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WHEN WILL CHINA BE NUMBER ONE?

in Vehicle Production, Oil Use, CO_2 Emissions

DOE Briefing on the Argonne report: "*Projection of Chinese Motor Vehicle Growth, Oil Demand, and CO_2 Emissions through 2050*"
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Michael Wang, Hong Huo, and Larry Johnson

Center for Transportation Research

Argonne National Laboratory

Dongquan He

The Energy Foundation, Beijing, China

U.S. Department of Energy

UChicago Argonne LLC

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This Study Was Intended to Answer These Questions

If China experiences the vehicle growth patterns of other developed countries in the past 50 years,

1) How much growth will there be for China's total vehicle population in the next 40 years?

2) How much petroleum demand would be needed to fuel Chinese vehicles?

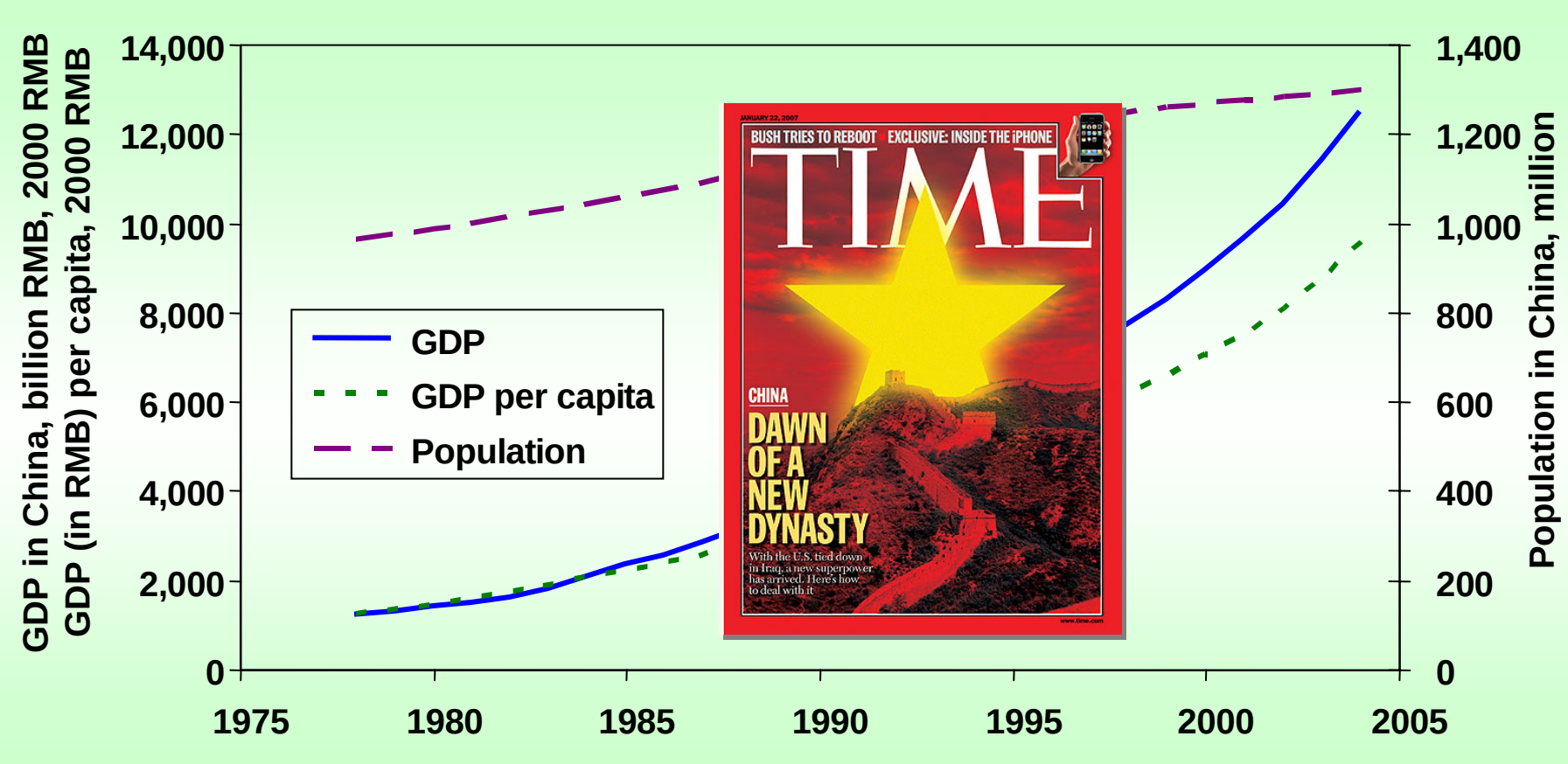
3) How much CO_2 emissions would be produced from such growth?

Background: Recent Argonne Activities in Transportation Analysis and Research

U.S. Department of Energy recognized the transportation-energy nexus early and began some China projects at Argonne

- Olympics cooperation
  - Beijing-Chicago Friendship Cities for Sustainable Development
  - Feasibility study of CNG sanitation trucks
- Training of technical staff in lifecycle analysis (GREET)
  - Beijing Sustainable Development Commission
  - China Automotive Technology And Research Center (CATARC)
- Licensing and training for PSAT (Powertrain Systems Analysis Toolkit)
  - CATARC was the first license
  - 6 more recently added in China (60 organizations license PSAT)
- Technical analysis (e.g., motor vehicle projections)

The U.S. Media Is Now Referring to China as an Economic Powerhouse



Source: China Statistics Yearbook, 2005

- **GDP grew at an annual rate of 9.5% (real RMB) over the past 20 years**
- **GDP increased by 6 times (real RMB) between 1980 and 2000**
- **In 2002, a new goal was set to increase China's GDP by 4 times between 2000 and 2020**

China: Big Changes in a Big Country

- In 1990, private car ownership was virtually non-existent
  In 2006, 7 million vehicles were sold in China; nearly all manufactured there

- In 1992, China was a net exporter of oil
  In 2006, China imported 45% of it's oil, second only to the US

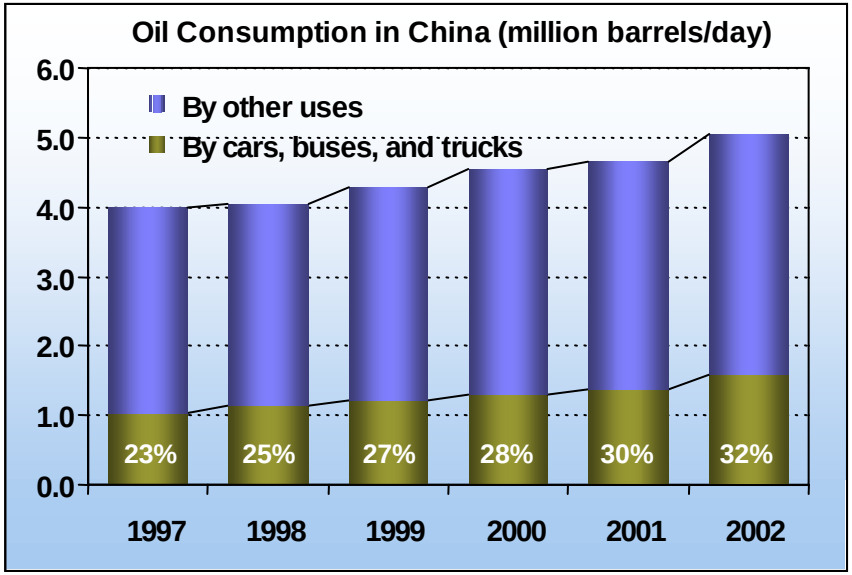
- In 2006, 16.5 millions light-duty vehicles were sold in the US
  By 2020, Chinese motor vehicle sales could equal current US sales
  By 2050, China sales could be 40-60M/yr!

