Everything You Need To Know About EVs

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Owner of an EV for 3+ Years

Background

- MSEE from Purdue & Business Training at Penn State, Harvard, & Northwestern
- Software Development and Management Bell Labs 1970-1999
- COO of Data Visualization Company, CTO of Energy Industry Data Supplier and Securities Brokerage
- Consultant to Fermi National Laboratory Open Science Grid
- Currently - Web Design & Developer for 2 non-profits

Outline

- History of EVs
- EV Market Status Worldwide
- EV vs ICE Characteristics
- EV Economics
- Batteries and Charging
- EV Driving Experience Locally and Long Distance
- Myths Debunked

Definitions

- ICE – An Internal Combustion Engine powered vehicle
- EV or BEV – An electric vehicle powered only by batteries
- PHEV – A Plug-in Hybrid Electric Vehicle. An ICE vehicle with an Electric motor and batteries to provide all electric for ~50 miles for urban travel. Long distance travel reverts to a regular Hybrid.
- Hybrid (HEV) – An ICE vehicle with an Electric motor and some batteries (a few miles of range). Increases efficiency and mpg.
- MPGe – Miles per Gallon Equivalent for EVs - NHTSA & EPA standard 2013

  Miles traveled * Energy in 1 gallon of gasoline)/Total Energy in Battery Used

  20 * 34 kWh / 5 kWh = 116 MPGe

Early History of EVs

- 1880-1894 – First Practical Electric Cars based on Lead-Acid battery (1859)
- 1890 – First Successful Electric built in US by Iowa chemist Oliver Fritchle
- 1895-1920 – Golden age of Electric Taxis, Vans, & EVs for Society Women
- By 1900, 30% of vehicles in NYC were electric
- 1900-1910 – Many EV brands, 90% of Taxis in NYC were EVs, Many Delivery Services Started using EV Delivery Wagons
- Electricity was in 35% of homes by 1920. Also people could install a power plant in their stable for charging.
- 1910 - NYC had 100s of public charging stations
- The wives of Edison, Ford, & Rockefeller all had Electric Cars

Early History of EVs

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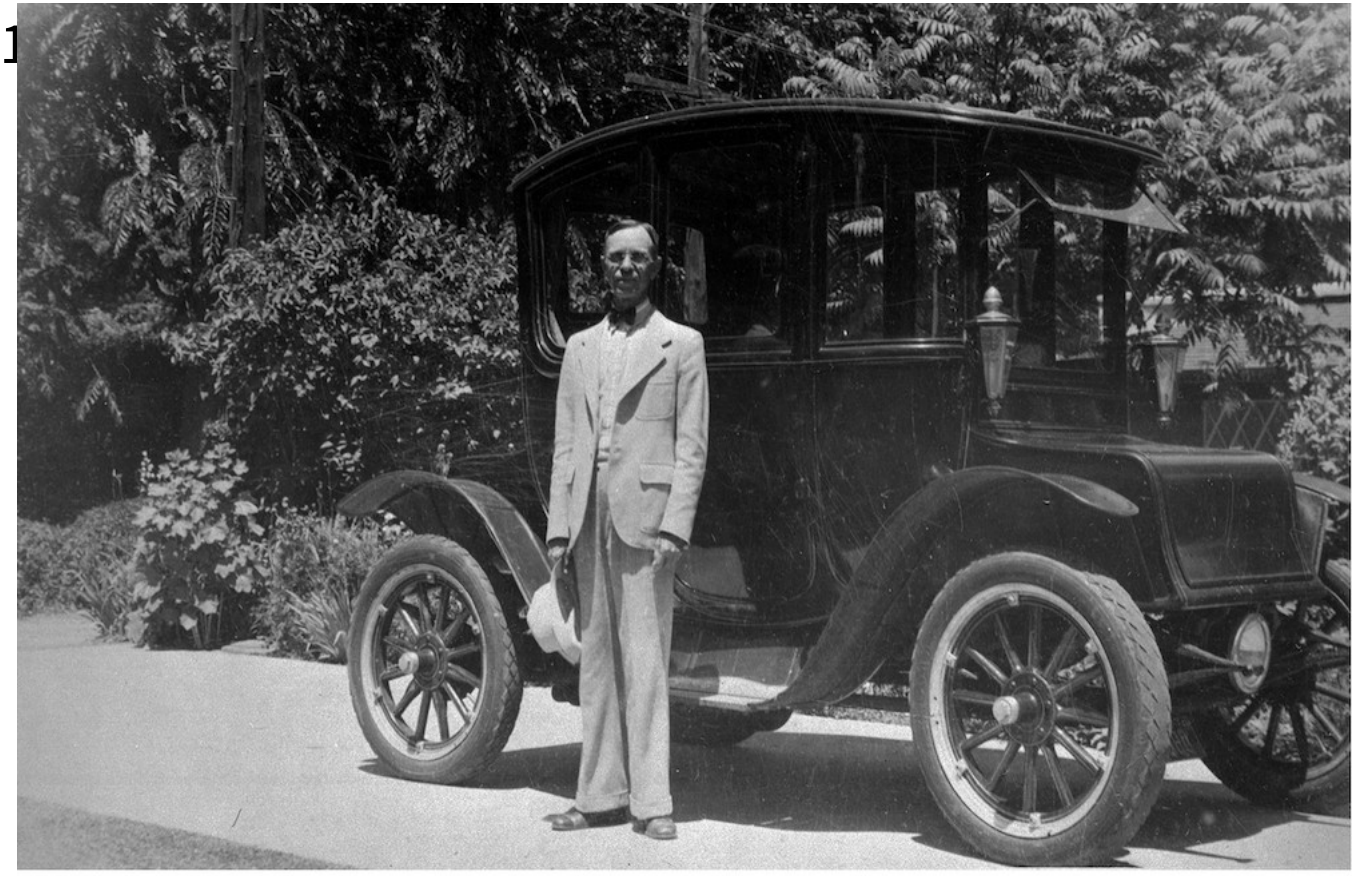


Oliver O. Fritchle stands in front of one of his cars. | 10025305, History Colorado

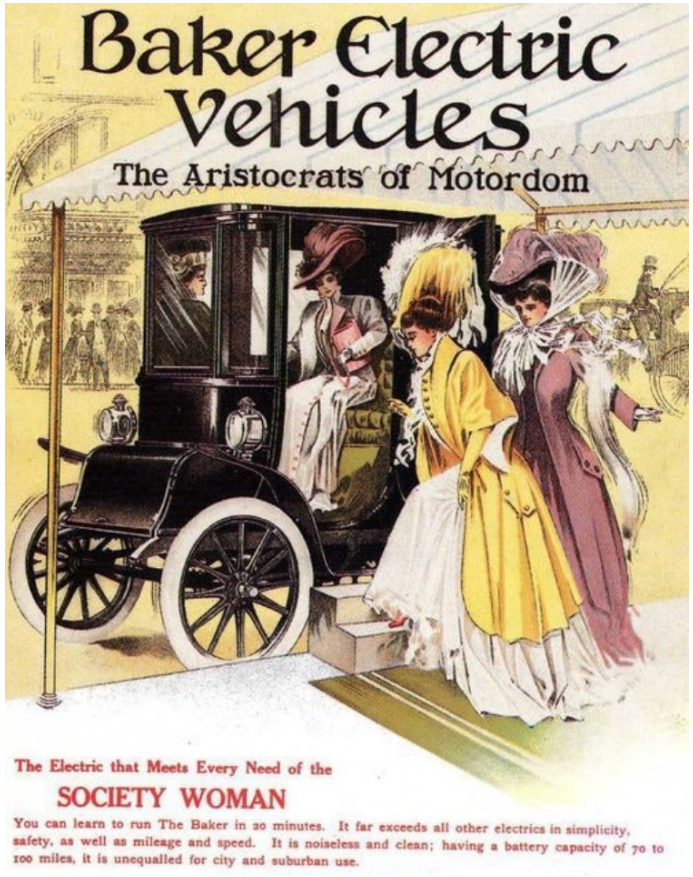
Early History of EVs

1906 Detroit – An Electric Wagon Delivering Beer

From: Detroit News

Early History of EVs

Electric Cars were marketed to Women (clean, quiet, no crank)



From: tumblr.com

Early History of EVs

What happened to this great start?

