The Energy Efficiency Potential of Global Transport to 2050

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Increased energy efficiency is crucial to the sustainability of global transportation.

- It should be possible to more than double transportation energy efficiency by 2050.
- This should be sufficient to hold transportation energy use at today’s level.
- Threats to energy efficiency improvement?
  - The Energy Paradox:
    - Markets tend to undervalue energy efficiency
    - Underinvestment in technology and R&D
  - Rebound: “emergent” property of energy systems?
    - Direct effect of lower energy cost/km
    - Indirect effect on economic growth and energy prices
Petroleum provides 95% of the energy for global transport, which accounts for 27% of global final energy use.

Transport energy use is expected to more than double by 2050 under BAU.

Global Transport Energy Use by Mode, 2007
(exajoules)

Road
Air
Water
Rail

103

IEA, Energy Technology Perspectives 2010.
The overall energy efficiency of U.S. passenger vehicles is on the order of 1%. Though an extreme example, it is reasonable to infer potential for major improvement.

Proposed fuel economy standards require more than a doubling of miles per gallon by 2025. Can it be done cost-effectively?

Fuel Economy Cost Estimates: MIT On the Road in 2035

- NRC 2002: 2012
- MIT: 2035
- TAR Path A: 2025
- TAR Path C: 2025
- NRC 2011: 2020
- NRC Optimistic: 2020

Incremental Retail Price Equivalent vs. Percent Increase in Kilometers per Liter Gasoline Equivalent Energy

- Battery Electric Vehicle
- PHEV 30
- H2 FCV
- 2035 Advanced Conventional Vehicles
- 2035 Hybrid Vehicle
The “energy efficiency paradox” seems to apply to heavy-duty vehicles, as well, which would explain why Japan, the EU, the US and China are all implementing efficiency standards for heavy-duty vehicles. (US: 9-23% reduction in fuel consumption)
Other modes also have substantial potential to reduce fuel consumption cost-effectively.

- **Air transport uses 10% of transport energy.**
  - Next Gen aircraft –40% fuel burn vs. 2005 by 2020: IATA
  - “wing–body” “double–bubble”: –50 to –70% by 2035

- **Water transport is 7% of transport energy use**
  - –60% by 2050: IEA (includes speed reduction)
  - –15% to –30 by 2020 at <$100/tCO₂: IMO

- **Rail Transport uses only 4% of transport energy**
  - –18% to 24% near term: IEA, USDOT
  - –50% by 2050: Argonne Nat’l Lab.
Accomplishing reductions in energy intensity of 50% or more could hold global transport energy use to today’s level in 2050.

Table 1. Impact of Transport Energy Efficiency Improvement on Energy Use in 2050 (Exajoules)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Energy Use 2007</th>
<th>Growth Rate %</th>
<th>Extrapolated Energy Use 2050</th>
<th>Efficiency Improvement (% reduction)</th>
<th>Efficient Energy Use 2050</th>
<th>Energy Use With Rebound 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>103</td>
<td>2.0%</td>
<td>241</td>
<td>70%</td>
<td>72</td>
<td>87</td>
</tr>
<tr>
<td>Air</td>
<td>11</td>
<td>3.0%</td>
<td>39</td>
<td>60%</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>Water</td>
<td>9</td>
<td>2.0%</td>
<td>21</td>
<td>50%</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Rail</td>
<td>5</td>
<td>1.0%</td>
<td>8</td>
<td>50%</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>128</td>
<td></td>
<td>309</td>
<td></td>
<td>102</td>
<td>121</td>
</tr>
</tbody>
</table>
The proposed 2017-2025 US standards will put the LDV industry on a “climate sustainable” path toward oil independence.
Every major automobile manufacturing nation has fuel economy or CO₂ emissions standards. Why?

