International Institute for Applied Systems Analysis
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science for global insight

Breaking down non-cost barriers to technology adoption is critical for the transport-energy transformation

International BE4 Workshop
London, UK
April 20-21, 2015

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Charlie Wilson, Hazel Pettifor (UEA)
Kalai Ramea (UC-Davis)
Oreane Edelenbosch (PBL)
Zhenhong Lin (ORNL)

ADVANCE project

- EU-FP7 project funded for four years (01/2013 – 12/2016) with 5.7 Mio €
  - ADVANCE: “Advanced Model Development and Validation for Improved Analysis of Costs and Impacts of Mitigation Policies”

- Integrated assessment and energy-economy modeling teams:

  PIK (DE; REMIND, MAgPIE), **IIASA** (AT; MESSAGE),

  PBL (NL; IMAGE/TIMER), **FEEM** (IT; WITCH),

  IPTS (EU; GEM-E3, POLES), **UCL** (UK; TIAM-UCL),

  UPMF, Enerdata (FR; POLES), **ICCS/NTUA** (GR; PRIMES, GEM-E3)

  CIRED (FR; IMACLIM)

- Topical research teams:

  DLR (DE; RE integration & resources),

  UEA (UK; consumer choice) & **Utrecht University** (NL; energy demand),

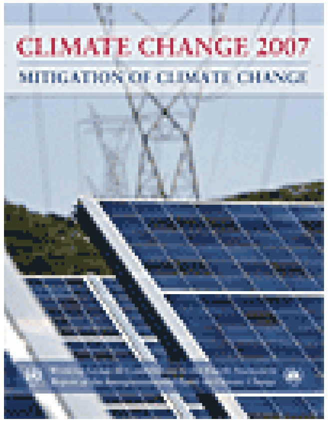
  NTNU (NO; Material flows & LCA)

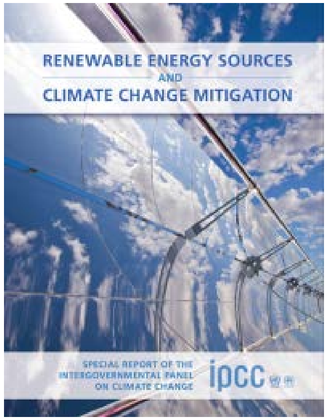
- International collaborators:
  - Non-EU modeling teams: **JGCRI** (GCAM), **NCAR** (iPETS), **NIES** (AIM), **RITE** (DNE21+)
  - Further international expertise: **NREL** (renewable energy sources), **PIAMDDI & EMF** (Model diagnostics & comparison), **Simon Fraser Univ.** (energy demand)

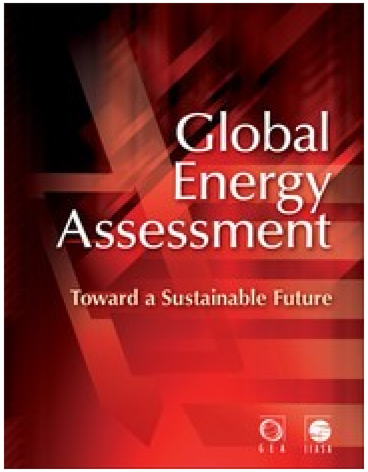
The context of ADVANCE: Exploring transformations

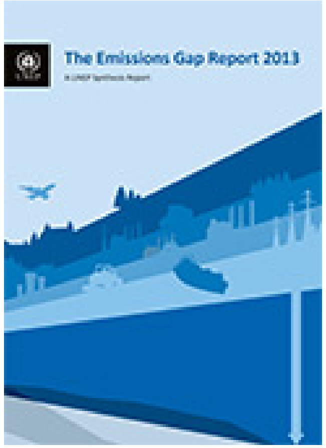
- Whole-systems models - Integrated Assessment Models (IAMs) and E4 models - are central tools for the analysis of climate change mitigation and sustainable development pathways, both globally and nationally.

- A large number of IAM scenarios have been generated over the past few years, and form an important basis for international assessments like the IPCC AR5, UNEP Gap Report, Global Energy Assessment etc. (~1200 scenarios in AR5 DB)









Modelers continue to hone their "map-making" ability

ADVANCE aims to develop a new generation of **energy-economy and integrated assessment modeling** tools.

The goal is to improve the mapping tools in key areas:

- with strategic importance for the assessment of mitigation pathways
- where substantial improvements are needed

Source: Wikimedia Commons

Source: NASA

Source: Wikimedia Commons

Key areas for model improvement…

- **End-use technologies** providing energy services, drivers of energy demand, and potentials for energy efficiency improvements (WP2)

- **Heterogeneity** of consumer preferences, and how behavioral changes affect energy demand (WP3)

- **Innovation**, technological change and uncertainty (WP4)

- **Supply-side bottlenecks**: system integration of variable renewable electricity (VRE), material and energy requirements, infrastructure lock-ins, land-water-energy-nexus (WP5)

Objectives of ADVANCE WP3

(Task 3.1: Improving the representation of demand-side heterogeneity in IA and E4 models)

New methodologies

Draw upon empirical evidence and detailed behavioral studies to inform the modelling

Increase the heterogeneity of consumer groups in IAM transport sectors

Better reflect (non-cost) barriers to advanced vehicle adoption in models

New answers to novel questions

Quantify the climate policy cost implications of capturing these barriers

Understand which policy levers can reduce the barriers over time, by how much, and for whom

Participants in ADVANCE WP3, Task 3.1

- Review of empirical micro-studies led by **UEA**, supported by IIASA.

- Pioneering models for first implementation of behavioral aspects done by **IIASA (MESSAGE) and PBL (IMAGE)**.

- Further implementation/model development will be conducted by **UCL (TIAM), FEEM (WITCH), PIK (REMIND), ICCS (GEM-E3), and DNE-21+ (RITE)**.

Research Questions

- **Which consumer/driver attributes can be incorporated into IAMs in order to improve transport sector heterogeneity and better reflect barriers to technology adoption?**

- **How are IAM transport scenarios impacted by these improved representations of behavior and heterogeneity? (w.r.t. technology choice, climate policy costs, etc.)**

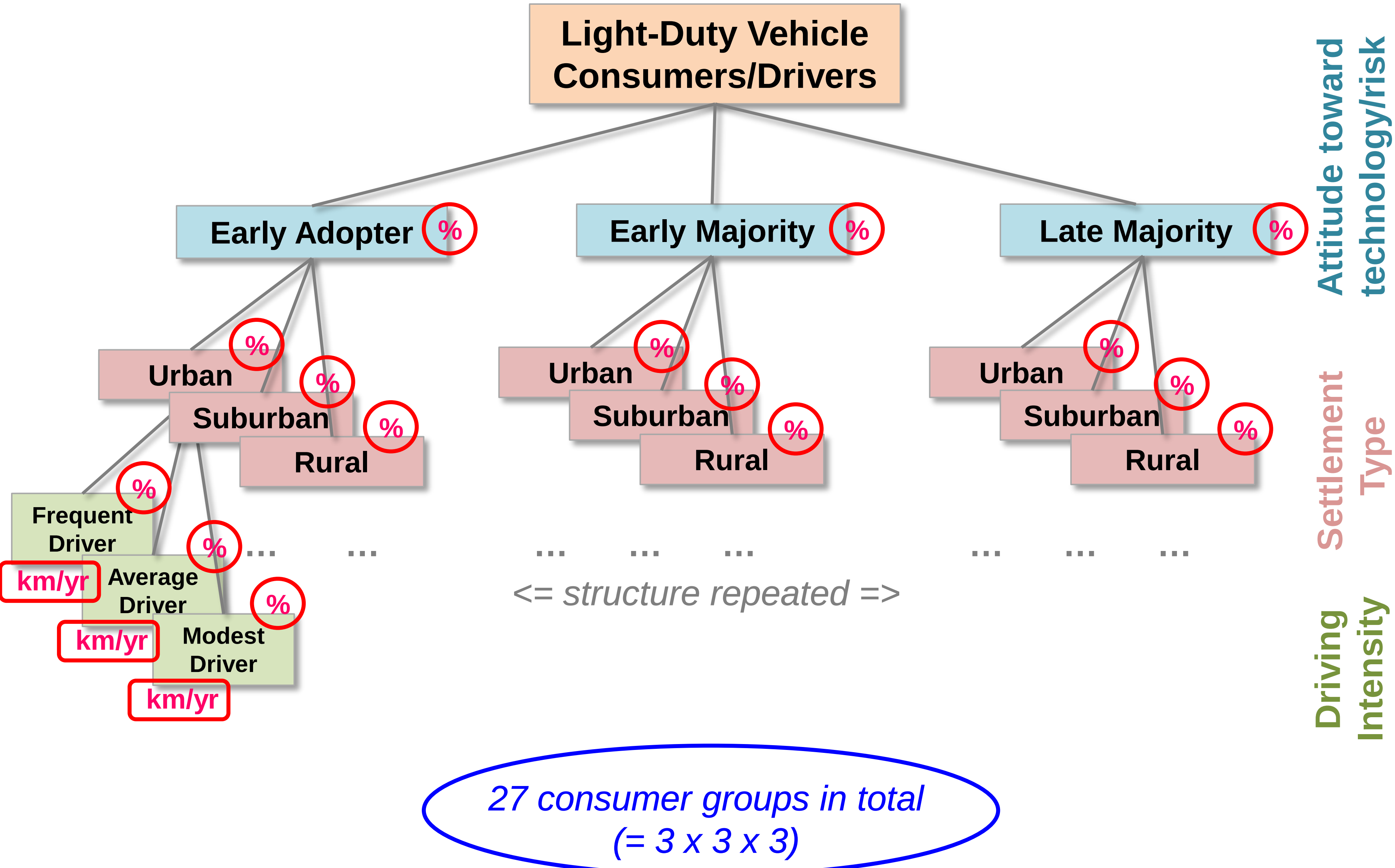
- **What incentives (policy and financial) might help to nudge consumer/driver behavior in a desired direction?**

