Thinking About an Electric Car?

By Green Steps members Tom Kent and Stan DeOrsey

So are a lot of other people. In Norway, 77% of new vehicle registrations in 2020 were electric vehicles. In California, electric charge stations outnumber gas stations by two to one. GM has committed to all electric vehicles by 2035; Volvo plans this by 2030. Electric or hybrid vehicles are cleaner, and as the electric power grid itself continues to improve, they will become progressively better over time. Electric vehicles got off to a bit of a rocky start, but they have come of age.

Here are some lists of presently available electric vehicles:
https://en.wikipedia.org/wiki/List_of_electric_cars_currently_available
https://www.plugincars.com/cars

Quick Glossary

EV: electric vehicle, either gas+electric or pure electric
ICE: internal combustion engine (note: gas *engine* vs. electric *motor*)
BEV (battery electric vehicle): a vehicle that runs entirely on battery power, and does not have a gasoline engine
MPGe: miles per gallon of gasoline equivalent
Regenerative braking: when headed downhill, a great deal of energy must be dissipated to slow the vehicle. In ICE designs, brake pads convert this energy into heat, and wear on the brake pads. EV motors double as generators, and can convert some or most of this energy back into electricity, storing it in the batteries

Frequently Asked Questions

Why are there several kinds of electric vehicles?

Electric vehicles fall into two broad categories: *hybrid*, and *battery electric vehicles (BEVs)*. Hybrid vehicles combine an internal combustion engine, DC motors, and batteries, any of several clever ways, to achieve the necessary range. BEV vehicles contain only batteries and DC motors. (By "DC motor," we mean "motor that runs on batteries." Actual motor types vary.)

Hybrids evolved originally because it took years to develop viable BEVs, due to problems of battery capacity and the need to recharge. Hybrids remain a viable choice today. BEVs have also become viable.

In the next section, these two broad categories are broken down into several types.

Why consider an electric vehicle?

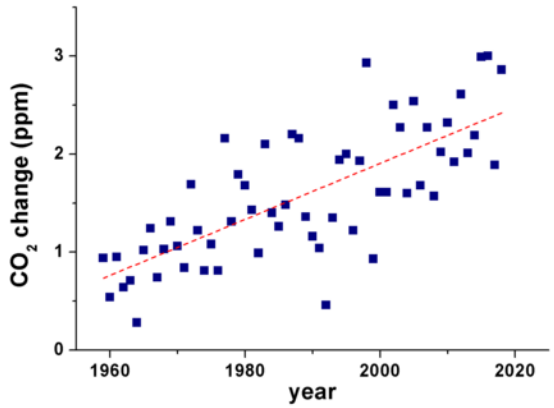
Electric vehicles do not inject carbon dioxide (CO_2) into the atmosphere. However, the electricity *production* does, in amounts that vary based on the way it is generated. Most states, including Maine, produce clean enough electricity to be a much preferable choice. While it is not possible to significantly reduce the CO_2 produced by ICE vehicles, it *is* possible to improve the electric grid.

Many EVs charge in your garage, so you always leave with a full "tank." (And if you have solar power, the cost is much lower and your CO_2 contribution is much lower.)

This US Department of Energy site compares vehicle fuel economy.
https://fueleconomy.gov/feg/Find.do?action=sbsSelect

Why is carbon dioxide a problem?

Atmospheric CO_2 annual growth rose 300% since the 1960s, as shown in this chart from Wikipedia:

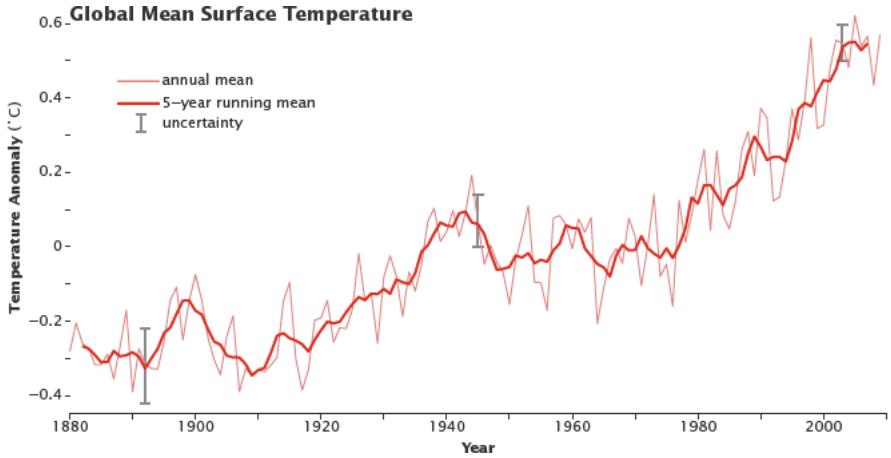


A gallon of gas weighs about six pounds, but after reacting with air, produces nineteen pounds of carbon dioxide. (Think about it: 100 gallons of gasoline yields **one ton of CO_2!**) On average, that is 4.6 metric tons per year per vehicle. Transportation accounts for 28% of CO_2 emissions.

https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle

Carbon dioxide is the dominant greenhouse gas, though methane also plays a role. Together they are increasing global temperatures rapidly.

