
ELECTRIC VEHICLES — ARE THEY RIGHT FOR YOU?



BRIAN ANDERSON



Senior Research Program Manager (retired)

Medtronic Corporate
Minneapolis, Minnesota

40 YEARS

Hardware/software product development in multiple industries

25 YEARS

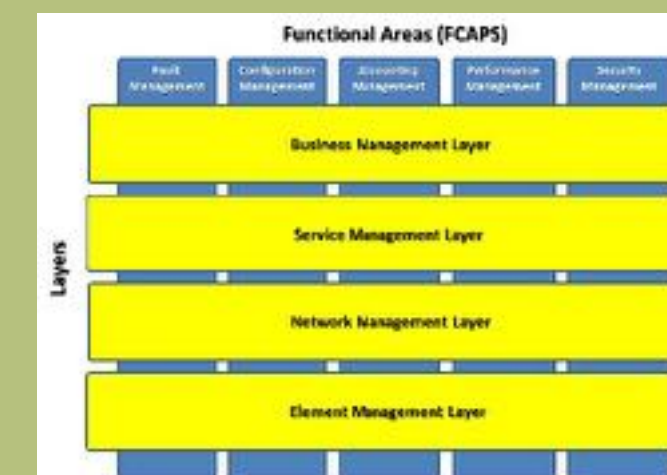
Medical device software development and quality

About Me

- ❖ Hometown: Portage, Wisconsin
- ❖ Current Residence: Plymouth, MN
- ❖ Family: Wife Karen, Son Tor (30), Daughter Louise (23)
- ❖ EV driver since Oct 2015
- ❖ Home powered by solar since Sep 2015

Professional Experience

- ❖ RF Design - 2-way radios & power amps
- ❖ Automotive Diagnostic Software
- ❖ Telecommunications Systems and Software
- ❖ Medical Device Systems and Software



Fun Facts

- ❖ At Argonne National Labs outside Chicago, my father conducted experiments using CP-5. This sparked my interest in science and engineering.
- ❖ Of the 18 countries I have visited, 5 begin with the letter 'I' (there are only 9 in total).
- ❖ My Tesla Model 3 was on display at the State Fair for several days in 2018.

Hobbies

- ❖ Camping /Hiking
- ❖ Cycling
- ❖ Music
- ❖ Travel
- ❖ Electric vehicle & Renewable Energy advocacy

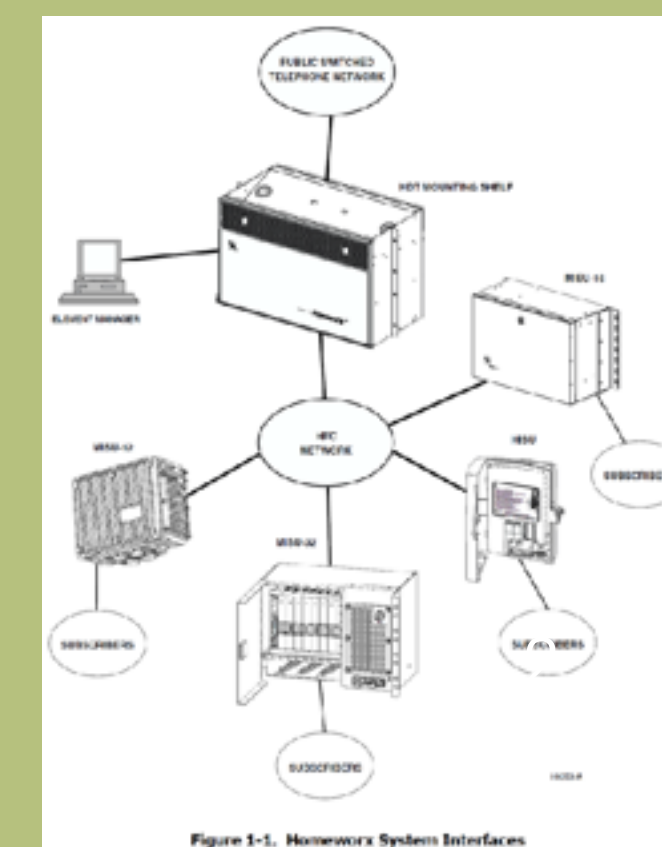
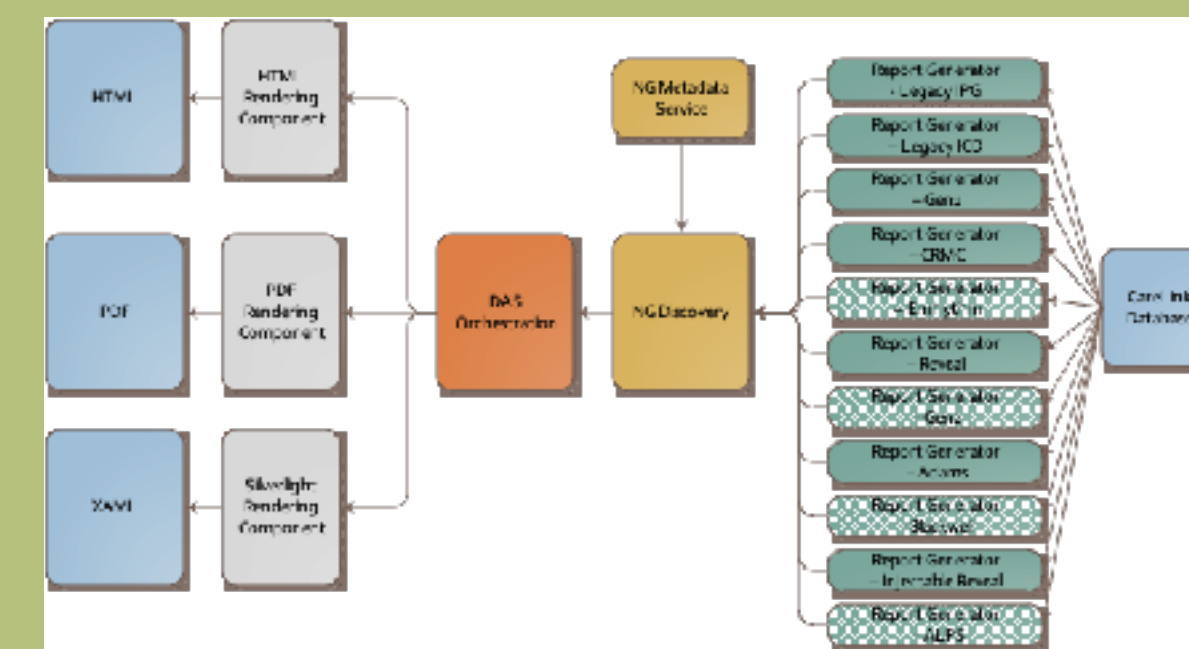


Figure 1-5. Homework System Interfaces



Our EV experience started in 2015 with leasing a BMW i3 and we have been 100% EV since March 2020.



BMW i3 charging at Carlton College in Northfield, MN

Topics





















- ◆ Basics: Terms, Differences to Internal Combustion Engine Vehicles
- ◆ Electricity: Power and Energy
- ◆ Charging (How, How Long, When, Where)
- ◆ Environmental and Financial Cost Savings (including changes to US EV tax credit)
- ◆ Electric Vehicle Models and Market

ELECTRIC VEHICLE BASICS

There are some new terms to learn when talking about the future of personal transportation.

