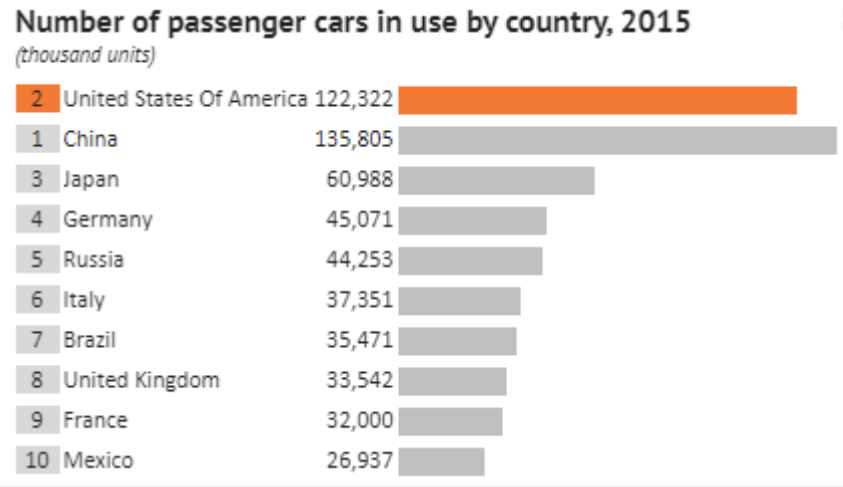
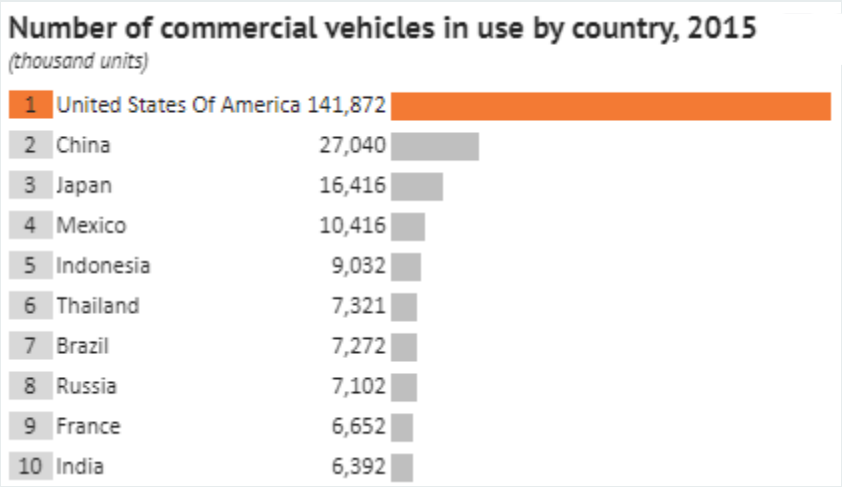
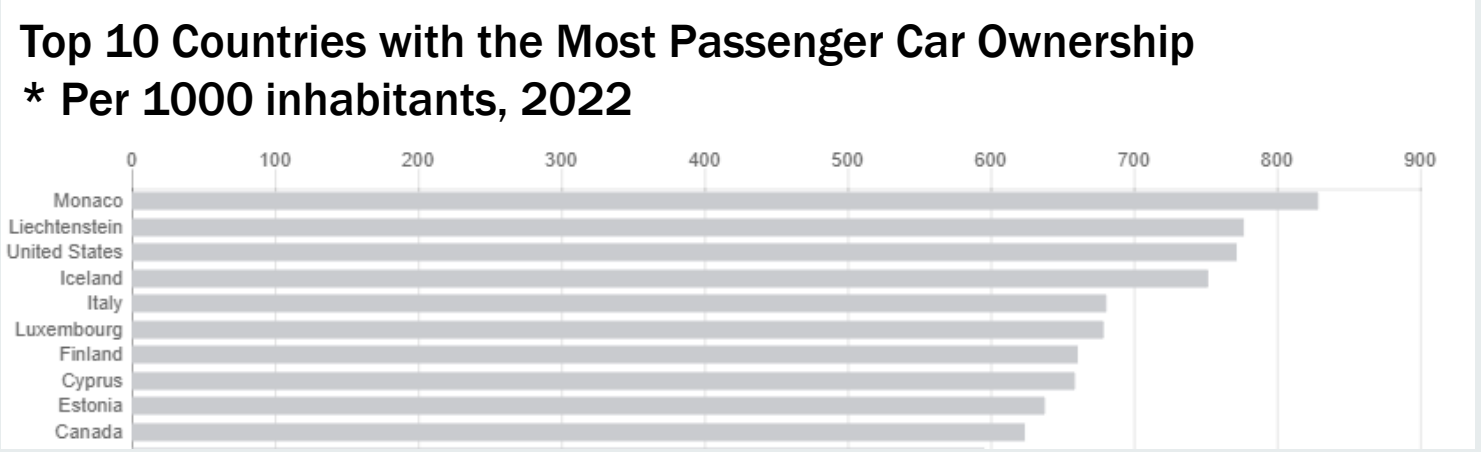
CARS & BATTERIES

HOW MANY CARS?