- In the 2030's, China's oil consumption and CO2 emissions could equal US's today

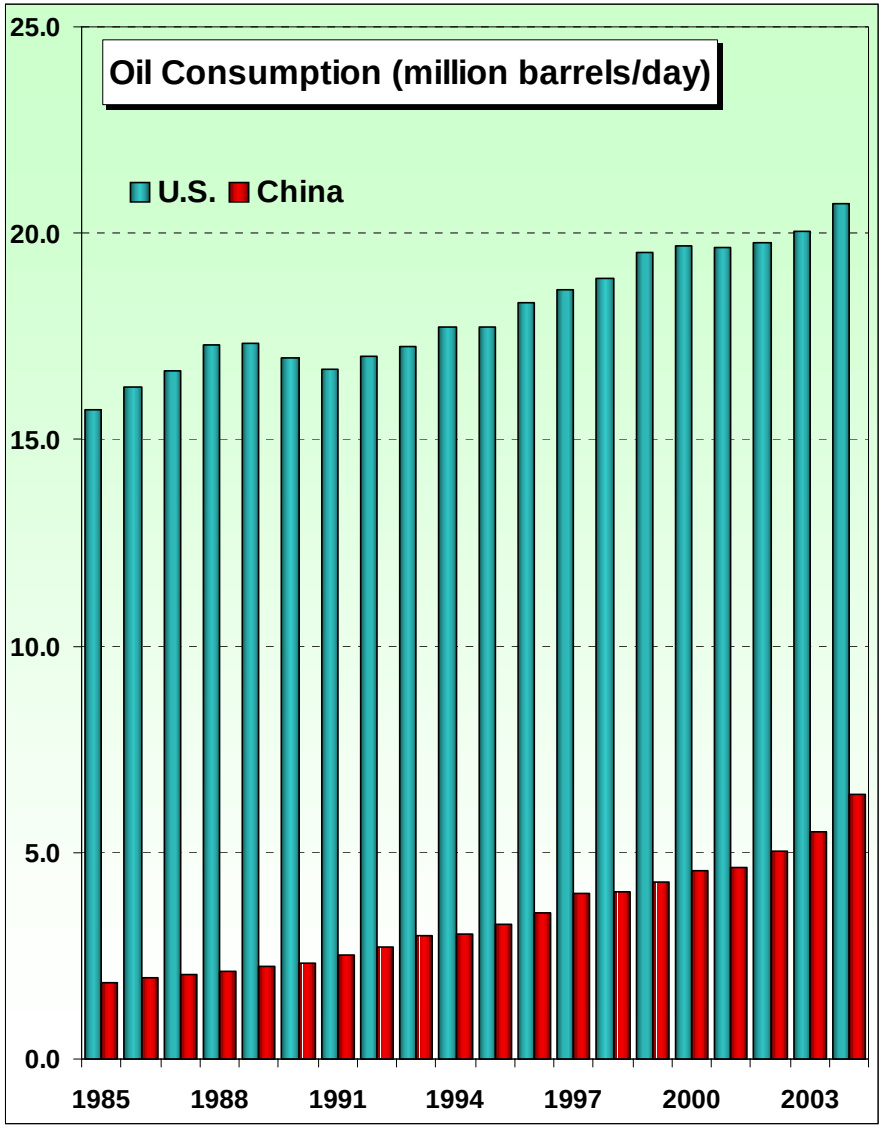
- What are the implications globally for:
  - petroleum
  - carbon emissions
  - materials
  - the world economy

Chinese Oil Consumption Has Increased Significantly

- In 2004, Chinese oil use was approximately 1/3 of U.S. oil use
- Oil use has increased by 7% annually over the past 15 years
- Beginning in 1993, China became a net oil importing country; in 2006, it imported near 45% of its oil
- Now, China now is the #2 oil consuming country
- Share of oil use by motor vehicles is now small, but it is increasing rapidly



Source: He et al., 2005.



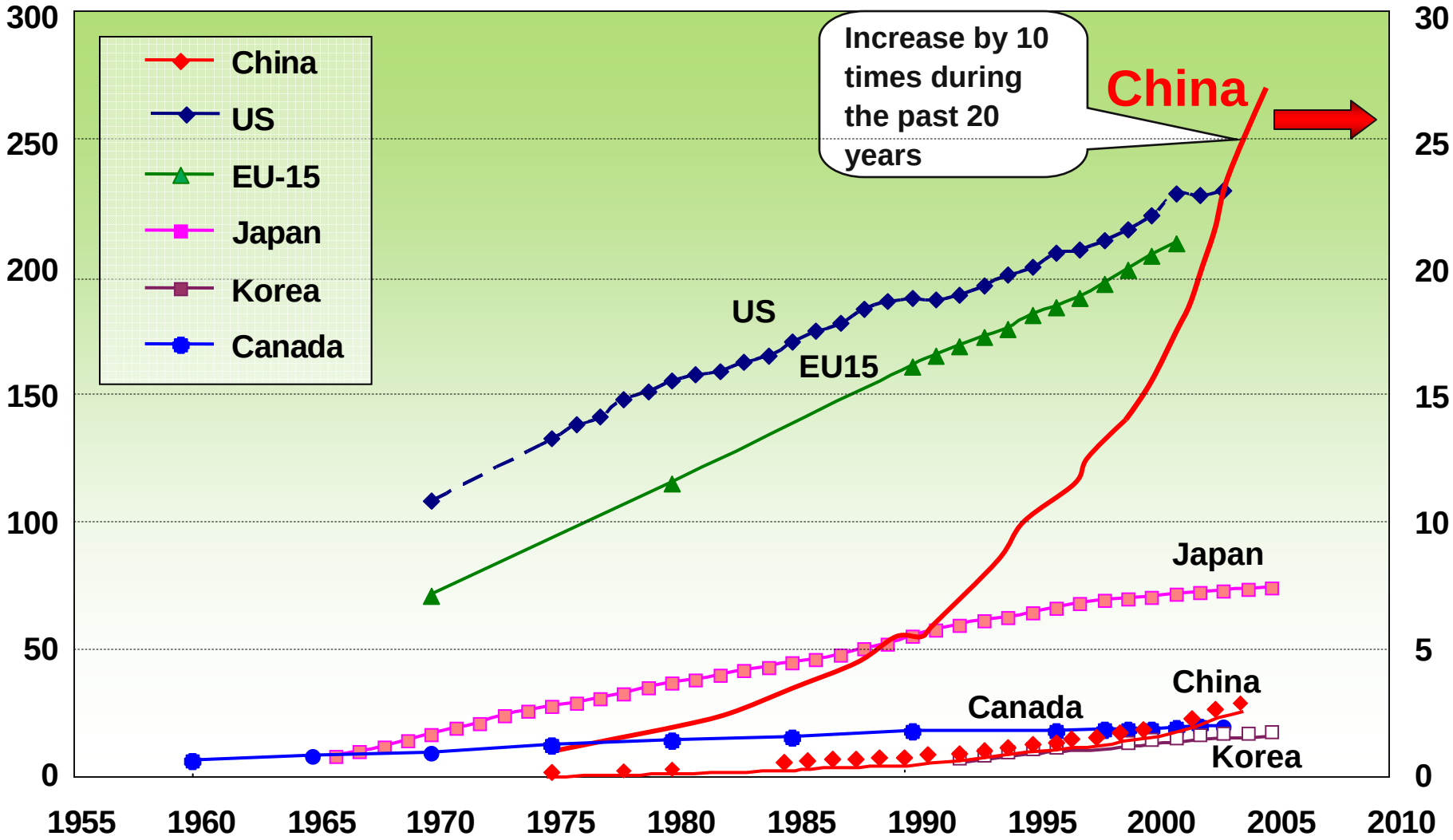
Sources: Davis et al, 2006; China Energy Statistics Yearbook 1991-2004.

