INEL-96/0080-Qtr 3

January 1997

Idaho
National
Engineering
Laboratory

Electric and Hybrid Vehicle Program Site Operator Program Quarterly Progress Report for April through June 1996 (Third Quarter of Fiscal Year 1996)

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Electric and Hybrid Vehicle Program

Site Operator Program

Quarterly Progress Report for April through June 1996 (Third Quarter of Fiscal Year 1996)

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Published January 1997

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Prepared for the
U.S. Department of Energy
Assistant Secretary for Energy Efficiency and Renewable Energy (EE)
Under DOE Idaho Operations Office
Contract No. DE-AC07-94ID13223

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Executive Summary

Program Overview

The U.S. Department of Energy (DOE) Site Operator Program was initially established to meet the requirements of the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976. The Program has since evolved in response to new legislation and interests. The goals of the Site Operator Program include the field evaluation of electric vehicles (EVs) in real-world applications and environments; the advancement of electric vehicle technologies; the development of infrastructure elements necessary to support significant electric vehicle use; and increasing the awareness and acceptance of EVs by the public.

The Site Operator Program currently consists of eleven participants under contract and two other organizations that have data-sharing agreements with the Program (Table ES-1). The participants (electric utilities, academic institutions, and Federal agencies) are geographically dispersed within the United States and their vehicles see a broad spectrum of service conditions. The current electric vehicle inventories of the site operators exceeds 250 vehicles.

Several national organizations have joined DOE to further the introduction and awareness of electric vehicles, including:

- EVAmerica (a utility program) and DOE conduct performance and evaluation tests to support market development for electric vehicles
- DOE, the Department of Transportation, the Electric Transportation Coalition, and the Electric Vehicle Association of the Americas are conducting a series of workshops to encourage urban groups in Clean Cities (a DOE program) to initiate the policies and infrastructure development necessary to support large-scale demonstrations, and ultimately the mass market use, of electric vehicles.

The current focus of the Program is the collection and dissemination of EV operations and performance data to aid in the evaluation of real-world EV use. This report contains several sections with vehicle evaluation as a focus, including:

Electric Vehicle Testing Results

An examination of the DOE and EVAmerica sponsored 1994, 1995, and 1996 performance testing of fourteen EVs. Performance indicators such as acceleration, braking, range, and energy efficiency are examined on a per vehicle basis and as trends. The tested vehicles range from conversions to the most recently tested EVs, including Toyota's RAV4 and General Motors' EV1.

Energy Economics of Electric Vehicles

This section compares the energy costs per mile of three internal combustion vehicles at gasoline prices ranging from $1.15 to $1.80 per gallon, to the energy cost per mile for four EVs that have energy efficiencies of 3, 4, 5, and 6 miles per kilowatt-hour (kWh), and per kWh energy costs ranging from $0.03 per kWh to $0.40 per kWh.

Table ES-1. Site Operator Program Participants.

Entity	Principal Thrusts of Program Effort
Arizona Public Service Co.	a, b, d
Kansas State University	a, b, c, d
Los Angeles Dept. of Water & Power	a
Orcas Power and Light Co.	a, b, d
Pacific Gas and Electric Co.	a, b, d
Platte River Power Authority	a, b, d
Potomac Electric Power Co.	a, b, d
Sandia National Laboratory*	a
Southern California Edison Co.	a, b, d
Texas A&M University	a, c, d
University of South Florida	a, b, c, d
U.S. Navy,* Port Hueneme, CA	a
York Technical College	a, b, c, d

a. Fleet evaluation, vehicle test
b. Infrastructure development
c. Technical education
d. Public awareness

* Sandia and the Navy are not Site Operators, but they do share information with the Site Operator Program, and this information is provided to the reader of this report.

Site Operators Activities

This section provides details of the activities at each site operator, including EV operations, maintenance, energy use, public awareness and education efforts. More that a dozen different types of EVs are in use, with a variety of battery types, and vehicle applications.

This report and the results of DOE/EVAmerica performance testing are available electronically over the internet. The WWW site also includes operations data captured by on-board data acquisition systems, and a user-friendly interface that allows point-n-shoot plotting, and custom and canned queries of the operations, performance, and specifications database. The WWW home page is located at http://ev.inel.gov

Acknowledgement

The principle author thanks each of the Site Operator participants for their input, active participation, and timely comments in the form of their quarterly reports. The Site Operator Program report incorporates text and data from the quarterly reports that each of the Site Operator participants submit. Because of the significant amount of text that is draw from each of the individual Site Operator's reports, each of the individual Site Operators are listed as co-authors. However, any errors, emissions, or inaccuracies are the singular responsibility of the principle author.

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Contents

Introduction

The Site Operator Program was initially established by the Department of Energy (DOE) to incorporate the electric vehicle activities dictated by the Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976. In the ensuing years, the Program has evolved in response to new legislation and interests. The Program currently includes eleven sites located in diverse geographic, meteorological, and metropolitan areas across the United States. Information is shared reciprocally with two additional sites (U.S. Navy and Sandia National Laboratory) that are not under Program contract.

The goals of the Site Operator Program include the field evaluation of EVs in real-world applications and environments; the advancement of electric vehicle technologies; the development of infrastructure elements necessary to support significant electric vehicle use; and increasing the awareness and acceptance of electric vehicles (EVs) by the public.

The current participants in the Site Operator Program and their locations are shown in Figure 1. In previous quarterly reports, a Table provided detailed information on several EVs that have been performance tested. (This testing is a cooperative effort between the U.S. Department of Energy and EVAmerica). The Table has been eliminated and the reader is directed to the Site Operator Program World-Wide-Web (WWW) internet Home Page for EV performance testing information. Additional information on the WWW site includes past quarterly reports, EV specifications, operations data captured by on-board data acquisition equipment, and database queries. The WWW address is http://ev.inel.gov

The Site Operator Program is managed by personnel of the Electric and Hybrid Vehicle Program at the Idaho National Engineering Laboratory (INEL). The current principal management functions include:

- Technical and financial monitoring of programmatic activities, including periodic progress reports to DOE.
- Data acquisition, analysis, and dissemination. The data from the Site Operators are made available to users through the INEL Site Operator Database at the WWW site and through this report.
- Coordination of Site Operator efforts in the areas of public awareness and infrastructure development (program-related meetings, and educational presentations).

This issue of the Site Operator Program Quarterly Report contains the following sections:

- A brief perspective of the Program history and goals
- A general discussion of EVAmerica performance testing results and an indication of performance testing trends over the years 1994, 1995, and 1996.
- A discussion about the Energy Economics of EVs in comparison to internal combustion vehicles
- The Site Operator Activities provide more specific information concerning the Program participants and their overall interests, their programmatic activities, and their experiences with EVs and accompanying problems. Detailed information on EV activities at each Site Operator include operations, maintenance, and EV tests of components.

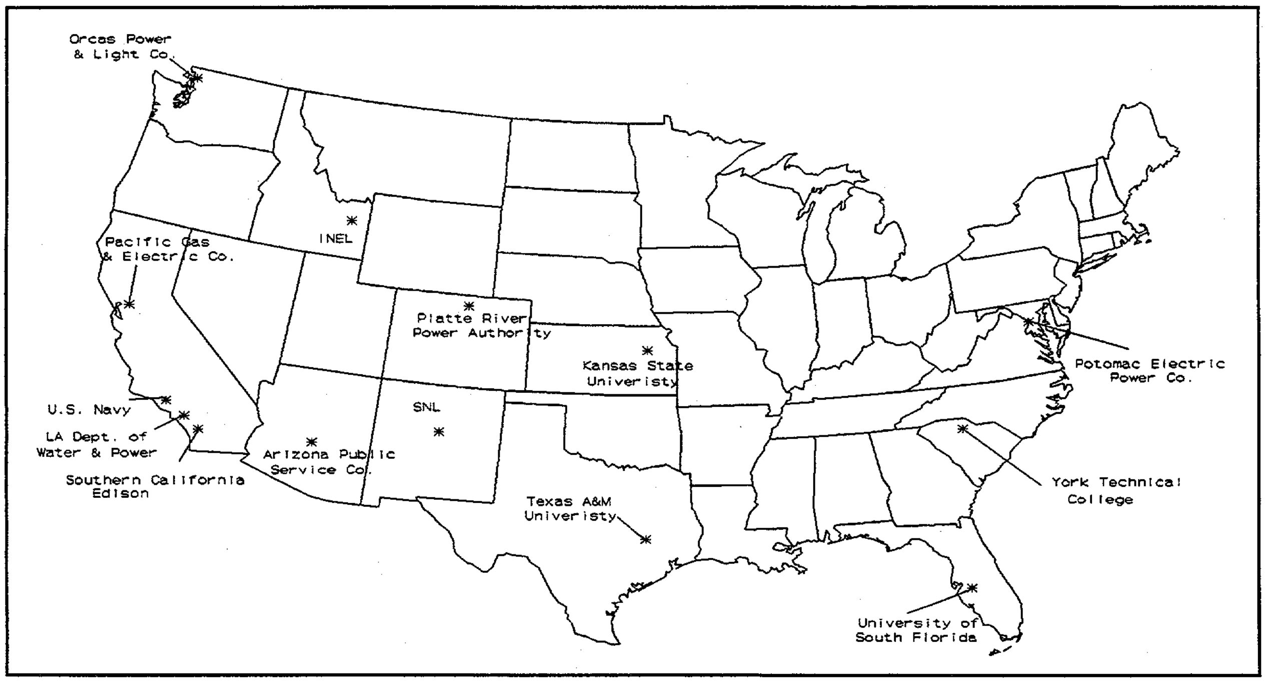

Figure 1. Site Operator Program participants.

Program Experience Overview

The Site Operator Program has evolved substantially since its inception in response to the Electric Vehicle Research and Demonstration Act of 1976. In its original form, a commercialization effort was intended but this was not feasible for lack of vehicle suppliers and infrastructure. Nonetheless, with DOE sponsorship and technical participation, a few results (primarily operating experience and data) were forthcoming.

In the early 1980s, DOE emphasis shifted to data collection and interpretation. A mechanism was set up to support participating sites. However, several problems soon became apparent:

- Too much data was required
- Data collection methods were primitive
- Data quality was suspect
- Database operation was ineffective.

The contract for the Program was transferred to the INEL in 1987 and the basic premises of the Program were refined subsequent to the INEL takeover, to emphasize the following efforts:

- Operating and maintenance data collection, analysis, and dissemination
- Public demonstrations to promote general awareness of this developing technology.

Both of these efforts have been fruitful. In particular, practical methods and equipment now exist for acquiring and handling operating data, with increasingly broad distribution of relevant information.

The current Program comprises eleven sites and over 250 vehicles, of which about 50 are latest generation vehicles. DOE partially funds the Program participant expenditures and the INEL receives operating and maintenance data.

As noted elsewhere in this report, participants represent several widely differing categories: electric utilities, academic institutions, and federal agencies. While both the utilities and the academic institutions tend to establish beneficial relationships with the industrial EV community. Program participant efforts reflect varying combinations of day-to-day use, laboratory testing and evaluation, and successful promotion of public awareness by demonstrations, exhibits, and media dissemination of related activities and information.

The utilities have been concerned with infrastructure needs for electric vehicle operation, particularly those required for battery recharging. Several candidate technologies have been investigated and developed for commercial use. In addition, the problems associated with operating and maintaining an EV fleet have been scoped and workable solutions devised and implemented.

The academic institutions and electric utilities have been productive beyond the original Program scope in the areas of:

- Charging methods, both curbside and solar
- EV performance testing results
- Vehicle operating data acquisition, via mobile data acquisition systems (MDAS)
- Training courses and related materials for maintenance personnel and operators
- Field testing of experimental or prototype vehicles and components.

The INEL has worked closely with Program participants to improve acquisition methods and data quality. The INEL has also established a central database and arranged for the dissemination of a spectrum of EV-related information. Through Program reports, INEL also gains a broad picture of the state of EV technology and accompanying public awareness.

Some tentative conclusions can be drawn about the current state of EV technology and operation:

- The industry is evolving as product offerings are becoming more technologically advanced.
- Product prices should decrease and the technology continue to increase as most of the major automakers have announced product offering schedules.
- The effects of climate are adequately documented by inputs from widely differing locations.
- Battery technology is a major limitation in achieving range and vehicle cost goals.
- Conversion of vehicles originally designed for internal combustion engine power can frequently severely reduce payload capability and the service life of key components.
- Charging hardware and software has advanced to the point that greater than 50% of a battery pack capacity can be recharged in minutes.

- Production of useful data may be limited where up-to-date equipment is not available. Some of the operating units monitored by the program are approaching a 20-year service life.

Several states (notably, California and Massachusetts) have or are considering regulatory mandates or voluntary agreements to increase the use of electric vehicles for environmental benefit. Their eventual effectiveness is dependent upon establishing a viable EV manufacturing industry and an adequate infrastructure for vehicle operation and service.

In the context of these requirements, several national organizations have joined DOE and the major auto manufacturers in promoting EV use, including:

- EVAmerica is a utility-led program intent on accelerating the development and introduction of electric vehicles into the marketplace. A key effort is performance and field test evaluation.

- DOE, the Department of Transportation, the Electric Transportation Coalition, and the Electric Vehicle Association of the Americas are conducting a series of workshops in ten Clean Cities to encourage urban groups to initiate the policies and infrastructure development necessary to support large-scale demonstrations, and ultimately the mass market use of electric vehicles.

- The Partnership for New Generation of Vehicles (PNGV) in America has been established as a joint Federal-Industrial-Academic effort to identify and evaluate vehicular transportation alternatives, including energy storage devices and alternative fuels.

Another organization, the Electric Vehicle Research Network, is an EPRI-sponsored group of 11 electric utilities who field test EVs, but are not Program participants.

A change of Program direction in the future is expected. Probable candidates for operator testing and data acquisition are hybrids, advanced EVs (i.e., designed as such rather than conversions), add-on or replacement key components (i.e., energy storage devices, system control, and driveline), and devices resulting from PNGV findings.

Electric Vehicle Performance Testing

The DOE Site Operator Program, in conjunction with EVAmerica, will be conducting EV performance testing during the current year, as well as having tested vehicles during the previous three years (1996, 1995 and 1994). Fourteen vehicles (Table 1) have completed testing to date, with the latest test vehicle being a General Motors EV1. The testing has been performed with stringent testing procedures and minimum qualification standards that vehicles must meet to be accepted for testing. These standards and procedures are intended to allow a vehicle-to-vehicle and year-to-year comparison of vehicle performances. Not only are performance trends established by using a standardized testing methodology, but more importantly, based on the results of this testing, potential fleet purchasers of EVs can now have greater confidence that his or her expectations of vehicle performance will be met if a vehicle passes the performance tests.

The average performance attributes for the two vehicles tested during 1996, the three vehicles tested during 1995, and the nine vehicles tested during 1994 are plotted below (Figure 2). The deltas (Figure 2) represent the increase or decrease in average performance for each of the three annual test groups. For instance, the first group of bars represent the average distance (in miles) achieved when running the vehicles around a test track at a constant speed of 45 mph; the results are grouped by the year they were tested. The 1995 test group saw a 27% increase in average mileage compared to the 1994 test group, while the 1996 test group experienced a 32% increase in mileage compared to the 1995 test group. The average range (82.6 miles) for the 1995 vehicles, when driven at a constant speed of 45 mph, increased by 27% compared to the 1994 test group (64.8 miles). The single vehicle maximum range at a constant speed of 45 mpg for the 1995 test group was 106 miles and the maximum for the 1994 test group was 88 miles for a single vehicle (Figure 3). The increase in range for the 1996 test group was primarily driven by the EV1, which went a total of 135 miles, while the Toyota RAV4 went a distance of 82 miles. Both of the 1996 tested vehicles used lead acid batteries while one of the 1995 vehicles used nickel metal hydride batteries which increased the average range for the 1995 test group.

The second set of bars in Figure 2 shows that the average range (50.8 miles) for the 1995 EVs driven at a constant speed of 60 mph increased 19% (Figure 2) compared to the 1994 test group (42.8 miles), while the 1996 vehicles went 31% further than the 1995 vehicles. Within the 1995 test group, the maximum individual vehicle range at 60 mph was 71 miles, while the 1994 individual vehicle maximum range at 60 mph was 57 miles (Figure 4), and the EV1 went 89 miles.

Table 1. Performance testing results from the Site Operator Program/EVAmerica 1996, 1995, and 1994 testing of electric vehicles. This is a partial list of testing results for the 14 vehicles tested during the three years. Some vehicles failed to complete some of the tests and this is noted. (Complete testing performance profiles for all of the vehicles can be obtained by accessing the Site Operator Internet home page at http://ev.inel.gov).