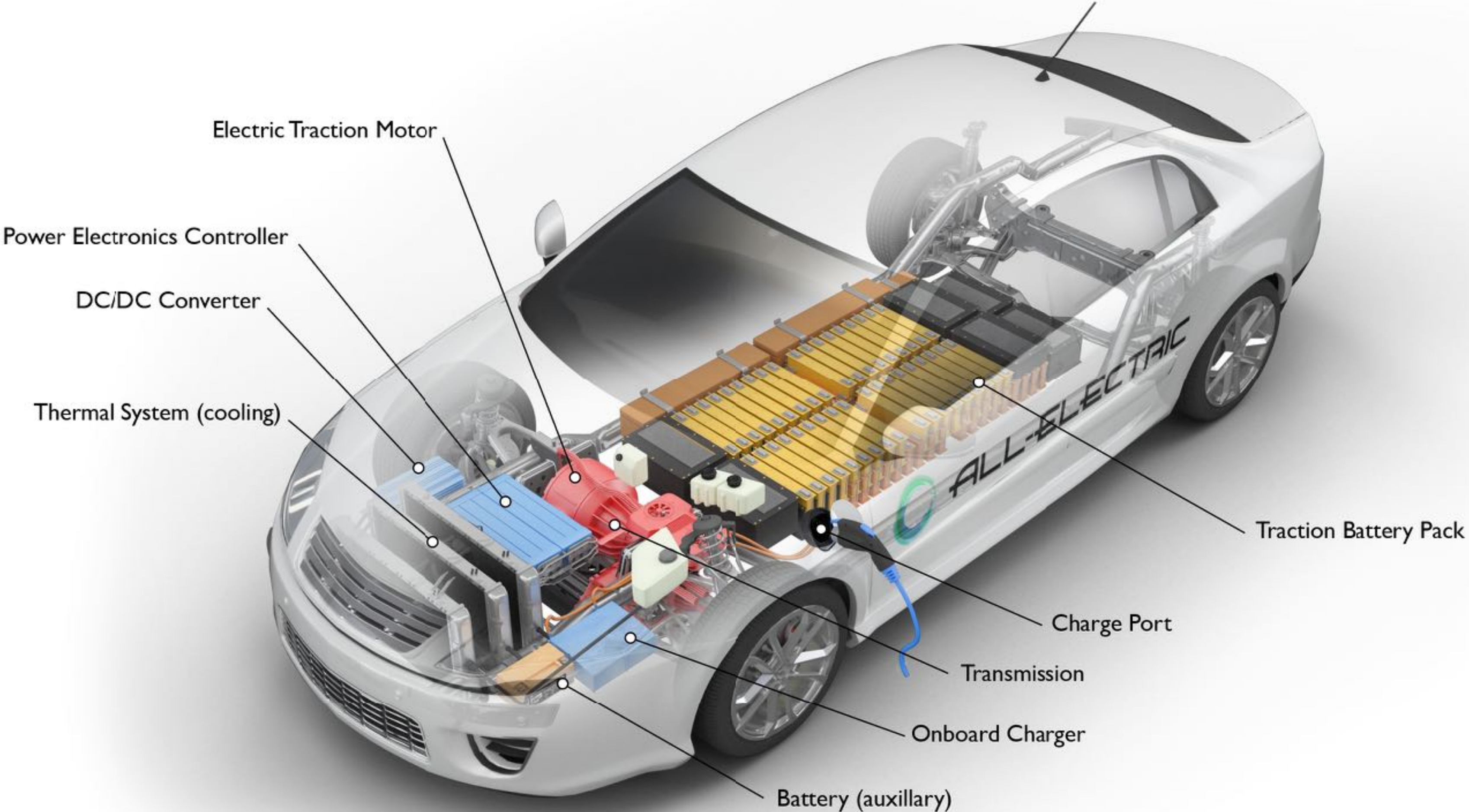
| Term | Definition |
|-------------|--|
| BEV | Battery Electric Vehicle |
| CCS | Combined Charging Standard |
| DCFC | DC Fast Charger |
| EV | Electric Vehicle |
| EVSE | Electric Vehicle Service Equipment (for L1 & L2 AC charging) |
| ICE(V) | Internal Combustion Engine (Vehicle) |
| NACS | North American Charging Standard |
| PHEV | Plug-in Hybrid Electric Vehicle |

The source of energy for a vehicle is key to understanding its environmental impact. For example, hybrids are 100% fossil fuel powered.

| |  |  |  | PHEV  | BEV  |
|--------------------------|---|---|---|---|---|
| | | CONVENTIONAL | HYBRID | PLUG-IN HYBRID | ALL-ELECTRIC |
| SOURCES OF ENERGY | |  Internal Combustion Engine Vehicle (ICEV) |  |  +  |  |
| CONSUMPTION | |  |  +  |  +  |  |
| EMISSIONS | |  |  |  |  |