Chinese Vehicle Classifications Are Different from Those in Other Countries

- **Motor Vehicles**
  - **Highway Vehicles (HWVs)**
    - **Trucks**
      - Heavy-duty Trucks (HDTs), GVW>=14 metric tons
      - Medium-duty Trucks (MDTs), GVW=6-14 metric tons
      - Light-duty Trucks (LDTs), GVW=1.8-6 metric tons
      - Mini Trucks (MiniTs), GVW<1.8 metric tons
    - **Buses**
      - Heavy-duty Buses (HDBs), TVL>= 10 meters
      - Medium-duty Buses (MDBs), TVL=7-10 meters
      - Light-duty Buses (LDBs), TVL= 3.5-7 meters
      - Mini Buses (MiniBs), TVL < 3.5 meters
    - **Cars**
      - Large Cars (LCs), DV >= 1.6 L
      - Small Cars (SCs), DV < 1.6 L
  - **Motorcycles (MC)**
  - **Rural Vehicles (RVs)**
    - 3-Wheels RV
    - 4-Wheels RV

GWV: gross vehicle weight; TVL: total vehicle length; DV: displacement volume

Historical Growth in Vehicle Population Shows the Beginning of Fast Growth in China (Millions of Cars, Buses, and Trucks)

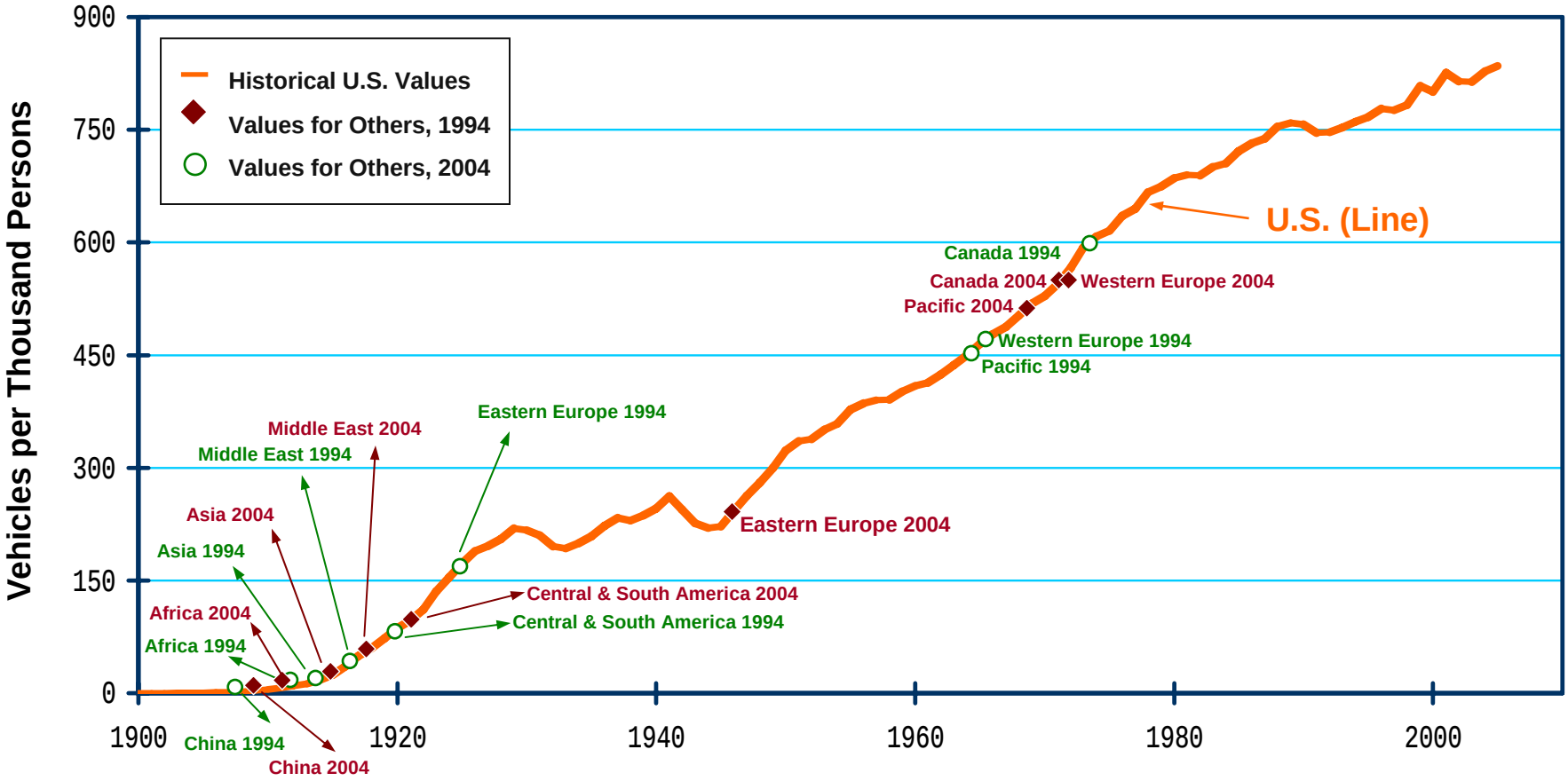


Sources: Davis et al., 2006; China Statistics Yearbook 1995-2005; EC-DGET, 2003; and other sources.