- Oil was discovered in Texas and gasoline became cheap
- Ford's production line produced a car for $650 while the average price of an Electric Car were $1750
- Marketing had cemented the view that an EV was a Woman's Car
- Electric Starters become common in the 1920s
- EVs at the time were only feasible in the city due to short range
- The Great Depression finished off the EV industry by 1935

Recent History of EVs

- New battery technology available (Lithium Ion)
- In the early 1990, the California Air Resources Board pushed for lower emissions vehicles
- In response, Honda, Chrysler, Ford, GM, Nissan, & Toyota developed EVs
- The largest program was GM's EV1; ~1100 cars were leased to customers
- Program ended after 2 years with GM forcing the cars to be returned (against the customers' wishes) and most EV1s were crushed
- Dealers sued CARB and got mandate neutered
- Public protests by EV drivers' groups upset by repossession of their cars caused Toyota to sell 328 RAV4 EVs until 2002. Toyota continues to support these cars.

Basically, automakers did not want to sell EVs and wanted it to look like there was no demand.

First Modern EV Company

Tesla - Created July 1, 2003 by Martin Eberhard and Marc Tarpenning

- Elon Musk invested $6.35M of $6.5M in 2006 to enable production of an expensive ($60K) sports car based on an electrified Lotus from the UK. Musk became CEO and hired J. B. Straubel from AC Propulsion (Li battery & electric motor expert).
- Tesla Roadster (~$80K) prototype shown in 2006 that changed the view of an EV. Won Time Magazine Best Inventions 2006: Transportation. Produced 2008-2012. Total ~2500
- Model S Large Luxury Sedan ($70K-$125K), with unheard of performance, features, and range. CR: "This car performs better than anything we've ever tested before. Let me repeat that: Not just the best electric car, but the best car. It does just about everything really, really well." Produced 2012-Present. Total through 2020: ~300,005
- Model X Large Luxury SUV ($80K-$125K) concept 2012. Only SUV to receive 5 star Safety Ratings in all Categories. Produced 2015-Present. Total through 2020: ~140,000
- Model 3 Small Sedan introduced 2016 with $35,000 ($40K - $50K) base price target. Produced 2017-Present
- Model Y Small SUV/CUV debuted 2018. Produced 2020-Present Total 3/Y through 3Q21: >1.5M

Tesla's mission is "to accelerate the world's transition to sustainable energy"

Aside from Tesla, breaking into the U.S. auto industry is so difficult that the last company to do so successfully was Chrysler - in 1925!