Electric Vehicle Components

All-Electric Vehicle



afdc.energy.gov

Comparison of Internal Combustion Engine (ICE) and Electric Vehicle—Design

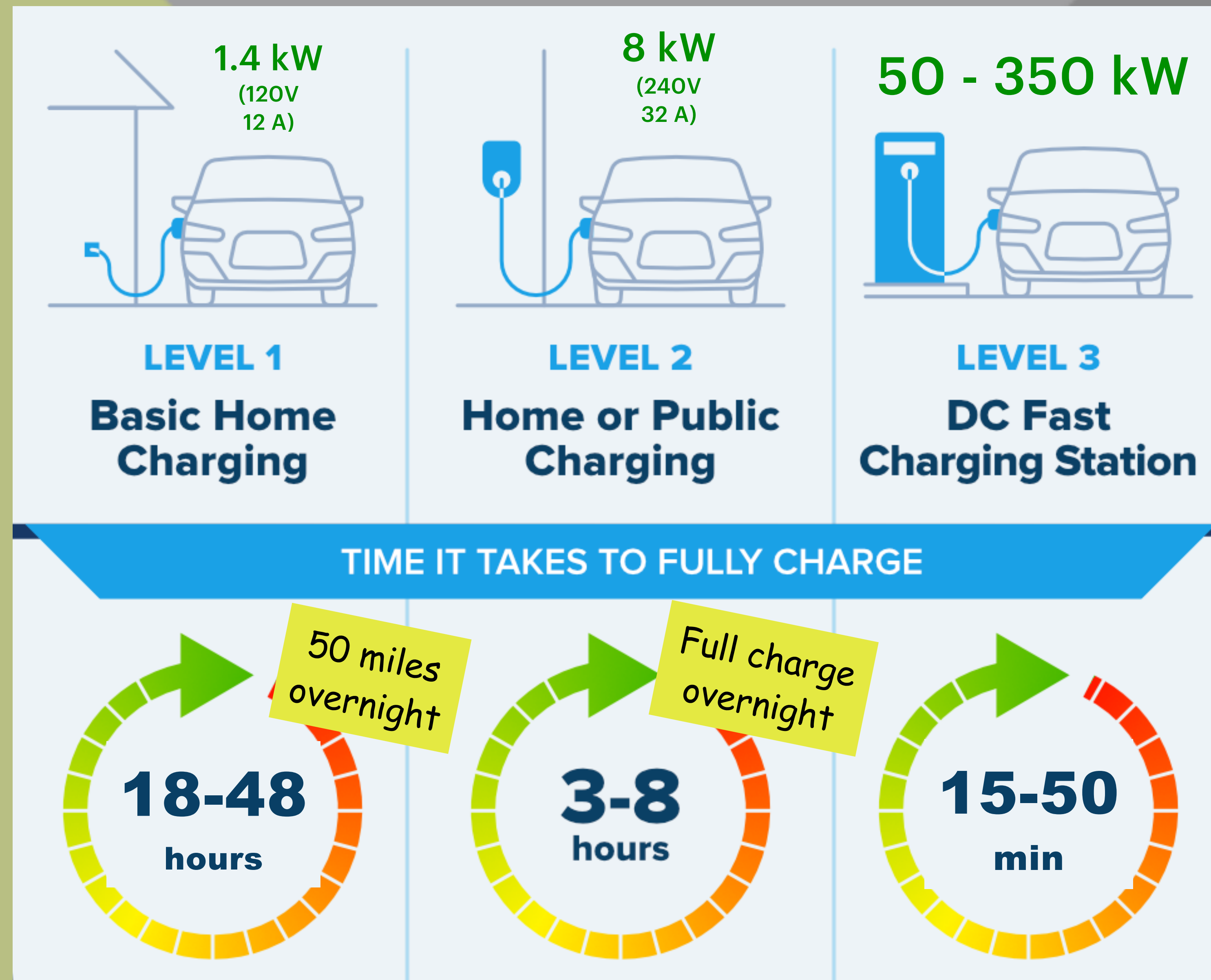
| | ICE | EV |
|--------------------------------------|---|---|
| Powertrain Components | 2000 | 20 |
| Maintenance |  |  |
| Energy efficiency (source to wheels) | 15-25% | 75-85% |
| Energy cost / mile | \$\$\$ | \$ |
| Torque curve |  |  |

Comparison of Internal Combustion Engine (ICE) and Electric Vehicles—Ownership Experience

| | ICE | EV |
|--------------------------------------|---|--|
| Recharging / refueling at home | Not available | Plug in at home |
| Recharging / refueling locally | Local gas station | Public DCFC or L2 (AC) |
| Recharging / refueling on road trips | Gas station | DCFC (car nav) |
| Driving | Baseline | Instant torque No engine noise Low center of gravity Regenerative braking |
| Health and safety impacts | Fuel and exhaust both toxic Fuel explosively flammable | No fuel, no emissions |
| Winter driving | Slower warm-up, idling wasteful, can't idle in closed spaces | Fast warm-up Preheating in closed spaces Range loss when parked outside |

ELECTRIC VEHICLE CHARGING

There are three levels of Electric Vehicle charging.



There are several types of Electric Vehicle charging equipment.

EVSE (home connector)
L1-L2 120V or 240V AC



Public EVSE
L2 208-240V AC



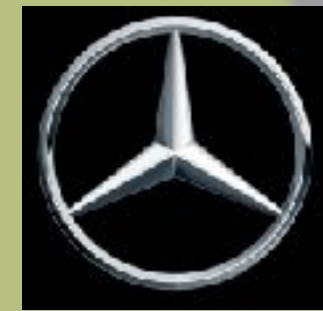
Public DC Fast Charger
L3 - Main Battery DC Voltage

| CONNECTORS | LEVEL | ALL OTHER MAKES | TESLA |
|---|-------|---|--------------|
| Wall outlets (Nema 515, Nema 520) | 1 | With EVSE | With EVSE |
| J1772 (SAE) | | ✓ | With adapter |
| Nema 1450 (RV plug) | 2 | With EVSE | With EVSE |
| Tesla HPWC | | With adapter | ✓ |
| SAE Combo CCS | 3 | ✓ | With adapter |
| Tesla supercharger | | Brands adopting NACS SC locations with Magic Dock | ✓ |

Starting in late May 2023, several automakers and charger manufacturers have adopted Tesla's NACS



