Future Transportation in the Shared Socioeconomic Pathways

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Background

- Transportation currently accounts for about a quarter of all CO₂ emissions globally
  - Passenger transportation accounts for about 70% of this
- Historical demand has increased with income
- Continued income growth is expected

Source: Shafer 1999

Projected - SSP2

Source: IIASA SSP Database
Transportation emissions mitigation appears to be especially costly, among sectors of the economy.

In the scenarios below, the marginal abatement costs are equal across sectors.

In each of these two scenarios, the costs for reductions in the long term are high enough to justify the near-term retirement of emissions-intensive capital — coal electric power plants (energy system behavior will be addressed more fully in Section 6).

Absent dramatic changes to the existing capital stock, as is the case in the REF and RE scenarios with the 167 Gt CO$_2$-e policy, the scenarios show little variation in near-term emissions. The reason for the lack of technology-related differentiation between scenarios is that most emissions mitigation will take place on the investment margin, and the investment margin in the U.S. energy transformation sectors over the next decade is not large enough to allow for substantial deployment of new low-emissions capital (again, this issue will be addressed in more detail in Section 6).

It should be noted however that opportunities for deployment of advanced energy technologies to cut near-term emissions will be higher in rapidly growing economies such as China and India.

With respect to long-term emissions pathways, a salient characteristic of all of the 167 Gt CO$_2$-e scenarios, and the majority of the 203 Gt CO$_2$-e scenarios, is that emissions in 2050 exceed the targets upon which the cumulative emissions policies are based (Fig. 4). This behavior, consistent with the near-term banking noted above for the 167 Gt CO$_2$-e policy scenarios, is indicative of the difficulty of meeting the sorts of deep, mid-century emissions reductions explored in this study. Without the appropriate technologies to make such reductions less costly, they may be difficult to achieve, and the challenge will only increase beyond 2050 as deeper and deeper reductions are required.

This, again, emphasizes the importance of technology in the long run.

Part of the difficulty of achieving such deep reductions towards 2050 is the difficulty of abatement of non-CO$_2$ greenhouse gases. The scenarios examined here employ assumptions regarding non-CO$_2$ mitigation based on marginal abatement cost functions developed by the U.S. EPA in support of EMF 21 (U.S. EPA, 2003; see also Smith and Wigley, 2006). Under these assumptions, reductions in non-CO$_2$ greenhouse gases take place at relatively low CO$_2$ prices, but further reductions are unavailable beyond a price of approximately $55 per ton (Fig. 6).
Motivation and Methods

Motivation: to enhance understanding of...

- Importance of social and economic trends for future passenger sector
- Emissions mitigation potential in the transport sector
  - Service demand reduction, modal shifting, vehicle downsizing, vehicle efficiency improvement, vehicle fuel switching, upstream emissions reduction

Methods

- Improve the technological and regional detail of the transportation sector of the GCAM integrated assessment model
  - Base-year calibration data and future projections
  - Ensure that the transportation sector results are consistent with existing well-regarded transportation-only models
- Assess the outcomes across a range of socio-economic and emissions mitigation futures
Socio-economic Scenarios

Socio-economic scenarios are from the IPCC’s Shared Socio-economic Pathways (SSP)

- Intended to span a range of plausible futures of challenges to climate change mitigation and adaptation
- Implemented as population (solid lines) and per-capita GDP (dotted lines)
Per-capita travel in 2050 in the SSPs
Modal Shifting in Transportation in the SSPs
Energy Intensity of Transportation in the Scenarios (SSP2 shown)

Average Energy Intensity of Passenger Travel (MJ/PKT)
Fuel Consumption and Emissions – Developing Regions
Fuel Consumption and Emissions – Developed Regions

Per capita PPP GDP
Thousands 2005US$

Population in Million

Developed Regions

Total TTW CO2 emitted from passenger
Travel in 2050 (MT CO2/year)

Total Fuel consumed by passenger travel in EJ

SSP  2005  SSP1  SSP2  SSP3  SSP5

PPP GDP
(Trillion 2005 US$)

40  60  80
Climate Change Mitigation Scenarios

- Emissions scenarios are from the IPCC’s Representative Concentration Pathways (RCPs)
  - Intended to span a range of plausible futures of greenhouse gas emissions

![CO2 Concentrations Graph]

- RCP2.6
- RCP4.5
- RCP6.0
- RCP8.5

ppmv

1980 2000 2020 2040 2060 2080 2100 2120
Responses to the 4.5 W/m² Mitigation Policy: Light Duty Vehicles in 2050

- These scenarios observe a mild degree of fuel-switching and vehicle intensity improvement.

![Graph showing changes in various factors from the Reference Scenario](image-url)
Tank to Wheel Energy and Emissions from Passenger Transportation
Well to Wheel Energy and Emissions from Passenger Transportation
Conclusions – What have we learned?