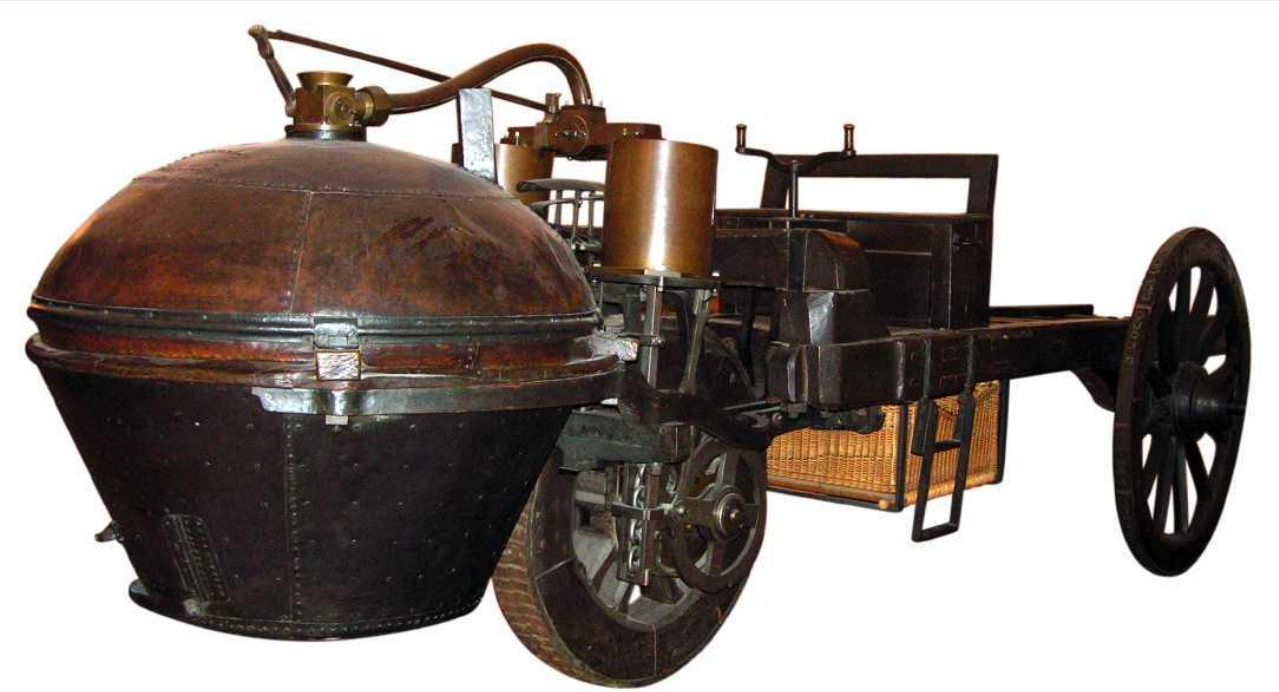


https://knoema.com/infographics/gfwhcg/the-world-s-top-car-owning-countries

https://w3.unece.org/PXWeb/en/CountryRanking?IndicatorCode=44

THE FIRST AUTOMOBILE ?

- 1769: The first self-propelled vehicle was built
  - Nicolas Cugnot, a French military engineer, developed a steam powered road-vehicle for the French army.
  - Used to haul heavy cannons.
  - Reportedly reached walking speed and carried four tons.



STEAM-POWERED TAXIS

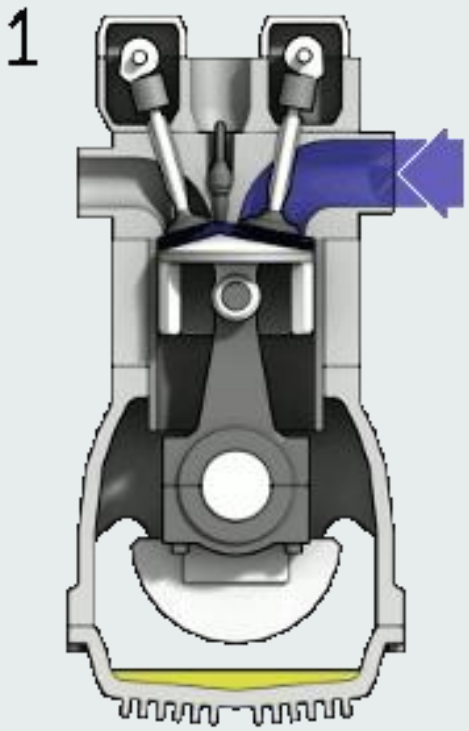
- **1801: Britain's steam carriages**
  - Richard Trevithick improved the design of steam engines, making them smaller and lighter with stronger boilers generating more power.

- Powered by coal, used to heat a 180 liter water tank.
- Range of about 15 km (9.3 mi).
- Could carry 8 people. Used as taxis.
- Not a commercial success.
- Expensive to construct.

  "Required two men and a bag of coal to do what a horse drawn vehicle could do with one man and a bag of hay."

4 STROKE ENGINE

- **1876: Nikolau August Otto Developed 4-Stroke engine**



- **Down Stroke 1:** Bulb opens as piston goes down allowing for the intake air/fuel
- Intake valve closes
- **Upstroke 1:** Piston compress air/fuel mixture
- **Down Stroke 2:** Called the "Power Stroke" the air/fuel mixture is ignited with a spark, the high temperature increases the pressure forcing the piston down
- Exhaust valve opens
- **Upstroke 2:** Piston goes up forcing the exhaust out
- Exhaust valve closes

LEGISLATION VS. INNOVATION

- In Britain, the Locomotive Act of 1865 restricted the speed of horse-less vehicles to 4 mph in open country and 2 mph in towns.
- The act required three drivers for each vehicle (driver, stoker, red flag man walking 60 yards ahead).

1886 BENZ MOTORWAGON

ELECTRIC VEHICLES

Morrison EV

- **1892:** William Morrison of Des Moines, Iowa, designs America's first electric car.
  - 4 horsepower motor
  - 24-cell battery, which weighed 768 lbs (half the vehicle's weight).
  - Capable of reaching speeds of up to 14 mph.

- 1896: First Road Traffic Death
  - Bridget Driscoll, a 44-year old mother of two from Croydon, stepped off a curb and was hit by a passing motor car near Crystal Palace in London. She died from head injuries.
  - The driver, Arthur Edsell, was doing just 4 mph at the time.
  - The coroner, returning a verdict of accidental death.

    "I trust that this sort of nonsense will never happen again."

THE COMPETITION BEGINS

- 1800s: horses were major part of supply chain.
  - Trains for long distance transport, horses for local transport
- 7 million horses in the US in 1860, over 25 million in 1900.

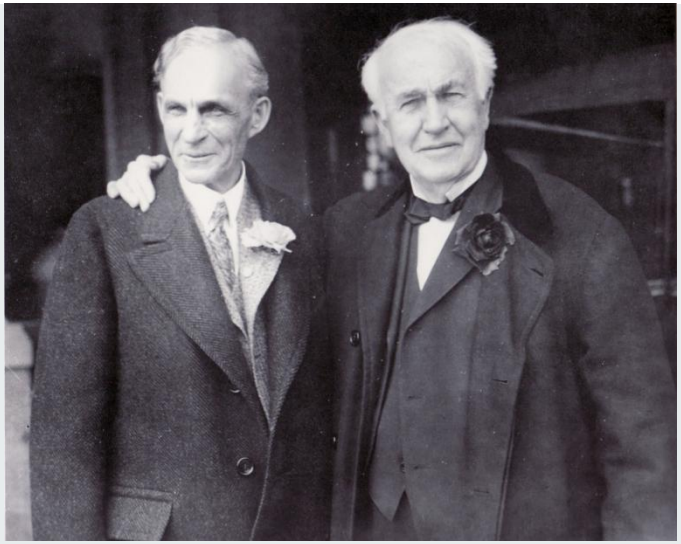
- In 1900, horse density in major urban centers was 426 horses per square mile.
  - Stables on almost every block.
- Over 15,000 horse carcasses per year in city streets.
- Between 800,000 and 1.3 million pounds of manure each day in New York City.

COMPETING TECHNOLOGIES

- **1900:** The automobile market is equally divided between the three contenders of steam, gasoline, and electricity.
  - In the USA, of all the cars manufactured, 1,684 are steam-driven, 1,575 are electric, and 963 are gasoline engines.

Type	Steam	Electric	Gas
~ Year Invented	1769	1842	1886
Pros	• Only needed water and something to burn usually coal. • Quiet • Relatively clean	• Electricity in many houses • Easy to drive • Clean, quiet, and vibration free • No fumes	• Could go long distances • Easy to refill on the road.
Cons	• Needed time to warm up (~30 min) • Have to add water often • Produce lots of heat	• Marketed towards women • In town driving only • Took a while to charge	• Hard to get started (starter) • Dirty • Noisy

EDISON AND FORD



- Henry Ford worked for Thomas Edison before starting his own company. Edison encouraged Ford to pursue the gas engine.
- **1908:** Henry Ford introduces the gasoline-powered Model T Ford at a price of $850 (~$20,000 in today's terms).
  - Its 10-gallon tank gives it a range of between 125-200 miles.
- **1909:** Edison introduces new and improved nickel-flake battery
  - Extends EV range to as much as 100 miles between charges, can be recharged in half the time and lasts up to ten times longer than lead-acid alternatives.
  - Cannot withstand heavy use, requires diligent maintenance.
  - Badly affected by cold weather
  - Very large, and its cost more than tripled that of typical lead-acid batteries.

