The Potential Market for Electric Vehicles: Results from a National Survey of Commercial Fleet Operators

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ABSTRACT

Successful commercialization of electric vehicles has been hindered by a lack of data pertaining to both desirable vehicle configurations and potential market size. The objective of the study on which this paper is based was to redress these data inadequacies pertaining to commercial sector fleet vehicles through information obtained from fleet managers about vehicle travel requirements, cost and range trade-offs, and operational practices. The study was commissioned by the Electric Power Research Institute and the Detroit Edison Company as part of their ongoing research agendas that focus on electric over-the-road vehicles (EVs). The study's findings with respect to the size and characteristics of the potential market for electric vehicles in commercial fleets are presented. Information is given on fleet size, range requirements, and vehicle use patterns. In addition to general information about commercial fleets, the data are analyzed in terms of key factors associated with EV performance, such as miles traveled per day, availability for recharging, and the need for high-speed travel. Data for the study were obtained through telephone interviews with fleet managers in commercial establishments throughout the United States. A total of 583 interviews were conducted during 2 months of the fall of 1983. The probability sample of establishments was drawn from a comprehensive list compiled by Dun and Bradstreet. Because scientific sampling procedures were used, it was possible to translate the sample data into estimates for the entire nation with known degrees of precision.

Although electric-powered vehicles date to the earliest part of the automobile age, they have never gained prominence as a means of over-the-road transportation. Although emerging technology has enhanced their potential to do so, successful commercialization has been hindered by a lack of data pertaining to both desirable vehicle configurations and potential market size. The objective of the study on which this paper is based was to redress these data inadequacies pertaining to commercial sector fleet vehicles through information from fleet managers about vehicle travel requirements, cost and range trade-offs, and operational practices. The study was commissioned by the Electric Power Research Institute (EPRI) and the Detroit Edison Company as part of their ongoing research agendas, which focus on electric over-the-road vehicles (EVs).

In this paper the study's findings with respect to the size and characteristics of the potential market for EVs in commercial fleets are presented. Information is presented on fleet size, range requirements, and vehicle use patterns. In addition to general information about commercial fleets, the data are analyzed in terms of key factors associated with EV performance, such as miles traveled per day, availability for recharging, and the need for high-speed travel.

STUDY DESIGN

A probability sample of establishments was drawn from a comprehensive list compiled by Dun and Bradstreet. Fleet managers in establishments throughout the United States were contacted by telephone and 583 interviews were conducted during 2 months of the fall of 1983. The overall response rate for these interviews was 92 percent. Because scientific sampling procedures were used, it was possible to translate the sample data into estimates for the entire nation with known degrees of precision. To the extent that there is systematic bias in the data (because of undercoverage in the list used for sampling), estimates of market potential reported here can be considered conservative. A complete discussion of the survey, sample, and procedures can be found in the final project report (1).

MARKET POTENTIAL VERSUS MARKET PENETRATION

In a discussion of the market for electric vehicles in commercial fleet operations, two different but related issues should be distinguished: the size of the potential market, and possible EV penetration into it. An extreme upper boundary on the potential market for commercial EVs is the total number of commercial vehicles in use. A more practical definition of market potential, and the one used for this study, recognizes that EVs available in the near-term future cannot substitute for all commercial vehicles because of such performance characteristics as limited range and speed, and recharging requirements.

Market penetration, the degree to which EVs capture the potential market, must take additional market-limiting factors into account. Some of these are specific to EVs and some are more general and affect the adoption of many innovations. As shown in the following list, factors that influence market penetration tend to be more qualitative and uncertain

than those that define market potential. Market penetration will be affected by

- The costs of purchasing, operating, and maintaining EVs compared with conventional vehicles;
- The cost of electricity and the cost and availability of petroleum fuels;
- The quality and reliability of services provided by the EV infrastructure (e.g., the availability of repair facilities and parts);
- Attitudes and perceptions about the benefits of EV adoption (e.g., their quiet and clean operation, low maintenance, and protection against oil cut-offs);
- Attitudes and perceptions about the risks of EV adoption (e.g., their inability to meet all performance requirements, their unproven track record, their uncertain battery life, and the existence of a limited and immature infrastructure); and
- Organizational and individual resistance to changes made necessary by the adoption of EVs.

This study concentrated on market potential and touched only indirectly on likely penetration. The primary reason for this was that potential buyers cannot be expected to provide accurate information about whether they would purchase EVs or conventional vehicles under different sets of circumstances because they do not have, and indeed cannot have, any real experience with EVs in commercial fleet operations. It should be recognized, for example, that even commercial EV users in the U.S. Department of Energy (DOE) EV Demonstration Program have not had experience with EVs in a context that simulates mass market EV quality and infrastructure (2).

