Developing a First-Ever National Mobile Source Emissions Inventory for China

Presented by:

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Introduction to VECC-MEP

- VECC-MEP is China’s national vehicle emission policy research center under the Ministry of Environmental Protection (MEP).
- Provides technical support and policy analysis to various departments of MEP, as well as city and provincial-level governments.
- Three divisions:
  1) New Vehicle Compliance Office
  2) Policy and Regulatory Research Department
  3) Logistics Department
- Long-standing cooperation with US EPA on issues of in-use vehicle compliance, fuel quality, emissions control program management, and more.
• Rapidly increasing vehicle population in China, especially private cars:

- At end of 2007, ~44 million on-road civil vehicles, plus 7 million low speed agricultural vehicles and 90 million motorcycles
Vehicle Examples
Recent city-level emissions inventory research in Beijing indicates that motor vehicles in Beijing are responsible for about three-quarters of ambient CO and NOx concentrations and about half of VOC concentrations.

To control vehicle emissions, China is quickly implementing a host of policies, including:

- Euro IV-equivalent tailpipe emission standard in Beijing; Euro III nationwide
- Retrofit / scrappage programs
- Restrictions on high-emitting vehicles
- Improving compliance management
- National R&D programs and subsidies for new technology vehicles
- Implementing cleaner fuels
In late 2006, MEP initiated a first-ever national pollution source census for all sectors. An emissions inventory is critical for developing effective, targeted emissions reduction programs.

- Base year is 2007.
- Results to be published in mid-2009.
- VECC-MEP is in charge of the mobile source component of the census.
- Initially considering 4 pollutants: CO, HC, NOx, PM10, plus CO\textsubscript{2}.
- Planning to incorporate off-road mobile sources: construction equipment, river boats.
- Not included in first inventory: trains, ships, planes.
Project Goals and Structure

• Accurate estimate and projection of China’s national mobile source emissions, by vehicle type and pollutant, annually from 1995 – 2025.

• Development of a software emissions model that may be used by local cities and provinces in China to calculate their own mobile source emissions inventories.

• Three parts:
  1) Data collection (fall - winter 2007 - 2008)
  2) Methodology and model development (spring - fall 2008)
  3) Inventory creation (winter - spring 2008 - 2009)
Existing International Models

- One of the key first steps – identify international models already in use / under development:
  - MOBILE / NMIM (US)
  - MOVES (US)
  - EMFAC (CA, HK)
  - COPERT (Europe)
  - HBEFA / TREMOD (Europe)
  - CMEM
  - IVE (international)

- Questions:
  - Which could be adapted for use internationally?
  - Which methodologies are appropriate for China?
    - “Next generation” models like IVE and MOVES (based on power demand) represent better accuracy…is there an opportunity to leap-frog?
  - Which include default data / equations that could be used in China?
Considerations in Developing Model

- Identify existing databases and key data limitations
  - China has strong existing database of light duty vehicle zero mileage emissions from emissions testing
  - On the other hand, China very little real world complete vehicle emissions results for heavy duty vehicles

Result: different methodologies for LDV and HDV
China Vehicle Emissions Model (CVEM)

- CVEM is a software model for calculating mobile source emissions from cities and provinces in China.
- The methodology behind the software combines elements of international models MOBILE, COPERT, and IVE model according to available data and resources.
  - A MOBILE-type methodology is used for hot running and cold start emissions from light-duty vehicles and motorcycles.
  - A COPERT-type methodology is used for evaporative emissions.
  - An IVE-type methodology is used for heavy-duty and low-speed vehicles.
- VECC-MEP managing overall project and light-duty vehicle and motorcycle components; Tsinghua University managing heavy-duty and low-speed components.
Emission and Activity Types

• Two general categories of emissions:

Total emissions = tailpipe emissions + evaporative emissions

• Tailpipe emissions can be further categorized as cold start or hot running, and by road type:

Tailpipe emissions = cold start emissions + hot running emissions
= urban emissions + suburban emissions + highway emissions

• Some key variables affecting emissions:

**Location data:**
- Temperature
- Altitude
- Fuel properties
  - Ethanol content
  - Sulfur content
  - RVP

**Vehicle activity data:**
- Average speed by road type
- Vehicle Specific Power (VSP) bin allocation
- Driving share by road type
- Annual vehicle miles traveled (VMT)
- Number of cold starts per day
- Average trip length

**Vehicle fleet data:**
- Vehicle population by type, model year, and emission standard
- Odometer mileage
Emissions amount = vehicle amount x VMT x emission factor (EF)

- Emissions amount is by vehicle type (including emission standard) and pollutant.
- Three key factors:
  - Vehicle amount
  - Vehicle miles traveled (VMT)
  - Emission factor (g/km) (Includes a number of correction factors for speed, temperature, altitude, etc)

