Long Trips in a Battery Electric Car (BEV)

tinyurl.com/BEVsLongTrips

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May 2018 Tesla Model 3 Long Range RWD, ~300-miles range, >47,000-miles, ~130 MPGe

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ICEV = Internal Combustion Engine Vehicle (e.g., Honda Civic, 32 MPG)

HEV = Hybrid Electric Vehicle (ICEV + ~1-kWh Li-Ion battery)(e.g., Toyota Prius, 56 MPG)

PHEV = Plug-in Hybrid Electric Vehicle (ICEV + ~20-kWh battery & plug)

(e.g., Toyota RAV4 Prime, 42 miles electric, 38-94 MPG, Average: ~67 MPG)

BEV = Battery Electric Vehicle (~80-kWh battery & plug)(e.g., Tesla Model 3, 131 MPGe)

EV = PHEV or BEV

kWh = battery energy, kW = battery charging power

SOC = battery State Of Charge (0%-100%)

Burning 1-gallon gasoline = 33.7 kWh, MPGe = (33.7 kWh/G)*(X mi/kWh)

First Question

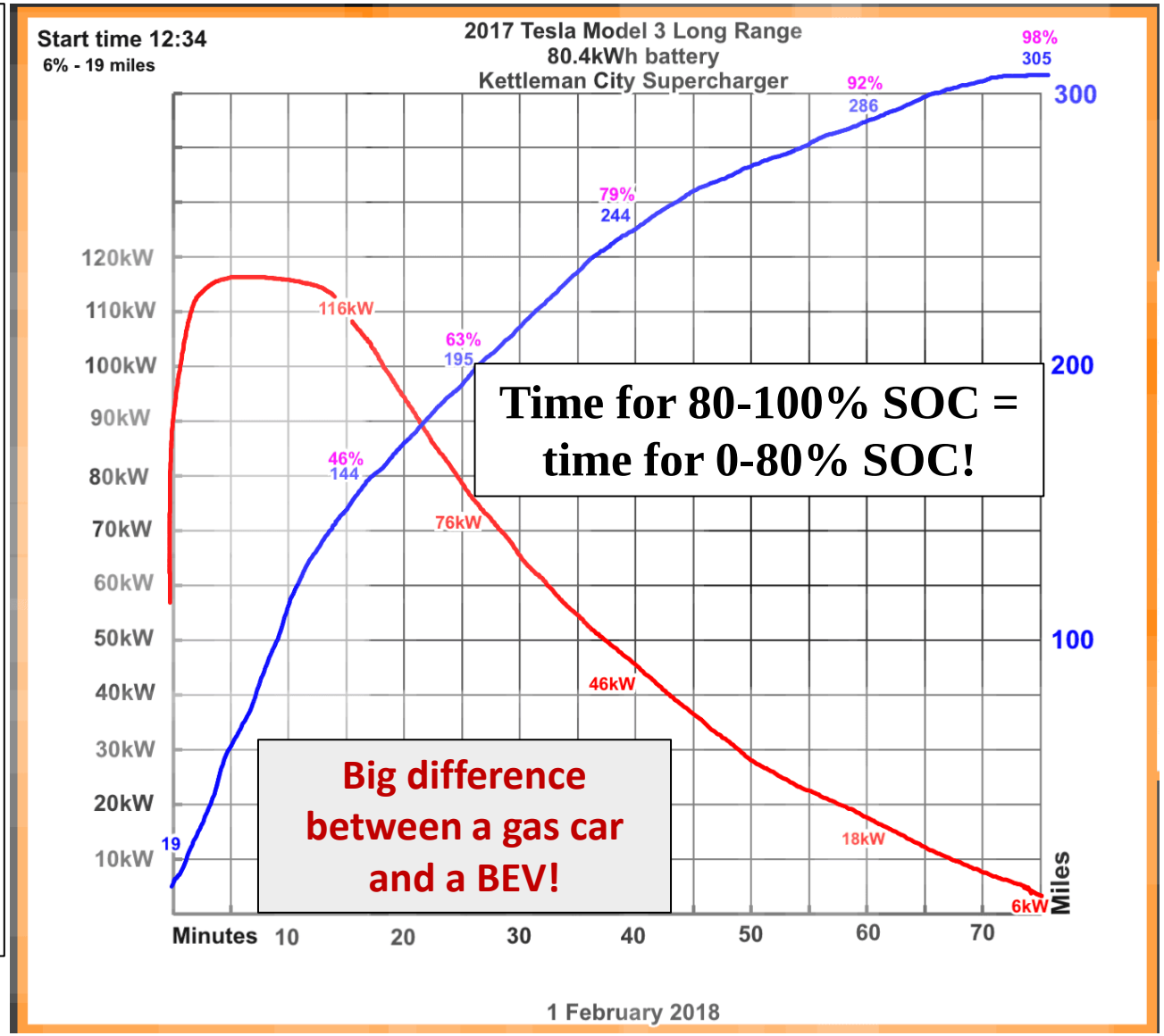
- First question people ask about battery electric cars: How long does it take to charge it?
- Answer: **That is not a relevant question.**
- The relevant question is: Can you drive a BEV on long trips without long delays charging?
- Answer: **Yes, if it is a BEV with over 250-miles range that has an extensive and reliable fast-charging network available to it on highways (e.g., Tesla).**