Tesla Model S

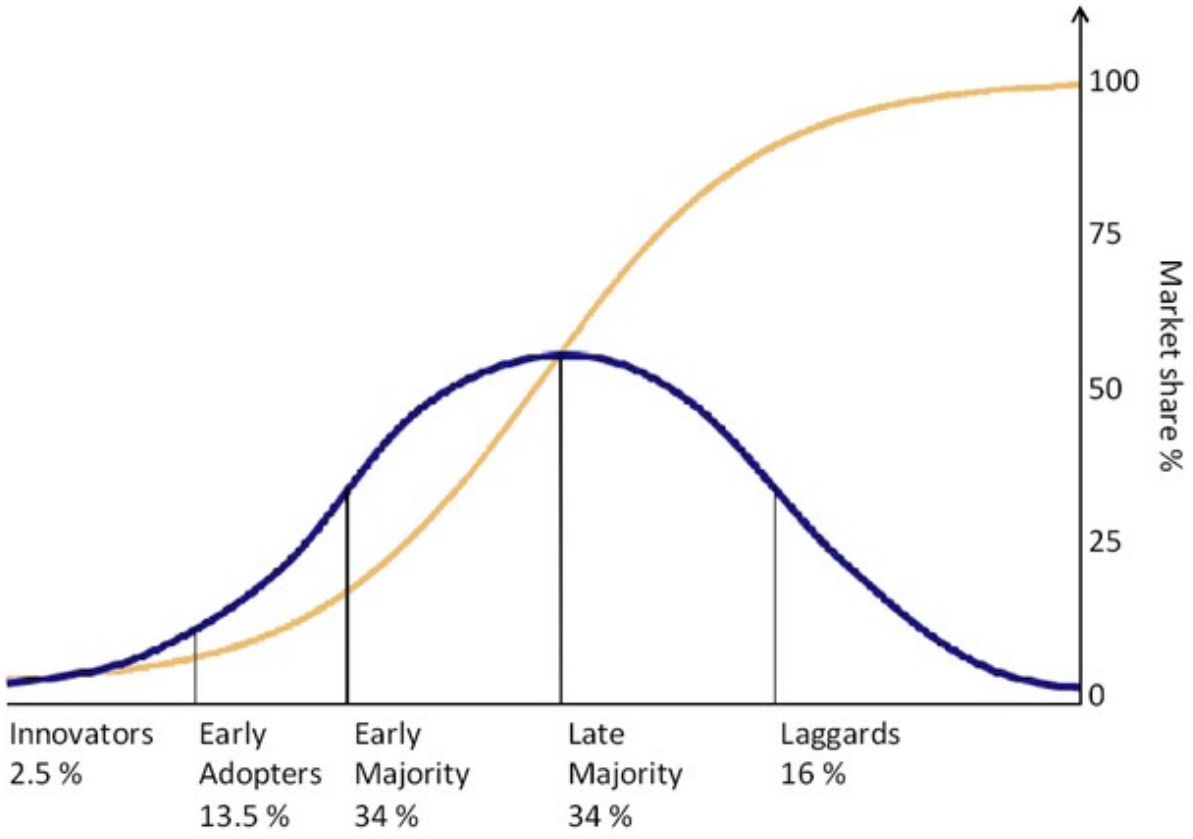
Tesla Model X

Tesla Model 3

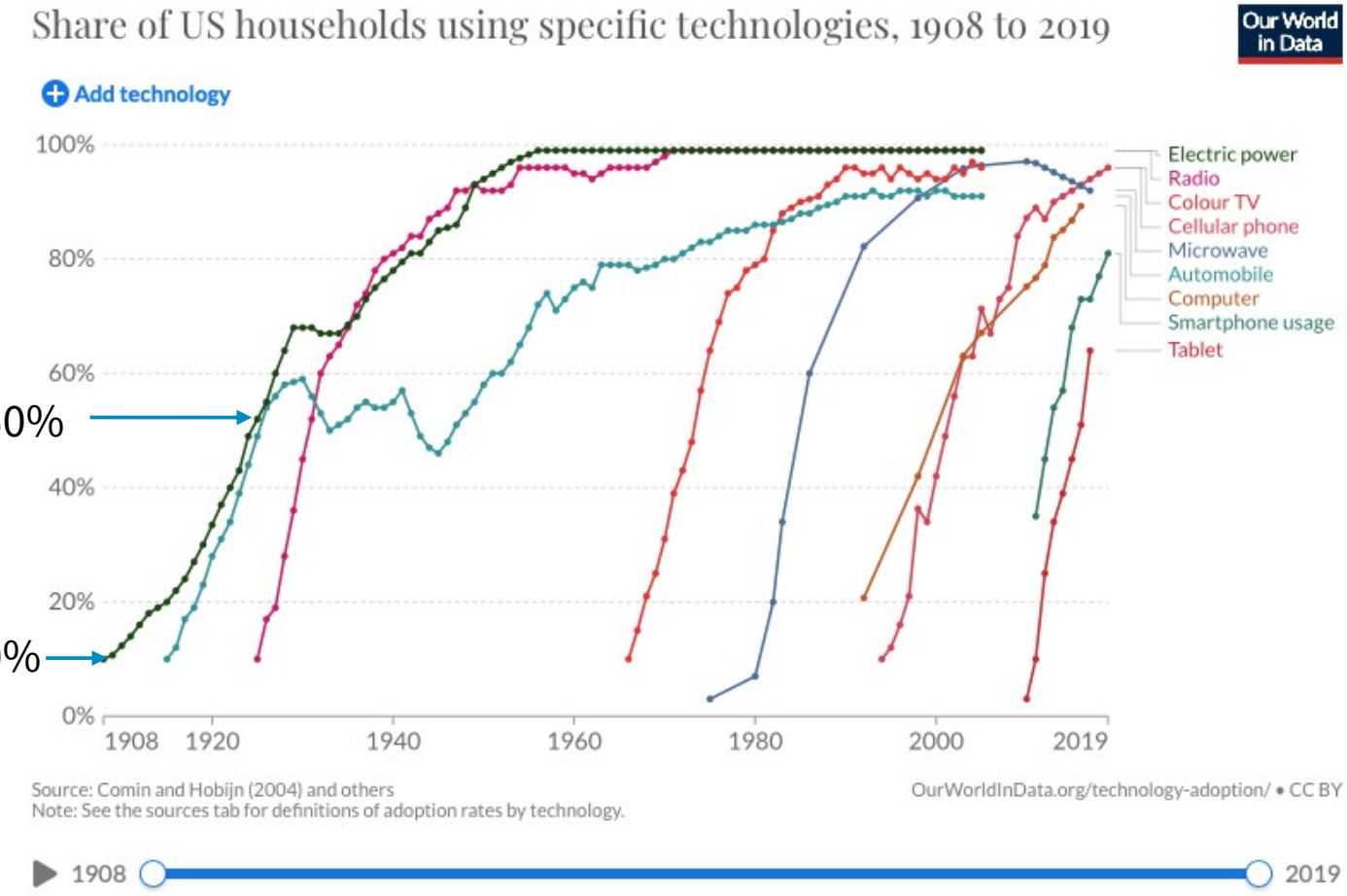
Tesla Model 3 Interior

Tesla Model Y

Technology Adoption Curve



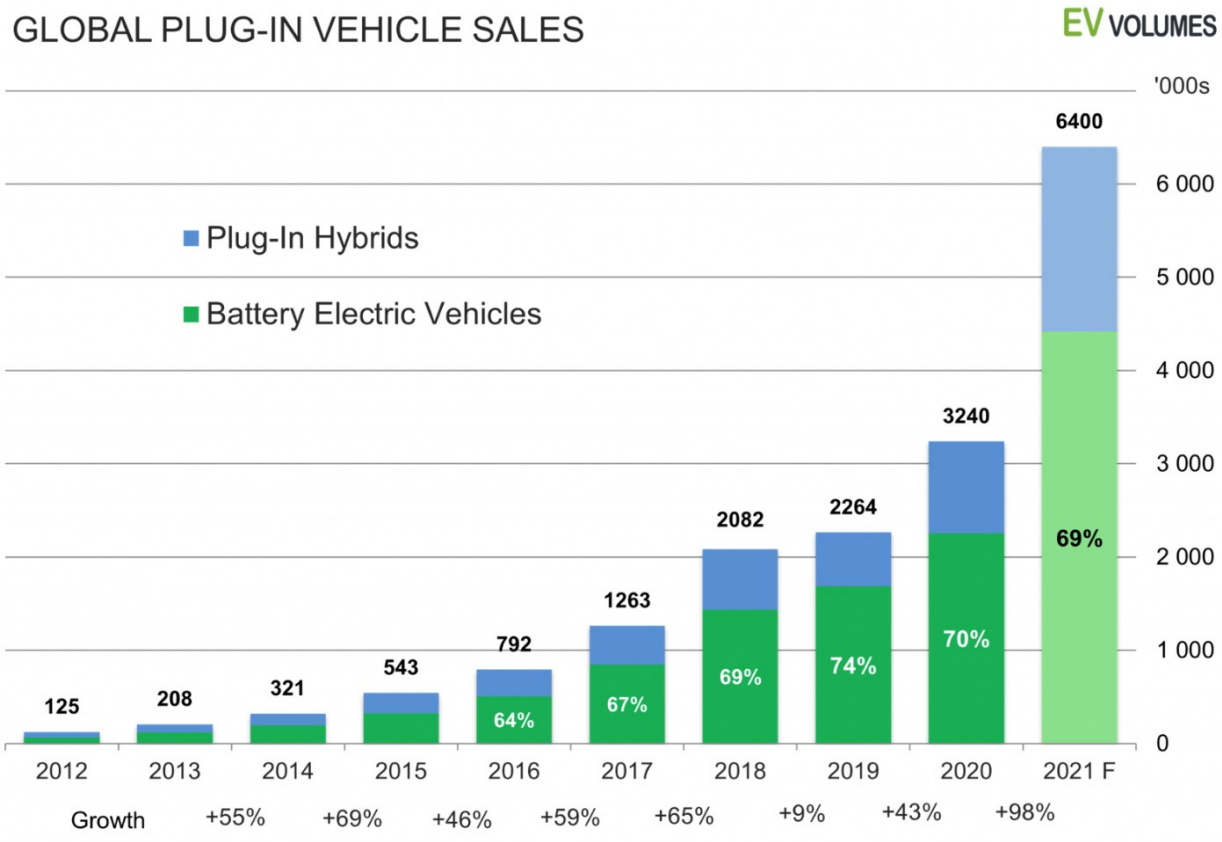
Past Technology Adoption Curves



Autos 1925 >50%

Autos 1910 10%

EV Adoption



Note: The Auto Industry wants to include PHEVs (and sometimes even Hybrids) with BEVs, so BEV only data is hard to find.

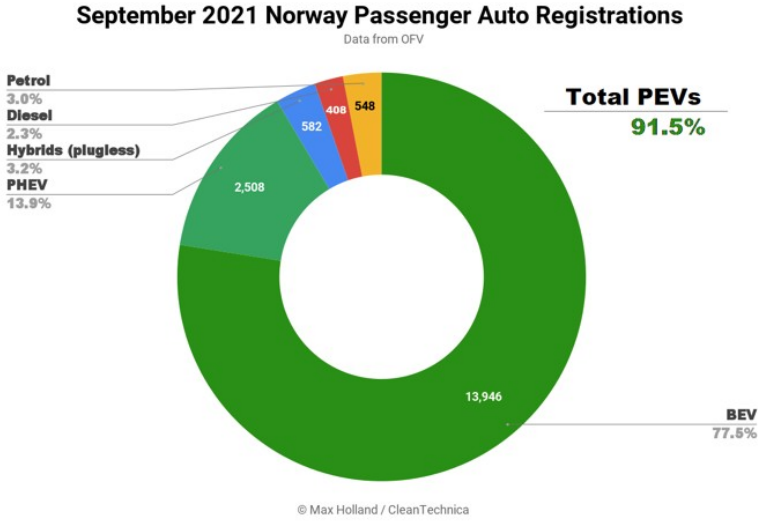
EV Adoption

EV Adoption Rate is Exponential and limited by Manufacturing Capacity

Europe

- 3Q21 BEVs were 9.8% of all cars sold in the EU
- 9/21 the Tesla Model 3 was the best selling car (of any type) in the EU
- 9/21 BEVs were 15% of all cars sold in England

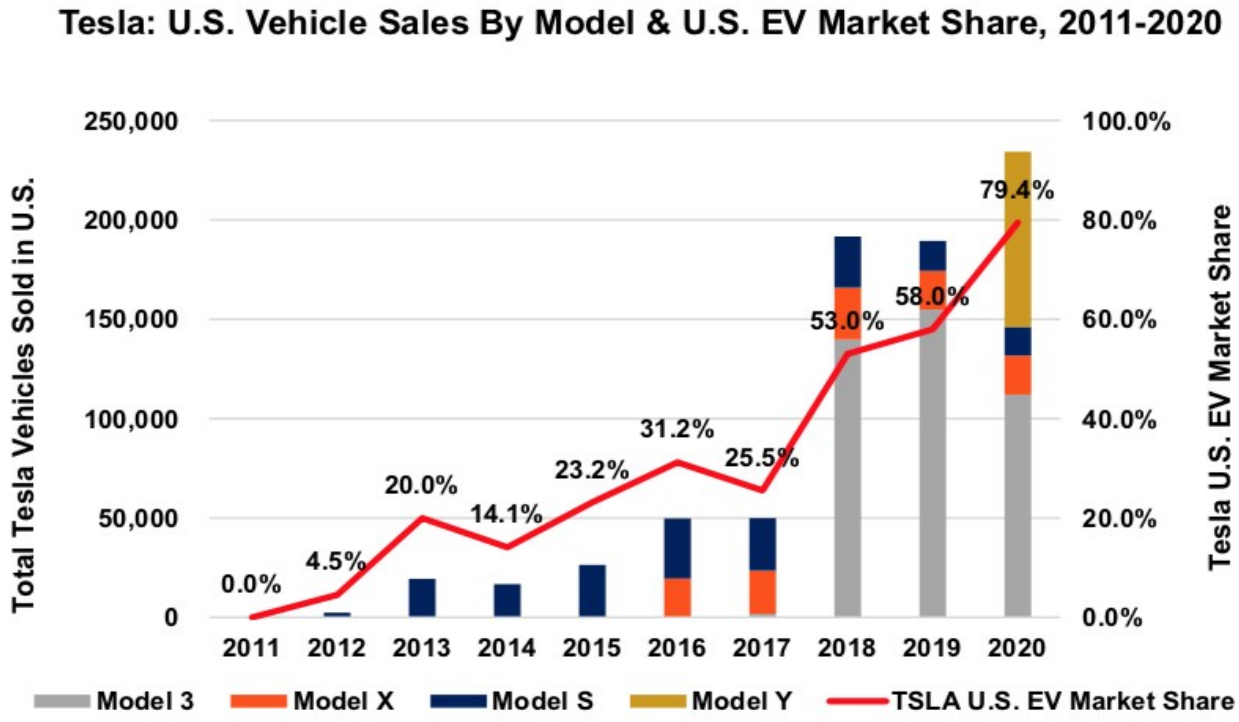
Norway hit the 10% EV market share in 2014



