

The Electric Vehicle Fleet Experience at Southern California-Edison

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Southern California-Edison (SCE) currently operates the largest fleet of electric vehicles (EVs) in North America. SCE's EV experiences began in 1987 with prototype and electric conversions, such as the Conceptor G-Van, the Pentastar TEVan, and U.S.E. Sedan. Between 1994 and 1997, after the passage of the Energy Policy Act of 1992, SCE began using early OEM EVs, such as the Ford Ecostar and Chrysler TEVan, as well as early Toyota RAV4 EVs. The current fleet consists of 295 battery electric vehicles, primarily Toyota RAV4 EVs used by meter readers, with an additional 33 Ford Th!nk and GEM neighborhood electric vehicles used at company field offices for security patrols. The EV fleet has accumulated approximately 15 million zero-tailpipe-emission miles. In addition, the EV Technical Center (EVTC) in Pomona is constantly testing a variety of hybrid, plug-in hybrid, and fuel cell vehicles for potential use in Southern California-Edison's fleet.

This paper chronicles EV fleet operational experiences by Southern California-Edison and insights into lessons learned from dealing with deployment obstacles. Much of the information focuses on the Toyota RAV4 EV due to the relatively large number of these vehicles in the fleet.

Keywords: EVTC, EV, Maintenance, Electro-Drive, RAV4EV

1. INTRODUCTION

Southern California-Edison (SCE) is committed to the deployment of cost-effective and energy efficient electro-drive transportation technologies to meet EPA requirements. SCE's fleet of approximately 2,400 light-duty vehicles, includes 260 Toyota RAV4 EVs, and approximately 40 neighborhood electric vehicles (e.g., GEMs and Th!nks), that operate at more than 40 different field locations throughout SCE's 50,000 square-mile service territory. The EV fleet currently averages about 110,000 miles per month. Since 1987, the EV fleet has traveled over 14.5 million miles, and is the largest working EV fleet in North America.

There are presently no major automakers manufacturing on-road EVs. Since 2003, SCE's Electric Transportation (ET) and Transportation Services Departments (TSD) acquired additional Toyota RAV4 EVs that other fleet operators returned to Toyota as leases ended.

SCE operates a state-of-the-art, ISO 9001:2000 registered, EV Technical Center (EVTC) in Pomona, California, that performs testing and evaluation of all electro-drive transportation technologies. The EVTC

started evaluating EVs and batteries in 1993. Today its operations include the testing and evaluation of advanced energy storage devices, hydrogen fuel-cells for mobile and stationary applications, hybrid electric vehicles, fuel cell vehicles, and plug-in hybrid electric vehicles. The EVTC's projects have included clients and partners such as the US Department of Energy, the National Laboratories, aero-space agencies, auto and battery manufacturers, the Electric Power Research Institute, and California state agencies.

2. FLEET DESCRIPTION

Since the 1970s, SCE has played an active role in evaluating and deploying EVs. These efforts began with early market conversions, then preproduction original equipment manufacturer (OEM) prototype vehicles and a limited number of commercially available production EVs. Today, SCE operates almost 300 EVs. The company's role as an EV fleet operator as well as a fuel provider offers a unique perspective on the benefits and obstacles presented by the deployment of EVs in a "real-world" working fleet.

2.1 Early Days (1970s – 1996)

In the 1970s, SCE responded to the nation's transportation fuel shortage crisis by testing and evaluating EV conversions. The EV conversions

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had limited range and performance compared to conventional internal combustion engine vehicles. SCE renewed its EV program in 1987, when regional air pollution concerns increased.

In 1988, SCE broadened its participation in the EV arena by building stakeholder support for energy efficient EV technologies. Through the Electric Power Research Institute (EPRI), SCE partnered with stakeholders to advance the technical potential of EVs. The work of the United States Advanced Battery Consortium (USABC) began in 1991 to improve EV battery technology. Recognizing SCE's expertise in EVs and batteries, several manufacturers asked SCE to test EV products in a real-world fleet environment.

