

Comparing ICE and EV operating costs

A learn in 30 presentation

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ICE =

Internal Combustion Engine

- For personal transportation, as of now most people in the US own a car with an ICE
- ICE fuel efficiency varies but has improved over time
- Knowing your Miles Per Gallon (MPG) and the cost per gallon will help you understand the operating cost saving when using an EV or PHEV

EV = Electric Vehicle

- EVs are now made and sold by Tesla, major US car makers, and foreign car makers
- EV purchases were 8% of the US new passenger vehicle market in calendar year 2022.
- See Geof Goodrum's January 20, 2023 presentation on his new Kia EV, found on the PATACS web site Recent Meetings page.
- For precision, Geof's presentation refers to EV as Battery Electric Vehicle (BEV).

Objections to EVs

- Price is too high
- Range is too low
- Cannot find charging stations (see Washington Post columns in July and August 2023)
- It takes too long to charge, compared to filling a gas tank
- I expect many EV owners will opt to do quick “top it off” recharges frequently.

PHEV =

Pluggable Hybrid Electric Vehicle

- The Toyota Prius Prime is a PHEV, including a battery with sufficient EV mode range for everyday local driving, plus an ICE.
- I traded in my 2015 Prius Prime for a 2020 Prius Prime in May 2023.
- The 2020 Prius Prime battery enables up to 32 miles of pure EV mode driving.
- In Hybrid mode, the Prius Prime range is 540+ miles using about 8.5 gallons of gasoline plus battery power.

Battery

- The term Battery in this presentation refers to a large high-capacity battery, not the 12 volt battery in an ICE car
- PHEVs also include a 12 volt lead-acid battery to start the ICE
- Sometimes the PHEV big battery is called a traction battery.

Advantages of PHEVs

- You can taste-test the feel and behavior of EV by driving a PHEV locally in EV mode.
- In some Hybrid mode driving conditions, the ICE engine will add energy to the battery.
- Each PHEV includes an AC-powered charger.
- Charging a PHEV overnight at home is practical and inexpensive.
- You can make long trips in Hybrid mode without frequently recharging.

Advantages of PHEVs

- In college, I took an Intro to Economics course.
- I learned about the **Theory of Alternative Goods**: when various goods serve the same purpose, consumers can select based on price, features, availability etc.
- PHEVs let you select a fuel, gasoline or electricity, based on price, local availability, etc.
- When the Colonial pipeline was hacked, and gasoline vanished in the mid-Atlantic, I ran my PHEV on electricity for more than a week.

Regeneration

- Going downhill, EVs and PHEVs can use the electric motor as a **generator**
- The generated electric energy is stored in the battery.
- Interesting experiences while descending Spruce Knob in West Virginia, Pike's Peak in Colorado, or I-476 between Allentown and Philadelphia

Fundamentals of Charging EVs and PHEVs

Critical Facts about Charging an EV or PHEV: Capacity

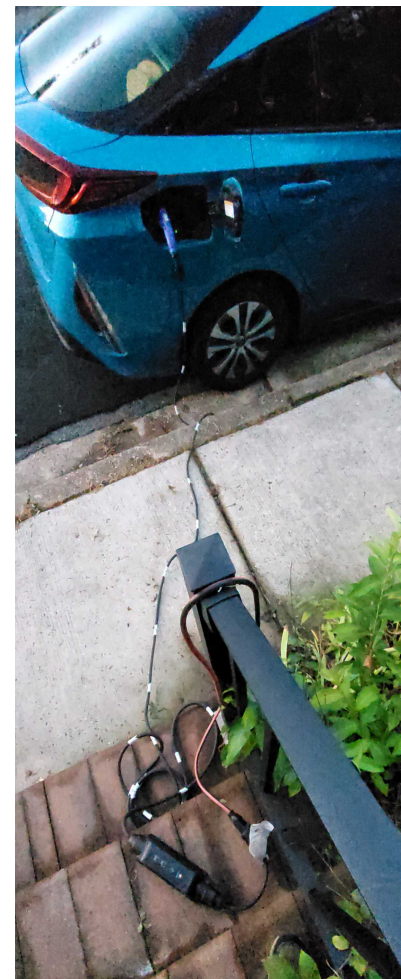
- Just like a gas tank, an EV or PHEV battery has a **capacity**, a limit on its storage and therefore the range (distance that can be traveled on a fully charged battery).
- The limit is expressed in **kilowatt-hours (kWh)**, and sometimes also in range.
- My 2020 Prius Prime limit is **3.3 kWh**.
- 2023 Prius Prime limit is 6.6 kWh.
- EV limit is much higher: Tesla model 3 XR is **58 kWh**.

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Charging at home using 120 Volt Alternating Current

- My Prius Prime charger, using 120 volts AC, will fill up my 3.3 kWh Prius Prime battery in 5 hours 20 minutes, according to my dashboard.
- The charger's power delivery rate is < 1 kW.
- Fully charging overnight at home is practical.
- When I rent a vacation home, charging overnight is effectively **zero-cost** because my rental payment covers use of the rental house electric service.



Critical Facts about Charging an EV or PHEV: charging speed

- Every EV or PHEV sets its own **ceiling** on the **speed at which its battery can be charged**.
- The speed is expressed in **kilowatts (kW)**
- The 2020 Prius Prime speed ceiling is 3.3 kW
- The 2023 Prius Prime speed ceiling is 6.6 kW
- EV speed ceilings are typically much higher, **50 kW or greater**. Tesla model 3 XR appears to be above 90 kW.
- Charging speed limit info is not easy to find.

