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

science for global insight

Improving the behavioral realism of global integrated assessment models: an application to consumers' vehicle choices

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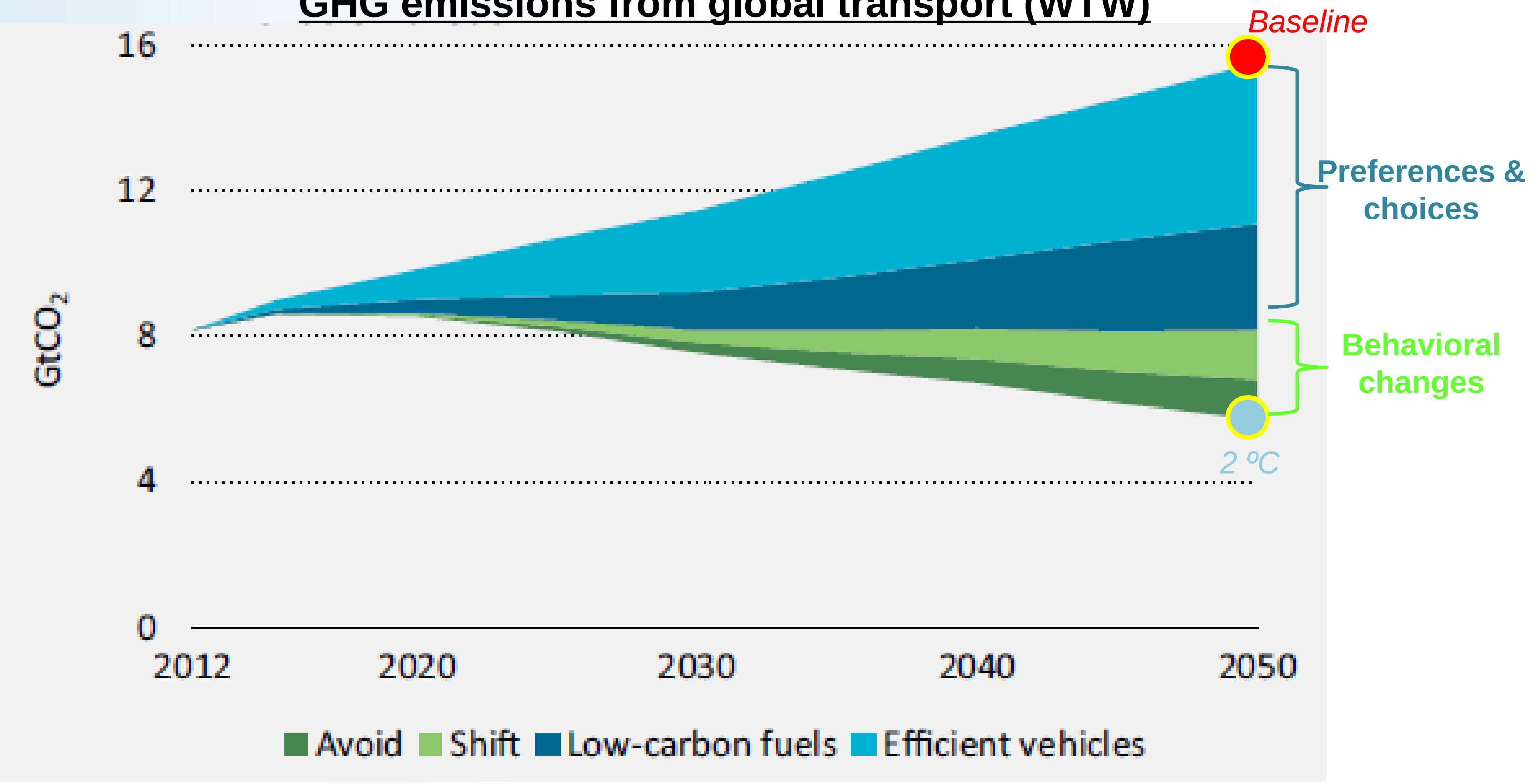
There's more to modeling transport "behavior" than just mode choice

GHG emissions from global transport (WTW)



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

ADVANCE project

- EU-FP7 project funded for four years (01/2013 – 12/2016)
  - 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)

ADVANCE is all about developing next-generation models…

- **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, non-energy infrastructure, 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-monetary) preferences for advanced vehicle adoption in models

New answers to novel questions

- Quantify the climate policy cost implications of capturing these preferences
- Understand which policy levers can impact preferences over time, by how much, and for whom

Research Questions

- **Which consumer/driver attributes could/should be incorporated into IAMs in order to improve transport sector heterogeneity and behavioral realism?**
- **How are IAM transport scenarios impacted by these improved representations of heterogeneity and behavior? (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?**

Evidence from the empirical literature

(1) How important and/or useful for IAMs are different behavioral features for vehicle adoption?
(2) Which features can be feasibly implemented in global models?

