Trends in Electric Vehicles

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ANL contributions sponsored by DOE Vehicle, Building Technology Programs

Clean Cities EV Educational Event

La Crosse WI, September 11, 2019 (8:45-12pm CDT)

Presentation Topics

1) What is Argonne National Lab and Interoperability Center?

2) EV charging history, New EVs, Electric vehicle charging rates

3) Context- Liquid Fuel Dispensing vs Electric ‘Fueling’

4) Example EVSEs/Displays (AC, DC); First Candidate Brands?

5) HB44 Dispensing Measurement Tools: ANL SmartLoadDAQ©

6) Question and Answer (during or after presentation)

What is Argonne National Lab and the EV-Smart Grid Interoperability Center?

ANL was designated as the first National Laboratory in 1946, initially formed to support Enrico Fermi's work (Univ. of Chicago) on the Manhattan Project. (CP-1 75th Anniversary)

Center for Transportation Research

Some Statistics

Budget: $760M
Staff: 3350
Location: Lemont IL
Area: 1700 acres
Multidiscipline research including energy, materials, computing, nuclear, bio, etc

What is Argonne National Lab and the EV-Smart Grid Interoperability Center?

ANL hosts the US EV-Smart Grid Interoperability Center, in conjunction with JRC in Ispra Italy, to develop and validate EV charging standards as well as research grid impacts

Smart Energy Plazas at bldgs 300 and 362

Some Statistics

50 AC EVSEs Site-wide

PV Fed Charging- 80kW

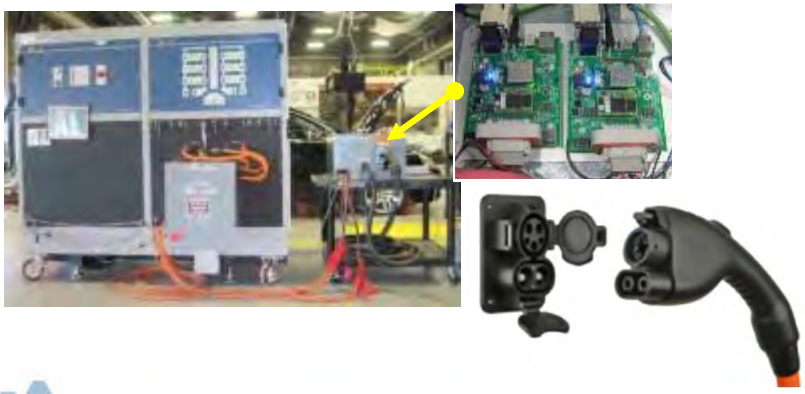
DC Fast Chargers: 25kW, 50kW, 200kW, 350kW

Wireless: 50kW

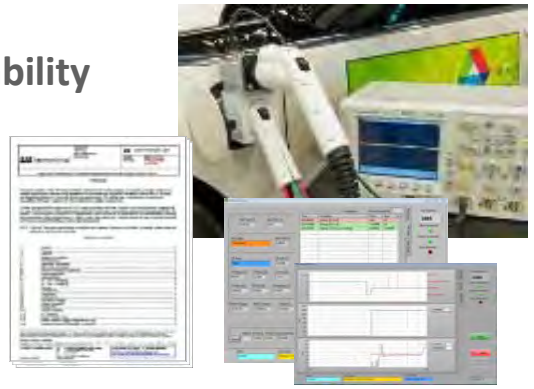
ANL EV-Smart Grid Interoperability Standards and Technology Development for EV Charging

SAE J1772-v6
PEV Compliance
Requirements, test equipment, procedures

SAE J2847/2-v2
DC Charging Communication
Requirements, test equipment, procedures, enabling technology



SAE J2953
PEV-EVSE Interoperability
Requirements, test equipment, procedures



SAE J2954
Wireless Charging
Requirements, standard test fixture, procedures

SAE J2847/6
Wireless Charging Communication
Test equipment, procedures, enabling technology

Electric Vehicle Charging 101

- **ALL** US electric vehicles can charge from AC sources via the SAE J1772 coupler (from 6A/120vac to 80A/240vac) {30A typ.}
- **Some** electric vehicles can accept DC power from an external charger (called DC Fast Charging); three couplers tied to specific manufacturers (Tesla only), CHAdeMO (Nissan), J1772-DC CCS (combo, everyone else); from 12kW to 400kW Chevy Bolt accepts 80kW, Tesla up to 120kW, Porsche ~400kW
- **SOON** electric vehicles will also include wireless charging receivers from 3kW to 11kW to 50kW, to 500kW+(heavy duty)

- **Commercial/MD/HD Vehicles:** Work in progress; pilot fleets in 2019, production 2020. SAE J3068 (480vac, up to 133kW); CharIN consortium coupler 1500vdc/3000A max (up to 4.5MW) for 30 minute turn around of trucks loading, buses on route

Charging Couplers and Charging Rates (up to 350kW)

Type of Charging	Level 1 – 110V (~1.4kW)	Level 2 – 220V (~7.2kW)	DC Fast Charger (50kW)	Tesla SuperCharger (140kW)	Extreme Fast Charging (350kW)*
Charging Station 101	Provides same electricity as a regular electrical outlet	More powerful than Level 1 charging	DC current directly supplied to vehicle	Only available for Tesla vehicles	Provides significantly faster charge rates than anything else on market
		Comprises the majority of stations in the U.S	Commonly adds 40 to 60 miles of range in ~20 minutes	Offers fastest charging rate currently available	
Range Gained per Hour of Charge	3-5 miles	25 miles	100 miles	330 miles	787.5 miles
Time to Charge for 200 miles	40 hours	8 hours	2 hours	36.55 mins	15.25 mins

COMBO 2 (EU) (CCS) COMBO 1 (US) CHAdeMO (Japan) GB/T (China) Tesla (AC/DC)

Rediscovering What Others Have Advocated in the Past, Implemented Today w/New Technology

Need: 150A DC coupler for 'wide adoption of PEVs'….

Delivered: 100+ years ago- 30,000 BEVs used this coupler in 1913

Figure 3.25: 150 A charging plug with handle[101]

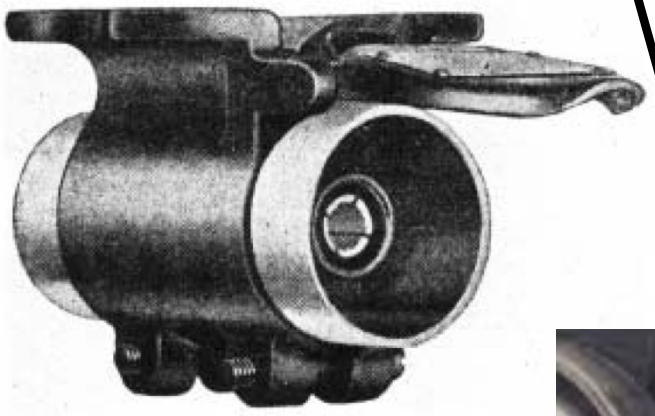
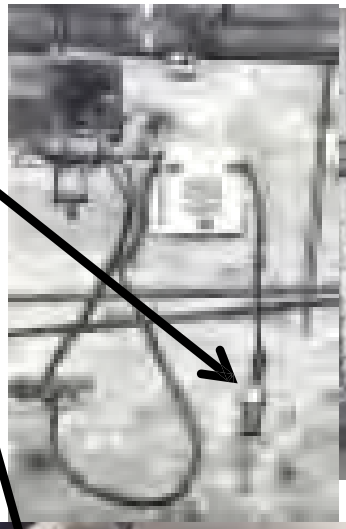


Figure 3.26: 150 ampere-hour (sic) charging receptacle[102]

