Ambition to Action:
Clean Air for Health and the Climate

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CLIMATE & CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS
a UNEP convened initiative

Two Decades of Progress in Vehicle Emission Control: Insights and Opportunities for Asia

SCHOOL OF ENVIRONMENT TSINGHUA
清华大学环境学院

CLEAN AIR ASIA

ENERGY FOUNDATION
能源基金会

Two Decades of Progress in Vehicle Emission Control: Insights and Opportunities for Asia

MODERATOR

Le Yin
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Energy Foundation China

Day 1 Conference | 15 November

Two Decades of Progress in Vehicle Emission Control: Insights and Opportunities for Asia

KEYNOTE PRESENTATION

Michael P. Walsh
Board Member Emeritus
International Council on
Clean Transportation

Day 1 Conference | 15 November

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Motor Vehicle Pollution Control in PRC
How It All Began

A Retrospective and Prospective Study on 20 Years' Mobile Source Emissions Control in Megacities of PRC

November, 2023

Michael P. Walsh
Board Member Emeritus,
International Council on Clean Transportation

1995 The World Bank Launches B – 9 – 3 Project

- **Insignificant Motor Vehicle Population, Very Modest New Vehicle Market**
- **ECE Emissions Standards on Paper But Not Enforced**
- **Poor Quality Fuels – High Sulfur, Only Leaded Gasoline**
- **NEPA Takes the Lead To Develop a Vehicle Pollution Control Program**
- **Support Team – CRAES, BARI, Tsinghua, World Bank Consultants/Experts**
- **Broad Scope of Work**
  - Collect All Available Vehicle Emissions Data; Create Inventory
  - Develop Compliance Strategies for New & Existing Vehicles
  - Explore Options to Produce Cleaner Vehicles and Fuels

Some of the Key Players

An International Advisory Team

- **NEPA (Li Pei) Wanted To Review the Global Experience Before Deciding How PRC Would Proceed**
- **I Recruited International Experts**
  - Jan Karlsson from the Swedish EPA knew the European Program and
  - Takuro Miyazaki from Japanese EPA knew the Japanese program
- **Our Goal Was To Provide Objective Information Regarding US, EU and Japanese Programs To Enable PRC To Make Wise Decisions**
- **Professors Hao Jiming And He Kebin And Several Tsinghua Graduate Students Were Very Involved As Well**
- **Our First Meeting Was in September 1995**

A 2 Year Process Ensued Debating and Discussing Many Issues

- **For Example:**
  - Should PRC Develop its Own Driving Cycles?
  - Qualified Test Laboratory Availability (CATARC?)
  - Compliance Program? Type Approval System, Europe or US Approach?
  - Staffing Needs – How Many, What Skill Set (CRAES?)
- **NEPA Decision: Follow Europe**
  - Some Familiarity with UN ECE System
  - Largest International Manufacturer, VW, based in Europe
  - US, Japan Too Complex

Major Remining Challenge – Fuel Quality

- **Amendments to Atmosphere Pollution Control law passed by the Standing Committee of the National People's Congress on August 29, 1995, Authorized NEPA To Adopt Vehicle Emissions Standards**
- **But It Did Not Confer Legal Authority To NEPA To Set Fuel Quality Standards**
- **At Request of the State Council, NEPA Convened A Major Workshop in Shanghai in March 1997**
  - Attendees Included Representatives From Major Ministries And Commissions That Had Responsibilities In The Areas Of Vehicle Manufacturing, Planning, Finance, Science And Technology Support For Vehicles, Oil Refining And The Environment, Including Several Cities.
  - At Workshop, Sinopec Said It Was Ready To Deliver Unleaded Gasoline Nationwide By 2000 If The National Government Provided The Necessary Investment; The Necessary Technical Research Had Already Been Carried Out And They Knew What Upgrades Were Needed And What It Would Cost.
  - The Environmental Bureaus Of Three Major Cities (Beijing, Shanghai, And Guangzhou) Stated That They Wanted And Needed Unleaded Gasoline.

Participants in Fuels Workshop

Seminar Showed Public Alignment Of Unconditional Support For Unleaded Gasoline By Each Of The Ministries Including The State Planning Commission,
The Finance Ministry And
The State Science And Technology Commission

Starting To Create A World Class Vehicle Emissions Control Program

- **Regarding Fuels State Council Announced:**
- From January 1, 2000, Only Lead-free Gasoline Could Be Produced in PRC,
- From July 1, 2000, All Cars Must Use Unleaded Gasoline
- From July 1, 1999, Gasoline Stations In Major Cities, Including Provincial Capitals And Special Economic Zones, Should Only Sell Lead-free Gasoline.
- From July 1, 2000, All Gasoline Stations Nationwide Should Only Sell Lead-Free Gasoline.

- **Regarding Vehicles**
- From January 1, 2000, Car Manufacturers Must Make All Their Models Suitable For Use With Lead-free Gasoline.
- From April 1, 2000, All New Cars Must Comply With Euro 1 Catalyst-based Emissions Standards.
- Beijing Went First As Of January 1, 1999. Shanghai Followed On July 1, 1999.
- Beijing Introduced Euro 1 Standards For Heavy Duty Gasoline* and Diesel Engines By January 1 2000.
- Nationally, SEPA Introduced Heavy Duty Standards According To The Following Schedule:
- Euro 1 Certification July 1, 2000; Production July 1, 2001
- Euro 2 Certification July 1, 2003; Production July 1, 2004.

* All heavy duty engines in Europe were diesel so US EPA 1982 standards were used

International Cooperation and Collaboration Very Important To Help PRC Over The Years (Partial List)

- Argonne National Labs (Michael Wang)
- Chuck Freed (Former US EPA)
- US EPA (Margo Oge and Staff)
- European Union (Misc.)
- Energy Foundation China (Michael Walsh)
- International Council on Clean Transportation

The integrated “vehicle-fuel-traffic” emission control system

- **After 20 years of practice, PRC has established the integrated “vehicle-fuel-traffic” emission control system**

Simultaneously improving vehicle emissions and fuel quality standards

- Continuously tighten emission standards for new vehicles
- Fully implement of China 6/VI emission standard

Intelligent decisions

- Big-data intelligent transportation system promotes precise vehicle emission control

In-use vehicle supervision

- I/M programs integrated by annual emission inspection
- Remote sensing and OBD
- Phasing-out older vehicles

Clean transportation energy

- Promoting new energy vehicles
- Promoting the application of ethanol gasoline, biodiesel and other biofuels

Transportation optimization

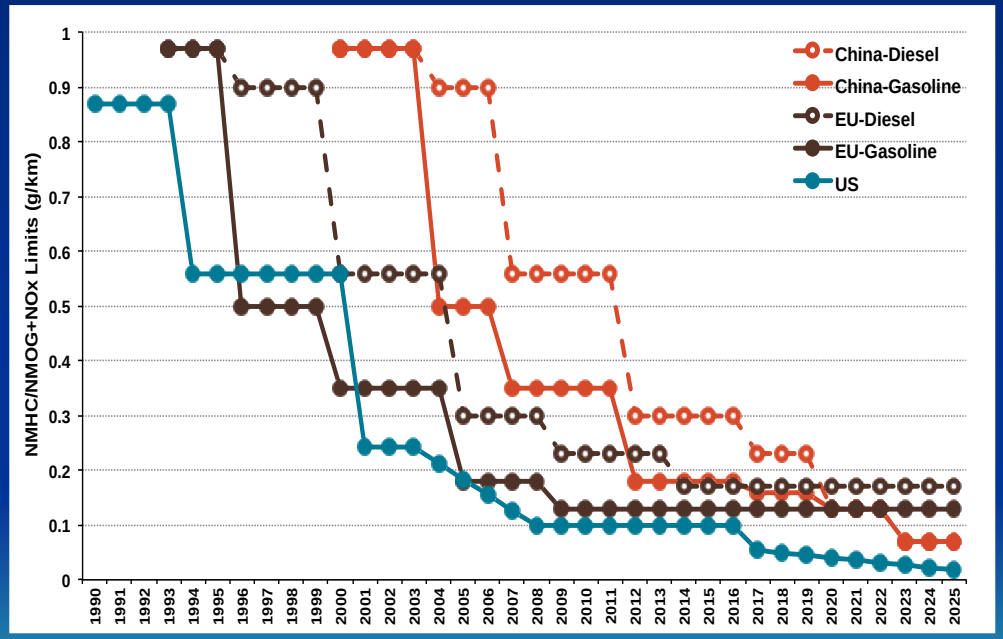
- Prioritizing public transport strategy
- Optimization for freight transportation structures

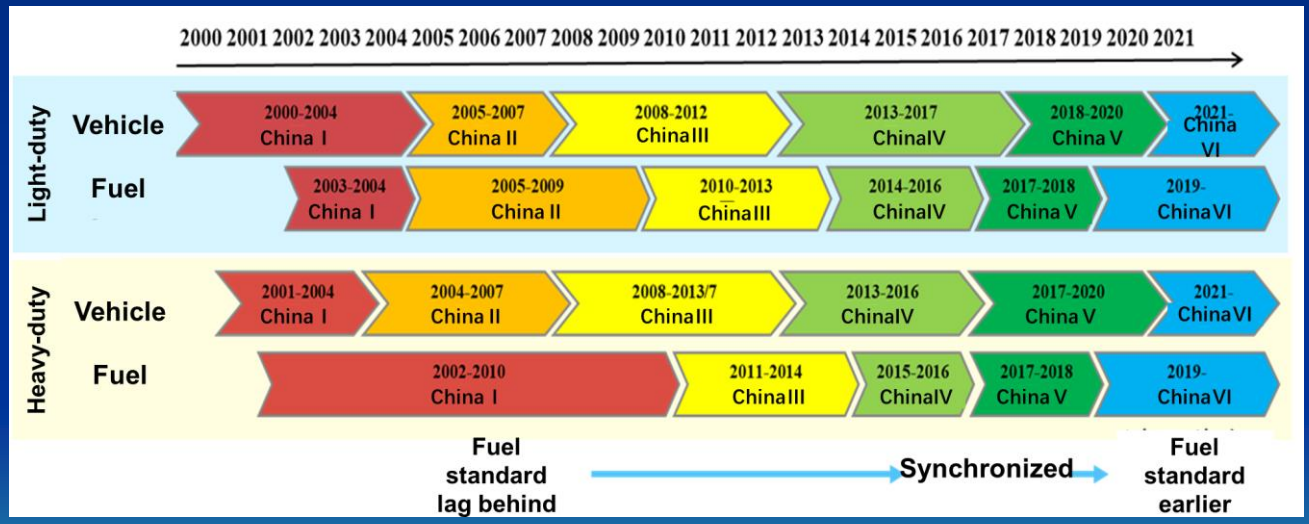
Some major actions in 2018-2020

- ***Three-Year Action Plan of Blue-Sky Defense***
- ***Action Plan for Battle Against Diesel Truck Pollution***
- ***Action Plan for optimization of freight transportation structures***

New Car Emissions Standards Have Been Greatly Tightened PRC Which Started Late Has Surpassed Euro 6

Fuel and vehicle now have been synchronized as a system to enhance the emission control of new vehicles: China 6/VI regulations in terms of fuel-neutral concept, pollutant emission limits, evaporative emission limit, on-board monitoring (OBM) requirements are more strict than Euro 6/VI





Schedule of national standards for new vehicles and fuels

International Comparison NMHC/NMOG + NOx (g/km)

Advanced technologies for in-use vehicle monitoring

- The in-use inspection and maintenance (I/M) programs: annual emission inspection, random inspection, mini-PEMS and remote sensing
- Beijing initiated the first-ever remote OBD monitoring program in the world

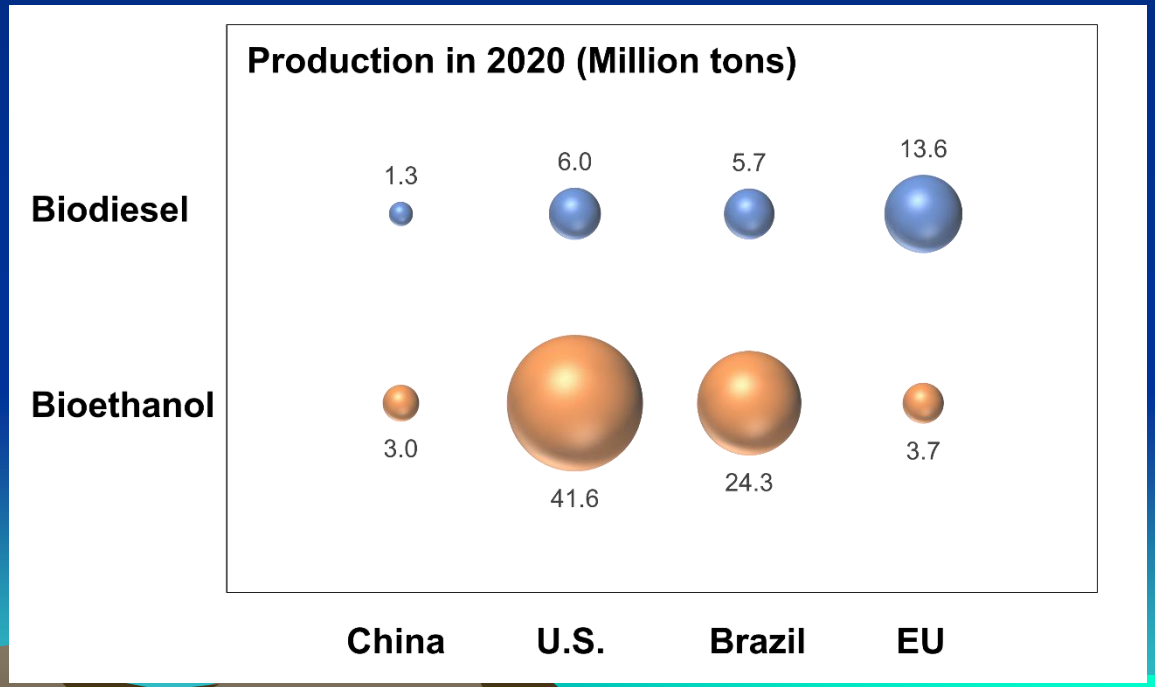
In-use inspection and maintenance

OBD monitoring

Diversification of transportation energy and application of biofuel

- **E10 ethanol gasoline is sold in 15 provinces in PRC to varying extents, with ~ 3 million tonnes of bioethanol supplied**
- **Shanghai has implemented the widespread use of biodiesel in buses and trucks**
- **More efforts are needed to promote development of biofuels in PRC**