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
	CO_2 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)

Modeling approach (two-stage)

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

2. **Monetize non-cost vehicle purchase considerations by bringing "disutility costs" from a vehicle choice model into MESSAGE**

External collaborators

International Institute for Applied Systems Analysis

IIASA

ADVANCE

Tyndall°Centre®
for Climate Change Research

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

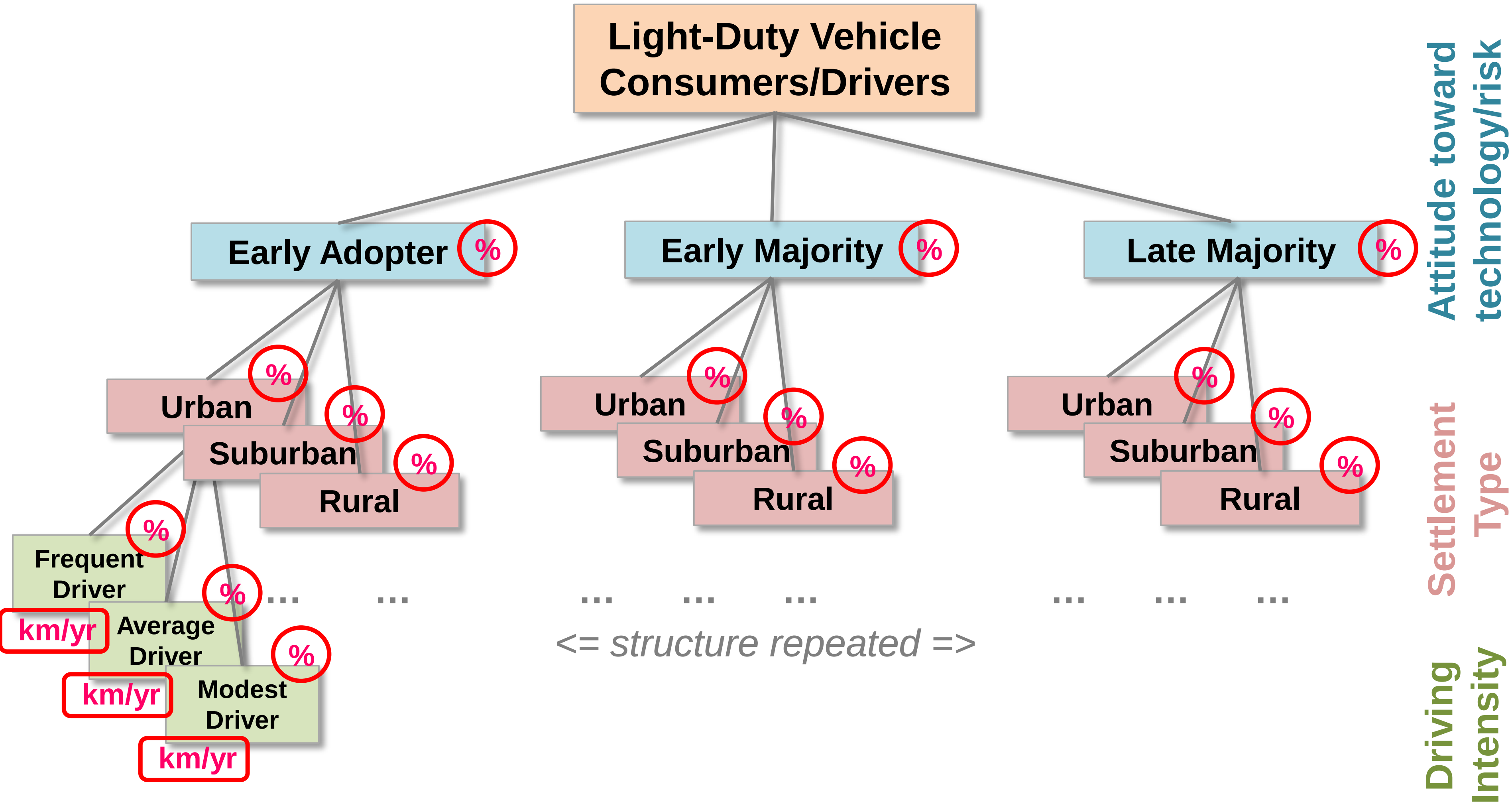
UCDAVIS
UNIVERSITY OF CALIFORNIA

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

OAK RIDGE
National Laboratory

(Z. Lin, D. Greene)

Disaggregation of LDV market

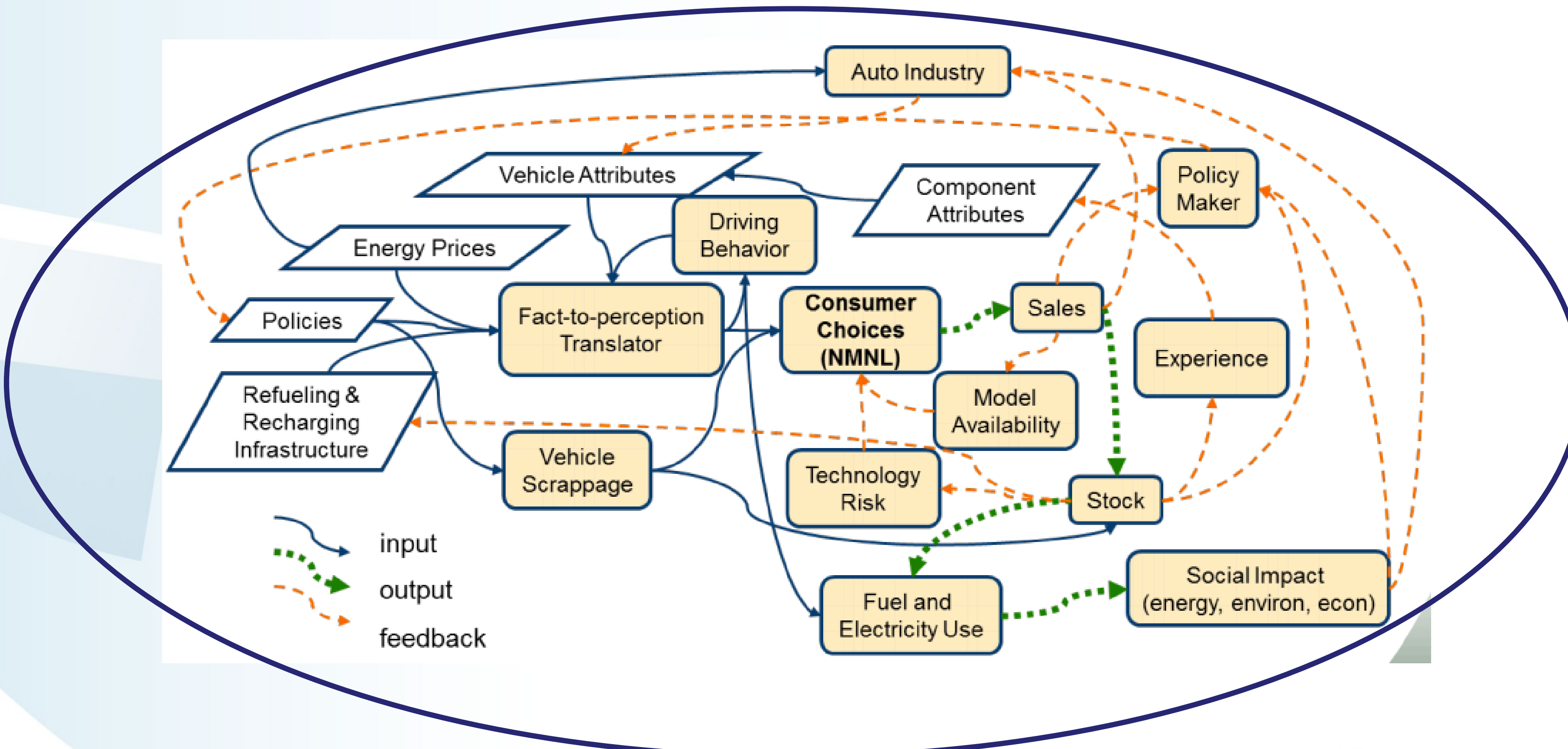


27 consumer groups in total (= 3 x 3 x 3)

