Consumer preferences for EVs

ECI 189G: Lecture 8

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Spring 2022
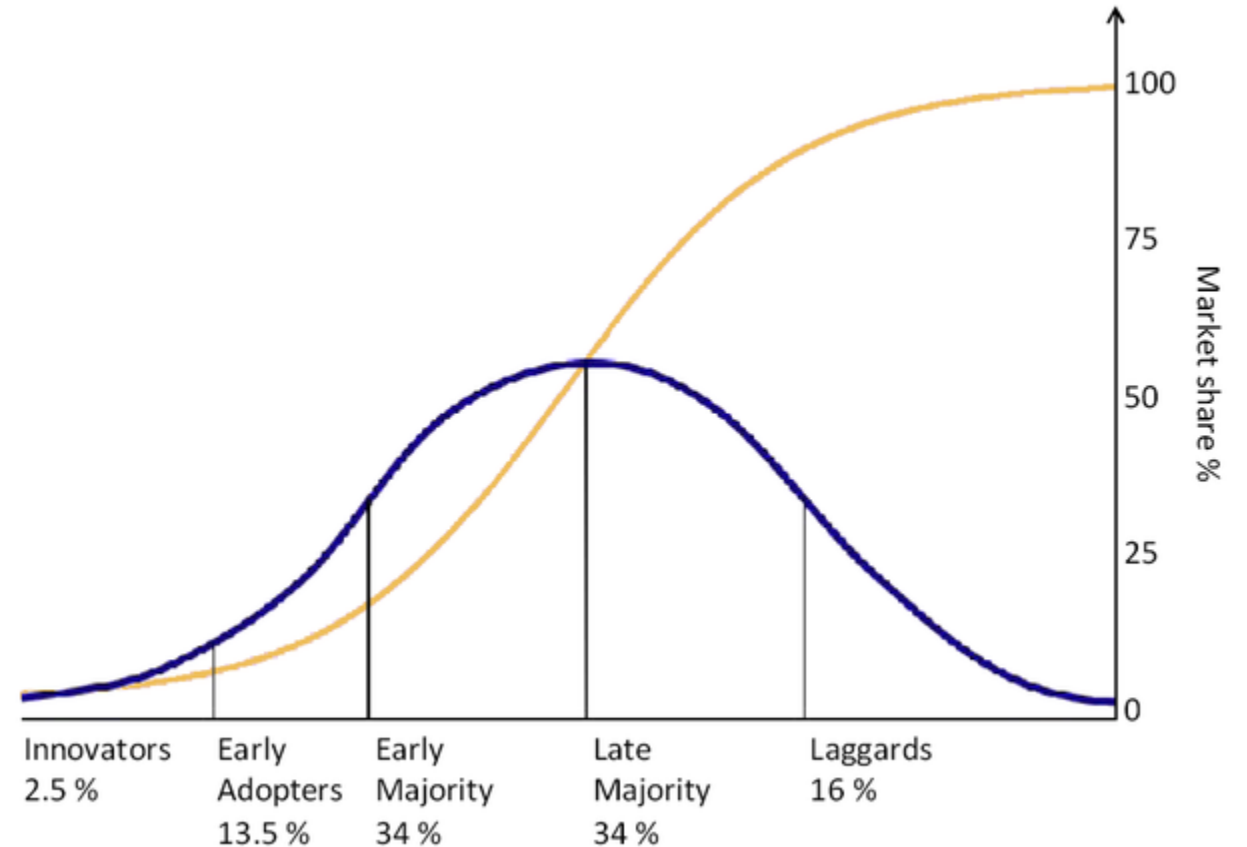
Technology Adoption

Who wants to buy electric vehicles?

- Why do we care about learning about EV buyers?
  - What populations of drivers are buying EVs—and who *isn't* buying an EV?
  - How many more people will buy EVs as prices come down? Or as range increases? Or as infrastructure becomes more available?
  - What aspects of EVs should policy target? Technology? Infrastructure? EV buyers? EV producers?

Diffusion and adoption theory

- This is a standard technology adoption curve
- Consumers tend to adopt technologies at different rates
- The population of adopters is broken down into categories that determine the "first" to the "last" buyer

Innovators 2.5 % | Early Adopters 13.5 % | Early Majority 34 % | Late Majority 34 % | Laggards 16 %

Market share %

100, 75, 50, 25, 0

Examples of technology adoption

- While not exactly the same, many technologies have consistently followed "S-shaped" adoption curves
- Technology adoption trends give us confidence that growth will happen, it's just a question of how fast/slow

Technology adoption by households in the United States
Technology adoption rates, measured as the percentage of households in the United States owning, or the adoption rates of, a particular technology. See the sources tab for definitions of household adoption, or adoption rates, by technology type.
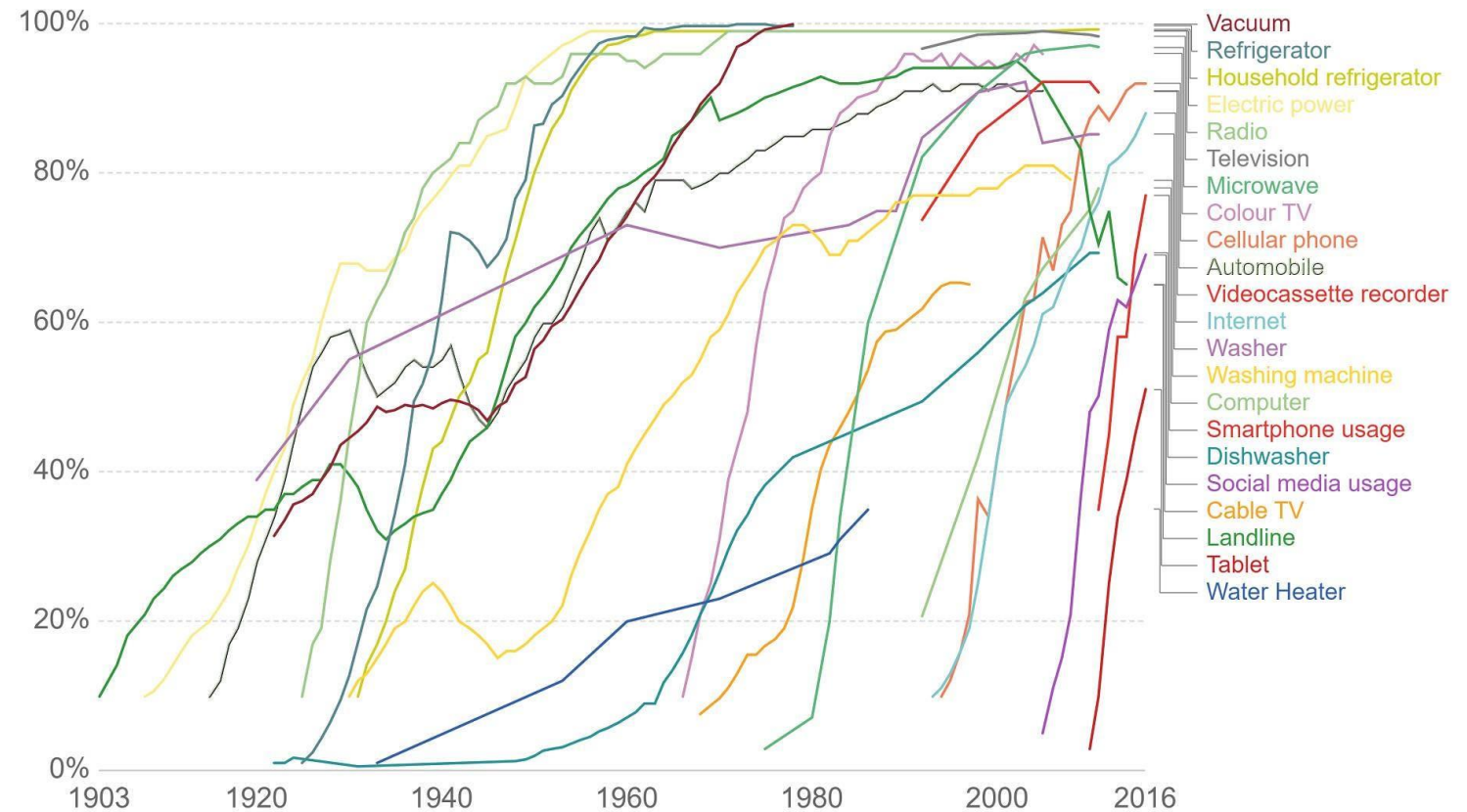
Source: Comin and Hobijn (2004) and others
OurWorldInData.org/technology-adoption/ • CC BY-SA

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Electric vehicle adoption curve

- In 2016, the International Council on Clean Transportation released this figure, helping to place different regions on the technology diffusion curve

- 6 years later, where are we now?