Vehicle Growth Projection in This Study Is Based on Vehicle Stock Projection in A Given Year

- While vehicle growth projection could be made on the basis of annual vehicle sales, doing so may not be reliable for an emerging, fast growing auto market as being experienced in China
- Instead, this study projects total vehicle stock in a given year
- Steps of projecting vehicle growth and fuel demand in this study
  1. On-road vehicle stock
  2. Composition of vehicle types in total vehicle stock
  3. Vehicle mileage traveled (VMT) per vehicle
  4. Vehicle fuel economy
     (in MPG or kilometers per liter of fuel)

One Indicator of Economic Development Is the Number of Motor Vehicles per Capita



In terms of vehicles per capita, China is about where the U.S. was in 1914

Source: Transportation Data Book, Vol. 25, ORNL, 2006

Highway Vehicle Ownership Projection is Done with the Gompertz Function

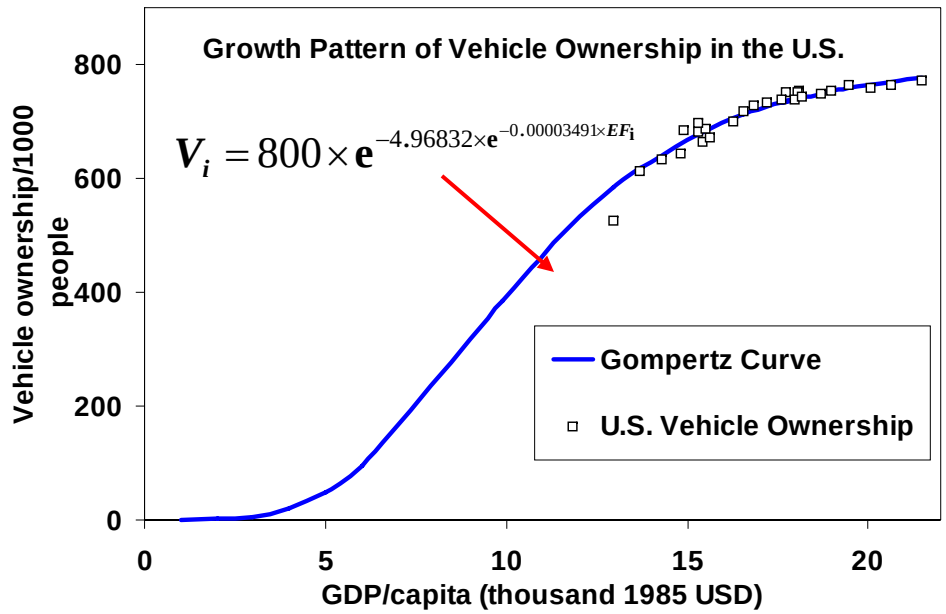
- **An typical S-shape growth function which includes:**
  - A slow-growth period in the beginning
  - A booming period in the middle
  - A saturated period toward to the end
- **Vehicle ownership is related to per-capita GDP**
- $$V_i = V^* \times e^{\alpha e^{\beta EF_i}}$$

V_i – *Vehicle ownership*

V^* – *Saturation level of vehicle ownership*

EF_i – *per-capita GDP*

α and β – *parameters that determine the shape of the S-shape curve*



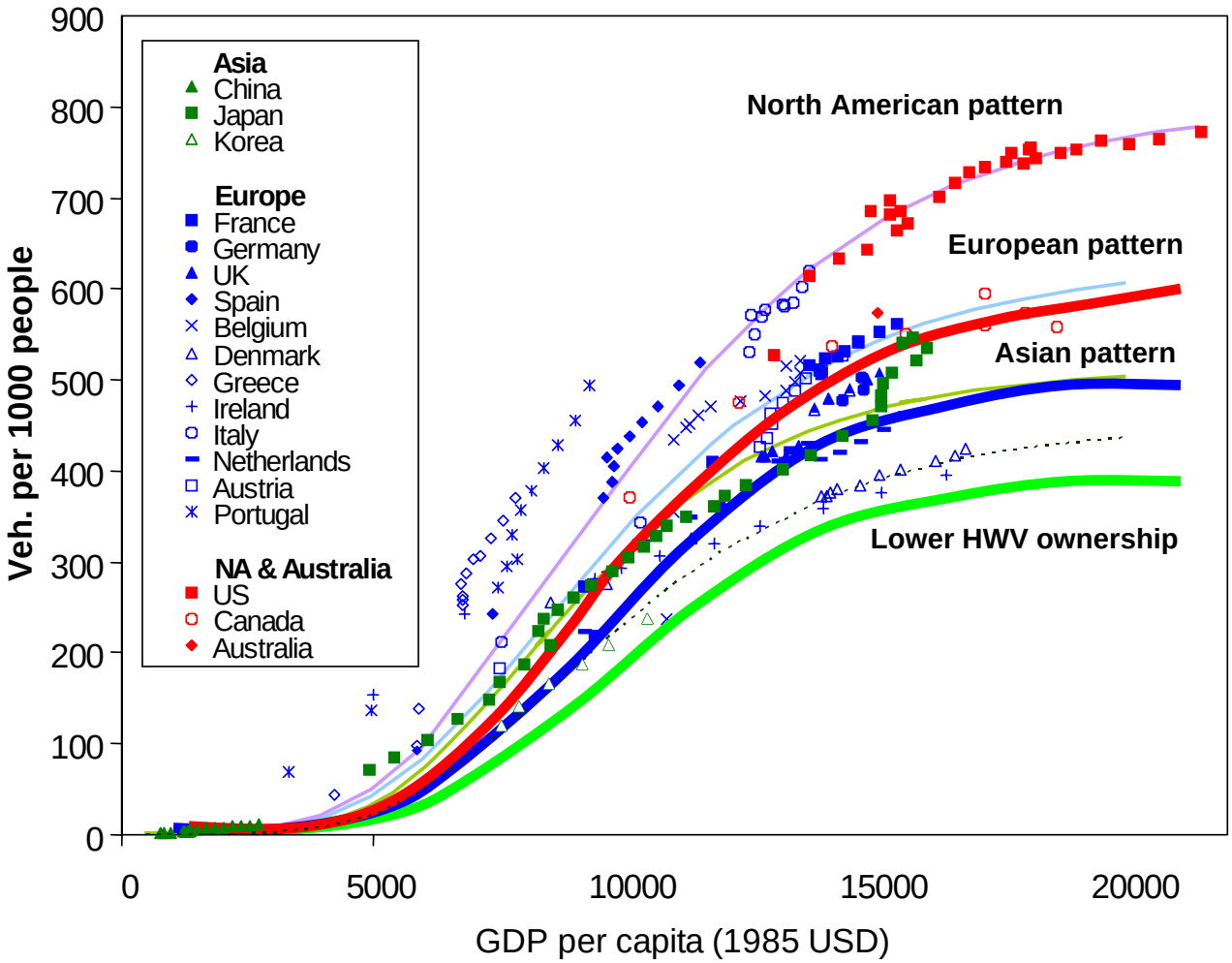
Sales by Model Year and Type Was Back-Calculated from Total Vehicle Stock, Market Share, and Survival Rate

