Mobility 2030: Human Factors, Technology, and Climate Constraints

SATW Congress
August 29-30, 2008
Yverdon-les-Bains

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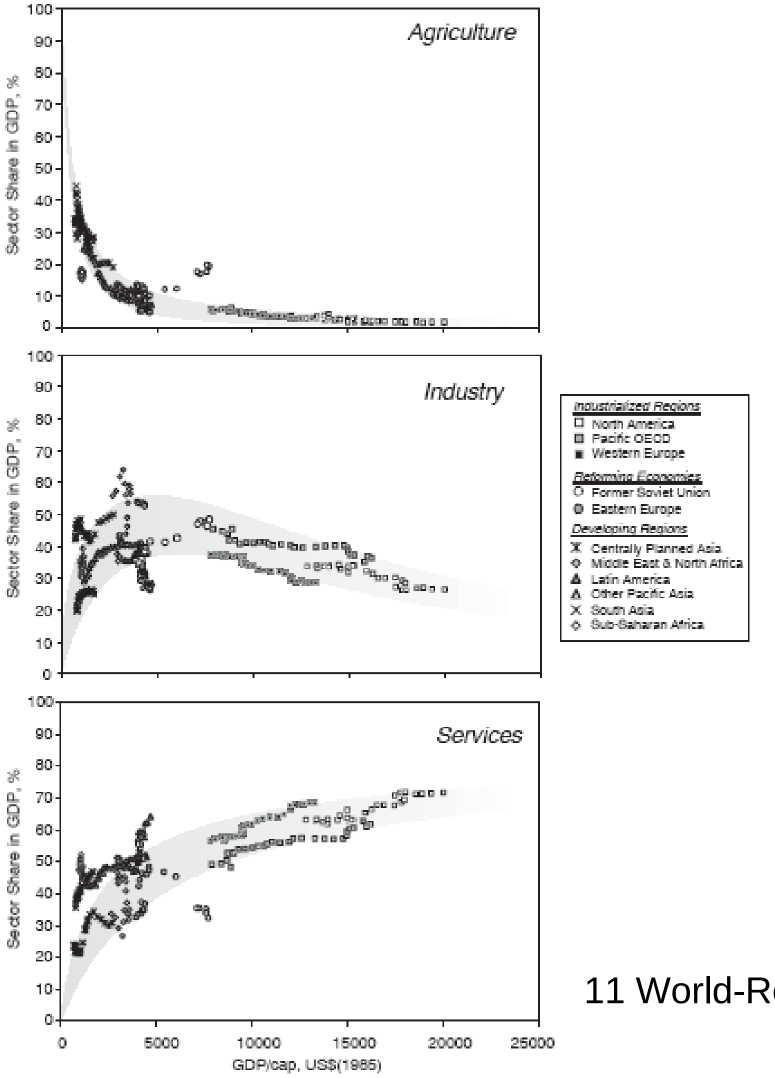
STRUCTURAL CHANGE IN THE ECONOMY



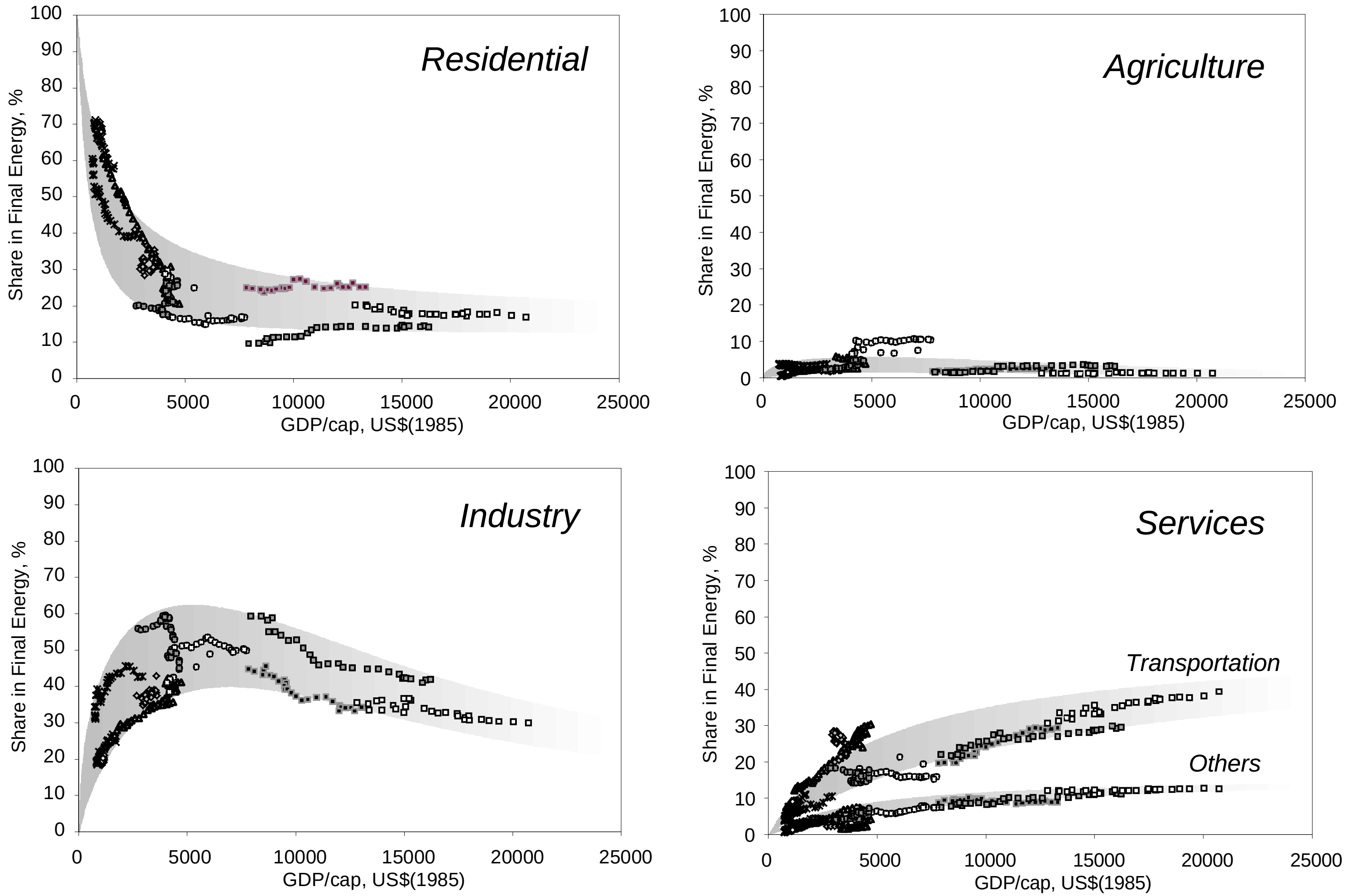
<u>Sector shifts due to:</u>

1. Different income elasticities for goods and services produced by each of the three sectors
2. Competitive advantage for each of the sector's industries
3. Changing needs of society

11 World-Regional Data series: 1971 - 1998

Source: Schäfer A., 2005, Structural Change in Energy Use, *Energy Policy*, 33(4): 429-437.

