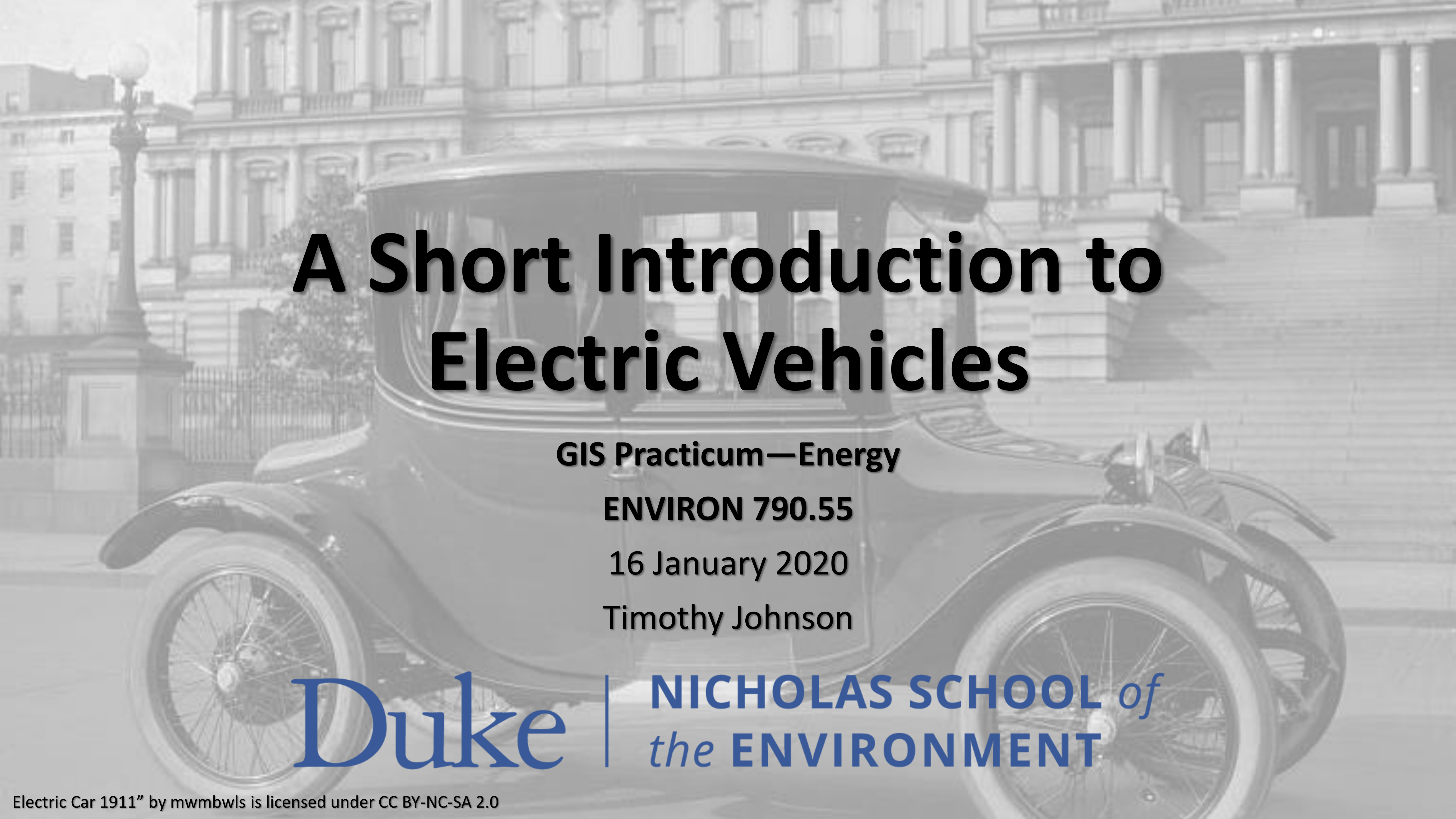

A Short Introduction to Electric Vehicles

GIS Practicum—Energy

ENVIRON 790.55

16 January 2020

Timothy Johnson

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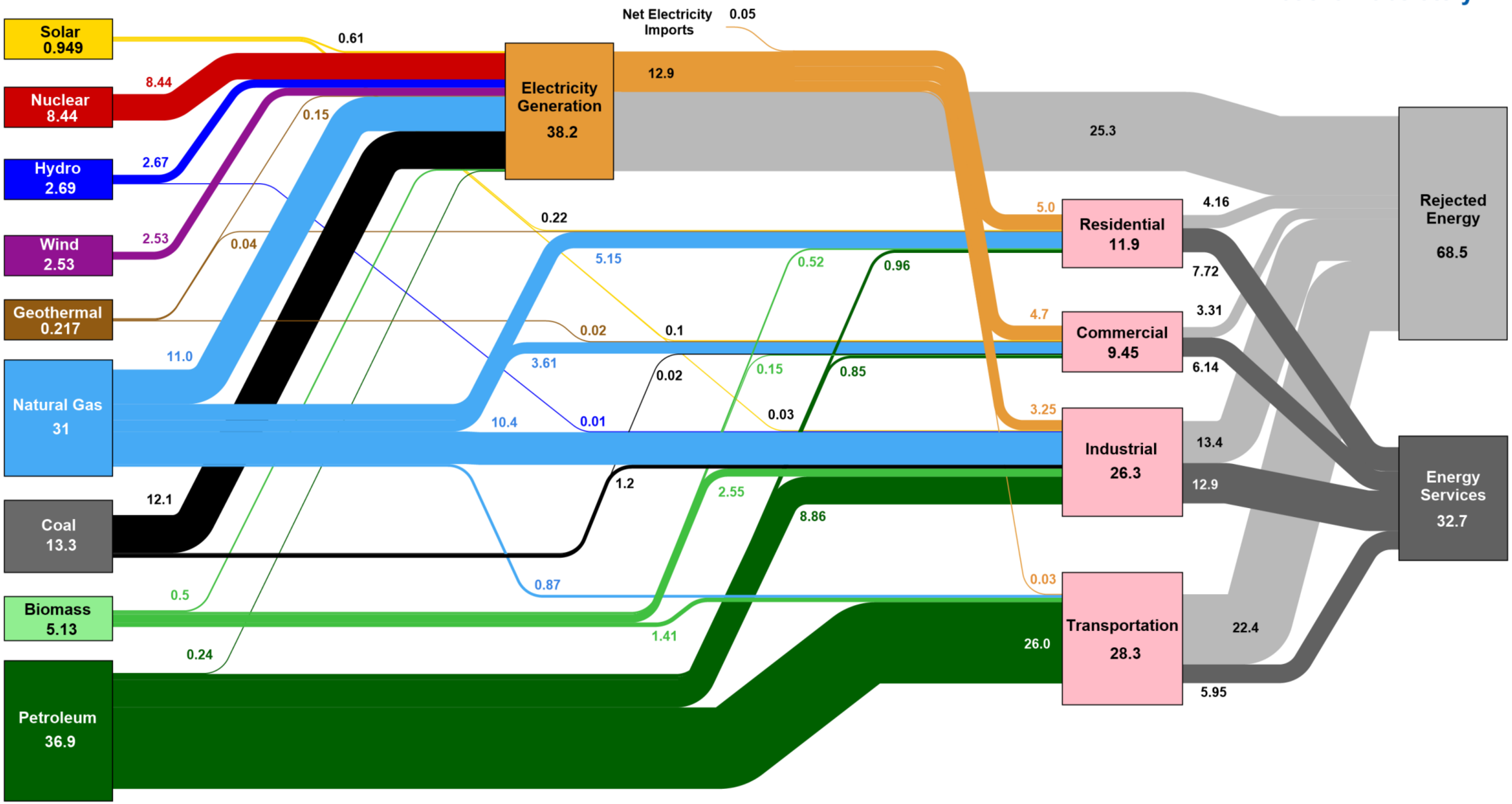
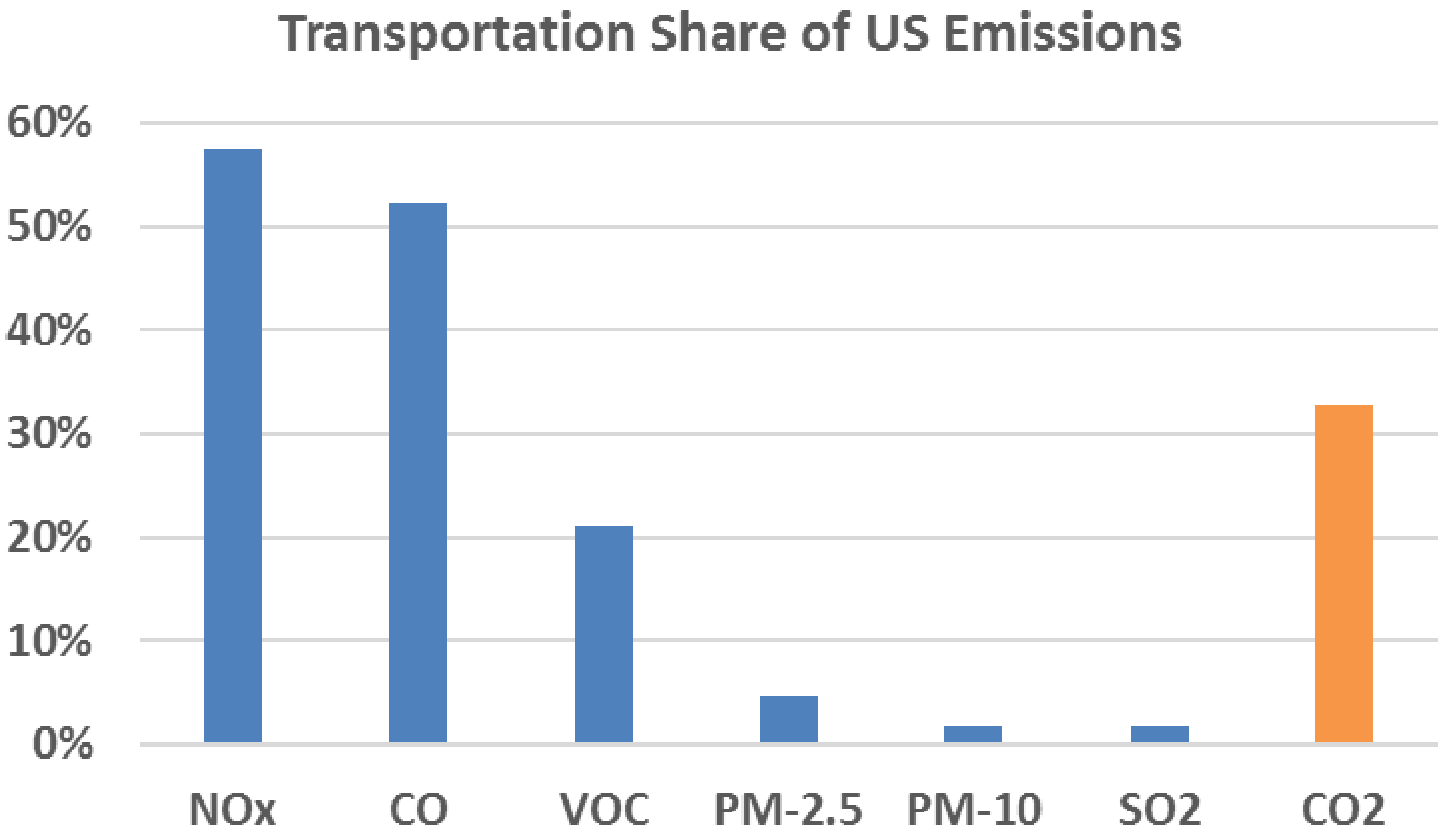
Estimated U.S. Energy Consumption in 2018: 101.2 Quads

