Understanding current and future potential PEV buyers: Implications for policy

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May 11, 2016

International Energy Agency

Transport, Energy Efficiency and Behaviour Workshop

SFU

Sustainable Transportation Action Research Team (START)

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

Preference and lifestyle heterogeneity among potential plug-in electric vehicle buyers

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Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Anticipating PEV buyers' acceptance of utility controlled charging

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nature energy

ANALYSIS

PUBLISHED: XX MONTH XXXX | ARTICLE NUMBER: 16013 | DOI: 10.1038/NENERGY.2016.13

Moving beyond alternative fuel hype to decarbonize transportation

Noel Melton[1,2]*, Jonn Axsen[2] and Daniel Sperling[3]

Opinion: B.C. should enact a zero-emissions mandate

Electric vehicles are an easy route to revving up climate change abatement

BY JONN AXSEN, SPECIAL TO THE VANCOUVER SUN SEPTEMBER 16, 2015 true

SFU

Electrifying Vehicles

Insights from the Canadian Plug-in Electric Vehicle Study

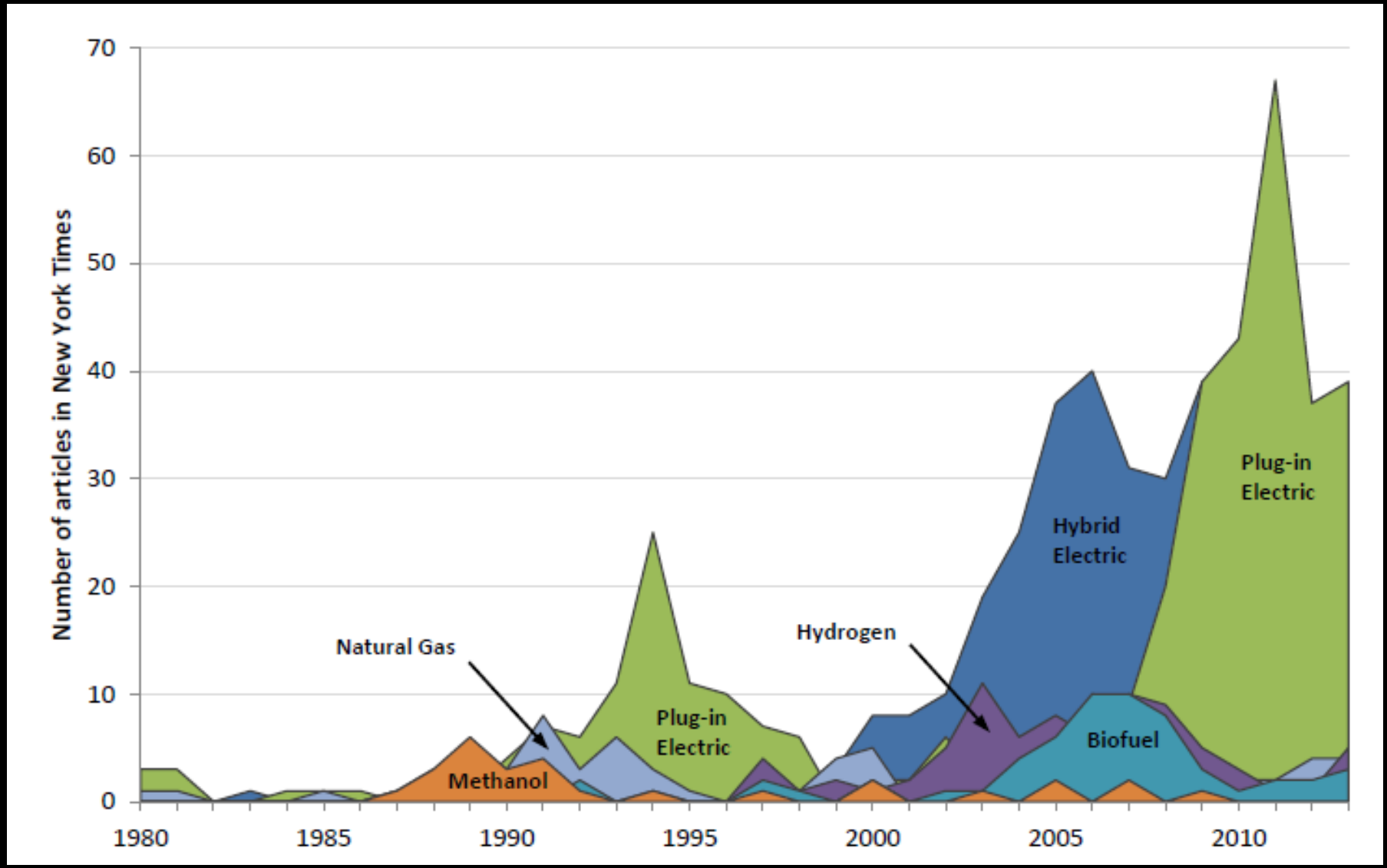
Jonn Axsen • Suzanne Goldberg • Joseph Bailey
Sustainable Transportation Research Team
Simon Fraser University

July 2015

Canadian PEV Study Report now available

http://www.rem.sfu.ca/people/faculty/jaxsen/cpevs/

Following media attention for different alternative fuels (New York Times 1980-2013)



Source: Melton, Axsen & Sperling (2016), *Nature Energy*

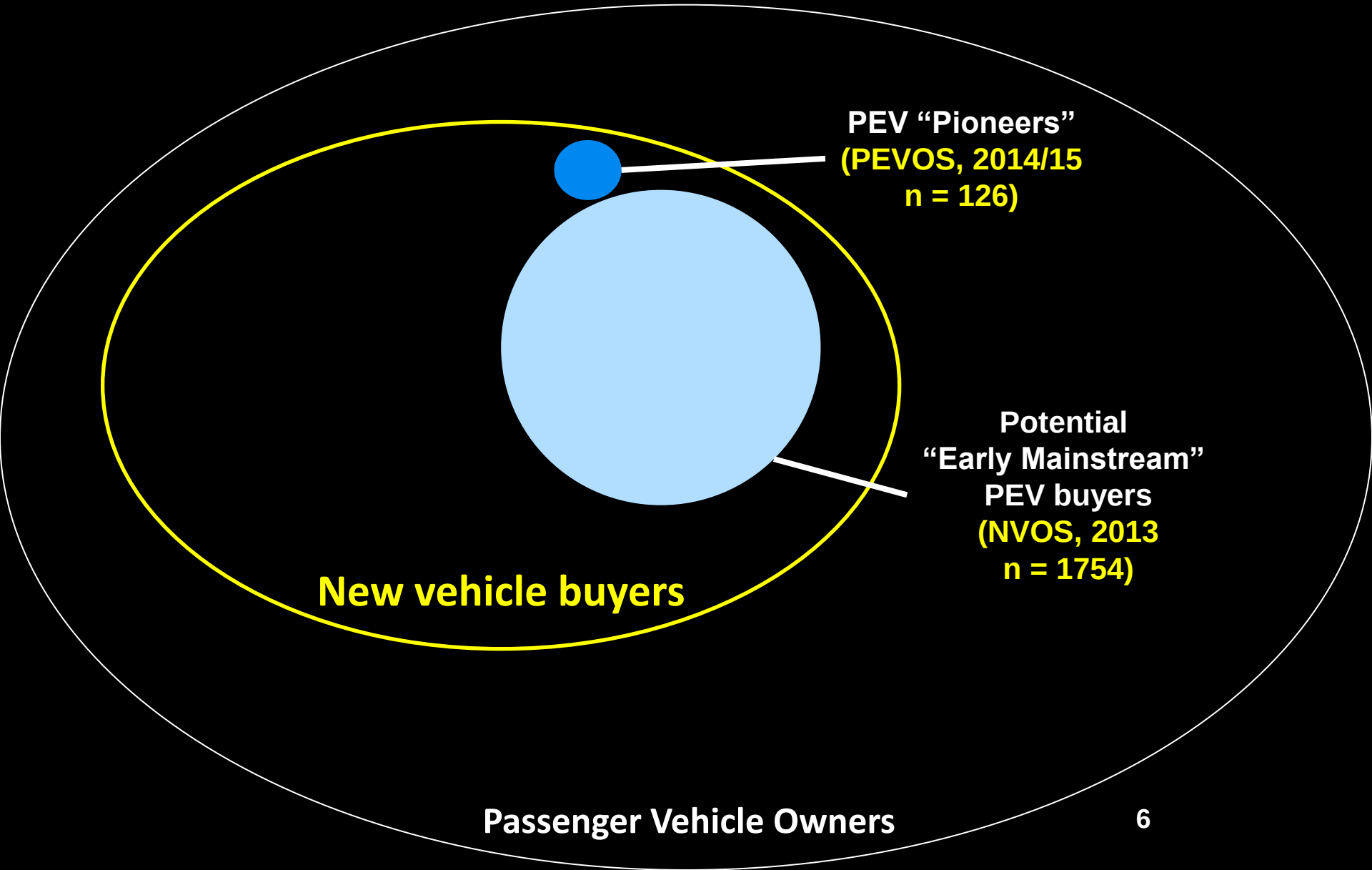
Focusing on the Canadian market…

- Compare PEV "Pioneers" with the potential mainstream market.
- Forecast PEV sales (among potential future buyers) under different policies.

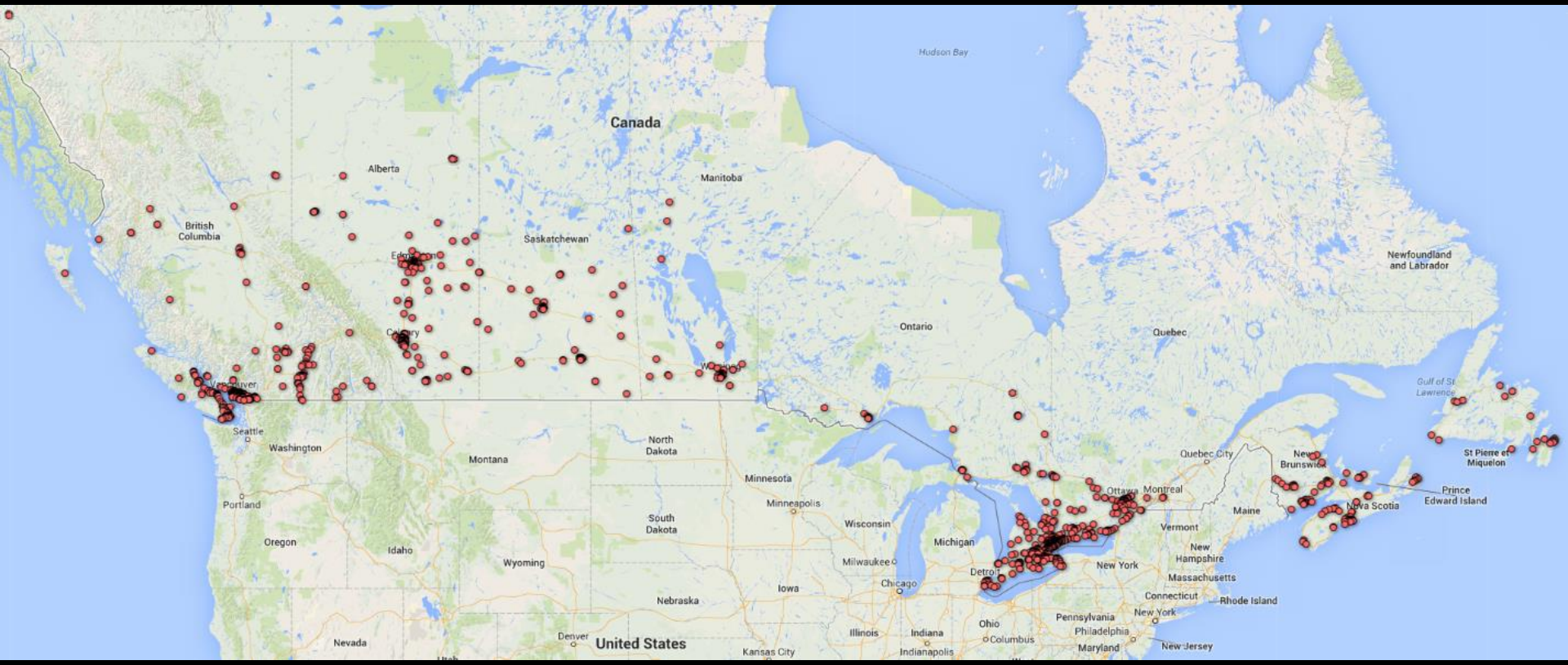
1) Data collection:

The Canadian Plug-in Electric Vehicle Study (CPEVS)