RIVIAN



HONDA



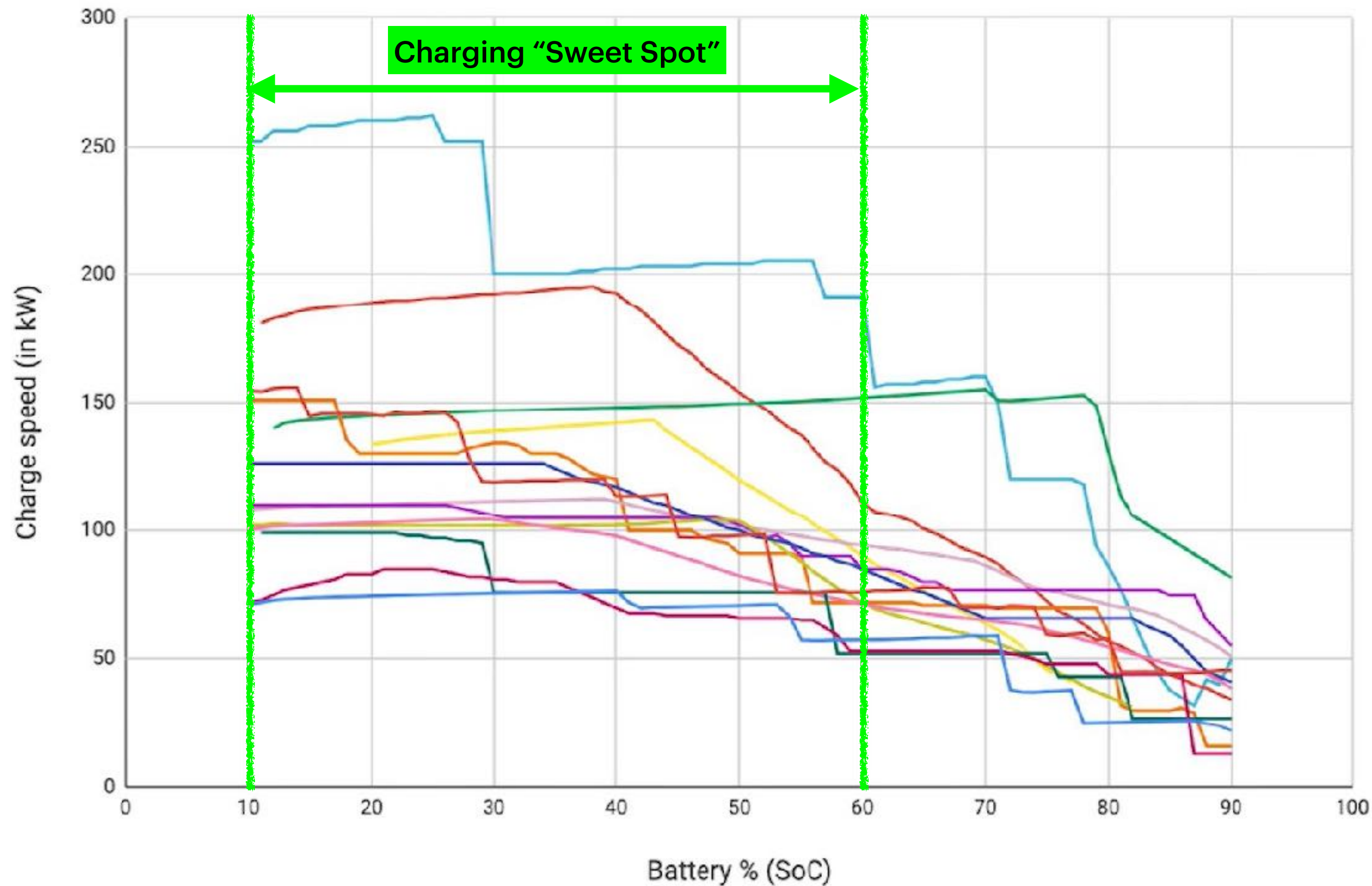
SUBARU



Sources: <https://www.thedrive.com/guides-and-gear/which-cars-nacs-charge-plugs>
<https://electrek.co/2023/05/25/ford-will-add-tesla-plug-to-its-electric-vehicles-in-surprising-move/>

Electric Vehicle Charging Curves (DCFC)

Charge curves at 300 kW chargers



- Porsche Taycan
- Tesla Model 3 LR
- Tesla Model S/X LR (CCS adapter)
- Audi e-tron
- Polestar 2
- Mercedes EQC
- Mercedes EQV
- Tesla Model 3 SR+
- VW ID.4 & Skoda Enyaq iV (82 kWh)
- Jaguar I-PACE
- Peugeot e-208/2008 & Corsa e-Corsa/Mokka & DS3 Crossback E-Tense
- Fiat 500e
- Hyundai Kona & Kia e-Niro (64 kWh)
- BMW iX3

Note: Horizontal axis is not proportional to time. Percentage added per unit time varies with real-time charging power.

Percent added / minute =

$$\left(\frac{\text{Charge power}}{\text{Battery size}} \right) / 60 * 100$$

Example:

$$\left(\frac{150 \text{ kW}}{75 \text{ kWh}} \right) / 60 * 100 = 3.3\%$$

Application Examples

Charging at Home (nightly)

- Charge from EVSE — Level 2 (240V x 40A = **9.6 kW**)
- Max State of Charge (SOC) set to 80%*
- 75 kWh battery, arrive home at 50% SOC
- Adding 80 - 50 = 30% of battery = **22.5 kWh**
- **Charging completed in 22.5 / 9.6 = 2h 20m**

* maximizes battery longevity and is plenty for local driving because you start every day fully charged



Electrify America station, Grants, NM
Tesla Model Y and GMC Hummer

Road Trip Charge Stop

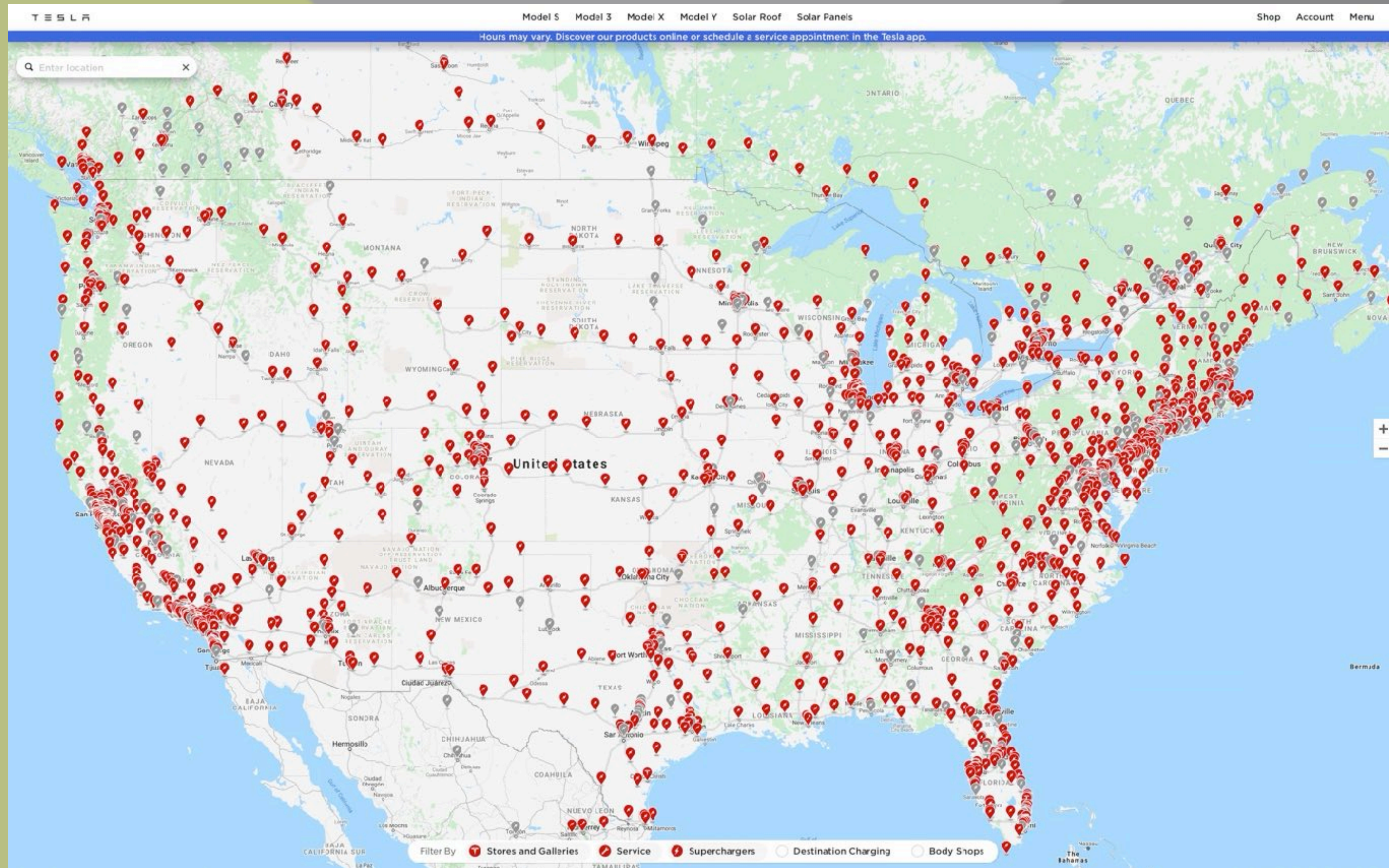
- Charge at DCFC — assume 180 kW max, 110 kW average power
- 75 kWh battery, arrive with 20% SOC (15 kWh)
- Next charger is 120 miles down the road
- Vehicle range at highway speed is 240 miles
- Need to add 50% SOC
- **Time required = ((75 kWh * 0.5) / 110 kW) / 60 min/hr = 20.5 minutes**