Important Differences between BEV Charging Stations and Gasoline Stations

- For **local & regional driving** most BEVs usually are charged at **level-2 chargers (J1772 or Tesla plug, 240-volts, 7-16 kW AC)** in **driveways, garages**, streets, parking lots and work places. **Home charging is a big deal! I estimate that 98% of my Tesla's charging is done in my garage!**
  - Some BEVs are charged using a standard electric outlet (**level 1, 120-volts, 1.4-kW AC**), using a inexpensive portable charger, overnight for **very slow charging (local driving)**.
- Many businesses and other locations have level-2 chargers available for public use in parking lots.
- This greatly reduces the number of **fast chargers** (**level 3, 50-350 kW, 480-volts DC**) needed compared to gasoline stations; most are needed **near highways for long trips**.

Typical BEV Fast-Charging Curve

A physical reason why to **not charge to near 100%, except overnight before a trip**. Also, **battery lasts longer**.



Red curve = charging power (kW)

Blue curve = SOC(%, kWh) & range(miles)

Charging power rapidly declines as SOC increases.

Charging a Battery is Like Filling a Stadium

- The **stadium effect** occurs when charging a BEV battery.
- The battery quickly charges at low SOC, then slows down when charging at high SOC.
- Think of how quickly a stadium fills up when the doors first open; there are many open seats, so it is easy to find the one you want.
- Eventually, there are only a few open seats here and there, and people have to maneuver around to find the spot they want; filling those seats takes longer.
- The same situation applies to charging a BEV battery.
- It is easy for electrons to flow from the battery's anode to the cathode and take up empty space at low SOC; as time goes on and less space is available (high SOC), it takes longer for the electrons to fill in the space. (Here "space" is a missing electron slot in a metal oxide.)

LDR Long Trips in 2018 Tesla Model 3 Long Range

- **Blacksburg VA to central Texas in 2018.**
- **Blacksburg VA to central Florida in 2019 & 2020.**
- **Blacksburg VA to central Oklahoma in 2021.**
- Possible because of ~300 miles range and reliable Tesla Superchargers at less than 150-miles intervals.
- Tesla has "plug-and-charge" for easy charging.
- Tesla plans to open Superchargers to other BEVs by 2022, but possibly not with "plug & charge".

Some Affordable Midsize BEVs that Can Take Long Trips (reliable charging network?)

1. Tesla Model 3 (RWD & AWD) sports sedan
2. Tesla Model Y SUV
3. Ford Mustang Mach-E SUV
4. Volkswagen ID-4 SUV
5. Volvo XC40 Recharge SUV
6. Polestar 2 (Volvo subsidiary)
7. Audi Q4 e-tron SUV

Teslas have the Tesla plug; most other BEVs have the CCS (Combined Charging System) plug. A plug adapter is required to use both types of fast chargers.

Details about these seven BEVs are at the end if needed.

Checking Out Long-Trips Capability of a BEV

- Find a desired BEV either at a dealer or a friend's place.
- Start the **on-board navigation (Is it up-to-date?)**.
- Set up navigation to a place several hundred miles away that you will likely want to visit. Also, plan a 1,000-miles or longer trip.
- See what the BEV screen shows where and how long to charge at each charging location on the route.
- Compare the route selected to the route you would prefer to travel.
- If the BEV is not a Tesla, compare it to the same trip in a Tesla using Tesla Superchargers, if possible. (Tesla is the standard.)