Norway is now at 65% share

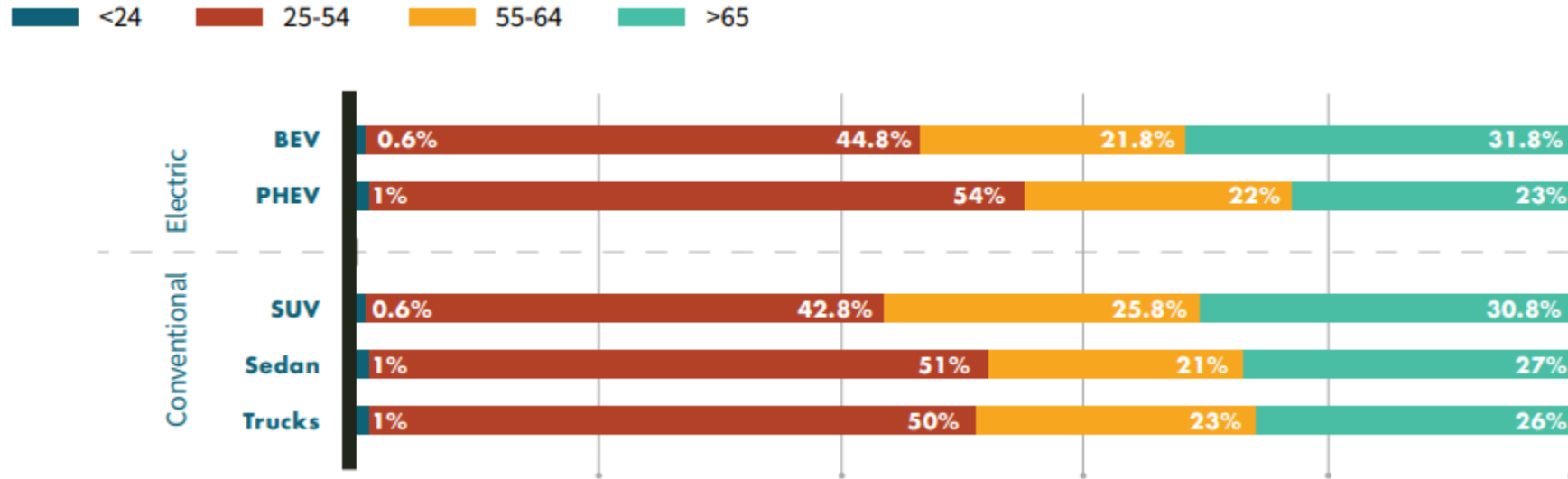World is at 7% market share

California is now at 10% share
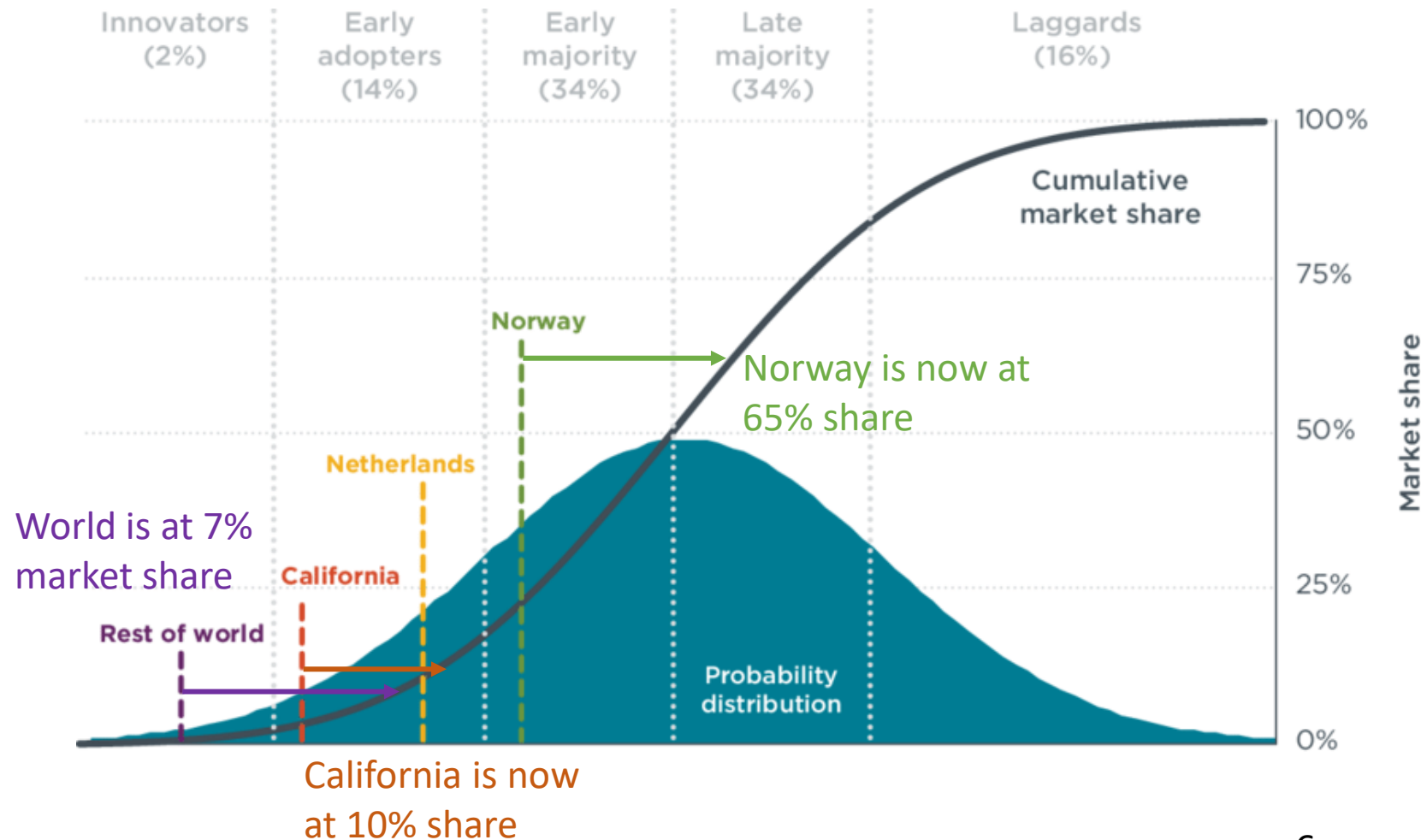
Demographics
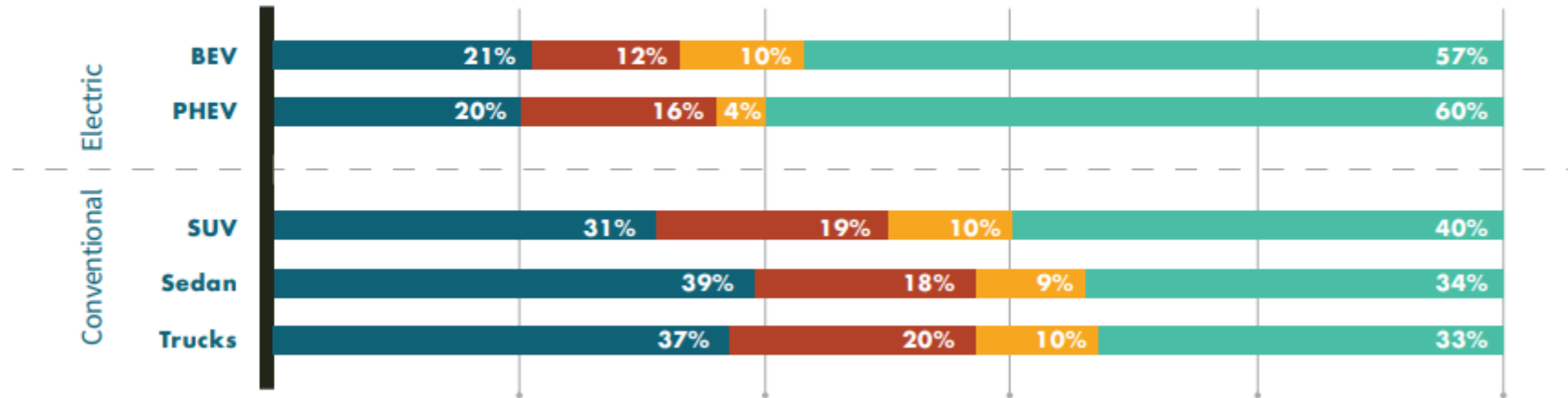
Who is buying EVs now?

Age of EV buyers (2019)

- Actually, not *too* different in age distribution, a larger proportion of older buyers
- Note that the bins are not even! 25-54 is a very large age range

Income of EV buyers (2019)

Legend: <$50k | $50k-$75k | $75k-$99k | >$100k

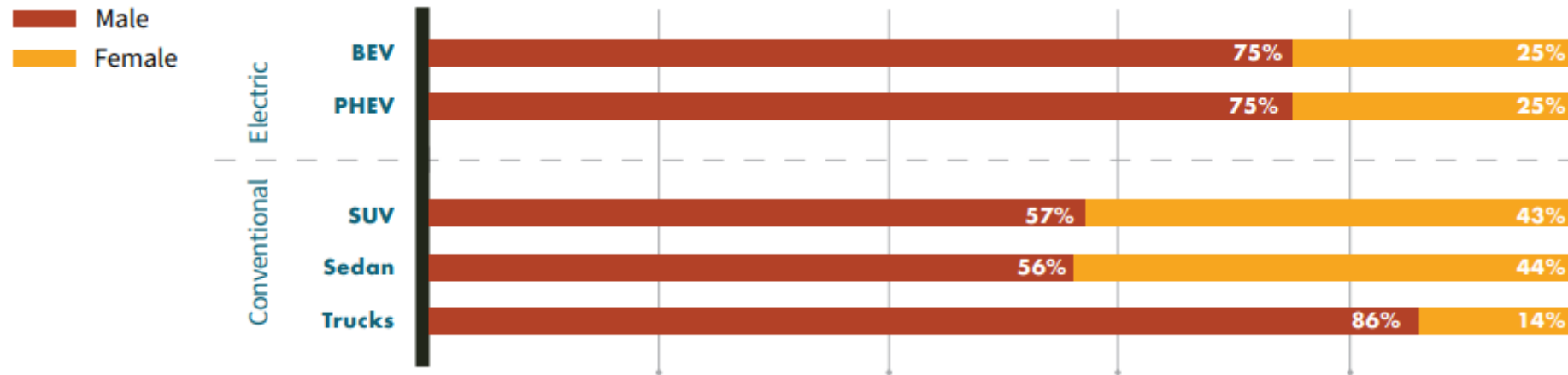|	<$50k	$50k-$75k	$75k-$99k	>$100k
Electric				
BEV	21%	12%	10%	57%
PHEV	20%	16%	4%	60%
Conventional				
SUV	31%	19%	10%	40%
Sedan	39%	18%	9%	34%
Trucks	37%	20%	10%	33%

