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

Presented by:

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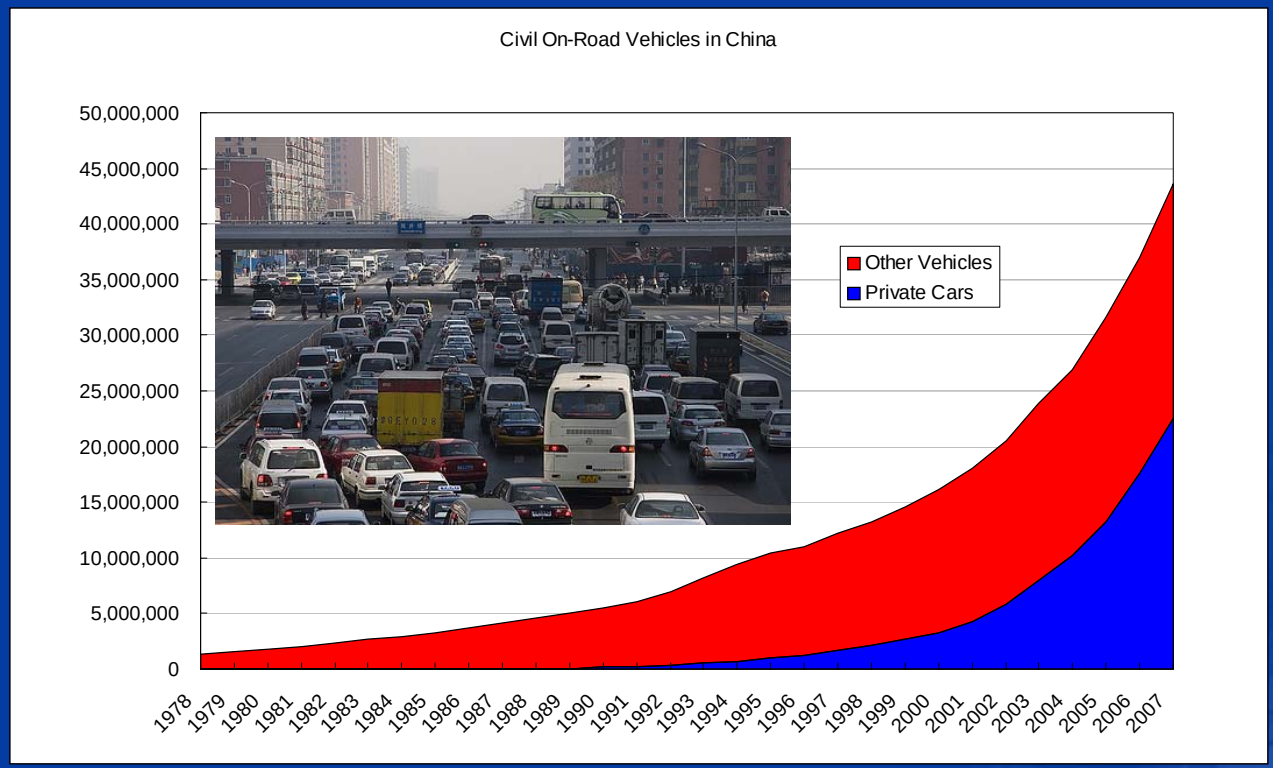
Introduction to VECC-MEP

- 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.

Context (1)

- 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









Context (2)

- 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

Project Background and Introduction

- 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_2.
- On-road mobile sources: passenger and commercial vehicles, motorcycles, low-speed vehicles (agricultural vehicles).
- 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

Hot Running Emissions Methodology Overview

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

EFhot = BEF x SCF x TCF x LCF x FCF x ACF

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

HDV and Low-Speed EF:
"VSP" based

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

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.