Biodiesel and its feedstocks

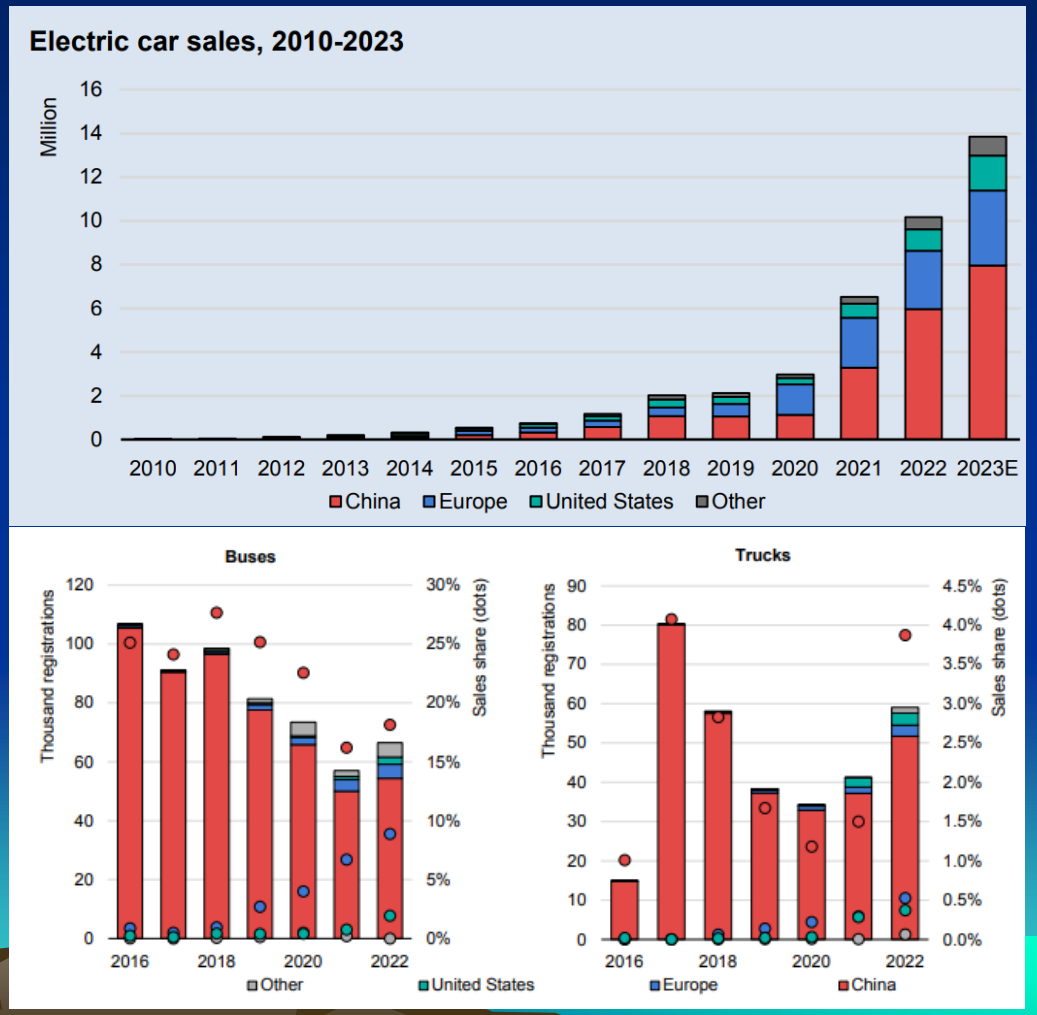


Comparison of biofuel production

Going Forward, New Energy Vehicles Are Key To Solving Air Pollution and Climate Problems

- PRC launched a series of policies to promote the production and sale of NEVs (mostly electric vehicles), including purchase subsidies, tax exemptions, infrastructure construction, and privileges in vehicle registration
- The Result: PRC is The World's Largest Producer and the Largest Market
- New energy vehicles account for 26% of Chinese vehicle sales in 2022

Electric vehicle sales

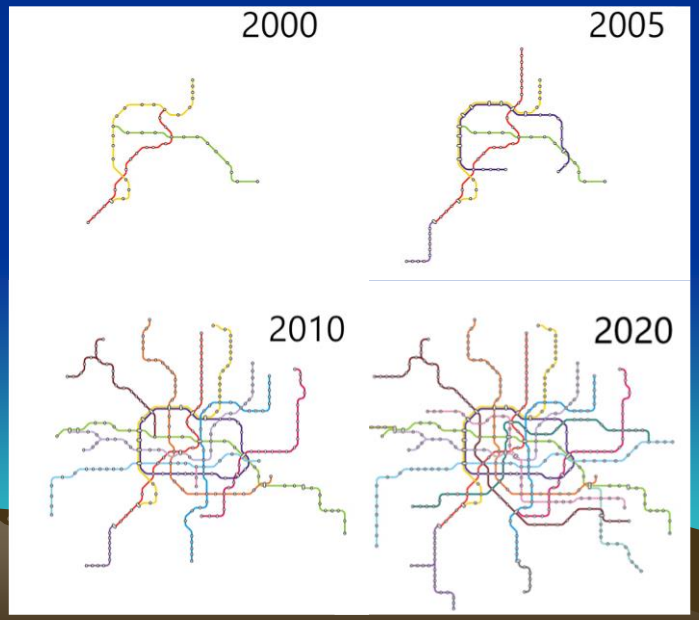


Source: IEA

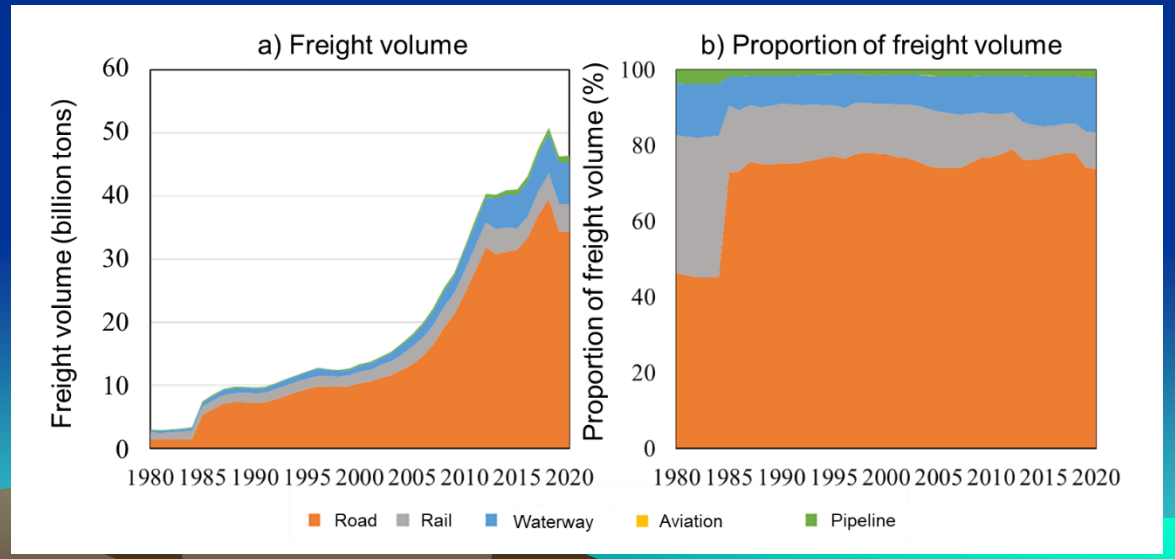
Promotion for sustainable travel modes and optimization for freight transportation structures

- *Prioritizing Public Transport*: Megacities have made remarkable progress in public transport development, like Shanghai and Beijing having subway operating mileages exceeding 700km
- *Road-to-rail* and *Road-to-waterway*: Railway cargo share grew at annual growth rate of ~7% from 2017 to 2020. The adjustment of the transportation structure is still in its initial stage

Development of public transport in Shanghai



Trend of freight volume and structure in PRC



Blue Skies after the megacities' efforts

Outlook

- Deep emission abatement is critical for improving air quality and addressing climate change synergistically
- Enhancing the leading role of standards and technologies and increasing control of vehicle emissions from internal combustion engines (ICEs)
- Clean and low-carbon energy transition for the transportation sector can heavily promote the green development of the automotive industry
- Strengthening infrastructure development and improving service performance to facilitate green travel systems and optimize freight structure
- Exploring intelligent and innovative solutions for managing vehicle emissions in the era of the IoT and big data


Thank You

Two Decades of Progress in Vehicle Emission Control: Insights and Opportunities for Asia

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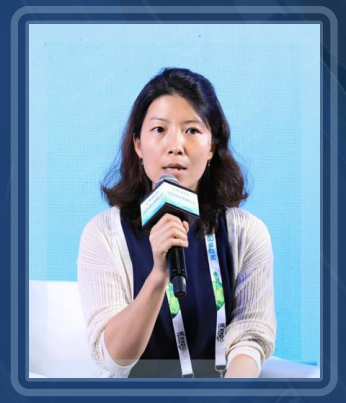

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20 years' mobile source emission control in megacities of PRC

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Nov. 15 2023

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Megacities serve as pioneers in building integrated "Vehicle-Fuel-Traffic" control system

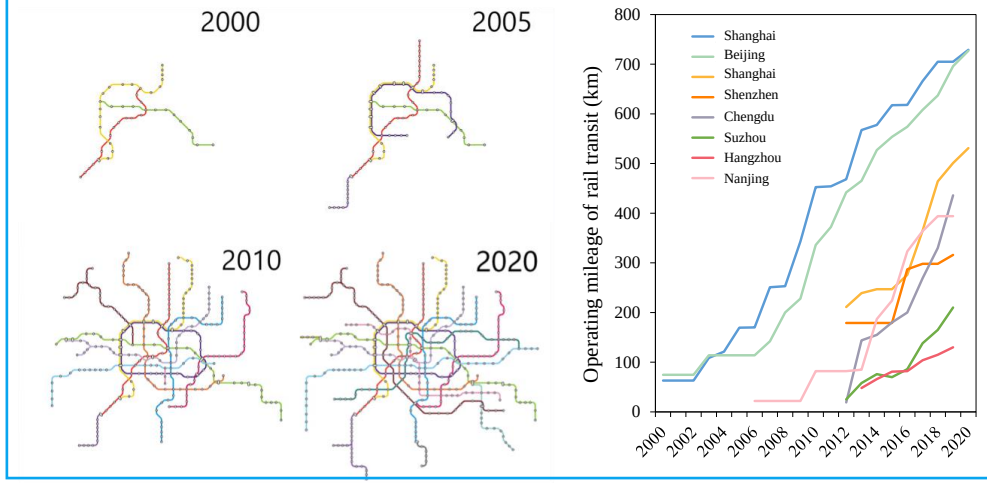
	Area (km^2)	Population (million)	GDP per capita (k CNY)	Vehicle population (million vehicles)
	16,410	21.9 Annually 2.4% ↑	165 Annually 10.0% ↑	6.57 Annually 9.1% ↑
	6,341	24.9 Annually 2.2%↑	157 Annually 8.6%↑	4.69 Annually 11.5% ↑
	1,997	17.6 Annually 4.7%↑	158 Annually 8.1%↑	3.59 Annually 12.5% ↑
	14,335	20.9 Annually 3.2%↑	85 Annually 11.1%↑	6.03 Annually 11.1% ↑

National level: ***Population: 1.4 billion, GDP per capita: 72k CNY (eq. to 10k USD)***

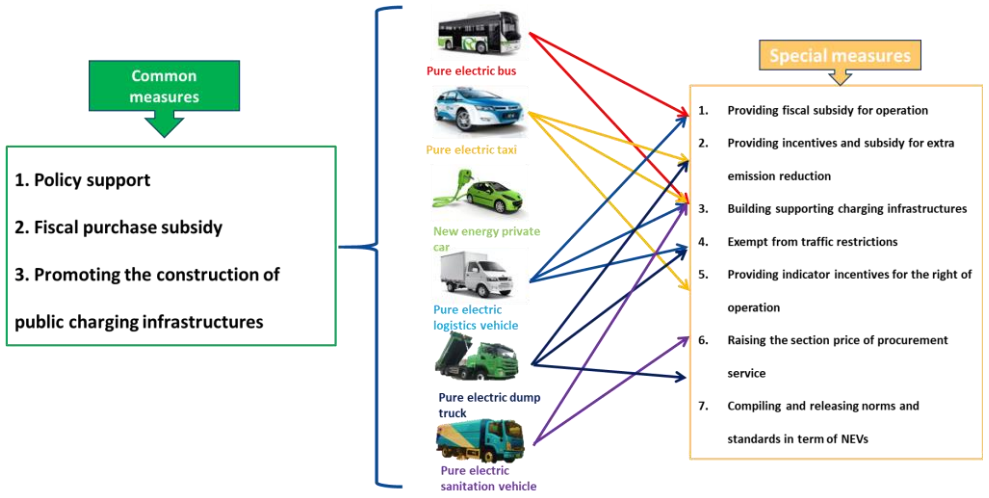
City-specific practices tailored to unique characteristics