	Constant speed range		Acceleration 0 to 50 mph	Maximum Speed	Battery		Time to Recharge
	@ 45 mph (miles)	@ 60 mph (miles)	@ 50% SOC (sec)	@ 50% SOC (mph)	Manufacturer	Type	Hrs.Min
Vehicles tested during 1996							
General Motors EV1	135.2	89.1	6.7	80	Delphi	Valve regulated lead acid	5.18
1996 Toyota RAV4 EV	81.7	54.7	13.3	78	Matsushita	Valve regulated lead acid	8.47
1996 average performance	108.5	71.9	10.0	79			7.02
Vehicles tested during 1995							
1995 Solectria E-10 (1995 Chev. S-10 P/U)	80.8	49.9	17.4	68	Hawker	Sealed lead acid	11.11
1995 Solectria Force (1995 Geo Metro)	105.9	70.9	18.5	70	GM Ovonic	Nickel metal hydride	8.57
1994 Baker EV100 P/U (GMC full size P/U)	61.2	31.5	14.9	71	GM Ovonic	Nickel metal hydride	7.50
1995 average performance	82.6	50.8	16.9	70			9.19
Vehicles tested during 1994							
Solectria S-10 Pickup (Chevrolet S-10)	72.8	39.5	21.7	66	Hawker Energy	Sealed lead acid	6.52
Solectria Force (Geo Metro)	49.5	26.6	21.5	70	Hawker Energy	Sealed lead acid	3.54
US Electricar Pickup (Chevrolet S-10 Pickup)	70.7	47.3	20.1	71	Hawker Energy	Sealed lead acid	15.40
US Electricar Sedan (Geo Prizm)	59.3	41.5	16.2	81	Hawker Energy	Sealed lead acid	8.12
BAT International Pickup (Ford Ranger)	55.4	44.0	not achieved	not achieved	Trojan	Flooded lead acid	not available
BAT International Metro (Geo Metro)	88.4	51.6	26.0	67	Trojan	Flooded lead acid	10.40
BAT International Metro (Geo Metro)	47.1	39.6	16.5	81	Optima	Prototype deep cycle	not available
Dodge Caravan (Dodge Caravan)	86.4	57.0	33.9	62	Picher	Nickel iron	5.07
Unique Mobility Pickup (Ford Ranger)	53.5	38.3	30.3	70	Optima	Prototype deep cycle	10.50
1994 average performance	64.8	42.8	23.3	71			8.45

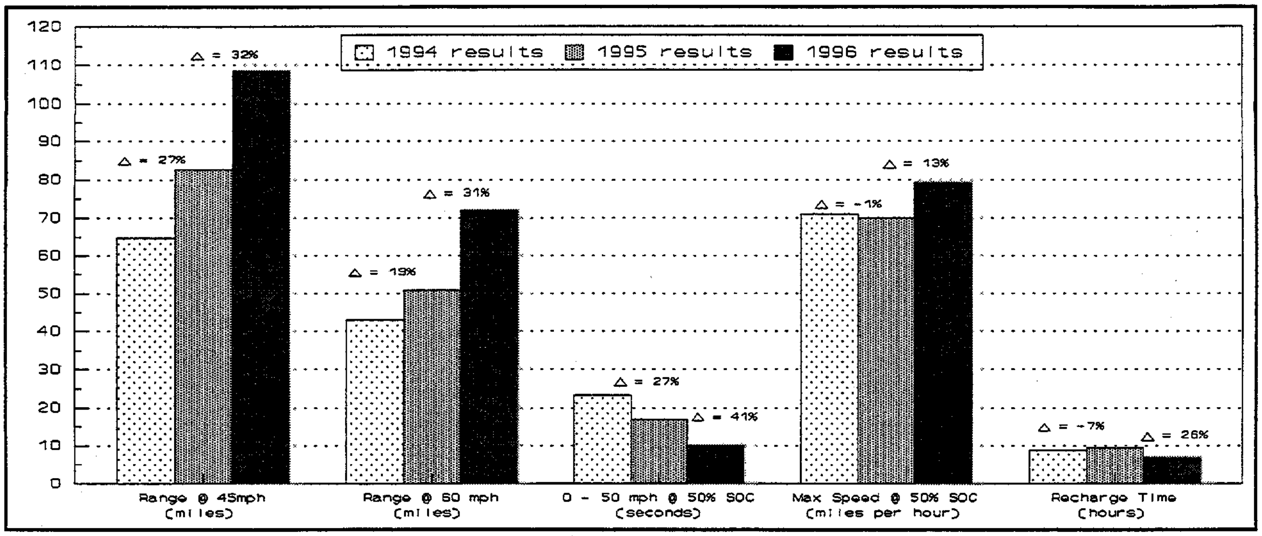

Figure 2. Site Operator Program and EVAmerica performance trends for 1996, 1995 and 1994 tested electric vehicles. The average test results for each group of vehicles are plotted, and the listed variances are the deltas between the group averages.

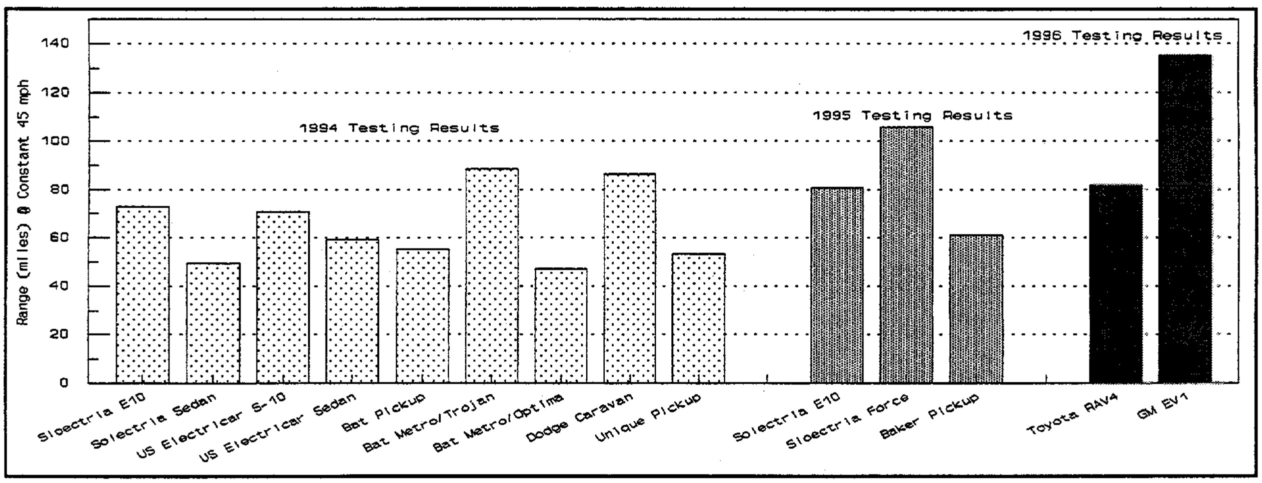

Figure 3. Per vehicle range (miles) results for constant speed tests at 45 mph.

Acceleration tests from zero to 50 mph (Figure 2, third set of bars), performed at a state of charge of 50%, were performed on the 1996, 1995 and 1994 EVs. The 1995 EVs, as a group, accelerated on average 28% faster (16.9 seconds) that the 1994 group (23.3 seconds), while the 1996 vehicles accelerated 41% faster (10.0 seconds) than the 1995 group. The single fastest acceleration time for the 1996 test vehicles was 6.7 seconds, for the 1995 test vehicles it was 14.9 seconds, and for the 1994 group the fastest acceleration time of 16.2 seconds. Two of the 1994 vehicles took over 30 seconds to accelerate to 50 mph (Figure 5).

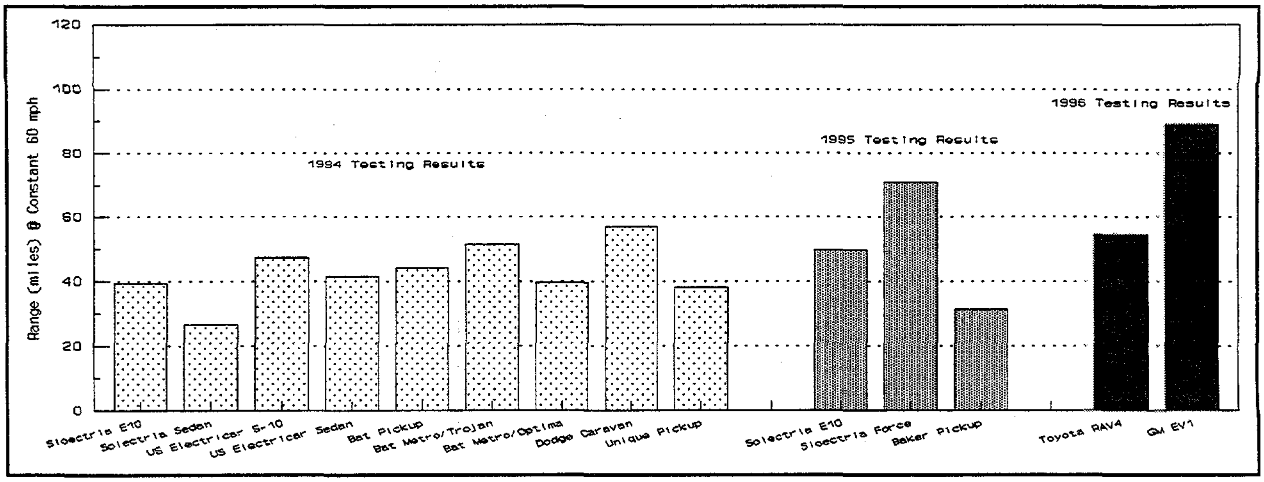

Figure 4. Per vehicle range (miles) results for constant speed tests at 60 mph.

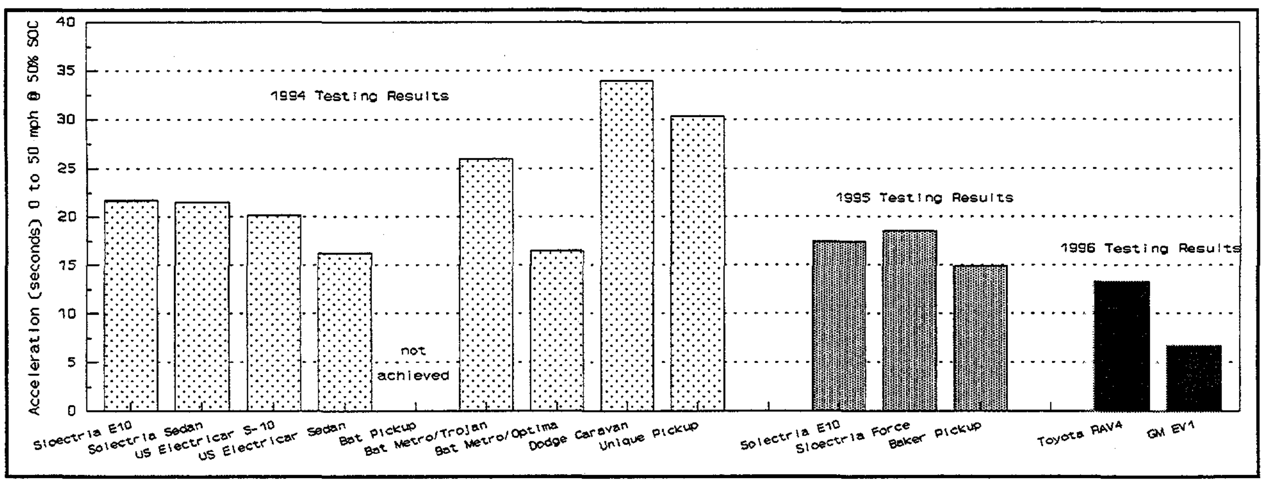

Figure 5. Acceleration (seconds) test results for zero to 50 mph acceleration at 50% state of charge.

The 1995 vehicles, as a group, displayed a 1 mph slower average maximum speed than the 1994 test group (Figure 2, fourth set of bars). However, this slight (1.4%) decrease in speed may be acceptable given the previously discussed significant increases in range and acceleration. Also, the 1995 test group had all of their maximum speeds within 2 mph of the average, while two of the 1994 test vehicles were more than 5 mph below the average, and three of the 1994 test group EVs failed to reach the performance goal of 70 mph for maximum speed (Figure 6).

The charging results for the two groups indicated that 6.5% more time was required by the 1995 test vehicles to recharge their batteries than the 1994 test group. This increased recharge time, which translates to an average total time to recharge of 9 hours and 19 minutes for the 1995 group, is 34 minutes longer than the 1994 group (Figure 2, fifth set of bars). This increase in charging time should be considered in the context that the 1995 vehicle group included one vehicle equipped with Nickel Metal Hydride batteries. The Nickel Metal Hydride batteries generally have higher energy storage capabilities, providing the enhanced range results. As a generally newer and more advanced battery than the lead acid batteries mostly used by the 1994 test group, the charging methodologies used to charge the Nickel Metal Hydride batteries may not have been as advanced as those for the lead acid batteries and this may be a reason for the longer recharging times exhibited by the 1995 test group. The 1996 vehicles recharged 26% faster than the 1995 rate. The General Motors EV1 recharged in five hours and 18 minutes (Figure 7).

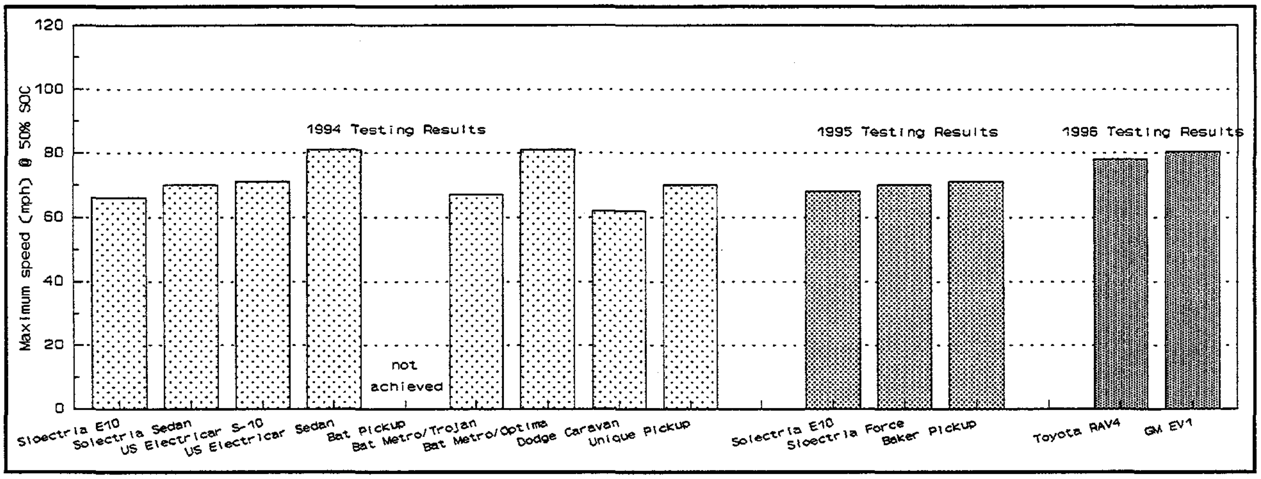

Figure 6. Maximum speed (mph) achieved by each vehicle when testing at a 50% state-of-charge.

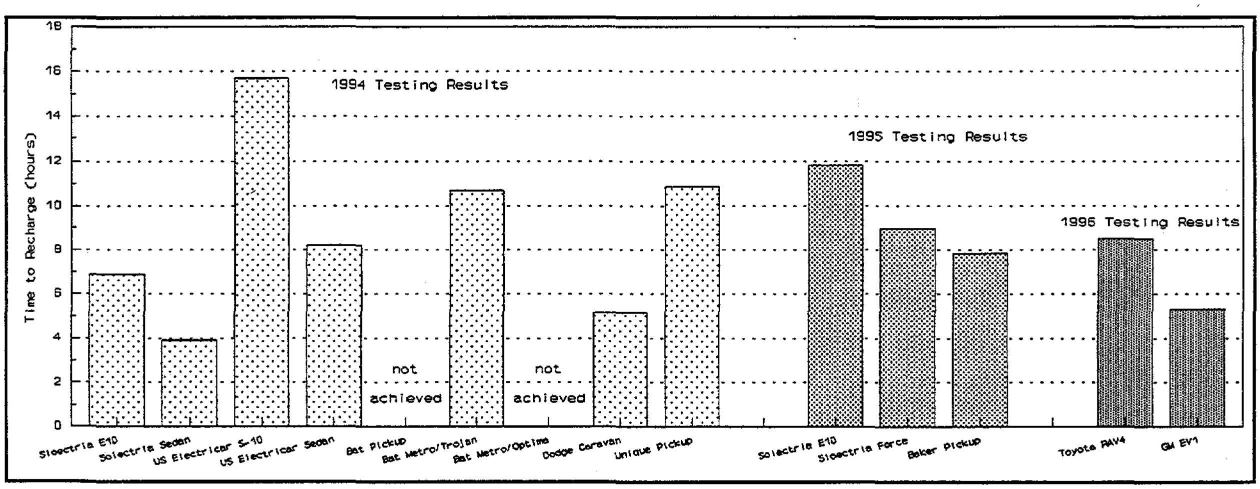

Figure 7. Time (in hours) to recharge each vehicle's battery pack.

The Society of Automobile Engineers standard practice J1634 was used to examine the driving cycle energy efficiencies of the 14 vehicles. The energy efficiency, on a mile per kWh basis, ranged from just over 2 miles/kWh for several vehicles to over 6 miles/kWh for one of the 1996 test vehicles (Figure 8).

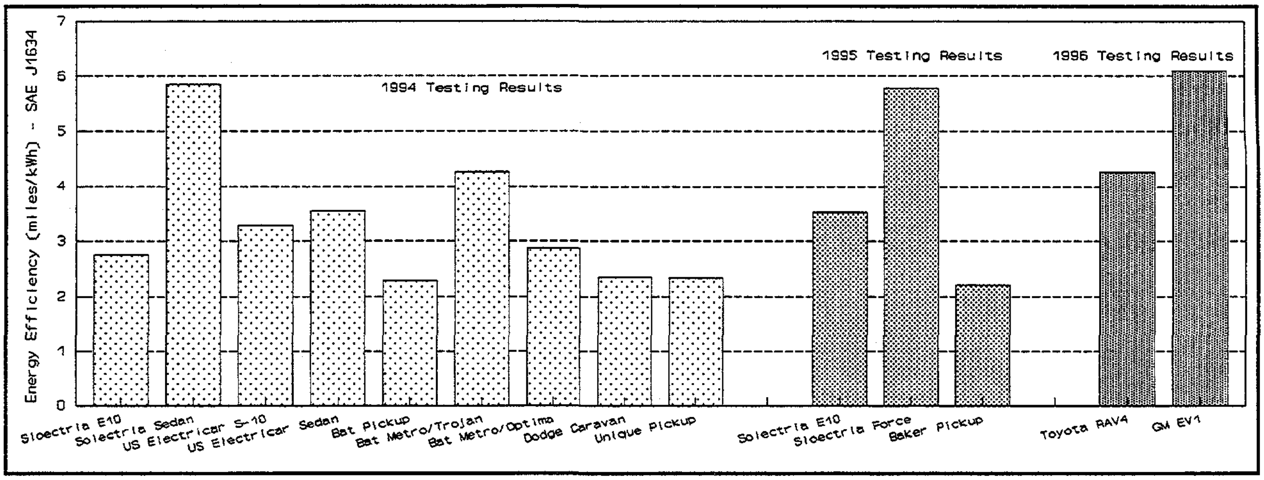

Figure 8. Driving Cycle energy efficiency (miles/kWh) of each vehicle. SAE J1634 standards used to define the driving cycle.

Energy Economics of Electric Vehicles

This section takes a look at the energy economics of EVs and how they compare to the energy costs of vehicles fueled by internal combustion engines (ICE). The energy costs are discussed for seven types of vehicles: three gasoline-powered ICEs that get respectively get 18 miles per gallon (mpg), 24 mpg, and 30 mpg; and four electric vehicles that respectively go three, four, five and six miles per kWh of electricity. The last Site Operator's Quarterly Report originally touched on this subject, but this discussion has been expounded, with dynamic comparisons of electricity efficiencies and variable fuel costs (for electricity on a per kWh basis and for a gallon of gasoline). The use of an ICE that gets 18 mpg has been included as this is the ICE pickup type of vehicle that a utility would most likely replace with an EV pickup or minivan from General Motors, Ford, Chrysler, or a vehicle converter. An EV what gets 3 miles per kWh has also been included, given that this is probably the bottom range for energy efficiency that a new EV pickup/minivan would experience.