... AND IN THE ENERGY SYSTEM



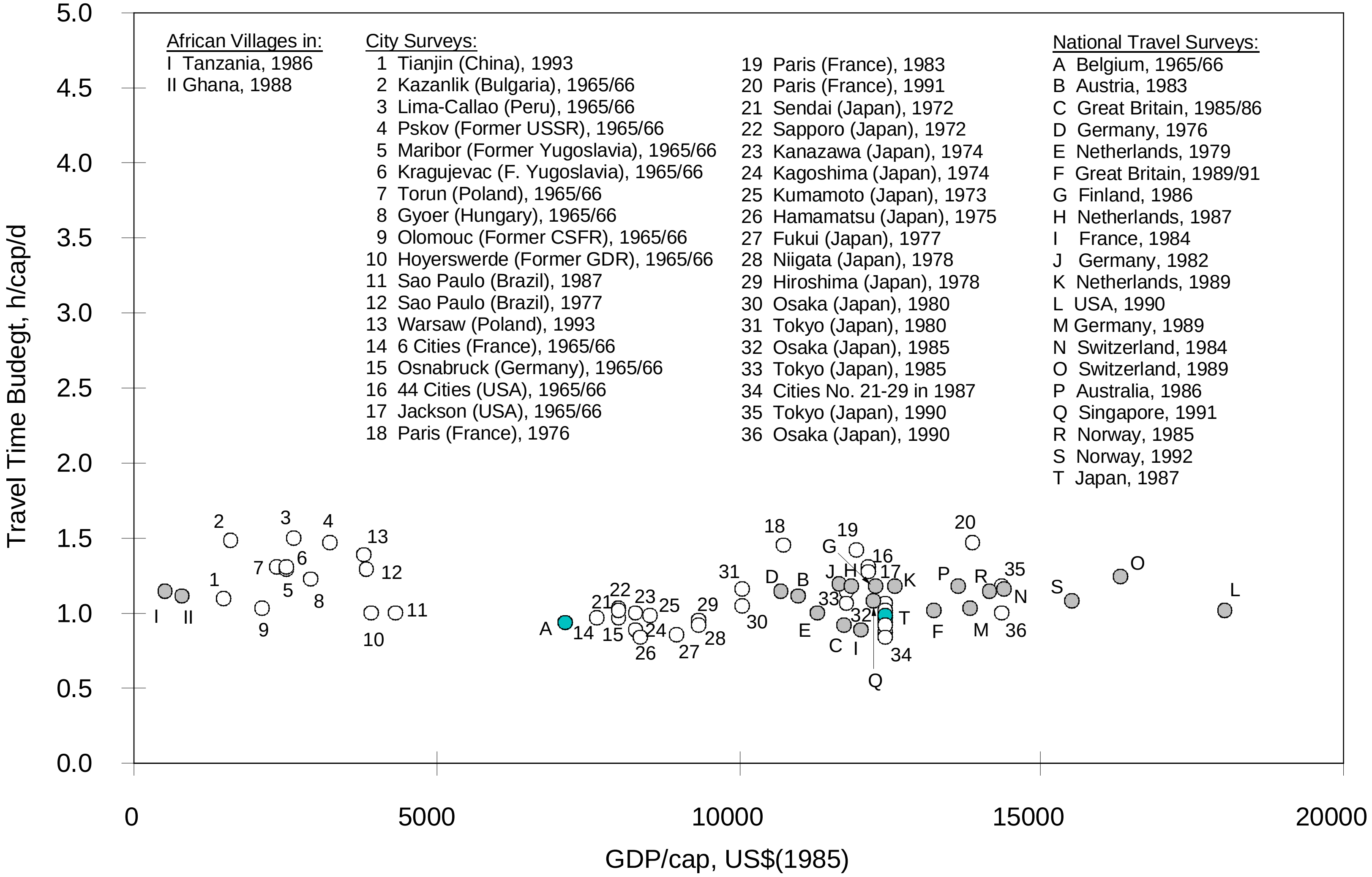
Source: Schäfer A., 2005, Structural Change in Energy Use, *Energy Policy*, 33(4): 429-437.

GREENHOUSE GAS EMISSIONS: IDENTITY

$$GGE = \frac{GGE}{E} \cdot \underbrace{\frac{E}{VKT} \cdot \frac{VKT}{PKT}}_{\frac{E}{PKT} = Energy\ Intensity} \cdot PKT$$

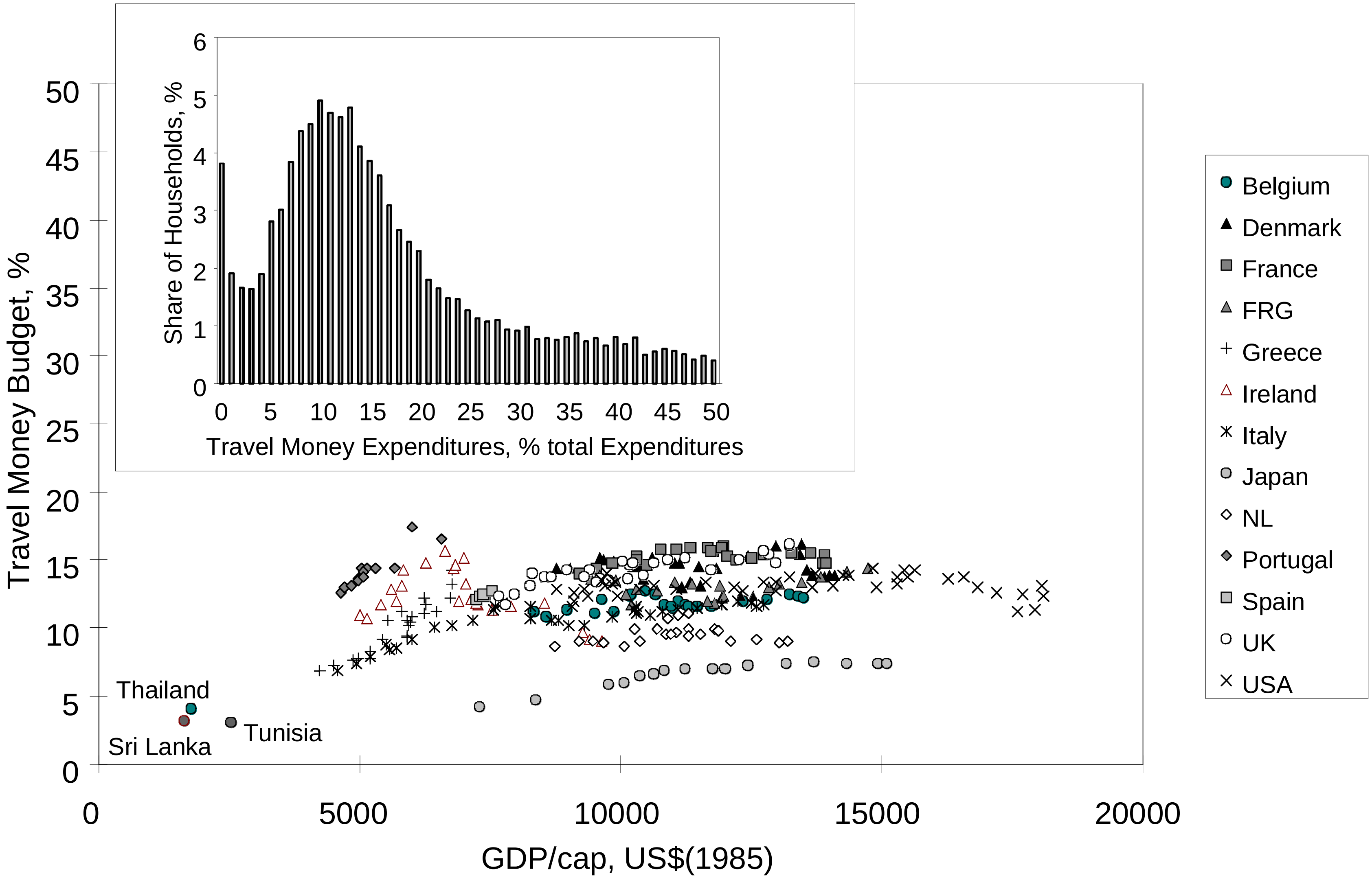
TRAVEL BUDGETS: MICROMOTIVES ...