Need: Indoor and Curb Side Charging Station

Delivered: 100 years ago- 46k miles on Electric Taxi Fleet in Detroit



Indoor Charging Stations

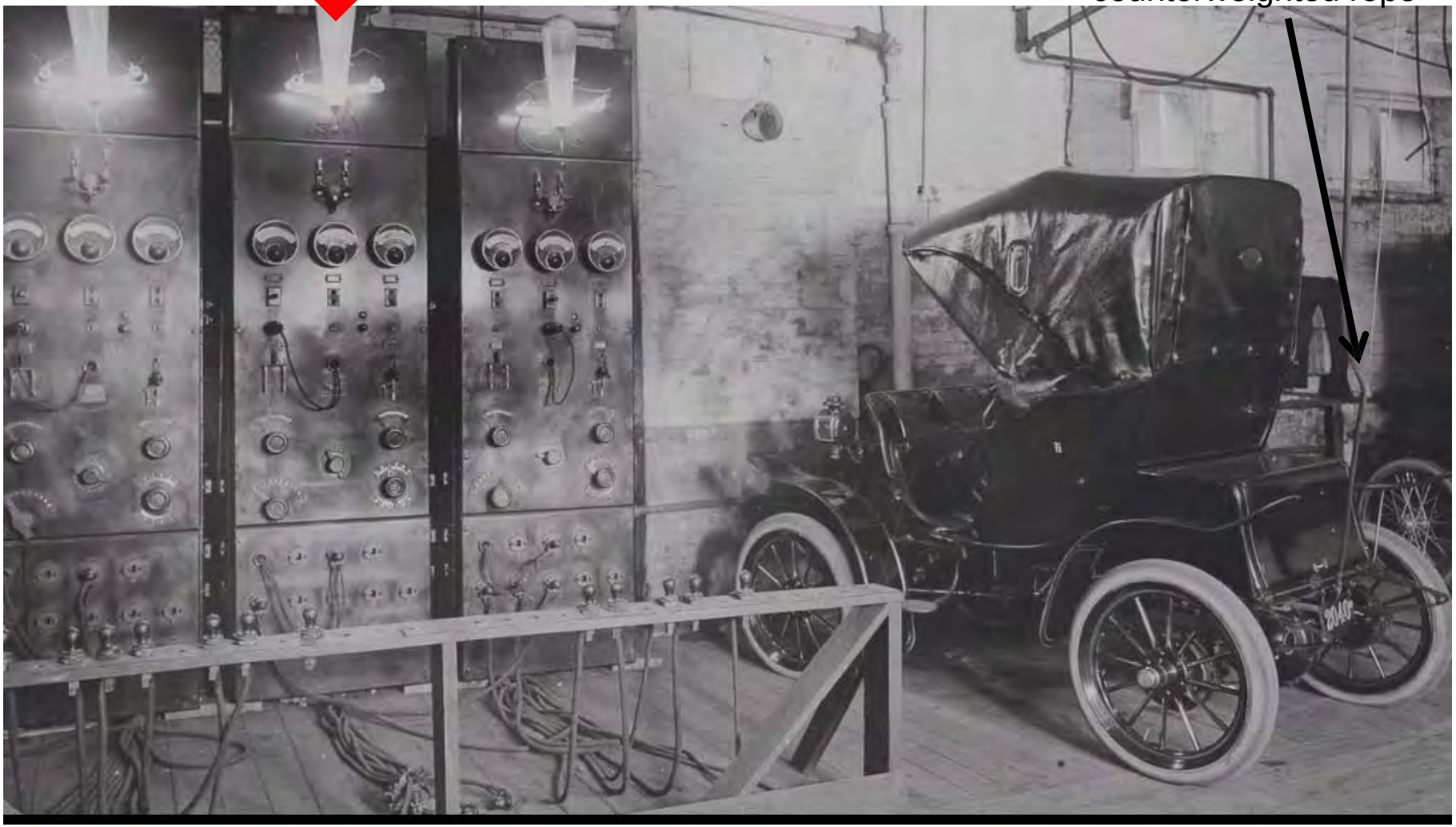
Outdoor Curb-Side Charging Port

8

Central Garage DC Charging stations (~1910)

(bright light on top is rectifier tube)

Note cable management counterweighted rope



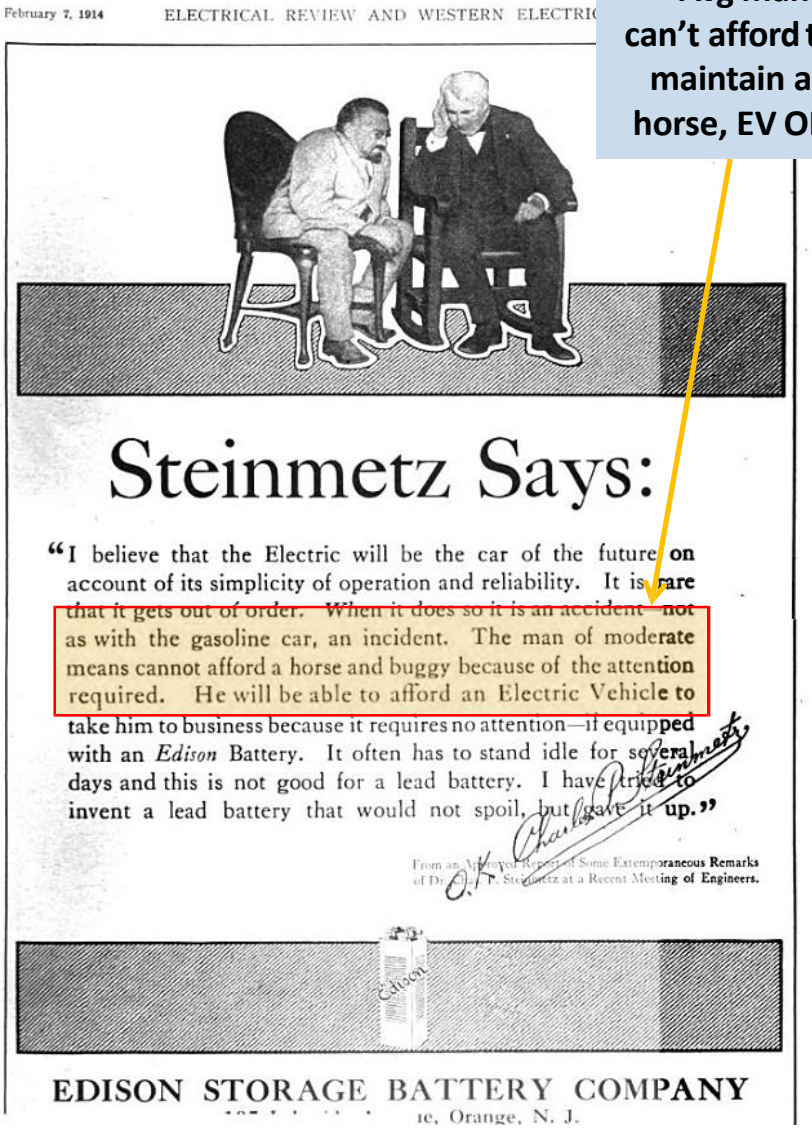
110 Year Old Value of Electric Transportation

8000 Chargers in use, 1910

6kW DC Off-board Charging in 1910

Also called 'Wattstation'

~ Avg man can't afford to maintain a horse, EV OK



Historical Perspective On EV Batteries- GM Electrovair (~50 Years Ago)

- Batteries in front and rear of vehicle, rear drive motor and rear electronics/cooling

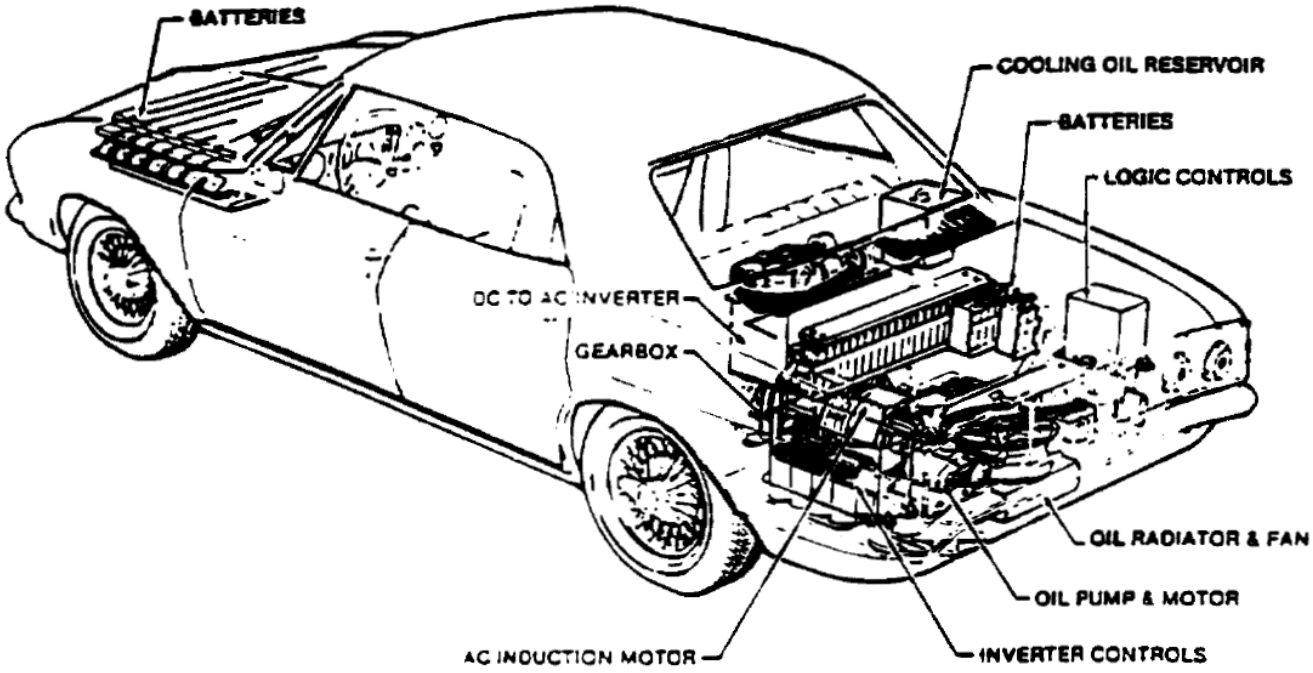
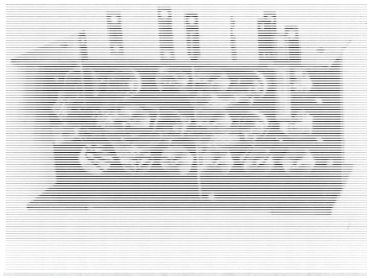
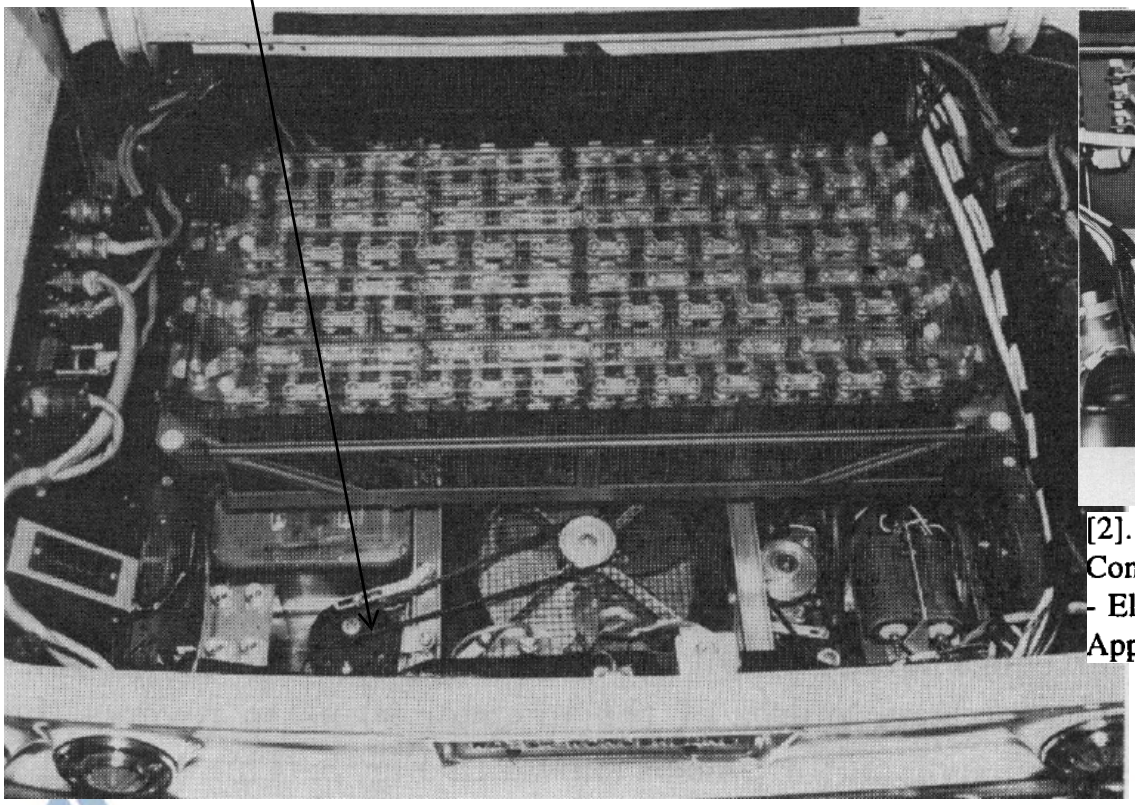