SCE actively participated in the testing of vehicles for fleet use (e.g., the proof of concept Chrysler TEVan minivan conversion). The acquisition of 15 General Motors G-vans, converted full-sized vans, jump-started SCE's EV fleet. SCE formed the Electric Transportation Department (ET) in 1991, one of the first of its kind in the nation. ET soon became known as experts in electric vehicle charging infrastructure, EVs, electric busses, electric trains, and battery systems.

2.2 The Acquisition Process

In the late 1990s, OEM EVs were available with a typical three-year lease. Vehicle purchase was not an option offered by manufacturers, with the exception of the Ford Ranger EV. Vehicle leases provided the operators the benefit of a full-warranty that covered the vehicles for the duration of the lease, plus electric powertrain upgrades if available or necessary. Leasing also allowed the manufacturers to provide the needed support to their customers for the relatively new technology, and enabled the manufacturers to offer the vehicles at lower costs while controlling the proximity of their products.

Additionally, leasing EVs allowed users to follow the technology advancements. After leases expired, users often had the option to lease a second-generation vehicle that was likely to provide a great step-up in technology. One example of this was GM's EV1, the first OEM vehicle made available in December 1996. First-generation EV1s used lead-acid batteries that provided a maximum driving range of approximately 60 miles. In late 1999, the second-generation EV1 was offered with a nickel-metal-hydride (NiMH) battery, more than doubling the driving range up to 150 miles per charge.

3. EVS IN THE REAL WORLD (1997 – 2007)

In 1997, SCE developed an EV fleet implementation plan that incorporated a strategy to comply with EPA's Act using only EVs. SCE achieved all plan milestones through the end of 1999 when the EV fleet exceeded 300 vehicles.

SCE's approach focused on "market not mandate" to place EVs in fleet service. The strategy involved acquiring vehicles, determining where they should be placed based on operational demands, and finally educating employee-drivers. This "mission-match" approach used the EV TripPlanner® program, developed by SCE's Geographic Information and Analysis Systems (GIAS) organization in conjunction with the Electric Transportation Department, to analyze routes and predict EV range. The EV TripPlanner® program accounts for distance, elevation, vehicle model characteristics and accessory loading. This approach assured the appropriate vehicle was selected and resulted in the highest number of successful EV deployments. The "mission-match" approach also created driver confidence in EVs and enabled SCE to continue to satisfy EPA's requirements.

To support EV progress and to obtain real-world results, SCE tested the long-term durability of five Toyota RAV4 EVs powered by Panasonic Nickel Metal Hydride batteries. SCE completed baseline range tests and capacity tests at C/3 and C/5 discharge rates. On November 8, 2002, a RAV4 EV reached a milestone by traveling 100,000 miles on the original battery pack. By April 1, 2003, two additional RAV4 EVs hit the 100,000-mile mark. These EVs demonstrated the robust quality of the NiMH batteries and their potentially long-lives. Figure 1 shows the first three RAV4 EVs to reach 100,000 on their original battery packs.

3.1 Training

SCE conducts an on-going EV driver training program to educate employee drivers, (i.e., primarily meter readers, field service representatives, and supervisors) on the safe and efficient operation of EVs. The curriculum includes driving habits, car care, vehicle and driver safety, charging problems, and behind the wheel lessons. Electric Transportation collects EV driver surveys bi-annually to receive operational feedback.

3.2 Mileage Tracking

Electric Transportation produces an EV Fleet Status Report quarterly. The report contains a broad range of EV data such as charger type, current location assignments, assigned application, odometer reading, and driver survey results.

4. LESSONS LEARNED

SCE's fleet experience clearly shows that EVs can meet long-term fleet applications on a daily basis. The knowledge gained from deploying and operating EVs in a large utility fleet, over a 50,000 square-mile service territory with significant climatic differences, has proven valuable. Figure 2 shows the cumulative mileage and quantitative benefits from operating the EV fleet.