Beijing: Remote OBD monitoring

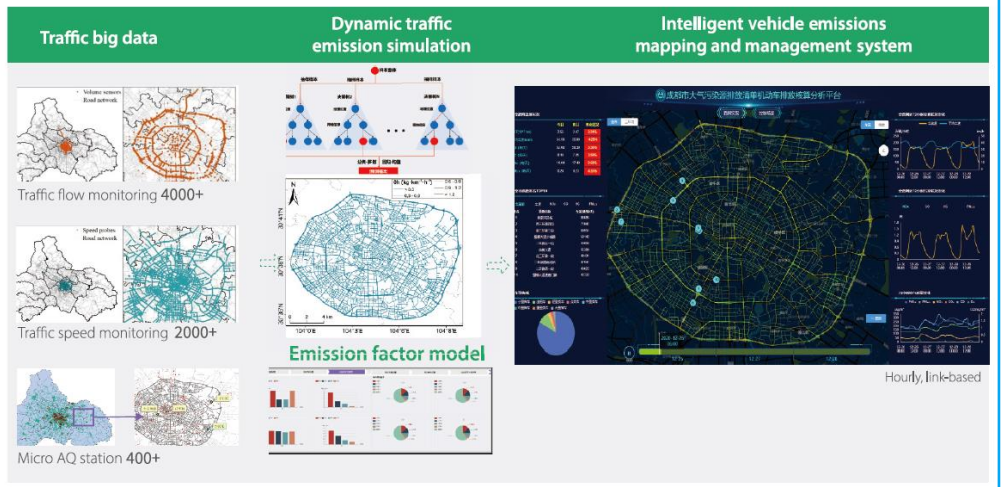
Shanghai: Public transportation



Shenzhen: E-mobility



Chengdu: Big data application



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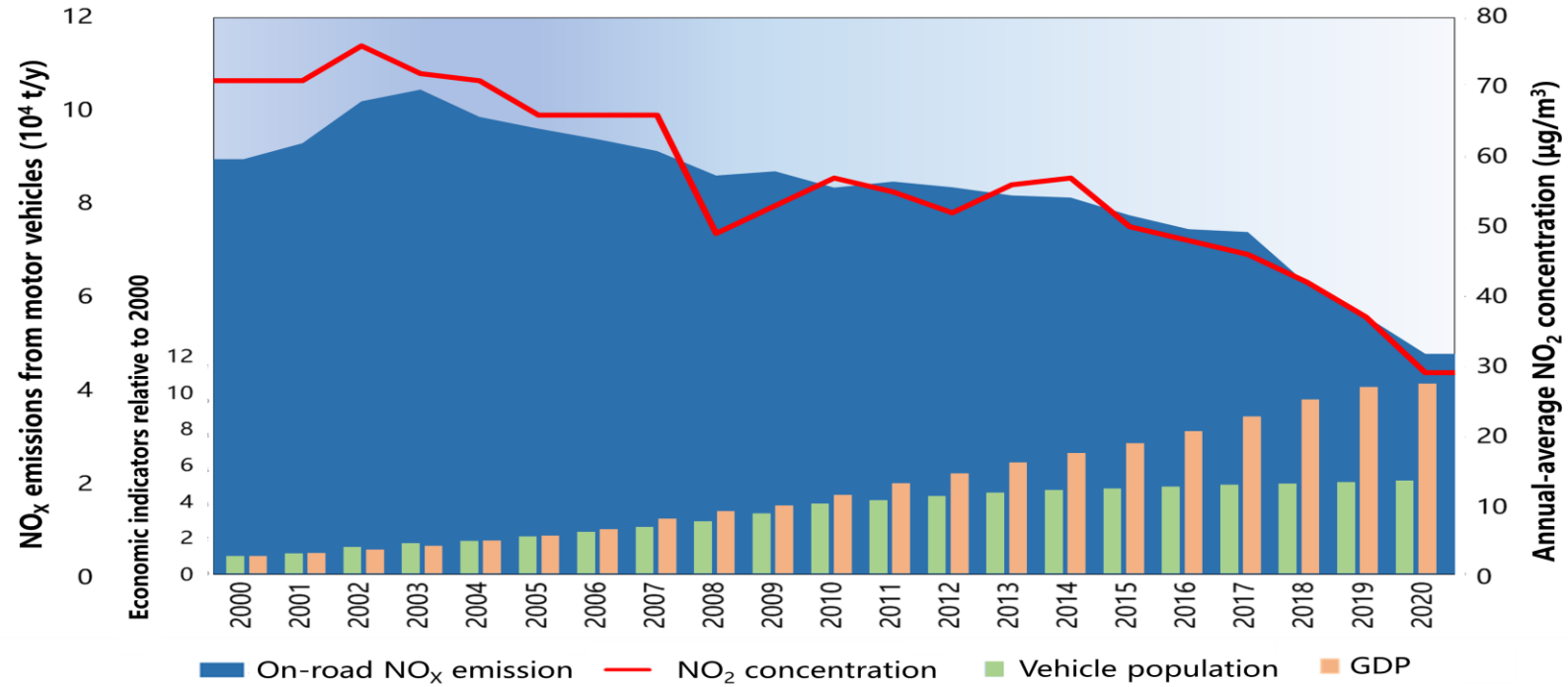
Beijing: Remote OBD monitoring for heavy-duty diesel vehicles

Beijing has successfully decoupled the deterioration of air pollution from fast motorization

- Beijing's annual average NO_2 and $PM_{2.5}$ concentrations met the national ambient air quality standards (NAAQS) for the first time in 2019 and 2021, respectively
- The decreasing trend of NO_2 concentration over the past two decades has aligned closely with the significant reduction in NO_X emissions from on-road vehicles

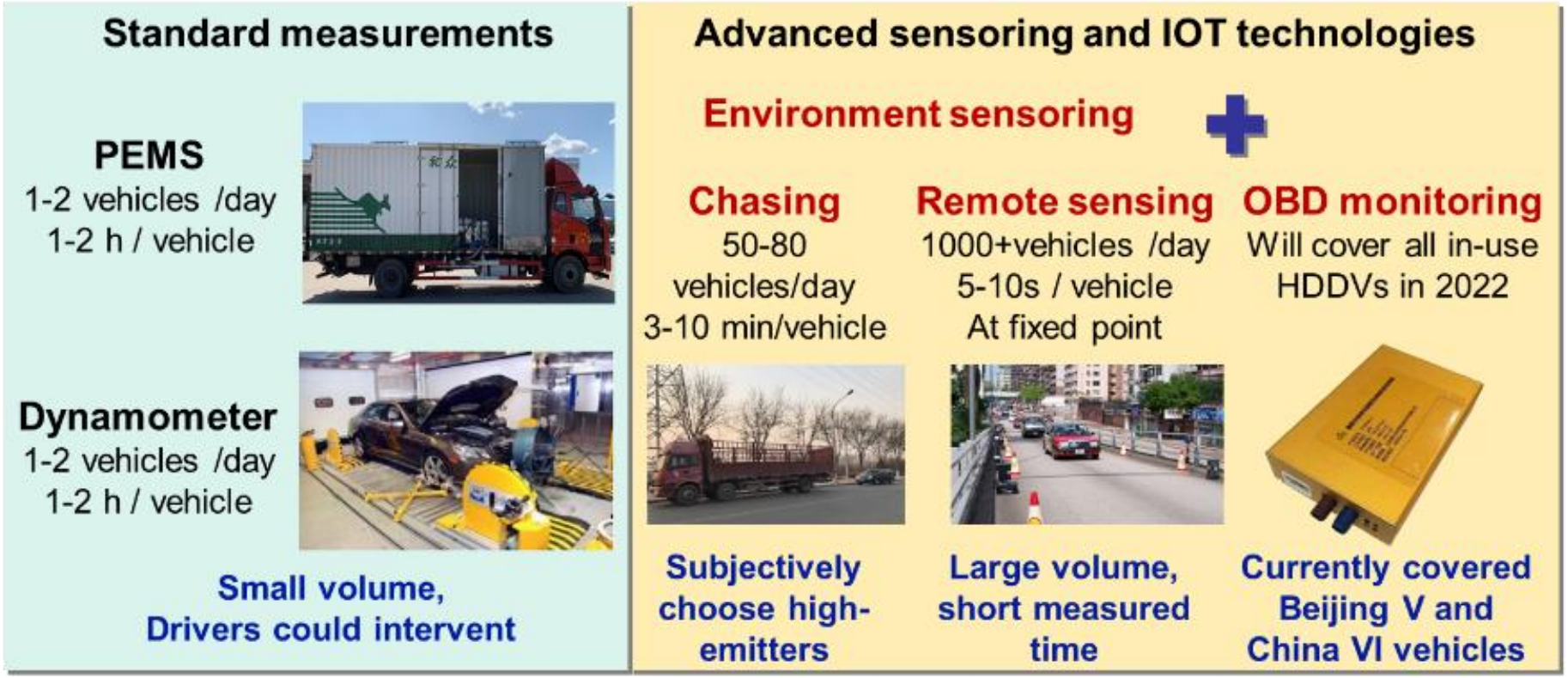
The trend of vehicle population and NO_2 concentration in Beijing, 2000-2020



Enhancement of the control on in-use vehicles

- Beijing has established a comprehensive I/M system for in-use vehicle emission control, including annual inspection, mini-PEMS, on-road random inspection, etc.
- Promoting advanced supervision technologies and accelerating the construction of the supervision platform to enhances **the real-world monitoring of in-use vehicles**

Real-world emission monitoring system and key technologies for HDVs



From On-board Diagnostic (OBD) to On-board Monitoring (OBM)

- **OBD-I & OBD-II:** Electronic Control Unit (ECU) collects the real-time data from on-board sensors to diagnose the operation of the vehicle engine, emission control system, and fuel system
- **Remote OBD monitoring:** Incorporated with emission sensors, the on-board terminal collects and uploads real-time driving and emission data of pollutant concentrations (NO_X)

OBD-I

1982
General Motors designed OBD-I system

- **Offline check**
- **Diagnostic Trouble Code and MIL**

OBD-II

1994
SAE standardized OBD-II

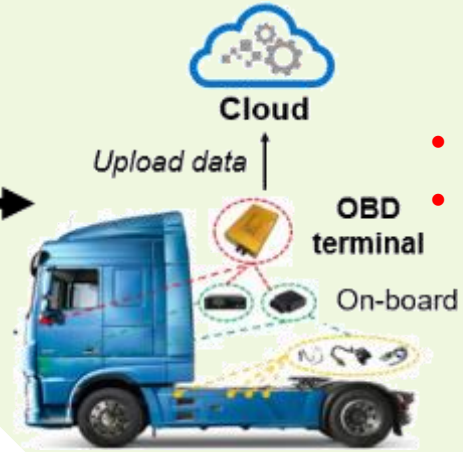
+ emission sensors

on-board terminals

Remote OBD monitoring

2017
Beijing mandates HDVs to equip OBM

2020
PRC mandates Stage VI HDVs to equip OBM



- **Online system**
- **Real-time emission monitoring**

Development of Beijing and national OBD regulations

- Beijing: **the first city** in the world to require **remote online monitoring** of heavy-duty vehicle emissions and energy consumption in the full life cycle
- The implementation of OBD-based remote monitoring in Beijing further promoted the development of national standards (China VI for heavy-duty vehicles)

Jun, 2018

China VI standard (including OBD monitoring requirements) was released

May, 2020

Beijing OBD Remote Terminal Installation Management Measures

Jul, 2023

China VI-b implemented, requiring the installation of OBD monitoring terminals and the uploading of collected data

Dec, 2017

Local standard for OBD monitoring was released in Beijing

Jan, 2020

Beijing Regulations on Installation of Remote OBD Monitoring Terminals

Dec, 2021

Technical specification for emission remote supervision system of heavy-duty vehicles (HJ 1239.3-2021)

Beijing
National

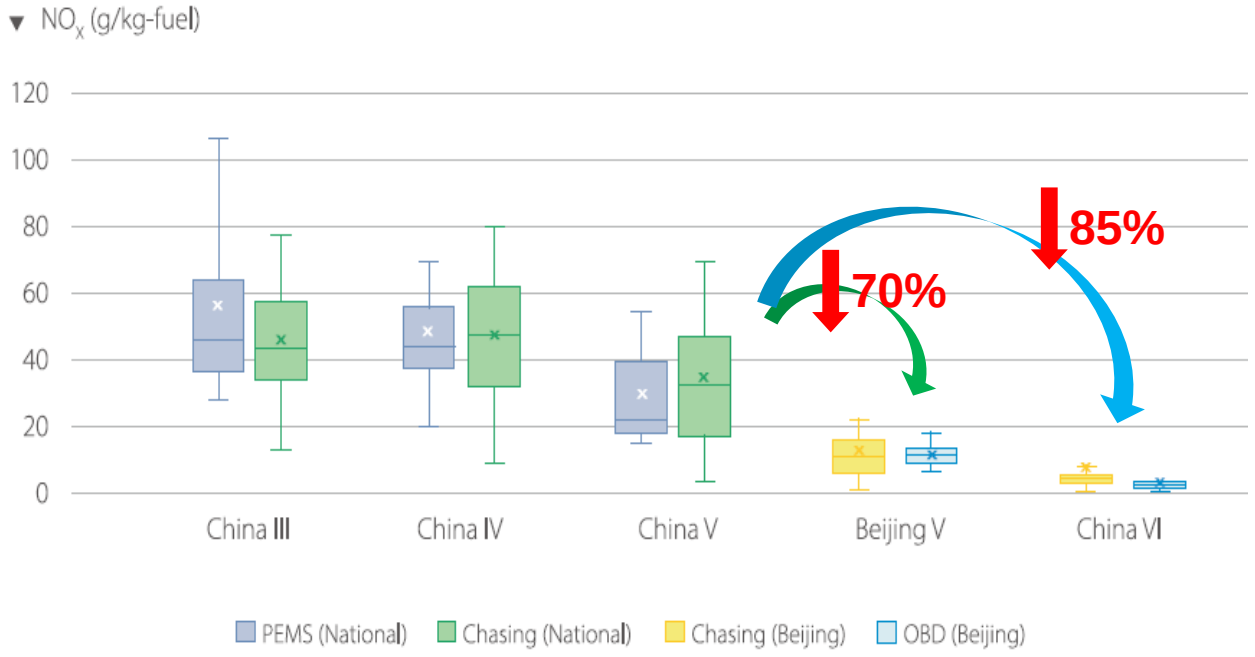
Implementation of OBD monitoring on HDDVs in Beijing

- Beijing established a Heavy-duty Diesel Vehicle On-board Emission Monitoring Platform, more than **160,000** heavy-duty diesel vehicles have been connected

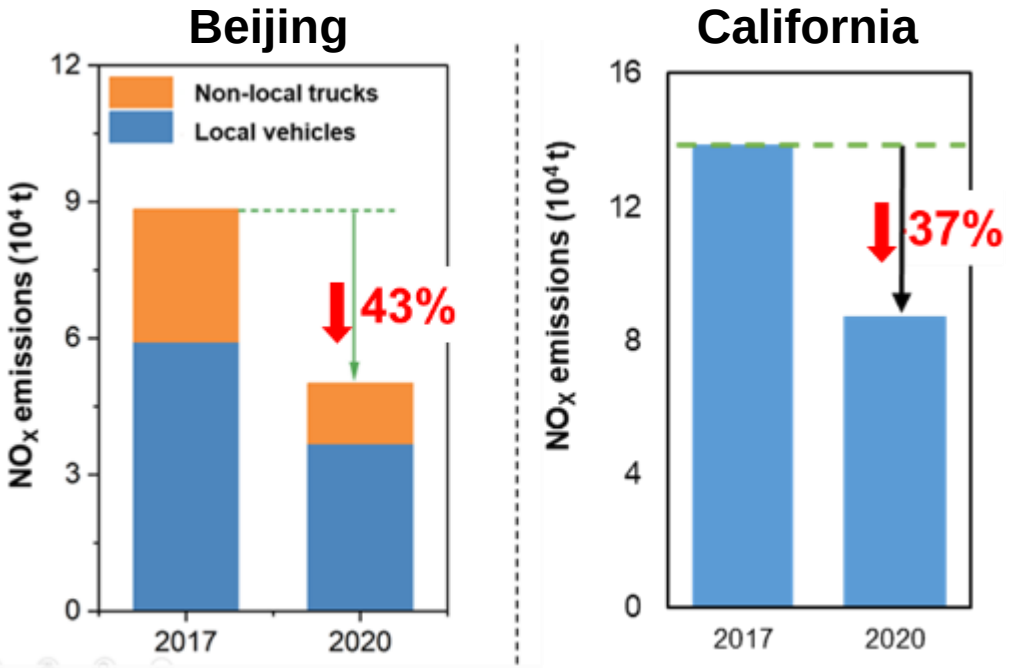
Significant reduction of HDDV NO_X emissions

- The strict and efficient remote OBD leads to a significant reduction of NO_X emissions from heavy-duty diesel vehicles (HDDVs) in Beijing
- Annual NO_2 concentrations decreased by **37%**, with ~40% attributed to diesel vehicle emission controls

NO_X emission factors from heavy-duty fleets based on PEMS, Chasing, and Remote OBD



NO_X emissions from HDDVs



THANK YOU

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Shanghai: Public Transport Development