From NASA, https://earthobservatory.nasa.gov/features/GlobalWarming:



Don't electric cars have limited range?

Hybrid vehicles switch to gas when the battery is low, so their range is limited by the size of the gas tank. Their range is up to 600 miles. Early BEVs had limited range. A few still do. Current generation BEVs have a range of up to 350 miles.

Are electric cars reliable?

Battery electric vehicles are much simpler designs with fewer parts. They are potentially much more reliable than ICE vehicles. Hybrid vehicles, those combining an ICE and electric systems, are more complex, hence potentially less reliable, though some manufacturers overcome this with superb engineering.

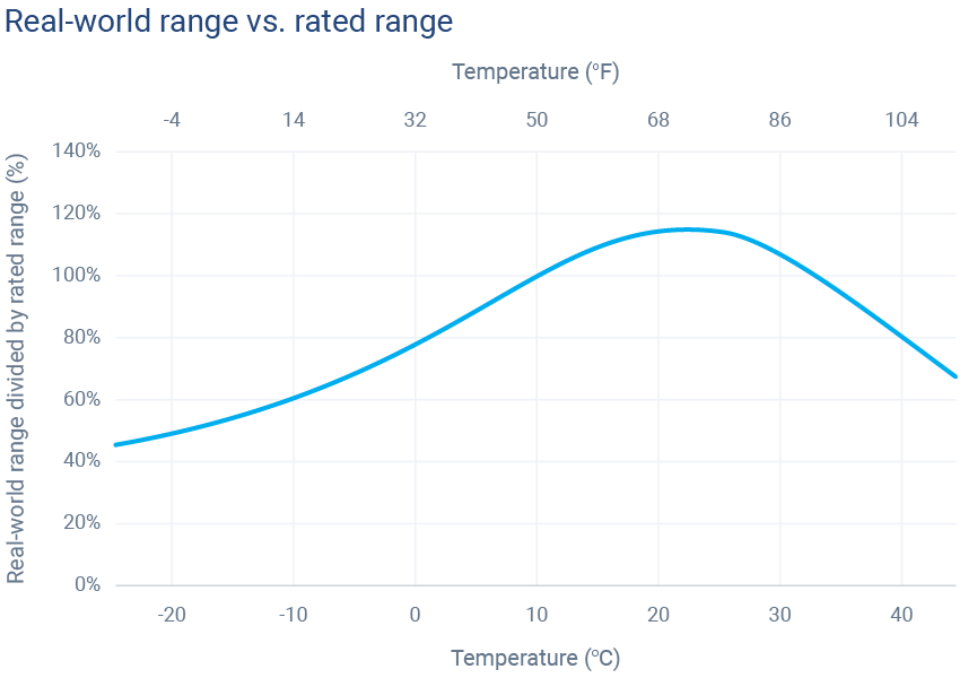
Battery life in current generation BEVs generally exceeds the vehicle lifetime. Tesla quotes a projected battery life of 500,000 miles. Most hybrids list shorter lifetimes for batteries: 100,000 miles or 10 years.

Are electric cars reliable in the winter?

Lithium-ion batteries perform differently at different temperatures—higher than stated range at ideal temperatures (around 70°F), lower at higher temps, and much lower at very cold temps. When it is hot, use of A/C diminishes range. When it is cold, ICE vehicles heat the cabin using waste heat from the engine, but EVs must use battery power for heat. Below –10°F, range may be reduced by 50% or more. Garaging your vehicle helps with this.

This helps to estimate range reduction at different temperatures.
https://www.geotab.com/blog/ev-range

This is taken from the site above, and shows how battery efficiency decreases on either side of ideal temperatures.



For hybrid vehicles, the gas engine range is essentially unchanged, so this isn't important. But for BEVs, the reduced range can be very significant.

Many EV designs employ multiple DC motors, and since motor are independently controlled, better traction is possible in slippery conditions, compared to differentials.

Are EVs cheaper to own?