4.1 Vehicle Deployment

EVs are capable of a wide variety of missions with the exception of when long distances must be driven. Range in most cases was more of a perceived problem than a real one. In a few instances the potential EV users had to be reassured that their driving routes would be within the range capabilities of the EV. SCE's EV TripPlanner was utilized as part of the route evaluation process.

ET personnel instructed drivers on how an EV works, driving tips, and charging directions. The training is important to develop EV driver confidence.

Climatic conditions, particularly high daytime ambient temperatures proved challenging. Although charged primarily at night, in some instances RAV4 EVs experienced heat-related problems. Canopies were installed at some SCE charging locations to reduce radiant heating to control heat related charging failures. The cleaning of the EV's battery cool vents, located on each rear side panel, also helped reduce battery over-heating problems.

4.2 Vehicle Operation

The performance characteristics of OEM designed EVs made the transition from ICE vehicles relatively seamless. Minor reconfiguration of the RAV4 EV rear passenger space was transformed into an extended and protected cargo area. The vehicles were also equipped with radios and other fleet specific equipment.

Due to an abnormal rate of tire failures, ET specified a more robust tire. However, maintenance records continue to indicate a high incidence of tire replacements. This problem is partially due to the severe driving conditions of some meter reader routes. Additional driver education was provided in an effort to reduce tire-related incidents.

Traffic accidents did occur, and six RAV4 EVs were damaged beyond economic repair. No serious injuries were reported and no accidents were traced to the



Figure 1: 100,000-miles Toyota RAV4 EVs

Fleet Statistics	> 295 active EVs in the fleet, 262 RAV4s > 3 currently active OEM vehicle models > 14,342,000 total miles driven since 1989
Maintenance Benefits	> 2,870 oil changes not needed > \$100,400 labor and material saved > 1,370 smog checks avoided > \$47,900 saved
Energy Use	> 7,171,000 kWh of clean electricity used > 717,000 gallons of gasoline saved
Energy Cost	> \$845,400 in electricity costs > \$2,409,000 in gasoline costs avoided > Net savings of \$1,763,600
Environmental	> 14,300 quarts of oil saved > 1,700 tons of pollutants saved from emission > 7,700 tons of tailpipe CO₂ avoided

Figure 2: Cumulative EV fleet benefits as of May 2007

electric nature of the vehicles.

Proper vehicle charging rapidly became an automatic discipline with drivers. In most cases, the number of miles driven between charges was well below the range capability of the EV.

4.3 Vehicle Efficiency and Reliability

The Toyota RAV4 EV achieved over two miles per ac kWh. This mileage was dependent on driving styles and the use of air conditioning, heating, and other accessories. ET determined that well-driven and regularly discharged RAV4 EVs achieved at least half a mile more per kWh (i.e., 2.5 miles/kWh) than the rest of the fleet. EV reliability remained solid throughout the study period, even as the EVs aged. Figure 3 displays the numbers of EVs in SCE's fleet, the types of EVs, and cumulative mileage since 1990.