**LDV and MC EF:** “average speed” based

$$EF_{hot} = BEF \times SCF \times TCF \times LCF \times FCF \times ACF$$

BEF = basic emission factor; Speed, Temperature, Load, Fuel, Altitude

**HDV and Low-Speed EF:** “VSP” based

$$EF = \frac{\sum_{k=1}^{13} (ER_k \times F_k)}{v \times CF}$$

ER = emission rate in VSP bin k, F is time in bin k, v is speed, CF is correction factor(s)
Data Inputs Summary

• Data sources are both original research / surveying and international experience.
• In fall, 2007, VECC-MEP completed a series of emission factor research and vehicle activity surveys around China.
• Driving cycle data from fall 2007 survey of 17 cities in China.
• Road share data from driver surveys (questionnaires) in 6 cities in China.
• Certain fleet information data (e.g. odometer mileage) collected from manufacturers from maintenance check-ups in 345 cities in China.
• Vehicle amounts from annual registration data from public security bureau and CAAM/CATARC annual yearbook.
• Emission factors and correction factors from VECC-MEP or partner research or international precedent.
  – Emissions certification testing
  – Dynamometer testing
  – PEMS testing
Data Collection Photos

Installing a PEMS device on a heavy duty truck in Beijing suburbs.

Light duty passenger vehicle dynamometer testing at CRAES.
CVEM Software

- **Location inputs:**
  - Temperatures by month
  - Altitude
  - Fuel ethanol and sulfur content; RVP

- **Vehicle inputs:**
  - Vehicle type, population, new registrations per year
  - Vehicle activity data
    - Driving share by road type
    - Driving speed by road type
    - Number of cold starts per day
    - Average trip length
    - VMT

- **Outputs (by vehicle type and pollutant):**
  - Hot emissions
  - Cold emissions
  - Evaporative emissions
  - Total emissions
CVEM Software User Interface

- Like COPERT, “run wizard” guides user through data input
- Data can also be imported / exported from / to Excel
- Current output is text only; still developing analysis and graphing capability
Initial National Inventory Results – NOx (1)

- Distribution by vehicle type (not including motorcycles):

  China 2007 Nationwide Vehicle Distribution (not including Motorcycles and Scooters)

  - Taxis: 3%
  - Heavy Duty Trucks: 9%
  - Other Buses: 5%
  - Public Buses: 1%
  - 3 and 4-wheeler Commercial Vehicles: 13%
  - Light and Medium Commercial Vehicles: 13%
  - Passenger Cars: 56%

  China 2007 Nationwide Mobile Source NOx Inventory - Share by Vehicle Type (not including motorcycles and scooters)

  - Heavy Duty Trucks: 42%
  - Passenger Cars: 8%
  - Public Buses: 5%
  - Other Buses: 27%
  - 3 and 4-wheeler Commercial Vehicles: 3%
  - Taxis: 6%
  - Light and Medium Commercial Vehicles: 13%
Initial National Inventory Results – NOx (2)

- Note disproportionately high share of emissions from HDVs:

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Vehicle Quantity Percentage Share</th>
<th>NOx Emissions Percentage Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxis</td>
<td>3%</td>
<td>6%</td>
</tr>
<tr>
<td>Passenger Cars</td>
<td>56%</td>
<td>8%</td>
</tr>
<tr>
<td>Public Buses</td>
<td>1%</td>
<td>5%</td>
</tr>
<tr>
<td>Other Buses</td>
<td>5%</td>
<td>27%</td>
</tr>
<tr>
<td>Light and Medium Commercial Vehicles</td>
<td>13%</td>
<td>3%</td>
</tr>
<tr>
<td>Heavy-Duty Trucks</td>
<td>9%</td>
<td>42%</td>
</tr>
<tr>
<td>3 and 4-wheelers</td>
<td>13%</td>
<td>9%</td>
</tr>
</tbody>
</table>

Results not yet verified by MEP
Conclusions and Key Lessons

- Emissions inventories are critical for developing targeted control policies and tracking progress.
- China’s experience shows that even developing countries with limited data can develop reasonable inventories.
- Some key reasons for success:
  - Didn’t try to reinvent the wheel of methodology
  - Started from a foundation of existing data
  - Prioritized new data acquisition
  - Worked with international experts throughout entire process
- Important next steps:
  - Recognize and be open about limitations
  - Work towards transparency
  - Can China’s experience be a model for other developing nations?
  - China to host an International Emissions Inventory Conference?
Thanks! 谢谢！
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Appendix
Hot Emissions Model Overview

EF = New vehicle EF * deterioration factor * speed factor * other correction factors

\[ EF = \sum_{k=1}^{13} \left( E_{R_k} \times F_k \right) / v \times C'F \]
Implementation of tailpipe emission standards following Europe’s precedent; “time lag” decreasing.
### Selected Data Results (1)