In China, BEVs are 4.6% of the Market (statista.com)

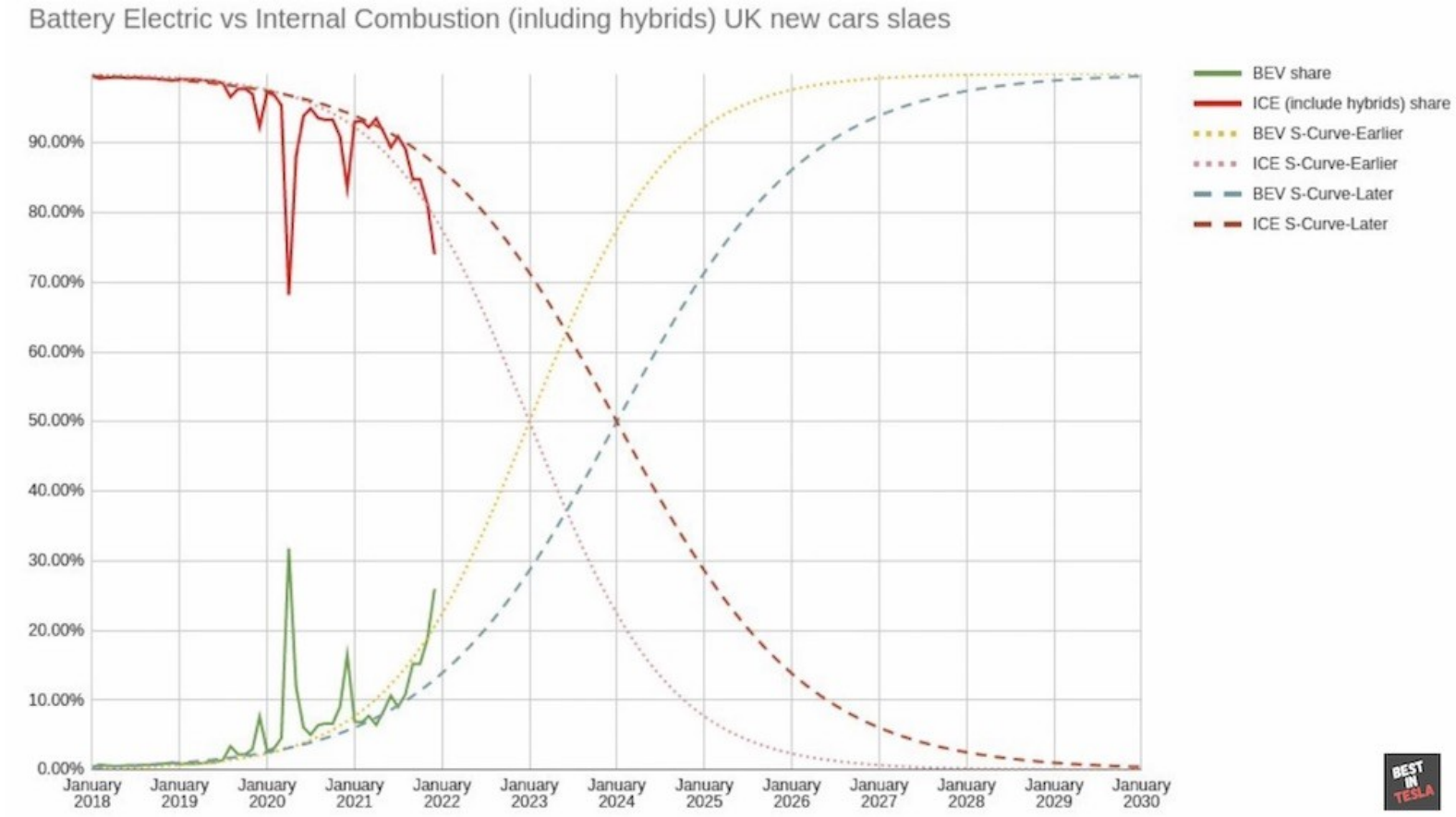
EV Adoption - US

US: Since Tesla has sold the vast majority of EVs in the US, it is a good representation of the current US market.
9/21; EVs were 2.6% of all vehicles sold in US. For all of 2021, EVs will be about 2% market share



1.1M BEVs were sold in China in 2020

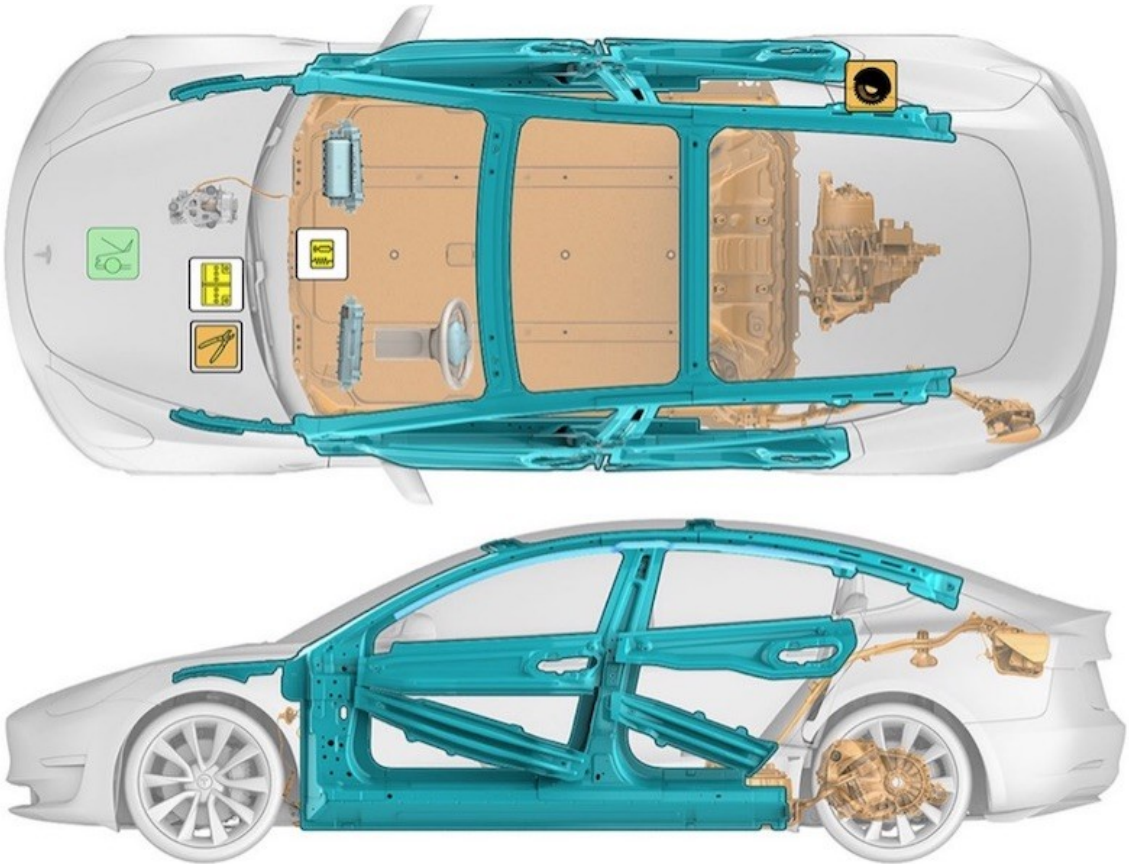
EV Adoption – UK



EV vs ICE

Measure	EV	ICE
Acceleration	Excellent - Fastest production car	Mediocre at best or low mileage
Energy Efficiency	~80%	~20%
Cornering	Little/No body roll; Like a Sports Car	Noticeable body roll
Emergency Handling	Excellent (>50 mph) Moose Test	Fair (35 mph) to Good (45 mph)
Noise	Only wind & tire noise	Same plus engine noise
Winter/Summer Comfort	Excellent, heated/cooled in garage	Fair, car must be outside & running to heat/cool cabin
Maintenance Effort/Cost	Excellent, only wipers, cabin filter in 2 yrs. 1 time in 2 yrs; Your time 15 min	Poor, requires ~6 mo oil/filter change, brake pads, air cleaner. Emission Test. ~3-5 times in 2 yrs
Convenience	Refuel in garage	Find gas station
Range	Most ~200-300 miles, few ~400-500 miles; Limited fast charging (Except Tesla)	Most >400 miles: Gas ~everywhere
Refuel Time	12 Min – 8 Hours and you are not there	8 Min plus time to drive to station