Modeling Approach

1. Disaggregate IAM transport modules so that LDV demands reflect a heterogeneous set of consumers

2. Monetize non-cost vehicle purchase considerations (barriers to technology adoption) by bringing "disutility costs" from a vehicle choice model into IAMs

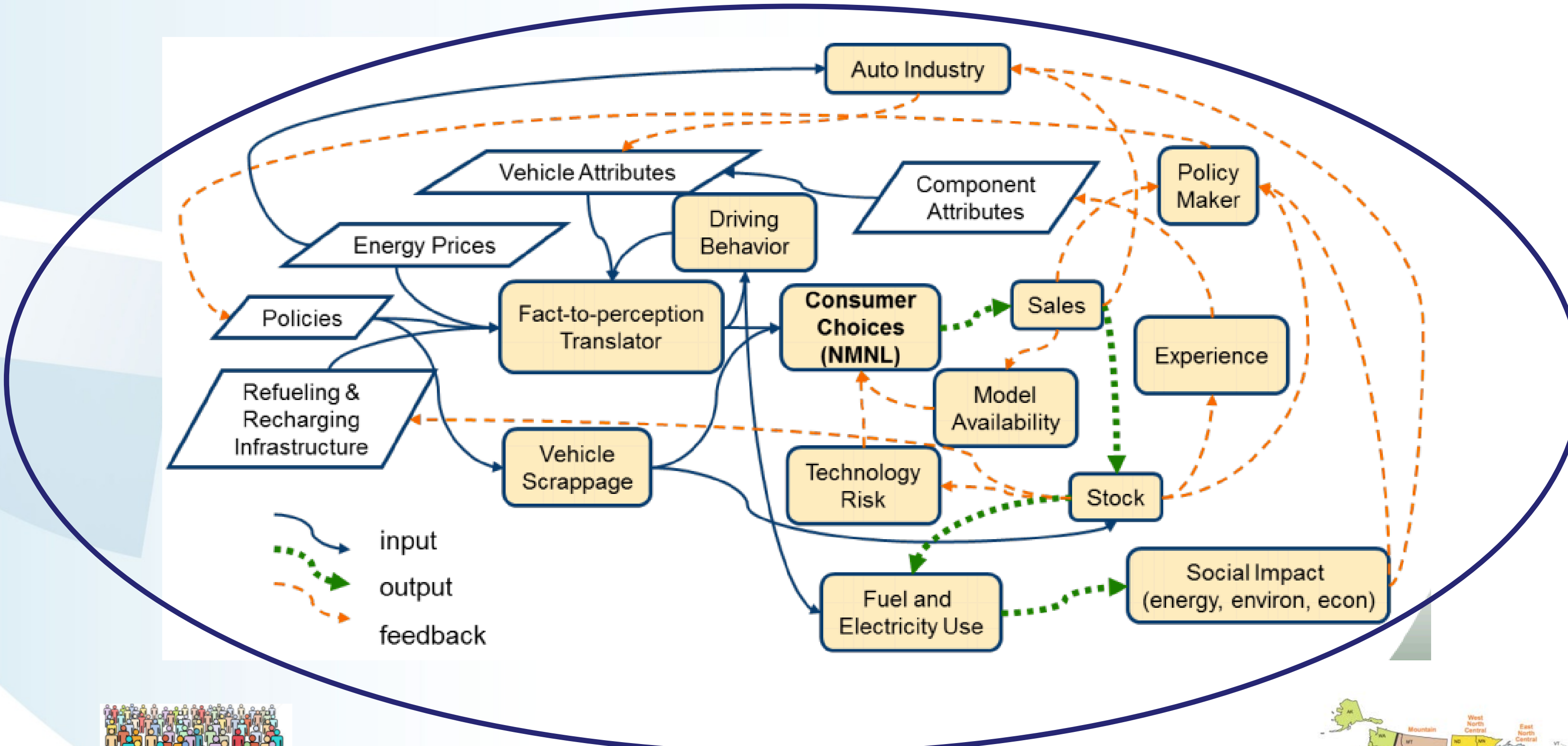
Disaggregation of LDV Mode/Demands



Implement disutility costs from NMNL Model into IAMs

MA^{3}T (Market Allocation 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



1458 consumer groups

Nationwide Model (9 regions in the US)