A perspective on the PEV market: Now and future

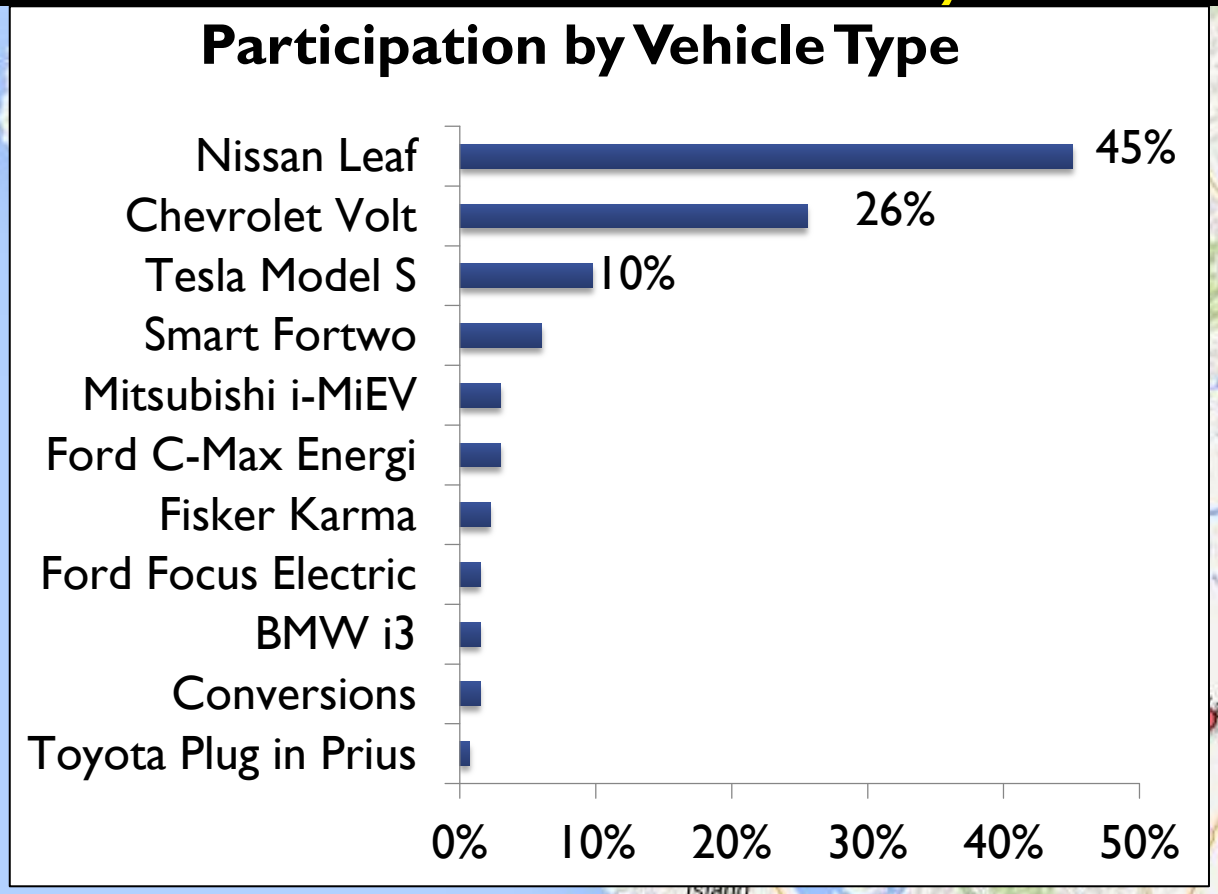


Canadian "Mainstream" Survey (n = 1754), representative of new vehicle buying households



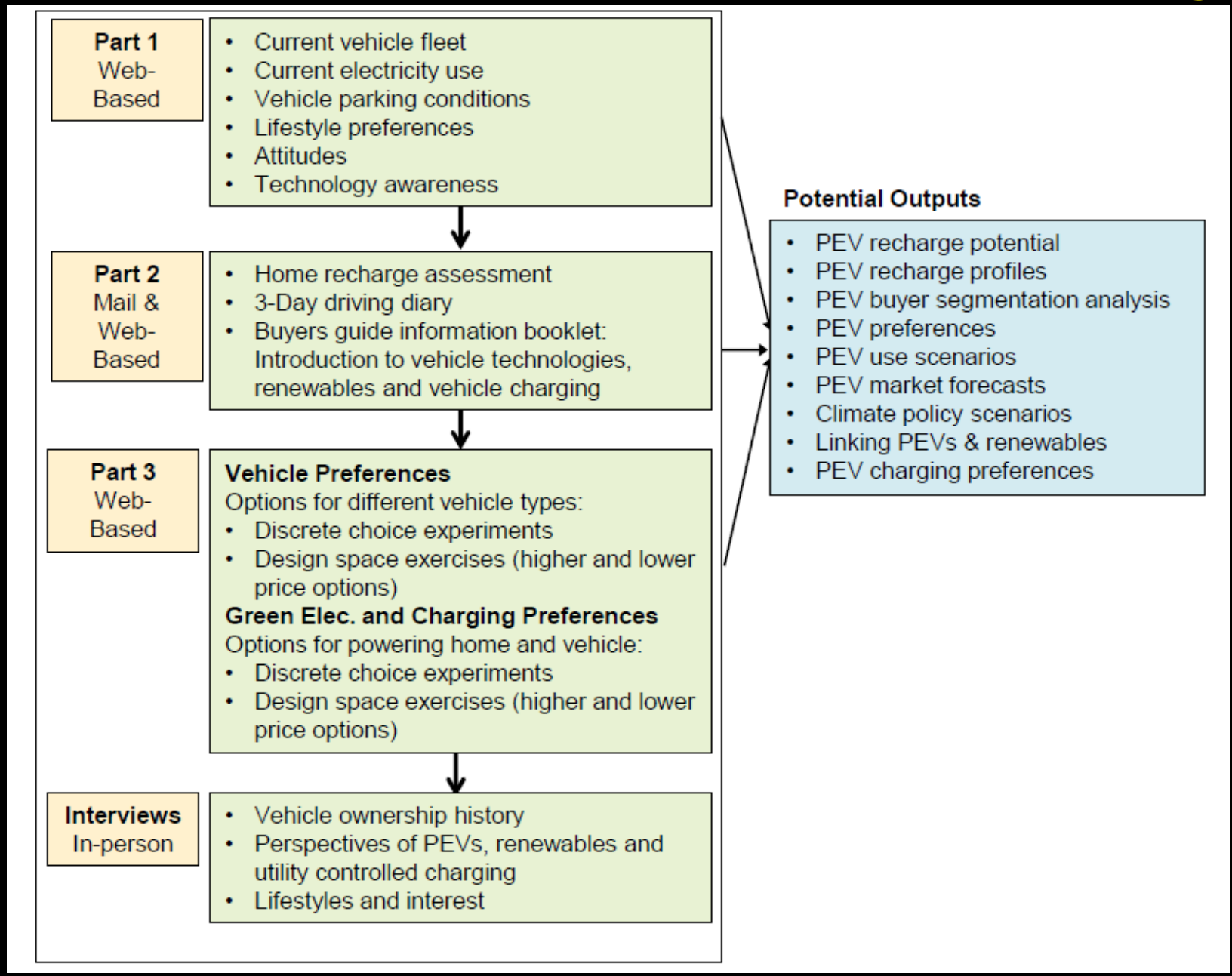
Source: Axsen et al. (2015), *Electrifying Vehicles*

PEV owners survey ("Pioneers")
British Columbia, 2014-15, n = 126



Participants (BEV+PHEV) across BC

CPEVS: Reflexive, multi-method design



PEV interest determined through discrete choice experiment and "design space" exercise

Which version of your HONDA CIVIC would you like to purchase?

1. Use the drop down menus to select the upgrades that you would like.
   - Select an 'electric range' **first**, and then a 'refuel or recharge time'.
   - The purchase price will change based on your selected upgrades.
2. Select the vehicle that you are most likely to buy next.

Ensure that all of the dropdowns are filled even if you do not plan on selecting one of the vehicles

Remember to be realistic: consider budget constraints and consult other household members if you would normally do so.

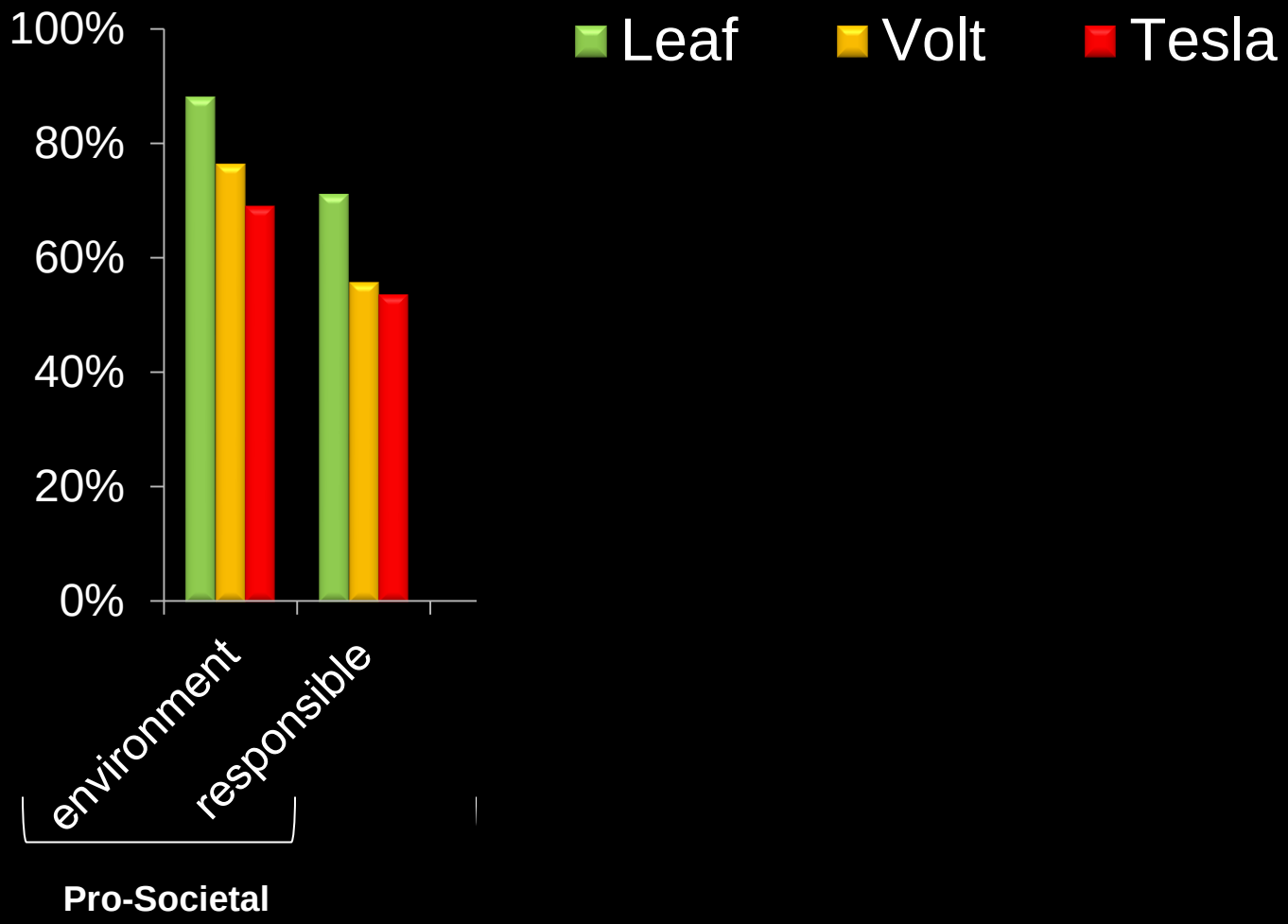
Click HERE to open the example response that we provided earlier in a new window.