Fig. 1 CUTAWAY VIEW OF GENERAL MOTORS ELECTROVAIR



Electrovair Electronics Packaging
532V Silver Zinc Batteries

- Batteries in center of rear of Corvair, electronics wrapped on the sides, motor below (belt driven fan)



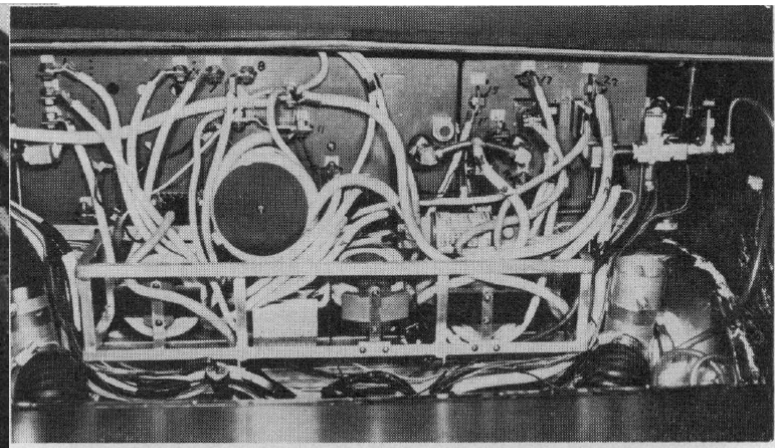


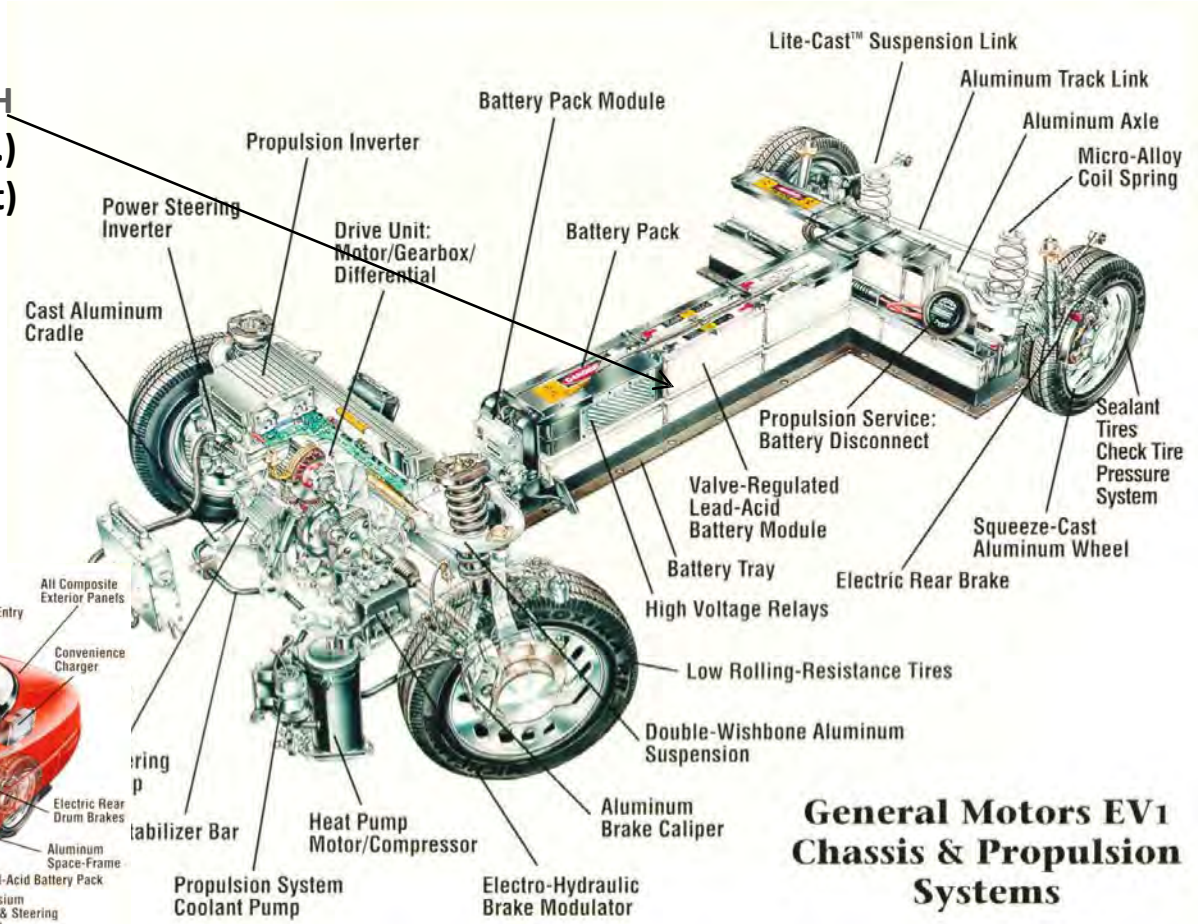
Fig. 12. Layout of modulator and inverter.

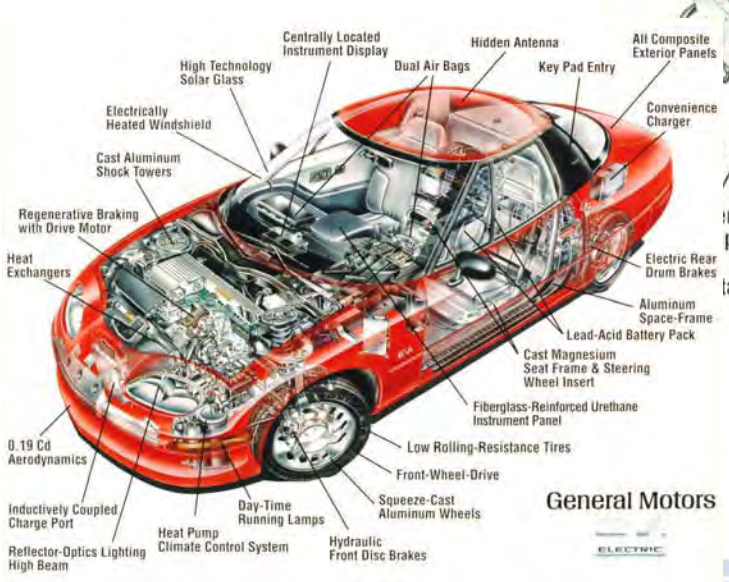
[2]. T. Salihi, P.D. Agarwal et al, " Induction Motor Control Scheme for Battery Powered Electric Car (GM - Electrovair I)", IEEE Trans. on Industry and General Applications, Sept./Oct. 1967, PP. 463-469.

