Making electric mobility happen:

Insights from a reflexive, multi-method research program

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ANALYSIS

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Moving beyond alternative fuel hype to decarbonize transportation

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

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Energy Policy

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

No free ride to zero-emissions: Simulating a region's need to implement its own zero-emissions vehicle (ZEV) mandate to achieve 2050 GHG targets

Maxwell Sykes, Jonn Axsen*

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Technological Forecasting & Social Change

How policy can build the plug-in electric vehicle market: Insights from the REspondent-based Preference And Constraints (REPAC) model

Michael Wolinetz[a,b], Jonn Axsen[b,*]

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Evaluating plug-in electric vehicle policies in the context of long-term greenhouse gas reduction goals: Comparing 10 Canadian provinces using the "PEV policy report card"

Noel Melton[a,b,*], Jonn Axsen[b], Suzanne Goldberg[b]

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Transportation Research Part D

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

How might potential future plug-in electric vehicle buyers differ from current "Pioneer" owners?

Jonn Axsen, Suzanne Goldberg*, Joseph Bailey

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Contents lists available at ScienceDirect

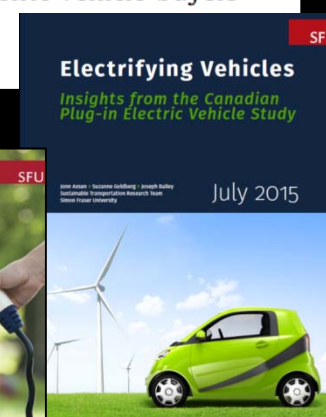
Energy Research & Social Science

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

Original research article

Confusion of innovations: Mainstream consumer perceptions and misperceptions of electric-drive vehicles and charging programs in Canada

Jonn Axsen, Brad Langman, Suzanne Goldberg*



Overview

1) Why electric vehicles?
2) A multi-method, reflexive approach
3) Insights from interviews
4) From interviews to surveys
5) From surveys to models
6) From research to policy evaluation

1) Why electric vehicles?

Huge variety among plug-in vehicles

Plug-in Hybrid (PHEV)

Toyota Prius PHV

20 km → ~800 km gasoline

Chevy Volt

~56 km → ~500 km gasoline

Pure Electric (EV)

Nissan Leaf

~117 km electric range

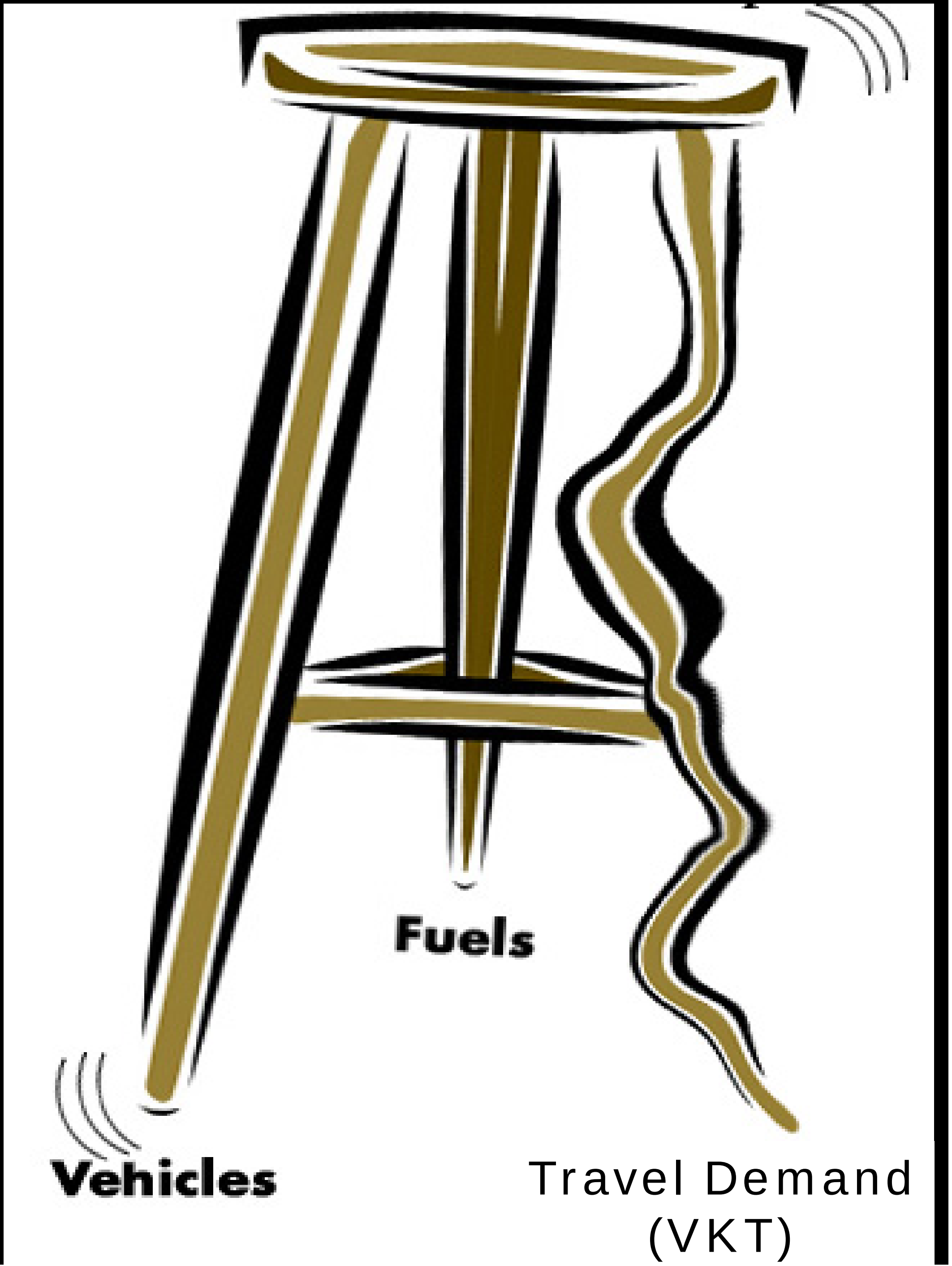
Tesla Roadster

~300km electric range

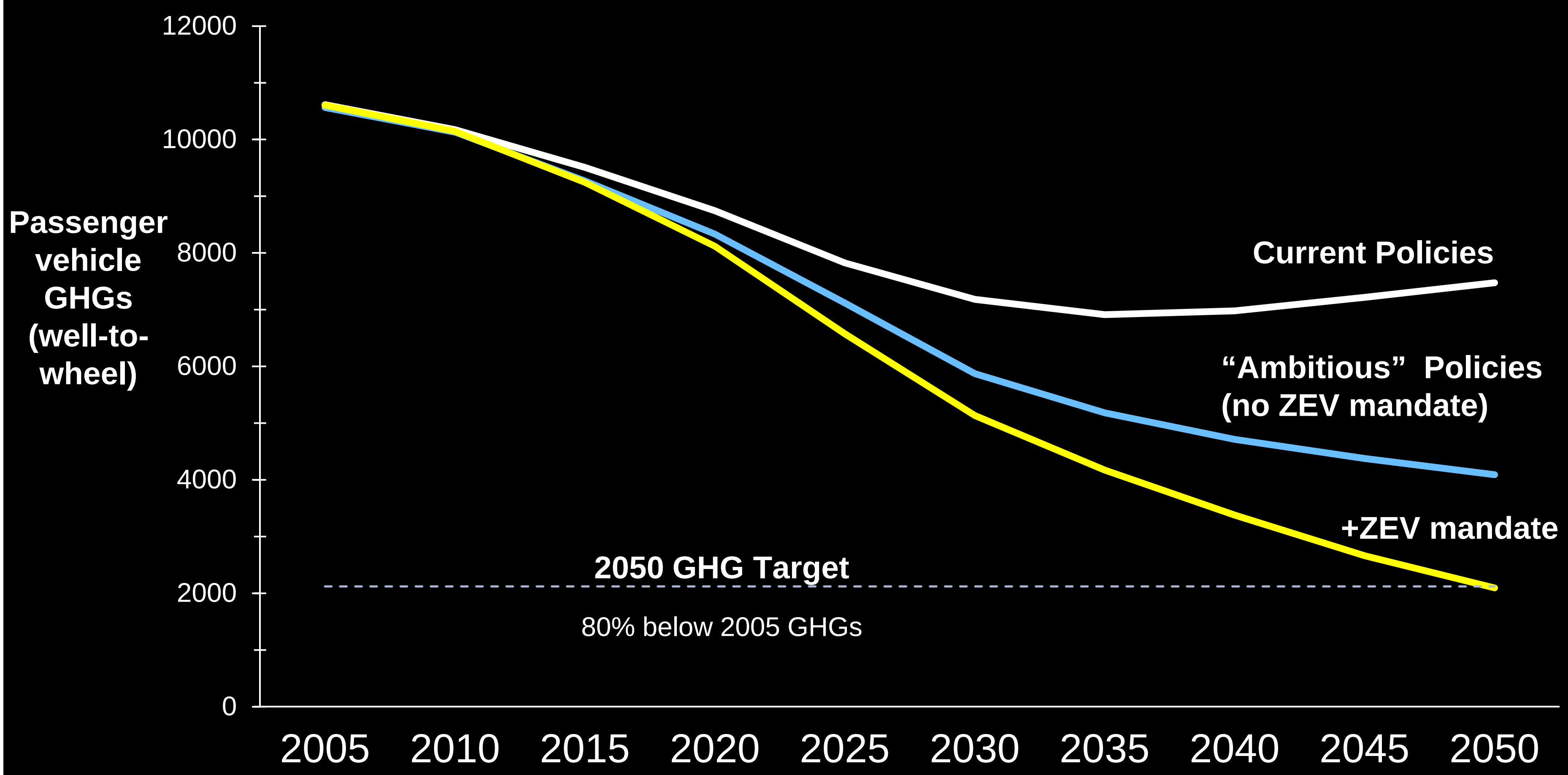
Comparing Battery Sizes: 4 kWh, 16 kWh, 24 kWh, 53 kWh

Bigger picture: three-legs of the transport GHG mitigation "stool"