While there are other variables that affect the total life-cycle costs of EVs, only the energy costs are examined here. It is acknowledged that other costs, such as the initial capital costs of the vehicle and a charger (if off-board), minus any applicable tax deductions or tax credits, can have significant impacts on total life-cycle costs. However, many of these cost comparison questions are difficult to quantify for EVs. For instance, should the cost of GM's EV1/Impact be compared to an ICE that has similar range, or similar luxury (like a Lexus?), or similar handling and acceleration (like a Porsche?). Capital and/or leasing costs will be examined in future Quarterly Reports when the capital/leasing costs to obtain an EV from original equipment manufacturers are better quantified.

Assumptions

In order to perform the energy economics comparison, several assumptions must be employed and these assumptions can generate controversy, as not all are willing to accept the same set of assumptions. To mitigate this potential controversy, the assumptions used are clearly stated and hopefully reasonable.

- An Energy Information Agency publication[1] (*Alternative to Traditional Transportation Fuels*) lists the 1992 United States automobile mpg value of 21.6 mpg, with this value historically increasing at an average annual rate of 2.6% per year for the previous 19 years. This equates to a calculated 1996 rate of 23.9 mpg. However, it is assumed that the newer ICE vehicles would have a higher value. For this reason the value of 30 mpg is included. However, utility use vehicles can include low mpg characteristics, so the

[1] Energy Information Administration. *Alternative to Traditional Transportation Fuels*. June 1994. Table 13. U.S. Department of Energy. Washington, D.C.

24 mpg and 18 mpg ICE vehicle profiles are included.

- An EV baseline efficiency value of 4.0 miles/kWh is assumed for the analysis. There is no strong historical basis for EV fleet efficiency, given the continuous increases in EV technology over short periods of time and the relatively short history of OEM-built EV availability. However, some miles per kilowatt-hour information is available, including the GM EV1/Impact which exhibited an energy efficiency of over 6 miles/kWh in the SAE J1634 test performed by EVAmerica (Figure 8). With the exception of the Baker pickup (of which only a very limited number were built), the other four 1995 and 1996 EVAmerica performance tested EVs all obtained greater than 3 miles per kWh. In fact, 8 of all 14 EVs tested by EVAmerica exceeded the 3 miles/kWh value, and 5 EVs exceeded 4 miles/kWh as did both of the 1996 test vehicles (Figure 8).

- The next assumption is the cost of gasoline. Based on the February twenty-third Lundberg Survey of 10,000 gas stations nationwide, the average pump price for gasoline was 119.13 cents. The prices for unleaded gas at self-serve pumps were 112.42 cents for regular, 122.64 for mid-grade, and 131.20 cents for premium. At full-service pumps, the nationwide average prices for regular, mid-grade, and premium unleaded gas were 149.01 cents, 157.87 cents, and 164.80 cents, respectively.[2] By June 7, the average reported price for all grades of gasoline had risen to 136.96 cents per gallon.[3] Additional media reports cited examples of gasoline approaching $2.00 per gallon. The analysis uses a cost of gasoline for an ICE as ranging between $1.15 to $1.82 per gallon.

- The cost of electricity may be the most difficult assumption to reach agreement on, given the many different rates by region, day-of-the-week, on-peak, off-peak, off-off-peak, partial peak, and other adjustable rates per kWh of use. However, the national average for residential customers is known, and through December of 1995, the kWh rate for the year was averaging about 8.5 cents/kWh.[4] During the month of December 1995, the per kilowatt-hour rate in the United States ranged from about 14 cents in New Hampshire to 4.5 cents in Washington State. The California average was about 11.5 cents/kWh. All of these rates are residential, which assumes at home charging. The other types of rates include commercial (7.75 cents/kWh), industrial (4.73 cents/kWh), and others (6.70 cents/kWh). The "others" category includes street lighting, railroads, and sales to other public authorities. As previously mentioned, an additional complication is the range of variable kWh rates by time-of-day, and these rates can range from 3 cents to over 30

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[2] Idaho State Journal, February 26, 1996, P B4, *Biz Briefs: Gas Prices Jump Again, Up 1.5 cents*, Pocatello, Idaho.

[3] Idaho State Journal, February June 11, 1996, P B4, *Biz Briefs: Average Gas Price Up 1.62 cents*, Pocatello, Idaho.

[4] Energy Information Administration. *Electric Power Monthly*. January 1996. Table 60. U.S. Department of Energy. Washington, D.C.

cents/kWh for residential EV consumption in California. Because of possible rates associated with different charging scenarios, a range of 3 cents to 40 cents per kWh is used for the analysis. Each of the four EVs, with energy efficiencies of 3, 4, 5 and 6 miles per kWh, use the 3 to 40 cents per kWh range in the analysis.

Results

While it is possible to equate the heat (Btu) content of a kWh and a gallon of gasoline, it is less complicated to simply divide the cost per gallon ($1.15 to $1.82) of gasoline by the number of miles per gallon, and to divide the cost per kWh by the number of miles per kWh to get fuel costs on a per mile basis. This is done and graphed (Figure 9) for comparison purposes. To understand the relationships between the costs, the graph is read as follows.

- The solid vertical line labeled "24 mpg $1.30 per gallon" represents the fuel cost per mile for a gasoline powered vehicle that gets 24 mpg and uses gasoline priced at $1.30 per gallon. At $1.30 per gallon, the per mile energy cost is determined by where the vertical line bisects the bottom scale (5.4 cents per mile). The per gallon cost of gasoline uses the right scale (Gasoline cost per gallon). At $1.40 per gallon the per mile energy cost shifts to about 5.8 cents and at $1.50 per gallon the per mile energy cost is about 6.3 cents.

- The solid vertical line, labeled "4 miles/kWh @ 10 cents/kWh" represents the fuel cost per mile (2.5 cents) for an EV that has an energy efficiency of 4 miles per kWh and a fuel cost of 10 cents per kWh. To read the graph, find the point at which the 4 miles/kWh line bisects 10 cents per kWh (left scale), follow the vertical line down to the Energy cost per mile X-axis (2.5 cents per mile). At 5 cents per kWh (left scale), the per mile energy cost (bottom scale) is about 1.3 cents per mile; at 20 cents per kWh, the per mile energy cost is about 5 cents; and at 30 cents per kWh, the per mile energy cost is about 7.5 cents.

- The other lines can be read in a similar manner to determine the fuel costs per mile. For instance, the line labeled "5 miles/kWh," represents the fuel cost per mile for an EV that has an energy efficiency of 5 miles per kWh. Using the left scale (Electricity cost per kWh), one can compare the electricity cost per kWh and the cost per mile. At 5 cents per kWh (left scale), the per mile energy cost is 1 cent (bottom scale); at 10 cents per kWh, the per mile energy cost is 2 cents; and at 15 cents per kWh, the per mile energy cost is about 3 cents.

The reader can compare the per mile energy costs for EVs and ICEs for each of the energy efficiencies and at various energy costs. For instance, the 24 mpg ICE profile, at $1.40 per gallon, has a per mile gasoline cost of about 5.8 cents. Using the national average cost of about 8 cents for a kWh of electricity, the 4 miles per kWh EV has an energy cost of 2 cents per mile; significantly lower than the ICE vehicle. To further the discussion, the 4 miles/kWh EV will always have lower per mile energy costs than the 24 mpg ICE vehicle when the cost of electricity is lower than 21 cents per kWh and the cost of gasoline is at $1.30 per gallon or higher. If the EV owner has the option of charging her EV at night with California off-peak charging rates under 4 cents per kWh, the cost per mile for electricity is about 1 cent for all four EVs.

As seen in the graph (Figure 9), the per mile cost to fuel an EV can be significantly lower than the cost to fuel an ICE. The consumer has the ability to control his/her behavior to fuel the EV, provided of course that the consumer does not try to exceed the vehicles's maximum range on any given day. Attempting to exceed the vehicle's range would likely require on-peak refueling at a public recharging station. Such recharging could include the use of more expensive peak-energy costs, as well as a payment to the charging station for this convenience.

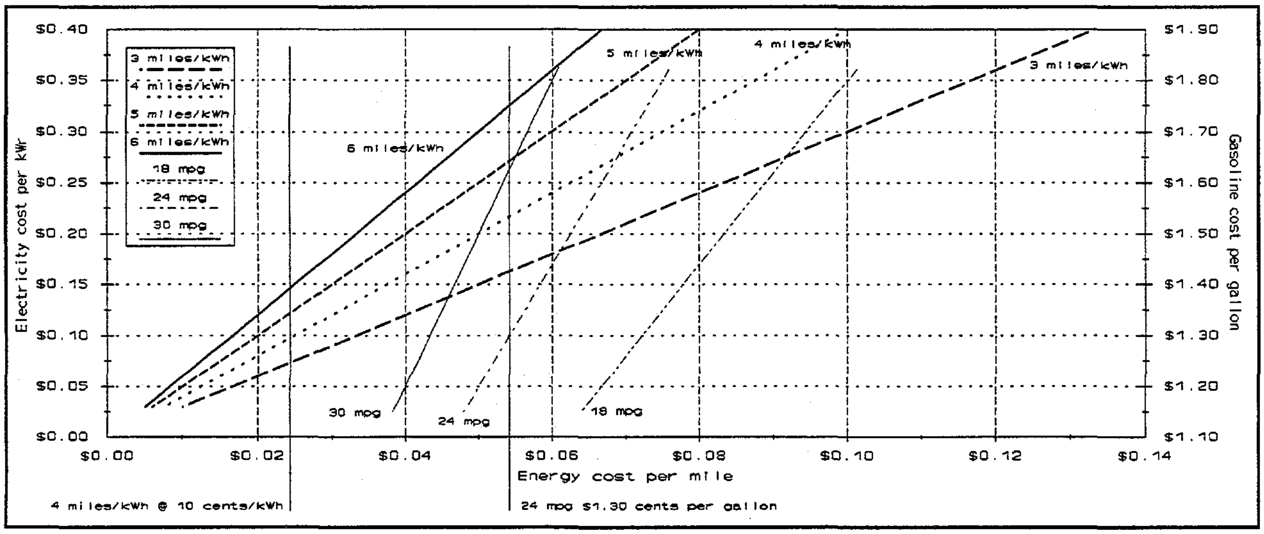

Figure 9. Comparison of the fuel cost per mile for a gasoline fueled vehicle, and the fuel cost per mile for an electric vehicle (EV) at varying kilowatt-hour energy rates and EV efficiency rates of 4 miles/kWh, 5 miles/kWh, and 6 miles/kWh.

Other EV cost factors to be considered include the cost to replace the battery pack, the initial capital cost of the vehicle, tax incentives, and the avoidance of ICE costs that EVs do not incur. These avoided costs include the 3,000 mile oil changes, the replacement of the muffler system, timing belt replacements, tune ups, changing the antifreeze and fuel filter, and other miscellaneous costs. Of course EVs will have maintenance costs that are unique to EVs. Future Quarterly Reports will attempt to examine these issues and compare the cost tradeoffs. It may be difficult to quantify some EV benefits, including the noise and pollution reductions, and the shifting away from dependence on foreign fossil fuels that will someday prove to be of a finite quantity.

Site Operator Activities

This section contains an overview of the activities at each of the eleven Site Operators, the U.S. Navy, and Sandia National Laboratory. The Site Operator Participants, the U.S. Navy, and the Sandia National Laboratory currently employ a total of 257 vehicles (Figure 10) that constitute a variety of models, manufacturers, and converters (Figure 11). Table 2 contains a listing of the types of vehicles at each of the Site Operators. The EV operations, maintenance, and performance data presented for the site operator vehicles is for the January, February, and March 1996 period, unless otherwise noted.

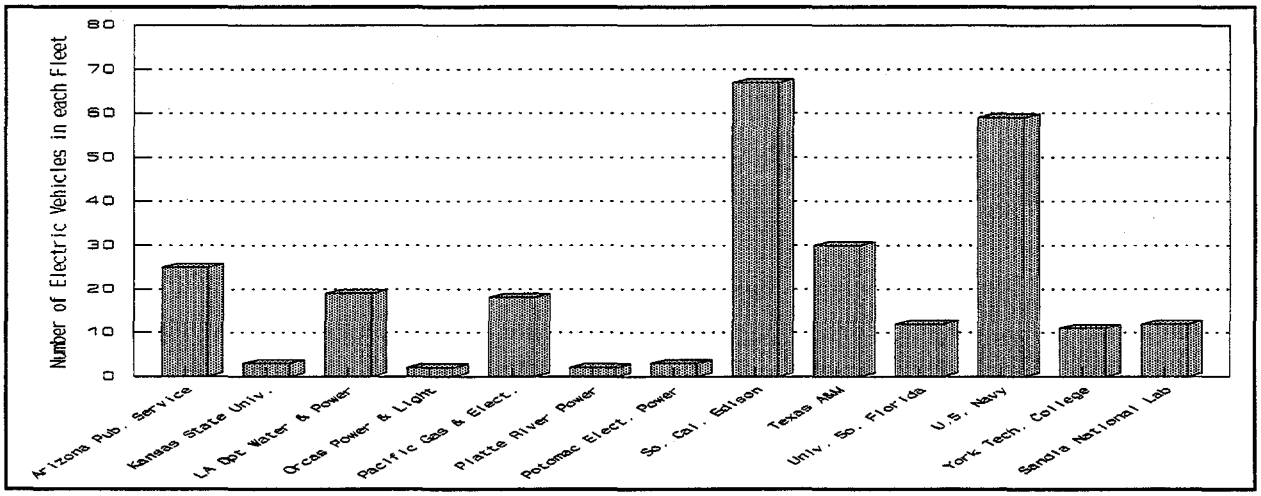

Figure 10. Number of vehicles by Site Operator.

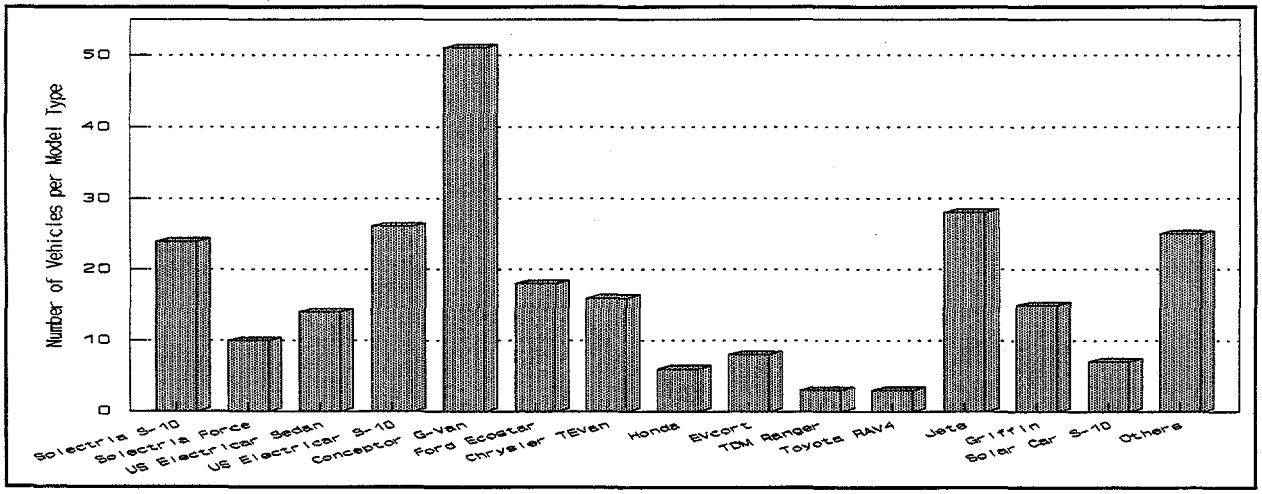

Figure 11. Number of vehicles by model/manufacturer/converter.

Table 2. Site Operator Program vehicle fleet.

Arizona Public Service Company

Conceptor G-Van	4 ea.
Spartan/GE S-10	1 ea.
Chrysler TEVan	1 ea.
Solectria Force	2 ea.
Solectria S-10	6 ea.
DTS S-10	1 ea.
Brawner Motorsport S-10	1 ea.
US Electricar S-10	3 ea.
TOTAL	19

Kansas State University

EVcort sedan	2 ea.
TDM Ford Ranger	1 ea.
	3

Los Angeles Department of Water and Power

Conceptor G-Van	6 ea.
Unique Mobility van	1 ea.
Chrysler TEVan	4 ea.
US Electricar S-10	4 ea.
US Electricar sedan	4 ea.
TOTAL	19

Orcas Power and Light Company

Jet Ford Escort	1 ea.
Solectria Force	1 ea.
TOTAL	2

Pacific Gas and Electric Company

Conceptor G-Van	3 ea.
Honda	3 ea.
Toyota RAV4-EV	1 ea.
Ford Ecostars	5 ea.
Kewet El Jet	1 ea.
US Electric S-10	5 ea.
TOTAL	18

Platte River Power Authority

Soleq EVCORT sedan	2 ea.
TOTAL	2

Potomac Electric Power Company

Solectria S-10	3 ea.
TOTAL	3

Sandia National Laboratory

Jet Electricas	12 ea.

Table 2. (continued)

Southern California Edison Company

Conceptor G-Van	13 ea.
Solectria Force	5 ea.
Ford Ecostar	13 ea.
Solectria S-10	2 ea.
US Electricar S-10	10 ea.
BAT Metro sedan	1 ea.
BAT Ranger pickup	1 ea.
US Electricar sedan	10 ea.
Chrysler TEVan	2 ea.
Honda CUV-4 sedan	3 ea.
TDM Ranger	2 ea.
Toyota RAV4	2 ea.
Nissan AVENIR (Sedan)	1 ea.
AC Propulsion (Honda)	1 ea.
Venus Ranger	1 ea.
TOTAL	67

Texas A&M University

Conceptor G-Van	15 ea.
Jet Ford Lynx	1 ea.
Chrysler TEVan	9 ea.
Solectria Force	1 ea.
GM Opal	1 ea.
US Electricar S-10	3 ea.
TOTAL	30

U.S. Navy

Jet	16 ea.
Griffin	15 ea.
Solectria S-10	13 ea.
Conceptor G-Vans	7 ea.
Taylor Dunn	1 ea.
Manufacturer not known	5 ea.
Shuttle Bus	2 ea.
TOTAL	59

University of South Florida

Conceptor G-Van	2 ea.
Solar Car Corp. S-10	7 ea.
Florida Power S-10	2 ea.
Mitsubishi Mirage	1 ea.
TOTAL	12

York Technical College

Conceptor G-Van	1 ea.
Jet Escort Sedan	3 ea.
Unique Sedan	1 ea.
US Electricar S-10	1 ea.
Bear Skin Escort	1 ea.
Volkswagen Pickup	3 ea.
Solectria Force	1 ea.
TOTAL	11

(York maintains for others - 6 EVs

Total All Sites 257

Arizona Public Service Company

Arizona Public Service (APS) maintains and operates 19 electric vehicles of various types (Figure 12) in its EV Program. During this reporting period, APS retired two Unique Mobility sedans, one Solar Car sedan, and three Soleq EVCort sedans. One of APS's G-Vans is operated by the City of Phoenix and another is operated by the City of Scottsdale. The remaining 17 EVs are operated by APS in the Phoenix area. Both passenger and cargo vehicles are represented. While some of the vehicle usage is demonstration, often under loan or lease arrangements, the main objective is to test and evaluate the viability of electric vehicles, and to collect operation, maintenance, and battery data in everyday utility use. Technical information is coordinated and exchanged by Electric Transportation Applications with DOE, INEL, Potomac Electric Power Company, EVAmerica, Solectria, Hughes, Hawker Energy, Norvik, GM Ovonics, the Advanced Lead-Acid Battery Consortium, GNB, and the Electric Power Research Institute (EPRI).