- Definitely substantially richer crowd buying EVs
- Much fewer at the lower end of the income spectrum buying EVs
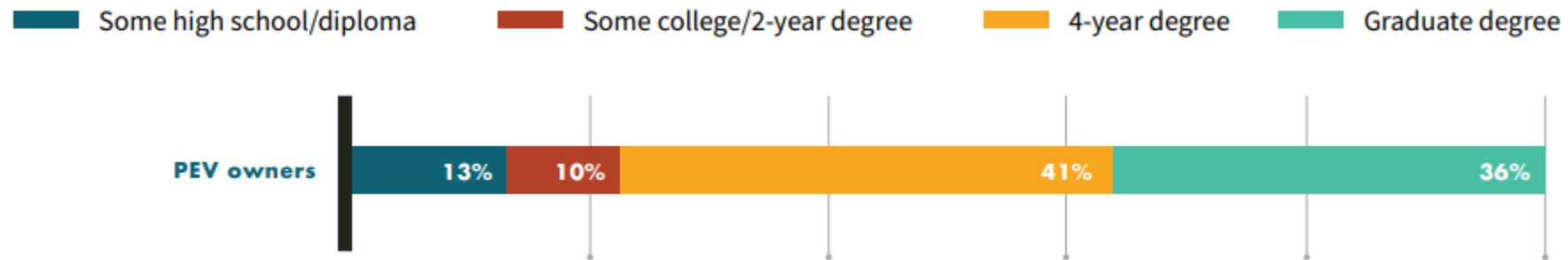
Gender of EV buyers (2019)

- Disproportionately higher number of males purchasing EVs (only outpaced by gasoline trucks)

Ethnicity of EV buyers (USA 2014, CA 2018, Overall 2015)
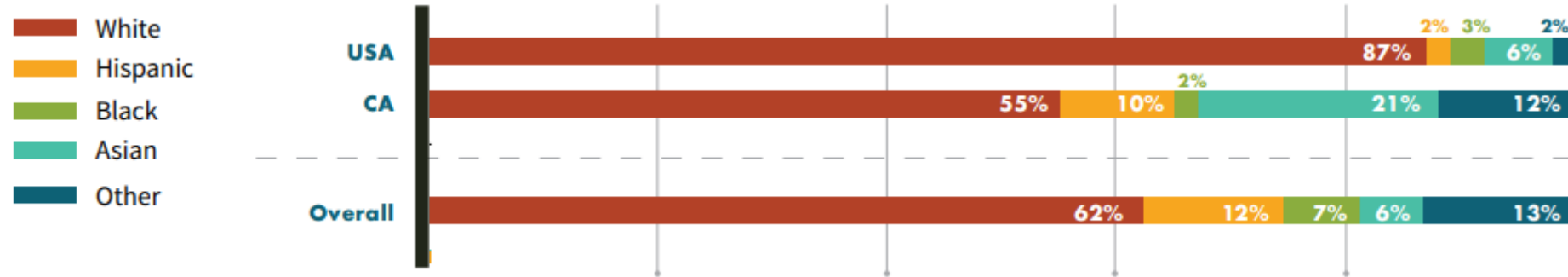
- Large regional differences in ethnicity of buyers between California and the rest of the country
- Across the US, disproportionately more white people purchase EVs

Education of EV buyers (2017)

	Some high school/diploma	Some college/2-year degree	4-year degree	Graduate degree

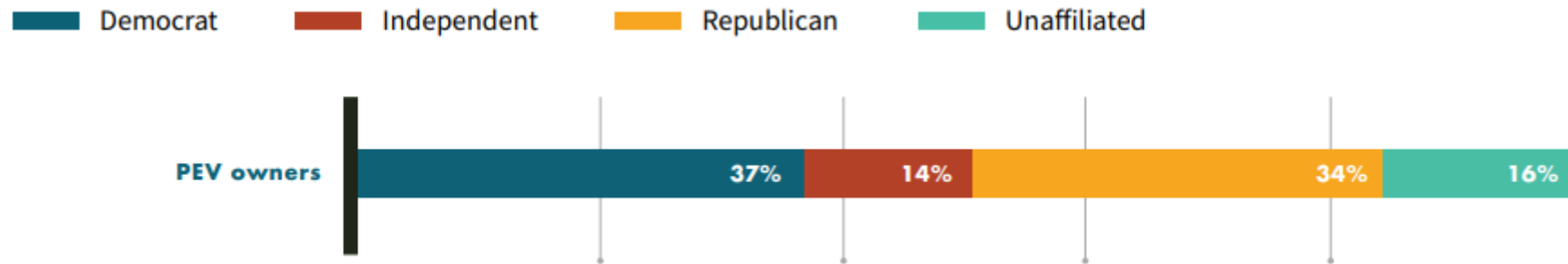**PEV owners** — 13% | 10% | 41% | 36%

- EV buyers tend to be more educated
- Note that many of the demographic factors are correlated, the effects are not necessarily causal (i.e. buyers are not purchasing EVs *because* they are highly educated)

Number of vehicles in household (2020)

- With a new technology, and concerns about "range anxiety", having a backup car can be a critical factor!

Political affiliation of EV owners (2017)

| Democrat | Independent | Republican | Unaffiliated |

PEV owners: Democrat 37%, Independent 14%, Republican 34%, Unaffiliated 16%

- Ownership by political affiliation is [surprisingly?!] even across major political parties

Where are buyers located? (USA)

California Dominates with EV Registrations

California remains far out in front as the state with the most electric vehicle registrations, accounting for 42 percent of the 1.02 million light-duty all-electric vehicles on the country's roads as of the end of 2020.

U.S. ELECTRIC VEHICLES
States ranked by light-duty all-electric vehicle registrations, 2020
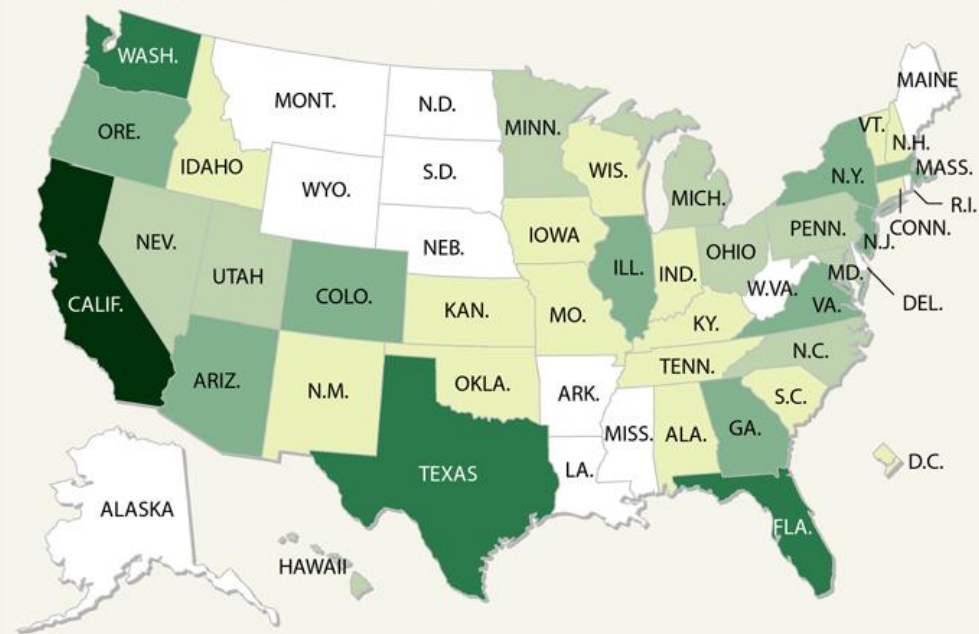
100,000+	50,000-99,999	20,000-49,999	10,000-19,999	2,000-9,999	<2,000

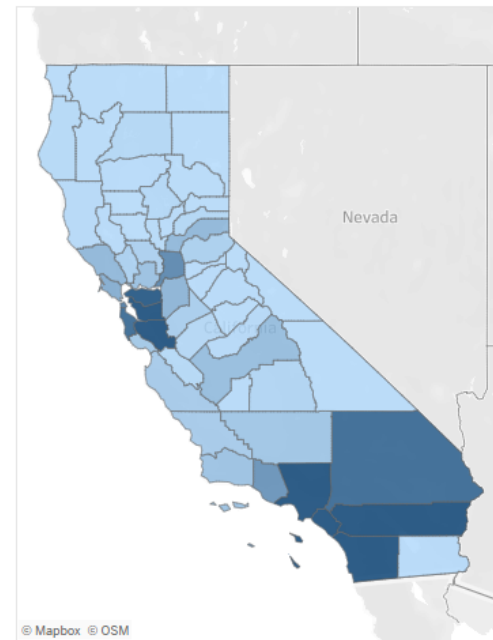| State	Count	State	Count	State	Count
California	425,300	Utah	11,230	District of Columbia	2,360
Florida	58,160	Nevada	11,040	Idaho	2,300
Texas	52,190	Hawaii	10,670	Iowa	2,260
Washington	50,520	Michigan	10,620	Vermont	2,230
New York	32,590	Minnesota	10,380	Delaware	1,950
New Jersey	30,420	Connecticut	9,040	Louisiana	1,950
Arizona	28,770	Tennessee	7,810	Maine	1,920
Illinois	26,000	Indiana	6,990	Nebraska	1,810
Colorado	24,670	Missouri	6,740	Rhode Island	1,580
Georgia	23,530	Wisconsin	6,310	Arkansas	1,330
Oregon	22,850	South Carolina	4,390	Alaska	940
Massachusetts	21,010	Oklahoma	3,410	Montana	940
Virginia	20,510	Kansas	3,130	Mississippi	780
Maryland	17,970	Alabama	2,890	West Virginia	600
Pennsylvania	17,530	New Hampshire	2,690	South Dakota	410
North Carolina	16,190	Kentucky	2,650	Wyoming	330
Ohio	14,530	New Mexico	2,620	North Dakota	220

SOURCE: U.S. Department of Energy Alternative Fuels Data Center

PAUL HORN / Inside Climate News

Where are buyers located? (CA)

- The California Energy Commission tracks sales of EVs throughout California
- County-level registration is still a relatively low resolution to conduct analysis!

