

# Southern California-Edison's Experience with the Hydrogen Demonstration Project

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Environmental and energy security concerns are driving federal agencies to evaluate alternative domestically produced energy. Among the various technologies studied, the U.S. Department of Energy (DOE) launched a five-year demonstration project named "Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project" to investigate the feasibility of hydrogen as a transportation fuel. To achieve the objective, the DOE selected a team of industry leaders to design, construct and operate a system consisting of various hydrogen fueling stations and fleet of fuel cell electric vehicles. One of the selected teams consists of Chevron Technology Ventures Inc., Hyundai American Motor Co., UTC Fuel Cells, and Southern California-Edison (SCE). Each team member is responsible for a key task: Chevron — design and build the hydrogen fueling station, Hyundai and UTC — build the Fuel Cell Electric Vehicles, and SCE — site-owner, characterize and operate the system in a real world setting.

The hydrogen fueling station was built at the corporate offices of SCE in Rosemead, California. This station is capable of maintaining a minimum storage capacity of 60 kg, a daily production and dispensing capacity of 40kg, a fueling pressure of 5,000PSI, and a maximum vehicle fueling time of five minutes. As an electric utility company, SCE will perform a detailed power analysis of the station and determined key functions, such as system power demand, efficiency, and reliability. Prior to fleet assessment, SCE characterized the performance of three fuel cell electric vehicles at its EV Technical Center in Pomona, California. This characterization included both freeway and urban drive-range testing. In addition, the vehicles will be deployed to various sites throughout the SCE service territory for fleet assessments. Among the various test sites will be Palm Springs, designated as the hot-climate site.

This project demonstrates the ability of hydrogen to be a possible source of sustainable domestic transportation energy. The lessons learned in this project provide valuable knowledge to the partners by conducting project tasks, such as permitting, code compliance, vehicle characterizations, fleet assessment, and infrastructure installation.

**Keywords:** Hydrogen, Fuel Cells, Infrastructure

## 1. BACKGROUND

National concerns over energy security and the environment have prompted federal agencies to further investigate domestically produced, environmentally friendly sources of transportation energy. In 2003 the U.S. Department of Energy (DOE) initiated a five-year demonstration project named "Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project" designed to determine the feasibility of hydrogen as a transportation fuel. Specifically, the purpose of

the project is to conduct a "real world" performance evaluation of both fuel cell electric vehicles (FCEV) and the hydrogen infrastructure that supports them.

The DOE selected four teams of industry leaders to design, construct, and operate a controlled system composed of a fleet of light duty FCEVs and a network of hydrogen producing/dispensing fueling stations. One of the four teams consisted of Chevron Technology Ventures (project leader) and Hyundai American Motor Company. Each member is responsible for a specific task associated with the system. Chevron was to construct and operate four hydrogen fueling stations throughout the United States, while Hyundai was to provide the fleet of FCEVs used at the sites. Among the various locations, Chevron selected Southern California-Edison (SCE) to be a site host for one of the California stations. As part of its agreement, SCE collaborated with

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Chevron to construct the station at the corporate office of SCE in Rosemead, California. In addition, SCE is to evaluate a small fleet of FCEVs by operating them in real world applications.

## 2. INTRODUCTION

Southern California-Edison (SCE) is committed to the evaluation and deployment of advanced, cost effective, energy efficient electro-drive technologies as an outgrowth of its mission to provide safe and reliable electrical service to its customers, and as a response to air quality based regulations driving the growth of the electro-drive transportation industry. SCE has pledged to deploy electric vehicles (EVs) in its fleet. SCE's commitment to these technologies stretches beyond conventional battery EVs and into other advanced systems including Hybrid Electric Vehicles (HEV), Plug-In Hybrid Electric Vehicles (PHEV), and Fuel Cell Electric Vehicles (FCEV).

Although many technical barriers still need to be overcome before hydrogen fuel cells can become commercially viable, this technology has the potential to provide a domestic source of transportation fuel. SCE is working with both private and government entities to support the development of these technologies. For the DOE hydrogen demonstration project, SCE agreed to provide a construction site for the fueling station, assist with construction permitting, assist with public outreach, vehicle/station characterizations (DOE views the vehicles and the supporting infrastructure as one system and not independent of each other), and a controlled fleet deployment.