At the risk of overgeneralizing, they are about the same. Try this U.S. Department of Energy Vehicle Cost Calculator:
https://afdc.energy.gov/calc/

Here is one article on the subject:
https://www.caranddriver.com/shopping-advice/a32494027/ev-vs-gas-cheaper-to-own/

Here in Maine, Efficiency Maine lists dealers offering instant and mail-in rebates up to $2000 for qualifying EVs:
https://www.efficiencymaine.com/evehicles/electric-vehicle-rebates/

Federal tax credits of up to $7500 are available for many EVs. GM and Tesla no longer qualify for these credits because they have already sold more than 200,000 vehicles, presently the upper limit.
https://www.fueleconomy.gov/feg/taxevb.shtml

Don't electric cars take forever to charge?

It takes up to 14 hours to charge a BEV from a 110V outlet, or up to 3 days if the charge rate is reduced in order to avoid overloading a household circuit. In normal use, though, the battery does not discharge very far, so recharge time is shorter. Hybrid vehicles have smaller batteries that charge more quickly. BEV owners can install a 220V outlet to greatly increase the charge rate. Charging at charge stations is much faster, though it varies depending upon manufacturer. Tesla super–chargers reach 80% in 20 minutes.

For many users who travel less than 150 mi/day, *most charging happens in their own garage*, and there is rarely a need to stop at a charger. Overnight charging also reduces peak electric demand.

An existing garage outlet is typically rated at 110V, 15 amps. Because the circuit is likely shared with other loads, you may not be able to draw power at or near the full capacity. Chargers are available for different charge rates based on available power. If you need faster charge rates for a BEV, consult an electrician.

See *The Electric Vehicle Charging Problem:* https://youtu.be/pLcqJ2DclEg.

Are charge stations difficult to find?

- For hybrids, the gasoline engine provides backup, so charge stations are not needed.
- For BEVs, some manufacturers have subbed out charge station creation, leading to good coverage for high-traffic cities and spotty coverage for long distance interstate travel.
- For Teslas, charge station layout is more evenly distributed, planned by the manufacturer, and the nav system fits charge stations into the trip during long trips. There are also 20,000 superchargers for very fast charging.
- For hydrogen-fueled vehicles, home charging is not possible. There is spotty coverage in CA and little elsewhere in the US at this time.

Charging stations in Maine:

https://thesunriseguide.com/electric-vehicle-charging-stations-in-maine/

From Cy Kendrick:

> To answer your question about charging stations, the one at the Duck is free. There are two free ones at Fort Andros. There are two at Hannaford, but you have to pay. I have never used those, so I don't know how they work. I have used the one at Oceanview because my barbershop chorus rehearses there...also free. There are also six free Tesla ones and six free universal ones at LL Bean. We have used those. Those are the only ones I know of, although there must be more. There are apps that tell locations. Unfortunately they don't always help. There is one at Sebasco resort. All the chargers are 220V. We looked into getting one in our garage, but it was going to be about $2000, so we decided to see how our 110 outlet would work. It has never been a problem. Tesla chargers can't be used in other cars, but I understand that Tesla has an adaptor that lets them use any charger.

NOTE: There are several incompatible charging standards, though adapters are often available, so be careful to find those suitable for your vehicle.

Are electric cars powerful enough?

Early electric cars seemed more like golf carts. Current designs have ample power, accelerating faster than most ICE vehicles. DC motors produce high torque at any speed, vs. ICEs, which provide maximum torque only over a narrow speed range. This means electric vehicles accelerate much faster and run more efficiently, and no transmission is needed.

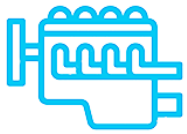
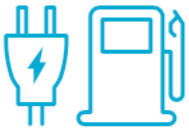
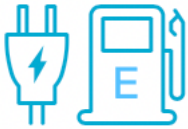
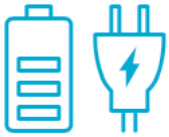
Vehicle Designs

Vehicles fall into three broad categories:

- Internal combustion engines rely entirely on gasoline and gasoline engines, using a battery only for starting. (Diesel engines are a type of ICE.)
- BEVs rely entirely on large battery arrays charged at home or at charging stations, using one to four electric motors instead of a gas engine.
- Hybrids rely on a battery array of varying sizes, depending upon design, to provide motive power via DC motors. When the batteries near exhaustion, a gas engine takes over. A special type of hybrid, an extended range electric vehicle, uses only electric motors, and uses the gas engine to recharge the battery array.

