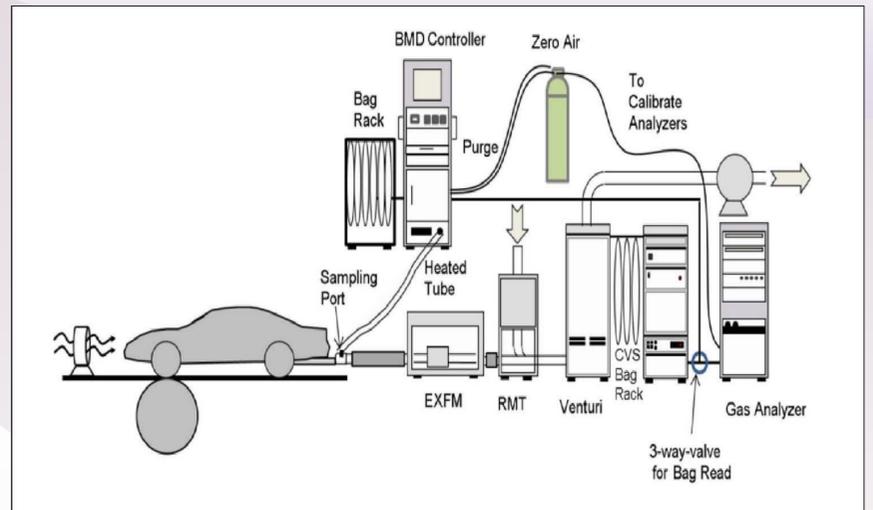


# Plug-in Hybrid Electric Vehicle Emission Testing

## OVERVIEW

In order to label the fuel economy and emission factors of a specific vehicle model, vehicles are tested on a dynamometer for different driving cycles. Tailpipe emissions such as CO<sub>2</sub>, CO, THC, NO<sub>x</sub> are sampled by either the constant volume sampling (CVS), or bag mini diluter (BMD) emission measurement systems for government certification. With the continual implementation of ever stricter emission controls, low-emission vehicles pose challenges to the accuracy of the sampling systems. Plug-in hybrid electric vehicles (PHEVs) which consume both gasoline and grid electricity further challenge not only the testing instrumentation, but also the test procedures. In this project, a prototype Toyota Prius PHEV was tested using the California Air Resources Board preliminary test procedure with both traditional CVS and BMD systems, as well as other new test methods such as a fuel flow meter, and CVS continuous sampling, in order to find alternative and optimal methods for PHEV fuel economy and pollutant emission testing.



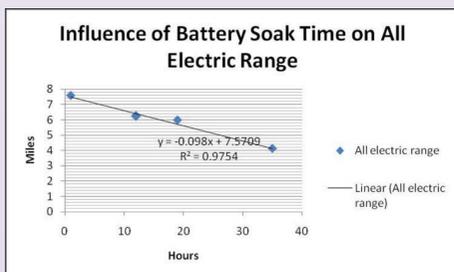
PHEV testing schematic diagram

## GOALS

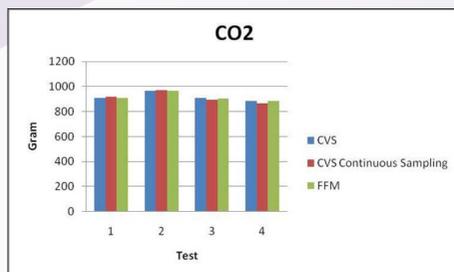
The research goal was to assess emissions test methodology, test protocols, and instrumentation applied to plug-in hybrid electric vehicle.

## RESULTS

1. Battery self discharging is a significant issue for PHEVs. With the soak time increasing after the battery is fully charged, the all electric range, or equivalent all electric range, decreases. It is recommended that the government test procedure should include a battery hot start (short soak after full charge) and cold start (long soak after full charge) in order to find a more representative all electric range, or equivalent all electric range, for a specific PHEV.



All electric range decreases with increasing soak time after battery full charged

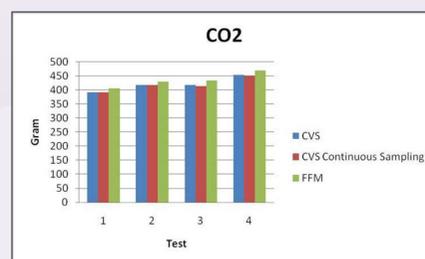


Mass CO<sub>2</sub> from different sampling methods in engine hot start cycle

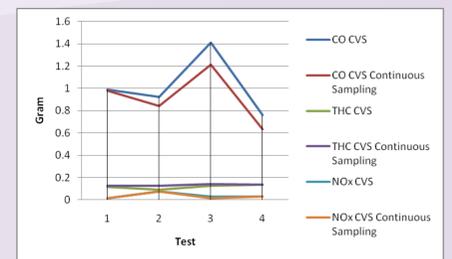
## RESULTS (continued)

2. In engine hot start driving cycles, the calculated CO<sub>2</sub> mass is consistent from CVS, CVS continuous sampling, and the fuel flow meter. However, in the engine cold start driving cycle, CO<sub>2</sub> mass from CVS and CVS continuous sampling are consistent, but repeatedly lower than the fuel flow meter. By comparing the instantaneous mass of CO<sub>2</sub> from CVS continuous sampling and the fuel flow meter, it is concluded that the difference in cold start emissions is due to a small portion of emissions left in the tailpipe and the sampling line.

3. For pollutant emissions (CO, THC, and NO<sub>x</sub>) CVS and CVS continuous sampling show consistent results, except when under-sampling occurs in the CVS continuous method due to the analyzer being out of range. The BMD system consistently shows lower pollutant emissions than the CVS.



Mass of CO<sub>2</sub> from different sampling methods in charge depleting engine cold start cycle



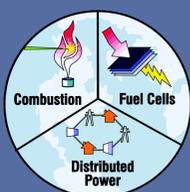
Masses of CO, THC, and NO<sub>x</sub> from different sampling methods in charge depleting engine cold start cycle

## RECENT PUBLICATIONS/PAPERS

D. Allgood, T. Brown, S. Samuelsen, (2010) *Comparison of constant-volume sampler and bag minidiluter emissions measurements of a plug-in hybrid electric vehicle*, International Journal of Engine Research, Vol. 11

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