Electric Vehicles

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Intro

Are EVs a win-win?

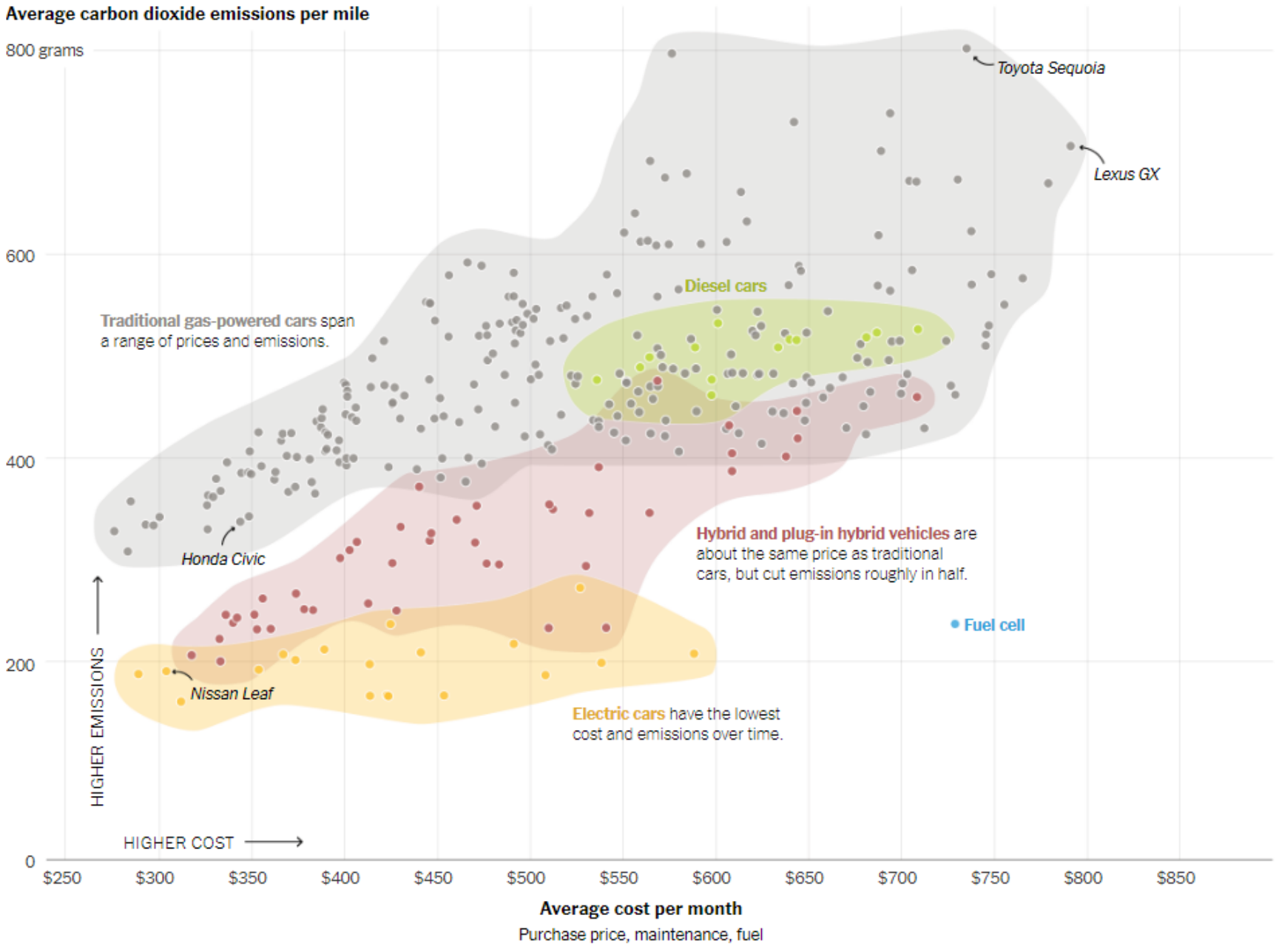
Electric Cars Are Better for the Planet – and Often Your Budget, Too

By Veronica Penney Jan. 15, 2021

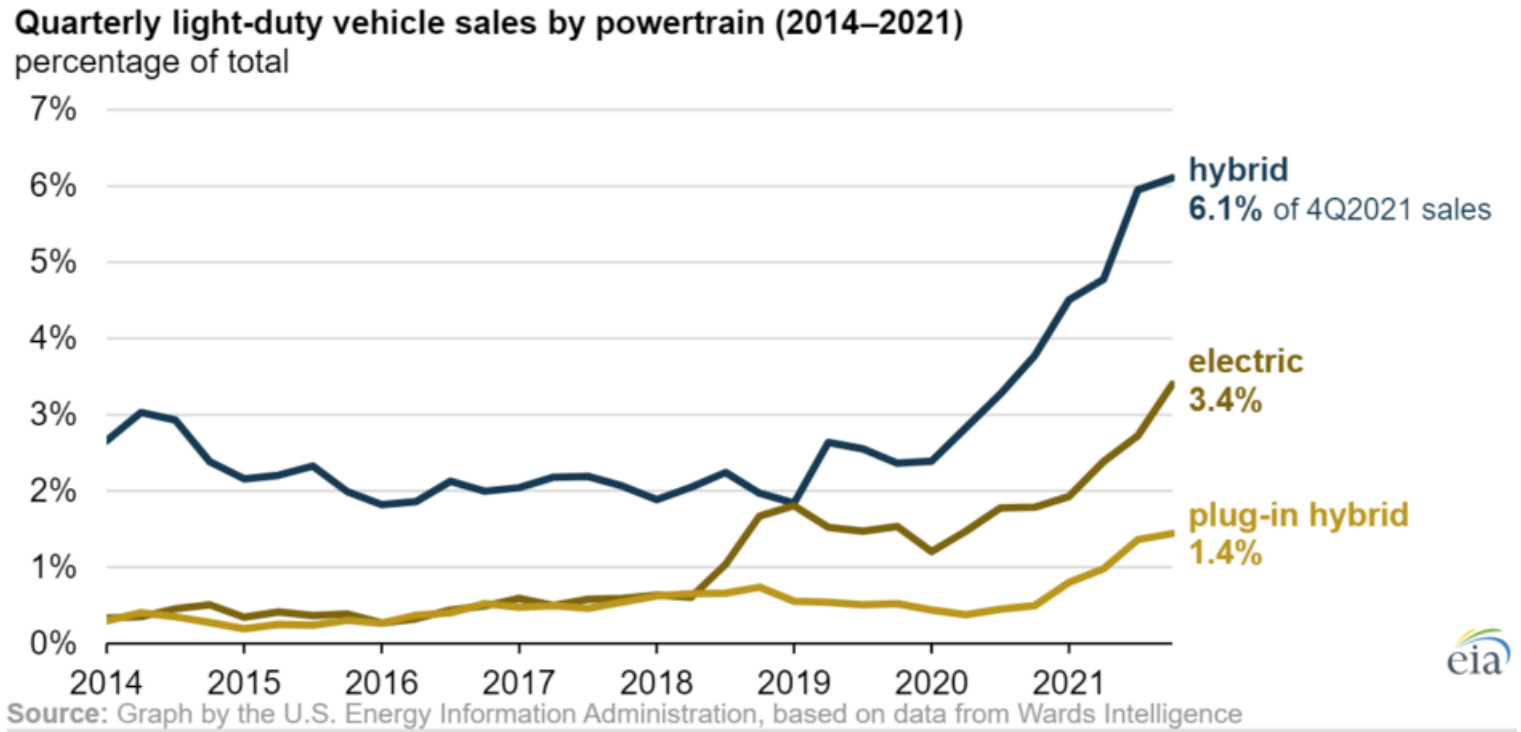
Electric vehicles are better for the climate than gas-powered cars, but many Americans are still reluctant to buy them. One reason: The larger upfront cost.

New data published Thursday shows that despite the higher sticker price, electric cars may actually save drivers money in the long-run.

Are EVs a win-win?



Share increasing, but still very small



Outline

- Lecture 1: Why EV sales are so low (and how to increase them)
- Lecture 2: Environmental benefits

Response questions

1. What do you think the key determinants of electric vehicle demand are?
2. The New York Times article suggests that EVs often save consumers money. Yet they have very low market shares. What are some reasons for that?

Back to the energy paradox

Utility from owning car

$$u(m_j) - c_j - (p_j m_j e_j)/(1+r) + \xi_j$$

- [+] utility from driving m_j miles
- [-] up-front cost to buy (c_j)
- [-] lifetime cost to drive $(pme_j)/(1+r)$
- [+/-] non-driving amenities (ξ_j)

Back to the energy paradox

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- [-] up-front cost to buy (c_j)
- [-] lifetime cost to drive $(pme_j)/(1+r)$
- [+/-] non-driving amenities (ξ_j)

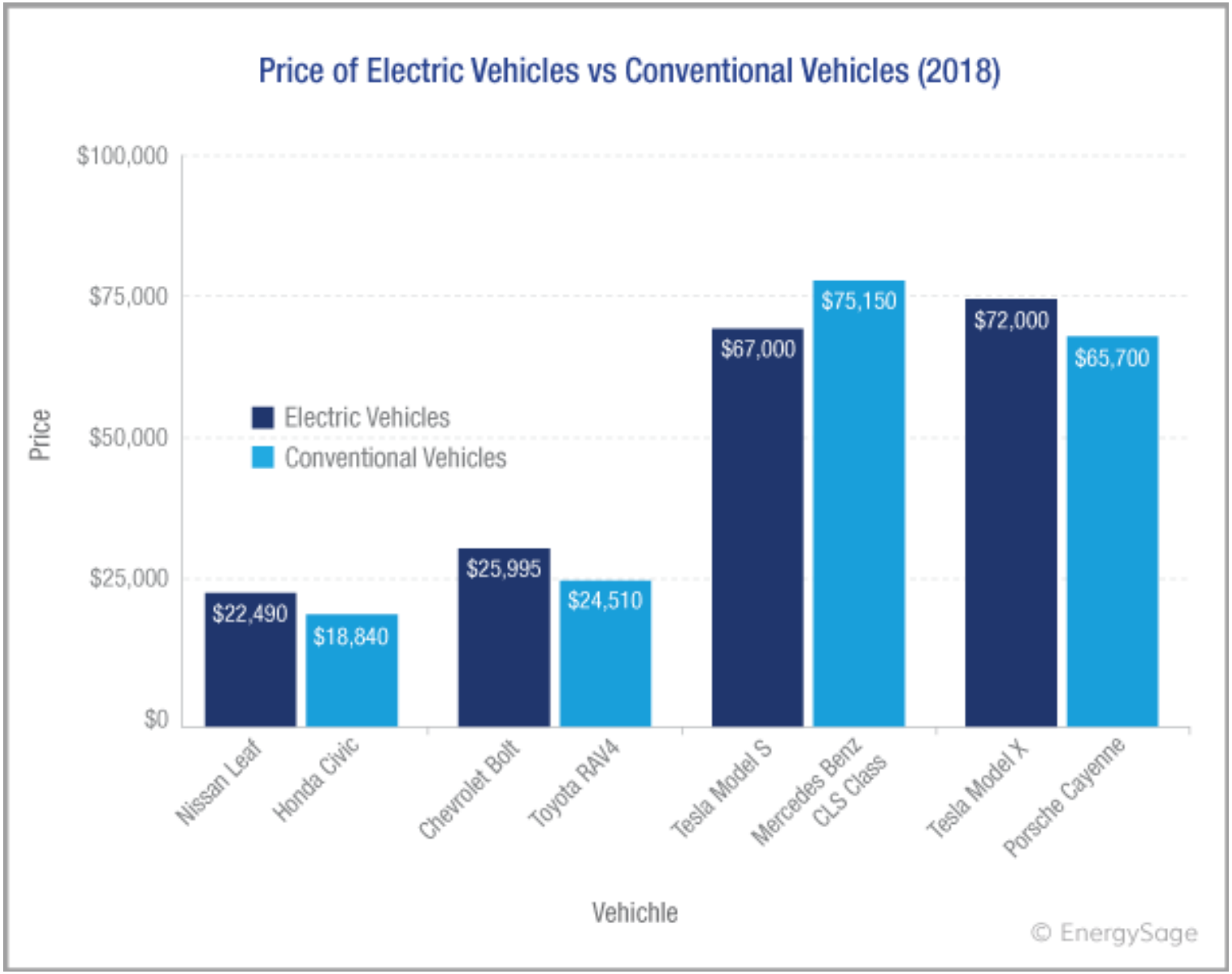
Purchase EV (E) instead of ICE (I) if utility is greater.

Which the are biggest barrier to EV's?

How would you design a policy to increase takeup?

Subsidies

EVs can now compete on price (after subsidies) in most segments

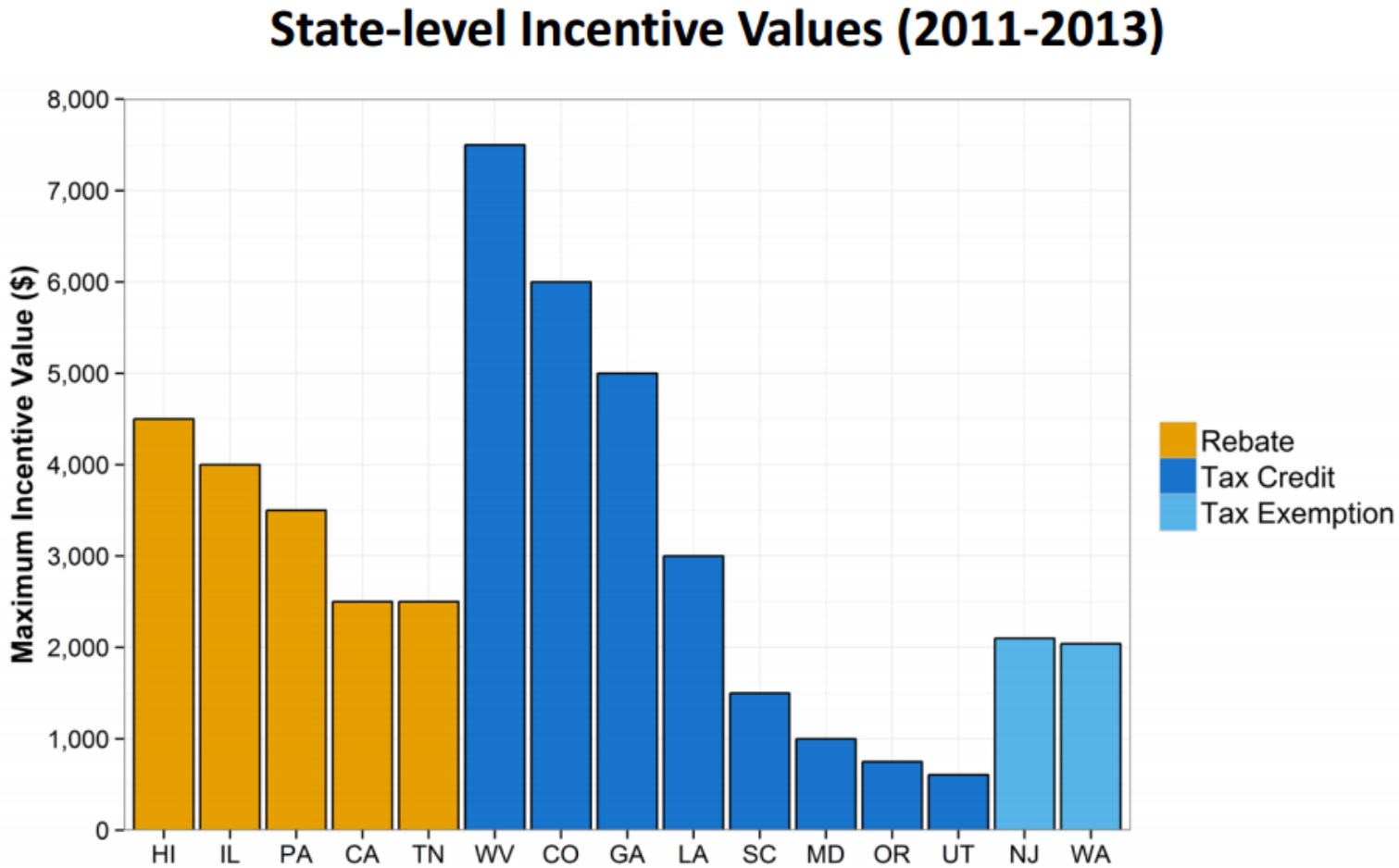


EVs growth in US driven by numerous levels of subsidies

Examples of Incentive Types

State	Incentive Type	Value	Dates	Description
Washington	Tax exemption	$2,000	2009 – present	Sales and use tax exemption on purchase of electric vehicle.
California	Rebate	$2,500	March 2010 – present	Electric vehicles are eligible for a maximum $2,500 rebate through the California Clean Vehicle Rebate Program.
Maryland	Tax credit	$2,000	October 2010 – June 2014	Electric vehicles are eligible for a tax credit based on vehicle battery capacity.
North Carolina	HOV access	–	May 2011 – present	Electric vehicles may travel in HOV lanes regardless of the number of passengers in the vehicle.