- Annual sales can be back-calculated with vehicle population, market share, and survival rate

$$VP_{year} = \sum_{Type}\sum_{age}\left(Sales_{year-age} \times Market_{year-age,type} \times SR_{age,type}\right)$$

- Back-calculation of annual sales is influenced by:
  1) market shares of vehicle types and classes and
  2) vehicle retirement schedules
  - Future market shares consider
    - *Chinese government policies such as those encouraging small cars*
    - *The trends of the auto industry such as the increase in the share of heavy-duty trucks and larger buses and the increase in diesel vehicle share*
    - *Historical trends of increased passenger car shares in developed countries*
  - Vehicle retirement schedules (affecting survival rates) consider
    - *Scrappage requirements in place in China*
    - *Historical trends in Japan and the U.S.*

Vehicle Stock Was Forecast According to 3 Saturation Rates, Then Annual Sales and Model Types Were Derived



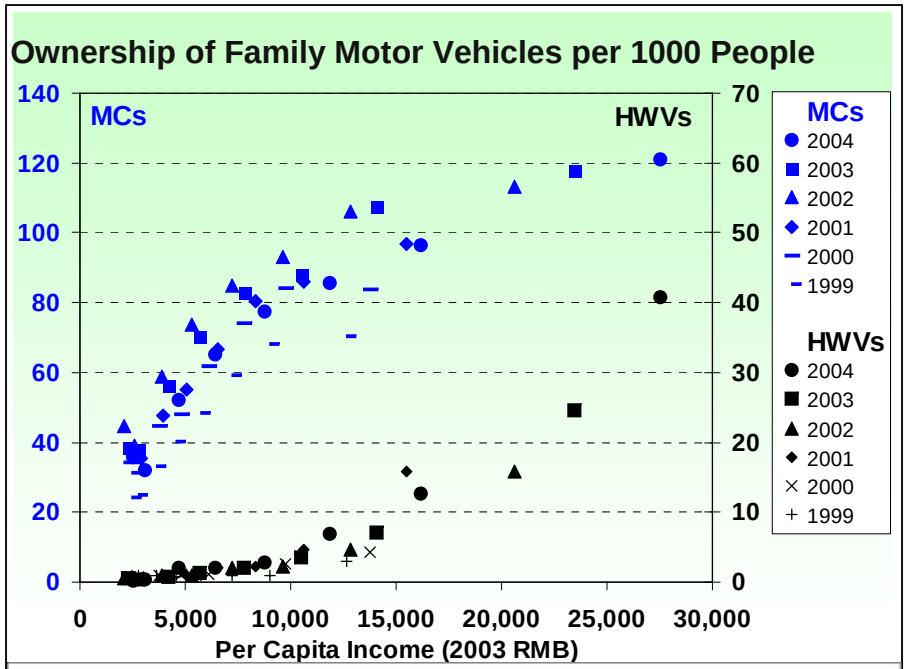
Sources: Davis et al, 2006; U.S Census Bureau website; China Statistics Yearbook; and other sources

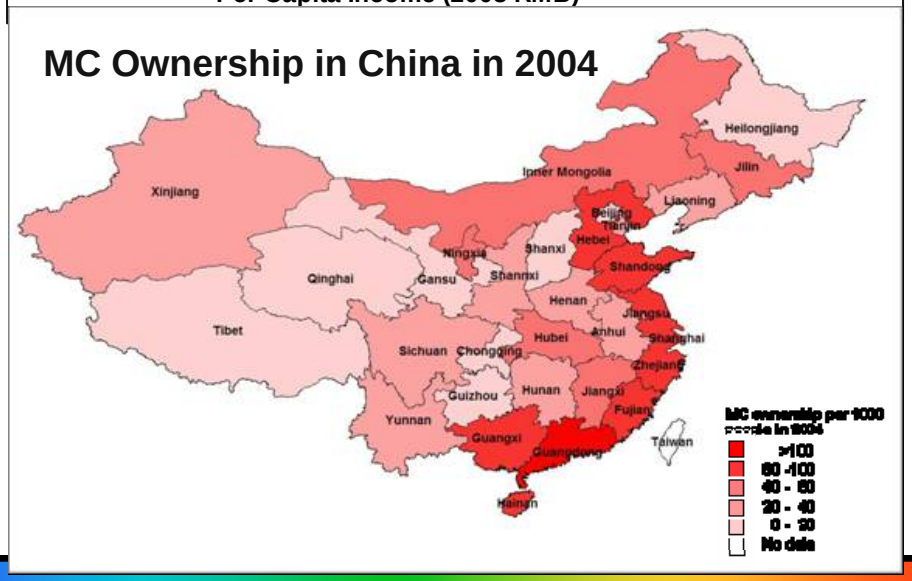
Three Scenarios Were Established in This Study

- **A high-growth scenario**
  - To follow the European pattern with a saturation level of 600
- **A mid-growth scenario**
  - To follow the Asian pattern with a saturation level of 500
- **A low-growth scenario**
  - To assume a lower growth curve with a saturation level of 400