Vehicle Type	Electric Range	Gasoline Fuel Use	Refuel or Recharge Time	Purchase Price	I CHOOSE
 A Gasoline HONDA CIVIC	None	**6.16** L/100km	5 mins.	**$ 25,000**	Gasoline
 A Hybrid HONDA CIVIC	None	**4.12** L/100km	5 mins.	**$ 26,380**	Hybrid
 A Plug-in Hybrid HONDA CIVIC	Electric for the first: 32 km (+$2,680)	**4.12** L/100km	Level 2: 0.9 hrs (+$2500)	**$30,180**	Plug-in Hybrid
 An Electric Only HONDA CIVIC	Electric only for: 200 km (+$13,820)		Level 1: 32.5 hrs (+$0)	**$ 38,820**	Electric

Source: Axsen et al. (2015), *Electrifying Vehicles*

2) The PEV “Pioneers”

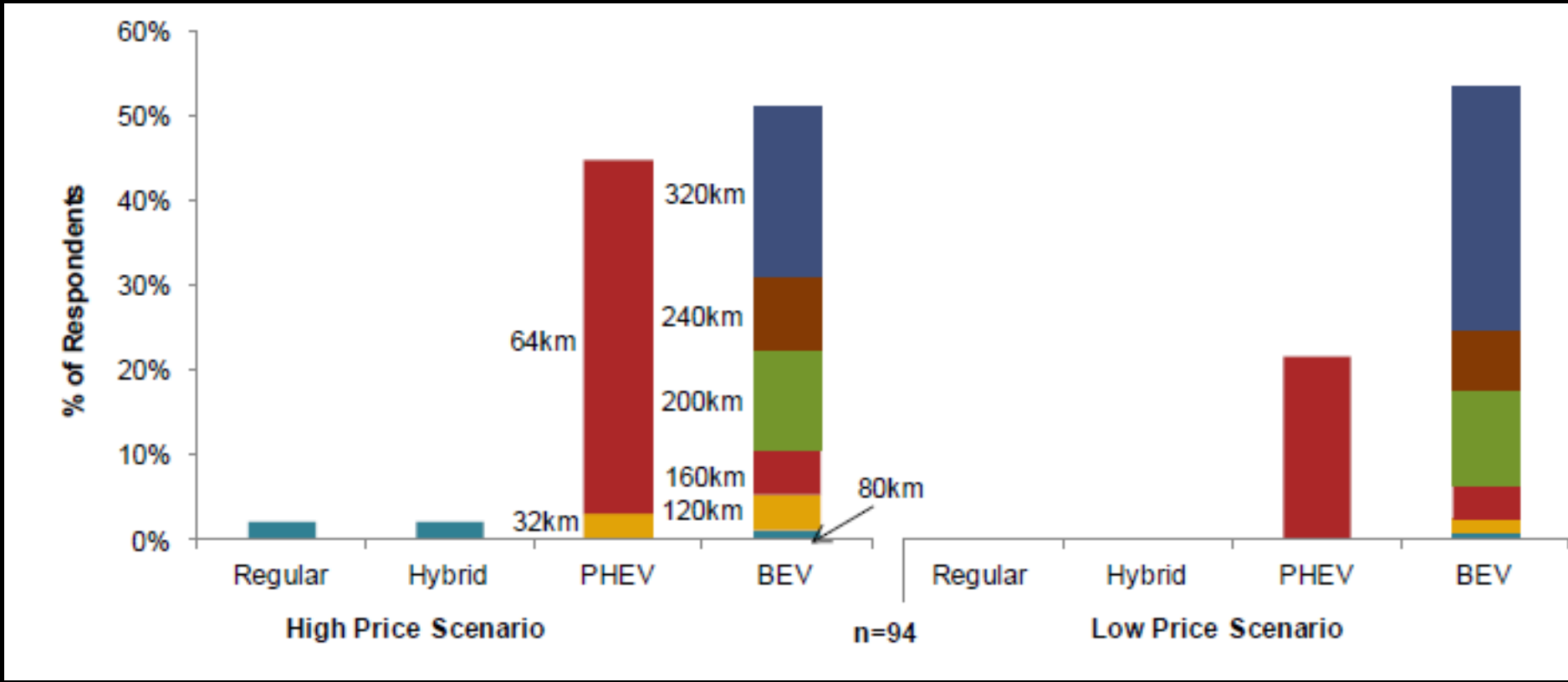
“Images” that PEV owners associate with their PEV



n= 59(Leaf); 32 (Volt); 12(Tesla)

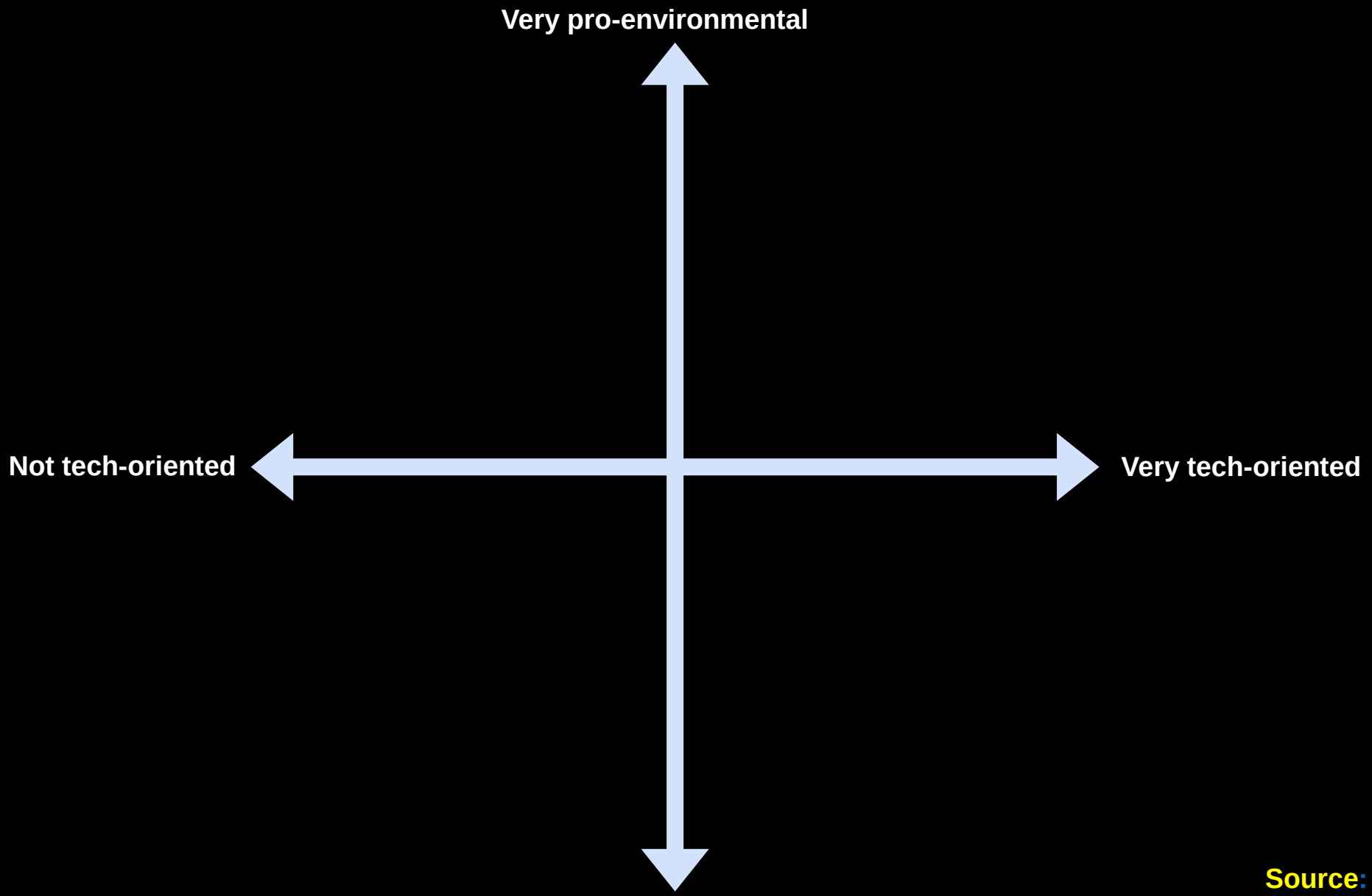
Source: Axsen et al. (2015), *Electrifying Vehicles*

Preferences: PEV Pioneers love their PEV, tend to prefer BEV (over PHEV)



Source: Axsen et al. (2015), *Electrifying Vehicles*

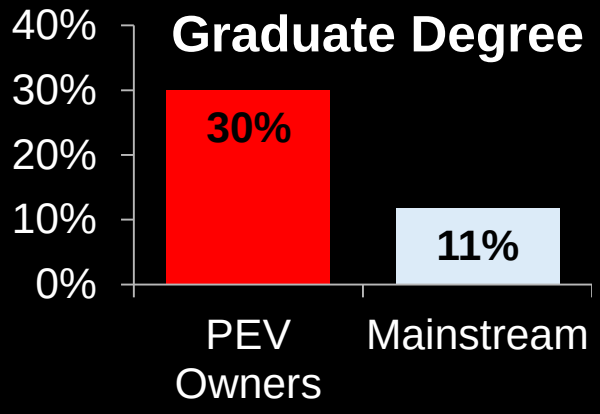
Motivations: 4 lifestyle segments of Pioneers

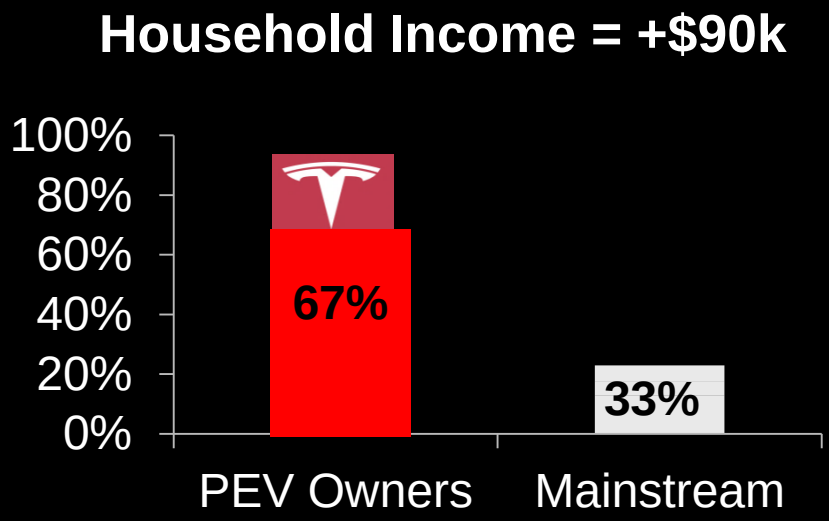


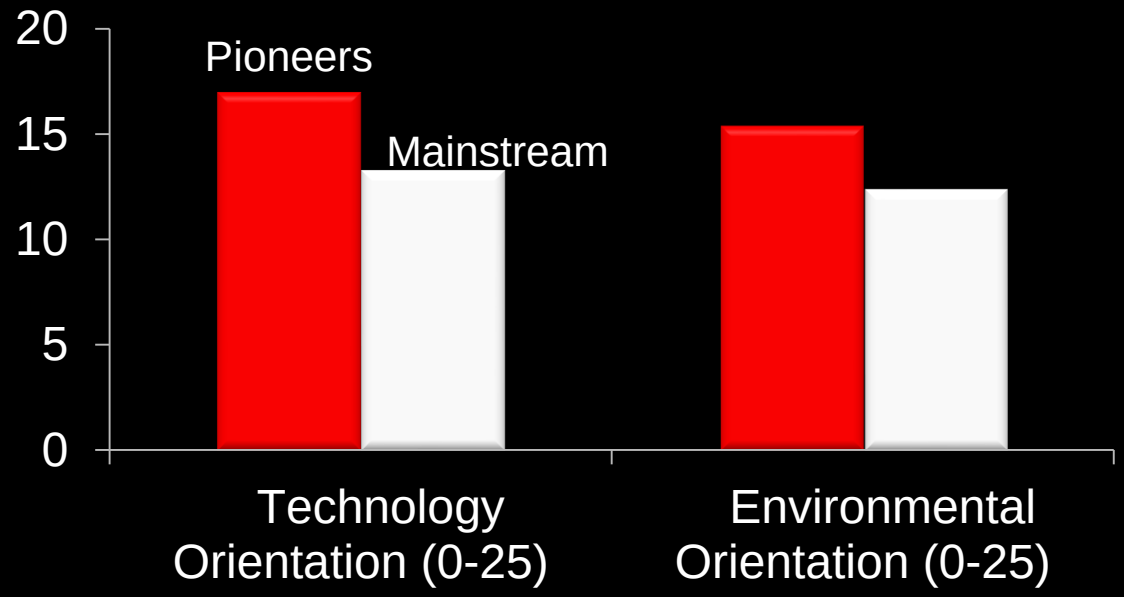
Source:
Axsen et al. (2015), *Electrifying Vehicles*

3) Comparing Pioneers to the potential “Mainstream”

PEV "Pioneers" are more highly educated, higher income, "greener" and more "techie"