LIGHT-DUTY ZEV		TOTAL LIGHT-DUTY
CUMULATIVE SALES	**ANNUAL SALES**	**ANNUAL SALES**
Sales through 2021	Sales in 2021	Sales in 2021
1,054,095	250,279	2,016,192
BEV / PHEV / FCEV	BEV / PHEV / FCEV	ZEV Sales Share
663,014 / 379,125 / 11,956	183,933 / 63,141 / 3,205	12.41%

Fuel Type | Range | Number of New ZEV Sales
- Electric ≥ 200 miles: 174,736
- Electric < 200 miles: 9,197
- PHEV: 63,141
- Hydrogen: 3,205

Make | Model | Number of New ZEV Sales
- Tesla Model 3: 67,262
- Tesla Model Y: 61,022
- Tesla Model S: 6,532
- Tesla Model X: 2,319
- Toyota Prius Prime: 14,275
- Toyota RAV4 Prime: 7,988
- Toyota Mirai: 2,514
- BMW 5 Series: 3,924
- BMW 3 Series: 3,086
- BMW X5: 2,490
- BMW X3: 1,543
- BMW i3 REx: 1,404
- BMW i3: 1,286
- BMW i8: 180
- BMW 7 Series: 81
- Chevrolet Bolt EV: 12,313

SELECT FILTERS
- Year: 2021
- Map Filter: County
- County: (All)
- Fuel Type: (All)
- Make: (All)

Number of Vehicles: 1 — 10,000
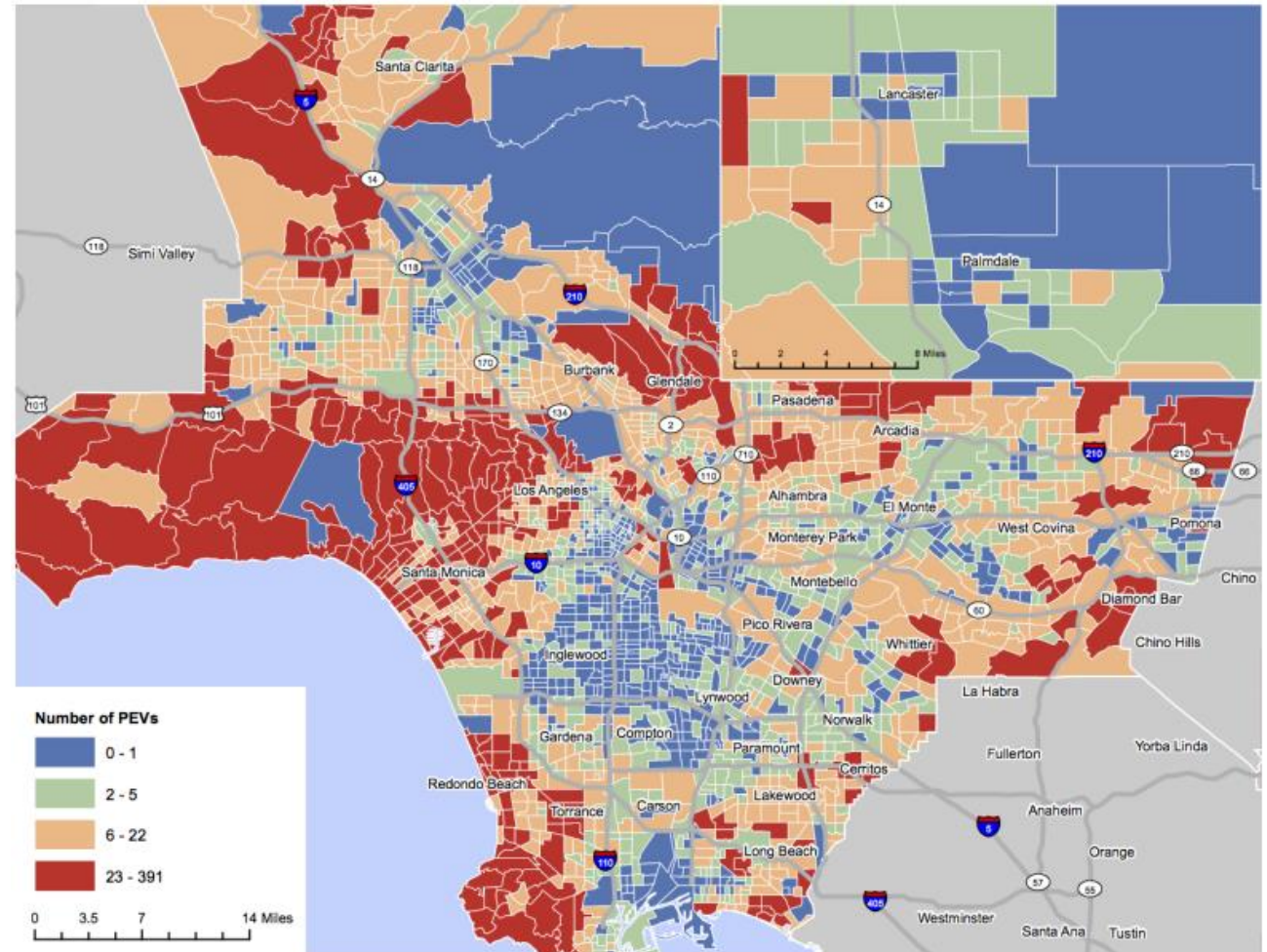
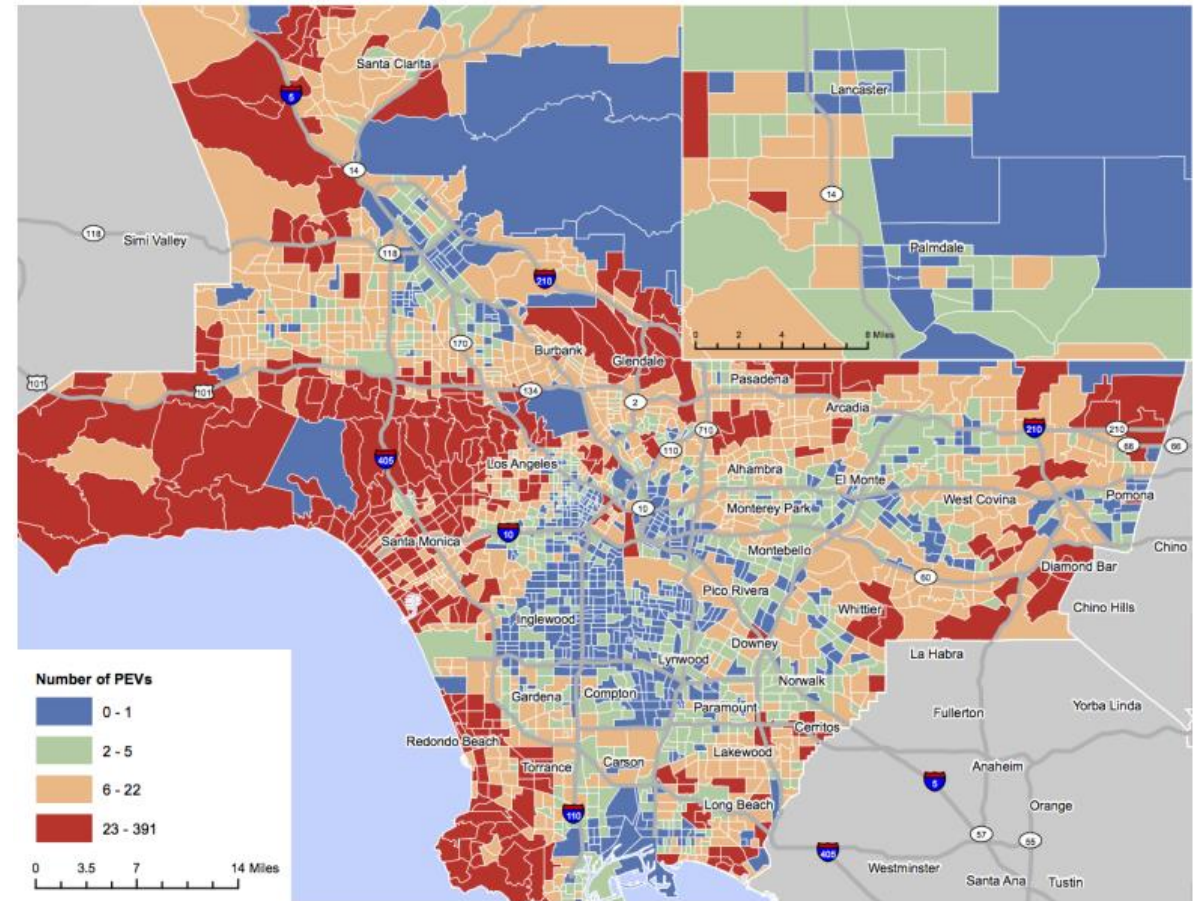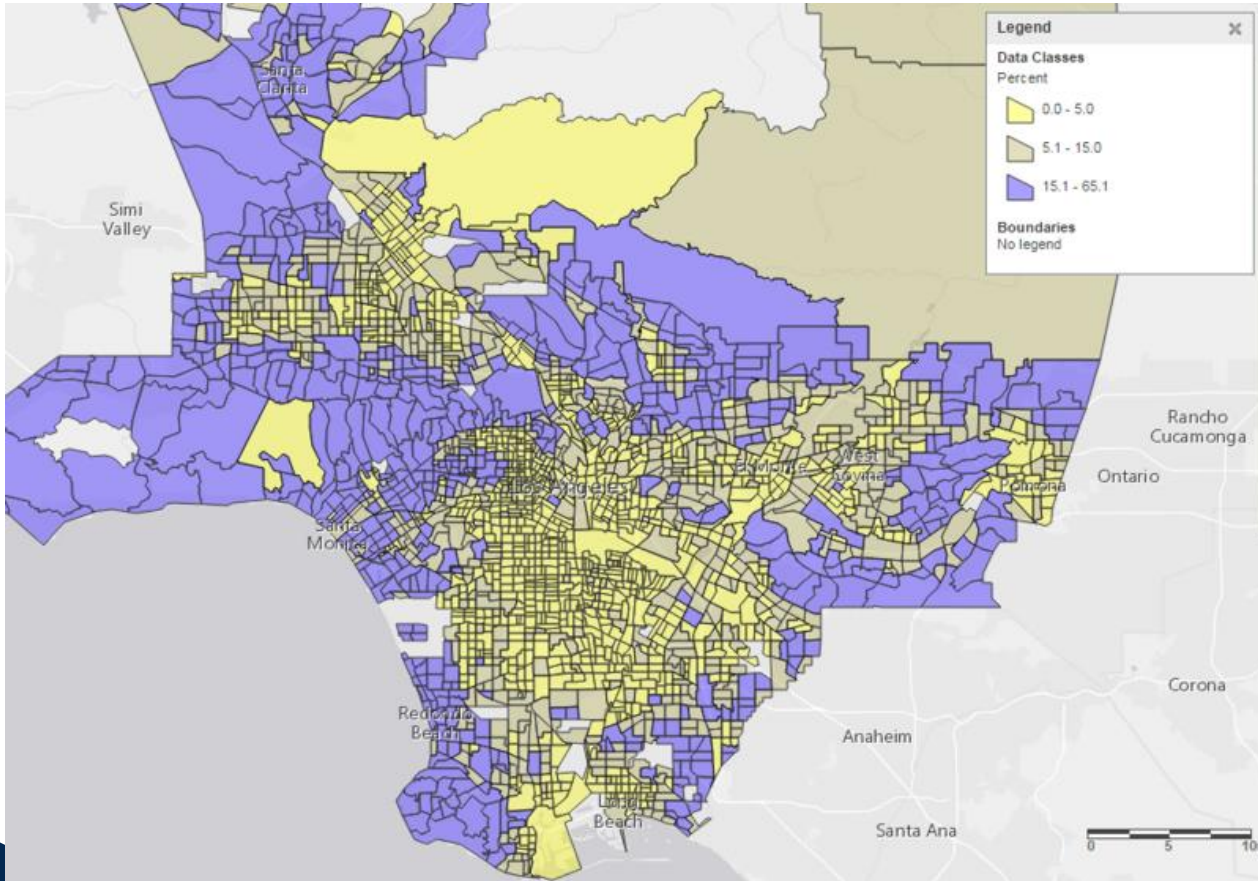# Registrations in Los Angeles (2017)