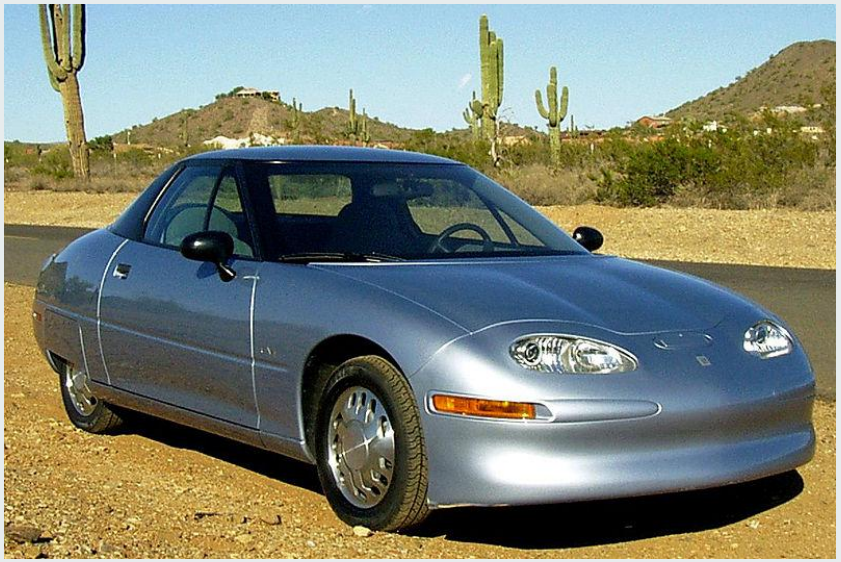
THE BEGINNING OF THE END FOR ELECTRIC (AND STEAM)

- **1911:** Key development
  - Working for Cadillac's design and development department, Charles Kettering invented the electric ignition and starter motor. Cars could now start themselves.
  - Kettering later introduced independent suspension, and four-wheel brakes.
  - ** By 1930, most of the technology used in automobiles today had already been invented.

- **1912:** Sales of electric vehicles peak
- **1915:** Price of the Model T Ford drops to $440 (~$9,000 in today's terms), and in 12 months over 500,000 are sold.
- Price of an electric car remains over $1,000.
- **1920s:** Gasoline-powered vehicles' victory over electric vehicles becomes evident. Production of electric cars come to end.

COME BACK OF ELECTRIC CAR?

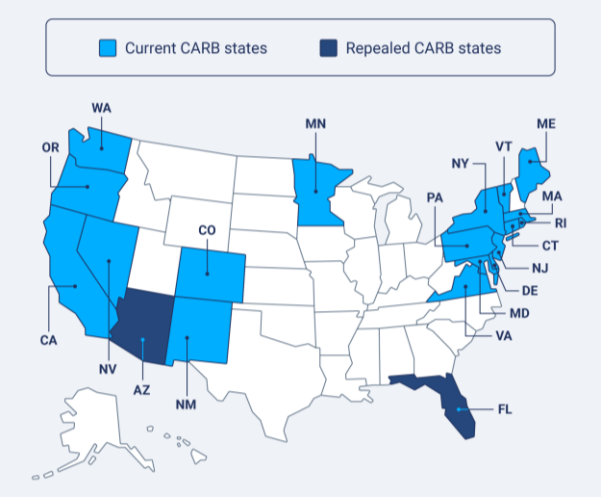
- **1996:** GM started leasing is EV 1. The first modern electric car.
- **2003:** GM took back all of the leases EV 1 and destroyed most of them.



EMISSIONS REGULATIONS

- **1965: Emissions regulations in California introduced**
  - Controls on harmful emissions initially introduced in California, the rest of the world soon followed suit.
  - Safety devices also became mandatory – before this, manufacturers only included seat belts as optional extras.

- **1967 California created CARB (California Air Resources Board) which regulates air emissions including car emissions**
  - California system is more complicated and revolves around car companies earning credit for producing zero emissions vehicles and low emissions vehicles



- **1970 United States created EPA (Environmental Protection Agency) which enforces the Clean Air Act**
  - 1975: The Corporate Average Fuel Economy (CAFE) standards are enacted.
    - US wide program
    - Requirements on fuel economy (miles per gallon) of passenger cars.
    - First took effect in 1978 – 18 mpg.