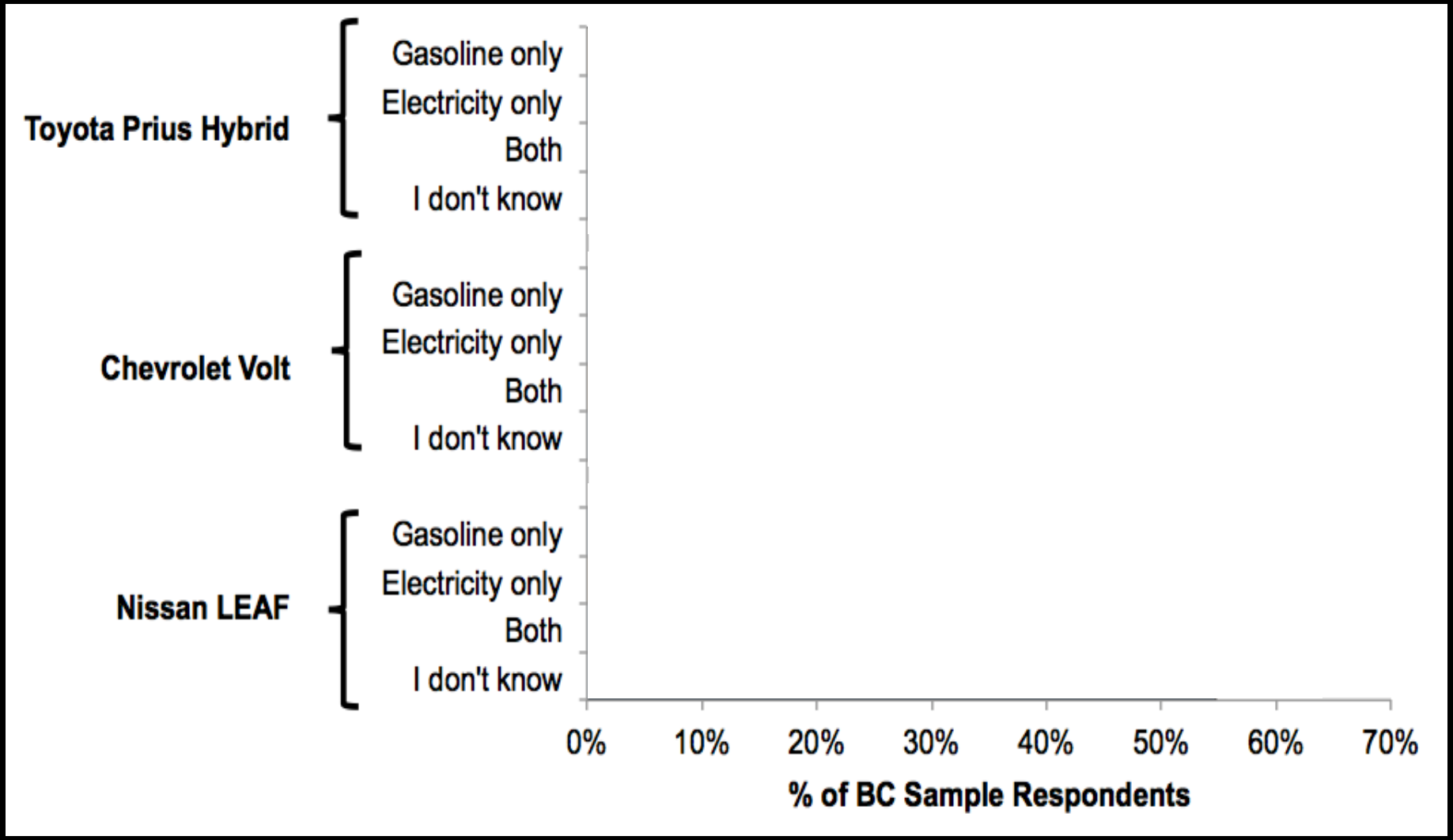




Source: Axsen et al. (2015), *Electrifying Vehicles*

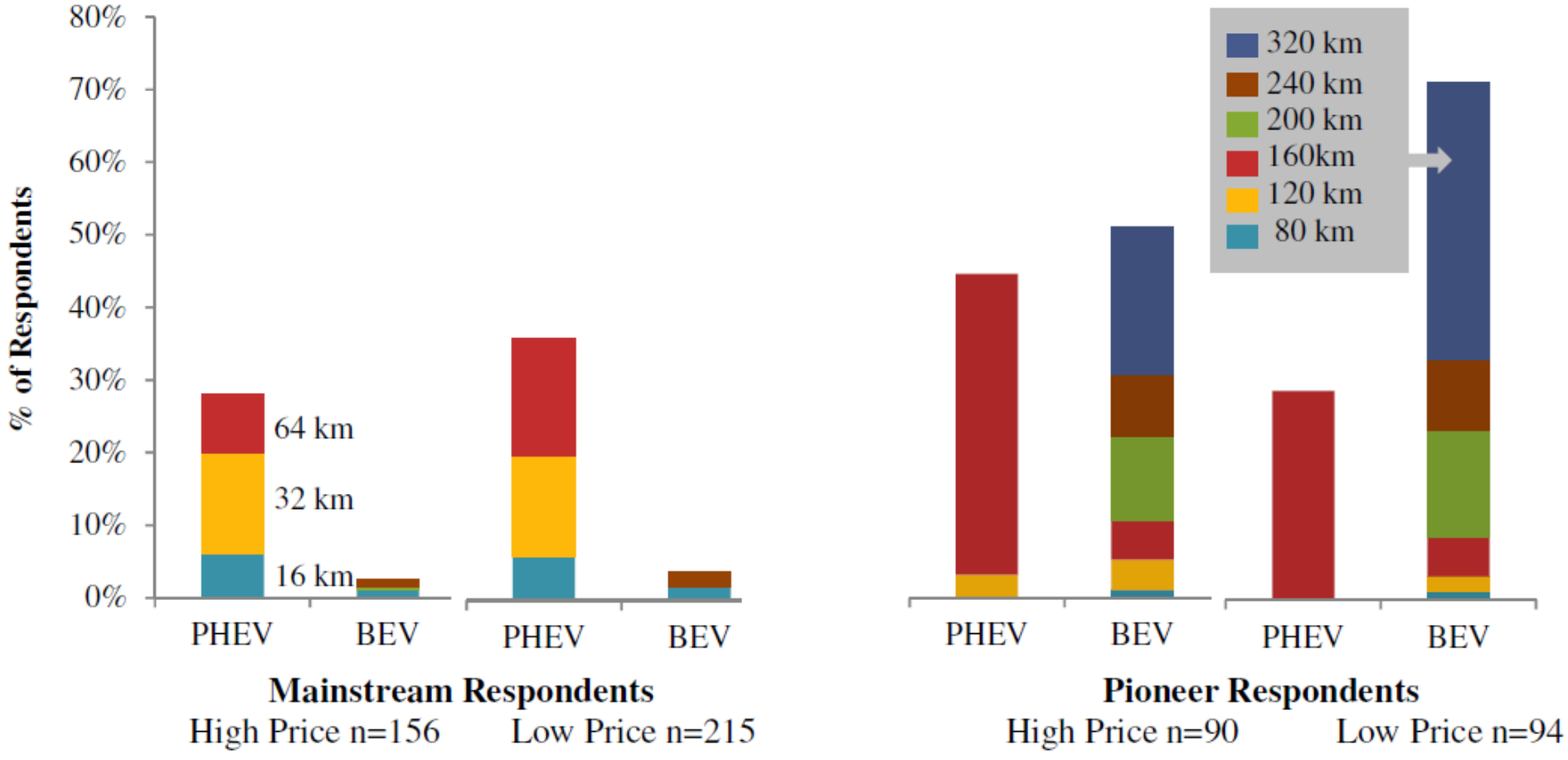
Mainstream awareness is low

"How is each of the following vehicle fueled?



Source: Axsen, Bailey and Kamiya (2013), CPEVS 2013 Preliminary Report

Mainstream buyers are more attracted to PHEVs, not so much BEVs



Source: Axsen and Goldberg (Under Review), *Transportation Research Part D*

4: PEV forecasts….
the Respondent-based Preference and Constraint (REPAC) model

Comparing PEV policies

Demand-focused policies

Purchase incentives — Rebates, tax breaks, fee reductions

Supply-focused policies

Adapted from: Lutsey et al. (2015), *ICCT White Paper*

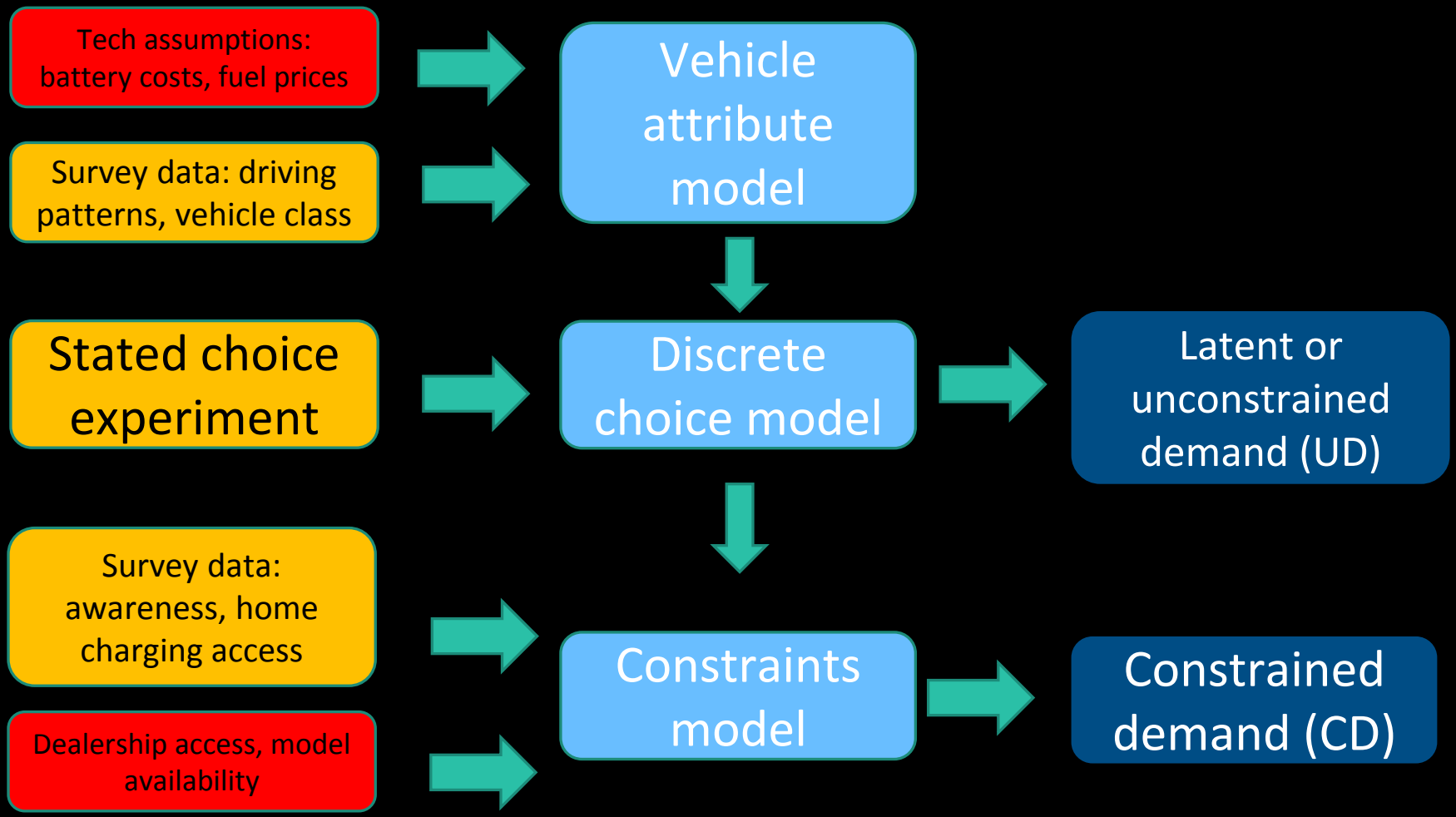
Responding to critiques of alternative fuel vehicle forecast studies

Al-Alawi and Bradley's (2013) recommendations for a "useful" model:

1. **Better represent consumer behaviour:**
   - Use consumer data (survey, e.g. choice model)
   - Represent financial and non-financial motivators
2. **Model vehicle supply and actions of automakers**
   - Availability of PEV models (in dealerships)
   - Variety of PEV models
   - Vehicle class
3. **Model national and subnational policy**
   - Demand-focused policies (incentives, charging access)
   - Supply-focused policies (production requirements)

Source: Al-Alawi and Bradley (2013), *Renewable & Sustainable Energy Reviews*

The respondent-based preference and constraint model (REPAC)



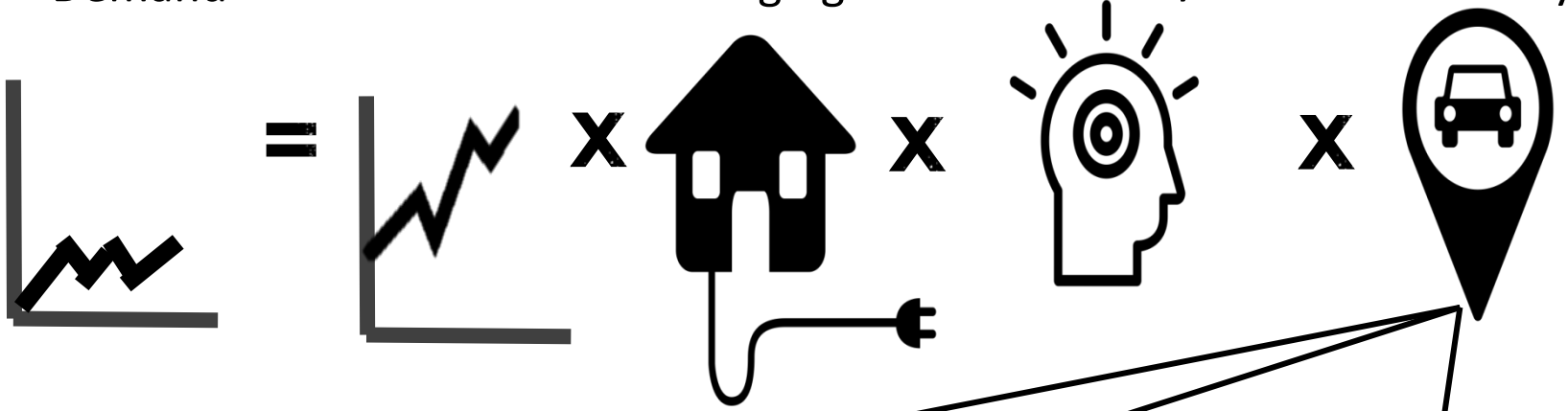
Thanks Amy Miele

Source: Wolinetz & Axsen (Under Review), *Technological Forecasting & Social Change*