**PASSENGER VEHICLE GHG EMISSIONS FLEET AVERAGE PERFORMANCE AND STANDARDS BY REGION**

- **Solid dots and lines:** actual data
- **Hollow dots and dashed lines:** nearest targets enacted
- **Smaller hollow dots and dotted lines:** proposed targets

**Regions:**
- Australia
- California
- United States
- Canada
- China
- South Korea
- Japan
- European Union
If there is no uncertainty, the net value of higher fuel economy is the difference between the present value of future fuel savings and the price increase. (NRC, 2002)

\[ PV = \int_{t=0}^{L} P_t M_o e^{-\delta t} \left( \frac{1}{E_o} - \frac{1}{E_1} \right) e^{-rt} dt \]

**Price and Value of Increased Fuel Economy to Passenger Car Buyer, Using NRC Average Price Curves**

Assumes cars driven 15,600 miles/year when new, decreasing at 4.5%/year, 12% discount rate, 14 year vehicle life, $2.00/gallon gasoline, 15% shortfall between EPA test and on-road fuel economy.
Quantifying uncertainty, a 25% increase in new car fuel economy is optimal and has a net present *expected* value of $405.

**Distribution of Net Present Value to Consumer of a Passenger Car Fuel Economy Increase from 28 to 35 MPG**

- Mean = $405
- X \leq -$1556: 5%
- X \leq $2941: 95%

**2005 Dollars**

Relative Frequency
According to prospect theory (2002 Nobel Prize in Economics), typical consumers magnify potential losses relative to gains and exaggerate the probability of loss. "A bird in the hand is worth two in the bush."
Loss-averse markets would decline the increase in MPG, as would a consumer requiring a three-year payback.
The undervaluing of energy efficiency implies under-utilization of cost-effective technologies and under-investment in R&D.

Price and Value of Increased Fuel Economy: Assuming Certainty, Loss Aversion and 3-year Payback, $1.70/gal.
Will energy efficiency improvement really reduce energy use?

**Rebound effect:** lower energy cost → greater use of energy services, increased real income and increased consumption.

**Direct rebound effect** decreases with energy’s share of total costs. **Indirect rebound** decreases with energy’s share of total expenditures.
The great energy transformations of the past were driven by technology and market forces. Creating a transition for the public good poses a new challenge.

Holding transportation energy use to today’s level buys time for the transition and helps make it affordable. But it won’t happen without:

- Technological advances
- Public policy intervention
THANK YOU.
The NRC’s 2010 study indicated substantial, cost-effective technological potential to reduce heavy truck fuel consumption.

<table>
<thead>
<tr>
<th>Vehicle Class</th>
<th>Fuel Consumption Reduction</th>
<th>Capital Cost</th>
<th>Breakeven Fuel Price ($/gallon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor-trailer</td>
<td>51%</td>
<td>$84,600</td>
<td>1.10</td>
</tr>
<tr>
<td>Class 6 box truck</td>
<td>47%</td>
<td>$43,120</td>
<td>4.20</td>
</tr>
<tr>
<td>Class 6 bucket truck</td>
<td>50%</td>
<td>$49,870</td>
<td>5.40</td>
</tr>
<tr>
<td>Class 2b pickup</td>
<td>45%</td>
<td>$14,710</td>
<td>4.80</td>
</tr>
<tr>
<td>Refuse truck</td>
<td>38%</td>
<td>$50,800</td>
<td>2.70</td>
</tr>
<tr>
<td>Transit bus</td>
<td>48%</td>
<td>$250,400</td>
<td>6.80</td>
</tr>
<tr>
<td>Motor coach</td>
<td>32%</td>
<td>$36,350</td>
<td>1.70</td>
</tr>
</tbody>
</table>
The National Academies of the G8+5 called for urgent action to address climate change and endorsed a 50% reduction in global emissions over 1990 levels by 2050.

“The IPCC 2007 Fourth Assessment of climate change science concluded that large reductions in the emissions of greenhouse gases, principally CO₂, are needed soon to slow the increase of atmospheric concentrations, and avoid reaching unacceptable levels. However, climate change is happening even faster than previously estimated; global CO₂ emissions since 2000 have been higher than even the highest predictions, Arctic sea ice has been melting at rates much faster than predicted, and the rise in the sea level has become more rapid. Feedbacks in the climate system might lead to much more rapid climate changes. The need for urgent action to address climate change is now indisputable. For example, limiting global warming to 2°C would require a very rapid worldwide implementation of all currently available low carbon technologies.”

May 2009

Emphasis added.
Oil dependence cost the US more than $500 billion in 2008. Oil independence doesn’t mean using no oil or importing no oil.