ELECTRIC VEHICLES — ARE THEY RIGHT FOR YOU?

Brian Anderson

Jul 13, 2023

BRIAN ANDERSON

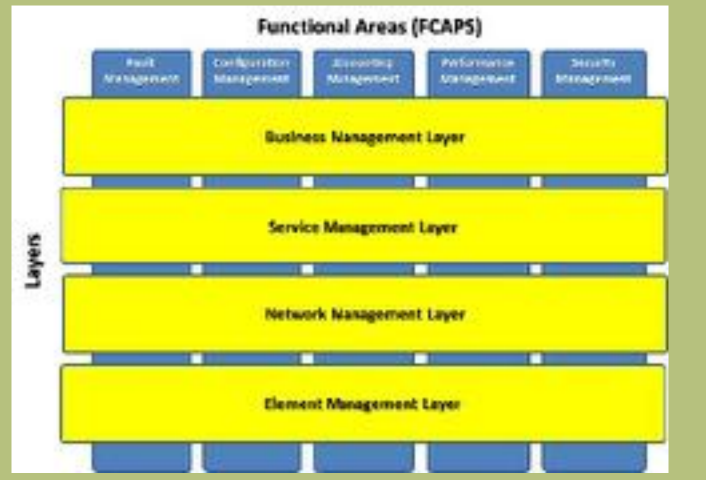
Senior Research Program Manager (retired)
Medtronic Corporate
Minneapolis, Minnesota

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



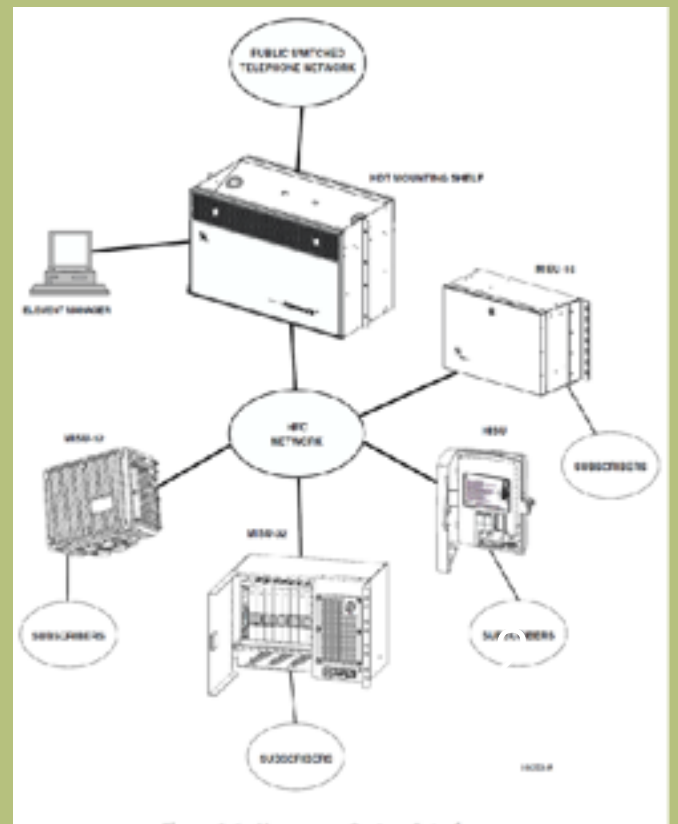
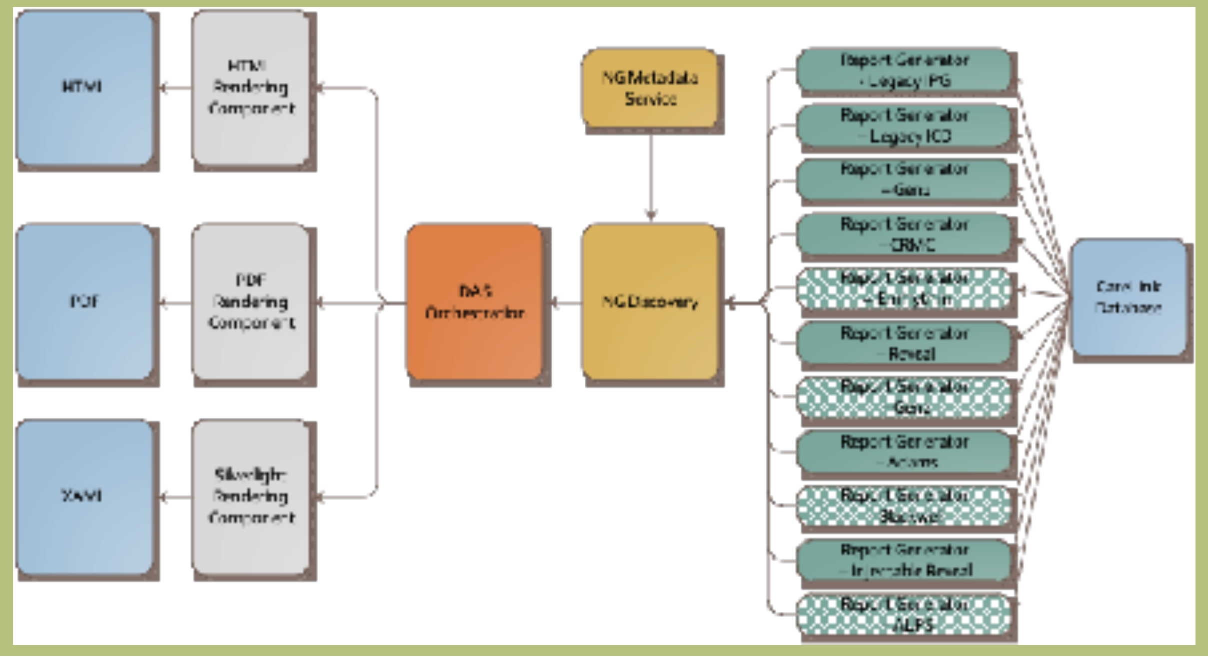


Figure 1-1. Homeworx System Interfaces



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).
- I love to talk to people about electric vehicles and renewable energy. One year, my Tesla Model 3 was on display at the State Fair for several days.

Hobbies
- Camping /Hiking
- Cycling
- Tree Care Advisor
- Music
- Travel
- Electric vehicle & Renewable Energy advocacy

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

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2017 Chevy Bolt

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Tesla Model 3 pick-up day (May 2018)

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2020 Chevy Bolt and 2020 Tesla Model Y (100% electric garage)

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Tesla Model Y towing Safari Condo Alto and charging at Supercharger

Topics

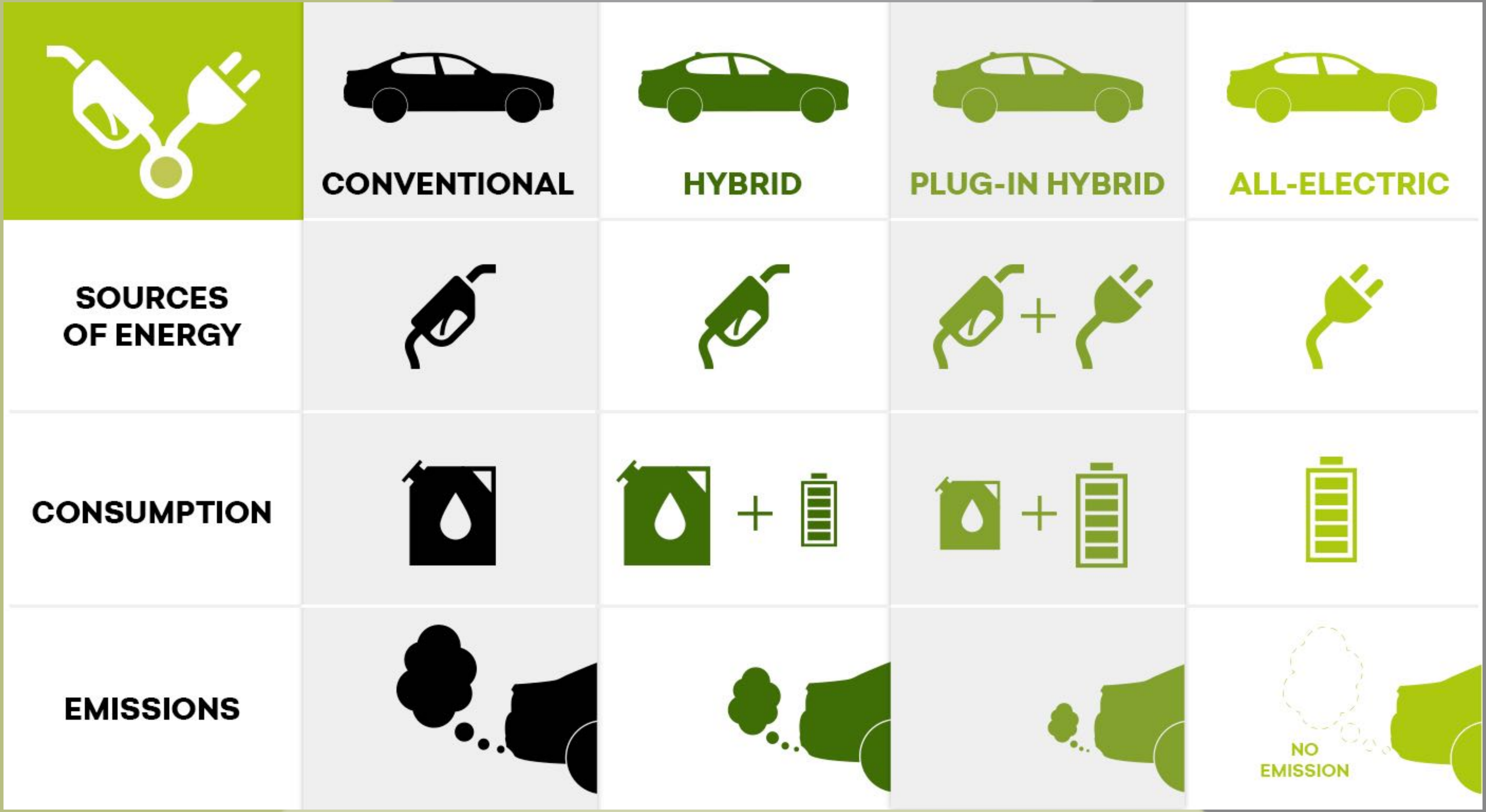
- Basics: Terms, Differences to Internal Combustion Engine Vehicles
- Electricity: Power and Energy
- Charging (How, How Long, When, Where)
- Environmental and Financial Cost Savings (including changes to US EV tax credit)
- Electric Vehicle Models and Market

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 it's environmental impact. For example, hybrids are 100% fossil fuel powered.



