

# The Path to Near-Zero Vehicle Emissions: Applying California's Experience To China

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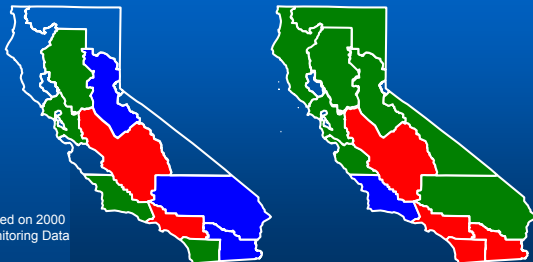
## Overview

- California
  - Air Quality and Emission Reduction Strategy
  - Status of the Zero Emission Vehicle (ZEV) Regulation
  - The California Fuel Cell Partnership
  - Reducing Climate Change Emissions from Vehicles
- China
  - Rapid Vehicle Growth
  - Environmental & Energy Impacts
  - The Path Forward- Applying California's Experience

## Air Pollution is Widespread

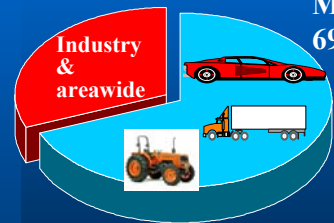
Days Over State  
Ozone Standard

Days Over State  
PM10 Standard



0-5 Days    6-50 Days    50-100 Days    >100 Days

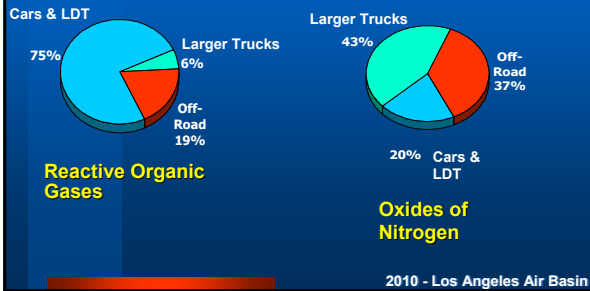
## Motor Vehicles are Dominant Emission Source



Mobile -  
69%

Industry  
&  
areawide

## Many Vehicle Sources are Major Emitters



## The Challenge

- 22 million cars in California
- Average age of passenger cars is 10 years
- Average daily mileage of 35 miles
- California VMT continues to grow ~2% per year

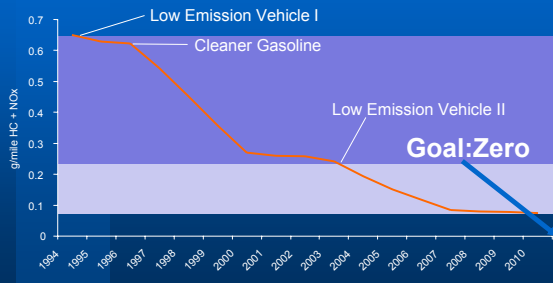
## The Low-Emission Vehicle/Zero Emission Vehicle Solution

- Analysis in 1990 showed that conventional technology would not be sufficient
- Some part of the fleet had to emit near “zero” levels
- LEV/ZEV program adopted

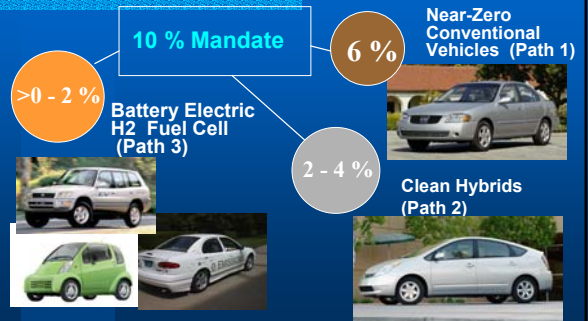
## What Has Happened Since 1990?

