Energy End-Use: Transport

Modal Share of Global Energy Use and CO₂ Emission in Transport Sector

Energy Use 2007
96 EJ

- Road 72.8%
- Air 11.0%
- Ship 10.1%
- Rail 2.6%
- Others 3.5%

CO₂ emissions 2007
6.6 GtCO₂

- Road 72.9%
- Air 11.2%
- Ship 11.1%
- Rail 2.0%
- Others 2.8%
Global Freight Movement in Trillion Tonne-km/Year

Total movement up 3.7%/yr, 1990 - 2003

- Water
- Road
- Rail

Trillion tonne-km/year


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Passenger Motorized Travel in some OECD Countries

The graph illustrates the relationship between per capita GDP (2000 US$ at PPP) and per capita motorized travel (passenger km/yr) for various OECD countries. The countries included in the graph are the United States, Canada, Australia, France, United Kingdom, Sweden, Germany, and Japan. The data shows a general trend where increasing per capita GDP correlates with increased motorized travel, reflecting economic and lifestyle factors.
Modal Split of Passenger (Top) and Freight Transport (Bottom; Air Freight not Included) in Terms of Passenger-km and T-km

Energy End-Use: Transport

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Energy End-Use: Transport

Estimated Motorized Passenger Travel Split By Mode

- 3Ws
- 2Ws
- Light Trucks
- Cars
- Minibuses
- Buses
- Buses
- Rail
- Air

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Vehicular Penetration in 2006 of Several Developed and Developing Countries

- **USA**: High penetration of cars, moderate other-4wheelers, and low 2-wheelers.
- **Japan**: Similar to the USA, with a slightly lower number of 2-wheelers.
- **Germany**: High penetration of cars and other-4wheelers, with a moderate number of 2-wheelers.
- **Mexico**: Moderate penetration of cars, low other-4wheelers, and high 2-wheelers.
- **Brazil**: Low penetration of cars and other-4wheelers, high 2-wheelers.
- **Malaysia**: Moderate penetration of cars and other-4wheelers, with a moderate number of 2-wheelers.
- **China**: Low penetration of cars, moderate other-4wheelers, and low 2-wheelers.
- **India**: Low penetration of cars, moderate other-4wheelers, and low 2-wheelers.

Vehicle ownership (per 1000 people):
- **Cars**: Blue
- **Other-4wheelers**: Red
- **2-wheelers**: Green

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Passenger Transport Modal Shares of Several Cities in Developing Countries

São Paulo

- Bicycle: 1%
- Bus: 21%
- Walk: 37%
- Motorcycle: 1%
- Car: 31%
- Motorized private: 32%
- Motorized public: 30%
- NMT: 38%

Bangalore

- Bicycle: 2%
- Bus: 41%
- Walk: 16%
- Motorcycle: 35%
- Car: 5%
- Motorized public: 30%
- NMT: 38%
- Paratransit: 6%

Shanghai

- Bicycle: 25%
- Bus: 21%
- Walk: 31%
- Paratransit: 6%
- Car: 13%
- Subway: 4%
- Motorized private: 31%
- Motorized public: 56%

Dar es Salaam

- Bicycle: 3%
- Bus: 47%
- Walk: 50%
- Motorized public: 47%
- Motorized private: 7%
- Car: 7%
- NMT: 50%
Railway Traffic in the Major Regions

OECD-N. America
OECD-Europe
Japan
China
India
Russia
Others

Train transport activity (Billion p-km, t-km)
Energy Use in Railway Transport Systems in the Major Regions

- OECD-N. America: 95.6% Coal, 4.4% Electricity
- OECD-Europe: 36.3% Diesel, 63.7% Electricity
- Japan: 11.5% Coal, 88.5% Electricity
- China: 20.0% Coal, 65.7% Electricity
- India: 67.3% Electricity
- Russia: 36.1% Diesel, 63.9% Electricity
Energy Intensity of Domestic Transport System in Japan

Energy Intensity (MJ/p-km, MJ/t-km)