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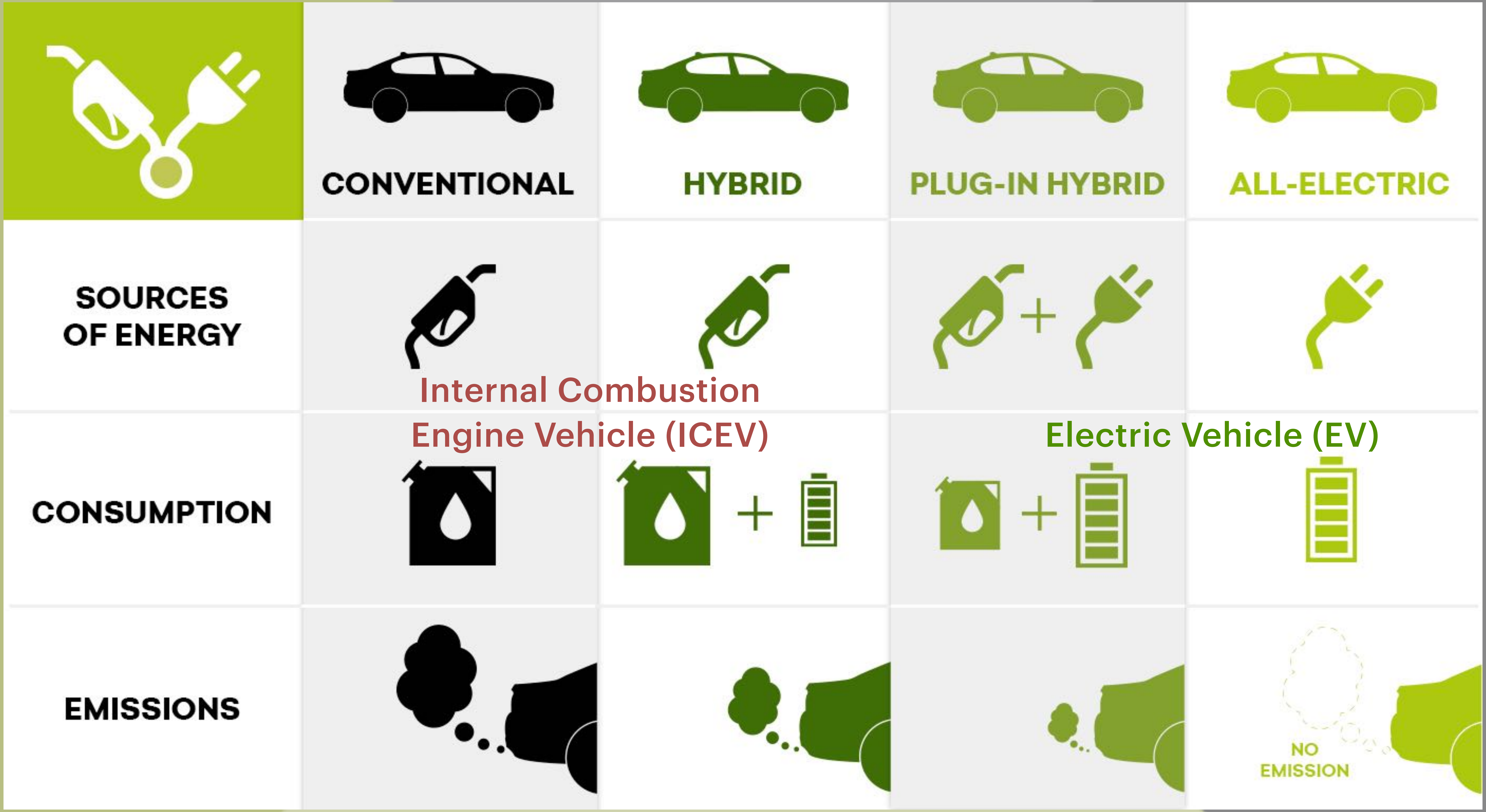

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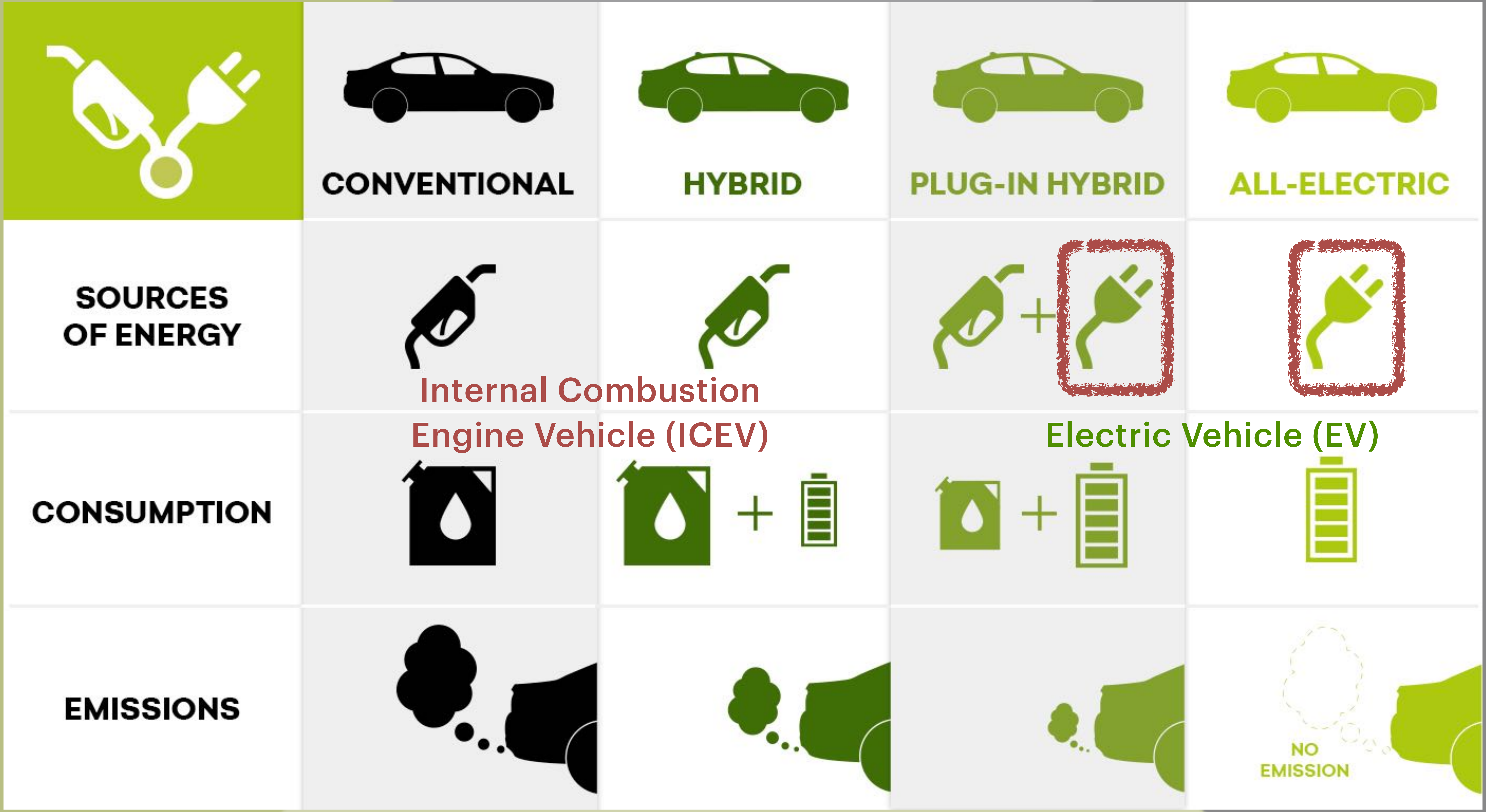