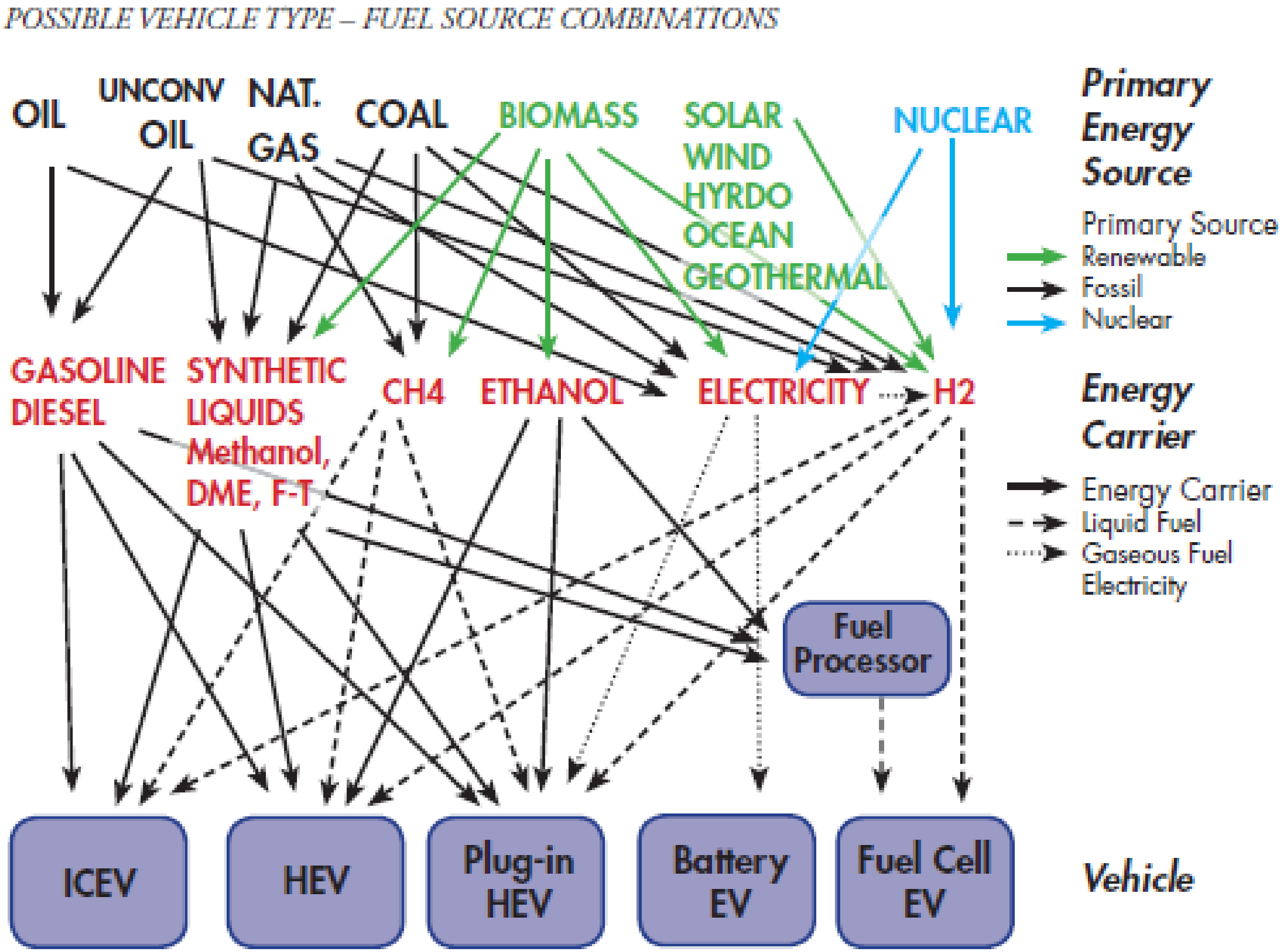


Source: LLNL March, 2019. Data is based on DOE/EIA MER (2018). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527



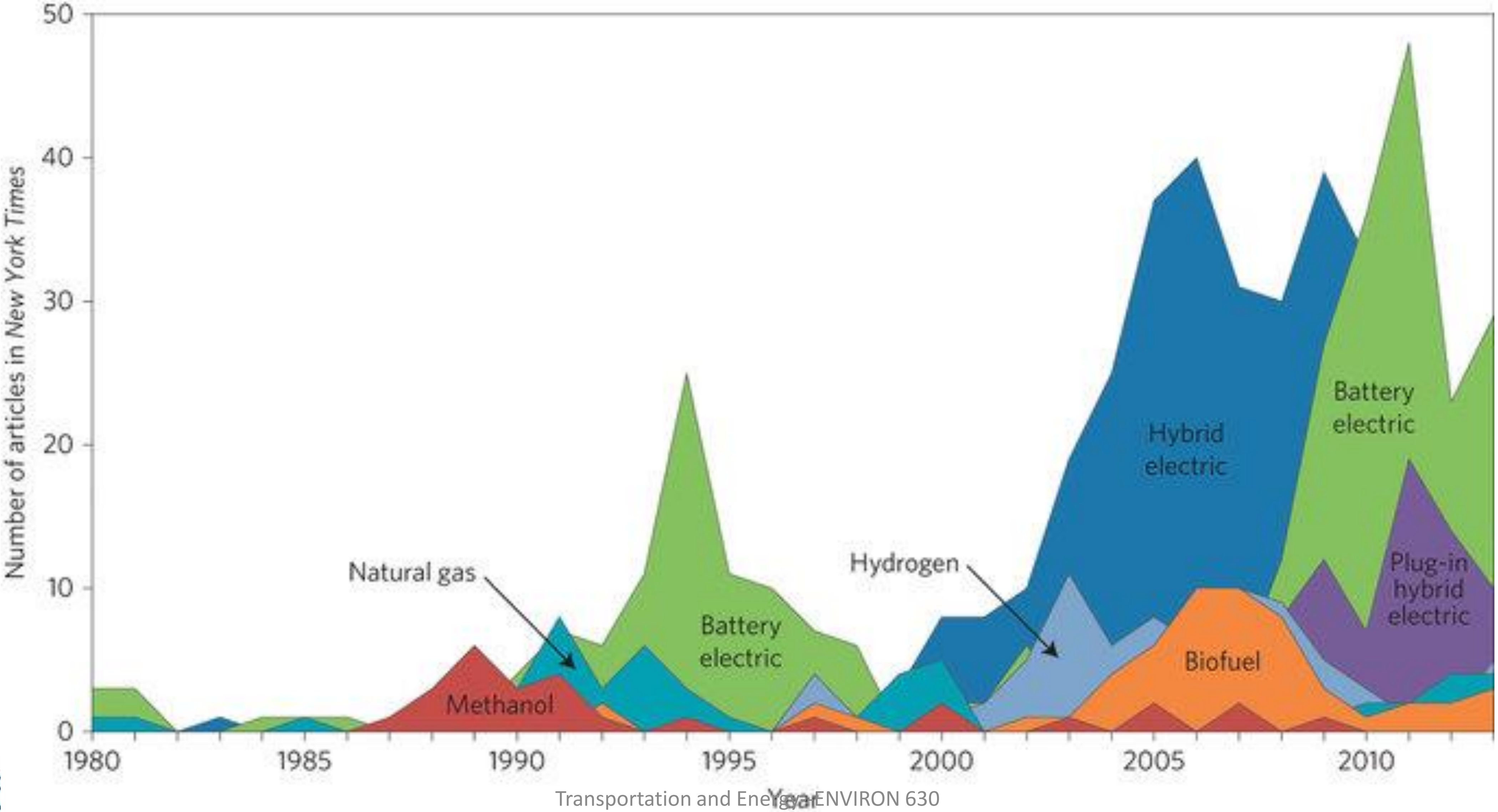
Stacy C. Davis, Susan E. Williams, and Robert G. Boundy (2018). Transportation Energy Data Book: Edition 36.1. Oak Ridge National Laboratory, ORNL-6992 (Edition 36.1 of ORNL-5198), cta.ornl.gov/data. Tables 11.4 and 12.1

Light duty vehicles: What's next?



Joan Ogden and Lorraine Anderson (eds.) (2011). Sustainable Transportation Energy Pathways: A Research Summary for Decision Makers. Davis, CA: University of California, Davis, Institute of Transportation Studies. p. 7

Alternative fuels in the news



Noel Melton, Jonn Axsen, and Daniel Sperling (2016). Moving beyond alternative fuel hype to decarbonize transportation. Nature Energy 1, Article number: 16013, doi:10.1038/nenergy.2016.13.

LDVs: Beyond internal combustion engines

Electrification is the primary alternative to internal combustion engines for light-duty vehicle powertrains

Options

Hybrid vehicles (HEVs)