Battery size determines two critical parameters: range while running on the battery, and charge time. Hybrids operate on battery power over a range of 0.5-97 miles, then switch to gas. BEVs have ranges from about 98 miles to 350. Bigger batteries take a *lot* longer to charge.

Here is a bit more detail. To see how various vehicles stack up in energy efficiency, see https://www.carboncounter.com.

	Internal combustion engine (ICE): Gasoline engine requires engine cooling, air filter, transmission, spark plugs, mechanical power transfer to wheels, differentials, oil, fuel distribution, etc. Mature technology. A gallon of gas weighs about six pounds, but after reacting with air, produces nineteen pounds of carbon dioxide.
	Hybrid: Combines ICE and DC motors, along with gasoline and battery array. ICE charges battery, so vehicle refuels only with gas. Battery has limited capacity, and it used in stop-and-go driving. Gas powers all highway driving. Regenerative braking helps to charge battery instead of being wasted. Hybrids are more efficient gas-powered vehicles.
	Plug-in hybrids (PHEVs). Like hybrids, but with larger batteries, large enough to be recharged, usually at home. About a 10-97 mile range on electric, then switches to gas. For many driving patterns, such as short commutes, the batteries are enough. At least some plug-in hybrids are capable of recharging the battery using the ICE.
	Extended Range Electric Vehicles (EREVs). Like hybrids, they have both a gas engine and batteries, but they only have electric motors, and the gas engine is used to charge the batteries.
	Fuel Cell vehicles. These are fully electric vehicles, but they differ from other electric vehicles in that they derive power from hydrogen fuel cells instead of lithium ion batteries. The primary waste product of fuel cell operation is water vapor, although a small amount of CO_2 is created too. Fuel cells are replenished with hydrogen quickly, as with gasoline vehicles, but require special hydrogen fueling stations. These stations are so far rare in CA and nearly non-existent elsewhere in the US. The dominant means of producing hydrogen at this time requires natural gas and high pressure steam, so although little CO_2 is produced, fossil fuels are still consumed. https://www.popularmechanics.com/cars/hybrid-electric/a22688627/hydrogen-fuel-cell-cars/
	Battery Electric Vehicles (BEVs). BEVs contain a large array of batteries, presently lithium ion batteries. These are on the underside of the vehicle, where they help provide traction and a low center of gravity. One to four DC motors are attached directly to wheels, or to wheel pairs, providing more efficient power transfer. Vehicles charge in home garages or via charge stations. Charge stations are not yet as numerous as gas stations, and may not be evenly distributed. Battery range is substantially reduced in cold weather, much more so than with ICEs. Range is about 60-310 miles.

	Teslas. Teslas are unusual among BEVs, having been developed from the ground up by a company with no existing investment in ICEs. Range is 238-310 miles. Charging stations are better distributed to accommodate long range trips. Nav system provides realtime updates about available charge stations and wait times. Superchargers can bring batteries to 80% of a full charge in 20 minutes. Maine has 13 superchargers; there are 20,000 nationwide. This takes the stress out of battery electric driving. Tesla sold 79.4% of BEVs registered in the US in 2020. "Overall, most Teslas have not been very reliable" *(Consumer Reports),* said by Elon Musk to be due to aggressive innovation. Closest service centers are in MA. Reliance on touch screens vs. traditional control layouts is arguably less ergonomic. Price: $31K-250K.

There is a comparison of EV designs table at the end of this document.

Choosing a Design

Consumer Reports introduced a "Green Choice" designation to their ratings, developed in conjunction with the Environmental Protection Agency's Smartway program:

- If you don't want the hassle of charging at all, or you don't have convenient access to an outlet, and you still want improved gas mileage, choose a hybrid rather than a plug-in hybrid.
- If you want to run on electric power for short hops or in stop-and-go traffic, but still want the security of a gas engine for longer trips, a plug-in hybrid or extended range hybrid are good choices. For example, if you like exploring off the beaten path, or simply have a daily commute, PHEVs are excellent choices.
- If you want to absolutely minimize your CO_2 footprint, and you can recharge in your garage, consider a BEV. A range of up to 350 miles covers most typical driving patterns, though long distance trips require more planning. BEVs are not yet a good choice for people who drive very long distances routinely.
- Teslas are currently the "gold standard" in BEVs, with a better network of chargers, and extremely fast superchargers. However, reliability is relatively low at this time, and they cost $31K-250K.
- Hydrogen fuel cell vehicles are not yet a viable option in Maine, due to lack of fueling infrastructure.