Furthermore, it is unfortunately true that there is no adequate theory to guide the estimation of the extent to which EVs might actually penetrate their potential market. Readers differ substantially in the assumptions they make regarding technology, price elasticities, individual and institutional resistances to change, future energy prospects, and commercial vehicle requirements. Because these varying assumptions must be thought of as largely educated guesses, the following data are presented in a manner that permits the reader to estimate market potential under alternate assumptions of potential EV range and other attributes.

CHARACTERISTICS OF COMMERCIAL FLEET VEHICLES AND TRIP PATTERNS

Total Number of Vehicles

On the basis of data collected in the survey, the total number of light-duty, over-the-road vehicles in commercial fleets is estimated to be 12.7 million. Somewhat less than half of these (5.6 million) are cars and station wagons, and the remainder (7.0 million) are light-duty trucks and vans. These estimates are lower than many other previously published estimates of commercial vehicle fleet size (2-6). Although the nature of the sampling frame may have produced some mild undercounting, the sampling procedures used in the study are considered far more reliable than those employed by other data sources. Comparison across the different data sources is hindered by the problem of noncomparable definitions. As used in this study, the terms vehicles, cars, trucks, and vans refer to light-duty over-the-road vehicles of these types weighing less than 5,000 lb. Hereafter, the term "cars" should be understood to include station wagons.

Typical Mileage Patterns

The distribution of fleet vehicles by miles typically traveled in a day is shown in Figure 1. As is evident, approximately one-fifth (19.8 percent) of all light-duty over-the-road vehicles are typically driven less than 30 miles per day (mpd), and almost half (46.1 percent) are typically driven less than 60 mpd. Only about one-third (35.4 percent) are typically driven over 90 mpd, a range that makes them unlikely to be replaced by EVs in the near future, given existing trip patterns and the lack of infrastructural facilities that make opportunity recharging feasible.

As can also be seen in Figure 1, light-duty trucks and vans compose more than half of the vehicles in

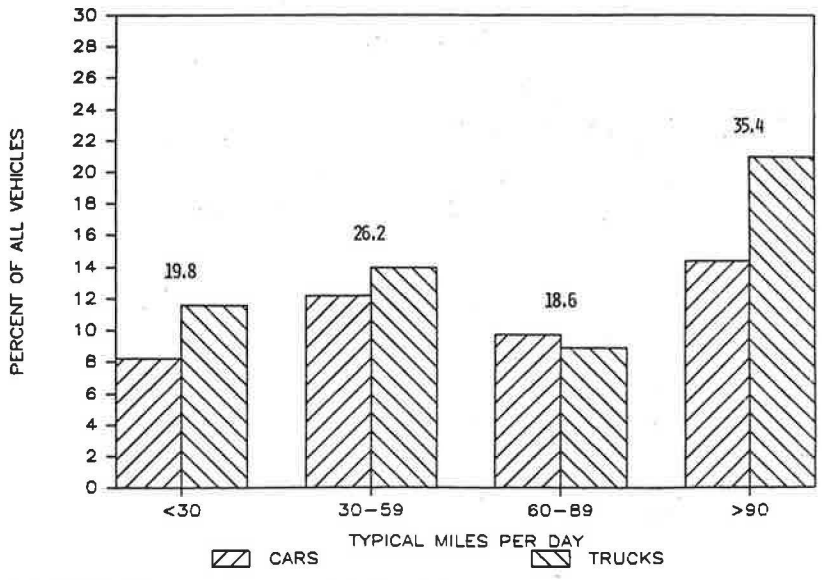

FIGURE 1 Typical daily range of fleet vehicles.

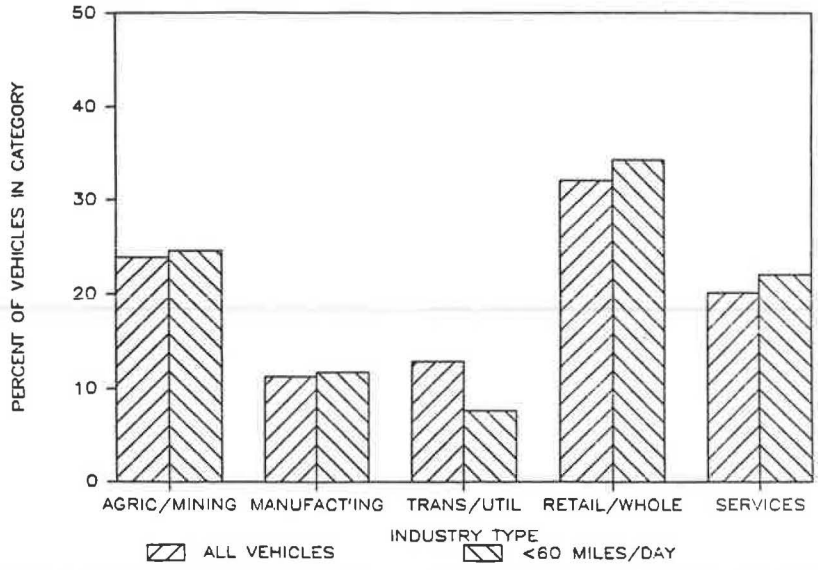

FIGURE 2 Distribution of vehicles by industry.

the two lower-mileage classes (they compose 59 percent of vehicles typically driven less than 30 mpd and 53 percent of those typically driven 30 to 59 mpd). Thus, in terms of vehicles typically traveling less than 90 mpd, the potential market for electric cars, trucks, and vans appears to be substantial (65 percent of all commercial vehicles). Based solely on this mileage criterion, market potential is somewhat greater for trucks and vans than for cars.