Technical

Since 1979, APS has logged over 666,000 miles on their EVs as part of the Site Operator Program. During the January, February, and March quarter, the APS fleet was driven 22,184 miles. The eleven vehicles in APS's "new" fleet were driven between 500 and 3,500 miles each (Figure 13) during the reporting period. The "new" fleet per vehicle availability ranged as high as 100% for the reporting period (Figure 14). The pack mileage (Table 3) ranges from zero to over 10,000 miles. The maintenance requirements for the "new" fleet vehicles are discussed below.

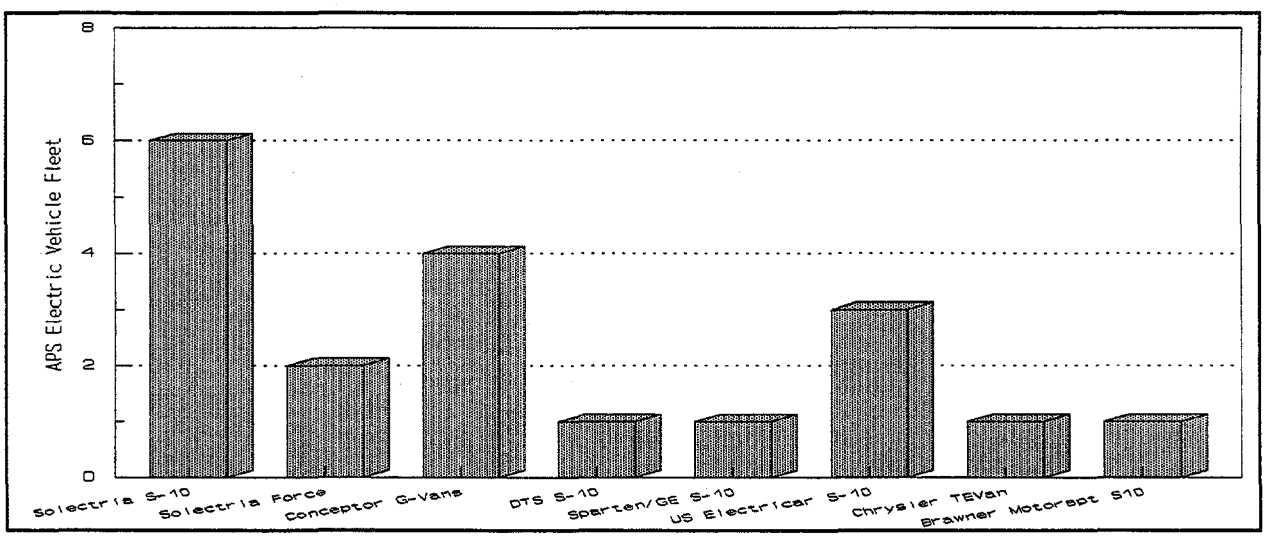

Figure 12. Number and types of vehicles in the Arizona Public Service electric vehicle fleet.

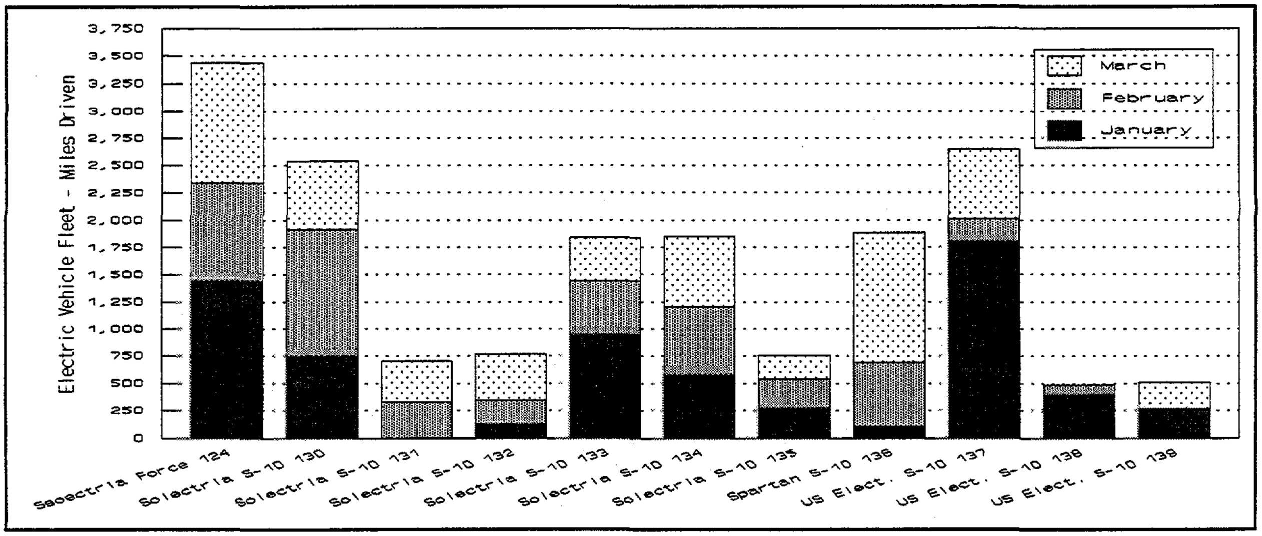

Figure 13. Miles driven by the "new fleet" vehicles in the Arizona Public Service electric vehicle fleet.

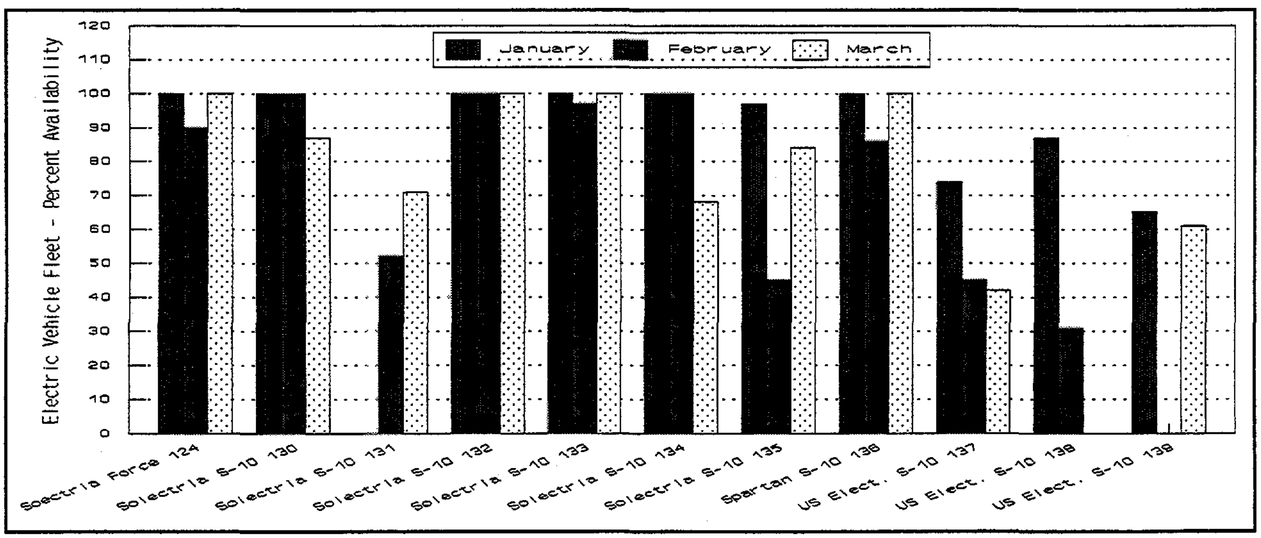

Figure 14. Percent availability of the "new fleet" vehicles in the Arizona Public Service electric vehicle fleet.

The time required, and the types of fleet maintenance, upgrade requirements, and testing performed on APS's "new fleet" EVs during the reporting period are listed below by their APS vehicle numbers.

- APS #124 - Vehicle recall on the motor controller, a potentiometer kit was installed; and a 60 mph range test performed -- no loss of availability. Warranted replacement of the charger and a battery module; and replacement of battery vent

O-rings -- three days of lost availability.

- APS #130 - Vehicle recall on the motor controller, a potentiometer kit was installed; and two 60 mph range tests performed -- no loss of availability. Four days were used to install an E-Meter, fix a power steering outage, and check the A/C, charger program, and noise.

- APS #131 - 131 was not available for 65 days for vehicle upgrades to install a Norvik quick charging port, install a Hughes port, install a charge/off/run switch and plugs and install a new E-Meter. A potentiometer kit was installed with no lost days. The defective battery pack was replaced and the installation of 4 thermocouplers required 4 days. Upgrades, requiring 9 days, included the instrument fault, E-Meter, tinted windows, and a tool box; broken wires on the DC/DC converter were also replaced during this period.

- APS #132 - A potentiometer kit was installed with no lost days.

- APS #133 - A potentiometer kit was installed with no lost days. Warranty work was performed that resulted in the loss of one day of availability. The warranty work was the removal of the 3 kW charger (returned to manufacturer) and the installation of new brushes in the A/C motor.

- APS #134 - A potentiometer kit was installed with no lost days. Ten days of availability was lost for upgrades that included installing an E-Meter, charger removal, installing thermocouple wires, and charging system reprogramming.

- APS #135 - A potentiometer kit was installed with no lost days. A radio was installed that required a single day. Upgrades, that required 16 days (7 days waiting for labor and parts), were performed that included low voltage rewiring and the addition of a 3-way charge switch, replacing fuses, repairing a turn signal and braking light, and the installation of a Hughes charger port and an E-Meter. Additional upgrades, requiring 5 days of lost availability, included checking the A/C brushes, replacement of the power steering unit, and the upgrading of the Hughes charger program.

- APS #136 - Four days were lost replacing the 12 volt battery, replacing the Norvik ID with a new profile, replacing the L.E. meter and shunt, replacing unidentified batteries, and the replacement of one failed module.

- APS #137 - During January, eight days were required for the replacement of 4 modules, modification to a shunt cable and mount, the installation of a transmission shim kit, and the replacement of the motor and transmission. An additional 16 days of availability was lost in February were lost to replace 2 modules, the replacement of 54 modules, replacement of the controller and heater, and the installation on an E-Meter. During March, 18 days were lost replacing 2 modules, installing a new main DC conduct 7 wiring, and the replacement of the A/C relay.

- APS #138 - During January, 4 days were lost replacing the controller, Hughes charge port, and kilovac relay, and the installation of a transmission shim kit. During February and March, 51 days were lost for battery pack replacement.

- APS #139 - During the reporting period, a total of 52 days were lost for the installation of a transmission shim kit, replacement of three batteries, the addition of torque washers to all of the batteries, and the replacement of the battery pack, replacement of the motor, transmission, heater, vacuum pump, and norvik charger. An E-Meter, Norvik quick charger, a battery box, and a pack disconnect were installed.

Table 3. Battery pack type in the eleven "new fleet" Arizona Public Service electric vehicle fleet. Some of the battery packs have been replaced during the reporting period.

	Battery	Pack miles	Installed date	Modules replaced
Solectria Force APS #124	Ovonic NiMH	7,369	Oct-95	1
Solectria S-10 APS #130	Hawker	5,479	Oct-95	0
Solectria S-10 APS #131	Hawker	278	Feb-96	0
Solectria S-10 APS #132	Hawker	1,383	Oct-95	0
Solectria E-10 APS #133	Hawker	10,659	Jan-95	5
Solectria E-10 APS #134	Hawker	5,873	Jan-95	0
Solectria E-10 APS #135	Hawker	751	Dec-95	0
Spartan S-10 APS #136	GNB	2,621	Sept-95	1
US Electricar APS #137	Hawker	765	Feb-96	2
US Electricar APS #138	Hawker	0	March-96	0
US Electricar APS #139	Hawker	241	March-96	0

Kansas State University

The Kansas State University (KSU) Site Operator Program is conducted at Manhattan, Kansas, in conjunction with the Kansas Electric Utilities Research Program (KEURP). The KEURP effort is a contractual joint venture of the seven major electric utilities that serve the residents of the State of Kansas; its mission is to undertake applied research and development to enhance reliability and minimize the cost of electric service in Kansas. Several industrial organizations within the state provide technical and financial support to the KSU Electric and Hybrid Vehicle demonstration program.

The KSU Site Operator Program is currently based on two Soleq EVcort electric vehicles and a Troy Design and Manufacturing (TDM) EV conversion Ford Ranger. Use includes routine transportation by the Program and the Engineering Technology Department, under differing weather and driving conditions.

TDM, with assistance from KSU, has started construction of a plant to convert Ford Ranger (pickups) gliders into electric vehicles and other alternate fuel vehicles in Manhattan, Kansas. Kansas State University has entered into an agreement to assist TDM in supporting the infrastructure and technical development for these vehicles.

Technical

An EVcort, DOE number 151, was driven 300 miles during the reporting quarter (Table 4). Assuming a price of $0.056/kWh for electricity, and an equivalent 25 miles per gallon for an internal combustion engine 1993 Ford Escort, the cost of operating the EVcort on electricity equates to $0.90 per gallon of gasoline. Possession of the EVcort is to be transferred to WestPlains Energy, a utility company in Great Bend, Kansas, later in the year.

The second EVcort, DOE number 152, was driven 447 miles during the reporting quarter (Table 4). Assuming a price of $0.056/kWh for electricity, and an equivalent 25 miles per gallon for an internal combustion engine 1993 Ford Escort, the cost of operating the EVcort on electricity equates to $0.84 per gallon of gasoline. Kansas City Power and Light, a Kansas City, Missouri, utility company is scheduled to take possession of this vehicle later in the year.

The TDM/Ford Ranger was driven 2,190 miles during the reporting quarter (Table 4). Assuming a price of $0.056/kWh for electricity, and an equivalent 22.5 miles per gallon for an internal combustion engine 1996 Ford Ranger, the cost of operating the Ranger on electricity equates to $0.54 per gallon of gasoline.

Public Awareness

- Program personnel testified to the State Senate and House Committees on Commerce and Economic Development about participation in alternative fuel vehicle development activities.

- KSU's College of Engineering has decided to enter the 1997 Department of Energy Solar Car Challenge.

Table 4. Operations summary for Kansas State University's two Soleq EVcorts.

	Miles	Daily Miles	Number of charges	Miles per charge	kWh used	mi/kWh
EVcort # 151						
This quarter	300	6.0	50	6.0	306	1.46
Vehicle total	9182	16.3	585	16.3	5827	0.98
EVcort # 152						
This quarter	447	6.0	68	6.0	287	1.56
Vehicle total	3616	12.0	445	12.0	3611	1.0
TDM Ford Ranger						
This quarter	2190	27.0	82	27.0	920	2.38
Vehicle total	4387	27.0	154	27.0	1877	2.34

Los Angeles Department of Water and Power

The Los Angeles Department of Water and Power (LADWP) is a municipal utility serving the citizens of Los Angeles. LADWP marked its eighth year of involvement in aggressively promoting the electric transportation agenda of Los Angeles' overall air quality improvement program and as a means of improving the region's economic competitiveness through the creation of new industries. LADWP currently operates twenty electric vehicles (Figure 15). LADWP's electric transportation program extends beyond vehicle deployment to include infrastructure, public transit development, public education and awareness, and regulatory activities.

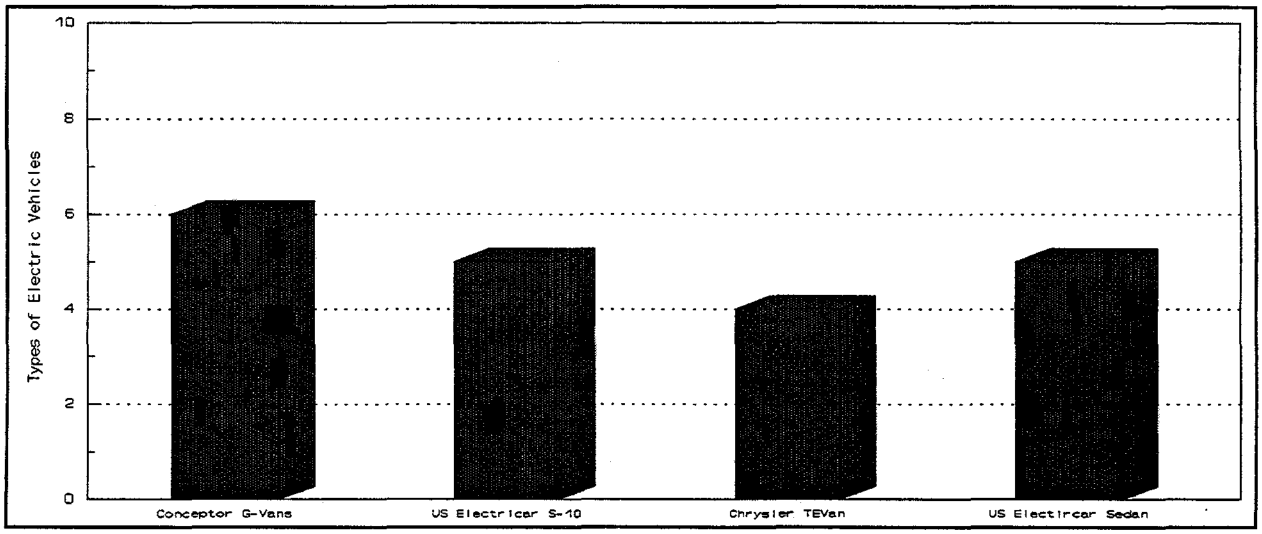

Figure 15. Number and types of vehicles in the Los Angeles Department of Water and Power electric vehicle fleet.

Technical

US Electricar S-10 Pickups. Tests performed on the five pickups continued to show a range of 55 to 60 miles under normal operating conditions. Some battery degration has occurred, resulting in reduced range. A complete charge takes approximately 21 kWh of energy and about seven hours. The pickups logged 1,169 miles during the reporting quarter. Several issues were addressed with the pickups, including:

- The decision was made to install hardcards on the MDAS data acquisition systems installed in some of the vehicles, to replace the often unreliable floppy discs for data storage

- A five speed manual transmission was installed in a second S-10, which has dramatically improved performance.