Weekend Cabin Visit

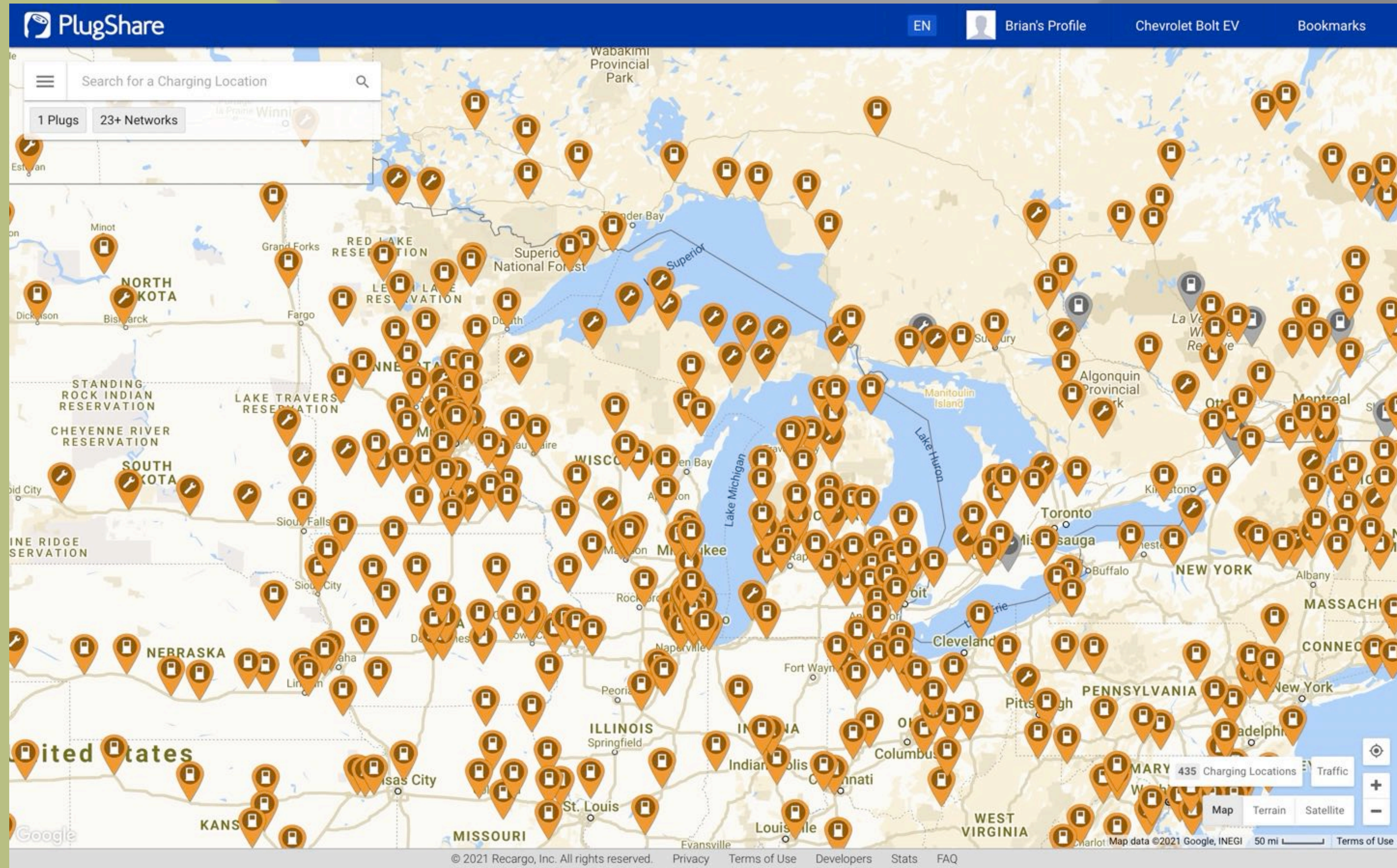
- Charge from wall outlet — Level 1 (120V, 15A circuit)
- 75 kWh battery, **arrive with 20% SOC** (75 x 0.2 = **15 kWh**)
- 8PM Friday - Noon Sunday (**40 hours**)
- 120V x 12A (80% of max) = **1.4 kW**
- 1.4 kW x 40 hours = **56 kWh**
- **Battery charged to (15 + 56 kWh) / 75 kWh = 95%**
- **75% added to battery SOC**



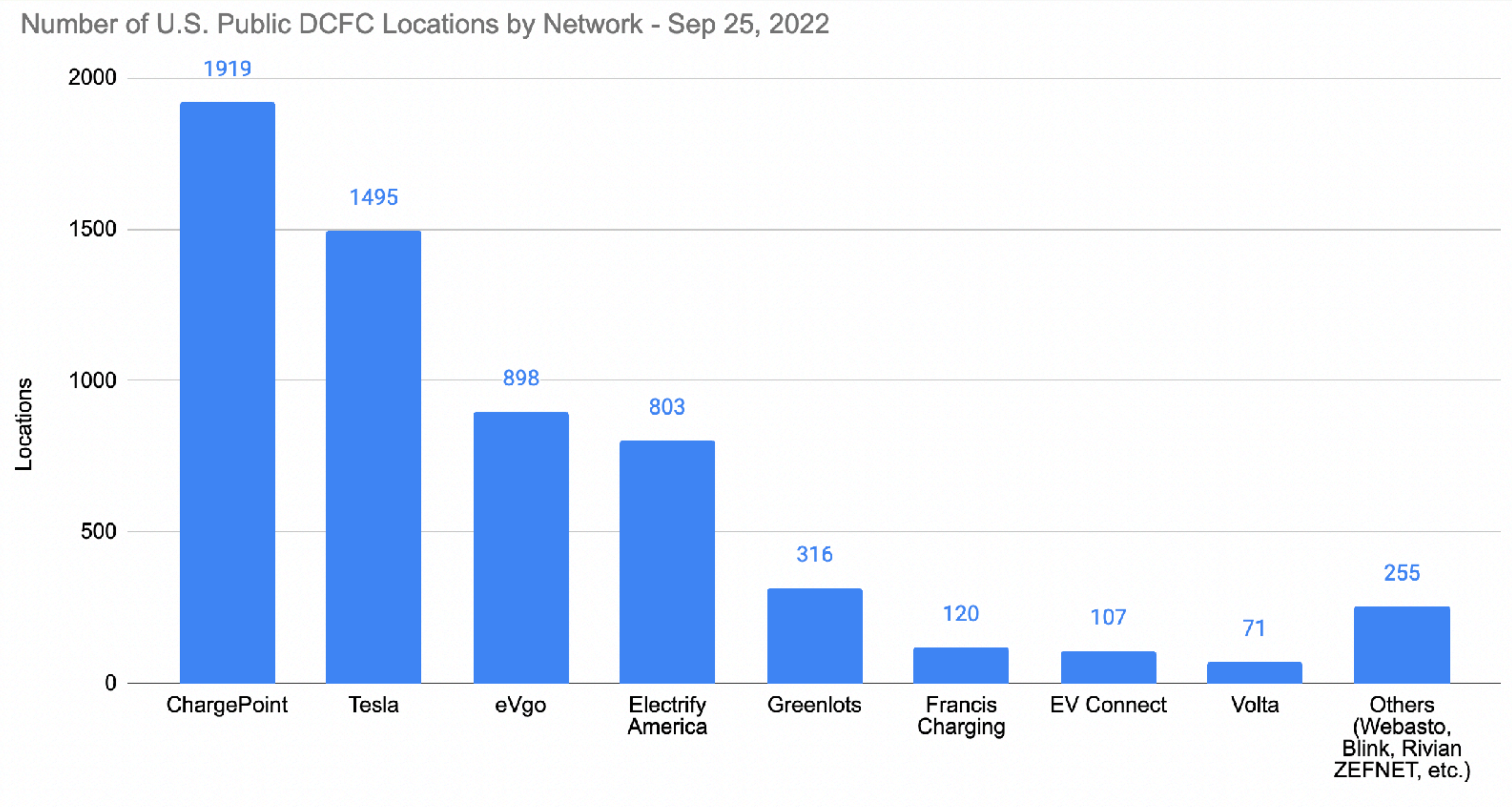
The Tesla charging network provides convenient travel to any location via the in-car navigation and automatic billing for energy.