All legs need to be addressed…



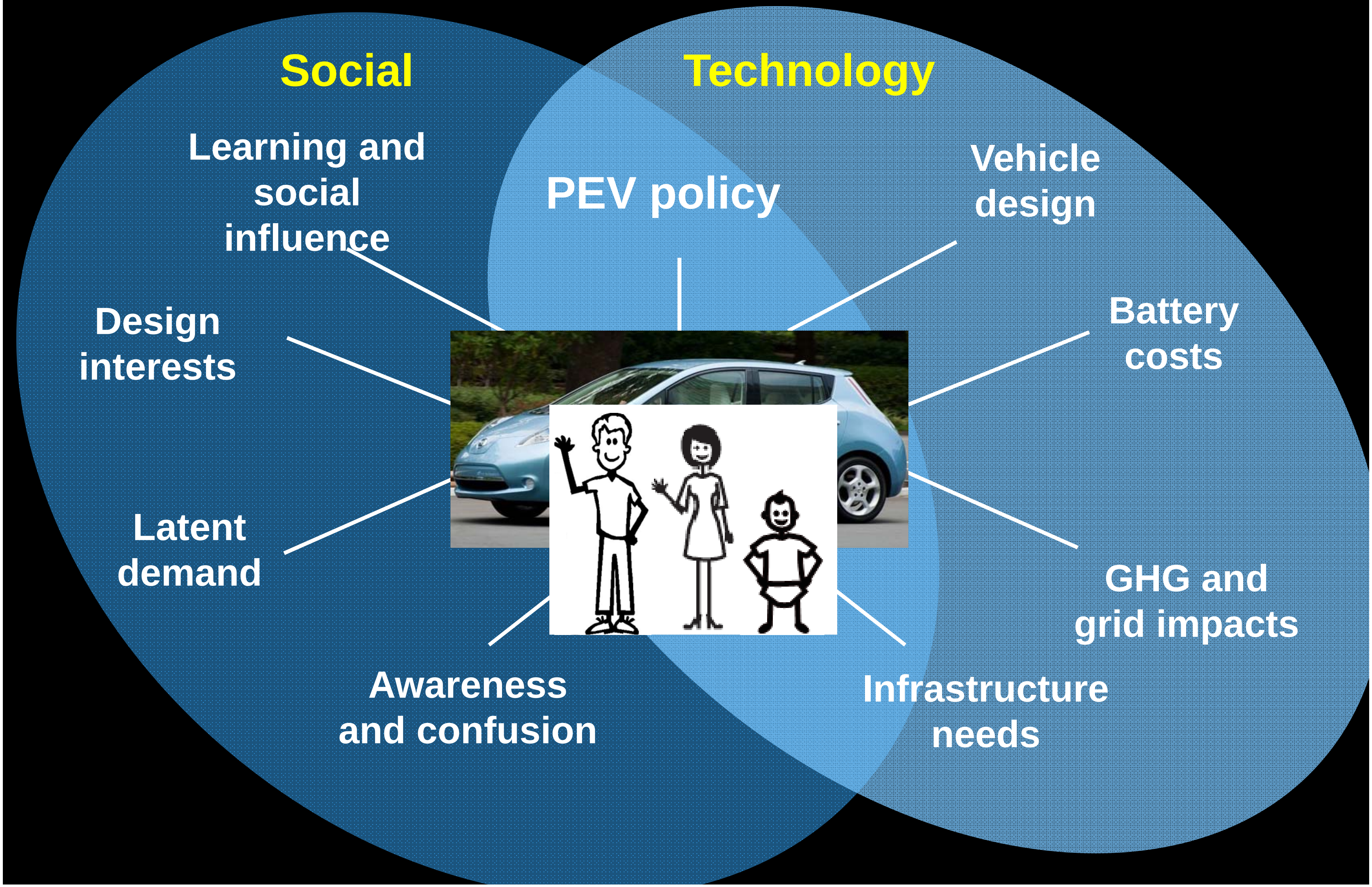
Long-term modeling suggests that PEVs can play an important role in GHG mitigation



"Ambitious" Policies	Carbon Tax: \$30/t 2015 to \$120/t 2050 ZEV Subsidies: \$5000 in 2015 and 2020	LCFS: 20% less GHG intensive w/ biofuels CAFE: 60% less fuel intensive by 2050

Source: Sykes and Axsen (2017), *Energy Policy*

…a socio-technical transition?



2) A reflexive, multi-method approach

“Qualitative” interviews
n = dozens

My Master’s work

“Quantitative” surveys
n = 100s or 1000s

Discrete choice model

Technology adoption models
(0-15 year time horizon)

Informing behavioural realism

Energy-economy system models
(20-40yr + time horizon)

2) A reflexive, multi-method approach

My Ph.D work

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n = dozens

“Quantitative” surveys
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Technology adoption models
(0-15 year time horizon)

Energy-economy system models
(20-40yr + time horizon)

What is “social influence”?

2) A reflexive, multi-method approach

My latest work

"Qualitative" interviews
n = dozens

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Technology adoption models
(0-15 year time horizon)

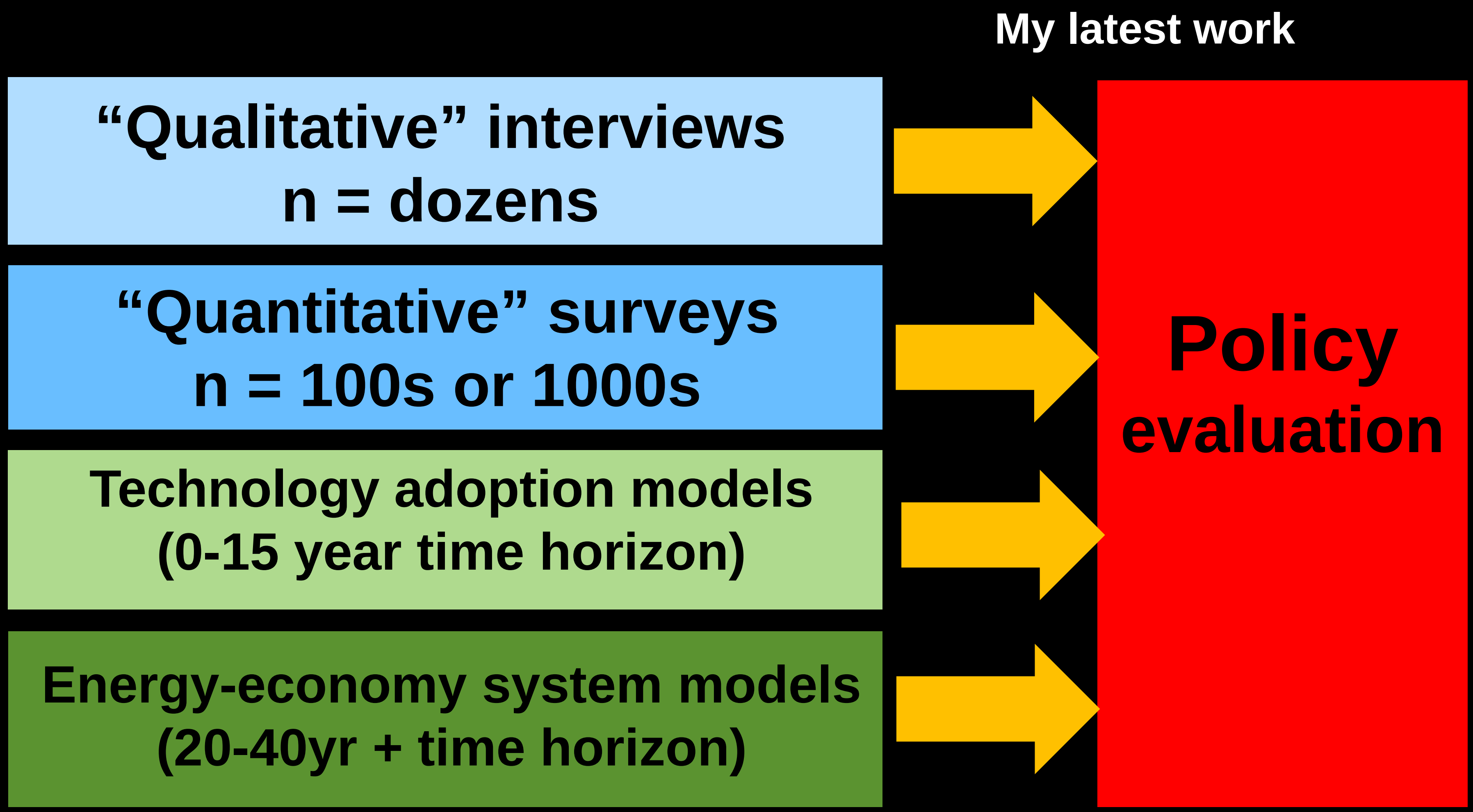
Energy-economy system models
(20-40yr + time horizon)

"Reflexive Participant" surveys

"Respondent-based" modeling

Behaviourally-realistic models

2) A reflexive, multi-method approach



3) Insights from Interviews

My latest work

“Qualitative” interviews
n = dozens

????

“Quantitative” surveys
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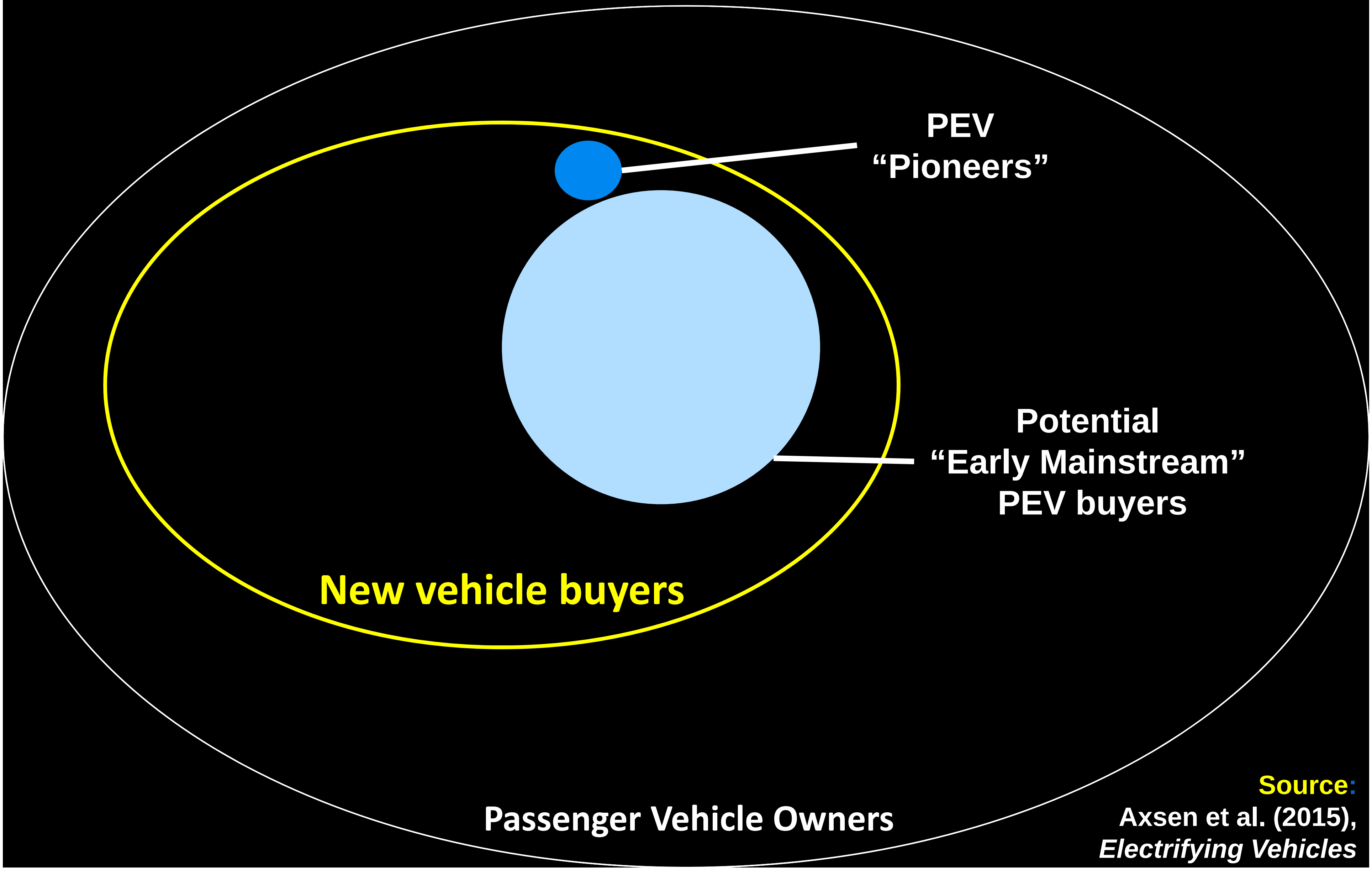
Technology adoption models
(0-15 year time horizon)

Energy-economy system models
(20-40yr + time horizon)

PEV consumer research: “Pioneers” and the “Early Mainstream”



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

Mainstream has low awareness…

The majority expressed confusion about **PEVs**:

“Is the Leaf electric or is it hybrid?” – Mr. Chen

“What’s the deal here? You don’t plug this in, the hybrid?” - Clair

And confusion about **vehicle-grid integration** and **V2G**.