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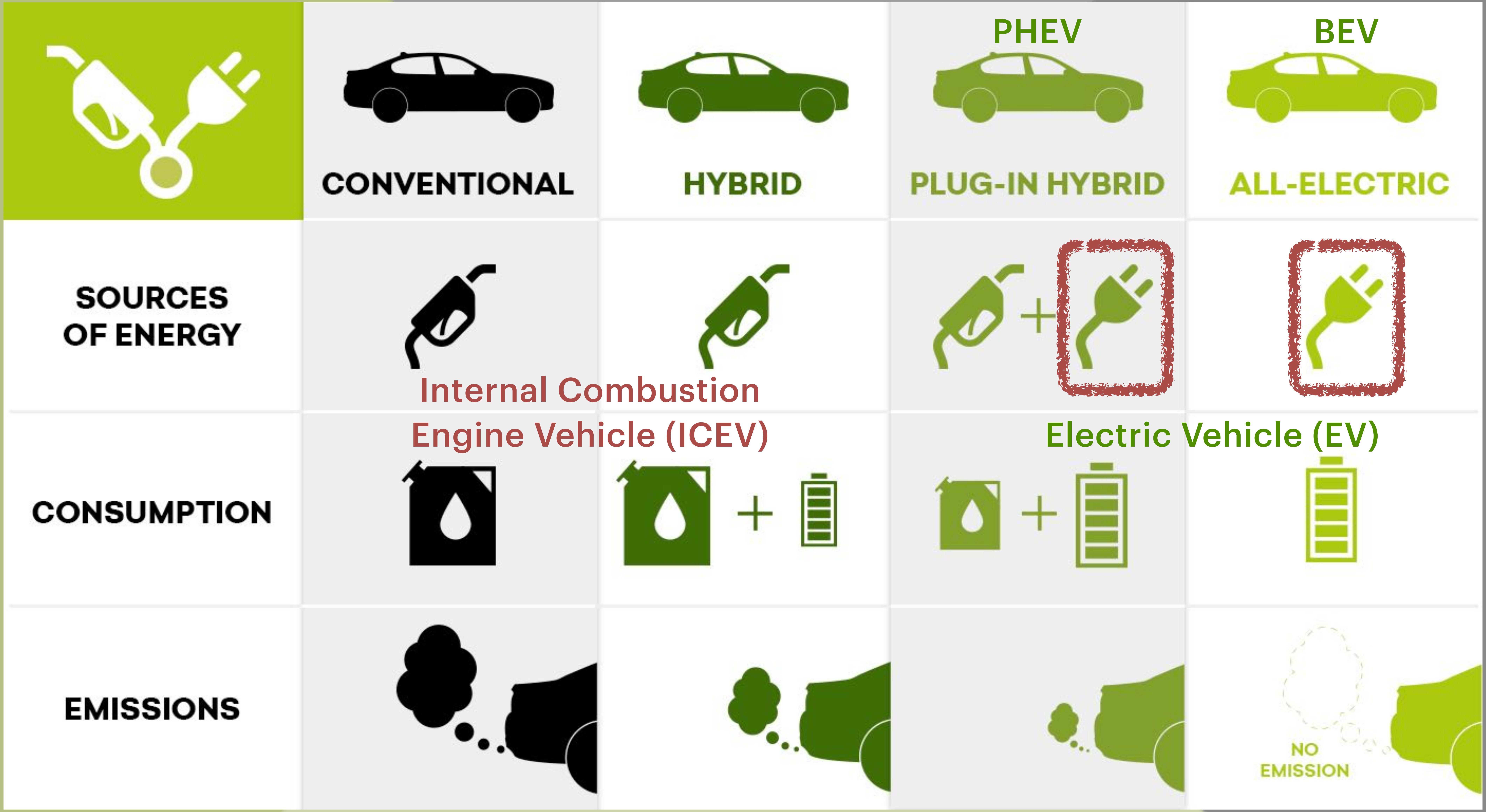
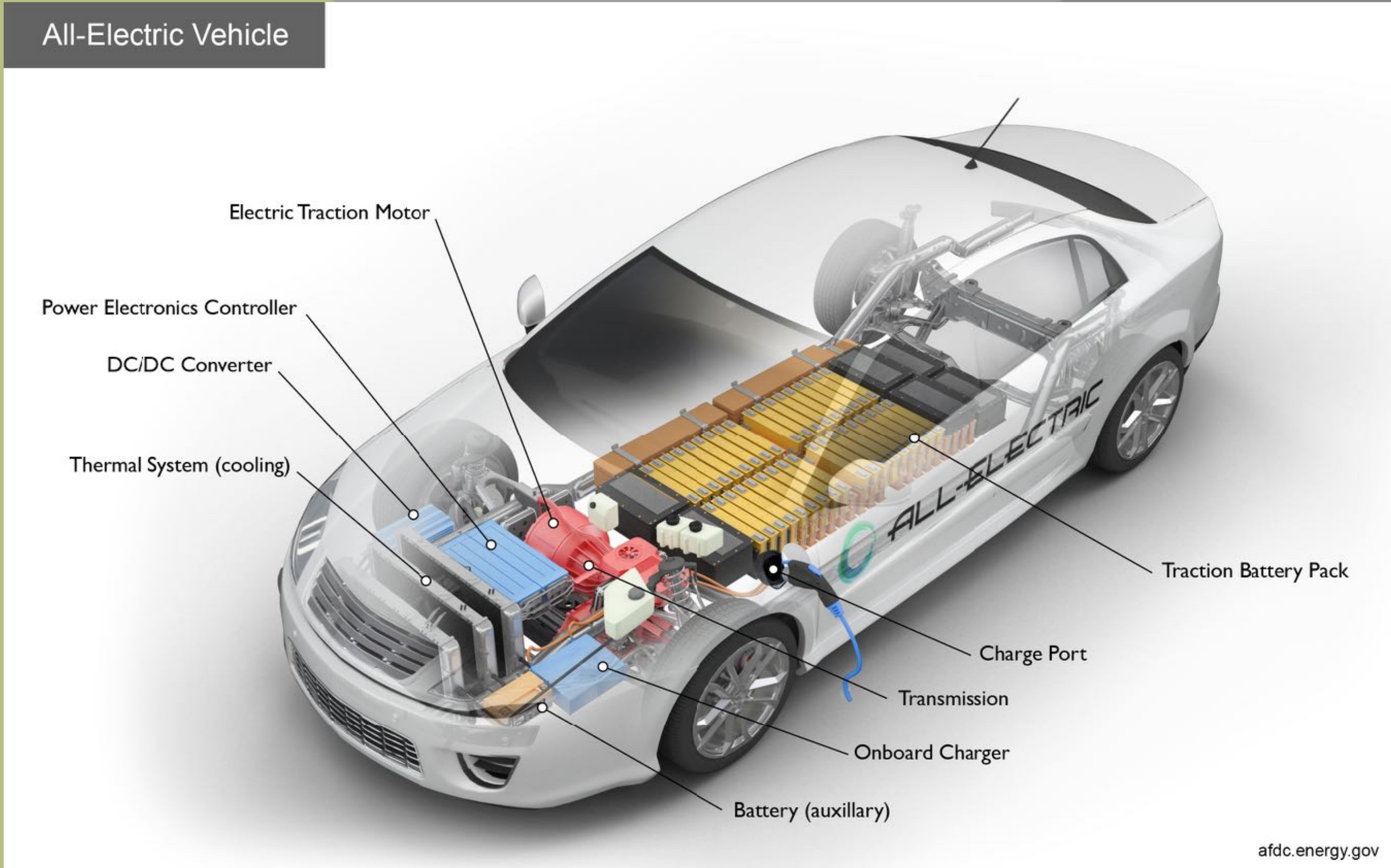


Electric Vehicle Components



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

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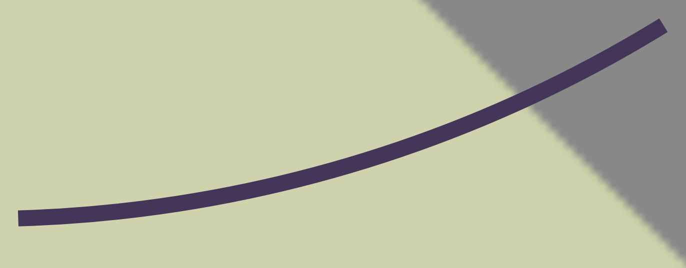
Torque curve		

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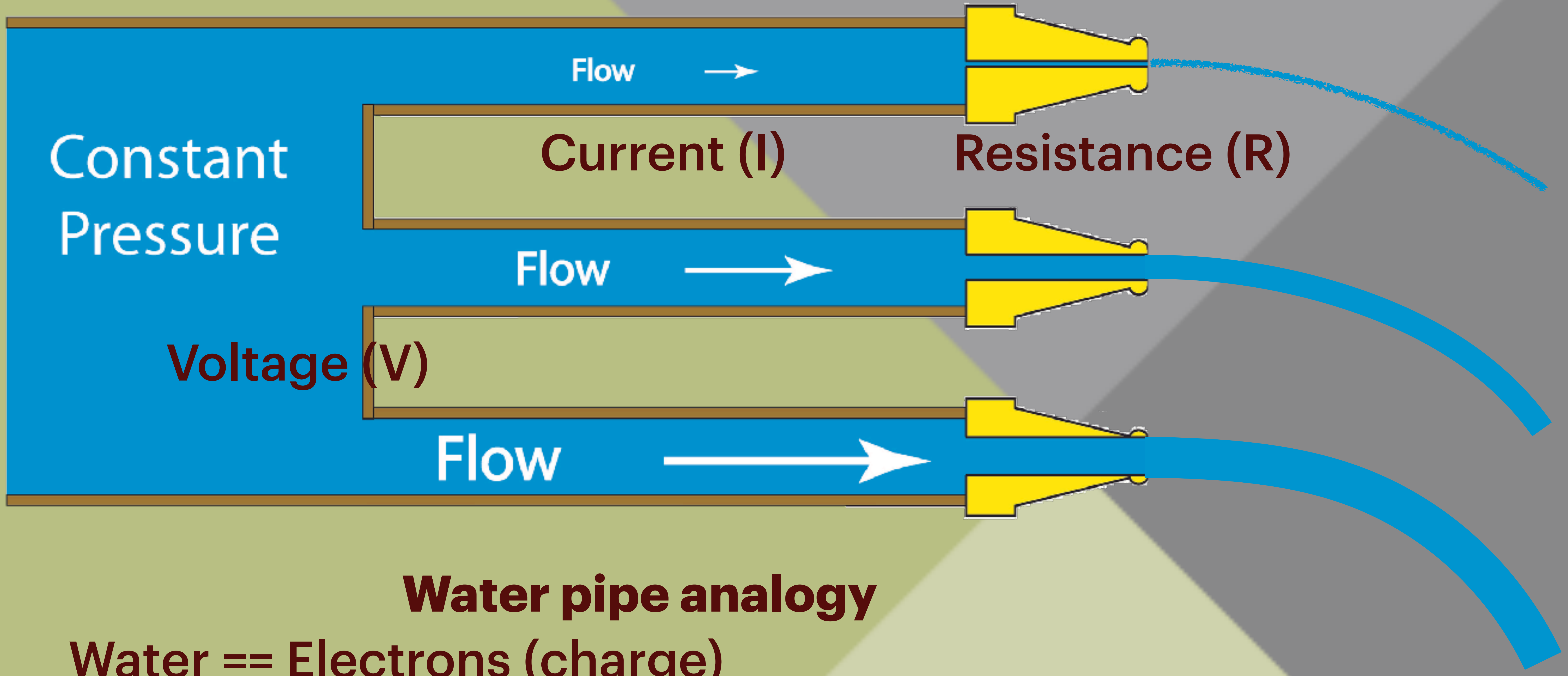
Getting to remote destinations	Plan to have enough fuel	Plan to have enough charge