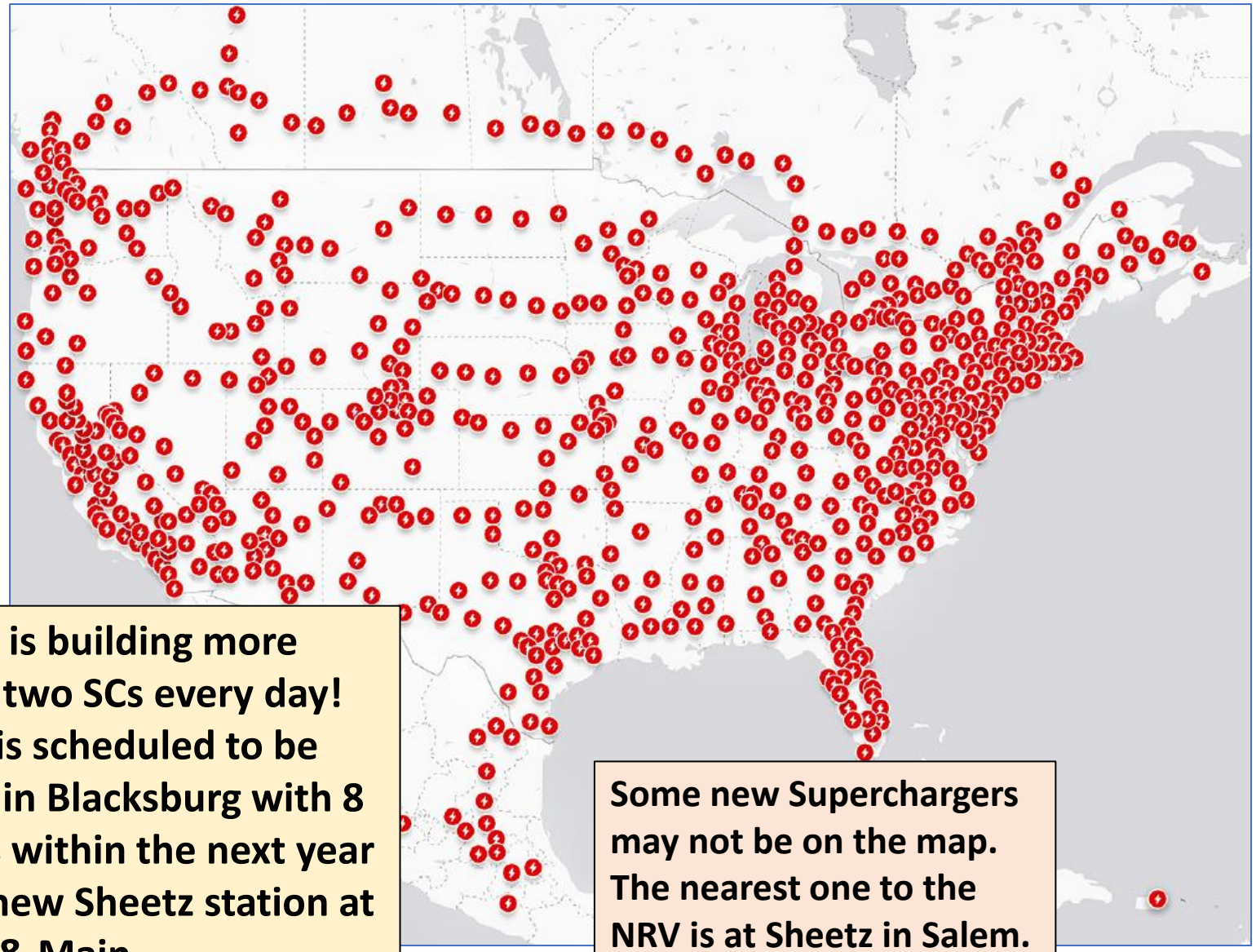
Alternate Planning for Long Trips in a BEV

- ABetterRoutePlanner.com (ABRP) can be used to plan trips for BEVs.
  - Specify the BEV.
  - Specify starting % SOC, for example, 98%.
  - Specify % SOC at next charger, for example, 15%.
  - Specify % SOC at destination, for example, 20%.
  - Specify many other items, e.g., more stops than the BEV needs. (I need about 50% more stops than my TM3LR needs.)
- Compare BEV's navigation's plan to ABRP's plan.
- **Fully charge only overnight at home or at a hotel! At travel stops, charge only enough to get to next charging station plus a reasonable safety margin (10%-20% SOC).**

Tesla's Dominance in Range and Fast Charging

Since Tesla has a decade's lead over other car companies in developing long-range BEVs and an extensive, reliable and fast expanding fast-charging network (Superchargers), I start with the details about how to use a Tesla for driving on long trips. Other BEVs will have many similarities.

Tesla Superchargers



Tesla is building more than two SCs every day! One is scheduled to be built in Blacksburg with 8 stalls within the next year at a new Sheetz station at First & Main.

Some new Superchargers may not be on the map. The nearest one to the NRV is at Sheetz in Salem.

These very fast (150-250 kW) chargers have Tesla-specific plugs; however, Tesla plans to open them up to other BEVs with CCS plugs in 2022, but possibly not with "plug-and-charge".

How to Drive a Tesla Long Distances

- **Charge to near 100% at home**.
- Use Tesla Navigation on the car screen. (Tesla updates it regularly OTA.)
- Charge at screen-indicated Superchargers or more often to the SOC needed to get to the next Supercharger on the route plus a desired reserve (10%-20% SOC).
- Choose a hotel with a level-2 (7-11 kW) charging station, or near a Supercharger, to **charge near 100% for the next day**. (Many good hotels have such "**destination**" charging stations, usually provided by Tesla. Use plugshare.com to find them.)
- With fast charging stations provided by Electrify America, EVgo and other networks, similar long trips will be possible for other long-range BEVs very soon. Tesla plans to open Superchargers to other BEVs in 2022 and provide an adapter for Teslas to use non-Tesla CCS stations.

What It's Like to Use Tesla Superchargers

- You can see a list of nearby Superchargers (SCs) on the Tesla large screen. Information is available about the number of available charging stalls and power (150/250 kW) at each SC. (Higher power soon!)
- SCs are at shopping centers, hotels, and gasoline stations, such as Sheetz and WaWa.
- Simply plug Tesla in and do what you need or want to do; payment is automatic to your credit card. "Plug & Charge"
- Can use Tesla screen while charging to play many games, listen to music, play chess, watch TV shows or movies using Netflix, YouTube or Hulu and sing along with "Caraoke". New entertainments are constantly being added by Internet updates.
- You can see charging status on your smartphone.
- Cost/kWh (~$0.25/kWh) is about twice home cost (~$0.13/kWh); building SCs is expensive. Tesla claims no profit from SCs.