... AND MACROBEHAVIOR: TTB



Source: Schäfer A. and D.G. Victor (2000) The Future Mobility of the World Population, *Transportation Research A*, 34(3): 171-205

AGGREGATE TRAVEL BEHAVIOR: TMB



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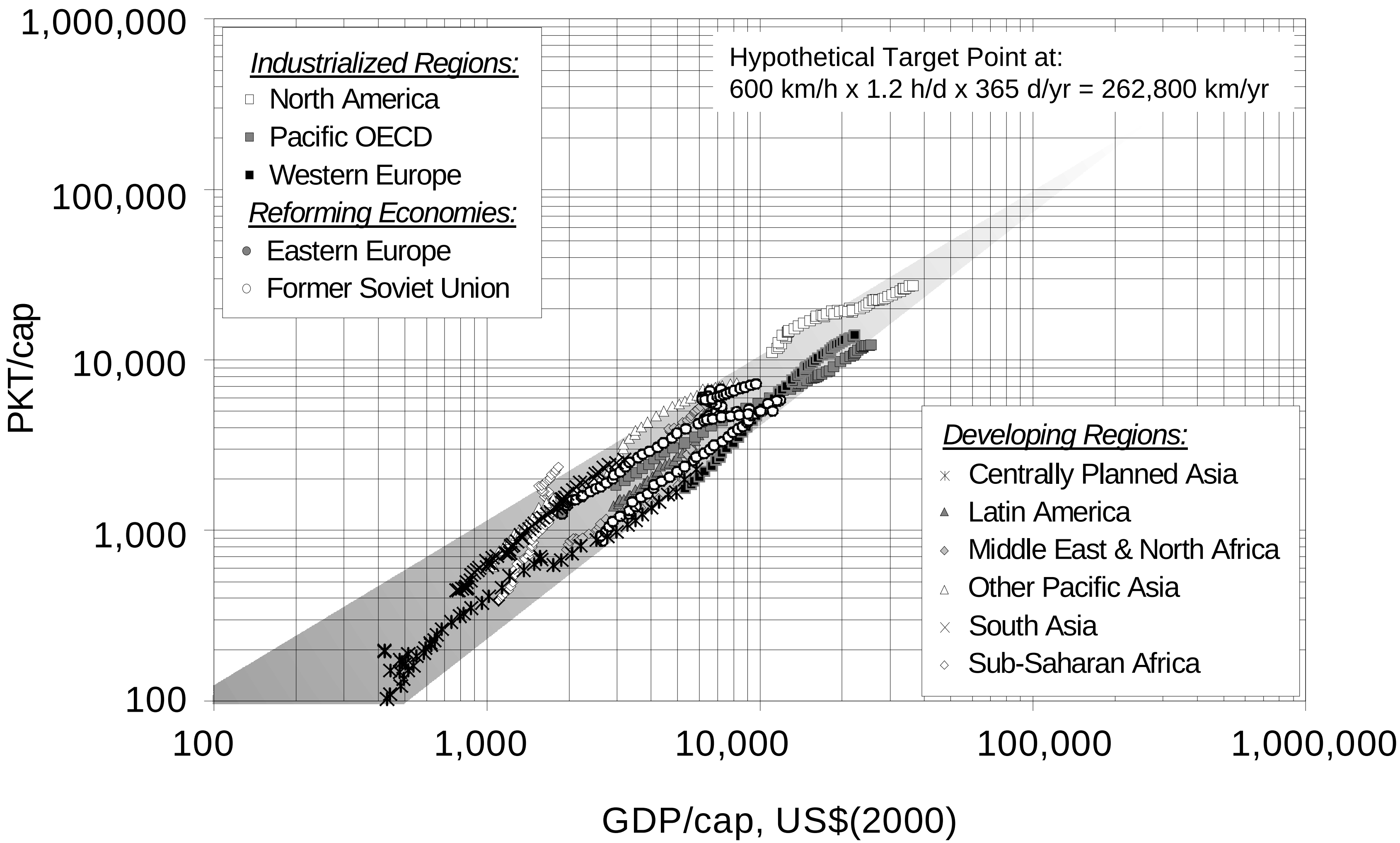
GLOBAL MOBILITY TRENDS (1950-2005)



Source: Schäfer A., Heywood J.B., Jacoby H.D., Waitz, I.A., 2009. Transportation in a Climate-Constrained World, MIT Press.

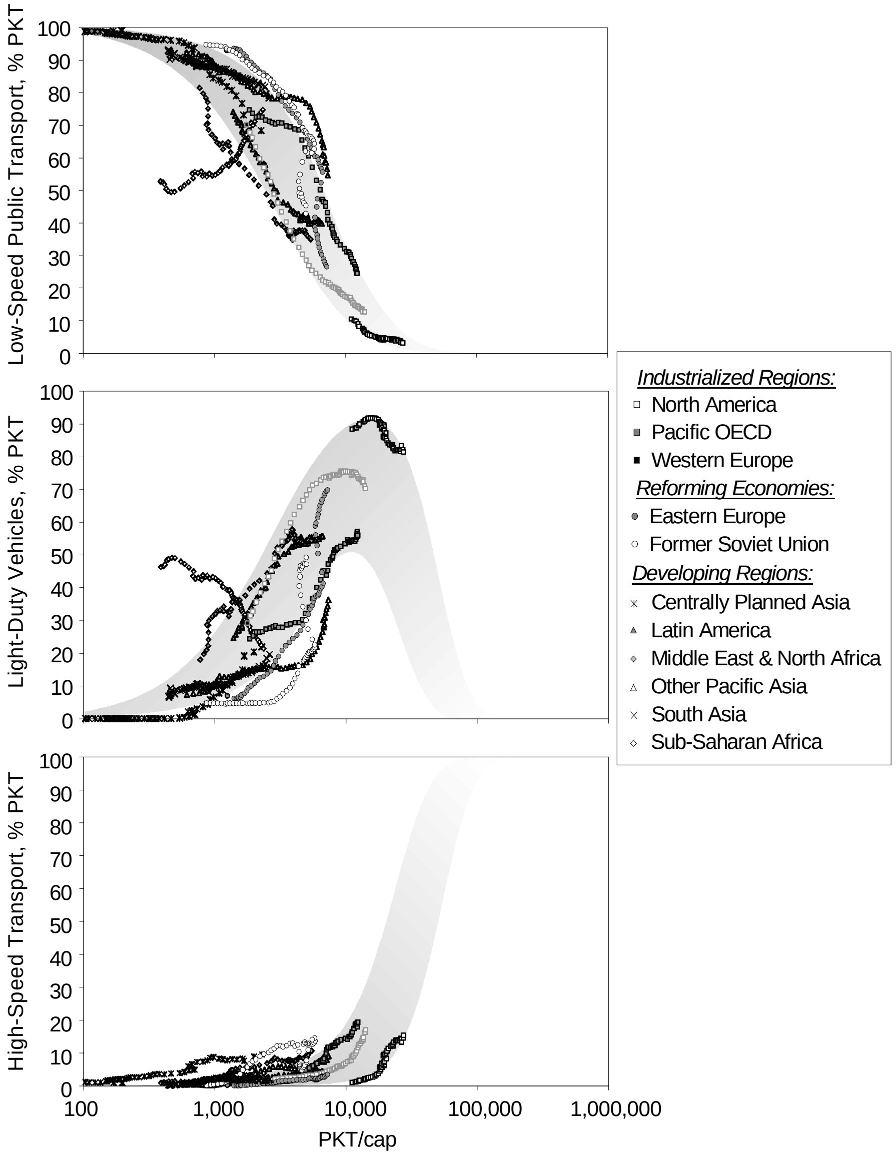
GLOBAL MOBILITY (BILL. PKM)

	1950	2005	2030	
			SRES-B1	EPPA-Ref
Total Industrialized	2,660	17,600	26,600	31,800
North America only	1,860	9,120	13,900	15,400
Western Europe only	625	6,630	10,100	13,000
Reforming Economies	254	2,260	3,430	3,480
Developing Countries	643	18,100	58,200	34,100
World	3,560	38,000	88,200	69,400

Note: Economic growth rates underlying mobility projections are based upon the IPCC SRES-B1 scenario and the MIT EPPA-Ref case.

