International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

science for global insight

Improving the behavioral realism of global integrated assessment models: assessing the impact on electric vehicle deployment

iTEM3 Workshop

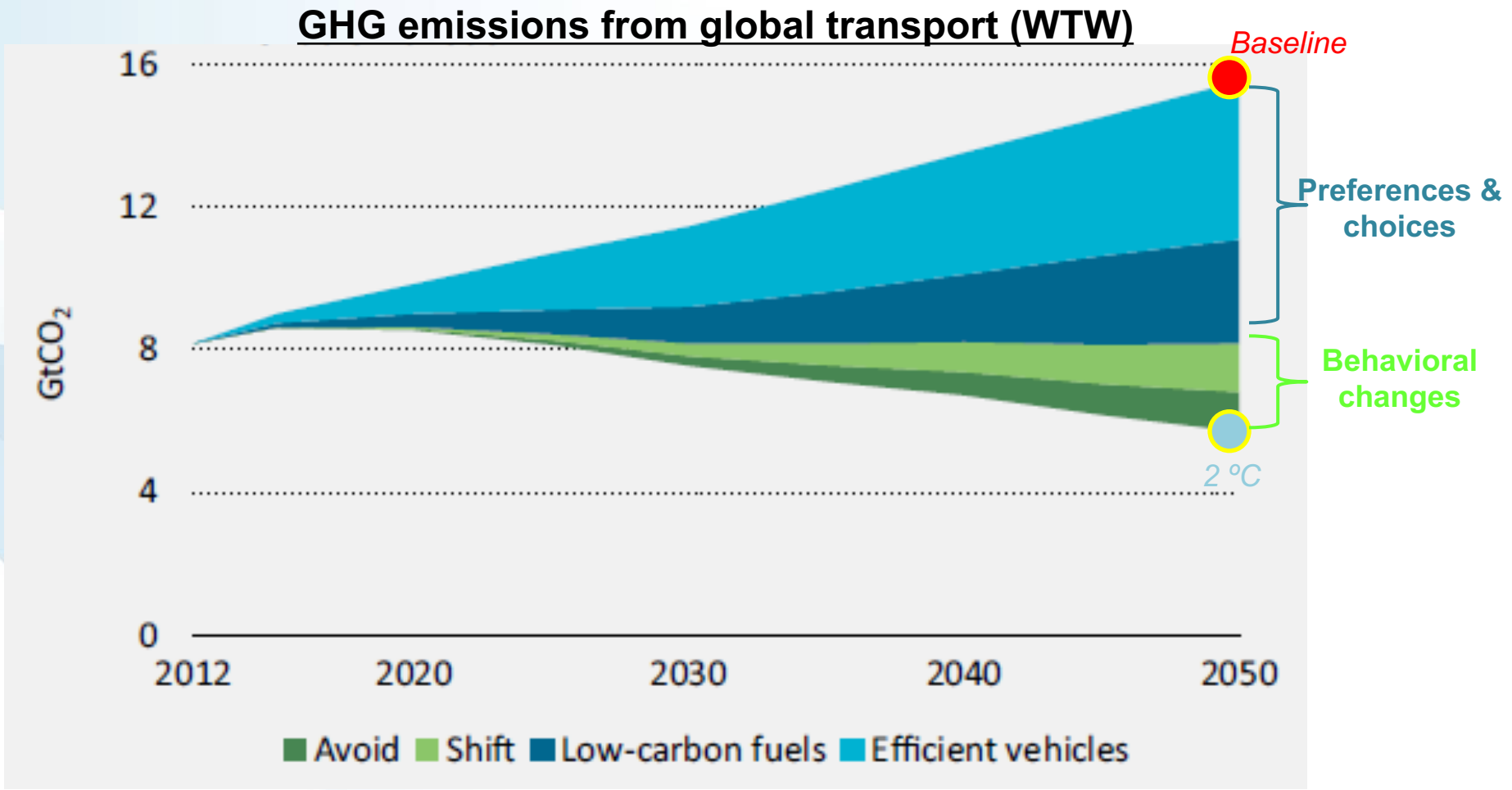
OECD (Paris, France)

October 26-27, 2017

David McCollum

(…along with many others at IIASA, UEA, FEEM, PBL, UCL, ICCS, CIRED, UC-Davis, ORNL, …)

There's more to modeling transport "behavior" than just mode choice or where people decide to live/work/shop/play



Source: IEA Energy Technology Perspectives 2015 (Fig. 1.15)

Ambitious targets for electric-drive vehicles have been announced

- Governments across the world have set ambitious targets for EDVs. (Collectively, by 2025, sales of ~7 million per year, or ~30 million cumulative stock)
- Automakers also have big plans. (e.g., VW Group has pledged that BEVs will comprise 20-25% of its annual sales by 2025; 2-3 million per year.)
- A consortium of companies, governments, and other organizations announced at the 2015 United Nations Climate Change Conference (COP 21) the "Paris Declaration on Electro-Mobility and Climate Change and Call to Action".

Paris Declaration on Electro-Mobility and Climate Change

& Call to Action

Lima – Paris Action Agenda

Transport contributes almost one-quarter (23 percent) of the current global energy-related greenhouse gas (GHG) emissions and is growing faster than any other energy end-use sector. GHG emissions from transport are anticipated to rise from today's levels by nearly 20 percent by 2030 and close to 50 percent by year 2050 unless major action is undertaken.

Limiting the global temperature increase to below 2 degrees Celsius requires changing this transport emissions trajectory, which involves the development of an integrated electro-mobility ecosystem encompassing various transport modes, coupled with the low-carbon production of electricity and hydrogen, implemented in conjunction with broader sustainable transport principles.

Source: http://newsroom.unfccc.int/media/521376/paris-electro-mobility-declaration.pdf

Stated targets:

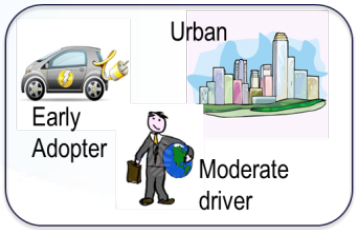
- 100 million electric-drive LDVs by 2030 (*~2 million today*)
- 400 million electric-drive 2/3-wheelers by 2030 (*~250 million today*)

Vehicle choices depend on more than just techno-economic considerations

- Technology adoption decisions (e.g., vehicle choices) are influenced by BOTH *financial* AND *non-financial* considerations.

- *Financial attributes*: upfront (capital) costs and expectations about future operating and fuel costs (affected by fuel efficiency)
  - Pretty well understood and nearly always included in energy-economy / systems models.
- *Non-financial attributes*: available models and brands, perceived risks, comfort, vehicle range and refueling/recharging station availability
  - Less well understood. Sometimes included in vehicle choice models (discrete choice or agent-based), but very rarely in energy-economy / systems models.

- Consumer preferences for these financial and non-financial attributes are very heterogeneous (within and across societies).



International Research Team

International Institute for Applied Systems Analysis

IIASA

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Univ. of East Anglia (C. Wilson, H. Pettifor)

UCDAVIS

UNIVERSITY OF CALIFORNIA

(K. Ramea, S. Yeh, D. Bunch, C. Yang)

OAK RIDGE National Laboratory

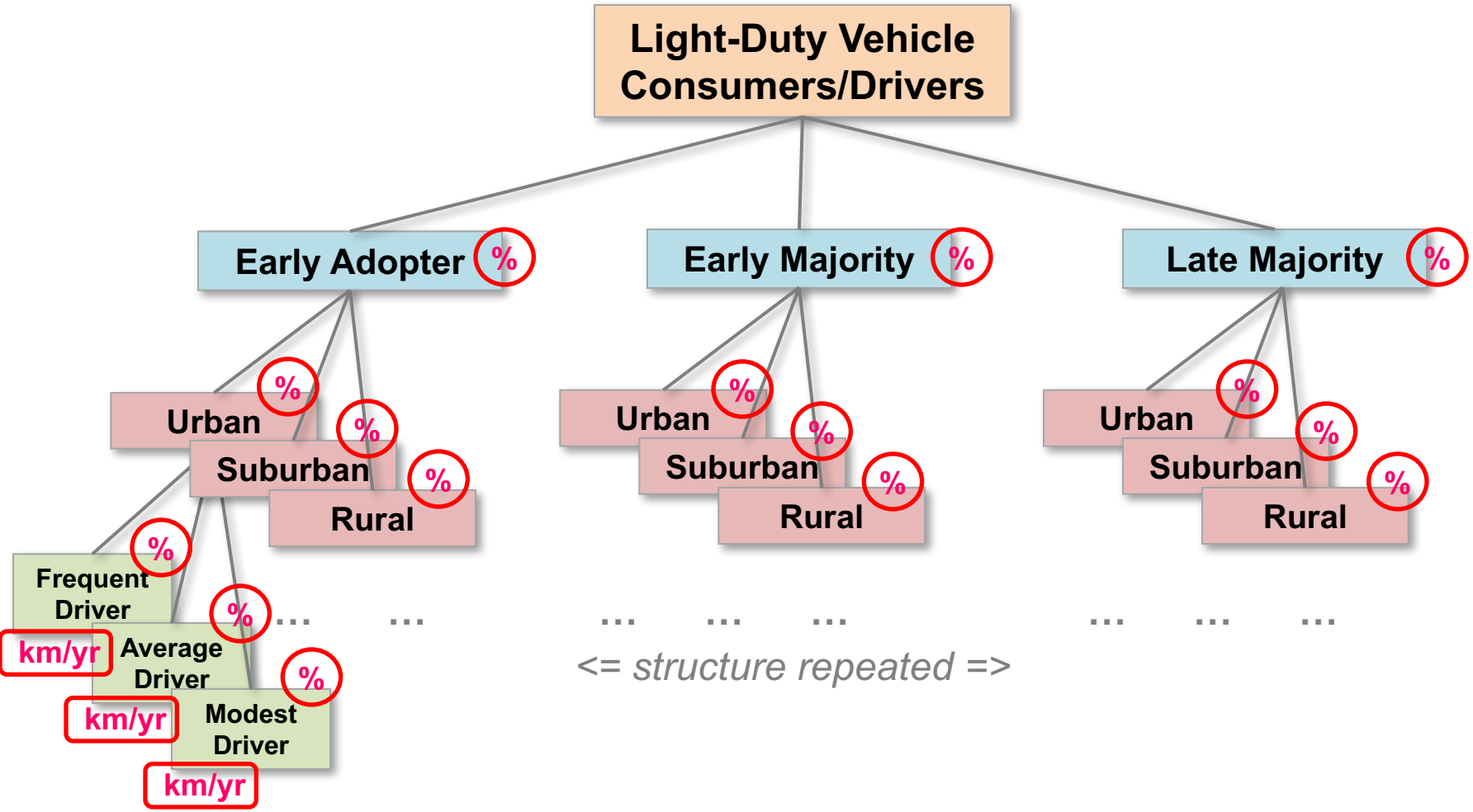
(Z. Lin, D. Greene)