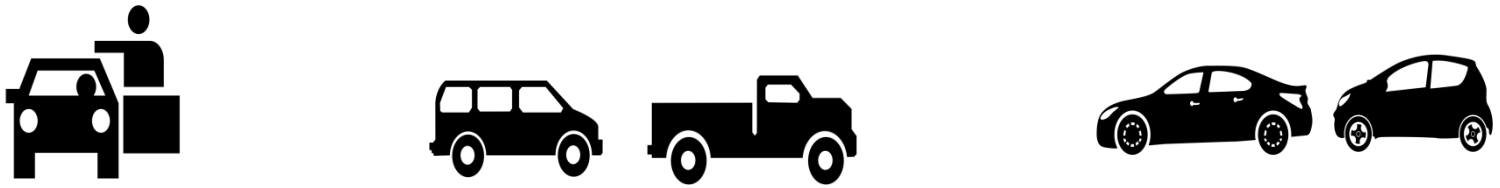
The respondent-based preference and constraint model (REPAC)

$$CD_{i,j} = UD_{i,j} * HC_i * PF_{i,j} * PA_{i,j}$$

Constrained Demand | Unconstrained Demand | Home charging | PEV familiarity | PEV availability



Dealership availability | Class availability | Model variety



Thanks Amy Miele

Source: Wolinetz & Axsen (Under Review), *Technological Forecasting & Social Change*

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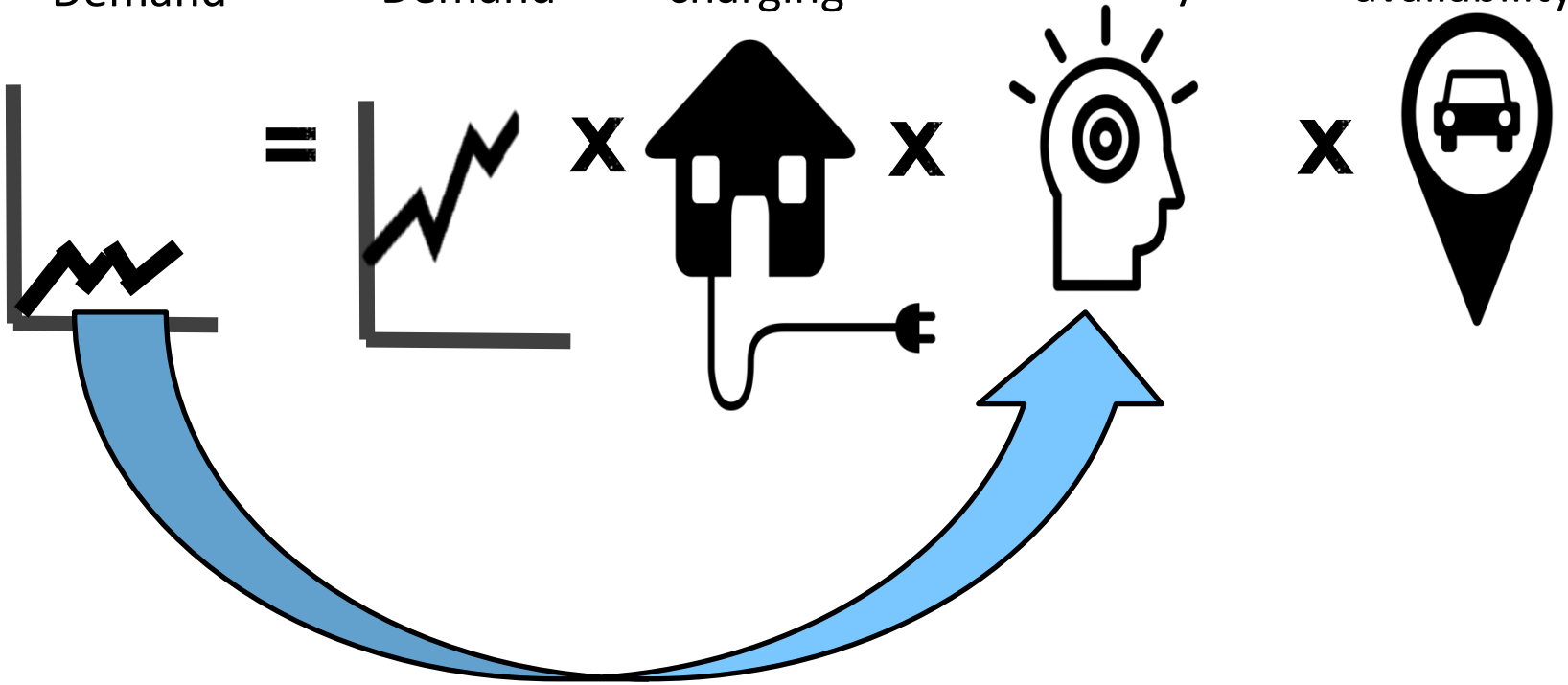


One feedback: As sales increase, consumer awareness increases

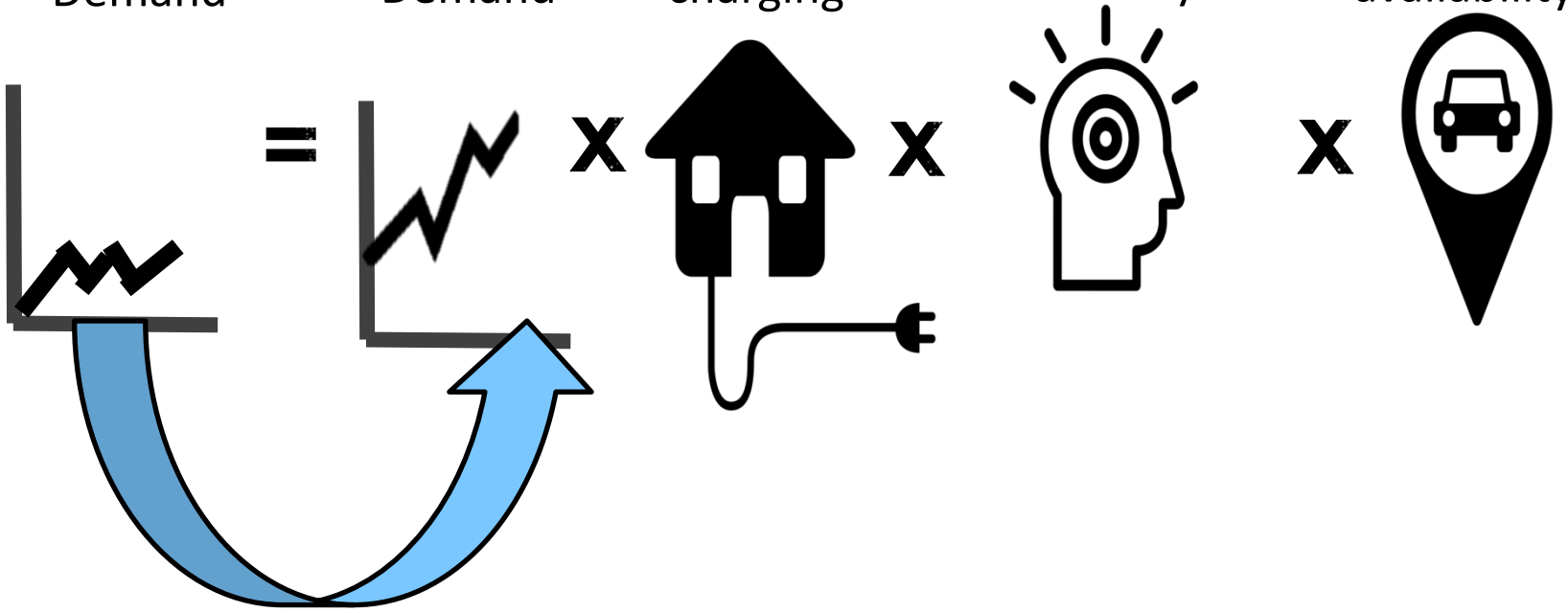
Thanks Amy Miele

Source: Wolinetz & Axsen (Under Review), *Technological Forecasting & Social Change*

The respondent-based preference and constraint model (REPAC)

$$CD_{i,j} = UD_{i,j} * HC_i * PF_{i,j} * PA_{i,j}$$

Constrained Demand | Unconstrained Demand | Home charging | PEV familiarity | PEV availability



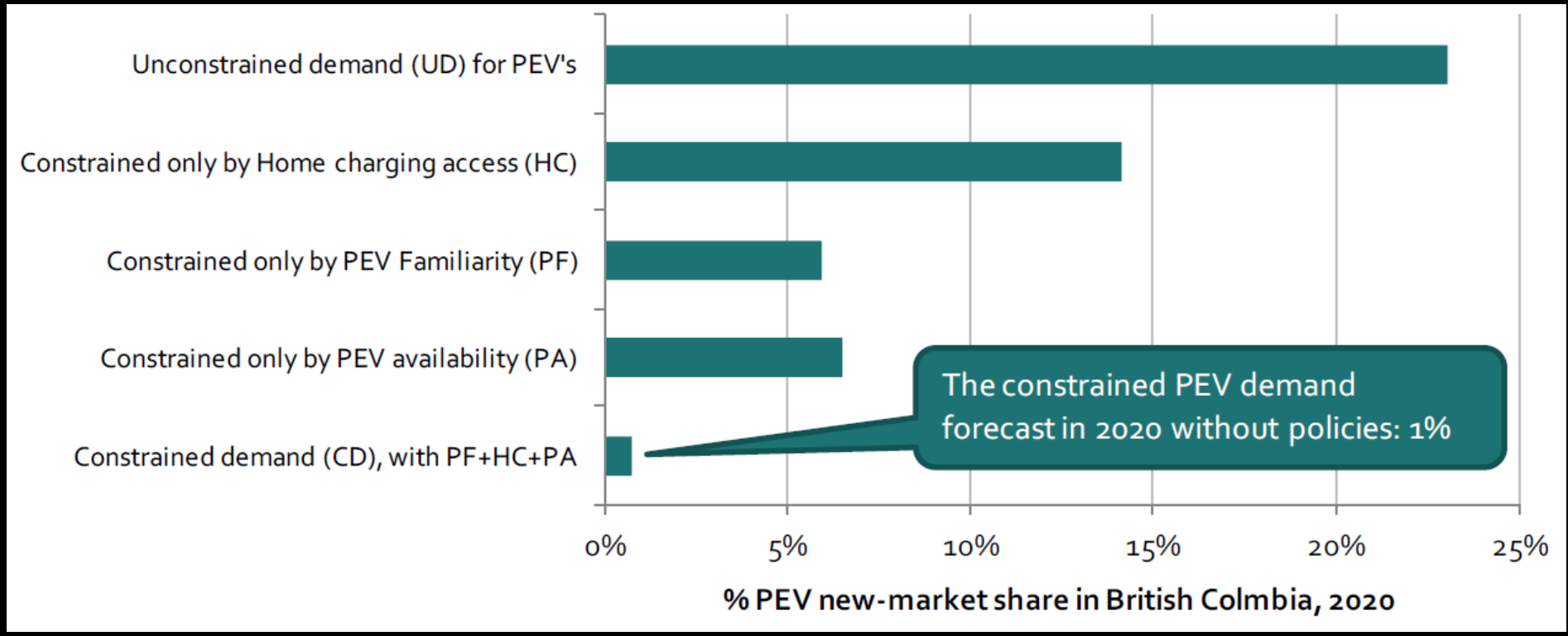
In the future, we'd like to add this feedback:

consumer preference dynamics

Thanks Amy Miele

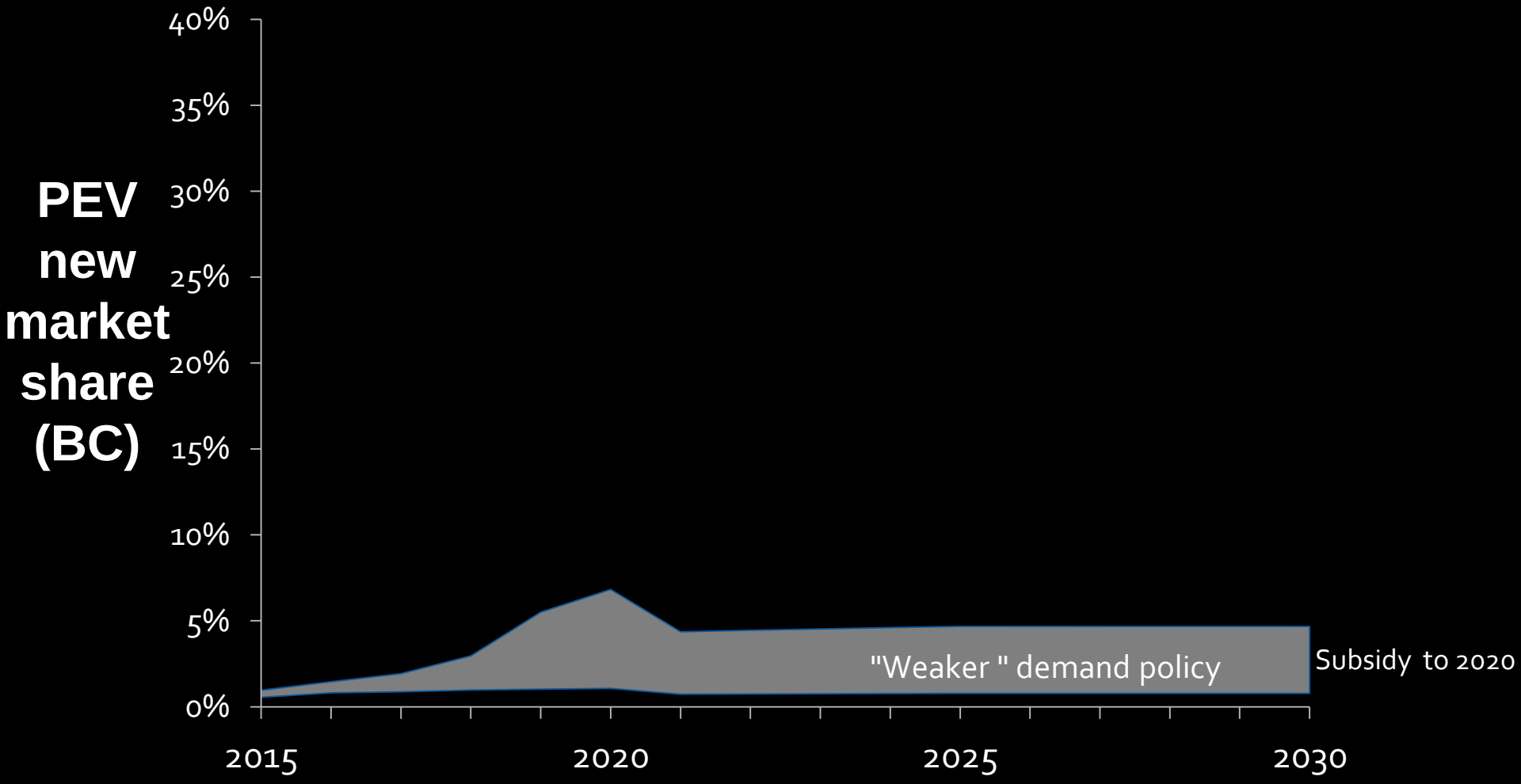
Source: Wolinetz & Axsen (Under Review), *Technological Forecasting & Social Change*