“That gets pretty complicated…” - Andreas

“[seems] futuristic” – Clair

“Oh god!” – Christine (in confusion)

Source: Axsen, Langman & Goldberg (2017), *Energy Research & Social Science*

Consumer perceptions are complex; as are processes of preference construction

Functional

Symbolic

Private

Societal

Sources: Axsen and Kurani (2012), *Environment and Planning A*
Axsen, Orlebar & Skippon (2013), *Ecological Economics*

Consumer perceptions are complex; as are processes of preference construction

	Functional	Symbolic
Private	What it does for you	What it represents
Societal	What it does for society	What it says to society

Sources: Axsen and Kurani (2012), *Environment and Planning A*
Axsen, Orlebar & Skippon (2013), *Ecological Economics*

4) From interviews to surveys

“Qualitative” interviews
n = dozens

“Quantitative” surveys
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Technology adoption models
(0-15 year time horizon)

Energy-economy system models
(20-40yr + time horizon)

The “Reflexive Participant” Approach to surveys

Perspectives on the "mainstream" consumer

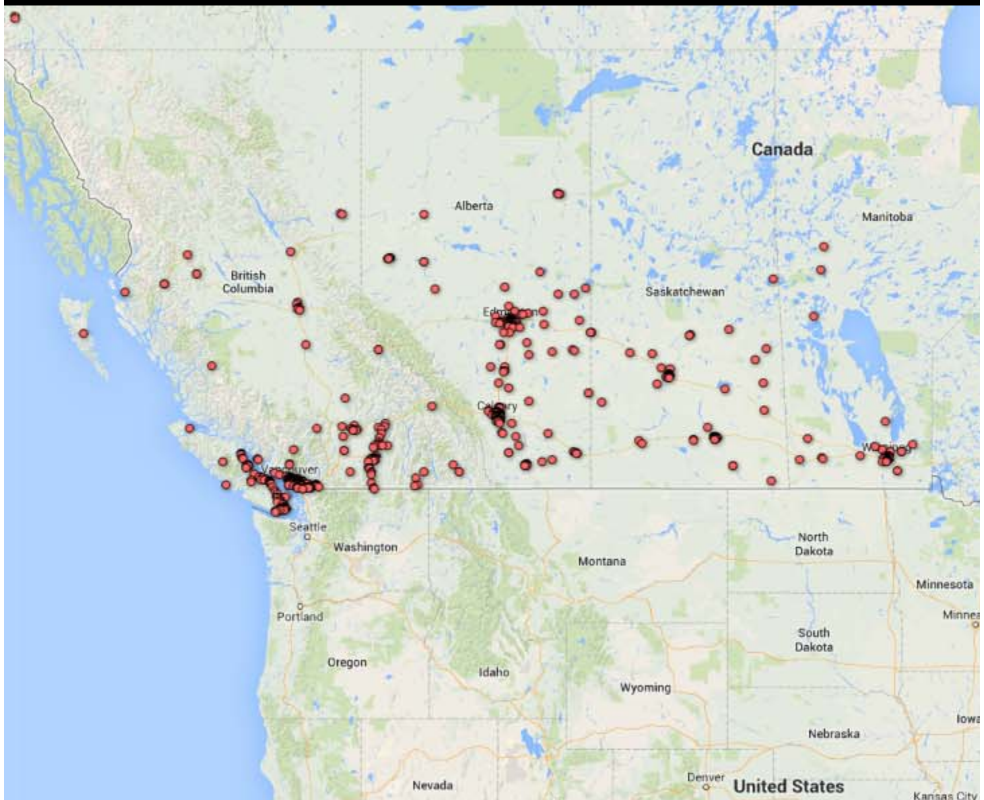
The "Rational Actor"….	The "Reflexive Participant"…
…has perfect information.	…might have little or no information
…has established preferences.	…might have unformed preferences
…has static preferences.	…can change preferences over time.
…can articulate those preferences.	…might have trouble communicating those preferences

The respondent: awareness, understanding, perceptions, preferences → **Method:** Survey, interview, model, analysis → **Representation of respondent** Results, interpretation, insights

The “Reflexive Participant” Approach

Flow of the conversation	Example instrument
Background: Tell me about your car	Inventory/narrative
Awareness: Have you heard of this tech?	“Test” questions
Initial perceptions: What do you think?	Belief questions
Explain more: Let me explain more	“Buyers’ Guide”
Reflexive experience: Go do something	Driving diary/demo
Response exercise: What would you like in… Context A, Context B, etc.	Design space
Follow up: Why did you select that?	Belief questions

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



Part 1 Web-Based	• Current vehicle fleet • Current electricity use • Vehicle parking conditions • Lifestyle preferences • Attitudes • Technology awareness
Part 2 Mail & Web-Based	• Home recharge assessment • 3-Day driving diary • Buyers guide information booklet: Introduction to vehicle technologies, renewables and vehicle charging
Part 3 Web-Based	**Vehicle Preferences** Options for different vehicle types: • Discrete choice experiments • Design space exercises (higher and lower price options) **Green Elec. and Charging Preferences** Options for powering home and vehicle: • Discrete choice experiments • Design space exercises (higher and lower price options)
Interviews In-person	• Vehicle ownership history • Perspectives of PEVs, renewables and utility controlled charging • Lifestyles and interest

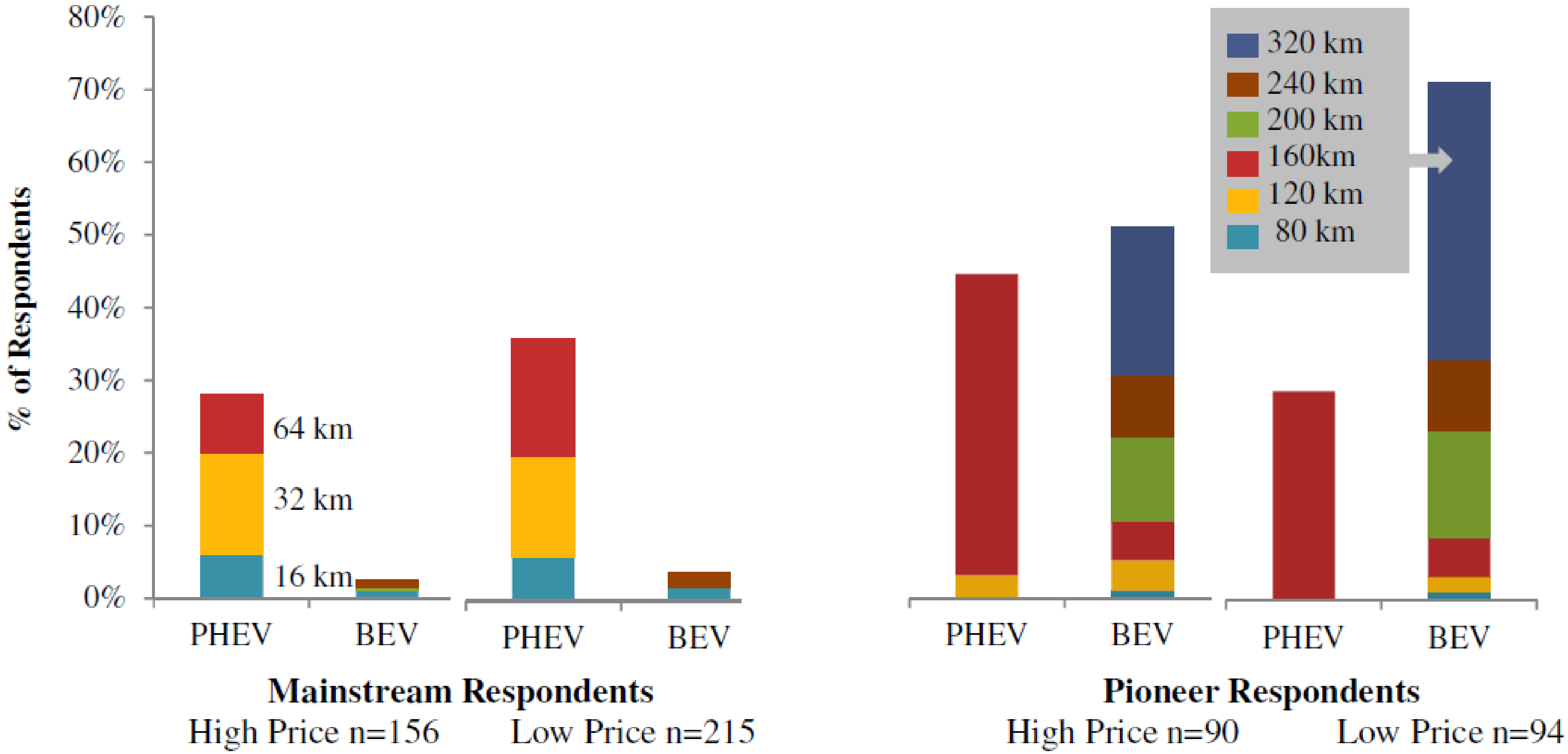
Source: Axsen et al. (2015), *Electrifying Vehicles*

“Design Space” Exercise

Click Here to open the example response that we provide earlier in a new window.

Vehicle type	Driving range	Gasoline fuel use	Refuel/ Home recharge time	Purchase price	I CHOOSE
		Gas		$	
A **conventional** RAM 1500 4X4 FFV	**750 km** gasoline	**15.2** L/100 km	5 mins	**$50000**	Conventional Please select ▼
A **hybrid** RAM 1500 4X4 FFV	**750 km** gasoline	**10.2** L/100 km	5 mins	**$51600**	Hybrid 1st Choice ▼
A **plug-in hybrid** RAM 1500 4X4 FFV	Electric for the first: Please select your answer ▼	**10.2** L/100 km	Time to fully charge empty battery at home Please select your answer ▼	**$0**	Plug-in hybrid Please select ▼
A **electric only** RAM 1500 4X4 FFV	Electric only for: Please select your answer ▼	None	Time to fully charge empty battery at home Please select your answer ▼	**$0**	Electric Please select ▼
A **hydrogen fuel cell** RAM 1500 4X4 FFV	**500 km** hydrogen	None	5 mins	**$61000**	Hydrogen 2nd Choice ▼

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



Source: Axsen, Goldberg and Bailey (2016), *Transportation Research Part D*

Stated choice experiment

Vehicle type	Range	Recharge/ refuel time	Destination recharging or refuelling access		Fuel cost	Purchase price & incentive	I CHOOSE
			Level 2	Fast or H_2 refuelling or	$	$	
Conventional Honda CIVIC	**650 km** gasoline	5 min.	–	–	**$32** /week	$25,000 - $0 **$25,000**	Conventional
Hybrid Honda CIVIC	**1070 km** gasoline	5 min.	–	–	**$20** /week	$26,380 - $0 **$26,380**	Hybrid
Plug-in hybrid Honda CIVIC	**575 km** First **72 km** electric	Home: **6 hrs.** Work: **–**	**25%** of destinations	–	**$18** /week	$30,180 - $5,000 **$25,180**	Plug-in Hybrid
Electric Only Honda CIVIC	**200 km** electric	Home: **6 hrs.** Work: **–**	**25%** of destinations	**None**	**$10** /week	$38,820 - $5,000 **$33,820**	Electric
Hydrogen fuel cell Honda CIVIC	**350 km** hydrogen	5 min.	–	**20%** of gas stations	**$10** /week	$41,230 - $0 **$41,230**	Hydrogen

Next

Click HERE to access the Vehicle Buyers' Guide

Latent-class choice model (LCM)

TABLE 5 Results for 5-Segment Latent Class Model (Canadian-wide sample, n=2124)

