Recurrent

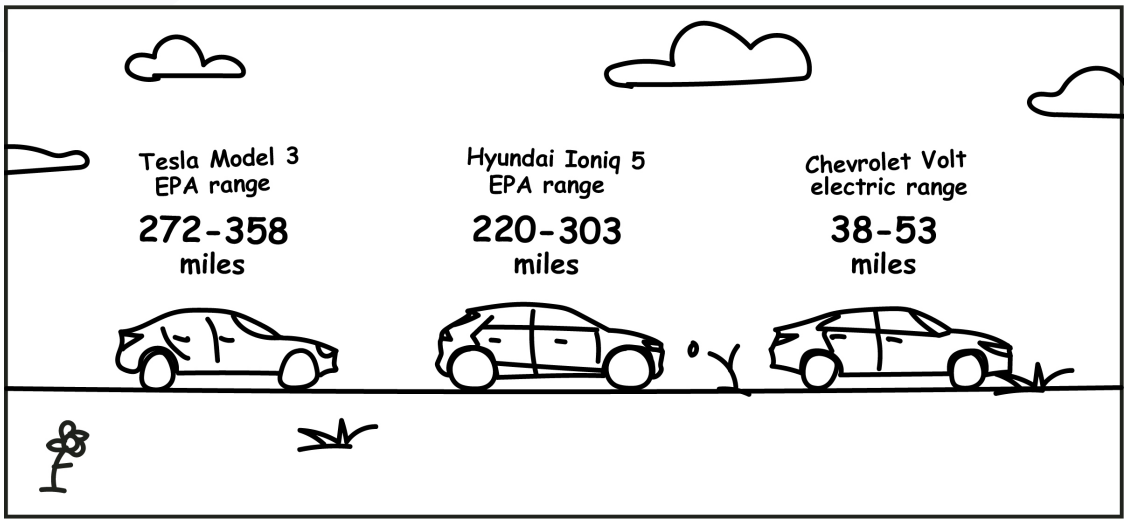
EV Range and Battery Guide

The Basics

Range is often a top consideration when buying an electric car. It simply means: how far can the vehicle drive on a single charge? Usually, when talking about range, the estimated total distance is measured from 100% charge, unless otherwise specified.

Examples:

- The range on my Chevy Bolt EUV is enough for my commute and all my errands. I only charge once a week!
- I've been driving all day so my remaining range is only 75 miles.
- When it's very cold here in the winter, I lose about 20% of my total range.
- My Chrysler Pacifica gives me 30 miles of electric range before the gas engine kicks in.



Range is not one number

Electric vehicle range can vary a lot – both between different models and for the same car on different trips. For a given vehicle make and model, the standard range that most people (in the US) refer to is the EPA (Environmental Protection Agency) rated range. This **EPA rated range** is determined under a set of rigorous and specific tests that control for temperature, speed, and incline. For instance, an older Nissan LEAF may have an EPA rating of 70 miles while a newer Tesla Model S may be rated for over 400 miles.

IMPORTANT:

The EPA *rated range* is not the same as *actual range*.

The **actual range** that a car gets is how far it can go under the real world conditions for a particular trip. Much like with a traditional gas car, how far you can go changes day to day. Lots of factors — both short term and long term — can impact how the actual range varies from the original, EPA rated range, and dashboard range. It all comes down to your efficiency and the state of your battery.

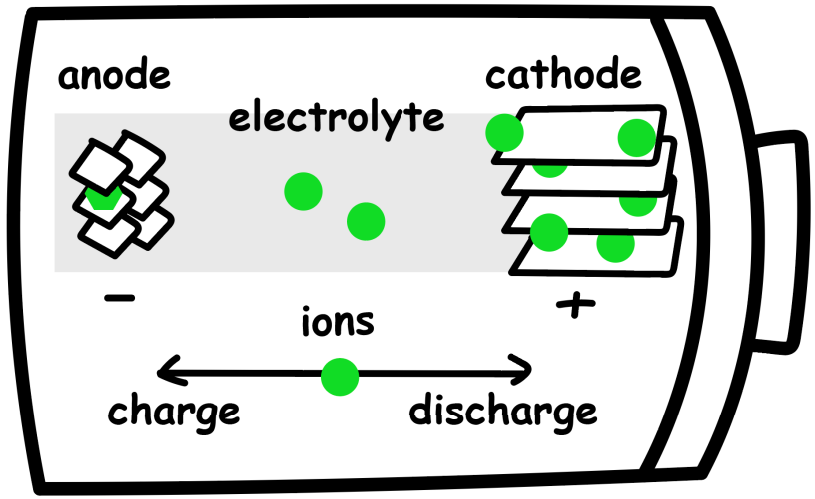
This guide explores many of the things that impact your vehicle's range so you can find the right electric car for you!