CA ZEV SALES

ANNUAL SALES

Sales in 2024

443,374

BEV	PHEV	FCEV
378,910	63,864	600

ANNUAL SALES

Sales in 2023

441,283

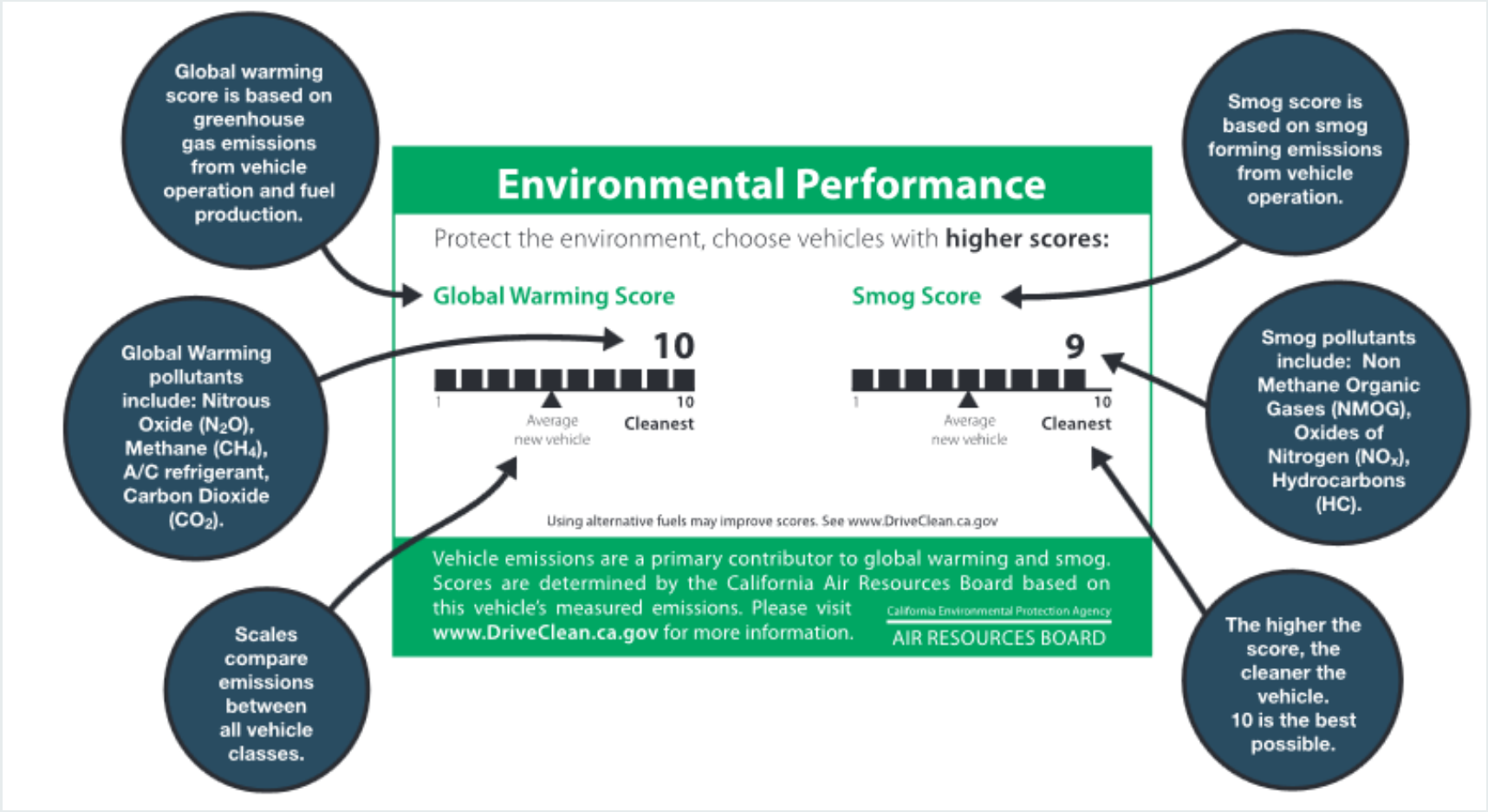
BEV	PHEV	FCEV
374,668	63,496	3,119

2024 California New Electric Vehicle Sales
(companies selling over 10,000 cars)

Brand	Amount	Percentage of BEV
Tesla	201,167	45%
Hyudai	24,089	5%
BMW	21,702	5%
Mercedes-Benz	19,423	4%
Kia	17,435	4%
Ford	17,202	4%
Jeep	10,935	2%
Chevy	13,955	3%
Toyota	13,068	3%
Audi	12,967	3%
Rivian	12,196	3%

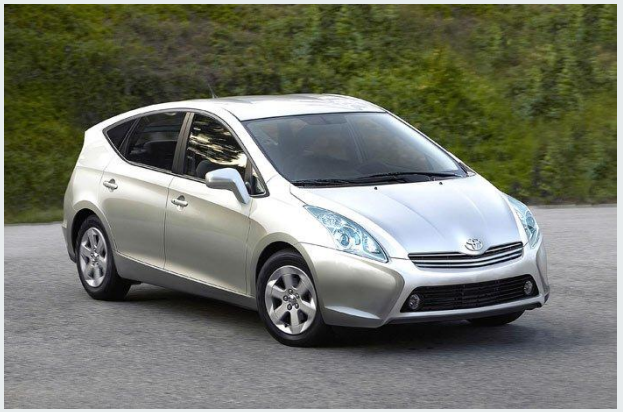
https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics-collection/new-zev

EMISSIONS REGULATIONS



TYPES OF ELECTRIC VEHICLES

- Partial Zero Emission Vehicles (PZEV)
- Hybrid
- Transitional Electric Vehicles or Plug-In Hybrid (TZEV)
- Electric Vehicle (BEV)



ELECTRIC VEHICLES

2024 BMW i5 eDrive40 Sedan (19 inch Wheels) X	2024 BMW 530i Sedan X
Electric Vehicle	Hybrid Vehicle Gasoline
	
Automatic (A1)	2.0 L, 4 cyl, Automatic (S8), Turbo
MSRP: $66,800	**MSRP: $57,900**
Electricity	**Premium Gasoline**
105 MPGe 104 105 combined city highway city/highway 32 kWh/100 mi	**30** MPG 27 35 combined city highway city/highway 3.3 gal/100mi
Electricity 295 miles Total Range	Gasoline 477 miles Total Range

APTERA

- Calsbad CA, company focused on making the most efficient “car” on the market
- Three wheel, two seater car, top speed 101 mph, 0-60 mph is 4 s.
- All electric car with build in solar panels.
- Crowd funded. The first cars will be sold to the people that gave the most money.
- Most likely will start selling in 2025? (50,000 orders so far)
- Can go up to 400 mi on a charge.
- On a sunny day can generate enough electricity to run the car 40 mi.
- For more information https://www.youtube.com/watch?v=TsYyJJFYRvc

ELECTRIC VEHICLES

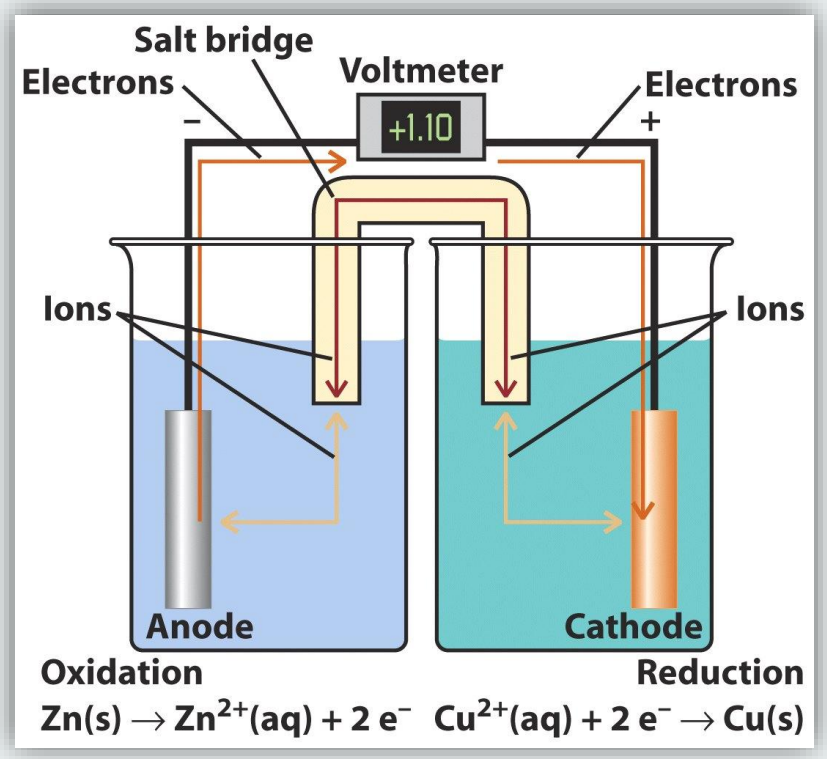
- Advantages of Electric Cars

- Disadvantages of Electric Cars

HOW BATTERIES WORK

- **Batteries:** A stored source of chemical energy that can produce e^-.
- Batteries contain two types of chemical materials that react and in the process produce e^-.
- Redox Reaction (Reduction/Oxidation reaction): A reaction in which electrons are transferred.

