Transportation CO$_2$ Emissions in Light of the Paris Agreement

Implications of Paris Workshop
Norwegian University of Science and Technology
March 5-6, 2017

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Summary

• Key Sector Characteristics
  • Already vast scale, but continuous growth in absolute and relative terms
  • Capital intensity, design trade-offs, consumer acceptance: risk management → long timescales
  • Socio-economic forces have pushed transportation system towards higher energy intensities

• Demand side
  • Steady growth since industrialization
  • Systematic shift toward faster modes
  • Societal trends and changing demographics

• Supply side
  • Reliance on high-density energy carriers → nearly complete dependence on oil products
  • Scalability challenges for low-carbon fuels
  • Emerging technologies & business models

• How to contribute to achieving the Paris Agreement
  • Policy measures need to address all these factors: scale, risk, demand side and supply side
  • Examples of rapid technology transitions exist
H₂ Production Requirements for 15 EJ of Gas. Equiv.

Number of additional 1 GWₑ nuclear reactors to satisfy current US LDV energy demand via water electrolysis-based H₂
H₂ Production Requirements for 15 EJ of Gas. Equiv.

Number of additional 1 GWₑₚ nuclear reactors to satisfy current US LDV energy demand via water electrolysis-based H₂

~800
Racing version of the front wheel driven, petrol-electric Lohner "Porsche" in 1900.

http://www.hybrid-vehicle.org/hybrid-vehicle-porsche.html

Hugo Junkers' 1924 design for a giant flying wing. The wing was to accommodate 26 cabins for 100 passengers, carry a crew of 10, and have enough fuel for 10 hours of flight.

http://www.century-of-flight.net/Aviation%20History/Flying%20Wings/Early%20Flying%20Wings.htm

95 years

73 years
Greenhouse Gas Emissions: Identity

\[ GGE = \frac{GGE}{E} \cdot \frac{E}{PKT} \cdot PKT \]
Invariants in Travel Behavior: Average Travel Time

Total Passenger Mobility Growth (1950-2005)

Shift Toward Faster Modes

Future Levels of Travel Demand

\[
\ln \text{pkt}_t = \gamma_0 + \gamma_1 \ln \text{pkt}_{t-1} + \gamma_2 \ln \text{gdp}_t + \gamma_3 \ln \text{gdp}_{t-1} + \\
+ \gamma_4 \ln \left( \sum_m e^{\nu_{m,t}} \right) + \gamma_5 \ln \left( \sum_m e^{\nu_{m,t-1}} \right) + \delta \cdot D + \varepsilon_t
\]

\[
V_{m,t} = \beta_0 + \beta_1 \ln (S_{h_m})_{t-1} + \beta_3 \left( \frac{V_{\text{ Pub}}}{S_{m,t}} + \frac{C_{m,t}}{(GDP/h)_t} \right) + \varepsilon_t
\]

\[
\ln \left( \frac{S_{h_{LDV}}}{S_{h_{Air}}} \right)_t = \beta_{LDV} + \beta_1 \ln \left( \frac{S_{h_{LDV}}}{S_{h_{Air}}} \right)_{t-1} + \beta_3 \left( \frac{V_{\text{ Surf}}}{S_{LDV,t}} - \frac{V_{\text{ Air}}}{S_{Air,t}} + \frac{C_{LDV,t} - C_{Air,t}}{(GDP/h)_t} \right) + \varepsilon_t
\]

\[
\ln \left( \frac{S_{h_{Pub}}}{S_{h_{Air}}} \right)_t = \beta_{Pub} + \beta_1 \ln \left( \frac{S_{h_{Pub}}}{S_{h_{Air}}} \right)_{t-1} + \beta_3 \left( \frac{V_{\text{ Surf}}}{S_{Pub,t}} - \frac{V_{\text{ Air}}}{S_{Air,t}} + \frac{C_{Pub,t} - C_{Air,t}}{(GDP/h)_t} \right) + \varepsilon_t
\]

Baseline development:
iterate VOT\textsubscript{LDV} to maintain time budget \( \rightarrow \) VOT\textsubscript{LDV(t)} (VOT\textsubscript{Pub} = VOT\textsubscript{Surf} = VOT\textsubscript{LDV(t0)} remains unchanged)

Automated vehicle introduction in 2030 (50% VOT\textsubscript{LDV(t)}):

\[
\ln \left( \frac{S_{h_{AV}}}{S_{h_{Air}}} \right)_t = \beta_{LDV} + \beta_1 \ln \left( \frac{S_{h_{LDV}}}{S_{h_{Air}}} \right)_{t-1} + \beta_3 \left( \frac{V_{\text{ LDV(t)}}}{2 S_{LDV,t}} - \frac{V_{\text{ Air}}}{S_{Air,t}} + \frac{C_{LDV,t} - C_{Air,t}}{(GDP/h)_t} \right) + \varepsilon_t
\]
Future Levels of U.S. Travel Demand: Baseline

Assumptions:

TTB = 1.3 h/cap/d

Potential Changes to Baseline Development

• Supply Side
  • Telecommunication substitutes vs. complements
  • Autonomous vehicles

• Demand Side
  • Sharing economy
  • Societal trends & changing demographics

• New Opportunities for Balancing Demand and Supply
  • New mobility services and actors
  • Mobility as a Service → personalized integrated & seamless mobility solutions

• Can above factors change the dynamics underlying passenger travel?
Scale Implications for Energy Intensity in Freight Trp.

The impact of scale on energy intensity in freight transportation Research Part D: Transport and Environment, August.

Air Transportation CO$_2$ Intensity and Stabilization Wedges

(US domestic air transportation, narrow body aircraft)

Rapid Technological Change is Possible: US Railroads

Fuel Shares: Yard, Passenger, and Freight Sector

CO₂ Intensity: Freight Railroads

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