Modeling approach (two-stage)

1. **Disaggregate IAM transport module so that the LDV market is comprised of a heterogeneous set of consumers**

2. **Monetize non-financial vehicle purchase considerations by bringing "intangible costs" ("(dis)utilities") from a vehicle choice model into the IAM**

Disaggregation of LDV market

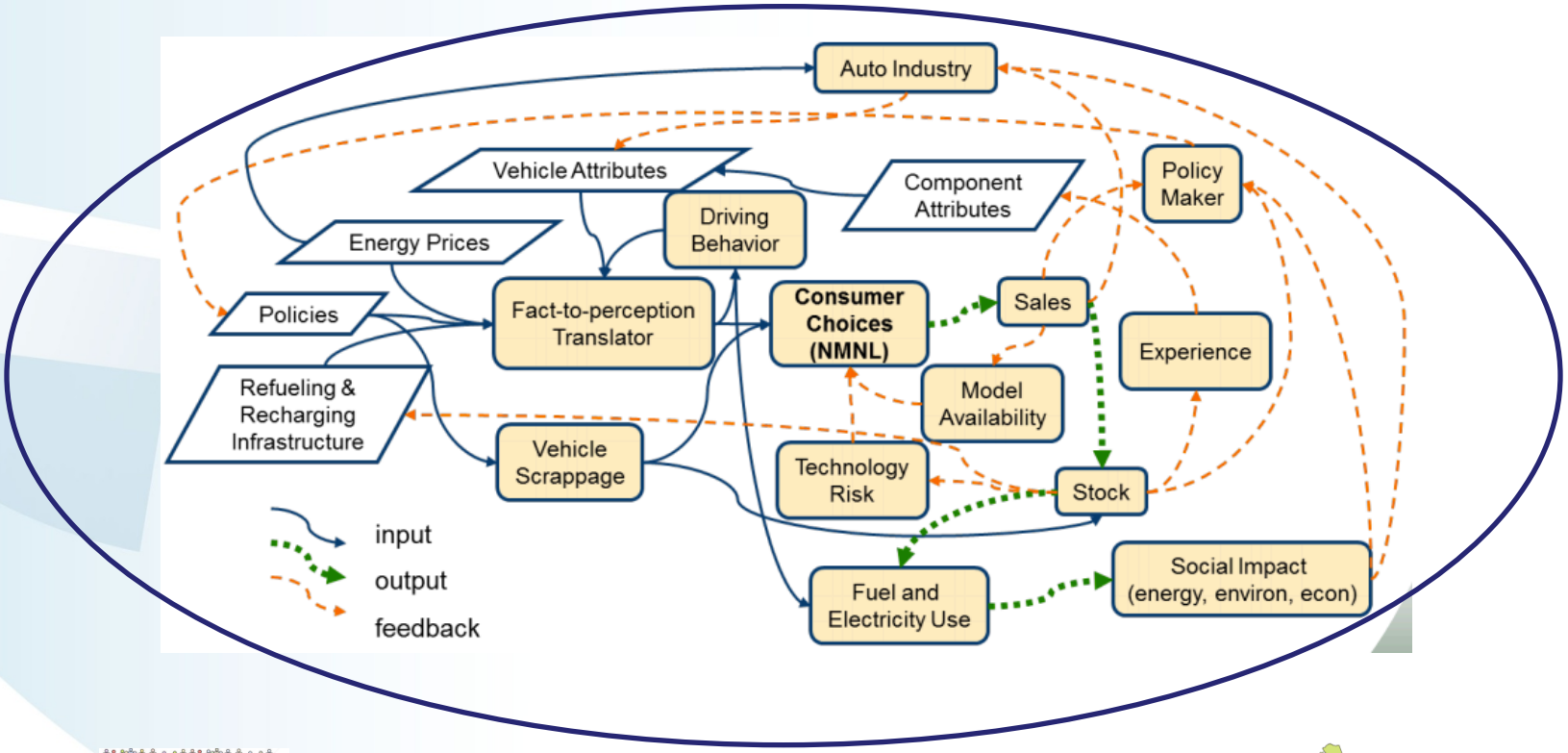


27 consumer groups in total
(= 3 x 3 x 3)

Calculate intangible costs using the MA^{3}T vehicle choice model

MA^{3}T (Market Acceptance of Advanced Automotive Technologies)

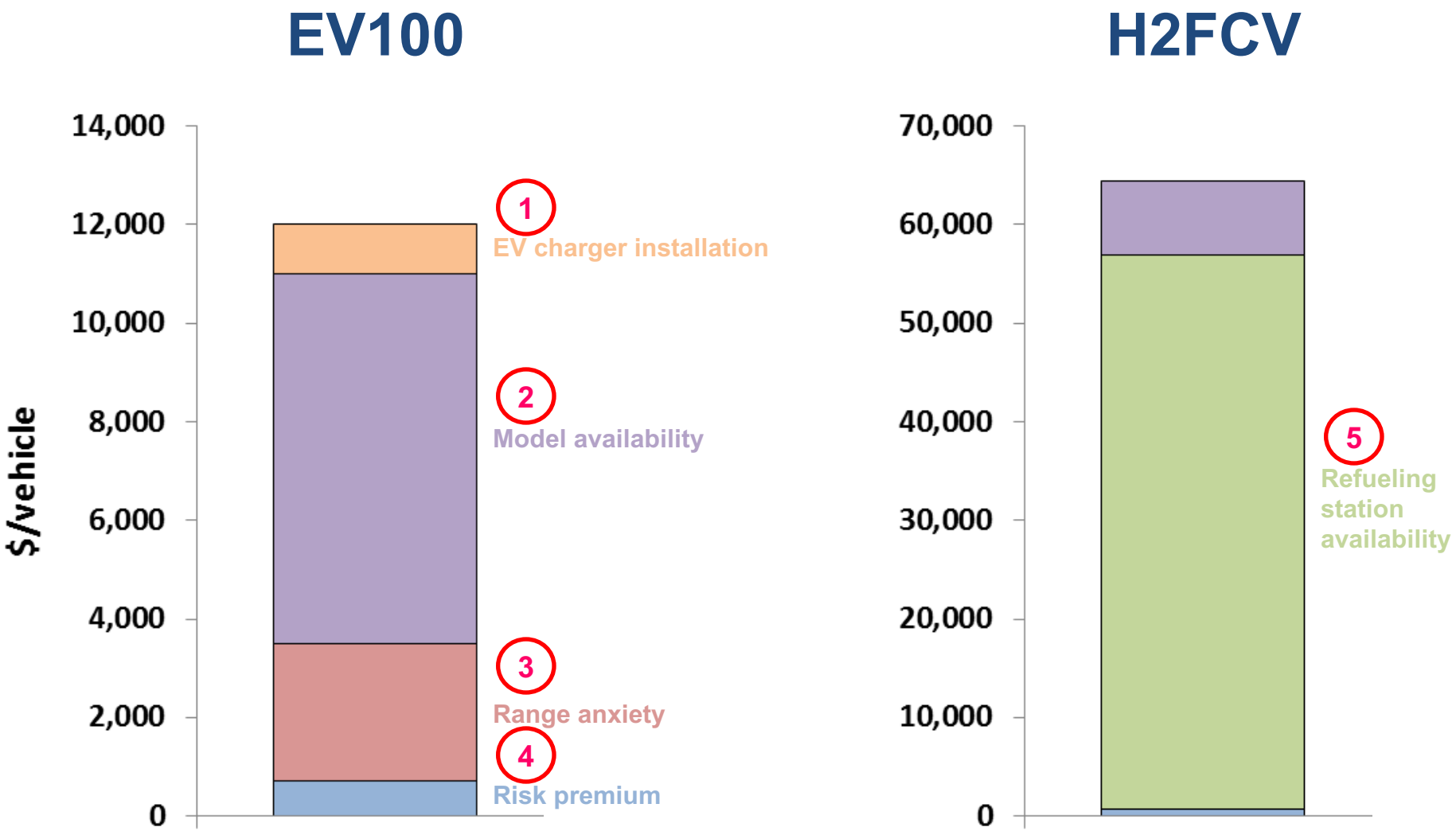
a scenario analysis tool for estimating market shares, social benefits and costs during LDV powertrain transitions, as resulting from technology, infrastructure, behavior, and policies