Cheng Huang

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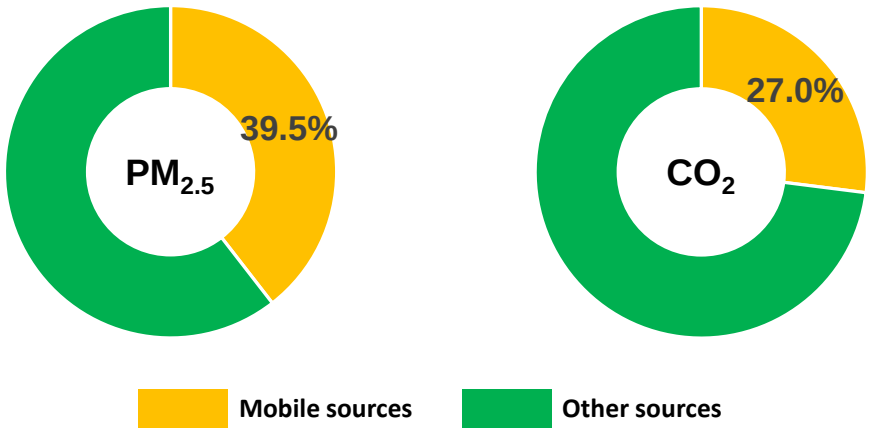
Nov 15, 2023

Overview of road transportation in Shanghai

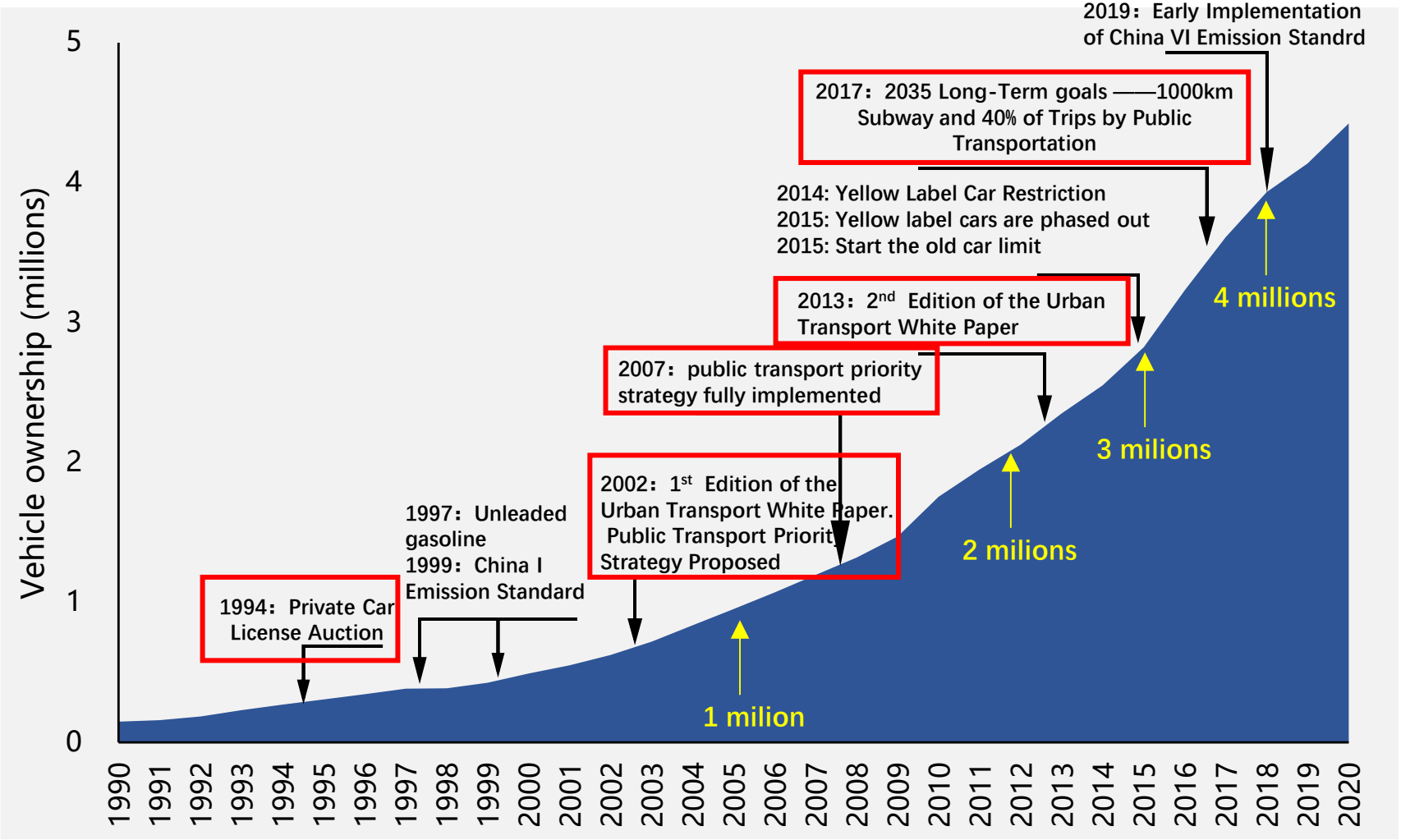
- **Area:** 6430 km^2
- **Population:** 24.9 million (+2.1%/year)
- **GDP per capita:** 175,384 Yuan (+6.8%/year)
- **Vehicle ownership:** 4.66 million (+11.3%/year)
- **Daily passenger trips:** 54 million (+1.7%/year)
- **Total freight:** 1.55 billion (+5.9%/year)

* The following data are for 2021
* % represents the growth rate from 2000 to 2021

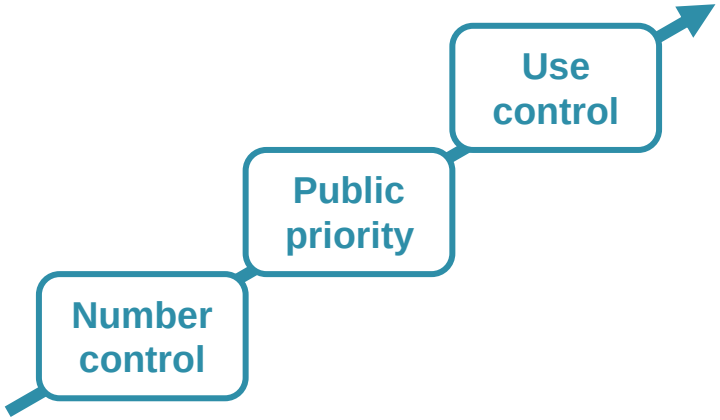


Distribution of Traffic Flow in Shanghai

Public transport priority policies implemented in Shanghai

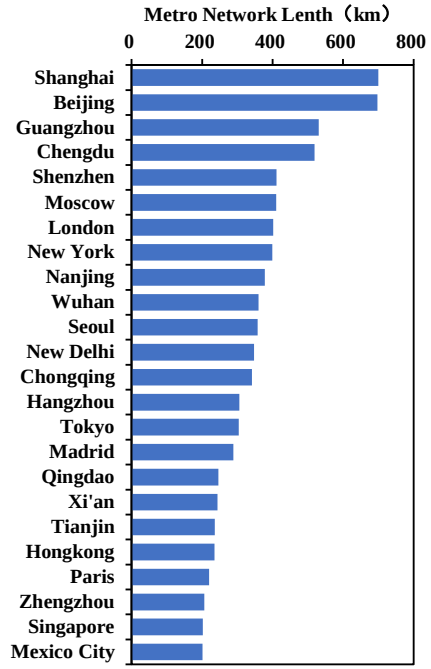


White Paper on Urban Transportation in Shanghai 2002&2013

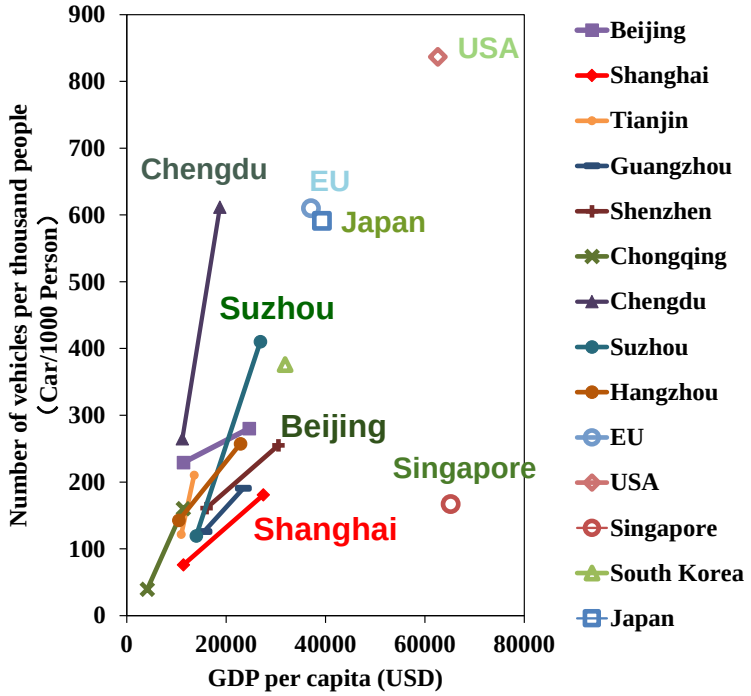


Public transport priority: License control + Rail transit development

- Shanghai synchronously initiated the construction of rail transit system and license control policy
- The total length reached 729 km by 2020, the longest in the world
- The growth rate of vehicle population has been effectively controlled, much lower than other large cities (comparable to the level of Singapore)



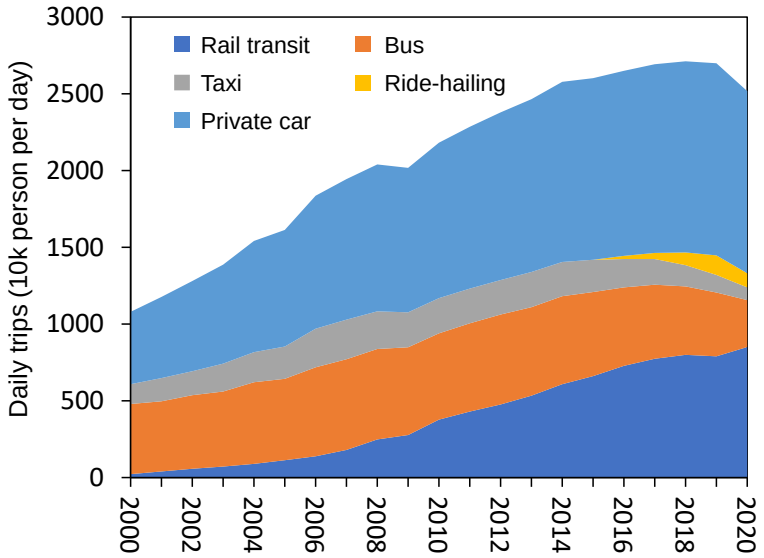
Evolution of Rail Transit Lines in Shanghai



Vehicle ownership of large cities in the world

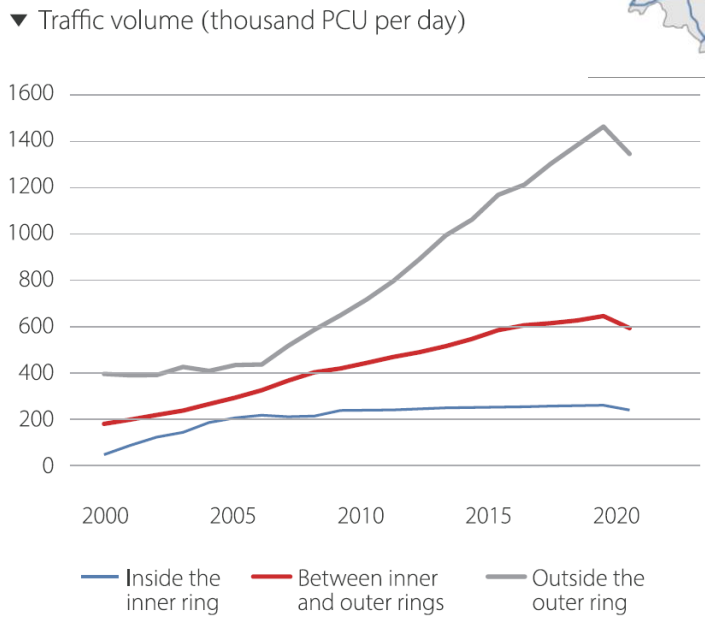
The proportion of public transport travel continues to increase

- By 2020, the public transport trips accounted for 35% of the total travels, lower than Tokyo, Seoul and London. The proportion of rail transit trips increased from 1% in 2000 to over 20%
- The traffic volume by vehicles in the central urban area has become stable since 2010, and its traffic and environmental pressures have been further alleviated



Trips by various modes of motorized transportation

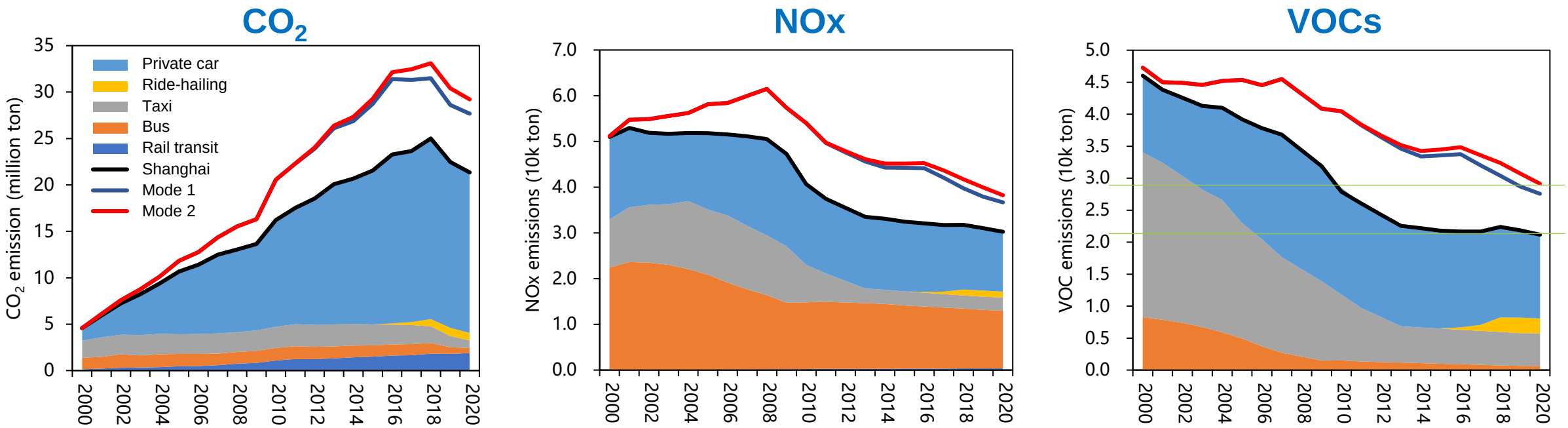
Cities	Slow traffic	Individual traffic	Public transit
	Modal split (%)		
London	26.3	38.0	35.7
Paris	40.3	40.1	20.1
New York	37.0	35.6	27.4
Tokyo	37.0	12.0	51.0
Seoul	20.4	23.1	56.5
Singapore	23.0	33.0	44.0
Shanghai	**45.0**	**21.0**	**35.0**
Beijing	40.4	32.1	27.5
Shenzhen	50.0	18.0	32.0
Guangzhou	45.0	25.8	29.2
Chengdu	53.0	21.0	26.0