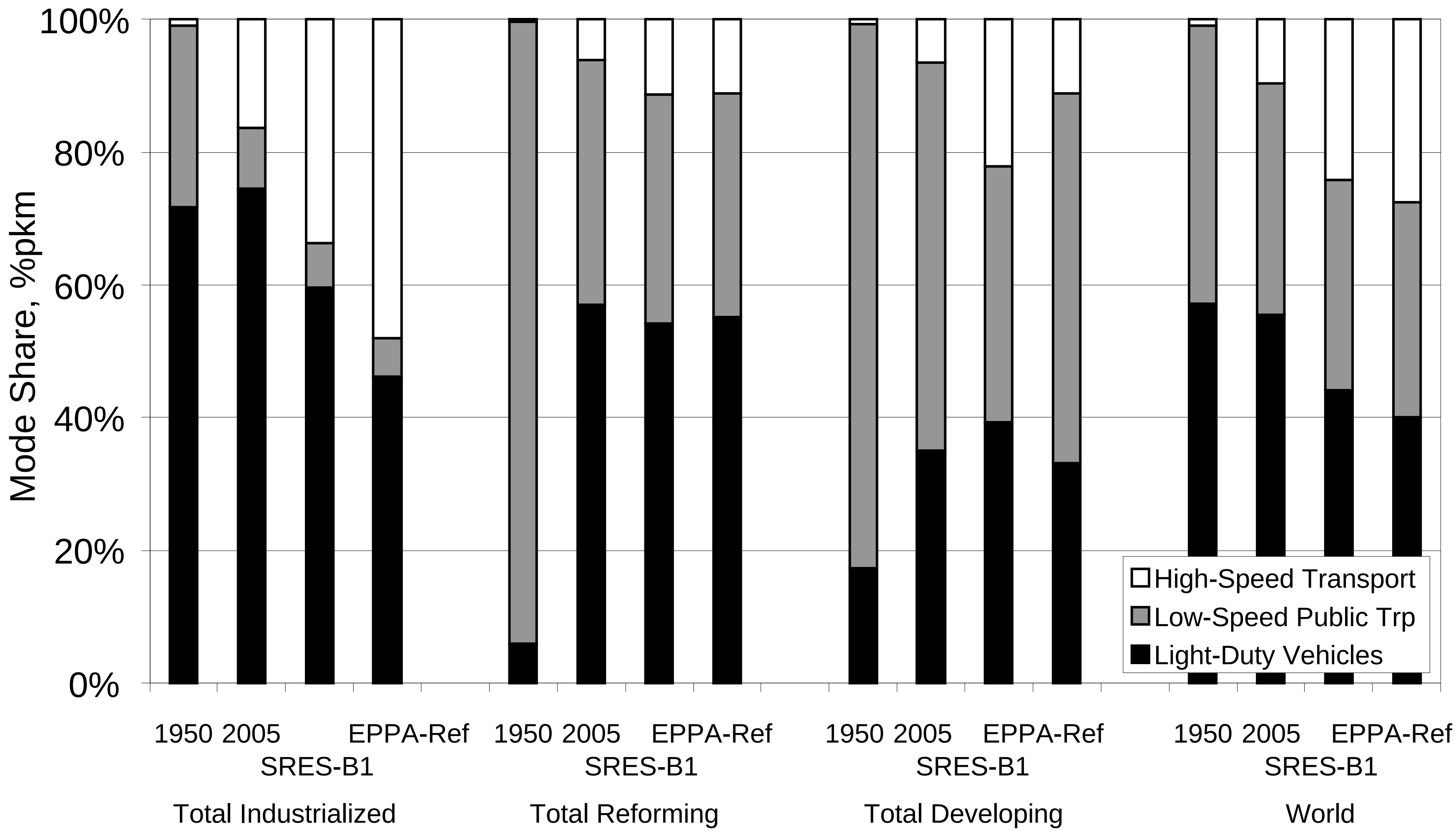
Source: Schäfer A., Heywood J.B., Jacoby H.D., Waitz, I.A., 2009. Transportation in a Climate-Constrained World, MIT Press.

SHIFT FROM SLOW TO FAST (1950-2005)



Source: Schäfer A., Heywood J.B., Jacoby H.D., Waitz, I.A., 2009. Transportation in a Climate-Constrained World, MIT Press.

MODE SHARES: 1950, 2005, AND 2030



Note: Underlying travel time budget = 1.2 hours per person per day

Source: Schäfer A., Heywood J.B., Jacoby H.D., Waitz, I.A., 2009. Transportation in a Climate-Constrained World, MIT Press.

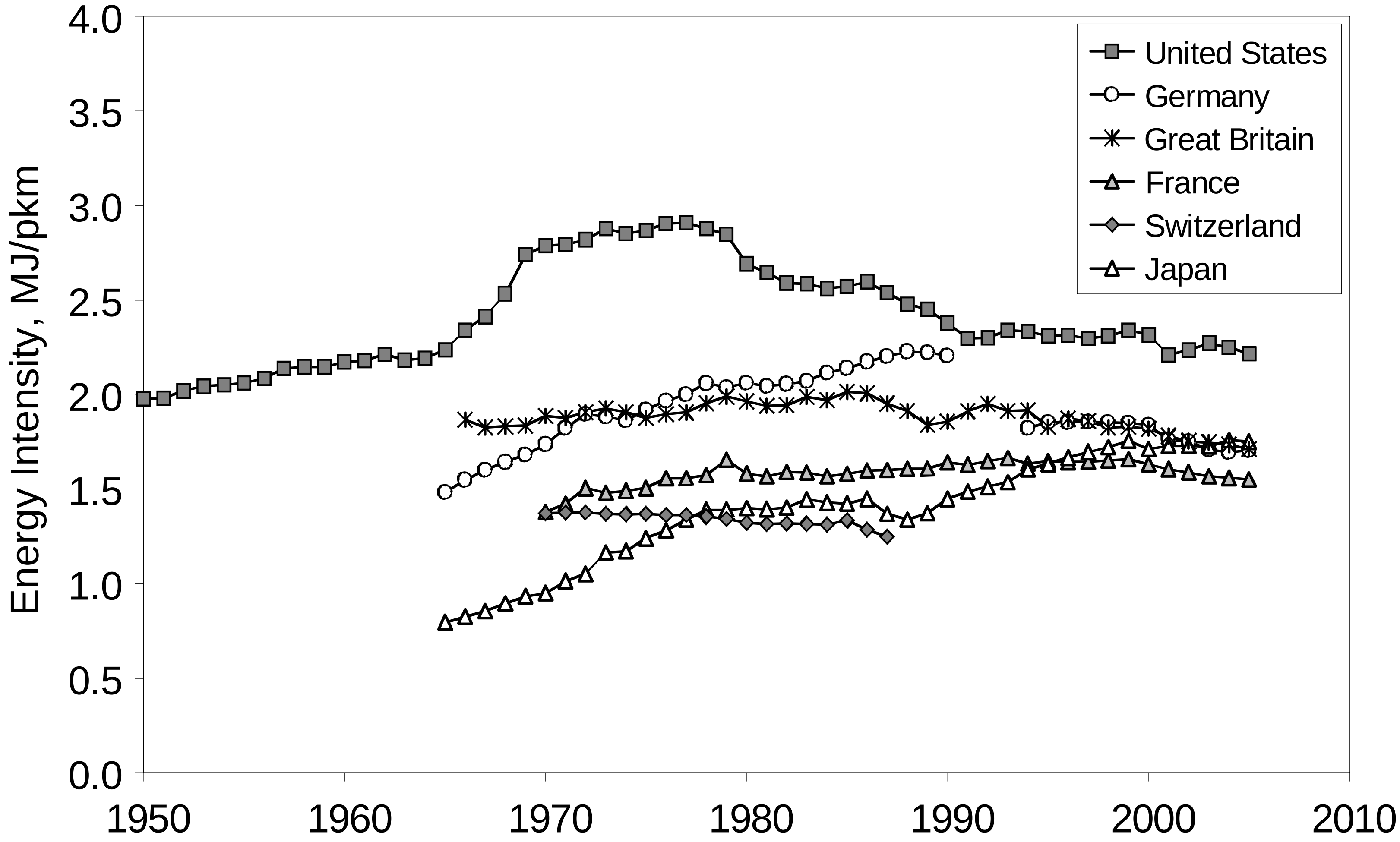
CAN GROWTH IN WORLD PKT ENDURE?

- Availability of / access to high-speed transport systems ($\Rightarrow$ air taxis, supersonic transport)
- Traffic congestion ($\Rightarrow$ innovation and adaptation)
- Telecommunication ($\Rightarrow$ complement vs. substitute)
- Energy resources ($\Rightarrow$ huge resource base, geographic location of reserves, low and declining consumer response to oil price increase)
- Environment ($\Rightarrow$ impact of global warming policies)

GGE IDENTITY REVISITED: E/PKT

$$GGE = \frac{GGE}{E} \cdot \underbrace{\frac{E}{VKT} \cdot \frac{VKT}{PKT}}_{\frac{E}{PKT} = Energy\ Intensity} \cdot PKT$$

TRENDS IN ENERGY INTENSITY



Source: Schäfer A., Heywood J.B., Jacoby H.D., Waitz, I.A., 2009. Transportation in a Climate-Constrained World, MIT Press.