OAK RIDGE National Laboratory

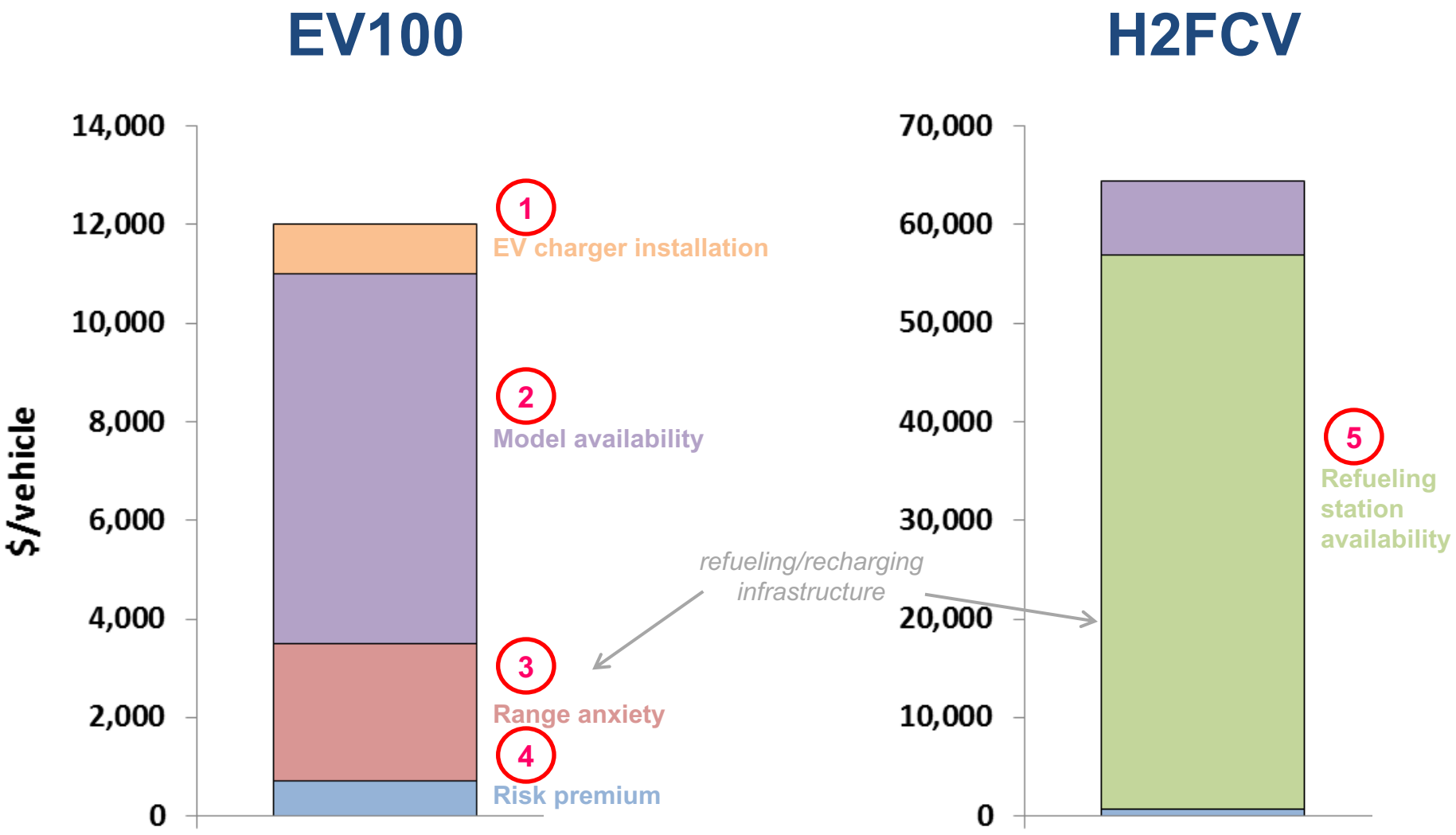
Source: ORNL & K. Ramea (UC-Davis)

Breakdown of intangible costs into non-financial attributes



Region: NORTH_AM; Year: 2030; Group: UREMA

Breakdown of intangible costs into non-financial attributes



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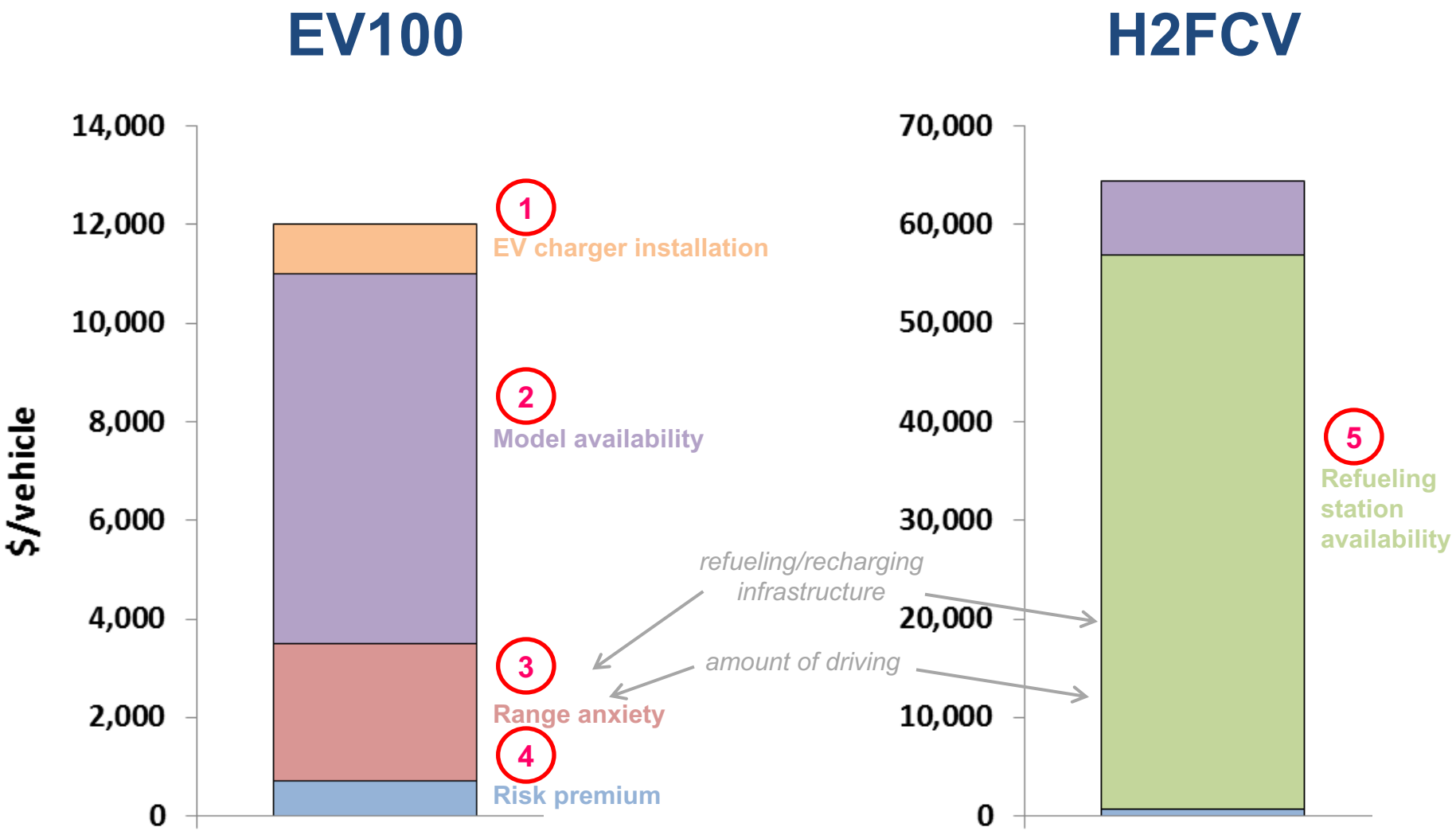