Comparison of CO_2 emissions in different transport modes

Emission reductions by the public transport priority policy

- Vehicle population in Shanghai is expected to be 50%~60% lower than the national average (Mode 1) and the fastest growing city (Mode 2)
- By 2020, total vehicle emissions of CO_2, NO_X, and VOCs were reduced by an average of 20%~25% compared to Mode 1 and Mode 2, respectively

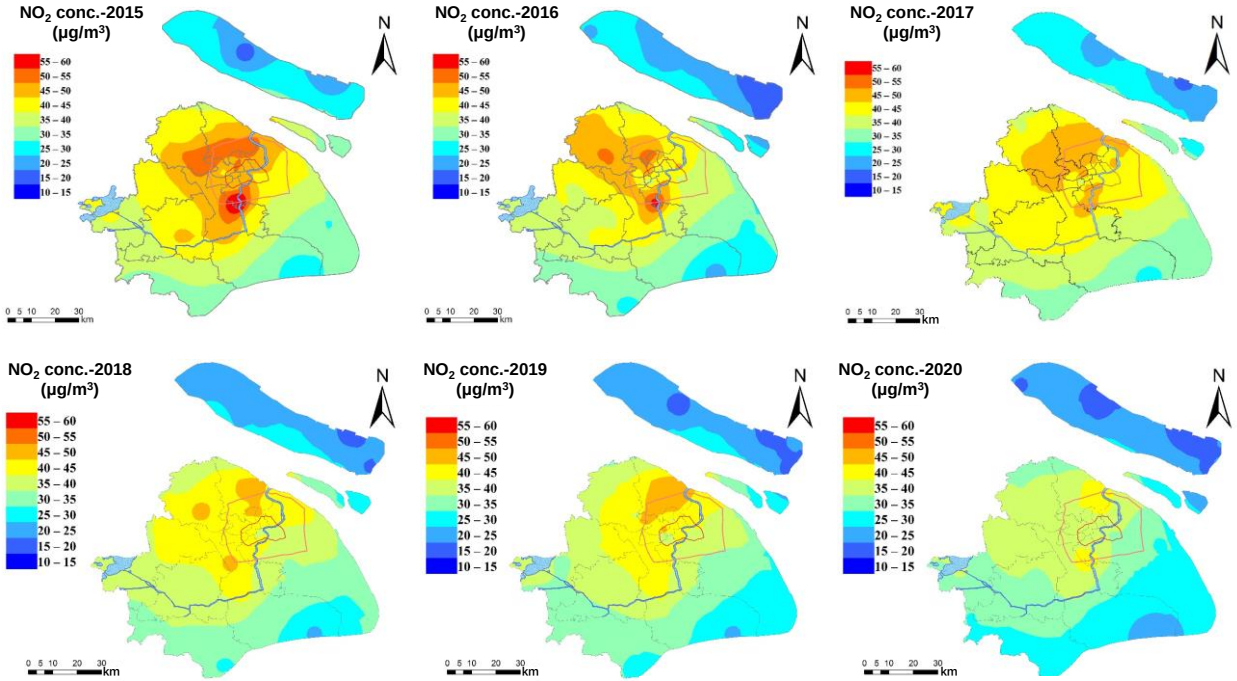


Emission reductions benefited from the changes of transport modes

Significant improvement in traffic-related air pollution

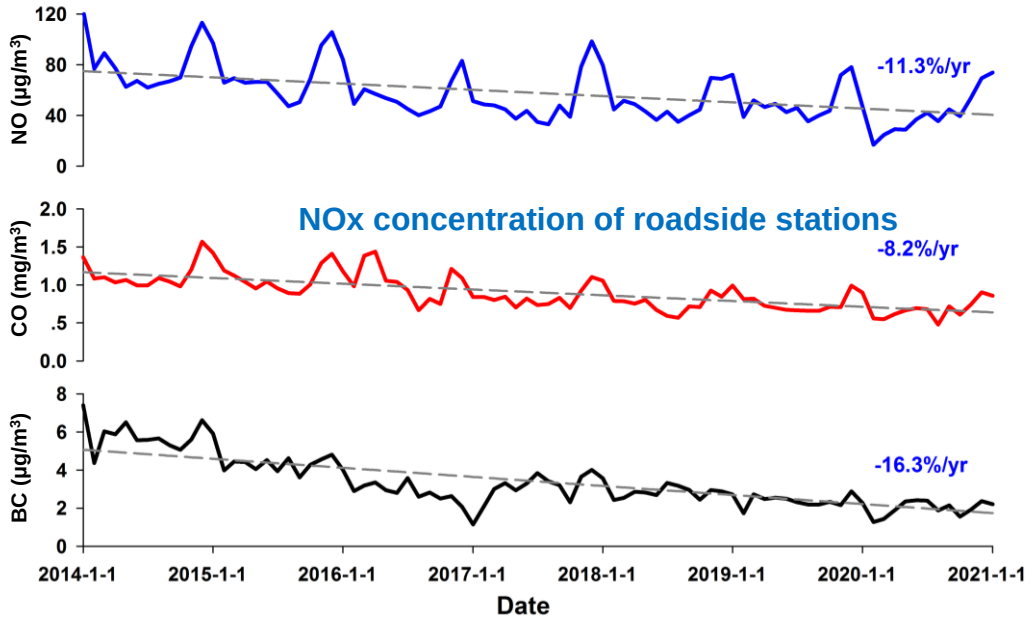
- The ambient concentrations of NO_2 in urban areas have decreased significantly
- NO, CO, and BC concentrations at urban roadside stations annually decreased by 11.3%, 8.2%, and 16.3%, respectively, since 2014

Spatial distribution of NO_2 concentration



Source: Shanghai Environmental Monitoring Center

Concentration changes at roadside stations



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Two Decades of Progress in Vehicle Emission Control: Insights and Opportunities for Asia

CHENGDU

Qinwen Tan
Director
Chengdu Academy of Environmental Sciences

BAQ 2023
BETTER AIR QUALITY CONFERENCE
15-17 NOV • MANILA

Chengdu: Big data intelligent transportation system for precise emission control

Qinwen Tan

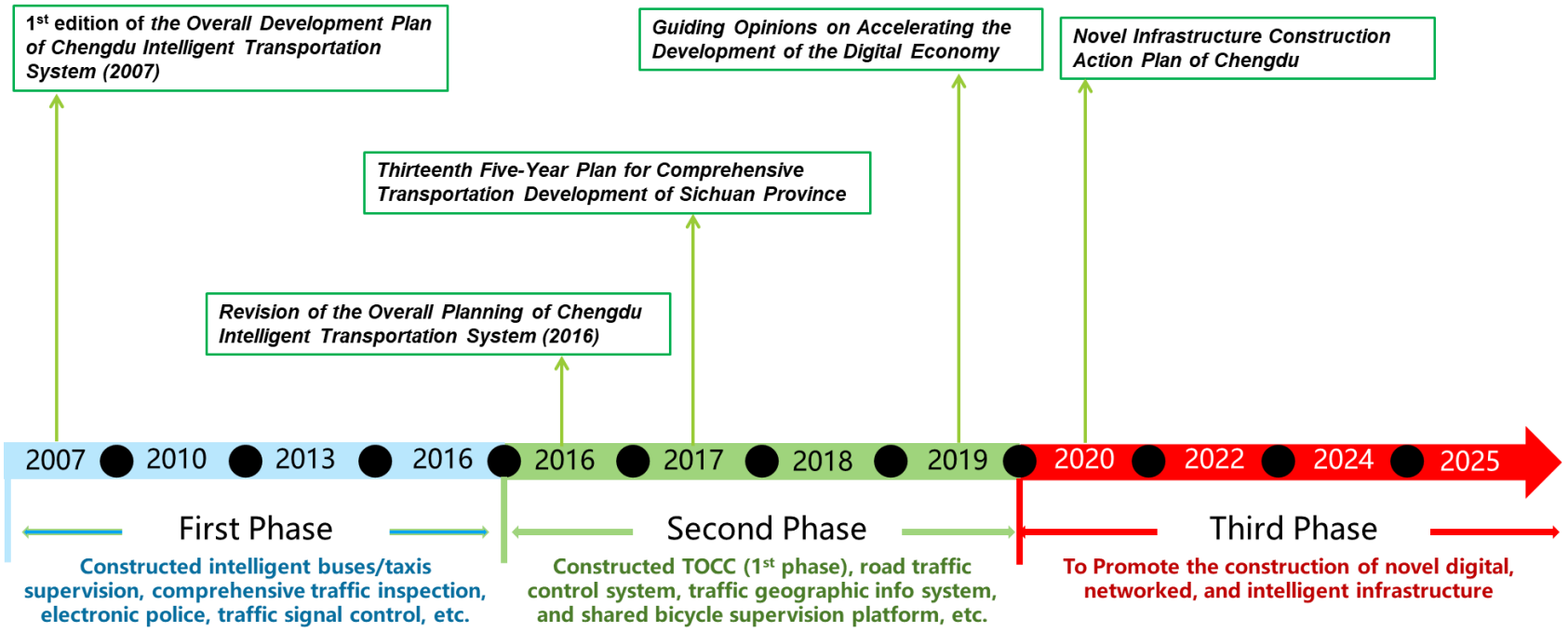
Chengdu Academy of Environmental Sciences

Nov 15, 2023

Development of intelligent transportation systems (ITS)

- The automobile ownership of Chengdu has exceeded 6.3 million in the mid 2023, making Chengdu the city with the largest vehicle fleet in PRC
- Instead of license control measures, Chengdu emphasizes addressing traffic and environmental issues through intelligent transportation technologies

Development of ITS in Chengdu

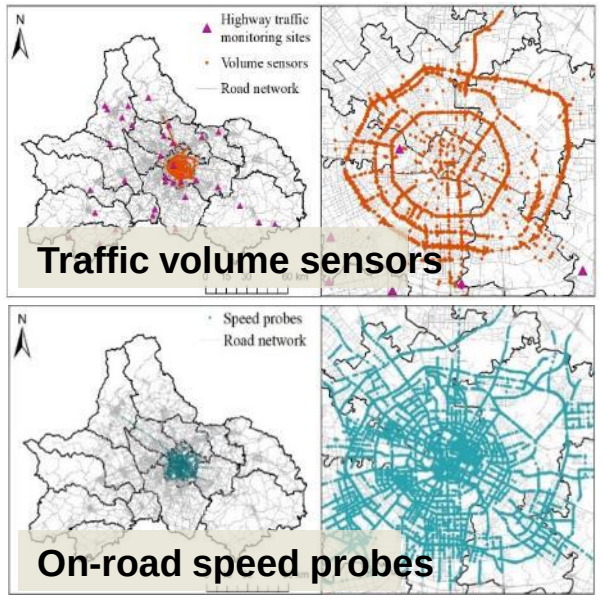


Road traffic sensors

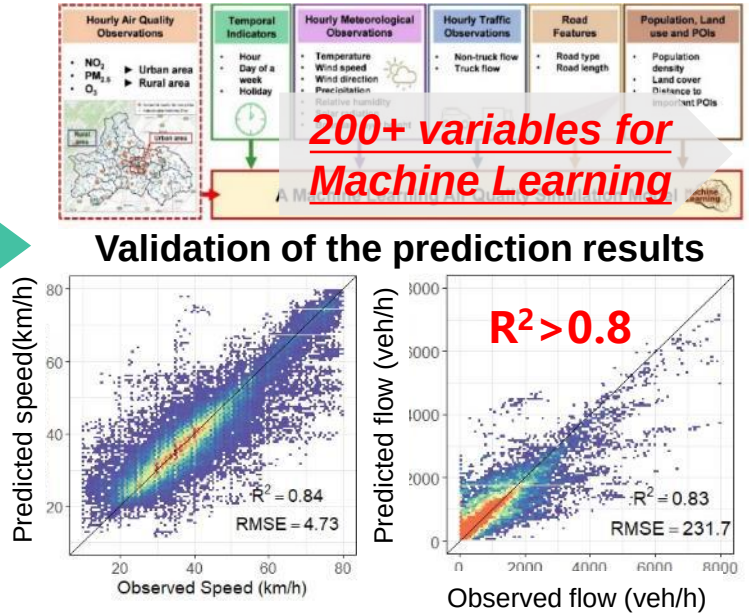
Dynamic vehicle emission modeling based on ITS

- By integrating traffic big data (e.g., 8000+ traffic sensors) and machine learning techniques, Chengdu has developed a data-driven dynamic model and decision-making system for intelligent vehicle emission control

