Energy Efficiency and Conservation Strategies in Vehicles and Transport Systems

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Transport Is Playing a Significant Role in Global Climate Change

### Contribution of on-road transport to national energy use, GHG, and CO\(_2\) emissions

<table>
<thead>
<tr>
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<th>Energy use</th>
<th>GHG emissions</th>
<th>CO(_2) emissions</th>
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<tbody>
<tr>
<td>The world</td>
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<tr>
<td>2005</td>
<td>10.7</td>
<td>17.0%</td>
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<td>2007</td>
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<td>The U.S.</td>
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<td>1990</td>
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<td>25.3%</td>
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<td>22.1%</td>
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<td>2010</td>
<td>28.1%</td>
<td>22.9%</td>
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<td>EU</td>
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<tr>
<td>1990</td>
<td>21%</td>
<td>12%</td>
<td>15%</td>
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<td>1995</td>
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<td>2008</td>
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<td>2000</td>
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<td>Japan</td>
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<td>1990</td>
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<td>2000</td>
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<tr>
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<td>2010</td>
<td>8.0%</td>
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<td>7.0%</td>
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*There is a great gap between China and developed countries in the contribution of road transport to national energy use and GHG emissions.*

*This contribution is increasing significantly in China, from 4% in 1997 to 7% in 2010.*

*Road-transport will become one of the largest energy consumers and GHG emitters in China in the near term.*

**CO\(_2\) emissions in the world in 2009 (IEA, 2011)**
Vehicle Population Is Growing Dramatically in China

Vehicle Population in China (1978-2012)

- Vehicle population in China was increased from 130 thousand to 120 million from 1980 to 2012, almost 100 times within 32 years.
- Vehicle ownership in China is still very low, 75 vehicle per 1000 people.

China become the largest vehicle market in the world in 2009

Share of vehicle stock and sales of China and the U.S. in 2012
The Dramatic Vehicle Growth Has Caused Various Energy and Environmental Issues in China

On-road transport is

- the main cause of the increasing dependence on imported oil;
- an important contributor to national GHG emissions;

Net imports of oil vs. road transport oil consumption
Policy Measures to Address the Issues

Energy Use = Vehicle use \times Fuel consumption rate

To reduce energy demand
- Fuel economy standards
- Phasing out old, low-efficient vehicles
- Alternative fuels (biomass-based, coal-based)
- Dieselization
- Alternative transport options (subways, railways)
- Reduce vehicle use (fuel tax, congestion fee, carpool, license control, use limitation)
- Traffic management

Emissions = Vehicle use \times Emission factor

To reduce GHG emissions
- Fuel economy standards
- Renewable/low-carbon fuels
- Phasing out old, low-efficient vehicles
- Alternative transport options
- Reduce vehicle use
- Traffic management
In 2012, the State Council of China proposed to lower the fuel consumption rate of light-duty passenger cars to 5L/100km by 2020.

[1] China’s target reflects gasoline fleet scenario. If including other fuel types, the target will be higher.
Fuel Economy Standards : Heavy-Duty Vehicles

Japan’s standard
- Issued in 2005, to be implemented in 2015
- Improved by 12% compared to 2002
- 8-10t (trucks): 15.3 L/100km
- >20 t (tractor-trailer): 47.6 L/100km

The US standard
- Issued in 2011, to be implemented in 2014
- Covers model year 2014-2017
- Improved by 7-20% from 2010 to 2017

China’s standards
- Waiting for final approval, expect to start in 2014
- 8.5-10.5t (trucks): 21.5 L/100km
- 46t (tractor-trailer): 47 L/100km

EU standards
- Under development
Phasing out Old Vehicles

Japan’s measures

- Offering up to 2500 USD for car owners to trade in vehicles 13 years old or older for new, environmentally friendly, fuel-efficient cars

The US measures

- “cash for clunkers” program: consumers could trade in old, “gas-guzzling” vehicles and receive vouchers worth up to $4500 to pay for new, more fuel-efficient cars.

Germany

- Offering 3320 USD if car owners scrap a car older than 9 years and buy a new car.