How I Plan a Long Trip in my TM3LR

- I use ABRP.com to plan the trip with the **setting of more stops than the TM3LR needs (I am 86.5 years old!)**, to compare the stops to the Tesla recommended stops.
- I use plugshare.com to study each Supercharger (SC) stop recommended by ABRP. (Plugshare has a trip planner, also.)
  - Read what users wrote about the facilities at or near the SC.
  - Look at photos users uploaded, to see the location of the SC.
- With nearly a full battery I set my final destination in my TM3LR navigation to see where it wants me to charge it and for how long at each stop.
- I compare the ABRP and Tesla routes and charging stops and make my own choices, usually added 50% more stops.

Blacksburg VA to Key West FL in 2018 Tesla M3LR

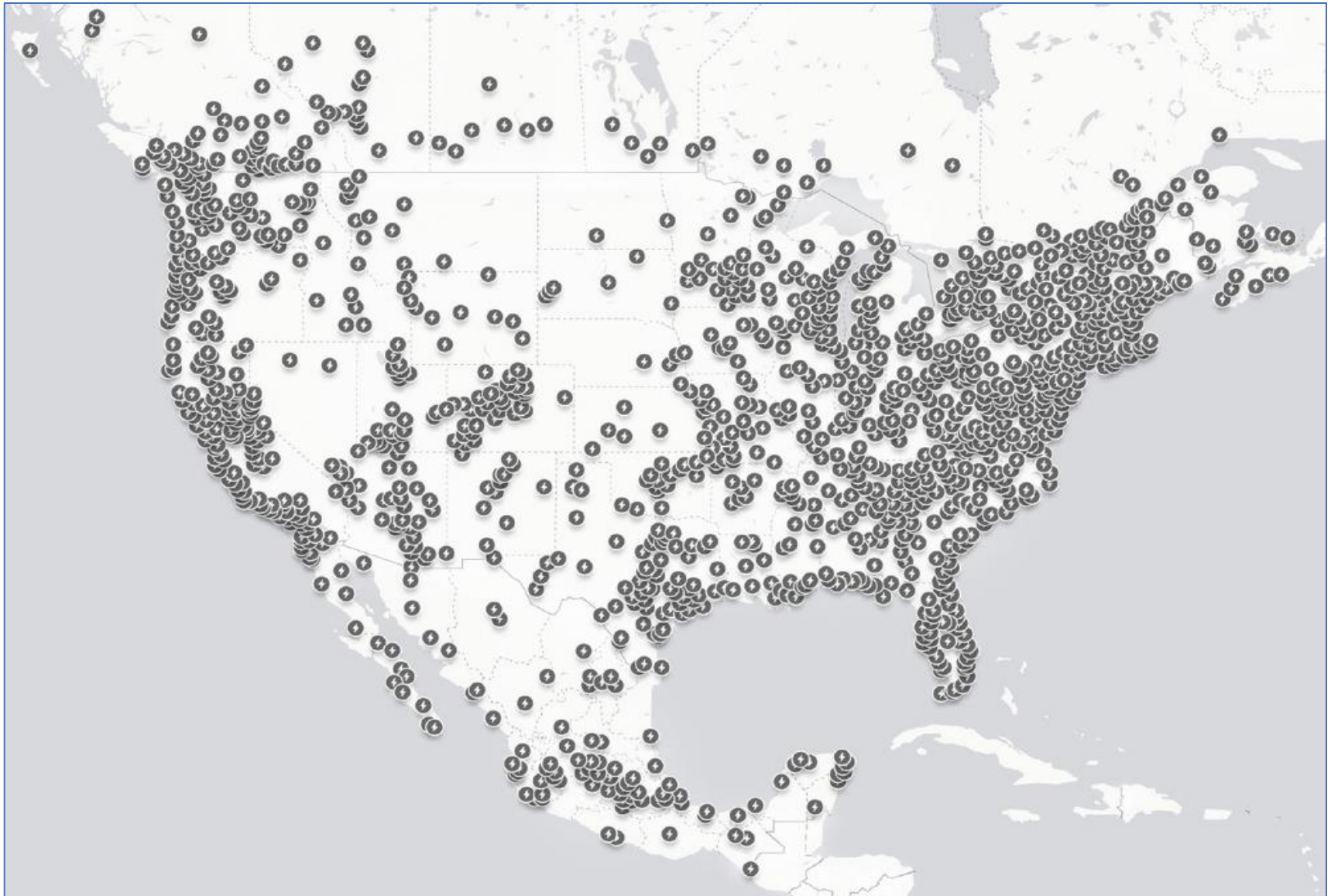
- Distance = 1074 miles; Time =18 hr 47 min; 57 mi/hr
- Charging duration = 1 hr 54 min; 565 mi/hr charging
- Driving duration = 16 hr 52 m; 64 mi/hr driving
- Averages: 134 mi/interval, 2.3 hr/interval, 14 min/charge
- **Supercharger cost = $46 (ICEV: 35 mpg & $4/gal=$123)**
- Superchargers' peak power: 2 @ 150-kW; 5 @ 250-kW

Blacksburg VA to Key West VA in a Tesla https://www.plugshare.com/trip-planner.html

There are 31 Superchargers on the route; it does not show several Superchargers a few miles off the route.