Note that the EPA range and the **actual range** may be different than the **dashboard range** remaining in a car as estimated by the car's onboard computer.

But first, what is an EV battery?

The “electricity” part of electric vehicles comes from big batteries. These batteries are lithium ion, just like your phone or your computer, but much larger and more durable. The specific battery chemistries can differ by brand, model and year, but all work on the same general principles.

Lithium is used in batteries because it is a light metal with a high electrochemical potential. That means it can produce more electricity using less material and space. Lithium ion batteries produce energy when lithium ions move from the negative electrode (or anode) to the positive electrode (or cathode). These same batteries are charged when the lithium ions move in the opposite direction. PS - “ions” are simply atoms that have unequal numbers of protons and electrons.



The movement of ions from side to side is the critical piece of charging and discharging a battery and the thing that generates electricity.

It’s important to know that the process of charging and discharging batteries is a physical process that happens in the structure of the battery, and a lot of the aging process is due to the physical wear and tear of pushing ions back and forth.

In short, if the ions are pushed more forcefully, or when the temperature is higher, they can damage the battery structure more.

Range & Range Loss

No matter how you treat your electric car, the battery will experience some degree of range loss eventually. It may be on a very cold day, or it may be after five years of driving. We'll explain the different types of range loss and how to help delay them

There are two types of range loss.

Long term range loss is permanent

Short term range loss is temporary

Imagine you had to run a mile after a long day or short night - you would probably run more slowly and less efficiently than when you're well rested. That's a short term energy loss that disappears with rest. We also tend to get a little slower with age, a natural part of the aging process. That is a long term and permanent shift in energy. The same is true in batteries. While short term range loss is caused by external factors and is reversible, long term range loss is permanent.

Drivers should understand each of the short term factors since it will affect day to day range. It's also important to learn what to expect from the long terms factors and how to avoid them.

Short Term Range Loss

Short term means that any loss in range is limited to that day, week, or season. Short term range loss does not indicate any battery health or range degradation but can mean that your efficiency is lower than normal.

What types of things cause short term range loss?