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

Example Disutility Cost Data

Units: 1000$/vehicle
Year: 2020

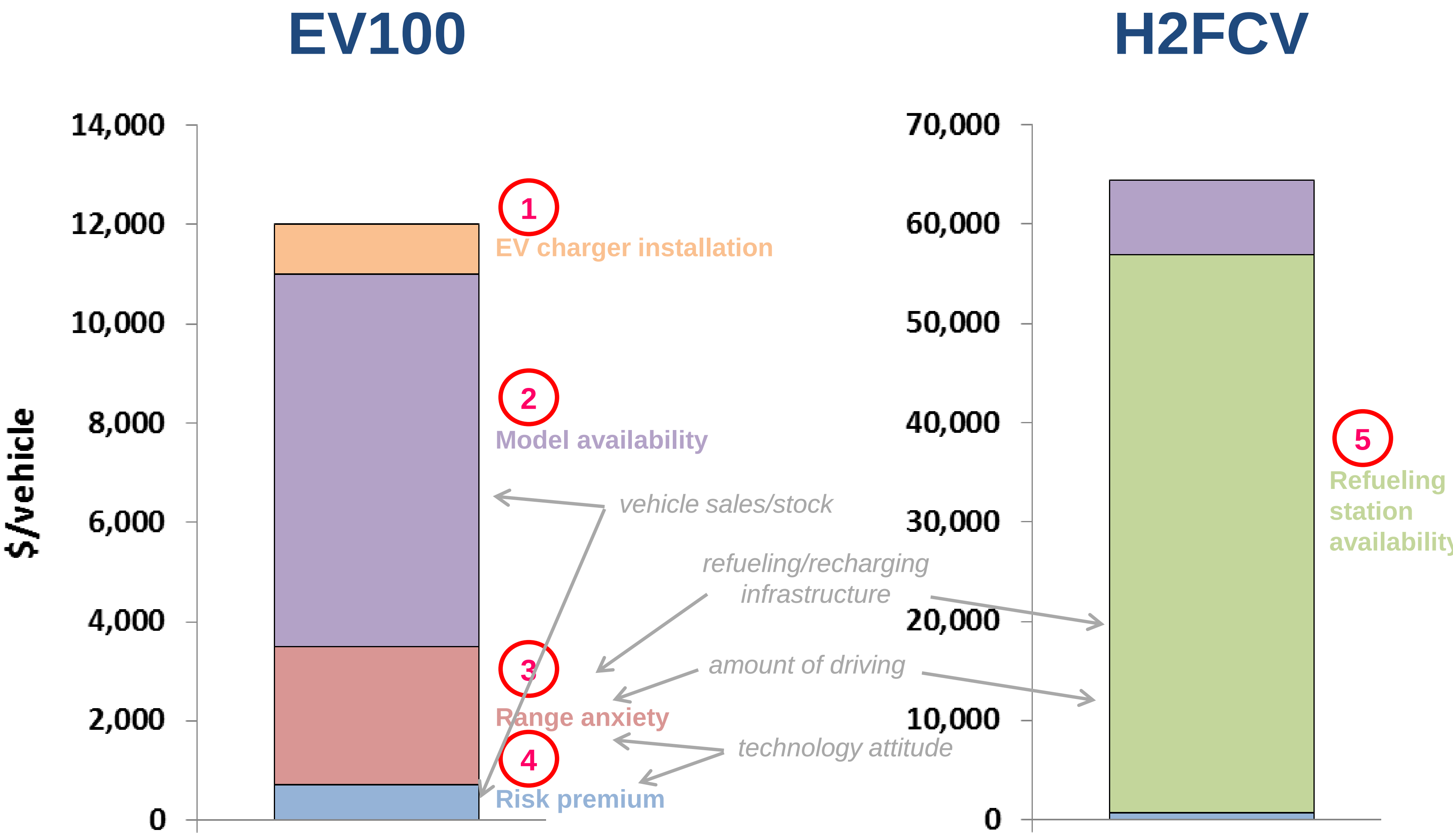
MA3T_ID	MA3T_tech_name	RUEAA	RUEAM	RUEAF	RUEMA	RUEMM	RUEMF	RULMA	RULMM	RULMF	SUEAA	SUEAM
1	Gasoline ICE Conv	0.45	0.00	1.20	0.45	0.00	1.20	0.45	0.00	1.20	0.50	0.03
2	Diesel ICE Conv	5.89	5.17	7.09	6.52	5.79	7.72	7.13	6.41	8.33	5.98	5.21
3	Natural Gas ICE Conv	13.47	9.64	19.78	16.50	12.67	22.81	19.48	15.65	25.79	13.90	9.87
4	Gasoline ICE HEV	1.88	1.44	2.61	1.92	1.48	2.65	1.96	1.52	2.69	1.82	1.41
5	Diesel ICE HEV	3.54	2.80	4.76	5.76	5.02	6.98	7.94	7.20	9.15	3.45	2.75
6	Natural Gas ICE HEV	13.52	9.63	19.92	16.54	12.66	22.95	19.51	15.63	25.92	13.03	9.37
7	Gasoline PHEV10	2.68	2.31	3.34	3.70	3.33	4.36	4.69	4.33	5.36	2.62	2.28
8	Gasoline PHEV20	3.00	2.67	3.61	5.00	4.67	5.62	6.97	6.64	7.59	2.95	2.64
9	Gasoline PHEV40	1.37	1.14	1.91	1.46	1.23	2.00	1.55	1.31	2.08	1.34	1.13
10	Hydrogen ICE	87.43	49.48	149.98	90.46	52.51	153.01	93.44	55.49	155.99	91.72	51.79
11	Hydrogen FC	79.56	45.24	136.13	82.59	48.28	139.16	85.57	51.25	142.13	77.87	44.34
12	Hydrogen FC PHEV10	53.21	27.51	103.30	56.21	30.51	106.31	59.16	33.46	109.26	52.94	27.68
13	Hydrogen FC PHEV20	50.77	26.16	97.13	53.73	29.13	100.10	56.65	32.04	103.01	49.48	25.57
14	Hydrogen FC PHEV40	36.72	18.89	77.32	39.70	21.87	80.30	42.63	24.80	83.23	36.26	18.81
15	EV 100 mile	12.86	10.77	22.15	22.30	18.11	40.88	45.34	34.87	91.79	12.68	10.77
16	EV 150 mile	17.08	11.07	26.46	30.49	18.47	49.25	65.34	35.28	112.25	16.90	11.07
17	EV 250 mile	20.29	10.91	30.40	37.28	18.52	57.50	82.45	35.55	133.00	20.11	10.91

etc. for all 27 consumer groups

Key:
RU (Rural) / SU (Suburban) / UR (Urban)
EA (Early Adopter) / EM (Early Majority) / LM (Late Majority)
M (Modest Driver) / A (Average Driver) / F (Frequent Driver)
Example: RUEAA = Rural + Early Adopter + Average Driver

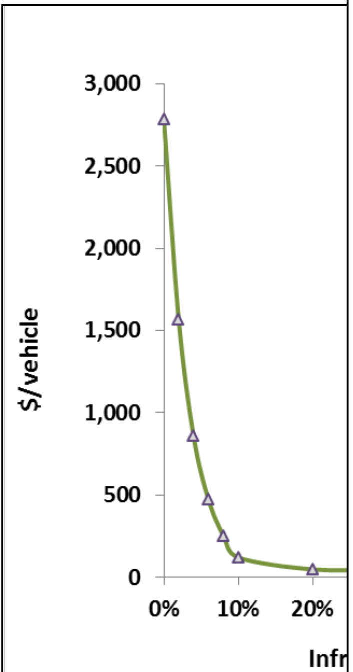
These disutility costs would be added to the standard capital costs of vehicles in models (in $/vehicle).

Breakdown of Disutility Cost Sub-components

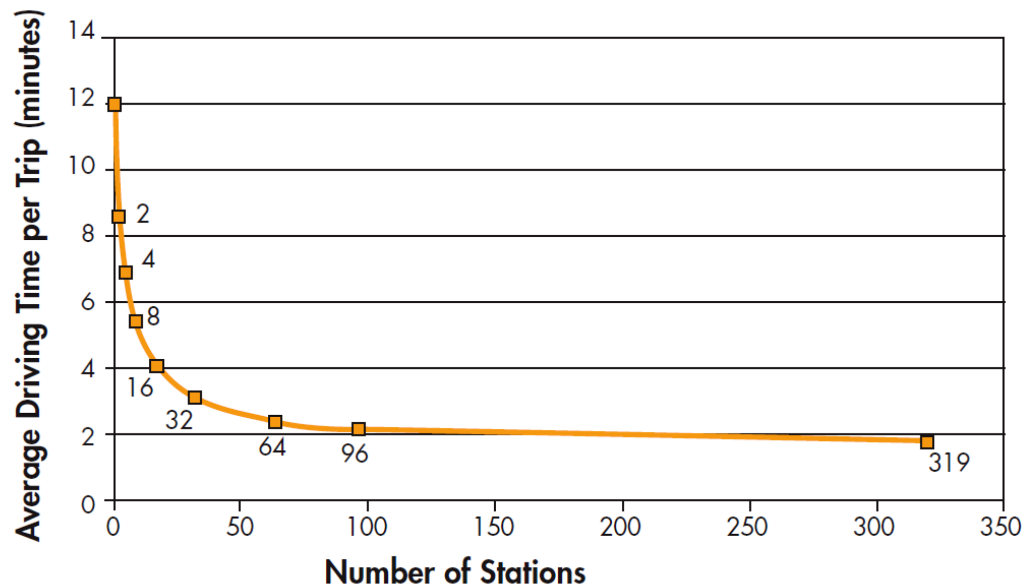


Region: NORTH_AM; **Year**: 2030; **Group**: UREMA

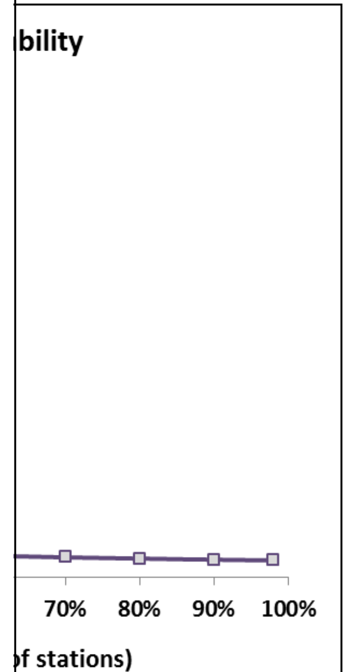
Sensitivity Analyses to Estimate Disutility Cost Sub-components