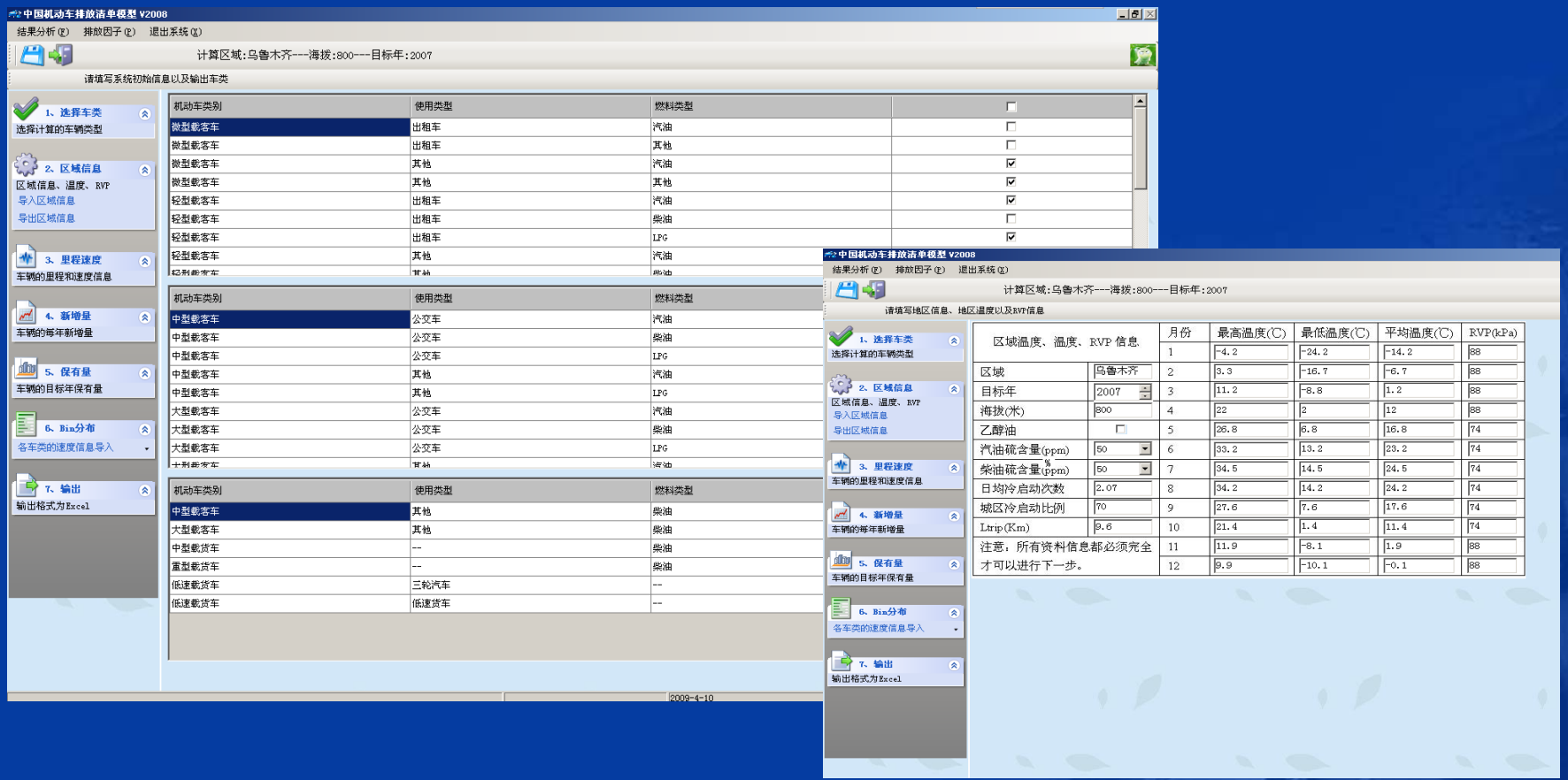
Light duty passenger vehicle dynamometer testing at CRAES.