GALVANIC CELL



- Electrode: Metal contacts.
- Electrolyte: Ionically conducting medium.
- Salt Bridge: Allows for the flow of ions but prohibits reactions from taking place.
- Anode: Is where oxidation occurs. (e^- leave from)
- Cathode: Is where reduction occurs. (e^- go to)

VOLTAGE

- What do you think effects the voltage of a battery?

- Battery Equation:

VOLTAGE

Standard Reaction Potentials at 298 K	
Half -Reaction	E°(V)
$F_2 + 2e^- \rightarrow 2F^-$	2.87
$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$	1.68
$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	1.51
$Au^{3+} + 3e^- \rightarrow Au$	1.50
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$	1.33
$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	1.23
$IO_3^- + 6H^+ + 5e^- \rightarrow ½I_2 + 3H_2O$	1.20
$Br_2 + 2e^- \rightarrow 2Br^-$	1.09
$AuCl_4^- + 3e^- \rightarrow Au + 4Cl^-$	0.99
$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$	0.96
$2Hg^{2+} + 2e^- \rightarrow Hg_2^{2+}$	0.91
$Ag^+ + e^- \rightarrow Ag$	0.80
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	0.77
$MnO_4^- + e^- \rightarrow MnO_4^{2-}$	0.56
$I_2 + 2e^- \rightarrow 2I^-$	0.54
$Cu^+ + e^- \rightarrow Cu$	0.52
$Cu^{2+} + 2e^- \rightarrow Cu$	0.34

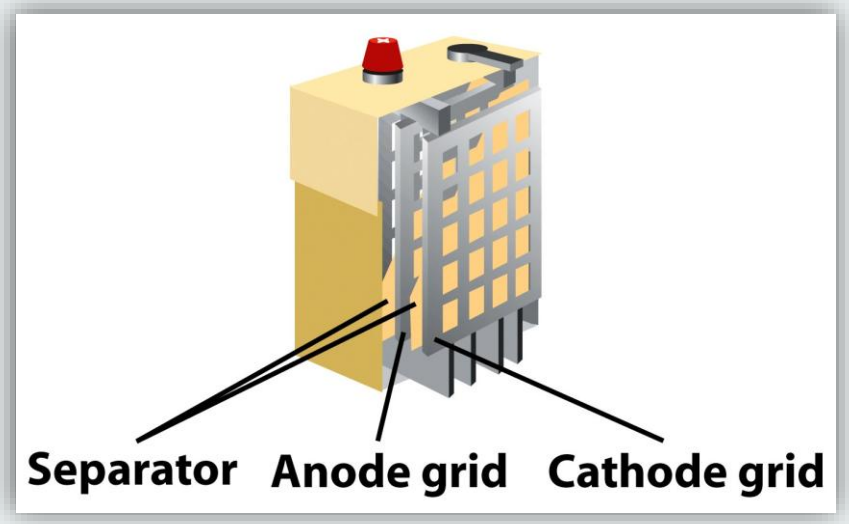
Standard Reaction Potentials at 298 K	
Half –Reaction	E°(V)
$SO_4^{2-} + 4H^+ + 2e^- \rightarrow H_2SO_3 + H_2O$	0.20
$Cu^{2+} + e^- \rightarrow Cu^+$	0.16
$2H^+ + 2e^- \rightarrow H_2$	0.00
$Fe^{3+} + 3e^- \rightarrow Fe$	-0.04
$Pb^{2+} + 2e^- \rightarrow Pb$	-0.13
$Sn^{2+} + 2e \rightarrow Sn$	-0.14
$Ni^{2+} + 2e^- \rightarrow Ni$	-0.23
$PbSO_4 + 2e^- \rightarrow Pb + SO_4^{2-}$	-0.35
$Fe^{2+} + 2e^- \rightarrow Fe$	-0.44
$Cr^{3+} + e^- \rightarrow Cr^{2+}$	-0.50
$Cr^{3+} + e^- \rightarrow Cr$	-0.73
$Zn^{2+} + 2e^- \rightarrow Zn$	-0.76
$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$	-0.83
$Al^{3+} + 3e^- \rightarrow Al$	-1.66
$Mg^{2+} + 2e^- \rightarrow Mg$	-2.37
$Na^+ + e^- \rightarrow Na$	-2.71
$Li^+ + e- \rightarrow Li$	-3.05

TYPES OF BATTERIES USED IN CARS

	Lead Acid	Nickel Metal Hydride	Lithium Ion
Invented	Oldest (1800)	1970	Newest (1980)
Toxic	Most		Least
Expense	Least		Most
Storage capacity (energy per space)	Lowest		Highest
Used in	All cars to run the electrical systems	Toyota Prius Honda Civic Hybrid Ford Escape Hybrid	Tesla Nissan Leaf Honda Fit Rav 4 EV
	Original EV used these batteries	Must be discharged fully to avoid memory problems	*Can be stored for a longer amount of time than the other 2 without loosing its charge *Works best if never fully charged or discharged *Do not work well in extreme temperatures.

BATTERIES

- Lead Acid

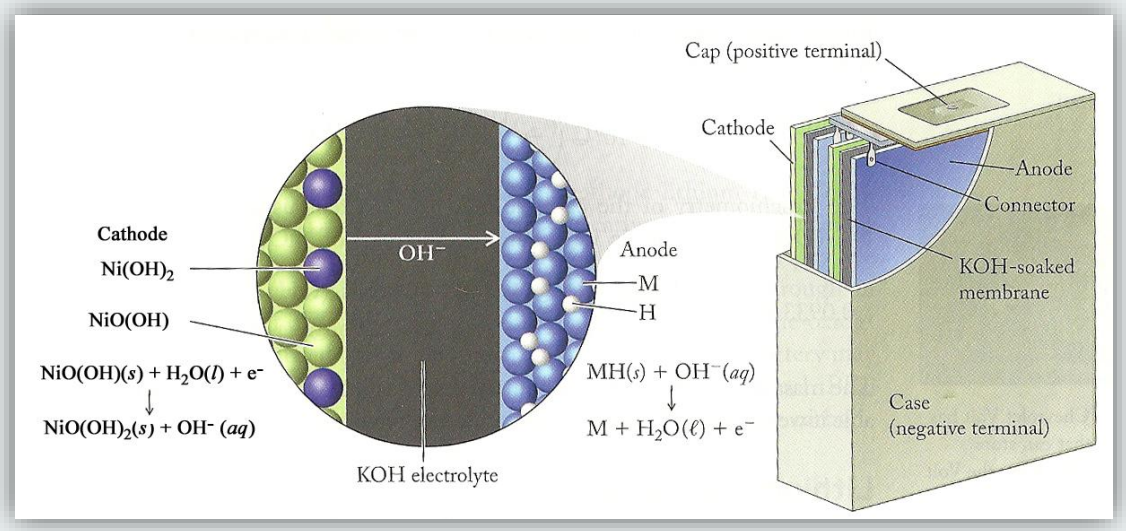


Anode Electrode: *Pb*
Cathode Electrode: *Pb covered with* PbO_2
Electrolyte: H_2SO_4
Voltage : *12 V*

$$\text{(A)}\quad Pb + HSO_4^- \rightarrow PbSO_4 + H^+ + 2e^-$$
$$\text{(C)}\quad PbO_2 + 3H^+ + 2HSO_4^- + 2e^- \rightarrow PbSO_4 + 2H_2O$$
$$Pb + PbO_2 + 2H^+ + 2HSO_4^- \rightarrow 2PbSO_4 + 2H_2O$$