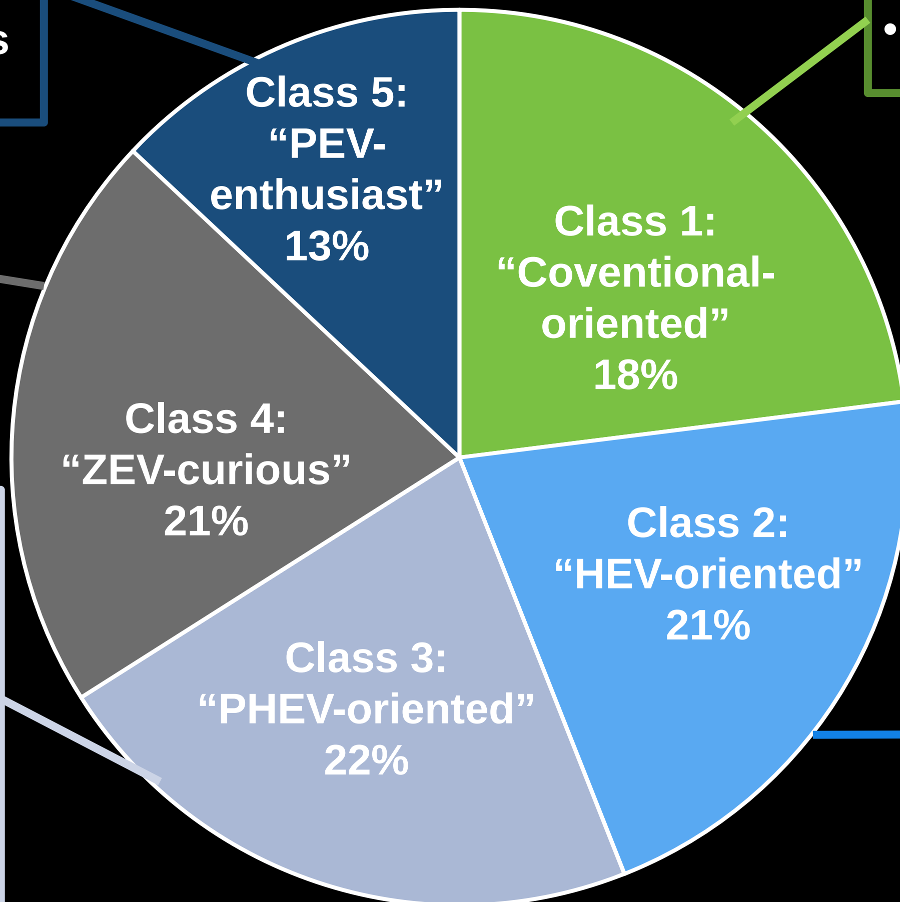
Segment name	CV-oriented		HEV-oriented		PHEV-oriented		ZEV-curious		PEV-enthusiast	
Percentage of respondents in segment	**23%**		**21%**		**22%**		**21%**		**13%**	
Latent Class Model										
Measure of vehicle interest (s)										
HEV	-2.87	***	1.48	*	1.30	***	0.653	*	1.07	*
PHEV	-4.92	***	-1.47	***	0.567	**	-0.603	**	2.63	*
BEV	-8.93	***	-5.32	***	-2.90	***	0.0782		1.89	*
HFCV	-4.94	***	-4.19	***	-2.39	***	0.0842		-1.11	
Measure of preferences (coefficients)										
PHEV range (km)	0.001450		-0.000832		0.00263		0.00350	*	0.000578	
BEV range (km)	0.00598		0.00513		0.00265		-0.00277	***	0.00101	
HFCV range (km)	0.000252		0.00227		0.00220	**	0.000335		0.00150	
Vehicle price (CAD$)	-0.000154	***	-0.000292	***	-0.000290	***	-0.000032	***	-0.000012	***
Fuel cost (CAD$/week)	-0.000225		-0.0133	***	-0.0160	***	0.000069		-0.000105	
Incentive value (CAD$)	0.000129	***	0.000133	*	0.000296	***	0.000079	*	0.000096	***
Home charging (Level 1 or 2)	-0.127		-0.249		0.650	***	-0.0172		-0.0422	
Workplace charging (Level 1 or 2)	-0.281		0.165		0.0519		0.117		0.188	
Public charging (% of destinations)	0.0120		0.00565		0.00260		0.00425		0.00194	
DC fast charging (access on major highways)	0.808		0.177		0.314	***	0.162		-0.240	
Hydrogen station availability (% of gas stations)	0.0171		0.0205		0.0156	**	0.00121		0.011	
Implied willingness-to-pay[a,b]										
Valuation of vehicle type ($ CAD)										
HEV (all else held constant)	$ (18,675)		$ 5,052		$ 4,476		$ 20,598		$ 87,981	
PHEV-60km (all else held constant)	$ (31,977)		$ (5,028)		$ 1,951		$ (12,396)		$ 215,907	
+ home charging					$ 4,188					
+ DC fast charging					$ 3,034					
BEV-220km (all else held constant)	$ (58,104)		$ (18,188)		$ (9,991)				$ 154,796	
+ home charging					$ (7,755)					
+ DC fast charging					$ (8,909)					
HFCV-500km (all else held constant)	$ (32,107)		$ (14,335)		$ (4,443)					
10% gas stations					$ (3,904)					
50% gas stations					$ (1,750)					
100% gas stations					$ 943					
Valuation of vehicle type ($ CAD)										
PHEV range (per km)							$ 110			
BEV range (per km)							$ (87)			
HFCV range (per km)					$ 8					
Fuel cost savings(per year)			$ 2,373		$ 2,876					
Incentive value (per $1000 incentive)	$ 838		$ 454		$ 1,019		$ 2,494		$ 7,897	
Home charging (of Level 1 or 2)					$ 2,237					
Workplace charging (of Level 1 or 2)										
Public charging (per % of destinations)										
DC fast charging (for access on major highways)					$ 1,082					
Hydrogen stations (per % of gas stations)					$ 54					

Segmenting respondents by PEV preference

- (+) HEV
- (++) PHEVs
- (+) BEVs and HEVs
- Not sensitive to attributes
- Enviro lifestyle

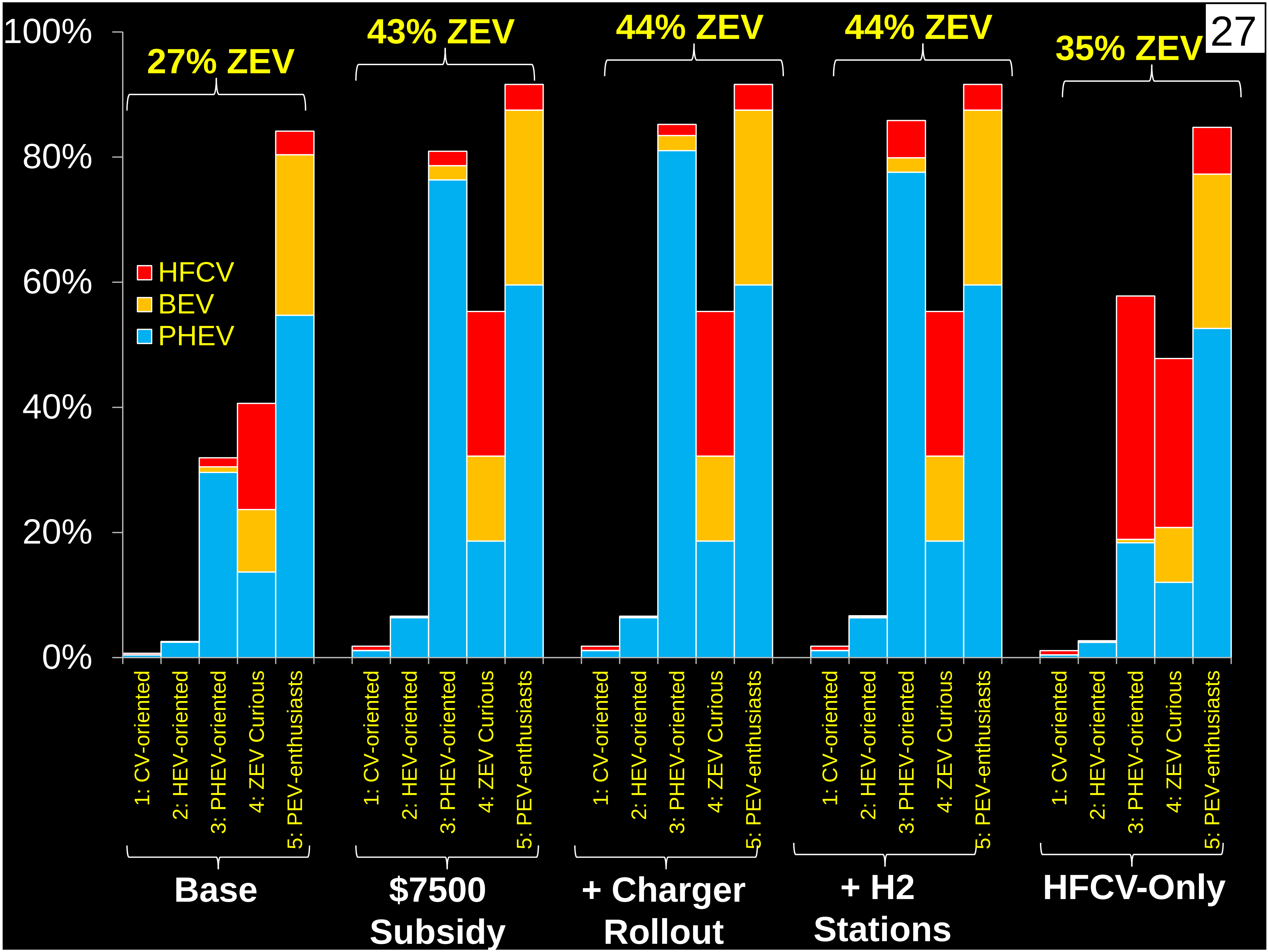
- (-) HEVs
- (-) BEVs

- (+) HEV
- (+/-) BEV
- Enviro lifestyle



- (+) HEVs
- (+) PHEVs
- (-) BEVs
- (+/-) HFCVs
- Fuel cost sensitive
- Sensitive to: fuel cost fuel/charge available
- Enviro concerned

- (+) HEVs
- (-) BEVs
- Fuel cost sensitive
- Enviro concerned


100%
80%
60%
40%
20%
0%
27% ZEV
43% ZEV
44% ZEV
44% ZEV
35% ZEV
HFCV
BEV
PHEV
1: CV-oriented
2: HEV-oriented
3: PHEV-oriented
4: ZEV Curious
5: PEV-enthusiasts
Base
$7500 Subsidy
+ Charger Rollout
+ H2 Stations
HFCV-Only