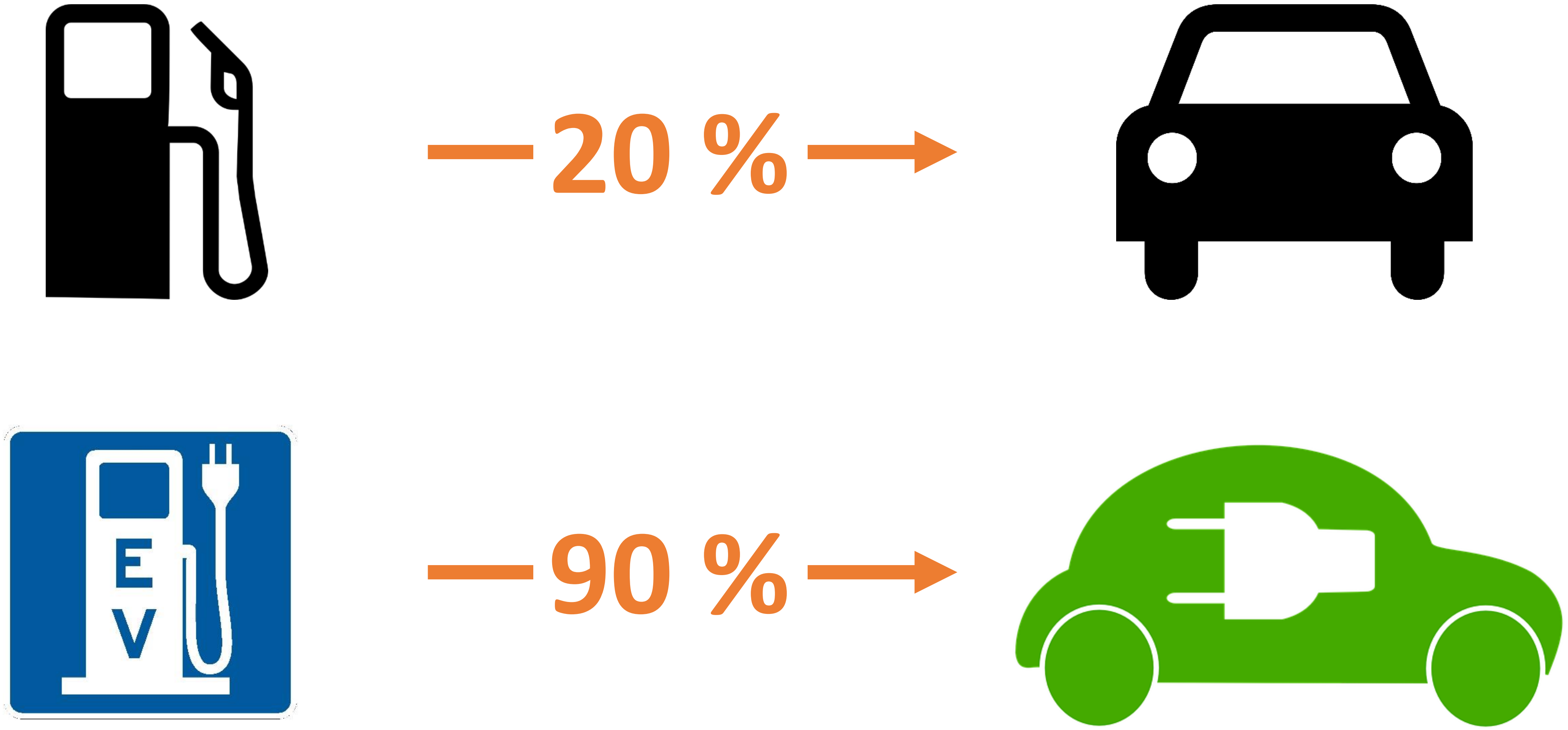
- Anything with 2+ power sources

Plug-in electric vehicles (PEVs)

- Plug-in hybrid electric vehicles (**PHEVs**)
- Electric vehicles (**EVs**, or battery electric vehicles: **BEVs**)

Fuel cell vehicles (FCVs)

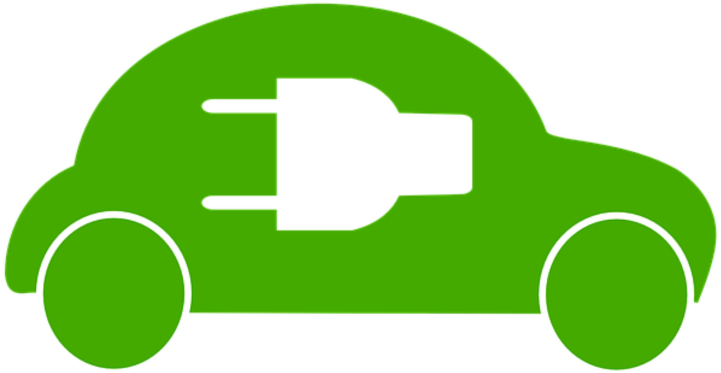
Why EVs?



If we only drove EVs

Power generation

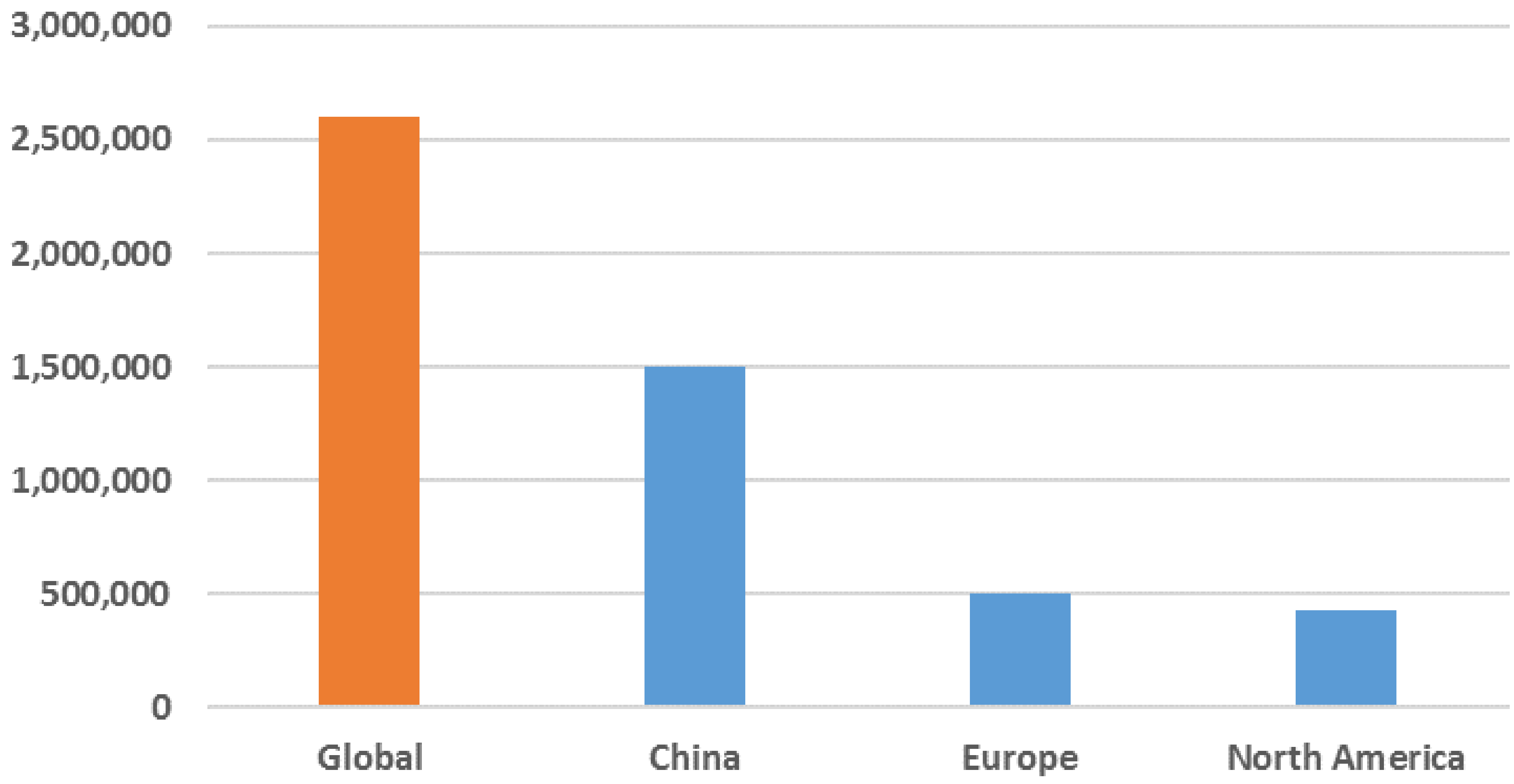
⬆ 25%



Vehicle energy use

⬇ 80%

BNEF 2019 EV Sales Forecast



China 2020 Goal: 4,600,000 EVs

Source: Bloomberg New Energy Finance

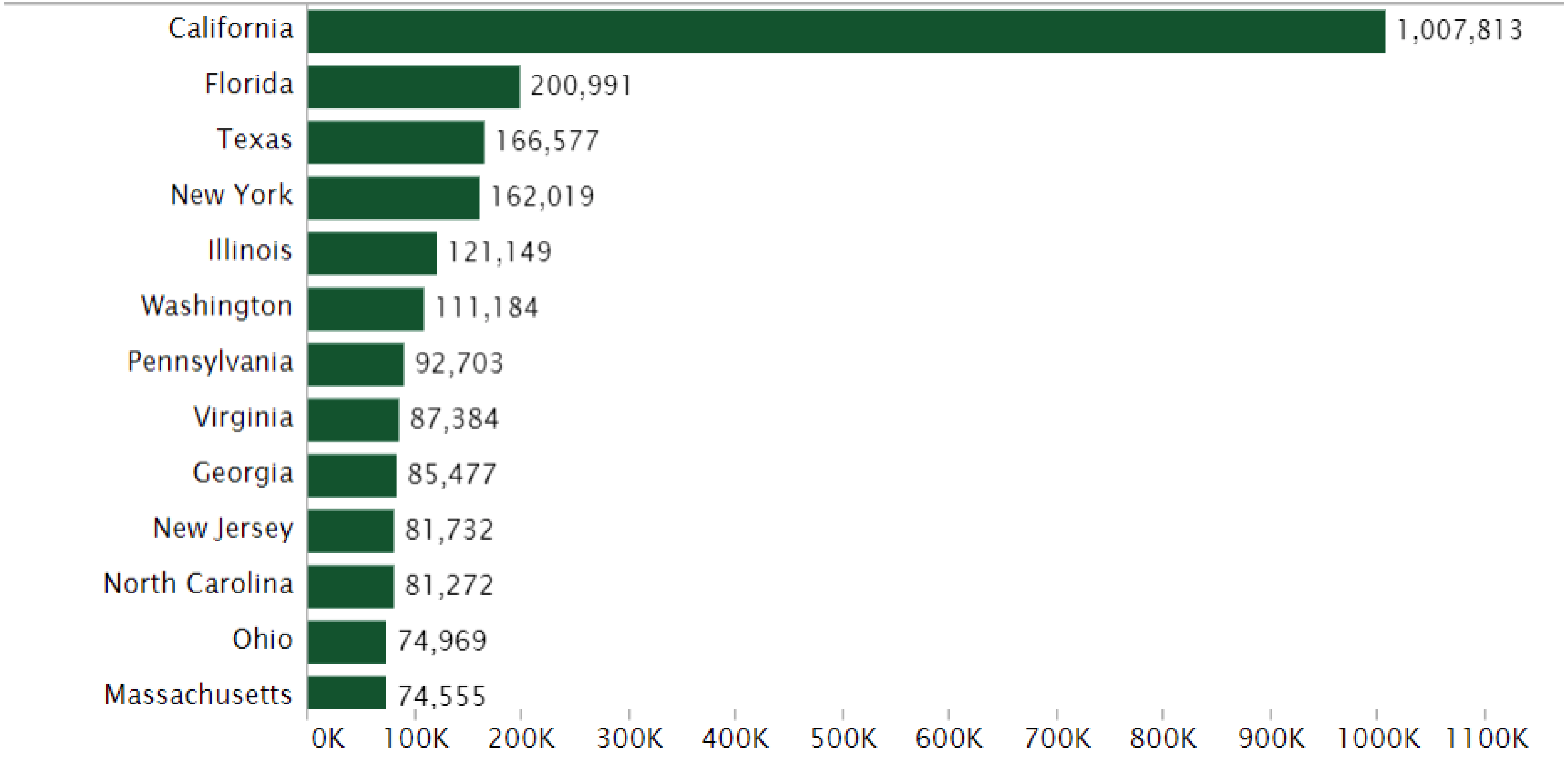
US PHEV and EV stats

0.5% of cars on road are EVs (including hybrids and FCVs)

