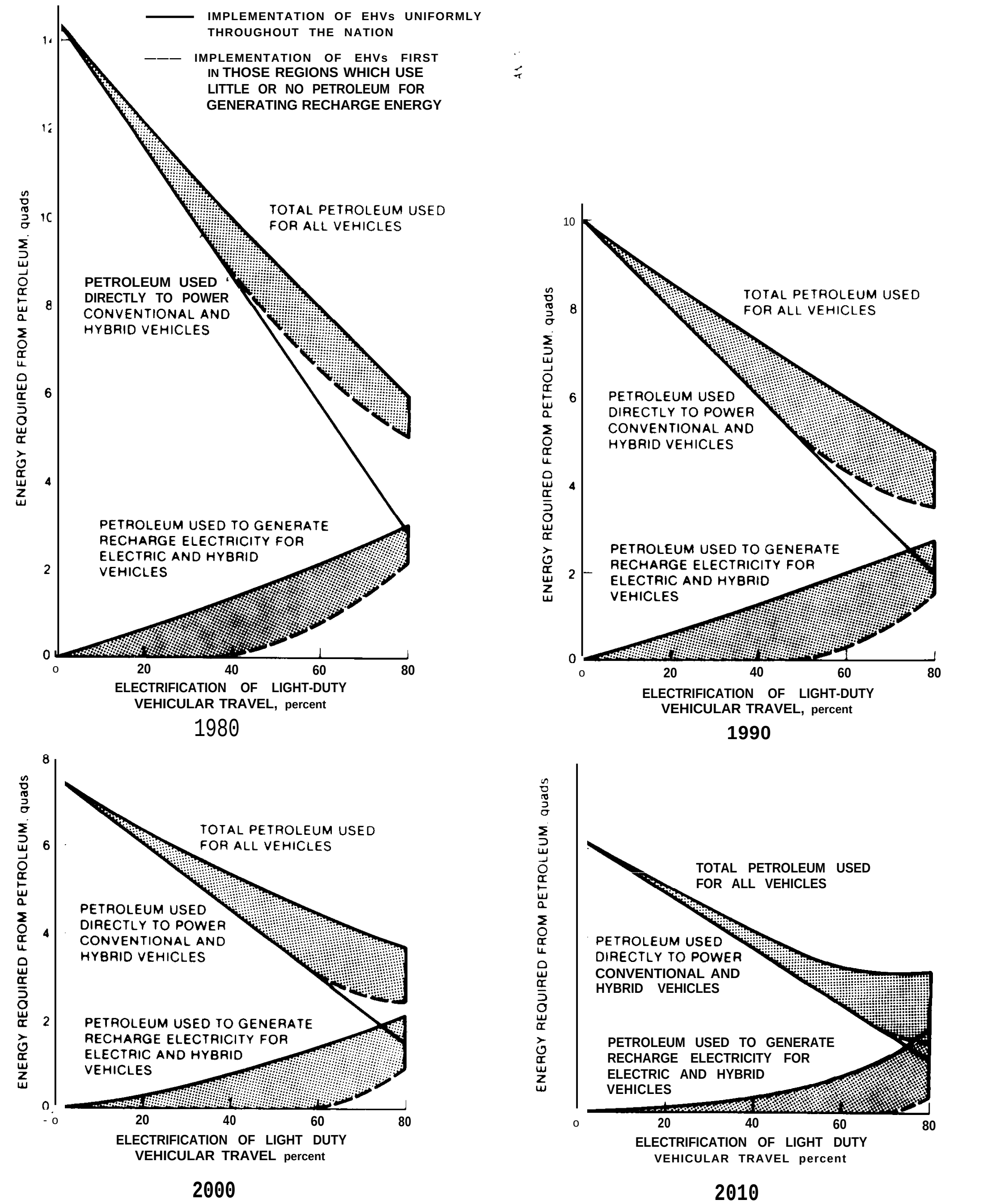
There would be little change in air pollution associated with 20-percent electrification of light-duty vehicular travel. Although the use of EHVs would result in a reduction in the amount of automobile emissions, there would be an increase in power plant emissions. The net effect would be only a slight improvement in overall national air quality. However, there would be larger regional variations that would



Source: Recharge Capacity Projection System (RECAPS), General Research Corporation

Assumptions: The RECAPS model schedules the use of nuclear, coal, and hydroelectric facilities before oil and gas facilities, and base-load facilities before intermediate and peaking facilities to minimize operating costs. Recharging is controlled to maximize the use of off-peak power available during late night and early morning hours when demand is lowest. The model makes use of capacity and demand projections developed by the electric utility companies in 1979. Energy required was assumed to be 0.5 kilowatt-hours per mile at the charging outlet This value reflects a mix of cars and light-duty trucks to electrify 20 percent of light-duty vehicular travel in 1980, 1990, 2000, and 2010 (Table 6.1). Vehicles were assumed to be distributed uniformly across the Unlited States based on population. They were also assumed to travel an average of 10,000 miles per year. Electrical distribution system efficiency was assumed to be 90 percent.

Figure 7.2 Projected Use of Fuel for 20 Percent Electrification of Light-Duty Vehicular Travel



Source: Recharge Capacity Projection System (RECAPS), General Research Corporation

Assumptions: The RECAPS model schedules the use of nuclear, coal, and hydroelectric facilities before 011 and gas facilities, and base-load facilities before intermediate and peaking facilities to minimize operating costs. Recharging is controlled to maximize the use of off-peak power available during late night and early morning hours when demand is lowest. The model makes use of capacity and demand projections developed by the electric utility companies in 1979. Energy required was assumed to be 0.5 kilowatt-hours Per mile at the charging Outlet This value reflects a mix of cars and light-duty trucks to electrify 20 Percent of light-duty vehicular travel in 1980, 1990, 2000, and 2010 (Table 6.1), Vehicles were assumed to be distributed uniformly across the Unlited States based on population. They were also assumed to travel an average of 10,000 miles per year. Electrical distribution system efficiency was assumed to be 90 percent. The results have been adjusted to account for power plant efficiency of 35 percent, refinery efficiency of 93 per. cent, and ancillary energy for oil recovery and transport of 34 percent

Figure 7.3 Petroleum Use by Electric, Hybrid, and Conventional Vehicles

TABLE 7.3

NATIONAL USE OF ENERGY WITHOUT AND WITH 20 PERCENT ELECTRIFICATION OF LIGHT-DUTY VEHICULAR TRAVEL, QUADRILLION BRITISH THERMAL UNITS PER YEAR

	1990			2000			0 0		
	Without	With	Percent Change	Without	With	Percent Change	Without	With	Percent Change
Nuclear	11	11.17	+ 1.6	17	17.35	+ 2.0	22	22.52	+ 2.4
Coal	28	29.01	+ 3.6	39	40.24	+ 3.2	49	50.30	+ 2.7
Oil	37	35.60	- 3.8	32	30.79	- 3.8	26	24.90	- 4.2
Other	26	26.11	+ 0.4	29	29.07	+ 0.3	32	32.07	+ 0.2
	102	101.89	- 0.1	117	117.45	+ 0.4	129	129.79	+ 0.6

Sources: The President's National Energv Plan. Vol. 1, 1979; and the Recharge Capacity Projection System (RECAPS , Genera Research Corporation

Assumptions: Total energy use projections without EHVs were derived from the President's National Energy Plan II submitted to Congress in the spring of 1979. These projections were selected because they assume "medium world oil prices" in 1980, and then a subsequent transition to "high world oil prices" by 2000, continuing to 2010. They also assume that various transitional and ultimate energy technologies will be developed, such as the use of direct petroleum substitutes, e.g., heavy oils, tar sands, synthetic liquids, and solar power.

provide an opportunity to encourage the use of EHVs selectively where they could have the greatest positive effect on air quality. The level of expected improvement in air quality would decline somewhat between 1980 and 2010 as conventional vehicles become cleaner, thus limiting the extent to which EHVs could improve future air quality.

Other environmental effects of EHV use are reduced urban traffic noise, effects on public health and safety (resulting primarily from the increased use of coal-fired and nuclear power plants) , thermal pollution from power plants, and reduced dumping of waste crankcase oil. The use of EHVs would reduce the urban traffic noise problem because these vehicles are inherently quieter to operate than conventional vehicles, particularly when compared to those with small, high-speed ICE engines or diesels. The other areas of concern would be little affected by 20-percent electrification of light-duty vehicular travel, but are mentioned here because they have been of recent public concern. Though their importance is difficult to estimate, especially in the case of risks from nuclear reactors, fuels, and wastes, all appear to be relatively minor considerations in relation to EHVs.

7.3.1 Air Quality

The amount of pollution produced by automobiles and electric utilities would change as a result of the widespread use of EHVs. Since EHVs do not emit pollutants when operating in the electric mode, except for small amounts of particulate due to tire wear, automobile emissions would be reduced in proportion to EHV miles driven. Power plant emissions, on the other hand, would increase to the extent that fossil fuels were used to generate the additional electricity needed for recharging. Analysis of the projected contributions of conventional automobiles and power plants to emissions between 1980 and 2010, in the absence of EHVs, shows the effect of the Clean Air Act of 1970 and its amendments (Table 7.4). Percent contributions of both automobiles and power plants are dropping. If the scheduled regulations are implemented and met in time, nearly 90 percent of all automobile emissions will be eliminated by 1985. Additional Clean Air Act requirements will also result in improved control of power plant emissions. These tend to limit the extent to which EHVs can improve overall national air quality, no matter how many are used to replace conventional vehicles. However, even at 20-percent electrification of light-duty vehicular travel, sufficient regional variation exists to warrant consideration of selectively encouraging EHV use in those areas where the greatest benefit could be achieved.

The regional variation in air quality resulting from the use of EHVs depends on the location of the power plants that serve the region, the fuels used to generate recharge electricity, the vehicle miles driven in electric mode, and to some extent, the characteristics of the region, including local emission regulations and vehicle mixes. For example, the population-weighted average of composite pollution indicators for the 24 largest air-quality control regions (AQCRs) in the

TABLE 7.4

PERCENT CONTRIBUTION OF AUTOS AND POWER PLANTS TO EMISSIONS

WITHOUT EHVs

Pollutant	Contribution of Vehicles, percent				Contribution of Power Plants, percent			
	1980	1990	2000	2010	1980	1990	2000	2010
Total Suspended Particulates	10	9	9	9	10	7	6	5
Sulfur Oxides	0	0	0	0	38	32	26	20
Nitrogen Oxides	20	14	14	14	23	21	20	19
Total Hydrocarbons	25	13	12	11	0	0	0	0
Carbon Monoxide	54	38	38	38	0	0	1	2

Source: Regional Emissions Projection System (REPS , General Research Corporation

Assumptions: Industrial growth projections were for 1977, and were obtained from the Department of Commerce OBERS model. Base year emissions data were for 1975, and were obtained from the National Emission Data System (NEDS . Electric utility growth projections were based on the Recharge Capacity Projection System (RECAPS) output generated both with and without EHV use. Emissions from facilities built after 1978 were assumed to be controlled to the level required by the new source performance standards proposed in or before 1978. Emissions from facilities built prior to 1978 were assumed to be controlled to the level defined in NEDS. These projections, therefore, do not fully reflect the effect of the 1977 Amendments to the Clean Air Act which require that states submit revised State Implementation Plans (SIPS) which assure that future air quality will satisfy the national primary standard. Analysis was based on the 24 most populated air quality control regions (AQCRs) in the United States. The results reflect population-weighted averages.