ELECTRICITY: POWER & ENERGY

Electricity Units — Ohm’s Law

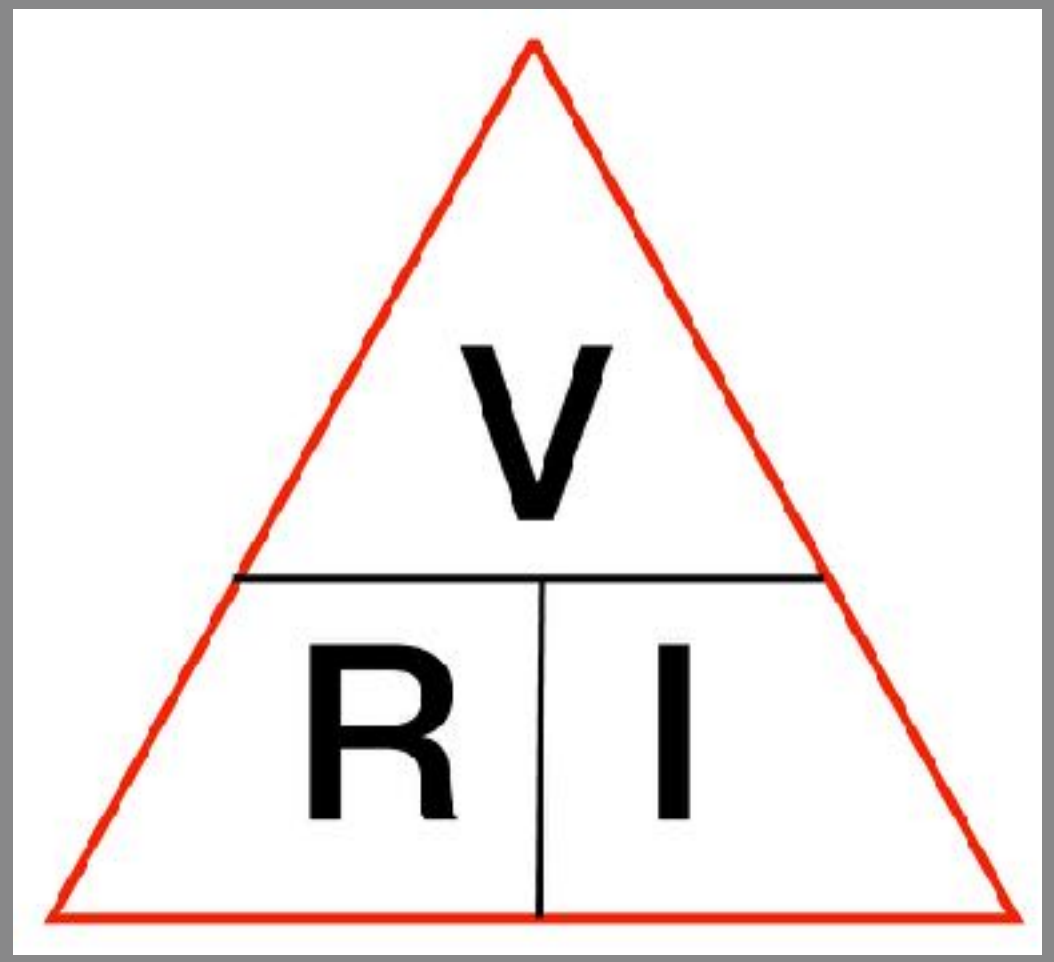


Ohms Law

V = I x R

I = V / R

R = V / I



Water pipe analogy

Water == Electrons (charge)

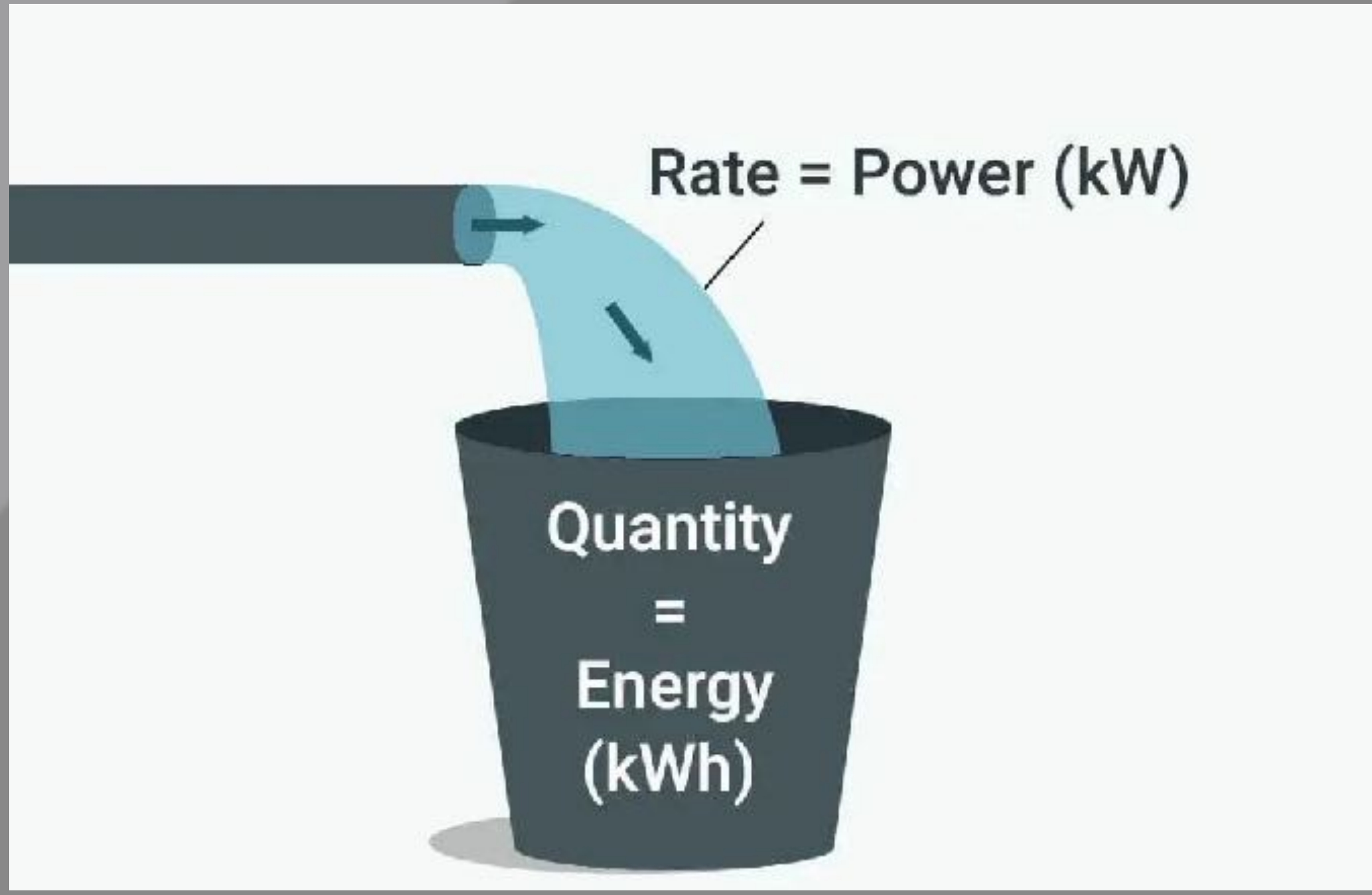
Pressure == Voltage

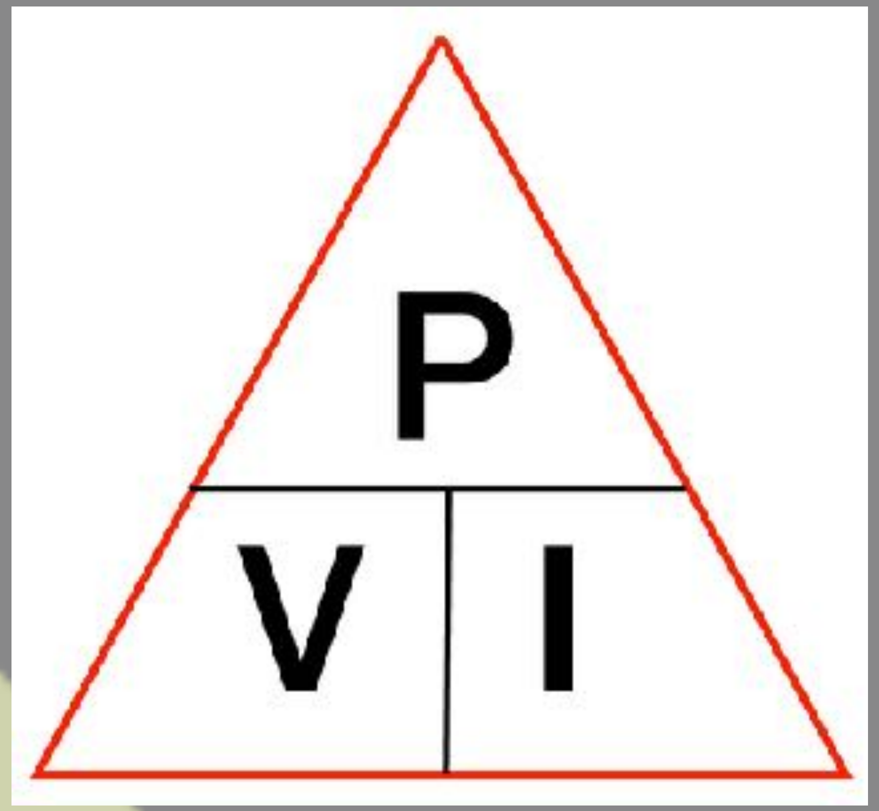
Water Flow == Current == Electron (charge) Flow