- Batteries fell short
  - performance
  - cost
- Conventional technology over-achieved (matched battery vehicle charging emissions)
- New near-zero emission technologies introduced
  - hybrids
  - gaseous fuels

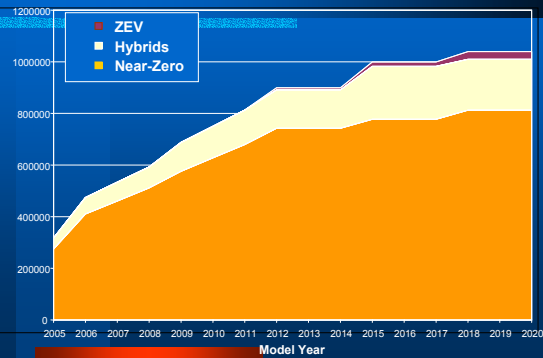
## Evolution of ARB Auto Controls Implementation: 1994 - 2010



## ZEV Regulation Restructured in 2003 for More Flexibility



## Vehicle Production Scenario (example)



## Path 1: Near-Zero Emission Conventional Vehicles

- Near zero exhaust emissions
- Zero evaporative emissions
- 15 year/150,000 mile warranty
- On-board diagnostics
- 140,000 sales in 2003
- 200,000 sales in 2004



## Path 2: Hybrid Electric Vehicles

- Three models now available
- More models coming
- ~ 20,000 sales expected in 2005



Lexus 400 H Hybrid  
(coming soon)

Toyota Prius Hybrid



Honda Civic Hybrid

## Hybrid Electric Vehicles

“ZEV enabling” technology:

- electric drive train
- batteries
- power management



## Incentives for Near-Zero Emission Hybrid Electric Vehicles

- Extra regulatory incentives (credits) encourage “strong” hybridization
- Incentives based on:
  - system voltage
  - power output of the electric motor
- Short term incentives for 42-volt systems

## Path 3: Battery Electric and Fuel Cell Vehicles

- Full size battery electric
- Neighborhood electric
- Fuel cell

## Full-Sized Battery Electric Vehicles



- Over 2,500 sold or leased
- Cost and range issues shifts focus:
  - smaller vehicles
  - fuel cells

## Neighborhood Electric Vehicles

25 mph top speed  
limited range  
2-4 passengers



Over 8,000 sold or leased in response to ZEV regulation



## Fuel Cell Vehicles

- Promising technology
- Significant cost, manufacturing and performance challenges
- Volume production expected 2010 or later



## Hydrogen Fuel Cell Benefits

- No direct smog-forming or greenhouse gas emissions
- Potential for extremely low lifecycle ("well to wheel") emissions
- Better fuel economy, greater efficiency
- Quiet and smooth operation

## Transition to Fuel Cells

- Prototype fuel cell vehicles now being demonstrated
- California Fuel Cell Partnership

## California Fuel Cell Partnership



- Promotes fuel cell vehicle commercialization
- Infrastructure
- Safety
- Public Education



## Fuel Infrastructure



- Liquid H<sub>2</sub> storage
- Delivers gaseous hydrogen at two pressures:
  - 3600 psi & 5000 psi
- Fill time ≤ 4 minutes

2400+ fueling events



## Fuel Cell Vehicles - Today



41 cars

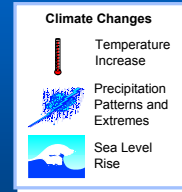
Over 122,000 miles

5,000+ riders/drivers

## Global Climate Change is a Major Challenge

- May be an opportunity for hybrid vehicles
- Technology mix will depend on fuel cell progress

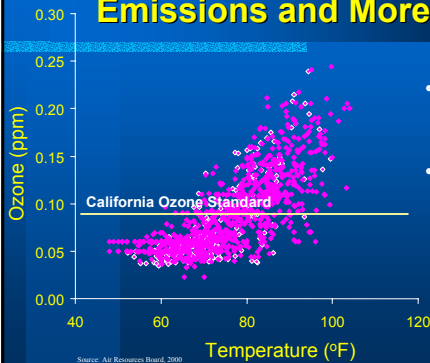
## Climate Change is a Major Concern for California



Source: Anne Grambsch, 1998



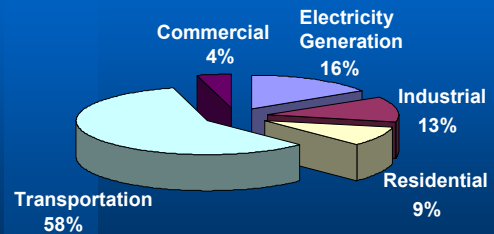
## Hotter Days Lead to Higher Emissions and More Smog



- Los Angeles Ozone Levels (1995-1998)
- 10 warmest years of the last century all occurred within the last 15 years.

