Introduction

There has been significant growth of plug-in electric vehicles (PEVs) in California as a result ofsocietal awareness of their environmental benefits, substantial improvement in battery technology and attractive federal, state, and local government incentives. California's goal is toreduce greenhouse gases to 40 percent below 1990 levels by 2030, and PEVs are expected to substantially contribute to this reduction. Besides helping to reduce pollutants and emissions,PEVs also can be used as a unique and essential method for energy storage.

The American Automobile Association and Federal Highway Administration state that a typical U.S. driver spends less than an hour each day in personal vehicles and drives an average of 37 miles per day, resulting in the vehicle being stationary for more than 23 hours each day. A modern PEV, when plugged into the electricity grid, could therefore serve as supplemental energy storage device by using the battery to provide electricity for peak demand and congestion. Drawing from the supplemental stored energy of the PEVs would reduce having the grid operator purchase additional energy storage.
Moving towards California's 2050 renewable target of reducing greenhouse gases by 50 percent below 1990 levels has been helped by large amounts of solar photovoltaic (PV) generation into California's electric grid. Excessive generation in the middle of the day from PV is the ideal time to charge the PEVs– a service the PEVs can easily provide especially in larger numbers.

Effectively managing the grid with PEVs using sensors, data, modeling, analysis and smart software-based controls, energy pricing, driver preferences, real-time and historical PEV charging information, renewable electricity generation on the grid, and grid capacity information would convert the PEVs into a high value storage asset and help manage inconsistent renewable energy generation. Therefore, the infrastructure for "smart" electric vehicle support equipment is essential to the success in growth of PEVs.

Vehicle-to-grid (V2G) and vehicle-to-building (V2B) technology takes grid impacts into accountand may provide additional value to customers, while supporting the grid. For example, V2Gand V2B enable a PEV to discharge energy into the grid or to support building loads whichhelps reduce peak loads and associated energy bills or can provide power to the customer
during times of power shortage. While most current PEVs only support unidirectional chargingfrom grid to vehicle, V2G and V2B technology allows power to flow in the reverse direction so aPEV can act as a battery energy storage system. Although a single vehicle may not provide largeamounts of power, large numbers of vehicles can be aggregated into a single resource allowingthe grid operator to draw significant amount of power.
Grid services help utilities resolve issues of reliability and stability. For example, PEV chargingcan be used to take excess energy during times of over-generation (such as during peak PV generation) or provide energy back to the grid when demand is high. The challenge with PEVs providing grid services is the ability to aggregate and control multiple PEVs for a coordinated response