2% of 2018 LDV sales electric

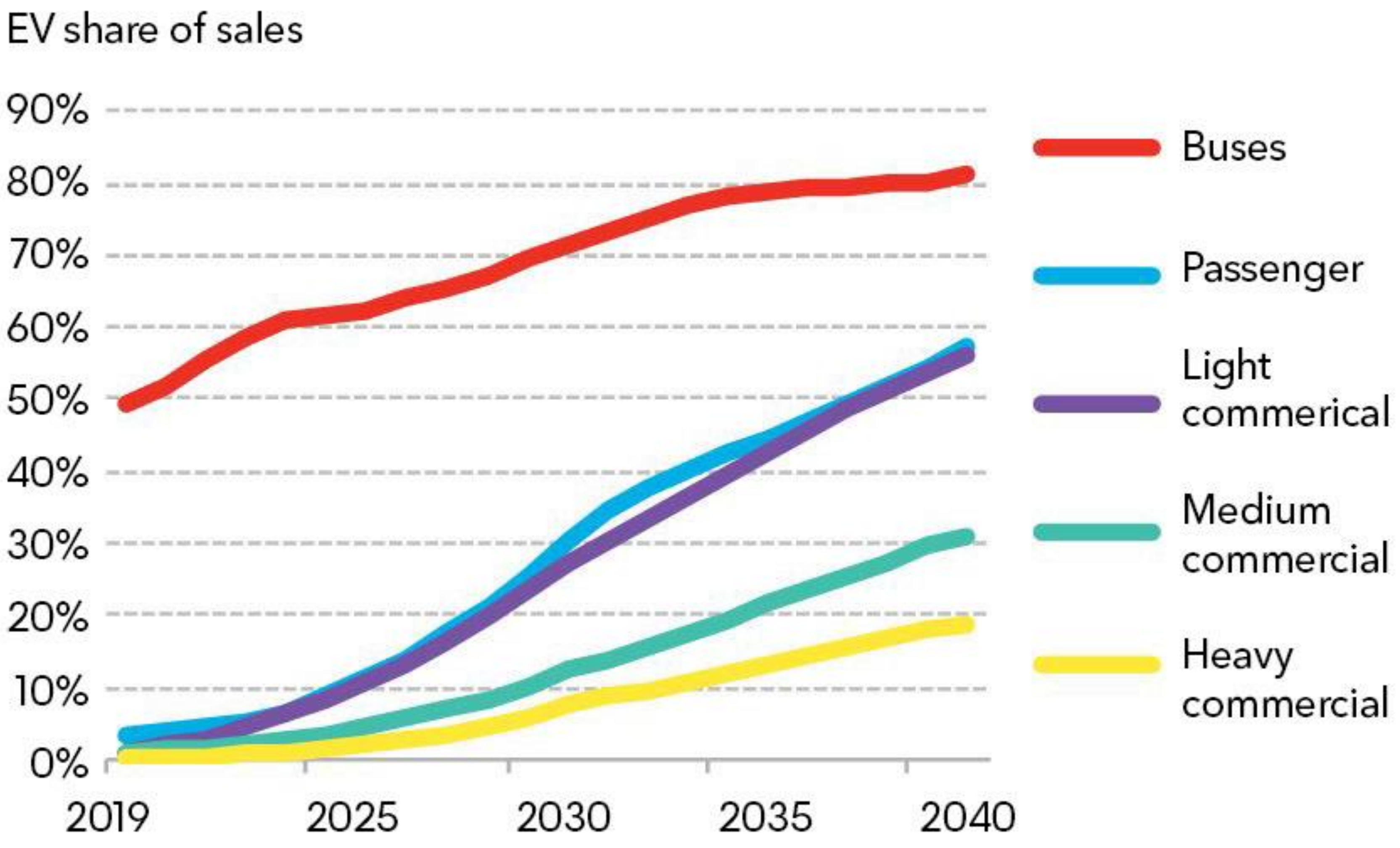
8% of CA 2018 LDV sales electric

Top States by ATV Sales



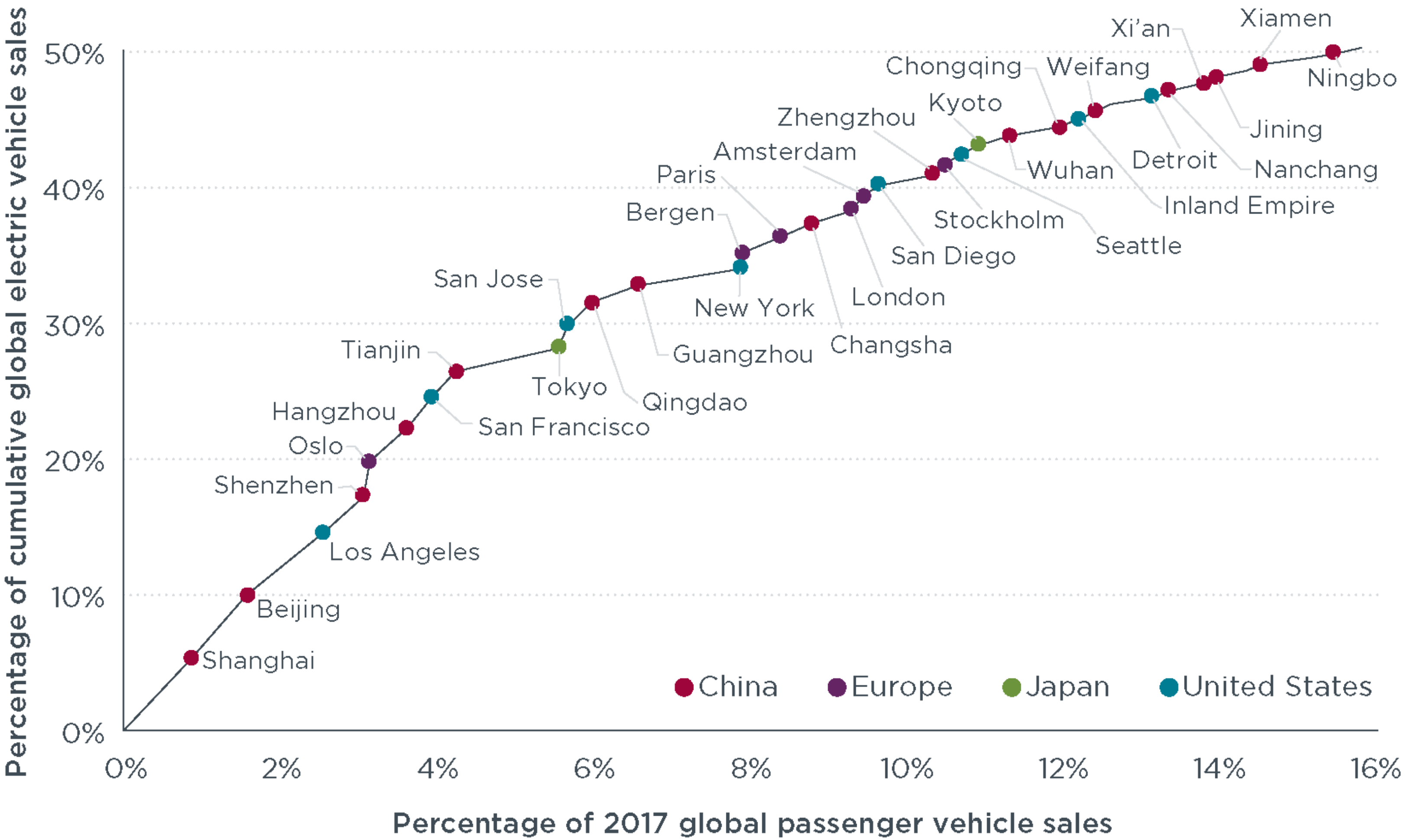
Alliance of Automobile Manufacturers (2018). Advances Technology Vehicle Sales Dashboard. Data compiled by the Alliance of Automobile Manufacturers using information provided by HIS Markit. Data last updates 1/2/2018. Retrieved 1/25/2018 from https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/

EV share of annual vehicle sales by segment



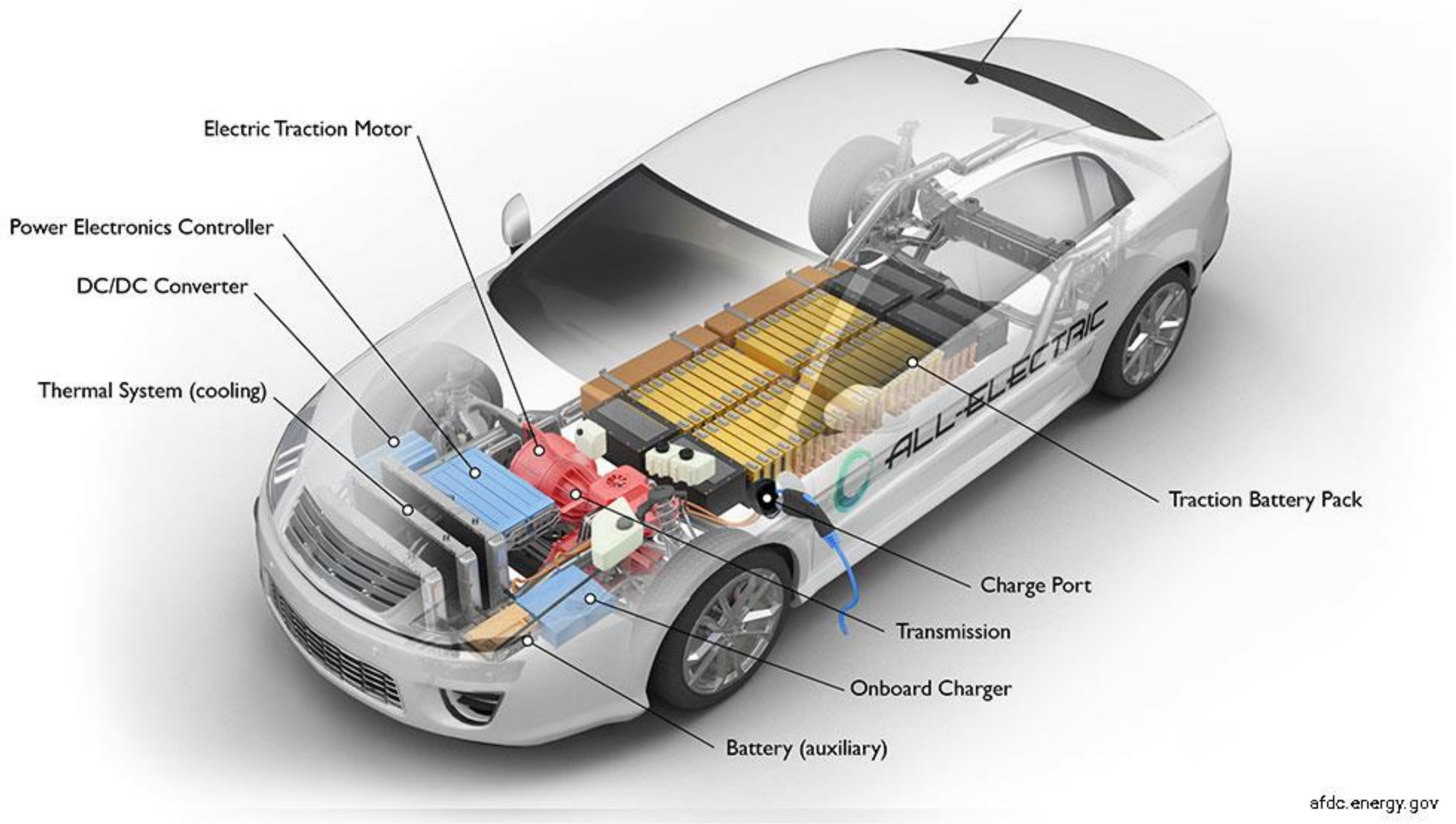
Source: BloombergNEF. Note: Passenger car and bus figures are global. Commercial vehicle segment adoption figures in both charts cover the main markets of China, Europe and the U.S.