In plugshare you can pick the Superchargers you prefer; much like choosing a gasoline station for an ICEV.

Tesla “Destination” Level-2 (7-11 kW) Chargers

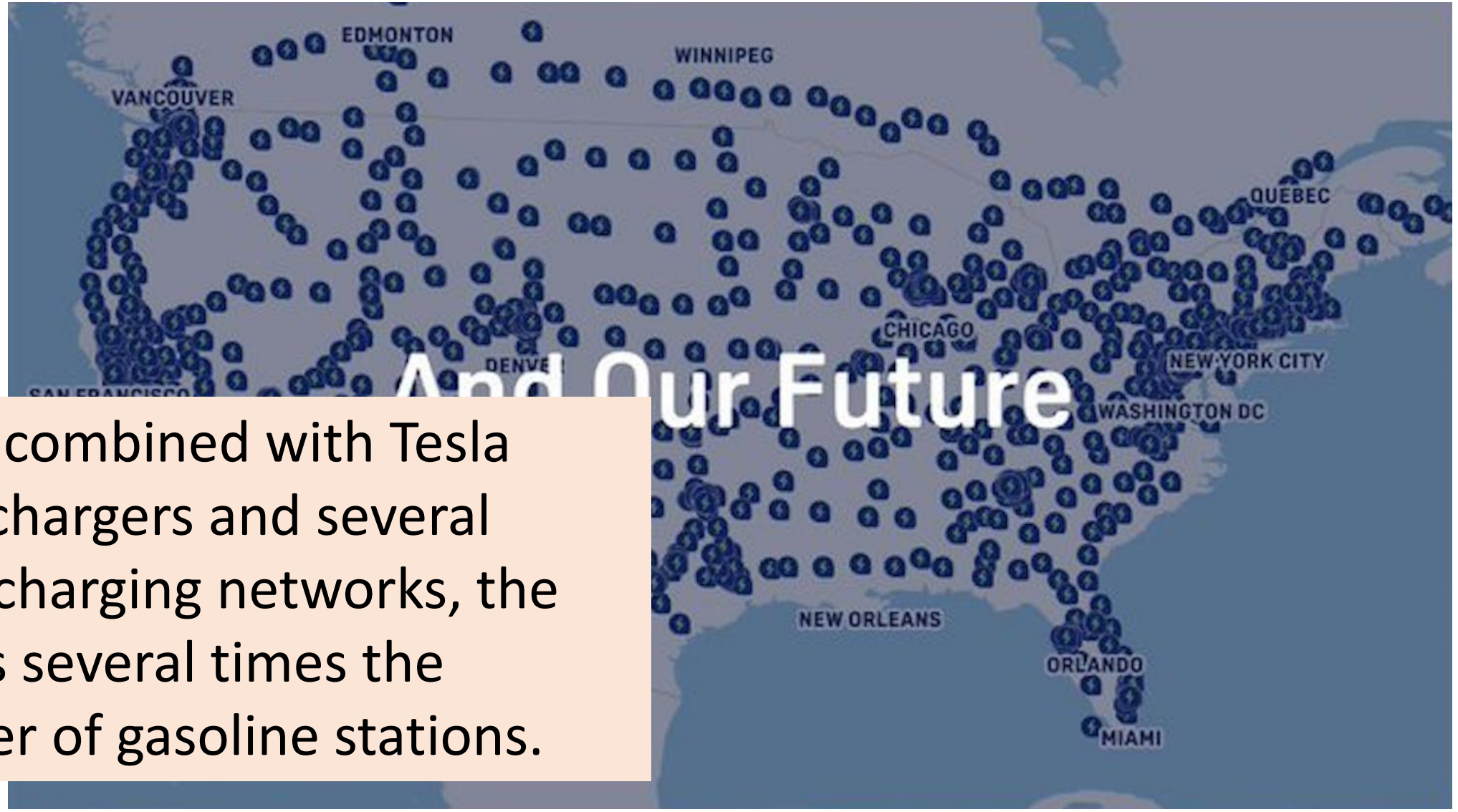


Tesla installs Tesla wall chargers for Teslas and J-1772 level-2 chargers for all BEVs to charge for free at hotels, parks, etc..

Electrify America Fast Chargers for all BEVs (Adapters are required for Teslas.)

Electrify America is building new charging stations at a fast pace.