TRAVEL TIME TO REACH A HYDROGEN STATION AS A FUNCTION OF NUMBER OF STATIONS IN AN URBAN AREA

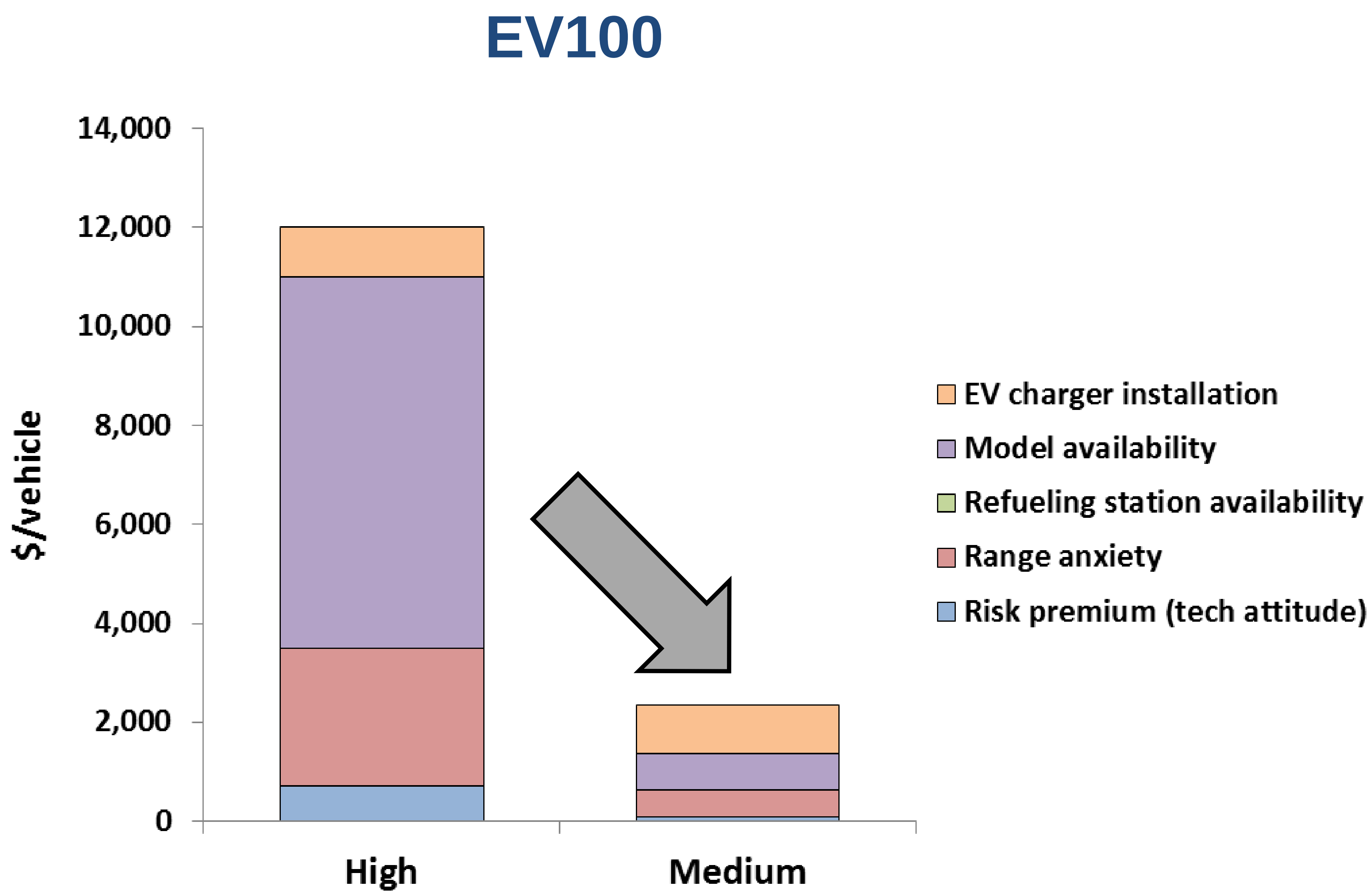


Not every existing fueling station in an urban area would need H_2 in order to provide convenience. Average driving time from home to an H_2 station goes down fast as H_2 becomes available at a relatively small fraction of existing stations. Source: M. Nicholas, S. Handy, and D. Sperling, "Usng Geographic Information Systems to Evaluate Siting and Networks of Hydrogen Stations," Transportation Research Record *1880 (2004): 126–34.*