Bloomberg NEF (2019). Electric Transport Revolution Set To Spread Rapidly Into Light and Medium Commercial Vehicle Market, 15 May 2019, https://about.bnef.com/blog/electric-transport-revolution-set-spread-rapidly-light-medium-commercial-vehicle-market/



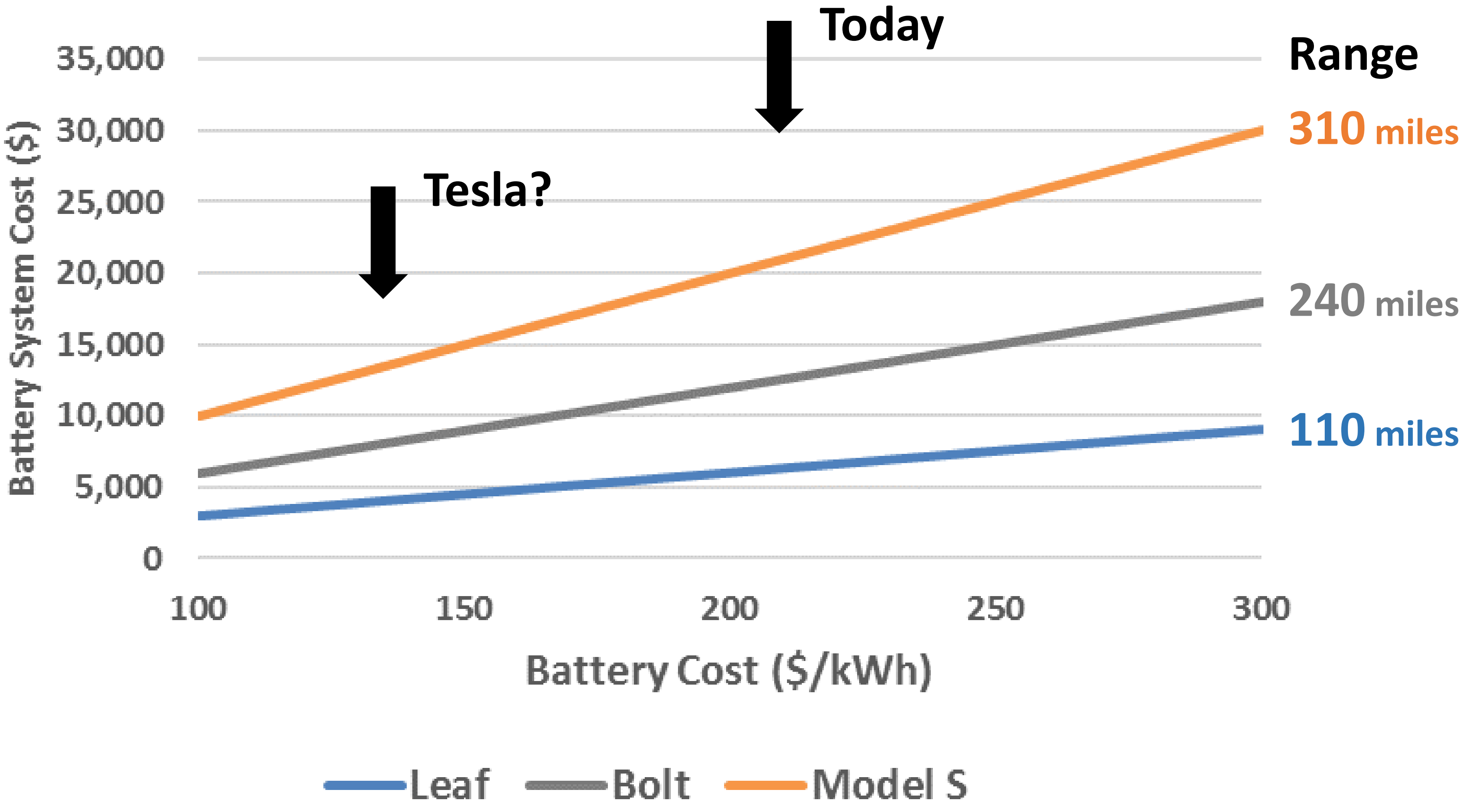
The International Council on Clean Transportation (ICTT). Electric vehicle capitals: Accelerating the global transition to electric drive, 30 October 2018, https://www.theicct.org/publications/ev-capitals-of-the-world-2018

All-Electric Vehicle

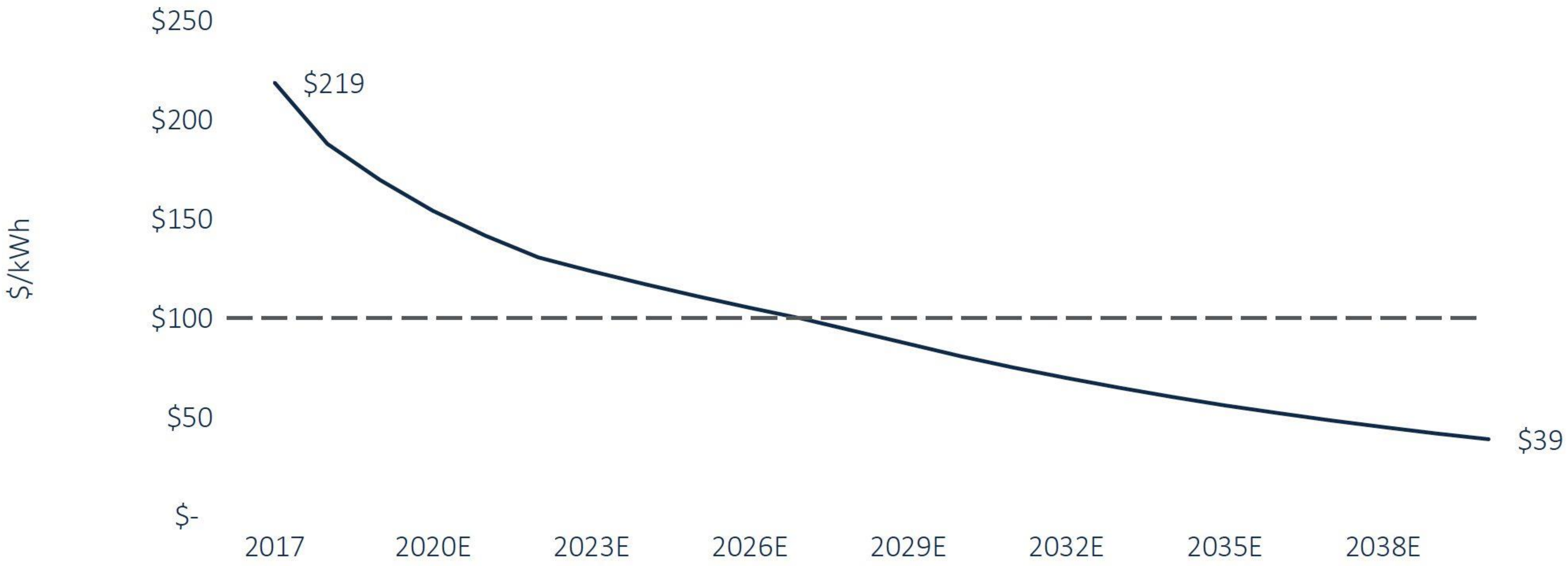


https://www.afdc.energy.gov/vehicles/how-do-all-electric-cars-work

Battery system cost vs per-kWh cost



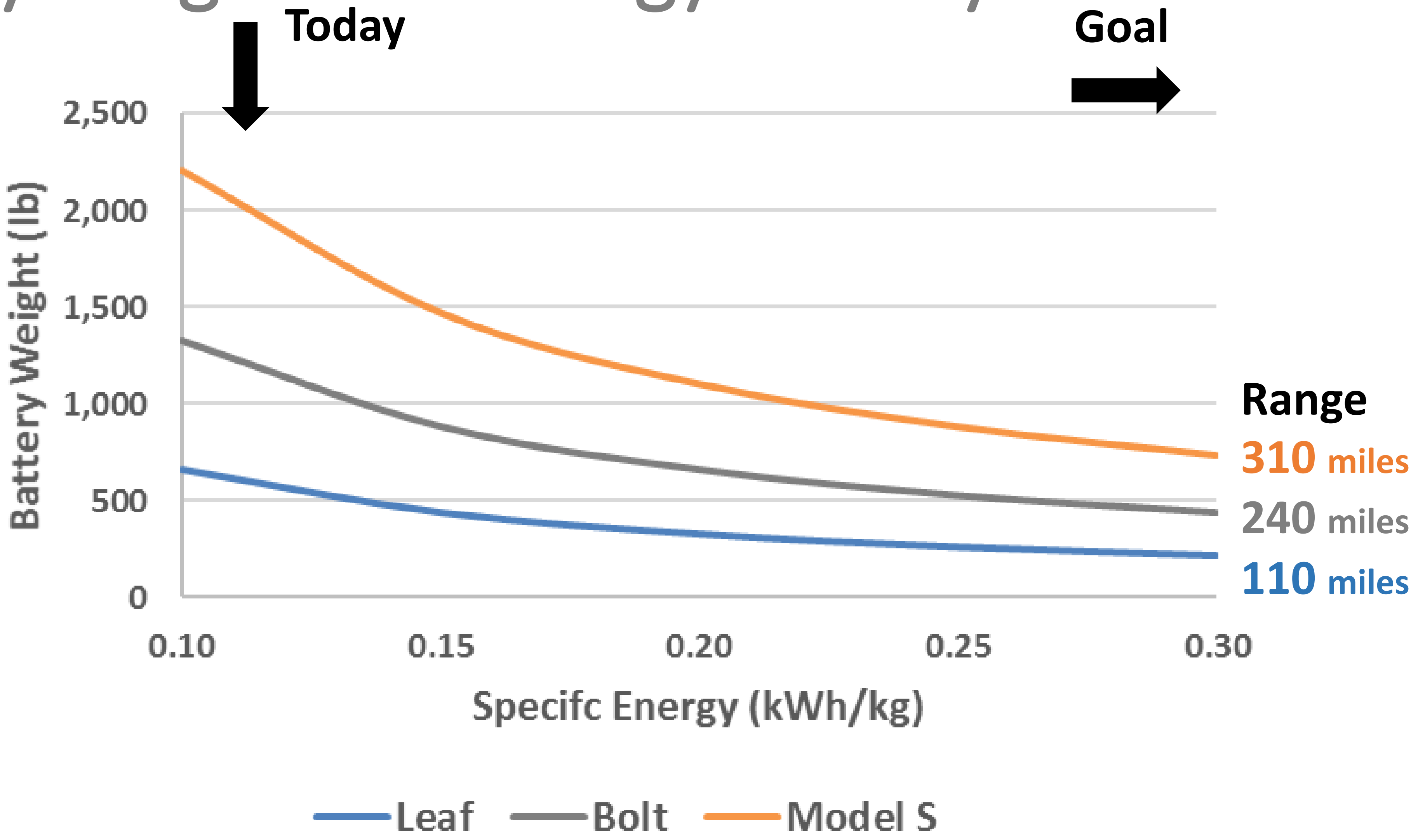
Battery Pack Price Forecast, 2017-2040E ($/kWh)