Souce: NREL 2015



Souce: NREL 2015

This is in addition to the federal tax credit of $2,500 to $7,500

A recent NREL study estimated the impact of these state level policies

Specification

$$\log(PersEV_{imt}) = \alpha_{im} + \beta Incentives_{imt} + \gamma EVSE_{imt} + \delta Demographics_{it} + \lambda Fuel\ Prices_{it} + \theta_{tm} + \varepsilon_{imt}$$

i: state, t: time; m: make

$PersEV$: new personal EV registrations per capita

$Incentives$: Maximum value of direct financial incentives and indicator for HOV lane access

$EVSE$: Stock of public electric vehicle supply equipment (EVSE)

$Demographics$: State-level demographics (full list included in appendix)

$Fuel\ Prices$: State-level gasoline and residential electricity prices.

Address potential endogeneity of charging infrastructure using instrumental variables technique.

Source: NREL 2015

NREL (2015 Results)

Incentive impacts for full sample of BEVs are positive, but not statistically significant

A $1,000 increase in tax credit value is associated with a 2% to 10% change in per-capita BEV registrations

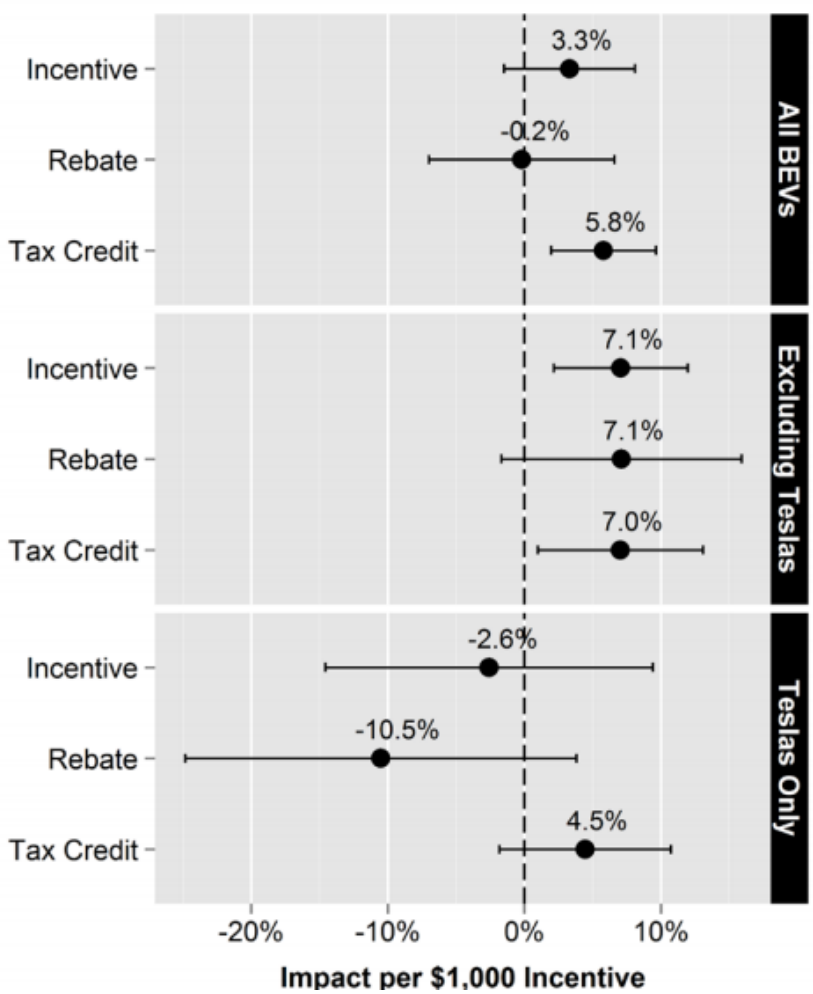
Impacts by vehicle make

- Non-Tesla vehicles: 2% to 12% impact per $1,000 of incentive
- Tesla vehicles: Tax credit impacts positive, but not statistically significant
- Tax exemption impacts could not be estimated due to lack of variation in policies during the study period

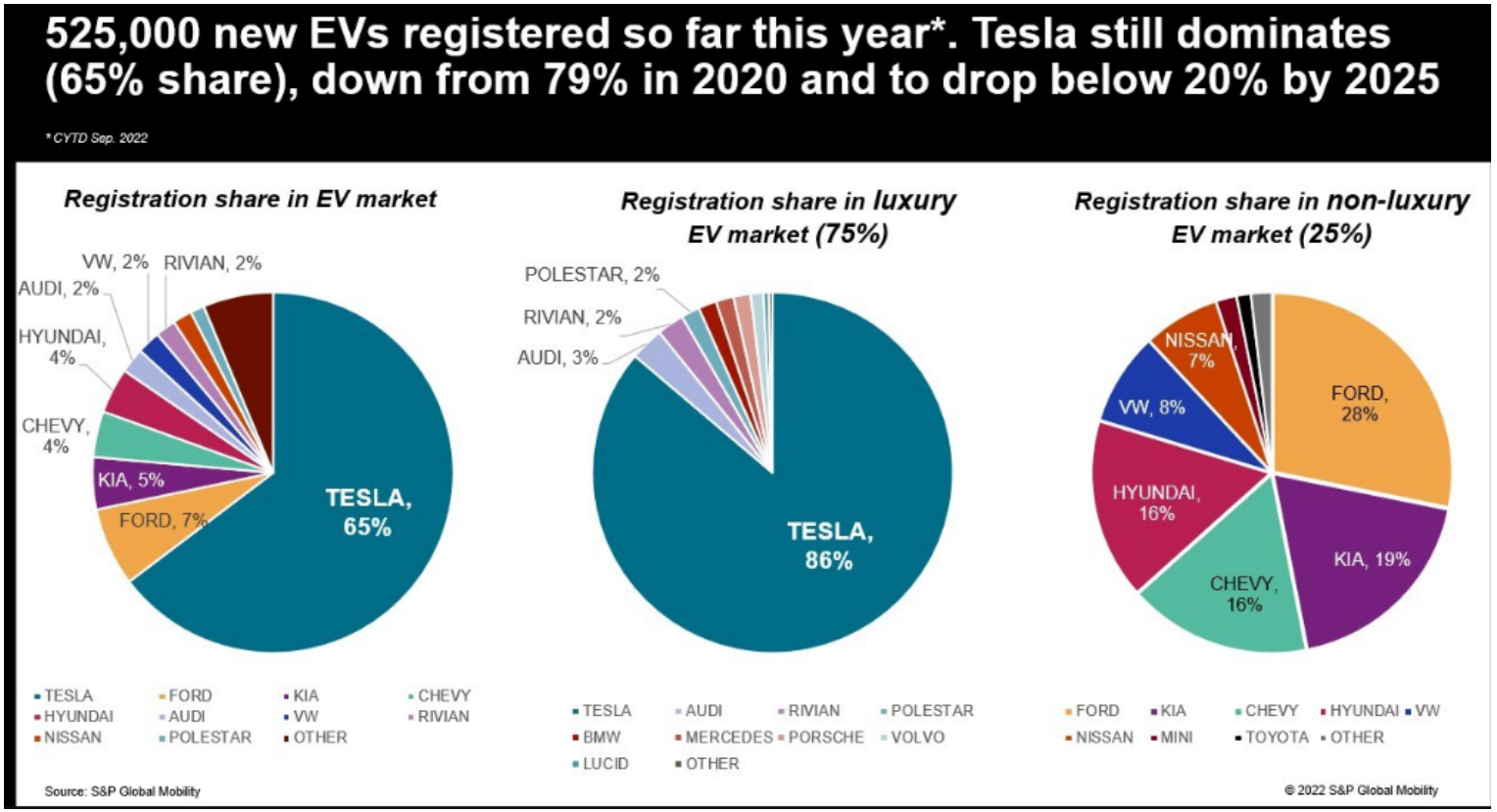
Results robust to endogeneity correction with chosen instrument

Estimated effect of charging infrastructure is positive, but not significant across specifications

- Positive correlation between EVSE and registrations for the subsample of Tesla vehicles.



Should we subsidize Tesla's?



Elon Musk's 2006 Tesla "master plan"

1. Build sports car
2. Use that money to build an affordable car
3. Use that money to build an even more affordable car
4. While doing above, also provide zero emission electric power generation options

Source: The Secret Tesla Motors Master Plan

Are EV subsidies equitable?

Are EV subsidies equitable?

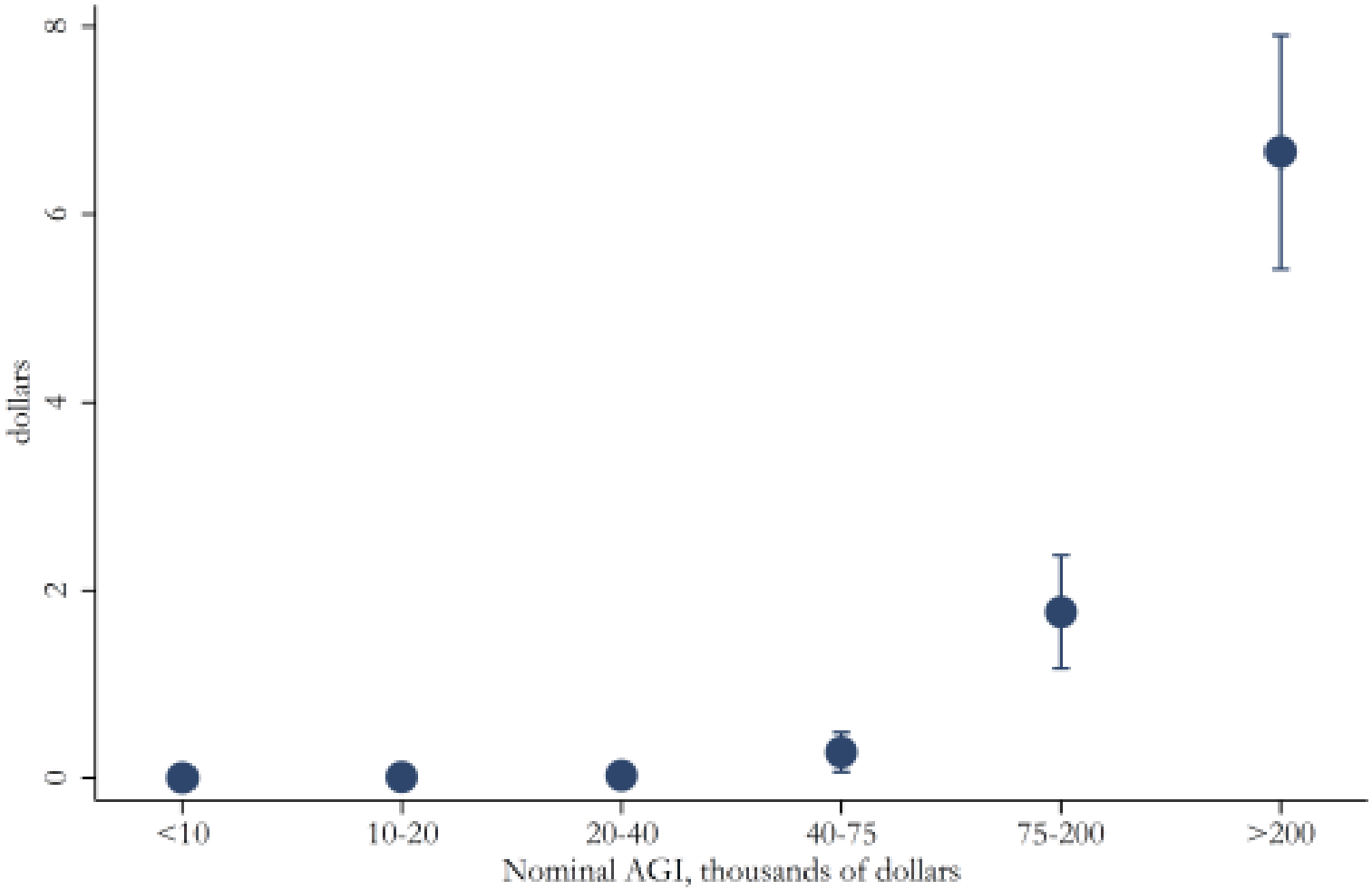
Borenstein and Davis (2016) look at the incidence of energy subsidies: appliances, alternative fuel vehicles, **EVs**

Qualified Plug-in Electric Drive Motor Vehicle Credit, an income tax credit for electric and plug-in hybrid vehicles.

The size of this credit ranges from $2,500 to $7,500 depending on the battery capacity of the vehicle.

For example, the Toyota Prius plug-in hybrid qualifies for a $2,500 credit whereas the Chevrolet Volt qualifies for a $7,500 credit.

Credit is concentrated in the highest incomes



Souce: Davis blog summary

Why is this?

Davis offers some possible explanations on his blog.

- These credits are non-refundable. You can use these credits to offset your tax bill, but you cannot go negative and receive a net payment from the IRS like you can with the Earned Income Tax Credit and many other tax credits.
- electric vehicles may still only be affordable for relatively high-income households. Even after the credit, electric and plug-in electric vehicles are expensive compared to equivalently-sized gasoline-powered vehicles.
- In California, electric vehicles owners are allowed to drive in high-occupancy vehicle lanes. The value of time is highly correlated with income so this could help explain why this credit is so highly concentrated in the highest income categories.