Region: NORTH_AM

Breakdown of Disutility Cost Sub-components

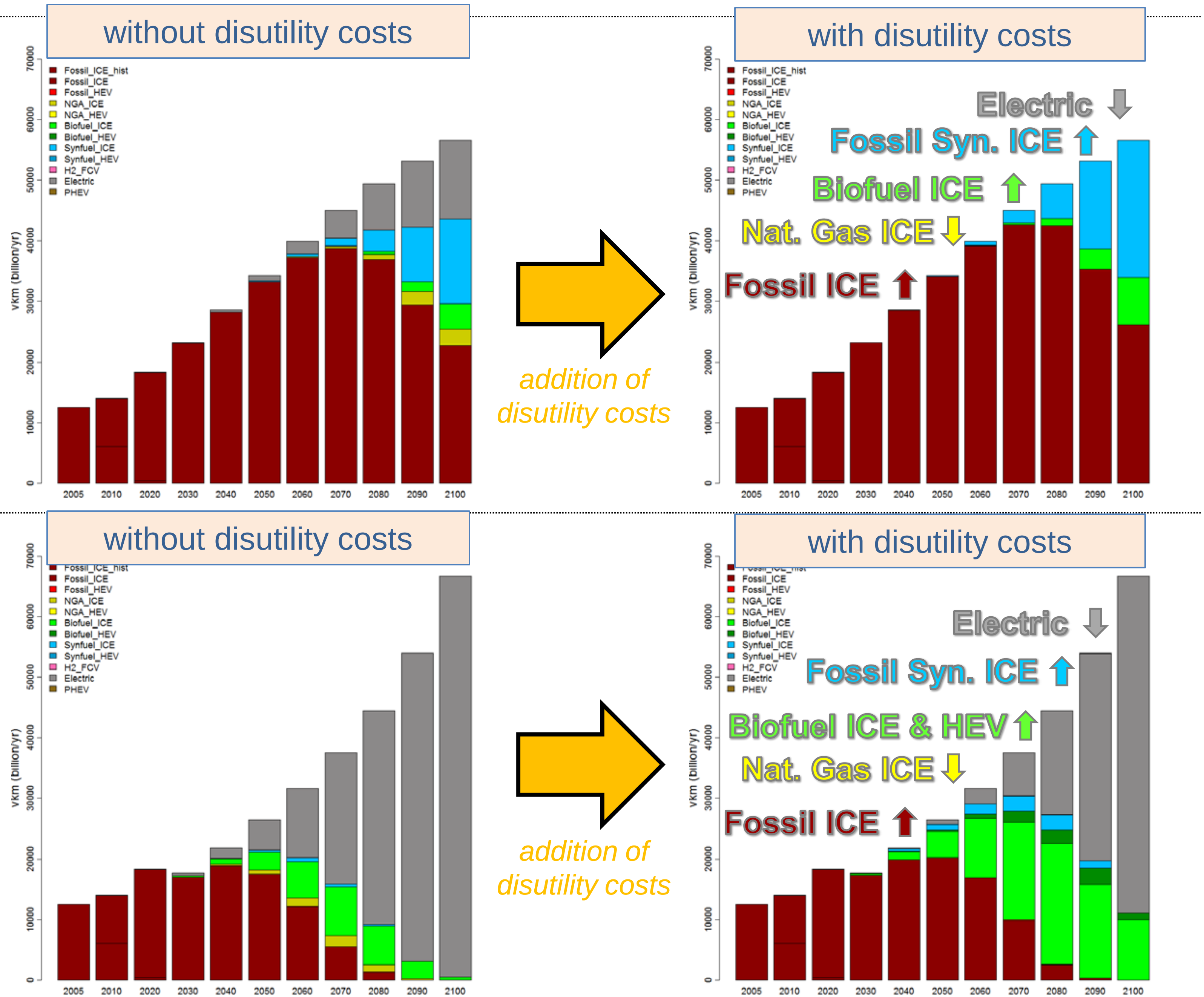


Region: NORTH_AM; Year: 2030; Group: UREMA

Adding disutility costs leads to slower uptake of AFVs

Baseline

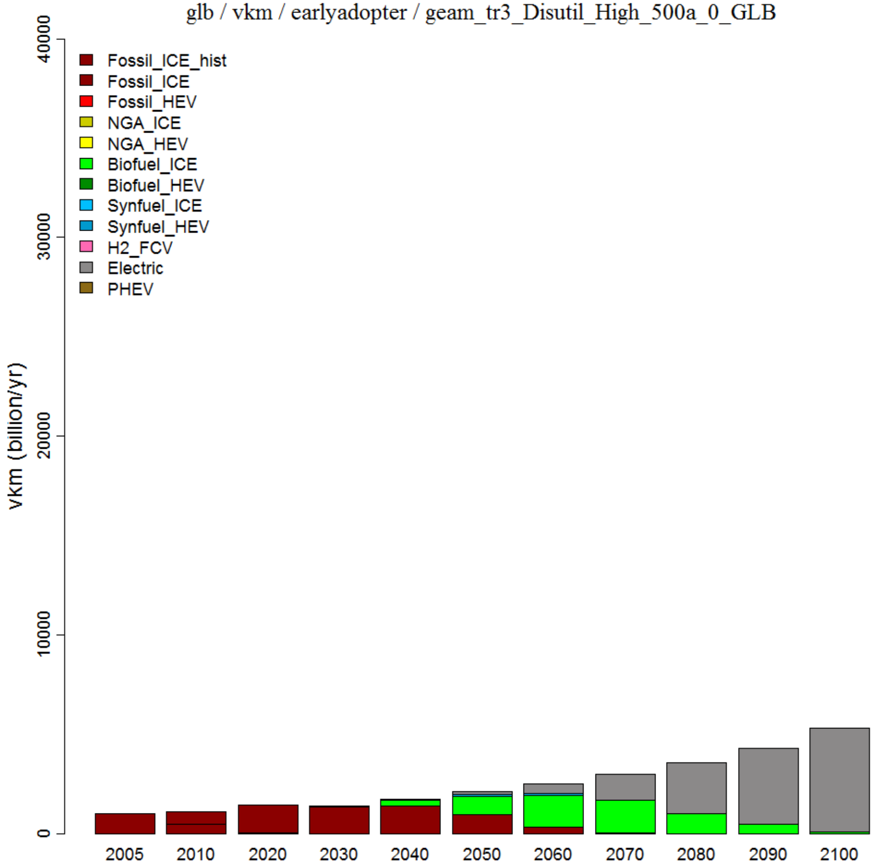
500 ppm CO_2eq



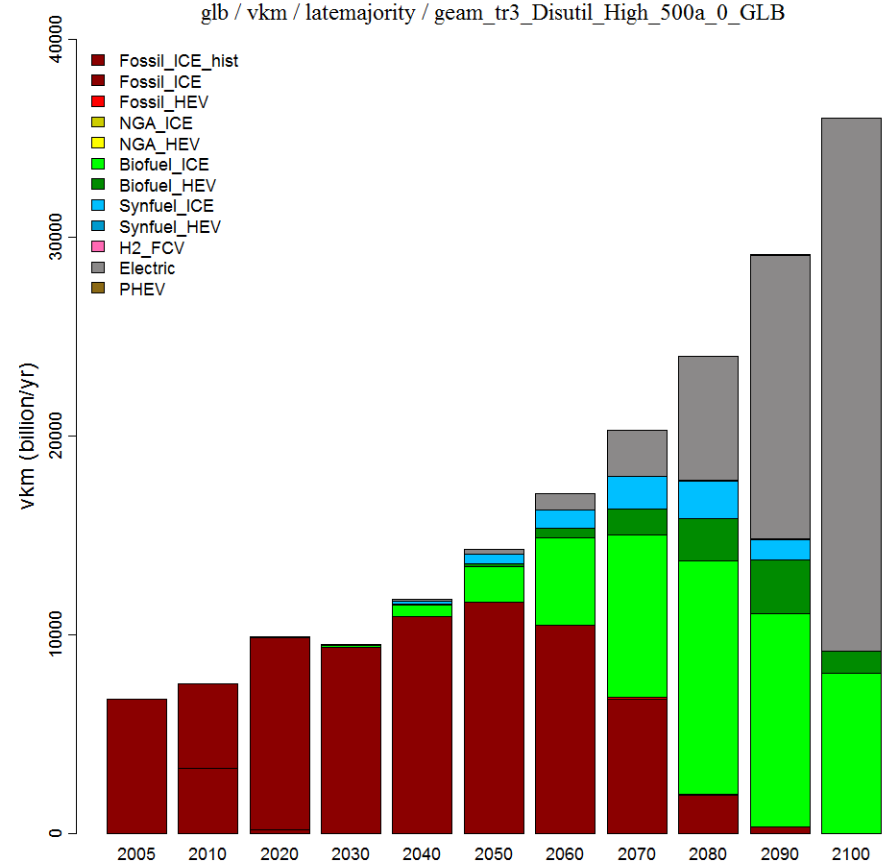
Certain consumer groups adopt AFVs much faster