Some Owner Comments

Toyota Prius Prime XLE

Vehicle type	Plug-in Hybrid
Charge stations	26,000 across the US
Charge time	5 hrs, 30 mins on a 110V outlet, 2 hrs, 10 mins on a 220V outlet
Battery longevity	Life of vehicle
Battery range	~25 mi
Gas mileage	54 MPG

From Rhonda Schorer, in Acton, MA:

- I get over 20 miles in pure battery mode, less if I have the heat or A/C on. I am unwilling to have a vehicle which takes me a long time to "fill up" when on a road trip. However the "plug-in hybrid" design solves two BIG problems for me.
- It runs on gasoline if I want it to or it needs to. In hybrid mode it is *much* more efficient (55 MPG?) than my old Yaris (35 MPG). PLUS I can just plug it into a regular wall outlet and not use any gas at all for running-around-town trips. These facts ameliorate my "CO_2 guilt."
- The 20+ miles in EV mode is sufficient to use in electric-only mode to drive around *in* Boston. I run on gasoline towards Boston on Rt. 2 to the top of the big downhill near Alewife, then I switch it to EV mode and put it back into gasoline mode only when I get back to the bottom of said hill. *All* of my driving *in* Boston is then in EV mode, so no idling wasting gas at stop lights, traffic jams, and crosswalks. Plus when I hit the brakes *some* of the kinetic energy goes back into the battery. These facts further ameliorate my "CO_2 guilt."

It seems that my Prius Prime emits less CO_2/mile than 12 of the 19 purely electric vehicles. https://www.carboncounter.com.

Toyota RAV4 Plug-in Hybrid

Vehicle type	Plug-in hybrid
Charge stations	Not needed, runs on gas when necessary
Charge time	12 hrs on 110V, 4.5 on 220V
Battery longevity	10 years or 100,000 miles
Battery range	46 miles
Gas mileage	38
Total range	600 miles

From Stan DeOrsey, at Highland Green:

The Toyota RAV4 Prime is a hybrid plug-in, new for 2021. I purchased the third one sold by Lee Toyota in Topsham in the fall of 2020, so not a year old yet. I purchased it for two reasons ... I already owned a gasoline RAV4 and loved it ... very easy to drive, handles well, lots of storage when something needs to be move or carried, and it sits high for good visibility. Plus Toyota has an excellent reputation for reliability. I have owned other Toyotas and been very satisfied. My one disappointment with their older cars was gas mileage, at 28 mpg for the old RAV4 I wanted better. The second reason for buying the new plug-in was gas mileage. I get 48 miles per full battery charge in warm weather (60+) and 38 miles on a full charge in cold weather (under 30). And when using gasoline, I now get 35 to 39 mpg.

I was not sure if plugging it in would be a problem, it is not. The cord is 25 feet long and plugs into a standard 110V outlet (GFI preferred). A transformer is attached to the cord and is heavy, they recommend hanging it from its own hook, which was trivial to install. I plug it in when the battery gauge is around half or below and let it be overnight. It takes about 12 hours to fully charge, well before morning. For my needs I have been driving around town and to Lewiston on just the battery and only buy gas much less than once a month. I have driven to Massachusetts and back on much less than a full tank of gas.

The RAV4 Prime is fun to drive, very responsive when passing or just pulling out. I have zero complaints and highly recommend it. The price is high but Maine gives you a $1000 rebate through the dealer and the federal government gives you $7,500 as an income tax CREDIT making the car reasonably priced.

Toyota RAV4 Hybrid

Vehicle type	Hybrid
Charge stations	Not needed
Battery longevity	10 years or 100,000 miles
Battery range	0.6 miles (i.e. stop-and-go traffic only)
Total range	474 miles
Gas mileage	32 MPG

From John Kent, in Albany NY:

I have a 2016 Toyota RAV4 hybrid, which I bought new and now have almost 85,000 miles on. It's the first year they were made, but my understanding is that much of the vehicle is the same as a Lexus hybrid SUV developed several years previously, so the design wasn't brand new. It differs from the regular RAV4 AWD in that the rear wheels are driven electrically, so there is no need for a drive shaft running to the rear, or a rear differential. That means more leg room in the back seat, and also probably leads to decreased maintenance expenses in the long run. I have been happy with the car, my only complaint is that the electric rear liftgate failed and cost $1200 to fix. Obviously, that was unrelated to the hybrid aspect. Otherwise I've had no problems. A few times the "infotainment" system has crashed and rebooted randomly, but not recently.

The fuel mileage isn't that impressive—I average about 29 MPG according to the car's meter, I never bother to check on it. If I did more city driving I would be getting better mileage. I rarely encounter stop and go traffic. The newer models are better. The 2021s are rated 40 MPG for hybrid (AWD), 30 MPG for AWD gas, and 94 MPGe for PHEV.