GM EV-1 Powertrain
~ 25 years ago

Gen 1 Lead Acid 1310lb, Gen 2 NiMH

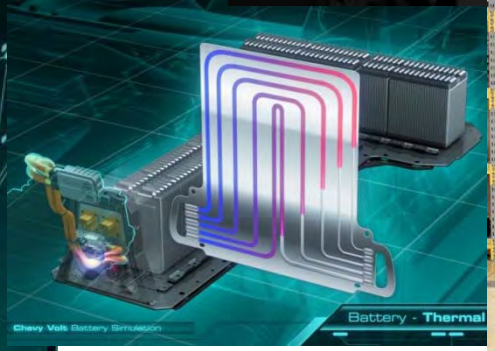
- **PbA- 16.5kWhr (3086 lbs curb wt.)**
- **NiMH- 26.4kWhr (2908 lbs curb wt)**





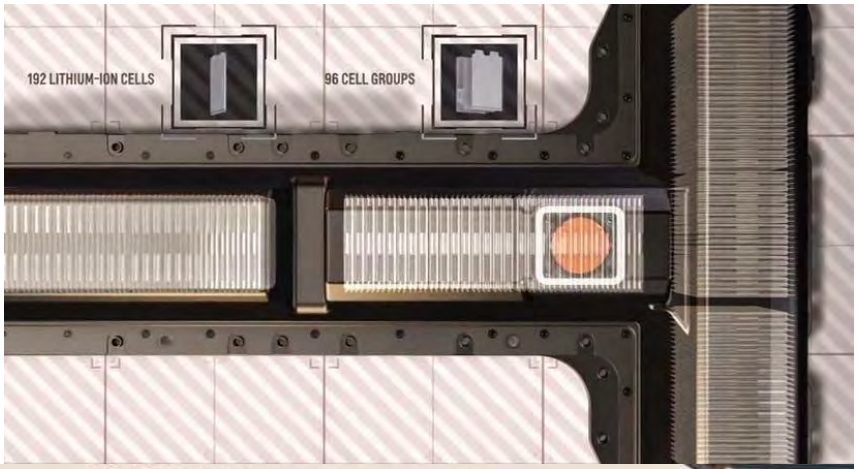
Chevy Volt EREV/PHEV (Gen 1)
~ 10 years ago

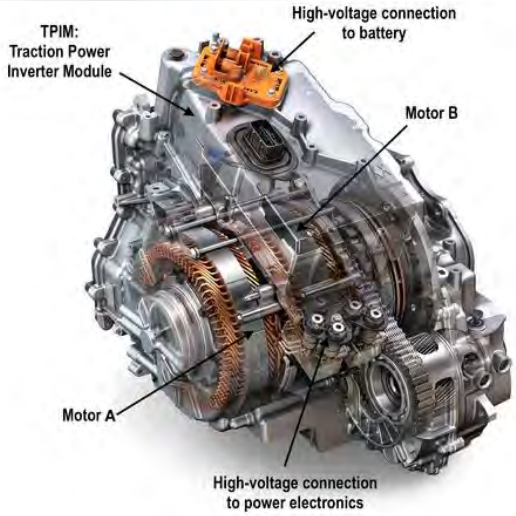
288 cells, 9 modules, 345v/45Ahr, 16kWhr, 435lb



Chevy Volt EREV (Gen 2) ~ 3 years ago (Oct 2015- Feb 2019)

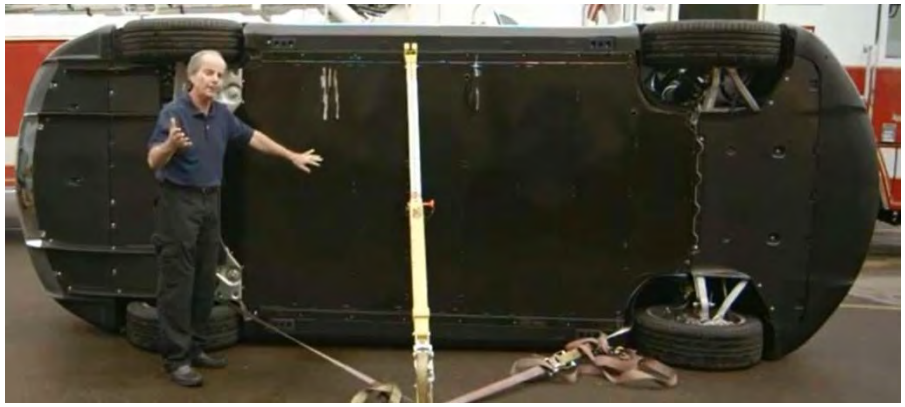
192 cells, 96 Cell groups, 18.4kWhr, 403lb

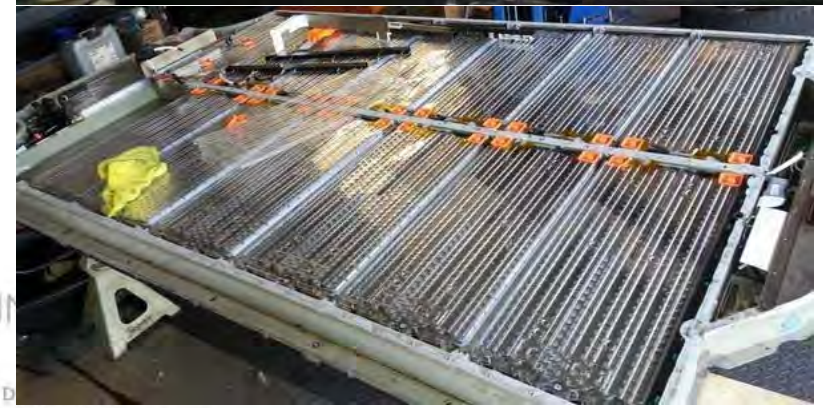




Tesla Model S, X- 100kWhr~Today

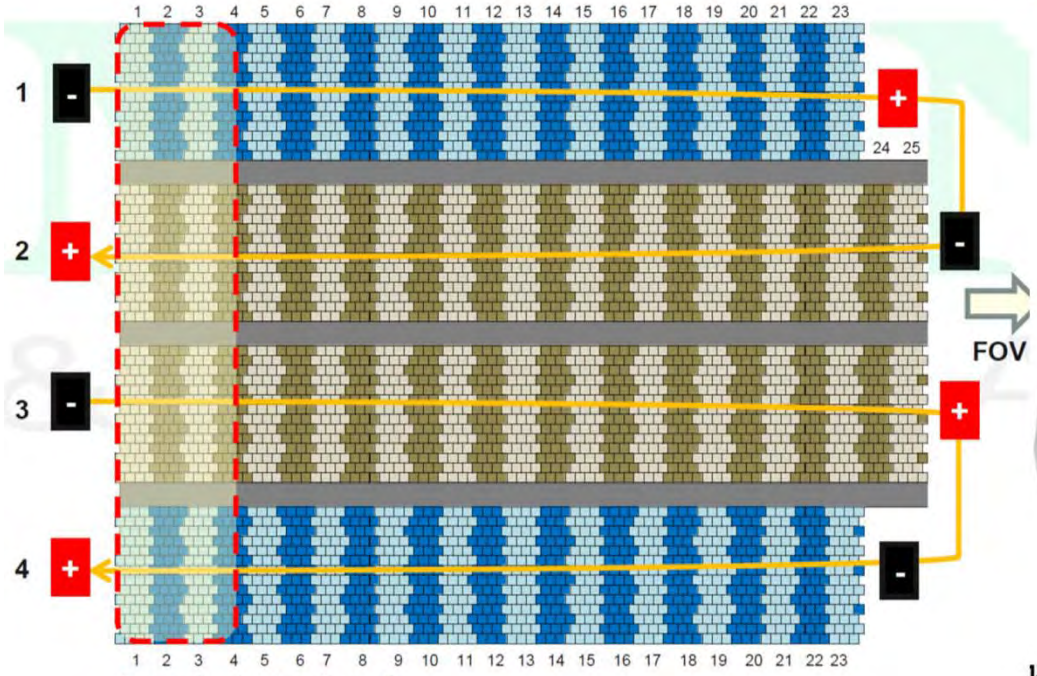
16 modules w/516 18650 cells; 8256 cells total; 400v/250Ahr=100kWhr

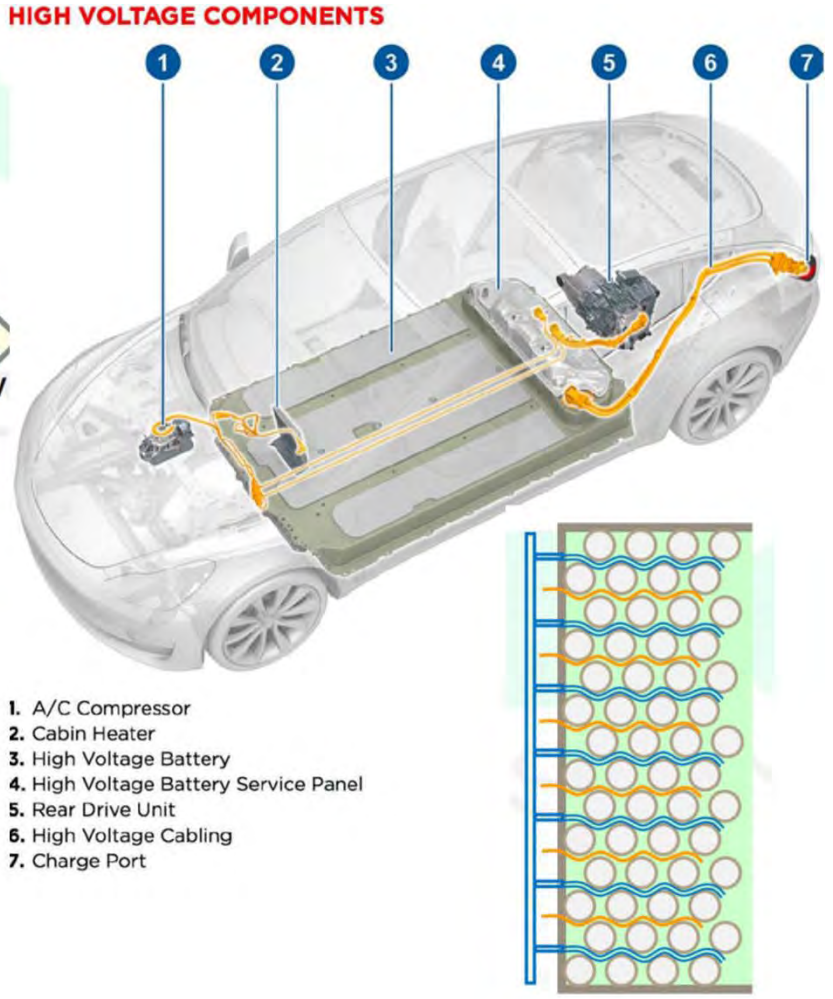




Tesla Model 3~Today

4416 cells (2170 size) in 4 modules; 23/25 bricks of 46 cells in each module; each row contains micro extrusion cooling channels between the cells; 480kg, 350v/214Ahr=75kWhr