Rapid acceleration and high-speed driving

Extreme outdoor temperatures

Driving uphill or with a lot of weight

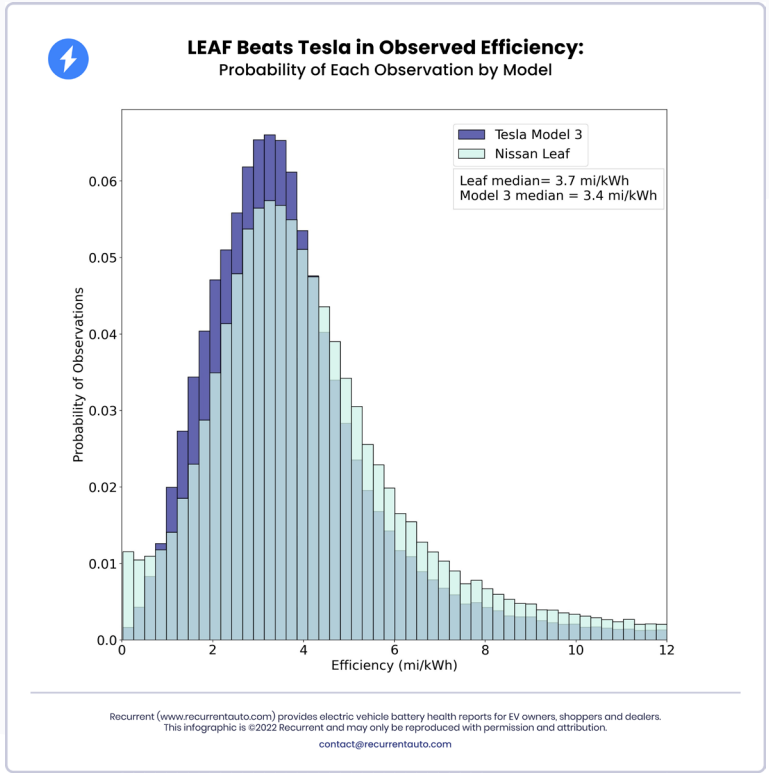
Acceleration and High-speed Driving

While vehicles with internal combustion engines will use fuel most efficiently on the highway, EVs see the best battery range when they are driven slower and on city streets. This does not mean that EVs aren't great for road trips, as many drivers can attest, but highway driving will not capitalize on **regenerative braking** in the same way that city driving will.

When a car brakes, it is slowing down and losing kinetic energy. Regenerative braking is simply taking the energy lost while slowing down and using it to charge the battery. It is all the more useful in an electric car since they are much heavier than a traditional car, so there is a lot more kinetic energy (energy from motion) to recapture.

In terms of terrain, EVs are not different from gas cars: accelerating quickly or going uphill will use energy more quickly than standard driving so you may notice a decrease in available range if you're racing uphill. Coasting downhill will use your battery's energy most efficiently, while towing a camper or loading up your car with boxes will use more energy.

Finally, EVs get overall better range at lower speeds, and that boils down to physics. Since an electric motor is so much more efficient than a combustion engine, things like air resistance matter a lot more when you're driving an EV. When you look at the formula for energy used, air resistance is proportional to speed squared. So, if you double your speed, you get **four times** the drag.

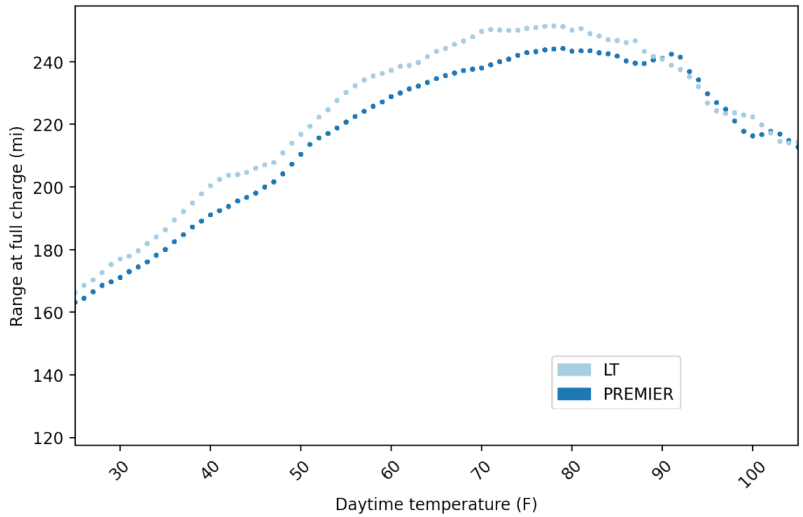


Outdoor Temperatures

"Why does my range drop when it's cold?" is one of the most common questions we hear so we wrote an **article** about it. Summary: cold weather tends to slow the chemical and physical reactions that make batteries work, and that temporarily decreases short term range. But, the real efficiency killer is the cabin heater. In a gas powered car, the combustion engine generates a lot of waste heat which can be funneled into the car to warm the driver and passengers. In an EV, there is not a lot of waste heat, so the battery has to use electricity to generate it. The best tip for preserving winter range? **Precondition!** (An EV term for warming or cooling your car before getting in it)

Hot temperatures are also a problem for short term range loss, but much less so, since the air conditioners tend to be more efficient than heaters. Some vehicles also have auxiliary batteries to support climate control, and many newer cars have started using heat pumps that use less energy than a traditional AC/heater. Consider an EV with an auxiliary battery or heat pump if you live in an area with extreme temperatures.