Source: Air Resources Board, 2000

## Transportation is California's Largest Source of CO<sub>2</sub>



## Climate Change Legislation in California

- Achieve maximum feasible and cost-effective reduction of greenhouse gas emissions from cars and light trucks
- 2009 and later model years

## Climate Change Regulation

- Regulations will provide flexibility, not mandate specific technology
- Hybrid vehicles will compete with other emerging technologies
- Hybrid's role will depend on developments in conventional and fuel cell technology - but increased sales seems certain

## Long-Term Vision

- The ultimate goal remains - zero-emission technology
- Must be energy-efficient; reduced climate impact
- California is taking the necessary steps now

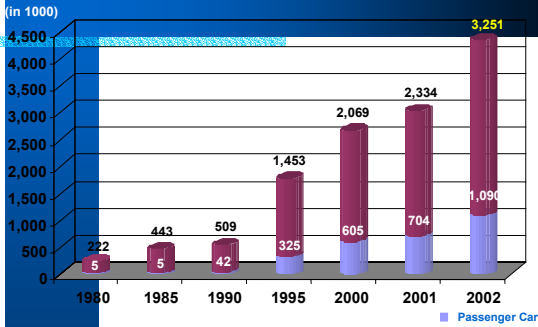


## Where Do We Stand in China?

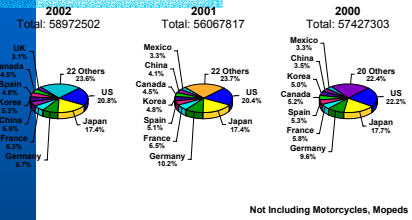


Outline:  
Vehicle Trends & Forecasts  
Associated Problems  
Air Pollution  
Global Warming  
Oil Imports  
Advanced Technologies Could Help Solve These Problems

## Vehicle Production in China 1980 - 2002

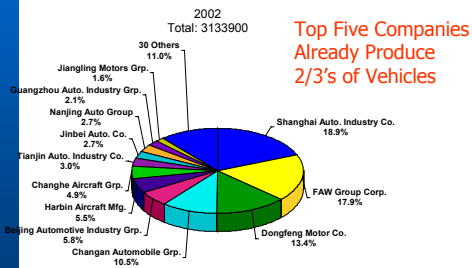


## Vehicle Production By Country



China Is Now 5th Largest Producer in the World

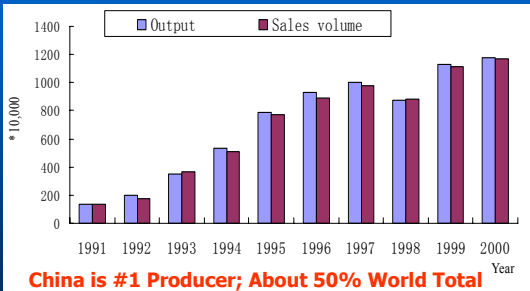
## Motor Vehicle Production By Manufacturer



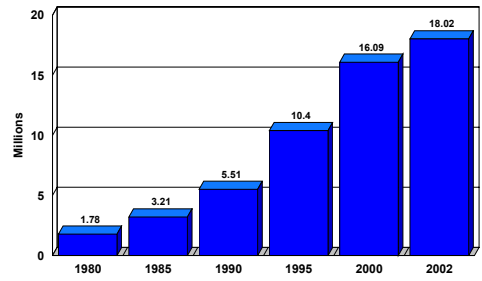
## Recent Investments in China's Vehicle Industry Indicate Substantial Future Growth

- FAW – VW; \$1 Billion Venture with Toyota
- DMC – recent link with Honda;
  - \$1 Billion Venture with Nissan; Peugeot JV
- SAIC – joint venture with VW & GM;
  - Already Largest Car Sales in China; GM-Daewoo JV
- Chang'an Automotive Group - Ford Increased Investment By \$1.5 Billion