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

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



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

Disutility costs specific to consumers/technologies

Units: 1000$/vehicle
Year: 2020

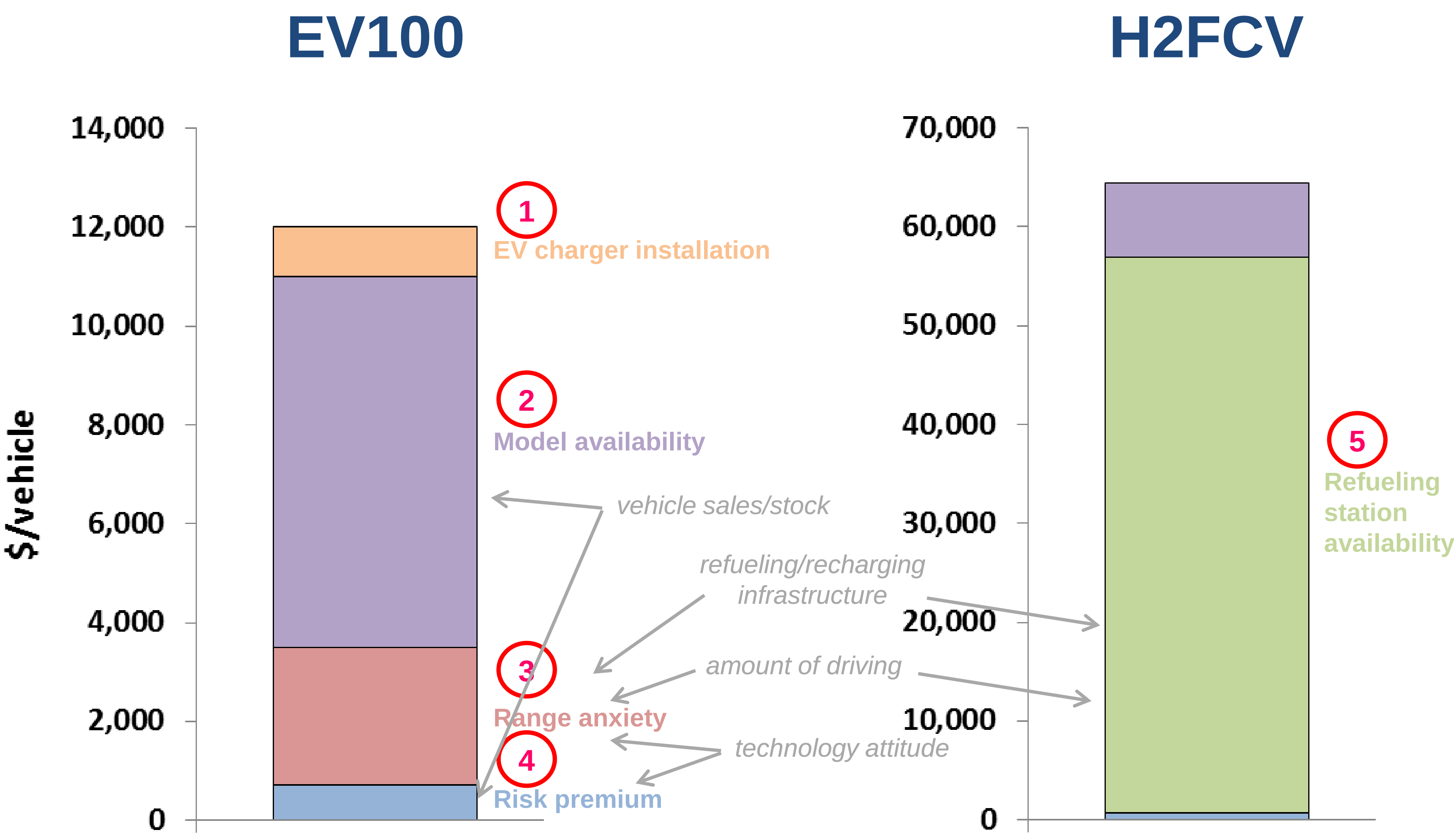
MA3T_ID	MA3T_tech_name	RUEAA	RUEAM	RUEAF	RUEMA	RUEMM	RUEMF	RULMA	RULMM	RULMF	SUEAA	SUEAM
1	Gasoline ICE Conv	0.45	0.00	1.20	0.45	0.00	1.20	0.45	0.00	1.20	0.50	0.03
2	Diesel ICE Conv	5.89	5.17	7.09	6.52	5.79	7.72	7.13	6.41	8.33	5.98	5.21
3	Natural Gas ICE Conv	13.47	9.64	19.78	16.50	12.67	22.81	19.48	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