This is a general problem with EE subsidies

	Percent of Credit Received by Income Category (in thousands)						Concentration Index
	$0–$10	$10–$20	$20–$40	$40–$75	$75–$200	$200+	
Panel A. Clean Energy Tax Credits							
Residential Energy Credits	0%	1%	10%	28%	48%	14%	0.606
Alternative Motor Vehicle Credit	0%	1%	9%	32%	47%	11%	0.584
Plug-in Electric Drive Vehicle Credit	0%	0%	1%	10%	54%	35%	0.801
Panel B. Other Major Tax Credits							
Earned Income Tax Credit	18%	49%	32%	1%	0%	0%	–0.415
Making Work Pay Credit	7%	14%	25%	28%	26%	0%	0.163
Child Tax Credit	2%	13%	31%	31%	23%	0%	0.185
First-time Home Buyer Credit	7%	6%	23%	40%	24%	1%	0.222
Foreign Tax Credit	0%	0%	1%	2%	9%	88%	0.954

Note: This table was constructed by the authors using U.S. Department of the Treasury, Internal Revenue Service, "Statistics of Income, Individual Tax Returns," 2005–2012. The first five income categories are approximate quintiles (18%, 17%, 24%, 21%, 18%), and 3% of tax returns fall in the last category. Residential energy credits includes both the NEPC and the REEPC. The Earned Income Tax Credit, Making Work Pay Credit, Child Tax Credit, and the First-Time Home Buyer Credit are all refundable, while the Foreign Tax Credit is not. See Appendix A for details.

Souce: Borenstein and Davis (2016)

Recent research suggests low and middle income households are very elastic

- Muehlegger and Rapson (2018) study the impact of the Enhanced Fleet Modernization Program in California
- Subsidies vary quasi-randomly by zipcode
- Estimated demand elasticity is -3.9, implying that a subsidy that decreases the buy-price of an EV by 10 percent will increase demand for that EV by 39 percent
- Unfortunately: small baseline quantity implies only a modest increase in total number of additional EVs.
- Punchline: it will take a LOT of money to get millions of these on the road.

Note on subsidy targeting and elasticity

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Joe Manchin's Faux Betrayal and an Endless Green Bill of Goods

The Inflation Reduction Act is welfare for the rich, not investment for places like West Virginia.

By Allysia Finley Follow
April 16, 2023 12:59 pm ET

SAVE PRINT TEXT 284

WSJ editorial highlights inframarginal point

Earlier this month, the administration released guidance on the law's "bonus" tax credits for green investment in "energy communities." Mr. Manchin wanted these enhanced credits to increase investment in fossil-fuel-producing places like West Virginia, which are harmed by the government's force-fed green-energy transition. But the Energy Department's map indicates that over half the country might qualify for the credits, including San Francisco and Greenwich, Conn. Are there abandoned coal mines under the estates of the rich and famous?

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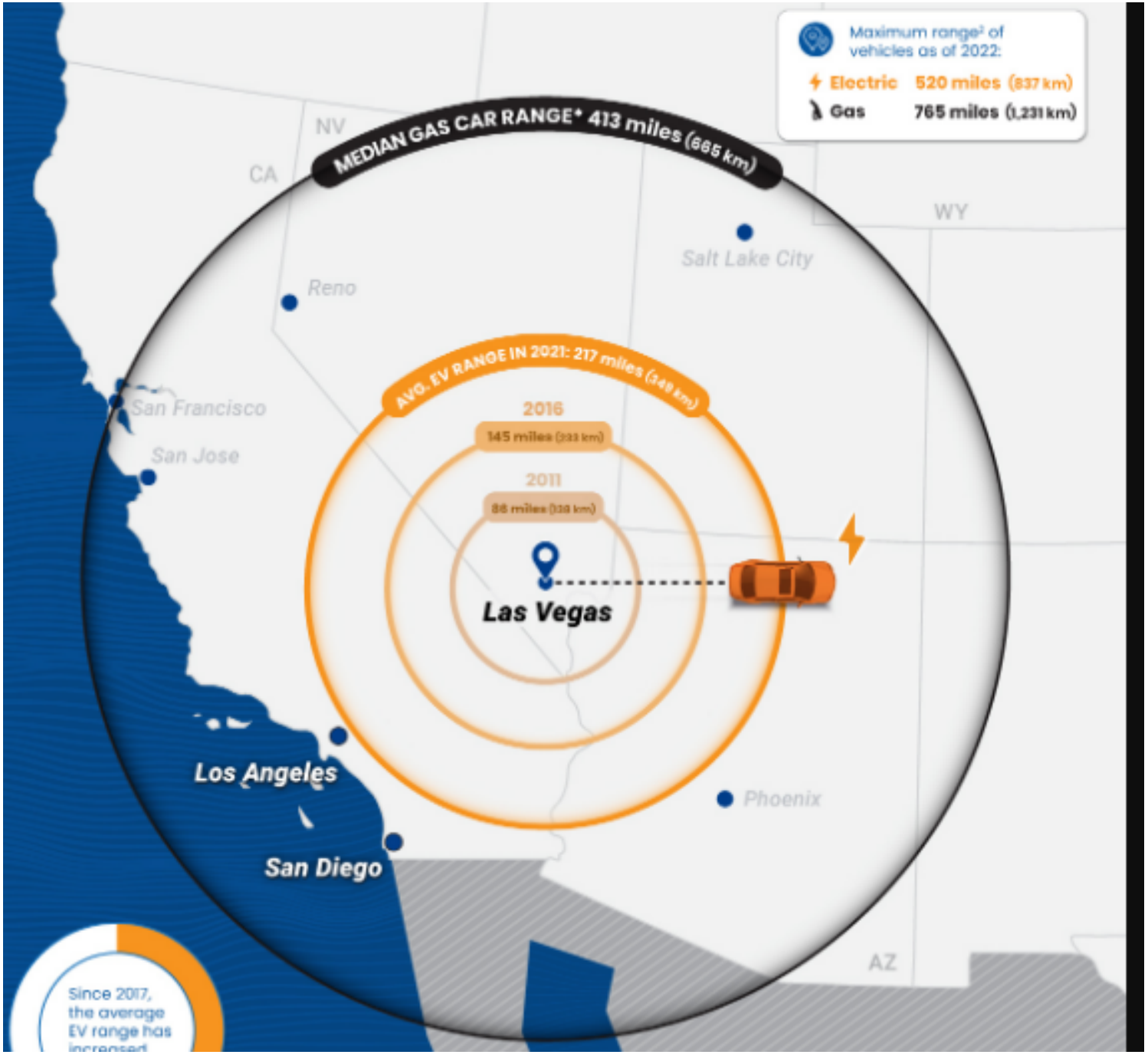
As it turns out, much of the law's climate spending is merely welfare for the affluent. Brookings predicts that 73% of electric-vehicle sales in 2030 would occur without the new subsidies. The government's Energy Information Administration last month estimated that the subsidies would increase electric vehicles' share of car sales only from 12% to 15% in 2030.

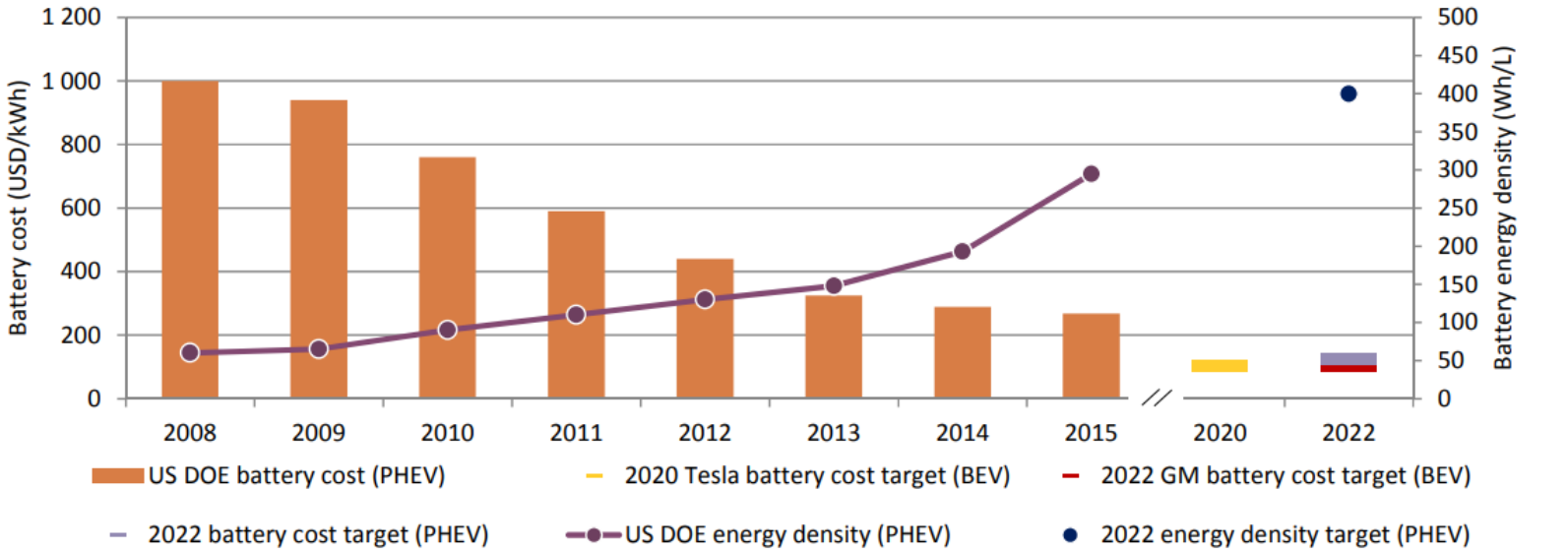
Charging

Main barrier isn't price, it's "range anxiety"

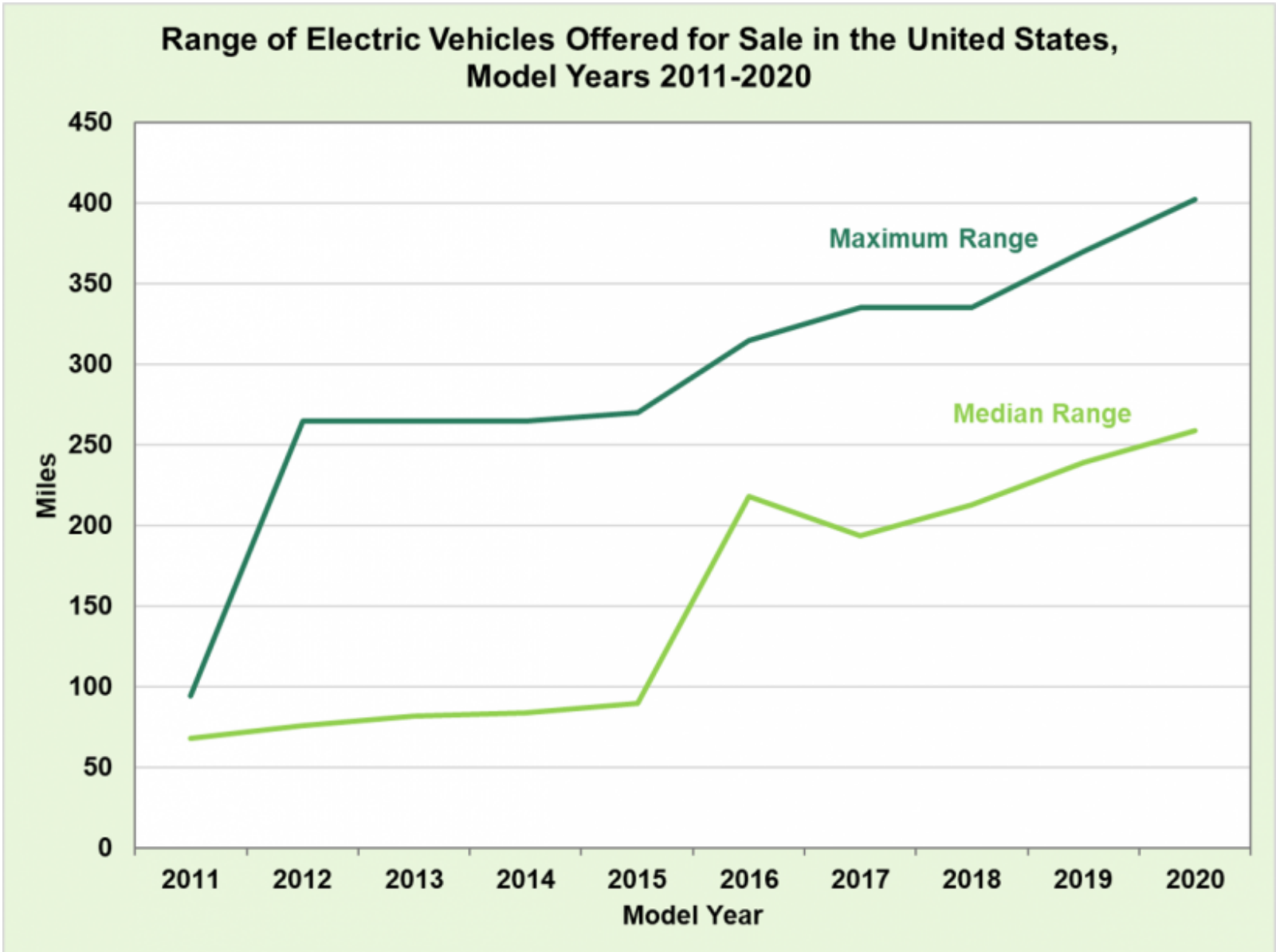


Battery costs have come down and density increased

Figure 2 • Evolution of battery energy density and cost



Notes: USD/kWh = United States dollars per kilowatt-hour; Wh/L = watt-hours per litre. PHEV battery cost and energy density data shown here are based on an observed industry-wide trend, include useful energy only, refer to battery packs and suppose an annual battery production of 100 000 units for each manufacturer.


Range of Electric Vehicles Offered for Sale in the United States, Model Years 2011-2020
Maximum Range
Median Range
Miles
450
400
350
300
250
200
150
100
50
0
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Model Year

How long do you think the typical trip is?

