

# Moving Electric Transportation Forward: The Many Faces of Electric Vehicles

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First-time attendees to classic car shows are frequently surprised to see vintage electric cars tucked in among the Model T's and A's. Electric cars were quite popular in the early 1900's when speed limits were generally less than 20 mph and top speeds for most vehicles were less than 40 mph. As gasoline-powered cars became more technologically advanced, however, they began to literally out-pace their electric counterparts. A key selling point of the internal combustion engine (ICE) was the ability to go further and get there faster.

Since electric vehicles (EVs) were first retired in the 1930's, there have been several attempts to revitalize the EV market in the United States. In the late 1960's, concerns over air pollution were a key driving force as Congress passed the Clean Air Act and the first bill promoting electric vehicles as a means for reducing air pollution. The Arab oil embargo in 1973 provided further impetus for electric vehicles as gasoline prices rose and lines at filling stations grew longer. This environment gave birth to the CitiCar in 1974, advertised as "the first licensable all electric passenger vehicle in America" [1]. Limited driving range and top speeds of less than 40 mph curtailed the success of EVs in America, however, until General Motor's Impact concept car turned heads with speeds of up to 75 mph and a range of 75-150 miles on a single charge [2]. GM's EV1, based on the Impact, was introduced in 1996 in a limited lease-only program, but GM canceled the program in 2003 voicing concerns over profitability, liability and maintenance as well as lack of wide-spread consumer interest due to the relatively limited range.

The issues of driving range and cost are still the plague of mass-produced electric vehicles. There are many situations, however, in which today's electric vehicles are substantially more practical than "traditional" gasoline-powered vehicles. Delivery and public transit vehicles in urban settings are current targets for EV manufacturers. An electric motor is ideal for the low speed stop-and-go traffic inherent in such routes, and the limited range afforded by a battery system is not a significant complication when routes and schedules are defined. The environmental benefits of an electric vehicle – zero tailpipe emissions and minimal noise –

are also of greatest benefit in an urban setting. This issue of the journal presents four purely electric vehicles designed for use in specific settings: a "Personal Electric Vehicle" designed for a single traveler at highway speeds with up to a 45 mile range between chargings [3]; a public transit electric bus utilizing ultracapacitors charged via an inductive charging system; a light electric vehicle designed for use in urban postal deliveries; and a two-seater urban commuter car with a maximum speed of 40 mph. All of these applications are able to take advantage of the benefits of EVs while meeting performance requirements in their respective situations.

Predicting the performance requirements for a particular application is challenging. Many studies use standardized driving schedules that have been developed to mimic different scenarios. The Japan 1015, New European Drive Cycle, and the U.S. Environmental Protection Agency's (EPA's) Urban Dynamometer Driving Schedule (UDDS) are styled to mimic driver demands in an urban setting. Drive cycles such as the EPA's Highway Fuel Economy Test (HWFET) are more representative of highway driving, including higher speeds and longer distances between stops. These simulation tools idealize "typical" driving behavior, but these tools are not global in nature. One approach for estimating driver demand in a highly specific scenario is to install instrumentation in conventional vehicles to monitor actual use [4, 5]. This more rigorous approach is useful in evaluating performance requirements (e.g., range, power) for market acceptance in a given market segment, as seen in the article by Kondo et al. in this issue.

The use of hybrid systems to extend the range or power of a pure electric vehicle is one approach to extending EV application and improving fuel economy of ICEs [6]. A wide variety of hybrid systems are currently in use and ideally are designed to best match vehicle performance with expected driver demand [7]. One unique application for HEVs discussed in this issue is a heavy-duty "Trouble Truck" used by utility services. Traditionally, the diesel engines in these trucks must be used to power lifts and other equipment while stationary work is being conducted. In contrast, the hybrid version is able to shut down the ICE and utilize battery power for stationary operations. ICE fuel economy is thereby maximized by designing the hybrid

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systems to meet the needs specific to the application.

Improved fuel economy and reduced emissions are arguably two of the prime drivers for the development of EVs and HEVs; quantifying the effects of hybridization on these parameters is therefore paramount. Studies have shown that even mild hybridization can significantly improve fuel economy [8, 9]. Fuel economy calculations are more complex, however, when the use of electricity from the grid to charge batteries in a PHEV is considered. Both fuel economy and environmental implications of PHEVs strongly depend on the initial energy source for the grid electricity as well as the distance the PHEV is driven on a daily basis (i.e., if the vehicle is routinely operated in all-electric or in hybrid mode) [10, 11]. Two articles in this issue explore the implications of PHEV use in the United States with regards to energy independence and emissions. Hybrid vehicles utilizing a fuel cell rather than an ICE are also under consideration. The implications of this type of hybrid vehicle are explored in more detail in this issue as well.

Improved energy storage and vehicle efficiencies will be required for purely electric vehicles to replace the traditional "family car" at equal performance [6, 12, 13, 14]. Energy storage will be addressed in more detail in the October issue of the WEVA Journal. But for the present, consider these articles which look at electric vehicles which are available today and the environmental and societal implications of the electric vehicles which will likely be available in the near future.

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