Industry Type

If those vehicles typically driven less than 60 mpd are defined as having potential for near-term EV substitution, the next issue from a market perspective is the industries in which they are concentrated. Figure 2 shows the industrial distributions of all light-duty over-the-road vehicles and those typically driven fewer than 60 mpd. As is evident, these two distributions are quite similar. This suggests that EV marketing should be directed toward the same industries as those toward which internal combustion engine (ICE) vehicle marketing is currently directed.

Currently, the primary users of ICE vehicles and potential users of EVs are retailers and wholesalers (32.1 percent of low-mileage vehicles) followed by construction, agricultural, and mining establishments (23.9 percent of all vehicles and 24.6 percent of low-mileage vehicles). In terms of numbers of vehicles, the least promising industries for EV adoption are those in the transportation, communications, and utility sectors. Of interest, however, is a related finding that the relatively limited number of vehicles in these sectors may be offset by a higher-than-average willingness to consider using EVs on the part of their fleet managers.

Fleet Size

Figure 3 partitions the data by fleet size and shows that about half (50.5 percent) of all light-duty

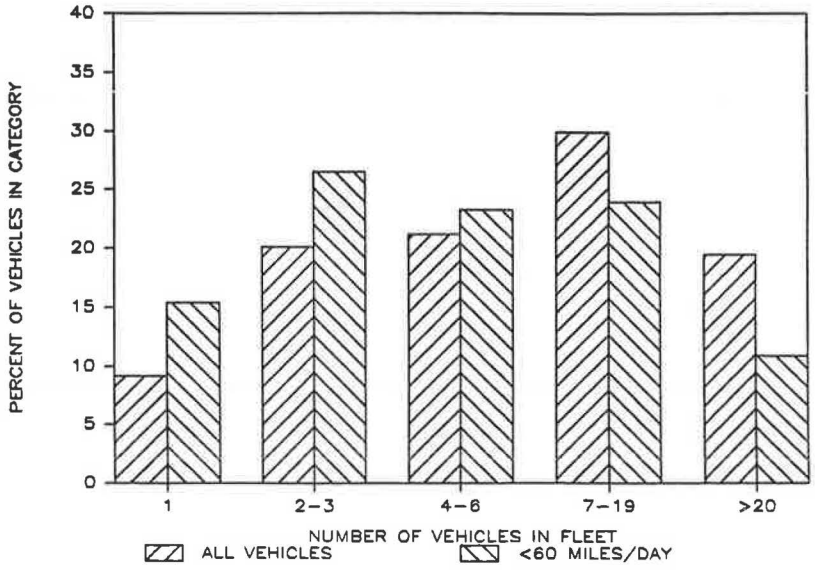

FIGURE 3 Distribution of vehicles by fleet size.

over-the-road vehicles are in fleets with six or fewer vehicles. These smaller fleets, however, account for approximately two-thirds (65.2 percent) of all low-mileage vehicles. In other words, low-mileage vehicles tend to be concentrated in relatively small fleets. Although large fleets (those with more than 20 vehicles) account for about one-fifth of all commercial vehicles (19.5 percent), only about half of these have trip patterns commensurate with the expected mileage limitations of EVs.

Ability to Modify Trip Patterns

The discussion has thus far centered on proportions of vehicles typically driven less than 30, 60, or 90 mpd. But typical low-mileage usage is not a sufficient mileage criterion for EV substitutability; occasional, but nonetheless necessary, high-mileage trips would render such EV substitution unfeasible. Thus, two further mileage attributes must be considered: whether typical low-mileage vehicles are occasionally driven more than the likely EV maximum range, and if they are, whether different vehicles could be used to make the occasional higher-mileage trips.

The data given in Table 1 indicate that although 20 percent of all vehicles in commercial fleets are typically driven less than 30 mpd, over half of these (56 percent) must occasionally be driven beyond the 30-mi range. Looking next at the 26 percent of all vehicles typically driven between 30 and 60 mpd, over half (59 percent) are occasionally driven over 60 mpd and over two-fifths (41 percent) are occasionally driven over 90 mpd.

A comparison of mileage patterns for cars and trucks shows them to be relatively similar; however, cars are more likely to take occasional longer trips than trucks.

