Development in Emission Inventory for Transportation in China

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Background

The rapid increase in vehicle population in China has been severely taxing the energy and material resources, and also posing a challenge to the mitigation of CO$_2$ and urban criteria air pollutants.
Total vehicle population will continue to increase rapidly, and will reach 210-240 million units in 2020, and 410-530 million units in 2030!

No matter which growth scenario, China will become the leading country in vehicle population within the next 15 years.
Major On-road Transportation Research Areas in THU

- Emission factor model and high-resolution emission inventories for on-road vehicles in major cities and regions of China
  - Chassis test and on-road tests with PEMS for LDVs and HDVs
  - Emission factor model development for Beijing, Macao, and other cities
  - High resolution emission inventory integration with urban traffic flows
  - Comprehensive environmental impact assessment tools for different control measures and policies

- Life-cycle assessment of energy, CO2 and environmental impacts of new advanced technologies and alternative fuels
  - Both fuel-cycle and vehicle-cycle are included: feedstock recovery, fuel production, vehicle operation, vehicle material recovery and production, and vehicle assembly and disposal
  - Vehicle/fuel systems: HEV, PHEV, EV, CNGV/LNGV, EtOH, BD, etc.
Current status and future trends in vehicle emission control in China: 2010-2030

- Current status and future trends in emission control regulations
  - **New vehicle emission standards:**
    - Light duty vehicles: Euro 4 (now) to Euro 6 (~2020)
    - Heavy duty vehicles: Euro 3 (now) to Euro 6 (~2025)
  - **Fuel quality:** 50 ppm S nationwide in ~2015-2020; and 10 ppm S in ~2025-2030
  - **Restriction in vehicle travel demand and total population:** such as stop driving one day a week, restriction in new vehicle purchase, etc., might be popular in many major cities of China

- In the future, three major vehicle categories need to pay special attention:
  - **Heavy-duty diesel vehicles (HDDV):** high emission profiles, high VKT, etc.
  - **Off-road vehicles:** poor emission controls, poor fuel quality, etc.
  - **New-energy and alternative fueled vehicles (e.g., EV, CNGV):** totally different emission profiles in life-cycle point of view
THU has developed a detailed emission database with thousands of tested vehicles

- Real-world on-road vehicle measurement
  - Gaseous air pollutants and PM (both mass and number concentrations)
  - Driving cycle development and vehicle activity database
- Chassis dynamometer and remote sensing measurement
Vehicle emission factor models for Beijing and other cities in China have been developed

**Emission factor model for Beijing vehicle fleet (EMBEV 1.0)**

**Vehicle category of EMBEV V1.0:**
Light-duty passenger vehicle 1 (G)
Light-duty passenger vehicle 2 (G, D)
Medium-duty passenger vehicle (G, D)
Heavy-duty passenger vehicle (G, D)
Light-duty truck (G)
Heavy-duty truck 1 (G, D)
Heavy-duty truck 2 (G, D)
Heavy-duty truck 3 (G, D)
Motorcycle (G)
Bus (G, D, CNG, hybrid)
Taxi (G)

*Note:* G = gasoline, D = diesel, CNG = compressed natural gas, hybrid = hybrid diesel-electric

1. **Emission measurement:** 1500 LDGVs dynamometer tests and 150 HDDVs PEMS tests
2. **Modeling methodology:**
   a. For LDGVs, basic emission factors (BEFs) under a typical driving cycle and then corrected by a series of operating conditions (e.g., speed, fuel quality, I/M, air-conditioning, etc.)
   b. For HDDVs, an operating mode binning methodology based on VSP and vehicle speed.
Major findings on NOX emissions for HDDVs: no reduction was found based on PEMs.

These new on-road test results indicate that previous estimates of total NOX emissions for HDDV fleet may be significantly underestimated. This would also result in 4% increase in estimation of national anthropogenic NOX emissions.

Wu, Zhang, Hao, ACP, 2012 (in press)
City-Region-Nation: integration of three levels in resolution for emission inventory development

On-road Sources
(Cars, trucks, buses, taxis, etc.)

Off-road Sources
(Forklifts, boats, ships, tractors, etc.)