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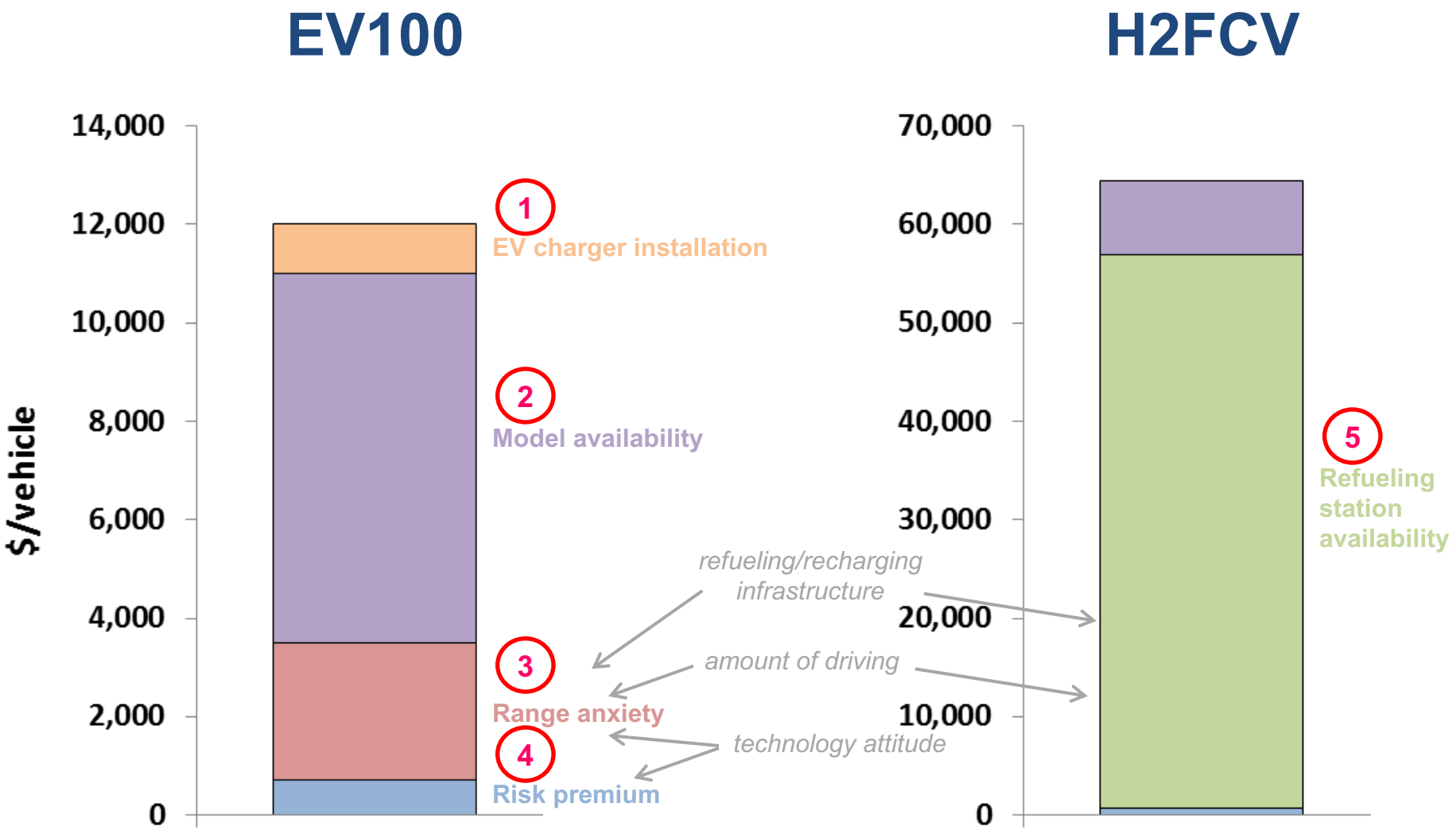

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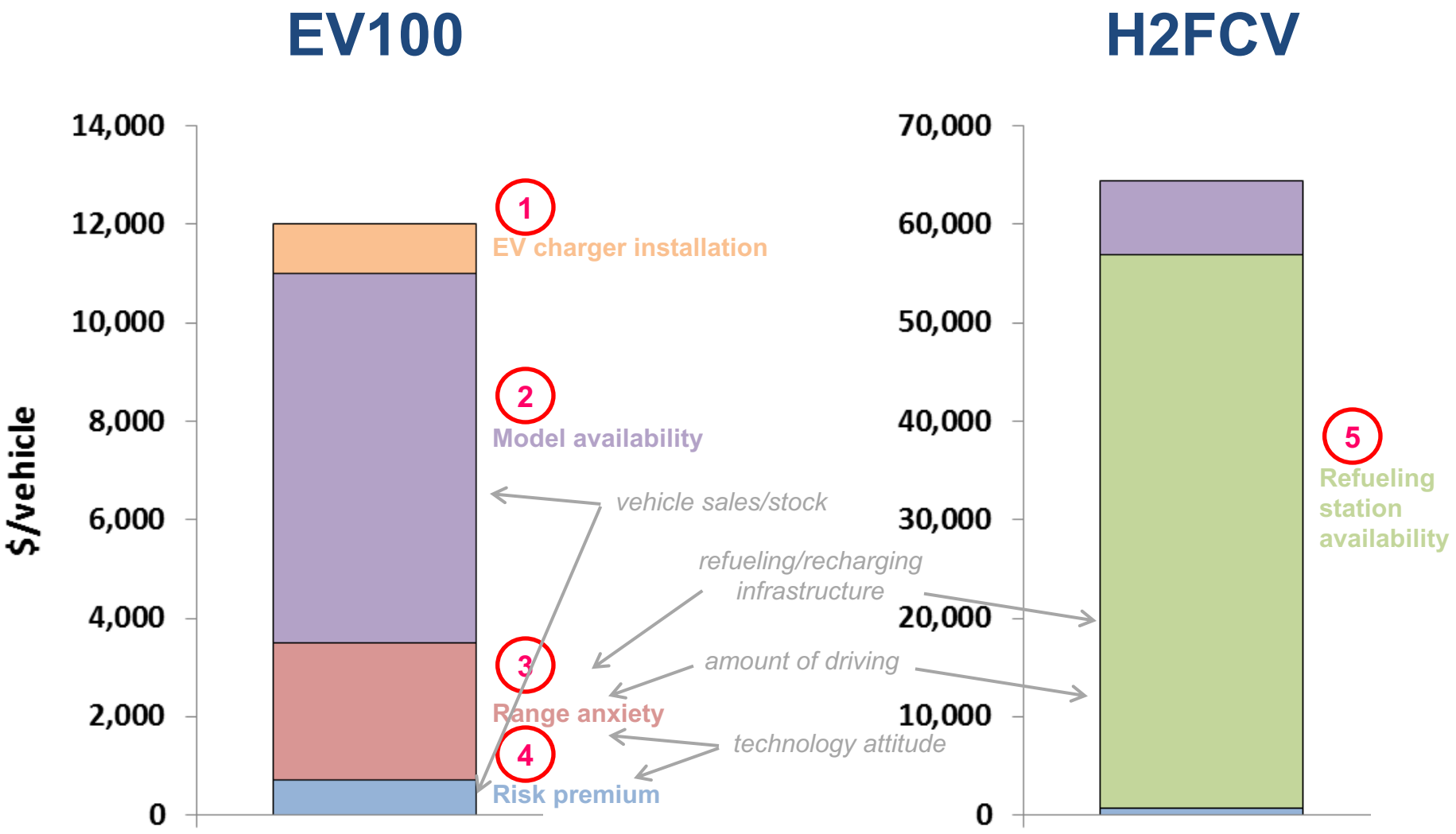
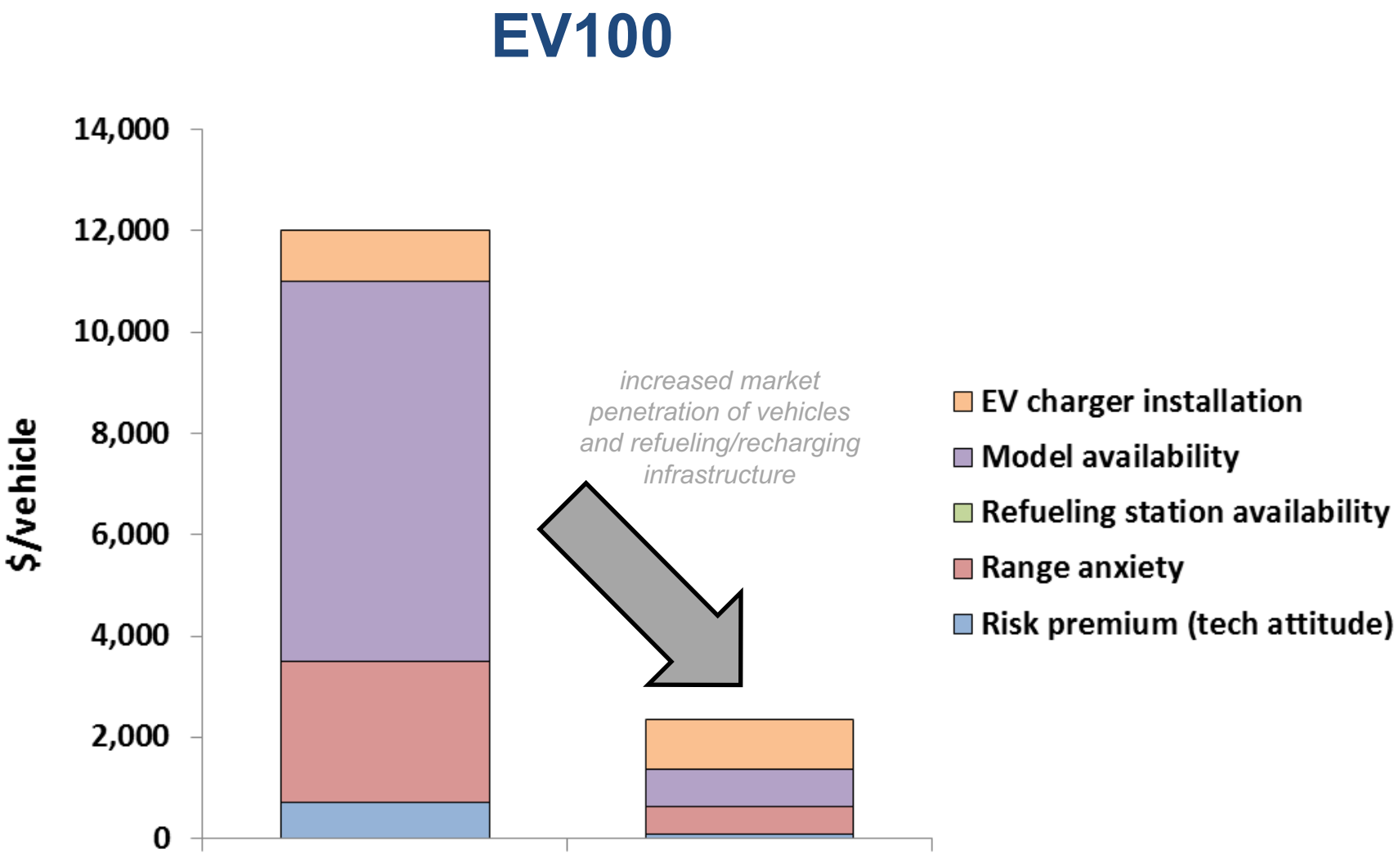