BATTERIES

- Nickel Metal Hydride



Anode Electrode: *MH*
Cathode Electrode: *NiO(OH)*
Electrolyte: KOH
Voltage : *~1.2 V*

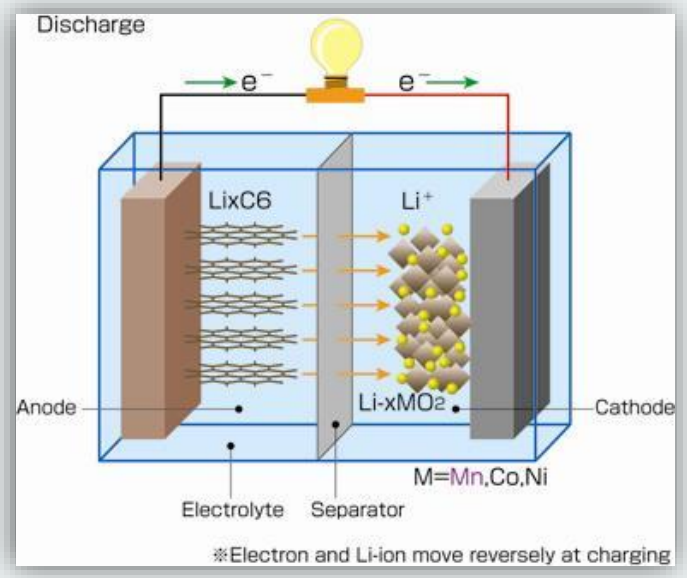
(A) $MH + OH^- \rightarrow M + H_2O + e^-$

(C) $NiO(OH) + H_2O + e^- \rightarrow Ni(OH)_2 + OH^-$

$NiO(OH) + MH \rightarrow M + Ni(OH)_2$

BATTERIES

- Lithium Ion



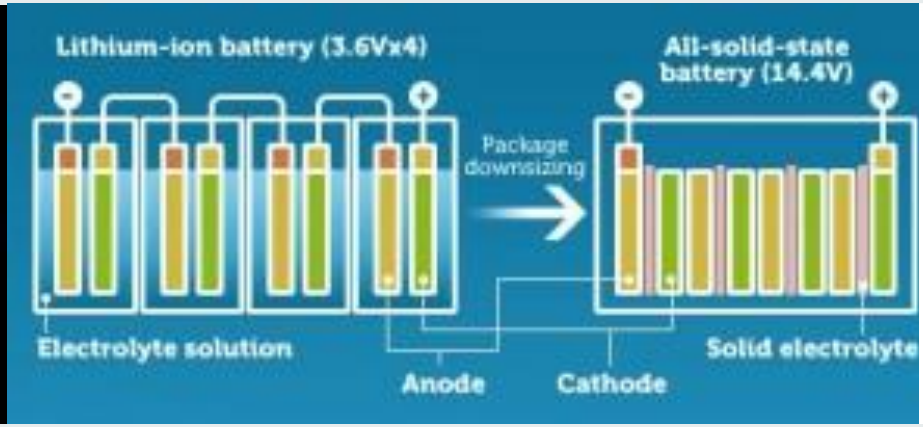
Anode Electrode: Li_xC_6
Cathode Electrode: Li_xMO_2
Electrolyte: Li salt in an organic solvent
Voltage : *3.5-4.5V*

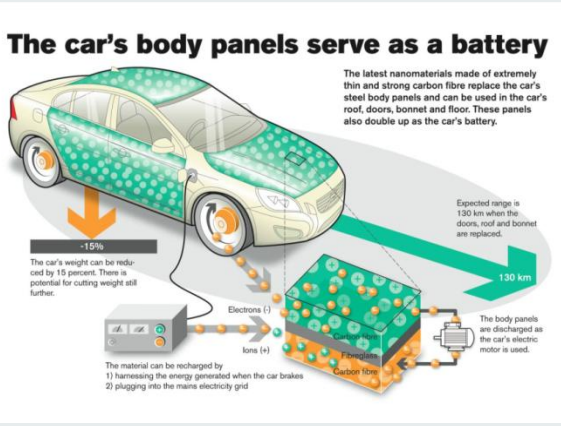
(A) $Li_nC \rightarrow C + nLi^+ + ne^-$
(C) $Li_{1-x}MO_2 + nLi^+ + ne^- \rightarrow LiMO_2$

$$Li_{1-x}MO_2 + Li_{y+n}C \rightarrow Li_yC + LiMO_2$$

BATTERY FUTURE

- Future Batteries
  - Aluminum graphite
  - Improve the Li battery (solid state)
  - Maybe not even a battery
    - Supercapacitors
    - Hydrogen fuel cells





SOLVING THE BATTERY PROBLEM

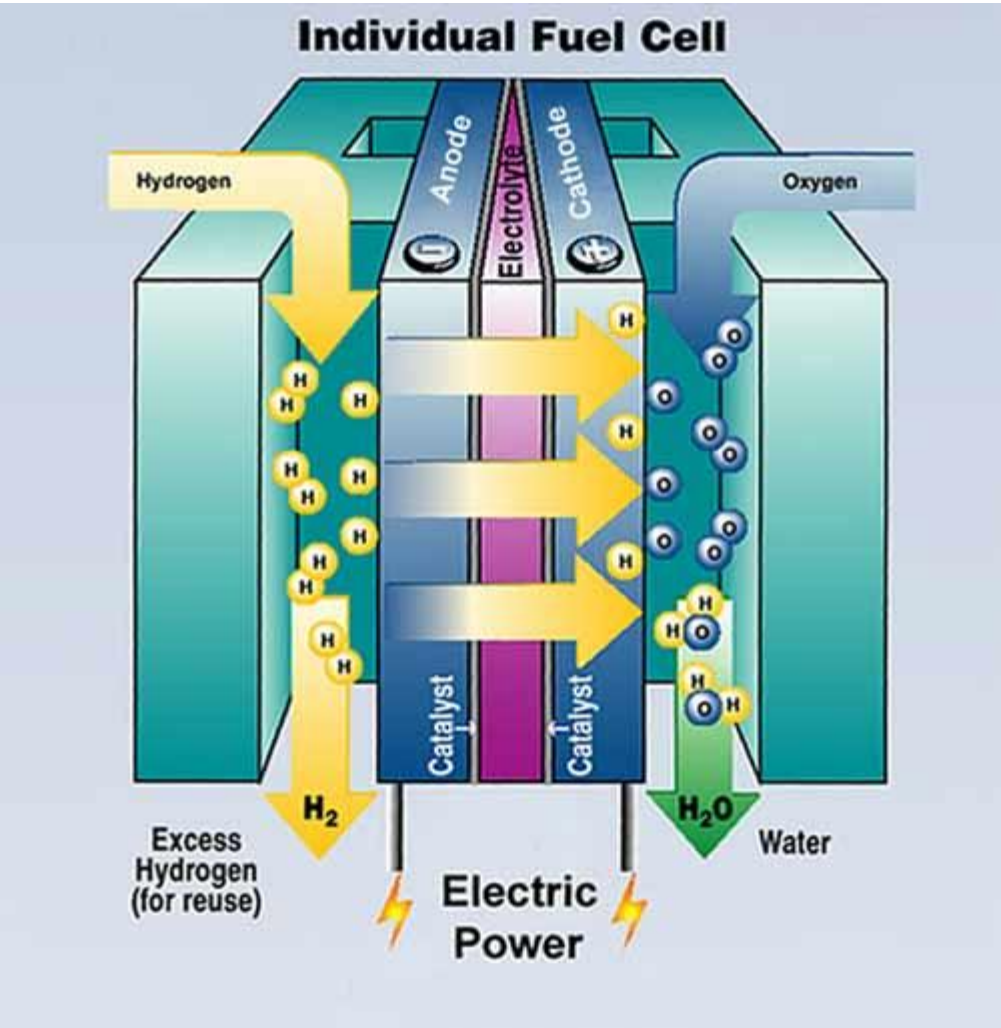
- Challenges with EV
  - Range
  - Charging Time
- What solutions are there?
  - Charge car at night
  - Electric charging stations
  - Battery swap stations
  - Other ideas???