5) From surveys to models

"Qualitative" interviews
n = dozens

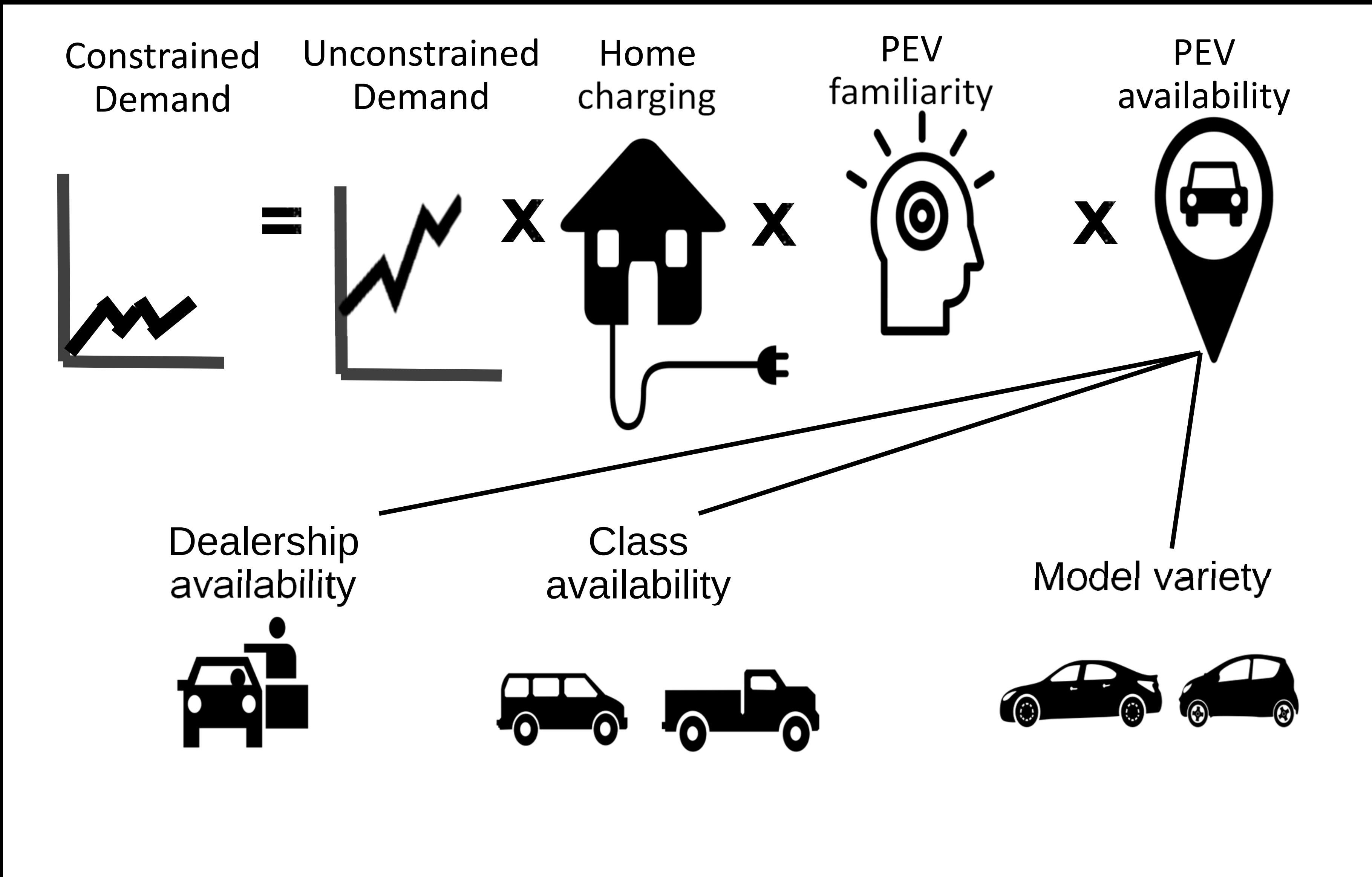
"Quantitative" surveys
n = 100s or 1000s

Technology adoption models
(0-15 year time horizon)

Energy-economy system models
(20-40yr + time horizon)

"Respondent-based modeling"

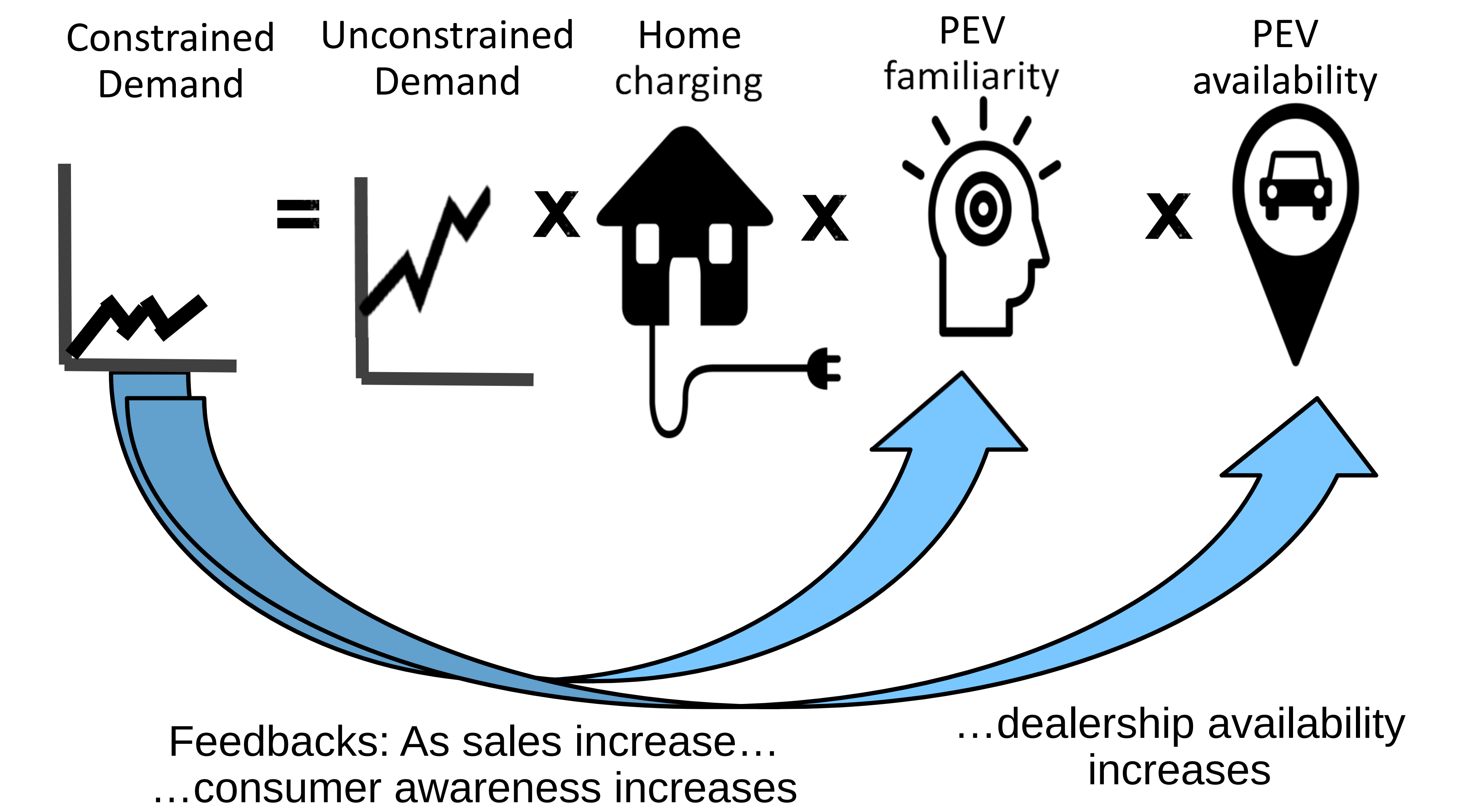
The respondent-based preference and constraint model (REPAC)



Thanks Amy Miele

Source: Wolinetz & Axsen (2017), *Technological Forecasting & Social Change*

The respondent-based preference and constraint model (REPAC)



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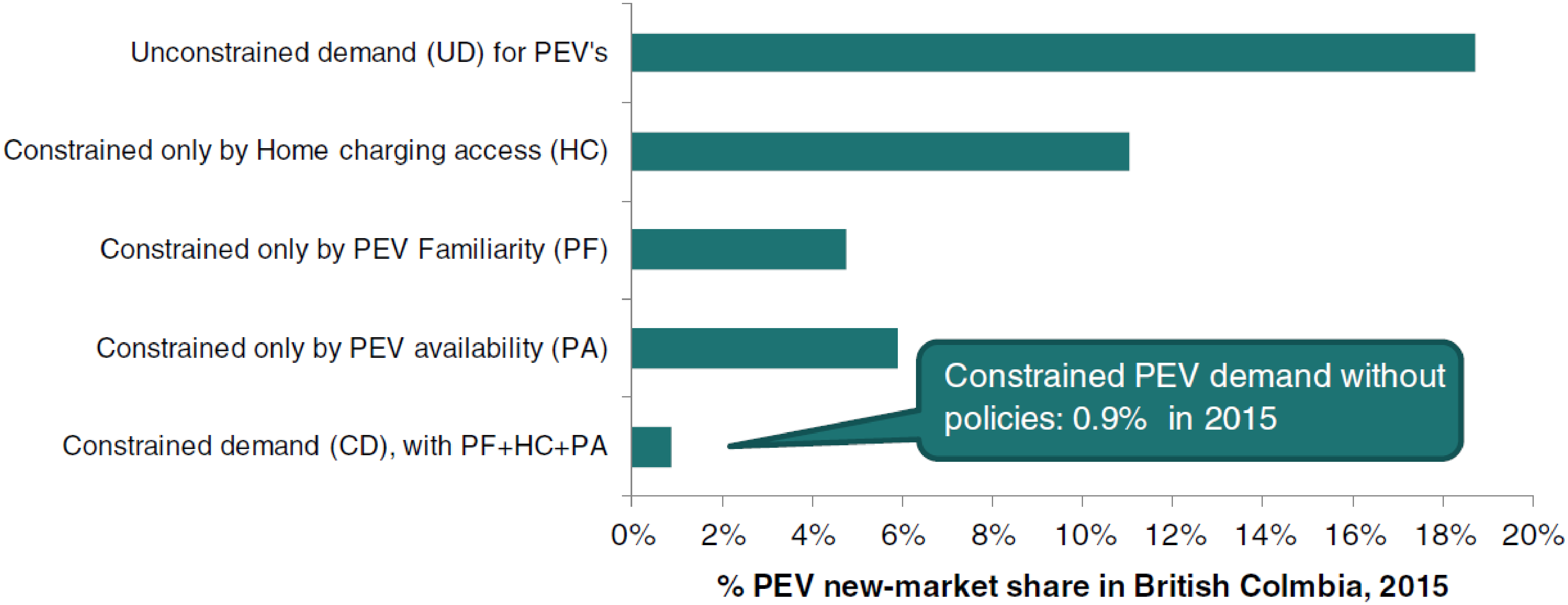
Source: Wolinetz & Axsen (2017), *Technological Forecasting & Social Change*

Latent demand and barriers to PEV sales



Source: Wolinetz & Axsen (2017), *Technological Forecasting & Social Change*

Comparing PEV policies

Demand-focused policy

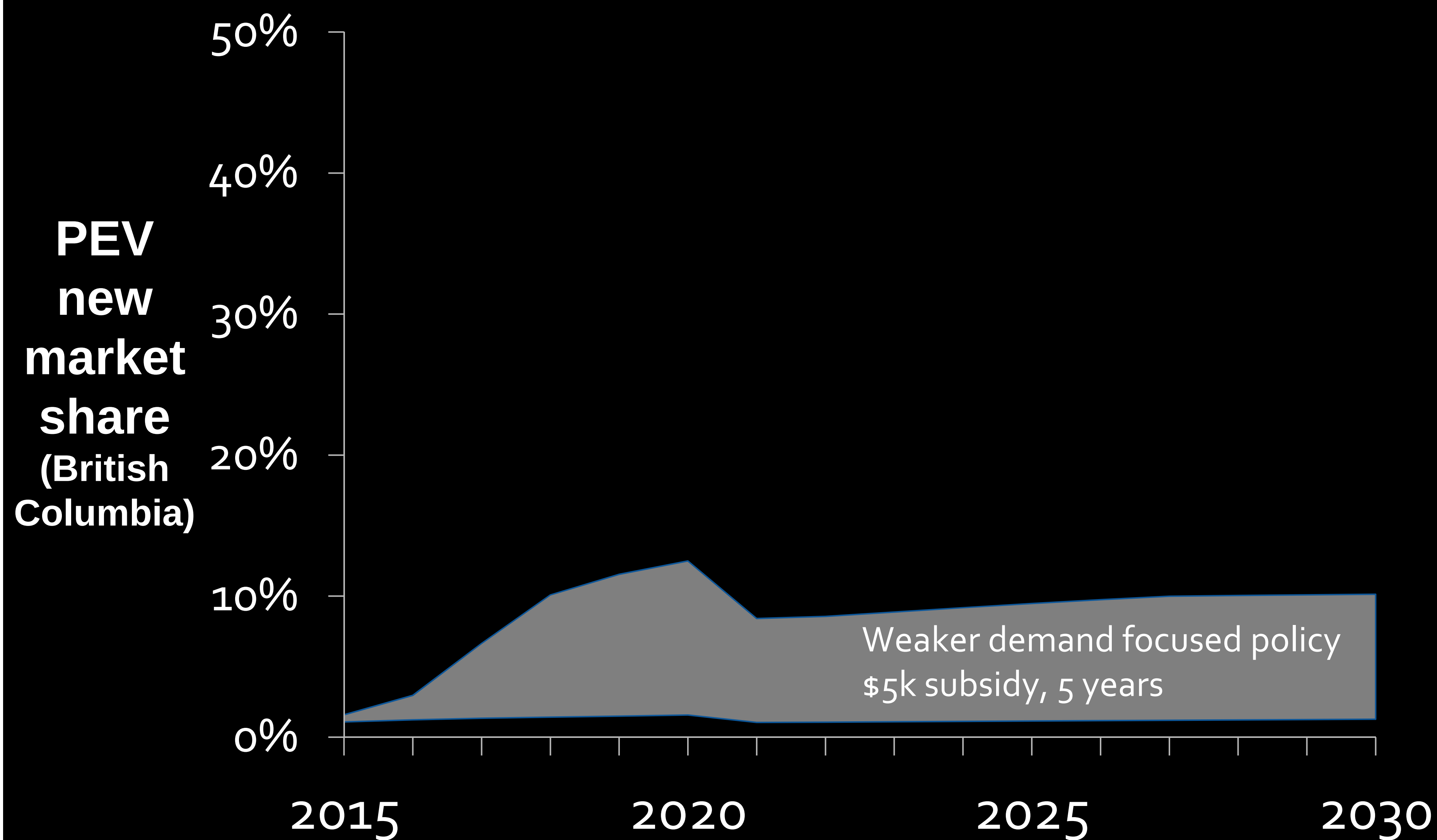
- Purchase incentives
- Non-monetary incentives (HOV lane, etc.)
- Charger deployment