- Researchers often use much higher resolution data (figure from UCLA report employing DMV registration data)

- Even within a single (or two) county, there is still substantial variation in where people are buying EVs

Number of PEVs
- 0 - 1
- 2 - 5
- 6 - 22
- 23 - 391

Income vs EV registrations in LA

Distribution of high-income households across LA

Registrations in San Francisco Bay Area (2018)

- Per capita adoption of EVs tend to hold up slightly better over time

- The Bay Area has disproportionately higher adoption than many other regions in CA

- Within the Bay Area, the Silicon Valley area has very high adoption (San Jose, Sunnyvale, Mountain View, Palo Alto, etc)

% EV's of Vehicle Registrations
- 0 - 2.5
- 2.6 - 5
- 5.1 - 7.5
- 7.6 - 10
- >10
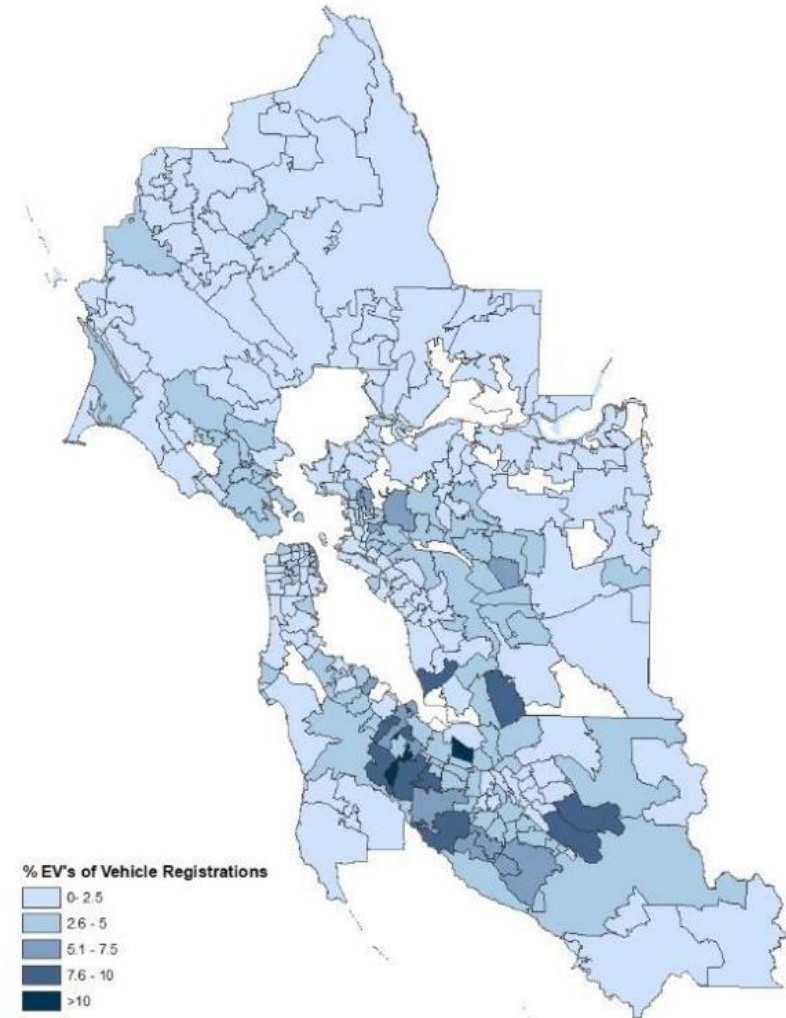
How big is the potential buyer market?
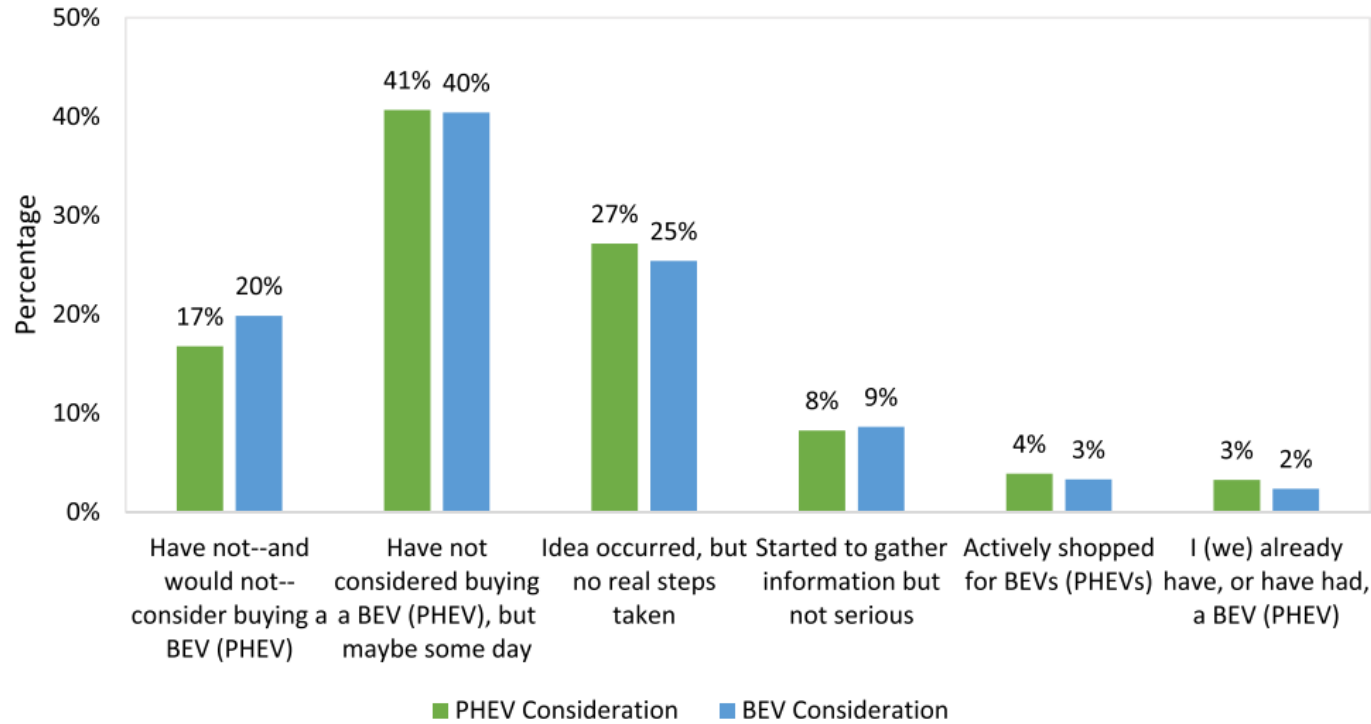
Figure 2. 'Have you considered buying a BEV for your household?' and 'Have you considered buying a PHEV for your household?' (n = 847).