Opening size == Resistance

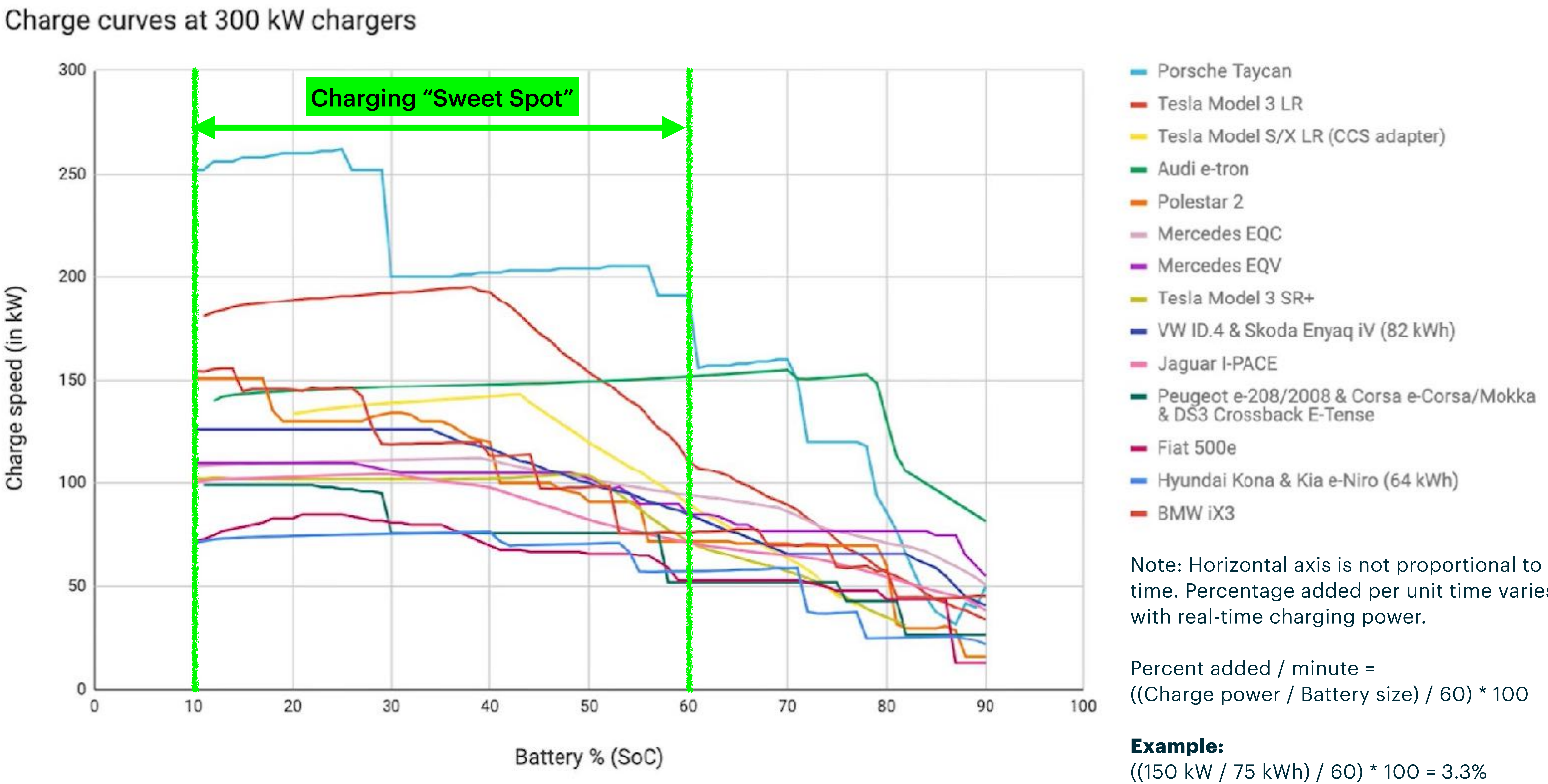
Power and Energy

- Analogy
  - **Power** == Water Flow
  - **Energy** == Amount of Water in Bucket
- Units
  - **Power —** Watts (W) / Kilowatts (1000 Watts)
  - **Energy —** Watt-hours (Wh) / Kilowatt-hours (1000 Wh)
- Formulas
  - **Power** (Watts) = Volts x Amps
  - **Energy** (Watt-hours) = Power x Time
- Examples
  - 240 Volts x 40 Amps = 9,600 Watts (9.6 kW)
  - 9.6 kW x 8 hours = 77 kWh





Electric Vehicle Charging Curves (DCFC)



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

Percent added / minute =
((Charge power / Battery size) / 60) * 100

Example:
((150 kW / 75 kWh) / 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% to maximize battery longevity (plenty for local driving because you start every day with 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**

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

Road Trip Charge Stop

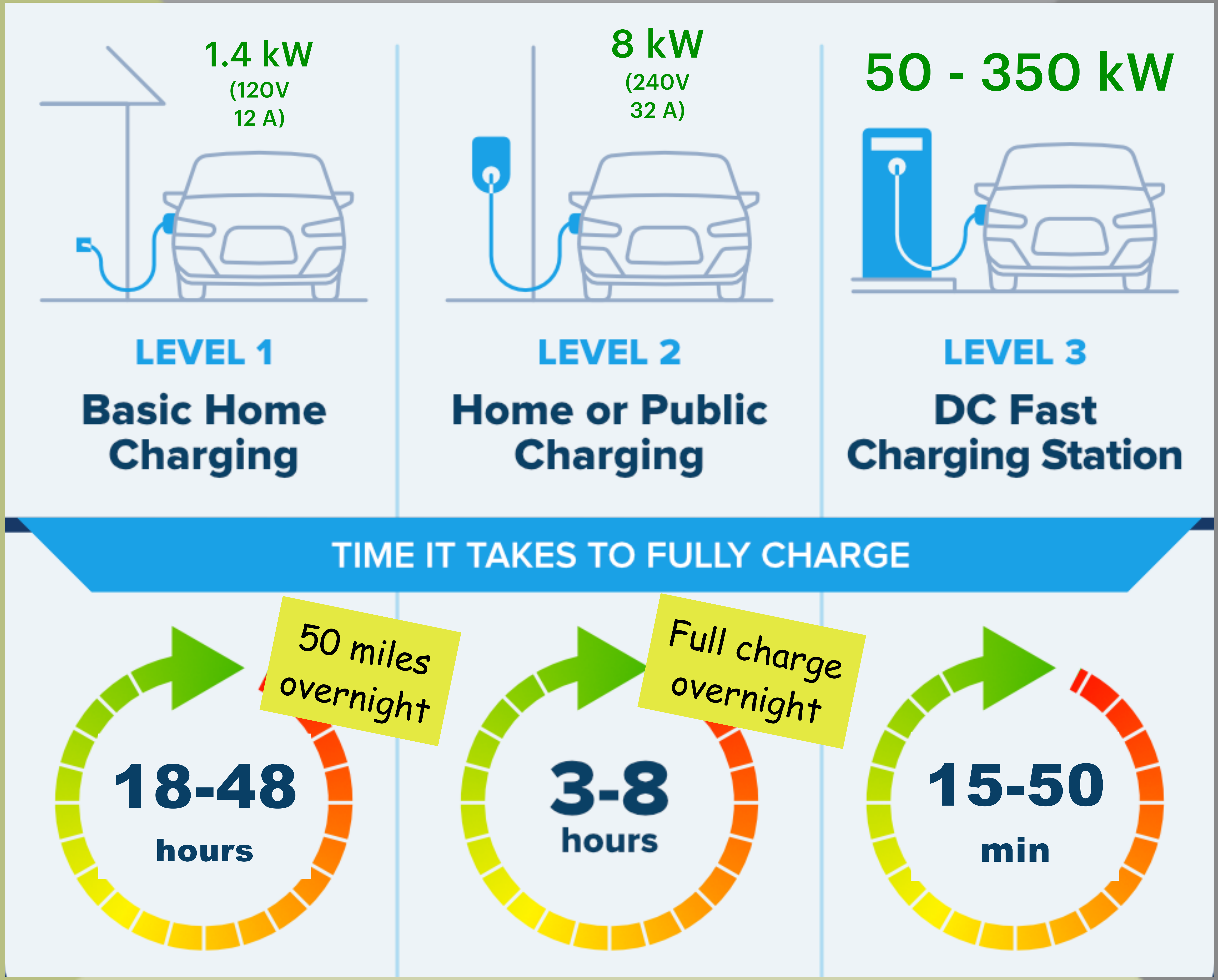
- Charge at DCFC — assume 180 kW max, 110 kW average power
- 75 kWh battery, arrive with 20% SOC (15 kWh)
- Next charger is 120 miles down the road
- Vehicle range at highway speed is 240 miles
- Need to add 50% SOC
- **Time required = ((75 kWh * 0.5) / 110) / 60 = 20.5 minutes**

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**

ELECTRIC VEHICLE CHARGING

There are three levels of Electric Vehicle charging.