Critical Facts about Charging an EV or PHEV

- The **least possible charge duration** for an empty EV or PHEV battery is the capacity divided by the enforced charging speed ceiling.
- Example: 2020 Prius Prime PHEV
- $3.3 \text{ kWh capacity} / 3.3 \text{ kW speed limit} = 1 \text{ hour}$.
- In reality, charging is **non-linear**, especially the final 20%.

Charging at a station with a higher kW delivery than your car can accept

- Doing so will not harm your PHEV or EV and will not harm the charging station.
- The car sets and enforces the max kW rate that the car can accept.
- The charging station will deliver at the kW rate of your car even if the car rate is much lower than the charging station's max kW delivery rate.

John's Tip

- To maximize charging speed and minimize charging duration on the road, find a charging station that delivers power at or above the max rate accepted by your EV or PHEV.
- Charging stations on the road are often located at many spots where you might expect to spend considerable time: shopping centers, grocery stores, hotels and campgrounds, colleges, national parks and state parks, even libraries and medical facilities. Also at some Wawa, Sheetz and Royal Farms.
- Use the PlugShare app to find ALL charging stations.

Charging stations are fallible

- Sometimes a charging station will fail.
- Occasionally a customer service agent can do a remote reboot, and the problem is fixed.
- Sometimes the company must send a service tech to the charging station for an onsite fix, which may take a few days.
- Be prepared to find another charging station.

Level 2 charging stations cost per kW varies a lot

- I have personally found Level 2 charging stations that cost me nothing per kW, 10 cents per kWh, 22 cents per kWh, and 49 cents per kWh.
- What I care about most is **charging quickly**, not the cost. Even at 49 cents per kWh, I can fully charge my Prius Prime battery for less than \$2.
- Most charging stations I have examined do not accept credit cards. To pay, install and use the network app corresponding to the charging station brand.

How to pay for use of a public charging station

- Install the app for that brand of charging station.
- Configure the app to use your credit card.
- At the charging station, use the app to identify yourself to the station.
- The station will unlock and enable its charging plug for you to use.
- The station will charge your credit card when you disconnect from the charging station.

How can you charge at home when you own an EV?

- It is possible to have a Level 2 charger installed at home.
- If possible, make sure your Level 2 charging station kW delivery rate is equal to or greater than your EV charging ceiling.
- Make sure the charging station plug is compatible with your EV charging socket.



Calculating and Comparing Fuel Costs

Apples and Oranges? No

- We can compare costs directly using **Cents Per Mile**.
- My PHEV in EV mode can travel about 30 miles on a fully charged battery. That is enough for most of my car uses.
- The **cost per mile** is $11 \text{ cents} * 3.3 \text{ kWh} / 30 \text{ miles} = \mathbf{1.2 \text{ cents per mile}}$.
- EV cost per mile may be somewhat higher because the cost per kW is usually higher.
- Charging an EV to 100% of battery capacity using 120 volts AC cannot be accomplished overnight.

EVs generally cost more per mile

- The battery is much heavier than a PHEV battery, so more of the energy per mile is devoted to transporting the battery itself.
- Per-kWh cost may be 22-36 cents or more
- DC Fast charging stations generally charge more per kWh than Level 2 charging stations, because the kW delivery rate by DC Fast stations is much higher and the cost of charger construction is higher.
- Faster delivery requires more expensive charging station hardware.

Tesla Superchargers have an economic advantage

- Tesla designed its Superchargers for **low cost of construction**, about 25% of the construction cost of most other DC Fast charging stations.
- I learned that by reading investment news, not tech news.
- Many car makers have reached agreement with Tesla to allow their EVs to use Tesla Superchargers: Ford, GM, Hyundai, Volvo, Mercedes-Benz.
- Tesla calls its charging socket and plug the North American Charging Standard (NACS).

Calculating gasoline costs as Cents per Mile

- Find the cost of a gallon of fuel.
- Find the MPG, the number of miles you can travel on that gallon.
- Divide cost per gallon by MPG.
- Example: \$3.599 per gallon / 30 MPG = **12 cents per mile.**
- **That is 10 times the 1.2 cent cost per mile running my PHEV in EV mode**

Brass Tacks

- Using the Cents per Mile approach, we can directly compare operating costs.
- When using a DC Fast charger for an EV, the cost per mile may be as high as 5 cents, but still much less than 12 cents per mile for gasoline.
- As EVs become more popular, gasoline use will decline and gasoline prices will increase (and possibly gas stations will begin to disappear).
- As EVs become more popular, charging station competition will increase and prices per kW may decline.

I rented a Tesla Model 3 for 2 days

- My daughter borrowed my PHEV, and I had to deliver my photo entries to the Delaware State Fair, to meet the Fair's entry deadline.
- I recharged at a Tesla Supercharger located at a Royal Farms store on US 13 in Sussex County, Delaware.
- Battery level in 30 minutes went from 4% to 84%. Impressive! I ate my lunch and checked email.
- Tesla Supercharger use may be the best secret feature of a Tesla car.

Market News

- **Chevy Bolt EV** is alive again!
- Bolt was the least expensive EV built in the US.
- Chevy discontinued Bolt in early 2023
- Later demand for Bolt so overwhelmed Chevy that the company has changed its mind.

Zero-cost charging

- I already mentioned one situation where electricity for charging is free: a vacation rental home.
- There are public charging stations where the cost to charge is zero.
- A few of those zero-cost charging stations are solar-powered in the daytime, therefore providing **carbon-free electricity**.
- Preview of Coming Attractions: **How to find zero-cost charging stations** will be the subject of a later presentation.

The End