## 3. INFRASTRUCTURE

### 3.1 Rosemead Fueling Station Planning, Permitting, and Public Outreach

Although the name implies that the SCE Rosemead hydrogen fueling station was constructed in Rosemead, California, the survey mapping shows the station is in an unincorporated area of Los Angeles County. Hence, Chevron submitted all the design plans to L.A. County Planning, Building and Fire Departments for permitting. Each of these departments plays a particular role in the permitting process and has individual requirements. It is very important for the construction applicant to be informed and understand that some processes may require extensive time.

#### 3.1.1 PLANNING

The city planning department typically insures that the submitted plans are consistent with zoning restrictions.

If the project is within the allowed activities, the planning commission will generally approve the plans and allow the applicant to proceed to the building safety design check. If the process is not within the allowed parameters, the planning commission will typically hold a series of public hearings to allow governmental administrators and public citizens to voice their opinion on the construction. For the station's site SCE chose a location zoned for grazing recreational activities and small scale energy generating facilities, including solar arrays. L.A. County concluded that the proposal was not within the zoned requirements and submitted the plans for public hearing. Ultimately there were no protests and the station was given permission to proceed.

#### 3.1.2 PERMITTING AND CONSTRUCTION

Once the planning commission gave permission to proceed nine months after application, Chevron submitted all the design plans to the building safety and fire departments. In this phase of the project city officials typically look for code compliance of the submitted documents. Initially city officials viewed the station as a typical gasoline dispensing facility and felt the design did not meet requirements. The uniqueness of the hydrogen fueling station did not fit the convention of typical construction projects. The design team then approached the city and explained the differences along with the built in redundant safety systems. The officials made a few additions and allowed the construction to proceed. As part of the permitting requirements, the county asked Chevron to include fire sprinklers and fire hydrants along the public sidewalk adjacent to the building. This requirement was a routine measure associated with other similar installations. The permit for construction was granted three months after the submittal. These are some of the lessons learned:

- o Current building and electrical codes did not address many of the issues related to production, storage, and dispensing of hydrogen for transportation purposes.
- o Governmental requirements may add unexpected design parameters, including fire hydrants and/or fire sprinklers. These items may significantly affect both the budget and the construction schedule.
- o Third parties such as utility companies may require longer installation periods, and these issues should be addressed early in the process.
- o Conventional business IT infrastructure may not be suitable for the transfer of large data files. High speed internet from a cable company may be more suitable than a telephone company's infrastructure.



Figure 1: SCE Rosemead hydrogen fueling station

Ultimately, county officials were generally interested and valued the importance of the project. Although they did not have the proper code adoption, departments such as fire prevention offered assistance in collaborating with the design/construction team to build a safe and effective facility.

Chevron completed construction in late March 2007 and achieved various milestones, including the first station to be integrated into a corporate administrative site, the first electrolyzer technology in the Chevron network of stations, and the first to have card access. The station is capable of producing 40kg of hydrogen gas at 5,200PSI daily with a storage capacity of 60kg. The dispenser is capable of fueling a vehicle with up to a 4kg tank (with communication) within five minutes. The station has been operating since its completion with minor disruptions.

### 3.1.3 PUBLIC OUTREACH

In addition to the outreach required by the planning commission, Chevron and SCE took a proactive approach in educating the public about this project. Various town-hall meetings were scheduled to allow interested parties to inquire about the station. The public praised the effort to find alternative solutions to our growing transportation energy problems. Initially the public was concerned with safety and inquired as to the safeguards associated with the station. Once the questions were addressed by the various systems in place, the public was satisfied.

SCE, Chevron, and the California Fuel Cell Partnership invited local fire department engine

companies to attend a series of training modules. The training covered proper methods to responding to vehicle and station emergency situations. The forum allowed fire officials to ask questions about the design and a first hand tour of the facility. Overall the fire department was very impressed with the methods and strategies Chevron designed to mitigate the potential of any hazardous situation. Additionally, SCE invited local governmental officials including the mayor of Rosemead, city council, and local school district board members to tour the station and view the state-of-the-art facility. The school district was further interested in combining efforts with SCE to teach school age children about alternative fuels for transportation.

## 4. VEHICLES

### 4.1 Vehicle Testing

In late February 2007, SCE received the first three of a series of Hyundai Tucson FCEVs. The vehicles were shipped to SCE's EV Technical Center (EVTC) in Pomona, California for initial testing and evaluation. The ISO-9000:2001 certified facility passes all vehicles through a series of tests prior to releasing them into the company's fleet. These tests insure that the vehicle is capable of adequately performing the required tasks. Furthermore, the testing also serves to give the team insight into the vehicle's reliability and performance.