There are several types of Electric Vehicle charging equipment.

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		Locations with Magic Dock	✓

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

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Public EVSE
L2 208-240V AC

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Public EVSE
L2 208-240V AC

Public DC Fast Charger
L3 - Main Battery DC Voltage

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SAE Combo CCS	3	✓	With adapter
Tesla supercharger	3	Locations with Magic Dock	✓

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

Sources: https://www.thedrive.com/guides-and-gear/which-cars-nacs-charge-plugs
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RIVIAN

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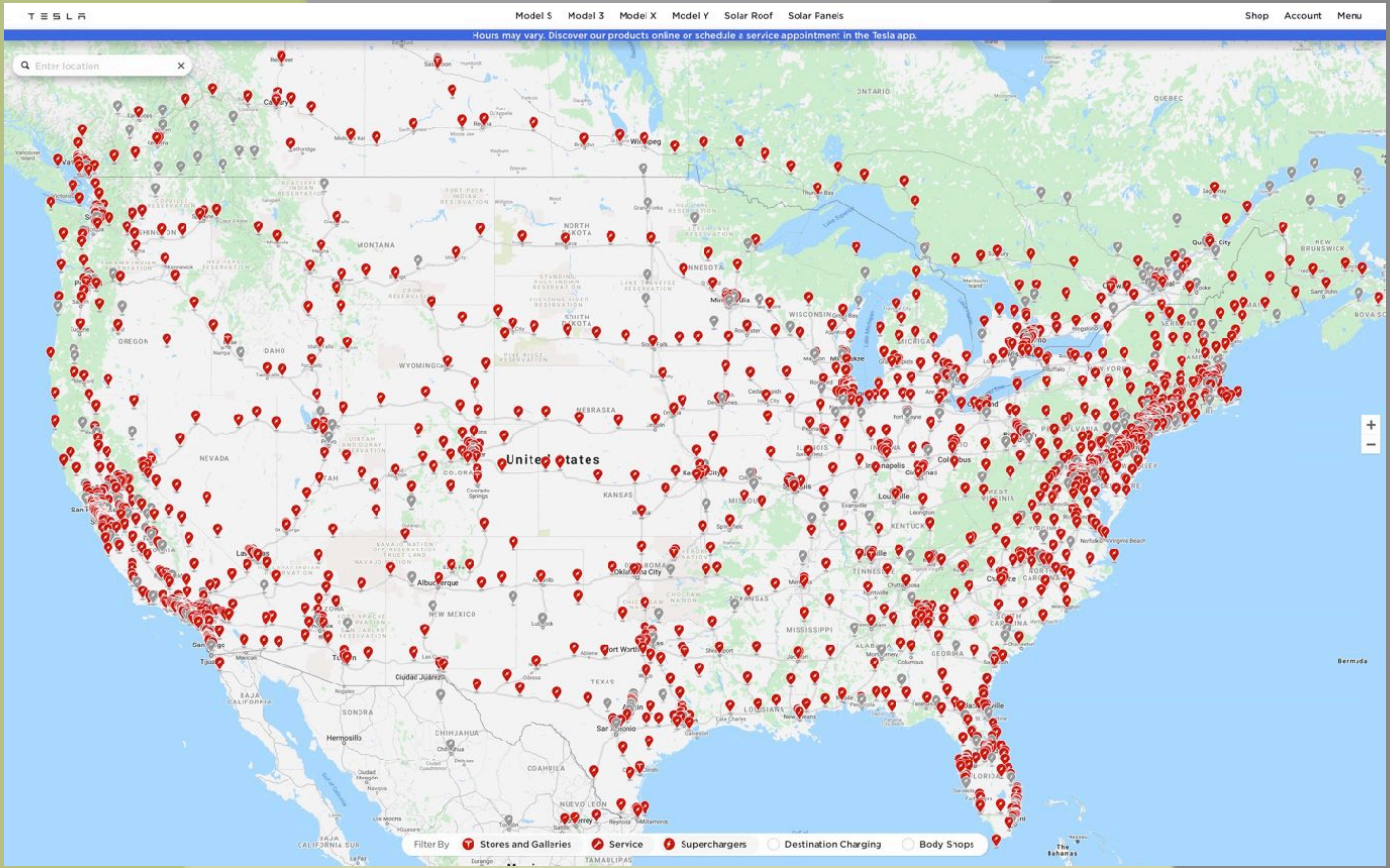
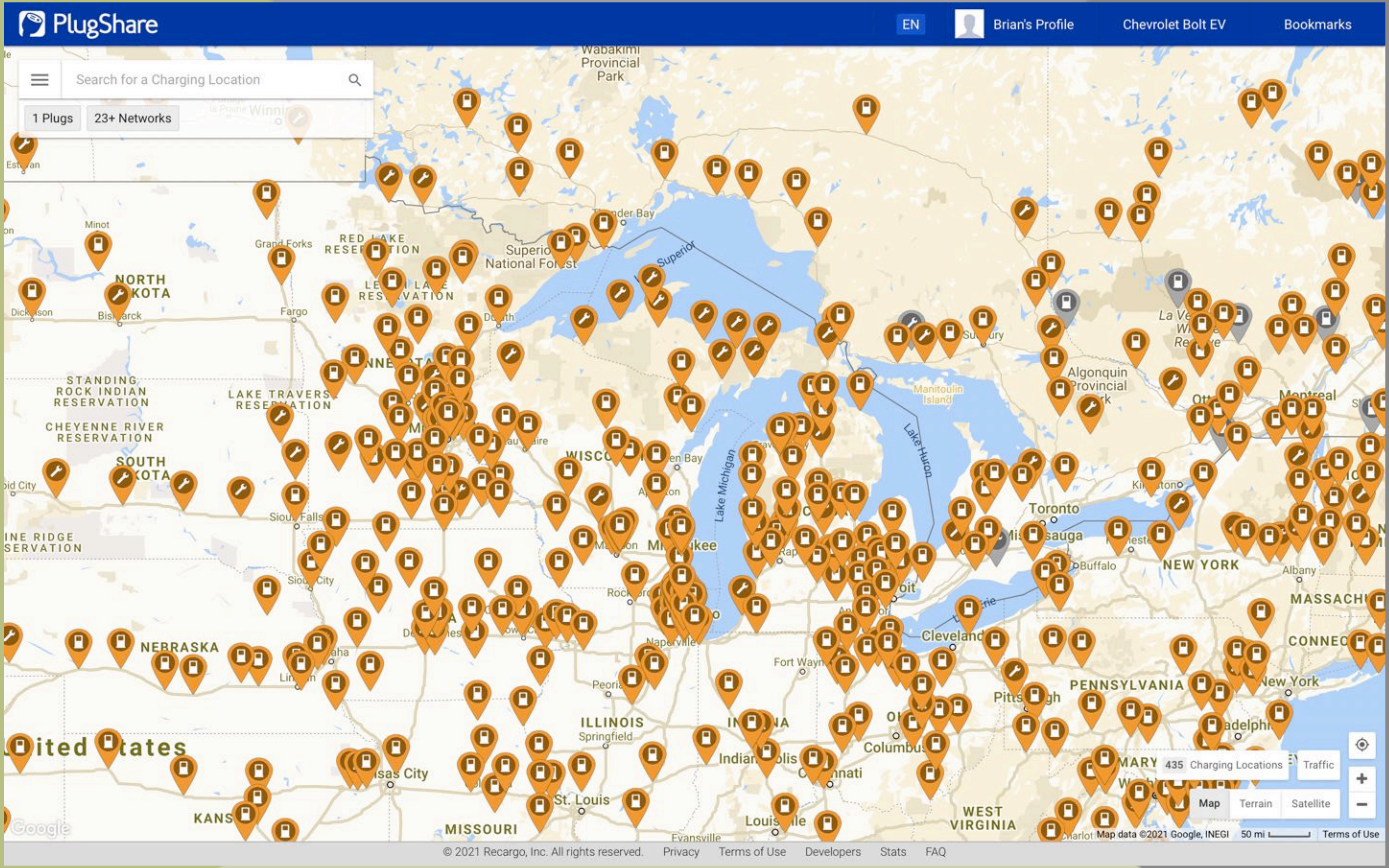
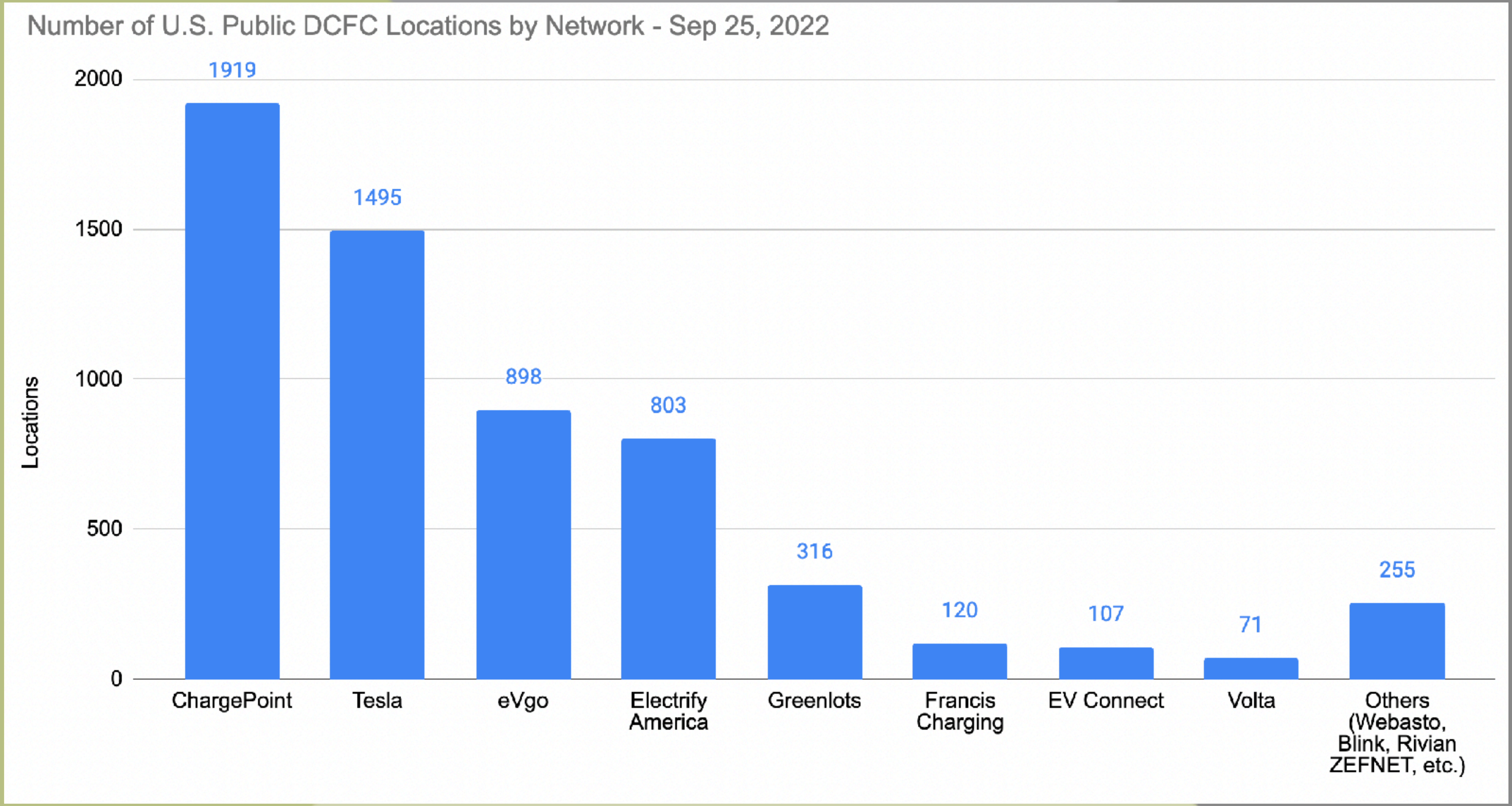
The Tesla charging network provides convenient travel to any location via the in-car navigation and automatic billing for energy.