Projection of Motorcycles and Rural Vehicles Takes A Different Approach

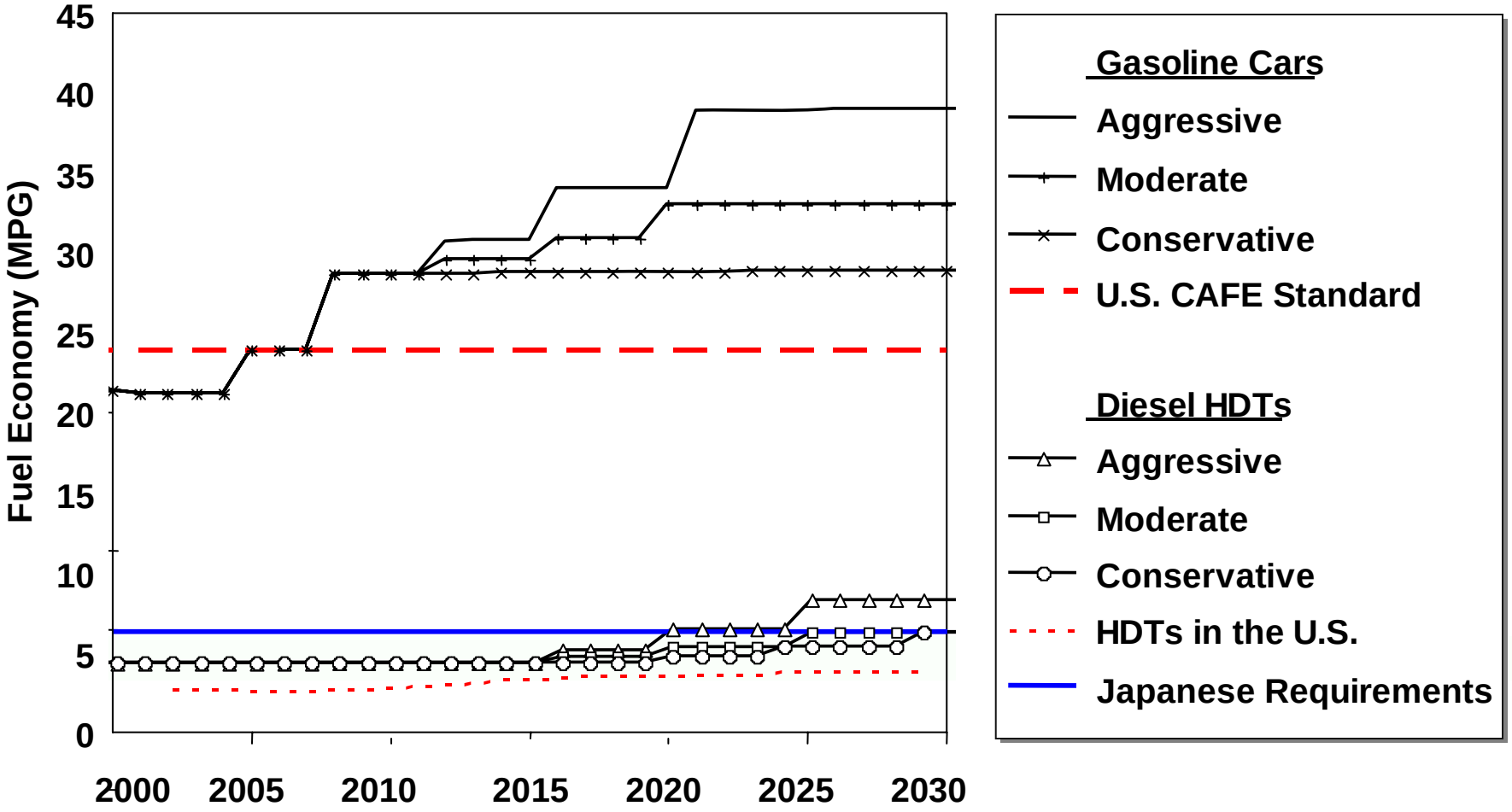
- **Unique characteristics of MCs and RVs in China**
  - Popular transportation modes due to much lower price
  - Are being or will be displaced by cars or trucks as income rises
  - Restrictions by central or local governments
  - But still have a huge potential for growth
- **MC and RV stocks are projected by considering**
  - Distribution of income levels among regions
  - Geographical characteristics determining MC usage
  - Other factors such as policies and restrictions





Source: China Statistics Yearbook, 2000-2005

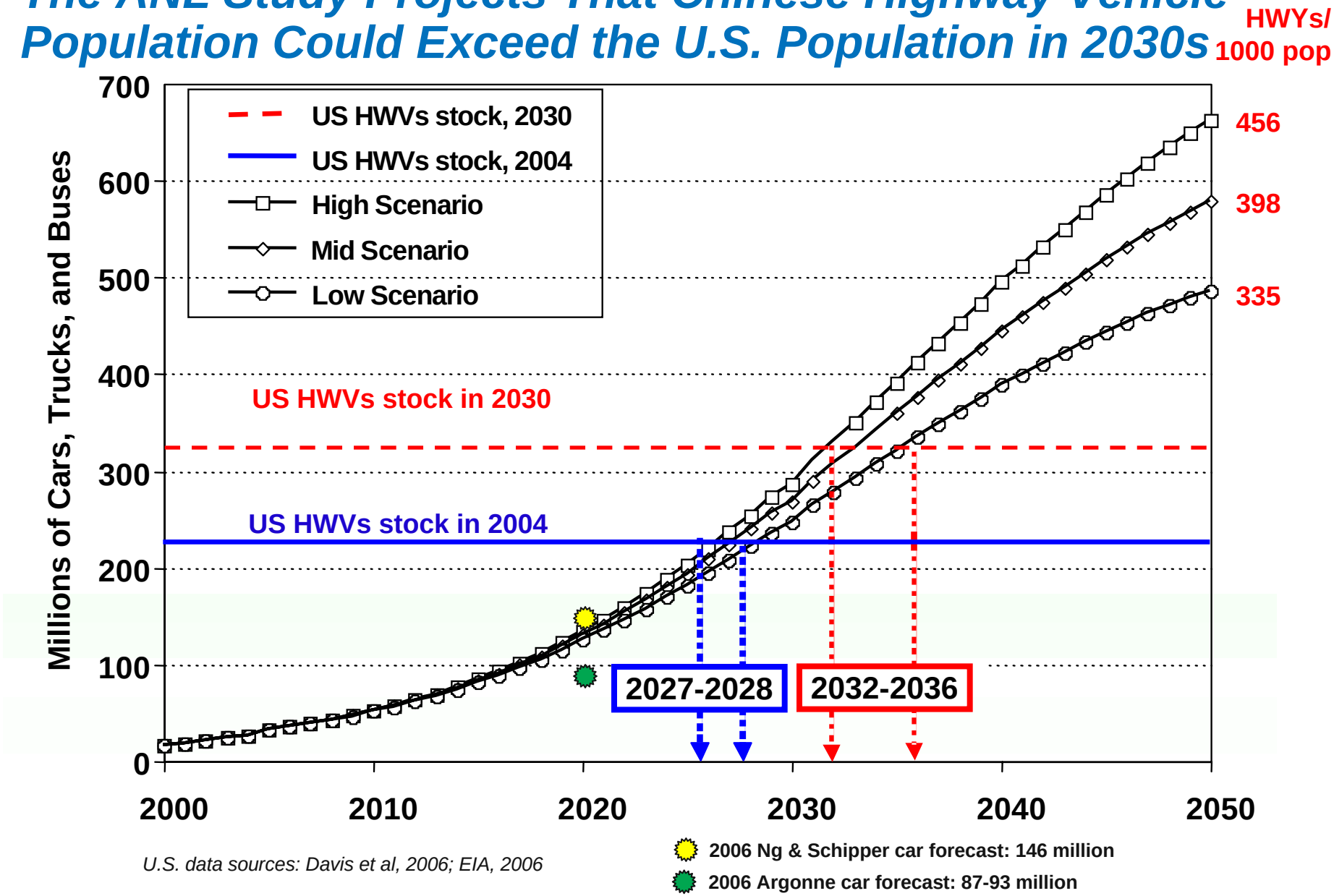
In the Three Vehicle Fuel Economy Scenarios, Chinese Vehicles Are More Efficient than the U.S.



Notes: (1) Data for cars are averaged values of the whole car fleet
(2) HDTs here have weight of >14 metric tons in China , 16–20 metric tons in Japan; >11.8 metric tons (26,000 lb) in the U.S.