United States in 2000, given 20-percent electrification of light-duty vehicular travel, shows a 2.4 percent improvement (Table 7.5). However, two AQCRs--San Francisco and San Diego--would experience more than a 5-percent improvement in air quality, and another eight--Boston, Seattle, Denver, Los Angeles, Miami, Washington, D.C., Buffalo, and Dallas--would experience an improvement of more than 3 percent. On the other end of the spectrum, overall air quality would decrease if EHVs were used in Pittsburgh. This is because those power plants required to generate recharge energy are primarily located in the urban area itself. Furthermore, these plants are primarily coal-fired, thus increasing the urban sulfur-dioxide problem,

To set the impact of EHVs on air quality in perspective, it is first necessary to understand the expected trends of future air quality in the absence of EHVs (Fig. 7.4). In general, the main air pollution problems through the year 2010 are projected to be total hydrocarbons and total suspended particulate, which will increase 35 and 16 percent, respectively, Both are now, and will continue to be, significantly above the 1975 standard. On the other hand, new federal standards proposed in 1978 for sulfur oxides, nitrogen oxides, and carbon monoxide can be expected to control these pollutants. Although sulfur oxides and nitrogen oxides will increase 6 percent and 14 percent, respectively, they will continue to be below the standard. Carbon monoxide will be reduced by 44 percent, but will still be slightly above the standard. All these projections are based on 1978 state implementation plans (SIPS), and will change as these plans are updated and new regulations are promulgated.

The national impact on air quality of 20-percent electrification of light-duty vehicular travel will result in a rise in sulfur oxides and decreases in nitrogen oxides, total hydrocarbons, and carbon monoxide (Fig. 7.5). Total suspended particulate will be little affected. Sulfur oxides in 1980 would be increased by about 3.5 percent, but would decrease to less than one percent above the 2010 level over the next 30 years. Nitrogen oxides would be reduced by 1 to 2 percent over the 1980-2010 time frame. Total hydrocarbons would be reduced by 5 percent in 1980, but would be about 2 percent under expected baseline levels in 2010. Carbon monoxide initially would drop by 10 percent in 1980, but would stabilize at over 6 percent in 2010. This general trend of significant initial impact, tapering off to modest levels by 2010, is primarily due to the fact that federal standards for both conventional automobiles and power plants will tend to reduce the potential effect of EHVs on national air quality.

7.3.2 Urban Traffic Noise

The importance of noise pollution and its control have been recognized in recent years in legislation at all levels of government. In particular, the Federal Noise Control Act of 1973 established as a national policy the control of emissions of noise that are detrimental

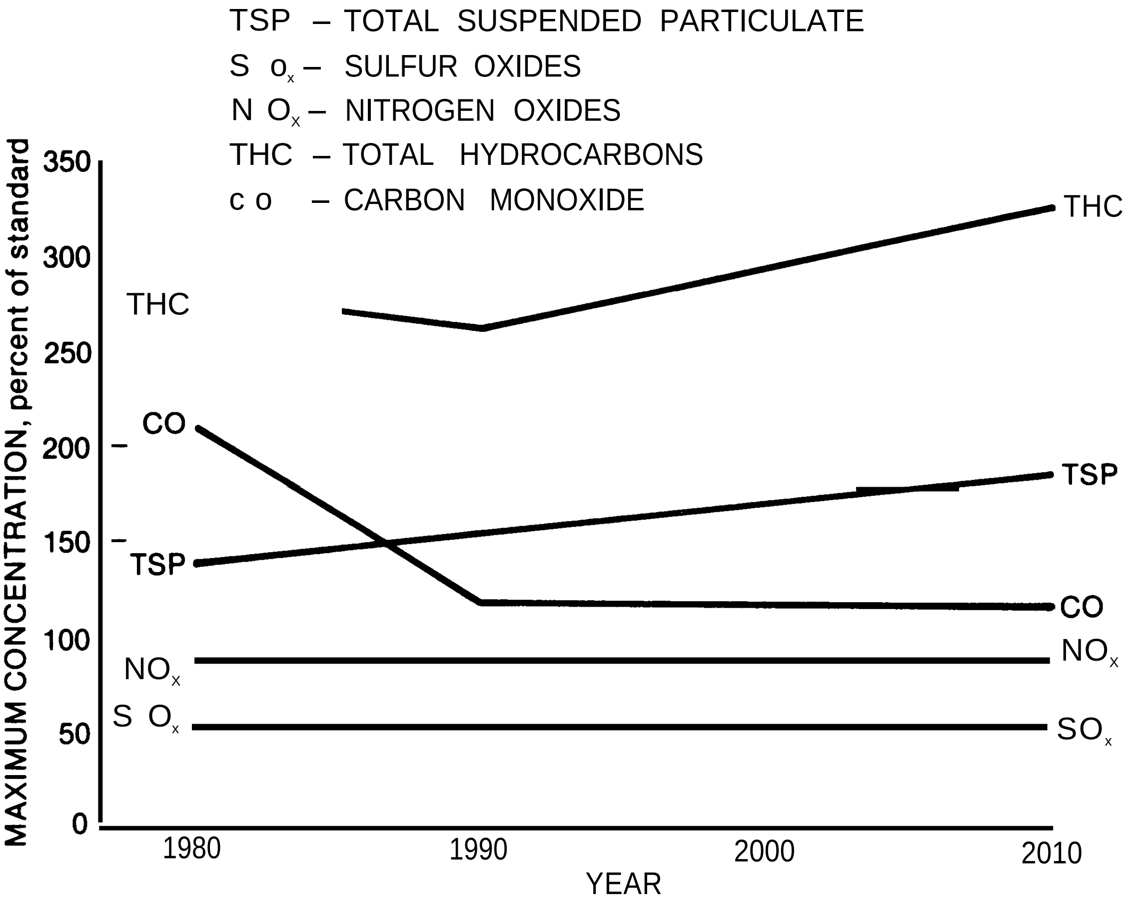
TABLE 7.5

CHANGE IN THE SEAS COMPOSITE POLLUTION INDICATOR
WITH 20 PERCENT ELECTRIFICATION OF LIGHT-DUTY VEHICULAR TRAVEL

Air Quality Control Region	Decrease in Pollution Indicator Resulting from Use of EHVs, percent 2000
San Francisco	5.5
San Diego	5.4
Boston	4.1
Seattle	3.8
Denver	3.5
Los Angeles	3.4
Miami	3.4
Washington, D.C.	3.2
Buffalo	3.1
Dallas	3.0
New York	2.7
Atlanta	2.5
Detroit	2.3
St. Louis	1.9
Philadelphia	1.8
Minneapolis-St. Paul	1.8
Baltimore	1.7
Chicago	1.6
Cleveland	1.6
Milwaukee	1.6
Kansas City	1.5
Houston	1.2
Cincinnati	0.9
Pittsburgh	-1.6
Population-Weighted Average	2.4

Source: Regional Emission Projection System (REPS), General Research Corporation; and Strategic Environmental Assessment System (SEAS), originally developed by several private corporations for EPA and now under the control of the Environment Division of DOE.

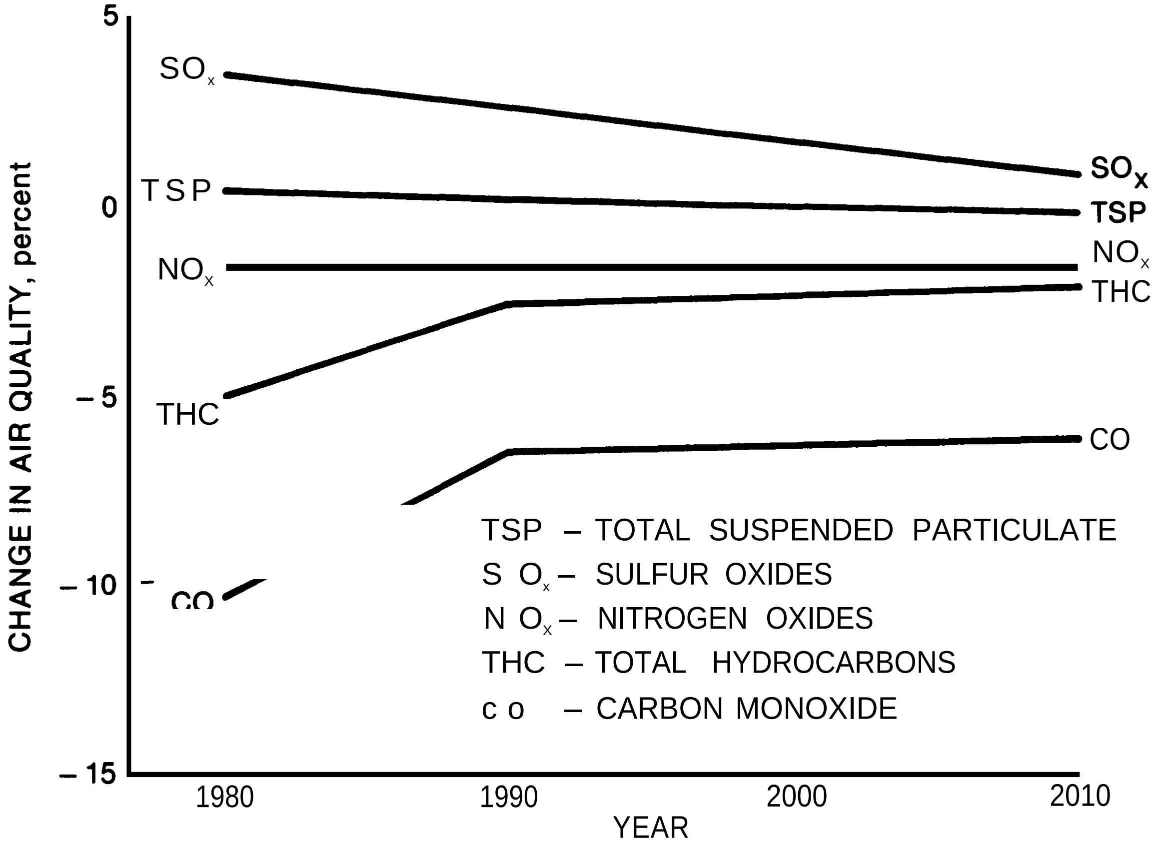
Assumptions: Industrial growth projections were for 1977, and were obtained from the Department of Commerce OBERS model. Base year emissions data were for 1975, and were obtained from the National Emission Data System (NEDS). Electric utility growth projections were based on the Recharge Capacity Projection System (RECAPS) output generated both with and without EHV use. Emission and air quality control levels were based on new source performance standards proposed in 1978. Emissions from facilities built prior to 1978 were assumed to be controlled to the level defined in NEDS. These projections, therefore, do not fully reflect the effect of the 1977 Amendments to the Clean Air Act which require that states submit revised State Implementation Plans (SIPS) which assure that future air quality will satisfy the national primary standard. Analysis was based on the 24 most populated air quality control regions (AQCRs) in the United States. The results reflect population-weighted averages. The specific pollution indicators were calculated using a formula developed for SEAS which weights each major pollutant type according to impact on human health to arrive at a single composite figure.