Source: Wood Mackenzie, *Transport in Transition: The Rise of the Electric Vehicle*, May 2018

https://www.greentechmedia.com/articles/read/6-charts-showing-the-renewables-threat-to-gas

Battery weight and energy density



	Prius HEV	Prius Prime PHEV	Nissan LEAF EV	Tesla Model-S EV
Mileage Equivalent	54 (c) 50 (h)	55 (c) 53 (h) 133 (EV)	124 (c) 99 (h)	113 (c) 105 (h)
Battery Size (kWh)	1.3	8.8	40	100
Range (miles)	588	640 (comb) 25 (EV)	150	285
MSRP ($)	23,475	29,500	29,900	75,000
Battery Type	Li-ion	Li-ion	Li-ion	Li-ion

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All images and data are from vehicle manufacturer websites and www.fueleconomy.gov, September 2019

EV Charging levels

Charging: 3 levels, characterized by voltage and power

AC Level 1

- 120V, up to 1.92 kW depending on current (amperage) limits

AC Level 2

- 240V, 3.4 kW (residential) to 19.2 kW (commercial)

DC Fast Charging

- 400 to 600V, 40 to 120 kW
- Tesla Supercharger network moving to 250 kW
- ABB's 350kW charger is currently the fastest commercially available
- Many EVs are limited to 50 kW

Charger costs

AC Level 1

- Nothing to install

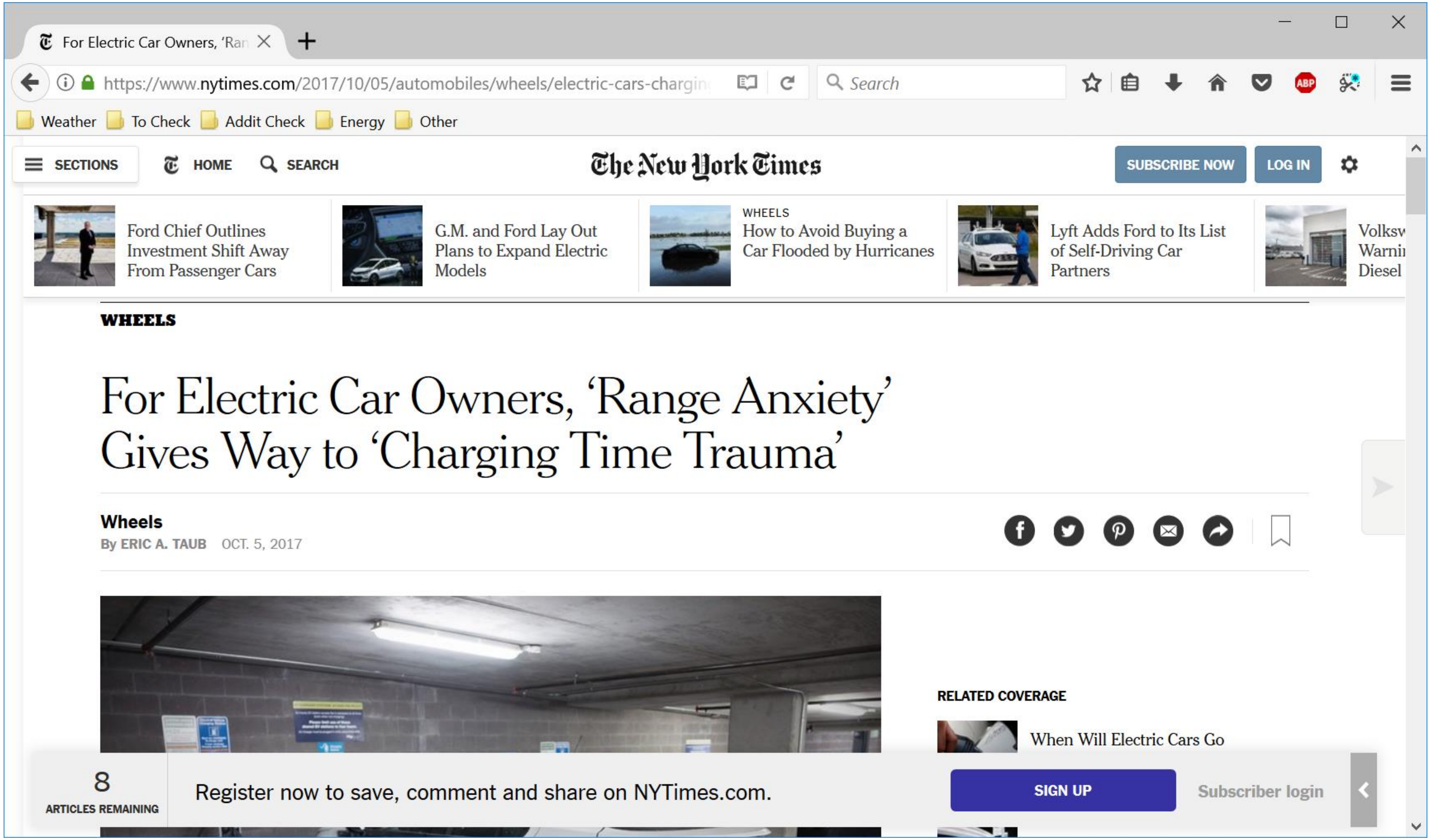
AC Level 2

- Home < $1,000
- Workplace $3,000 to $5,000

DC Fast Charging

- $25,000 to $200,000 per unit depending on power output

(Source: McKinsey & Co.)



For Electric Car Owners, 'Ran

https://www.nytimes.com/2017/10/05/automobiles/wheels/electric-cars-chargin

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For Electric Car Owners, 'Range Anxiety' Gives Way to 'Charging Time Trauma'

Wheels

By ERIC A. TAUB OCT. 5, 2017

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Charging time

Approximation: Divide usable battery size by charger (or vehicle) power rating

- Plug-in Prius + Level I charger: 8.8 kWh/1.92 kW = 4.6 hours
- Tesla Model S + Supercharger: 100 kWh/120kW = 0.83 hour

Actual charging times also depend on battery power acceptance rating

DC charging

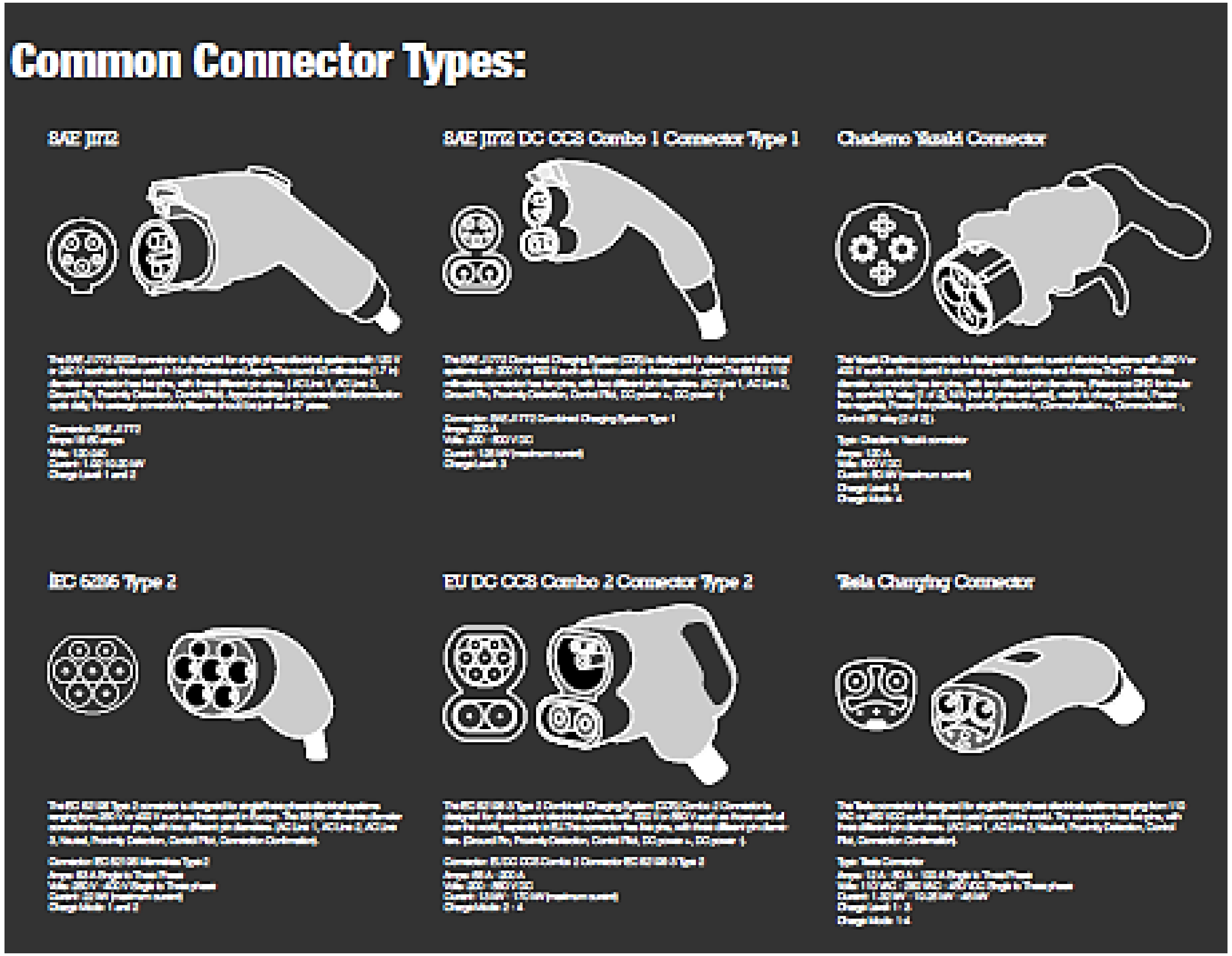
DC charging infrastructure

120 kW (soon to be 250 kW) Tesla Supercharger

70 to 150 kW CHAdeMO Japanese and Asian cars

90 to 150 kW SAE J1172 combo American and German cars

→Standardization required



http://www.ev-institute.com/images/media/Plug_World_map_v4.pdf

Where is your car?