- Survey of the Sacramento area in 2020
- The majority of consumers (~60%) aren't thinking about EVs, arguably as high as 85-90%!
- Other areas may be different, maybe higher consideration in other counties…but some maybe lower as well

Knowledge and Awareness

How much does the public know about electric vehicles?
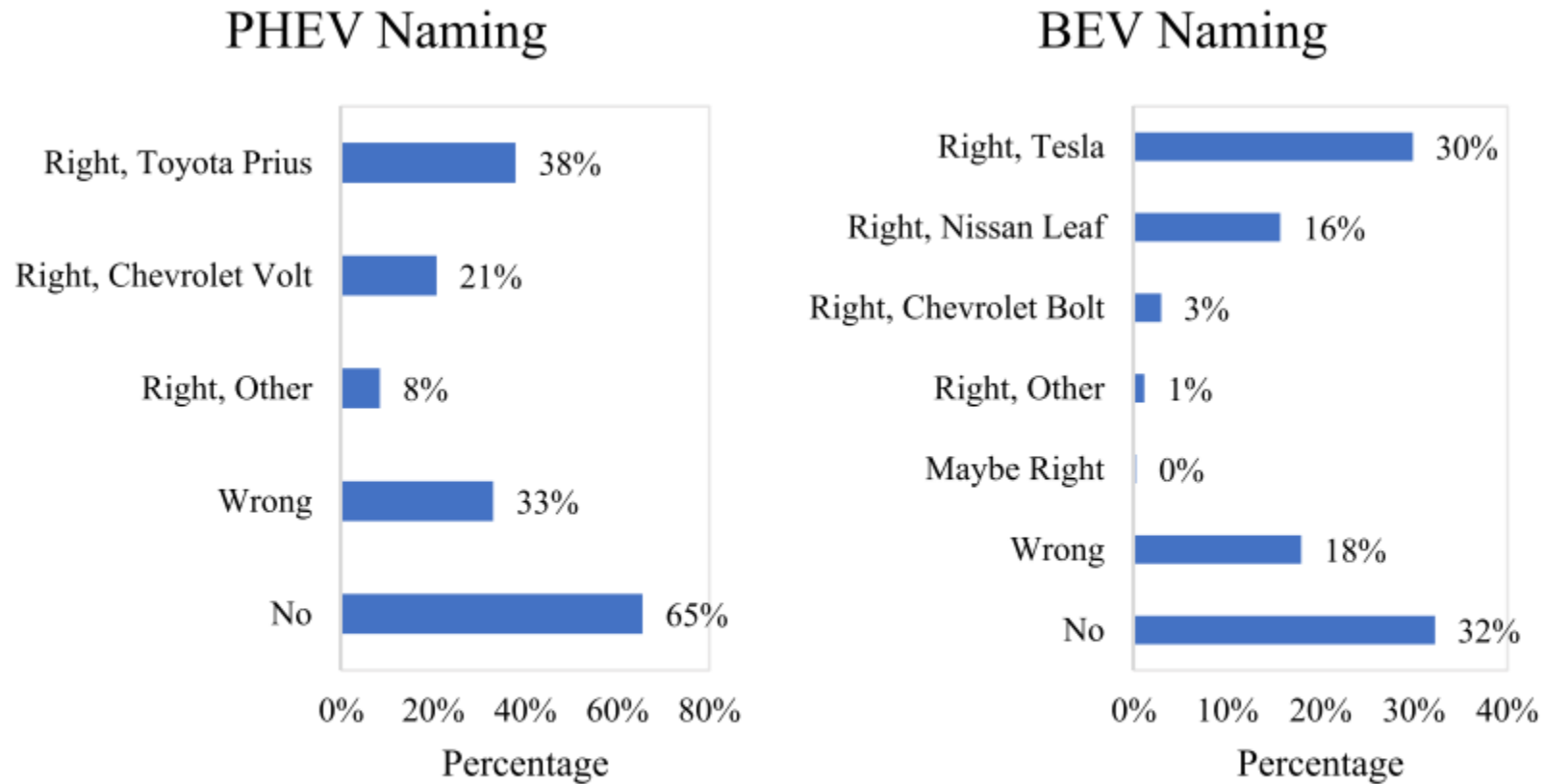
Figure 5. Whether survey takers were able to name a PHEV for sale in the USA (left), and whether they can name a BEV (right) (n = 887).

Is the public aware of incentives?
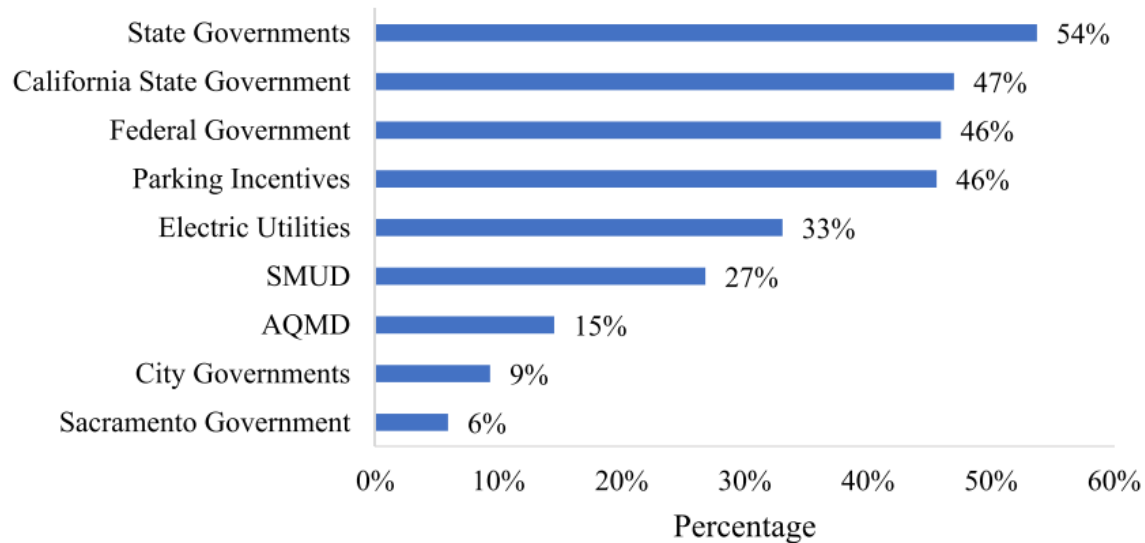
Figure 6. Percentage of respondents reporting that the mentioned government entity or agency is offering incentives for PEVs and whether parking incentives are available (parking incentives was asked in a sperate question since they are not offered by one single entity) (n = 847).
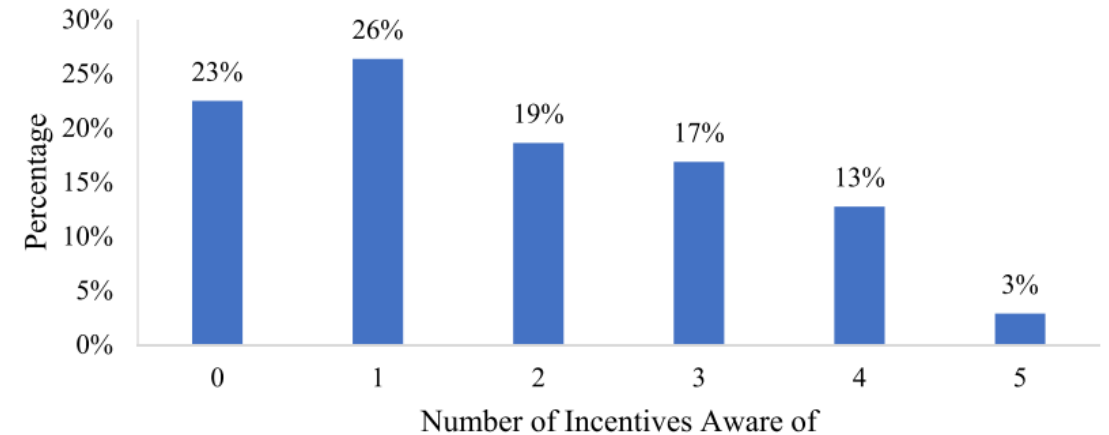
Figure 7. Count of number of incentives respondents report being aware of (n = 847).

- There are very substantial monetary (and non-monetary) incentives that are available for buying an EV
- To what extent are buyers aware of these incentives? (perhaps higher adoption if people knew about them!)

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Increasing EV awareness (2017)

- What have stakeholders done to increase knowledge of all things related to electric vehicles?
- ICCT shows a qualitative table of efforts in different regions throughout the world
- What lessons can be learned amongst different regions' efforts?

| Region	Information and tools					Public events		Exposure to EVs from fleets					Regional planning		Consumer awareness campaigns	Youth education and professional development	Awards and recognitions	Auto dealer awareness activities	Consistent Signage and labeling
	General information	Cost comparison	Public charger location	Incentives	Model availability	Ride and drive	EV showcase	Public fleet	Government fleet	Carsharing/Rental cars	Company cars	Tourism	Action plan/Initiative	Demonstration projects					
Germany	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	
Netherlands	X	X	X	X		X	X	X	X	X	X		X	X		X			
Norway	X	X	X	X	X			X	X	X	X		X	X					
United Kingdom	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X			
California	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X
Oregon	X	X	X	X	X		X	X	X	X	X	X	X	X			X	X	X
Northeast U.S. States	X	X	X	X	X	X	X	X	X	X		X	X	X	X			X	X
British Columbia	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Québec	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Beijing								X	X	X	X		X						
Shanghai						X	X	X	X	X			X	X					

Consumer preferences

Measuring consumer preferences

- What factors influence purchasing decisions?
    - Is it something about the vehicle/technology?
    - Is it the availability of infrastructure?
    - Is it something about the individual?
    - What is the relative value of these attributes?
- Can we "quantify" these preferences?
- How might purchasing decisions change as these factors are altered?