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.



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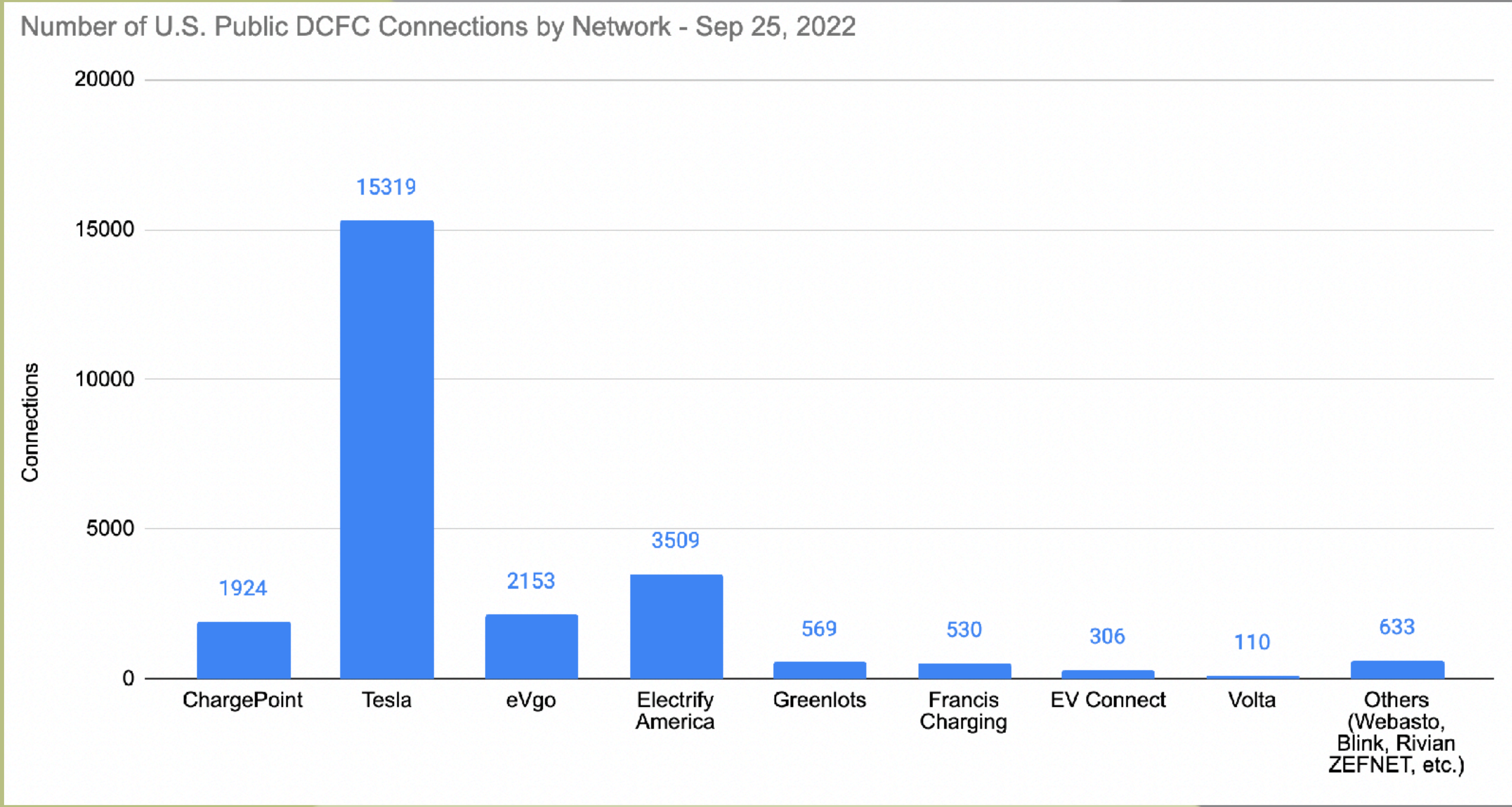

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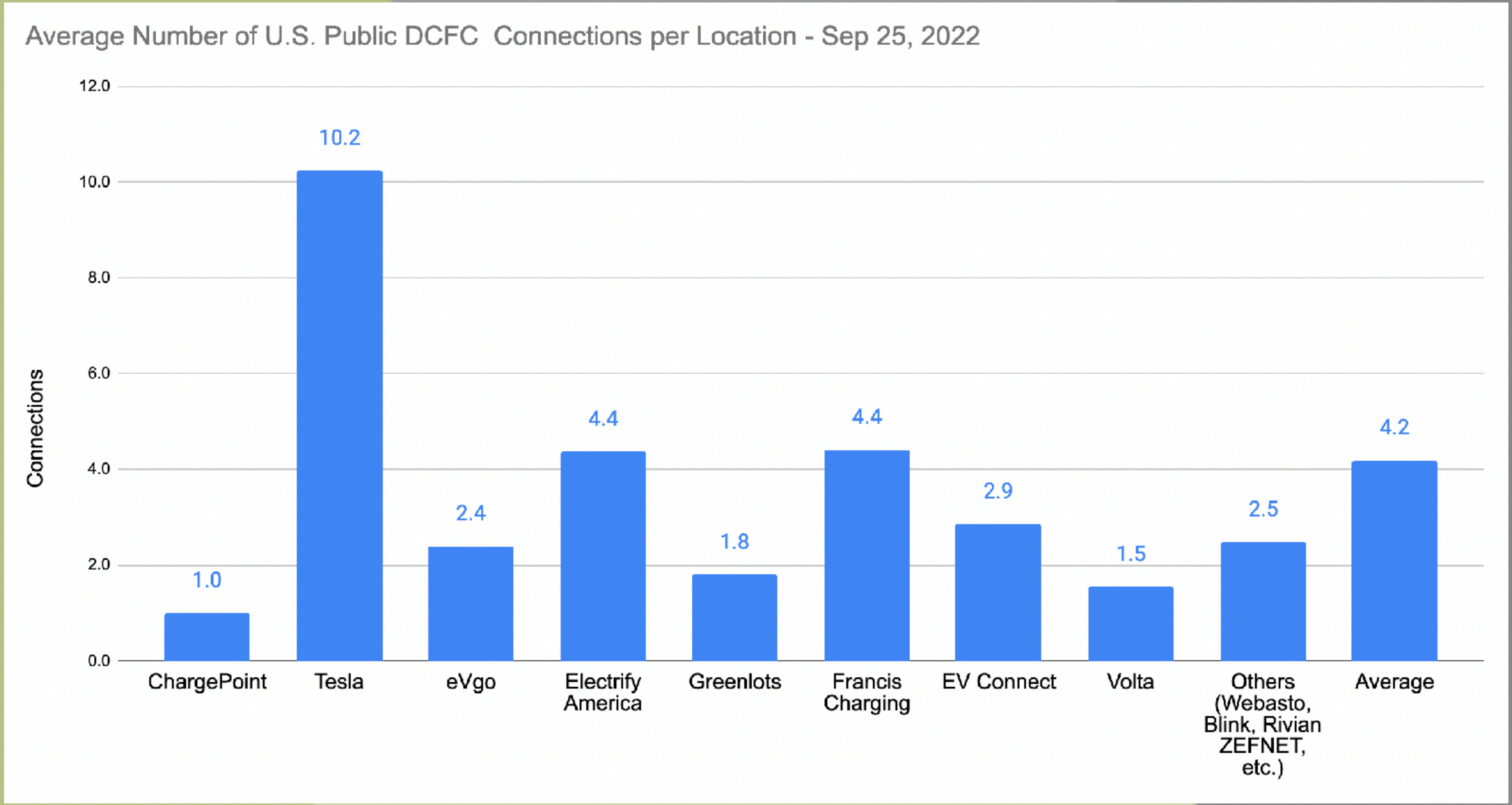

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The number of **public DCFC locations** per Electric Vehicle is **already 4 times** the number of **gas stations** per ICE Vehicle.