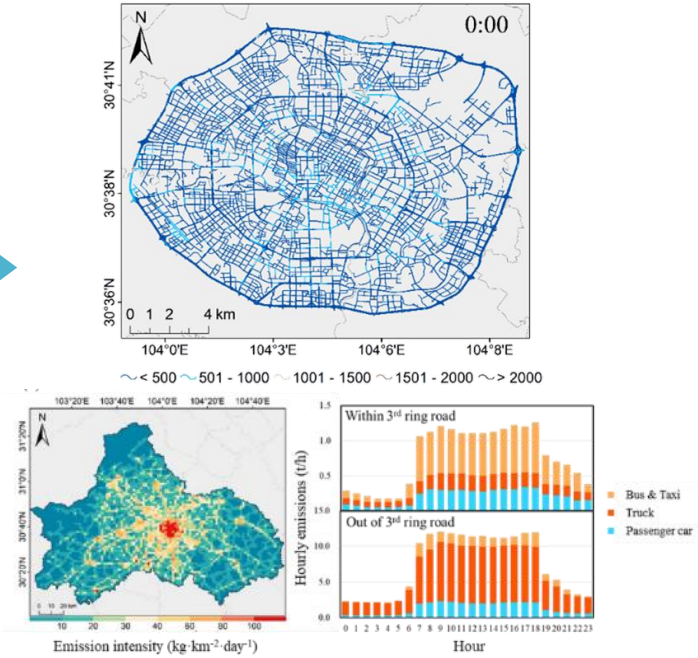
Traffic big data



Dynamic traffic emission modeling

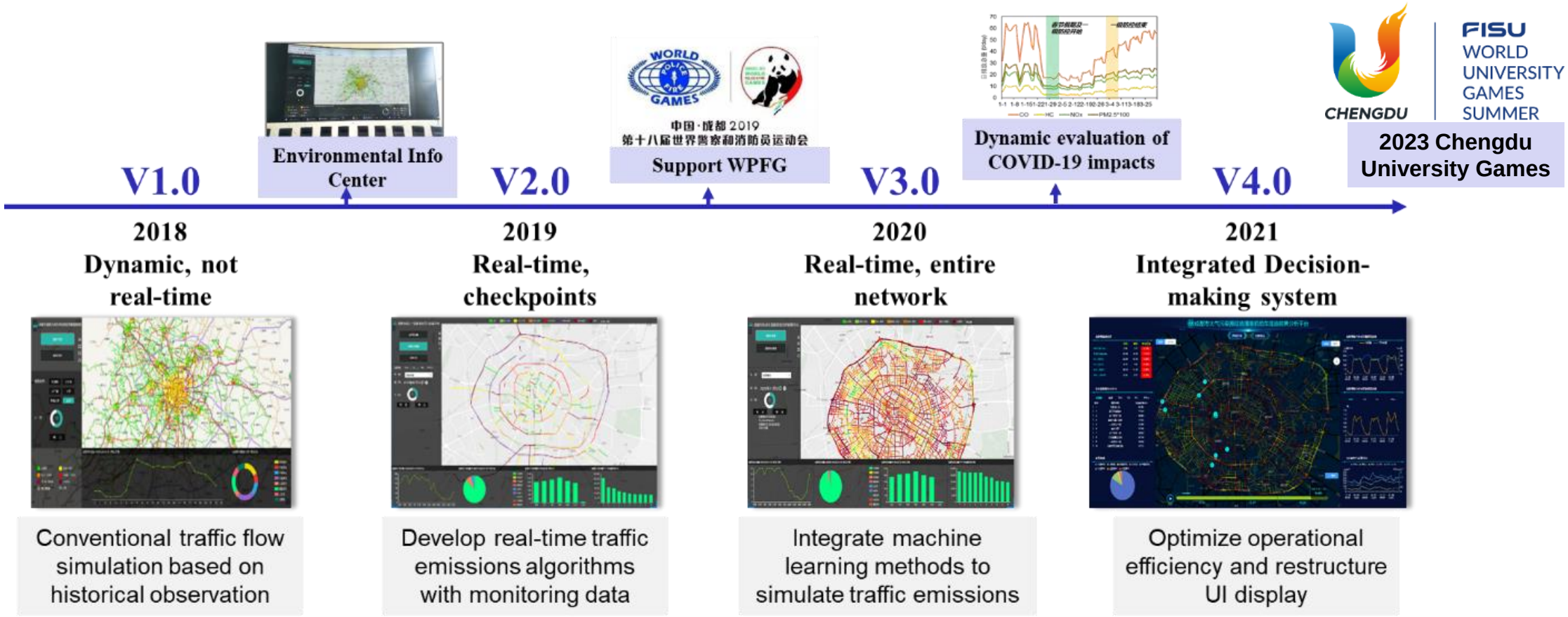


High-resolution emission mapping



The evolution of the decision-making system

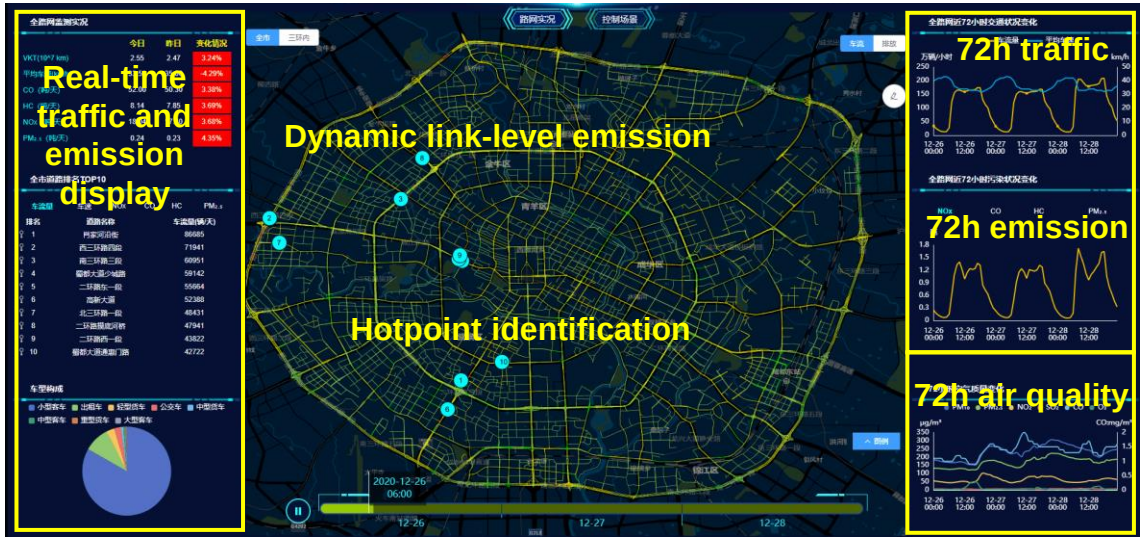
- Starting from 2018, the system has undergone several rounds of updates and enhancements, aiming for higher resolution and real-time functions
- The latest version supports a 72-hour dynamic tracking of traffic emissions and benefits of vehicle emission control in both short- and long-term scenarios



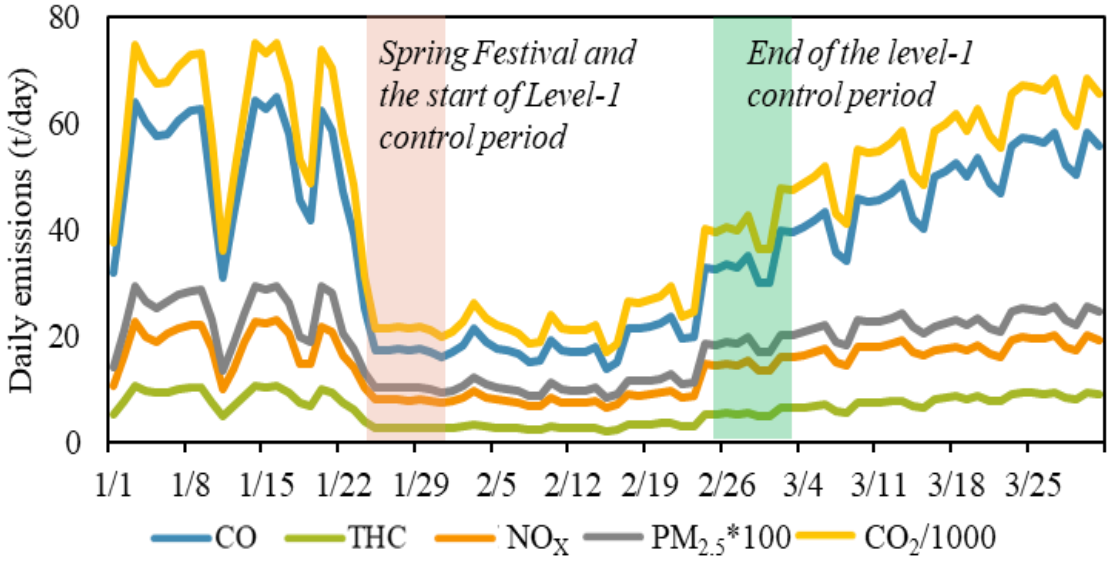
Case 1: Tracking vehicle emission changes during the COVID-19 pandemic

- The pandemic led to a sharp reduction in traffic activities, this system accurately tracked the emission reduction resulting from the traffic changes during the COVID-19
- The traffic flow in Chengdu decreased by 59%, average vehicle speed increased by 16%, resulting a reduction of 50-60% of vehicle emissions in the urban area

Real-time display of traffic and emissions



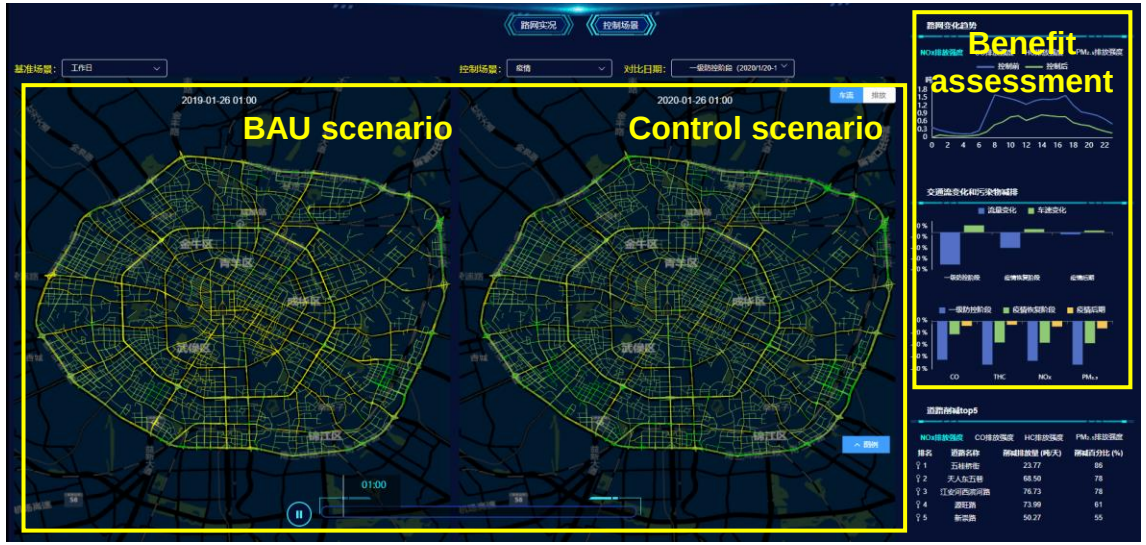
Dynamic tracking during the COVID-19



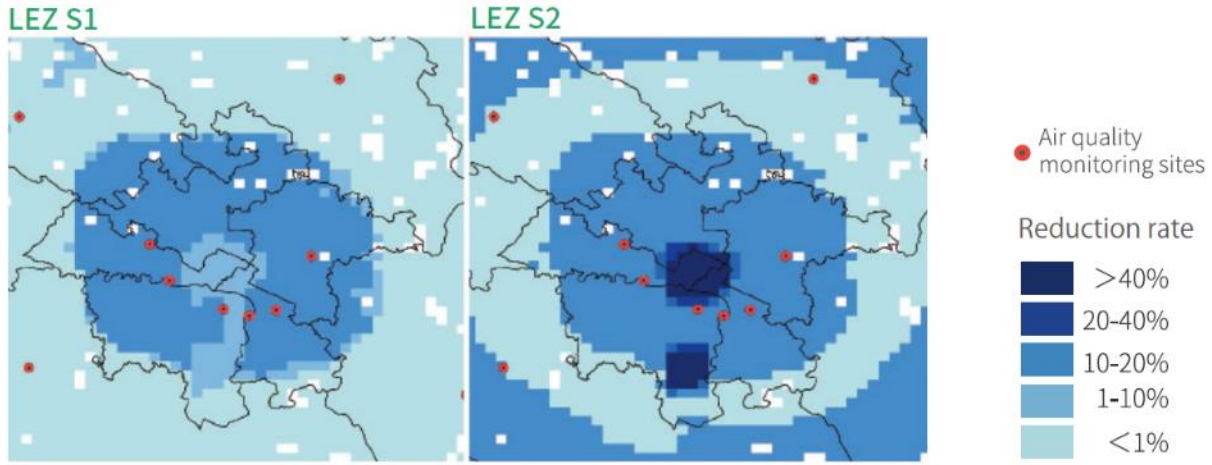
Case 2: Benefit assessment for low-emission zone policy

- The implementation of the Low Emission Zone (LEZ) policy will significantly reduce traffic intensity and vehicle emissions, leading to improved air quality
- The LEZ policy can be further integrated with NEV promotion as a ***Green and Low-Carbon Zone*** that mitigates both air pollution and CO_2 emissions