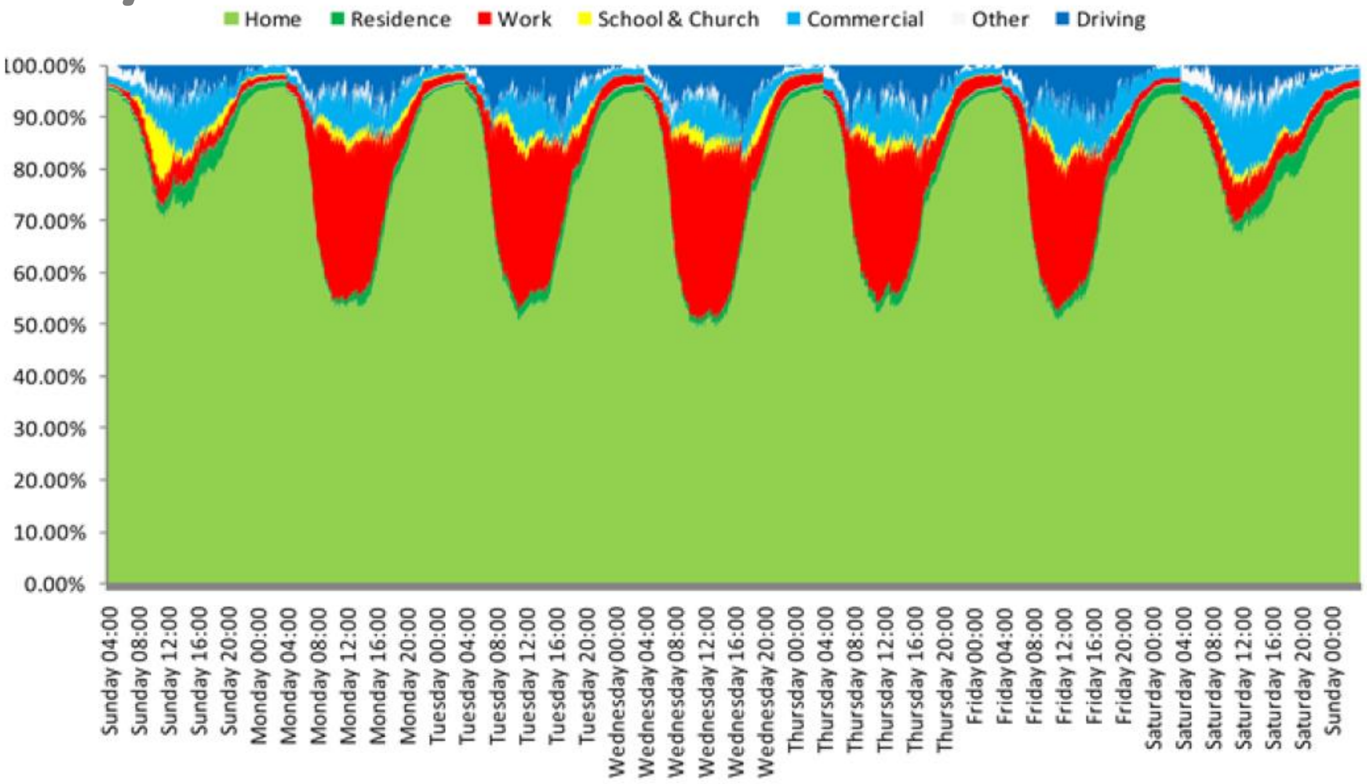


FIGURE 5-2 Vehicle locations throughout the week on the basis of data from the 2001 National Household Travel Survey. SOURCE: Tate and Savagian (2009). Reprinted with permission from SAE paper 2009-01-1311 Copyright © 2009 SAE International.

National Research Council (2015). Overcoming Barriers to Deployment of Plug-in Electric Vehicles. Committee on Overcoming Barriers to Electric-Vehicle Deployment; Board on Energy and Environmental Systems; Division on Engineering and Physical Sciences; Transportation Research Board; National Research Council. Washington, DC: The National Academies Press.

NREL analysis

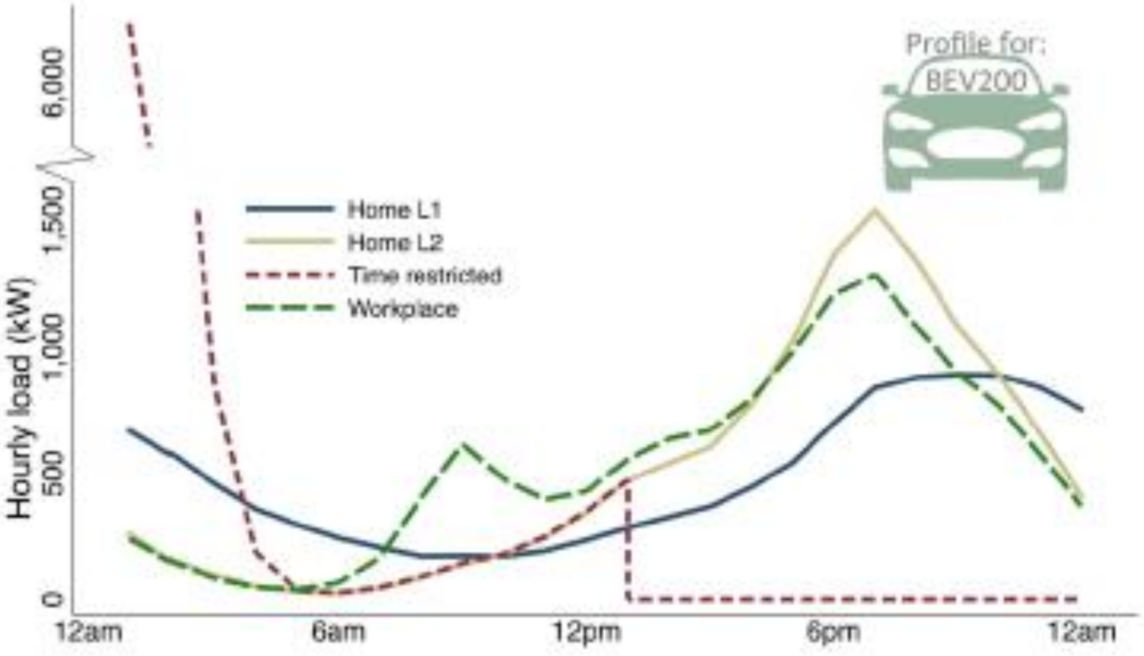
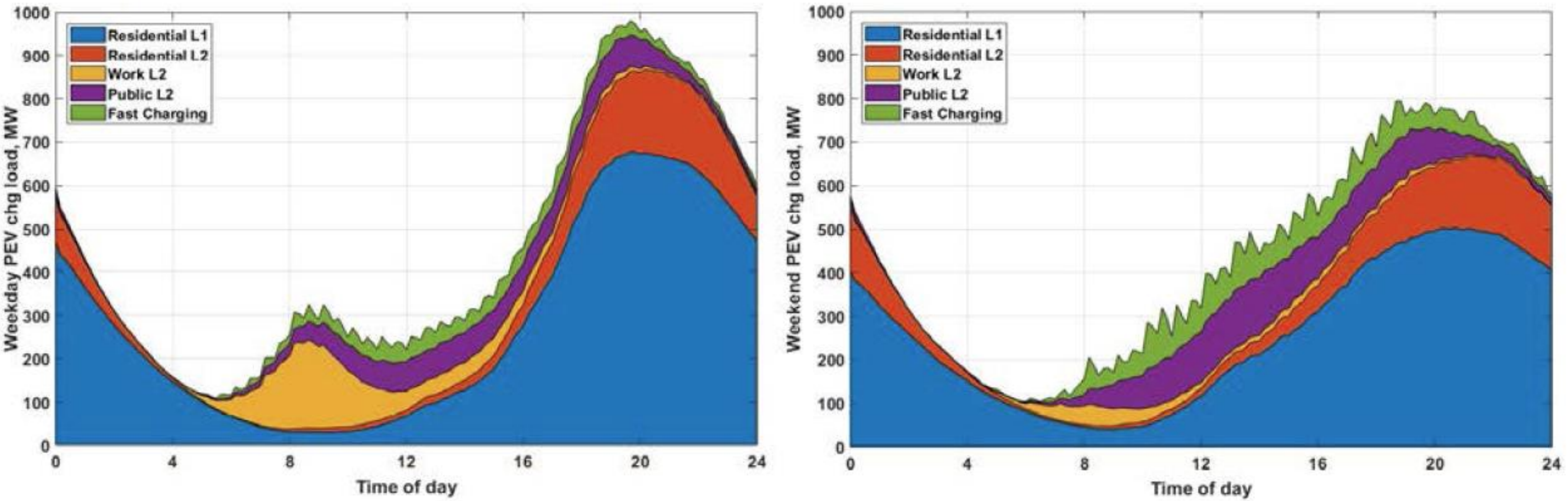


Figure 7. BEV load profile by scenario

Note: The scale in the figure is capped at 1,500 kW for presentation purposes (the time restricted scenario peaks at 6,200 kW at 12 a.m.).

Joyce McLaren, et al. (2016). Emissions Associated with Electric Vehicle Charging: Impact of Electricity Generation Mix, Charging Infrastructure Availability, and Vehicle Type. National Renewable Energy Laboratory, Technical Report NREL/TP-6A20-64852.