SOLVING THE BATTERY PROBLEM

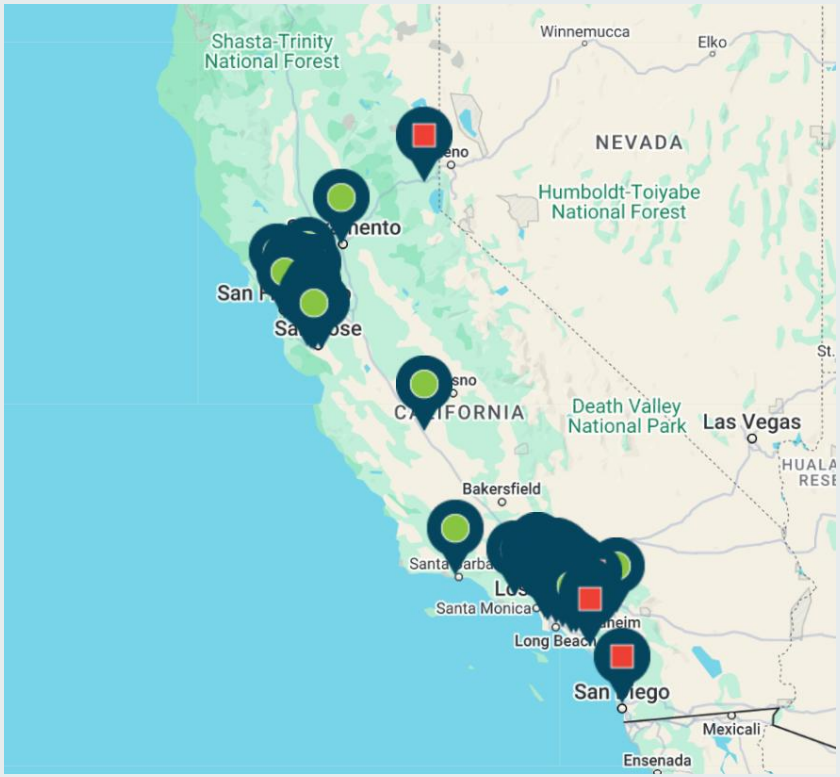
better place

Battery Switch Technology Demonstration

FUEL CELL


Individual Fuel Cell
Hydrogen
Anode
Electrolyte
Cathode
Oxygen
Catalyst
Catalyst
H_2
H_2O
Excess Hydrogen (for reuse)
Water
Electric Power

FUEL CELL



Green Dot= Full Service
Red Square = Off Line

https://cafcp.org/stationmap

WHAT DOES THE FUTURE OF CARS LOOK LIKE?

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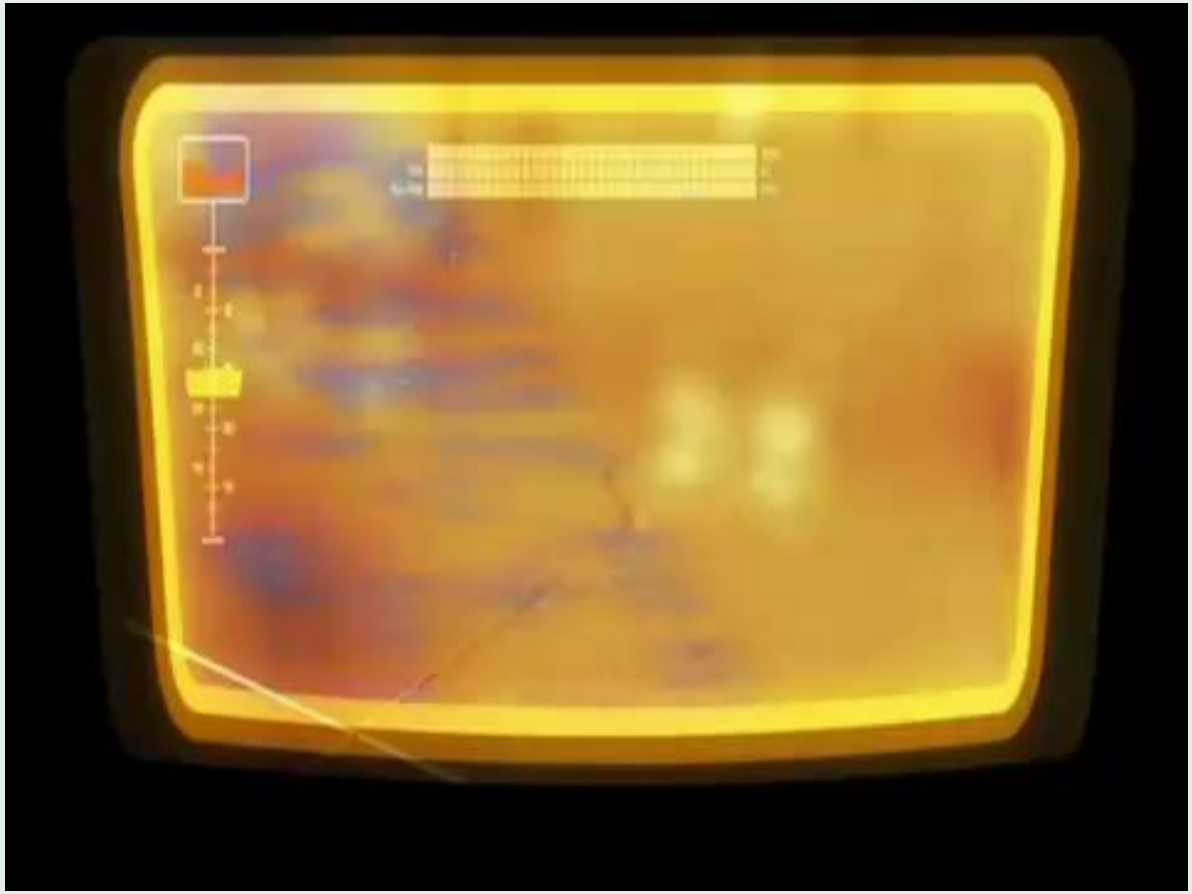
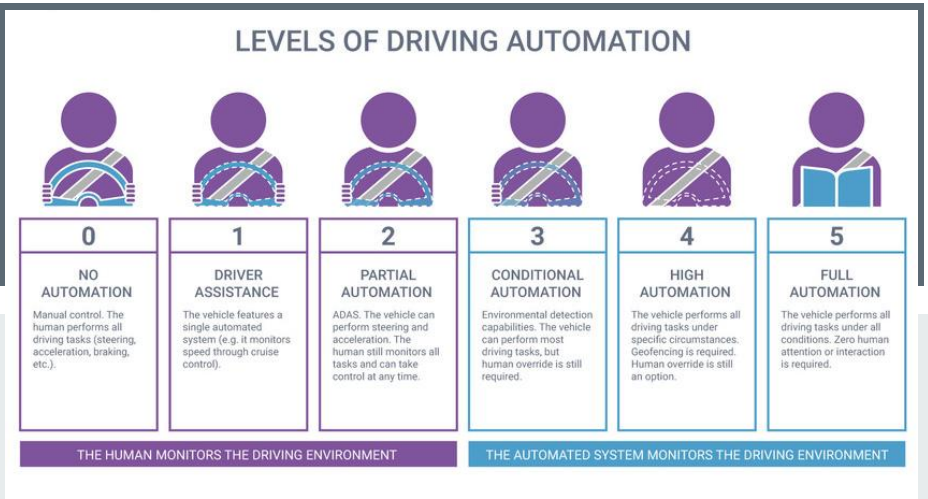