Region: NORTH_AM; Year: 2030; Group: UREMA

Intangible costs may come down over time



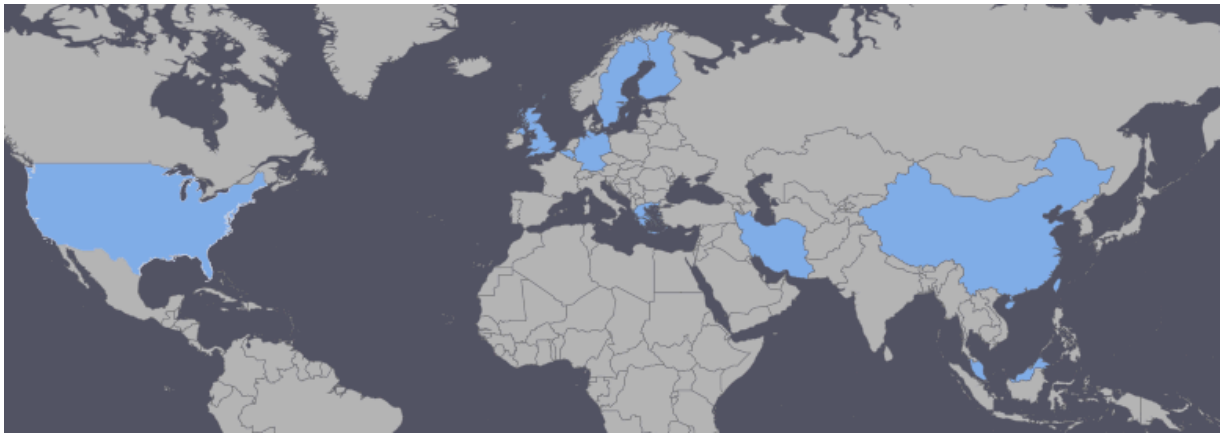
Region: NORTH_AM; Year: 2030; Group: UREMA

Calculation of regional multipliers to translate MA^{3}T numbers for US to other countries

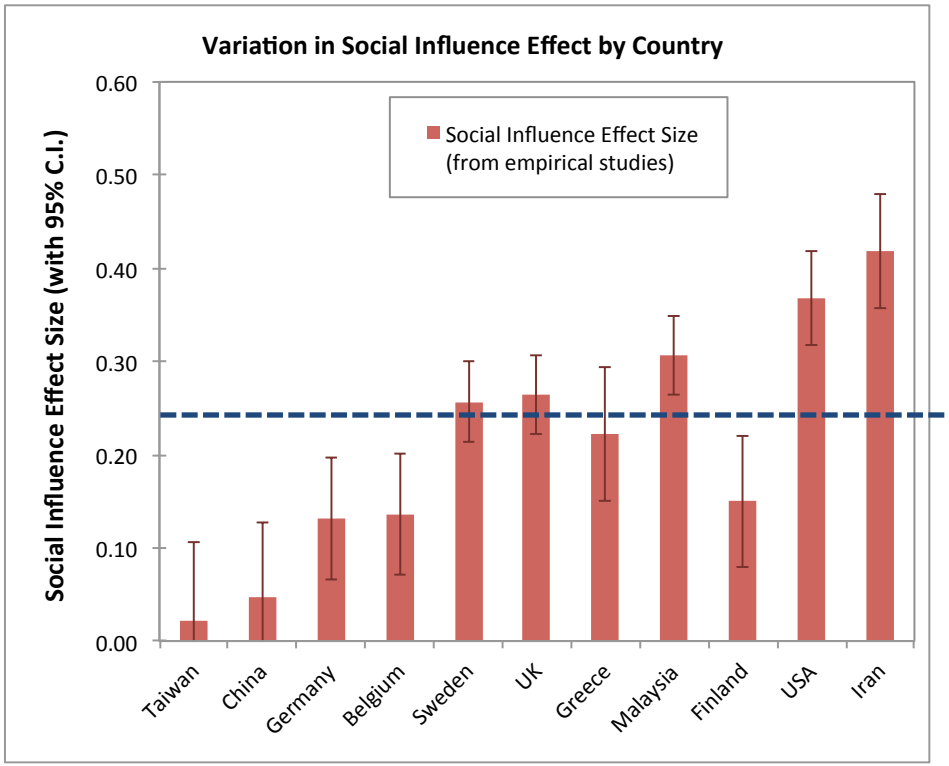
1. Range anxiety
   - Willingness to pay (WTP) for increased vehicle driving range (100 miles) calculated from a meta-analysis of 33 studies, yielding over 100 WTP ratios for a number of different countries (Dimitropoulos et al., 2013).
   - These estimations are used to predict WTP values for other regions by fitting an exponential best-fit to known WTP data points as $y = 493.914*e^{0.0001566x}$ (where y=WTP and x=average annual mileage).
   - Multipliers are then based on the ratio between each regionally-aggregated WTP and the USA estimate of US2013_{ppp}$ 2,423.
2. Refueling station availability
   - WTP for increased refueling density (+10% station coverage) calculated based on 6 empirical studies for USA, Europe, and Japan (Wilson et al., 2014).
   - An exponential best-fit is estimated from these WTPs as $y = 525.73*e^{0.00009x}$ (where y=WTP and x=annual average mileage).
   - Multipliers are then based on the ratio between each regionally-aggregated WTP and the USA estimate of US2013_{ppp}$ 2,792.
3. Risk premium
   - See the following slides…

Comparing studies from different countries allowed the effect of **cultural differences** on social influence to be tested

empirical studies were based on samples from 11 different countries



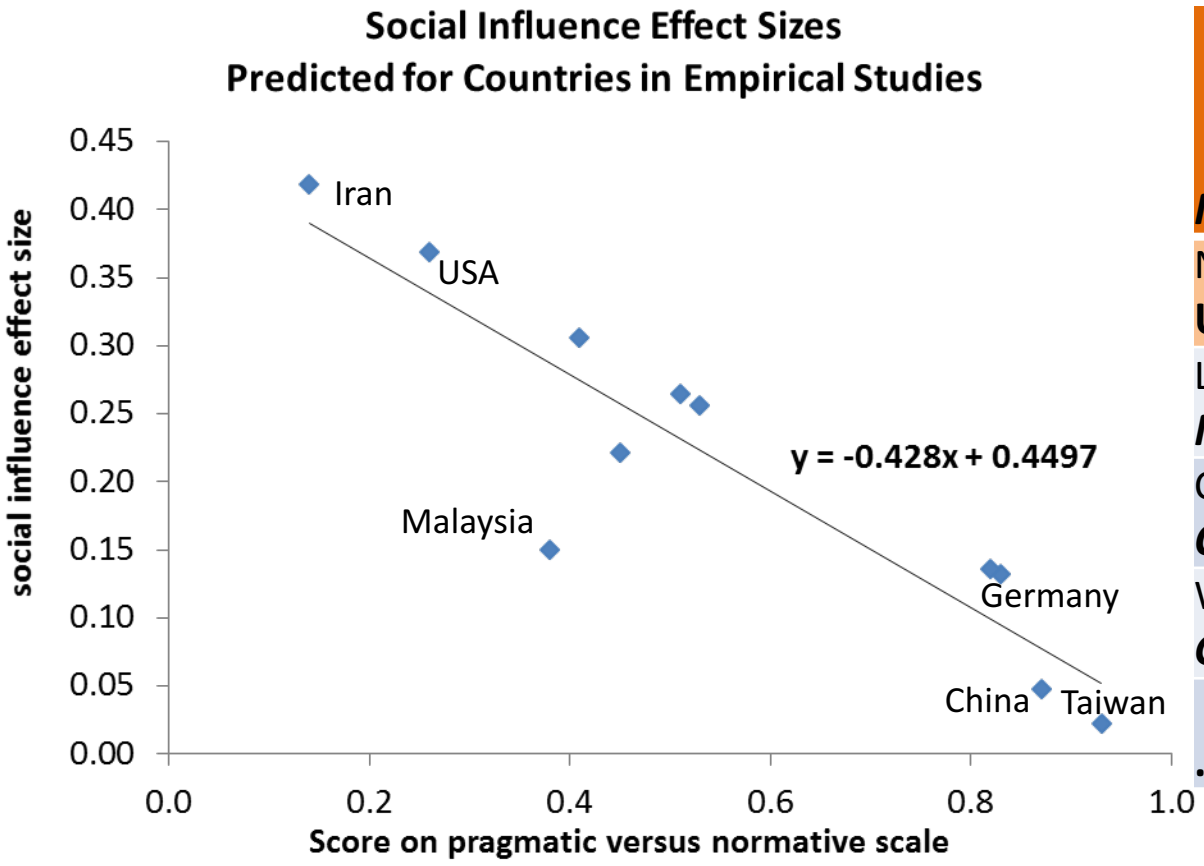
size of social influence effect on vehicle choice varied between countries



global average effect size = 0.241

Relationship between social influence effect and cultural values enables **regional parameterisations**

use of empirical relationship → to rescale USA data



MESSAGE regions	*Social influence effect 'multiplier'*
North America	
USA	**1.00**
Latin America	
Mexico	***0.94***
Centrally Planned Asia	
China	***0.13***
Western Europe	
Germany	***0.36***
.....	.....