The EVTC developed a special testing procedure for Fuel Cell Electric Vehicles based on the established Electric Vehicle test plan. The methodology of the newly developed FCEV test plan is as follows:

#### 4.1.1 NAMEPLATE DATA COLLECTION

All applicable nameplate data, serial numbers, and ratings for all tested components are collected and recorded. This data is important to log in order to keep track of the version of the software and hardware of the vehicle, since this technology can change rapidly.

#### 4.1.2 WEIGHT DOCUMENTATION

Using a certified scale, the weight of the vehicle is measured. The curb weight is subtracted from the GVWR to determine the available payload.

#### 4.1.3 RANGE TESTING

##### 4.1.3.1 Urban Tests

Prior to beginning the test the odometer reading and starting ambient temperature is recorded. The attendant fills the tank according to the fueling instructions at



the station. Then the start-of-test data (odometer, fuel level, ambient conditions, DAQ and vehicle gage data) is recorded. The vehicle is then driven to the urban Pomona loop using the route depicted in Figure 2. The urban Pomona loop is a local street route of about 20 miles with approximately 50 stops signs and traffic lights. The test is conducted on the Pomona loop in a manner that is compatible with the safe flow of traffic for the determined distance. The distance to the Hyundai/Chevron station is driven at the start and finish. In between, standard Pomona loops are driven (see QSTP-11-01). Data is recorded at five-mile intervals (or at intervals determined by the vehicle's fuel and/or charge meter) meter readings, odometer mileage, and DAQ mileage, and fuel flow data if available.

At the end of the test the vehicle is parked close to the station. The vehicle is not fueled at this time. In addition the end-of-test data (odometer, fuel level, ending ambient conditions, DAQ and vehicle gage data) are recorded.

The urban range tests are conducted in the following test configurations:

**UR-1** – Minimum payload (driver only) with no auxiliary loads.

**UR-2** – Minimum payload (driver only) with the following auxiliary loads on: air conditioning set on high with external vents closed, fan high, low beam headlights, and radio. A thermocouple temperature is used to continuously record the temperature of the air-conditioned outlet air from the center cabin vent and the cabin ambient temperature at mid-cabin chest level.

**UR-3** – UR-1 test is repeated at the vehicle's maximum legal weight limit (without exceeding the gross axle weight ratings).

**UR-4** – Repeat the UR-2 test at the vehicle's maximum legal weight limit (without exceeding the gross axle weight ratings).

Once the data is gathered the vehicle's fuel consumption per mile is calculated. The tests are repeated until the fuel consumption per mile differs by less than 5.0% from the preceding result, or a maximum of three drives per test.

#### 4.1.3.2 Freeway Tests:

Like the urban loops the vehicle is fueled prior to the test and all pertinent data is recorded. The vehicle (with windows closed) is then driven in a manner that is compatible with the safe flow of traffic. The driver