Sources: Japan's Advisory Committee for Energy and Natural Resources, 2006; EIA, 2006

The ANL Study Projects That Chinese Highway Vehicle Population Could Exceed the U.S. Population in 2030s



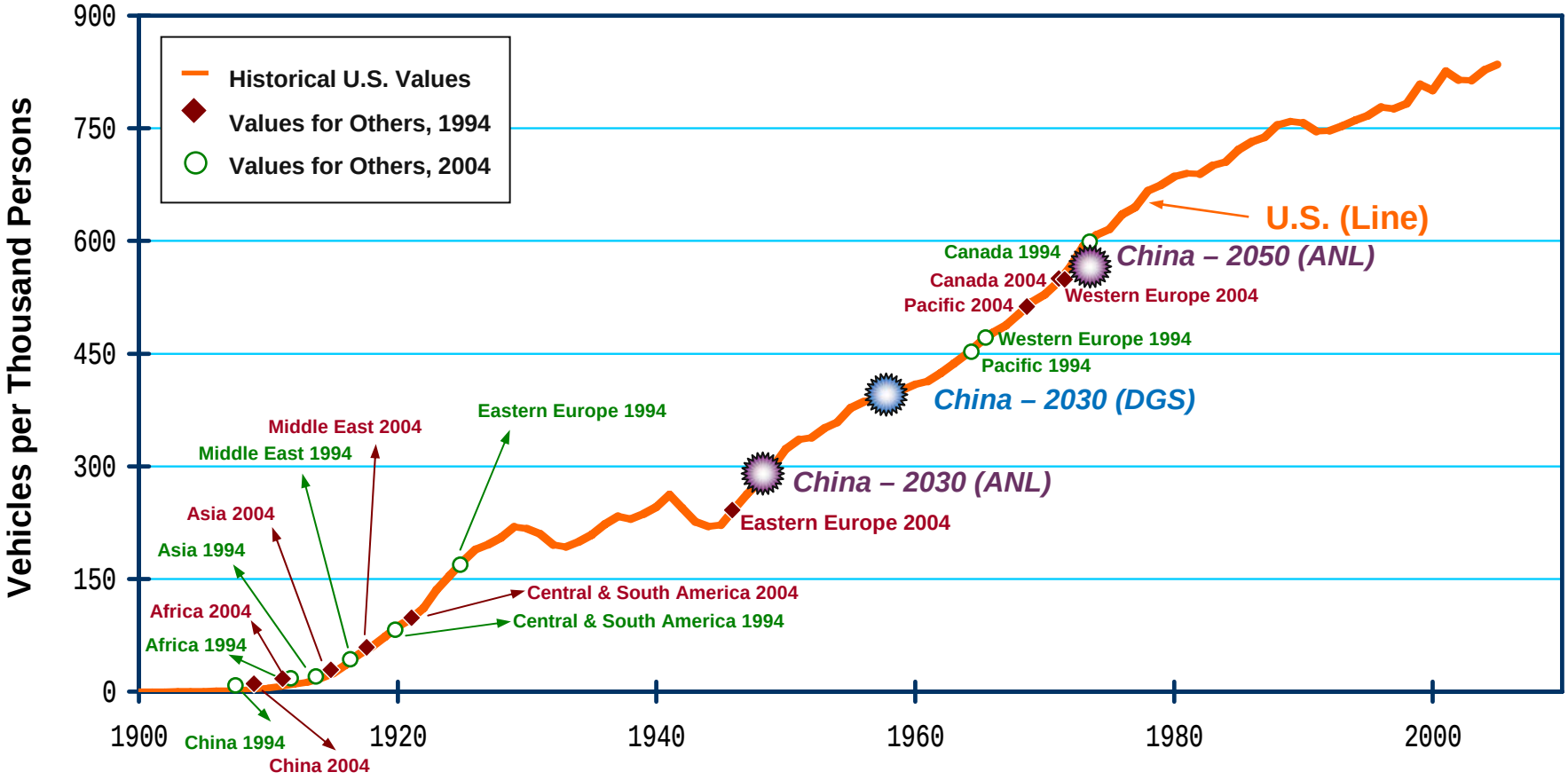
U.S. data sources: Davis et al, 2006; EIA, 2006

Comparison Between Argonne Projection and the Dargay, Gately, Sommer Projection (2006)

	DGS (2006)	Argonne		
		Low	Middle	High
Saturation level: vehicles/1k people	**807**	400	**500**	600
2030 projections				
Total motor vehicles: millions	**390**	247	**269**	287
Vehicles/1k people	269	174	189	202
2050 projections				
Total motor vehicles: millions	N/A	486	578	662
Vehicles/1k people	N/A	335	398	456

Note: Motor vehicles here exclude motorcycles and rural vehicles.

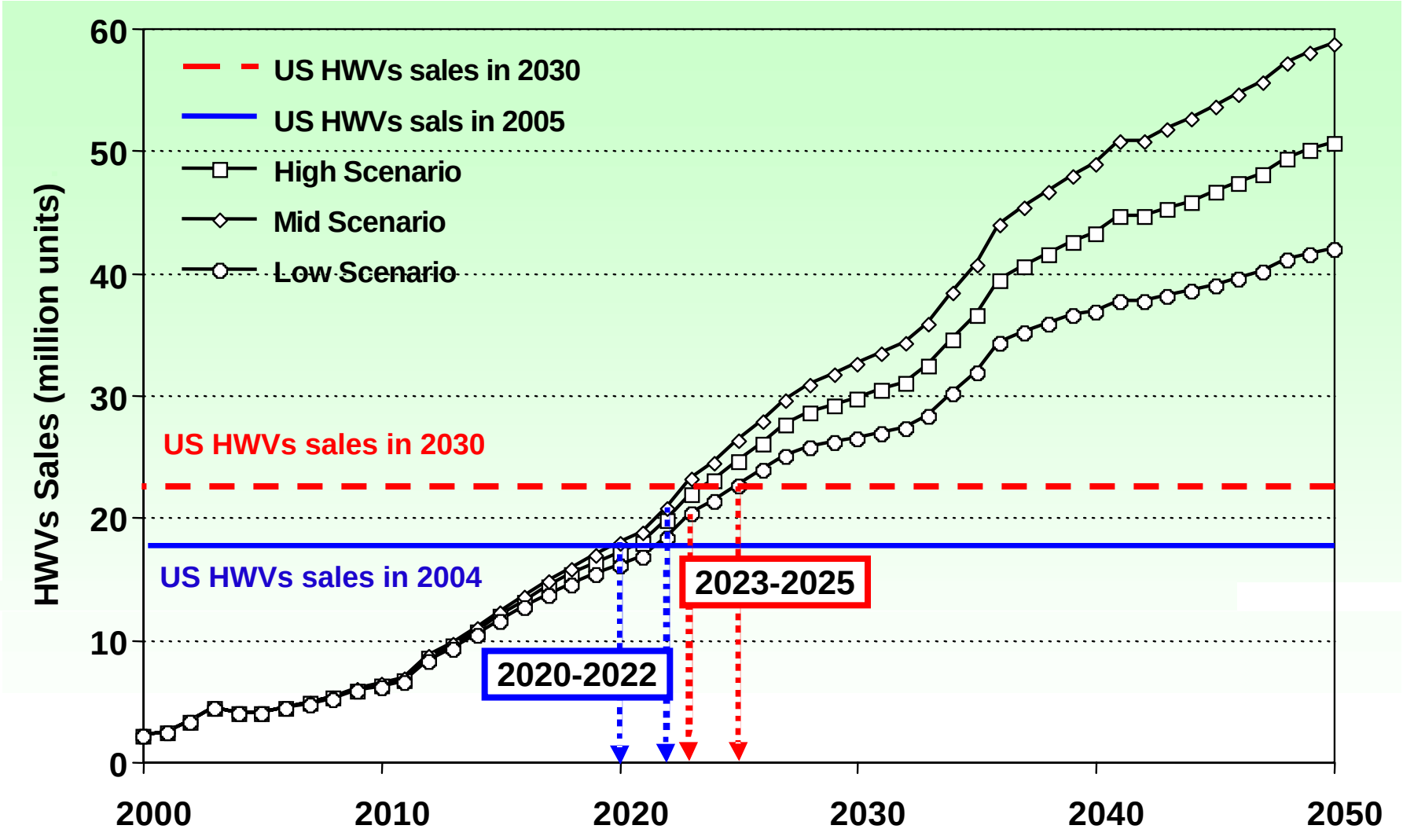
Where Would China Rank in 2030 and 2050?