generalizable approach to global modelling

Results

Three parts

1. Initial modeling with MESSAGE
2. Ongoing model comparison exercise (6 IAMs)

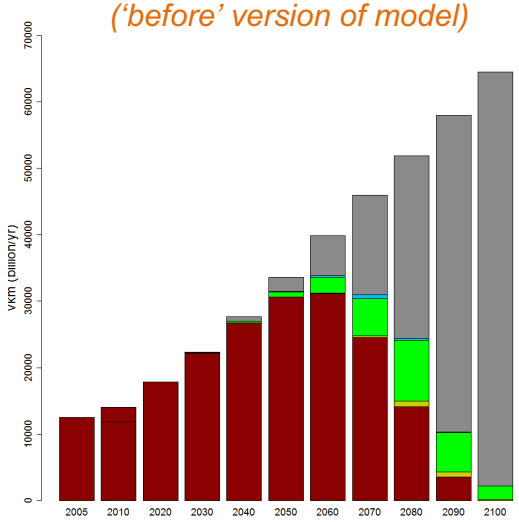
In MESSAGE-Transport, considering non-financial preferences leads to lower/slower uptake of EDVs

Scenario: ~600 ppm CO_2eq in 2100 (2.7 ºC)

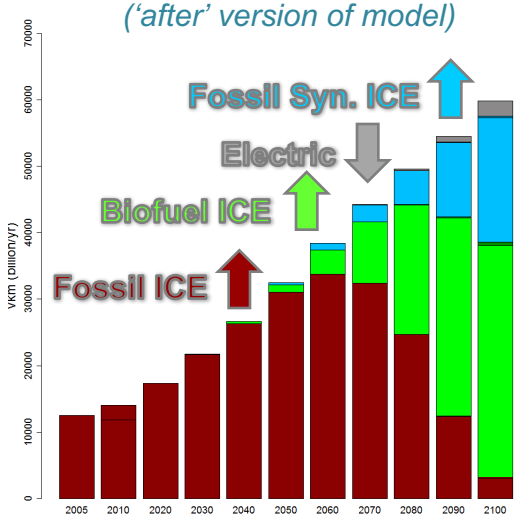
Results: vehicle-km by vehicle type, aggregated across all consumer groups; global

Perfectly rational consumers (cost-minimizing; mean representative decision agents)

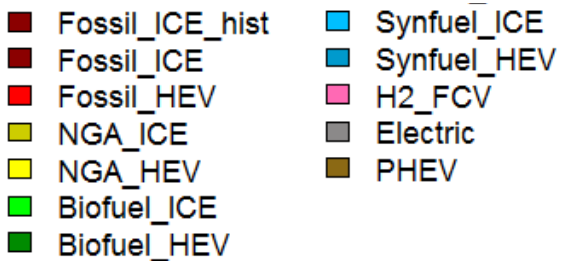
Intangible Costs Not Represented
('before' version of model)



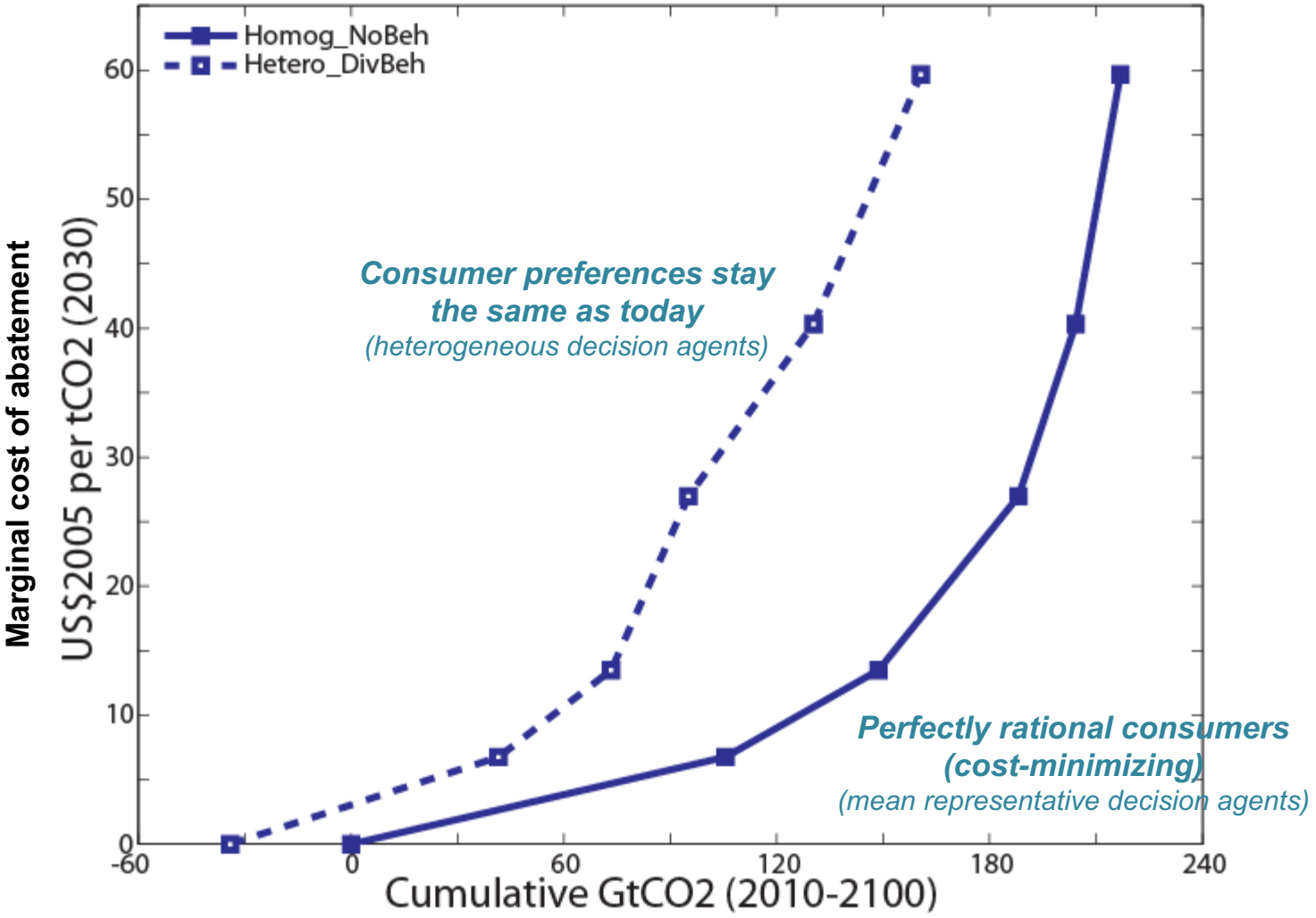
Intangible Costs Frozen at Initial Values
('after' version of model)



Consumer preferences remain the same as today (heterogeneous decision agents)



Explicitly representing heterogeneous behavioral features (non-financial preferences) has a significant impact on model results



(Reductions from baseline; LDVs only)

McCollum et al. (2016), TRD

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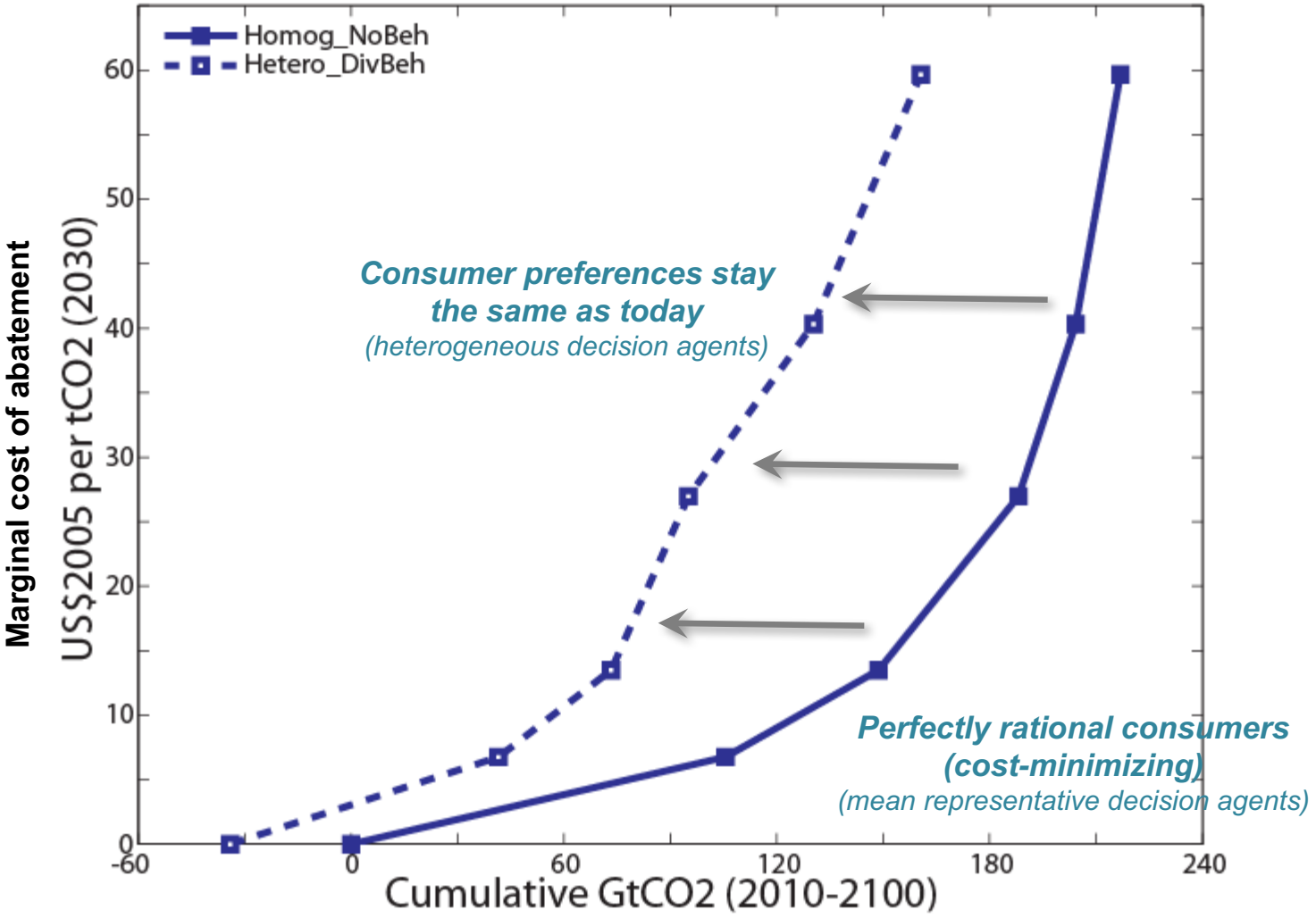