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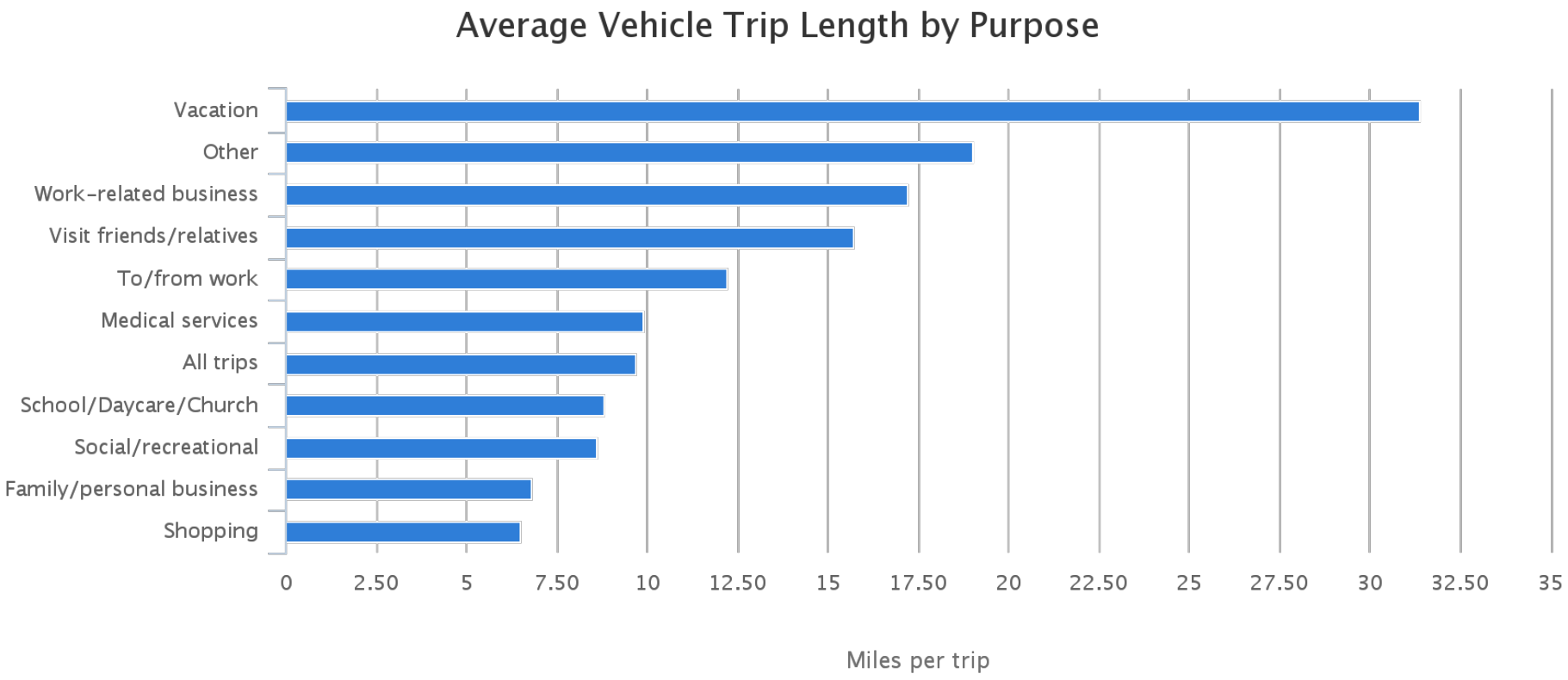

Last updated: May 2012
Printed on: April 6

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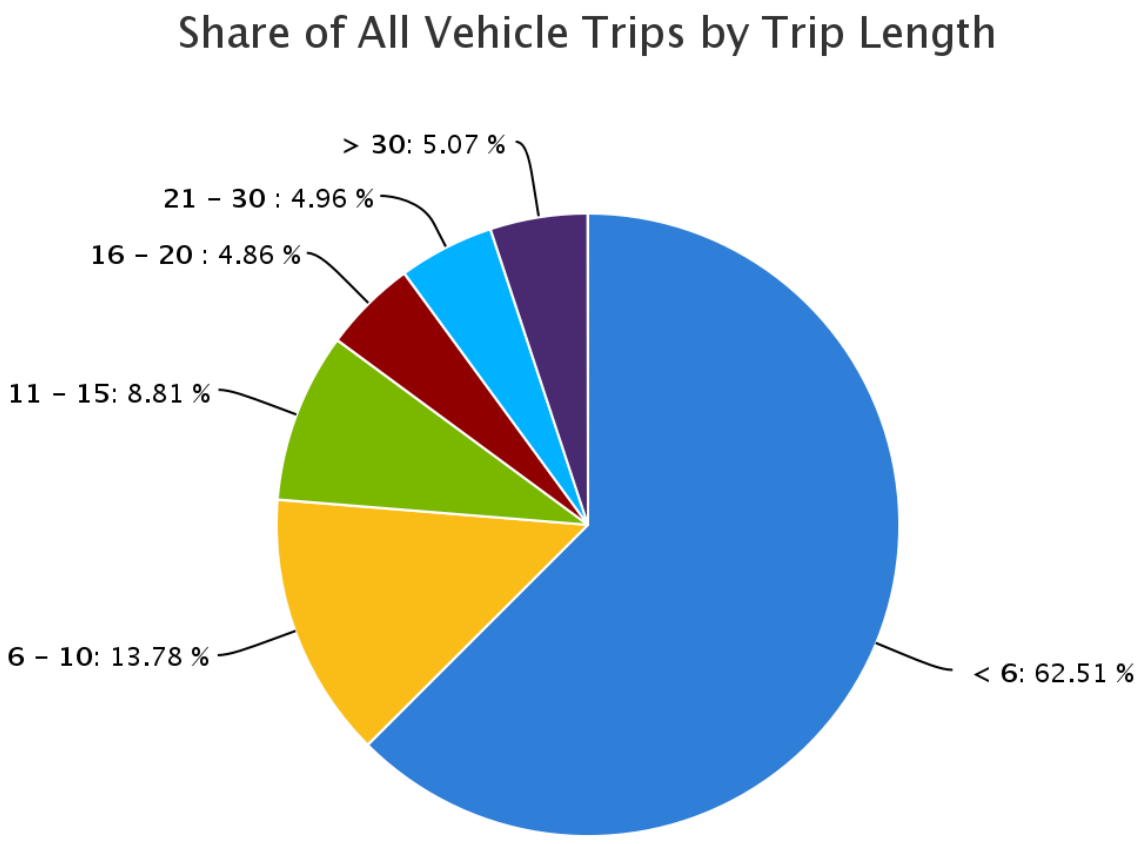

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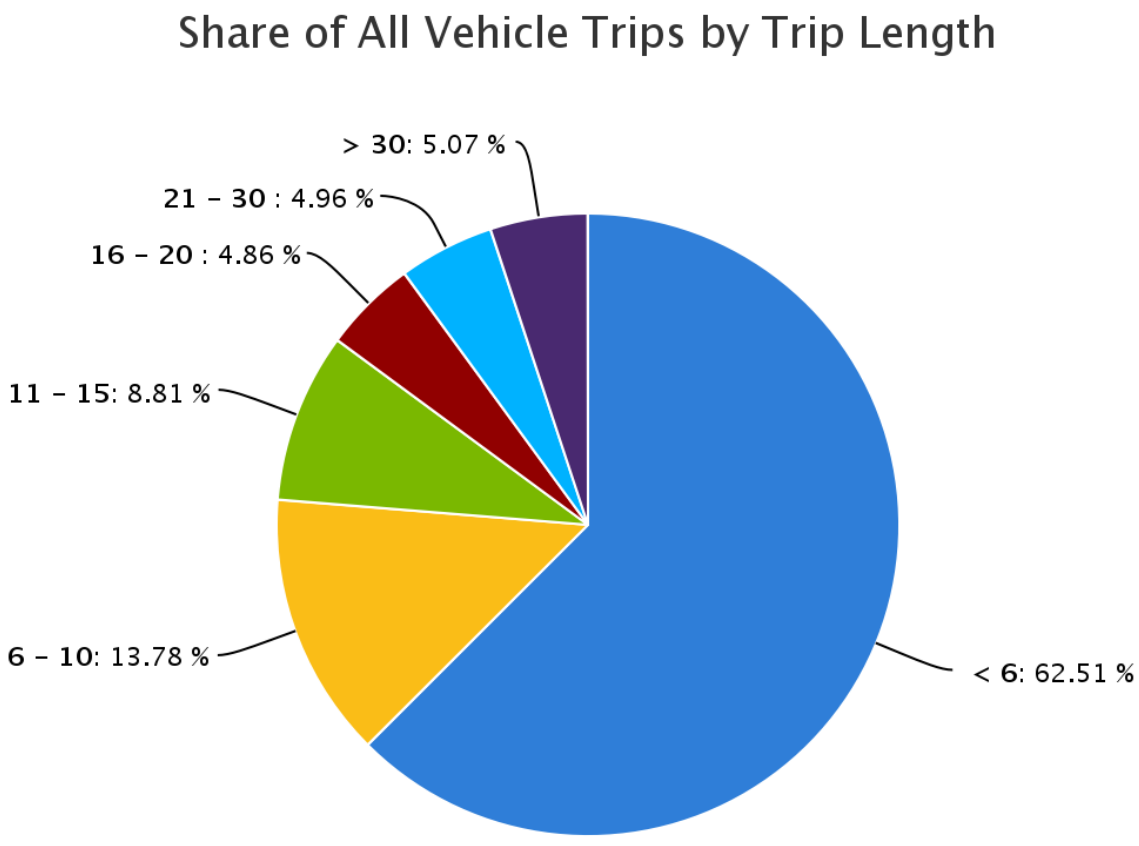


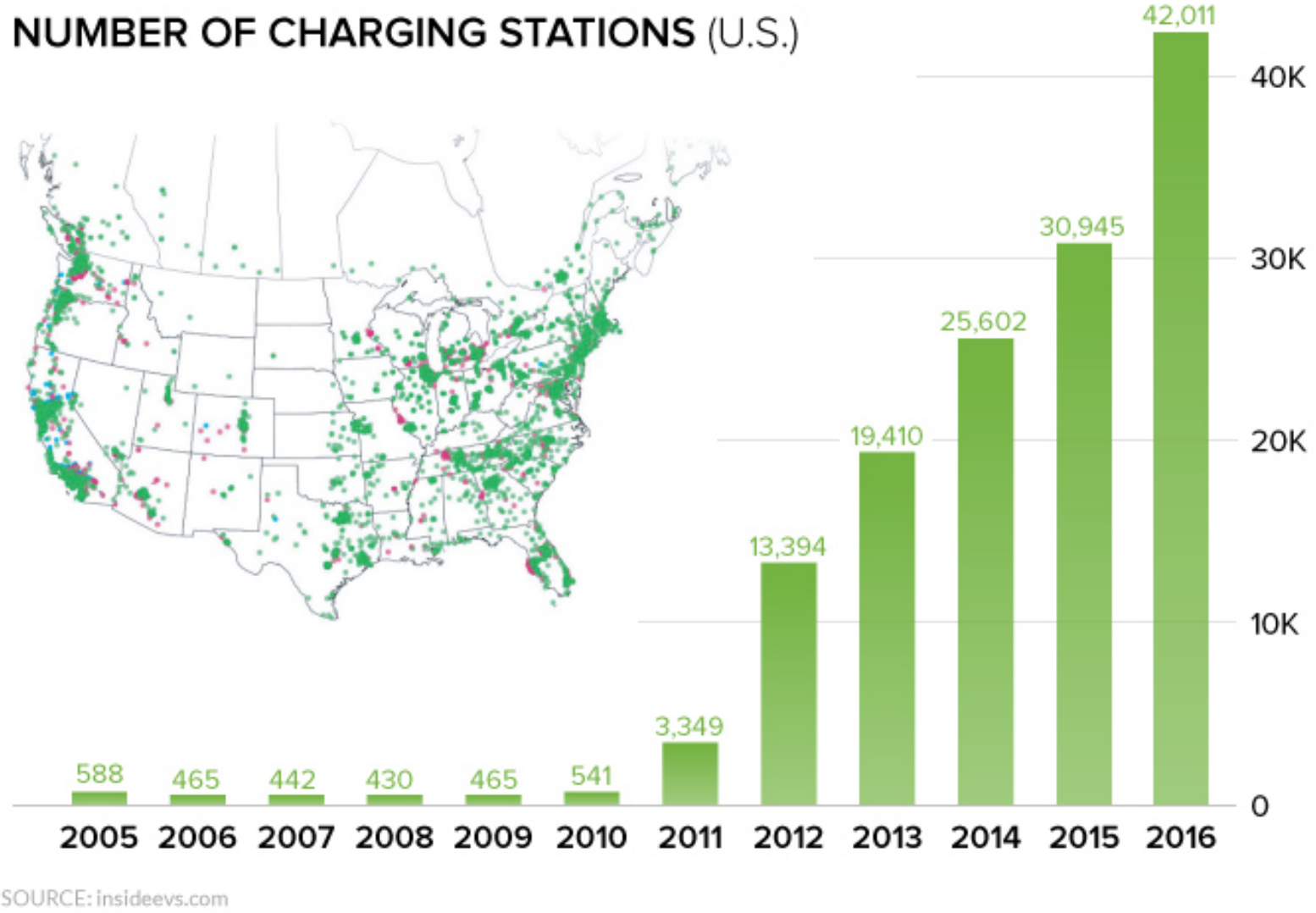
Last updated: September 2011
Printed on: April 6

Why is range such a big issue for car buyers?

Charging options

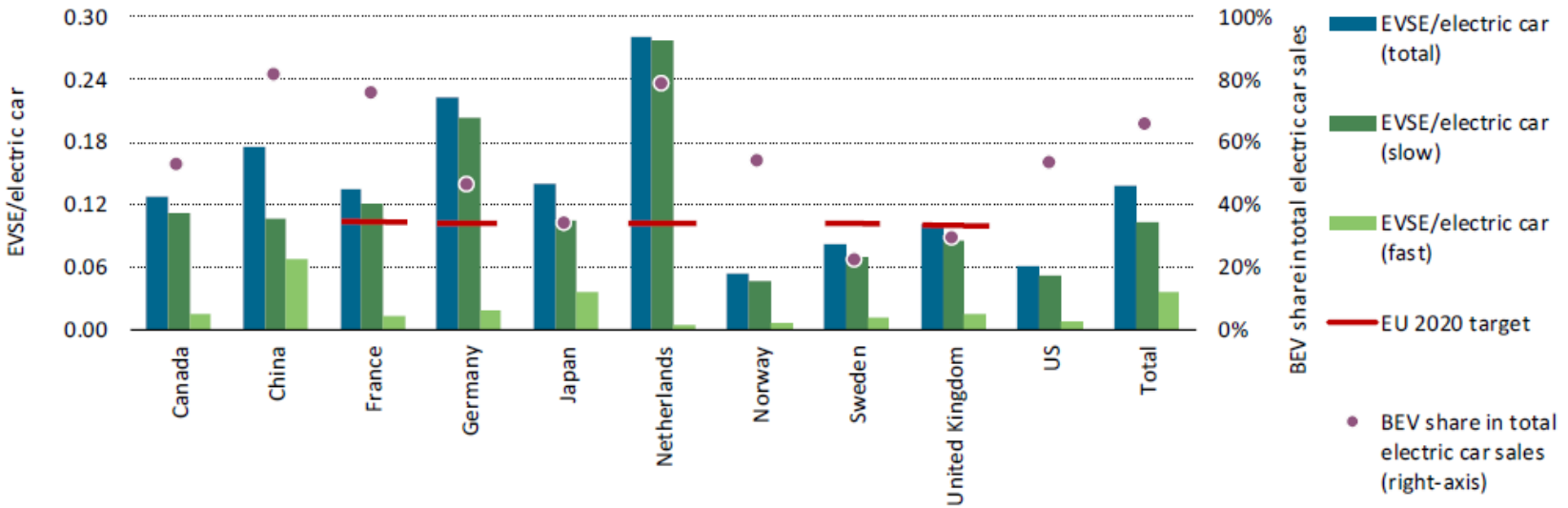
- Many drivers of all-electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) will charge their vehicles overnight at home
- AC Level 1 (120V)
  - 2-5 miles of driving per hour of charging
- AC Level 2 (240V)
  - 10-20 miles of driving per hour of charging
  - costs about $2K to buy and install
- DC Fast Charging
  - 50-70 miles per 20 minutes of charging
  - Tesla has a unique port and charger system (called superchargers)