500 ppm CO_2eq

with disutility costs

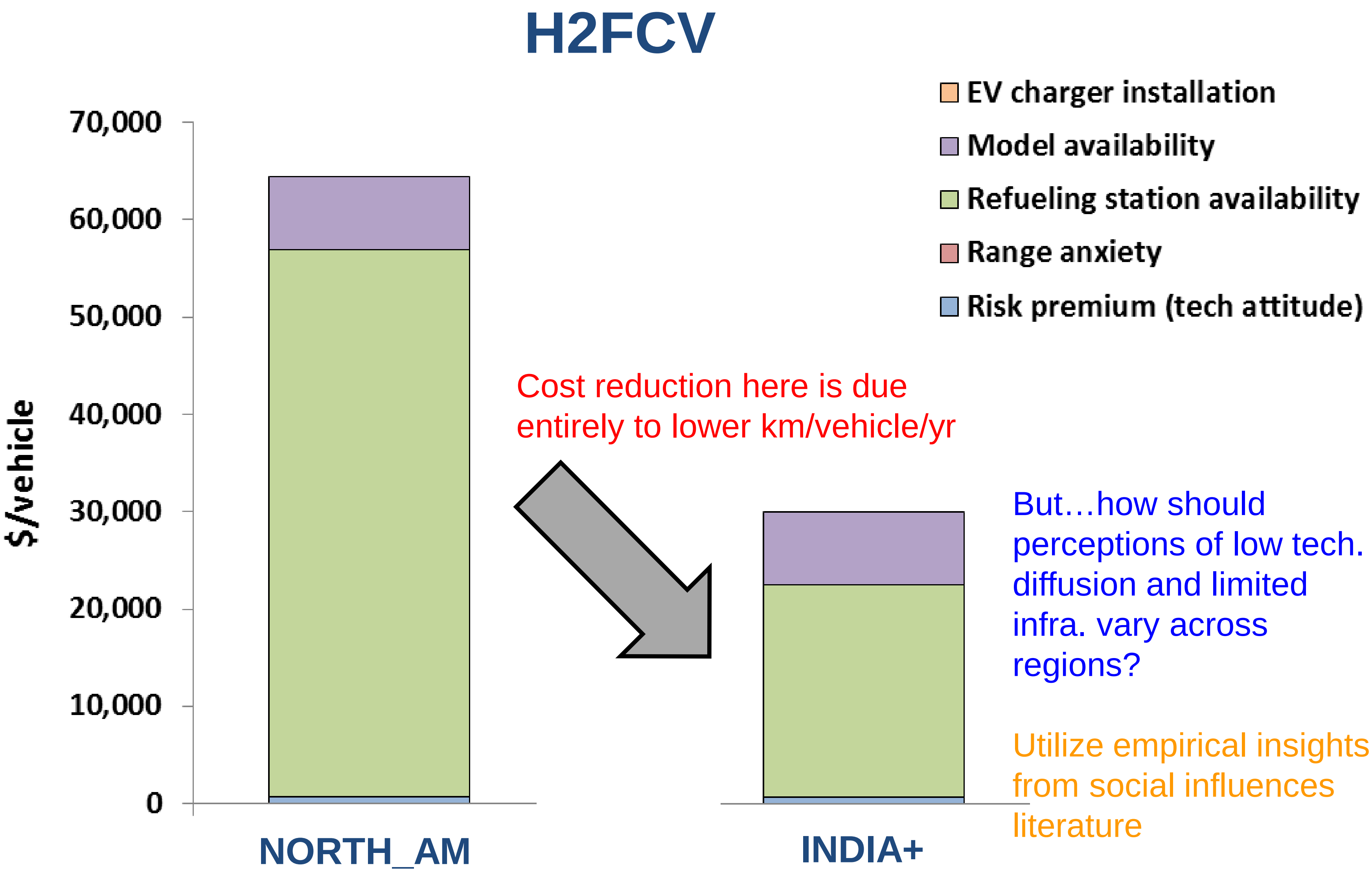


Early Adopters



Late Majority

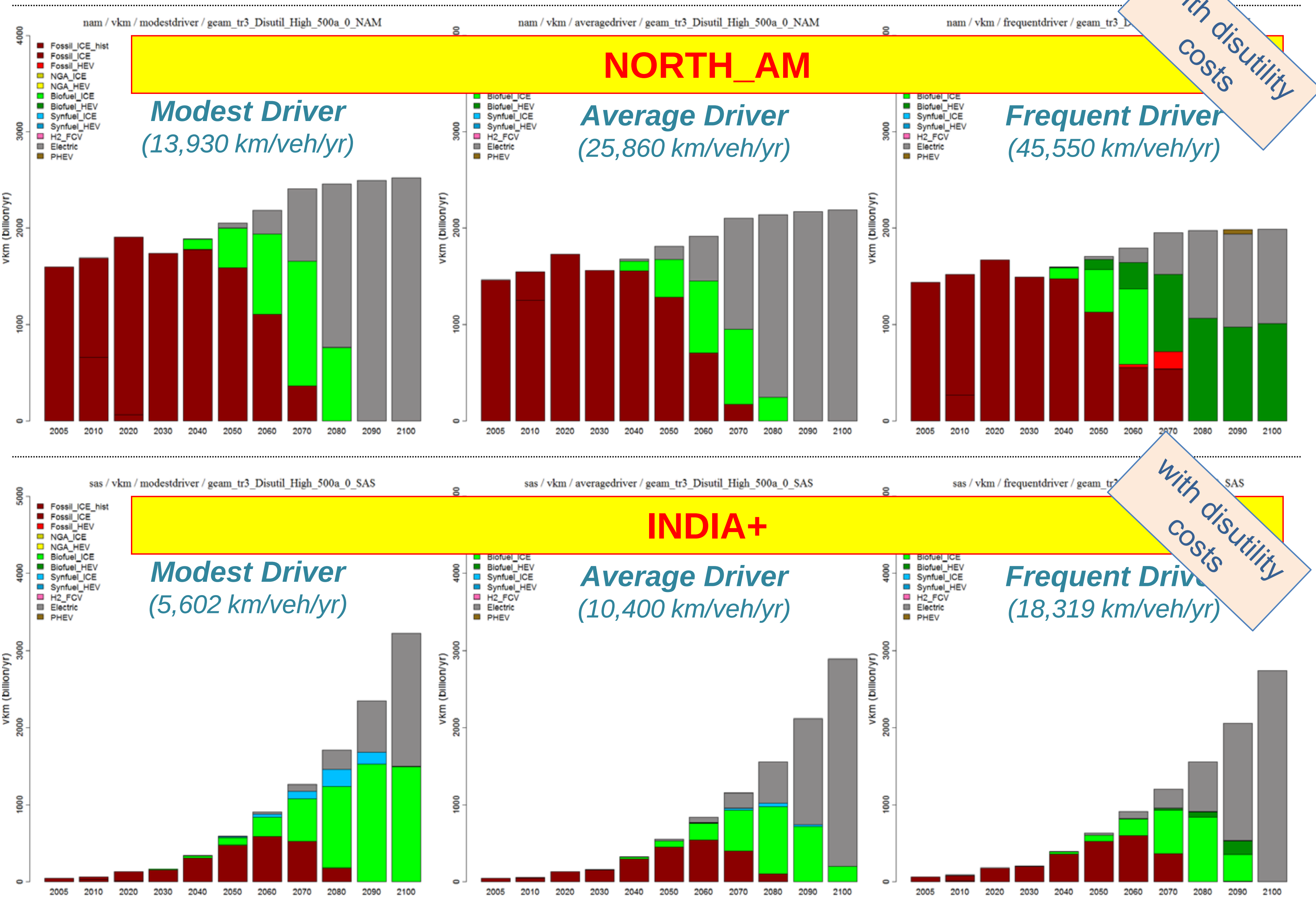
Regional Differences in Disutility Costs



* H2 refueling infrastructure coverage and H2FCV diffusion are at 0%.

Year: 2030; Group: UREMA

Comparison of regional results in a 500 ppm CO_2eq scenario



Research Questions

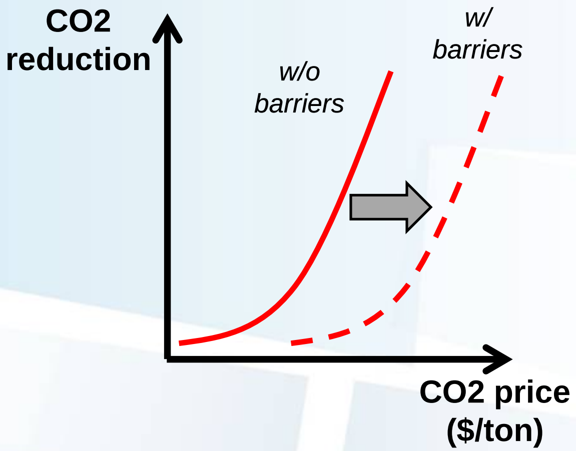
- **How are IAM and E4 transport scenarios impacted by improved representations of consumer heterogeneity/behavior and better reflections of barriers to technology adoption? (w.r.t. technology choice, climate policy costs, etc.)**
- **What incentives (policy and financial) might help to nudge consumer/driver behavior in a desired direction?**
- **How much can be achieved by changing behavior and preferences?**

Expected Findings and Policy Insights

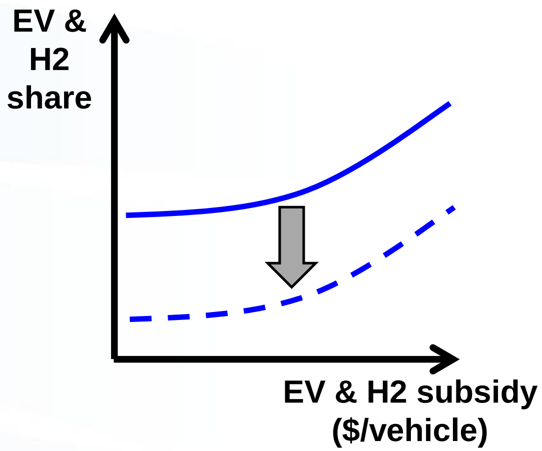
- **The inclusion of non-cost barriers to technology adoption in the decision-making algorithms of models leads to a considerably slower u[illegible]e of advance vehicles than under normal [illegible]umptions.**
  - **e.g., in climate policy s[illegible] electricity/hydrog[illegible]**
- **If these [illegible] removed, climate policy costs ma[illegible]ly higher.**
- **Policies supporting early-stage infrastructure can bring down these barriers, while vehicle purchase subsidies can help compensate for them in the early market phase.**

Quantification needed

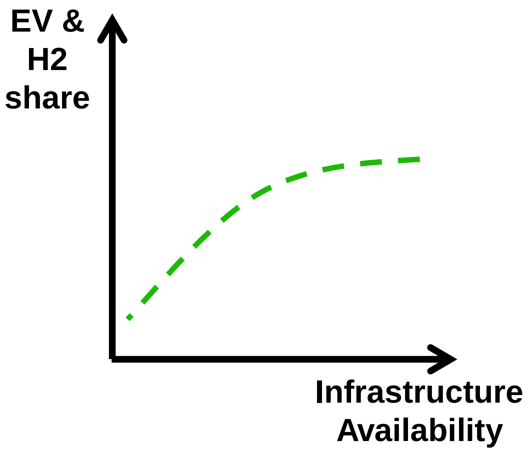
Expected Findings and Policy Insights



Marginal abatement cost (MAC) curves will likely shift once models better reflect heterogeneity and non-cost barriers to technology adoption.



The impact of vehicle subsidies can be analyzed; these will be affected by heterogeneity and non-cost barriers to technology adoption.



Policies supporting the development of early-stage recharging/refueling infrastructure can aid the diffusion of new technologies.

Questions?

Comments?