Third party networks also cover the US and are expanding rapidly.



DC fast charging infrastructure is already robust and is in a high-growth mode. Tesla has fewer locations, but more connections / location.



Data from AFDC (<https://afdc.energy.gov/>)

The number of **public DCFC locations** per Electric Vehicle is **already 4 times** the number of **gas stations** per ICE Vehicle.

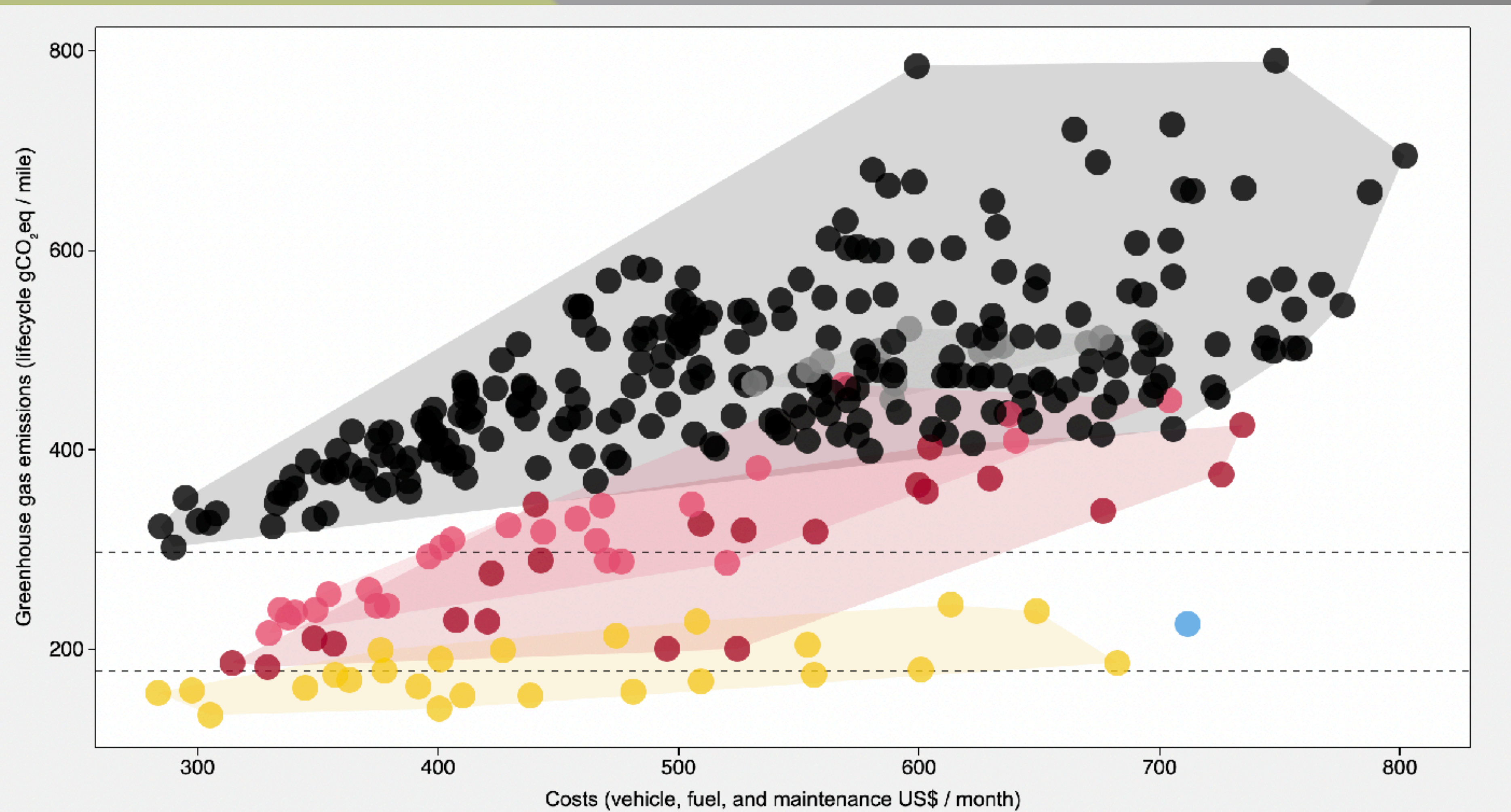
| | ICE | EV | |
|---------------------|-------------|-----------|------|
| Total vehicles | 290,000,000 | 3,900,000 | 1.3% |
| Locations | 115,000 | 6,000 | 5.2% |
| Vehicles / location | 2,522 | 650 | 3.9 |

And remember as an EV Owner, you will be charging at home 80% - 90% of the time!

EV Source: <https://www.bloomberg.com/news/articles/2022-04-08/plug-in-ev-fleet-will-soon-hit-a-20-million-milestone>

ELECTRIC VEHICLE ENVIRONMENTAL AND FINANCIAL COST SAVINGS

Lifecycle Greenhouse Gas Emissions and Cost / Mile for All Vehicle Fuel Types (Minnesota Gas Prices and Grid Emissions)



LEGEND

- Internal combustion engine (gasoline)
- Internal combustion engine (diesel)
- Hybrid
- Plug-in hybrid
- Battery electric vehicle
- Fuel cell vehicle

Data and methods

Greenhouse gas emissions account for the entire lifecycle, including vehicle production and battery production, supply chains raw materials, the fuel use cycle and vehicle disposal (GREET2), as well as the fuel production cycle (GREET1).

Note: other pollutants such as Nitrogen Oxides, Carbon Monoxide and particulates (PM2.5 and PM10) are **not** included.