Chargers have been growing rapidly



US lags behind other countries

Figure 3.3 • Ratio of publicly accessible charging outlets per electric car for selected countries, 2017

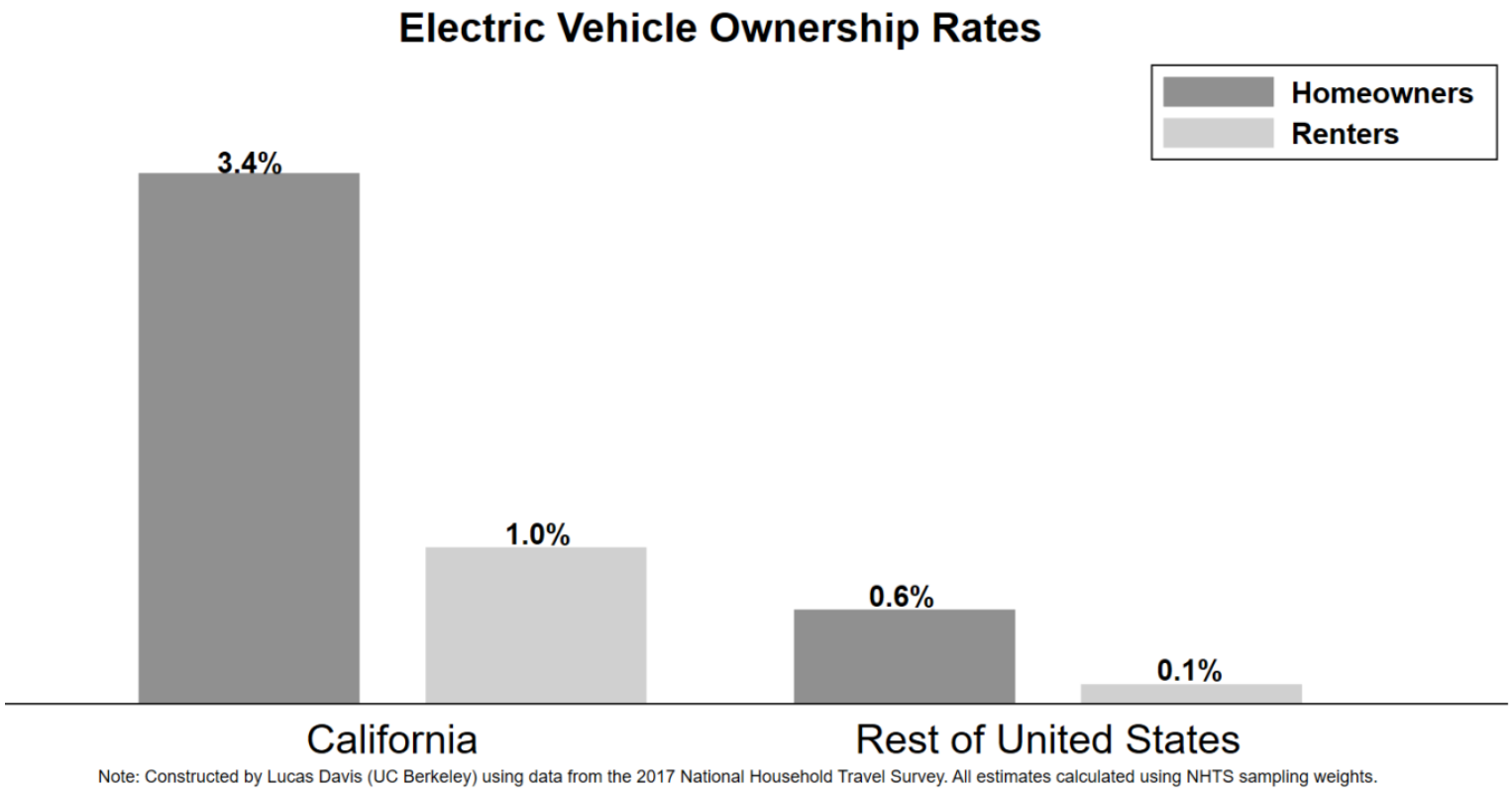


Notes: Data are based on the same assumptions as Figure 3.1 and Figure 3.2. The 2020 EVSE/EV target is the goal of the EU AFI Directive which stipulates that member states should ensure that publicly accessible charging points are built with adequate area coverage, suggesting a minimum of one recharging point per ten electric cars.

Should we subsidize chargers instead of cars?

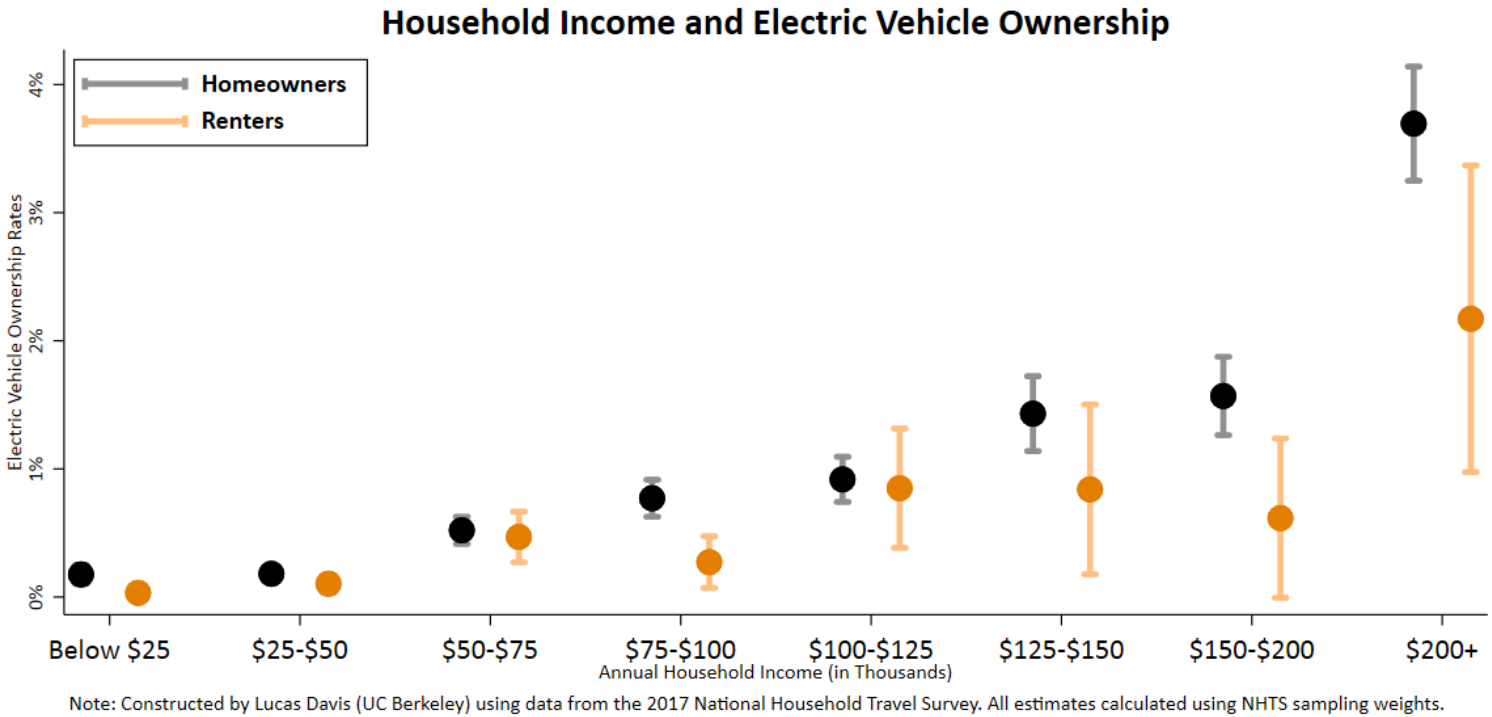
What are some arguments for / against this?

Apartments rarely have charging



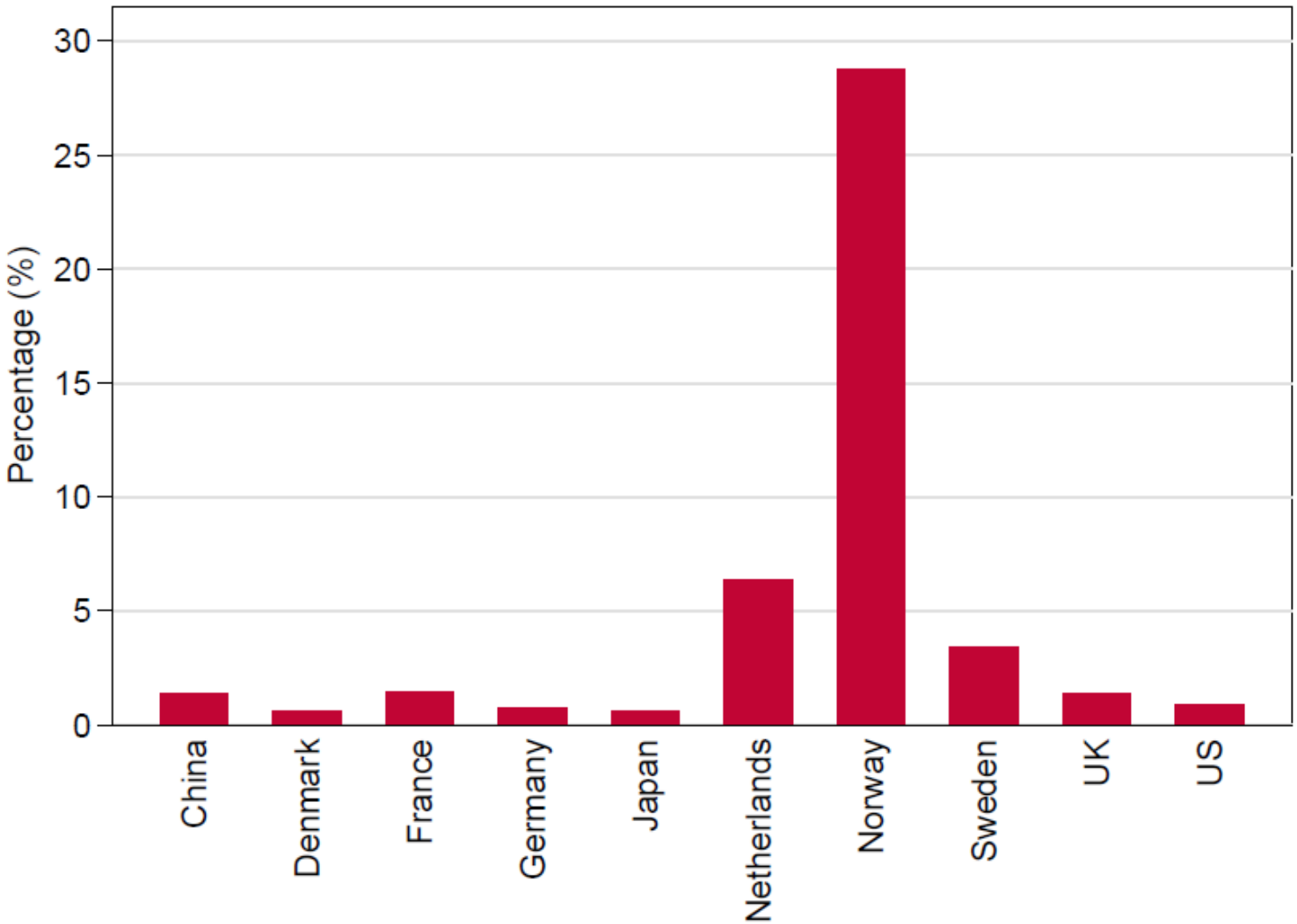
Source: Davis 2018

This isn't just about income



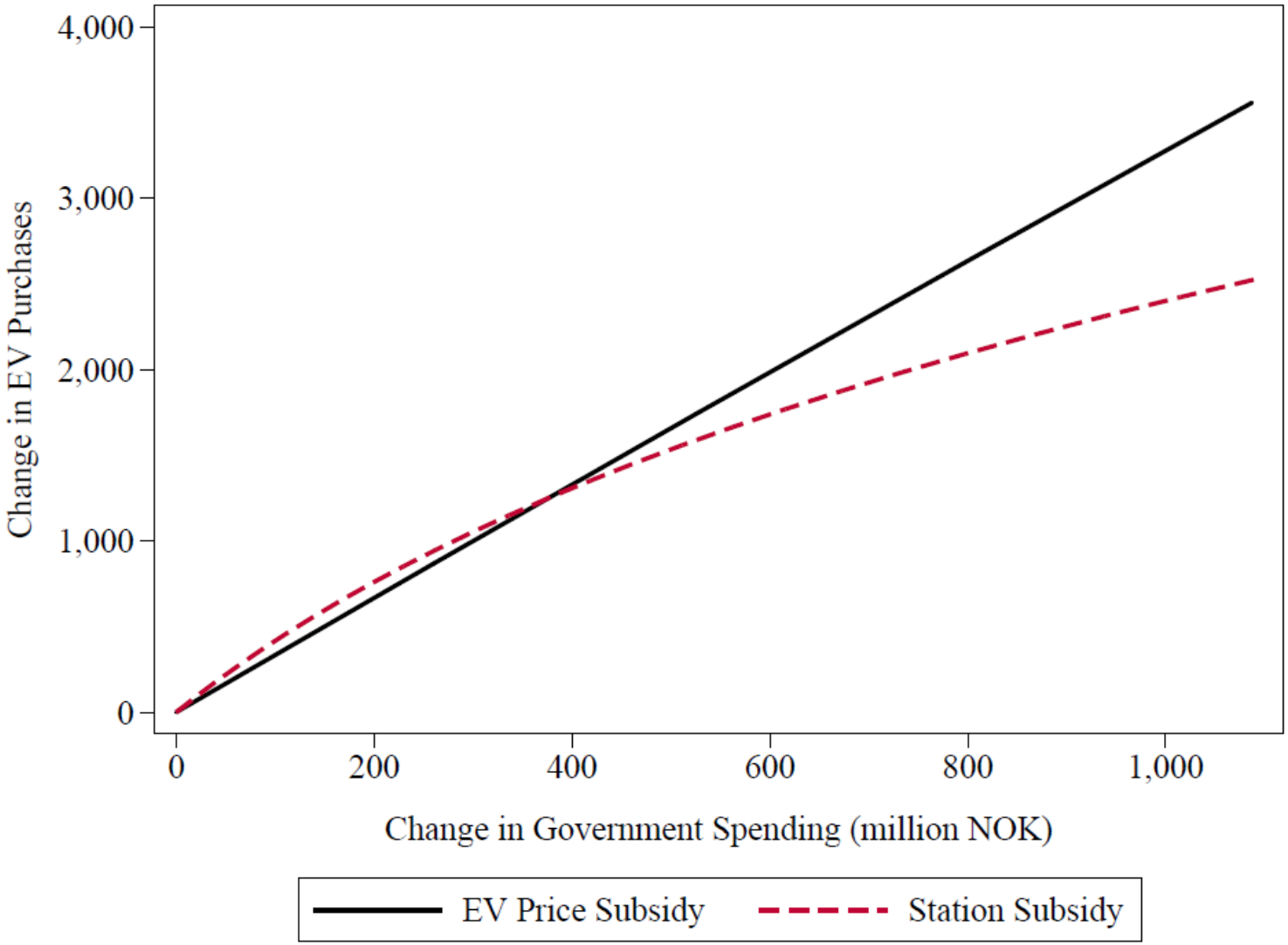
Source: Davis 2018

Springel (2018) tries to answer this question in Norway



Source: Springel 2018

Finds at high levels its cheaper to subsidize stations



Source: Springel 2018

Problem 2: Not all chargers are compatible

Figure 1: Types of Level 3 (DC, Fast) Charging Standards

Level 3 (DC, Fast) Charging Standards		
 Combo	 CHAdeMO	 Tesla
BMW: i3 GM: Bolt, Spark EV Volkswagen: e-Golf Ford Chrysler Daimler	Nissan: LEAF Mitsubishi: i-MiEV Kia: Soul EV Toyota Peugeot Citroën	Tesla: Model S, X

