



Role of the EV Button in Prius PHEV conversions

Davide Andrea, V.P. of Engineering, Hybrids Plus Inc.
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Synopsis:

Common wisdom says that, in order to minimize gasoline use in Prius converted to PHEV (Plug-in Hybrid Electric Vehicle), it must be operated in the EV Mode as much as possible. It also says that, consequently, vehicles that do not have an EV Button cannot achieve the PHEV performance of a Prius. This paper shows that, in reality, low gasoline usage can be obtained whether or not the EV Mode is used. In addition, counter-intuitively, the pollution generated from using the EV mode is higher than not using it.

The EV Mode in a Prius.

A Prius HEV has an EV Button on the dashboard that, when pressed, requests that the vehicle delay the turning on of the engine, and operate as an Electric Vehicle (EV Mode). The Prius honors this request if the engine is off, the speed is sufficiently low, and the battery is sufficiently charged. The Prius ends this EV Mode when it requires the additional power of the engine. It is said that, starting with a charged battery, the Prius can go up to about 1 mile on EV Mode. The button is not installed in vehicles for the North American market, though many hobbyists have retrofitted their Prius by adding such a button.

The EV Mode as part of a PHEV conversion.

It is not necessary to use the EV mode in PHEV conversions, yet most PHEV systems rely on it to achieve high mileage (mpg). The systems will do the electrical equivalent of pressing the EV button as much as possible, so that the engine will stay off as much as possible. If the engine is off, the mpg is infinite, by definition. Therefore, the average mpg as the engine goes off and on, is higher than it would have been without using the EV Mode.

Unfortunately, the Prius changes the MFD screen display when it enters the EV Mode, and it beeps 3 times whenever it ends the EV Mode. Therefore, PHEVs that use the EV Mode change screens and beep quite often.

Effects of EV Mode on mileage.

On a relatively short term, and in city driving, the mpg of a Prius PHEV that relies on the EV mode is indeed higher. But, over the entire range that the PHEV Prius can drive using energy from its battery, it really doesn't matter whether that energy is used all in the first few miles (at very high mpg), or it is used more moderately over a longer distance (at lower mpg). In other words, the EV Mode simply encourages the Prius to use-up all the electrical energy very quickly, over a short distance. Again, all this applies only to city driving; in highway driving, the EV Mode cannot be used, due to high power demand.

There is also a secondary issue that can result in lower mpg, unrelated to engine temperature. In a PHEV conversion that relies on the EV mode, when the engine does come on, it tends to operate more time in regions of lower efficiency (at low load). This is true whether the engine is cold or hot.

Therefore, counter-intuitively, using the EV Mode during normal driving will actually reduce, not increase, the overall mpg.

Effects of EV Mode on emissions.

Normally, a few seconds after the Prius is turned on, it will start its engine. Typically, at that point, the Prius is driven at low speed, and the engine is not needed for traction, so that it can occupy itself with just warming-up itself and the catalytic converter, for the purpose of getting quickly to a temperature in which it can operate with low emissions. After having done so, the engine goes off.

In a PHEV that relies on the EV Mode, the engine doesn't have a chance to warm up, but is instead required to come on when the Prius is under high acceleration or high speed, at which point it is still cold. Therefore, at that point, the Prius will pollute above the levels allowed by its AT-PZEV rating. Eventually, the engine will warm-up, so its emissions should fall back to where they would be in a standard Prius. However, the fact that the engine is used more often in regions of lower efficiency means that the emissions in a PHEVs that rely on the EV Mode remain higher even with a warm engine. One might think that it would be possible to drive exclusively in EV Mode, producing no emissions at all. But, in reality, it is very difficult to remain in EV Mode for more than a few miles: the Prius will soon turn on the engine even if the driver is very careful trying to avoid that.

Advantages of not relying on the EV Mode.

Having seen how the EV Mode does not give the expected increase in mpg, but, on the contrary, results in worse mpg and emissions, let's discuss the performance of a PHEV conversion that do not rely on the EV Mode. The fact is that the software in the Prius, when left alone, is very adept at minimizing emissions and maximizing mileage, for a given set of conditions. To increase the mileage, all one needs to do is change one condition: the indication of how much electrical energy is available. A side advantage of not relying on the EV mode is that the Prius will not suddenly change the screen it displays, and it will not suddenly beep (as the EV Mode is entered and exited).

Test results.

It is difficult to compare mpg of various vehicles, under varying conditions. The only reliable way of doing so is to use a single vehicle under laboratory conditions, on a dynamometer. On an anecdotal basis, Hybrids Plus PHEV conversions, which do not rely on the EV Mode, have reported mileage similar to or even higher than other PHEVs, which do rely on it (in the range of 80 to 150 mpg). Testing by Argonne National Labs on two PHEVs, which do rely on the EV Mode, have shown excessive emission when first starting up (compared to a standard Prius) and operation of the engine outside its optimal range.

PHEV conversion of vehicles that lack an EV Button.

Just as a PHEV conversion of a Prius does not require the EV Mode, vehicles that do not have the option of an EV button may be converted to PHEV just as well and with comparably good results. In particular, a Ford Escape converted to PHEV by Hybrids Plus achieved a mileage of 140 mpg in preliminary testing in city driving – even higher than a Toyota Prius PHEV.

Conclusions.

The EV Button is a nice convenience for the driver, but is not necessary, and indeed is disadvantageous, when used as an integral part of a PHEV conversion: in general, mileage in a Prius PHEV is actually better, and emissions are lower, if the EV Mode is not requested by the PHEV system.

References:

Testing and Analysis of Three Plug-in Hybrid Electric Vehicles (SAE 2007-01-0283) Argonne National Lab. <http://www.transportation.anl.gov/pdfs/HV/399.pdf>
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