**Note:** Average urban speeds depends greatly on city.

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Annual VMT (nationwide average, km)</th>
<th>Average Speed (nationwide average, km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxis</td>
<td>138,000</td>
<td>35.3</td>
</tr>
<tr>
<td>Passenger Cars</td>
<td>25,216</td>
<td>35.3</td>
</tr>
<tr>
<td>Public Buses</td>
<td>45,757</td>
<td>15.6</td>
</tr>
<tr>
<td>Other Buses</td>
<td>114,800</td>
<td>15.6</td>
</tr>
<tr>
<td>Light-Duty Commercial Vehicles</td>
<td>44,000</td>
<td>35.3</td>
</tr>
<tr>
<td>Heavy-Duty Trucks</td>
<td>105,600</td>
<td>33.8</td>
</tr>
<tr>
<td>Low Speed Goods Vehicles</td>
<td>23,000</td>
<td>14.3</td>
</tr>
<tr>
<td>Low Speed 3-Wheeled Vehicles</td>
<td>30,900</td>
<td>22.7</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>6,612</td>
<td>28.0</td>
</tr>
</tbody>
</table>
**Selected Data Results (2)**

**BEF for CO for Micro and Small Passenger Cars (g/km)**

<table>
<thead>
<tr>
<th>Vehicle Size and Use</th>
<th>Fuel</th>
<th>2000 and earlier (Euro 0)</th>
<th>1/1/01 - 12/31/04 (Euro 1)</th>
<th>1/1/2005 - present (Euro 2)</th>
<th>1/1/06 Beijing and Guangzhou (Euro 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro Passenger</td>
<td>Gasoline</td>
<td>14.83</td>
<td>1.44</td>
<td>0.84</td>
<td>0.78</td>
</tr>
<tr>
<td></td>
<td>Diesel</td>
<td>14.83</td>
<td>1.44</td>
<td>0.84</td>
<td>0.78</td>
</tr>
<tr>
<td>Small Passenger</td>
<td>Gasoline</td>
<td>16.73</td>
<td>2.06</td>
<td>1.26</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Diesel</td>
<td>2.00</td>
<td>1.74</td>
<td>0.91</td>
<td>0.78</td>
</tr>
</tbody>
</table>

**SCF for Small Passenger Cars**

<table>
<thead>
<tr>
<th>Emission Standard</th>
<th>Pollutant</th>
<th>Speed Correction Factor</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro 0</td>
<td>CO</td>
<td>$y = 6.7479V^{-0.5313}$</td>
<td>0.8084</td>
</tr>
<tr>
<td></td>
<td>HC</td>
<td>$y = 29.025V^{-0.9337}$</td>
<td>0.9458</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>$y = 0.0002V^2 - 0.0056V + 0.4161$</td>
<td>0.9046</td>
</tr>
<tr>
<td>Euro 1, Euro 2</td>
<td>CO</td>
<td>$y = 16.303V^{-0.9333}$</td>
<td>0.9869</td>
</tr>
<tr>
<td></td>
<td>HC</td>
<td>$y = 17.996V^{-0.9916}$</td>
<td>0.9619</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>$y = 0.0009V^2 - 0.0657V + 1.6247$</td>
<td>0.9384</td>
</tr>
</tbody>
</table>

**LDV accumulated km vs. vehicle age**

All equations built into software model...
Vehicle Types and Classification

For this project, vehicle types are specified according to China Public Security Bureau classification system used to track vehicle registration statistics. Overall 34 types by type, size, fuel.

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Size</th>
<th>Fuel</th>
<th>Emission Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Vehicles (bus, taxi, other)</td>
<td>micro, small, medium, large</td>
<td>gasoline, diesel, LPG, other</td>
<td>Euro 0-4</td>
</tr>
<tr>
<td>Commercial Vehicles</td>
<td>micro, light, medium, heavy</td>
<td>gasoline, diesel</td>
<td>Euro 0-4</td>
</tr>
<tr>
<td>Low-Speed Vehicles</td>
<td>three-wheeled, four-wheeled</td>
<td>diesel</td>
<td>Euro 0-4</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>standard, scooter</td>
<td>gasoline</td>
<td>Euro 0-4</td>
</tr>
</tbody>
</table>

VECC-MEP has paired vehicle registration data with emission standard implementation dates to estimate annual quantities of vehicle types by tailpipe emission standard and fuel type.
Initial National Inventory Results – NOx (3)

- Distribution by fuel

China 2007 Nationwide Vehicle Distribution by Fuel Type (not including Motorcycles and Scooters)
- Gasoline: 68%
- Diesel: 31%
- Other: 1%

China 2007 Nationwide Mobile Source NOx Inventory - Share by Fuel Type
- Gasoline: 33%
- Diesel: 65%
- Other: 2%

Results not yet verified by MEP