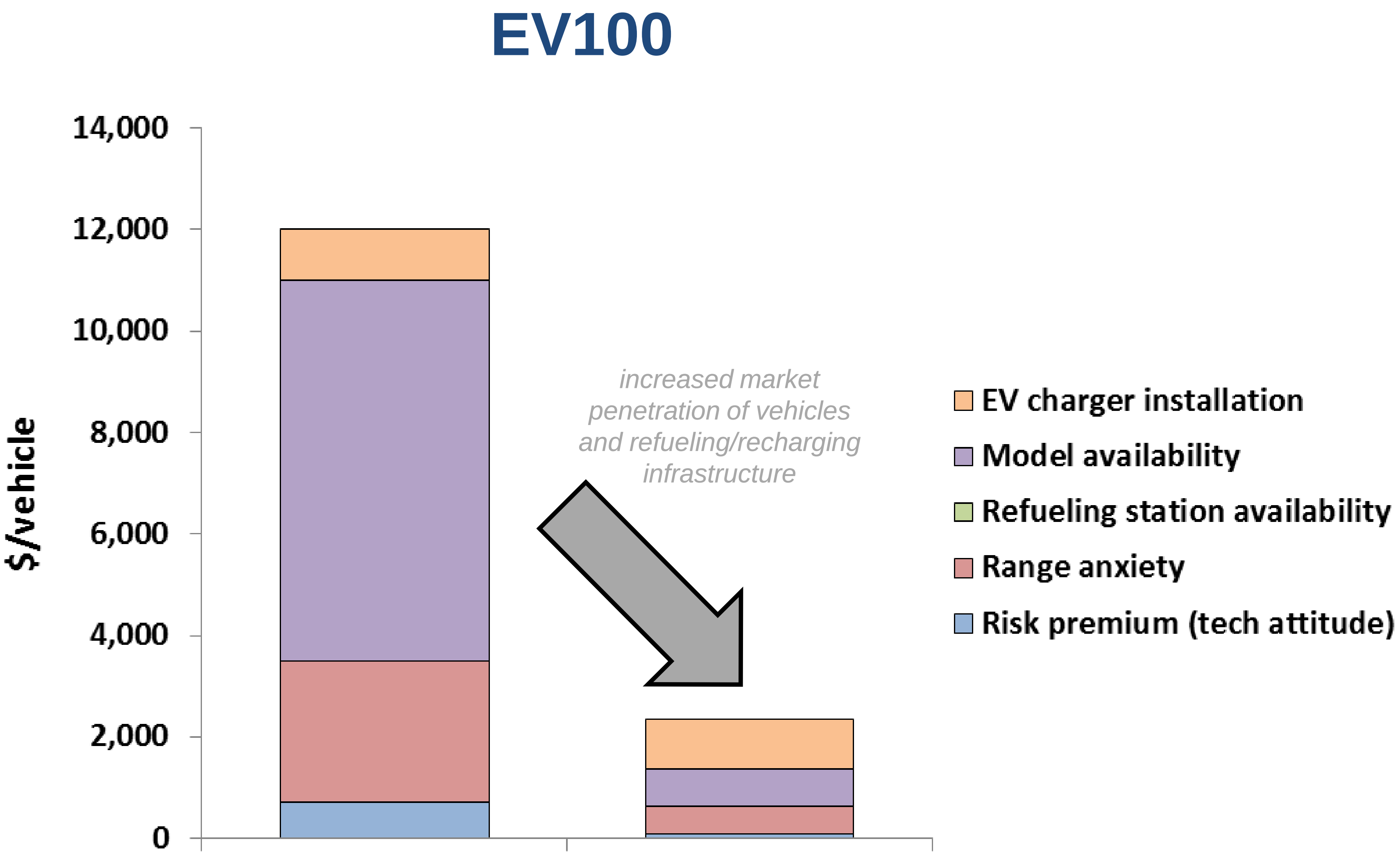
These disutility costs would be added to the standard capital costs of vehicles in models (in $/vehicle).