EV Mechanics



Buying An EV Will Change You

- You will look at gas stations a place where ICE owners go to suffer
- You will start to hate the smell of ICE cars
- Never again will you leave the house with an low fuel tank
- You will one day get into an ICE car and not like it
- You will get used to preconditioning the car cabin
- You will get used to single pedal driving and love it
- You will not miss the car dealer
- You will get used to the car helping drive on relaxing long trips
- You most likely will not be buying another ICE car
- You may become annoying to friends and family

Range

For EVs, Range needs to be viewed from a different perspective

- US drivers average only 30 miles driven per day
- Only 10% average more than 60 miles per day
- Only 1% average more than 100 miles per day

But an EV can easily begin every day with a full (80%-90%) battery, so 200 miles of range is sufficient for almost all normal use.

Long distance travel is most easily done with ~300 miles of Range; but 250 miles will work (with a few extra stops).

EV Challenges

Short term:
- EVs are battery/manufacturing limited
- Slow response by legacy auto manufacturers → lack of supply

Medium term:
- Battery supply will be limited for some time
- Many are threatened by EVs (Oil Industry, Auto Suppliers, Auto Parts)
- Fast charging infrastructure buildout
- Residential charging infrastructure (Apartments, Condos, Urban)

Longer term:
- Residential charging infrastructure (Apartments, Condos, Urban)

EV Economics

Factors

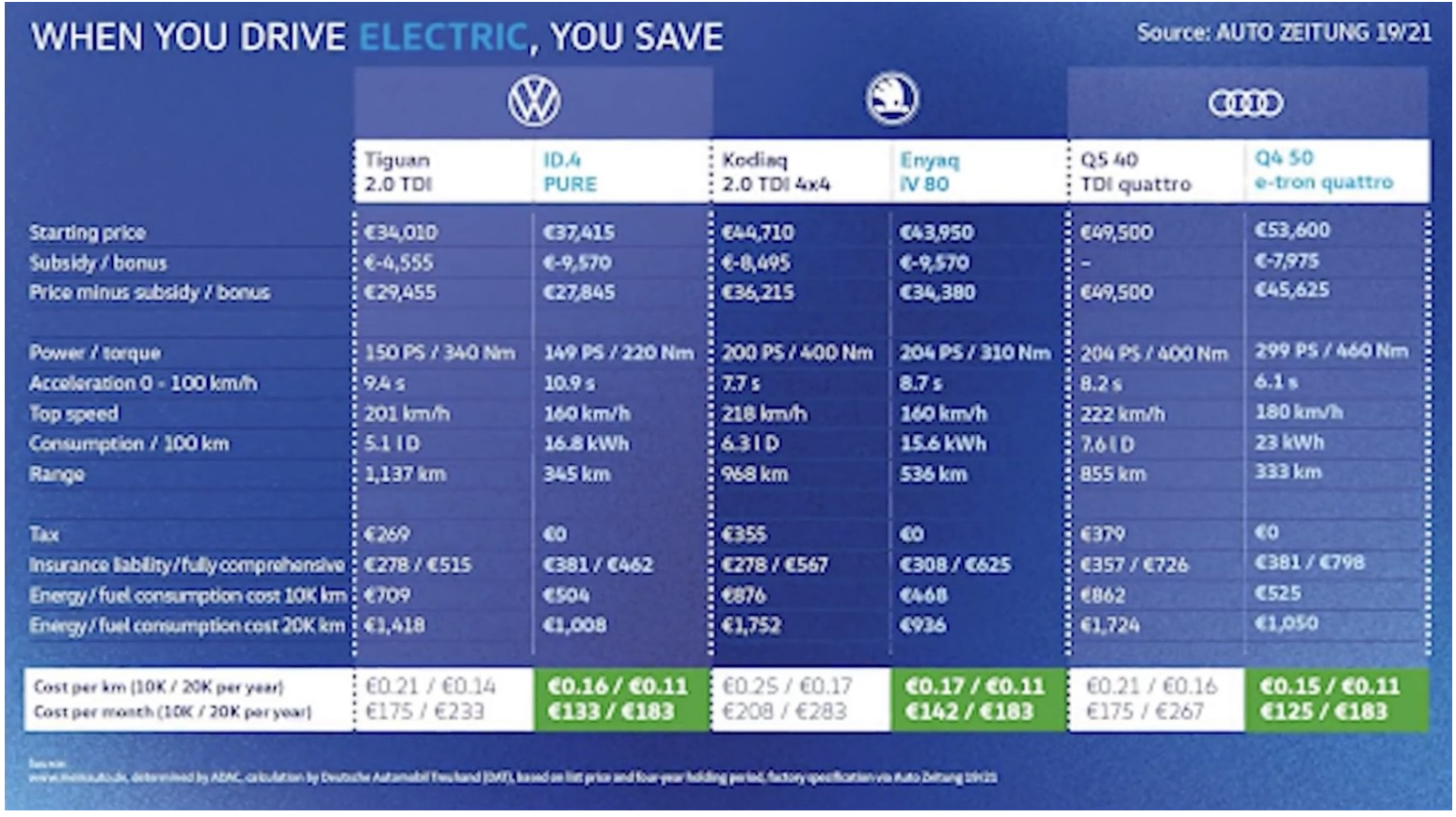
- EV Purchase Price exceeds competing ICE cars by $5,000 - $15,000
- Fuel costs for an EV are 25%-35% of ICE fuel costs ($0.03 vs $0.12 / mile)
- Maintenance costs are significantly less for EVs over 5 years (no oil/filter changes, air filter, brake pads, engine maintenance, etc.)
- Resale values currently are much higher for EVs

Fuel: Assume 15,000 miles/year @ 30 mpg for ICE car
ICE Fuel: 15,000/30 * $3.50 = $1750 ($0.117/mile)
EV Fuel: 15,000/4 (mi/kWh) * $0.11 = $412 ($0.027/mile)

Most analyses show that a Tesla Model 3 is economically equivalent to a similarly equipped Toyota Camry or Honda Accord after 5 years.

EV Economics

Herbert Diess, CEO of VW, has shown owner 5 year costs of VW's EVs vs their corresponding VW ICE vehicles for Germany.