Extra slides

References and Documentation

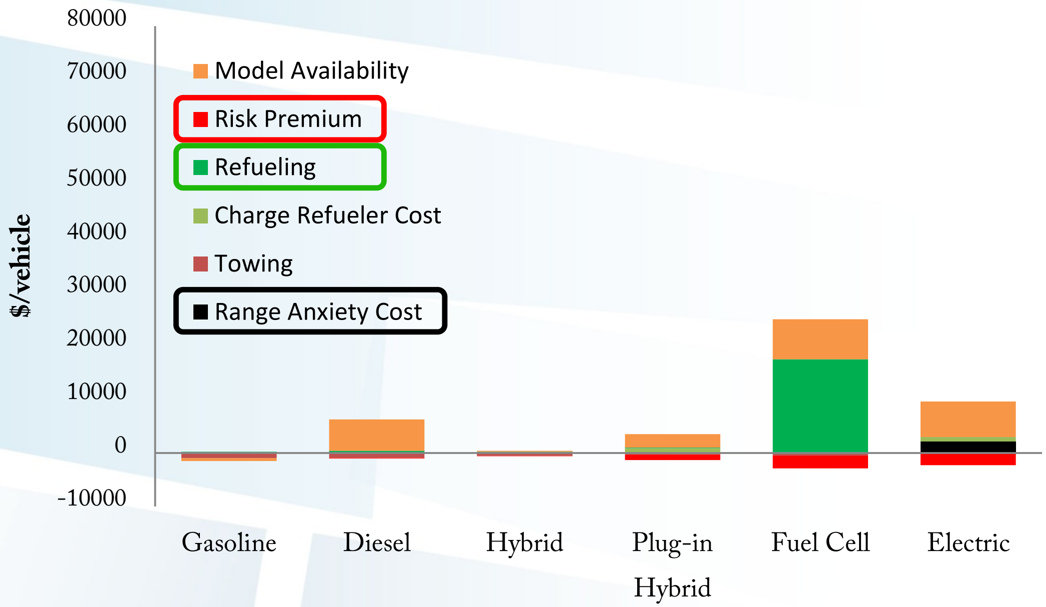
- **Kalai Ramea's (UC-Davis) IEW-2013, IAMC-2013, and BE4-2015 presentations**
- **ORNL MA^{3}T website: http://cta.ornl.gov/ma3t/**

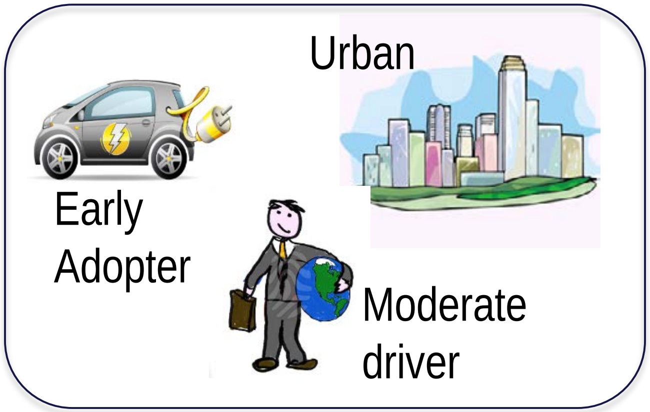
So far, 5 published and 5 working papers result from the MA3T project.

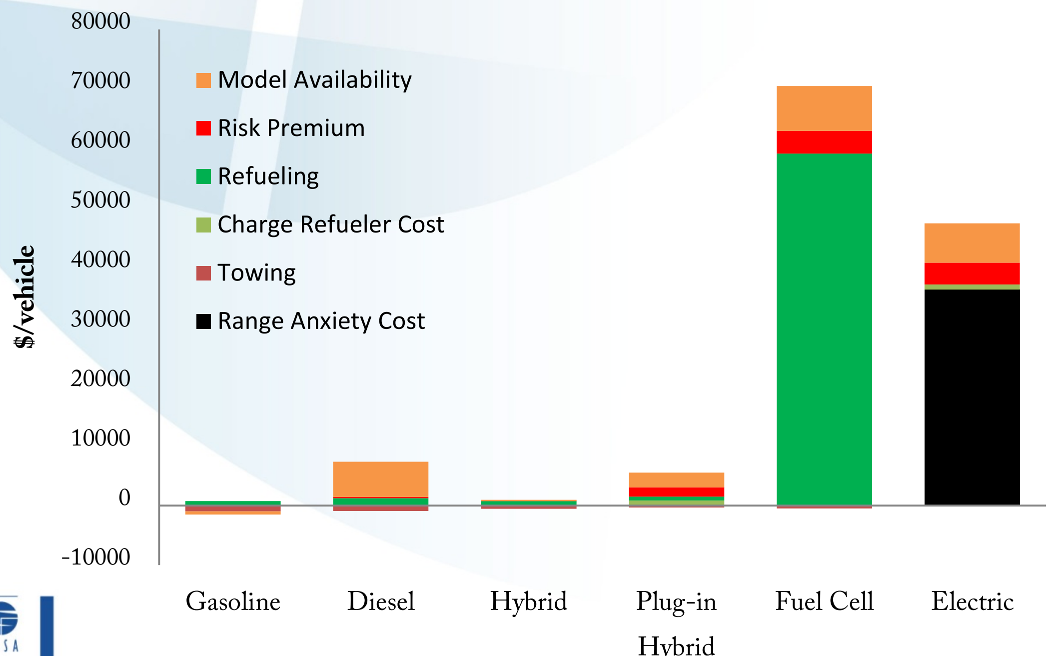
- **Published peer-review articles**
  - Lin, Z., Dong, J., Liu, C., & Greene, D. (2012). Estimation of Energy Use by PHEVs: Validating Gamma Distribution for Random Daily Driving Distance. Transportation Research Record, 2287(1), 37-43.
  - Lin, Z. (2012). Optimizing and Diversifying the Electric Range of Plug-in Hybrid Electric Vehicles for U.S. Drivers. International Journal of Alternative Powertrains, 1(1), 108-194.
  - Dong, J., & Lin, Z. (2012). Within-day recharge of plug-in hybrid electric vehicles: Energy impact of public charging infrastructure. Transportation Research Part D: Transport and Environment, 17(5), 405-412.
  - Lin, Z., & Greene, D. L. (2011). Promoting the Market for Plug-In Hybrid and Battery Electric Vehicles: Role of Recharge Availability. Transportation Research Record, 2252(1), 49-56.
  - Lin, Z., & Greene, D. L. (2011). Assessing Energy Impact of PHEVs: Significance of Daily Distance Variation over Time and Among Drivers. Transportation Research Record, 2252(1), 99-106.
- **Working papers**
  - Lin, Z.. BEV Range Optimization. Submitted and revising.
  - Greene, D.L., Lin, Z, Dong, J. Analyzing the Sensitivity of Hydrogen Vehicle Sales to Consumers' Preferences. Submitted manuscript.
  - Lin, Z, Dong, Greene, D.L.. Hydrogen Vehicles: Impacts of DOE Technical Targets on Market Acceptance and Societal Benefits. Submitted manuscript.
  - Dong, J., Liu, C., Lin, Z.. Charging Infrastructure Planning for Promoting Battery Electric Vehicle Market: An Activity-Based Assessment Using Multiday Travel Data. Working paper
  - Documentation for the Market Acceptance of Advanced Automotive Technologies (MA3T) model. Working paper.

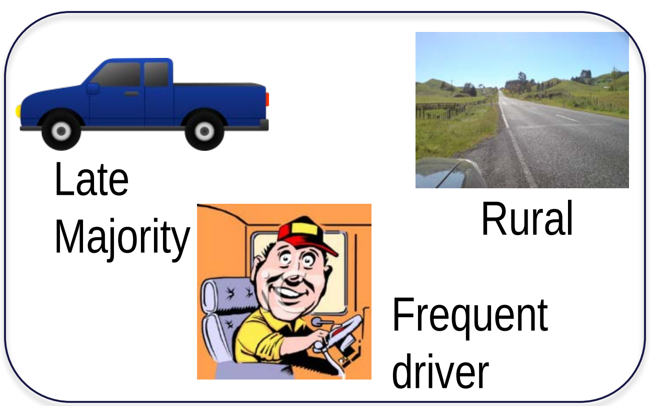
Source: Zhenhong Lin (ORNL)

Components of Disutility Cost (illustrative, 2020)