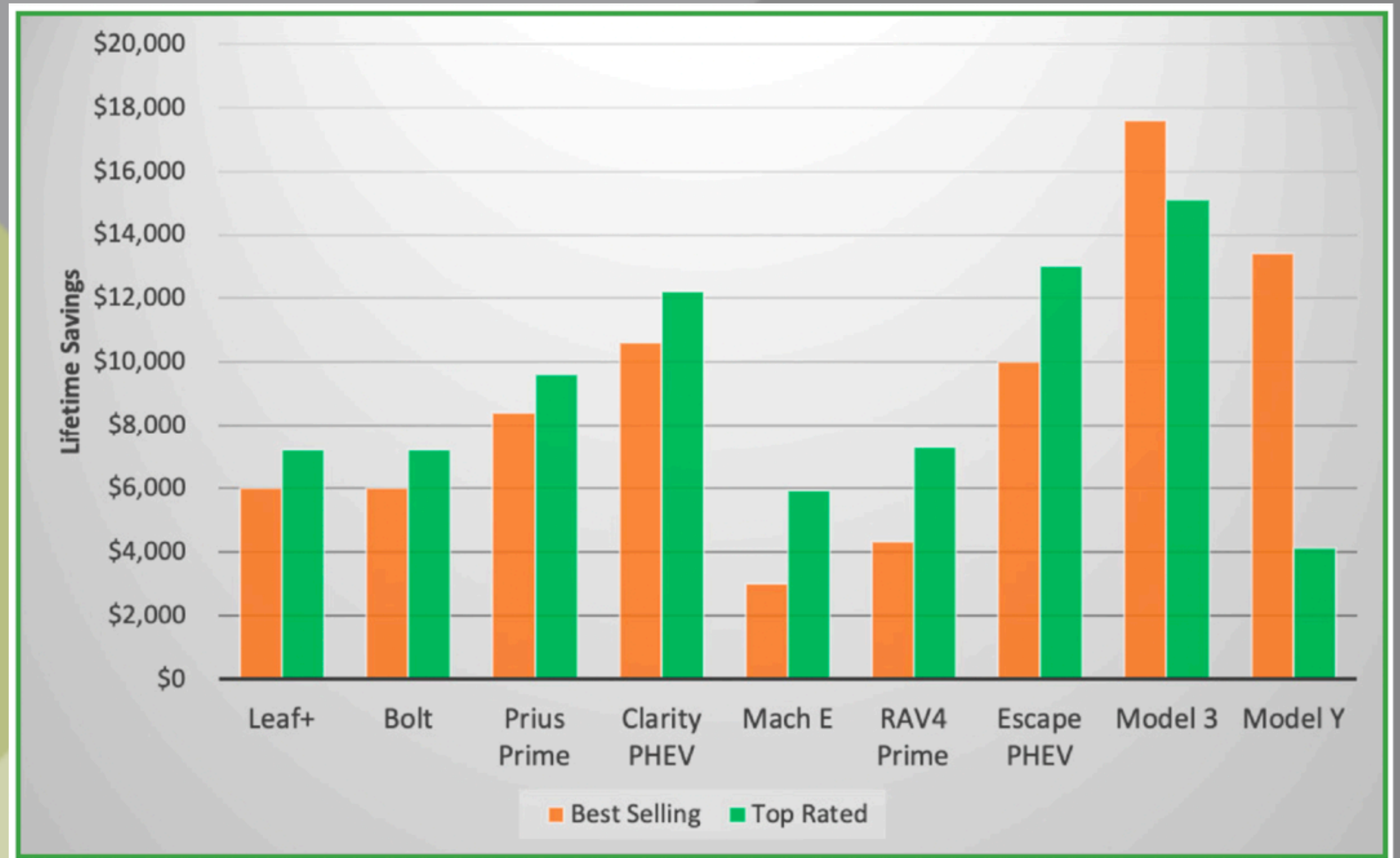
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Source: <https://www.carboncounter.com/#!/explore>

Mainstream EVs are less expensive to own and operate than equivalent ICEVs.

Lifetime savings of Best Selling EVs under \$50,000 compared to Best Selling & Top Rated ICE vehicles in each EV's class

Consumer Reports



| EV model and trim | Leaf E+ S+ | Bolt LT | Prius Prime LE | Clarity PHEV | Mach E Select | RAV4 Prime SE | Escape PHEV SE | Model 3 SR Plus | Model Y LR |
|---------------------|----------------------|---------|----------------|--------------|---------------|---------------|----------------|-----------------|------------|
| Best Selling | Civic Hatchback LX | | | Camry LE | RAV4 LE | | 330i | RX 350 FWD | |
| Top Rated | Elantra GT automatic | | | Legacy 2.5 | CX5 Sport | | A4 | QX50 Pure | |

Source: <https://www.consumerreports.org/hybrids-evs/evs-offer-big-savings-over-traditional-gas-powered-cars/>

Inflation Reduction Act (IRA)—EV credit requirements

- ❖ Vehicle assembled in North America, effective on passage
- ❖ Battery assembly (half of credit) and “critical” materials (other half of credit):
 - ❖ No “foreign entities of concern”
 - ❖ Sliding percentage by year of assembly / processing in North America
- ❖ Price caps: Cars \$55,000, Trucks/Vans/SUVs \$80,000
- ❖ Income limits: Single \$150,000, Head of household \$225,000, Joint \$300,000
- ❖ Eligible models: <https://www.fueleconomy.gov/feg/taxcenter.shtml>

Source: <https://techcrunch.com/2022/09/02/a-complete-guide-to-the-new-ev-tax-credit/>

EV MODELS AND AVAILABILITY

Cars



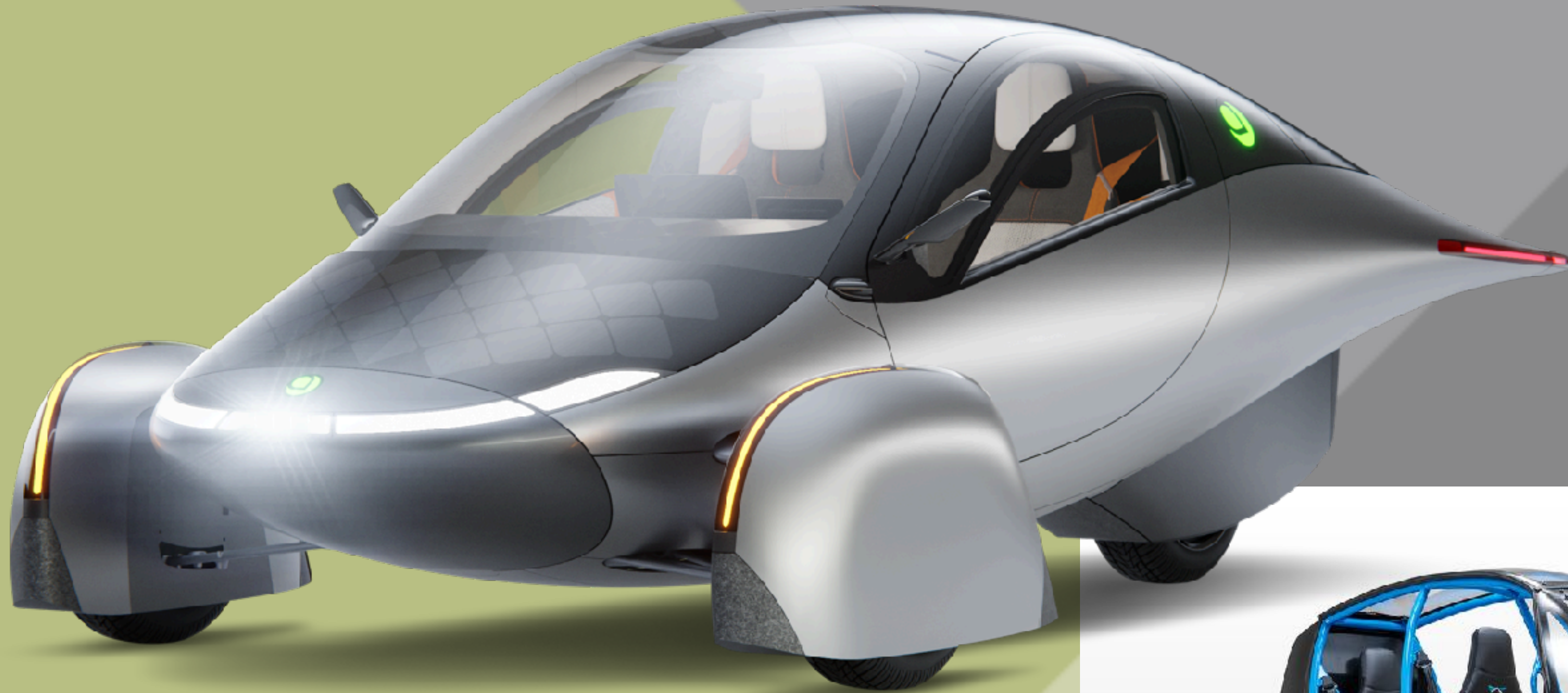
SUVs & Vans!