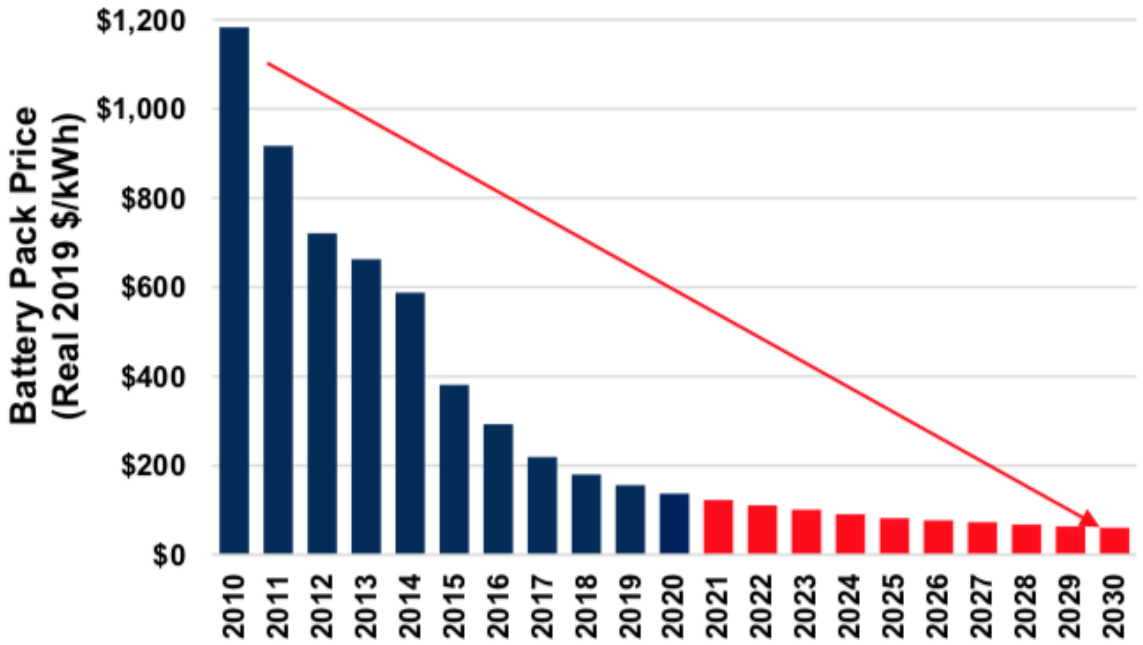
WHEN YOU DRIVE ELECTRIC, YOU SAVE

Source: AUTO ZEITUNG 19/21

	Tiguan 2.0 TDI	ID.4 PURE	Kodiaq 2.0 TDI 4x4	Enyaq iV 80	Q5 40 TDI quattro	Q4 50 e-tron quattro
Starting price	€34,010	€37,415	€44,710	€43,950	€49,500	€53,600
Subsidy / bonus	€-4,555	€-9,570	€-8,495	€-9,570	-	€-7,975
Price minus subsidy / bonus	€29,455	€27,845	€36,215	€34,380	€49,500	€45,625
Power / torque	150 PS / 340 Nm	149 PS / 220 Nm	200 PS / 400 Nm	204 PS / 310 Nm	204 PS / 400 Nm	299 PS / 460 Nm
Acceleration 0 - 100 km/h	9.4 s	10.9 s	7.7 s	8.7 s	8.2 s	6.1 s
Top speed	201 km/h	160 km/h	218 km/h	160 km/h	222 km/h	180 km/h
Consumption / 100 km	5.1 l D	16.8 kWh	6.3 l D	15.6 kWh	7.6 l D	23 kWh
Range	1,137 km	345 km	968 km	536 km	855 km	333 km
Tax	€269	€0	€355	€0	€379	€0
Insurance liability / fully comprehensive	€278 / €515	€381 / €462	€278 / €567	€308 / €625	€357 / €726	€381 / €798
Energy / fuel consumption cost 10K km	€709	€504	€876	€468	€862	€525
Energy / fuel consumption cost 20K km	€1,418	€1,008	€1,752	€936	€1,724	€1,050
Cost per km (10K / 20K per year)	€0.21 / €0.14	**€0.16 / €0.11**	€0.25 / €0.17	**€0.17 / €0.11**	€0.21 / €0.16	**€0.15 / €0.11**
Cost per month (10K / 20K per year)	€175 / €233	**€133 / €183**	€208 / €283	**€142 / €183**	€175 / €267	**€125 / €183**

EV Economics

The big driver of EV costs is the cost of the batteries.



Credit: CFRA

Charging: AC

There are many misunderstandings about EV Charging.
There are 2 basic charging methods – AC & DC:

AC: Charging from any AC source. EVs have an onboard AC (120V-240V) to DC (400V-800V) Converter to charge batteries at relatively slow rates.

- Plug into an outlet anywhere from 120V 15A - 20A to 240V 30A – 60A
- 120V chargers (L1) charge at 2-3 miles added per hour (1.4 – 1.9 kW)
- 240V chargers (L2) charge at up to 18-35 miles added per hour (5.7 – 11.5 kW)
- L2 Destination chargers at stores, restaurants, & hotels (all are 240V)

There are 2 plug types: Tesla and J1772 with simple adapters between them
Charging is fully automated: Car indicates time required to charge depending on the % of full charge you have set and kW available from the source.

Charging: AC

Charging: DC

DC: High speed charging from an DC source. Directly charges the battery after car communicates with charger to negotiate Voltage needed and Maximum Current.

Tesla calls them Superchargers. Charging rates are typically between 75 kW and 350 kW depending on the charger and the car. Tesla has the most extensive worldwide network by far.

The other largest companies are Electrify America, ChargePoint, EVgo, & EV Connect. Many of these provide many more L2 chargers than DC (but don't distinguish between them on Map)

- Mostly used for long distance travel or for commercial vehicles (e.g. taxis)
- Charging rates depend on battery level and battery cooling
- Miles added per hour can be as high as 1000 (for ~10 min)
  All this is automated: Car will tell you how long the charge will take depending on the % of full charge you have set.

There are 2 plug standards: Tesla & CCS with adapters between them

Charging: DC

Charging: DC

A Typical Tesla Trip

A trip is started with a “full” battery (90% or above)
Enter (say) your destination and the car plans a route and suggests charging stops

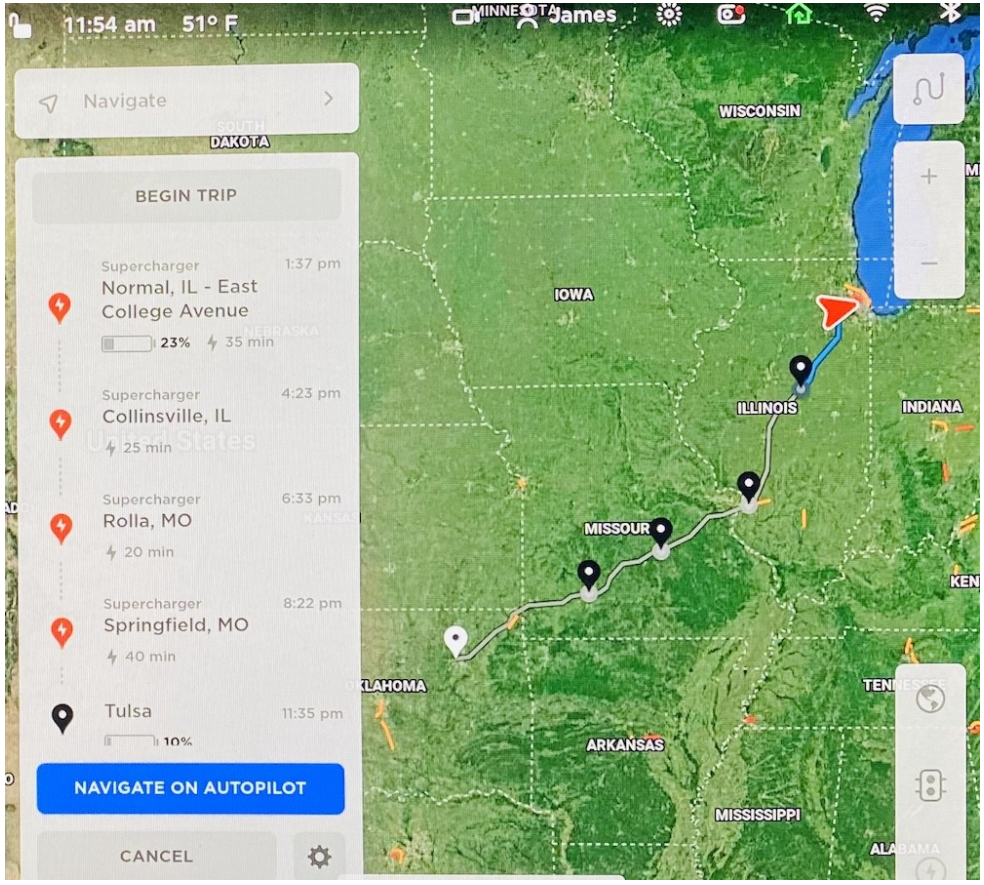
Mid morning: (2.5 – 3 hours or 150 – 200 miles). Stop at a Supercharger, plug in and take a rest stop with bathroom and coffee/snack. Car has enough charge to continue in 15 – 20 minutes (often before I finish my coffee)

Lunch time: (after another 2 – 3 hours). Stop at Supercharger, plug in and go to lunch. Car is always charged enough before lunch is over. (30 – 40 min)

Mid Afternoon: (2.5 – 3 hours or 150 – 200 miles). Stop at a Supercharger, plug in and take a rest stop with bathroom and drink. Car has enough charge to continue in 15 – 20 minutes