Breakdown of disutility cost sub-components



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

Breakdown of disutility cost sub-components



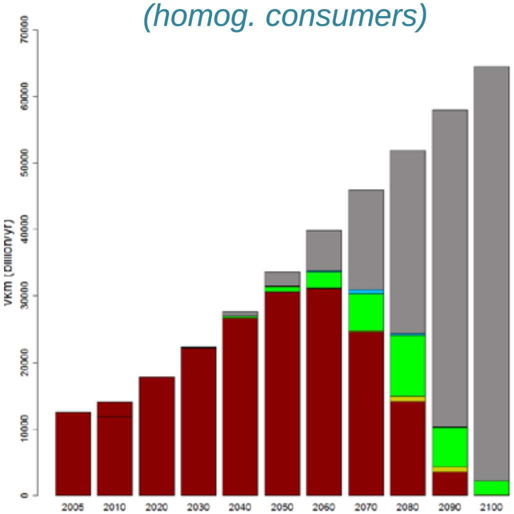
Region: NORTH_AM; Year: 2030; Group: UREMA

LDV effects: considering non-monetary preferences leads to lower/slower uptake of AFVs

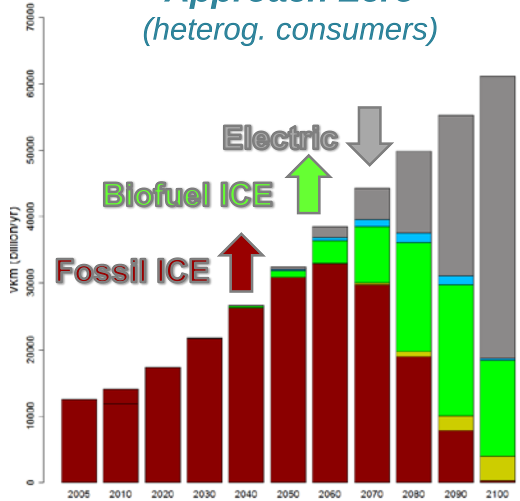
Scenario: ~600 ppm CO_2eq in 2100 (2.7 ºC)

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

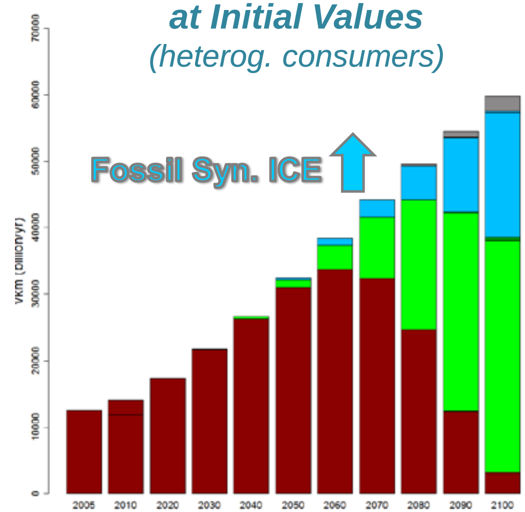
Disutility Costs Zero
(homog. consumers)

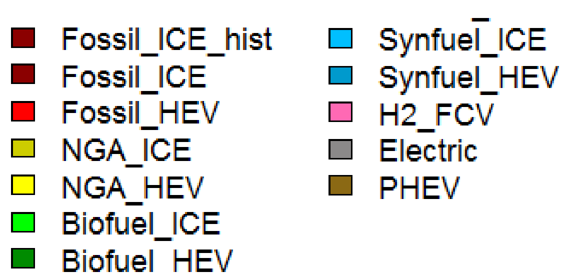


Disutility Costs Approach Zero
(heterog. consumers)