TABLE 1 Mileage Attributes of Light-Duty Commercial Cars and Trucks Typically Driven Less Than 90 mpd

Attribute	Typical Daily Mileage (mpd)		
	<30	30-59	60-89
Estimated no. of vehicles (millions)	2.5	3.3	2.3
Percent of all vehicles in commercial fleets	20 (±4)[a]	26 (±4)	18 (±3)
Average mpd traveled	17	44	72
Occasional higher-mileage trips (%)			
>30 mpd	56	na[b]	na
>60 mpd	38	59	na
>90 mpd	na	41	60

[a] All ± values given in this report represent 95th percentile confidence ranges.
[b] na = not ascertained.

Although the occasional need for longer trips could substantially reduce EV substitution potential, a closer review of the data provides a somewhat different perspective. Overall, 46 percent of the fleets had vehicles that averaged less than 60 mpd, but that occasionally traveled more than this range. About 25 percent of all vehicles fell into this category. However, 21 (±6) percent of these establishments indicated that it would be quite easy to assign the longer trips to other vehicles, and another 16 percent said that it would not be difficult to do so. In terms of vehicles (rather than establishments), approximately 21 percent of the vehicles surveyed never had to travel over 60 mpd, and the trip patterns of an additional 9 percent (25 x 37 percent) could be somewhat easily modified to remain within a 60-mi range. Overall, then, the trip patterns of 30 percent of the commercial fleet could be structured, with little or no change, to never exceed a range of 60 mpd. Although the 30 percent figure represents a reduction of one-third from the 46 percent of all vehicles that typically do not exceed 60 mpd, it still represents over 3.5 million vehicles.

Fixed Routes

Another dimension of range variance that could affect EV substitution potential is the extent to which low-mileage vehicles are assigned to fixed routes. For example, in the case of EVs with a 60-mpd range, fixed routes of just under 60 mpd would be excellent candidates for EV substitution because the probability that vehicles would have to exceed the maximum mileage limits would be greatly reduced. In this regard, however, the number of vehicles with fixed route assignments does not provide cause for great optimism, especially with respect to cars. Only 4 percent of cars and 20 percent of trucks typically driven 30 to 60 mpd (see Table 2) are currently assigned to fixed routes. Although not a large percentage even for trucks, this suggests that as many as half a million light-duty trucks operate on fixed routes of less than 60 mpd.

Mileage, of course, is not the only criterion affecting EV substitutability. Fleet managers were therefore asked a number of questions about other use patterns of relatively low-mileage vehicles that would affect substitutability. The responses to these questions, presented in Table 2, allow market potential to be estimated under more refined assumptions of substitutability.

Frequent Stops and Starts

One advantage of EVs relative to ICE vehicles is their efficiency in situations requiring frequent

TABLE 2 Selected Use Attributes of Commercial Vehicles

Attribute	Typical Daily Mileage (mpd)					
	Cars and Wagons			Trucks and Vans		
	<30	30-59	60-89	<30	30-59	60-89
Stopped more than 100 times/day with engines running (%)	2	12	29	9	9	36
Engines stopped and restarted more than 20 times/day (%)	1	8	37	11	27	51
Compact or smaller (%)	22	15	19	11	8	15
Assigned to fixed routes (%)	na	4	5	na	20	5
Left on company premises overnight (%)	na	21	25	na	66	68
Parked 2 or more hours at a time during day	na	82	78	na	90	69
Average miles driven at >40 mph	na	5.8	8.0	na	3.4	11.2

stops during which engines are left running, or where engines are frequently stopped and restarted. With regard to these two stop/start patterns, current low-mileage car usage is not overly favorable. Only 2 percent of cars typically driven less than 30 mpd and 12 percent of cars typically driven between 30 and 60 mpd are stopped with their engines left running more than 100 times a day. The numbers for trucks--9 percent for each mileage category--are somewhat more favorable in terms of EV market potential.

With regard to engine stopping and restarting, the outlook for electric trucks is considerably better than for electric cars. Eleven percent of trucks typically driven less than 30 mpd, and 27 percent typically driven between 30 and 60 mpd, stop and restart their engines more than 20 times a day. This represents over 500,000 light-duty trucks and vans. The comparable percentages for cars are only 1 and 8 percent, respectively, or fewer than 150,000 vehicles.

Vehicle Size

Most EV designs to date have been built around relatively small and light (exclusive of batteries) body shells. To the extent that ICE vehicles with relatively low mileage requirements are also small, the potential for EV substitution is enhanced. As can be seen in Table 2, the percentage of low-mileage cars that are compact or smaller models is relatively low (22 percent of cars typically driven less than 30 mpd and 15 percent of cars typically driven between 30 and 60 mpd) as is the percentage of trucks (11 and 8 percent, respectively). Although this does not bode well for EV substitutability, it should be noted that the larger car and truck models currently in use might not be necessary from a functional standpoint. It is possible that compact or smaller models might be used equally well but, for some reason, they currently are not. This conjecture would certainly be suggested by the fact that only about 30 percent of all commercial trucks and vans typically carry payloads greater than 500 lb. Furthermore, only 38 percent of all truck and van payloads are considered especially large for their weight (i.e., have relatively large volume).