The car has three settings—eco, normal, and sport—which modulate the throttle to improve mileage. I usually use normal and occasionally switch to sport if I want to pass someone. However, I find that I adjust to the computer's throttle modulation in normal (or especially eco) mode by subconsciously trying to defeat it. In other words, whenever I want to accelerate I floor it, knowing that it will react gradually. The last time I drove another car was one that belonged to my employer, and I kept forgetting not to floor it. I nearly gave my co-workers whiplash. (That was in pre-COVID times.)

Hybrids like mine have an "EV Mode" button. However, it's useless. As soon as you depress the accelerator more than a few microns, or begin to go uphill, it shuts off and says 'EV mode not available.' The electric drive system is only meant to supplement the ICE. As long as it efficiently uses all the power generated by braking, it doesn't matter. There wouldn't be any advantage to being able to drive a few miles on electricity only, since all the electricity the car has to use comes from the ICE, directly or indirectly, since you can't plug it in.

I can't really think of anything I don't like about it. If I had to buy a new car tomorrow I would very likely go for the 2021 RAV4 hybrid.

Tesla Model 3

Vehicle type	Battery electric vehicle, 2018 model
Charge stations	About 40,000; 20,000 superchargers
Charge time	110V: 3 miles/hour of charge; 220V/50A: overnight
Battery longevity	Predicted to be 500,000 miles
Battery range	Standard: 220 mi; long-range: 310 mi

From John Gross, in Winthrop ME:

John explains that he installed solar power several years ago, so much of his charging electricity is provided by his solar array. He is very pleased with the Tesla, and "babies" it, avoiding its use in salt and sand. He uses it for fairly regular trips between Winthrop and Portland, about a 2 hour and 20 minute round trip. He rarely travels longer distances, and occasionally recharges at the LL Beans superchargers. The chargers are easy to use, billing his credit card automatically. He has never had trouble finding a charger. For charging, John installed a 220V, 50A charger in his garage, which cuts the time for a full charge to overnight. He leaves it connected all the time, since the charger maintains it at an ideal level, and usually doesn't charge past 270 miles in range, for longer battery life.

John's curiosity about Tesla was initially piqued by the company's namesake, Nikola Tesla. This inspired his faith in Tesla engineering. He says the car feels sporty and is "just a dream to drive. It has incredible pick-up." He told us how sometimes the snappy acceleration gets him out of otherwise uncomfortable situations promptly, like being sandwiched beside a semi.

We asked about winter range. He said range drops at least 20% in the winter, and more if you use the heaters and seat heaters. Handling is "terrific, like a 4 wheel drive," because of the two motors (front and back) the bottom-mounted batteries' weight and low center of gravity.

He found it difficult at first to use the touch screen, which takes attention away from the road for some functions handled by controls normally positioned on the dash or steering column. Examples: heat, fan, lights, wipers, and navigation. He says he has adjusted, and rests his hands on the screen edge to provide a reference for his thumb to find a given control. He also did not adapt immediately to regenerative braking mode. When enabled, it provides quick deceleration automatically, and John disliked ceding some control to the brakes. Now he is comfortable with them. He decided against the autopilot option because he prefers to be "in charge and awake."

Repairs? There haven't been any. Turns out the nearest Tesla repair centers are in Massachusetts, though a place in Topsham performs basic maintenance.

Would John buy another Tesla? "In a heartbeat."

2017 Chevy Bolt

Vehicle type	Battery electric (BEV)
Charge stations	About 40,000 compatible charging stations
Charge time	2 hrs to 3 days depending on charge rate
Battery longevity	Warranty for 8 years or 100,000 miles
Battery range	238 mi
Gas mileage	n/a

(Don't confuse Chevy Bolts with Chevy Volts, like I did!)

From Cyrus Kendrick, at Highland Green:

We absolutely love our Bolt. It's billed as going 238 miles when fully charged, but that is very dependent upon the driving conditions. The 238 miles is based on getting 3.9 miles per kilowatt hour. In the summer, driving around town so I'm not going too fast, that can go up to well over 5 M/kWh. Highway driving in the summer brings it down to the low 3's. Highway driving in the winter can bring it to the low 2's with the heat on.

The acceleration is phenomenal, and instant. There is also very little maintenance on the Bolt. Obviously no oil change, but not much else either. A gasoline engine has over 2000 moving parts. The bolt has about 20.