OFFSETTING TRENDS

+ E/PKT

Shift toward faster and more energy-intensive modes

Trend toward larger and more powerful light-duty vehicles

Declining occupancy rates in light-duty vehicles

Shift toward smaller aircraft

Changes in aircraft stage

length toward extremes

- E/PKT

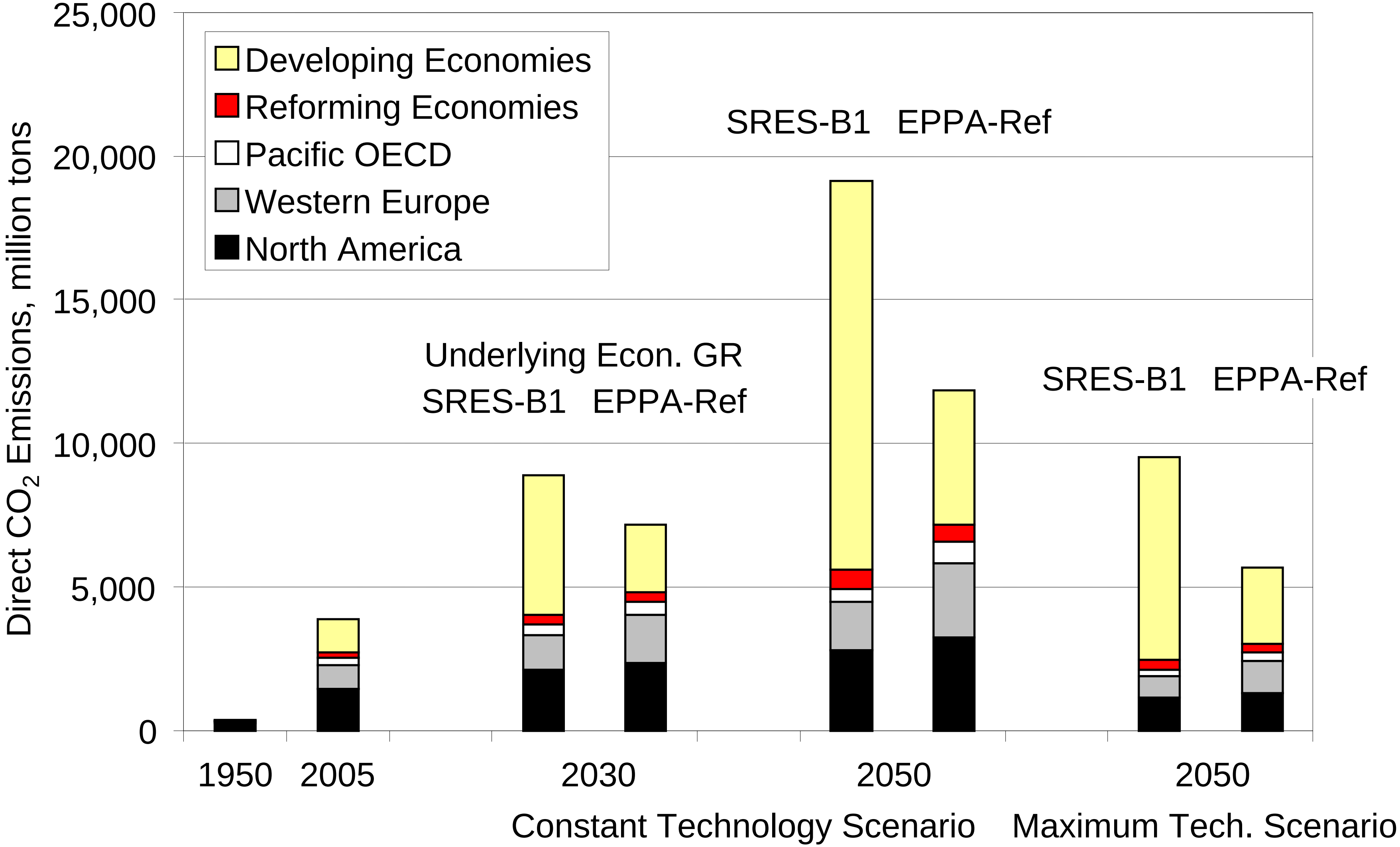
Fuel efficiency improve-ments of all modes

Rising occupancy rates (passenger load factors) in air traffic

OPPORTUNITIES FOR REDUCING E/PKT

- Reducing driving / flight resistances
- Increasing powertrain / aero-engine efficiency
- Potential: reduction of E/VKT by about half of average new 2030 vehicle compared to average new ground / air vehicle today
- Fleet turnover would then translate these new technology characteristics into fleet characteristics by 2050

WORLD PAX TRAVEL: CO_2 EMISSIONS



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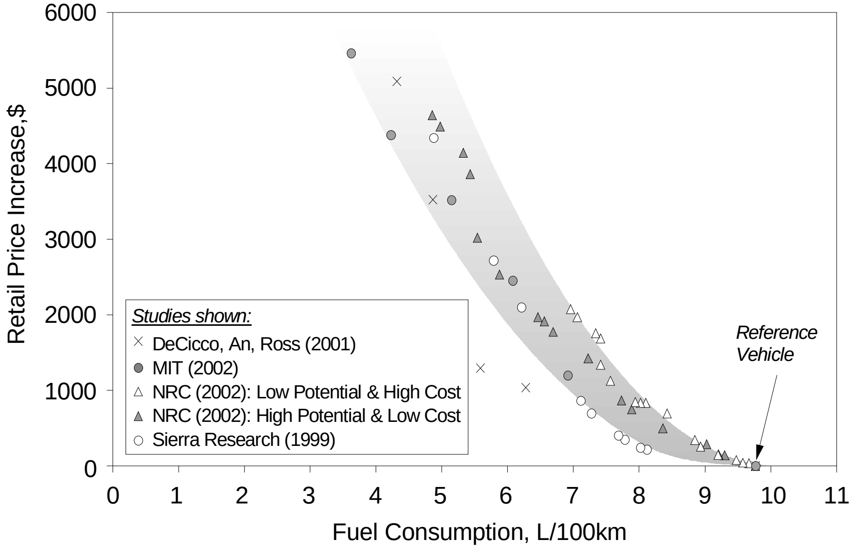
BARRIERS TO GHG EMISSION REDUCTIONS



- High extra costs for significant reductions in fuel consumption (all other factors equal)
- High implicit consumer discount rates (≈ 3 year amortization period for fuel-saving technology)
- Long time scales for “sensible” fleet impact of new, fuel-saving technology (20 – 35 years, depending on technology; 50+ years for low- fuels)
- Thus, need for policy measures

Chart: Schäfer A., Heywood J.B., Jacoby H.D., Waitz, I.A., 2009. Transportation in a Climate-Constrained World, MIT Press.