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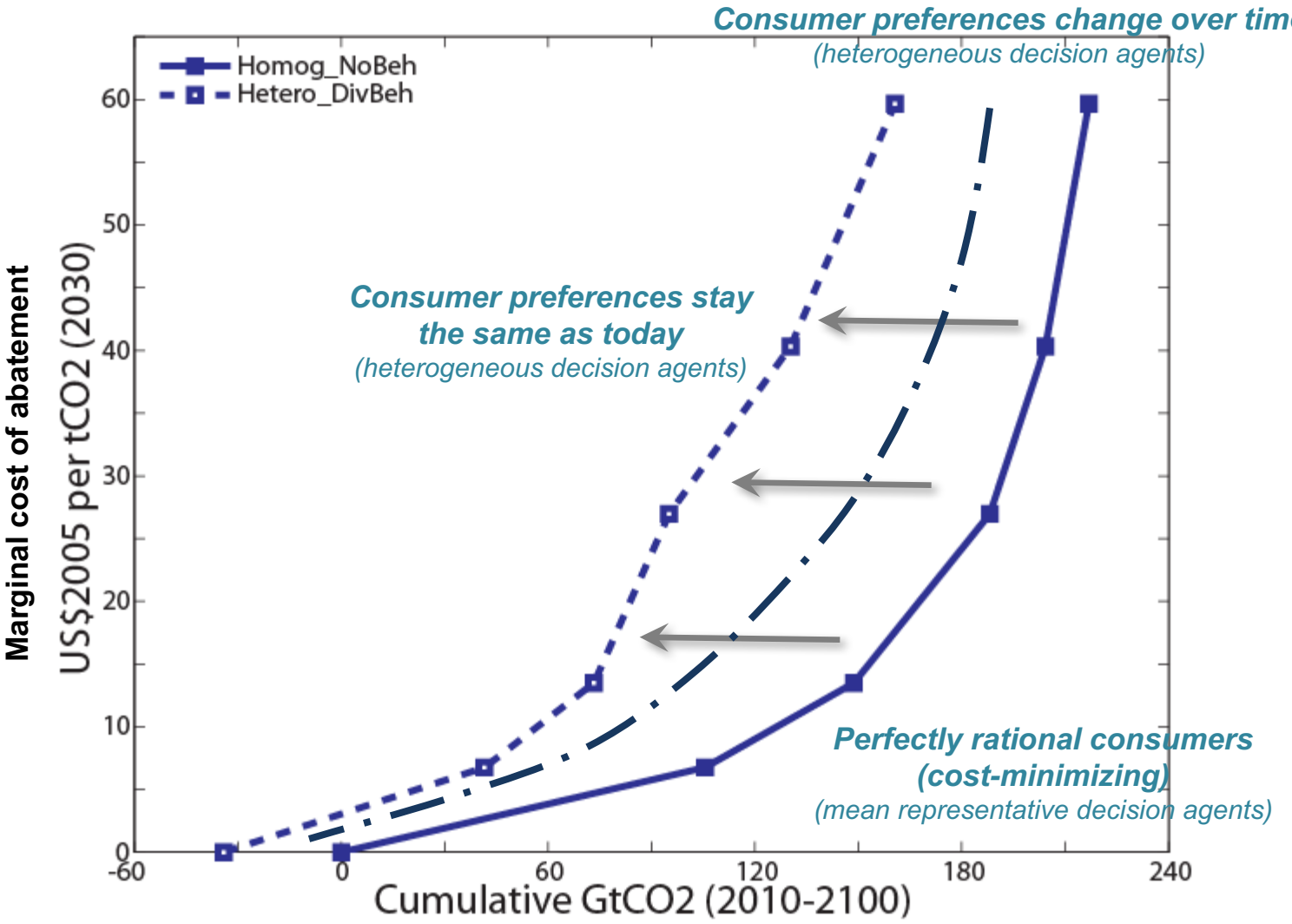

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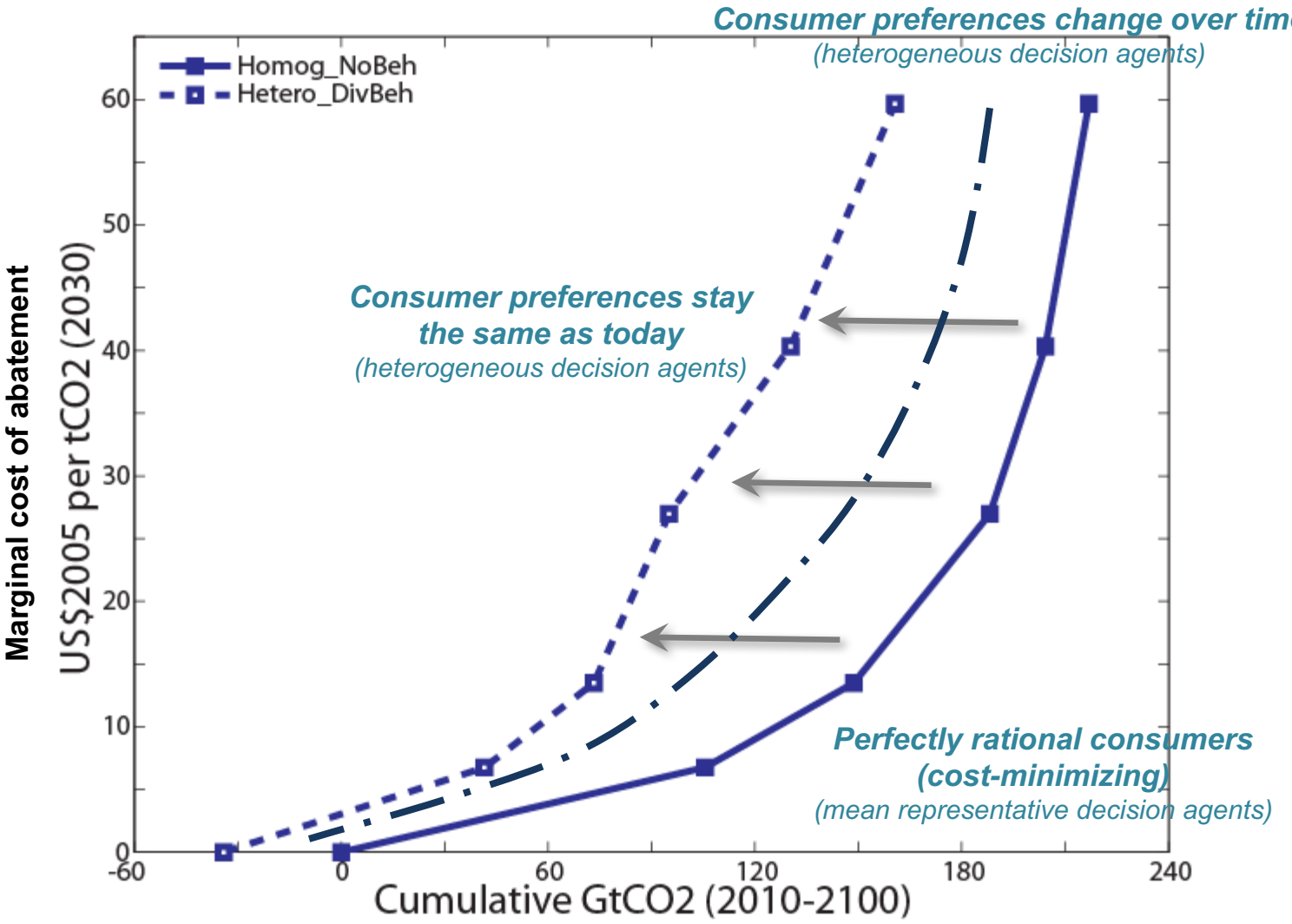