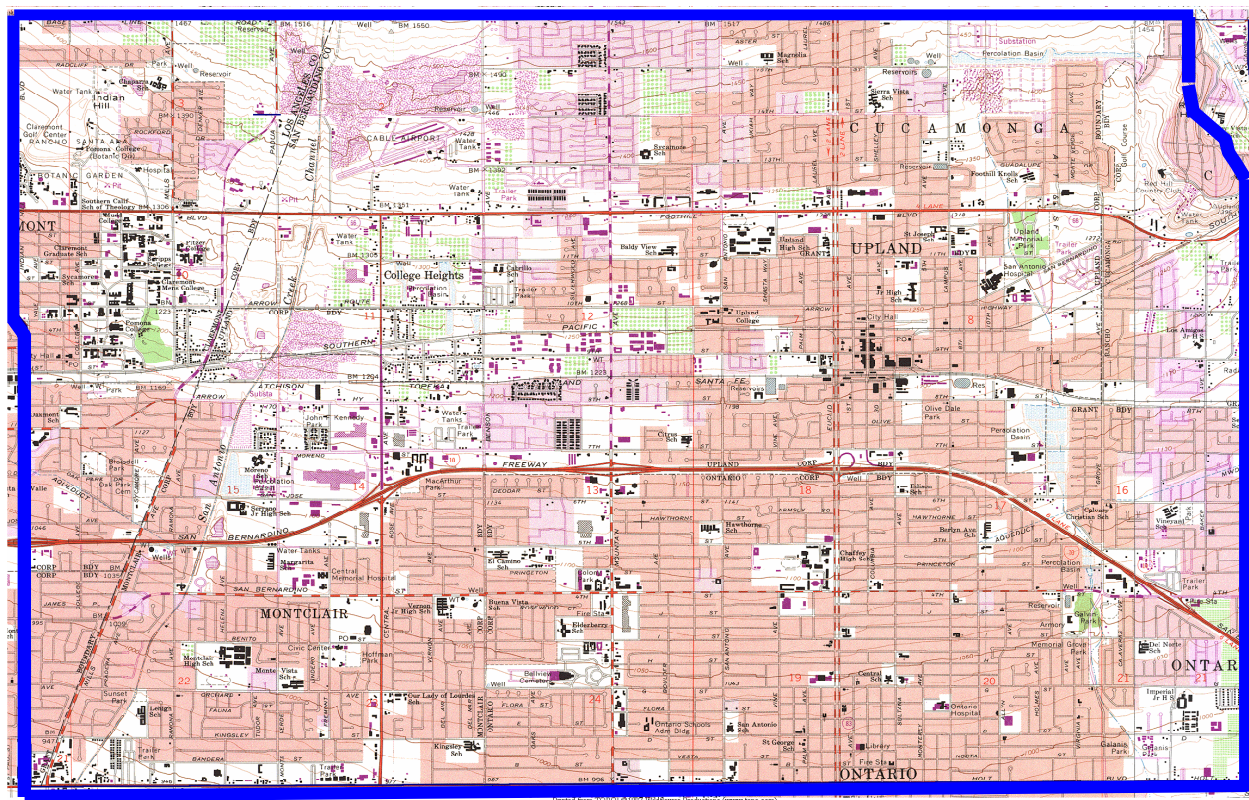


Figure 2: Urban Pomona loop

tries to maintain the vehicle at a constant power or fuel consumption rate, of a steady 65 mph on the freeway. All vehicles are tested on the freeway Pomona loop, that is a loop on four local freeways of approximately 37 miles (one transition requires one-half mile on access roads); see Figure 3.

The urban range tests are conducted in the following test configurations:

**FW-1** – Minimum payload (driver only) with no auxiliary loads.

**FW-2** – Minimum payload (driver only) with the following auxiliary loads on: air conditioning set on high with external vents closed, fan high, low beam headlights, and radio. Use thermocouple temperature loggers to continuously record the temperature of the air-conditioned outlet air from the center cabin vent and the cabin ambient temperature at mid-cabin chest level.

**FW-3** – Repeat the FW-1 test at the vehicle's maximum legal weight limit (without exceeding the gross axle weight ratings).

**FW-4** – Repeat the FW-2 test at the vehicle's maximum legal weight limit (without exceeding the gross axle weight ratings).

#### 4.1.4 PERFORMANCE TESTING

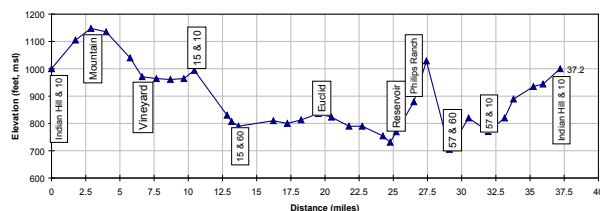
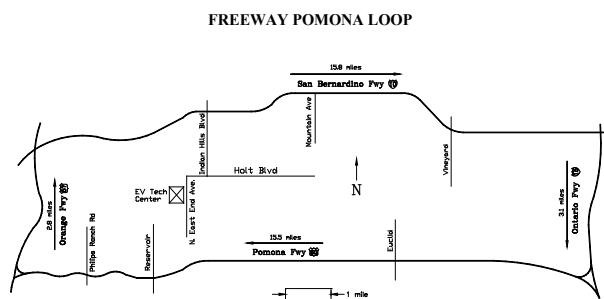


Figure 3: Freeway Pomona loop

The acceleration tests are designed to measure peak power capability of the vehicle and fuel cell stack on the test track. An accelerometer performance computer is used to measure the time, speed, and acceleration during these tests. The tests will be performed in the sequence and number described in the process below to minimize heating effects on the system.

##### 4.1.4.1 Acceleration

The FCEV is accelerated from a stop to over 60 mph at maximum power. The test is repeated two times in opposite directions (to average the effects of wind and grade) at the following tank levels: 100%, 80%, 60%, 40%, and 20%, as measured by the FCEV's fuel level gage. The data generated is used to obtain the time for 0-30 mph and 0-60 mph.