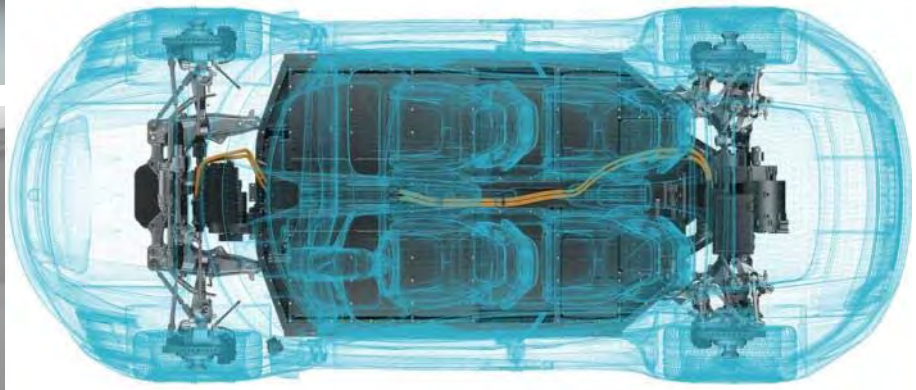




Flood of New Electric Vehicle Models Announced - VW Group claims all 300 product line vehicles with electric variants by 2030; 80 more by 2025 (6 years)

Porsche Taycan (under $200k) - 350kW Charging 600hp, dual motor (800vdc) 500km range

0-200kph 12 sec, 0-60mph 3.5 seconds; 350kW charging, emotion camera, gesture input, hologram

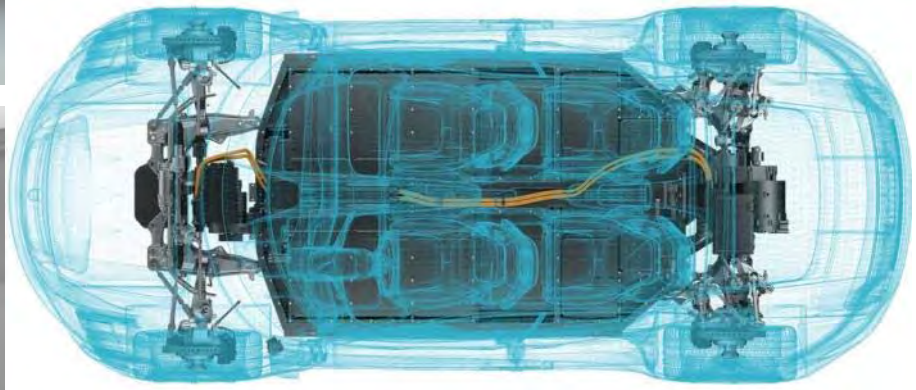


VW ID R; (Pike's Peak) Racing Improves the Breed 2425lbs/1100kg, 680hp/500kW, 480lbft/650 Nm resulting in 0-62mph=2.25 sec.; Record is 8:57 for 12.42miles/19.99km; 82.8mph average (tight turns)

Flood of New Electric Vehicle Models Announced - VW Group claims all 300 product line vehicles with electric variants by 2030; 80 more by 2025 (7 years)

Porsche Mission E (eta 2020)- 350kW Charge Rate 600hp, dual motor (800vdc) 500km range

0-200kph 12 sec, 0-60mph 3.5 seconds; 350kW charging, emotion camera, gesture input, hologram

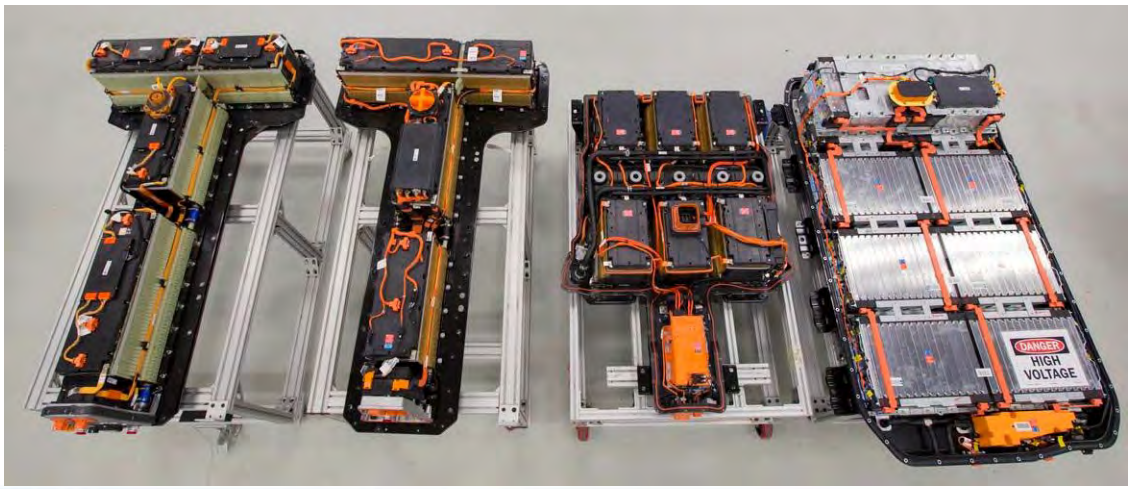


Battery replacement life and costs; BEVs-Hybrids Degradation different than failure

Typical EV Battery Warrantees; 8 years/100k miles; 10 years/150k miles (state by state)

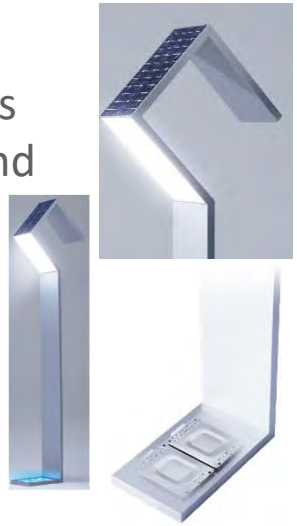
- Internet price references:
  –**Chevy Bolt** (60kWhr), list price of full pack is $15,734; GM notes that after 7+ years, there have been no Chevy Volt battery pack degradation warranty claims
  –**Nissan Leaf** (2018)- Refurbish program w/4R Energy; 24kWhr-$2736, New exchange price; 24 kWh-$5928; 30 kWh-$7269; 40 kWh-$7479
  - Ford Focus EV($10k in 2012, $8500 in 2018)
- Battery degradation is not failure; (Nissan 2015 law suit settlement; replacement of 2011-2012 Leaf packs, due to misleading limits on thermal/fast charge operation

GM Battery Packs:
Gen1-Gen Volt
Spark EV
Bolt EV



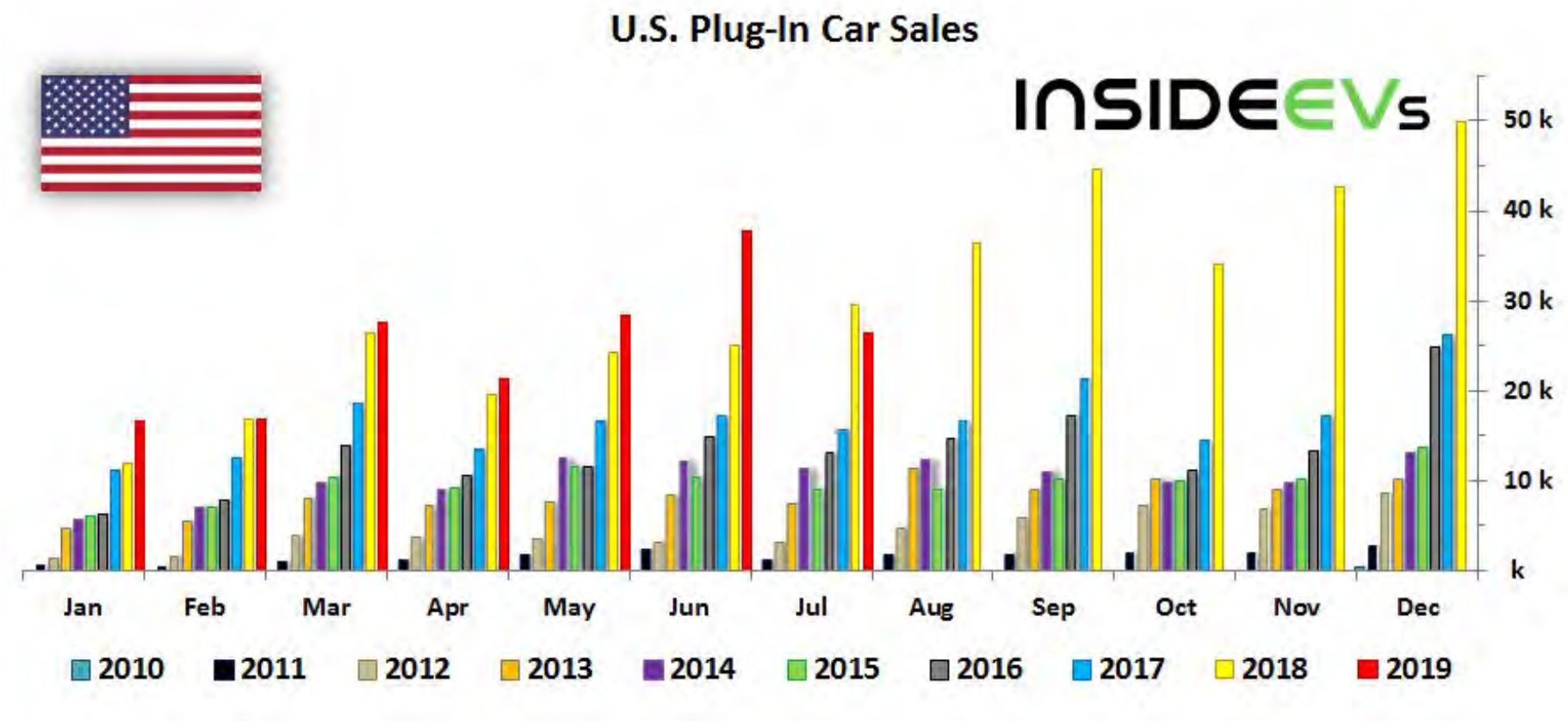
Battery Secondary Use Standards- Assessing Health, Repurposed Assets