DRIVERLESS CARS

- 1939 World's Fair the Futurama exhibit featured a exhibit by General Motors on the Autonomous Cars
- 1980s a vision-guided vehicles were experimented with in both Europe and the United States (not in traffic)
- 1990s the invention of LIDAR (light radar) and autonomous cars started driving in traffic with some human help.
- 2005 Google developed robotic vehicle
- 2012 Nevada, California, and Florida provides licenses for corporations to drive autonomous cars on their roads
- Many automotive manufacturers such as General Motors, Ford, Mercedes-Benz, Volkswagen, Audi, BMW, Volvo, and Cadillac have begun testing driverless car systems:

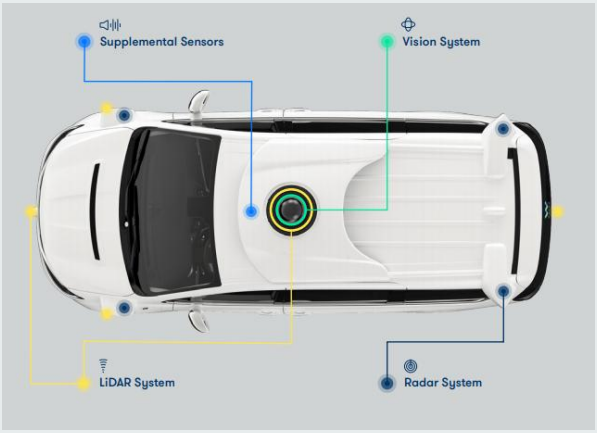
DRIVERLESS CARS



Levels of Self Driving

- Level 0
  - No Driving Automation
- Level 1
  - Driver Assistance
  - Ex: Adaptive cruise control
    - Keeps the car at a fixed distance behind another car but driver has to steer.
- Level 2
  - Partial Driving Automation
    - Vehicles controls both steering and accelerating/decelerating but human must sit in drivers see and can take control any time.
  - Ex: Tesla Autopilot
- Level 3
  - Conditional Driving Automation
    - Have “environmental detection” capabilities (lidar and advance sensor fusion and processing power, built in redundancies should a component fail) and can make informed decision for themselves.
    - No cars sold in the US have this yet. The Audi (Volkswagen) A8L was built with this but because of laws shipped without the key hardware and software to achieve level 3 functionality. However is being sole in Europe.
- Level 4
  - High Driving Automation
    - These vehicles can intervene if things go wrong or there is a system failure. Do not require human interaction in most circumstances.
    - Humans can manual override.
    - Usually have restrictions on restrictions on where the can go and how fast they can go (this is what the rider sharing services are using)
- Level 5
  - Full Driving Automation
    - Cars do not have steering wheels or acceleration/braking pedals.

DRIVERLESS CARS



- Autonomous Car
  - LIDAR (allows car to see 200 m in all directions)
  - Radar
  - GPS
  - Video cameras
  - Position Estimators

DRIVERLESS CARS

FLYING CAR

ELECTRIC VERTICAL TAKE-OFF AND LANDING (EVTOL)

Pivotal (Helix) – Palo Alto

- Can be purchased (2024)
  - $190,000-$260,000
- 1 seater
- 20 mi flying range
- https://pivotal.aero/

Doroni (H1)- Florida

- Accepting Preorders, trying to get out by 2026
  - $350,000
- 2 seater
- Can drive short distances
- 60 mi flying range
- https://doroni.io/

FLYING CAR

Model A (by Alef) - California

- eVTOL
  - Fully electric
- Pod that drivers sit in rotates
- 8 propellers under front and back of car
- Vehicle operates sideways in air
- Will enter production in 2025.
- $300,000

https://alef.aero/

FLYING CAR

Liberty (Pioneer or Sport) (by Pal V) - Netherlands

- Need a pilot license to fly
- Both available for preorder will deliver in 2026?
- Pioneer – Limited Edition only 90 vehicles worldwide ($599,000) will be delivered before the sport model
- Sport – ($5000,000)
- Price includes flying lessons
- Takes manual intervention to switch
  - Can be done in under 5 minutes
- 817 mi road range
- 310 mi flying range

https://www.pal-v.com/en/

FLYING CAR

Switchblade (by Samson Sky) - Oregon

- Need pilot license
- Initial cost = $170,000
- Can convert between car and airplane in 3 minutes
- Will be sold as an Experimental Category aircraft
  - Owner must build 51% of the vehicle.
    - They will spend 1 week at Samson and be guided by staff.
- Will announce its first official flight soon.
- Deliveries of the vehicles in the next few years

https://www.samsonsky.com/

FLYING CAR

Aska A5 (by Samson Sky) - California

- Is an electrical Vertical Take-Off and Landing (eVTOL) vehicle
  - This is a hybrid
- A full scale test car has been build and is being tested.
- 4 seater
- Flight range 250 miles
- Company plans to bring to market 2026.

https://www.askafly.com/