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

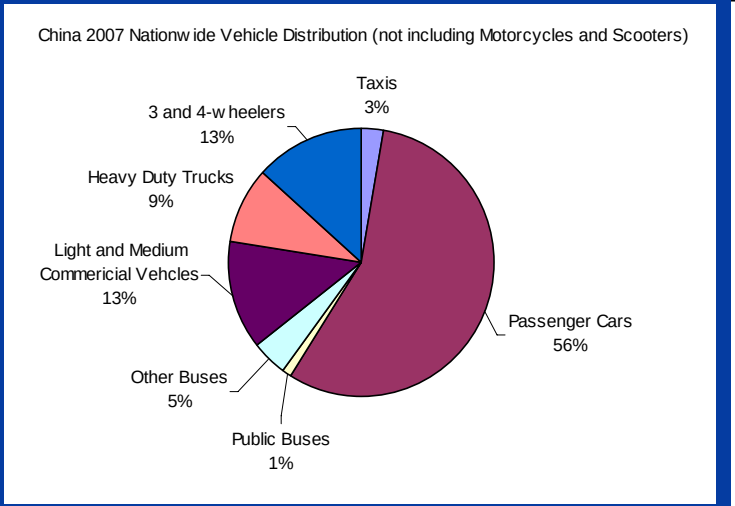
CVEM Software User Interface

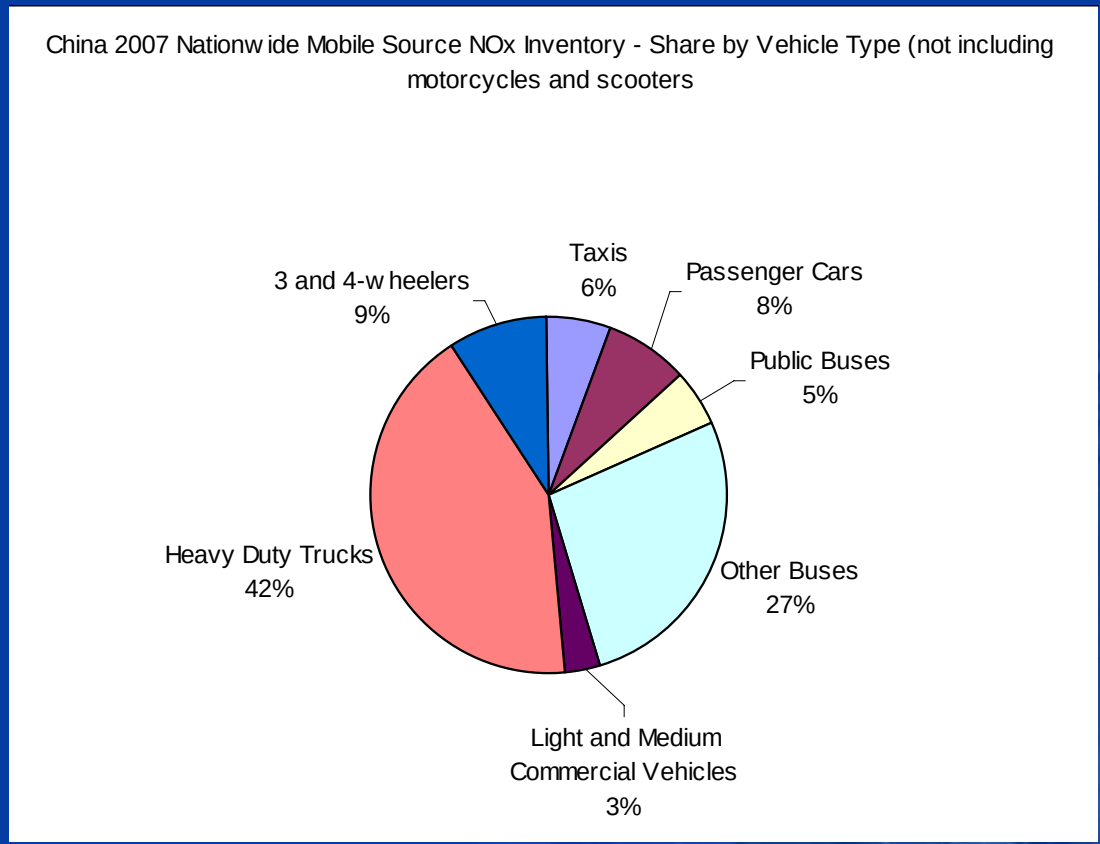
- Like COPERT, “run wizard” guides user through data input
- Data can also be imported / exported from / to Excel
- Current output is text only; still developing analysis and graphing capability