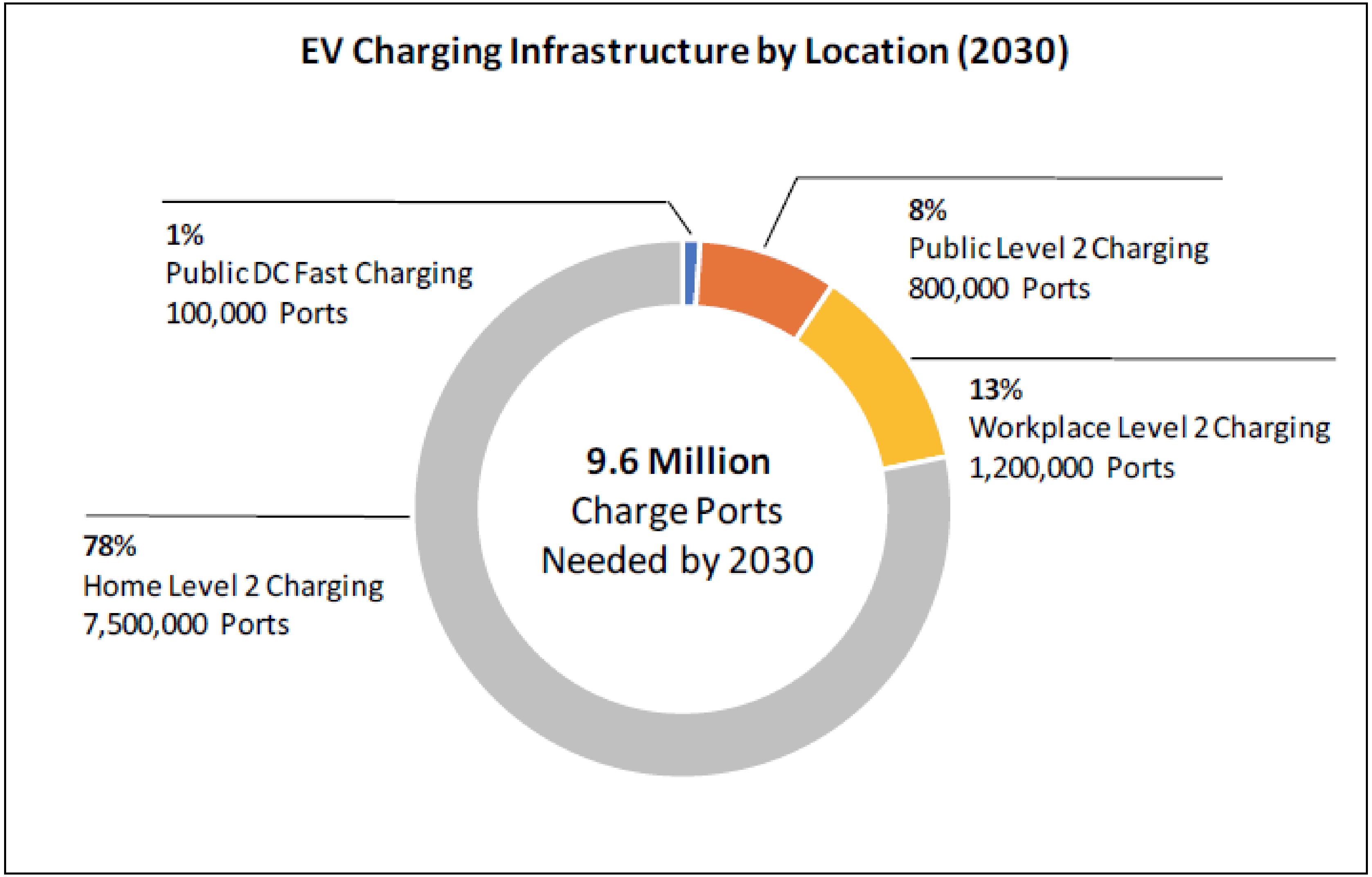
Figure ES.2: PEV Charging Load Profiles in 2025



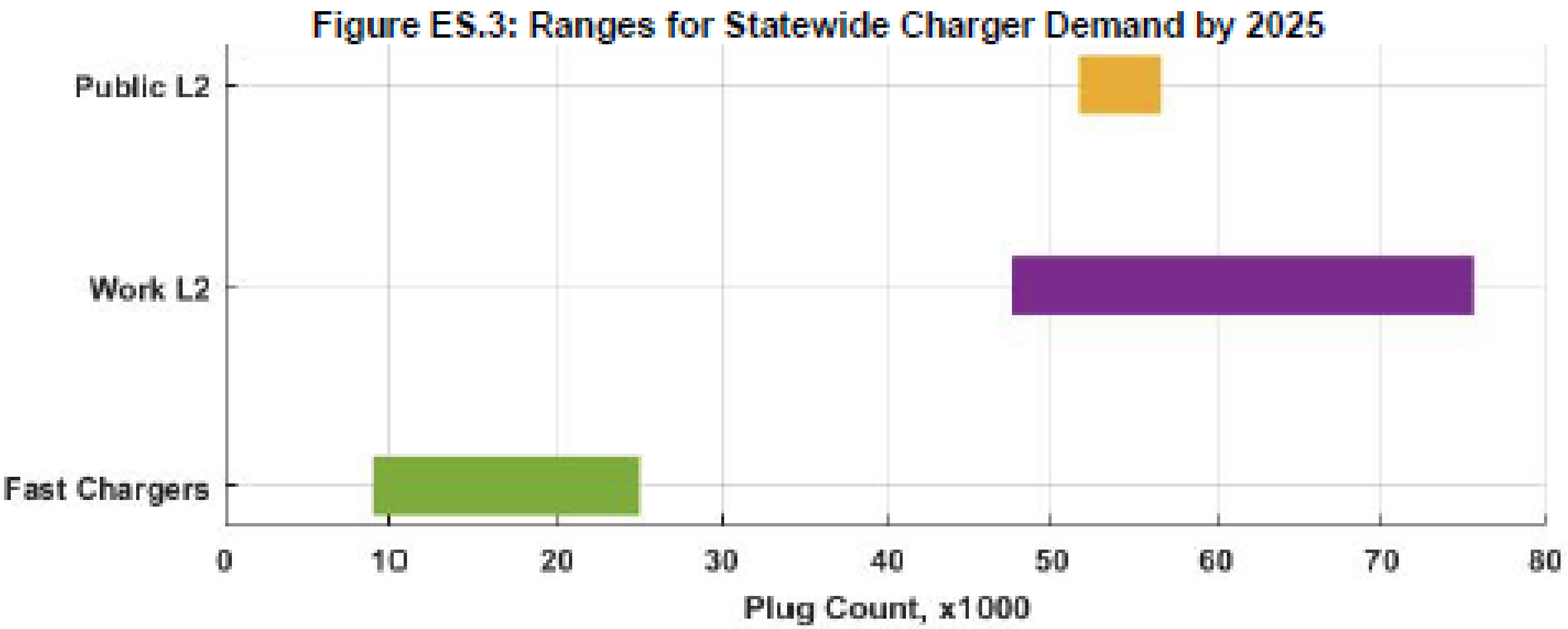
Source: California Energy Commission and NREL

Bedir, Abdulkadir, Noel Crisostomo, Jennifer Allen, Eric Wood, and Clément Rames. 2018. California Plug-In Electric Vehicle Infrastructure Projections: 2017-2025. California Energy Commission. Publication Number: CEC-600-2018-001.

Figure 5. EV Charging Infrastructure in 2030 Based on EEI/IEI Forecast



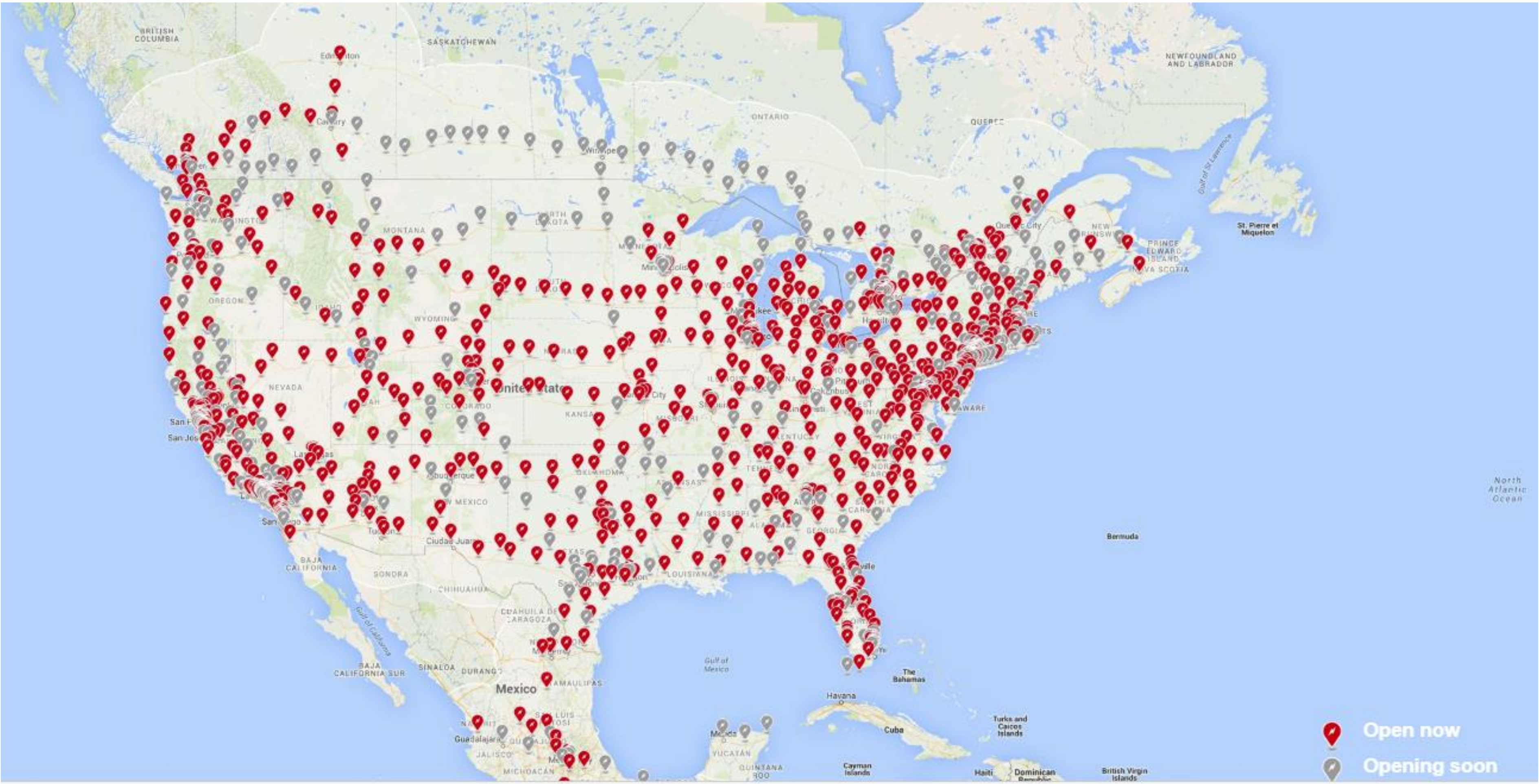
Adam Cooper and Kellen Schefter (2018). Electric Vehicle Sales Forecast and the Charging Infrastructure Required Through 2030. The Edison Foundation Institute for Electric Innovation and Edison Electric Institute, November 2018.



Source: California Energy Commission and NREL

Bedir, Abdulkadir, Noel Crisostomo, Jennifer Allen, Eric Wood, and Clément Rames. 2018. California Plug-In Electric Vehicle Infrastructure Projections: 2017-2025. California Energy Commission. Publication Number: CEC-600-2018-001.

Tesla’s North American Supercharger network



https://www.tesla.com/supercharger

Electrify America “Cycle 1” network

VW: $2 billion to promote vehicle electrification

https://www.electrifyamerica.com/our-plan

Electric vehicle supply equipment (EVSE): Components

Charging unit

- May have one or multiple vehicle connections

Power supply

- Transformer
- Switchgear

Brad Berman. The Ultimate Guide to Electric Car Charging Networks. Plugincars, July 13, 2018, https://www.plugincars.com/ultimate-guide-electric-car-charging-networks-126530.html

EVSE: Public siting options

Surface lots

Parking decks and garages

On-street

Rest stops

Retail establishments

Truck-stops

EVSE siting requirements and considerations

Power supply

- 480V to 600V for DC, or 208/240V for L2
- Distribution system capacity

Communications network connection

Something for people to do

Safety

- Lighting
- “Eyes” (to prevent vandalism)

Signage and wayfinding

EVSE siting requirements and considerations

Space

- Parking: 9’ x 18’ (14’ + 18’ for disabled)
- EVSE: Must not block right of way or pose tripping hazard

Potential demand

Number of chargers

Existing EVSE?

Out of flood zone

Ventilation