##### 4.1.4.2 Maximum Speed

In this test the vehicle is continued to accelerate until the maximum speed is reached. The test is conducted twice in opposite directions at both 100% and 20% fuel tank levels.

##### 4.1.4.3 Acceleration – 30 to 55 mph

Accelerate the FCEV from a steady 30 mph to 55 mph at maximum power. The test is performed twice in opposite directions at the following fuel tank levels: 100%, 80%, 60%, 40%, and 20% (after the above tests).

##### 4.1.4.4 Braking

Brake the vehicle from a steady 25 mph without skidding the tires. This test is performed four times in opposite directions. The performance computer is used to determine braking distance. This test will be performed between 50% and 60% fuel tank level.

#### 4.5 Vehicle Fueling

The vehicle is preferably tested in a manner such that the test drive begins with a full tank, and then the tank is refilled to the same point. It is important for the testing to try to maintain the same conditions during each fill. Temperature and pressure affect the fill of gaseous hydrogen. Therefore, the tests should be conducted at the same time each day, and fueling should be conducted at the same time and temperature. Ideally, the vehicle will be parked overnight at the fueling station.

Each test vehicle is fueled each morning before each drive. Once completed, the vehicle is parked in close approximation to the station, but is not fueled until the

following morning to ensure consistent fill conditions. All station fill data, as well as on-board pressure data, vehicle data acquisition information, and dash gage details are recorded prior to start of test.

## 5. SYSTEM ANALYSIS

As mentioned earlier, the DOE views the fueling station and the vehicles as a complete system. SCE gathers the recorded data and provides analysis of the “well to wheels” efficiency of the system. SCE equipped the station with an advanced power analyzer to gather data relating to the production, storage and dispensing of hydrogen. This data, along with driving and fueling data, will provide the basis for a quantitative analysis of the process. To the right are some of the parameters measured and analyzed at the station.

As an electric utility company, SCE is interested in understanding the system impact the hydrogen infrastructure may pose on the electric grid. To determine the true power characteristics of the fueling station, the following parameters will be calculated or analyzed:

- o Real and reactive power characteristics
- o Power conversion efficiency
- o Energy conversion efficiency
- o Power demand
- o True power factor
- o Total harmonic distortion
- o Total demand distortion
- o Audible noise level

In addition, a correlation between the various station processes and the electric characteristics will be established. This analysis will determine the efficiency and system impact of the station’s sequence of operation including: hydrogen generation, compression/storage, dispensing and idle.

## 6. NEXT STEPS

SCE and Chevron will perform an in-depth analysis of the system once additional data is collected from the fueling station and the vehicles. SCE will deploy the verified reliable vehicles into the fleet, and collect operational data. Furthermore, SCE is investigating the possibility of installing a photovoltaic system capable of supplying the station with completely renewable energy. SCE expects to have completed a full system characterization by the end of 2007.

## AUTHOR

Mr. Salazar is a test engineer at Southern California Edison’s Electric Vehicle Technical Center. His

Item	Parameter
1	Mass Flow Rate (Slow Fill)
2	Mass Flow Rate (Fast Fill)
3	Starting Vehicle Pressure
4	Final Vehicle Pressure
5	Starting Vehicle Temperature
6	Final Vehicle Temperature
7	Quantity of Gas Delivered
8	Filling Faults
9	Mass Electrolyzer Production Rate
10	Compressor Type
11	Compressor Number of Stages
12	Compressor Efficiency
13	Compressor pressure ratio
14	Compressor mass flow rate
15	Compressor volume flow rate
16	Gas Properties at Inlet of Compressor
17	Gas Properties at Outlet of Compressor
18	Number of Fills per day
19	Number of Fills per week
20	Number of Fills per month
21	Faults, Errors, Failures since opening
22	Leakage Detected
23	Water Inflow
24	Oxygen Outflow mass
25	Start and Stop of Gas Production

Table 1: Station and vehicle parameters

projects include system impact evaluations of various electro-drive technologies. Among his diversified responsibilities, he is the project manager for the development of the newly constructed fuel cell testing site at the EV Technical Center in Pomona and the SCE representative for the DOE’s hydrogen demonstration project. His broad background in power and control systems enables him to develop custom instrumentation for complex testing of vehicles and advanced energy storage devices.

Mr. Salazar’s educational qualifications include a Bachelor’s of Science in Electrical Engineering from the California State Polytechnic University at Pomona. He is currently completing his Master’s degree at the University of Southern California. Mr. Salazar holds a valid Professional Engineer’s License in the State of California in Electrical Engineering.