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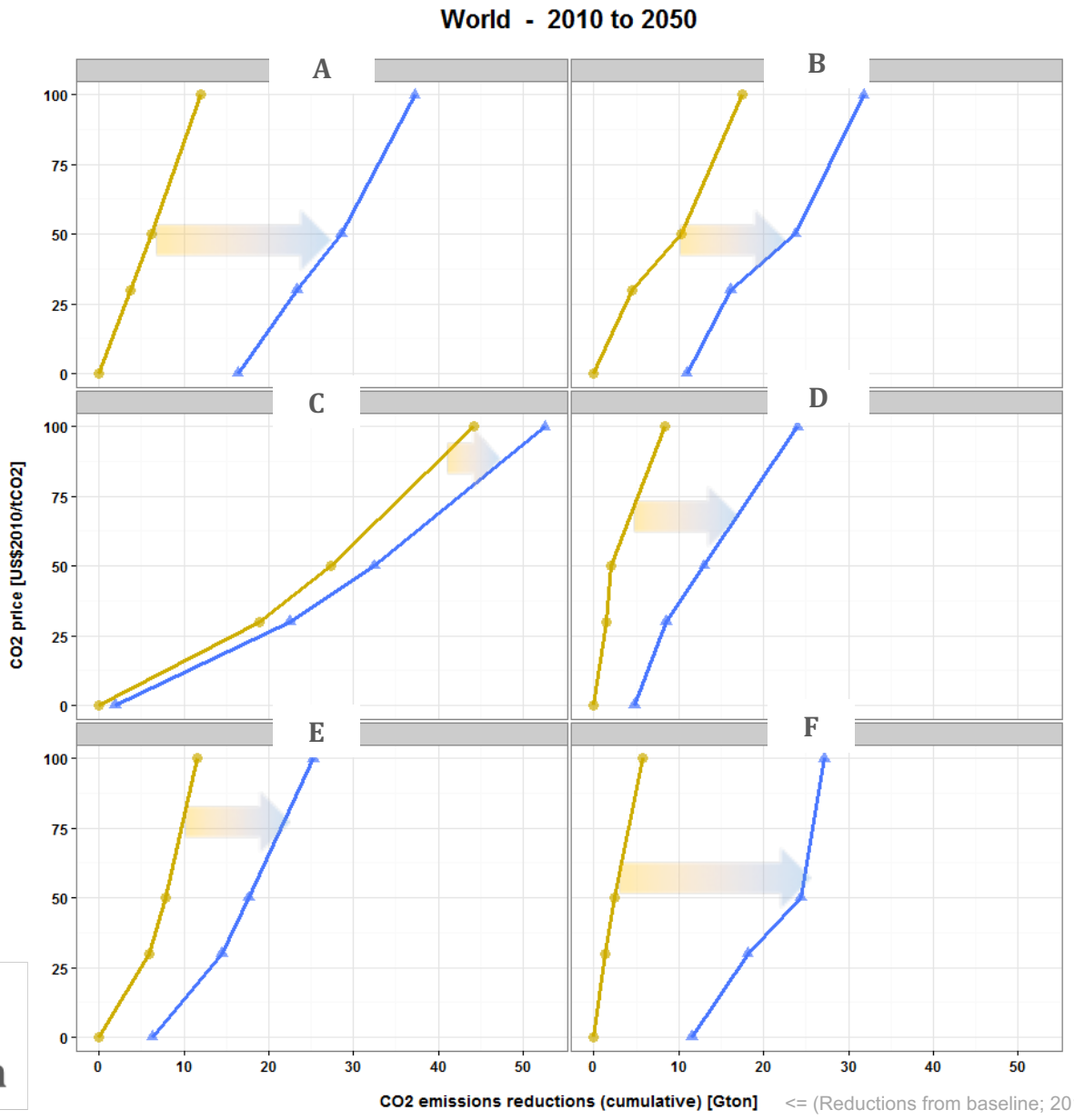
Consumer behavior can be an accelerator of change …
but dedicated policies/measures are needed to influence preferences



<= (Reductions from baseline; 2010-50; LDVs only)

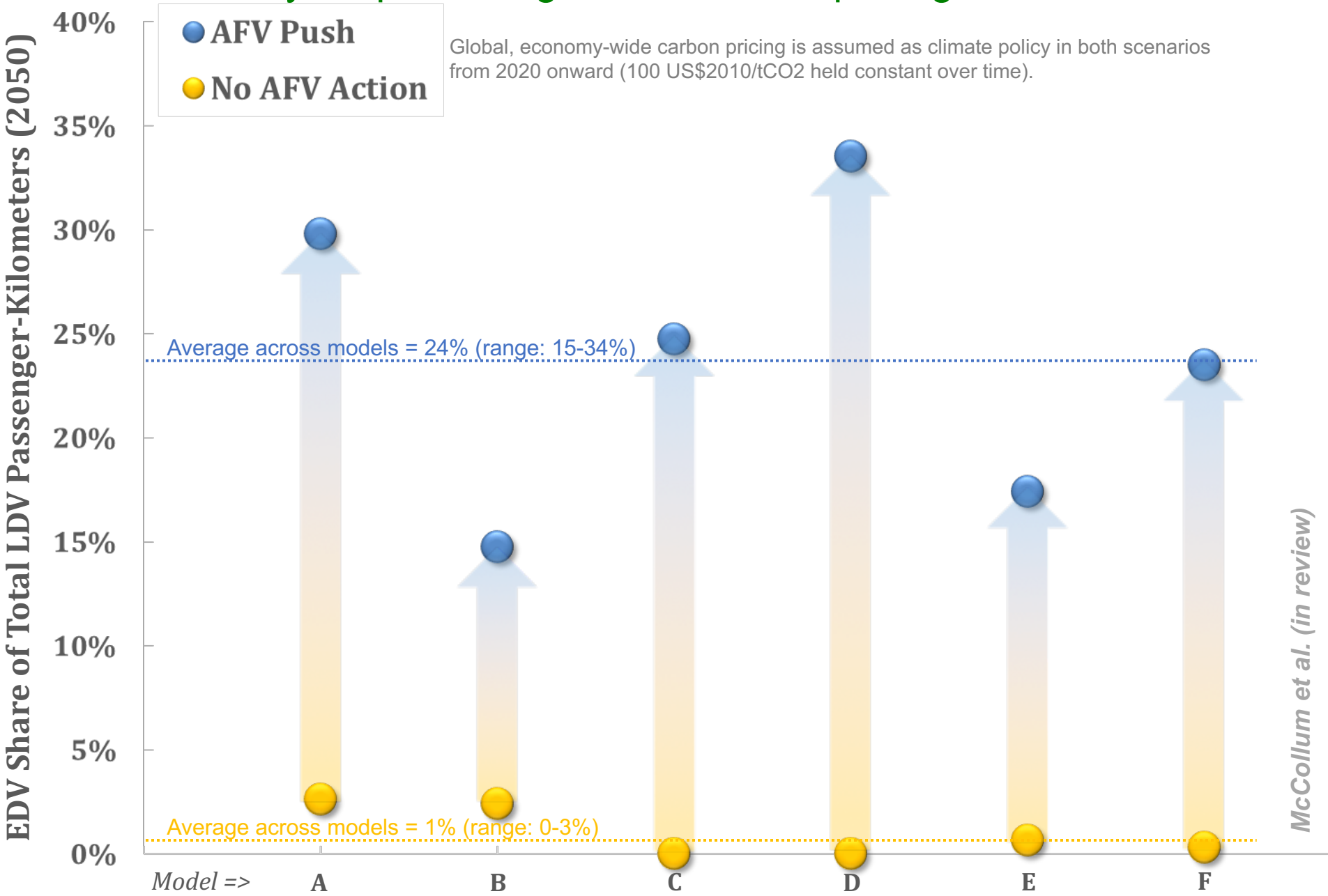
McCollum et al. (in review)

Multi-pronged efforts to promote advanced vehicle adoption are more effective than a single sectoral or economy-wide policy

			Sectoral strategies and policies										
			Targets for cumulative vehicle sales, sales quotas, vehicle mandates	Vehicle efficiency or emission standards	Vehicle sales incentives (purchase subsidies, tax credits, fee-bates, reduced registration fees)	Vehicle manufacturer support (RD&D, production subsidies)	High transport fuel taxes (also carbon taxes or pricing)	Government and company vehicle procurement policies, other demonstration & test fleets	Trialling in car clubs or car-sharing networks	Recharging and refuelling public infrastructure investments	Workplace or home charging incentives	Preferential parking or roadway access; reduced congestion charges or tolls	Promotions, social marketing, outreach, information campaigns
Consumer preferences	***Financial***	***Upfront capital cost***	+		++	++		+					
		Fuel cost		+			++			+	+		
	Non-financial	***Risk aversion***	+	+	+			++	++			+	++
		Model variety	++			+		+	+				+
		Refuelling availability	+				+	++	++	++	++		+
		Range anxiety				+		+	+	++	++		++
Example countries where strategies and policies have been implemented			Norway, Netherlands, UK, USA (10 states with California mandates), China, France, Germany	Norway, Netherlands, UK, USA, Japan, China, France, Germany	Norway, Netherlands, UK, USA, Japan, China, France, Germany	Norway, Netherlands, UK, USA, Japan, China, France, Germany	Norway, Netherlands, UK, France, Germany	UK, USA, Japan, China, France	France, Germany, Netherlands, USA	Norway, Netherlands, UK, USA, Japan, China, France, Germany	USA, France	Norway, Netherlands, UK, USA, Japan, France, Germany	Norway, Netherlands, UK, USA, Japan, China, France, Germany

Notes: ++ indicates a strong or direct influence on consumer preference; + indicates a weak or indirect influence on consumer preference; based on authors' assessment. The selection of countries here represented >90% of global electric vehicle sales in 2014.

Sectoral actions targeting consumers' non-financial preferences are necessary for promoting EDVs; carbon pricing is insufficient



How consumers perceive electric-drive vehicles (EDVs) is critical to their success

- A consortium of companies, governments, and other organizations announced at the 2015 United Nations Climate Change Conference (COP 21) the "Paris Declaration on Electro-Mobility and Climate Change and Call to Action".
- The **"Paris Declaration" goal of 100 million EDVs** on the world's roads by 2030 seems **perhaps a bit ambitious**, according to the six global IAMs.
- Only one of this study's models achieves that aspirational goal in the most stringent policy scenario, whereas the others are considerably lower.

Paris Declaration on Electro-Mobility and Climate Change

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Questions? Comments?

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