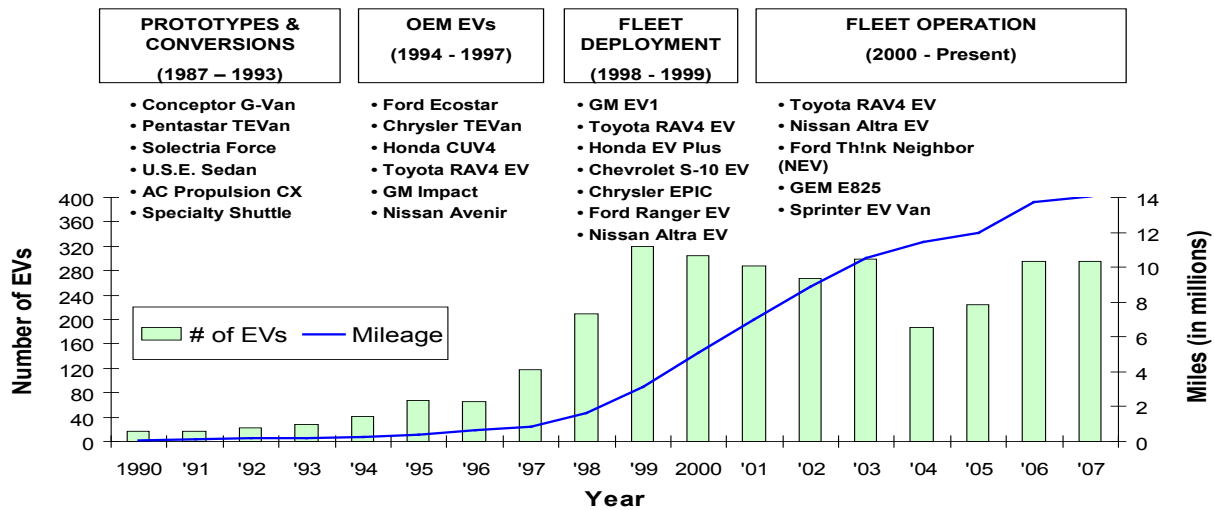


Figure 3: EVs in the SCE fleet since 1990

4.4 Charging Infrastructure and EV Charging

A systematic charger inspection program implemented early during EV deployment helped increase user satisfaction by enhancing hardware reliability. Regular servicing of chargers at SCE facilities lowered maintenance costs. This program also determined that environmental conditions, such as ambient temperature, do not appreciably affect the number and type of charger problems. However, hot weather can cause an EV to prematurely stop charging due to high battery temperature.

In addition, driver errors, vehicle system malfunctions, clogged cooling vents, and other issues caused a relatively small number of charging incidences. ET corrected the root causes of charger failure and implemented charging infrastructure solutions. Current charger availability is at 99%.

4.5 Impacts on the SCE Grid

Calculations show that a fleet of approximately 300 EVs would create a connected load that theoretically could generate a coincident charging load of 1.8 megawatts. This would equate to about one-hundredth of 1% of the typical 10,000 to 20,000 MW total customer load on the SCE system. Since most EV charging is done during off-peak evening periods, the EV load is well within the existing generating capacity available to SCE.

EV performance characterization tests document that the RAV4 EV chargers produce no adverse effects

on the power quality of the grid. No users reported problems with computers or other electronic equipment associated with EV charging.

5. BENEFITS AND CONCLUSIONS

EVs provide many benefits, such as emission reductions and reduced maintenance and fuel costs, as well as reduced dependence on foreign oil. Zero-emission vehicles are significant contributors to reducing air pollution caused by automobiles. EVs are estimated to run 97% cleaner than internal combustion engine vehicles even when accounting for emissions at power plants generating electricity for charging. The 14.5 million miles logged by SCE's EV fleet have avoided 1,700 tons of air pollutants and more the 7,700 tons of tailpipe CO₂.¹

EVs have lower fueling costs and fewer maintenance requirements. In its 18 years of operation, the SCE EV fleet saved the company over \$2.5 million in avoided petroleum fuel costs. In addition, since deploying the EVs, over 1,500 smog checks were avoided.

Deploying reliable vehicles that fit the mission is most important. SCE performs reliability tests on new-technology vehicles before placement with client organizations to assure operator satisfaction. In 2003, SCE added 22 Ford Th!nk neighborhood electric vehicles to its fleet. Due to their size, these vehicles are limited in their applications compared to the RAV4 EVs. The RAV4 EVs transport meter readers efficiently, and with minimal environmental impacts. Other EV uses include security patrols, and educational outreach

activities.

ENDNOTE

Sources: Bevilacqua Knight, Inc., and Greet Transportation Fuel Cycle Analysis. Estimates do not account for power plant emissions.

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