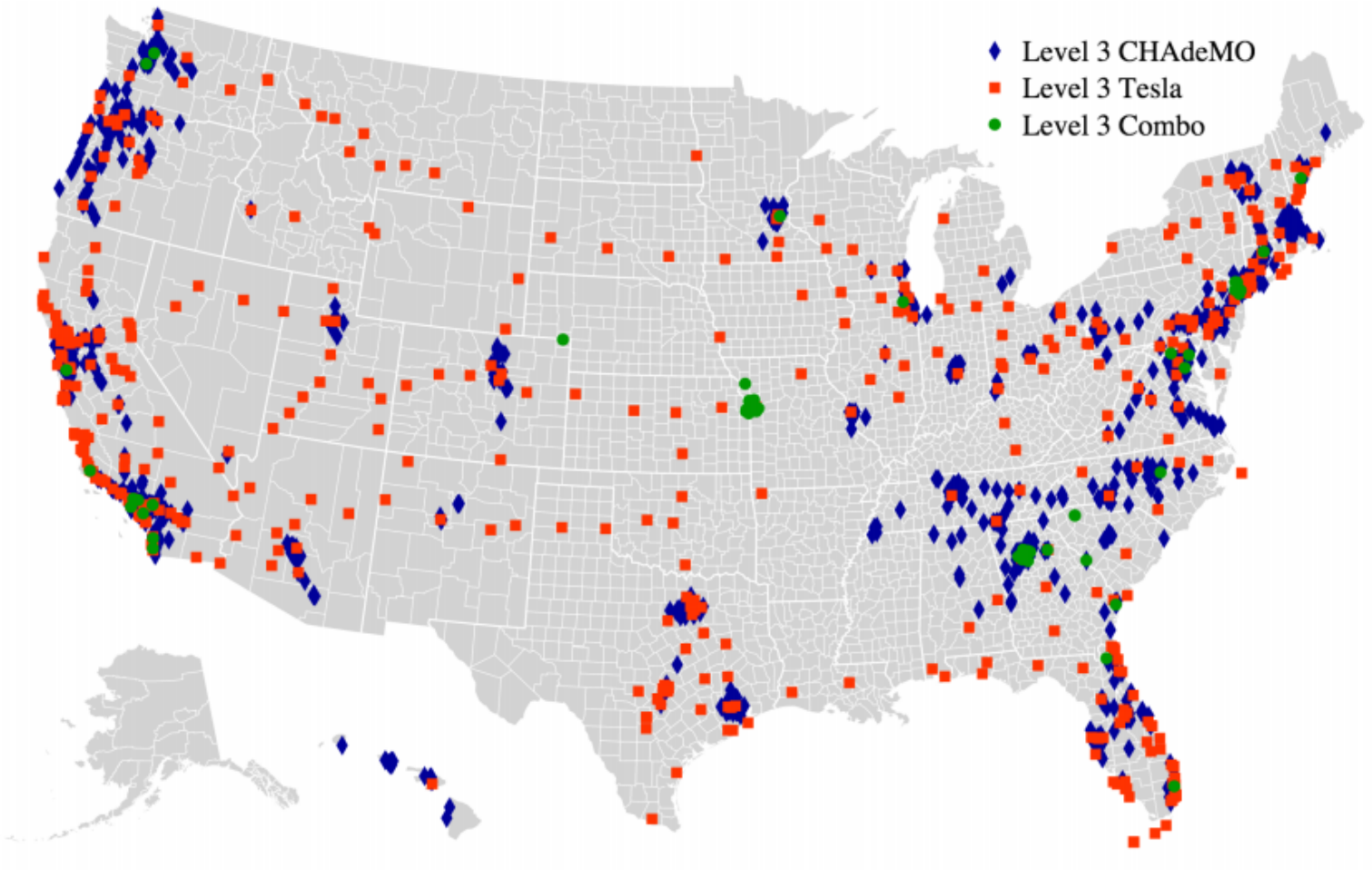
Notes: The DC fast-charging protocols have distinct connector shapes. Not all electric vehicles on the market are capable of DC fast-charging. The make and model of cars compatible with each protocol is listed, along with automakers who have pledged support for a particular protocol but do not currently sell cars that have fast-charging capabilities. Image source: Alternative Fuels Data Center.

Source: Li 2017

This is actually a common problem

Implications of incompatibility

Figure 3: Level 3 (DC, Fast) Charging Locations Plotted on a U.S. Map



Source: Li 2017

Should we mandate compatibility?

What do you think will happen to the market?

Should we mandate compatibility?

What do you think will happen to the market?

Li 2019 finds:

- Under compatibility, firms would reduce investments in charging stations.
- Yet, the size of the electric vehicle market would still expand.
- Policy would be welfare-improving even taking into account the cutback in car manufacturer charging station investment.

Compatibility and Investment in the U.S. Electric Vehicle Market*

Jing Li†

January 27, 2019

Abstract

Competing standards often proliferate in early stages of product markets and may lead to socially inefficient investment. This paper studies the effect of unifying three incompatible standards for charging electric vehicles in the U.S. from 2011 to 2015. I develop and estimate a structural model of vehicle demand and charging network investment to quantify the impact of a uniform charging standard. Variation in federal and state subsidies identify the demand elasticities. Counterfactual simulations show moving to a uniform charging standard increases consumer surplus by $500 million; car manufacturers build 2.8% fewer charging locations and sell 20.8% more electric vehicles.

One example of complications that arise from imperfect competition

How did Tesla make some of its cars travel further during Hurricane Irma?

The electric-car giant gave customers a lifeline by remotely boosting their vehicles' battery capacity. But this act of kindness also highlighted that it had been selling identical cars at different prices

Why would Tesla do this?

Why would Tesla do this?

- Wanted to sell two quality levels in order to price discriminate
- Cheaper to make one battery (75 kWh not 60kWh)
- So profit maximizing to produce only high quality goods, but destroy some of that value in the market place
- This is the "damaged goods problem", and it arises in many settings (ie computer chips).

Environmental Benefits

Policy increase EV takeup. What are the environmental benefits

- The primary motivation of subsidizing EVs is environmental.
- How would you go about determining net benefits?
- What are the key factors which would make EVs be more / less socially beneficial?

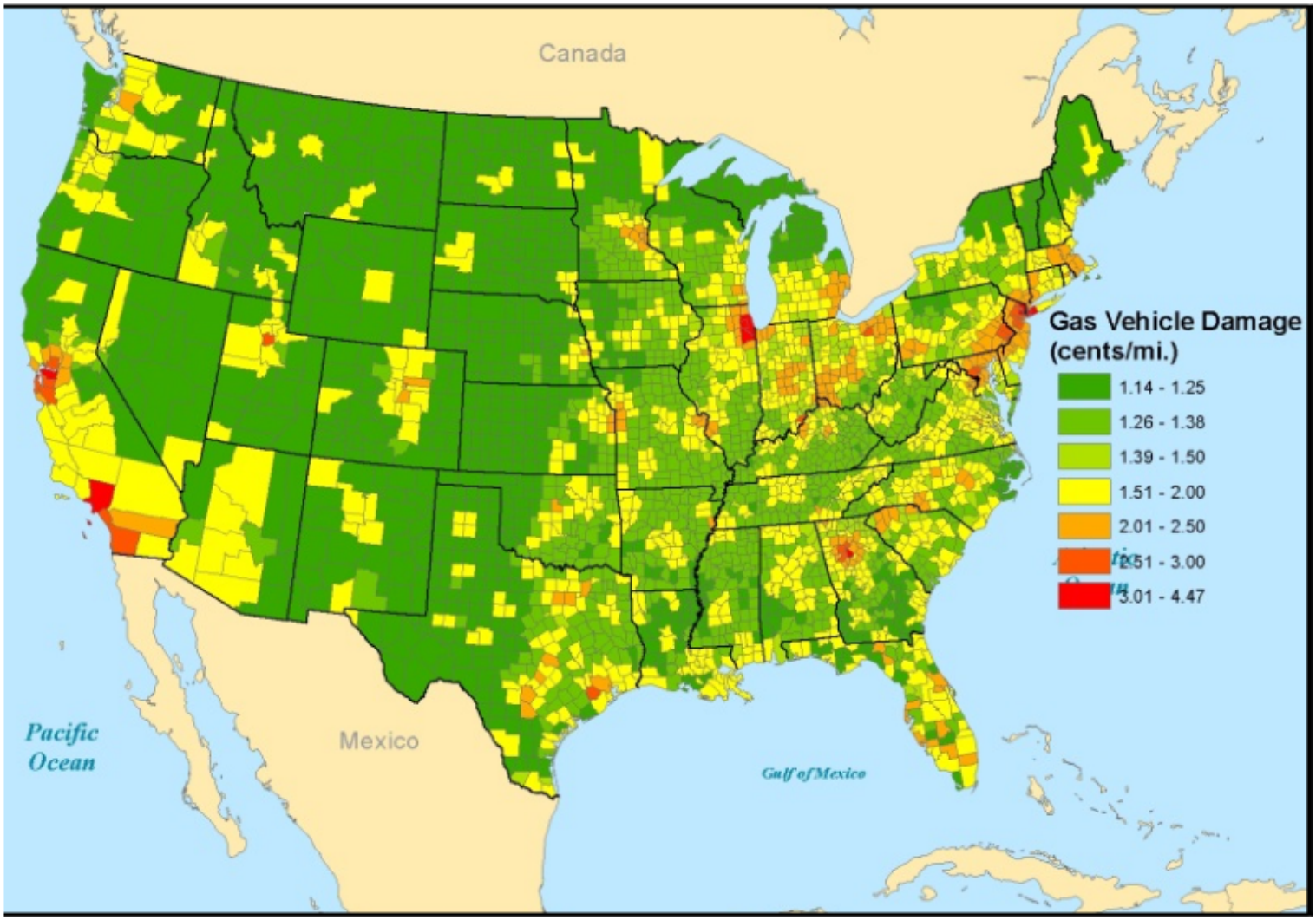
What is "Greener"? EV vs. Gasoline Vehicle?

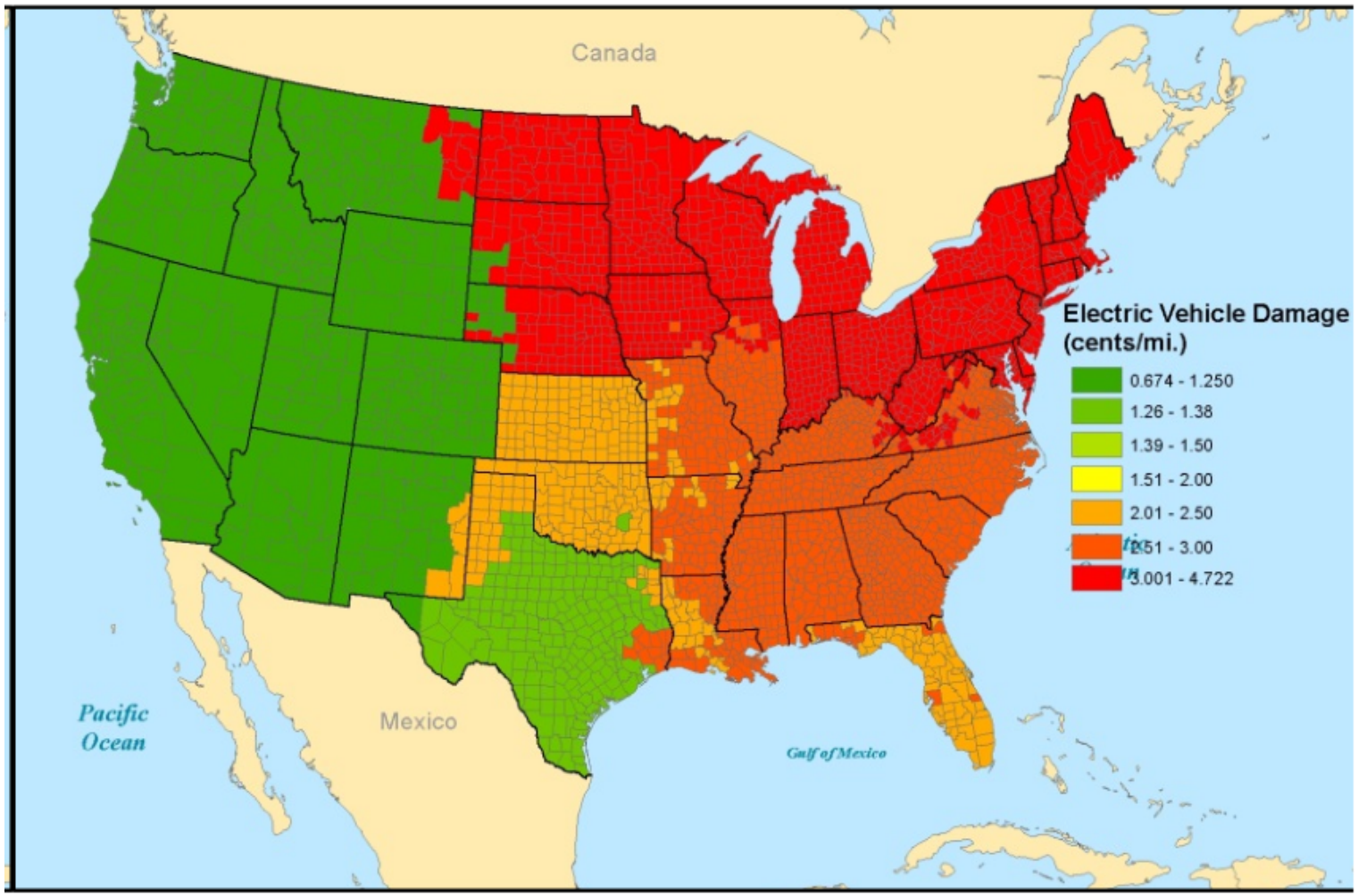
What is "Greener"? EV vs. Gasoline Vehicle?