China’ measures

- Encourage drivers to scrap their Euro 0 vehicles by offering 450-900 USD;
- Restrict mandatorily the use of Euro 0 vehicles in urban centers in some cities.

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In 2012, China’s State Council proposed to achieve accumulated sales of half a million new-energy vehicles (namely EVs) by 2015, and five million by 2020.
GHG Emissions of EVs are Highly Related to the Generation Mixes for Recharging EVs

Generation mixes differ significantly across provinces in China.
GHG Emissions Vary Significantly among Regions

Key remarks:

(1) in the North and Northeast regions, EVs have very limited benefit in GHG reduction, or even increase the emissions because of the high carbon-intensity of the grids, but electric vehicles can reduce GHG emissions in other regions.

(2) In the future, when combustion efficiencies of power plants improve and the share of coal-based electricity decreases, EVs are expected to reduce GHG emissions by over 20%.

Huo et al., *ES&T*, 2013
Alternative Vehicle and Fuel Options: Biofuels

The U.S.
- the U.S. Energy Independence and Security Act of 2007 required a yearly ethanol production of 36 billion gallons by 2022, which translates to 25% bio-ethanol blended into gasoline.

Brazil
- Mandatorily requires gasoline to be blended with 20-25% ethanol.

India
- mandating blending of 20% bio-diesel and bio-ethanol into diesel and gasoline, respectively, by 2017

Bio-Ethanol Production in the U.S., Brazil, and China in 2010
- The U.S., 13.0 billion gallons
- Brazil, 7.0 billion gallons
- China, 0.55 billion gallons

China’ measures
- Plans to put 10 million tons of bio-ethanol in the market by 2020, which is equivalent to 7-8% of blending ratio in gasoline.
GHG Benefits of Bio-fuels Depend on the Process Fuels

- **Corn**
  - NG
  - Coal
  - NG+DGS
  - Coal+DGS
  - DGS
  - Biomass

- **Fast trees**
- **Switchgrass**
- **Agriculture residue**
- **Sugarcane**

![Graph showing GHG emissions of different bio-fuels](image)

Wang et al., ERL, 2007

Wang et al., Energy Policy, 2011
A model is needed to project the future fleet change, and simulate how these measures affect vehicle fleet structure, vehicle use, and vehicle energy efficiency.
Simulating the Effect of the Policy Measures in the Future

FEEI model (Fuel Economy and Environmental Impact Model)

- Two projection modules
  - Vehicle Population Projection
  - Vehicle use projection

- Three databases
  - Fuel consumption rates
  - Emission factors
  - Fuel-cycle data of new-energy vehicles

- Policy scenarios
  - Fuel economy standards
  - Promoting diesel vehicles
  - Promoting advanced vehicles (hybrids and Evs)
  - Promotion of alternative fuels
  - Restriction of vehicle purchase and use
Policy Options Have Different Benefits in Oil Saving

Huo et al., Energy Policy, 2012

The energy demand of China’s on-road transport will continue to increase. It would be increased by 2-3 times by 2050.
Improving Fuel Economy Is the Best Choice to Reduce GHG Emissions

- Electric vehicles and alternative fuels have very limited benefit because the processes of electricity generation and bio-fuels production are highly carbon-intensive.
- Improving fuel economy will be the best option for now but it needs to be in place as soon as possible.

Huo et al., *Energy Policy*, 2012
Conclusion Remarks

- On-road transport is playing an important role in national energy supply and GHG mitigation strategies;
- Many measures have been taken, some of them can benefit both of energy security and the climate, while some may benefit one but harm the other one;
- The correlations between the policy measures and vehicle energy use and emissions are complicated;
- In the near term, improving fuel economy of vehicles is the most effective way to control energy use and emissions;
- In the midterm, advanced vehicles and alternative fuels would be effective when energy use and emissions of the upstream sectors (e.g. power plants, biofuel production plants) are getting better controlled.
- In the long term, enlarging the share of public transport and improving the traffic management will be the effective solution for China.
Thanks!