## Motorcycle Annual Production and Sales



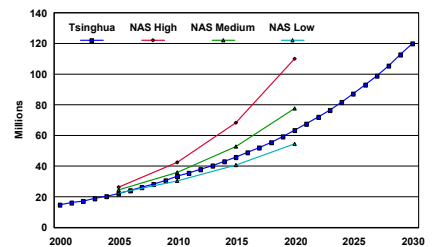
## China's Vehicle Population (Cars, Trucks & Buses)



## Vehicle Growth in Beijing is Exploding

- Growth in the Number of Cars in Beijing
  - ▶ From 0 to 1 million - 48 years
  - ▶ From 1 to 2 million - 6.5 years
  - ▶ From 2 to 3 million - est 3 years
- Relative Growth Rates
  - ▶ Average Annual Growth in Vehicles ~20%/year
  - ▶ Average Annual Growth in Road Network ~3.5%/year

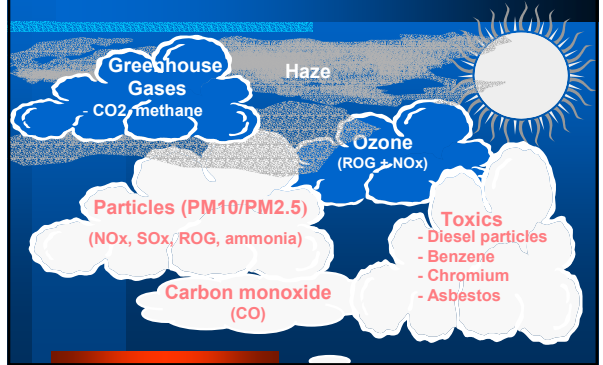
## Recent Forecasts of Chinese Vehicle Population



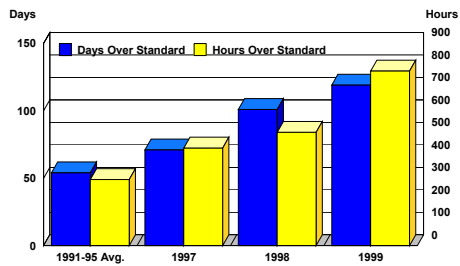
**Tsinghua Also Predicts About 200 Million MC By 2030**

## Air Pollution Problem is Already Severe

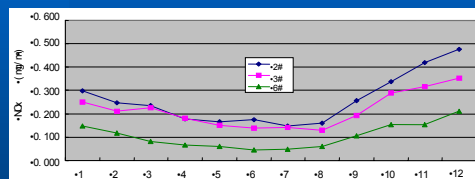
## What pollutants are of concern?



## Ozone Trends in Beijing



## BEIJING: NO<sub>x</sub> Concentration In 1998



2# and 3# monitoring stations are near to the arteries, and 6# monitoring station is far away from the arteries.

## China: Urban NOx Problems

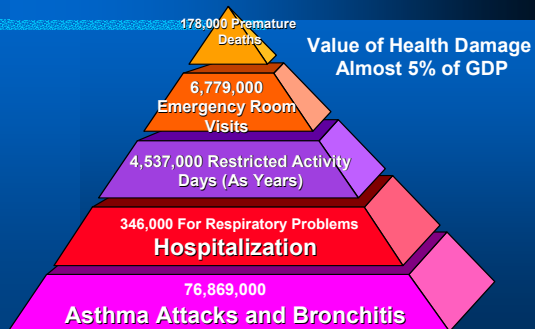
NOx Concentration in Chinese cities

year	No. Of cities	Non-attainment cities		Non-attainment for Class II standard		Non-attainment for Class III standard		Non-attainment cities for Class III
		number	rate (%)	number	rate (%)	number	rate (%)	
1995	88	32	36.4	3	3.4	0	0	
1996	88	27	30.7	25	28.4	2	2.3	Beijing, Guangzhou
1997	94	32	34.1	29	30.9	3	3.2	Beijing, Guangzhou, Shanghai
1998	96	32	33.3	29	30.2	3	3.1	Beijing, Guangzhou, Shanghai