Supply-focused policy

- ZEV mandate (sale requirements)
- Fuel efficiency standards
- Low-carbon fuel standards

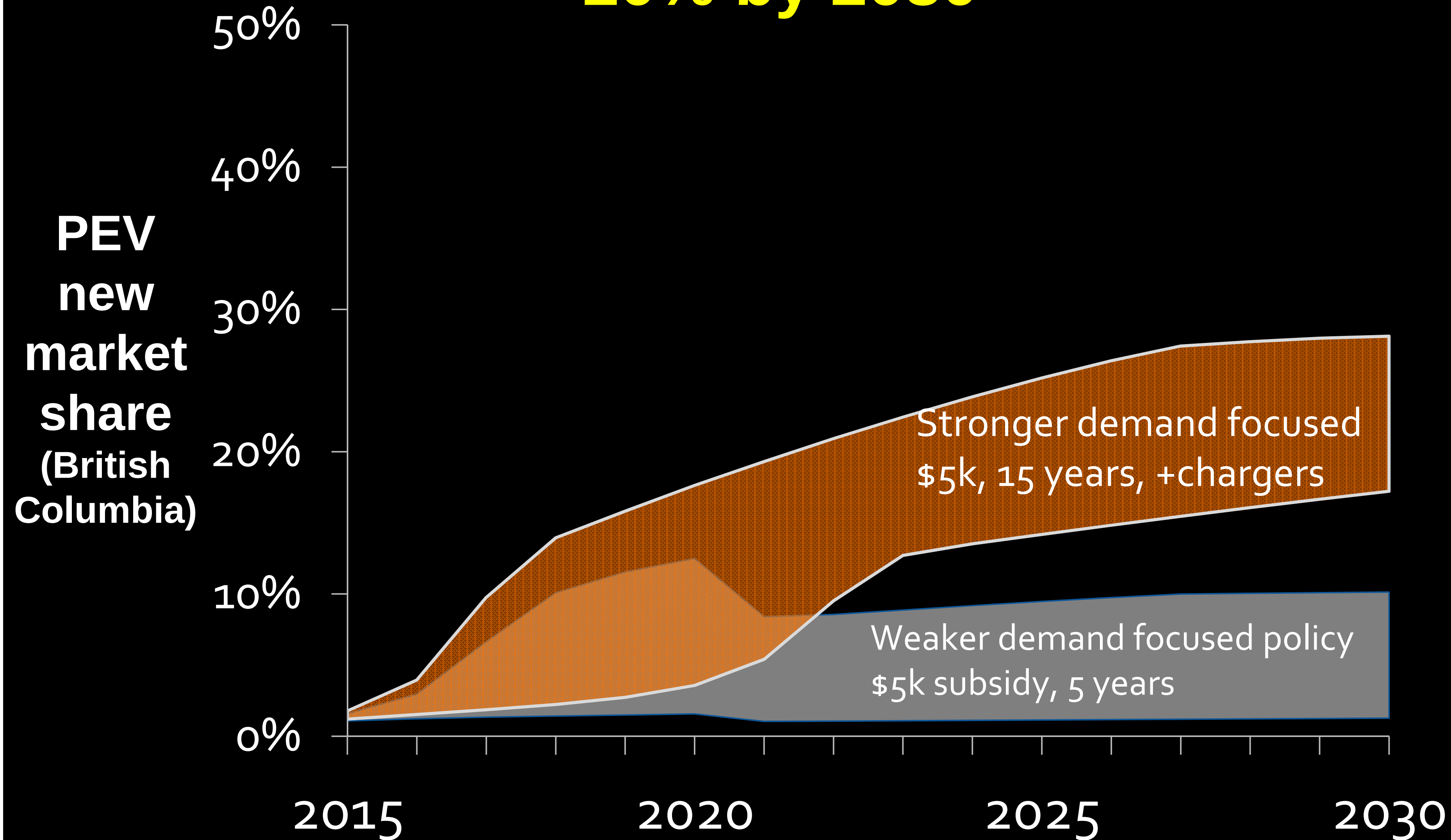
Adapted from: Axsen et al. (2017), *Energy Policy*

"Weaker" demand-focused policies might get us to 1% to 10% new market share…



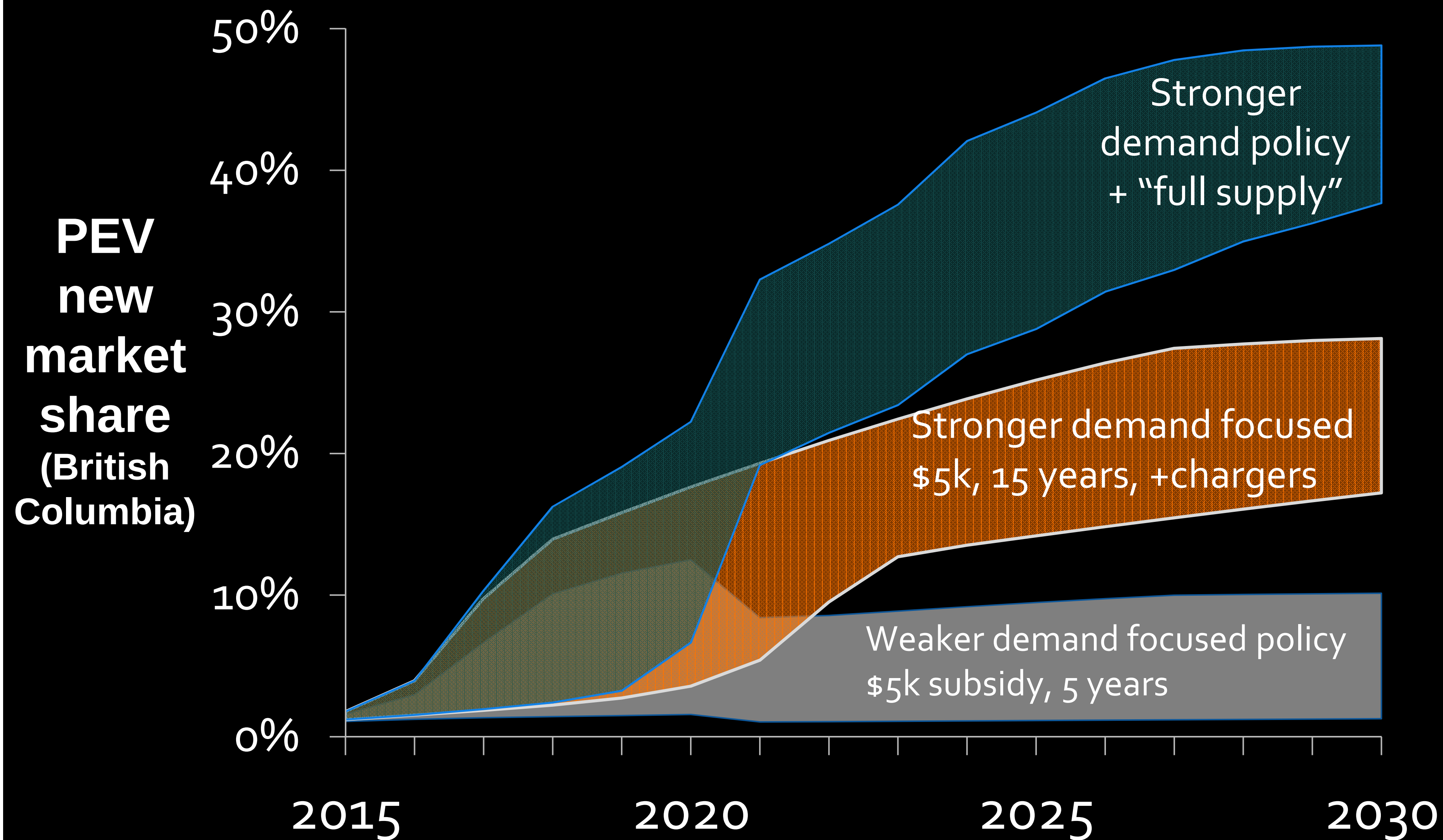
Source: Wolinetz & Axsen (2017), *Technological Forecasting & Social Change*

Continuing aggressive incentives and charger deployment could get up to ~20% by 2030



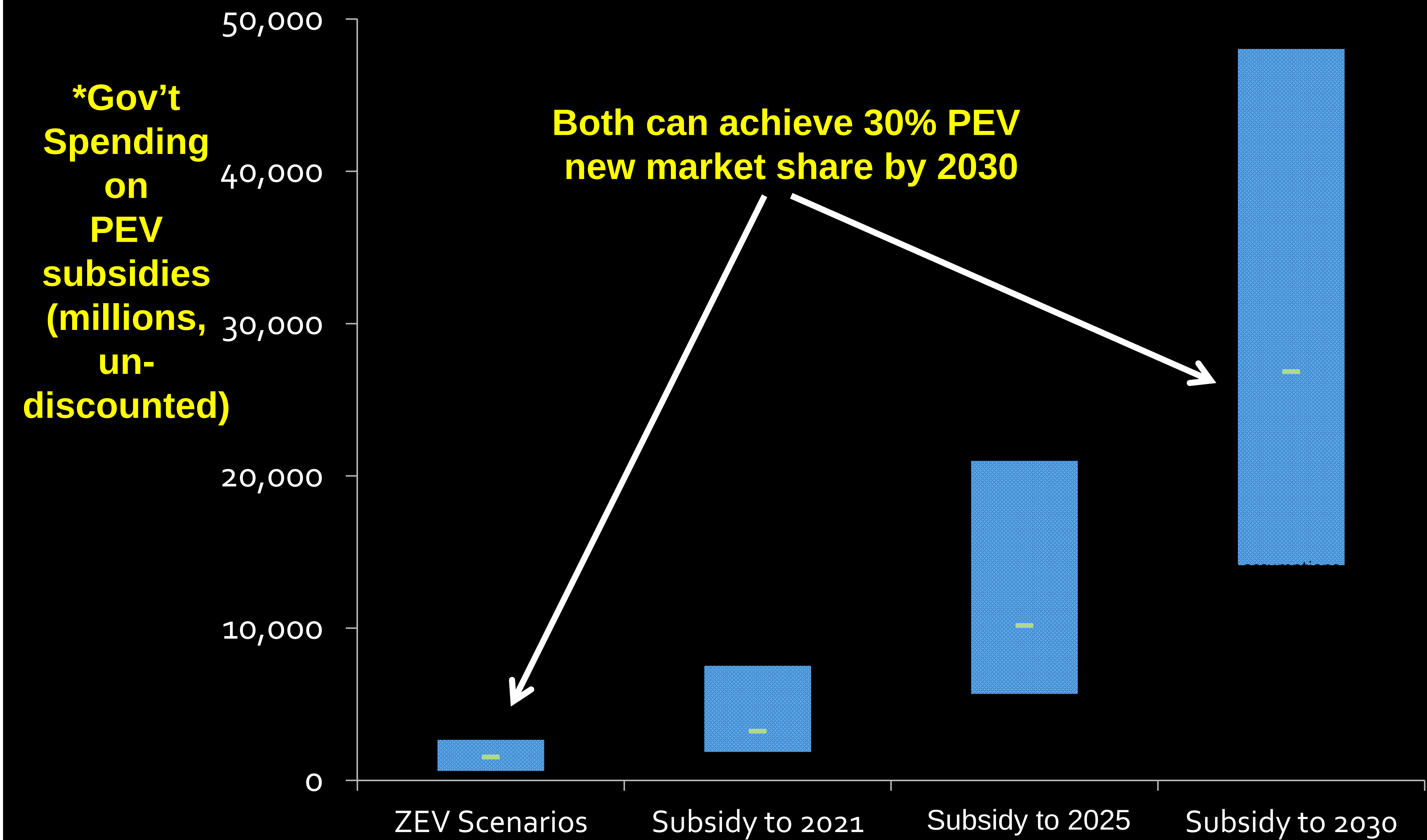
Source: Wolinetz & Axsen (2017), *Technological Forecasting & Social Change*