Source: Regional Emissions Projection System (REPS), General Research Corporation

Assumptions: Industrial growth projections were for 1977, and were obtained from the Department of Commerce OBERS model. Base year emissions data were for 1975, and were obtained from the National Emission Data System (NEDS). Electric utility growth projections were based on the Recharge Capacity Projection System (RECAPS) output generated both with and without EHV use. Emission and air quality control levels were based on new source performance standards proposed or promulgated in 1978. Analysis was based on the 24 most populated air quality control regions (AQCRs) in the United States. The results reflect population-weighted averages.

Figure 7.4 Air Quality Projections Without EHVs



Source: Regional Emissions Projection System (REPS), General Research Corporation

Assumptions: Industrial growth projections were for 1977, and were obtained from the Department of Commerce OBERS model. Base year emissions data were for 1975, and were obtained from the National Emission Data System (NEDS). Electric utility growth projections were based on the Recharge Capacity Projection System (RECAPS) output generated both with and without EHV use. Emission and air quality control levels were based on new source performance standards proposed or promulgated in 1978. Analysis was based on the 24 most populated air quality control regions (AQCRs) in the United States. The results reflect population-weighted averages.

Figure 7.5 Percent Change in Air Quality with 20 Percent Electrification of Light-Duty Vehicular Travel to the human environment, particularly those resulting from the use of transportation vehicles.[3] As a result, various regulations have been established to reduce truck, bus, and motorcycle noise (Table 7.6). Regulations have not yet been established for automobiles. Although automobiles account for more than 90 percent of all urban traffic, their contribution to total urban traffic noise in the mid-1970s was little more than half. Consequently, a reduction in automobile noise would have little noticeable impact unless also accompanied by a reduction in truck, bus, and motorcycle noise.

It is interesting to note that the recent trend toward smaller, more fuel-efficient vehicles may increase the contribution of automobiles to the overall noise problem. Automobiles powered by four-cylinder gasoline and diesel engines produce from 3 to 5 dB(A) more noise than conventional V-8 and six-cylinder engines.

Different levels of urban traffic noise affect different numbers of people (Table 7.7). It is estimated that nearly 95 million people are subjected to noise levels which begin to affect intelligibility of speech (55 dB day-night equivalent sound level) . Although only slightly more than one million people are subjected to relatively high noise levels (75 dB), the resulting impacts can be much worse, sometimes affecting human behavior. In fact, at sound levels above 85 dB, permanent hearing damage can occur if exposure is over a long period.

Electric propulsion of automobiles is inherently quiet. When operating in the electric mode, EHVs do not use an engine, radiator fan, air intake, or exhaust, all of which are major noise producers in a conventional car. The electric motor of the EHV is typically much quieter. A recent test by the Japanese government comparing electric and conventional economy cars found electrics to be 15-25 percent quieter when stopped, accelerating, and passing (Fig. 7.6).[5] Even when traveling at constant speed, the electrics were about 5 percent quieter.

Consequently, desirable reductions in traffic noise are likely with the widespread use of EHVs. Even though conventional cars may be made considerably quieter in the future, substitution of EHVs could reduce the future level of noise impact substantially (Fig. 7.7).[6] After current regulations have had their effects on truck, bus, and motorcycle noise, the overall noise impact would be reduced to 57 percent of the 1975 level, if conventional autos grow no noisier. EHV use could reduce urban traffic noise impact to as little as 27 percent of the 1975 level (at 100 percent EHV market penetration).

7.3.3 Health and Safety

Large-scale use of EHVs might affect public health and safety because of increased generation of electric power, modifications in vehicular design and capability, and changes in industrial working conditions, primarily in the battery manufacturing industry. However, the

TABLE 7.6

VEHICULAR NOISE LEVEL AND TRAFFIC MIX

Vehicle	Median Passby Noise Level at 50 feet. dB(A)[1] Present	After Regulation[2]	Percent of Urban Traffic
Heavy-Duty Trucks	85	71	1.0
Medium-Duty Trucks	77	71	6.0
Buses	79	75	0.5
Motorcycles	82	78	1.0
Automobiles	65	to be determined	91.5

Source: "Air Quality, Noise, and Health," Report of the Interagency Task Force on Motor Vehicle Goals Beyond 1980, US Department of Transportation, TAD-443.1, March 1976. Tables 6-5 and 6-6.

[1] Median automotive "passby noise" is expressed in terms of an A-weighted sound level (decibels), which ordinarily varies considerably with time, and is indicated directly by standard sound level meters. The A-weighting emphasizes sounds in the middle frequencies to which the human ear is most responsive. In quiet areas at quiet times of day, A-weighted sound levels may be as low as 30-40 dB A), while in very noise areas, they may exceed 1°° dB(A). The levels identified are composites which reflect the average level during cruise and acceleration conditions representative of urban driving.

[2] Levels expected by 1990.

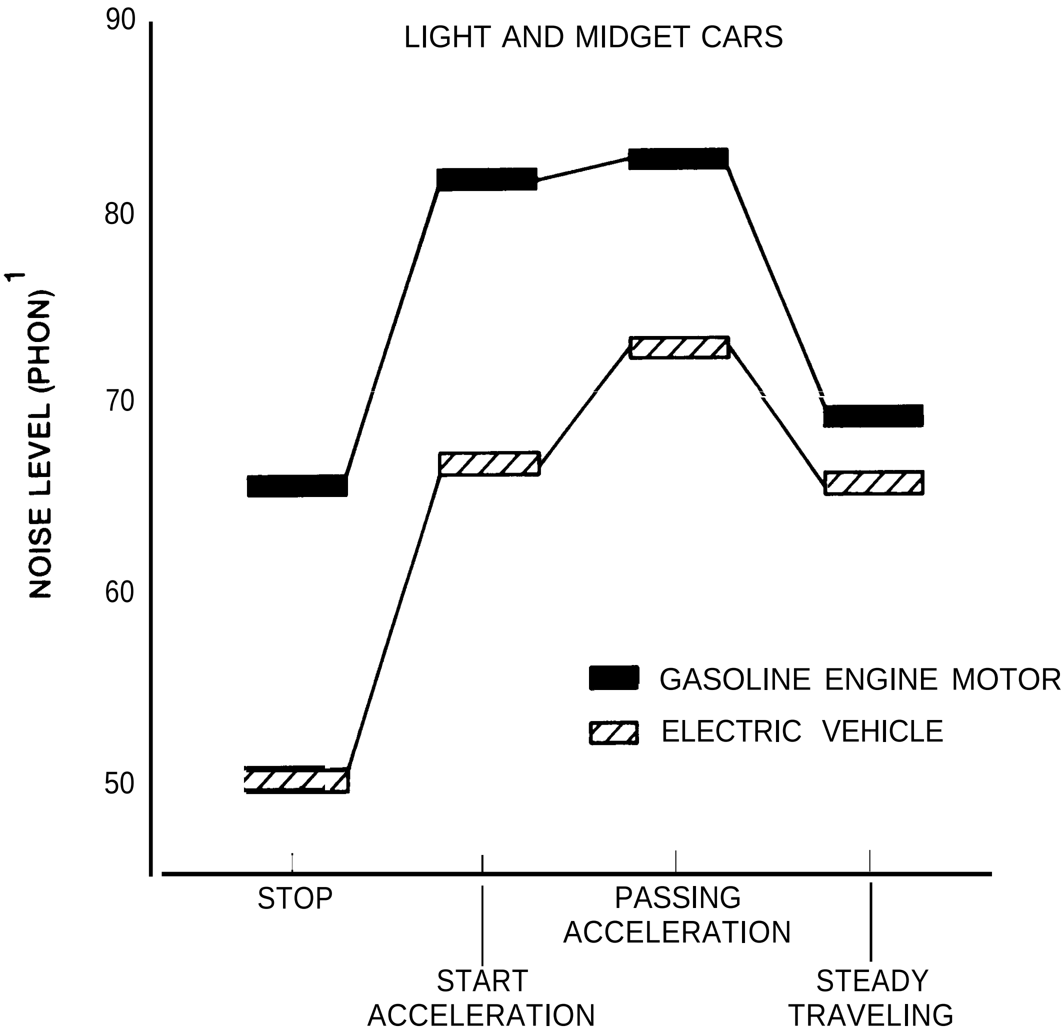
TABLE 7.7

ESTIMATED NUMBER OF PEOPLE SUBJECTED TO URBAN TRAFFIC NOISE

At or Above Outdoor Day–Night Equivalent Sound Level, (dB[1]	People, millions
55	93.4
60	5900
65	24.3
70	6.9
75	1.3

Source: "Air Quality, Noise, and Health," Report of a Panel of the Interagency Task Force on Motor Vehicle Goals Beyond 1980, US Department of Transportation TAD-443.1, March 1976. Table 6-4.