Availability for Recharge

Because EVs require "overnight" (6- to 10-hr) recharging, market penetration is more likely if recharging is a straightforward and easily initiated task. Although EVs could be recharged wherever there is access to electricity, it would clearly be more convenient (from the perspective of metering and facilities) to have them charged on company premises. In this regard, electric trucks appear to be far more promising than electric cars because approximately two-thirds (66 percent) of light-duty trucks and vans driven between 30 and 60 mpd are parked on company premises overnight, whereas only one-fifth (21 percent) of comparable cars remain on the premises overnight.

Vehicles typically traveling as many as 90 mpd could be replaced by EVs if parked long enough to permit opportunity recharging. Such recharging, of course, depends on the availability of recharging facilities, but the infrastructure is unlikely to be in place if the need is not demonstrated. In this regard, data are extremely encouraging. Over four-fifths (82 percent) of cars typically driven 30 to 60 mpd and three-fourths (78 percent) of those typically driven 60 to 90 mpd are parked for 2 or more hours at a time during the day. The numbers are equally optimistic for trucks and vans (see Table 2). Opportunity recharging would not make near-term EVs a viable alternative for vehicles traveling more than 90 mpd or less than 30 mpd. Therefore, in the interest of brevity, information about overnight and daytime parking was not obtained for these groups.

High-Speed Driving Requirements

Finally, EV range performance is typically better in situations that do not require extensive travel at speeds exceeding 40 mph. In this regard, data are quite encouraging for EV adoption. Cars typically driven 30 to 59 mpd average only 5.8 mpd at speeds exceeding 40 mph; comparable trucks average 3.4 mpd. Not surprisingly, higher-mileage vehicles (60 to 89 mpd) tend to be driven longer at these speeds (8.0 mi for cars and 11.2 mi for trucks).

The general picture that emerges from these statistics is that the potential market for EVs tends to be substantial, even under the assumption of some fairly stringent technological constraints. Of the two classes of vehicles studied, trucks appear to be more likely candidates for EV substitution than cars although neither type should be ruled out in terms of market potential.

Types of Vehicles Applications

Of concern from an EV design standpoint is what EVs are likely to be used for. To address this question, fleet managers were asked to what uses their low-mileage vehicles were applied. The type of applications vary quite widely with vehicle type, but only slightly with range. This is, cars and trucks are used for considerably different purposes, whereas the use patterns are relatively similar for vehicles in the less-than-30-mpd group and the 30- to 60-mpd group. Figure 4 shows the data for vehicles typically traveling less than 30 mpd. For cars typically traveling less than 30 mpd and for those typically traveling between 30 and 60 mpd, the most frequently mentioned use was for business appointments followed by commuting and use as executive vehicles. Also frequently mentioned was use for making pickups and running errands. The most common use for low- and relatively low-mileage light-duty trucks and vans was hauling and dumping (including snow removal), followed by commuting to and from jobs and making deliveries.

VEHICLE SUBSTITUTION CRITERIA

As indicated earlier, the maximum potential for substitution by EVs is in large part determined by the match between EV performance and the actual requirements of fleet vehicles. As the range, speed, and acceleration performance of EVs increase, so does the number of conventional commercial vehicles that might be replaced by EVs. In the previous section the use patterns of vehicles that fell within two alternative range specifications for future EVs (i.e., less than 30 mpd and less than 60 mpd) were examined. Each of these range specifications can be thought of as the first criterion for judging whether an EV might be substituted for a particular commercial vehicle.

In this section the 30- and 60-mpd criteria plus two additional substitution criteria are considered. The first is a more broadly defined criterion referred to as 60 mpd+, within which are all vehicles traveling less than 60 mpd plus those traveling