This chart plots the ranges of 1,000 Chevy Bolt models (LT and Premier trims) at different temperatures. You can see that some range is lost at both low and high temperatures.



Long Term Range Loss

Some aspects of long term range loss are unavoidable as batteries naturally degrade over time. Again, this baseline degradation is due to the physical stress caused by the movement of lithium ions, in addition to the normal reactions that occur within a battery to produce electricity. But, as EV owners, we can both add and avoid certain steps to maximize the battery lifespan so our cars can drive farther, longer.

A process known as ***calendar aging*** refers to battery degradation that happens regardless of use. ***Calendar aging*** leads to two sorts of degradation. *Capacity fade* is due to loss of active material in the battery, which is just a fancy way of saying there is less lithium free to produce electricity. There is also ***power fade***, which means that the lithium ions move less freely and are impeded by junk such as metallic build up or corrosion.

If calendar aging happens regardless of use, what control do you have over your battery health? There are a few things that speed up long term range loss.

Depth of discharge

High heat

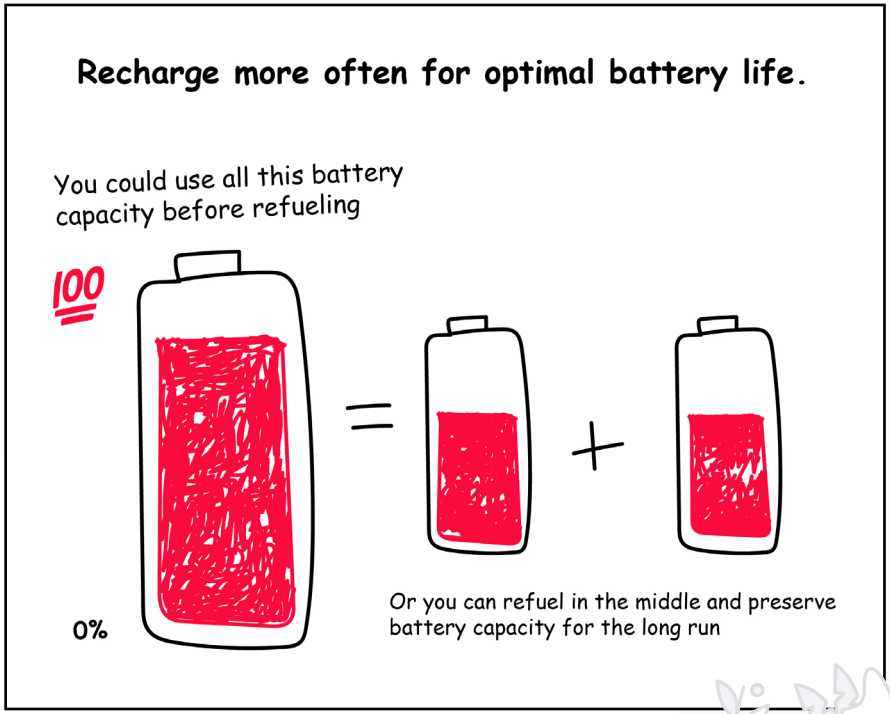
Frequent fast charging

LONG TERM RANGE LOSS

Depth of Discharge

Lithium ion batteries are sensitive to something called ***depth of discharge***, or how much battery you use in between charging. In other words, depth of discharge is the difference between your starting and ending state of charge when you use your EV. Using smaller depths of discharge can help preserve battery health, including lifetime, capacity and power.

The takeaway here is that rather than using 50% of your battery before recharging, you might use 20% of the battery, charge, and then use another 30%. Of course, only do this if and when it works for your lifestyle! Battery and range degradation from deep discharges are not so extreme that you should stress out about it - remember that your car is a tool that you should use to make your life easier.



LONG TERM RANGE LOSS

High Heat

Heat affects EVs in two key ways:

Storing an EV in high heat can cause unwanted chemical reactions to happen faster and more easily than when the battery is cool. These secondary chemical effects can lead to loss of lithium and degradation of battery materials.