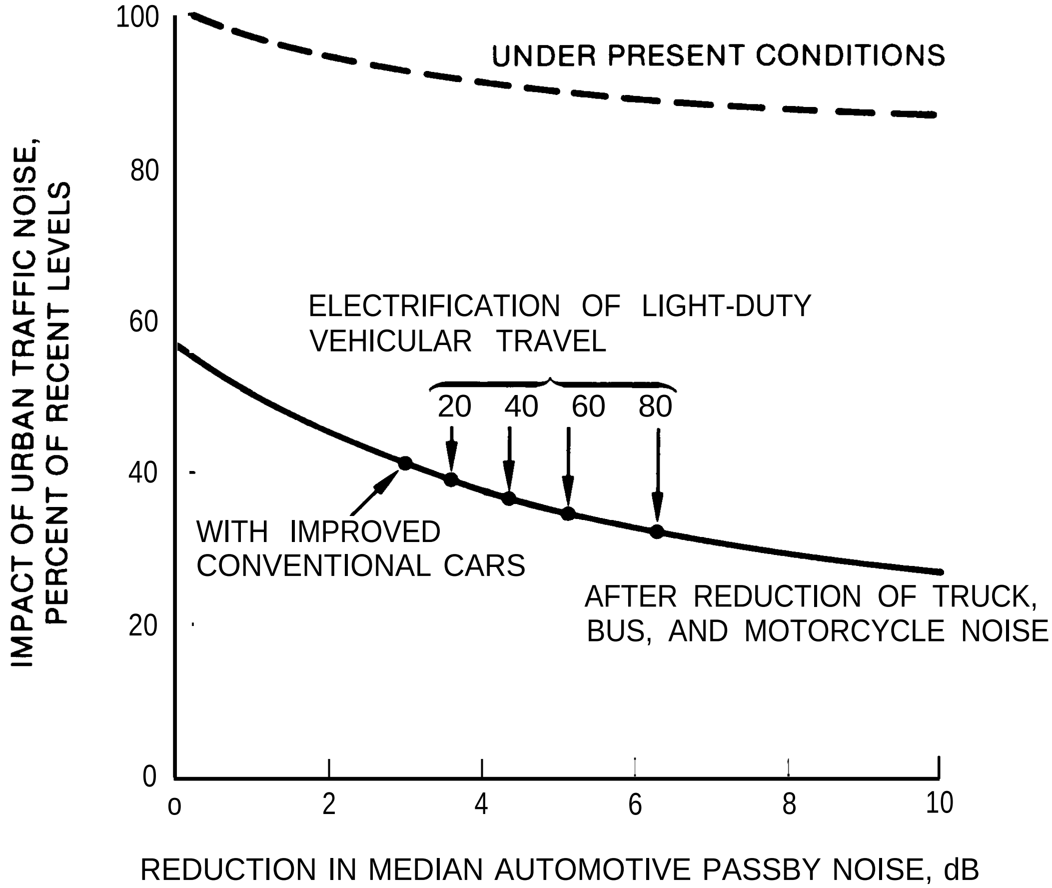
[1] The customary measure of the impact of urban traffic noise is computed from outdoor day-night equivalent sound levels. The computation combines the level of traffic noise with the number of people exposed at that level. It assumes that adverse effects of noise begin at a specific criterion, 55 dB, and that they reach a 100-percent level at 75 dB. At day-night equivalent sound levels of 55 dB outdoors, indoor levels may be near 45 dB, allowing 100 percent intelligibility for all types of speech. After a 20-dB increase above this level, intelligibility begins to drop very rapidly with further increases, supporting the assumption that few people would be adversely impacted at 55 dB, while at 75 dB, virtually everybody would be adversely affected.



Source: Research and Development of Electric Vehicles in Japan, Agency of Industrial Science and Technology, Ministry of International Trade & Industry and Society of Automotive Engineers of Japan, Inc. 1977.

[1] Noise levels are stated in phons, a unit of noise measurement which is technically different, but similar to, the dB(A) measure predominantly used in the us.

Figure 7.6 Measured Noise of Japanese Test Cars



Source: W. Hamilton, Electric Automobiles, McGraw-Hill Book Company, New York, 1979.

Assumptions: Noise standards for trucks, buses, and motorcycles are assumed to be in effect. Noise from sources other than transportation vehicles are assumed to remain constant. Data used to prepare this figure are for 1975. Improved conventional cars are expected to be about 3 dB quieter than present conventional cars. Electric cars are assumed to be 3.3 dB quieter than improved conventional cars.

Figure 7.7 Effects of Electric Cars on Urban Auto Noise and Traffic Noise Impact

impact is expected to be small at 20-percent electrification of light-duty vehicular travel.

The major factor to be considered is the effect of increased generation of electric power to recharge EHVs. If EHVs were recharged during off-peak hours, about 0.5 to 0.6 quadrillion additional BTUs would be required to electrify 20 percent of light-duty vehicular travel each year in the 1980-2010 time frame. However, since annual demand without EHVs is projected to increase over the same period, the contribution of EHVs to total electricity demand will decrease each year. In 1990, for example, the percentage of total demand attributed to EHVs would be 4.5 percent, but would drop to 2. 1 percent by 2010.

Although it is not expected that 20-percent electrification of light-duty vehicular travel would have much impact on public health and safety, expert opinion on the impact of any increase in power generation is divided, and much research in this area is currently being conducted. Consequently, a brief discussion of the major issues is presented here.

The detrimental effects of power plants on public health and safety have been repeatedly analyzed in recent years, largely because of the fierce public debate over the desirability of nuclear power.[7] The analyses show clearly that nuclear plants are not alone in presenting risks to health and safety; coal plants are also detrimental, primarily due to increased SO_x emissions (see Sec. 7.3.1).[8,9,10] While some parts of these analyses are relatively secure, other very important parts require assumptions which are little more than guesswork. It has therefore been impossible to determine conclusively whether nuclear plants are preferable to coal plants. It is clear, however, that use of EHVs would increase whatever the problems of nuclear and coal plants may be, even if only slightly.

Overall, there seems little question that by requiring added generation of electricity, EHVs could detract slightly from public health and safety. The effects, however, will surely be far less than proportionate to the extra electric energy required by EHVs. Since no additional facilities would be required, other than those already planned to satisfy normal future demand, EHVs need not cause an increase in the number of nuclear reactors subject to accidents. Moreover, where diversion of plutonium and sabotage of reactors are the serious risks, they may not be increased significantly by EHVs. If reactors are already numerous and shipments of nuclear materials among them are already frequent, additional shipments may have little practical consequence for would-be terrorists or saboteurs already presented with abundant opportunities for action.

Another detrimental impact of the generation of additional electric power using fossil fuels, primarily coal, is the creation of more acid rain. Large fossil fuel plants emit sulfur oxides and nitrogen oxides high into the atmosphere where they may be transported thousands of miles by prevailing winds. Such pollutants are often converted into sulfuric and nitric acids which eventually wash out in rain, sleet, hail, and snow. Although acid rain does not directly affect human health, it poses a real threat to both plants and wildlife which form the bulk of the eco-system. Many studies are currently being funded by the federal government to quantify the scope and severity of the acid rain problem, and to formulate effective ways to eliminate or reduce its impact. Although the technology needed to more strictly control power plant emissions currently exists, it is quite expensive, thus creating resistance by the electric utilities.

Crash safety of EHVs is currently in the early stages of research and development. However, it appears that structural design to accommodate a heavy set of batteries, as opposed to a fuel tank filled with gasoline, is well within current technology. In fact, batteries containing acids, chlorine, and other potentially hazardous chemicals may be less dangerous than a fuel tank filled with gasoline or diesel. This is often overlooked because gasoline is commonplace and accepted; but it is extremely flammable and can explode or burn upon impact. Since it is likely that EHVs will have to meet the same safety standards as conventional vehicles and will equal the lower-performance conventional vehicles in acceleration, their overall influence on the number and severity of auto accidents should be small. In fact, if lower-capability EHVs encourage more prudent driving, there may be positive benefits from their use. There are possibilities of electrical shock, explosive fires, or chemical and toxic gas hazards when operating and recharging EHVs, but these can be minimized through proper engineering and design.

Increased battery production using a variety of chemicals unfamiliar to the battery manufacturing industry could create new safety concerns. However, careful design and construction of new facilities and close monitoring by appropriate federal agencies should minimize the risks.

7.3.4 Thermal Pollution

EHVs would be about as efficient overall as conventional vehicles fueled from petroleum, if typical losses in electric utilities are included. They would thus have little effect on total energy used and eventually released as heat into the environment, In conventional vehicles, however, almost all this heat is evolved when and where the vehicles are driven. In EHVs, only about a third of the total heat would be released in this manner. The remainder would be evolved at a relatively few power plants during recharging, and concentrated releases of heat can potentially produce changes in local weather patterns. However, it is not expected that 20-percent electrification of light-duty vehicular travel would result in any significant impact on thermal pollution.

7. 3.5 Waste Oil

Lubricating oil in the crankcases of automotive engines is periodically drained and replaced with clean oil. The old oil is often collected and used for boiler fuel, for road oiling, for asphalt, and for other purposes. Nevertheless, substantial quantities of oil are more or less indiscriminately dumped into the environment,[14] particularly in rural areas where collection is presently unprofitable.

EHVs have no crankcases and require no periodic oil changes. To the extent that they were used, the problem of discarded oil from automobiles would be reduced. Overall, 20-percent electrification of light-duty vehicular travel in the United States would eliminate the use of about 130 million gallons of oil per year for automobile crankcase use. This amounts to almost 15 percent of all automotive demand for lubricating oils and 7 percent of all demand for lubricating oils.

7.4 ECONOMY

The substitution of electric and hybrid vehicles for conventional automobiles could affect the economy in several major ways. Purchase and operating costs affect consumers, changes in economic activity to manufacture, sell, and service automobiles affect employment, the expansion and retirement of various production facilities affect business capital investments, and changes in the importation of petroleum and battery materials affect the national balance of payments.

7.4.1 Consumers

Perhaps the most pervasive effect of EHVs in the near term would be the higher initial and life-cycle costs to motorists. Even with longer life and inexpensive electricity, near-term EHVs are still more expensive than conventional vehicles on a life-cycle cost basis at today’s gasoline prices. If consumers are forced to spend more on transportation, less of their disposable income is available for other purchases. This decrease in non-automotive expenditures would be felt throughout the economy. The higher cost of electric and hybrid vehicles might make their purchase less attractive to consumers. If the government wished to encourage electric or hybrid vehicle use, it might have to subsidize either the producers or the consumers, which would affect the national budget. In the future, an increase in gasoline price could bring the cost of EHV use more in line with the cost of using conventional vehicles, thereby negating these economic effects on consumers. Increases in battery life or decreases in battery price beyond those projected here are unlikely to reduce EHV costs by more than a small amount.

7.4.2 Capital Investment

Capital investment will be necessary to expand the production capacity to mine and process battery materials, to manufacture propulsion batteries, motors, controllers, and chargers, and to recycle battery materials. Little, if any, increase in investment for new electric utility capacity will be required, assuming overnight, off-peak recharging. Capital equipment associated with the manufacturing of internal combustion engines would be retired. However, the penetration of electric and hybrid vehicles will probably be accomplished over a period of years, during which portions of the aging capital equipment would be retired anyway. Major portions of the facilities and equipment used to produce conventional vehicles can be adapted for use in the product ion of electric and hybrid vehicles. The magnitude of capital investment and retirement has not been estimated,

7.4.3 Employment

The switch from conventional to electric and hybrid vehicles would alter the employment in those economic sectors involved in production, sales, and service. Overall, only 3.75 percent of US employment in 1974 was in potentially affected industries, with payrolls amounting to only 4.5 percent of the national total.