Initial National Inventory Results – NOx (1)

- Distribution by vehicle type (not including motorcycles):





Results not yet verified by MEP

Initial National Inventory Results – NOx (2)

- Note disproportionally high share of emissions from HDVs:

Vehicle Type	Vehicle Quantity Percentage Share	NOx Emissions Percentage Share
Taxis	3%	6%
Passenger Cars	56%	8%
Public Buses	1%	5%
Other Buses	5%	27%
Light and Medium Commercial Vehicles	13%	3%
Heavy-Duty Trucks	9%	42%
3 and 4-wheelers	13%	9%

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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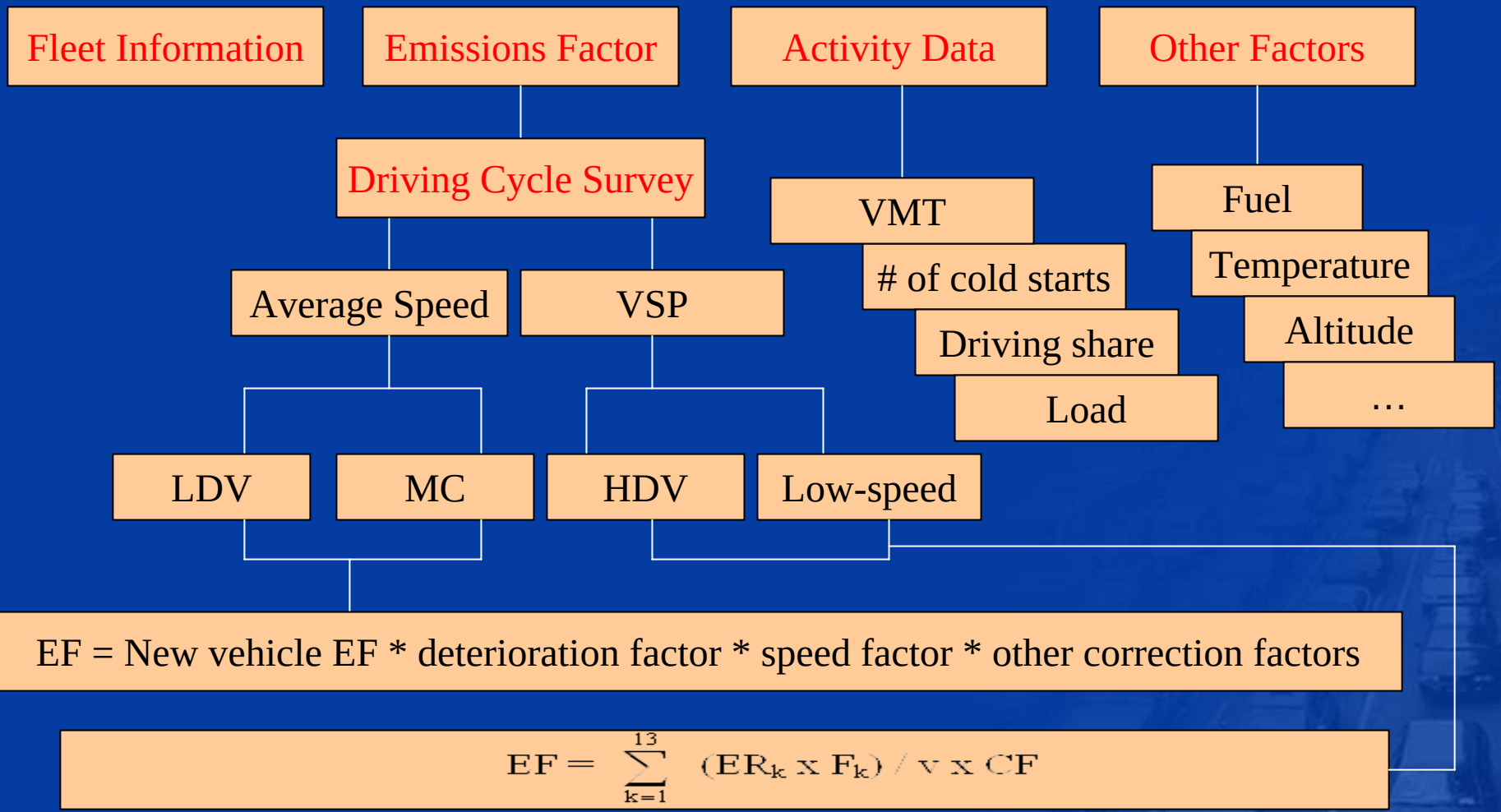
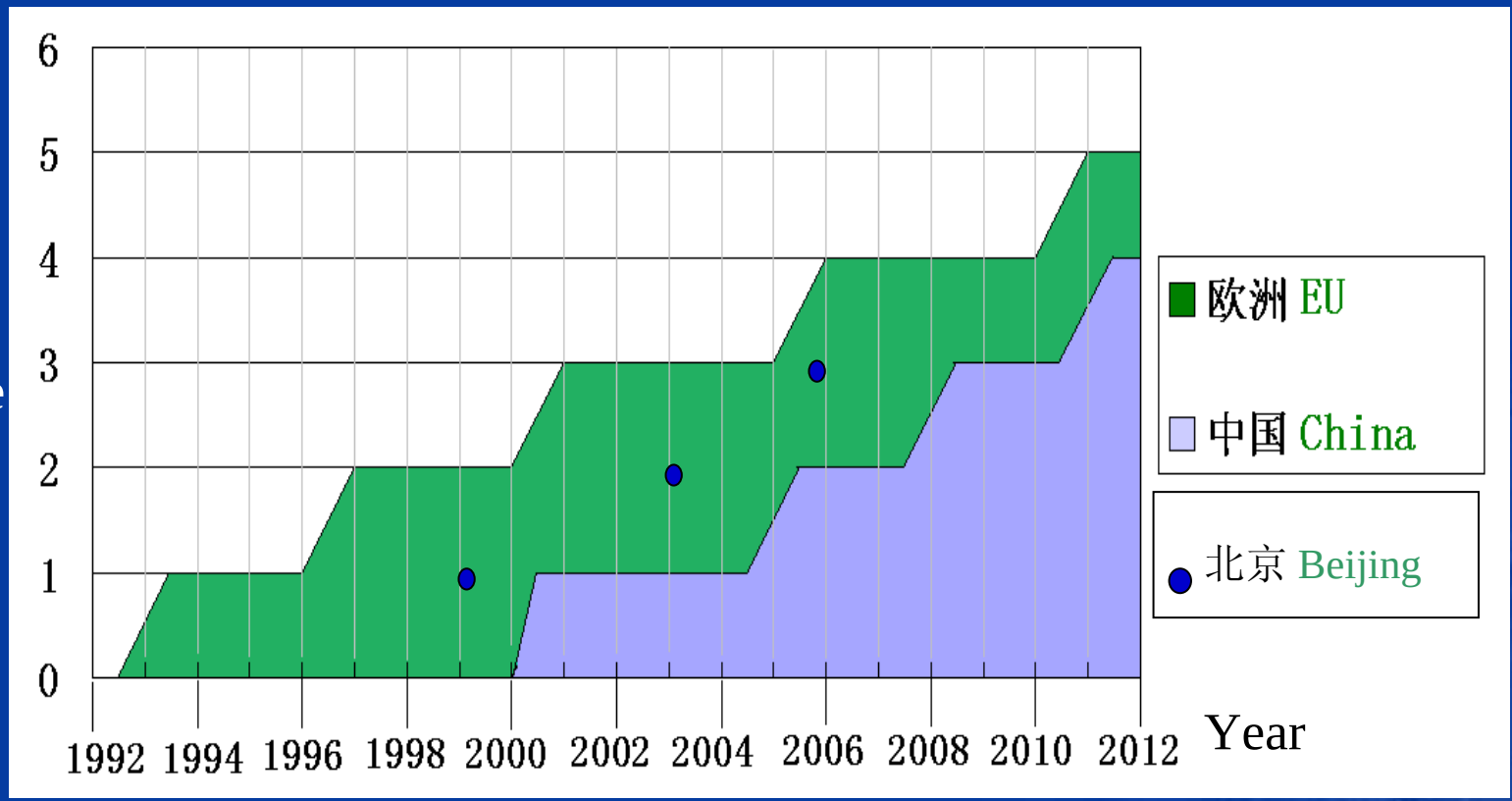
Appendix