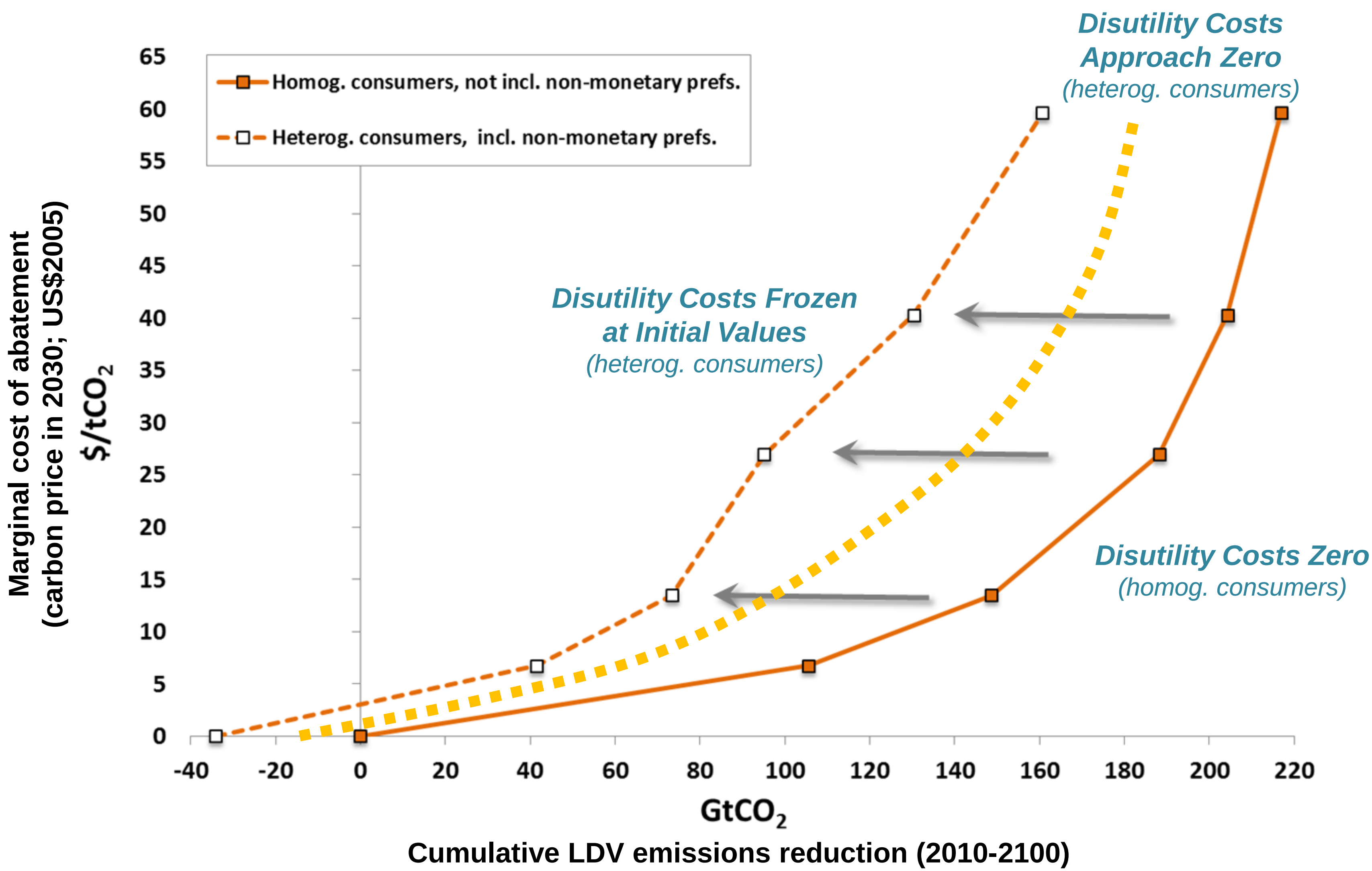


Disutility Costs Frozen at Initial Values
(heterog. consumers)





System-wide effects: shift in the MAC curve for LDV CO_2 abatement (Global)



Conclusions

1. **LDV mitigation of CO_2 likely to require stronger price-based incentives than IAMs typically suggest**

2. **Non-priced based policies needed as a complement (e.g., vehicle/fuel emissions standards, mandates and subsidies; refueling/recharging infrastructure support)**

3. **"Behavioral IAMs" can assess a much wider suite of policies than before (not only price-based policies) => crucial for future policy analyses**

4. **Modeling behavior is not easy => inter-disciplinary; requires that modelers work closely with social scientists**

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Questions?

Comments?