Charging an EV in high heat increases the effective force of the electric current that drives lithium ions from one node of the battery to the other, causing physical stress and damage on the receiving end. The higher the temperature, the more stress fractures and damage the battery node experiences. Little cracks and fractures in the battery material can accelerate loss of active lithium and provide surfaces for corrosion to grow.

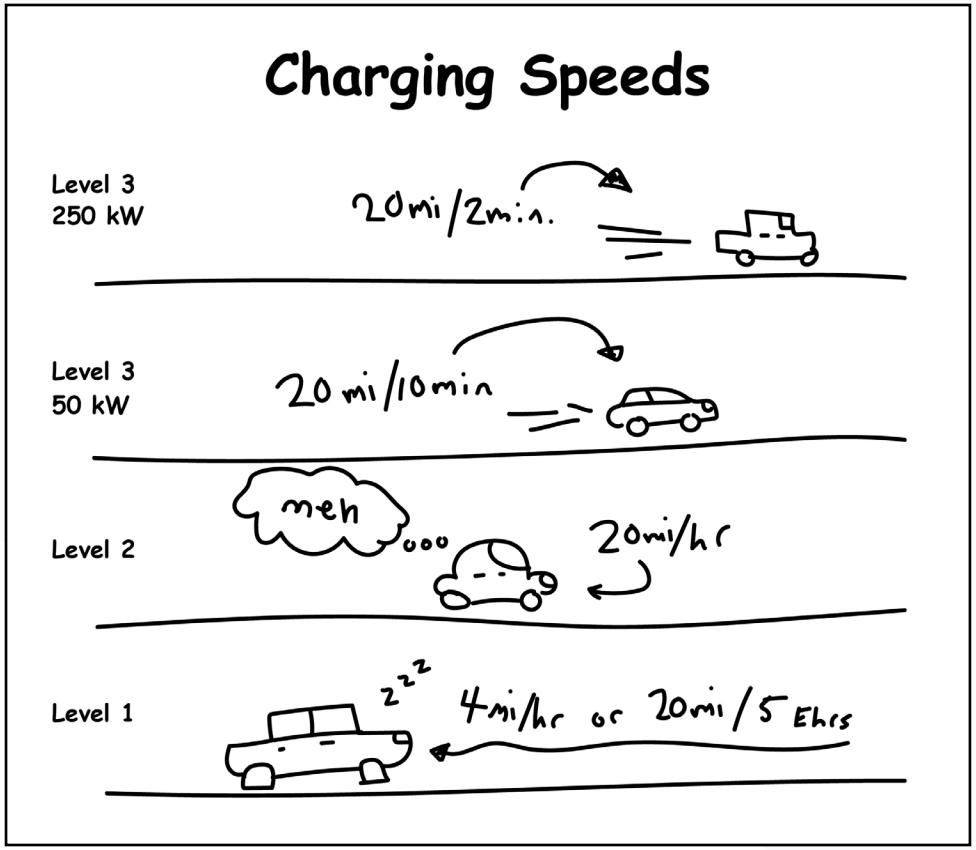
One particular consideration in terms of temperature and range is how your battery temperature is regulated. Many EVs, such as those from Tesla and Chevrolet, use liquid for thermal control and are generally able to regulate hot battery temperature better than vehicles that use passive air to cool batteries. Depending on the temperature variation in your region, you may want to consider the battery thermal management system for the longevity of your car.

Also consider that thermal regulation - for you or for your battery - will reduce the operational efficiency of your car, so you will get less range when you're using AC.