“Full” PEV supply needed to get up to 30% or higher



Source: Wolinetz & Axsen (2017), *Technological Forecasting & Social Change*

Multiple ways to push electric vehicles, but subsidies cost* 20-30 times more than ZEV mandate



Source: Axsen and Wolinetz (Under review), *Energy Policy*

6) From research to policy evaluation

"Qualitative" interviews
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Technology adoption models
(0-15 year time horizon)

Energy-economy system models
(20-40yr + time horizon)

Policy evaluation

Canada's Electric Vehicle Policy Report Card

Dr. Jonn Axsen
Suzanne Goldberg
Noel Melton

Sustainable Transportation Action Research Team
Simon Fraser University
November 2016

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

Evaluating plug-in electric vehicle policies in the context of long-term greenhouse gas reduction goals: Comparing 10 Canadian provinces using the "PEV policy report card"

Noel Melton[a,b,*], Jonn Axsen[b], Suzanne Goldberg[b]

METCALF FOUNDATION

Social Sciences and Humanities Research Council of Canada

Conseil de recherches en sciences humaines du Canada

Canada

Policy Goal:

To achieve long-term GHG mitigation targets, PEVs reach 40% of new vehicle market share by 2040 (IEA scenario) – that is an "A"

1

Identify electric vehicle supportive policies

2

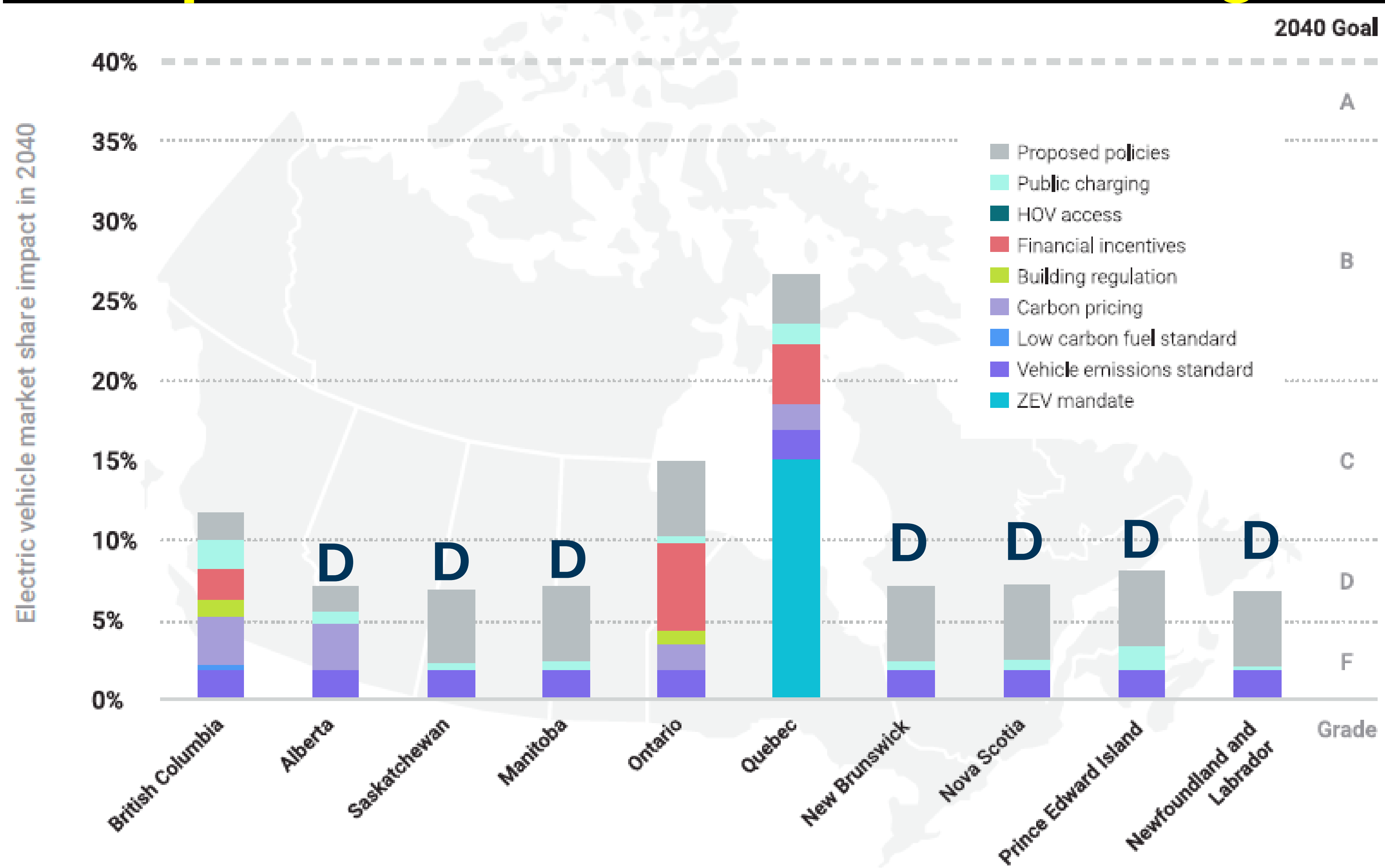
Evaluate the effectiveness of each policy

3

Assign letter grades to each province (based on the effectiveness of their policies)

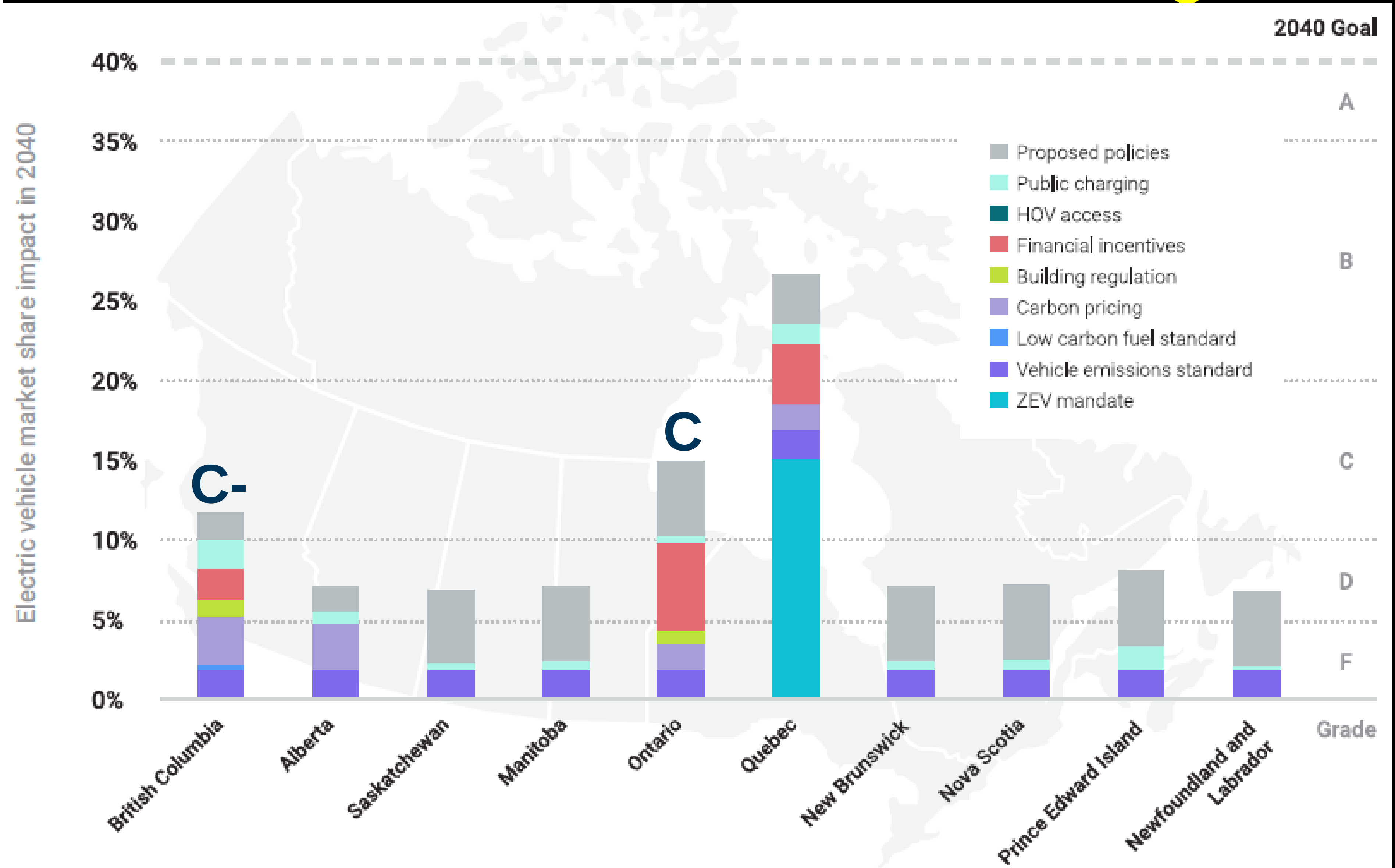
Adapted from: Axsen et al. (2017), *Energy Policy*