The biggest problem with the Bolt is that taking a long trip requires almost impossible planning. We drove to Florida last year and used our Subaru Outback. Recharging the Bolt has two problems. One is the availability of chargers, and the other is the length of time to charge. We do almost all our charging using our regular 110 outlet in the garage. This has not been a problem because it's in the garage most of the time, and we rarely run the battery down more than about half way. In our garage, a full charge starting from empty would take three days at 8 amps and two days at 12 amps. If convenient, we'll charge down at the Duck [220V]. A full charge from empty would take probably 6-8 hours, but usually a couple hour "top off" is what we have done there. There are chargers available that can give a 90 mile charge in a half hour. I have no idea where any of those are located, and we have never needed to do that, even on a day like a couple of years ago when Gail went to Lewiston, and I went to Kennebunk when she got back. There was no problem worrying about running low.

This may seem odd, but my biggest problem with the car is that AM radio is practically impossible to listen to unless you are close to the station. Way too much static, especially in the summer. Winter is not bad. I think I'm correct in saying that the Tesla does not have AM radio, just FM. Electric car manufacturers have not solved this problem, and probably won't since not a lot of people listen to AM any more.

The Bolt has a digital display that tells you the range that you have left. It also tells you the most and least miles you might get depending on driving conditions. This display changes with temperature. I have topped off the batteries at the Duck in the summer and had it say 280 miles

rather than the 238 in the specs. I've also topped it off in the winter with the temperature in the teens, and the range is more like 160 or so. Using heat or A/C does not have as much effect as I would have thought. If the display says I have 200 miles left and I turn on the heat, it would go down to 185. The Bolt has heated seats and heated steering wheel which don't seem to change the range much at all, and if it's not too cold, I just use those.

We have solar panels that were sized to include the Bolt (12,000 miles/year), so once you have the panels paid for, running the car is essentially free.

Owners at Highland Green

Resident	*Vehicle*	*Type*
Karen Bragaw	Nissan Leaf	BEV
Stan DeOrsey	Toyota RAV4 Prime	plugin hybrid
Rick Diamond	Toyota Prius Prime	plugin hybrid
Charlotte Hewson	Toyota Prius	plugin hybrid
Cy Kendrick	Chevy Bolt	BEV
Steve O'Keefe	Nissan Leaf	BEV

Comparison of EV Designs

	Internal Combustion Engine	*Hybrid*	*Plug-in Hybrid (PHEV)*	*Extended Range Hybrid (EREV)*	*Fuel Cell*	*Electric*	*Tesla*
Engine	Relatively complex, heavy, hot engine, most efficient only in ideal range of rotation rates	Internal combustion engine and DC motor(s). ICE provides all energy and recharges battery. Battery operates vehicle until it runs low, then ICE provides power	Internal combustion engine and DC motor(s); battery provides power until it runs low, then ICE is used. Battery is charged by plug-in	Internal combustion engine and DC motor(s); battery always used for motion. ICE recharges the batteries rather than running the car	DC motors, one per tire or one per tire pair. High torque, efficient at any rotation rate. No timing belt, pistons, plugs, etc.	DC motors, one per tire or one per tire pair. High torque, efficient at any rotation rate. No timing belt, pistons, plugs, etc.	DC motors, one per tire or one per tire pair. High torque, efficient at any rotation rate. No timing belt, pistons, plugs, etc.
Battery	Lead-acid, for starting only	Lithium-ion, small, provides first ~1 mi, then gas takes over	Lithium-ion, larger, provides first 10-97 mi, then gas takes over	Lithium-ion, large, provides full range of travel	Fuel cell uses hydrogen for all travel	Lithium-ion, large, provides full range of travel	Lithium-ion, large, provides full range of travel
Transmission	Yes	Yes	Yes	No	No	No	No
Power distribution	Mechanical distribution system, with efficiency losses	Mechanical distribution system, with efficiency losses	Mechanical distribution system, with efficiency losses	Multiple motors in some designs are more efficient, with better traction	Multiple motors in some designs are more efficient, with better traction	Multiple motors in some designs are more efficient, with better traction	Multiple motors in some designs are more efficient, with better traction