- Some vehicles experienced problems with prematurely drained auxiliary batteries during periods of non-operation.

Chrysler TEVans. A total of 1,802 miles were logged during the reporting period by the four TEVans. Several problems were encountered and fixed, including:

- Continuing problems with the transmission shifting systems

- Leaking battery watering systems requiring repairs

- Inaccurate state of charge gauges which results in low-battery indication

- Difficulties in starting some vehicles due to faulty connections

US Electricar Sedans. These five vehicles continued to maintain a 50 to 55 mile range under a variety of driving conditions. A full charge continues to take 6 to 8 hours and require 17 kWh of energy. The sedans logged 1,733 miles during the reporting quarter. One of the sedans is used as an employee car pool vehicle and the other four vehicles are used for fleet applications. The sedans had the following maintenance activities:

- Unexpected fault conditions caused a vehicle to suddenly lose power while in operation, requiring adjustments of controls

- Battery pack degradation caused the range on some of the sedans to be less than 40 miles until defective batteries were replaced.

Other Electric Vehicles. LADWP continued to support the maintenance and operation of six G-Vans. Two of the G-Vans are being operated at Los Angeles International Airport (LAX), and four are operated in LADWP's fleet. The Unique Mobility minivan is still not operational.

LADWP continued to support the operation of three 22-foot electric shuttle buses in the San Pedro Harbor area and one 31-foot electric bus at LAX. During the January, February and March reporting quarter, the three 22-foot shuttle buses consumed a total of 7,544 kWh of energy, logged 6,217 miles, and carried 12,089 passengers.

Public Awareness

Public awareness and education focused on several areas, including:

- Helping coordinate and facilitate the Los Angeles region "EV Ready" community Workshop Program to integrate activities throughout Southern California to make the entire region "EV-Ready"

- Helping to conduct outreach on Los Angeles' designation as the largest member of the national Clean Cities program, designed to create partnerships to increase the use of alternative fueled vehicles in the city.

- Distributing updated information on LADWP's infrastructure activities in the wake of General Motor's announcement that it would market a consumer-oriented EV starting in the fall of 1996

- Hosting a workshop for teachers on EV curriculum materials

- Continuing outreach to support existing electric public transit projects

Orcas Power and Light Company

The Orcas Power and Light Company (Orcas) of Eastsound, Washington, operates a Ford Escort EV that was converted by Jet Industries and a Solectria Force EV sedan. The Orcas electric utility serves customers in the islands of San Juan County, Washington. Orcas is actively encouraging EV ownership/operation by both public demonstrations and enlarging the necessary infrastructure with additional EV charging stations. San Juan County now has five public EV charge stations. There are a total of 13 EVs (11 private EVs + 2 Orcas EVs) operating in the county.

Technical

Orcas reports driving their two EVs a total of 216 miles during the reporting period. The milage efficiency for Orcas' Escort was 0.84 miles/kWh and for Orcas's Solectria Force the efficiency was 2.7 miles/kWh (Table 5).

Table 5. Orcas Power and Light Company's vehicle performance profile.

Vehicle	Total Miles Driven	Miles per day driven	Miles per month	Average kWh/mile	Average Miles/kWh
Ford Escort	41	6	37	1.19	0.84
Solectria Force	175	8.5	68	.37	2.7

Public Awareness

A research project, titled *Estimating the Potential for Electric Vehicles in Rural Cooperatives*, is being conducted by Q4 Associated for the National Rural Electric Cooperative Association. During October, survey materials and software were received at Orcas; the survey has been sent to 500 of Orcas' randomly selected accounts. It is expected that this survey will be well received and the response rate will be high, given the high visibility of EVs in San Juan County.

Orcas has ordered a booklet titled *Electric Vehicles: A Moving Story*, for dissemination to it customers. The booklets address various EV-related issues, including: how they work, performance, economics, reduced emissions and pollution, energy efficiency, batteries, reduced dependance on foreign oil, and battery and charging operations. The booklets direct the reader to obtain additional information about EVs from various national organizations such as the Edison Electric Institute.

Pacific Gas and Electric Company

Pacific Gas and Electric Company (PG&E), a public utility based in California's Bay Area, currently has 18 vehicles in its fleet of EVs (Figure 16) and they continue to be used extensively (Figure 17) in day-to-day operations. PG&E has built a strong EV program that addresses:

- Vehicle development and demonstration
- Infrastructure
- Public education
- Commercialization groups

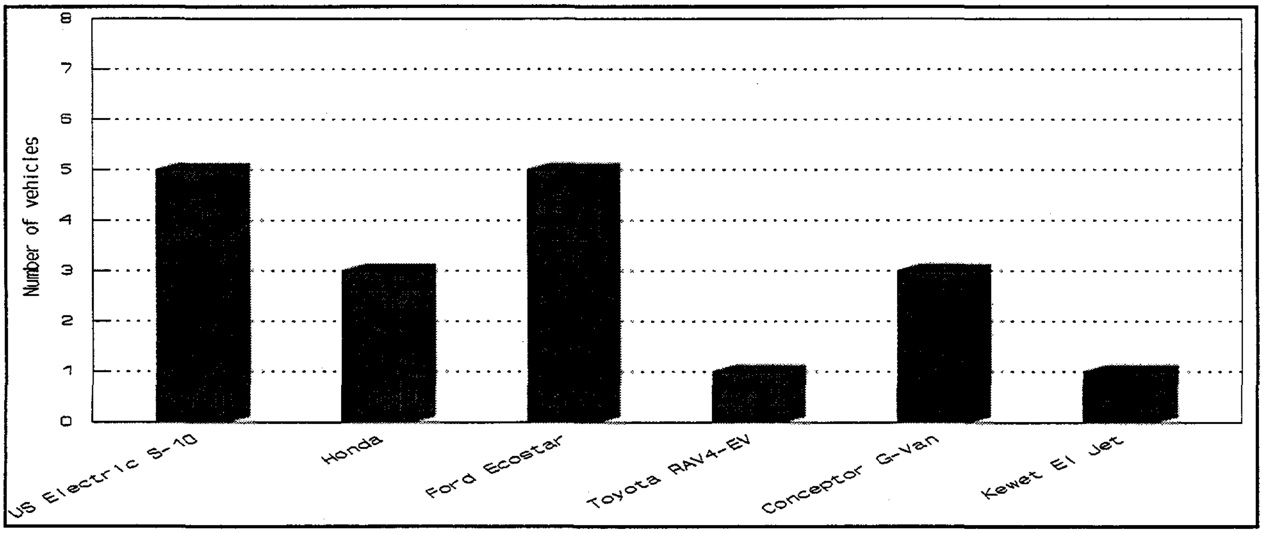

Figure 16. Number and types of vehicles in Pacific Gas and Electric's electric vehicle fleet.

Technical - Fleet Activities

Ecostars. PG&E's five Ecostars, which use sodium-sulfur batteries, report a consistent range of greater than 90 miles and a top speed of 70 mph. The Ecostars are used by meter readers, customer service representatives, electrical inspectors, parts delivery personnel, and commuting employees. During the first quarter of 1996, PG&E replaced the auxiliary batteries on all five Ecostars. In addition, the upper power electronic control unit was replaced on one vehicle, and a new traction battery pack was installed in another vehicle. The Ecostars are typically charged at the service center at 240 volts, and occasionally slow-charged at home by employees at 110 volts.

Hondas. While the three Hondas have only been getting 35 to 40 miles per charge, they have demonstrated an excellent reliability record. The vehicles operated with no failures during this reporting period. Honda plans to replace the lead-acid battery pack in one vehicle with a nickel-metal hydride battery pack.

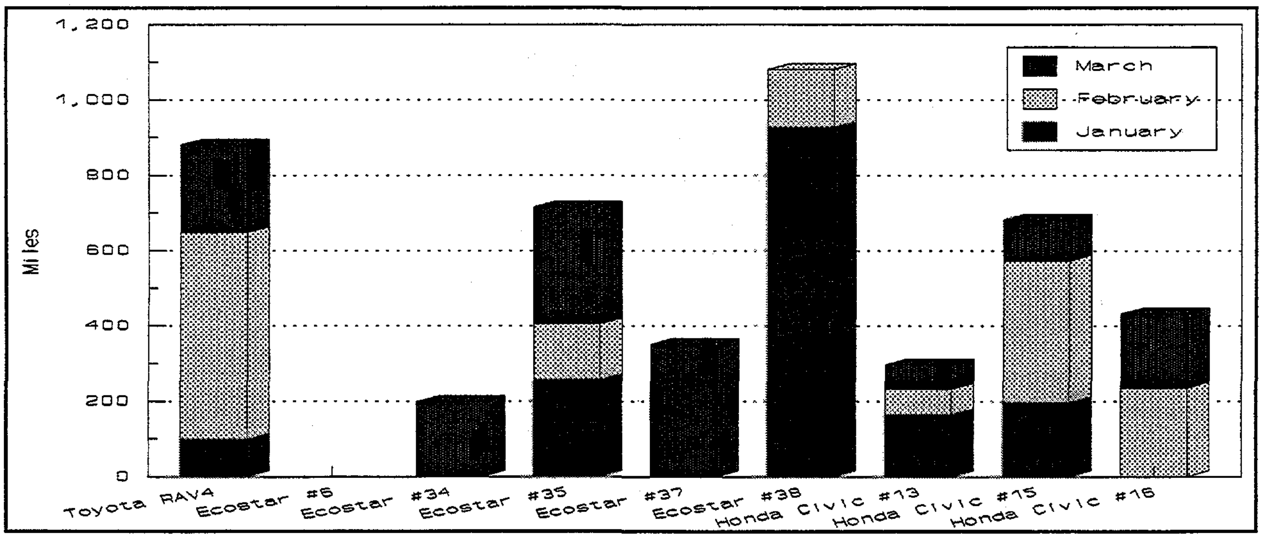

Figure 17. Quarterly mileage totals for nine of Pacific Gas & Electric's electric vehicles.

Toyota RAV4-EV. PG&E received a RAV4 during January and it will be tested under a wide variety of operating conditions during the next two years. Since its arrival, the vehicle has been used daily without any problems.

U.S. Electricar Chevy S-10 conversions. The five US Electricar S-10s had been used for meter reading, parts pickup, and other missions, but fell into disfavor with PG&E drivers, who consider them unsafe to drive as the S-10s can not achieve speeds above 35 mph. Charging times have proved too long to be practical and the current positioning of the ground fault circuit interrupter on the vehicles potentially leaves the drivers at risk to electrical shock. The vehicles are inoperable until the following modifications can be made.

- A Wavedriver controller/charger is being installed in one S-10
- A coherent Power charger system is being installed in a second S-10
- The Hawker batteries in a third S-10 are being replaced with an Electrosource Horizon battery pack and a Badicheq management system. This vehicle will be charged by an off-board Wavedriver charger.
- A fourth S-10 will use a Hughes charger.

G-Vans. PG&E possesses three G-Vans. Two are in San Luis Obispo, where they are used for Phase 3 of the rapid battery interchange project with Cal Poly State University. The third G-Van remains at PG&E's San Ramon R&D Facility; the motor is out of the vehicle and there are no current plans to return the vehicle to operating condition.

Kewet El Jet. The Kewet El Jet remains at the San Ramon R&D facility, inoperable due to dead batteries.

Other Electric Vehicles. PG&E also has four electric buses. A 22-foot Specialty Vehicle Manufacturing passenger bus is currently on loan to the City of San Luis Obispo, and it is operating reliably. This bus is used as a lunchtime shuttle and a group transport by arrangement. A 22-foot U.S. Electric bus is located in Fresno and used for similar purposes; it did not experience any failures this quarter. A 31-foot Specialty Vehicle bus is in Yosemite National Park as part of the shuttle bus demonstration project. A 35-foot APS bus has been returned to the vendor for the repairing of several deficiencies.

Public Awareness

PG&E's outreach efforts include loaning electric cars and buses to various communities; providing literature and vehicles at regional Ride & Drives; and making presentations at schools, Earth Day events, and other events as invited.

Infrastructure Evaluation

EMF Protocol Development. In December 1994, PG&E hired a subcontractor experienced in EMF measurement to revise the draft protocol into two levels. Level I provides basic characterization with hand-held meters, while Level II provides a much more extensive characterization. The protocol was completed and is currently under review for finalization by the Load Management Committee of the Infrastructure Working Council.

Fast Charge EV Test Facility. PG&E sponsors the EV Test Facility at CAVTC in Haywood, California. PG&E is currently writing the protocols for a fast charger, to be delivered to CAVTC by fall 1996. During the reporting period, PG&E acquired two Wavedriver chargers to be used in the development of a 180 kW fast charger. Chassis dynamometer tests designed to measure range, speed, acceleration, energy consumption, and recharge time with different states of charge were conducted in January on a Honda Civic EV. A Ford Ecostar, a Toyota RAV4 EV, and several U.S. Electricar S-10s will be tested through the fall of 1996. Tests on the S-10s will evaluate vehicle performance with various configurations of charging systems and batteries.

Rapid Battery Interchange Program. PG&E is a cosponsor of the Rapid Battery Interchange Program at California Polytechnic, which is a demonstration of the rapid automated exchange of battery packs. The fully automated sites are intended to function much like conventional service stations. "Refueling" occurs in a matter of minutes through exchange of the vehicles's used battery packs for fully-charged battery packs. Phase 3 of the Program, a full-scale multi-vehicle road test, began during the fall of 1995 and is scheduled to be completed in 1997.

Other Electric Vehicle Activities

PG&E is working with the Bay Area Air Quality Management District and other groups to demonstrate "station cars." These cars are leased to local business employees to be driven between their residences and Bay Area Rapid Transit (BART) stations, between BART and work, and for running daytime errands. Leasing costs are estimated at $100 to $150 per month plus insurance; maintenance and emergency road service are included in the fee. The project employs a Norwegian car, the Citi by Personal Independent Vehicle Co. (PIVCO). Nine vehicles are currently in operation; most are leased by employees of SyBase, an Emeryville software firm participating in the demonstration. The demonstration will include a total of forty vehicles by June 1996.

PG&E has installed charging stations at the Ashby BART station in Berkeley to provide 120 volts or 208 volts charging for up to 19 vehicles. Battery charging can also occur at home. Additional demonstrations will take place at two other BART stations. Work to accommodate the PIVCO vehicles at the Walnut Creek BART station should be completed in the spring of 1996, and PG&E is seeking customers to participate in the demonstration from the newly-opened Colma BART station.

Platte River Power Authority

The Platte River Power Authority (PRPA) operates two Soleq EVcort electric vehicles (Table 6) as part of its participation in the Site Operator Program. The Soleq EVcorts are Ford Escort station wagon conversions. PRPA, a political subdivision of the State of Colorado, maintains and operates facilities for generation and wholesale distribution of electrical energy to four Colorado municipalities: Estes Park, Fort Collins, Longmont, and Loveland. The thrust of PRPA activities under this program is threefold:

- Evaluate the year-round performance, operational costs, reliability, and life-cycle costs of electric vehicles in the front range region of Northern Colorado.

- Evaluate an EV's usability and acceptability as a pool vehicle.

- Develop, test and evaluate, and demonstrate components to be used in charging EVs.

The vehicles are operated in a real-world environment, for personnel transportation and public demonstrations.

Table 6. Platte River Power Authority vehicle fleet description.

Vehicle	DOE No.	Battery Type	No. of Battery Modules	System Voltage	Charger Type	Charger Voltage
Soleq EVcort	355	Sonnenschein Lead Acid Gelled-electrolyte	18 (6 volt)	108	Soleq (onboard)	110
Soleq EVcort	356	Sonnenschein Lead Acid Gelled-electrolyte	18 (6 volt)	108	Soleq (onboard)	110

Technical

Both EVcorts are equipped with an onboard load profile meter that continually integrates the AC energy used for charging over every 15-minute time period; the data is stored with its corresponding time interval. All vehicle charge data is automatically captured by the meter without any action by the vehicle user. The meter data is downloaded once a month by the City of Fort Collins when the other Platte River Facility meters are read. The meter data, along with monthly vehicle odometer data, is compiled and used to produce a Quarterly Operational

Summary report (Table 7).

During the reporting quarter, vehicle No. 355 was driven a total of 255 miles and its energy efficiency was 1.1 miles per kWh; vehicle No. 355 was driven a total of 169 miles and its energy efficiency was also 1.1 miles per kWh. The cold winter weather in the Fort Collins area deceases the range of the vehicles, and driver comfort becomes an increasing issue since the performance of the electric heating systems in the Soleqs are marginal during the winter months.

Table 7. Monthly summary of the onboard meter and the odometer data for the Platte River EVs. N/A signifies that no charging was done during that month.

	Total Energy Usage (kWh)		Miles Driven		Miles/kWh	
	EVcort 355	EVcort 356	EVcort 355	EVcort 356	EVcort 355	EVcort 356
Jan.	88.6	0.0	98.4	7.8	1.11	n/a
Feb.	94.0	65.9	117.5	71.2	1.25	1.08
March	40.5	84.6	38.9	89.7	0.96	1.06
Total	223.1	150.5	245.8	168.7	1.14	1.12

Potomac Electric Power Company

The Potomac Electric Power Company (PEPCO), serving over 1.6 million people in the Washington, D.C. area, operates three EVs in the Site Operator Program. The principal vehicle use is fleet service. With the exception of one county, the entire 640 square-mile service region is classified as a serious, ozone non-attainment area, and PEPCO is considering whether to utilize electric vehicles to meet the requirements for fleet conversion to alternative fuels.

The objectives of the PEPCO EV program include:

- Generate local interest in EVs in the Washington, D.C. metropolitan area
- Demonstrate the capability of existing and emerging EV technology to the Washington, D.C. community
- Evaluate the current ability as well as support the future development of EV components and systems to meet the challenges of fleet driving requirements
- Demonstrate PEPCO's commitment to supporting EV development and the Clean Air Act objectives
- Assist in the education of the utility industry as to the current and projected future status of EV development so that informed EV purchase decisions can be made
- Work to establish a self-sustaining market for EVs which would in turn result in higher EV reliability and lower per unit costs.

Three EVs were delivered to PEPCO during the previous year for integration into PEPCO's corporate fleet as part of the EVAmerica field test evaluation. Two of the vehicles are 1995 Solectria E-10's which were ordered under a cost share agreement with DOE. The third EV is a 1994 Solectria E-10 that was converted under the ARPA Program and assigned to PEPCO to manage. All three of these vehicles are equipped with MDAS units for data acquisition.

Technical

The three Solectria pickups traveled a total of 719 miles during the reporting period (Figure 18). They consumed a total of 179 kWh for charging, and they had an average energy efficiency of 4 miles per kWh.