Adding various constraints to understand present and short-term sales



Source: Wolinetz & Axsen (Under Review), *Technological Forecasting & Social Change*

Demand-focused policies can get PEVs only so far…



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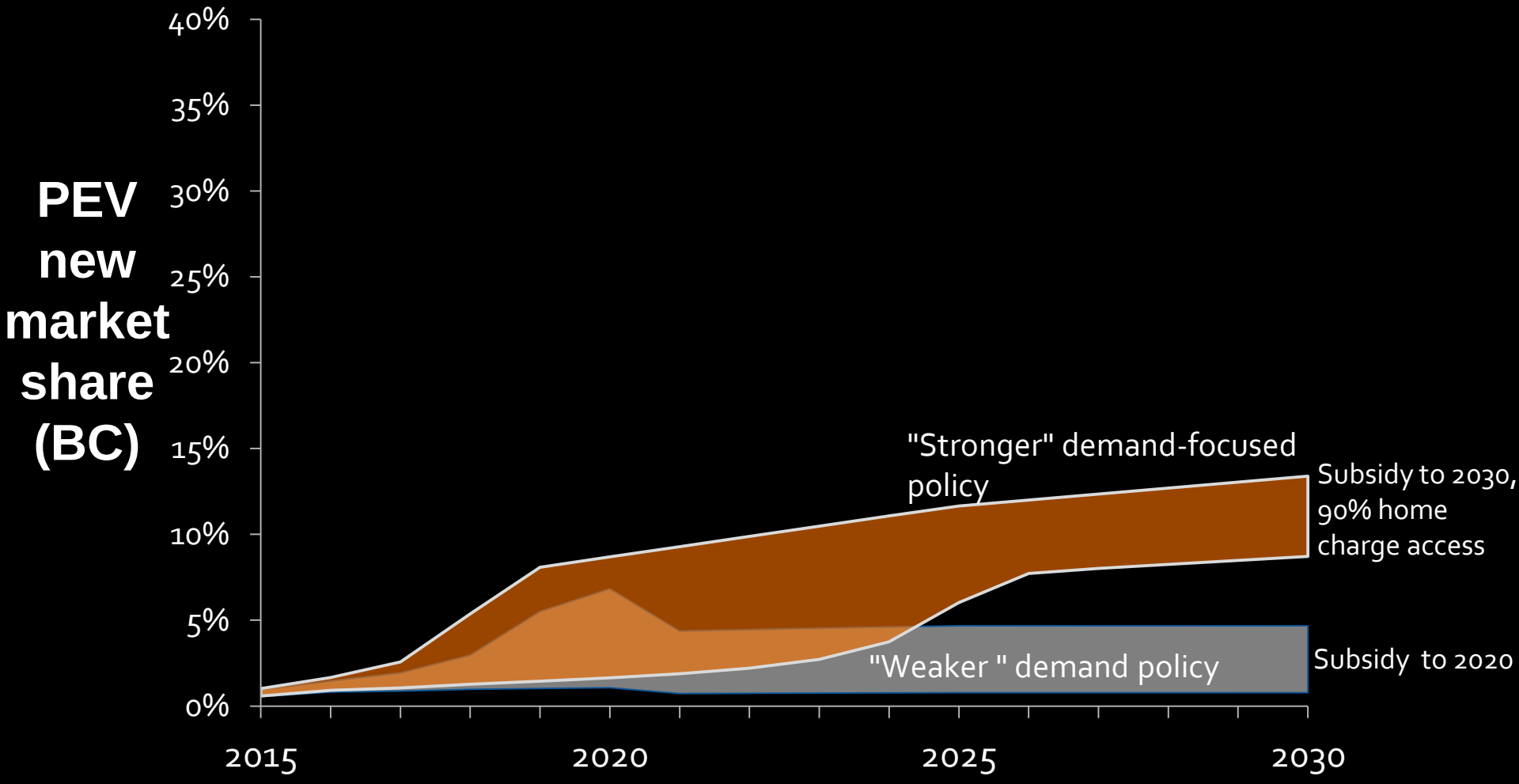
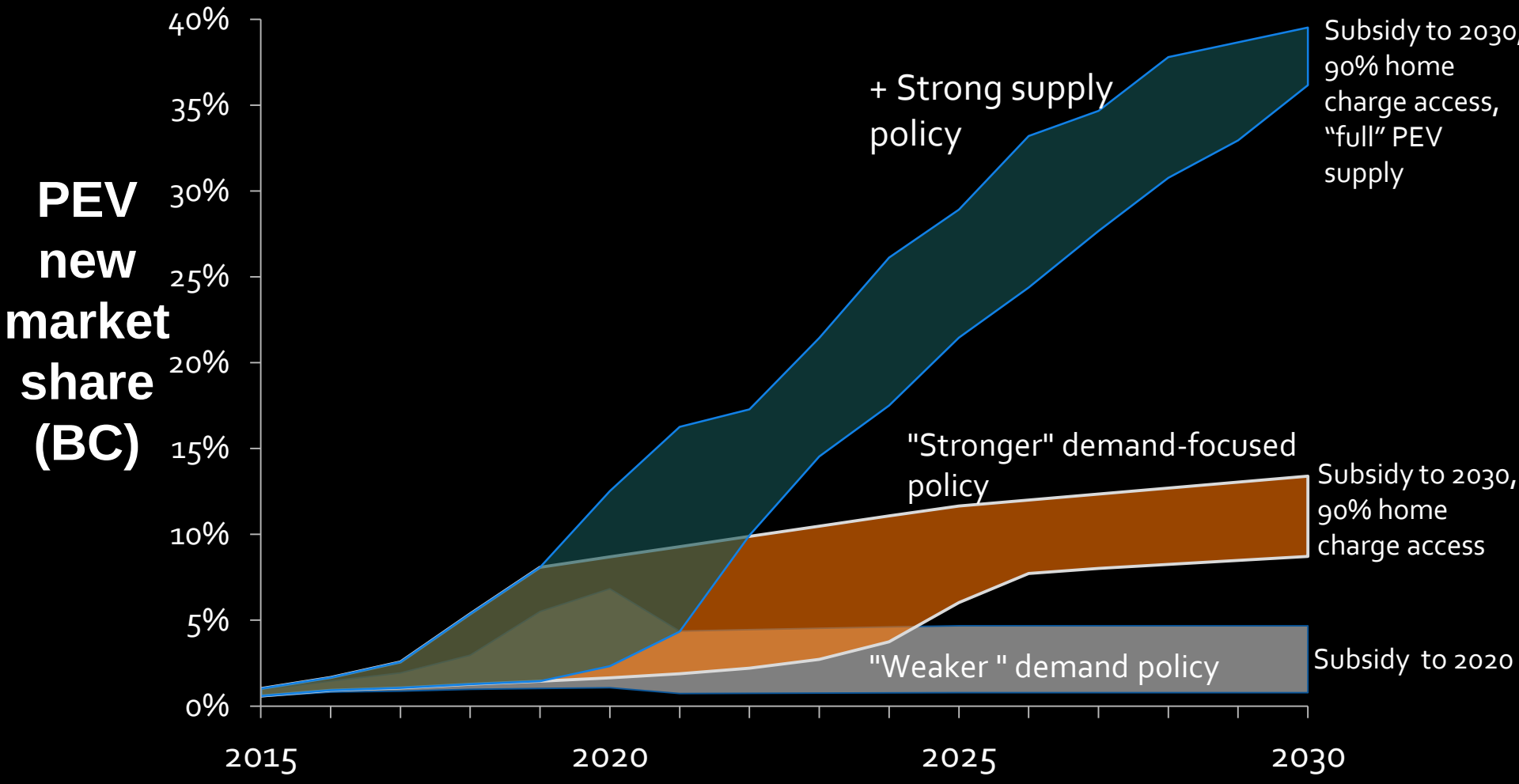


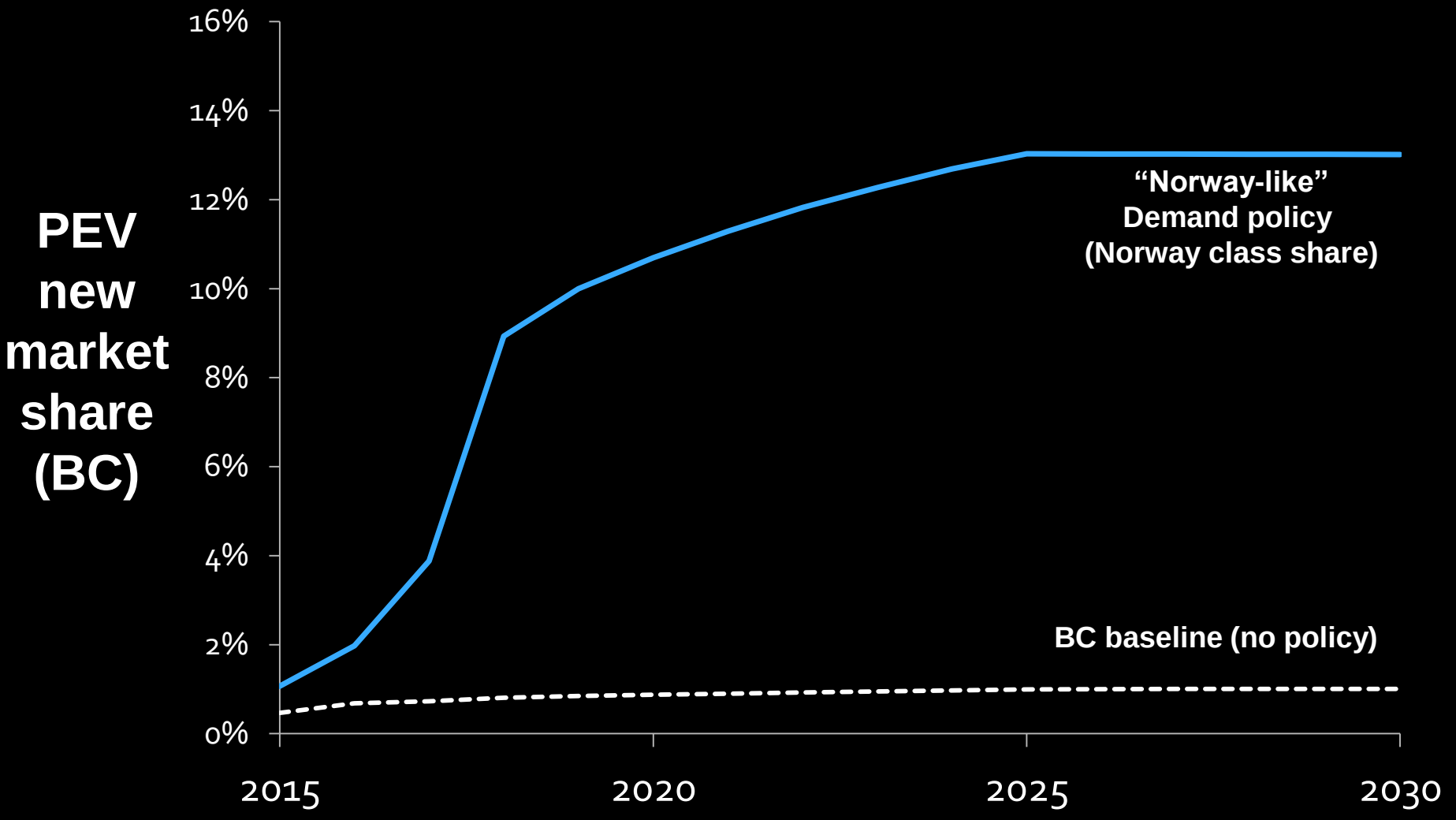
Source: Wolinetz & Axsen (Under Review), *Technological Forecasting & Social Change*