Grades across Canada….
7 provinces in the "D" or "F" range



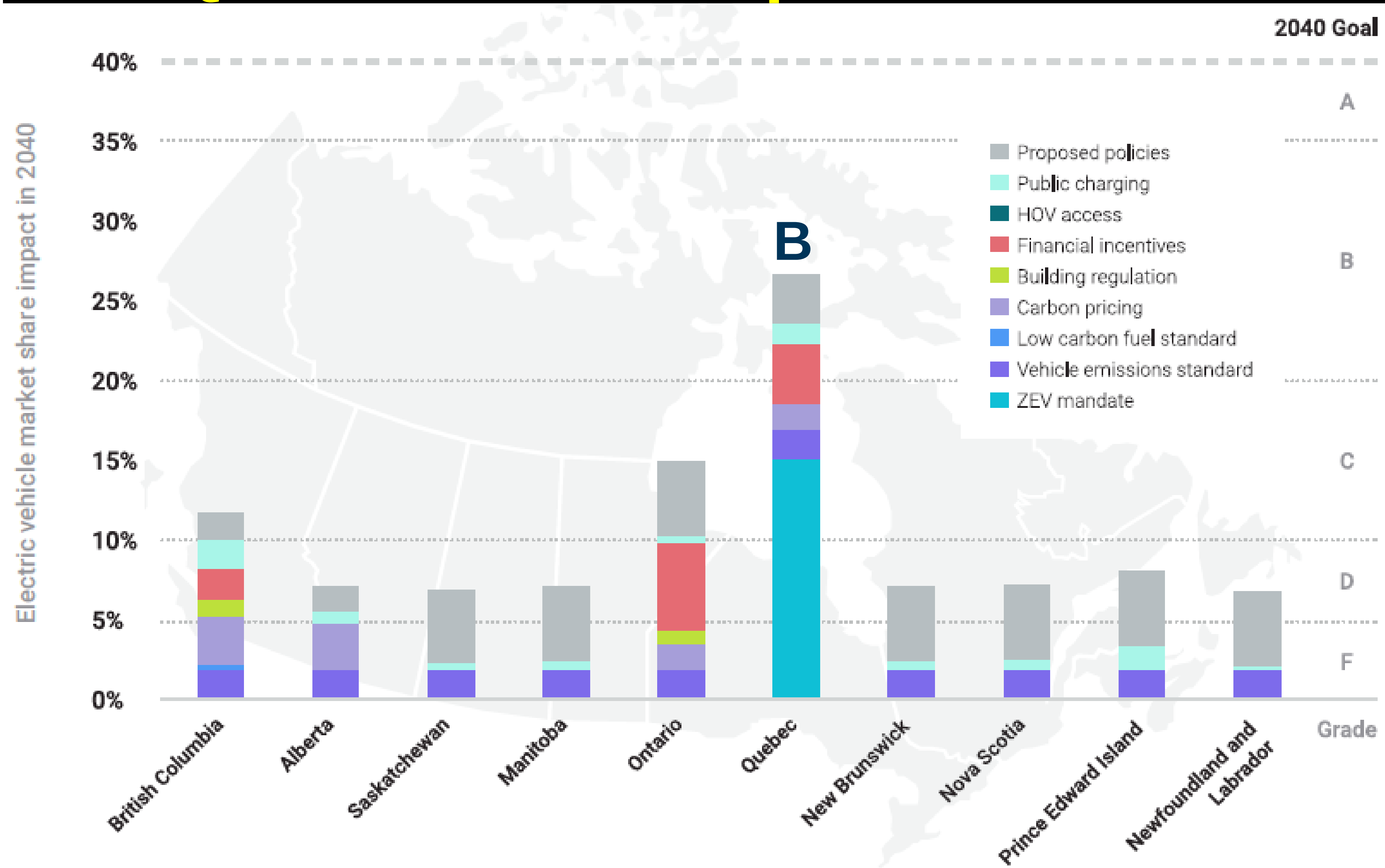
Adapted from: Axsen et al. (2017), *Energy Policy*

Grades across Canada….
Ontario and BC in the "C" range



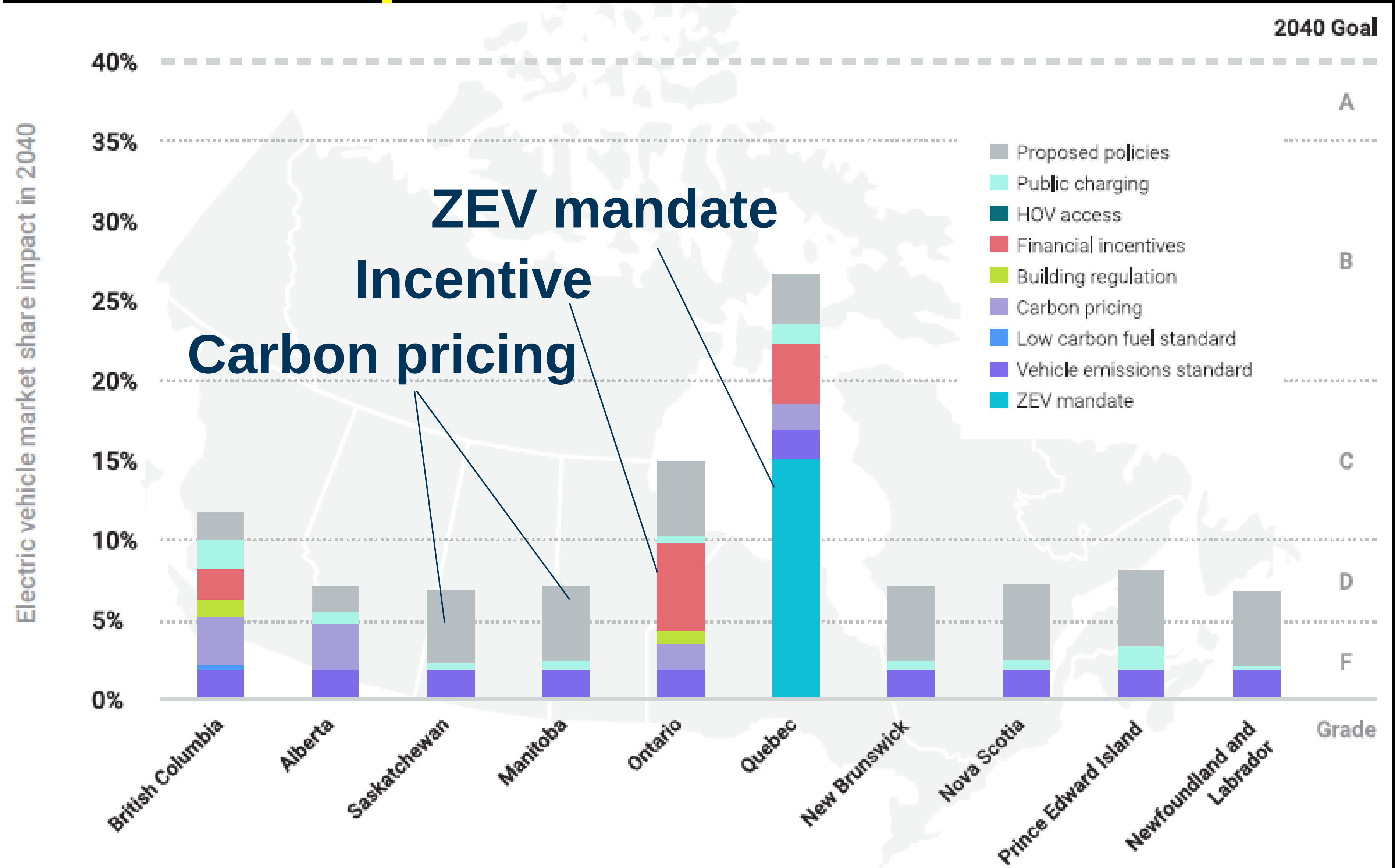
Adapted from: Axsen et al. (2017), *Energy Policy*

Grades across Canada….
Quebec is our inspiration at "B"



Adapted from: Axsen et al. (2017), *Energy Policy*

What are the most effectives climate policies in Canada?

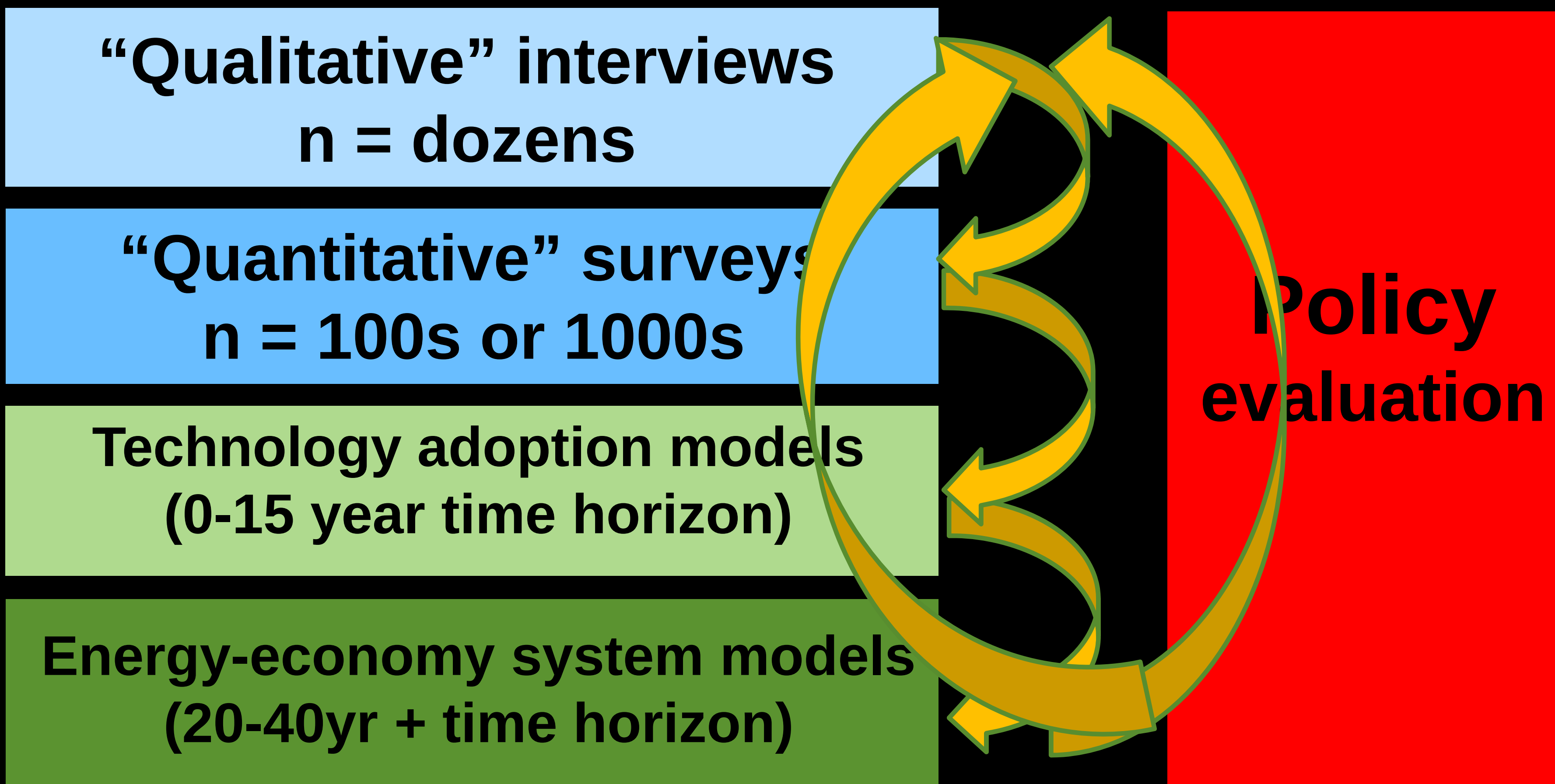


Adapted from: Axsen et al. (2017), *Energy Policy*

World-leading policy can raise all grades

Province	Current policies*	Current + proposed*	Current + proposed* + “Norway-like”	Current + proposed* + “California-like”
Canada	C−	C	B+	B+
British Columbia	C−	C−	B	B+
Alberta	D	D	B	B+
Saskatchewan	F	D	B	B+
Manitoba	F	D	B	B+
Ontario	C−	C	B	B+
Quebec	B−	B	A	B+
New Brunswick	F	D	B	B+
Nova Scotia	F	D	B	B+
Prince Edward Island	F	D	B	B+
Newfoundland and Labrador	F	D	B	B+

Methodological conclusions…



Missing methods? historical case studies, stakeholder interviews, random experiments

Policy implications

- PEVs can play an important role in GHG mitigation
- “Latent” demand is there – but widespread uptake isn’t likely to happen without policy
- Strongly policy needed, likely supply-focused (e.g. ZEV mandate)
- Need improved understanding of supply side
- Other methods, theories