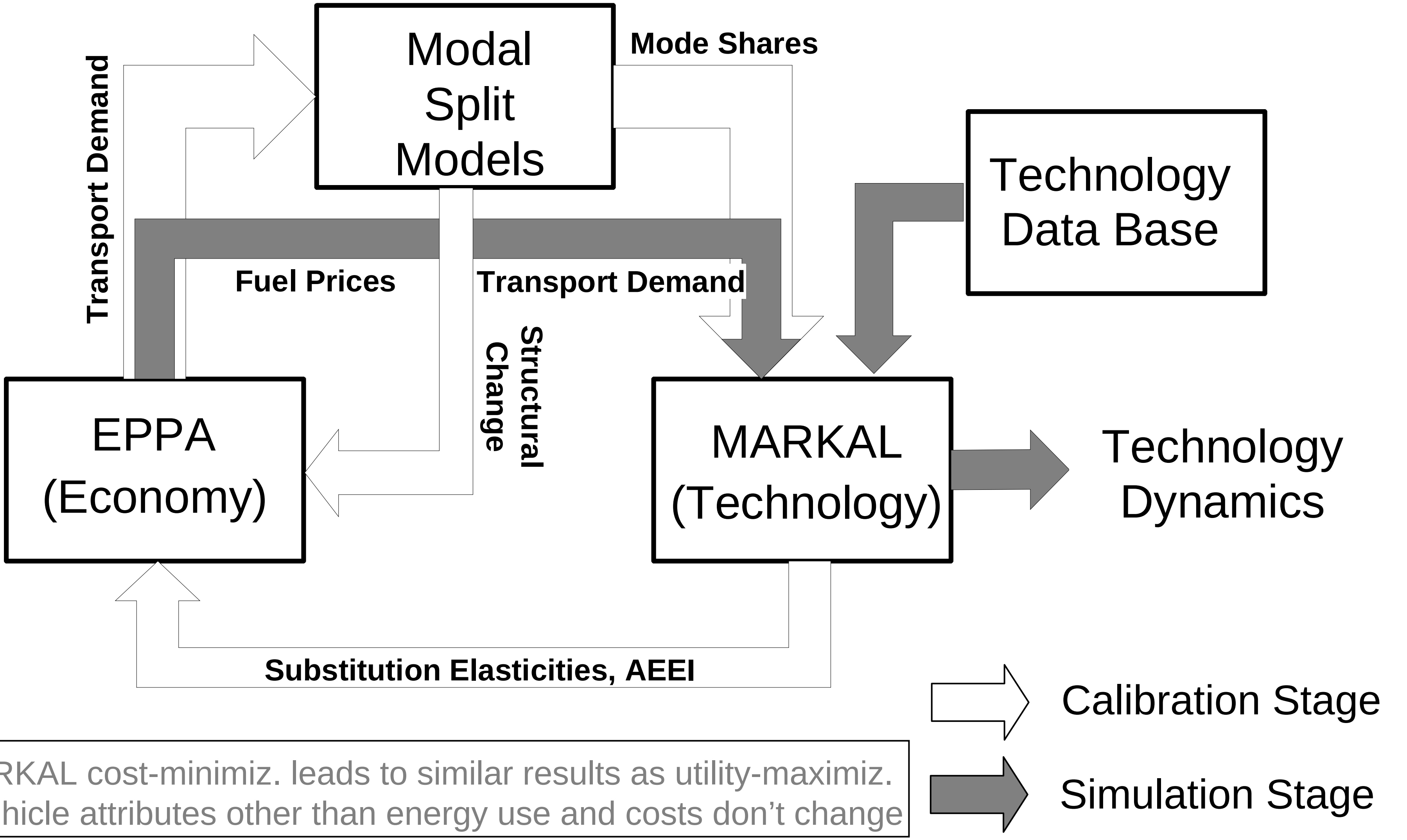
GGE IDENTITY AGAIN: POLICIES

$$GGE = \frac{GGE}{E} \cdot \underbrace{\frac{E}{VKT} \cdot \frac{VKT}{PKT}} \cdot PKT$$

$$\frac{E}{PKT} = Energy\ Intensity$$

- Market-based versus regulatory
- Criteria include economic efficiency, transparency, equity, consumer acceptance, time-to-impact
  - Subject to other environmental impacts, interaction with existing policies, international competition, foreign policy implications of oil imports, etc.
- Economy-wide carbon tax or cap-and-trade system most efficient, also affects “3 out of 3”
- Impact on travel demand differs, but very small

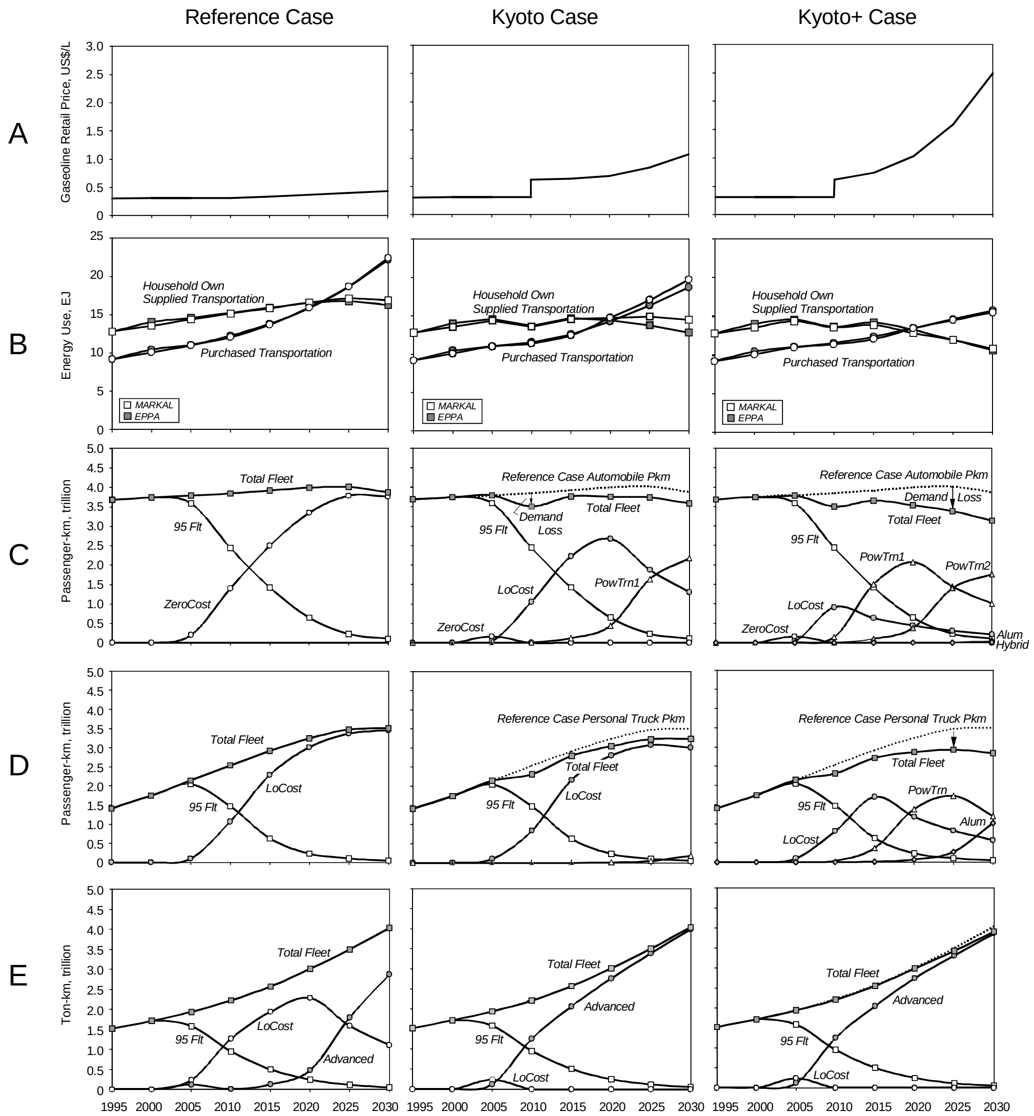
EXAMPLE: ECONOMY-WIDE CARBON TAX



MARKAL cost-minimiz. leads to similar results as utility-maximiz. if vehicle attributes other than energy use and costs don't change

Source: Schäfer A., Jacoby H.D., Technology Detail in a Multi-Sector CGE Model: Transport under Climate Policy, *Energy Economics*, 27(1): 1-24.