Electrify America Fast Chargers for all BEVs by End of 2025

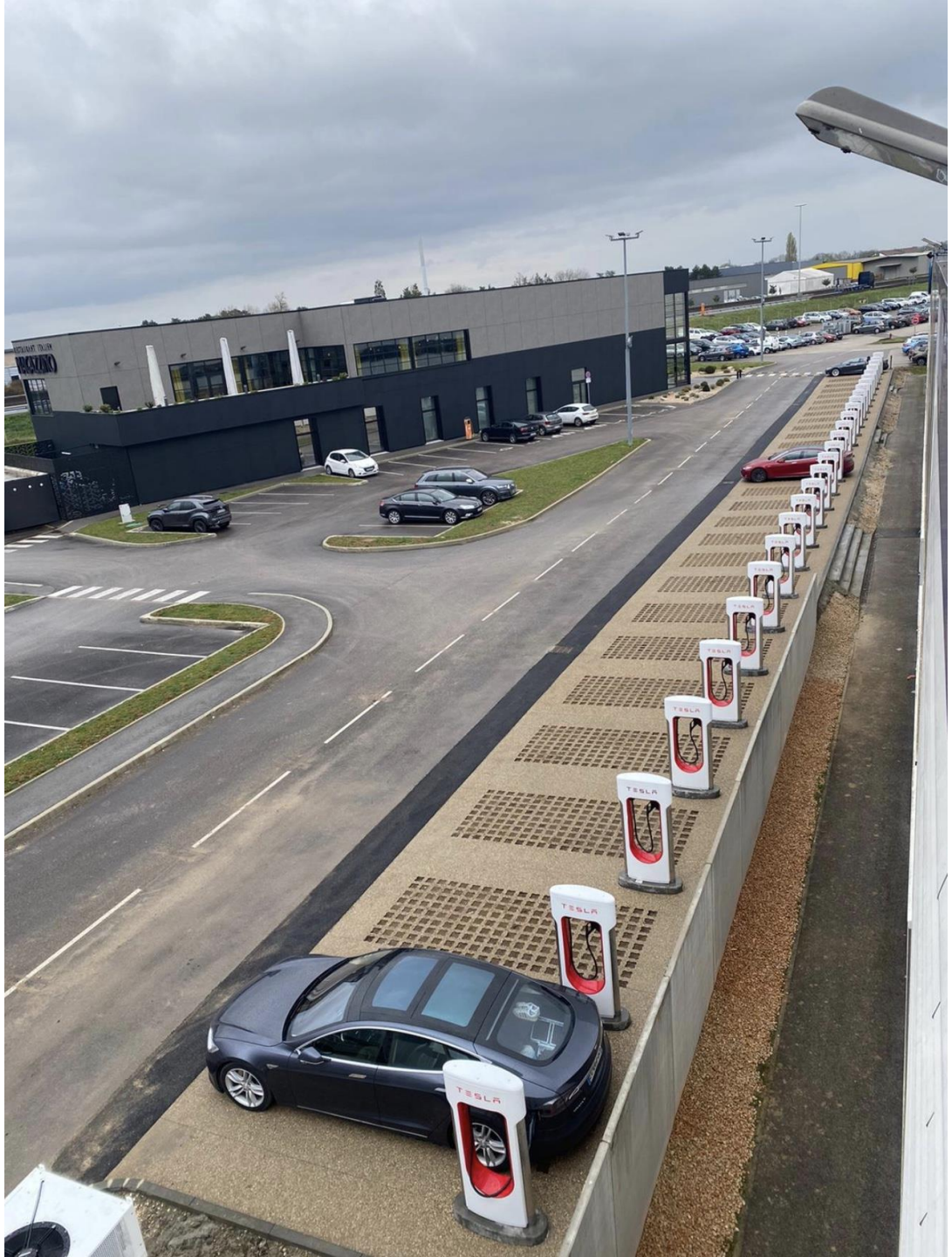


When combined with Tesla Superchargers and several other charging networks, the total is several times the number of gasoline stations.

Conclusion

- BEVs with **range > 250 miles** can travel on long trips with fast charging.
- **Tesla Superchargers** are more than sufficient to charge Tesla BEVs quickly; the number of Superchargers at **250-kW charging power** are increasing quickly. Future Superchargers may reach 350-kW power.
- Other fast charging networks are being built quickly for other BEVs.
- When **Tesla opens its Superchargers to other BEVs in 2022**, the availability of fast-charger stalls near highways will be several times the number of gasoline-station stalls.
- For **regional driving** most BEVs usually will be charged at level-2 chargers (7-11 kW) in **garages, driveways, work places**, shops, streets, parking lots and work places; **this greatly reduces the number of regional fast chargers needed compared to local gasoline stations**. Many such chargers already exist and are being installed rapidly.

Glen Allen Virginia Supercharger with 18 stalls.



28 Tesla Supercharger stalls in a row in France.

Tesla has 100 Superchargers in Shanghai China with a total of 1000 stalls!

Tesla Supercharger with 56 V3 (250 kW) stalls in Firebaugh California. Energy is solar!

