Science You Can Use

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Dear Science: I read the column you wrote a few months ago on whether all-electric passenger vehicles (AEs) could be a significant near-term part of the solution to the price-of-gasoline and climate change problems. You used the Chevy Bolt as an example of an AE. I think the Tesla Model 3 is a better example than the Chevy Bolt for these comparisons. Do you agree? -- Buck R.

Dear Buck: To evaluate the Tesla Model 3 (which in the following I will call the "TM3"), we need a few definitions and some evaluation criteria.

Some definitions. An *internal-combustion-engine powered* passenger *vehicle* (ICE) is powered entirely by an internal-combustion engine; an ICE is the most common type of passenger vehicle today. An *all-electric* passenger vehicle (AE) is a vehicle powered entirely by onboard batteries that must recharged. A *hybrid* passenger vehicle (HB) has an onboard gasoline engine that charges onboard batteries that in turn supply power to electric motors that propel the vehicle. A *hybrid plug-in* passenger vehicle (HBP) is a vehicle that can operate as a hybrid; alternately, it can operate (in today's models, typically for not more than about 50 miles) like an AE does by drawing power from a set of onboard batteries that is charged from an outside source.

The *energy efficiency* of a vehicle is the amount of energy the vehicle requires to traverse a given distance under specific test conditions. If the vehicle is an AE, energy efficiency can be expressed in miles per kilowatt-hour. If the vehicle is an HB, energy efficiency can be expressed in miles per gallon. If the vehicle is an HBP operating entirely on battery power, its energy efficiency can be expressed the same way an AE's is; when operating as an HB does, an HBP's energy efficiency can be expressed just like an HB's is.

Comparison criteria. Here are some frequently used comparison criteria, adapted for the TM3 (in (A)-(F) and (a) – (f) below, the phrase "the alternatives" means "today's most energy-efficient ICEs, HBs, and HBPs"):

A. How does the purchase price of a TM3 compare to the alternatives?
B. How does the energy price per mile for the TM3 compare to the alternatives?
C. Is the carbon dioxide emitted per mile by an AE less than that of the alternatives?
D. What is range between recharges of the TM3 compared to the range of the alternatives?
E. How long does it take to charge the batteries in a TM3 in your house and on the road?
F. Are commercial charging stations "on the open road" located as conveniently as gas stations are today?

Evaluation. Given these definitions and criteria, we can evaluate the TM3 compared to the alternatives.

a. The purchase price of a TM3 is about $47,000 - $55,000, depending on options. This is comparable to the price of today's most energy-efficient HBs and HBPs.
b. The TM3 can travel about 4 miles on a kilowatt-hour (kWh). Let's suppose the price of a kWh is $0.15. To travel 100 miles, the TM3 would require (100 mi/4 mi per kWh) x

($0.15 /kWh) =) $3.75.   Let's suppose that gasoline is $3.50/gallon. Today's most energy-efficient HBs or HBPs have an energy efficiency of about 50 miles/gallon. To travel 100 miles, therefore, those HBs or HBPs would require ((100 mi/50 mi/gallon) x $3.50/gallon =) $7.00 of gasoline – about twice the price of the energy required for the TM3.

c. An Argonne National Laboratory report states that *if* the energy used by a TM3 is produced by burning carbon fuels (coal or natural gas) to generate electricity, the most energy-efficient AEs and the most energy-efficient HBs and HBPs produce about the same amount of carbon dioxide per mile. If the energy used to power a TM3 comes from a solar photovoltaic system, however, the TM3 produces no carbon dioxide per mile.
d. Tesla says the range between required re-chargings of the standard TM3 is about 300 miles. This is roughly comparable to the range between refuelings of the alternatives.
e. The fastest TM3 charger that can be installed in a typical house would require about 7 hours to bring the TM3's fully discharged batteries to full charge. The fastest Tesla chargers (which Tesla calls "superchargers") outside your house will take 15 minutes to provide a charge good for about 200 miles. This means that if you take a road trip that is longer than 200 miles, and you don't want to spend more than 15 minutes at a charging station, you need to plan your route so that the longest distance between successive supercharging stations is no greater than about 200 miles.
f. Tesla has built a network of about 1200 supercharging stations across the US. Most of these are located near large urban areas, or along Interstates and heavily traveled segments of the US Highway system. There are few if any Tesla charging stations in rural areas that are not near those highway systems.

For further information, see https://www.tesla.com/model3 .

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