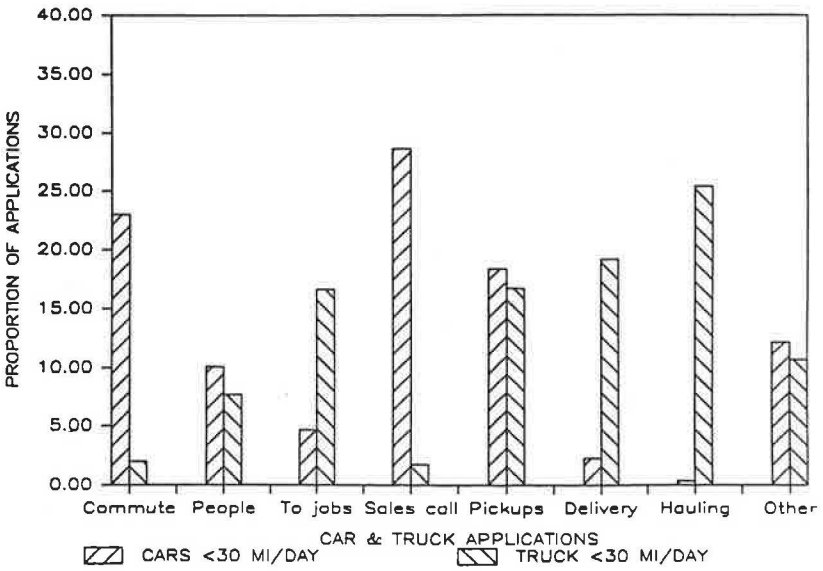

FIGURE 4 Applications for cars and trucks.

between 60 and 90 mpd that are parked for 2 or more hours during the day, and that also travel less than 8 mi at speeds greater than 40 mph. Falling within the second new criterion are those vehicles traveling less than 30 mpd plus those traveling between 30 and 60 mpd that are parked for 2 or more hours during the day, and that also travel less than 8 mi at speeds greater than 40 mph. This criterion is referred to as 30 mpd+. Electric vehicles parked for 2 or more hours could potentially extend their daily range capability through opportunity recharging (7). Similarly, EVs subject to only limited high-speed travel would have a greater overall range capacity.

The following analysis identifies the extent to which the trip patterns of existing vehicles can be met by EVs that have performance levels corresponding to the four criteria of 60 mpd+, less than 60 mpd, 30 mpd+, and less than 30 mpd. The analysis focuses on the total number of vehicles falling within each criterion.

Market Potential as Measured by EV Substitution Criteria

It will be recalled from the earlier discussion that the total number of light-duty, over-the-road commercial fleet vehicles was estimated to be roughly 13 million. As can be seen in Figure 5, over 7 million vehicles fall within the broadest substitution criterion (60 mpd+), and over 2.5 million fall within the narrowest criterion (less than 30 mpd). If only compact and subcompact vehicles are considered, as is done in the right-hand portion of Figure 5, the corresponding numbers are roughly 1.5 million and 0.4 million.

Although even the most conservative 0.4 million figure would represent quantity production from a manufacturing standpoint, the range of 0.4 million to 7 million is very large from a business planning standpoint. This uncertainty in the size of the potential EV market is a reflection of the vehicle

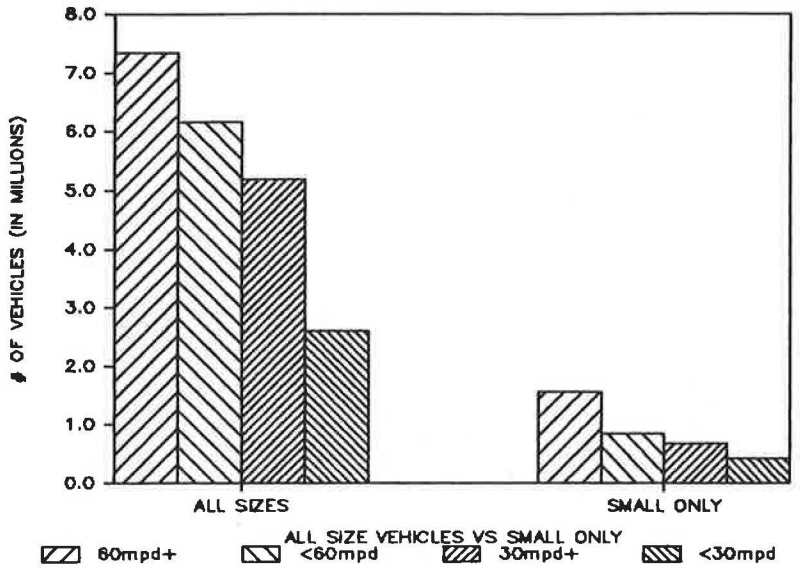

FIGURE 5 Maximum EV substitution potential under alternative substitution criteria: all size vehicles versus small only.

range assumptions built into the four substitution criteria. It is important to recognize then that future choices with respect to EV performance specifications are not just technical decisions. They are also choices about the size of the potential EV market.

Characteristics of the potential EV market are examined in the following section along other dimensions relevant to the marketing and vehicle specification choices that would need to be made for successful commercialization to occur. The findings are broken down in terms of fleet size, vehicle type and size, percentage of trucks in fleet, truck payload, regional differences, and industry groupings.

FLEET CHARACTERISTICS AFFECTING MARKET POTENTIAL

Fleet Size

As shown in Figure 6, the largest overall market for EVs is composed of moderate-sized fleets comprising 2 to 19 vehicles. This group represents about 75 percent of all vehicles falling within the EV substitution criteria. Of interest is that the large fleets (20 or more vehicles) represent only 5 to 10 percent of the commercial sector market for EVs.