Stated versus revealed preference

- **Stated preference** – survey-based technique that directly asks subject how they value something
    - *Pros*: better suited to analyze hypothetical scenarios (e.g. if a technology is not widely available); can directly ask about preferences
    - *Cons*: individuals might not behave in reality based on what they say
- **Revealed preference** – method of analyzing behavior based on actual behavior of individuals
    - *Pros*: behavior is grounded in reality since they are based on actual decisions that are already made
    - *Cons*: often much harder to obtain data, can also be tricky to elicit preferences due to confounding factors

Choice modelling

- Suppose you want to buy a car, and you are deciding between the following options:

Tesla Model 3

Toyota Camry

Mustang Mach E

BMW M4

Choice modelling

This is known as the choice set

Tesla Model 3

Toyota Camry

Mustang Mach E

BMW M4

Choice modelling

The objective of this work is to attempt to understand what it is about a particular choice that led a consumer to choose it.

Is it the price of the car? The size? The brand? The fuel efficiency? All of the above? This analysis can be very complex!

Tesla Model 3

Toyota Camry

Mustang Mach E

BMW M4

Survey methods (stated preference)

- With surveys, you can simply ask consumers directly why they make certain decisions
- Lots of tricky considerations in surveys:
  - How representative is the surveyed population?
  - Are you influencing the answer by asking questions in a certain way?
  - How do you know respondents are answering truthfully?
  - Are you asking the right questions to capture all nuances of decision making?
- Despite the difficulty of conducting a survey "correctly", it can be a powerful tool to elicit information that would be very hard to otherwise measure

Most important purchasing factors

How do the following factors influence whether or not you would consider an electric vehicle for your next vehicle purchase?
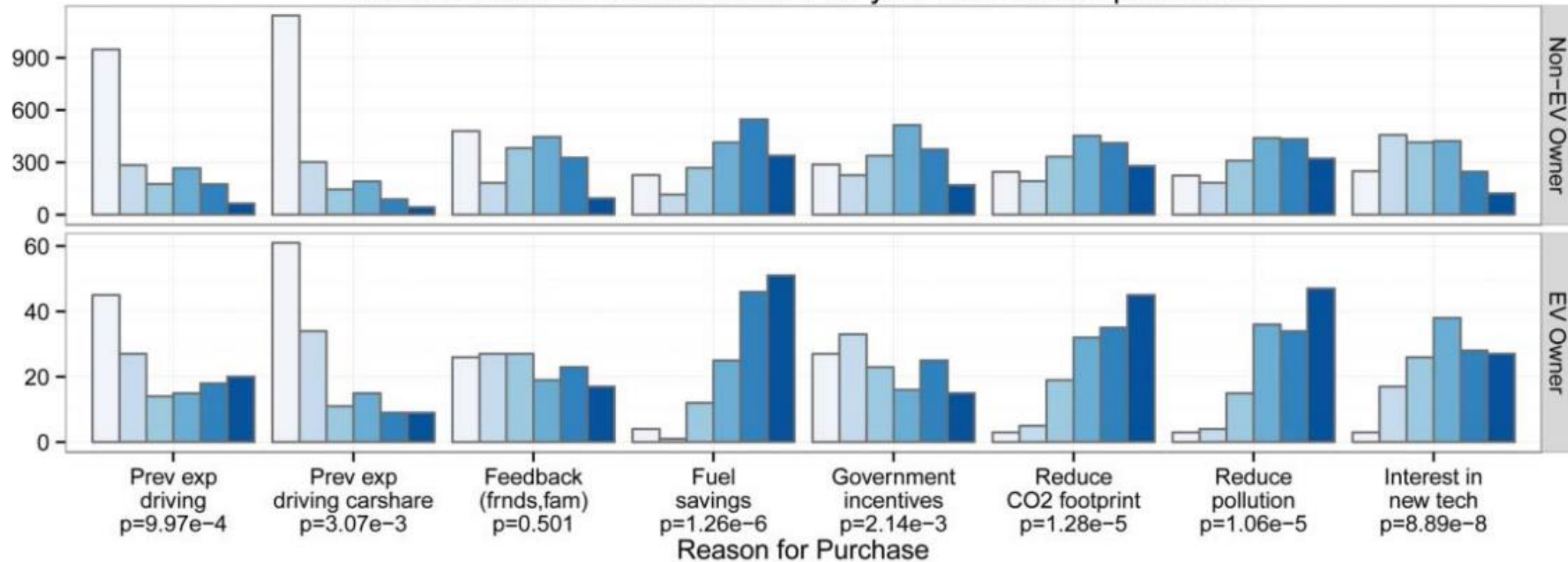
Identifying consumers by lifestyle, values, and attitudes

Table 7
Comparing lifestyle-based segments by characteristics (n = 1744).

| Variable | Potential early mainstream PEV buyers (n = 634) | | | | | | Other (n = 1120) | |
| | Pro-environmental PEV segments | | | Non-environment PEV segments | | | Designed HEV (n = 708) | Designed CV (n = 412) |
	Strong (n = 107)	Tech-enviro (n = 74)	Concerned (n = 119)	Techie (n = 106)	Open (n = 112)	Unengaged (n = 116)		
Lifestyle, values and attitudes								
Environment-oriented lifestyle (mean score, 0 to 25)***	17.2	18.3	12.3	12.1	11.2	10.1	12.1	11.5
Technology-oriented lifestyle (mean score, 0 to 25)***	16.0	18.0	10.2	17.3	13.3	10.9	13.1	12.4
Lifestyle liminality (mean score, −16 to +16)***	5.9	1.2	−1.6	−1.0	5.3	−2.4	0.5	−0.7
Environmental concern (NEP score, −16 to +16)***	11.5	2.3	11	6.2	3.8	2.1	5.4	4.2
Biospheric values (mean score, 0 to 12)***	11.2	9.5	10.1	9.1	8.9	7.9	9.1	9.0
Climate change is "serious problem." (%)***	68.2	40.5	66.4	31.1	21.4	12.9	29.9	24.3
Air pollution is "serious problem." (%)***	67.3	47.3	71.4	37.7	33.9	26.7	37.9	32.5

- This study classifies consumers into 6 "clusters" of potential purchasers based on attitudes/values determined from a survey
- Within the hierarchy of environmental vs non-environmental potential PEV buyers, there are each 3 further divisions of each group

Conjoint Example (stated preference)

If you were in the market for your next vehicle and these were the only alternatives, which would you choose?

Brand:	Ford	Chevy	Ford	Dodge
Type:	SUV	Truck	Truck	Truck
Engine:	V6, 3.6 liter	V8, 5.7 liter	V8, 4.2 liter	V8, 4.8 liter
Price:	$36,599	$42,999	$42,999	$45,999
	Selected	Select	Select	Select

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Price:	$36,599	$42,999	$42,999	$45,999
	Selected	Select	Select	Select

- If you ask this question many times to many people, and you randomize the attributes, you can figure out how much people value each attribute
- I can figure out how much you are willing to pay for a "Ford" vs a "Dodge"
- This is a great technique to ask about technologies that might not even exist yet or have no data! (e.g. electric pickup trucks)
- Drawbacks? Will people answer truthfully? Or even if they answer "truthfully", is that how they would behave when faced with the decision in the real world?

Conjoint example results

- The "Average" column essentially indicates the relative "importance" of a factor at a specific level
- The "utility" of a vehicle range increases most from 30 to 50 miles, 70 miles is still "good" but its utility increase is marginal
- The purchase cost is "best" at the lowest price
- …all from a conjoint analysis conducted in 1982! (long before EVs were on the market…)

TABLE 1
SUMMARY OF PART-UTILITIES FOR ELECTRIC VEHICLE
CHARACTERISTICS, ENTIRE SAMPLE

Factor	Level	Part-Utility Average	Part-Utility Standard Deviation
Range (miles)	30	2.4	1.4
	50	4.2	2.4
	70	4.5	1.8
Cruising Speed (miles/hour)	30	2.8	1.9
	45	3.4	2.3
	55	4.5	1.9
Battery Life (Years)	1	1.8	1.1
	2	5.1	1.9
	4	3.9	2.2
Battery Recharge (Time in Hours)	2	4.7	2.1
	5	3.6	2.2
	8	3.2	2.1
Passenger Payload (People)	2	3.4	2.1
	4	3.9	2.6
	6	4.3	2.1
Cargo Payload (Number of Grocery Bags)	3	2.7	1.6
	6	7.4	3.5
	9	3.7	1.9
Purchase Cost (Dollars)	5,000	4.5	1.8
	10,000	3.0	1.7
	13,000	2.8	2.0

[a] Rating scale varied from 1-never would purchase to 11-high likelihood of purchase; 6 was the neutral point.