Truths about Lithium-Ion Batteries in BEVs

- They lose capacity with usage, faster initially; Tesla loss after 200,000 miles ~10 %. My TM3LR has lost ~5.5% in 4 years & >47,000-miles. Degradation is steeper for the first 100,000 miles and then it slows down and stabilizes for the next 100,000 miles.
- Minimize capacity loss by keeping State of Charge (SOC) >0% and <100%. **A good rule for charging is 20% < SOC < 80%, except overnight before a long trip.**
- Time to charge from near 0% to 80% is about the same as charging from 80% to near 100%. **Charging is fastest at low SOC.**
- A BEV is about **10 times fire safer** than an ICEV:
  BEVs fires ~ **5/billion miles**; ICEVs fires ~ **55/billion miles**.

Truths about BEVs versus ICEVs

- EPA fuel economy: BEVs **> 100 MPGe**; ICEVs **< 50 MPG**
- **Electric kWh costs are slowly varying over time; gasoline gallon costs vary widely over time.** Electricity source is near infinite (solar & wind), gasoline petroleum source is finite.
- In most US locations, ICEV-fuel cost is about 3 times BEV-fuel cost.
- ICEVs have many more components and moving parts than BEVs; so **maintenance costs are considerably higher for ICEVs**.
- BEV manufacturing emits more carbon than does ICEV manufacturing, but much less in operation. **In US after driving a BEV for about 15,000 miles (Teslas about 3,500 miles). Over a typical car lifetime BEVs have much less carbon emissions than ICEVs.**

Least Expensive BEVs for Local Driving

2022 Nissan LEAF S

$7,500 federal tax credit

MSRP = $28,425 Range = 149 miles MPGe = 111

Least Expensive BEVs for Local Driving

2022 Chevrolet Bolt EV or EUV

No federal tax credit

MSRP = $26,595 Range = 259 miles MPGe = 120

Tesla Model 3

Consumer Reports: Tesla Model 3 is "most satisfying" car, more than Porsche or Corvette.

TM3 is managed by smartphone or RFID card or fob. Auto open and close with smartphone.

Average gasoline car in 2018: 25 MPG

Model	EPA Range (mi)	Efficiency (MPGe)	Price
Rear-Wheel Drive	267	132	$46,990
Long Range AWD	358	131	$57,990
Performance AWD	315	113	$62,990

TM3 had 8 Car-of-the-Year awards in 2018-20. Most American made car in 2021.

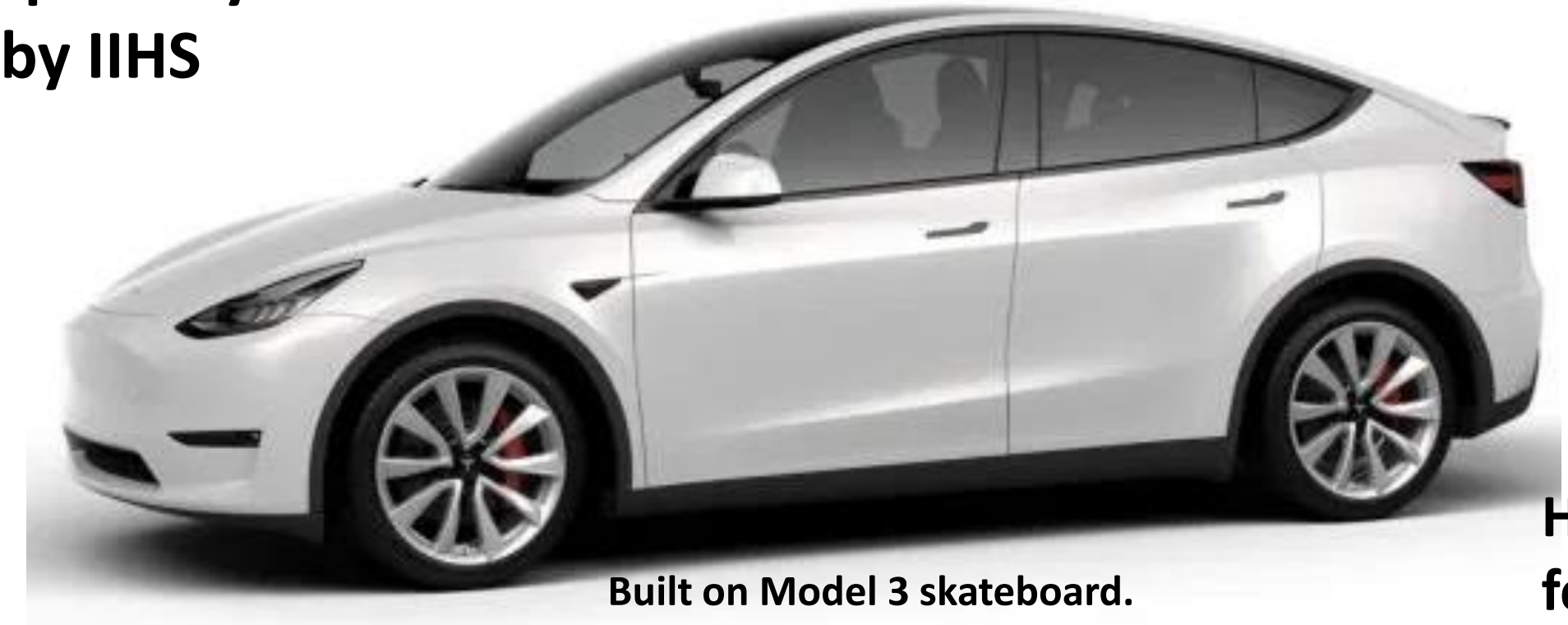
Autopilot software is included in all versions. Order online. If leased, returned to Tesla.