Supply-focused policies may be essential for PEV "success" (e.g. with 50+ models available)



Source: Wolinetz & Axsen (Under Review), *Technological Forecasting & Social Change*

Comparing “Norway-like” and “California-like” policies in Canada via REPAC



Source: Wolinetz & Axsen (Under Review), *Technological Forecasting & Social Change*

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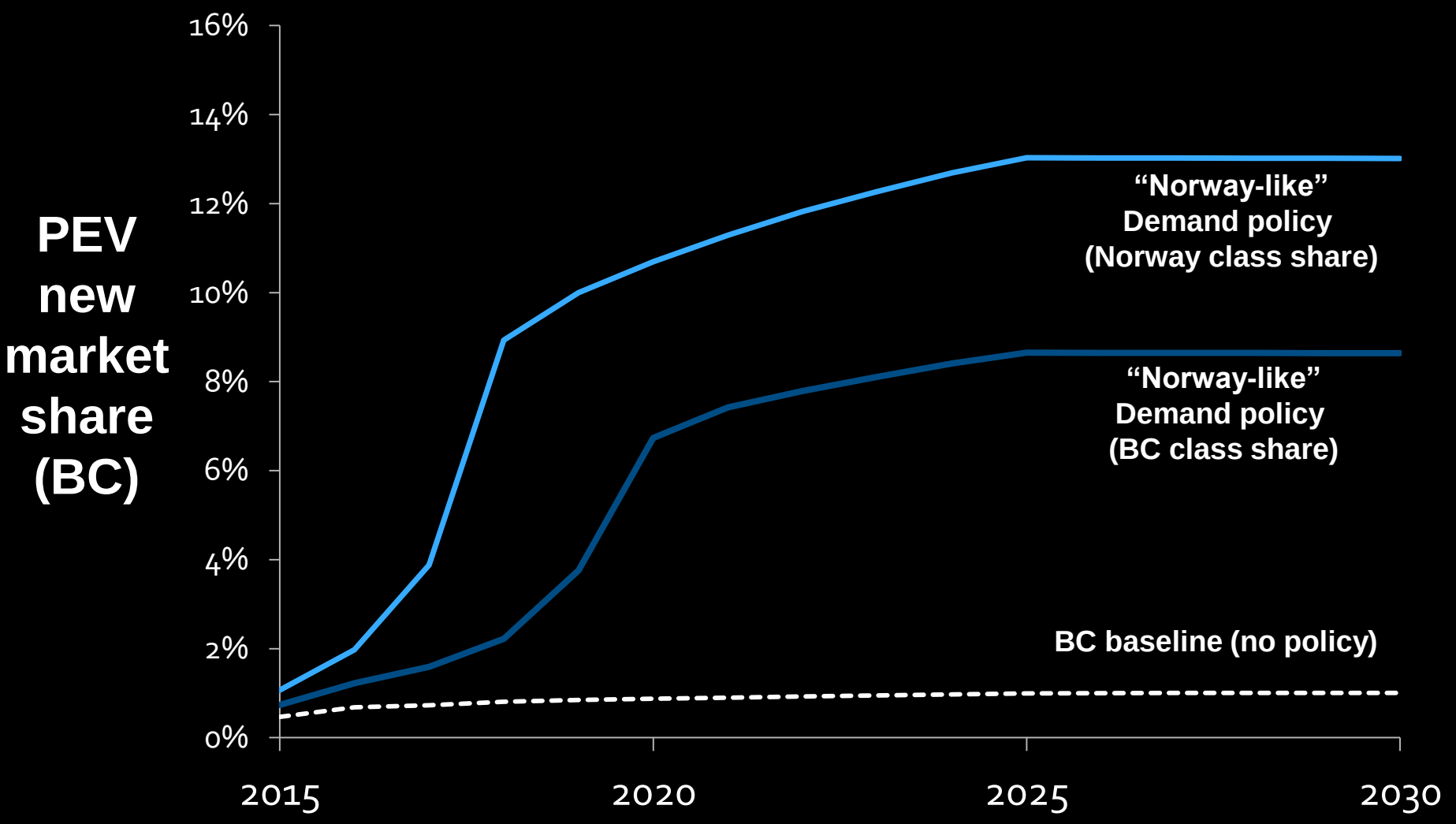

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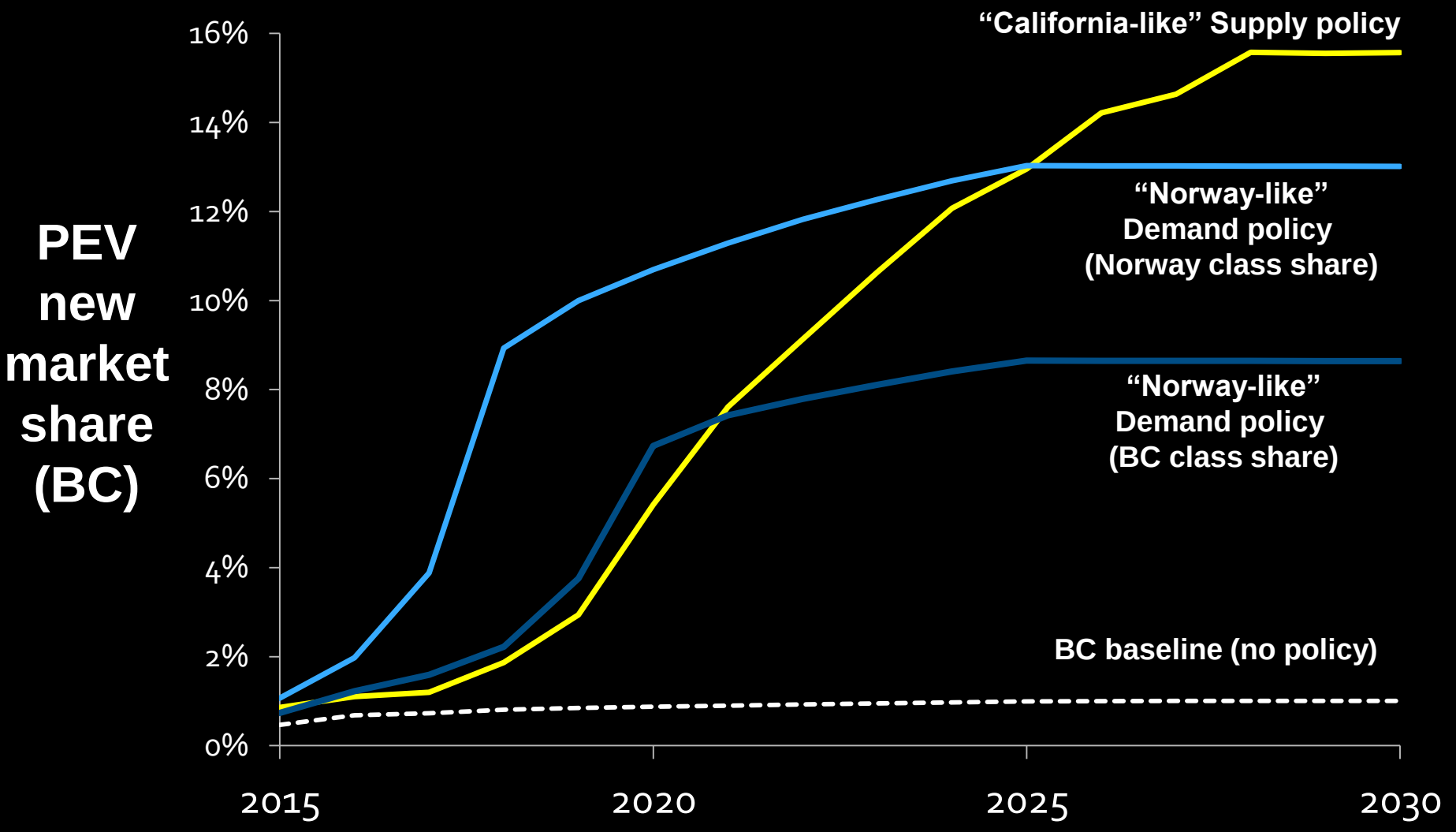
Comparing “Norway-like” and “California-like” policies in Canada via REPAC



Source: Wolinetz & Axsen (Under Review), *Technological Forecasting & Social Change*

Summary

PEV Pioneers	Early Mainstream
General	
• Higher income, education	• Lower income/education
• Green and/or techie lifestyle	• Variety of lifestyles
• Variety of motives (green, techie)	• Even wider variety of motives
PEVs	
• **Highly aware** and engaged with technology	• **Low awareness**, higher confusion (e.g. PHEVs, UCC)
• Tend to prefer **BEV**	• Greatly prefer **PHEVs**
• Public chargers not essential	• Public chargers not essential

REPAC relative to most PEV forecasting literature:

1. More pessimistic no-policy scenarios (e.g. 1-2% share)
2. More pessimistic about demand-focused policies (e.g. 2-12%)
3. Suggests that supply needs to increase, perhaps through supply-focused policy

Extra

California's ZEV Mandate

Sales requirement: "the most direct policy change any state can take to ensure increased PEV deployment"

- California: **~15% PEV new market share by 2025**
- Credits differ by vehicle (PHEV, EV, Fuel Cell)
- Credits can be traded among automakers (noncompliance = $5k per ZEV credit)
- US Regions: 8 other states have ZEV programs (Section 117 ZEV States)

Policy details from: Lutsey et al. (2015), *ICCT White Paper*

Critiques of alternative fuel vehicle forecast studies

Al-Alawi and Bradley (2013) summarize several studies that forecasts market share of electric drive vehicles. Four modeling approaches:

1. **Time-based diffusion models**: e.g. fitting an s-curve
2. **Constraints models**: e.g. % of population with garage, or with a particular commute distance
3. **Discrete choice models**: quantify consumer preferences, stated or revealed preference (or data-less)
4. **Agent-based models**: flexible, represents decision makers (consumers, even automakers), can be empirically-based or not

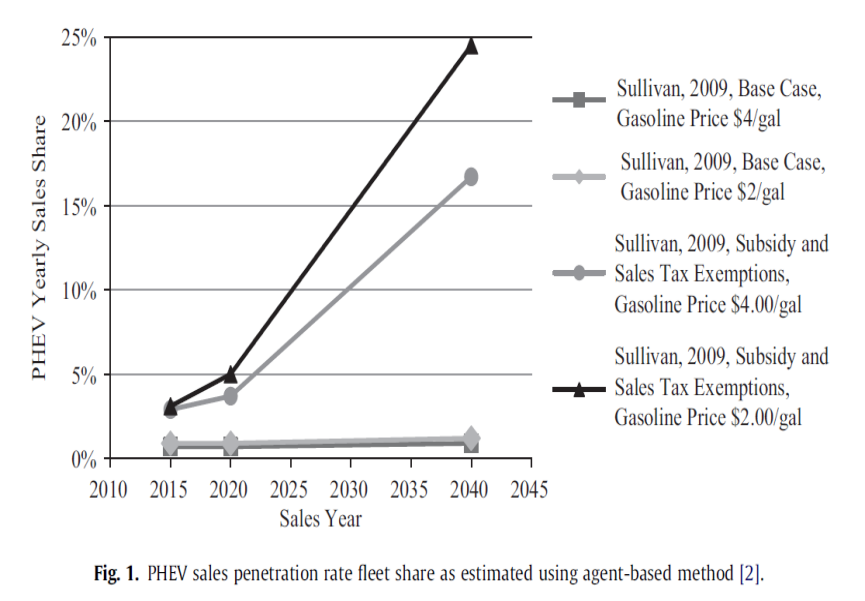


Fig. 1. PHEV sales penetration rate fleet share as estimated using agent-based method [2].

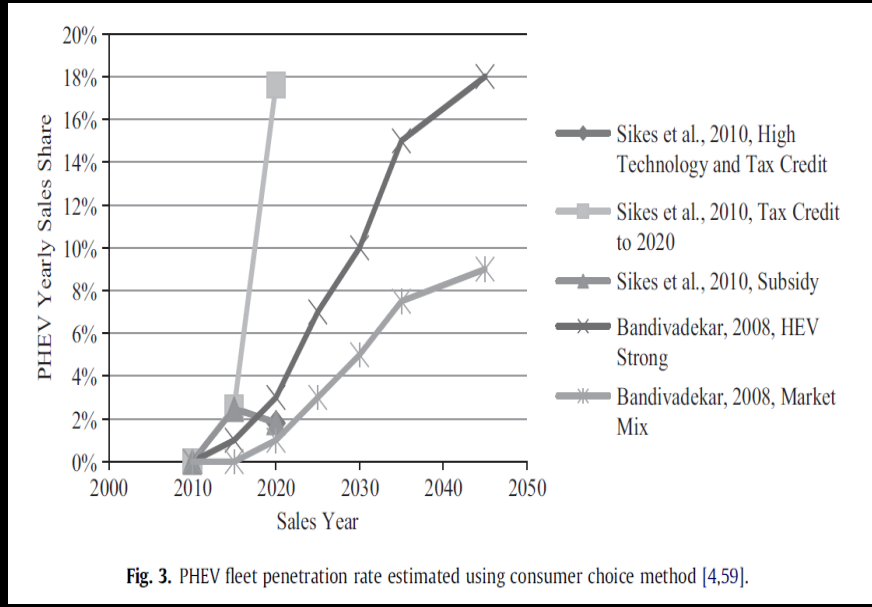


Fig. 3. PHEV fleet penetration rate estimated using consumer choice method [4,59].