Econometric approaches (revealed preference)

- Instead of asking people how they would behave, we examine sales data (they've already made their choice)
- How can we correlate and identify factors that led to these decisions?
- Variables include:
  - Macro-factors: GDP (economic strength), unemployment, gas prices
  - Vehicle specific attributes
- Determining causality relies on differences in space and time
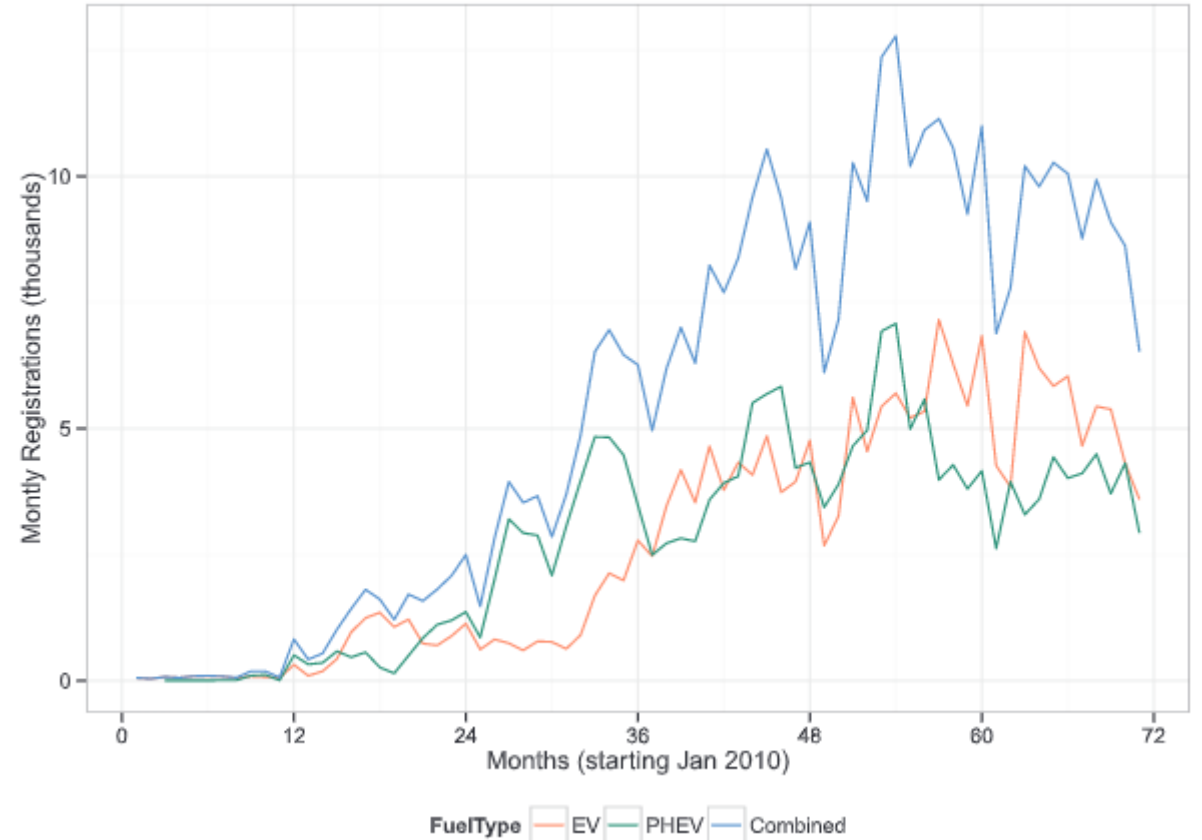
Econometric example results

Regression results on Log(Registrations).

	(1) General Model	(2)	(3) Knowledge Model	(4)	(5) LDV Model	(6)
Tax credit ($1000)	0.0441*** (4.94)	0.0259*** (3.83)	–	–	0.00891** (2.6)	0.0125*** (4.38)
Tax credit* Knowledge	–	–	1.94e-08*** (3.3)	3.23e-08*** (3.87)	–	–
HOV Access* HOV Density	0.000912** (3.12)	0.000473* (2.42)	0.000738** (2.99)	0.000562* (2.56)	− 0.0000689* (2.49)	− 0.0000301 (0.88)
EVSE credit ($1000)	− 0.101 (−1.83)	0.0196 (0.72)	− 0.0448 (−1.13)	− 0.0334 (−0.90)	− 0.00654 (−0.57)	− 0.0321* (−2.04)
L.log($R_{i,t-1,r}$)	–	–	–	–	0.760*** (26.45)	0.751*** (24.76)
Constant	1.086*** (10.32)	− 0.148 (−0.21)	–	–	–	–
Macro Controls		✓		✓	✓	✓
Fixed Effects	✓	✓	✓	✓	✓	✓
Cluster	✓	✓	✓	✓	✓	✓
Instruments	–	–	All article count	All article count	L(2–4). R	L(2–4). R
rk LM Stat	–	–	8.091	8.991	5.317	5.603
rk LM Prob	–	–	0.00445	0.00271	0.0701	0.0607
Adj R-square	0.0116	0.0665	0.0182	0.0502	0.112	0.129
N	18,644	18,644	18,473	18,473	11,296	11,296

t statistics in parentheses.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

We know that the attributes of the vehicle play an important role in consumers' decision making

We can estimate the effect of monetary incentives on increasing sales (every $1000 increases sales by ~4%)

Consumer knowledge of incentives can increase its efficacy

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Econometric examples continued

Table 5

Results A – EV registrations and Øcharging capacity (= abundance effect).

Dep. var.:	ΔEV		ΔBEV		$\Delta PHEV$	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
CS-augmented	no	yes	no	yes	no	yes
Long-run						
Ø charg. capacity (C_a)	0.37***	0.03*	0.16***	0.02*	0.20***	0.02**
(= abundance)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Error-correction term	−0.38***	−0.56***	−0.48***	−0.57***	−0.42***	−0.62***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Short-run						
l.ΔEV	−0.30***	−0.19***	−0.24***	−0.20***	−0.28***	−0.16***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
l2.ΔEV	−0.12***	−0.08***	−0.07***	−0.06***	−0.16***	−0.10***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
ΔC_a	−0.05**	0.01	−0.02	0.01	−0.04***	−0.00
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
l.ΔC_a	−0.08***	−0.03*	−0.06***	−0.03*	−0.04***	−0.01
	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
l2.ΔC_a	−0.07***	−0.01	−0.05***	−0.02	−0.03***	−0.00
	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)

As the abundance of stations increases, the corresponding number of EV registrations also increases (every 3 stations leads to about 1 extra EV adopted)
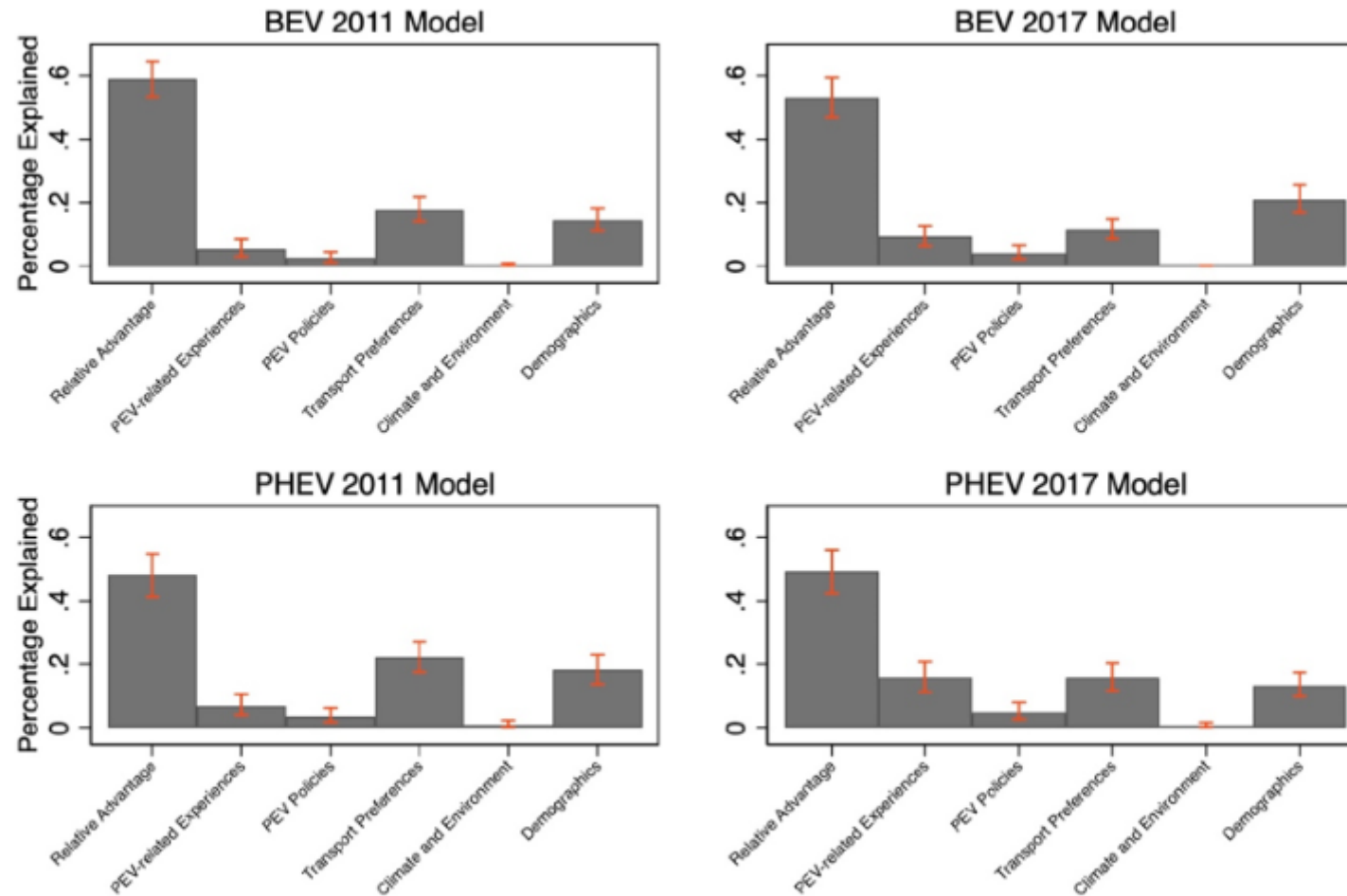
What's changed over time for buyers?

Fig. 4. R-Squared Decomposition Values (in Percentage of Explained Variation of the Dependent Variable) and 90% Confidence Intervals (in red). Notes: Confidence intervals obtained from bootstrapping with 2000 repetitions. Graphs are associate with the Table 2 regression results. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Consumer preference takeaways

- Don't worry about the specific effects and numbers from a single study: often disagreements about effects but scientific consensus

- Lots of factors influence vehicle adoption, these studies help to quantify these effects and identify the most important ones to consider—essential for stakeholders (think policymakers, automakers, etc)