Policy benefits evaluation

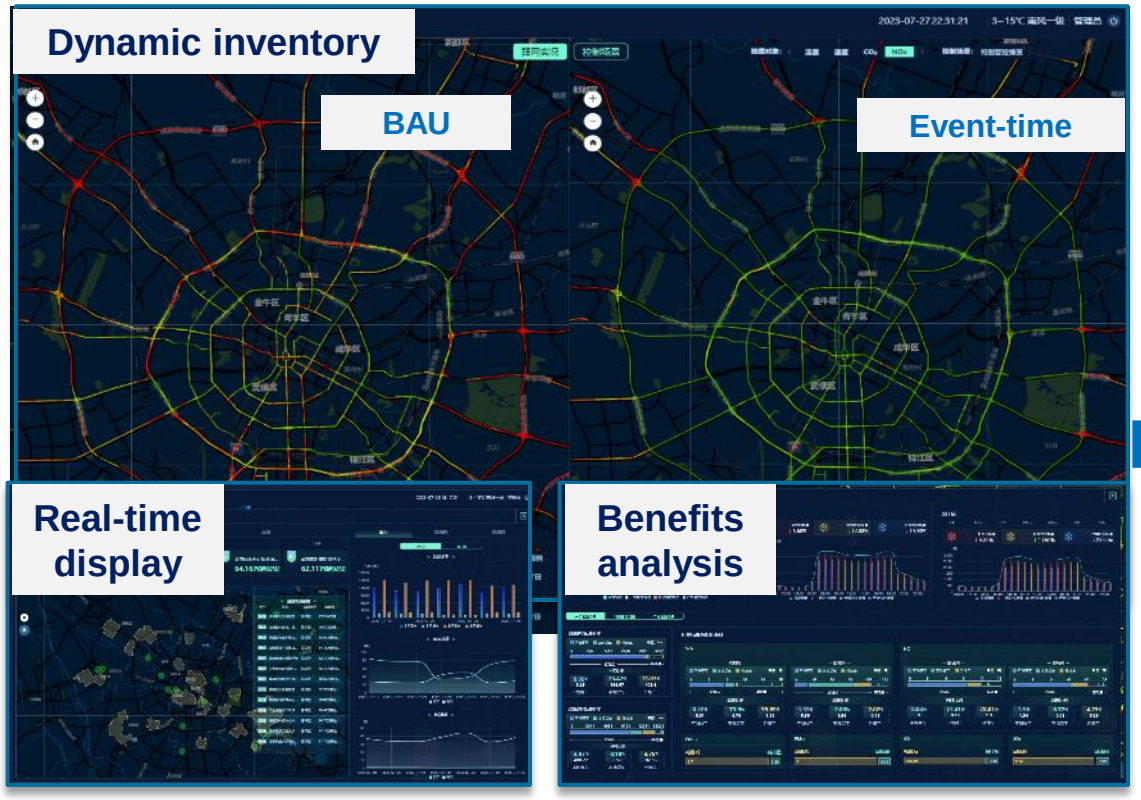


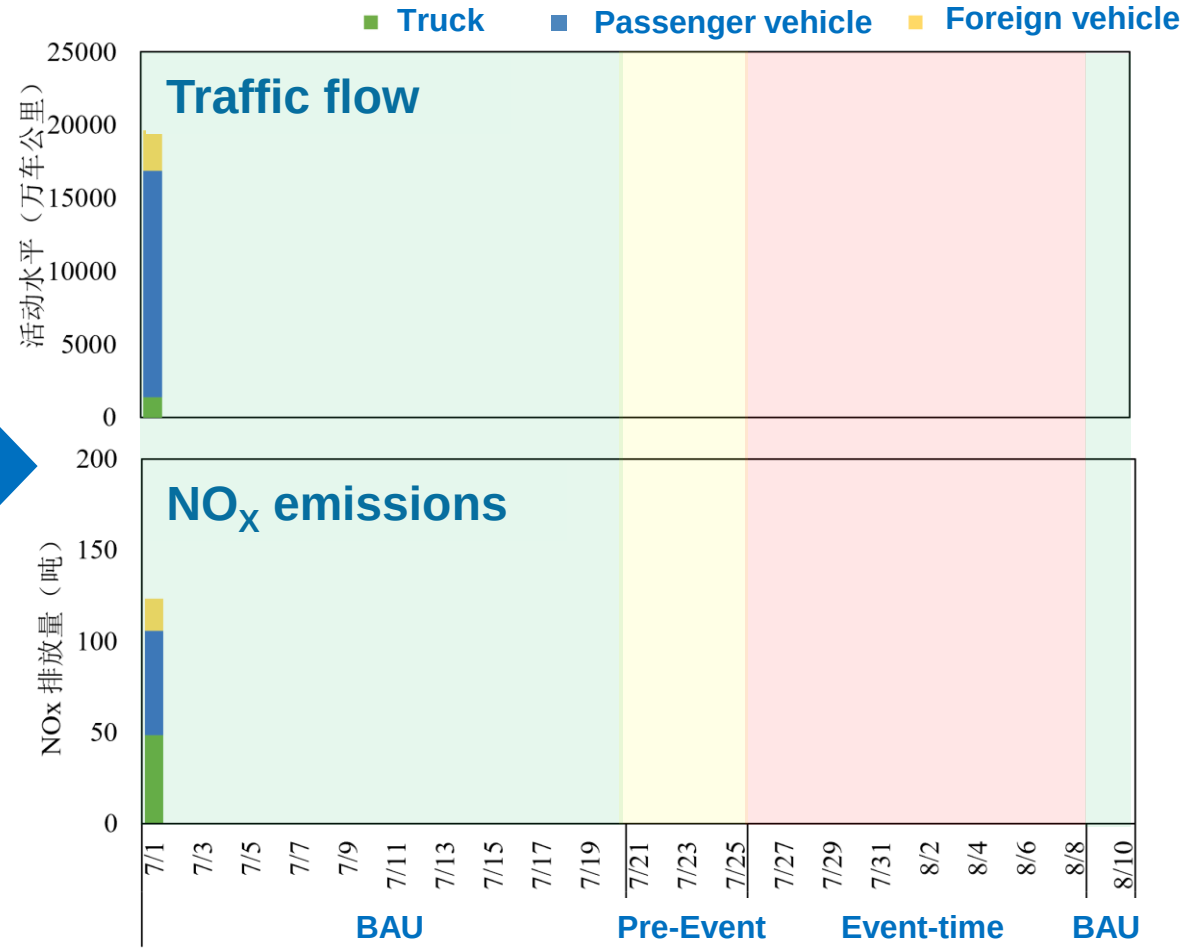
NO_X Reduction benefits of LEZ policy



Case 3: Application in 2023 Chengdu FISU World University Games

- The decision-making system was successfully applied during the Games, supporting real-time tracking of daily traffic and emissions throughout the event





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SHENZHEN

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BAQ 2023
BETTER AIR QUALITY CONFERENCE
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Shenzhen: A pioneer city promoting new energy vehicles

Shaojun Zhang

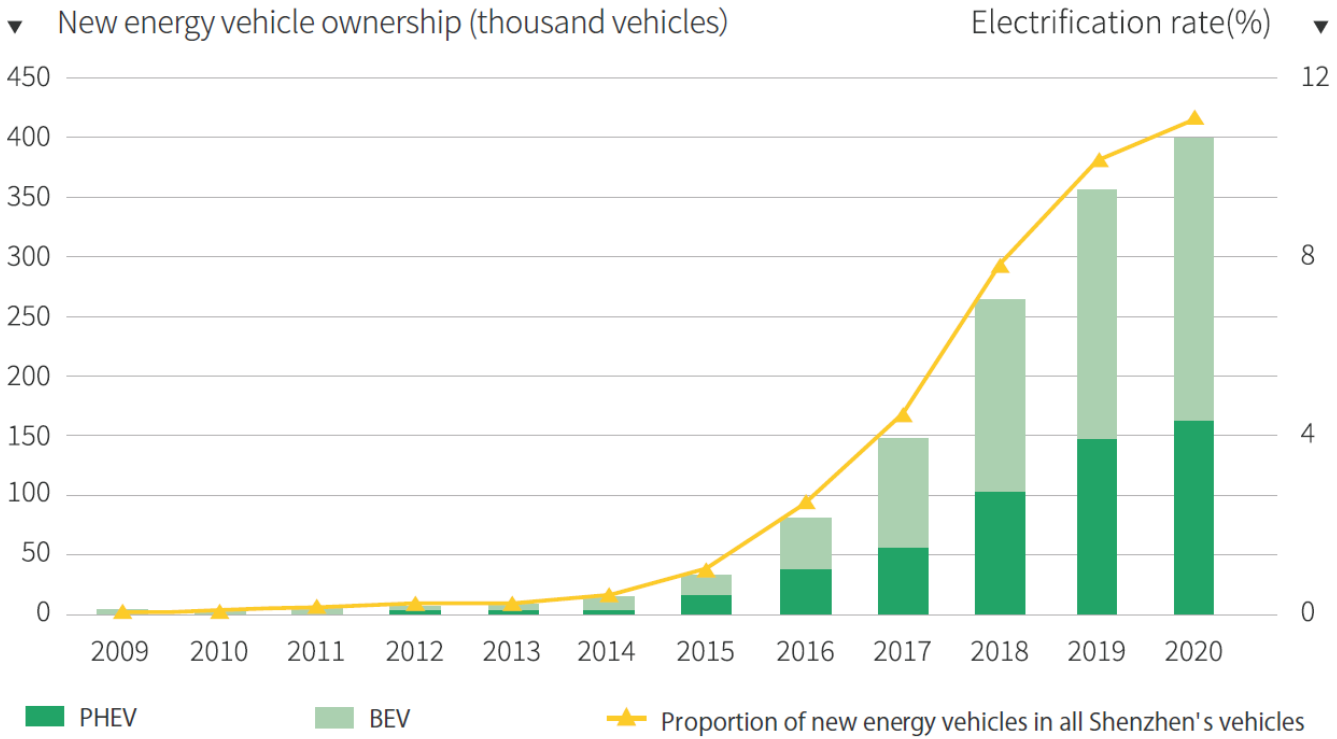
Tsinghua University

Nov. 15 2023

Shenzhen led the transition to NEVs in PRC

- Shenzhen has successfully deployed 400 thousand new energy vehicles (NEVs) by 2020, with the highest electrification rate (**11%**) among major cities in PRC

The growth of NEVs in Shenzhen, 2009-2020

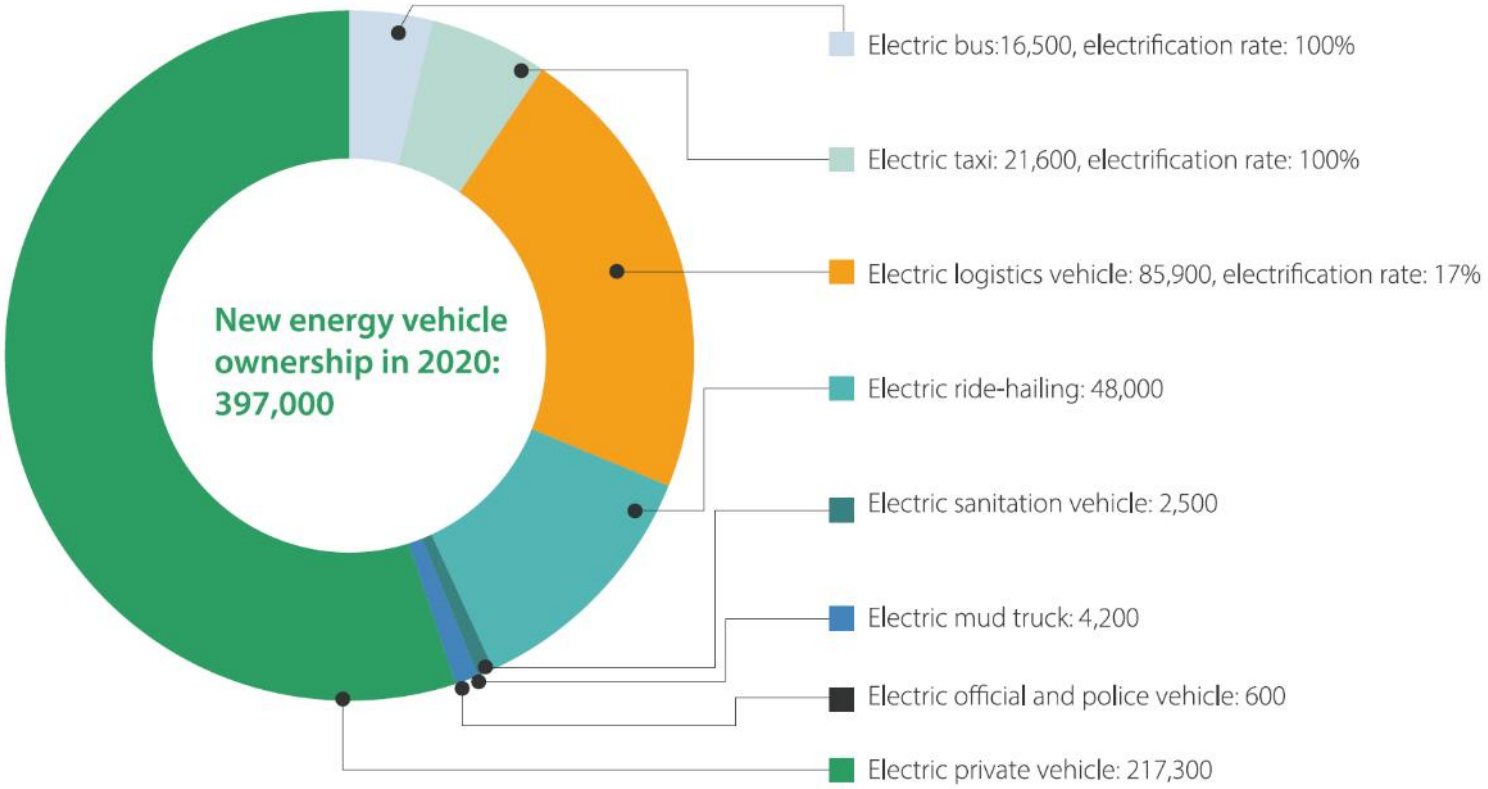


City	NEV amount (thousand)	Total vehicle population (million)	Electrification rate (%)
Beijing	412	6.57	6.3
Shanghai	424	4.69	9.0
Guangzhou	269	3.08	8.7
Shenzhen	**397**	**3.59**	**11.1**

Pioneer city of electrification of buses and taxi

- Shenzhen became the first city in the world with **100% electrification of buses and taxis**
- The number of **electric trucks** has ranked the **top across the world** in the past five years

Composition of NEVs promoted in Shenzhen, 2020



Electric bus

Electric taxi

Electric truck

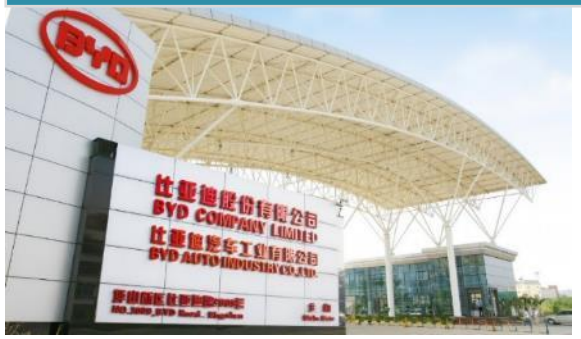
Comprehensive supports for the promotion of NEVs

- The rapid e-mobility promotion in Shenzhen are comprehensively supported by the development of infrastructure, industrial chains, subsidies and transportation policies.

Supporting infrastructure

- 93,000 public charging piles built
- Vehicle-to-pile ratio of 4.3:1

Industry chain development



- More than 2,000 NEV related enterprises
- Highest density of NEV enterprises in the world

Economic subsidies

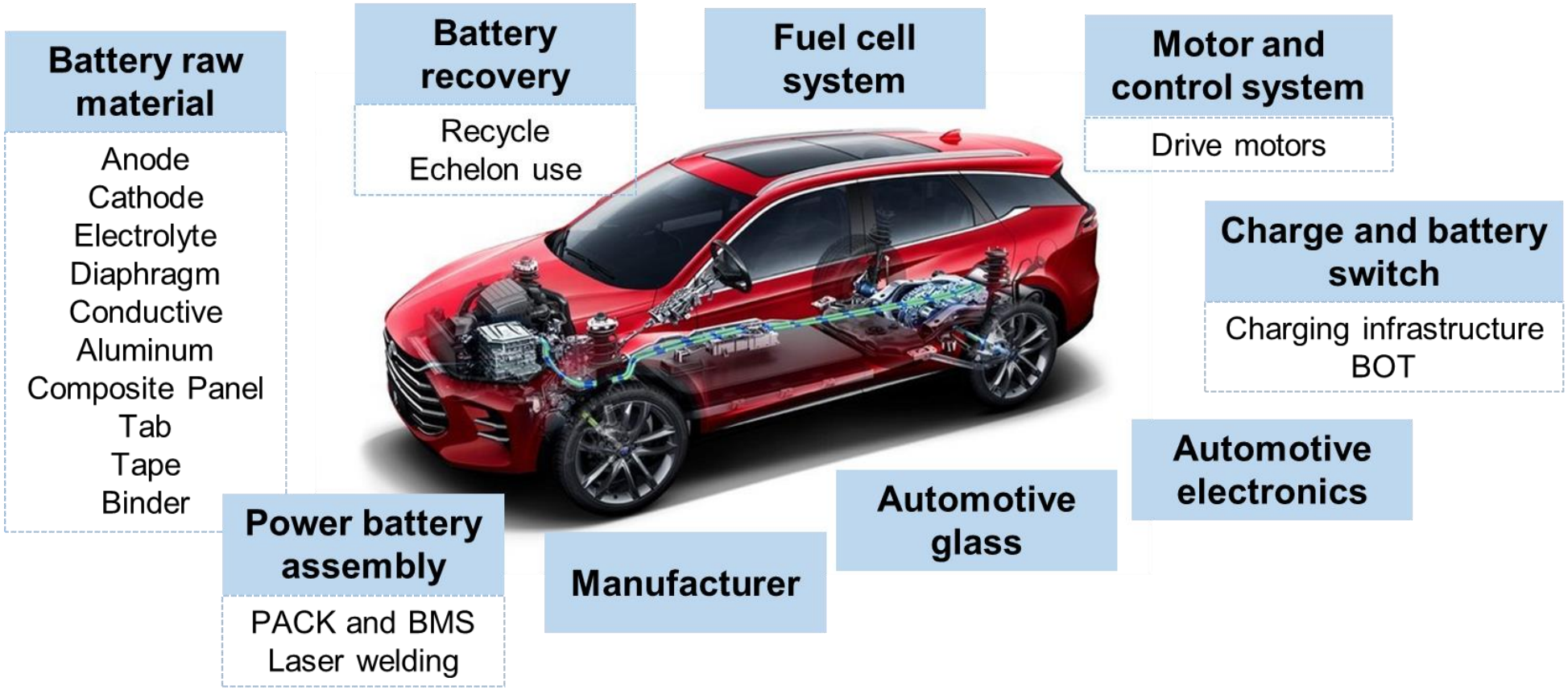
- Full-lifespan subsidies
- Charging subsidies
- Reduced parking fees