- SAE J2997 Committee formed to standardize procedures and definitions on dealing with secondary use batteries; including stationary storage and repurposing applications

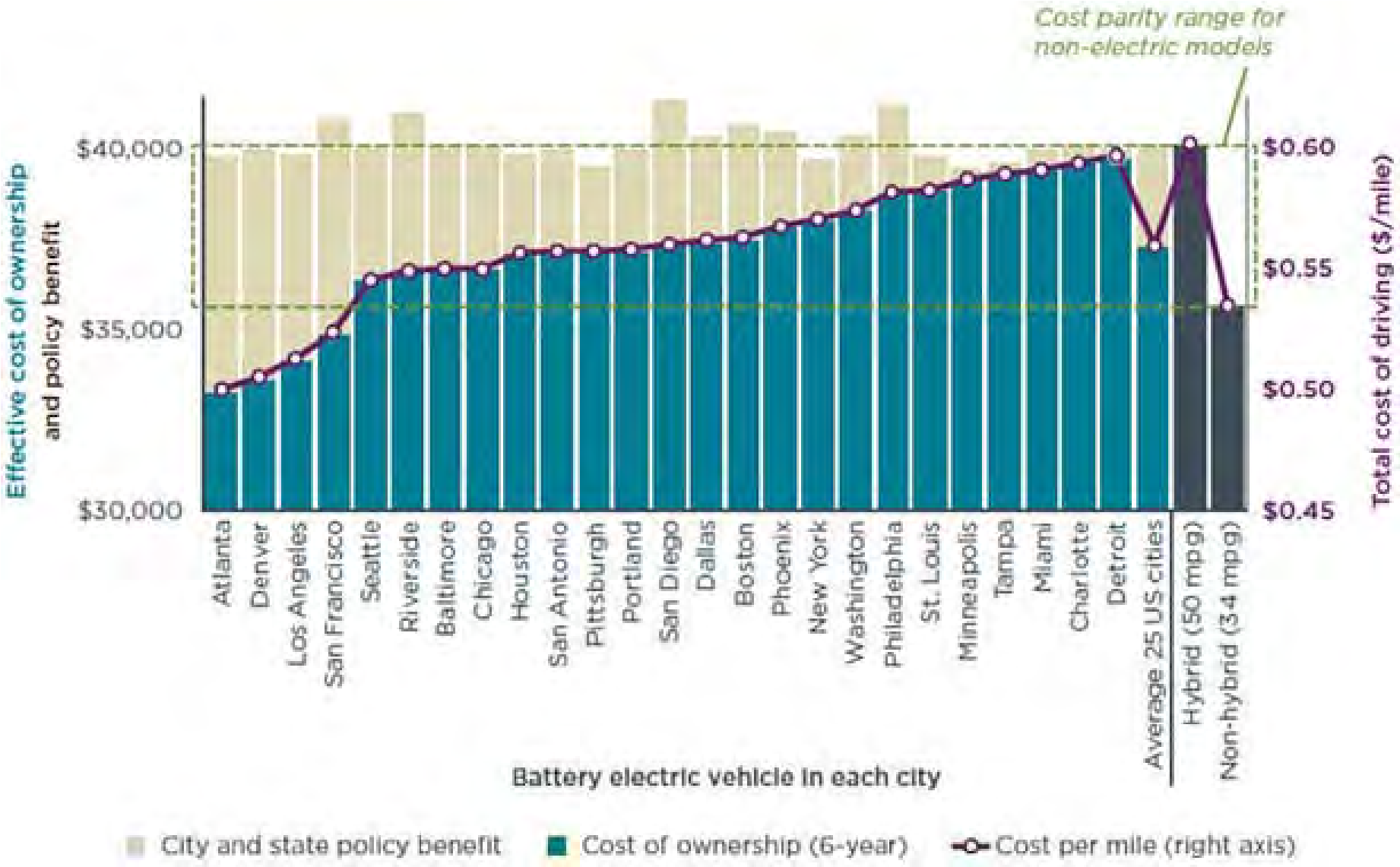


- ‘Reborn Light’ working with Nissan/4R Energy to PV/LED Light poles
- Spiers New Technology, packaged Leaf packs for EV charging;
- RE-STOR by Connected Energy co-located peak shaving for DC charging

US EV Sales: >1 Million total in ~10 years



Cost Parity Comparison of EV, PHEV, Hybrids, ICEs

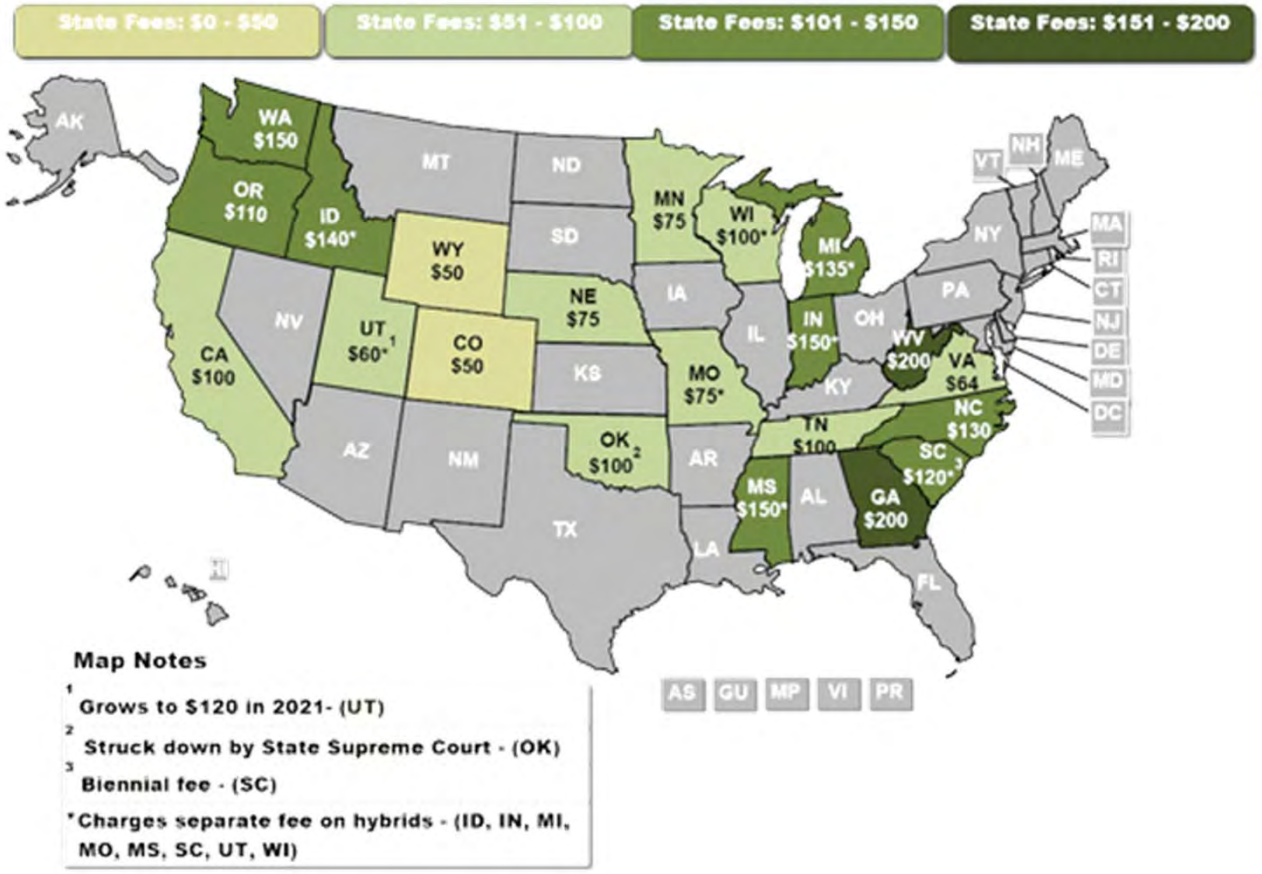


Total Cost of Ownership; Pre-Owned EV Options

- Used-car shopping site ‘Shift’ reports 4% of sales in 2019, triple that of last year.
- EVs account for less than 2% of new car sales in the US
- In 2018, Americans bought 17.3 million new cars and 40.2 million used ones.
- Used Nissan Leaf and Fiat 500e EVs often sell for under $10,000 ($30k MSRP)
- https://www.wired.com/story/now-used-car-lot-great-electric-vehicles-cheap/

Total Cost of Ownership- EV Registration Fees (extra fees to replace road repair fuel tax revenue)

- 20 states now have special fees for EVs; double that of just two years ago
- WI- $100 extra ($75+county taxes); already paying sales tax on electricity
- https://www.eenews.net/stories/1060126901