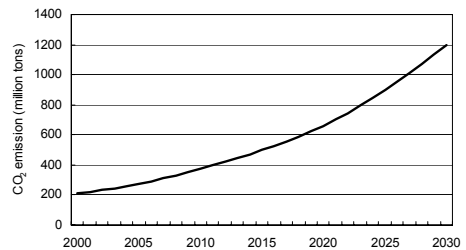
## Motor Vehicle Pollution in Urban Areas

- Motor vehicles contribute nearly 50% of NOx emissions in metropolitan cities
- About 1/3 of Major Cities Exceed ambient NOx NAAQS;
- CO concentration generally higher than national standard in traffic areas;
- Photochemical pollution emerging in big cities;
- Vehicles becoming a main source of air pollution in urban areas.

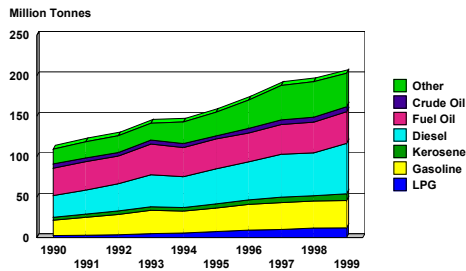
## Health Impacts of Air Pollution in China



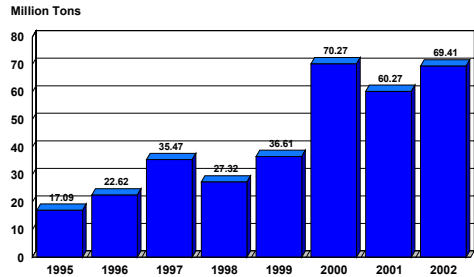
## Carbon Dioxide Emissions From the Road Transport Sector Are Skyrocketing



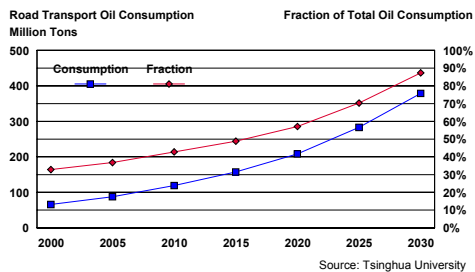
## Fuel Consumption Trends in China



## Oil Imports Have Grown Rapidly in China



## Current and Projected Road Transport Oil Demand in China



Road transport oil demand will be over 50% of the total by 2020, and almost 90% by 2030, making it the principal source of oil demand and oil imports at that time.

## Efforts in China To Address Urban Air Pollution

- Initial Clean Air Strategy Developed
  - ▶ Complete Lead Phase Out by 2000
  - ▶ European Emissions Standards Introduced For Cars & Trucks
  - ▶ Tax Incentives For Euro 2 Vehicles
- Individual Cities Supplementing National Actions
  - ▶ I/M Pilot Being Developed in Shanghai
  - ▶ Alternative Fuels For Buses & Taxis
  - ▶ Catalyst Retrofits in Beijing

## Fuel Quality Improvements

- Eliminated Very Low Octane Fuels
- Eliminated Lead Additives But
  - MTBE
  - MMT
- Gasoline Aromatics Limited To 40%
- Gasoline Olefins Limited to 35%
- Sulfur Levels Reduced But Still High

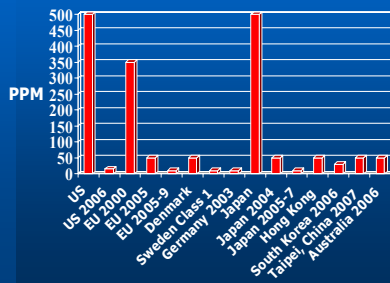
## Pollution Control Measures on Motor Vehicles

Emission Standards For New Vehicles

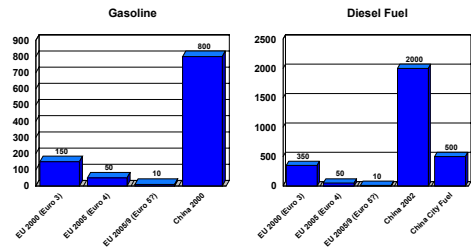
Time Category	Before 2000	2000	2001	2002	2003	2004	2005
PC	ECE 1503	EURO I	←	←	←	EURO II	←
LDV&LDT	ECE 1503	←	EURO I	←	←	←	EURO II
HDDV	None	←	EURO I	←	←	EURO II	←
Motorcycle	ECE R40	←	EURO I	←	←	←	EURO II