Major increases in employment will occur in industries associated with propulsion batteries, including the mining and processing of materials, the manufacturing and sale of the batteries themselves, and the recycling of the batteries to recover usable materials. Employment would also increase in sectors involved in the production and servicing of motors, controllers, and chargers. More people are involved in the distribution and sales of vehicles than are involved in their production. Distribution and sales of vehicles would continue with little change; therefore employment and payrolls in these sectors would be little effected.

Only some of the jobs pertaining to the manufacturing and servicing of internal combustion engines will be lost if hybrid vehicles replace conventional vehicles. Production workers will still be required to manufacture internal combustion engines and other vehicle parts, mechanics will still be required to service the ICE and other vehicle parts for which they have already been trained, and sane service station attendants will still be needed to pump gasoline. The level of ICE-related work would depend on hybrid vehicle design: hybrids most like ICE cars (high-performance hybrids) would lead to modest changes, whereas hybrids most like electric cars (range-extension hybrids) would lead to larger changes.

The maximum dislocation of jobs would occur if all conventional vehicles were replaced by electric vehicles, since all internal combustion engine production and service would disappear, gasoline production and sales would vastly decrease, and huge increases would occur in industries associated with propulsion batteries. If all vehicles were electric in the year 2000, over 800,000 jobs would be lost in ICE-related industries. Over half of these lost jobs would be from automotive service stations. Other sectors experiencing large employment losses include: automotive repair shops (-143,000), automotive supply stores (-107,000) , motor vehicle parts distribution (-84,000), and motor vehicle body and parts manufacturing (-54,000). However, job losses in these industries will be more than offset by employment gains in electrical equipment, mining, and battery manufacture, distribution, and sales. If all vehicles in the year 2000 contained lead-acid batteries, an estimated 850,000 new jobs would have been created; if lithium-metal sulfide batteries are used, newly created jobs would number over two million (Table 7.8). Although shifts between economic sectors occur, the overall change in employment and payrolls is insignificant, even in the extreme case of 100 percent electric vehicle penetration, amounting to about a one-percent increase (Tables 7.9 and 7.10).

7.4.4 Balance of Trade

One of the major goals of EHV use is the reduction of petroleum imports. Such a reduction would improve the nation's balance of trade. However, savings in petroleum imports will be offset to some extent by imports of battery materials.

Assuming the current percentage imports of battery materials and using their 1979 price, the cost of imported materials to electrify 20 percent of light-duty vehicular travel in the United States (25 percent of the US light-duty vehicle fleet) would be approximately 3.8 billion dollars if lead-acid batteries are used, or 20.3 billion dollars for nickel-zinc batteries (Table 7.11). Few or no imports would be required for lithium-metal sulfide batteries. These imports can be compared with a savings of about 220 million barrels of oil annually in 2000, which, at a nominal price of $30 per barrel for imported petroleum, yields a 6.6 billion dollar annual decrease in imports.[12]

Thus it appears that although initial requirements for battery material might add considerably to United States imports, their value would be recouped in a few years through reduced oil imports. There are many uncertainties, however, including the amount of imported petroleum used to generate electricity for recharging electric and hybrid vehicles, the extent to which increased demand for battery materials affect their price, and the extent to which additional demand beyond baseline projections for battery materials would be met by additional imports. The actions of cartels controlling petroleum, and perhaps some battery materials, are impossible to project.

The use of electric and hybrid vehicles is likely to improve the balance of payments in the future. By the year 2000, only a small percentage of fuel used to generate recharge electricity will be petroleum. In time, United States mining operations will be able to supply a greater percentage of battery materials, cutting down on imports if their prices have increased substantially. One of the major factors leading to a reduction in the balance of payments will be the development of efficient recycling which will develop once a significant

TABLE 7.8

IMPACTS OF 100 PERCENT USE OF ELECTRIC CARS ON EMPLOYMENT AND PAYROLL, BY INDUSTRY

Standard Industrial Classification	Industry	Employment Change, thousands			Payroll Change, millions Of 1977 dOllars		
		1980	1990	2000	1980	1990	2000
(independent of battery type)							
3592	Carburetor, piston, valve manufacturing	-24	-31	-37	-345	-450	-554
3622	Electric controls manufacturing	33	38	41	425	497	459
3694	ICE electric equipment manufacturing	15	14	11	425	230	187
3711,3714	Motor vehicle body and parts manufacturing	-56	-57	-54	-1000	-1173	1227
5012	Motor vehicle parts distribution	-57	-55	-84	-854	-819	-1360
5171,5172	Petroleum wholesalers	-35	-22	-28	-505	-339	-455
5531	Automotive supply stores	-67	-87	-107	-640	-858	-1075
5541	Automotive service stations	-293	-350	-410	-1741	-2112	-2499
7538,7539	Automotive repair shops	-93	-118	-143	-757	-948	-1141
	SUBTOTAL	-576	-667	-810	-5191	-5972	-7665
(-lead-acid batteries)							
1031,3332	Lead and zinc mining, smelting	73	86	107	994	1,254	1,665
3691	Storage battery manufacturing	196	214	224	2,648	2,985	3,212
	Battery distribution and sales	432	454	&67	5,753	6.536	7,099
	SUBTOTAL	701	754	798	9,395	10,775	11,976
(nickel-zfnc batteries)							
1031,3332	Lead and zinc mining and smelting	55	60	57	744	868	892
	Nickel and cobalt mining	43	37	35	796	915	1,332
3691	Storage battery manufacturing	518	587	622	6,996	8,197	8,903
	Battery distribution and sales	l,084	1,140	1,172	14,438	16,404	17,818
	SUBTOTAL	1,700	1,823	1,887	22,973	26,384	28,946
(lithium-sulfur batteries)							
	Nickel and cobalt mining			11			408
.	Lithium mining			27			863
	Molybdenum mining			12			402
3691	Storage battery manufacturing			699			10,005
	Battery distribution and sales			1,317			20,010
	SUBTOTAL			2,066			31,694

Baseline projections made by least-squares regression analysis of historical data published in County Business Patterns. Adjustments were made to the portion of activity estimated to be affected by electric vehicle production and use.

TABLE 7.9

IMPACTS OF 100 PERCENT USE OF ELECTRIC CARS ON TOTAL EMPLOYMENT IN INDUSTRIES DIRECTLY AFFECTED

Type of Battery Used In Electric Cars	Employment Change in Affected Industries: Thousands 1980	Thousands 1990	Thousands 2000	Percent US Employment 1980	Percent US Employment 1990	Percent US Employment 2000
Lead-Acid	126	87	-12	0.14	0.09	-0.01
Nickel-Zinc	1124	1156	1077	1.27	1.19	1.02
Lithium-Metal Sulfide	1287	1319	1255	1.45	1.36	1.19

TABLE 7.10

IMPACTS OF 100 PERCENT USE OF ELECTRIC CARS ON TOTAL PAYROLL IN INDUSTRIES DIRECTLY AFFECTED

Type of Battery Used In Electric Cars	Payroll Change in Affected Industries: Millions of 1977 Dollars 1980	Millions of 1977 Dollars 1990	Millions of 1977 Dollars 2000	Percent US Payroll 1980	Percent US Payroll 1990	Percent US Payroll 2000
Lead-Acid	4204	4803	4311	0.28	0.23	0.14
Nickel-Zinc	17782	20412	21281	1.19	0.97	0.70
Lithium-Metal Sulfide	19949	22813	24029	1.33	1.09	0.79

Basline projections made by least-squares regression analysis of historical employment and payroll data published in County Business Patterns. Adjustments were made to the portion of activity estimated to be affected by electric vehicle production and use.

TABLE 7.11

NOMINAL CUMULATIVE COST OF IMPORTED MATERIALS TO ELECTRIFY 20 PERCENT OF LIGHT-DUTY VEHICULAR TRAVEL IN THE UNITED STATES

Battery	Material Requirement, lb X 10^6	Percent Imported*	1979 Price per Pound†	Cost of Imports, billions of dollars
Lead-Acid:				
Lead	35.0	30	0.36	3.8
Nickel-Zinc:				
Nickel	1000	50	2.24	11.2
Zinc	6.0	50	0.20	0.6
Cobalt	0.5	100	16.95	8.5

*Current percent imported in absence of EHVs

†Source: L. G. Hill, The Impact of EHVs on Factor Prices and the Balance of Trade, Discussion Draft 16, Argonne National Laboratory, Illinois, October 1979.

level of EHV penetration is reached. Recycling will substantially reduce the demand for new battery materials.

7.5 RESOURCES

7.5,1 Imports of Battery Materials

The United States currently imports nearly all the cobalt, graphite, and aluminum ore and over half of its nickel. IQ Dependence on foreign sources for supplies of battery materials involves significant political considerations, especially if the reserves are concentrated in one or a few locations. The political stability of exporting countries affects the reliability of continued supply. Concentration of resources opens the possibility of market control in the form of monopolies or cartels which could manipulate the price and availability of materials required for batteries, A nickel cartel could be as damaging to an electric vehicle industry based on nickel-zinc batteries as the OPEC oil cartel is to the present auto transportation system. Fortunately, most battery materials are imported from Western-aligned nations, the major exception being cobalt, the majority of which is imported from Zaire and other politically unstable African countries (Table 7.12) .