VEHICLE TECHNOLOGY-DYNAMICS

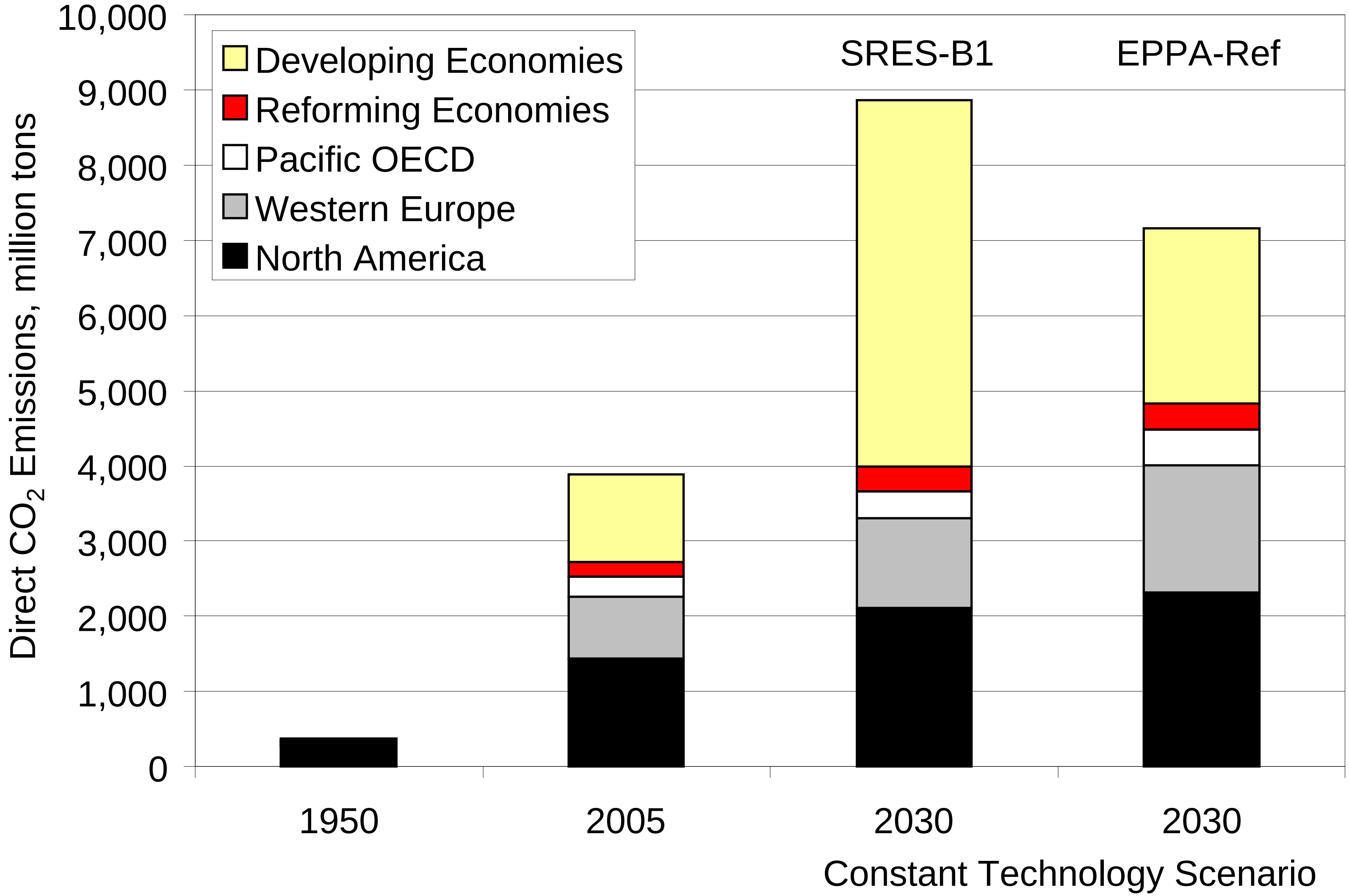


Source: Schäfer A., Jacoby H.D., Vehicle Technology Dynamics under CO_2-Constraint: A General Equilibrium Analysis, forthcoming in: *Energy Policy*

SUMMARY

- As a direct consequence of economic development, transportation may become the major final energy consumer and carbon dioxide emitter
- Strong forces in transportation system: rising income translates into rising travel demand and shift toward faster, more energy-intensive modes $\Rightarrow$ rising significance of air travel
- Low GHG-emission technology more expensive $\Rightarrow$ policies required to rebalance consumer preferences
- Significant potential for reducing GHG emissions, but sensible fleet impact only after 2030
- Evolutionary fuel efficiency improvements important
- Growth in travel demand likely to continue even under stringent emission reduction policies

WORLD PAX TRAVEL: CO_2 EMISSIONS



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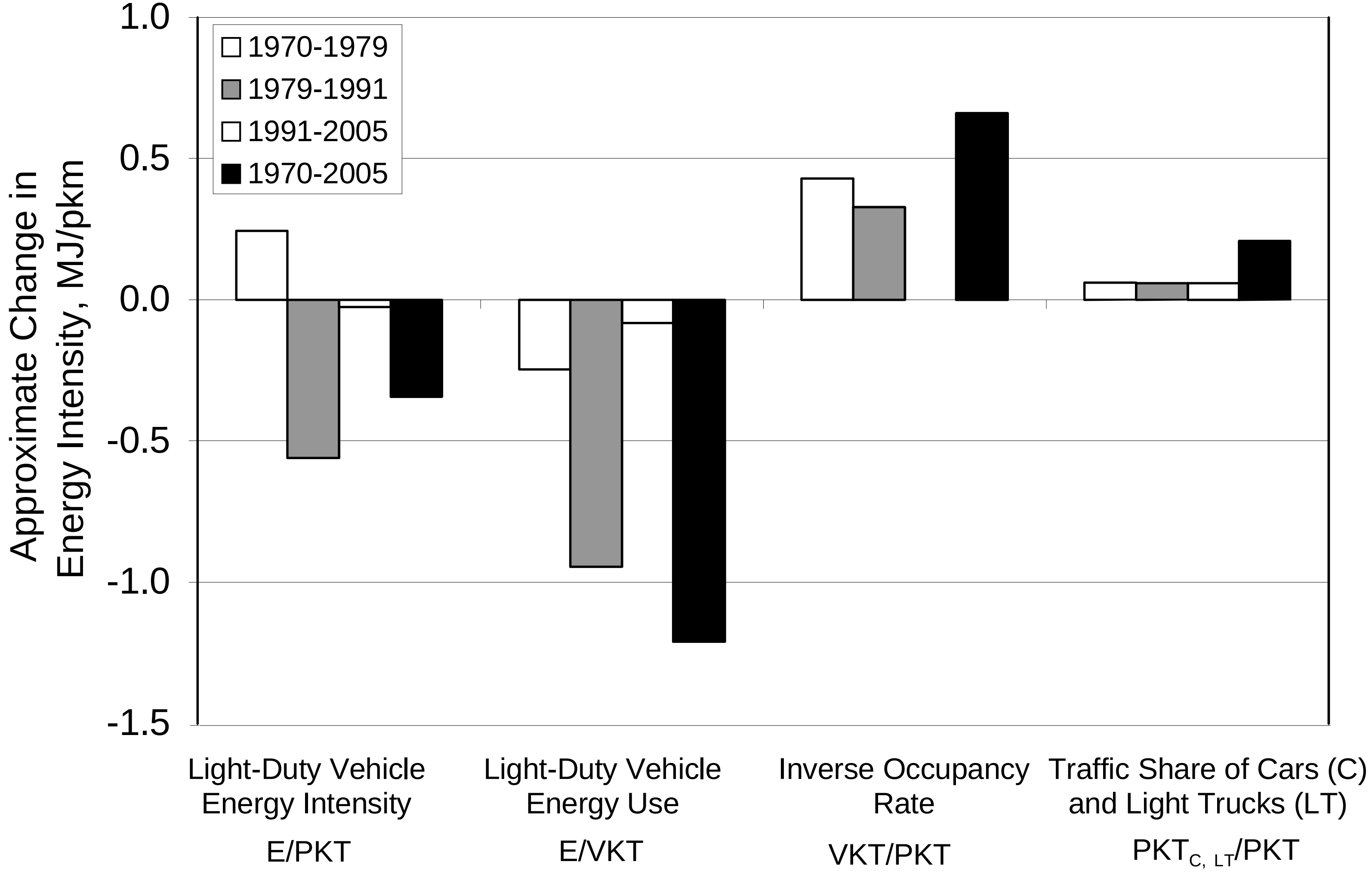
DETERMINANTS OF LDV ENERGY INTENSITY