Are There Environmental Benefits from Driving Electric Vehicles? The Importance of Local Factors†

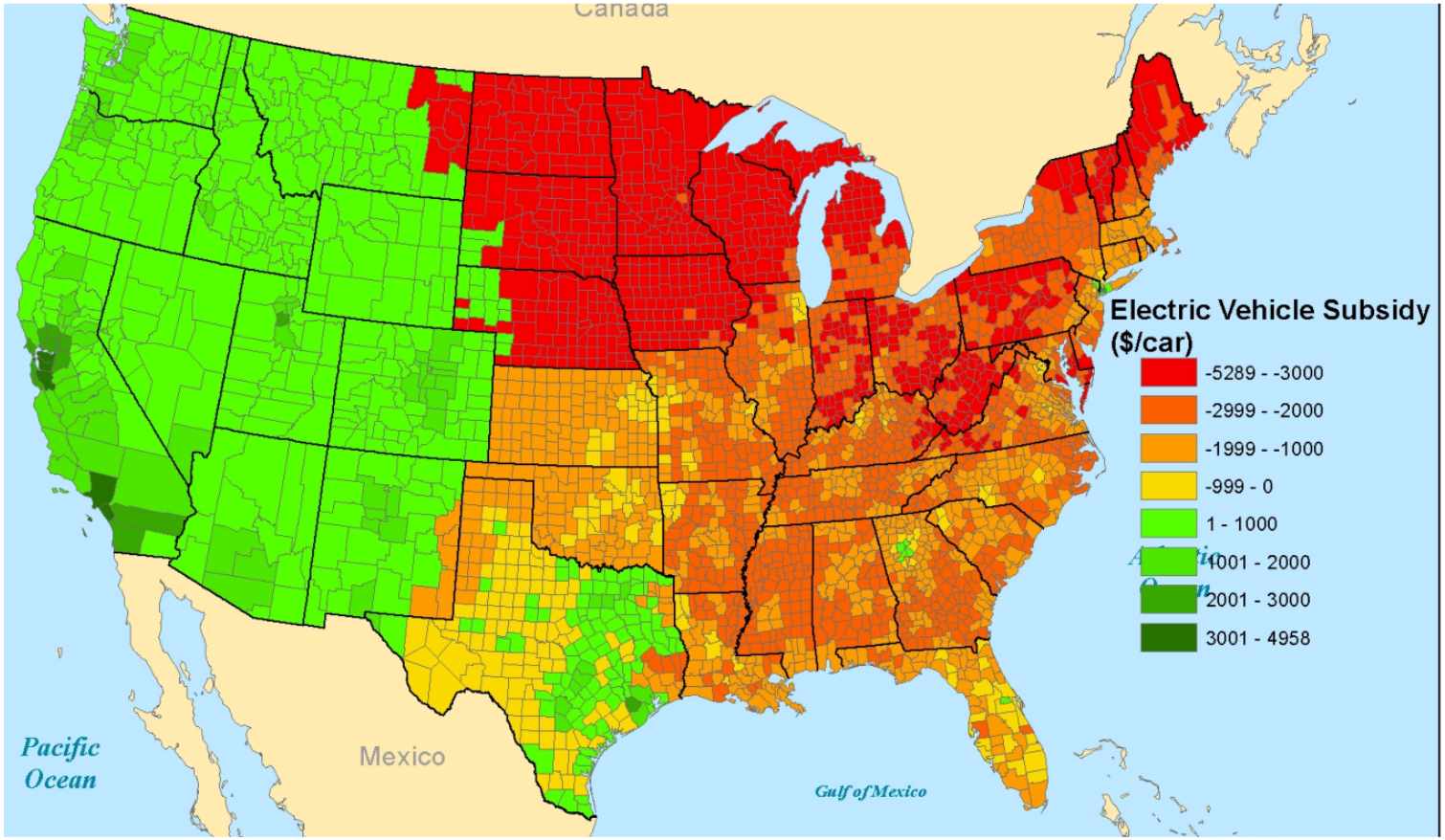
By Stephen P. Holland, Erin T. Mansur, Nicholas Z. Muller, and Andrew J. Yates*

We combine a theoretical discrete-choice model of vehicle purchases, an econometric analysis of electricity emissions, and the AP2 air pollution model to estimate the geographic variation in the environmental benefits from driving electric vehicles. The second-best electric vehicle purchase subsidy ranges from $2,785 in California to −$4,964 in North Dakota, with a mean of −$1,095. Ninety percent of local environmental externalities from driving electric vehicles in one state are exported to others, implying they may be subsidized locally, even when the environmental benefits are negative overall. Geographically differentiated subsidies can reduce deadweight loss, but only modestly. (*JEL* D12, D62, H23, L62, Q53, Q54, R11)


Canada
Gas Vehicle Damage (cents/mi.)
1.14 - 1.25
1.26 - 1.38
1.39 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 4.47
Pacific Ocean
Mexico
Gulf of Mexico

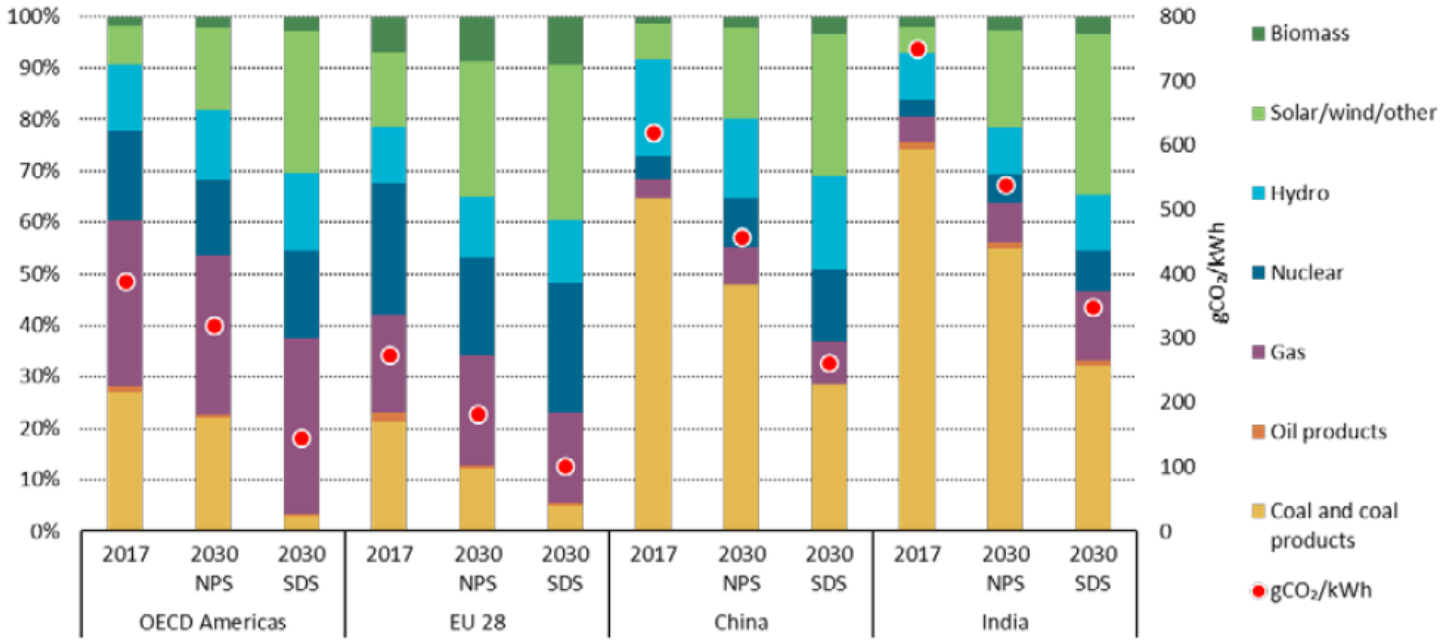

Canada
Electric Vehicle Damage (cents/mi.)
0.674 - 1.250
1.26 - 1.38
1.39 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.001 - 4.722
Pacific Ocean
Mexico
Gulf of Mexico

Map of Second-Best EV Subsidy (150k miles/car)



Is this hopeless?

Figure 6.9 • Power generation mix and carbon intensity by region, 2017 and 2030



Note: NPS = New Policies Scenario; SDS = Sustainable Development Scenario.

Source: IEA (2017b).

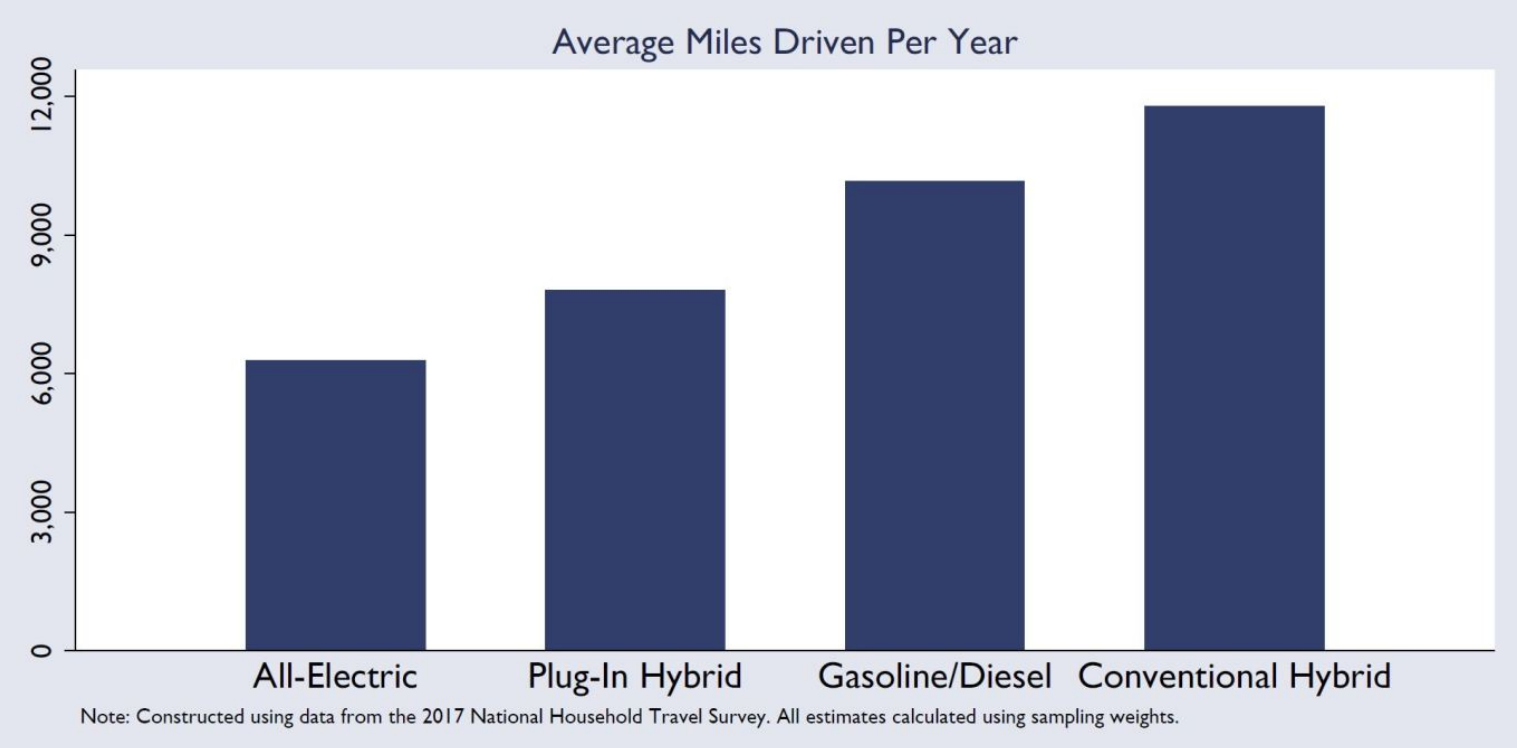
Key point: Today the carbon intensity of power generation differs considerably across regions, but the carbon intensity is projected to decline in each region by 2030.

When are EV's charged?

How much are EV's driven?

- Many US households have two cars
- Typically one is more efficient, and logs more miles (big trips, further commutes etc)
- Know EVs going to richer households.
- How many actual ICE VMT are being replaced by EVs?
- Notes that EV's probably have higher embedded emission from materials
- That looks much worse if people aren't driving them.

Davis 2018 finds EVs driven MUCH less (on average)

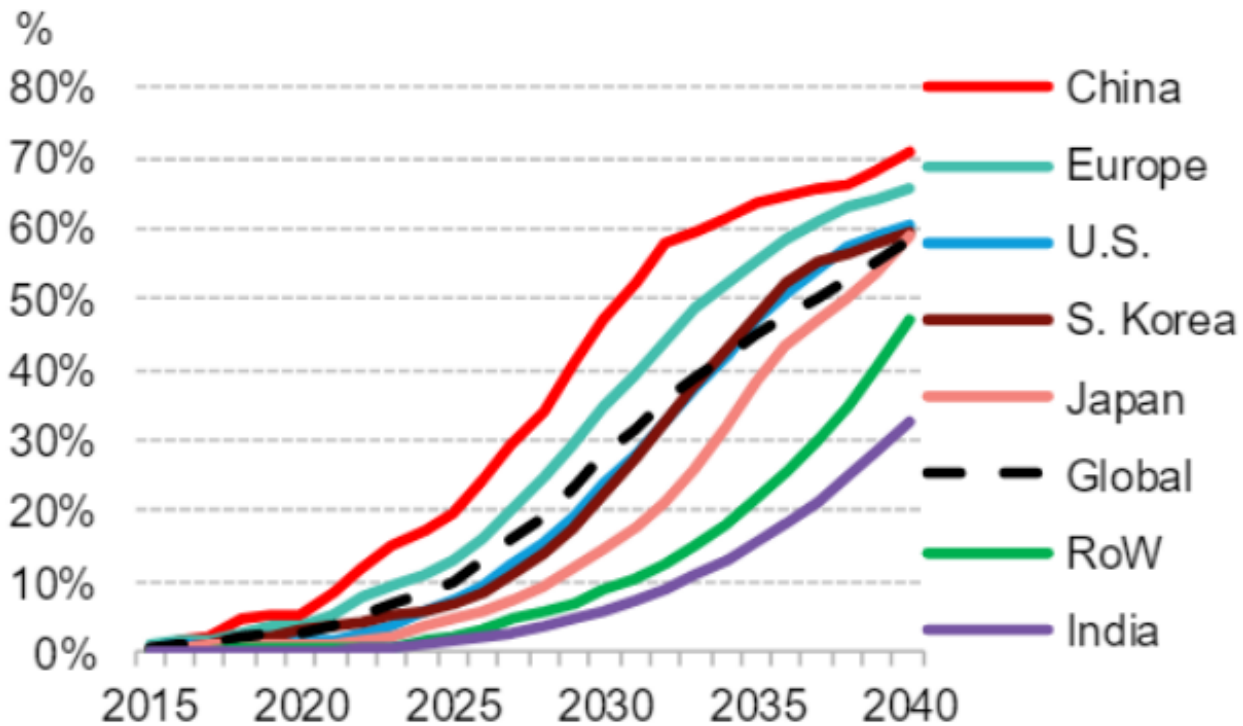


Source: Davis blog post (2018)

Wrap up

Expected to grow rapidly

Figure 2: Global long-term EV share of new passenger vehicle sales by region



BNEF Predicts cost parity in most markets in 2023.

EVs will overtakes ICE soon ...