During the reporting quarter, two of the pickups were tested for cold weather performance. As a result of evaluations conducted during the last quarter, vehicle S06 was not tested. The range was obtained by driving the vehicles on a carefully selected constant speed driving course which uses a section of the George Washington Memorial Parkway. This 10-mile course allows for constant-speed 45 mph driving. Table 8 shows the results of range testing that was performed on vehicles S07 and S08.

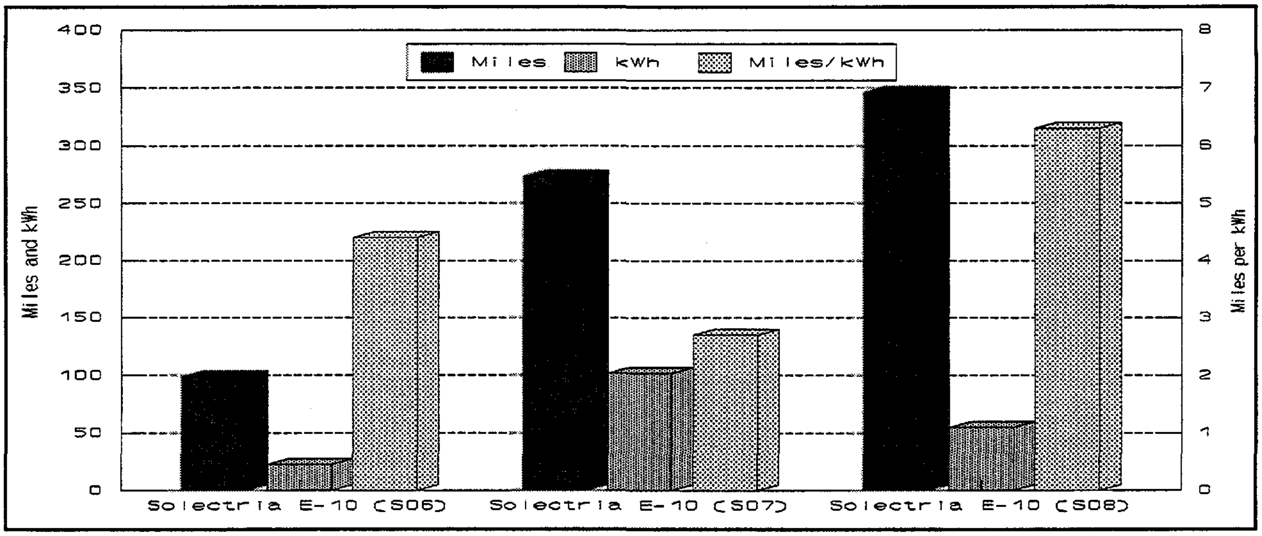

Figure 18. Total monthly vehicle miles and energy use for each of PEPCO's three Solectria E-10 pickups for the reporting quarter.

Table 8. Constant speed range test results at 45 mph, for two of PEPCO's Solectria S-10 pickups. Tests run on a 10-miles course on the George Washington Parkway in the Washington, D.C. area. The data includes Amp-hour (Ah) and odometer (Odo) readings.

Vehicle	Date	Ah Start	Ah End	Odo Start	Odo End
#S07	02/05/96	0.1	26.05	0	27.5
	02/18/96	-0.11	24.78	0	27.5
	02/22/96	-0.07	21.6	0	27.3
#S08	02/05/96	-0.17	48.47	0	46.7

After consulting with Solectria, it was determined that the batteries supplied for the S06 battery pack and the batteries supplied for the S07 battery pack were respectively from different manufacturing lots and that the differences in performance of the modules resulted in premature capacity loss. It was decided by Solectria that both battery packs would be replaced under warranty. The replacement batteries will be 12 volt, 38 Ah, Hawker Genesis modules. The modules for each pack will have consecutive serial numbers. Due to unusually severe winter weather, the vehicle usage for the remainder of the reporting period was limited. Table 9 shows the vehicle use data for the entire reporting period and Table 10 contains the charging information for the reporting period.

Table 9. Vehicle performance summaries for PEPCO's three Solectria S-10 pickups during the reporting quarter. The pickups are numbered S06, S07, and S08.

Parameters	Units	S06	S07	S08
# of days in use	days	4	12	32
Total # of trip cycles		3	29	70
Total Trip time	hours	2.7	10.2	15.0
Total time at rest	hours	0.2	1.2	0.8
Total distance driven	miles	99.1	273.7	346.1
Max. speed	mph	58.1	68.4	66.4
Average speed	mph	36.5	27.9	22.4
Max battery temp.	°C	31.1	29.3	22.5
Avg. battery temp.	°C	25.7	20.6	13.2
Total regen braking energy	Wh	2368	6095	0.0
Total air cond energy	kWh	0.0	2.6	5.5
Total discharge energy	kWh	22.9	71.8	92.4
Net DC energy efficiency	mi/kWh	4.3	3.8	3.7

Table 10. Vehicle charger summaries for PEPCO's three Solectria S-10 pickups during the reporting period. The pickups are numbered S06, S07, and S08.

Parameters	Units	S06	S07	S08
Total # of charger cycles		6	38	21
Total charge time	hours	27.9	180.3	74.6
Max. charge current	A	34.2	21.7	21.2
Avg. charge current	A	4.6	3.4	5.5
Max. battery temp.	°C	26.6	32.9	33.3
Avg. battery temp.	°C	20.6	19.6	21.2
Total charge energy	kWh	22.56	101.7	55.0
Gross DC energy eff.	Mi/kWh	4.4	2.7	6.3
Battery pack eff.	%	101.8	70.6	168.0

Sandia National Laboratory

This summary covers Sandia's operating experience for the 1996 fiscal year - October 1, 1995 to September 30, 1996. The Sandia National Laboratory's (SNL) program was a part of the DOE Site Operator Program from 1981 to 1990. Sandia is no longer a member of the Site Operator Program but it continues to provide an annual report of the operations of its 12 EVs to the DOE Site Operator's program.

The original EV fleet (1981) consisted of seven Electricas, manufactured by Jet Industries of Texas. Four additional Electricas were obtained from the U.S. Navy and the Public Service Company of New Mexico. They are small, two-door sedans with a curb weight of approximately 3,300 pounds; they are Ford Escort conversions. The Electricas have a range of 30 to 40 miles depending on missions, a top speed of 65 mph, and the energy efficiency varies from 0.33 to 1.3 miles per kWh for the reporting period. The total fleet mileage is 124,000 miles and the total fleet energy efficiency is 1.2 miles per kWh (Table 11).

Fleet Performance

Table 11. The 12 Electricas milage and energy use for the October 1, 1995 to September 30, 1996 period (last three columns), and total vehicle use (first two columns).

	Total vehicle performance		1996 Totals		
Vehicle	Odometer	KWh	Miles	kWh	Miles/kWh
22410	10,998	8,752	159	169	0.94
22411	8,887	9,934	465	530	0.88
22412	11,153	11,261	58	105	0.56
22413	15,395	8,142	149	284	0.53
22414	11,139	11,422	760	762	1.0
22415	14,300	3,656	327	289	1.14
22416	6,922	5,793	585	521	1.12
27433	12,391	10,678	305	233	1.32
27434	8,570	7,703	311	261	1.19
27436	8,549	10,464	304	242	1.25
27440	10,126	10,648	631	1,047	0.60
27661	5,744	5,012	317	957	0.33
Totals	124,174	103,465	4,371	5,400	(Average) 0.81

Fleet Problems

The following problems have been identified with the Electricas.

- The state-of-charge (SOC) systems are old and defective in nine of the EVs. The original Anderson units and parts can no longer be purchased. These will be replaced by Curtis SOC systems.

- Exhaust fans in the rear battery compartments have become inoperative. This is caused by corrosive acid vapors eroding the fan blades. They become unbalanced and eventually ruin the bearings in the 12-volt motors.

- The heaters are VW gasoline heaters. Logic, fuel pumps, and fuel lines are continuously requiring repairs.

- Some of the battery compartments are showing the results of aging and the effects of constant exposure to battery acids.

- Tires are old (13 to 15 years) and are showing cracks and wear. New tires are being installed when necessary.

- Failure of the 12-volt auxiliary battery system is one of the fleet's biggest problems. When this happens, the voltage drops below nine volts and the speed controller looses logic and the vehicle stalls. The reasons for failure are many, but mainly lack-of-charge. Too many components demand 12-volts (controller, fans, windshield wipers, lights, radio, etc) from the battery. When the traction battery pack is fully charged, the charger shuts off, including the 12-volt charging function. This leaves the 12-volt battery only partially charged and as a result, it is discharger below the 9-volt. A good DC-to-DC converter is needed to solve this problem. The 12-volt battery could possibly be eliminated if an efficient converter could be designed to idle at milliamperes from the traction battery until a key-switch command would turn it on to a full 40 amp, 12-volt capacity.

  A new generation II Sevcon regulated DC/DC converter with 84 to 126 volts input has recently been installed. The output is a nominal 13.5 volts regulated up to 25 amps continuous. It has insulated input-output so that the propulsion and auxiliary systems have separated grounds for safety. Evaluation of the unit started in November 1995 and it has proven to function satisfactory.

- The emergency switch causes some trouble by accidentally being pulled by drivers who think it is the parking brake release. This results in a service call and occasionally towing.

- Chargers fail to shut off when reaching the traction pack terminal voltage of 122 volts. Also, in some cases the back-up 16-hour turn-off timer fails. This results in over charging of the batteries and a shorter battery life. This is caused by aging components in the logic board and replacement boards are no longer available. The circuit has been copied and an a new board fabricated at Sandia. However, installation of the new board has been unsuccessful, so if a charger fails the only solution will be to replace the entire charging system.

- Five of the Electricas are equipped with old air conditioning units and none of these units function; replacement parts are not available.

- Two vehicles had to be towed to the repair facility because of discharged traction packs. Without a reliable SOC meter, the drivers simply run out of energy and are stranded. The new Curtis SOC meters should solve this problem.

Southern California Edison Company

Southern California Edison Company (SCE), an electric utility, currently operates and maintains 67 light-duty EVs as part of its participation in the Site Operator Program (Figure 19). Out of the 67 EVs, 15 are considered inactive for reasons such as the installation of a new battery pack; the pending donation or sale to other organizations; ongoing pack conditioning, warranty work, or upgrades; or they may be awaiting reassignment to another SCE organization. During this reporting period the 52 "active" EVs were driven a total of 54,400 miles, they averaged over 1,000 miles per EV for the reporting period, and they averaged 80 miles per EV per week. As evidenced by miles driven, EV use by SCE has increased significantly during the last four reporting periods (Figure 20). During the reporting period, a Honda CX converted by AC Propulsion, A Nissan Avenir EV, and two Toyota RAV4 EVs were added to the fleet. Fleet applications include:

- Meter Readers
- Field Service Representatives
- Service Planners
- Managers/Supervisors
- Mail Routes
- Pool Cars

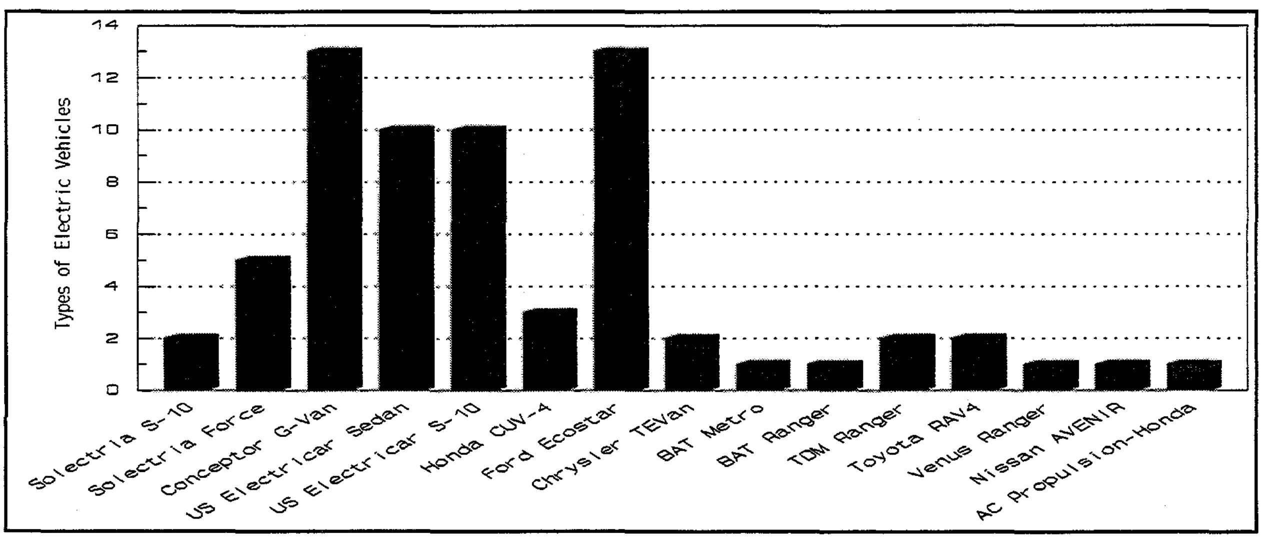

Figure 19. Number and types of vehicles in the Southern California Edison Company electric vehicle fleet.

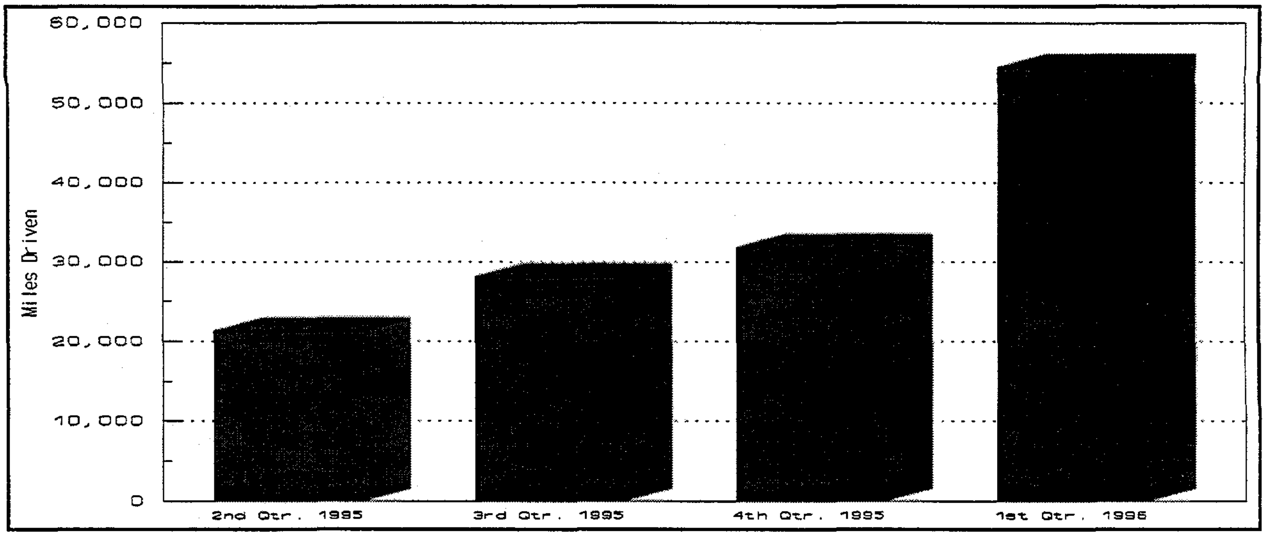

Figure 20. Miles driven by the Southern California Edison electric vehicle fleet during each of the last four reporting periods.

The SCE EV effort involves major roles in electric vehicle and component testing/evaluation, battery technology development, recharge infrastructure development, demand-side management, and overall technological leadership in meeting the air quality and transportation requirements of the area.

In filling the final role, SCE shares its technical expertise and test results with two California regulatory agencies: the South Coast Air Quality Management District and the California Air Resources Board. The results of this continuing cooperation can be seen in the electric shuttle operated by several Southern California cities and technical assistance in feasibility studies of truck and bus conversions.

SCE also provides support at many levels to the CALSTART program, which is intended to position California "high tech" industries in a leadership role as developers and suppliers of EV-related products. CALSTART's participation ranges from battery recycling processes and vehicle/infrastructure testing, to promoting public interest in zero-emission vehicles.

The Research, Development, and Demonstration Department of SCE has the primary responsibility for carrying out the tasks covered by the Site Operator Program. In turn, it has access to the necessary corporate resources and facilities/manpower.

Technical

SCE has implemented their own data acquisition system (DAS) in several SCE vehicles. The DAS consists of an "Alpha" kilowatt-hour meter and a "Silent Witness" trip logger. The SEC DAS measures fleet operations performance metrics such as miles per vehicle, miles per

AC kilowatt-hour, miles per trip, and recharge time and time of use. To date, 32 SCE vehicles have been equipped with this DAS system and most of SCE's remaining vehicles will be so equipped. The SCE instrumented fleet includes four Conceptor G-Vans, five Solectria Force sedans, two Solectria S-10 pickups, nine US Electricar sedans, seven US Electricar S-10 pickups, three Honda CUV4 sedans, one TDM Ranger pickup, and a Chrysler TEVan. SCE also continues to use the factory supplied data system for the Ford Ecostars. Most of the SCE EVs are equipped with lead acid batteries, except for a G-Van which uses a Nickel Cadmium battery pack, a US Electricar S-10 which uses nickel metal hydride batteries, and the Ford Ecostars which use sodium sulfur batteries. One of the Ecostars is a hybrid that uses the sodium sulfur battery.

The SCE EV fleet has a combined total mileage of over 430,000 with two vehicles having over 20,000 miles of use. Several other EVs have also accumulated over 15,000 miles each (Figure 21), and many of SCE's vehicles were utilized extensively during the three month reporting period (Figure 22).