Green logistics zones

- “Green Logistics Zones” in busiest areas: only allowing electric trucks to enter

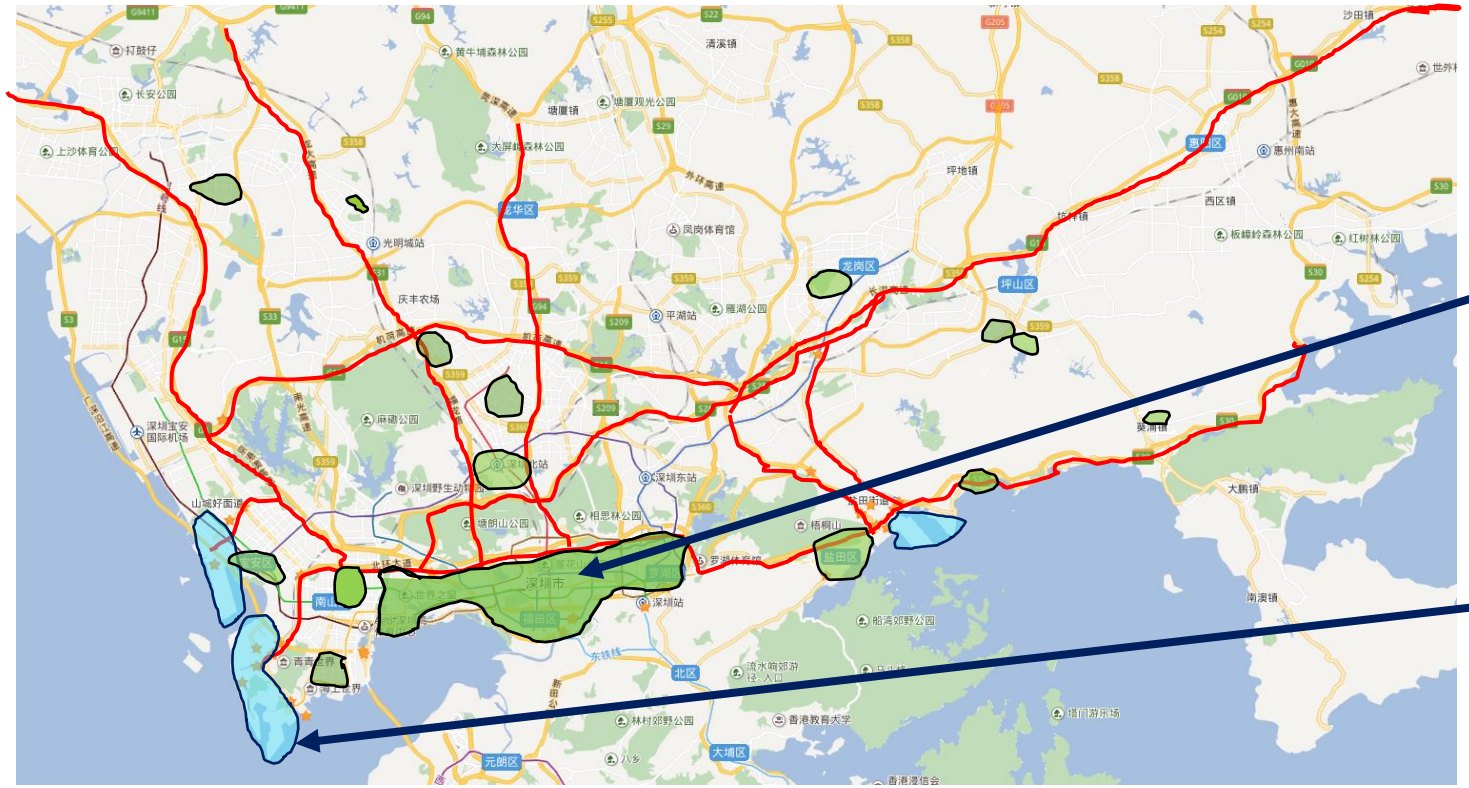
Development of the NEV industry chain

- Shenzhen places great importance on the local ecosystem of the NEV industry
- More than 2,000 NEV-related enterprises gathered in Shenzhen, making it one of the cities with the highest density of NEV enterprises in the world

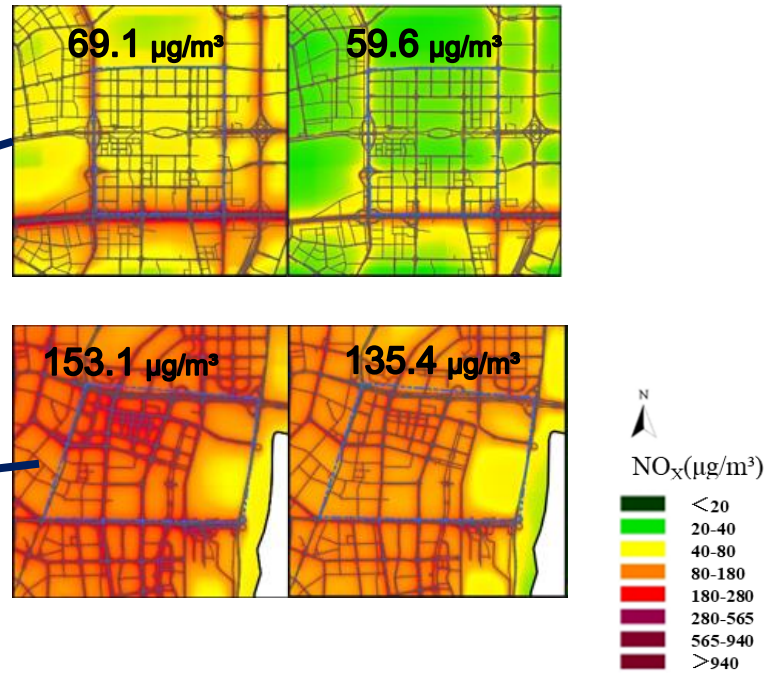


Pilot of “Green Logistics Zones”

- Shenzhen took the lead in setting up ***Green Logistics Zones*** in busy commercial areas and transportation hubs, which encouraged the adoption of electric logistics vehicles
- Shenzhen had 86,000 electric light-duty trucks by 2020 (electrification rate of 22%)



NO_X concentration reduction



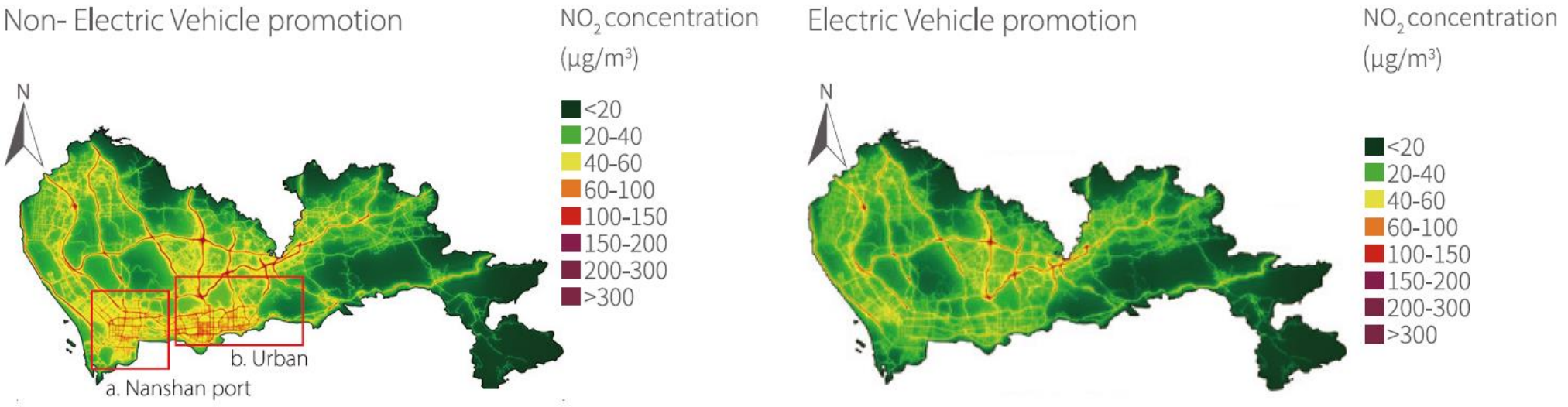
NEVs deliver air quality improvements and GHG mitigation

- The promotion of NEVs has reduced both the air pollutants and GHG emissions

NO_X	11,000 tons ↓	HC	2,400 tons ↓	$PM_{2.5}$	300 tons ↓	CO_2	540,000 t ↓

- Since 2014, ambient NO_2 concentrations in Shenzhen have significantly improved, with **35%** of the improvement attributed to fleet electrification

Air quality improvements due to the fleet electrification in Shenzhen



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QUESTIONNAIRE: *MOTOR VEHICLE EMISSION REDUCTION*

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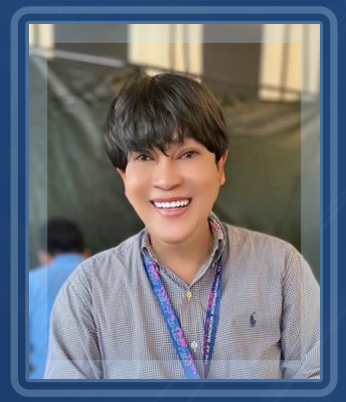
ROUNDTABLE DISCUSSION: Prospectives of leapfrogging and opportunities for Asian cities in mobile source emissions control



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Tsinghua University

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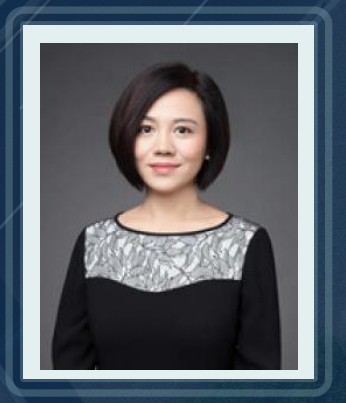
Senior Transport Researcher
Clean Air Asia

MODERATOR



Lu Fu
China Director
Clean Air Asia

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Q & A

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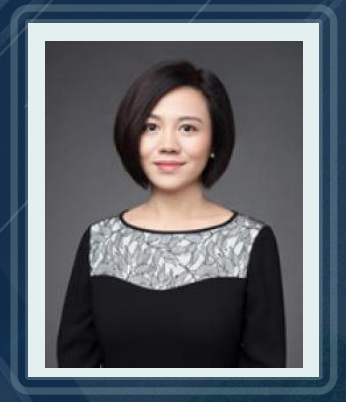
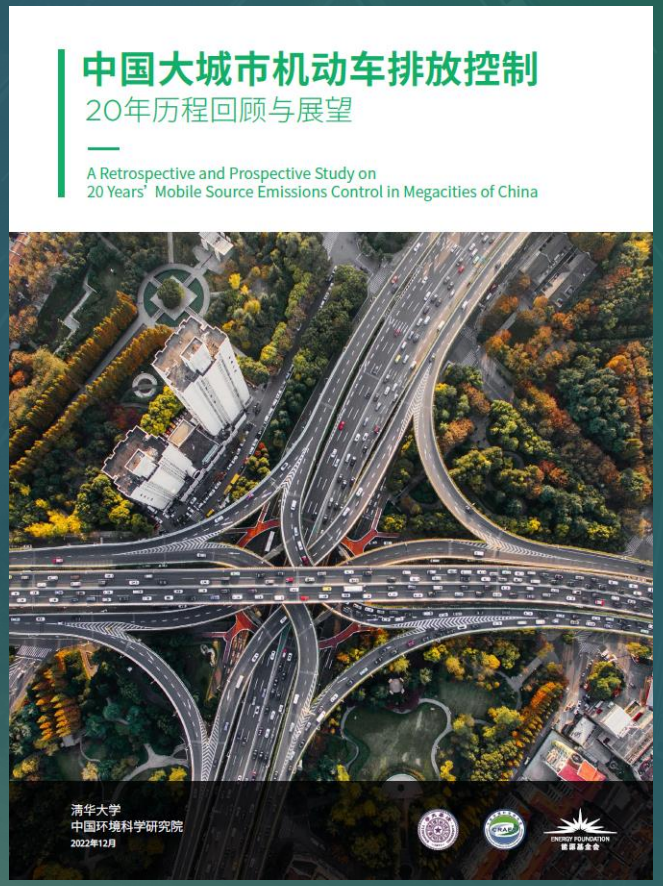
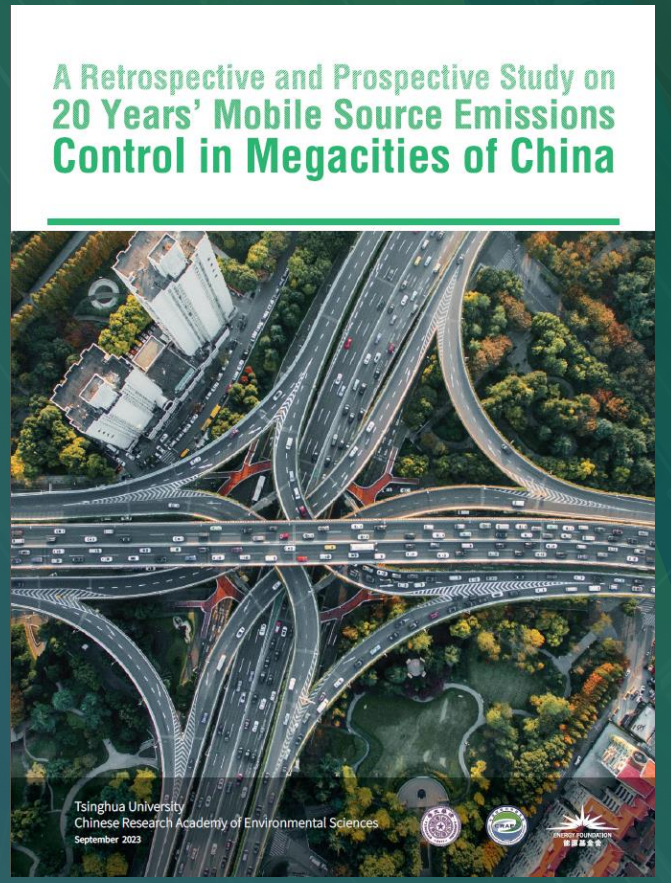


Lu Fu
China Director
Clean Air Asia

A RETROSPECTIVE AND PROSPECTIVE STUDY ON 20 YEARS' MOBILE SOURCE EMISSIONS CONTROL IN MEGACITIES OF PRC

LAUNCH CEREMONY





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QUESTIONNAIRE

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CLIMATE & CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS
a UNEP convened initiative