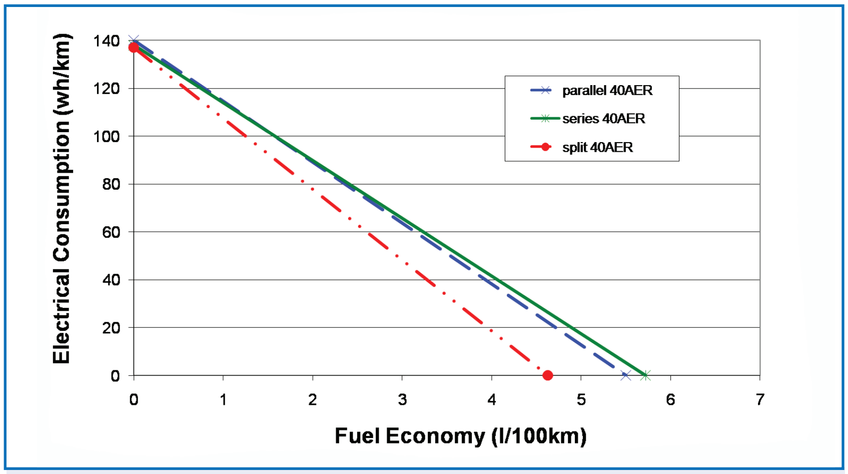
Powertrain Assessment

Argonne National Laboratory's Powertrain Systems Analysis Toolkit (PSAT) is used to design and evaluate a series of plug-in hybrid electric vehicles (PHEVs) with various "primary electric" ranges, considering all-electric and charge-depleting strategies. The objective is to quantify the impact of all-electric range on component performance requirements. The concern is that the peak power requirements for the battery and electric drive are much higher to achieve the same performance in electric and hybrid modes. This impacts the vehicle economics; higher energy and power requirements drive up costs of the battery and electric drive components, reducing the likelihood of production.



The figure above shows an example comparison of three powertrain configurations (parallel, series and power split). For each configuration, several control strategies are being assessed using both global optimization and heuristic optimization.

One of the main objectives of the U.S. Department of Energy's Plug-in Hybrid Electric Vehicle R&D Plan is to "determine component development requirements" through simulation analysis. PSAT has been used to design and evaluate a series of PHEVs to define the requirements of different components, focusing on the energy storage system's power and energy. Several vehicle classes (including midsize car, crossover SUV and midsize SUV) and All Electric Range (AER from 10 to 40 miles) were considered. The preliminary simulations were performed at Argonne using a power-split hybrid configuration with an energy storage system sized to run the Urban Dynanometer Driving Schedule (UDDS) in electric mode, as well as a sample of real-world drive cycle provided by the Environmental Protection Agency.

Additional powertrain configurations and sizing algorithm are currently being considered. Trade-off studies are being performed as ways to achieve some level of performance while easing requirements on one area or another. As shown in the figure below, the FreedomCAR Energy Storage Technical Team selected both a short-term and a long-term All Electric Range (AER) goal based on several vehicle simulations.

PSAT was also used to evaluate several control strategies and powertrain configurations to assess their impact on fuel efficiency. A generic global optimization algorithm for plug-in hybrid electric vehicle powertrain flows has been developed based on the Bellman optimality principle. Optimization results are used to isolate control patterns, both dependent and independent of the cycle characteristics, in order to develop real-time control strategies in Simulink/ Stateflow. These controllers are then implemented in PSAT to validate their performances. Heuristic optimization algorithms (such as DIRECT or genetic algorithms) are then used to tune the parameters of the real-time controller implemented in PSAT.

One outcome of the study showed that using charge-depleting, rather than all electric mode followed by charge sustaining mode, was more efficient when the vehicle is driven longer than its All Electric Range.

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