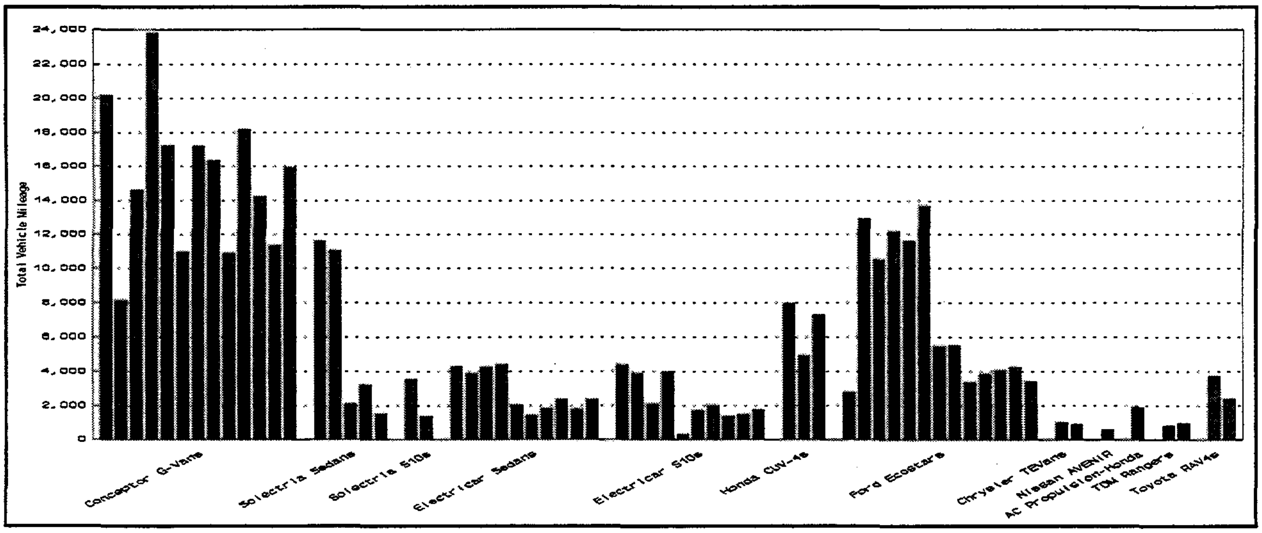

Figure 21. Reported total vehicle miles for the Southern California Edison EVs as of March 31, 1996.

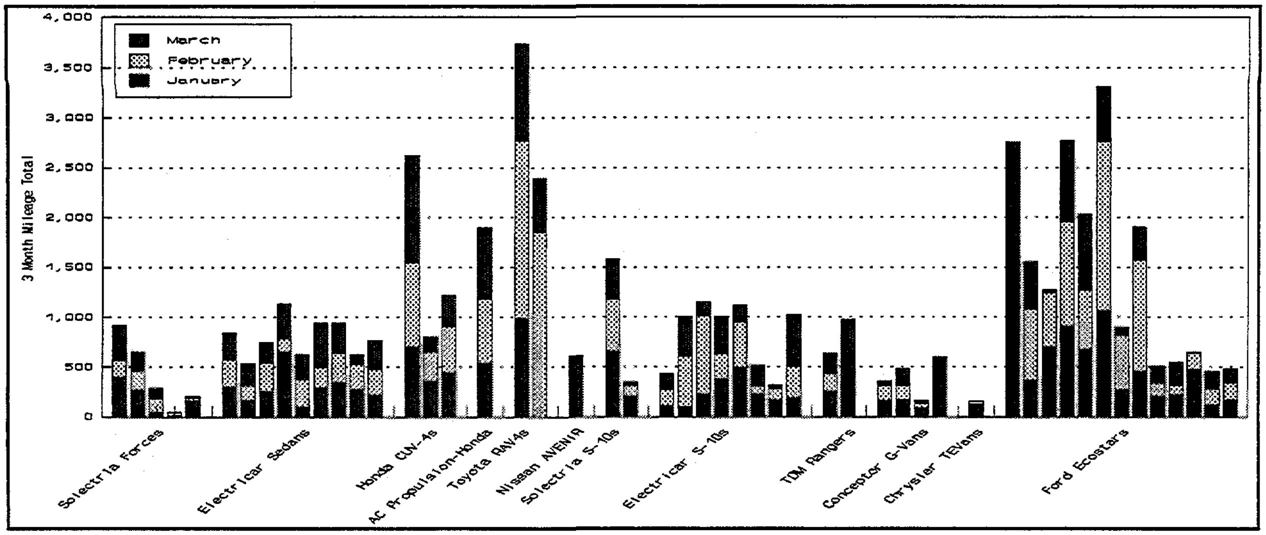

Figure 22. Reported mileage for individual Southern California Edison EVs that reported mileage during the 1996 months of January, February, and March.

Texas A&M University

Texas A&M University (TAMU) has been actively involved in the research, development and demonstration of EVs and hydrogen fuel cells. The Center for Electrochemical Systems and Hydrogen Research, with the help of the South Central Electric Vehicle Consortium (SCEVC) and DOE, has demonstrated and field tested 30 EVs (Figure 23) which have jointly accumulated over 140,000 miles. TAMU's EVs have been used in over 150 presentations and demonstrations. During the reporting period, two of the S-10s from US Electricar and two of the TEVans were driven over 3,000 miles (Table 12). These four vehicles individually had energy efficiencies of about 1 mile per kWh, and they demonstrated an average energy efficiency of 1.07 miles per kWh (Figure 24).

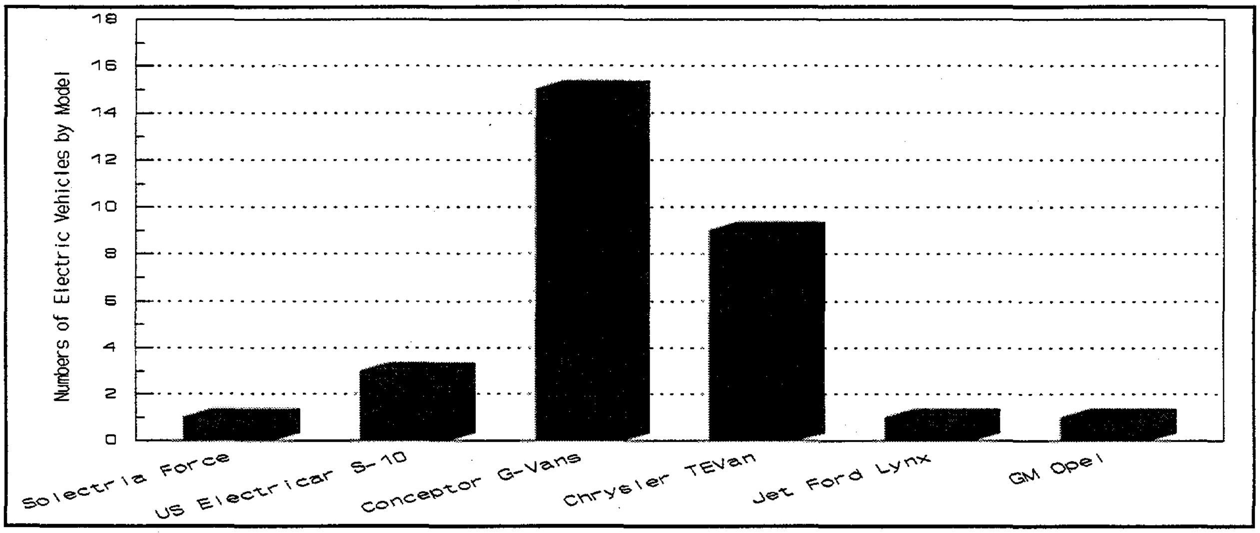

Figure 23. Number and types of vehicles in the Texas A&M electric vehicle fleet.

Table 12. Summary of TEVan performance at Texas A&M University.

	Miles				kWh			
	Jan.	Feb.	Mar.	Total	Jan.	Feb.	Mar.	Total
TEVan #623	391	469	409	1269	342	421	408	1171
TEVan #624	525	520	385	1430	479	521	337	1337
S-10 #628	42	14	34	90	38	19	36	93
S-10 #629	0	272	45	317	0	252	47	299
Totals	958	1275	873	3106	859	1213	828	2900

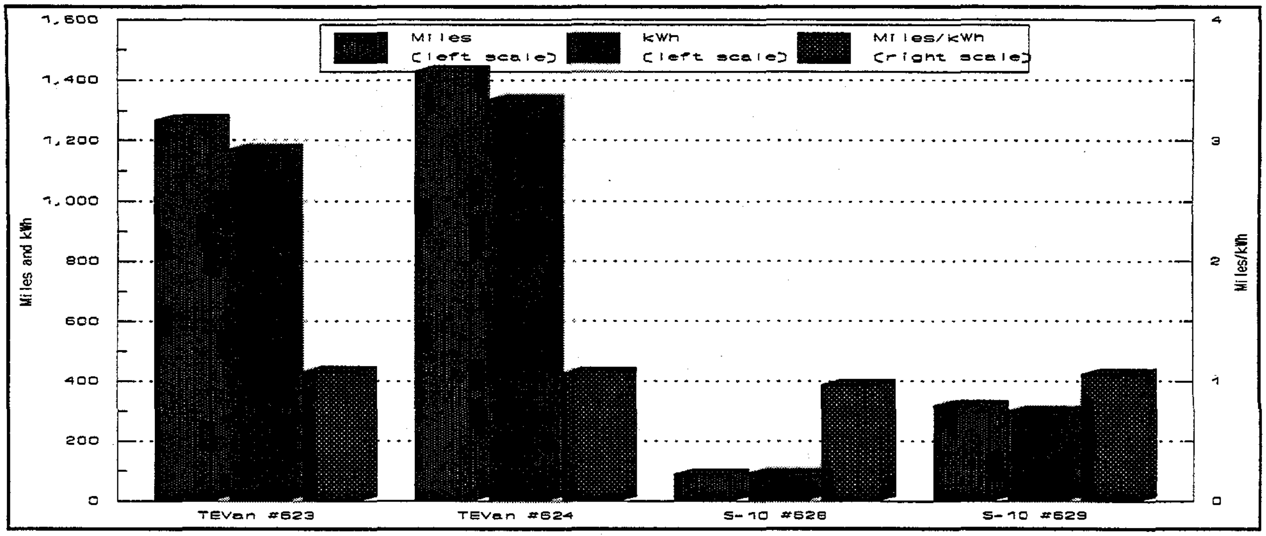

Figure 24. Miles driven and kWh energy use for two TEVans and two U.S. Electricars in the Texas electric vehicle fleet.

Technical

During the reporting quarter, TAMU reports that their three US Electricar trucks did not experience any significant problems. Two of the US Electricars had no maintenance expenses during the period. However, the US Electricar S-10 pickup, number 627, did experience some serious problems with the inductive charger. Initially, the auxiliary battery would discharge after a long period of using the inductive charger. It was observed that if the inductive charger remained plugged to the vehicle after the charging was complete, i.e. weekends and holidays, it would still discharge the auxiliary battery. The charger finally quit working by the end of February, and the truck was inoperable. The local Hughes Inductive Charger distributor in Dallas was contacted. They discovered a loose control wire to be the cause of the charger failure. Other tests were conducted to determine the cause of the discharge of the auxiliary battery during charging, but no current leak was detected. Hence, at the end of this reporting period, it has not been confirmed if the control wire was also the cause of the auxiliary battery discharge.

Other significant problems common to all three US Electricar S-10s are as follows:

- The cabin heater is insufficient to warm the cabin when the outside air temperature is below 40 degrees. The planned alteration is to recirculate the heated air instead of the 100% outside air that the heater is originally designed for.

- The air conditioners do not cool sufficiently at temperatures above 90 degrees. The recommended solution is to add another cooling fan at the condenser which will be done soon.

- The rear wheel brakes need improvement. A retrofit is planned per the US Electricar service bulletin guidelines.

- The rear drivetrain needs to be fitted with an additional leaf spring per the US Electricar service bulletin guidelines.

The US Electricar S-10s have performed better than the previous EVs. However, the combination of battery capacity, recharge time, and battery life has been the major difficulty in the commercialization of EVs, and these vehicles are no exception. They suffer form the above mentioned problems along with other charger, controller, and motor failures. Though the manufactures have improved these components a great deal, the consumer still has to work with the left over bugs. In the course of field testing these vehicles, the data reflects that range and driver comfort determines how much these vehicles get used. Maintenance expense and the availability of maintenance personnel and parts also has a bearing on the use of the EVs.

U.S. Navy

As seen in the below figure (Figure 25), the U.S. Navy has 59 EVs. The Navy's EVs represent several manufacturers and body styles, and a broad span of vehicle ages. The 59 EVs are located at eight different Navy facilities (Figure 26). The principal thrust of this Navy operation is fleet evaluation. The current age span of their EV inventory contributes substantially to a vehicle experience (rather than test) data summary. The Navy, as part of a larger Department of Defense procurement effort, has ordered more than 30 newest generation EVs. These vehicles, consisting of General Motors S-10s EVs and Chrysler EPIC EV minivans will be placed in fleet use during 1997.

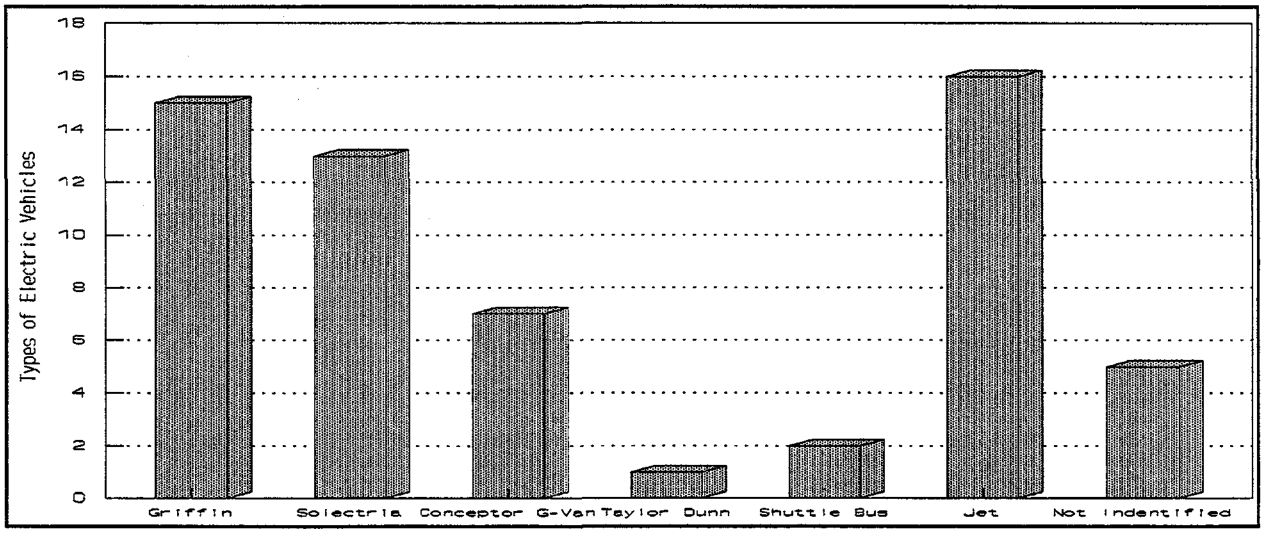

Figure 25. Number and types of vehicles in the US Navy's electric vehicle fleet.

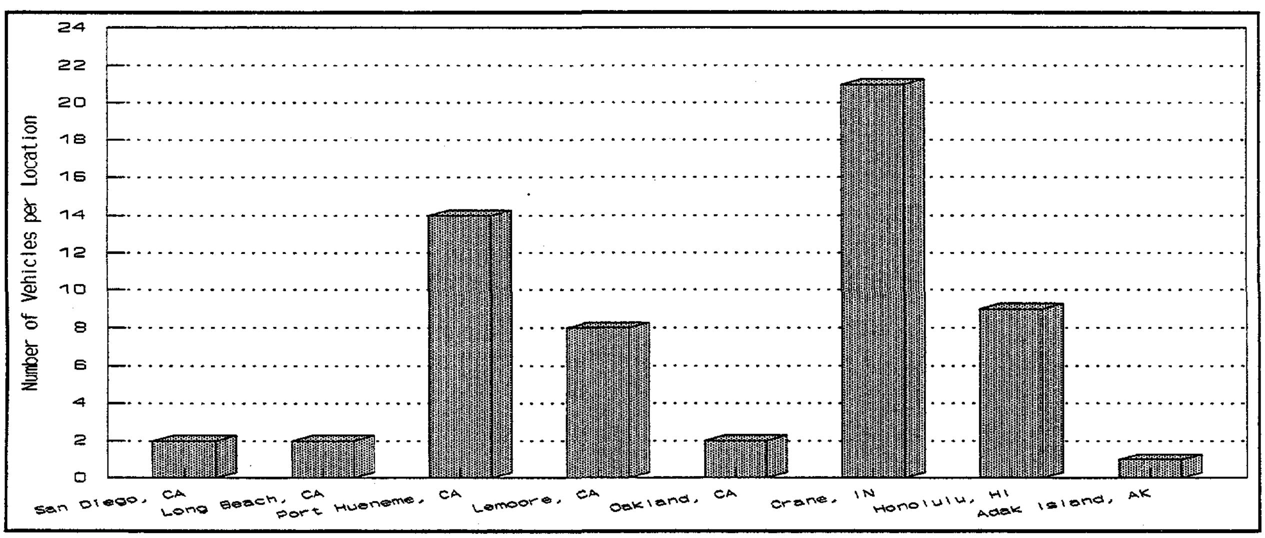

Figure 26. Locations of U.S. Navy's electric vehicle fleet.

University of South Florida

The University of South Florida (USF) at Tampa, monitors and tests 12 electric vehicles (Figure 27) as a participant in the Site Operator Program. USF's principal collaborating organizations are Florida Power Corp., Tampa Electric Co., Hillsborough County, and the City of Tampa. The purpose of the USF effort is to determine EV efficiency under commuter and fleet conditions in Florida. A part of this effort is the testing of a utility-interconnected photovoltaic 12 bay EV parking/charging system.

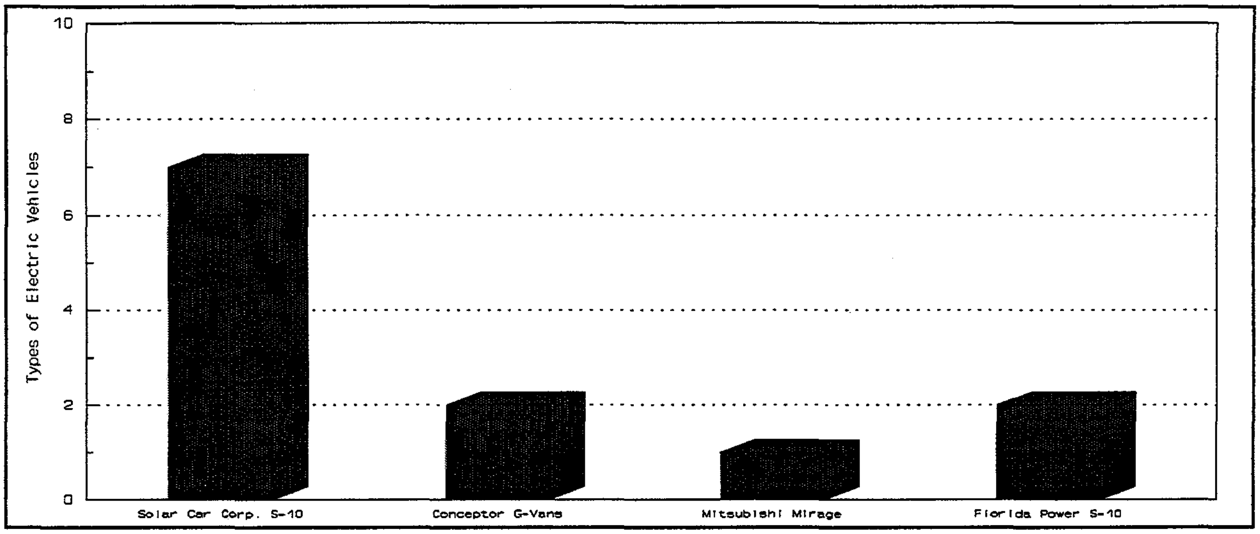

Figure 27. Number and types of vehicles in the University of South Florida electric vehicle fleet.