	Internal Combustion Engine	*Hybrid*	*Plug-in Hybrid (PHEV)*	*Extended Range Hybrid (EREV)*	*Fuel Cell*	*Electric*	*Tesla*
Braking	Disc brakes, braking by conversion to heat, no energy recapture	Regenerative braking provided by motors, some energy recaptured and stored in batteries, limited by battery capacity. Disc brakes still needed, but wear better	Regenerative braking provided by motors, significant energy recaptured and stored in batteries, limited by battery capacity. Disc brakes still needed, but wear better	Regenerative braking provided by motors, significant energy recaptured and stored in batteries, limited by battery capacity. Disc brakes still needed, but wear better	Disc brakes, braking by conversion to heat, no energy recapture	Regenerative braking provided by motors, significant energy recaptured and stored in batteries, disc brakes still needed, but wear much better	Regenerative braking provided by motors, significant energy recaptured and stored in batteries, disc brakes still needed, but wear much better
Cooling (of engine)	Fan, fan belt, radiator	Fan, fan belt, radiator	Fan, fan belt, radiator	Fan, fan belt, radiator	Not needed	Not needed	Not needed
Fueling	Gasoline	Gasoline	Gas; recharge at station or in garage	Gasoline	Recharge at hydrogen fuel station, so far in extremely short supply	Recharge in garage or at charge station	Recharge in garage or at charge station
Oil Changes	~10,000 mi	10,000-20,000 mi	10,000-20,000 mi	~10,000 mi	n/a	n/a	n/a
Heating (of people)	Waste heat from engine; no impact on range	Waste heat from ICE or resistive heat; low impact on range	Waste heat from ICE or resistive heat; low impact on range	Waste heat from engine; no impact on range	Resistive heat can be created closer to where it is needed; limits range a bit	Resistive heat can be created closer to where it is needed; limits range a bit	Resistive heat can be created closer to where it is needed; limits range a bit
Cooling (of people)	A/C, some designs reduce engine efficiency even when not in use	A/C, no penalty for non-use	A/C, no penalty for non-use	A/C, no penalty for non-use	A/C, no penalty for non-use; limits range	A/C, no penalty for non-use; limits range	A/C, no penalty for non-use; limits range
Extreme weather range penalty	Low	Low	Low	Higher	Low	Up to 50%	Up to 50%
Range	240-703 mi	250-400 mi	20 mi on battery; up to 600 on gas	Varies	Over 300 mi	58-351 mi	238-310 mi
MPGe	17-40	30-60	30-75			108-130	108-130
CO_2 production	High	Medium	Medium	Medium	Low	Low	Low

	Internal Combustion Engine	*Hybrid*	*Plug-in Hybrid (PHEV)*	*Extended Range Hybrid (EREV)*	*Fuel Cell*	*Electric*	*Tesla*
Refuel time	~5 minutes/300 mi	~5 minutes/300 mi	~5 minutes/300 mi	~5 minutes/300 mi	~5 minutes/300 mi	Usually zero if charged at home; up to 50 minutes on long trips	Usually zero if charged at home; about 20 minutes for 85% supercharge; up to 50 minutes at normal charger
Home charging	n/a	n/a	Standard outlet	n/a	n/a	Standard outlet has very long charge times; 220V outlet shortens charge time	Standard outlet has very long charge times; 220V outlet shortens charge time
# of fueling stations	Bazillions	Bazillions; can use gasoline until a charger is available	Bazillions; can use gasoline until a charge is available	Bazillions	Chargers spotty in CA (about 100), almost non-existent outside of CA	Chargers unevenly distributed, ample in cities, spotty in rural areas	>20,000 superchargers; many more slower chargers (supercharger adds 163 mi of range in 20 mins)
Acceleration	Limited by engine efficiency at some speeds	Excellent on battery; variable on gas	Excellent on battery; variable on gas	Excellent at all speeds	Excellent at all speeds	Excellent at all speeds	Excellent at all speeds
Handling	Variable, dependent on vehicle design	Variable, dependent on vehicle design	Batteries may add traction	Batteries may add traction	Batteries may add traction	Large, low mounted battery array provides low center of gravity and extra traction	Large, low mounted battery array provides low center of gravity and extra traction
Noise	Engine plus road noise	Road noise plus engine when ICE is running	Road noise plus engine when ICE is running	Engine plus road noise	Mostly road noise	Mostly road noise	Mostly road noise
Nav	No routing help needed	No routing help needed	No routing help needed	No routing help needed	No routing to chargers	No routing to chargers	Nav system has realtime charger status updates and routing to chargers

Green Steps is comprised of a group of Highland Green residents interested in supporting the sustainable health of our environment through education and action. Open to all residents. No invitation needed.

Meetings: First Monday of each month, 3:30 to 5:00 PM. Come join us!
https://highlandgreenlifestyle.com/residents/green-steps-tips/

Mission Statement

- Promote good stewardship of our shared environment.
- Support cost-efficient, effective initiatives that improve the health of our natural environment.
- Offer interesting and educational co-sponsored programming for the Highland Green and local community.