Of all the battery materials considered in this report, the United States is self-sufficient in or imports only snail quantities of boron,

TABLE 7.12

LOCATION OF BATTERY MATERIAL RESERVES AND RESOURCES

Material/Location	Percent of World Reserves	Percent of World Resources
Aluminum		
Australia	26	21
Guinea	26	17
Brazil	16	17
Jamaica	6	4
Greece	4	3
Cameroon	4	5
Boron		
United States	25	
USSR	25	
Turkey	25	
China	13	
Argentina	6	
Chile	6	
Chlorine		
United States		
Many Others		
Cobalt		
Zaire	28	31
Oceania	27	36
Zambia	14	14
Cuba	14	43
Canada	7	10
United States	--	31
Copper		
United States	20	20
Chile	20	11
USSR	9	6
Canada	9	8
Asia	7	10
Sea Nodules	- -	20
Graphite		
Mexico		
Malagasy Republic		
Sri Lanka		
United States		
Iron		
USSR	31	27
Brazil	17	13
Canada	12	13
Australia	10	9
India	6	4
United States	4	8
Lead		
United States	36	36
Canada	12	12
USSR	18	11
Australia	18	9
Lithium		
United States	44	44
USSR	27	19
Canada	13	14
Africa	13	10
Nickel		
New Caledonia	44	22
Canada	16	15
USSR	10	8
Australia	9	6
Indonesia	8	5
Cuba	6	16
Phillipines	2	6
United States	0.003	12
Sulfur		
Asia/Near East	30	17
Canada	21	28
United States	12	12
USSR	8	11
Spain	1	9
Zinc		
Canada	23	20
United States	20	19
Australia	12	13
USSR	8	9
Ireland	5	4

Source: US Bureau of Mines, Mineral Facts and Problems, 1975 Edition, us Government Printing Office, Washington, D.C. 1976.

chlorine, copper, lithium, and sulfur. Therefore, no problems in obtaining these materials are foreseen for the electric vehicle industry, although significant expansion of US lithium production will be required. While the United States has large resources of most battery materials, in the short run at least, it will continue to rely on foreign sources to supply battery materials. One reason for continued importation of these materials is that they can be obtained at less cost from countries where labor is less expensive than in the United States. Another reason is that higher-grade ores can be found outside the United States. In the cases of aluminum, graphite, and nickel, new technologies would need to be developed before deposits in the United States could be economically utilized. If the United States attempted self-sufficiency, costs would most likely increase significantly because of the use of more expensive labor, the development of new technologies, and the capital cost involved in expanding domestic industries.

Lead-Acid Batteries. The primary materials required for the production of lead-acid batteries are lead and sulfur. The United States now produces most of the sulfur needed domestically. Environmental restrictions will enforce a substantial production of sulfur recovered from petroleum refining, coal combustion, and other sources, so the supply of sulfur for use in batteries should be plentiful.

The United States produces about two-thirds of the lead needed to satisfy domestic primary demand (for new rather than recycled material) , but substantial increases in mining and smelting capacity would be required to continue supplying this percentage of projected primary demand if mass production of lead-acid propulsion batteries occurs.[14] Therefore, demand for lead by battery manufacturers would probably precipitate an increase in lead imports, at least in the short run, until recycling reduces the primary demand for lead for EHV batteries.

Nickel-Iron and Nickel-Zinc Batteries. The nickel-iron battery requires principally nickel and iron, plus smaller amounts of cobalt (used in the nickel electrodes), copper, lithium, and potassium. Nickel-zinc batteries require the same materials except for the substitution of zinc for iron. Nickel, cobalt, and some of the iron or zinc will be imported for these batteries.

Domestic primary production supplies only about 10 percent of the demand for nickel in the United States, with scrap accounting for another 20 to 30 percent.[13] over half of the nickel supply is imported, mainly from Canada. The potential supply of nickel from domestic sources is high, but production will require marked improvement over current technology for extracting nickel from low-grade ores. Deep sea mining is another possible source.

Nearly all of the cobalt used in the United States is imported, about 75 percent from Zaire. The political instability of nations in this area has recently caused interruptions in production. There is also evidence of the existence of a cobalt cartel, which could control cobalt prices and supplies.[15] Expansion of United States cobalt production is predicted, especially if nickel production is increased, since cobalt is a by-product of nickel mining, or if deep sea mining is implemented.

Approximately one-third of iron ore required by the United States iron and steel industries is imported. The price and availability of foreign ores may be influenced by organizations of producers. The USSR has the world's largest reserves and resources of iron ore, but it is also abundant in the western world.

In the recent past, the United States has imported one-third to one-half of its zinc requirements, principally from Canada. Zinc demand for battery materials could be met with existing reserves, but significant expansion of smelting capacity would be required.

Zinc-Chlorine Batteries. In addition to zinc, which is discussed above, the primary materials needed for the zinc-chlorine battery are chlorine and graphite. Chlorine can be readily supplied domestically, but the United States' demand for graphite is almost entirely fulfilled by imports from Mexico, Sri Lanka, and the Malagasy Republic.[13] The United States could increase its output of graphite, but at some expense to reactivate domestic sources. Graphite can be manufactured, but with present technologies the product is not suitable for all uses. Grades of graphite differ considerably, so some level of graphite importation will probably continue.

Lithium-Metal Sulfide Batteries. Aluminum, boron, chlorine, copper, iron, lithium, potassium, and sulfur are used in lithium-metal sulfide batteries. All the materials can be supplied domestically except some of the iron and aluminum. The United States imports about 90 percent of the raw materials (buaxite and alumina) required to produce aluminum. Principal exporting countries are Australia and Jamaica. Battery requirements for aluminum are a very small portion of total United States demand, so EHV production will not significantly affect aluminum imports. The United States has large deposits of lithium, most of which are undeveloped because of low demand. However, the amount of lithium needed for lithium-metal sulfide batteries will require extensive development of these resources.

7.5.2 Battery Materials Versus Petroleum

All natural resources exist in finite amounts. Increased demand for battery materials would spur exploration for new deposits, but the amount of material in these deposits is unknown. Ultimately, battery materials may not be any more plentiful than petroleum if the world switches to electric and hybrid vehicles. However, there is a major difference between the use of gasoline and the use of batteries for transportation propulsion: gasoline burns and is gone, requiring continual new supplies; battery materials can be recycled, and therefore new materials would be needed only to enlarge the fleet and to replace small amounts lost in recycling.

The United States probably has enough resources to be self-sufficient in the supply of most materials for batteries. However, self-sufficiency would involve considerable (presently unquantifiable) expenditures on the development of new technologies to process low-grade ores (especially in the cases of nickel and cobalt for nickel-iron and nickel-zinc batteries and graphite for zinc-chloride batteries) and on exploration and capital equipment to mine and process new resources. Such expenditures would probably be unwarranted if exporting countries maintain stable governments and good trade relations with the United States continue. The probability of continuing supplies from exporting countries is high, and the likelihood of cartel actions is low, except perhaps in the case of cobalt.

7.5.3 Effect on Prices of Battery Materials

Historically, real prices of most minerals and metals have not increased; that is, their cost trends have been stable or downward relative to the costs of other goods and services. The sharp rise in the cost of energy and the expense of pollution control in the 1970s have caused the cost of materials to rise recently. Continued exploration for new deposits and improved technologies for processing lower-grade deposits offset the depletion of known reserves, thereby mitigating price increases which could arise from the scarcity of materials, although materials from lower-grade deposits may be more expensive.

A recent study by Charles River Associates[15] has concluded that estimated reserves of battery materials are sufficient to satisfy the cumulative demand for these materials, even with widespread use of EHVs, so that major price increases are not expected to occur, except in the cases of lithium, nickel, and cobalt.

High levels of EHV production would create heavy demands for lithium (if lithium-metal sulfide batteries are produced), or for nickel and cobalt (if nickel-iron or nickel-zinc batteries are produced), which could exert significant upward pressure on the long-run price trends for these materials. Price effects have not been quantitatively estimated, but if producers were given sufficient lead time* to increase explora-

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* "Sufficient lead time" is very difficult to quantify. If production requires only the reopening of mines which have been shut down, sufficient lead time might be a year. If exploration and the erection of mining and processing equipment are required, five years might be a minimum time before production begins. If new technologies must be developed (as would be the case if domestic nickel, graphite, and aluminum ore deposits were to be exploited), the lead time required might be ten years or more. Another, perhaps more critical, consideration exists. Private firms will not begin to develop new sources until the increased demand has raised prices to the point where they can expect a reasonable return on investment.

tion and production capacity, the long-run price increases seem unlikely to exceed 10 to 20 percent. However, extremely rapid increases in production of lithium, nickel, or cobalt, without time to plan an orderly expansion, could result in a doubling or more of prices for these materials.[15]

These predictions of price trends assume continued availability of imports. A disruption of the world market for these materials, either because of political upheaval in exporting countries or the formation of cartels, could result in price fluctuations which are impossible to predict.

7.5.4 Competing Demands for Battery Materials

Massive demands for battery materials for EHVs could drive up costs and reduce supplies of materials for other applications. The relative demand for materials for EHV batteries and other uses are discussed in Sec. 5.4.3.

The principal uses for lead have been in transportation, mostly in storage batteries for starting, lighting, and ignition; in anti-knock compounds added to gasoline (which is being phased out); and as sheathing for electrical cable. Lead is also used in paints, ammunition, and construction.

Nickel is widely used to make alloys which are strong, corrosion-resistant, and useful over a wide temperature range. Such materials are of strategic importance, used in aircraft, ships, motor vehicles, and electrical machinery. The chemical and petroleum industries are the principal end users of nickel, chiefly in the form of alloys. Substitutes for nickel exist for almost all its uses, but they are generally more expensive and less effective.

Zinc is third among non-ferrous metals in terms of world consumption, following only copper and aluminum. It is used for alloying, protective coatings (galvanizing) , and in making rubber and paints. Principal uses for cobalt are in heat-, abrasion-, and corrosion-resistant' materials, high-strength materials, and permanent magnets. Cobalt is used in permanent magnets, aircraft and surface vehicle engines, machine tools, construction and mining, and paints and chemicals.

The largest uses of graphite are for foundry facings to provide for clean and easy recovery of metal castings, and for raising the carbon content of steel. Graphite is also used in heat-resistant, non-metallic ceramic materials, and lubricants and packings. It may also find increasing use in graphite-reinforced plastics. The best-known uses of graphite, in pencils and in brake and clutch linings, account for only about 9 percent of the demand for graphite.

Lithium compounds are used in the electrolyte of cells for producing aluminum and in ceramics, glass, and lubricants. Lithium metal, which accounts for only a small portion of current lithium demand, is used for the manufacture of synthetic rubber, Vitamin A, and anodes for premium primary batteries offering very high energy density and long shelf life. Though the demand for lithium is presently very small, rapid growth in demand is projected, though there is uncertainty about the amount. The generation of power through nuclear fusion, if commercially successful, could require amounts of lithium close to today's total identified resources, and substitution of other materials for this purpose is unlikely.

7.6 TRANSPORTATION

EHVs can satisfy nearly all normal driving needs of the general public, particularly in urban areas where travel distances and average speeds are moderate. Motorists who purchase and utilize EHVs will experience both advantages and disadvantages compared to owners of conventional vehicles. In general, EHVs will provide owners with the convenience of recharging at home using an assured electrical power supply. They will also be quieter to operate and may be more reliable and maintainable. The primary disadvantages will be that initial costs will be higher and life-cycle costs will be greater, at least until advanced batteries become commercially available by 2000 or until real prices of motor fuels rise substantially. Electrics, unlike hybrids, will also have less range than conventional vehicles.