The specific USF program objectives are:

- Gather data relating to the performance of EVs under actual commuter and fleet conditions
- Determine public acceptance of EVs through questionnaires and personal interviews with drivers
- Determine the specific regional vehicle maintenance requirements through the use of daily operation and maintenance logs
- Evaluate battery performance as a function of vehicle range and driving conditions
- Determine typical vehicle ranges for commercially available EVs during

commuter and fleet operations

- Evaluate the effect of an air conditioner on EV range and performance
- Determine the best role for photovoltaic systems in charging EVs
- Determine the technical feasibility and economic advantages of returning the extra power generated by the photovoltaic system to the power grid.

Technical

Vehicle Performance. Table 13 provides a summary of the performance characteristics for two of USF's EVs during the reported quarter. The performance results were obtained from data collected by Mobile Data Acquisition system (MDAS) units developed by the USF. The charging summaries are derived from driver logs. As can be seen in Table 13, the G-Van battery pack efficiency was 29%. Unfortunately, the range of this vehicle continues to decrease. However, the fact that the battery pack has accumulated over 11,000 miles may explain this downward efficiency trend.

During the reporting quarter, the G-Van was driven 610 miles and it had a mile to kWh (AC) efficiency rate of 0.58 (Figure 28). One of the S-10's (S01) was driven 325 miles and it had a mile to kWh (AC) efficiency rate of 1.02 (Figure 29). A second S-10 (S02) was driven 400 miles and it had a mile to kWh (AC) efficiency rate of 1.8 (Figure 30).

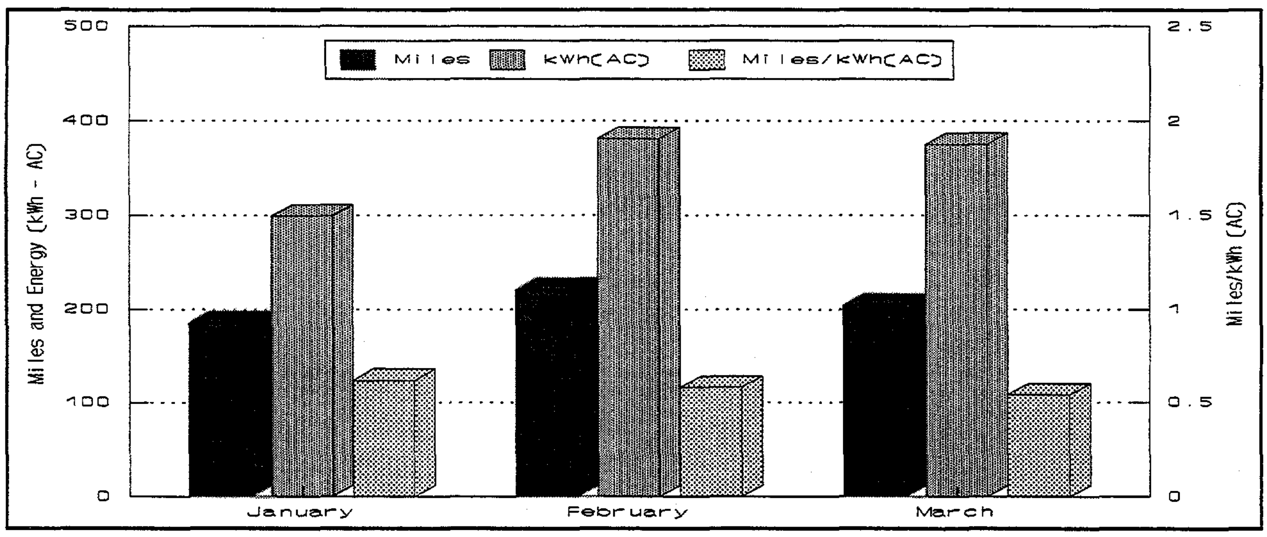

Figure 28. Total miles driven, kWh (AC), and miles per kWh (AC) for a G-Van (DOE# 650, USF# G01) at the University of South Florida. Miles and kilowatt-hour values use the left scale, and the miles/kilowatt-hour value uses the right scale.

Table 13. Vehicle performance results for two of the University of South Florida's EVs. The G01 vehicle is a G-Van and the S06 vehicle is a Chevrolet S-10 pickup Solar Car conversion.

Quarterly Trip Summary		
	G-Van DOE# 650, USF# G01	**SCC S-10 DOE# 658, USF# S06**
# of days in use (days)	73	28
Total # of trips	286	60
Total trip time (hours)	37.1	10.2
Total time at rest (hours)	10.1	3.0
Total distance (miles)	661	194
Average speed (mph)	22.3	19.5
Avg. battery temp. (°C)	25.9	25.0
Total A/C energy (kWh)	40.3	2.4
Total discharge energy (kWh)	362.7	73.9
Net DC energy eff. (mi/kWh)	1.8	2.6
Quarterly Charger Summary		
	G-Van DOE# 650, USF# G01	**SCC S-10 DOE# 658, USF# S06**
Total # of charges	38	26
Total charge time (hours)	176.9	139.2
Max charge current (A)	184.6	28.6
Ave. charge current (A)	21.6	12.3
Max. battery temp. (°C)	34.9	30.5
Avg. battery temp. (°C)	20.6	11.3
Total charge energy (kWh)	1247.1	186.7
Gross DC energy eff. (mile/kWh)	0.5	1.0
Battery pack eff. (%)	29.1	39.6

Battery Watering. Two EVs, a G-Van and S-10 pickup, both with lead acid batteries, required a total of 11 man-hours (Table 14) for battery watering during the reporting period.

Table 14. Battery watering requirements for a G-Van (DOE #650, USF #G01), and a Solar Car Corporation converted S-10 Chevrolet pickup (DOE #652, USF #S01).

Vehicle	Liters of water added	Miles between watering	Miles per liter of water	Man hours to water vehicle
G01	75	948	12.6	7.5
S01	10	388	38.8	3.5

Other Maintenance/Repair Activities

- On EVs S01 and S-2, all of the terminal posts were cleaned and painted. Grease was applied to help prolong corrosion from developing again.
- On S01, the on-board charger was defective and another one was installed. Also, the DC to DC converter broke down. An undersized temporary replacement was installed for charging purposes only.
- The G-Van (G01) had its 12 volts DC accessories battery drain down to less than 3 volts DC when the lights were left on. After another battery was installed in its place the vehicle operated with no apparent ill effects. After the original battery took a charge, it was again operational.

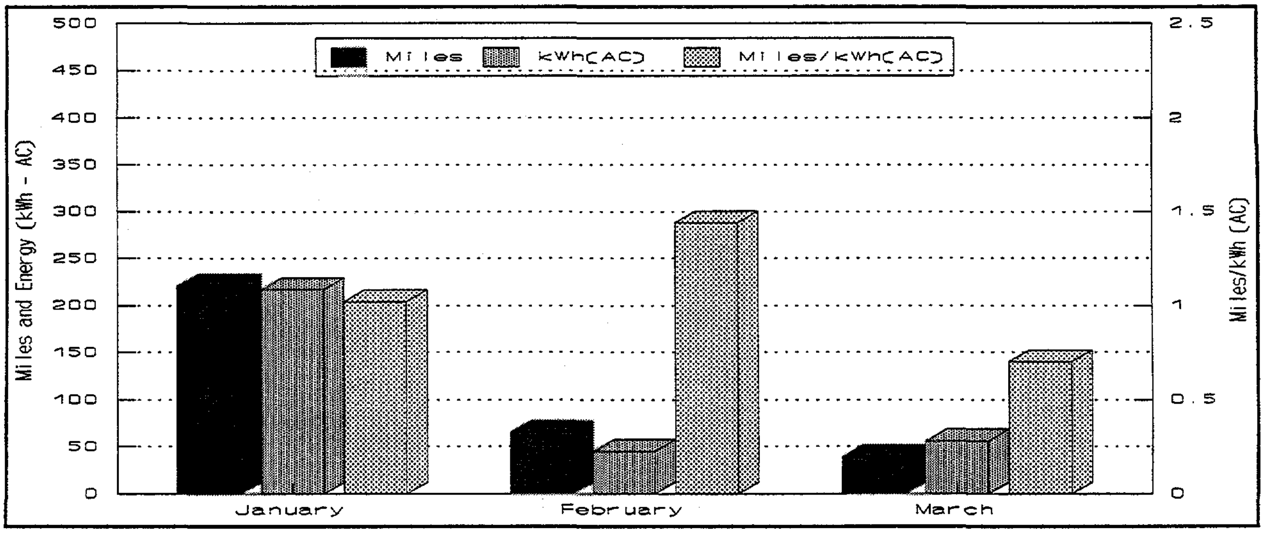

Figure 29. Total miles driven, kWh (AC), and miles per kWh (AC) for a converted Chevrolet S-10 pickup (DOE# 652, USF# S01) at the University of South Florida. Miles and kilowatt-hour values use the left scale, and the miles/kilowatt-hour value uses the right scale.

Air Conditioning Energy Use. The cumulative results from air conditioning (A/C) energy consumption data collected on the USF G-Van number G01, by the MDAS for the first quarter of 1996 is listed in Table 15. Row one is the total amount of energy discharger by the vehicle. Row two is the total energy consumed by the A/C. Row three is the percentage of the total discharge energy that the A/C consumed (row two divided by row one).

Photovoltaic Solar Power Charging Station. During the reporting quarter, the twelve-vehicle photovoltaic (PV) solar power charging station generated 5,513 AC kWh of energy. 1,249 AC-DC kWh, of the 5,513 AC kWh generated by PV station, was used to charge the EVs. Of the excess PV energy, 4,044 AC kWh was supplied to the grid.

Bus Program. The electric bus's range had decreased to less than 15 miles per charge, and it was determined that the battery was not being fully charged. The Trojan Battery Company supplied a corrective action plan that included changes to the charger and a battery pack recovery charge operation procedure to regain full battery capacity. The "A" battery pack has recovered to a range of 60 to 75 miles per charge, and the recovery work has started on the "B" pack.

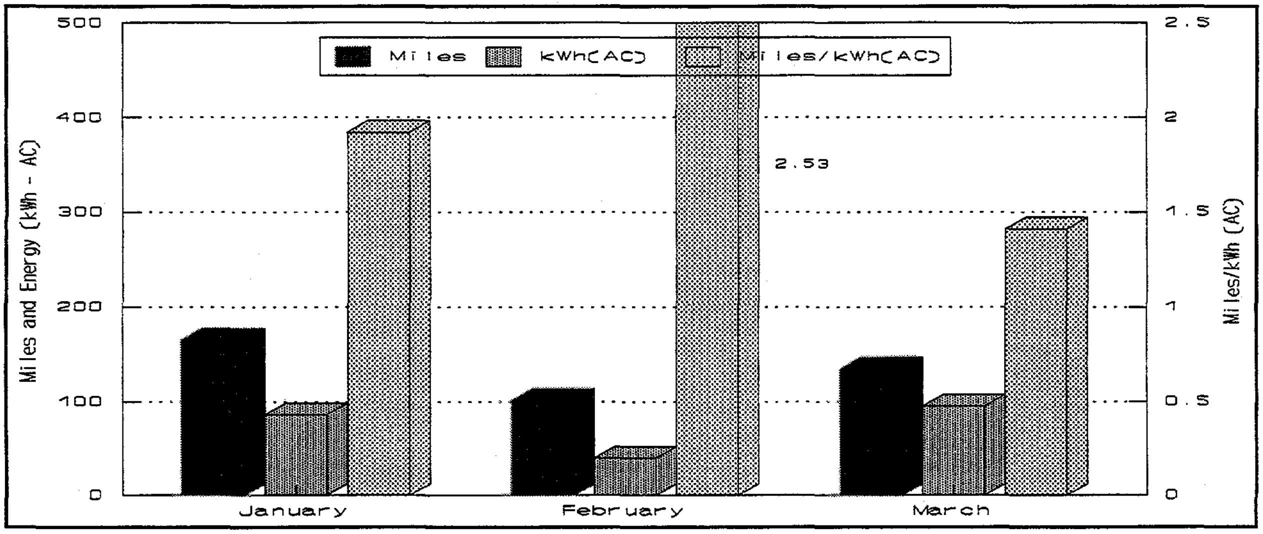

Figure 30. Total miles driven, kWh (AC), and miles per kWh (AC) for a converted Chevrolet S-10 pickup (DOE# 653, USF# S02) at the University of South Florida. Miles and kilowatt-hour values use the left scale, and the miles/kilowatt-hour value uses the right scale.

Table 15. Air conditioning energy consumption data for a USF G-Van.

	January	February	March	Total
Vehicle discharge energy	136.4	199.3	126.6	462.3
Total energy consumed by A/C (kWh)	1.09	1.01	5.3	7.4
Percentage of vehicle discharge energy consumed by A/C	0.8%	0.5%	4.2%	1.6%
Average ambient temperature (°F)	59.2	60.1	62.4	

Public Awareness

USF personnel were involved in several public awareness efforts this quarter, including:

- A lecture was presented to new engineering students on USF's EV and Solar Energy Program for Engineering Orientation.

- USF's Engineering Expo was held this quarter. Several staff members of USF's EV team informed the public as to the operation of the EVs and the photovoltaic system. Attendance exceeded several hundred people.

York Technical College

Located at Rock Hill, South Carolina, York Technical College operates 11 EVs (Figure 31). Interest in EV technology at York Tech goes beyond the nominal Program scope and is well demonstrated by the school's growing Electric Vehicle Program and emphasis on public awareness. Programmatic associations and interchanges continue with local electric utilities, other Program participants, municipalities, South Carolina State Energy Office, regional secondary schools and colleges, and the Clean Air Transport Association.

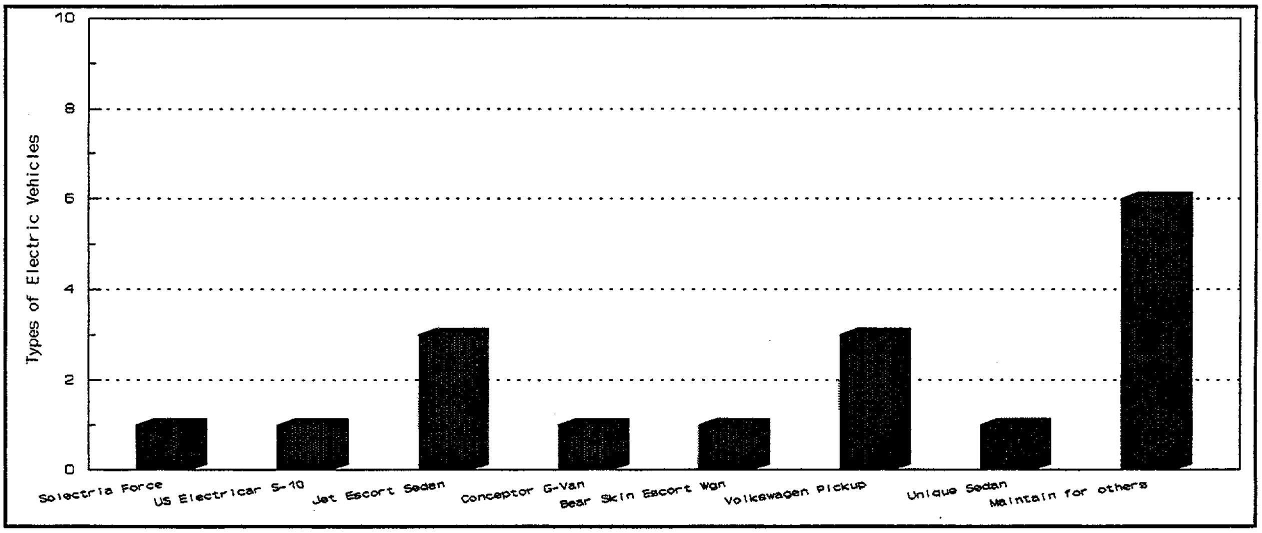

Figure 31. Number and types of vehicles in the York Tech electric vehicle fleet.

Technical

- Replaced the clutch in the City of Rock Hill's EV Escort sedan. New drive components were also installed.
- The EV G-Van came in for main pack battery watering and heater component replacement. Repairs were completed after a wiring harness was replaced.
- EV 422's electric drive belt was adjusted. An in-line fuse holder for the charger was replaced, and the amp hour meter was repaired.
- EV 405 was range tested at 16 miles, resulting in battery replacement.
- The PCU was replaced in the City of Charlotte Geo Prizm.

- A range test was performed on the City of Charlotte Geo Prizm; the range was 38 miles.

- The bed on EV 424 was removed to switch two current sensor leads for MDAS operation.

- Retrofitted new power steering lines on EV 424 and Duke Power's S-10 EV pickup truck.

- The bed was removed from Duke Power's S-10 pickup to switch the current sensor wires for the MDAS.

Public Awareness

York Tech's public awareness activities included the below events.

- Senator Bob Dole visited the York Tech campus and drove an EV during a visit to York Tech during February.

- A partnership between the Santee Cooper Power Authority and York Tech was announced. The partnership is to further the use and development of electric vehicles, as well as concentrate on the educational opportunities in the EV field and increase public awareness.

- Senator Fritz Hollings was driven approximately 30 miles from York, South Carolina, to Rock Hill, in an electric S-10 pickup.

- A 1918 Detroit Electric and a 1994 electric Saturn sport coupe, was well as several hands-on EV exhibits were placed in Discovery Place Museum in Charlotte, North Carolina, as part of the "Sprockets to Rockets" exhibit.

- Conducted four tours for the Fort Mill Middle School students in the EV lab.

- Gave an EV presentation and demonstration at Clover High School Automotive Program for Junior and Senior classes.

- Conducted two tours for the Technology in Society classes with approximately 25 students in each class.

- Conducted a tour of the EV lab for Great Falls Middle School.

- A presentation was given at Rock Hill School to a class of 25 Tech Prep math students in the 11th and 12th grades.

- A presentation was given at Rawlinson Road Middle School for approximately 60 math and science students.

- An Ev was taken to Lewisville Middle School for their Annual Career Fair.

- Conducted a presentation and demonstration at Independence Elementary School for four classes of first graders.