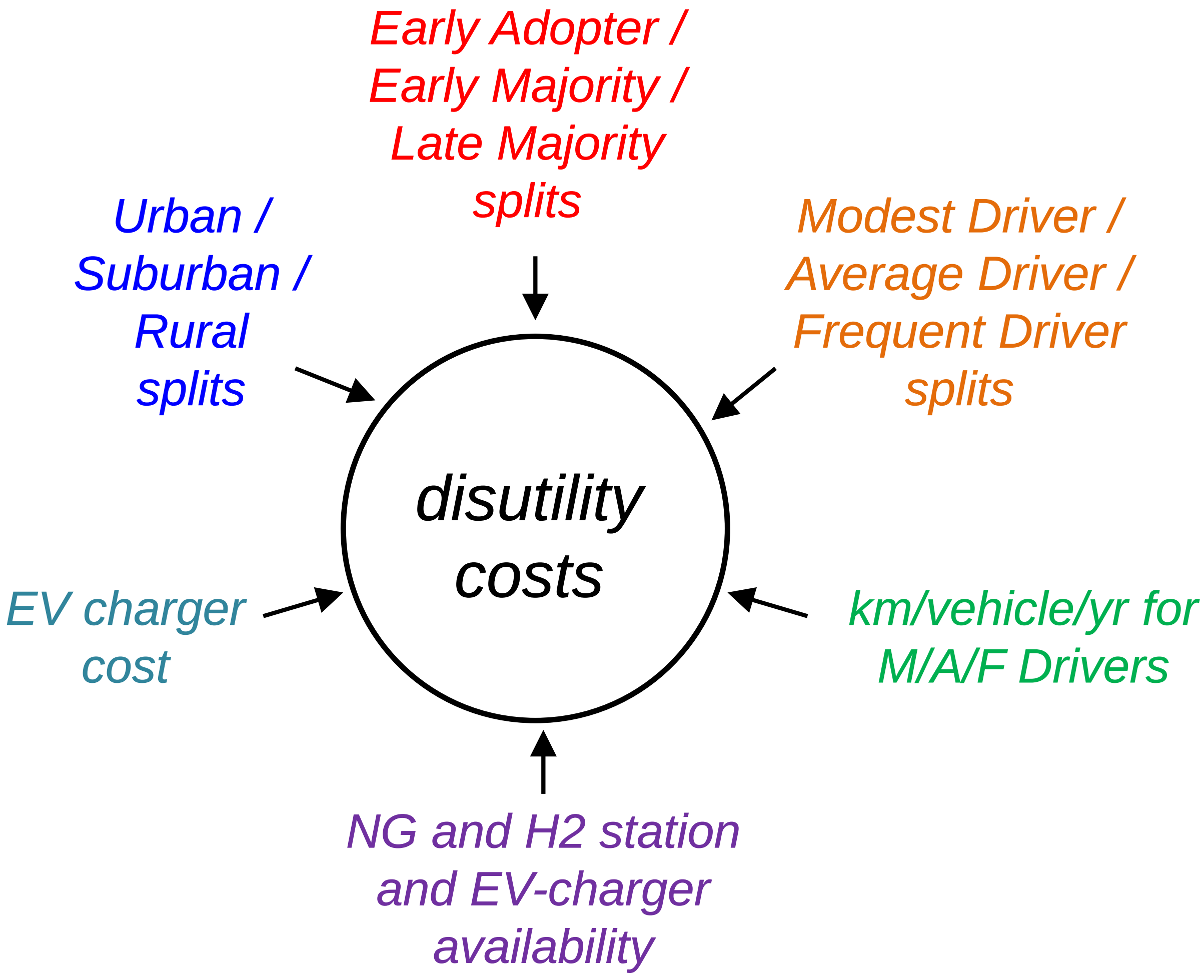
Source: Kalai Ramea (UC-Davis)

Which dimensions are uncertain, and which are the most important?

	Driver Type (km/veh/yr) (Modest / Average / Frequent)	Attitude to New Technology (Early Adopt. / Early Maj. / Late Maj.)	Settlement Type (Urban / Suburban / Rural)
Data availability, quality, uncertainty?	*Adequate*	*Lacking*	*Adequate*
Importance of dimension?	*Very Strong*	*Very Strong*	*Weak*

9 (= 3 x 3)
consumer groups are enough

Key determinants of disutility costs



All of these things could/should vary by region and over time. Also by scenario.

Workplan Proposal for Task 3.1

Year:	2014								2015											
Month:	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Project Month:	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Review of microstudies & Report on microstudies																				
Pioneering implementation in MESSAGE, IMAGE																				
Distribution of disutility cost data to other teams																				
Implementation in TIAM-UCL, WITCH, ReMIND, GEM-E3																				
Run scenarios based on updated model implementations																				
Multi-model transport paper																				

	Deadline for deliverable
	Work by IIASA
	Work by other teams
	Report/paper writing

Deliverable 3.2

Improving the behavioural realism of integrated assessment models of global climate change mitigation: a research agenda

(C. Wilson, H. Pettifor, D. McCollum)

- Submitted in Month 19 (July 2014), instead of originally planned delivery date of Month 30 (~June 2015)
- Now online at: www.fp7-advance.eu
- Derivative papers in preparation; insights currently feeding into modeling

ADVANCE

Project No 308329

ADVANCE
Advanced Model Development and Validation for Improved Analysis of Costs and Impacts of Mitigation Policies

FP7-Cooperation-ENV
Collaborative project

DELIVERABLE No 3.2
Report on micro-studies on behavioural changes and socio-spatial heterogeneities

Due date of deliverable: 30 June 2015
Actual submission date: 21 July 2014

Start date of project: 01/01/2013
Duration: 48

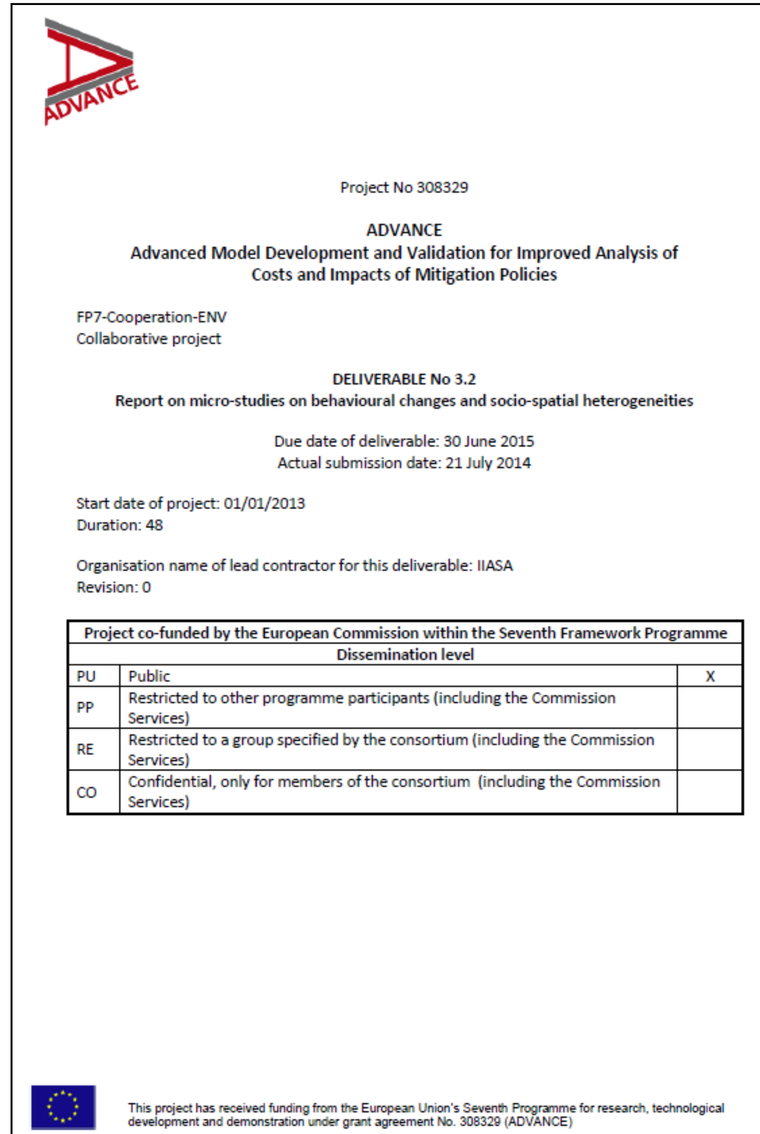
Organisation name of lead contractor for this deliverable: IIASA
Revision: 0

Project co-funded by the European Commission within the Seventh Framework Programme		
Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 308329 (ADVANCE)

Deliverable 3.2

- Specific focus on factors influencing alternative fuel vehicle purchase decisions
- Identifies importance and challenges for introducing behavioural features into IAMs.
  - typology of behavioural features
  - synthesis of current modelling approaches
  - empirical basis for behavioural features (focusing on AFVs)
    - discrete choice experiments (n=16)
    - social influence studies (n=72)



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IIASA

Motivation & Background

How important and/or useful for IAMs are different behavioural features in discrete choice models of vehicle adoption?

Behavioural Feature		Effect size / influence on choice
Heterogeneous decision makers	Age	high
	Value orientation	medium – low
	Gender	medium
	Environmental Awareness	high - medium
	Education	medium-low
Non-optimising heuristics	Driving practices	low
Non-monetary benefits	Refuelling network	high
	CO2 emissions	high - medium
	Range, battery time, warranties	high
Risk preferences (discount rates)	Refuelling location	high - medium
	Vehicle range	high - medium
	Fuel savings	medium
	Social influences	high - medium
Social influences	Neighbourhood effects	high - medium
Contextual constraints	Refuelling density	high
	Refuelling location	high
	Incentives	high

Source: Pettifor and Wilson (UEA)