Different Scale Emission Inventories

Nation
Each provinces

Region/City clusters
e.g. Jing-Jin-Ji, Yangtze-River-Delta, Pearl-River-Delta

City
High resolution emission inventory
City-Region-Nation: integration of three levels in resolution for emission inventory development

- **Database for each regions/cities:**
  - Calendar year, vehicle population, registered vehicle distribution...
  - Vehicle technologies...
  - Various fuel options...
  - Traffic flows and vehicle activity data...

- **Database for the calculation of emission factors**
  - Basic emission factors
  - Speed correction
  - Fuel quality correction
  - …
A comprehensive EIA tool was developed to evaluate the environmental impacts of different control measures in Chinese cities, such as Beijing, Guangzhou, Macao, etc, during the time period of 2000-2030.

Temporal control planning for big events, such as Beijing Olympics, Shanghai Expo, and Guangzhou Asian Games, was carefully evaluated.

Zhou, Wu, Hao, et al., AE, 2010;
New-energy vehicles and alternative fueled vehicles need to be carefully examined in China in the future.

**Conventional Spark-Ignition Vehicles**
- Conventional gasoline, federal reformulated gasoline, California reformulated gasoline
- Compressed natural gas, liquefied natural gas, and liquefied petroleum gas
- Gaseous and liquid hydrogen
- Methanol and ethanol

**Compression-Ignition Direct-Injection Hybrid Electric Vehicles: Grid-Independent and Connected**
- Conventional diesel, low sulfur diesel, dimethyl ether, Fischer-Tropsch diesel, E-diesel, and biodiesel

**Battery-Powered Electric Vehicles**
- U.S. generation mix
- California generation mix
- Northeast U.S. generation mix
- User-selected generation mix

**Fuel Cell Vehicles**
- Gaseous hydrogen, liquid hydrogen, methanol, federal reformulated gasoline, California reformulated gasoline, low sulfur diesel, ethanol, compressed natural gas, liquefied natural gas, liquefied petroleum gas, and naphtha

**Spark-Ignition Hybrid Electric Vehicles: Grid-Independent and Connected**
- Conventional gasoline, federal reformulated gasoline, California reformulated gasoline
- Compressed natural gas, liquefied natural gas, and liquefied petroleum gas
- Gaseous and liquid hydrogen
- Methanol and ethanol

**Spark-Ignition Direct-Injection Vehicles**
- Conventional gasoline, federal reformulated gasoline, and California reformulated gasoline
- Methanol and ethanol
New-energy vehicles and alternative fueled vehicles need to be carefully examined in China in the future.

Demonstration of HEV/PHEV/EV in 25 cities of China (2009-2012)

Legend
- 2500 units
- 1000 units
- EV
- HEV
- PHEV
HEV can achieve 30% reduction in petroleum use relative to ICEV; while PHEV50 can achieve 50% reduction, and EV almost eliminates the petroleum use.

In this study, we use a FE rate of 140% for HEV, 280% for CD mode and 120% for CS mode for PHEV50 (AER= 50 km), and 325%-375% for EV relative to ICEV. For ICEV, FE values are 8.5, 7.3 and 6.4 L/100 km for 2010, 2020, and 2030, respectively. (Wu, Yang, Hao, Energy Policy, 2012)
The impacts of energy use, CO₂ and air pollutant emissions are quite different

- The WTW CO₂ reduction benefit is much less for PHEV/EV for those regions (e.g., Jing-Jin-Ji region) with dominant coal-fired power plants.
- However, in those regions that already have a sizeable proportion of clean electric energy (e.g., Pearl-River-Delta region) will relieve the overall CO₂ burden substantially with promotion of PHEV and EV in the future. (Wu, Yang, Hao, Energy Policy, 2012)
The impacts of energy use, CO\textsubscript{2} and air pollutant emissions are quite different

For LDV, WTW NO\textsubscript{x} emission of EV is higher than ICEV by 50-100%, especially in those regions (e.g., Jing-Jin-Ji region) with dominant coal-fired power plants

WTW NO\textsubscript{x} emission of EV might be lower than ICEV after 2020 in those regions that already have a sizeable proportion of clean electric energy (e.g., Pearl-River-Delta region).

With a wide use of NO\textsubscript{x} control devices (e.g., SCR) in the next 10 years for coal-fired power plants, NO\textsubscript{x} emission of EV will decrease more rapidly than that of ICEV.
Thank you for your attention!

Questions and Comments?