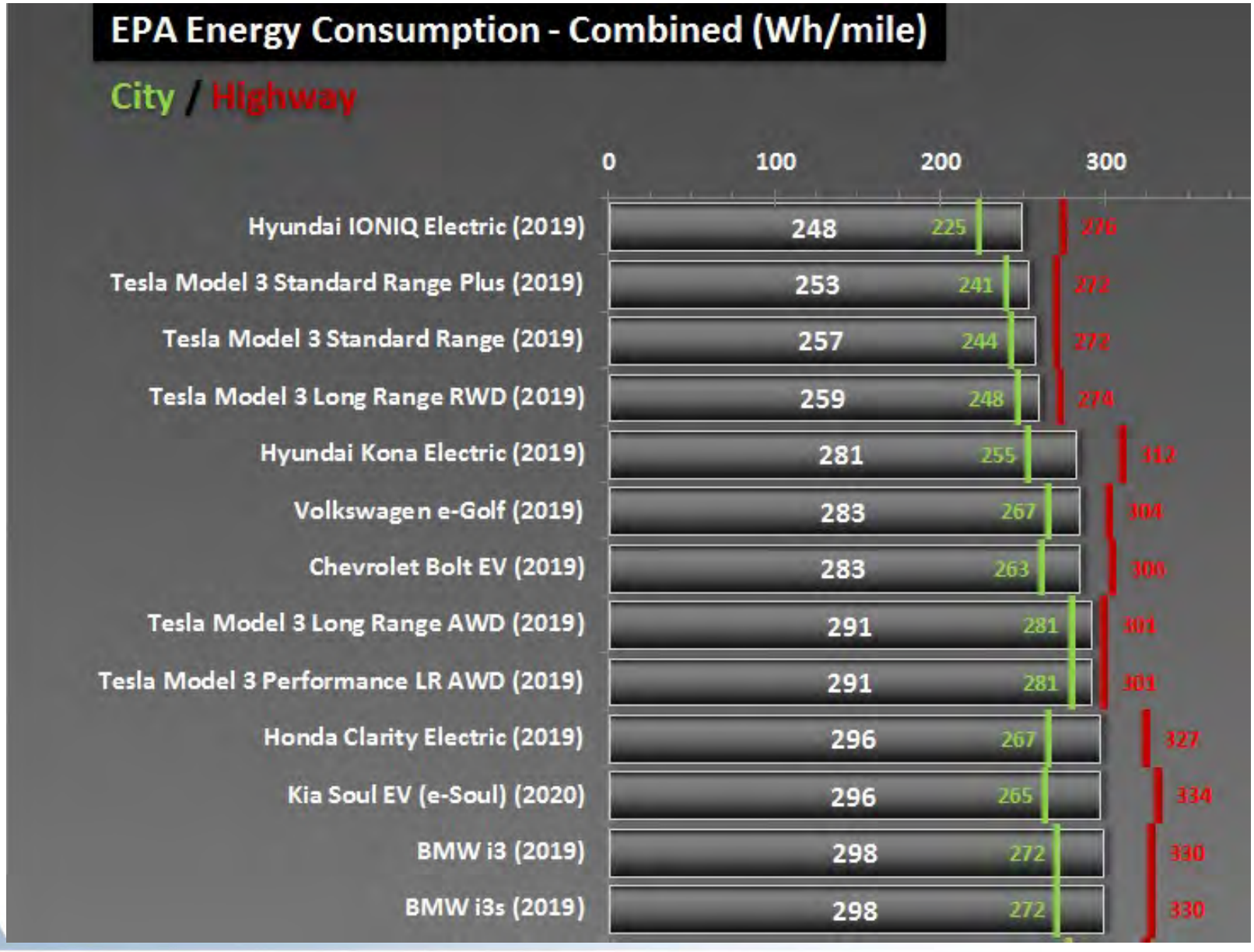


Battery Electric Vehicles for Sale in 2017
Eff., Range, Battery Capacity, Charging Rates

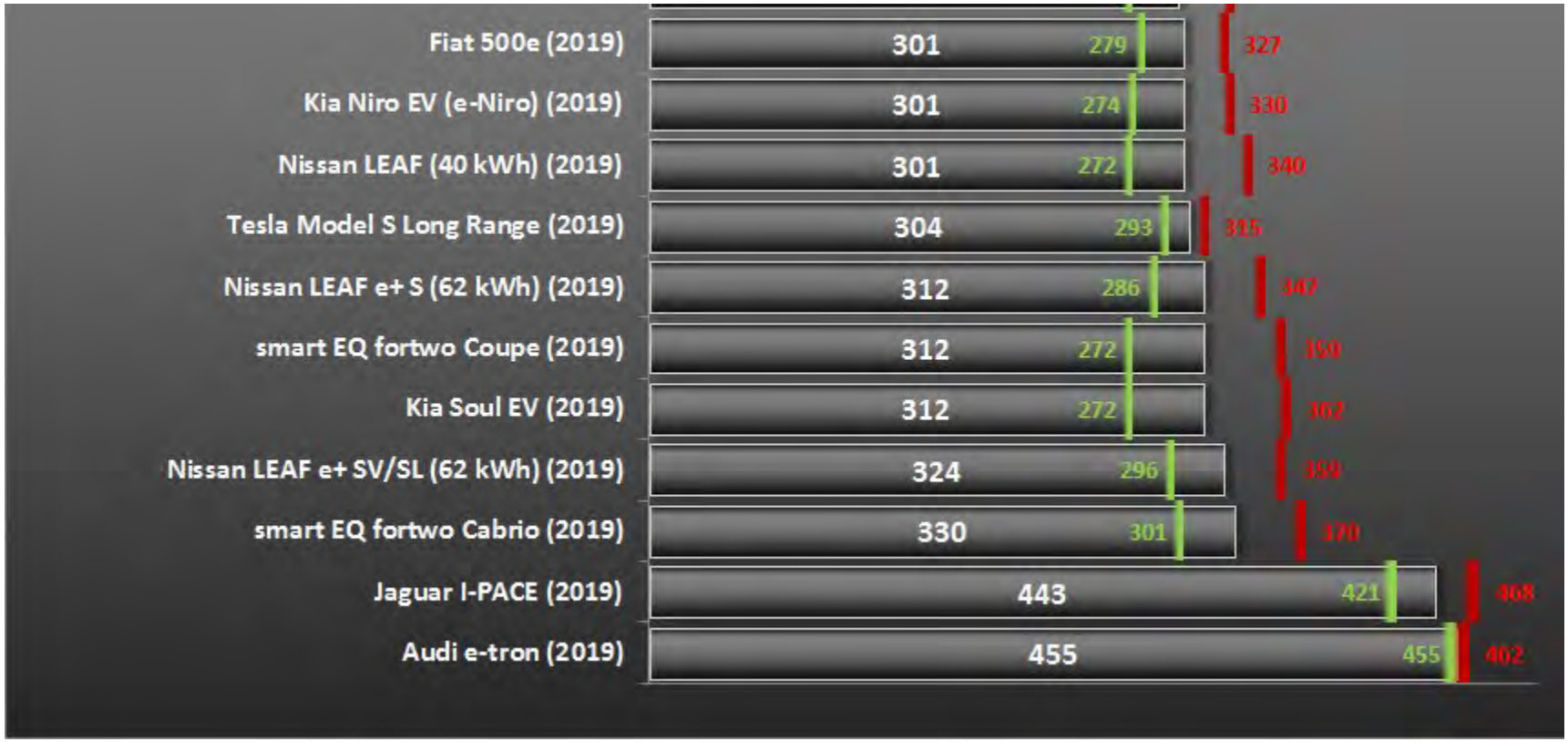
Brand	Model	Capacity kWhr	Charge rate-AC	DC Type	ZEV Miles	AC Whr/ mile	MPGe©	MPGe(city)	MPGe(hwy)
Hyundai	Ioniq	28	7	CCS?	124	**250**	**136**	150	122
BMW	i3 (60Ahr)	22	7.7	CCS	81	270	124	137	111
Chevy	Bolt	60	7.2	CCS	238	280	119	128	110
VW	e-Golf	24	7.2	CCS	83	280	119	126	111
BMW	i3 (94Ahr)	33	7.7	CCS	114	290	118	129	106
Nissan	Leaf	30	6.6	Cdm	107	300	112	124	101
Fiat	500e	24	6.6	NA	84	300	112	121	103
Mitsubishi	iMiEV	16	3.3	Cdm	62	300	112	121	102
Ford	Focus EV	23	6.6	NA	76	310	107	118	96
Kia	Soul EV	27	6.6	Cdm	93	320	105	120	92
Tesla	Model S-60D	60	10-19.2	TSC	192	320	104	101	107
Tesla	Model S-75D	75	10-19.2	TSC	240	330	103	102	105
Tesla	Model S-P100D	100	10-19.2	TSC	315	350	98	92	105
Tesla	Model S-P90D	90	10-19.2	TSC	270	350	95	92	100
Tesla	Model X-75D	75	10-19.2	TSC	220	360	93	91	95
Tesla	Model X-60D	60	10-19.2	TSC	176	360	93	91	94
Tesla	Model X-90D	90	10-19.2	TSC	257	370	92	90	94
Tesla	Model X-P90D	90	10-19.2	TSC	250	380	93	89	90
Tesla	Model X-P100D	100	10-19.2	TSC	289	390	86	81	92
Mercedes	B250e	28	10	CCS	85	400	84	85	82

Data compiled from www.Fueleconomy.gov search tool and various automotive websites

Comparison of Vehicle Range, Energy Consumption



Comparison of Vehicle Range, Energy Consumption



Miles per Charging Time Comparison; Vehicle Dependencies, Charging Equipment Dependencies