Source: Al-Alawi and Bradley (2013), *Renewable & Sustainable Energy Reviews*

Stated preference choice experiment…

Table 2
PEV choice model experimental design (6 choice sets per respondent).

Attributes	Next anticipated conventional vehicle	Hybrid vehicle	Plug-in hybrid vehicle	Electric vehicle
Purchase price	Selected by respondent	Conventional price 10% more 20% more 40% more	Conventional price 10% more 20% more 40% more	Conventional price 10% more 20% more 40% more
Weekly fuel cost	Selected by respondent	40% less 30% less 20% less 10% less	80% less 60% less 40% less 20% less	80% less 60% less 40% less 20% less
Electric-driving range	n/a	n/a	16 km 32 km 64 km	120 km 160 km 200 km 240 km
Home recharge access	n/a	n/a	Level 1 (1 kW) Level 2 (6 kW)	Level 1 (1 kW) Level 2 (6 kW)
Recharge time[a]	n/a	n/a	Calculated	Calculated

[a] The discrete choice experiment showed "recharge time" to respondents to help them understand the recharging needs of the PHEV or EV. Recharge time was calculated as the time required for the respondent to fully recharge a depleted battery using their home charger. This time is a function of the vehicle's electric driving range, the base vehicle type (where larger vehicle bodies are assumed to require more electricity consumption or have a higher kWh/mile), and the speed of the home charger (Level 1 or Level 2).

Source: Axsen et al. (2015), *Energy Economics*

Identifying five consumer segments (or classes) via a latent-class choice model

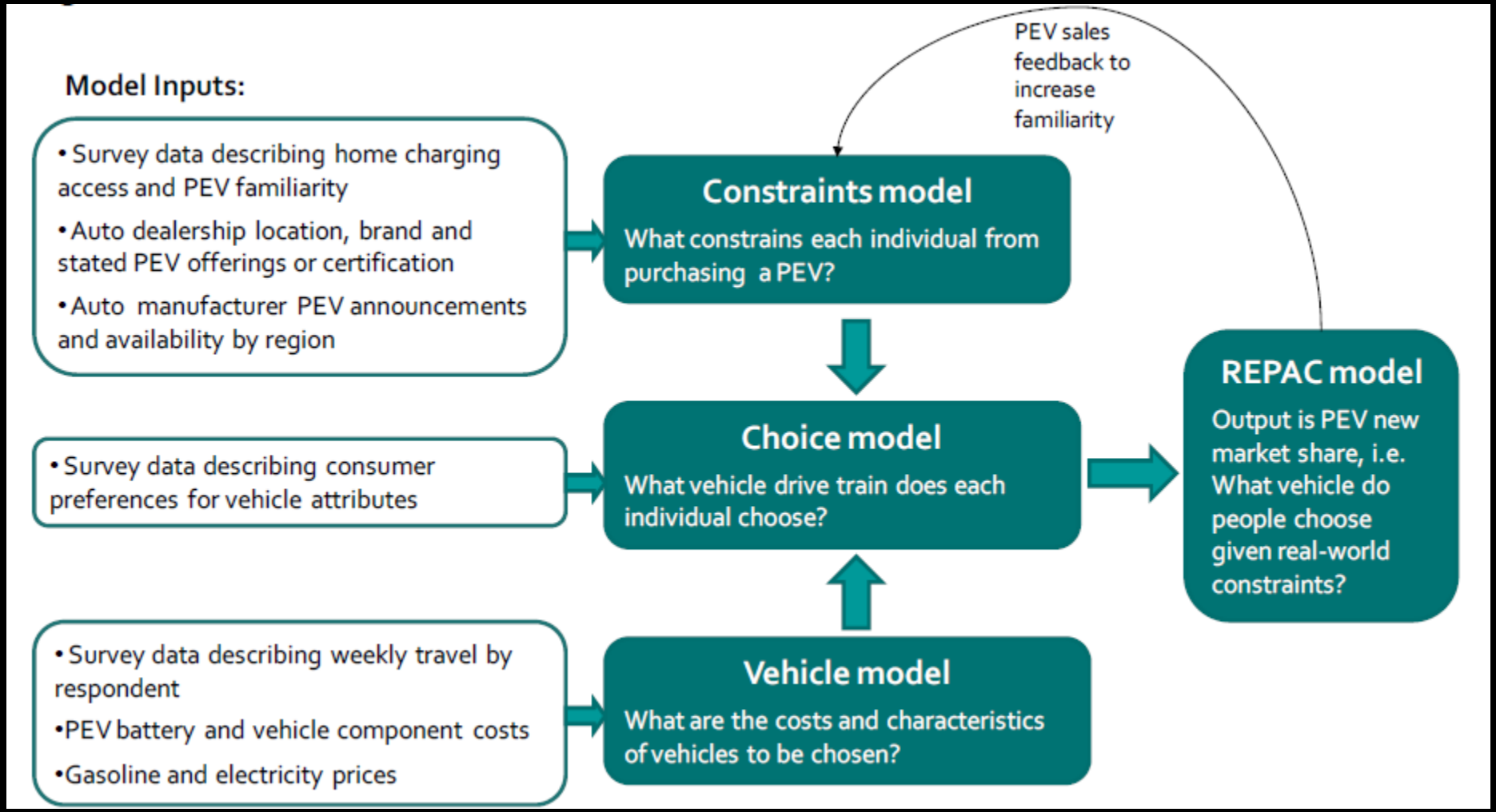
Table 4
Latent-class results for 5-class solutions (n = 1754).

Class label	PEV-enthusiast	PHEV-oriented	HEV-oriented	HEV-leaning	CV-oriented
Probability of membership	0.080	0.254	0.159	0.277	0.230
Discrete choice model					
HEV constant	0.64**	2.30***	2.65***	0.88***	−2.91***
PHEV constant	2.09***	3.22***	−1.37***	−0.11	−4.72***
EV constant	2.14***	−1.16**	−5.07	−3.10***	−2.15
Vehicle price (CAD$)	−0.00002***	−0.0002***	−0.0002***	−0.0006***	−0.0003***
Fuel cost (CAD$/week)	0.0002	−0.0407***	−0.0079***	−0.0387***	−0.0197***
PHEV range (km)	−0.0035	−0.0033	0.0118**	0.0065**	0.0039
EV range (km)	−0.0017	0.0038	0.0003	0.0057**	−0.0195
PHEV × Level 2 charging at home	0.11	0.51***	1.04***	0.51***	−0.20
EV × Level 2 charging at home	0.62***	1.20***	3.67	0.26	−1.08
Implied willingness-to-pay[a]					
Saving $1000/year in fuel		$3781	$670	$1258	$1126
HEV	$41,245	$11,090	$11,692	$1493	−$8637
PHEV[b]	$135,026	$15,568	−$6028		−$14,021
EV[b]	$137,794	−$5612		−$5246	
PHEV with Level 2 charging		$2444	$4602	$856	
EV with Level 2 charging	$39,981	$5805	$670	$1258	
Class membership model [relative to base]					
Constant	−6.0***	−1.9***	−0.5	[Base]	1.2***
Household size (number of people)	0.17*	0.10	−0.15**		−0.22***
$50,000 to $99,999 [Base = "<$50,000"]	0.18	−0.28*	−0.29*		−0.20
$100,000 to $150,999 [Base = "<$50,000"]	0.36	−0.21	0.15		0.15
$150,000 or more [Base = "<$50,000"]	−0.05	−0.28	0.15		0.12
Bachelor's degree [Base = "less than Bachelor's"]	0.43	0.15	−0.30*		−0.54***
Graduate degree [Base = "less than Bachelor's"]	0.12	−0.03	−0.38*		−0.94***
Live in Alberta [Base = "rest of Canada"]	1.14**	0.28	0.45*		−0.17
Live in British Columbia [Base = "rest of Canada"]	1.42***	0.42**	0.59**		−0.11
Live in Ontario [Base = "rest of Canada"]	0.75*	−0.04	0.03		−0.23
Technology-oriented lifestyle score	0.10***	0.02	−0.01		−0.04**
Environment-oriented lifestyle score	0.10***	0.09***	0.02		0.02
Environmental concern (NEP score)	0.06***	0.04***	0.03*		−0.04***
Liminality score	0.02	0.00	0.04**		0.03*

* Significant at 90% confidence level.
** Significant at 95% confidence level.
*** Significant at 99% confidence level.

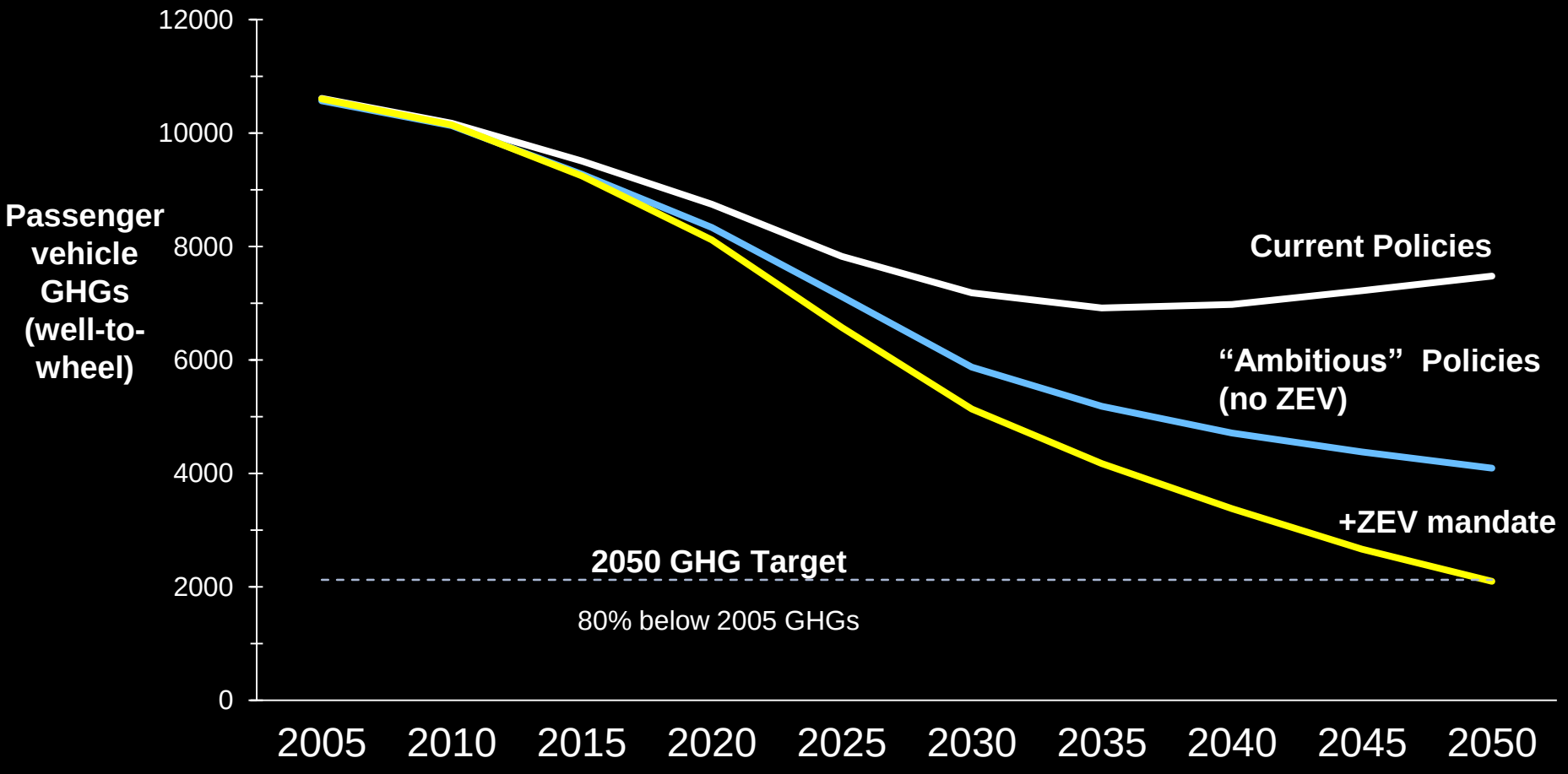
Source: Axsen et al. (2015), *Energy Economics*

Modeling PEV policy: The respondent-based preference and constraint model (REPAC)



Source: Wolinetz & Axsen (Under Review), *Technological Forecasting & Social Change*

A ZEV mandate may be essential to achieve 2050 GHG targets



"Ambitious" Policies		
	Carbon Tax: $30/t 2015 to $120/t 2050 ZEV Subsidies: $5000 in 2015 and 2020	LCFS: 15% less GHG intensive w/ biofuels CAFE: 60% less fuel intensive by 2050

Source: Sykes and Axsen (In Progress), Master's Thesis