Most EHV owners who live in single-family residences would be able to obtain electrical outlets for recharging at overnight parking places. These people would thus enjoy the convenience of at-home recharging instead of waiting in lines at service stations if the availability of gasoline again becomes critical. This is extremely important because the recent gasoline supply interruptions have clearly demonstrated that motorists place a high premium on minimizing the necessity of waiting in service station lines. Although hybrid vehicles will occasionally require gasoline, the vehicle's range in electric mode will provide the motorist with mobility in the total absence of gasoline, and with the opportunity to be quite selective in determining the best time to refuel.

Since EHVs are substantially quieter and more vibration-free than conventional vehicles, motorists will experience a somewhat smoother, more silent ride. In addition, the inherent reliability of electric motors and controllers in comparison to internal combustion engines may provide EHV owners with relief from many service and reliability problems. Recent figures for on-the-road failures of automobiles corroborate this expectation (Table 7.13). Nearly 85 percent of all on-the-road failures can be attributed to the internal combustion engine system.

TABLE 7.13

ON-THE-ROAD FAILURES OF AUTOMOBILES

Cause of Failure	Frequency, percent
Engine	8.6
Fuel System	13.6
Cooling System	27.3
Ignition System	18.2
Starting/Charging System	16.4
Total - Engine Systems	84.1
Transmission	5.7
Driveline	1.7
Brakes	1.2
Suspension	1.4
Electrical System	3.5
Other	2.4
Total - Remainder of Car	15.9

Source: William Hatch et al., Analysis of On-Road Failure Data, US Department of Transportation, DOT-HS-802 360, May 1977.

Battery reliability is also a legitimate concern because, until now, the industry has concentrated primarily on the production of lead-acid batteries used to start internal combustion engines. The widespread use of EHVs will require the production of a variety of new types of propulsion batteries which will experience greater loads under more severe conditions. Since the reliability of these new batteries has not yet been established, some concern is warranted. However, careful design, engineering, and production of batteries could result in total EHV systems that are more reliable than comparable conventional vehicles.

Other types of service and repair of components other than the electrical system and ICE should be similar for EHVs and conventional vehicles.

Hybrid systems may not be quite as reliable as electrics because they are more complex. However, this depends largely on the particular design selected for the vehicle. In the case of a simple range-extension hybrid, reliability may be comparable to that of an electric. In more complex designs, it may be lower. In either case, however, actual availability of the vehicle for driving may be greater than that of an electric because of the possibility of operating in either of two different modes if one fails. If the ICE fails, operation can continue in the electric mode. If the electric propulsion system fails, the ICE system can be used to power the vehicle. Only in those cases where both systems fail or the failure of one system precludes the operation of the other would the vehicle be totally disabled.

Both electric and hybrid vehicles may also be more maintainable than comparable conventional vehicles. A recent study of parts sales and labor requirements for repair and maintenance of conventional cars revealed that 72 percent of labor hours and 62 percent of parts sales were required for the engine and its fuel, ignition, cooling, and exhaust systems, none of which are present in an electric car.[6] Although conventional car maintainability is expected to continue to improve, current estimates indicate that maintenance cost per mile for electric vehicles may be some 60 percent less than for conventional vehicles. This is partly because electric motors are extremely reliable, and normally require very little maintenance. Periodic brush replacement is generally all that is required, and this is only done every year or two. Electronic components such as choppers and chargers are constructed in a modular fashion and are normally replaced as whole units, often at higher cost.

The only other major electrical component is the propulsion battery pack. In an EHV powered by a lead-acid battery system, the sheer number of cells needed greatly increases the chances of experiencing at least one cell failure within the system, given current battery technology. This is critical because loss of one or more cells can severely affect battery performance and corresponding effective battery range. This potential problem is further compounded in advanced battery systems, such as zinc-chlorine and lithium-metal sulfide which are not modular, but simply consist of a “black box.” Repair in these cases, unlike a lead-acid battery, requires more than the simple replacement of a Particular defective cell or module; instead, the entire system, in some cases, must be removed and disassembled to effect the repair. To what extent improved technology can eliminate or reduce these potential reliability problems is unclear.

Although hybrid vehicles utilize an ICE in addition to the electric system, the ICE is used for as little as 20 percent of total annual vehicle mileage. As a result, hybrid maintenance costs should be substantially less than for a conventional vehicle, but greater than for an electric. This is because most failures are a function of miles driven and conditions under which driving occurs. Cold-start driving and short trips, as well as stop-start driving, are particularly hard on a conventional vehicle; they present little or no problem for range-extension hybrids, but may raise significant problems for high-performance hybrids.

The major disadvantage of EHVs that motorists would incur is high initial cost (Table 7.14). It is estimated that near-term EHVs may range from 60 to 80 percent higher in initial cost than conventional vehicles. In the case of advanced vehicles, EHVs may range from 20 to 40 percent higher on a first-cost basis. This is important because potential buyers tend to place a high premium on dollars invested initially in comparison to savings over the vehicle's life cycle. Unfortunately, higher initial cost is inherent in EHVs because batteries are more expensive than gasoline stored in a tank, and heavy batteries require a heavier, more expensive vehicle structure.

Overall life-cycle costs in general will also be higher, at least in the case of near-term vehicles (Table 7.14). Given current electricity and gasoline prices, near-term EHVs would range from 3 to 20 percent higher than conventional vehicles. Even with the near-term zinc-chlorine battery, the electric would cost more to own than a conventional vehicle over its entire life. In the case of the advanced batteries, however, EHVs could be from 8 to 11 percent cheaper. If the public becomes aware that life-cycle costs rather than initial costs represent the 'bottom line," this could present a strong incentive to switch to EHVs.

The cost comparisons presented in Table 7.14 are all based on a gasoline price of $1.25 per gallon and an electricity price of 3 cents per kilowatt-hour. If gasoline prices rise relative to electricity, EHVs will become more cost-effective from a life-cycle standpoint.

If gasoline prices rise, but electricity prices remain constant (Fig. 7.8), all of the representative electric vehicles would have lower life-cycle costs than conventional vehicles at gasoline prices of $3 per gallon and above. In the case of hybrids, a price of $3.10 per gallon or higher would yield the same results. Although, from a realistic standpoint, electricity prices tend to follow a rise in the price of gasoline, they do tend to lag behind at first and then "catch up" later. This trend could create a large price differential much of the time.

Hybrids overcome the major disadvantage of electric vehicles, namely, limited range. This is particularly important in households having only one vehicle. However, advanced batteries are expected to provide EV ranges of 150 miles or more between recharges by the year 2000. This range would be adequate for 98 to 99 percent of all motorists in the largest urban areas on a given day, but it would suffice for no more than 90 percent of all miles driven on those days.

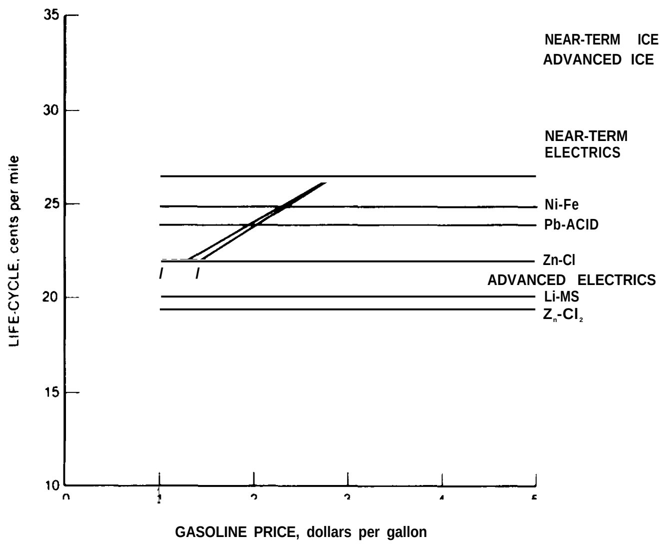
TABLE 7.14

COST COMPARISON OF ELECTRIC, HYBRID, AND CONVENTIONAL VEHICLES

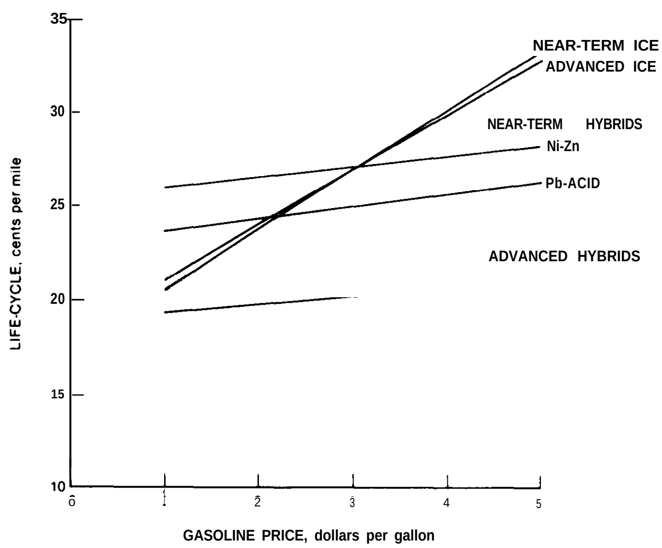
Vehicle	Initial Cost, 1980 dollars	Life-Cycle Cost, cents per mile
Electric		
Near-Term:		
Pb-Acid	8,520	23.9
Ni-Fe	8,400	24.9
Ni-Zn	8,130	26.6
$Zn-Cl_2$	8,120	22.0
Advanced:		
$Zn-Cl_2$	7,050	19.4
Li-MS	6,810	20.1
Hybrid		
Near-Term:		
Pb-Acid	8,020	23.7
Ni-Zn	7,770	26.0
Advanced:		
Li-MS	6,200	19.4
Conventional (ICE)		
Near-Term	4,740	21.4
Advanced	5,140	21.8

Source: Tables 3.5 and 4.2

Assumptions: These cost estimates were developed using a cost estimation model developed by General Research Corporation. The model used the EHV characteristics described in Sections 3 and 4 of this report as the basis for these estimates. Gasoline was assumed to cost $1.25 per gallon, and recharge electricity was assumed to be 3 cents per kilowatt-hour.



a. Electrics



b. Hybrids

Source: Tables 3.6 and 4.3

Assumption: The price of electricity was held constant at 3 cents per kilowatt-hour and the price of gasoline was varied from $1.00 to $5.00 per gallon.