Hot Emissions Model Overview



Context (3)



Implementation of tailpipe emission standards following Europe's precedent; "time lag" decreasing.

Selected Data Results (1)

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

Note: Average urban speeds depends greatly on city

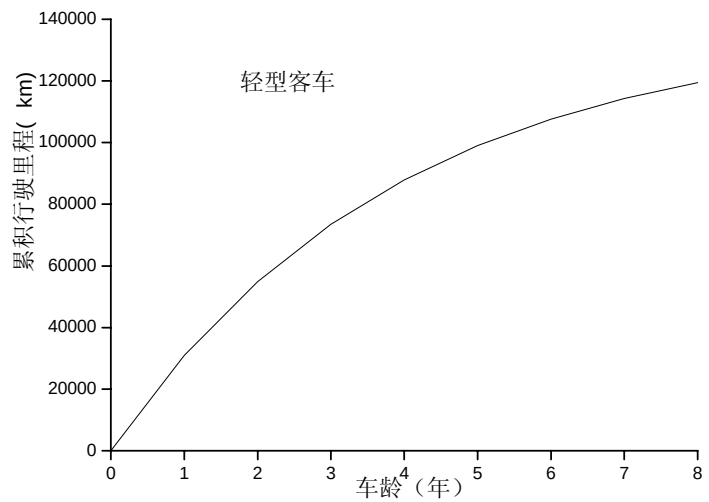
Selected Data Results (2)

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

		Registration date			
Vehicle Size and Use	**Fuel**	**2000 and earlier (Euro 0)**	**1/1/01 - 12/31/04 (Euro 1)**	**1/1/2005 - present (Euro 2)**	**1/1/06 Beijing and Guangzhou (Euro 3)**
Micro Passenger	Gasoline	14.83	1.44	0.84	0.78
	Diesel	14.83	1.44	0.84	0.78
Small Passenger	Gasoline	16.73	2.06	1.26	0.38
	Diesel	2.00	1.74	0.91	0.78

SCF for Small Passenger Cars

Emission Standard	Pollutant	Speed Correction Factor	R^2
Euro 0	CO	$y = 6.7479V^{-0.5313}$	0.8084
	HC	$y = 29.025V^{-0.937}$	0.9458
	NOx	$y = 0.0002V^2 - 0.0056V + 0.4161$	0.9046
Euro 1, Euro 2	CO	$y = 16.303V^{-0.9333}$	0.9869
	HC	$y = 17.996V^{-0.9916}$	0.9619
	NOx	$y = 0.0009V^2 - 0.0657V + 1.6247$	0.9384



