Global Transportation and Technology in MiniCAM

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Motivation

- Transport accounts for 33% of total CO$_2$ emissions and is the largest end-use source of energy-related CO$_2$ in the US (EIA).
- Transport accounts for 23% of global energy-related CO$_2$ emissions (IEA).
- Growth in the demand for transport services worldwide implies continued long-term growth in CO$_2$ emissions from the transportation sector.
- Ability to assess the impact of transportation policies and emerging vehicle technologies for lowering fuel consumption and emissions requires the ability to model differentiated transport services by mode and vehicle technologies.
  - Previous versions of the MiniCAM transportation representation did not include transport services by mode and vehicle technology for all global regions (except US).
Structure of MiniCAM Transportation Sector

► Old structure
- Aggregate transport service by fuel

► New structure
- Differentiated transport services (pass-km, ton-km)
- Modes (avg speed, km/hr)
- Vehicle technologies (load factor, fuel intensity, non-fuel cost per vehicle)
Cost of Transport Service and Transport Service Demand (Passenger)

\[ P_{i,L} = \left( \frac{P_{f,i,L}}{Eff_{i,L}} + P_{nf,i,L} \right) / LF_{i,L} + W_L / T_i \]

- vehicle \( i \) in region \( L \)
- \( P \) = cost of passenger service, per passenger km
- \( Eff \) = vehicle fuel economy
- \( P_{nf} \) = vehicle non-fuel cost
- \( LF \) = load factor (persons per vehicle)
- \( W \) = wage rate
- \( T \) = average vehicle transit speed

Time value affects modal competition with bias towards faster modes with increasing wage rate

Time value is included in the total transport service cost constraining service with rising wage rate

\[ D_{\text{pass},L} = a_{\text{pass},L} \times P_{\text{pass},L}^{rp} \times X_{L}^{\text{ry}} \times \text{Pop}_L \]

- \( X \) = income per capita
- \( \text{Pop} \) = population
Passenger Time in Transit

- Passenger time in transit for all modes (including walking) is strikingly constant across regions and income levels.
- Note that only motorized modes are modeled in MiniCAM.
- Including time value in service cost constrains time in transit.

**Shafer (historical)**

**MiniCAM (1990 - 2095)**

Passenger Service Demand

- Passenger service demand is linear with income

Light-Duty Transport Scenarios

- Light-duty passenger transport is the focus of the following study
  - Largest component of transport energy use and CO₂ emissions
  - Emerging new vehicle technologies are for light-duty service
  - No electric or H₂ vehicle technologies for Freight and Passenger Aviation & Bus services

- Climate policy (CP) scenarios impose an escalating carbon tax on all CO₂ emitting activities for all global regions
  - Carbon tax path is roughly consistent with a 450 ppm CO₂ stabilization

<table>
<thead>
<tr>
<th>Ref</th>
<th>No alternative-fueled vehicle technologies in light duty vehicles.</th>
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<tr>
<td>Elec</td>
<td>All light-duty vehicles are electric-powered starting in 2035.</td>
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<tr>
<td>H₂</td>
<td>All light-duty vehicles are hydrogen-powered starting in 2035.</td>
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<td>Ref CP</td>
<td>These scenarios have a global emissions price of $7.35 / t CO₂ in 2015, increasing at 5% per year (real) through 2095</td>
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Global Passenger Service Demand by Mode, and LDV Stock

- The fastest growth is in aviation due to increasing time value of transportation
- However, LDV is the largest component of passenger service, growing to about 3 billion vehicles in service by 2095
  - Developing world shifts from bus to LDV as incomes rise
Passenger Service Demand by Mode in China, India, and USA (no policy)

- High overall growth in transportation demands in China and India
  - Shift from bus to LDV
  - High growth in aviation
Global Service Demand across LDV Technology Scenarios

- Scenarios are set up so that service demand is relatively constant across technology scenarios
  - This allows analysis of effect of LDV technology on fuel consumption and CO₂ emissions
Global LDV fuel consumption by fuel type

- Electricity and hydrogen vehicles are more efficient than ICE vehicles at the end-use level.
- Electricity, hydrogen, and liquid fuels have different carbon intensities; effect on emissions is not clear.
  - The CO₂ emissions intensities of these fuels are influenced by available production technologies and climate policy.
Global Results: CO₂ Emissions by LDV’s

LDV-Ref

LDV-Elec

LDV-H2

LDV-Ref-CP

LDV-Elec-CP

LDV-H2-CP
Both electric and hydrogen LDV scenarios reduce demand of oil by 50%.

Electric LDV favors nuclear, renewables, and coal.

Hydrogen LDV favors gas at low to mid carbon prices, and biomass at high carbon prices.
Global CO₂ emissions and CO₂ concentrations

With or without a climate policy, by the end of the century, alternative LDV technologies:
- cut annual global CO₂ emissions by about 10 Gt / yr
- cut global CO₂ concentrations by about 40 ppmv
Conclusions

- New structure of the MiniCAM transportation sector with differentiated transport services by mode and vehicle technologies allows greater understanding of the global transportation sector and options for GHG emissions reduction.
  - Growth in the global demand for passenger and freight service
  - Modal shifts and their potential impact on fuel choice, fuel consumption and emissions
  - Impact of new vehicle technologies with alternative fuels
  - Comparison of CAFE and carbon policies
- Alternative vehicle technologies for Light-Duty Transport service alone could have significant impact on fuel consumption and CO₂ emissions
  - Significantly lower CO₂ concentrations (40 ppm less) are achievable with either an all electric or hydrogen light-duty transport system
  - An all electric or hydrogen light-duty transport system has significant implications for the energy infrastructure and fuel choice
    - Liquid fuel use by whole transportation sector is reduced by 50%
  - Vehicle technologies alone, electric or hydrogen light-duty, do not stabilize either emissions or atmospheric concentrations of CO₂, however.