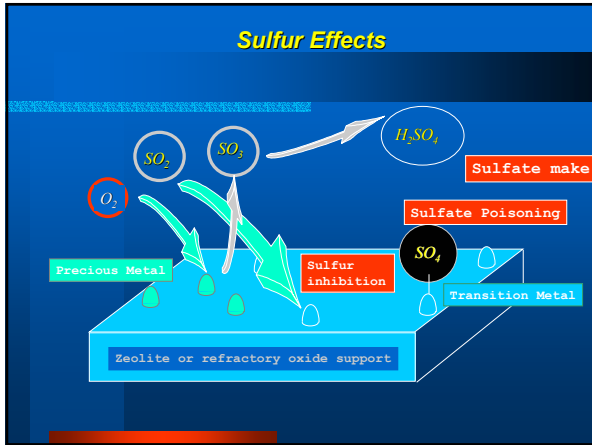
Beijing, Shanghai Introduced Euro 2 in 2003

## Ultra Low Sulfur Diesel Fuel Is Necessary For Continued Progress



## Maximum Sulfur Levels in Chinese & EU Fuels (PPM)





### Summary of Influence of Fuel Sulfur on Gasoline and Diesel Exhaust Emission Control Devices

● Control Technology	● Sulfur Effects
- TWC	- Sulfur Inhibition
- Oxidation Catalyst	- Sulfur Inhibition, Sulfation
- Lean NOx Catalyst	- Sulfur Inhibition, Sulfation
- SCR with Urea	- Sulfur Inhibition, Sulfation
- Catalytic Filters	- Sulfur Inhibition, Sulfation
- NOx Adsorbers	- Extreme Sulfur Inhibition
- Hybrid With TWC	- Sulfur Inhibition

- ### China Addressing Emissions & Energy Consumption But Not Yet On The Path To Zero Emissions
- 10<sup>th</sup> 5-Year Plan
    - Hybrid Vehicles Ready For Production
    - Prototype Fuel Cell Vehicle
    - Parity With EU Emissions Standards by 2010
  - Beijing "Green" Olympics
  - Shanghai World Expo
  - New Fuel Economy Program

- ### Advanced Technologies Could Play A Critical Role
- Substantially Reduce Conventional Urban Pollutants
  - Reduce Oil Consumption Through High Efficiency
  - Major Challenges:
    - Cost
    - Vehicle Availability

## Advanced Technology Alternatives

- Hybrid Vehicles
  - Available in Short Term
  - Very Low Pollution
  - Very Good Fuel Economy
  - Low Noise
  - Urban Buses & Trucks
    - Very Good in Stop&Go
    - Lowers Pollution Exposure
- Fuel Cell Vehicles
  - Longer Term
  - Near Zero or Zero Pollution Potential
  - 2 X Fuel Economy or More
  - Low Noise
  - Significant Challenges Remain
    - Cost
    - Infrastructure

## Next Steps in China

- Near Zero Sulfur Fuels
- Euro 4/5 Emissions Standards
- Fuel Efficiency Standards For Light Duty Vehicles
- Emphasize Hybrids For Special Events
  - Olympics
  - World Expo
- MOST Investment
- Offer Incentives To Offset Higher Price
- Special Concessions
  - Manufacturers
  - Fleet Managers

## Conclusions

- High Vehicle Growth Is Leading To Rapid Increases in Vehicle Emissions
- Air Quality Already Degrading
- Oil Imports Soaring
- Initial Pollution Control Effort Reflects A Good Start
- New Fuel Economy Program A Big Step Forward

## Conclusions (2)

- Most Vehicle Pollutants Will Continue To Go Up Without Additional Controls
- Goal Should Be State of the Art Pollution Controls by About 2010
- Much Cleaner Fuels Will Be Required
- Fuel Consumption/CO2 Must Continue To Improve
- Hybrids Could Help Substantially in Short Term
- Fuel Cells Could Play Important Long Term Role if Challenges Can Be Overcome