- Car
- Bus
- Rail
- Air

Passengers

- Truck
- Rail
- Shipping

Freight

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Energy End-Use: Transport

Trends in Schedule International and Domestic Traffic – World

[Bar chart showing billion passenger-km for international and domestic travel in 1985 and 2005.]
Regional Distribution Of Air Passenger Transport

1985:
- Europe: 21.1%
- Africa: 6.2%
- Asia/Pacific: 25.5%
- Middle East: 6.0%
- North America: 4.8%
- Latin America: 4.8%
- Other: 36.4%

2005:
- Europe: 39.4%
- Africa: 17.7%
- Asia/Pacific: 28.3%
- Middle East: 6.9%
- North America: 3.3%
- Latin America: 4.3%
- Other: 39.4%
Energy End-Use: Transport

Trends in Scheduled International and Domestic air Freight Traffic – World

![Graph showing trends in scheduled international and domestic air freight traffic from 1985 to 2005.]
Regional Distribution of Air Transport

1985
- Europe: 16.5%
- Asia/Pacific: 29.2%
- Middle East: 6.2%
- North America: 3.6%
- Latin America: 5.1%
- Africa: 39.4%

2005
- Europe: 18.3%
- Asia/Pacific: 38.0%
- Middle East: 7.4%
- North America: 3.2%
- Latin America: 1.9%
- Africa: 31.2%
Global Aircraft Fuel Burn, International and Domestic Traffic Combined

- Annual average growth
  - Aircraft Fuel Burn: 2.9% to 3.4%
  - Passenger Traffic: 4.8%
Energy End-Use: Transport

World Seaborne Trade

![Graph showing world seaborne trade](image)

- Crude oil
- Oil products
- Iron ore
- Coal
- Grain
- Others

Year:
- 1970
- 1980
- 1990
- 2000
- 2008

(Trillion tonne-miles)

(Trillion t-km)
Share of seaborne shipping fuel consumption by fuel type and engines

- **Distillate fuel**: 23%
- **Residual fuel**: 77%

- **Slow-speed engines**: 65%
- **Medium-speed engines**: 33%
- **Boilers**: 2%
Annual Average PM 10 Concentrations Observed In Selected Cities Worldwide
Modal Shares in World Vehicles in CO₂ Emissions

- Waterborne
- 2-3 Wheelers
- LDV
- Freight Trucks
- Air
- Buses
- Freight + Passenger Rail

2000 vs. 2005
GHG intensity per mode

Energy End-Use: Transport

GHG intensity (gCO₂-eq/t-km, log scale)

- Shipping
- Freight rail
- Road freight
- Air

GHG intensity (gCO₂-eq/p-km)

- Rail
- Bus
- 2-Wheelers
- Passengers LDV
- Air
Well-to-Wheel CO2 Emissions by Vehicle Engine Type

- **Gasoline**: 30-50%
- **Diesel**: 15-30%
- **Biofuels**: 10-40%
- **EV**: 80-90%
- **Fuel cell/H2**: Tailpipe

**Energy End-Use: Transport**
Projection of transport world energy use by mode and region

Exajoule (EJ)

Water
Air
Rail
Freight trucks
Buses
2-3 wheelers
LDVs

2000 2010 2020 2030 2040 2050

2000 2010 2020 2030 2040 2050

Africa
Latin America
Middle East
India
Other Asia
China
Eastern Europe
FSU
OECD Pacific
OECD Europe
OECD N. America
Bunker Fuel
Reference Scenario: Projected Changes in Oil Demand

Energy End-Use: Transport

Change of Oil Demand (EJ)

Transport
Industry
Building
Others

Rest of World
Other Asia
India
China
OECD
Passenger and Freight Transport GHG Emissions Baselines by Mode

Energy End-Use: Transport

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Carbon intensity of different biofuels as compared to gasoline

- Gasoline (CARBOB)
- Midwest corn Ethanol (Ave)
- California Ethanol (Coal)
- Biodiesel (Midwest, soybeans)
- Brazil Sugarcane Ethanol
- Cellulosic ethanol (farmed trees)
- Biodiesel (UCO)
- LNG (NA pipeline)
- LNG (Landfill gas)

Carbon intensity (gCO$_2$-eq/MJ of produced fuel)