	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

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

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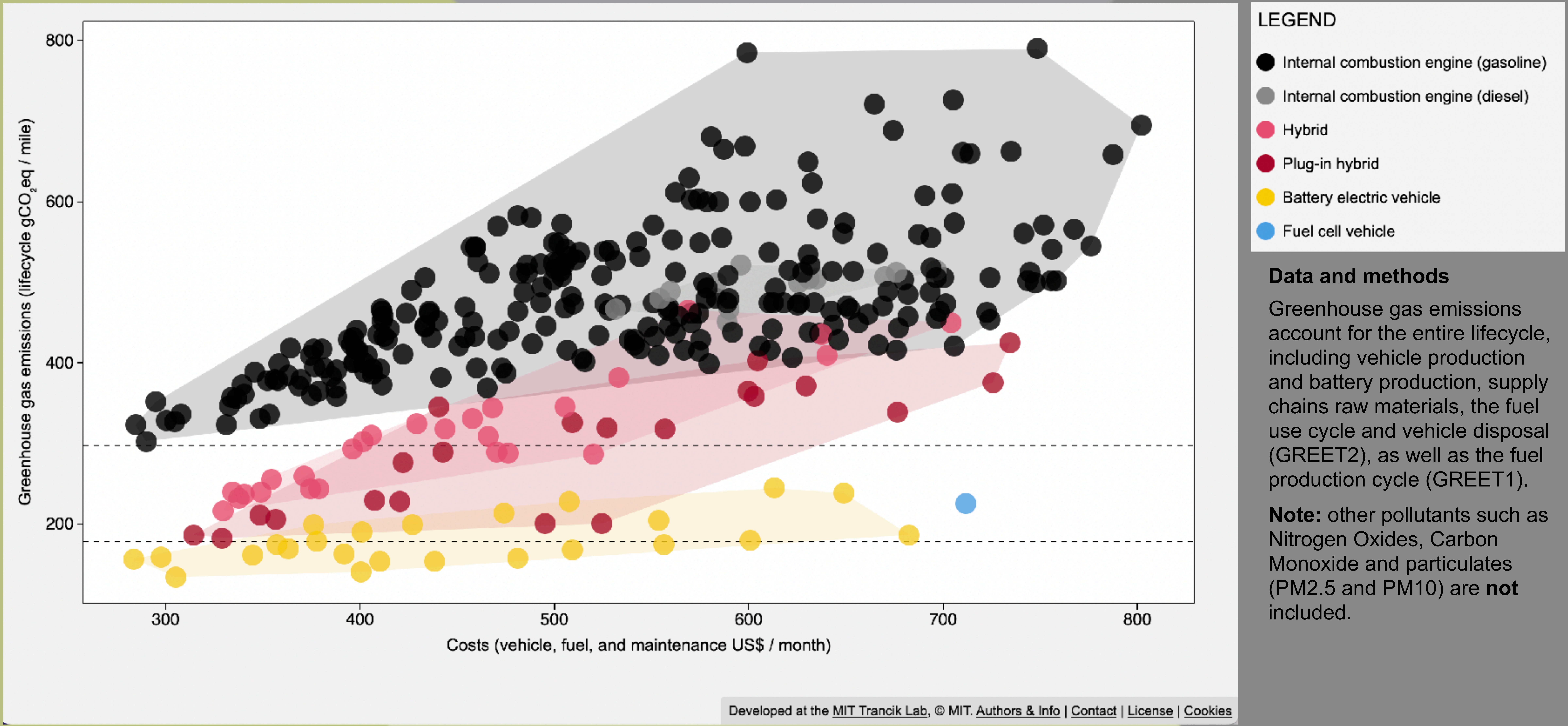
ELECTRIC VEHICLE ENVIRONMENTAL AND FINANCIAL COST SAVINGS

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



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.

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/

Connecticut Winter Round Trip

Two days driving each way plus nine days of local driving	Time (hh:mm)	Energy (kWh)	Miles
Highway Driving	42:31		2,802
Supercharging	9:32	898.3	
Supercharging sessions	27		
Time / SC session	0:21:10		
Supercharging vs. Driving Time	22%		

CT Trip Energy costs (3096 miles)

Total Supercharger Costs	$288.77
Energy cost / mi	**$0.10**
Cost / kWh	$0.32
Equivalent gallons of gas (23 mpg)	134.6
Cost of gas (premium) @ $4.13/gal	$556.01
Equivalent gas price	$2.14
Cost savings vs. gas	**48%**

ICE vehicle used for comparison: 2020 Volvo XC60 AWD

Inflation Reduction Act (IRA)—EV credit requirements

- Vehicle assembled in North America, effective on passage
- Manufacturer caps in place until Jan 1, 2023 (Tesla and GM)
- 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

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

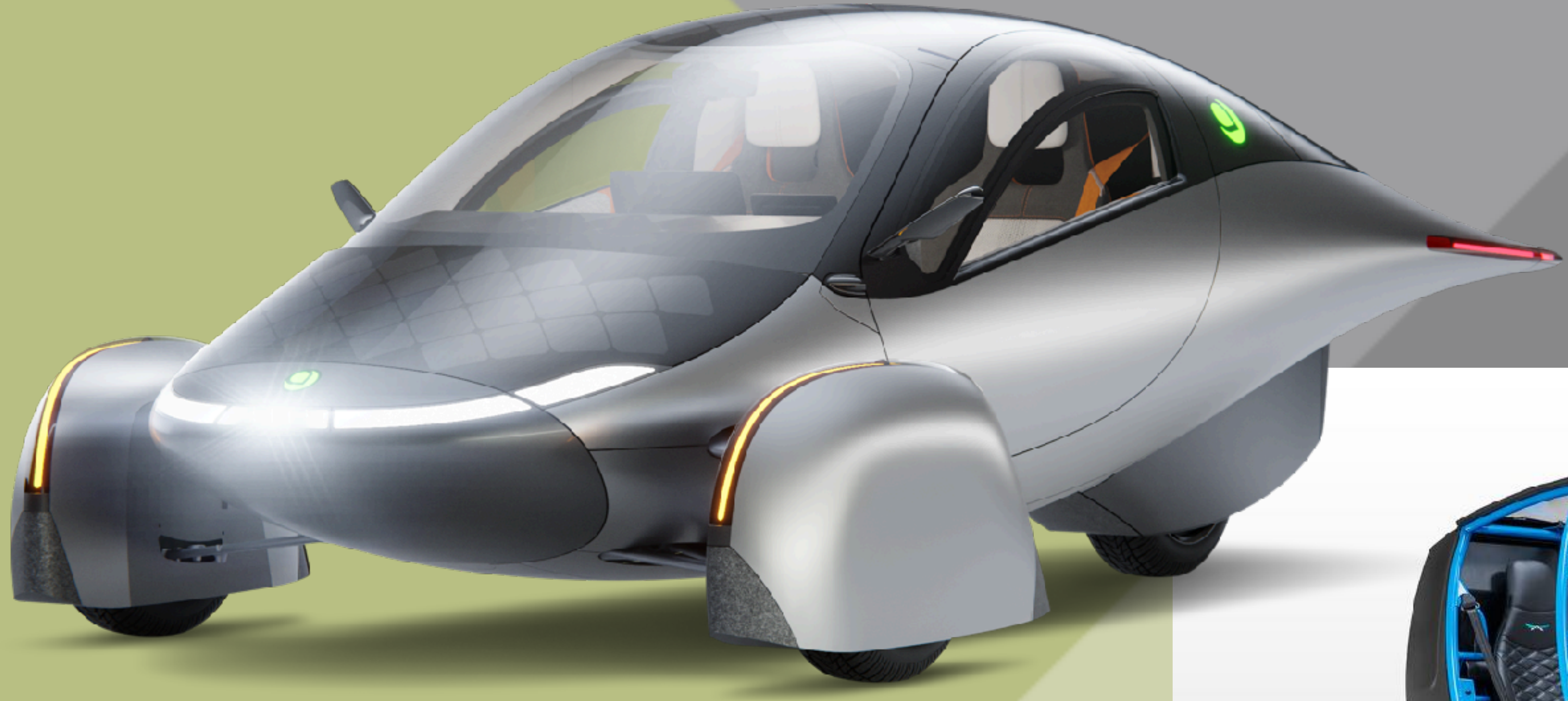
EV MODELS AND AVAILABILITY

Cars

SUVs & Vans!

Trucks!!

Autocycles!!!



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

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American Lung Association. Clean Air Choice. | MINNESOTA CLEAN CITIES

Manufacturer							Federal tax credit	Price after federal tax credit	Battery size (kWh)	Range		Charging rates (kW) L2/DCFC	Charging speed (miles/hr)			Performance				
Make	Model	Photo	Seating	EV Type	FWD/ RWD/ AWD	Base MSRP				Electric Range (miles)	Total Range (miles)		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	WD/ AW	$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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