High EV Substitution Potential of Trucks and Vans

The data suggest that light-duty trucks and vans represent the most promising initial market for EVs. The number of vehicles falling within each of the substitution criteria increases substantially with the percentage of trucks and vans in the fleet. Among fleets with no trucks or vans, for example, just under 1 million vehicles fall within the broadly defined 60 mpd+ criterion. By contrast, fleets composed of 75 to 100 percent trucks and vans contain over 2.5 million vehicles that meet the criterion. A similar pattern holds for each of the four criteria. Overall, less than 15 percent of all vehicles with

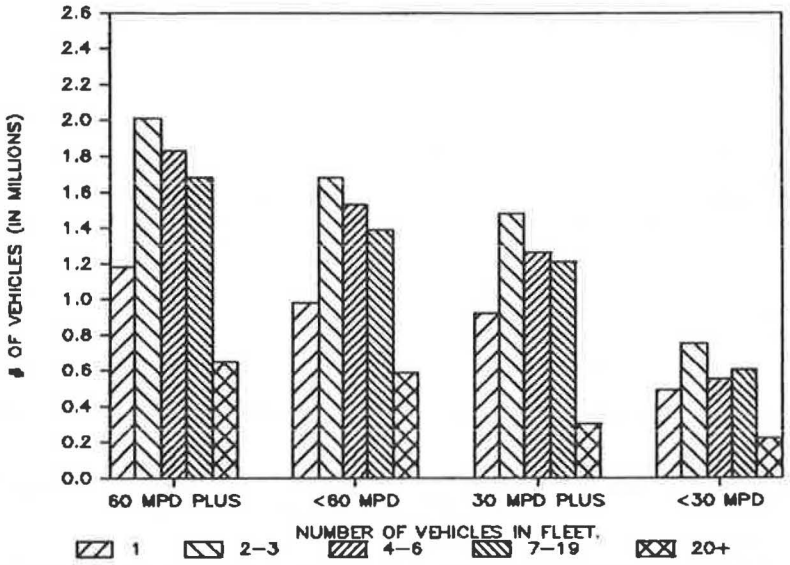

FIGURE 6 Maximum EV substitution potential under alternative substitution criteria: number of vehicles in fleet.

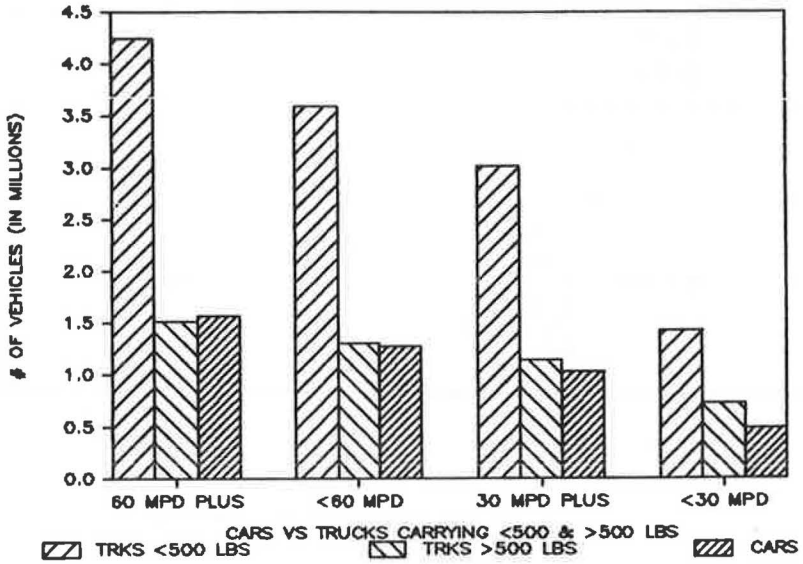

FIGURE 7 Maximum EV substitution potential under alternative substitution criteria: cars versus trucks carrying <500 lb and >500 lb.