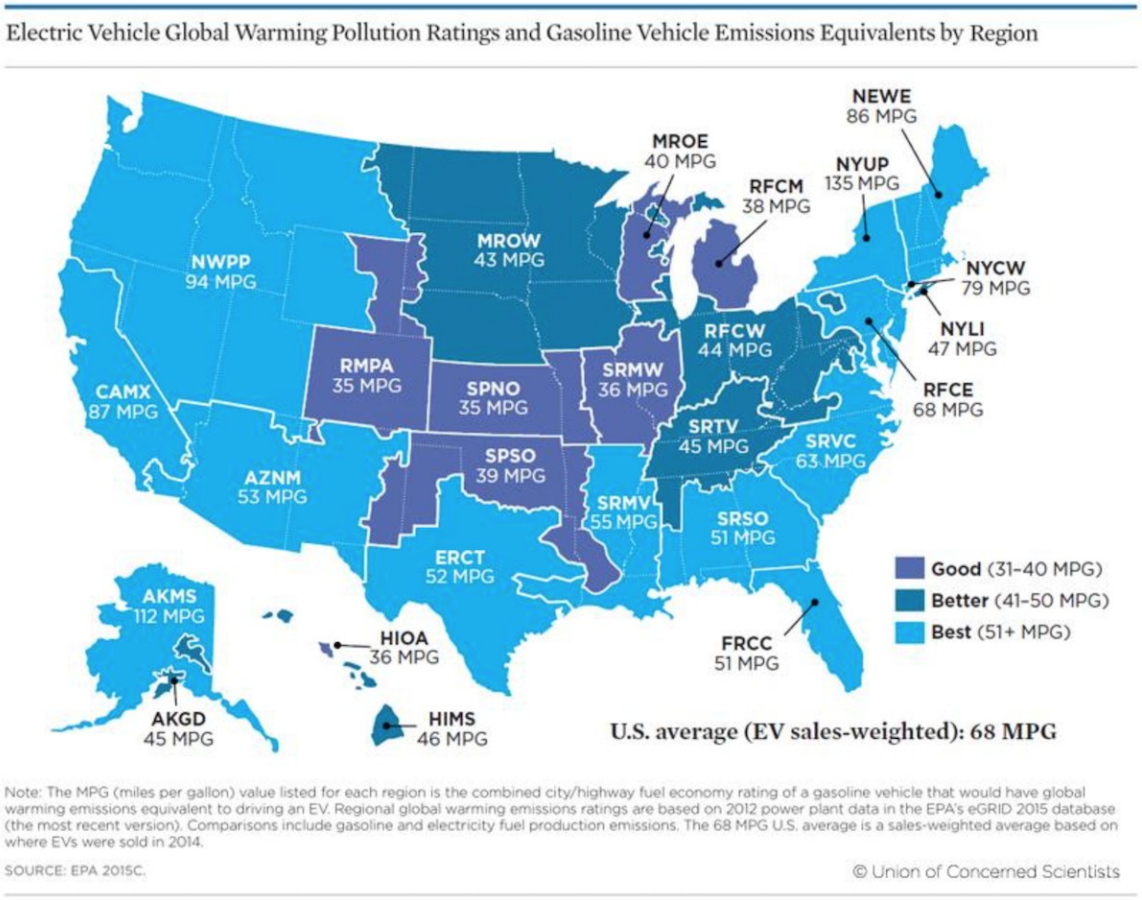
Arrive first day destination: (Total drive 500 – 600 miles). Stop at Hotel with Destination Charger. Plug in for overnight charge to restart next day at 90% charge.