- SAE Working Group on Charging Rate Reporting Methods Standard

Real Data: miles added vs. time

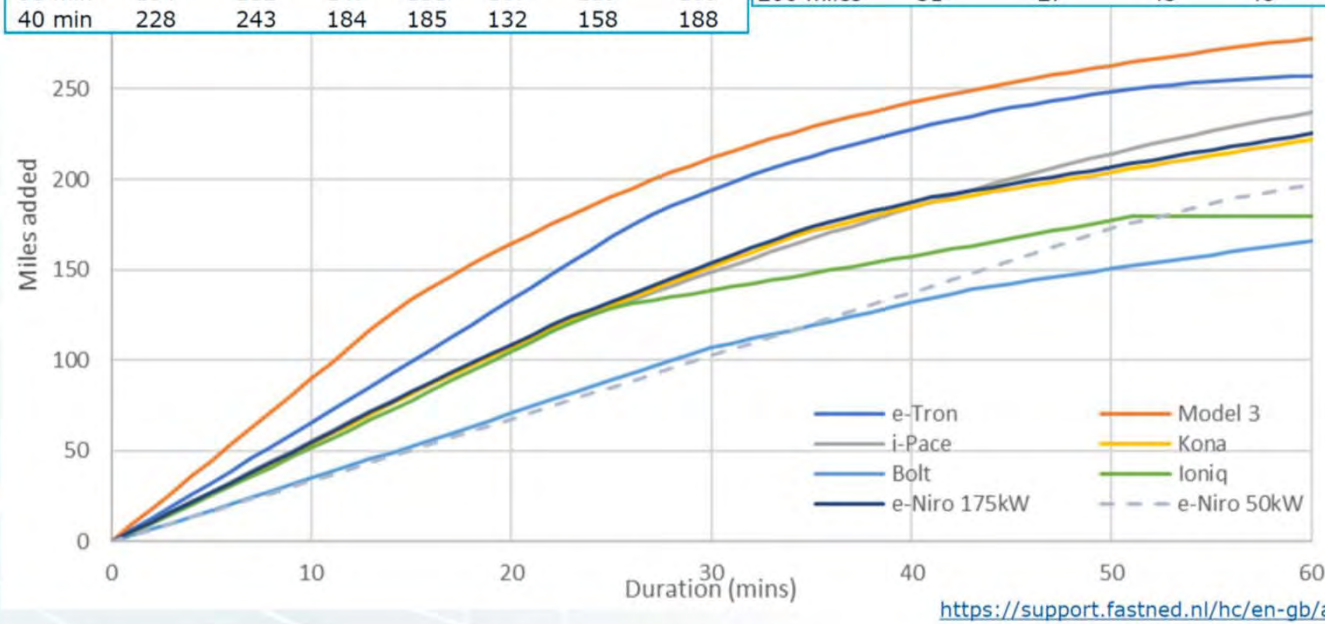
Vehicle Metric

MILES ADDED IN FIXED TIME

	e-Tron	Model 3	i-Pace	Kona	Bolt	Ioniq	e-Niro
5 min	32	45	27	27	17	26	27
10 min	66	90	55	54	35	51	55
20 min	133	164	107	107	71	105	109
30 min	194	212	149	151	107	139	153
40 min	228	243	184	185	132	158	188

TIME TO FIXED DISTANCE

	e-Tron	Model 3	i-Pace	Kona	Bolt	Ioniq	e-Niro
50 miles	8	6	9	9	14	10	9
100 miles	15	11	18	19	28	19	18
150 miles	22	18	30	30	50	36	29
200 miles	31	27	45	48	88	n/a	46



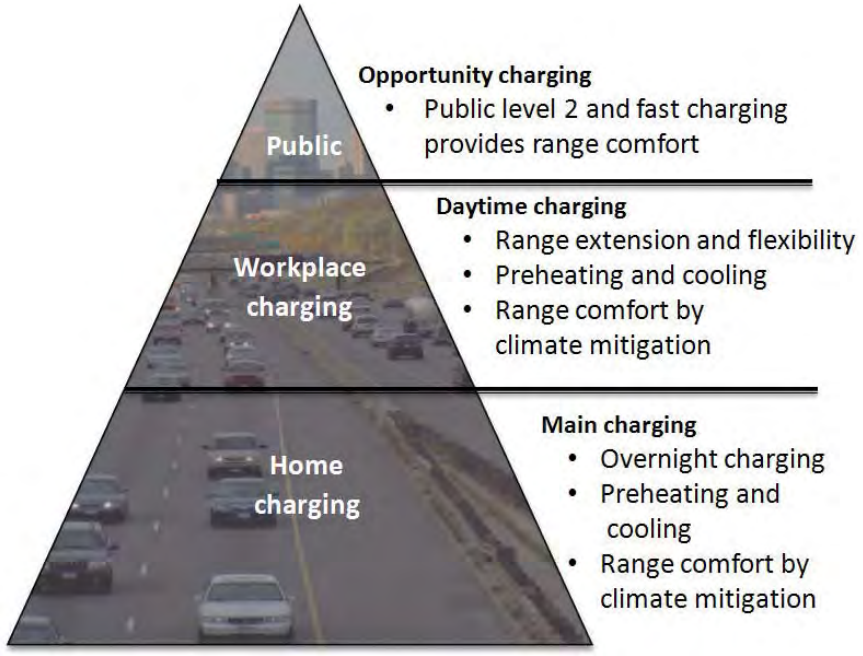
Note: model started at 10% SOC

Data extracted from published Fastned data. Cars tested on "175kW" charger→ charger is no the limitation for any of these vehicles

https://support.fastned.nl/hc/en-gb/articles/115015420127-175-kW-fast-chargers

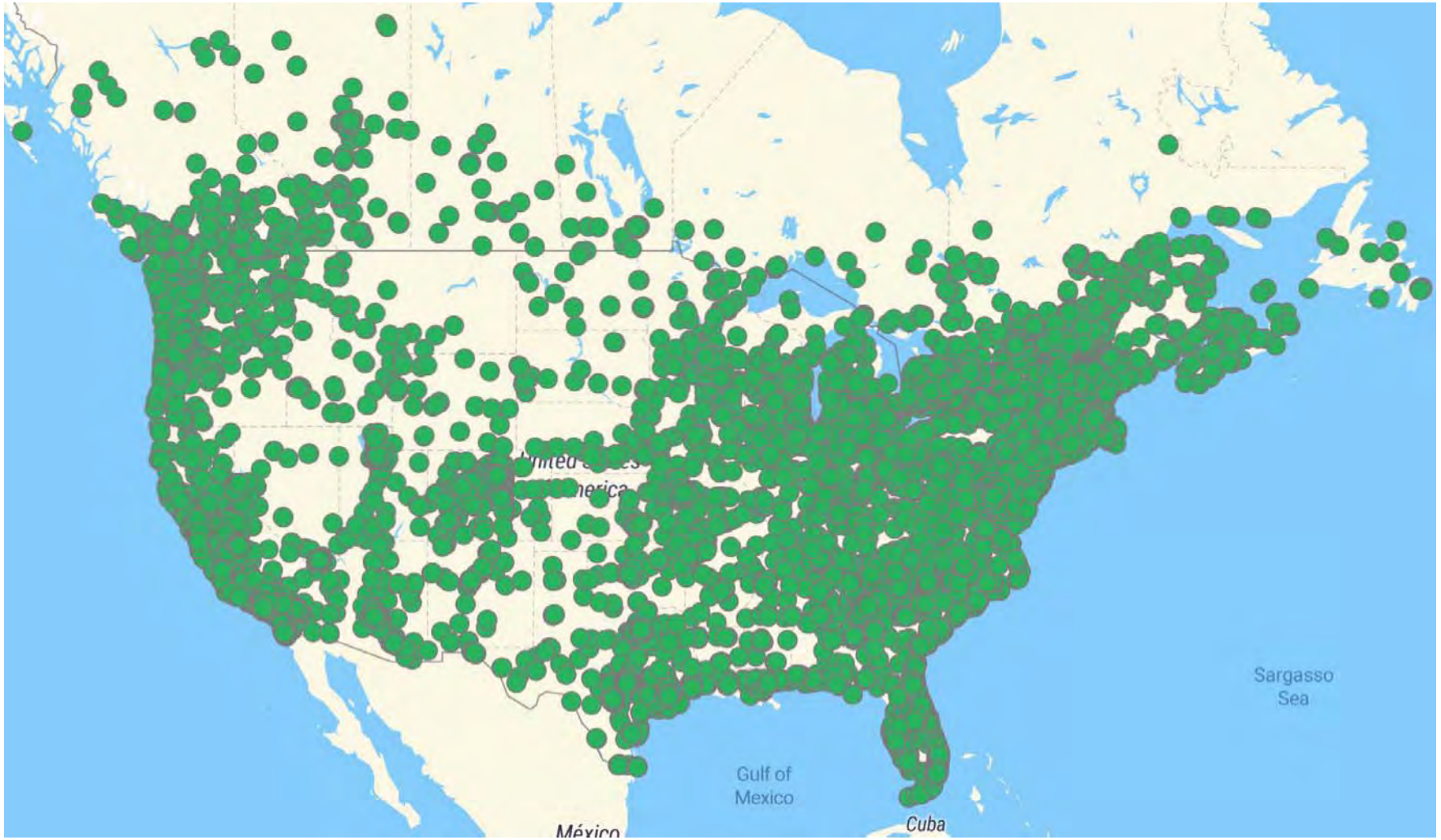
EV Charging Infrastructure- Dwell Time Impacts Charging Rate and Cost, Commercial Transactions

http://www.workplacecharging.com/



AFDC Based Map of EVSE Deployment; ~27,500 stations

https://afdc.energy.gov/fuels/electricity_locations.html#/find/nearest?fuel=ELEC



HB44-3.40 'Point of Sale': Analogy to Liquid Fuels and Residential Electricity Delivery

SAE J2836/1 Use Case Figures:

- **Red line** is liquid fueling point of sale.
- **Green line** is utility/premise 'point of sale' at the premise meter; edge of premises
- **Blue line** is at the tip of the conductive charging for vehicle electricity dispensing