Direct  Indirect

Gasoline baseline
LCA for Passenger Vehicles

Energy End-Use: Transport
LCA for Trains and Ships

Train

Operation 85.5%
Train production 1.9%
Infrastructure 12.7%

Ship

Operation 91.5%
Fuel production 6.7%
Material production 1.5%
Others 0.3%
Energy End-Use: Transport

Relative Amount of Energy Required for Different Supply Chains and Well-to-wheel GHG Emission for Various Powertrain/Fuel Combinations

- Gasoline (conventional)
- Gasoline (unconventional)
- Diesel (conventional)
- Diesel (unconventional)
- Hybrid (gasoline)
- Hybrid (diesel)
- Natural Gas
- PHEV (Coal)
- PHEV (Wind)
- BEV (Coal)
- BEV (Wind)
- Hydrogen FC Hybrid (SMR)
- Hydrogen FC Hybrid (Coal gasification)
- Hydrogen FC Hybrid (Electr-wind)
- Hydrogen FC (SMR)
- Hydrogen FC (Coal gasification)
- Hydrogen FC (Electr-wind)

Efficiency Loss

0% 20% 40% 60% 80% 100%

gCO2e/MJ delivered to vehicle wheels

0 100 200 300 400 500 600

- Feedstock
- Production
- Distribution Storage
- Vehicle
- Energy remaining

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Energy use in a typical gasoline passenger vehicle

- **Stanby/Idle**: 16-17%
- **Accessories**: 2%
- **100%**
- **Engine loss**: 61-62%
- **18-20%**
- **Drivetrain loss**: 5-7%

**Tractive Energy**
- Aerodynamic drag: 3%
- Rolling Resistance: 3-4%
- Inertia → Braking: 6%
Price Increase of Vehicle Due to Efficiency Increase

Energy End-Use: Transport

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Historical Relationship Between Vehicle Ownership and GDP per Capita

Energy End-Use: Transport

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Energy End-Use: Transport

Growth of Population and GDP by Region

- Africa
- Latin America
- Middle East
- India
- Other Asia
- China
- E. Europe
- FSU
- OECD Pacific
- OECD Europe
- OECD NA

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Energy End-Use: Transport

Total Stock of LDVs by Region

- Africa
- Latin America
- Middle East
- India
- Other Asia
- China
- E. Europe
- FSU
- OECD Pacific
- OECD Europe
- OECD NA

LDV Stock (millions)

Year:
- 2000
- 2020
- 2040
- 2060
- 2080
- 2100

Stock Growth:
- x2.9
- x4.7
Comparison of Survival Rate for Passenger LDVs

- Expected median lifetime of LDV:
  - Japan: 11.7 years (average: 7.2)
  - US: 13-15 years (9.4)
  - Europe: 12-15 years

![Graph showing survival rate vs vehicle age](image)
Trend of New Vehicle and Stock-average On-road Fuel Economy

Average new LDV Fuel Economy

Stock-average on-road fuel economy

- REF
- GEA-Supply
- GEA-Mix
- GEA-Efficiency

Energy End-Use: Transport
Energy End-Use: Transport

Growth of Stocks of LDVs and Trucks

<table>
<thead>
<tr>
<th>Year</th>
<th>Trucks</th>
<th>LDV</th>
<th>Total</th>
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<td>5050</td>
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<tr>
<td>2050</td>
<td>2100</td>
<td>3000</td>
<td>5100</td>
</tr>
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</table>
Growth of Passenger Transport Activity

- Air
- Train
- Other road
- Bus
- LDV

2005
- REF
- GEA-Supply
- GEA-Mix
- GEA-Efficiency

2030
- REF
- GEA-Supply
- GEA-Mix
- GEA-Efficiency

2050
- REF
- GEA-Supply
- GEA-Mix
- GEA-Efficiency

2100
Growth of Freight Transport Activity

<table>
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<tr>
<th>Year</th>
<th>REF</th>
<th>GEA-Supply</th>
<th>GEA-Mix</th>
<th>GEA-Efficiency</th>
<th>GEA-Supply</th>
<th>GEA-Mix</th>
<th>GEA-Efficiency</th>
<th>2030</th>
<th>2050</th>
<th>2100</th>
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Fuel Consumption Projection for Both Passenger and Freight Transport by Mode