Trip: Naperville to Tulsa



CO2 Emissions

2015 Map of equivalent lifetime CO2 emissions of EVs in equivalent MPG.

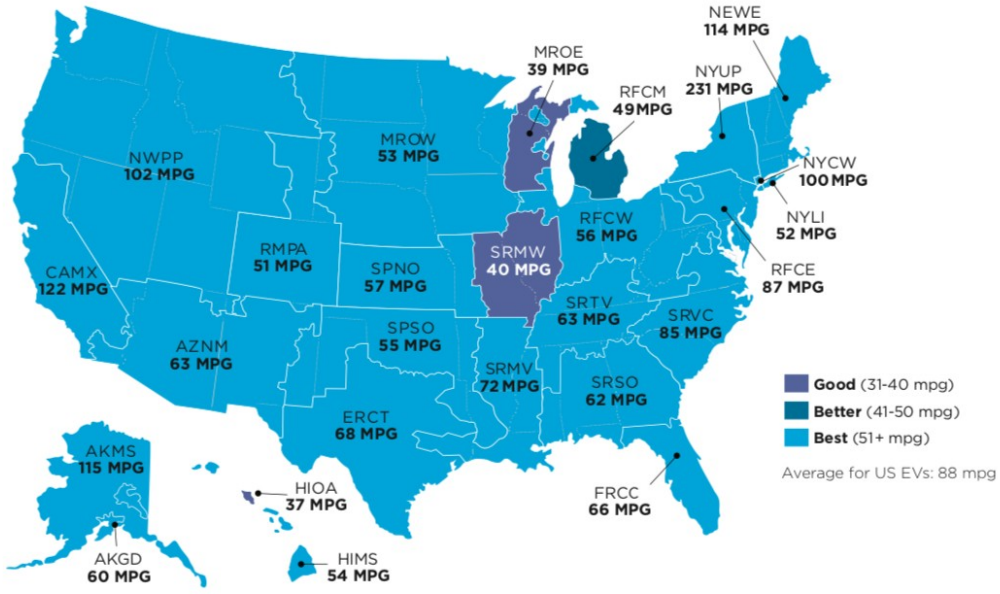


CO2 Emissions

2020 Map of equivalent lifetime CO2 emissions of EVs in equivalent MPG.

Drivers:
- Cleaner Grid
- More Efficient EVs

FIGURE 1. EV Emissions Vary by Regional Electricity Supply

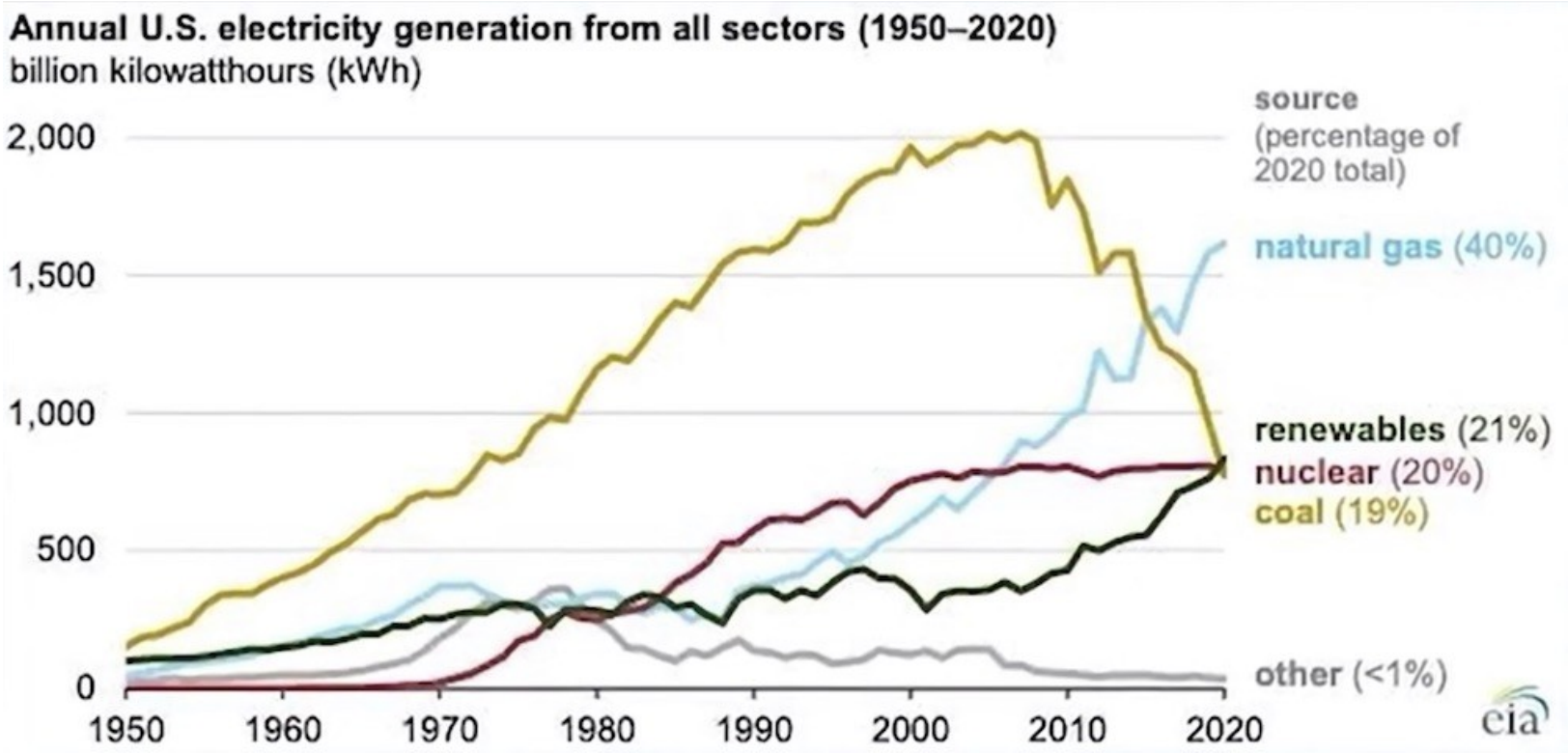


For each region of the US electricity grid, UCS calculated how the global warming emissions of charging and driving an average EV compare with those of a gasoline vehicle. The miles-per-gallon (mpg) value listed for each region is the combined city/highway fuel economy rating of a gasoline vehicle with emissions equivalent to the average EV. Nationally, the average EV is equivalent to a gasoline car that gets 88 mpg.

NOTES: Regional global warming emissions are based on 2018 power plant data in the eGRID2018 database (EPA 2020b). Comparison includes gasoline and electricity fuel production emissions estimates for processes including extraction, transportation, and refining, using the GREET 2019 model (ANL 2019). The 88 mpg US average is a sales-weighted average based on where EVs were sold from January 2011 through September 2019.

CO2 Emissions

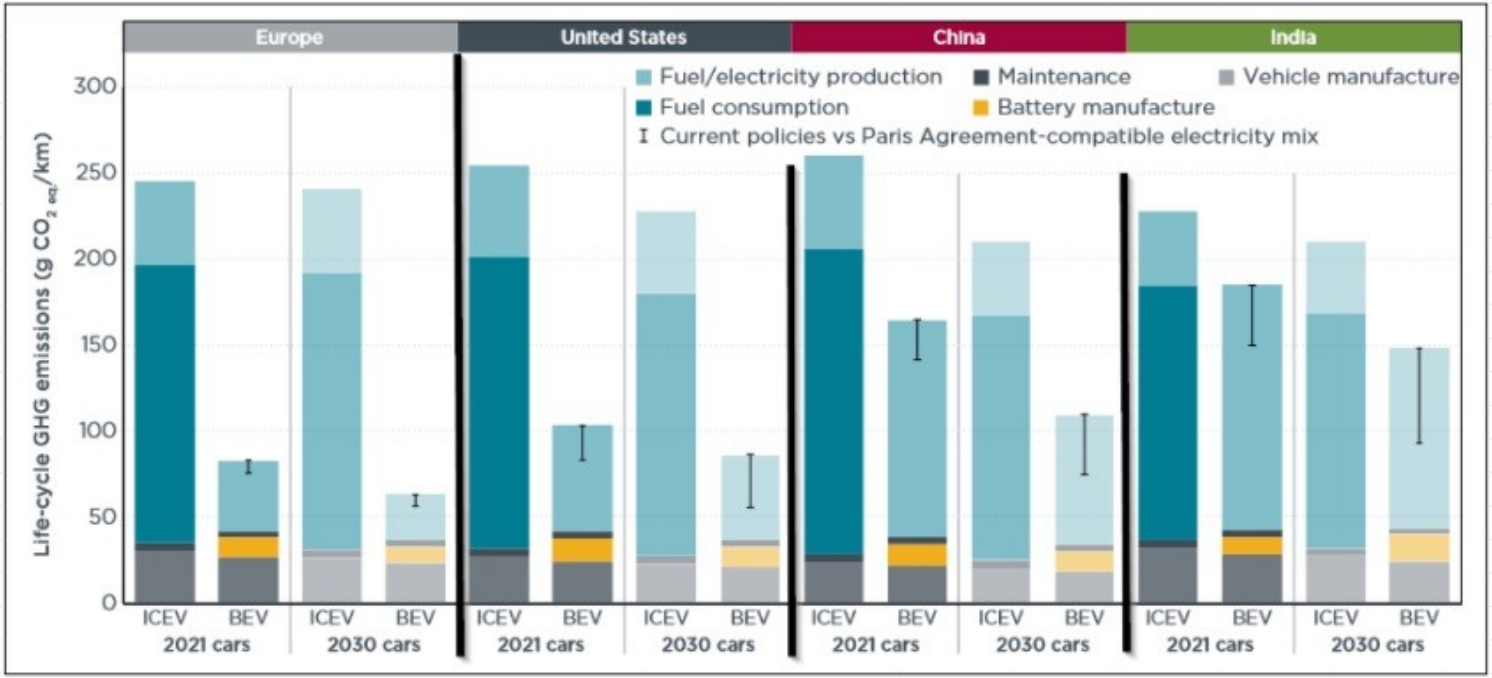
Improvement due to cleaner Electricity Generation in the US



Another Comparison of CO2

The International Council on Clean Transportation – Using real life data of 2021 Cars

https://theicct.org/publications/global-LCA-passenger-cars-jul2021



Expensive Metals In Cars

Catalytic Converter & Lead Acid Battery - Minerals					
Mineral	Price per Gram	MINIMUM		MAXIMUM	
		Grams	Total	Grams	Total
Rhodium (1-2 g)	$376.1600	1	$376.16	2	$752.32
Palladium (3-7 g)	$63.5700	3	$190.71	7	$444.99
Platinum (2-7 g)	$30.3200	2	$60.64	7	$212.24
Lead (40 - 60 lbs @ 60%)	$0.0020	18144	$35.92	27216	$53.88
	TOTAL	18150	$663.43	27232	$1,463.43

EV - Minerals (NMC532 battery chemistry)					
Mineral	Price per Gram	MINIMUM		MAXIMUM	
		Grams	Total	Grams	Total
Lithiuim	$0.0075	72000	$540.00	88000	$660.00
Cobalt	$0.0772	12600	$972.24	15400	$1,188.29
Manganese	$0.0021	18000	$37.08	22000	$45.32
Copper	$0.0096	28800	$275.78	35200	$337.06
Nickel	$0.0199	31500	$627.89	38500	$767.42
	TOTAL	162900	$2,452.98	199100	$2,998.09

Cobalt is Costly and is being reduced/eliminated

Nickel can be replaced by Iron – improving longevity at a cost of lower energy density

EV Myths Dispelled

1. EV are less “Green” than ICE cars (not true even including manufacturing)
2. Charging EVs takes hours (but you don’t care because you are sleeping)
3. EVs don’t work in the cold (absolutely the best car in the cold)
4. Fires – EVs often catch on Fire (212,500 ICE cars caught fire in 2018, killing 560)
   - Tesla has 10X fewer fires per billion miles driven than do ICE cars
   - Chevy Bolt EV does have more fires than ICE cars and has a recall
5. EVs are expensive (but not over 5 years for comparable cars)
6. EV batteries need replacement at great expense (Many now have about 400K miles without battery replacement)
7. Batteries will be a hazardous waste problem (Batteries will be recycled)
8. We don’t have enough minerals needed
   - Enough Lithium in 1 mine in Nevada to convert all US cars/trucks to EVs
   - Some battery designs eliminate the Cobalt, a relatively rare element
   - Nickel being replaced by Iron for some EVs

Useful Links to more Info

Charging

- https://www.tesla.com/supercharger
- https://www.electrifyamerica.com/locate-charger/
- https://www.plugshare.com (Requires registration – it is worth it!)
- https://www.chargepoint.com/ (Requires registration)
- https://www.evgo.com (Requires registration)

CO2 Info

- https://www.ucsusa.org/sites/default/files/2020-05/evs-cleaner-than-gasoline.pdf
- https://evtool.ucsusa.org (Find CO2 by specific car and location

2020 Tesla Impact Report

- https://www.tesla.com/impact-report/2020
- https://www.tesla.com/support/voice-commands

EVs are the Future

My Advice:
Do not buy a new car without taking test drives
of equivalent, available EVs
Be aware that an EV will take some retraining
Best if you can charge at home

1000 Free Supercharging Miles for both of us
if you decide to order a Tesla and use this link:
https://ts.la/jamesd62050

Q&A