► Across a wide range of socio-economic futures, the developing regions account for the majority of global travel demand, energy and emissions
  - The uncertainty in these regions is particularly large
  - Travel intensity in the developed regions declines due to technology advance; in developing regions it increases due to modal shifting and changes to larger vehicles

► Emissions mitigation in transportation is tightly linked with the energy supply system
  - The capacity of the system to cut emissions depends on both the consumer and supplier behavior
  - In these scenarios, the reduction in well-to-wheel emissions exceeds the tank-to-wheel emissions
Acknowledgements

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► We would also like to thank the GTSP sponsors for long-term support of transportation modeling at JGCRI.
Backup Slides
Passenger Transportation in 2005

The diagram illustrates the relationship between Per Capita Transportation (1000 PTK/year) and Per Capita GDP (PPP basis, Thousands 1990 US$) for various countries. The scatter plots show the energy intensity of passenger travel (MJ/PKT) and the share of LDV (Loots and Delivery Vehicles). Each point represents a country, with colors indicating different GDP ranges and symbols representing various transportation costs. The graph highlights how developed countries generally have higher transportation per capita than less developed countries.
# Shared Socioeconomic Pathways

<table>
<thead>
<tr>
<th></th>
<th>SSP1</th>
<th>SSP2</th>
<th>SSP3</th>
<th>SSP5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Name</strong></td>
<td>Sustainable Development</td>
<td>Baseline - Middle of the road</td>
<td>Fragmented World</td>
<td>Conventional Development</td>
</tr>
<tr>
<td>Economic Growth</td>
<td>Rapid especially in developing countries narrowing the gap between developed and developing regions by 2100</td>
<td>Baseline. By 2100, per capita GDP in most developing countries cross current average for developed regions (around US$35,000 per capita)</td>
<td>Slowest economic growth. Gap between developed and developing widens substantially.</td>
<td>Fastest economic growth. Per capita GDP in 2050 is almost 30-75% higher than Baseline (SSP2)</td>
</tr>
<tr>
<td>Income</td>
<td>Low</td>
<td>Baseline</td>
<td>High</td>
<td>Baseline</td>
</tr>
<tr>
<td>Population</td>
<td>Lower population - peaks at 8.5 billion in 2050 and then declines to 7.5 billion by 2100</td>
<td>Baseline population growth that peaks at 9.5 billion in 2070 and then declines to 9.1 billion by 2100</td>
<td>High population growth reach 12.5 billion by 2100 driven largely by Africa and India which have half the humanity in 2100</td>
<td>Similar to SSP1</td>
</tr>
<tr>
<td>Consumption patterns</td>
<td>Society evolves towards less material consumption</td>
<td>Baseline. Materially intensive consumption</td>
<td>Material intensive consumption with rapid growing demand for (personal) mobility. High ownership of private cars and 2Ws</td>
<td>Material intensive consumption with rapid growing demand for (personal) mobility. High ownership of private cars and 2Ws</td>
</tr>
<tr>
<td>(Consumerism, materialism)</td>
<td></td>
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<tr>
<td>Technological development</td>
<td>Rapid technological development focused on sustainable areas - clean renewables, advanced vehicle technologies</td>
<td>Medium technological progress</td>
<td>Slow technological progress especially in low-carbon technologies.</td>
<td>Rapid technological progress in traditional fossil-based systems. Clean technologies witness slower improvements</td>
</tr>
<tr>
<td>Urbanization</td>
<td>Rapid well-planned urbanization supporting mixed use development. Greater focus on public transits and active modes</td>
<td>Business-as-usual.</td>
<td>Unplanned urbanization. High levels of sprawl</td>
<td>Rapid planned urbanization that support sprawled development</td>
</tr>
</tbody>
</table>
Modal Shares as Function of Income
Comparison of total travel (Trillion PKT) across GCAM Regions
Comparison of total fuel consumed (EJ) for passenger travel across GCAM Regions

The diagram shows the fuel consumed in passenger transportation in 2050 (PJ/year) across different GCAM Regions. The x-axis represents the GCAM Region, and the y-axis shows the fuel consumption. The regions are divided into Developing and Developed categories. Each region is marked with different symbols and colors representing different scenarios (SSP) and shares of public transport (incl. non-motor) in total travel.
Comparison of TTW CO2 (Million Metric Tonnes) for passenger travel
Passenger transportation in 2050: Western Europe

The first graph gives the population and per capita PPP GDP (2005 US$) under four different SSPs, and adopted from the IIASA database. The size of the dots represents total PPPGDP (Trillion 2005 US$). The graph on right gives fuel consumption (EJ) and CO2 emissions by all passenger modes in 2050. The size of the dots represents total travel in Trillion PKT.
Passenger transportation in 2050: USA

The first graph gives the population and per capita PPP GDP (2005 US$) under four different SSPs, and adopted from the IIASA database. The size of the dots represents total PPPGDP (Trillion 2005 US$). The graph on right gives fuel consumption (EJ) and CO2 emissions by all passenger modes in 2050. The size of the dots represents total travel in Trillion PKT.
Passenger transportation in 2050: Africa

The first graph gives the population and per capita PPP GDP (2005 US$) under four different SSPs, and adopted from the IIASA database. The size of the dots represents total PPPGDP (Trillion 2005 US$). The graph on right gives fuel consumption (EJ) and CO2 emissions by all passenger modes in 2050. The size of the dots represents total travel in Trillion PKT.
Passenger transportation in 2050: India

The first graph gives the population and per capita PPP GDP (2005 US$) under four different SSPs, and adopted from the IIASA database. The size of the dots represents total PPPGDP (Trillion 2005 US$). The graph on the right gives fuel consumption (EJ) and CO2 emissions by all passenger modes in 2050. The size of the dots represents total travel in Trillion PKT.
Passenger transportation in 2050: China

The first graph gives the population and per capita PPP GDP (2005 US$) under four different SSPs, and adopted from the IIASA database. The size of the dots represents total PPPGDP (Trillion 2005 US$). The graph on right gives fuel consumption (EJ) and CO2 emissions by all passenger modes in 2050. The size of the dots represents total travel in Trillion PKT.