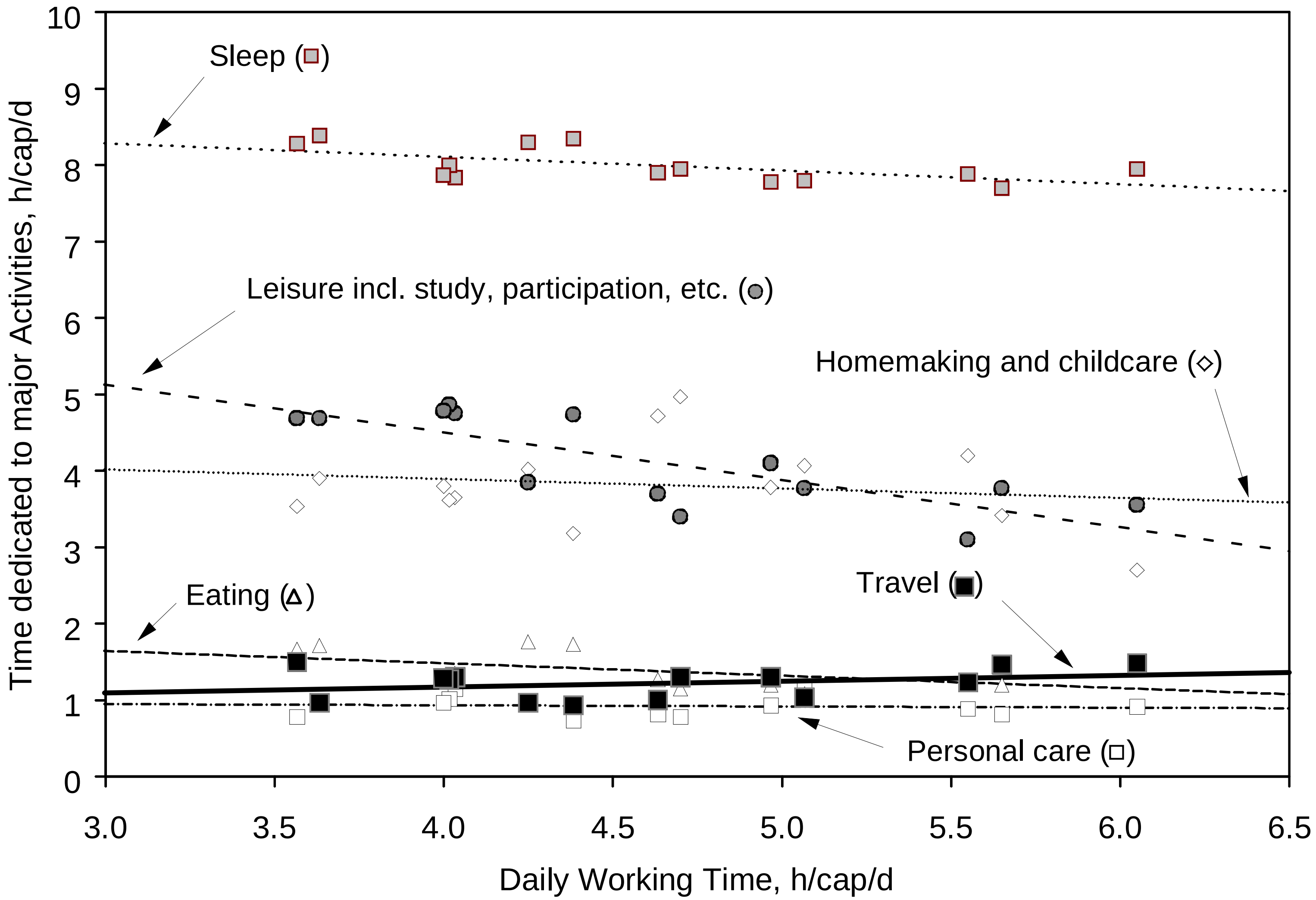


Source: Schäfer A., Heywood J.B., Jacoby H.D., Waitz, I.A., 2009. Transportation in a Climate-Constrained World, MIT Press.

HOW TO REDUCE LDV ENERGY USE?

- Demand and Supply Management
  - Car pooling, telecommuting, pricing measures to induce time and/or mode shift, land-use planning, etc.
  - Comparatively small potential, even if combined in packages
- Technology-Solutions
  - Increase energy efficiency
  - Single largest potential

STABILITY OF TRAVEL TIME BUDGET

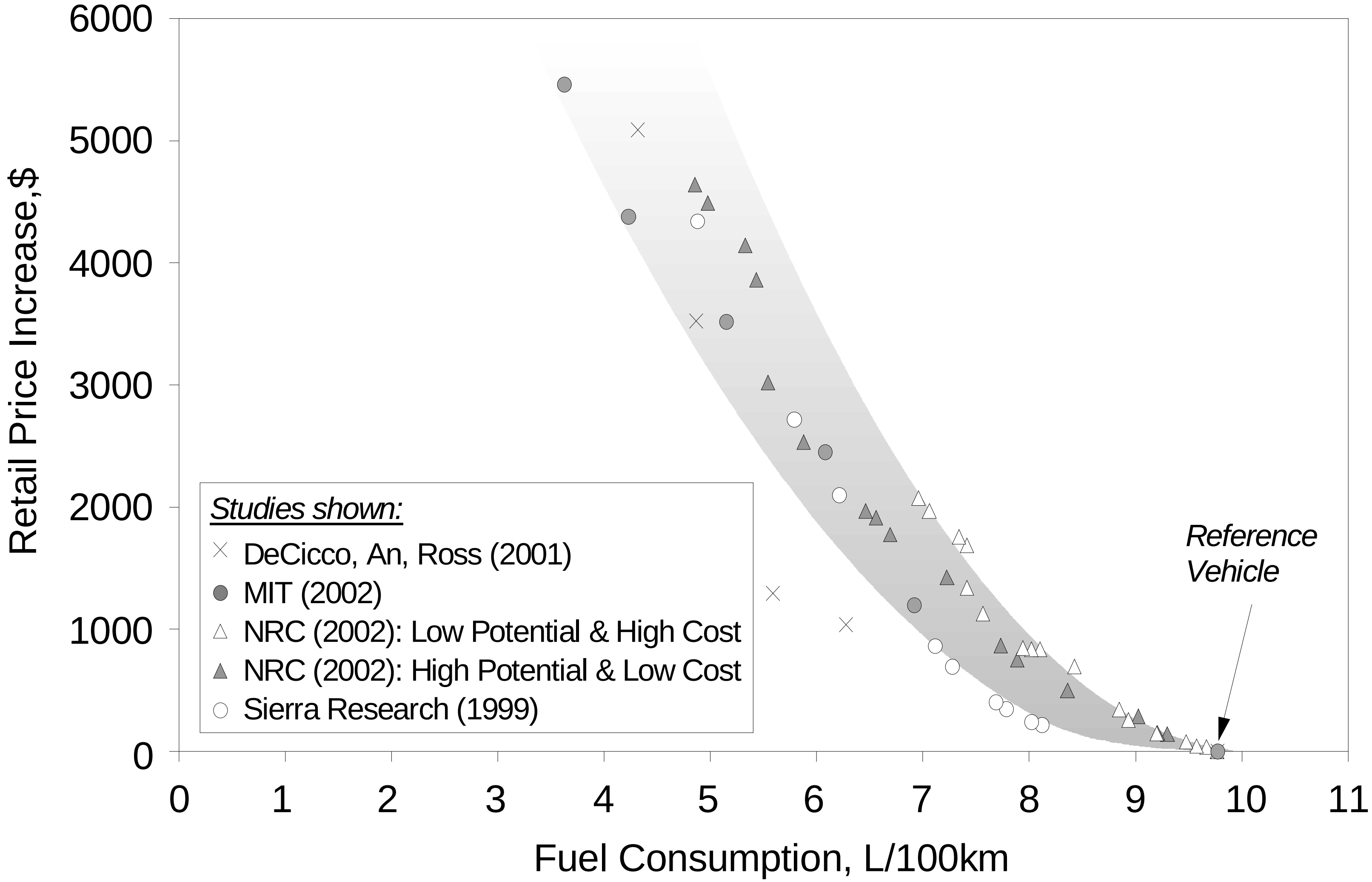


Note: Increase in time dedicated to sleep and leisure statistically significant @ 95% confidence, as opposed to changes in other time allocations.
Data source: Szalai et al.(1972), data from 11 countries, population between 18 and 65 years of age.

BARRIERS TO EMISSION REDUCTIONS

- High extra costs for significant reductions in fuel consumption (all other factors equal)
- High implicit consumer discount rates ($\approx$ 3 year amortization period for fuel-saving technology)
- Long time scales for “sensible” fleet impact of new, fuel-saving technology (20 – 35 years, depending on technology; 50+ years for low- fuels)
- Thus, need for policy measures

AUTOMOBILE FUEL EFFICIENCY & COSTS



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