LONG TERM RANGE LOSS

Frequent Fast Charging

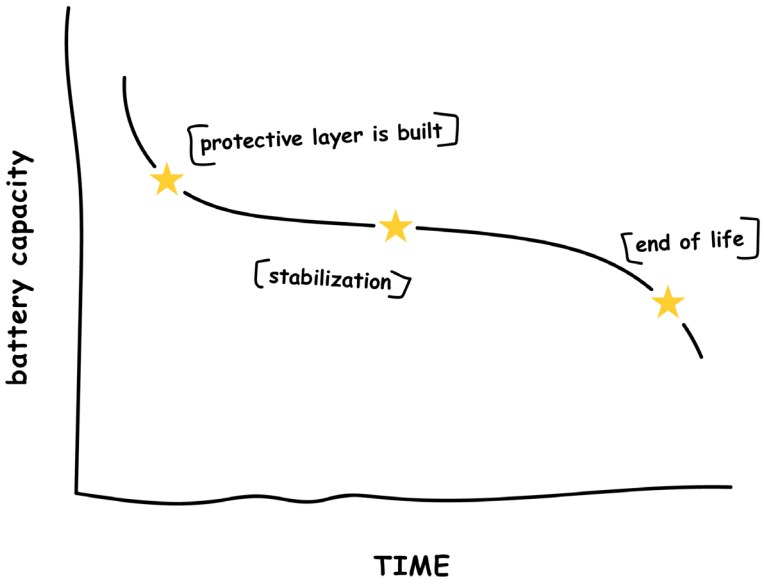
Similar to high heat, higher voltages generally lead to faster reactions. This often means that the “unwanted” chemical reactions that make batteries degrade happen faster, although studies are not conclusive on the magnitude of the effects. Using laboratory experiments on single battery cells as a guide, many experts suggest using fast chargers only occasionally or when necessary for road trips. It’s also a good idea to avoid fast charging when your battery is really cold, and never fast charge above 80%.



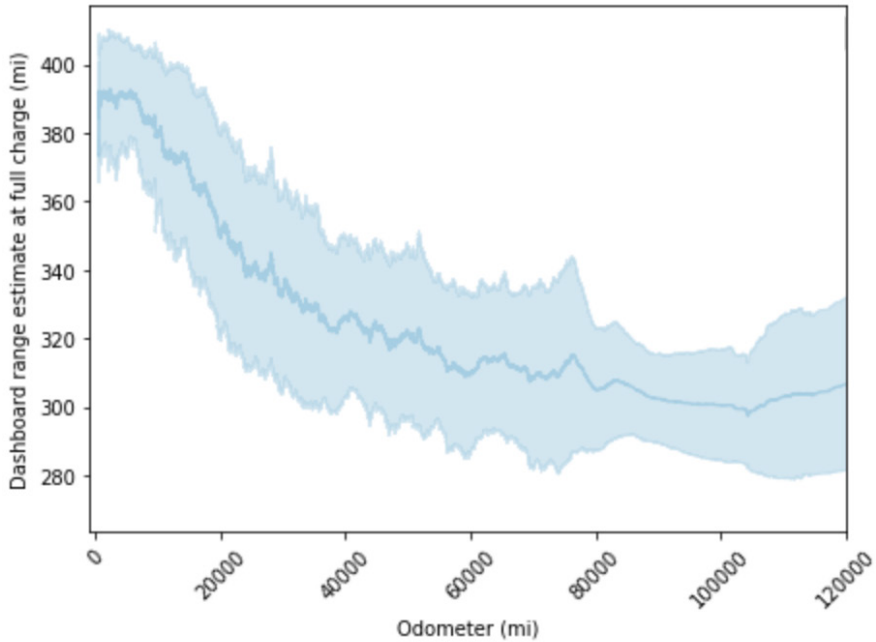
How much range is lost over time?

It depends. Our in-depth studies funded by the National Science Foundation found that an EV like a Chevy Bolt or Tesla Model 3 will lose 20 to 40 miles of max range in the first 20,000 miles before leveling off. After this, the range changes much more slowly. Battery degradation tends to follow an S-curve, where more range is lost in the earliest and latest stages of the battery's life.

General Trend



Real World



CONCLUSION

Monitoring your EV battery

An EV battery is the most expensive part in a car but it is both literally and figuratively a black box. It can be difficult for used car shoppers to check the battery before buying a car.

The best possible way to assess battery health would be to remove it from the car, ship it to a lab, and perform chemical testing. If that sounds costly, it's because it is!

The next best option is through machine learning: comparing one vehicle to many others. Recurrent supports thousands of **owners with free battery reports** who anonymously share a few data points each day and we aggregate that information to help all drivers understand their cars.

That includes EV shoppers. If you are shopping for an electric car check out our **shopping tool** to learn more.

And, if you just found the EV of your dreams and want to know more about the ins and outs of ownership, sign up for our **EV 101 email series.**