No current federal tax credit

US 2021 average price of a light vehicle was ~$40,000.

2021 & 2022 TMY top safety pick by IIHS

Tesla Model Y SUV



Built on Model 3 skateboard.

Model	EPA Range (mi)	Efficiency (MPGe)	Price
Long Range AWD	330	122	$65,990
Performance AWD	303	111	$69,990

No current federal tax credit

Has similar features as Tesla Model 3.

Tesla Gigafactories

- Fremont, California: 2010, Models S, 3, X, Y
- Reno, Nevada: 2016, mostly batteries, Semi
- Buffalo, New York: 2016, mostly solar panels (Tesla is an energy company.)
- Shanghai, China: 2019, Models 3, Y for Europe & Asia
- Brandenburg, Germany: 2022, Models 3, Y
- Austin, Texas: 2022, Models 3, Y, Cybertruck, Semi, Roadster

Ford Mustang Mach-E

Some Ford dealers have been adding high price increments to the MSRP, because of high demand and vehicle scarcity.

Federal tax credit = $7500

Model	EPA Range (mi)	Efficiency (MPGe)	Price
Standard Range RWD	247	100	$43,895
Standard Range AWD	224	93	$46,595
Long Range RWD	314	101	$48,700
Long Range AWD	280	97	$51,400
GT AWD	270	90	$55,595

Prices are rising rapidly due to scarcity, so these prices may be too low!

VW ID.4

Model	EPA Range (mi)	Efficiency (MPGe)	Price
Pro RWD	260	99	$39,995
Pro S RWD	250	97	$44,495
1st Edition RWD	250	97	$43,995
Pro AWD	249	97	$43,675
Pro S AWD	240	93	$48,175

Federal tax credit = $7500

Prices are rising rapidly due to scarcity, so these prices may be too low!

Hyundai Ioniq 5

Model	EPA Range (mi)	Efficiency (MPGe)	Price
SE Standard RWD	220	110	$39,950
SE RWD/AWD	303)256	114/98	$44,000
SEL RWD/AWD	303/256	114/98	$46,250
Limited RWD/AWD	303/256	114/98	$51,100

Federal tax credit = $7500

Prices are rising rapidly due to scarcity, so these prices may be too low!

Volvo XC40 Recharge

Federal tax credit = $7500

Range: 223 miles **MPGe: 85** **Price: $56,395**

Prices are rising rapidly due to scarcity, so this price may be too low!

Polestar 2 (Volvo subsidiary)

Federal tax credit = $7500

Range: 233 miles **MPGe: 96** **Price: $66,200**

Prices are rising rapidly due to scarcity, so this price may be too low!

Audi Q4 e-tron

Model	EPA Range (mi)	Efficiency (MPGe)	Price
40 RWD	250	78	$43,900
50 AWD	241	77	$49,900
Sportback AWD	241	77	$52,700

Federal tax credit = $7500

Prices are rising rapidly due to scarcity, so these prices may be too low!

BEV Plans of Some Legacy Car Companies

- **Ford**: Mustang Mach-E, F-150 Lightning, E-Transit; at least nine all-electric cars and car-based SUVs and at least three electric trucks, vans and larger SUVs. European lineup will be all-electric by 2030.
- **GM**: Chevrolet Silverado EV, GMC Hummer EV, Cadillac Lyriq; Chevrolet Bolt EV & EUV, Blazer EV, Equinox EV
- **VW**: ID-Buzz, ID-4, electrification with a goal to increase battery-electric vehicle (BEV) share out of the total sales (globally) to 20% in 2025, to 50% in 2030 and nearly 100% by 2040 in all major markets.
- **Chrysler**: Will only sell electric vehicles by 2028, Airflow
- **BMW**: iX, i4, i7, 4.5 million BEVs on roads by 2030
- **Volvo**: Our ambition is that around 50% of the cars we sell should be Pure Electric by 2025, XC40 Recharge

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- https://supercharge.info/changes
- https://www.electrifyamerica.com/
- https://www.evgo.com/

A pdf file containing the slides of this PowerPoint is online at **tinyurl.com/BEVsLongTrips**

My Anywhere-Bikes Rugged-Edition Etrike

- 500W 48V front-wheel motor.
- 749 Wh battery.
- 31? miles range with pedal assist.
- Weight: 83 lbs; with load: 400 lbs.
- $2,699 including delivery, 90% assembled.
- Owner manual.
- https://www.anywherebikes.com/products/anywhere-trike.
- I have a PowerPoint about etrikes: tinyurl.com/etrikescompare
  It describes several available etrikes.