Figure 7.8 Life-Cycle Costs of Electric, Hybrid, and Conventional Vehicles Versus Gasoline Prices

7.7 MAJOR UNCERTAINTIES

The major areas of uncertainty which must be considered in assessing the impacts of EHVs are the price and availability of hybrid fuels, improvements in battery technology, future sales of EHVs, growth of the electric utility industry, and improvements in conventional vehicles. History has demonstrated that projections of expected improvements in battery technology have tended to be overoptimistic. EHV sales are primarily uncertain because the future price and availability of petroleum fuels are unknown, and because consumers preference are uncertain. The electric utility industry is currently experiencing sharp declines in the growth rate of both electric generating capacity and electricity usage, making prediction of capability for recharging difficult. The extent to which the fuel economy of advanced conventional vehicles can be improved is also uncertain. If very fuel-efficient (60-100 mpg) vehicles become available, the market potential of EHVs could be sharply limited. Each of these major areas of uncertainty is discussed below.

7.7.1 Improvements in Battery Technology

It is clear that batteries are the key factor for practical EHVs. Electric motors and controllers are highly developed; they can be extremely quiet and reliable, and reasonably light and inexpensive. Since the beginning of the century, in contrast, it has been the batteries that have limited the range and speed of electric vehicles and kept them more expensive than automobiles with internal-combustion engines.

New kinds of batteries, however, offer prospects of greater improvements in the next decade than in the past eighty years. Improved lead-acid, nickel-iron, zinc-chlorine, and lithium-metal sulfide batteries are future possibilities which could double, triple, or even quadruple the amount of energy storage provided by the lead-acid "golf-cart" batteries now commonly used in electric cars. Developers of these batteries also expect operating life to increase as much as eight-fold, with corresponding reductions in life-cycle cost. Together, these improvements might dramatically relieve the principal disadvantages of electric drive.

Based on present progress and levels of effort projected for battery research and development, it seems likely that at least one of the battery types identified above will be successful. However, past performance clearly shows that battery development has usually not approached the expectations of developers. This may be due to the fact that it is so much easier to foresee a battery's potential performance than its implicit practical problems. The estimates presented here are intended to place reasonable upper and lower bounds on the prospects for future batteries.

7.7.2 Future Sales of EHVs

Under even the most optimistic battery projections, the success of EHVs in competing with conventional vehicles in the marketplace will depend primarily on the price and availability of gasoline relative to electricity. Price tags of EHVs will remain high despite major technological advances, due to the dominant cost of the batteries and, to a lesser extent, the fact that a heavier structure must be used to support these batteries. Although they would probably last longer than conventional vehicles because of the inherent longevity of their electric drive trains and are expected to require less maintenance and repair, large savings in fuel costs will be required to offset the extra initial costs of EHVs, particularly in the near term. The future price and availability of gasoline, however, cannot reliably be projected.

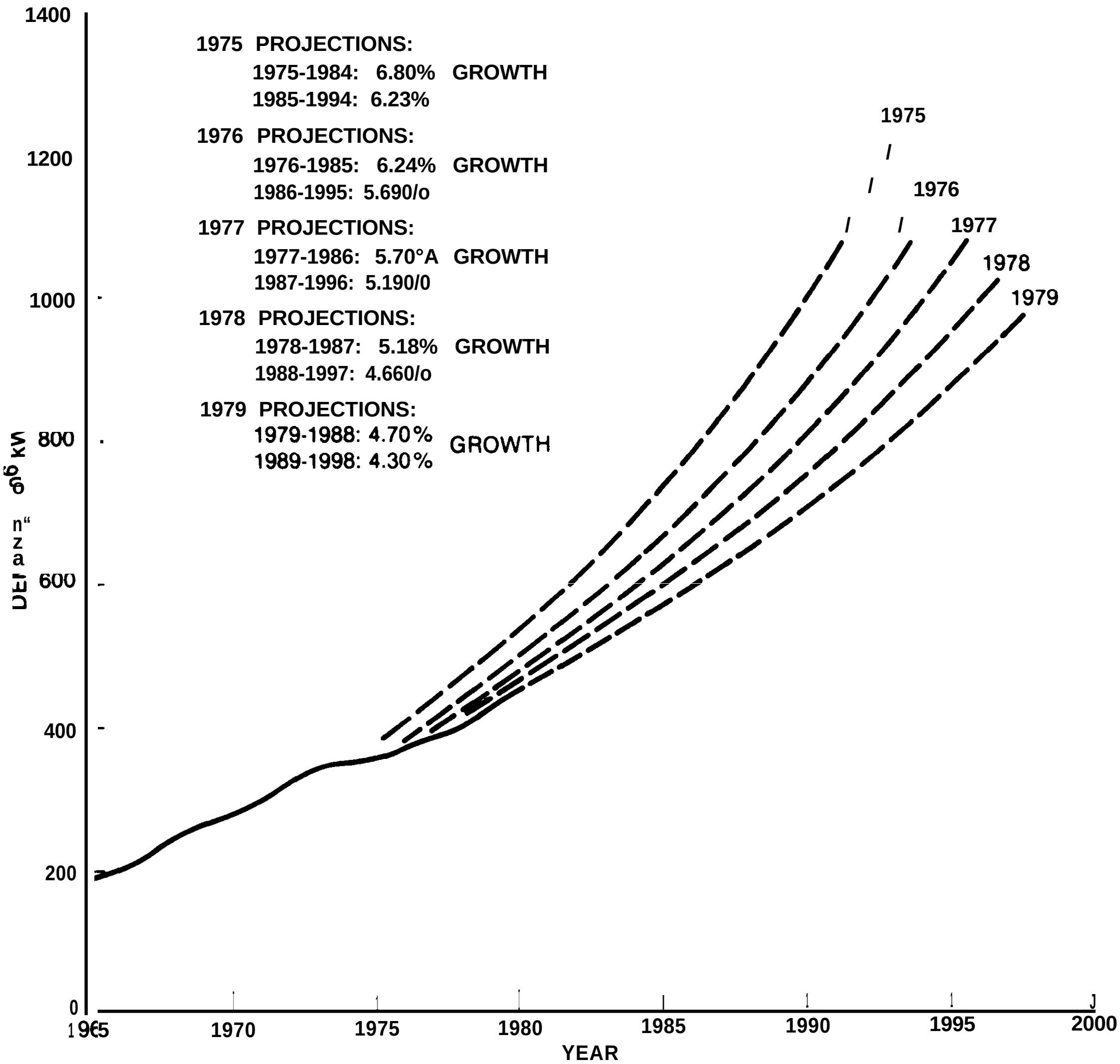
It is also uncertain whether buyers can readily adjust to vehicle range restrictions. Although we assume that travel patterns will remain the same, thus requiring EV owners to shift some travel to other vehicles or other modes of transportation, it is not clear whether this will actually occur. For example, rather than renting a conventional vehicle for trips beyond the effective range of an electric vehicle, an owner might simply prefer to forego many of these trips--and both the benefits and expenses.

7.7.3 Growth of the Electric Utility Industry

For many years, growth in the electric utility industry was remarkably predictable. With only minor variation from year to year, overall capacity and peak demand grew about 8 percent annually, doubling every eight to ten years. In the 1970s, however, this steady trend was interrupted. Although annual growth rates are highly dependent upon weather conditions, conservation measures, and the economic climate, it is estimated that the current average growth rate is from 3 to 4 percent per year.

Concerns for environmental quality and public safety have made it difficult or even impossible to obtain sites and construction permits for new power plants. Financing the huge expenditures needed to double capacity every ten years also has become a major problem. In the wake of the oil embargo of 1973-1974, the growth of demand dropped drastically, and utilities cancelled or postponed planned expansion accordingly. The national commitment to develop nuclear electric power faltered, future supplies of nuclear fuels began to appear uncertain, and public initiatives to restrict or prevent construction of nuclear power plants appeared in a number of states.

As a result, confident forecasting of supply and demand for electric power is no longer possible. Conditions have been changing too rapidly, and stability is not yet in sight. Since the 1973-1974 OPEC oil embargo, each new annual projection by the utility industry has embodied a lower rate of growth than in the previous year (Fig. 7.9). The difference in resultant projections made just two years apart is enormous: by 2000, it could be over twice the total peak demand actually recorded in 1970.



Source: Electric Power Supply and Demand for the Contiguous United States, Regional Electric Reliability Councils, US Department of Energy, 1 April 1975, 1976, 1977, 1978, 1979.

Figure 7.9 Recent Projections of Peak Summer Demand for Electric Power

On the supply side, there are uncertain prospects for making the transition to nuclear and coal-fired power plants to reduce petroleum consumption. Thus far it has been concluded that no additional power plants, other than those already planned for by the electric utility industry to meet normal future demand, would be needed to recharge EHVs if off-peak electricity is utilized. However, if the utilities are forced to build petroleum-fired power plants instead of nuclear and coal-fired plants, the fuel mix required to generate recharge energy would shift more toward petroleum, thus reducing the primary advantage of EHVs. If they cannot build replacement plants, then available capacity for generating recharge energy would be reduced.

This is a major area of uncertainty because the future status of conventional nuclear plants is doubtful, given the concerns of public safety, environmental protection, and the cost and availability of nuclear fuels. The question with coal is whether or not emission control technology can be improved enough to meet air quality standards without greatly increasing the price of electricity. The development of unconventional oil and gas in the synfuels program is in the early decision-making stages of development, and is also quite unclear. Although the industry could begin implementing new power plants which utilize more fuel-efficient equipment and retrofit some existing plants, these steps require substantial capital which is difficult to justify given demand that is down from earlier projections.

The prospects for transition to renewable resources such as solar and geothermal are even more unclear, as are the potentials of the advanced nuclear breeder reactor and fusion power. Furthermore, these sources are unlikely to have an effect until after the year 2010, rather than in the time frame considered in this report.

7.7.4 Improvements in Conventional Vehicles

In order to evaluate the utility of EHVs, it is necessary to make comparisons with those conventional vehicles that could provide the greatest competition for EHVs, namely, small urban cars. For the year 2010, it was assumed that the average new car could achieve a composite fuel economy of 55 miles per gallon, double the CAFE standard of 27.5 mpg for 1985. Light trucks were assumed to achieve about 37 miles per gallon. Since these are averages, some small cars and trucks would have higher fuel economy. However, there is great uncertainty as to whether these fuel economies will be required, attained, or surpassed.

On one side is the automobile industry, which has tended to resist external demands for rapid changes in technology. At the other is the Federal Government, which is currently striving to reduce petroleum consumption, with corresponding reductions in imports. Recent testimony before the Senate Committee on Energy and National Resources recommended that a target for Corporate Average Fuel Economy (CAFE) be set at 50 mpg for 1990, and 80 mpg for 1995.[16] Whether or not these targets could be achieved would depend largely on market characteristics and the associated incentives or disincentives. In any case, however, an average fuel economy of 50-80 mpg for new cars would entail major reductions in vehicle size, capacity, and performance, even with major improvements in automotive technology. If these levels of fuel economy are achieved by 1995, and continued to be improved upon, they would significantly reduce the primary advantage of EHVs, making them much less competitive.

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