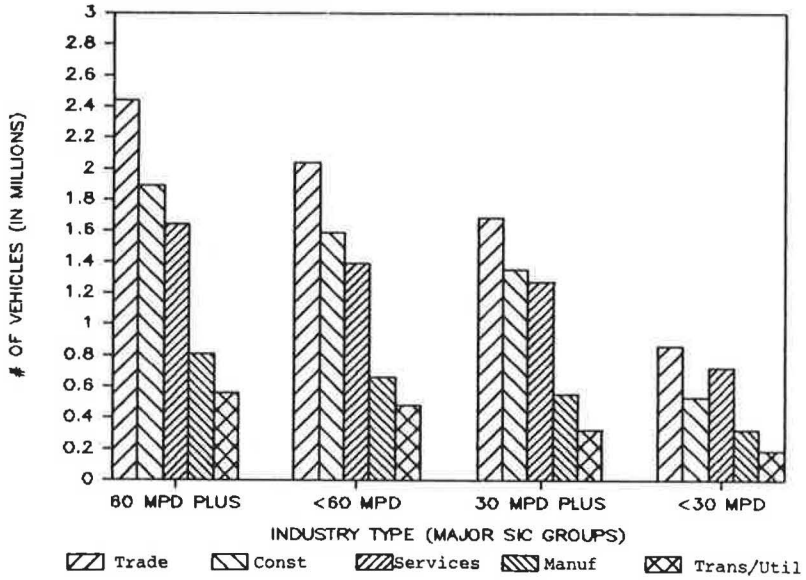

FIGURE 8 Maximum EV substitution potential under alternative substitution criteria: industry types.

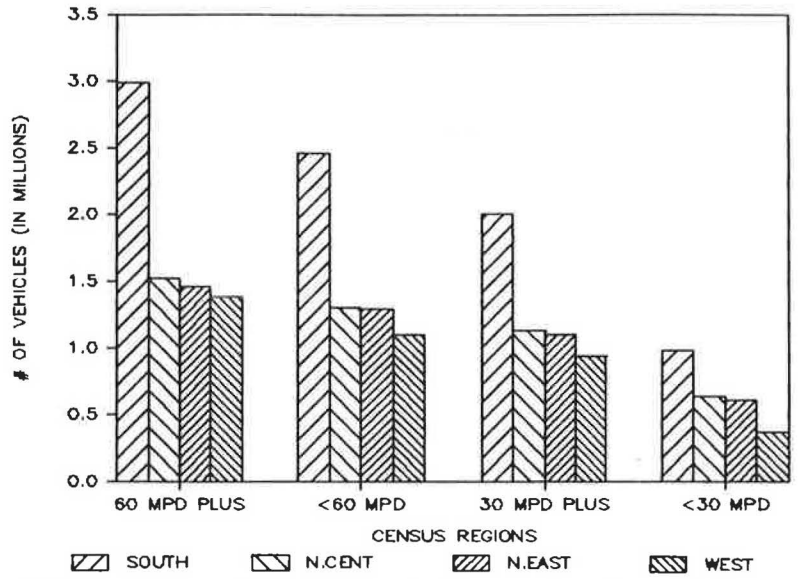

FIGURE 9 Maximum EV substitution potential under alternative substitution criteria: census regions.

high substitution potential reside in fleets having no trucks or vans.

Related evidence for the important role of trucks and vans is found in Figure 7, which divides all of the light-duty vehicles into three groups: trucks and vans carrying less than 500 lb of payload, trucks and vans carrying more than 500 lb of payload, and cars. Trucks and vans that typically carry payloads of less than 500 lb account for over 50 percent of all vehicles that fall within the high substitution potential criteria. In terms of number of vehicles, this group represents over 4 million vehicles within the 60 mpd+ criterion, and almost 1.5 million vehicles within the narrowly defined less than 30 mpd criterion. Overall, trucks and vans represent approximately 80 percent of all vehicles with high substitution potential as defined by the four criteria.

EV Substitution Potential by Industry Type

Figure 8 organizes the data in terms of the number of vehicles with high substitution potential in each of five major industry groupings: wholesale and retail trade; construction, mining, and agriculture; services; manufacturing; and transportation, communication, and utilities. The relative number of vehicles in each of the five groups shows a generally stable pattern across the four criteria. This suggests that design choices about range will not significantly change the types of industries in

which EVs have their greatest, or least, appeal. Overall, the trade, construction, and services sectors show the most promise for EV substitution.

EV Substitution Potential by Region

Figure 9 examines the distribution of vehicles with high substitution potential within four major census regions of the United States. Notice that the four range criteria show noticeable differences in the regional relationships. In the case of the 60-mpd+ criterion, for example, the South, with nearly 3 million vehicles, shows twice as many high-potential vehicles as does any other region. Furthermore, with about 1.5 million vehicles each, the north central, the northeast, and the western regions all show about equal potential. These patterns change significantly, however, if the vehicle range is limited to less than 30 mpd. In this case, the northern industrial states composing the northeast and north central census regions show a combined potential considerably higher than the South. In addition, the West shows considerably lower potential than any of the other regions. The significant change in pattern as range drops below the 30-mpd level appears to reflect the higher density that characterizes the northern industrial region in contrast to the West and South.

SUMMARY

The results reported in this paper suggest that a quite sizable potential market for electric vehicles does exist in the commercial sector based on currently existing patterns of vehicle usage. Depending on the eventual performance capabilities of production EVs, the potential market could be expected to be between 2.5 million and 7 million vehicles. Although many factors are likely to reduce actual market penetration to a level significantly below this market potential range, the data tend to support the view that, based on functional criteria, quantity production of a reliable and economical electric vehicle is a realistic objective.

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