Figure 5: Global annual passenger vehicle sales by drivetrain

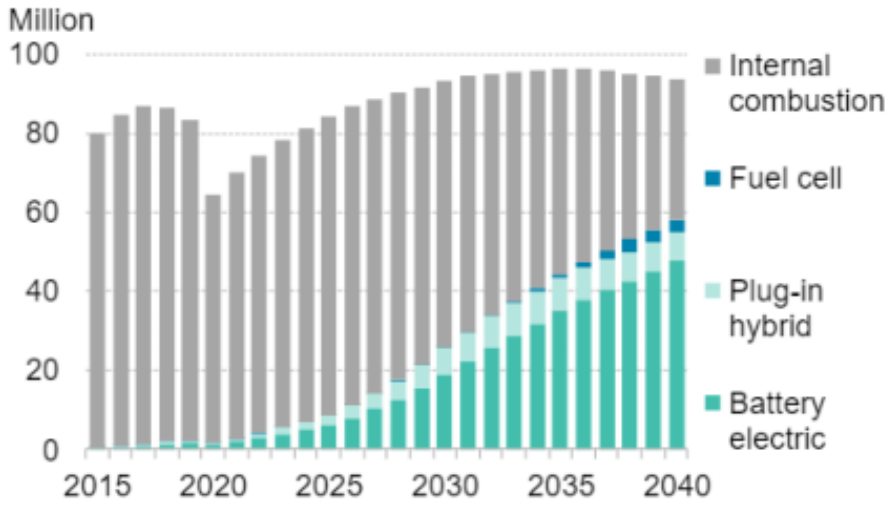
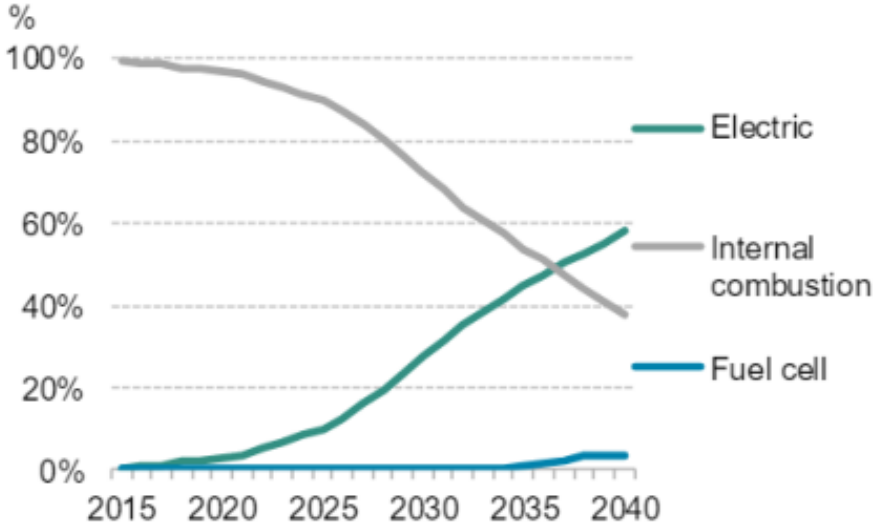


Figure 6: Global share of total annual passenger vehicle sales by drivetrain



Source: BNEF. Note: Electric share of annual sales includes battery electric and plug-in hybrid.

But share of *miles driven* will take a long time

Figure 7: Global passenger vehicle fleet by drivetrain

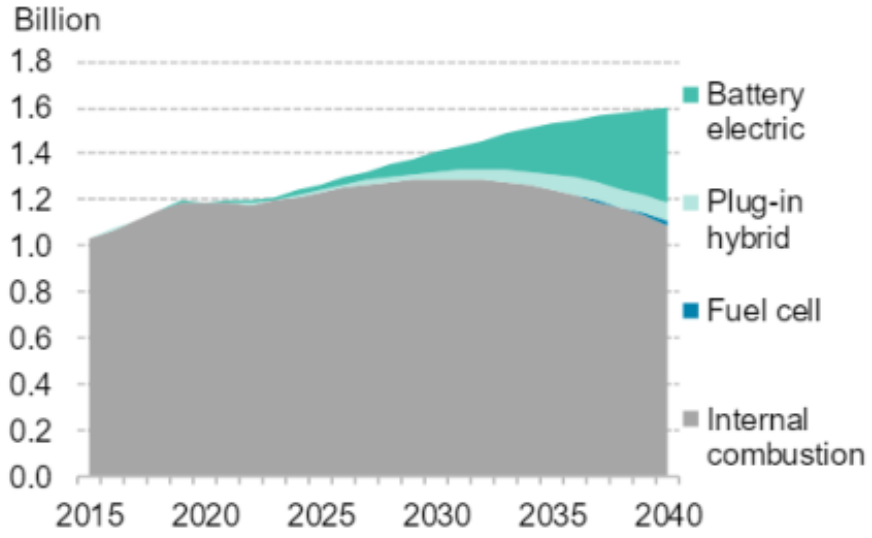
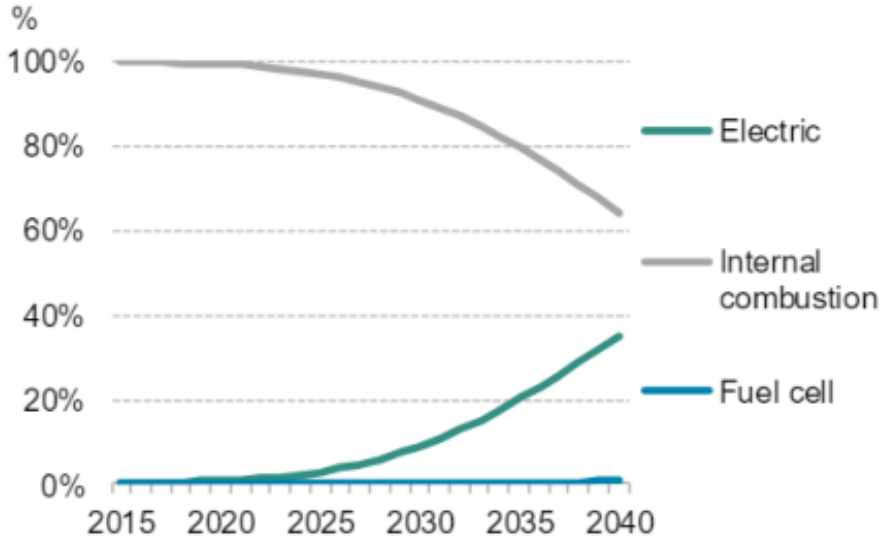


Figure 8: Global share of annual passenger vehicle distance traveled by drivetrain



Source: BNEF. Note: Electric kilometers includes battery electric kilometers and electric share of plug-in hybrids.

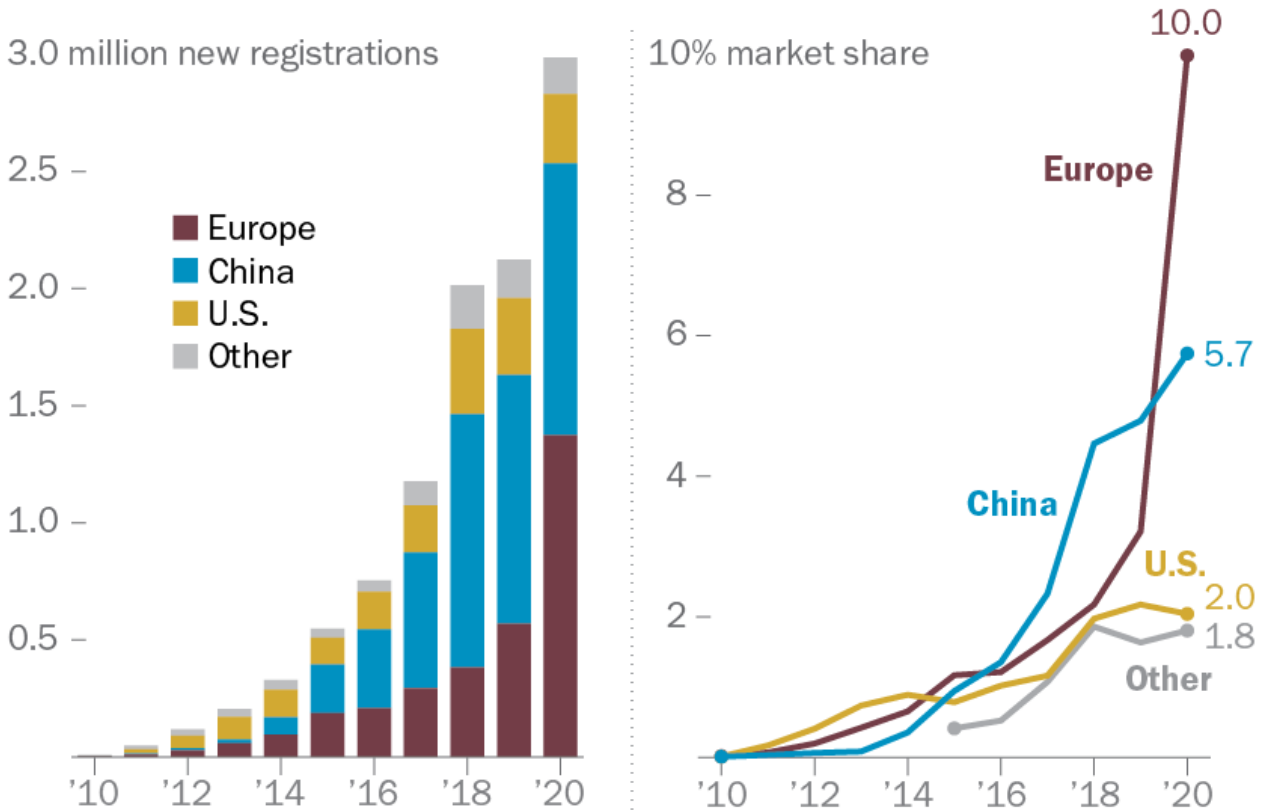
EV Summary

- EVs are clearly the future of transportation, and many governments have goals to supplant the ICE in the next decade.
- Incredible progress has been made and firms are clearly going to get better.
- Main limitations these days aren't price, but other attributes: range, charging, power, etc.
- Growth to date fueled by generous subsidies for the vehicles themselves. Smart policy might target these other dimensions.
- EVs only as green as the electric power grid.

Extra slides

Europe leads the way in new electric vehicle sales

New global electric car registrations and automobile market share, 2010-2020



Note: Electric car totals include all-electric, plug-in hybrid and fuel cell vehicles. "Europe" includes the 27 nations in the EU, plus Iceland, Norway, Switzerland and the UK. "Other" includes Australia, Brazil, Canada, Chile, India, Indonesia, Japan, Malaysia, Mexico, New Zealand, South Africa, South Korea and Thailand.
Source: International Energy Agency, "Global EV Outlook 2021."

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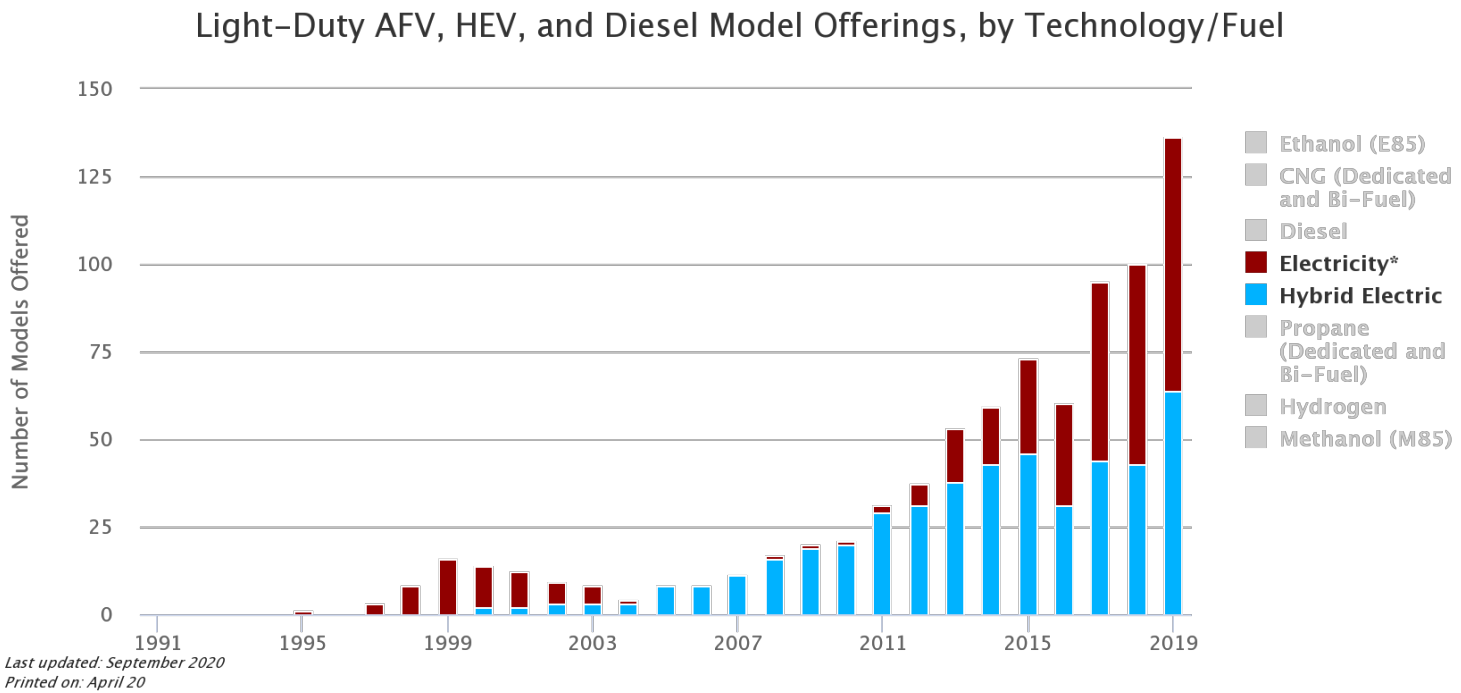
There are many EVs now on the market



Three types of EVs: HEVs, PHEVs, BEVs

Wide range of models now offered

Electric Vehicle Model	Electric Motor/ Battery Size	Energy Impact Score* (barrels petroleum/ year)	Driving Range *(miles)*	GHG Score**	Fuel Economy (mpge) *Combined/City/Hwy*	Starting MSRP
BMW i3	125 kW/21 kWh	0.2	81	10	124/137/111	$42,400
Chevrolet Spark	104 kW/20 kWh	0.2	82	10	119/128/108	-
Fiat 500e	83kW/24 kWh	0.2	87	10	116/122/108	-
Ford Focus	107 kW/23 kWh	0.2	76	10	105/110/99	$29,170
Kia Soul	50 kW/16.4 kWh	0.2	93	10	105/120/92	$31,950
Mercedes-Benz B250e	132 kW/28 kWh	0.2	87	10	84/85/82	-
Mitsubishi i-MiEV	49 kW/16 kWh	0.2	62	10	112/126/99	$22,995
Nissan Leaf	80 kW/24 kWh	0.2	84	10	114/126/101	-
smart fortwo	55 kW/17.6 kWh	0.2	68	10	107/122/93	-
Tesla Model S	285 kW/70 kWh	0.2	265	10	89/88/90	-

- EV performance has always been good (its a more efficient engine)
- The main challenge remains range anxiety