Trucks!!


















Autocycles!!!



There are a number of EVs available for purchase in the US.

US EV Info List (August 2022) Page 1 of 5

| Manufacturer | | | | | | | | | | Range | | | Charging speed (miles/hr) | | | Performance | | | | |
|--------------|----------------------|--|---------|---------|-------------|-----------|--------------------|--------------------------------|--------------------|------------------------|---------------------|-----------------------------|---------------------------|--------------|------------|-------------|---------------|----------------|-----------------------|------------------------------|
| Make | Model | Photo | Seating | EV Type | FWD/RWD/AWD | Base MSRP | Federal tax credit | Price after federal tax credit | Battery size (kWh) | Electric Range (miles) | Total Range (miles) | Charging rates (kW) L2/DCFC | Level 1 120V | Level 2 240V | DCFC 400+V | MPGe/MPG | Top Spd (mph) | 0-60 mph (sec) | Towing capacity (lbs) | Crash Ratings: IIHS/NHTSA |
| Audi | Q4 e-tron |  | 5 | BEV | AWD | \$49,900 | TBD | \$49,900 | 82 | 241 | 241 | 11/125 | 3 | 31 | 282 | 95 | 112 | 5.8 | 2600 | Not Rated |
| Audi | Q4 Sportback e-tron |  | 5 | BEV | AWD | \$52,700 | TBD | \$52,700 | 82 | 241 | 241 | 11/125 | 3 | 31 | 282 | 95 | 112 | 5.8 | 2600 | Not Rated |
| Audi | e-tron (S) |  | 5 | BEV | AWD | \$65,900 | TBD | \$65,900 | 95 | 222 | 208-222 | 9.6/150 | 3 | 22 | 278 | 78 | 124-130 | 4.3-5.5 | 4000 | Top Safety Pick +/ Not rated |
| Audi | e-tron Sportback (S) |  | 5 | BEV | AWD | \$69,100 | TBD | \$69,100 | 95 | 218 | 218 | 9.6/150 | 3 | 22 | 274 | 77 | 124-131 | 4.3-5.6 | 4000 | Top Safety Pick +/ 5 star |
| Audi | e-tron GT |  | 5 | BEV | AWD | \$102,400 | TBD | \$102,400 | 93 | 238 | 238 | 9.6/270 | 3 | 23 | 292 | 82 | 155 | 3.1-3.9 | 0 | Not Rated |
| Audi | Q5 TFSI e |  | 5 | PHEV | AWD | \$55,400 | TBD | \$55,400 | 17.9 | 20 | 390 | 7.4 | 2 | 14 | N/A | 61/26 | 130 | 5 | 4400 | Top Safety Pick +/ Not rated |
| Audi | A7 TFSI e |  | 5 | PHEV | AWD | \$75,900 | TBD | \$75,900 | 17.9 | 26 | 410 | 7.4 | 2 | 13 | N/A | 70/27 | 130 | 5.2 | 0 | Top Safety Pick +/ Not rated |
| BMW | i4 |  | 5 | BEV | RWD/AWD | \$55,400 | TBD | \$55,400 | 81 | 227-301 | 227-301 | 11/195 | 4 | 33 | 462.908 | 80-109 | 140 | 3.7-5.5 | 0 | Not Rated |
| BMW | ix |  | 5 | BEV | AWD | \$83,200 | TBD | \$83,200 | 112 | 315-324 | 315-324 | 11/195 | 3 | 28 | 393.4718 | 83-86 | 124 | 3.6-4.4 | 0 | Not Rated |
| BMW | X5 xDrive45e |  | 5 | PHEV | AWD | \$63,700 | TBD | \$63,700 | 24 | 31 | 400 | 3.7 | 2 | 5 | N/A | 50/20 | 130 | 5.3 | 0 | Top Safety Pick +/ Not rated |
| BMW | 330e |  | 5 | PHEV | RWD/AWD | \$42,950 | TBD | \$42,950 | 12 | 23 | 320 | 3.7 | 3 | 8 | N/A | 75/28 | 130 | 5.6 | 0 | Top Safety Pick / Not rated |
| BMW | 530e |  | 5 | PHEV | RWD/AWD | \$55,550 | TBD | \$55,550 | 12 | 21 | 350 | 3.7 | 2 | 8 | N/A | 69/27 | 146 | 6 | 0 | Top Safety Pick +/ Not rated |
| BMW | 745e |  | 5 | PHEV | AWD | \$95,900 | TBD | \$95,900 | 12 | 16 | 290 | 3.7 | 2 | 6 | N/A | 56/22 | 155 | 4.9 | 0 | Not rated / Not rated |

This table is updated by Jukka Kukkonen, Shift2Electric. Photos and information sources: Manufacturers' websites and www.fueleconomy.gov Get the latest version: www.EVInfoList.com

News Sources - where can I find out more and stay current?

- ◆ InsideEVs: insideevs.com
- ◆ CleanTechnica: cleantechnica.com
- ◆ Electrek: electrek.co
- ◆ GreenCarReports: www.greencarreports.com/news/electric-cars
- ◆ EV Obsession: evobsession.com

Source: EV News | Shift2Electric: www.shift2electric.com/evnews

References

- ◆ [Alternative Fuels Data Center: How do Electric Vehicles Work?](#)
- ◆ [Find Us | Tesla \(<https://www.tesla.com/findus>\)](#)
- ◆ [Plugshare \(<https://www.plugshare.com/>\)](#)
- ◆ [Alternative Fuels Data Center: Data Download](#)
- ◆ [Rochester Public Utilities Time of Use Program](#)
- ◆ [Carboncounter \(MIT\)](#)
- ◆ [Consumer Reports: EVs Offer Big Savings Over Traditional Gas-Powered Cars](#)
- ◆ [Aptera referral link](#)

Thank You for your attention

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