LDV accumulated km vs. vehicle age

All equations built into software model…

Vehicle Types and Classification

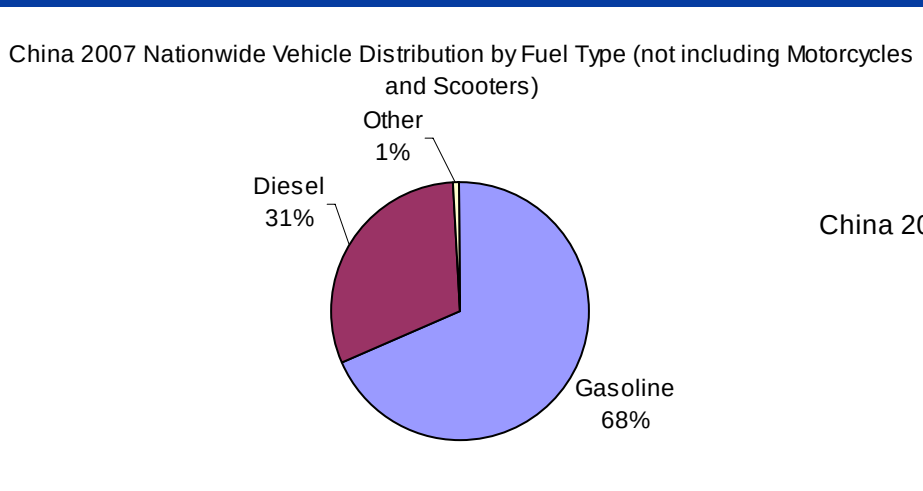
- For this project, vehicle types are specified according to China Public Security Bureau classification system used to track vehicle registration statistics. Overall 34 types by type, size, fuel.

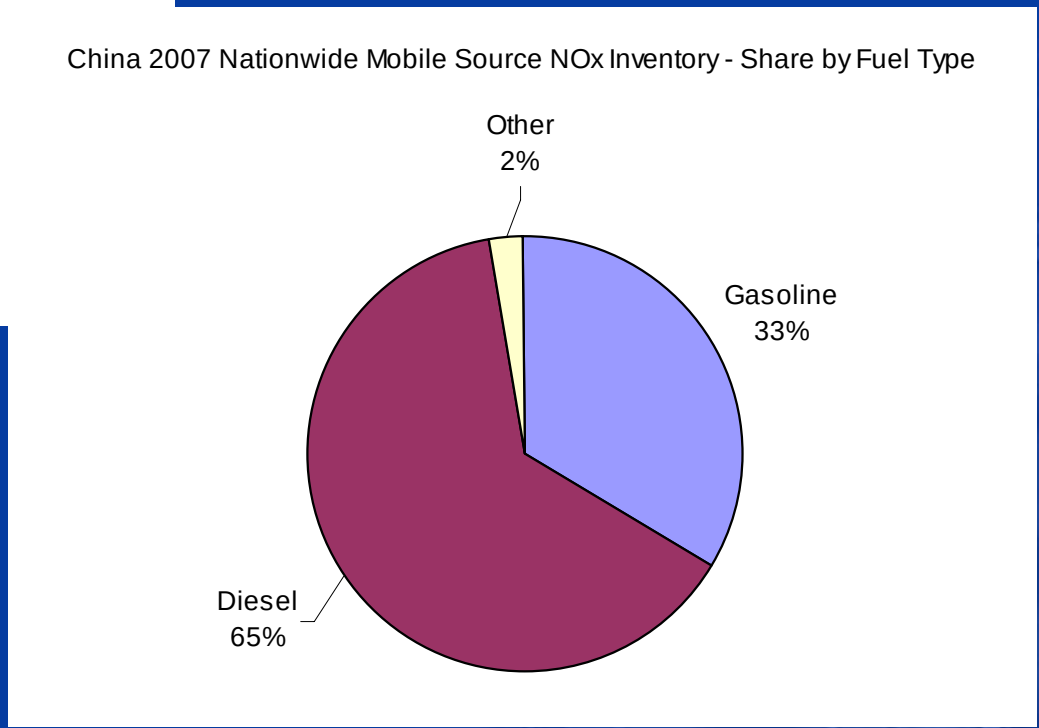
Vehicle Type	Size	Fuel	Emission Standard
Passenger Vehicles (bus, taxi, other)	micro, small, medium, large	gasoline, diesel, LPG, other	Euro 0-4
Commercial Vehicles	micro, light, medium, heavy	gasoline, diesel	Euro 0-4
Low-Speed Vehicles	three-wheeled, four-wheeled	diesel	Euro 0-4
Motorcycles	standard,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

- 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





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