- **Passenger**
  - REF
  - GEA-Supply
  - GEA-Mix
  - GEA-Efficiency

- **Freight**
  - Water
  - Train
  - Truck

Year:
- 2005
- 2030
- 2050
- 2100

Fuel consumption (EJ)
Worldwide Transport Fuel Use for the Whole Sector, Road Transport and LDV Only By Fuel Type

Energy End-Use: Transport

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Worldwide LDV Sales by Region

LDV sales (million vehicles per year)

- Africa
- Latin America
- Middle East
- India
- Other Asia
- China
- E. Europe
- FSU
- OECD Pacific
- OECD Europe
- OECD N. America

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Worldwide LDV Sales by Vehicle Type
Well-to-wheel CO₂ Emissions from Transport Sector for Reference and GEA Pathways: Tank-to-wheel (TTW), Well-to-tank (WTT)

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<th>Year</th>
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<th>GEA-Mix</th>
<th>GEA-Efficiency</th>
<th>REF</th>
<th>GEA-Supply</th>
<th>GEA-Mix</th>
<th>GEA-Efficiency</th>
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<th>GEA-Mix</th>
<th>GEA-Efficiency</th>
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Reduction of Well-to-wheel CO₂ Emissions for LDVs from Reference Scenario in GEA
Sensitivity Analyses for the EV Share in the GEA-supply Pathway, and the Reduction Rate of Vehicle Driving Distance per Vehicle (VT) and Fuel Efficiency (FE) in the GEA-efficiency Pathways

GEA-Supply

GEA-Efficiency

$\text{CO}_2$ emission reduction (Mt$\text{CO}_2$)

EV sales share (%)

VT

FE

Improvement ratio (%)
## Corridor Capacity of Different Modes of Transportation

<table>
<thead>
<tr>
<th>A)</th>
<th>Car</th>
<th>Bus</th>
<th>Bicycle</th>
<th>Coach</th>
<th>Pedestrian</th>
<th>Tram</th>
<th>Train</th>
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<tr>
<td>2000</td>
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<td>14000</td>
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<td>19000</td>
<td>22000</td>
<td>80000</td>
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<table>
<thead>
<tr>
<th>B)</th>
<th>MJ/p-km</th>
<th>1.65-2.45</th>
<th>0.32-0.91*</th>
<th>0.1</th>
<th>0.24*</th>
<th>0.2</th>
<th>0.53-0.65</th>
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<td>C)</td>
<td>€ p-km</td>
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<td>Fossil</td>
<td>Food</td>
<td>Fossil</td>
<td>Food</td>
<td>Electricity</td>
<td>Electricity</td>
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</table>

*Lower values correspond to Austrian busses, upper values correspond to diesel busses in Mexico city before introduction of BRT system.

Key:
A) Values are indicative for European and Asian cities and can vary significantly across cities, world regions, and particular situations. For example, BRT capacity can more than double with a second lane. Suburban rails in India can transport up to 100,000 passengers per hour.

B) Energy intensity in MJ per passenger km. SUVs can exceed depicted values for cars. Energy values for bus in the US are generally higher due to low ridership (Chester and Horvath, 2010). While BRT systems have similar energy efficiencies as normal busses, they provide significant systemic energy savings via modal shift, small bus substitution, and reduction in parallel traffic (Schipper et al., 2009). BRT systems can also be converted from oil based fuels to electricity and hydrogen.

C) Estimated infrastructure costs in euros per passenger kilometer are highest for subway systems and heavy rail. Costs for bus system can be significantly lower than for individual motorized transport. Infrastructure costs for non-motorized transport are very cost competitive and can realize significant social benefits.

D) Dominant fuels are given for each mode.
Energy End-Use: Transport

Energy Intensity Standards of Passenger Cars Extrapolated from Current Fuel Efficiency Standards

![Graph showing energy intensity standards of passenger cars](image)

- USA
- CA
- Japan
- EU
- China

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