In terms of vehicles per capita, China could easily be at the level developed Pacific-rim countries or even close to Western Europe

Source: Transportation Data Book, Vol. 25, ORNL, 2006

Annual Sales of Cars, Trucks, and Buses Show Tremendous Growth Over Time in China



Annual sales of Chinese highway vehicles were back-calculated from projected vehicle stocks in this study. U.S. data sources: Davis et al, 2006; EIA, 2006

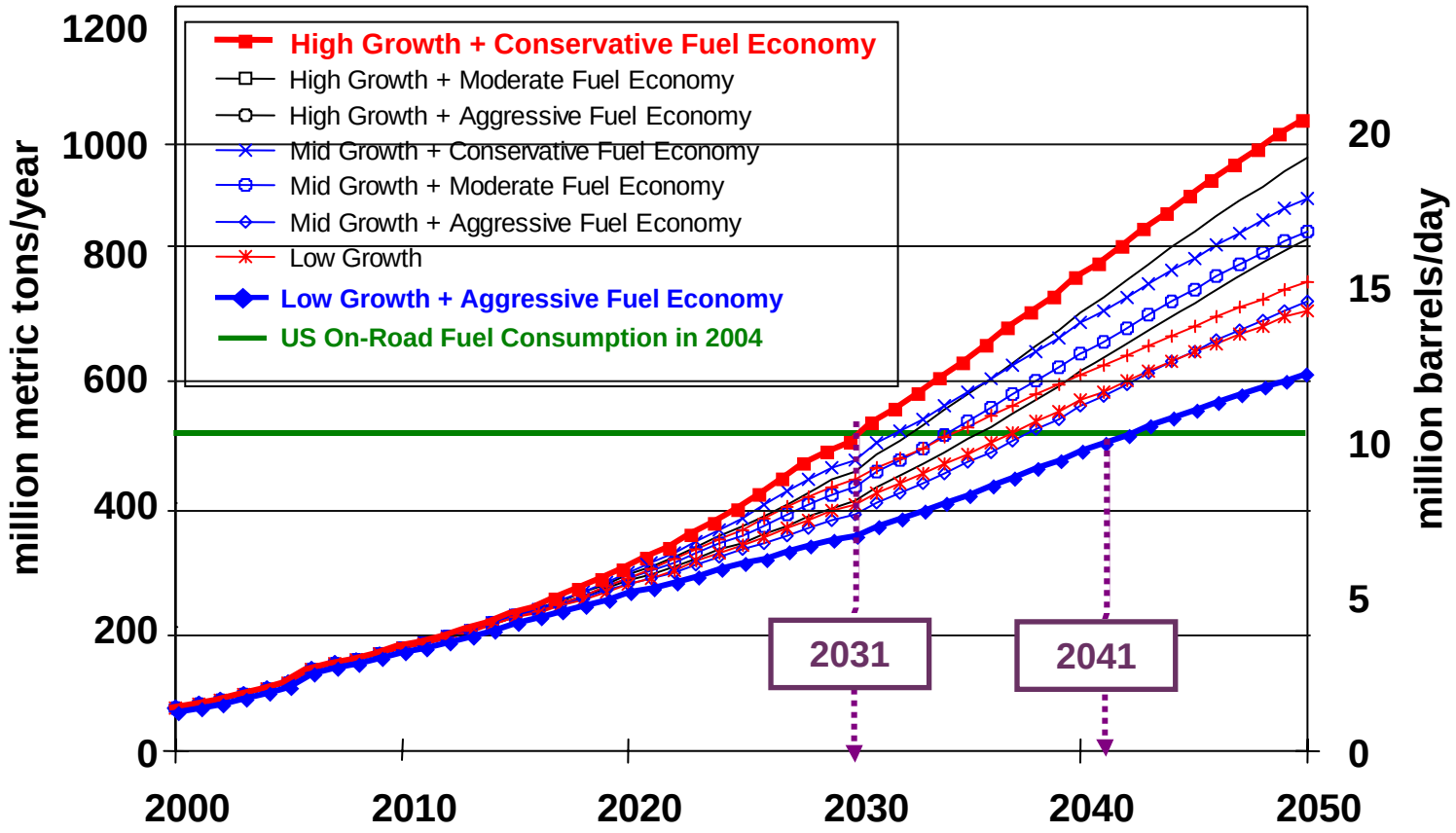
Vehicle Usage Intensity (i.e., Vehicle Miles Traveled) Affects Transportation Energy Projection

- **VMT Data Sources**
  - Near future: relying on available statistics, surveys, research, and government reports in China
  - Far future: following the trends in developed countries
- **Passenger Car VMT Trends**
  - 2000: 15k miles per year
  - 2030: 8.1k miles per year (the level in European countries in the 1970s)
  - 2050: 7.5k miles per year (the current level in European countries)
- **Truck and Bus VMT Trends**
  - These commercial vehicles tend to drive more distance
  - Used the trends in Japan and the U.S.
  - 2050: 34k miles for HDT, and 13k miles for LDT
- **MC VMT Trends**
  - Assumed a downtrend over time
- **RV VMT Trends**
  - Calculated by scrappage mileage and average scrappage age
  - Assumed a constant VMT over time for RVs

Vehicle Energy Intensity (i.e., Fuel Economy) Affects Transportation Energy Projection

- **Chinese government has made efforts to improve fuel economy**
  - *Passenger Vehicle Fuel Consumption Standards* were issued in 2004; the NAS conservative scenario was considered in these standards
  - The new standards help reduce fuel consumption rates by 15%
  - Standards for commercial vehicles and additional requirements for passenger vehicles are being considered
- **Fuel economy scenarios for this study**
  - Cars, light-duty buses, mini-buses, light-duty trucks, and mini-trucks:
    - *Fuel economy levels were based on the three fuel economy scenarios in the U.S. National Academy of Science study*
  - Heavy-duty trucks, medium-duty trucks, heavy-duty buses, and medium-duty buses:
    - *The Japanese HDV fuel consumption requirements were adapted*
  - Three scenarios were designed in this study
    - *Light-duty vehicles: assuming different paces of adopting NAS scenarios*
    - *Heavy-duty vehicles: assuming different paces of adopting Japanese HDV standards*

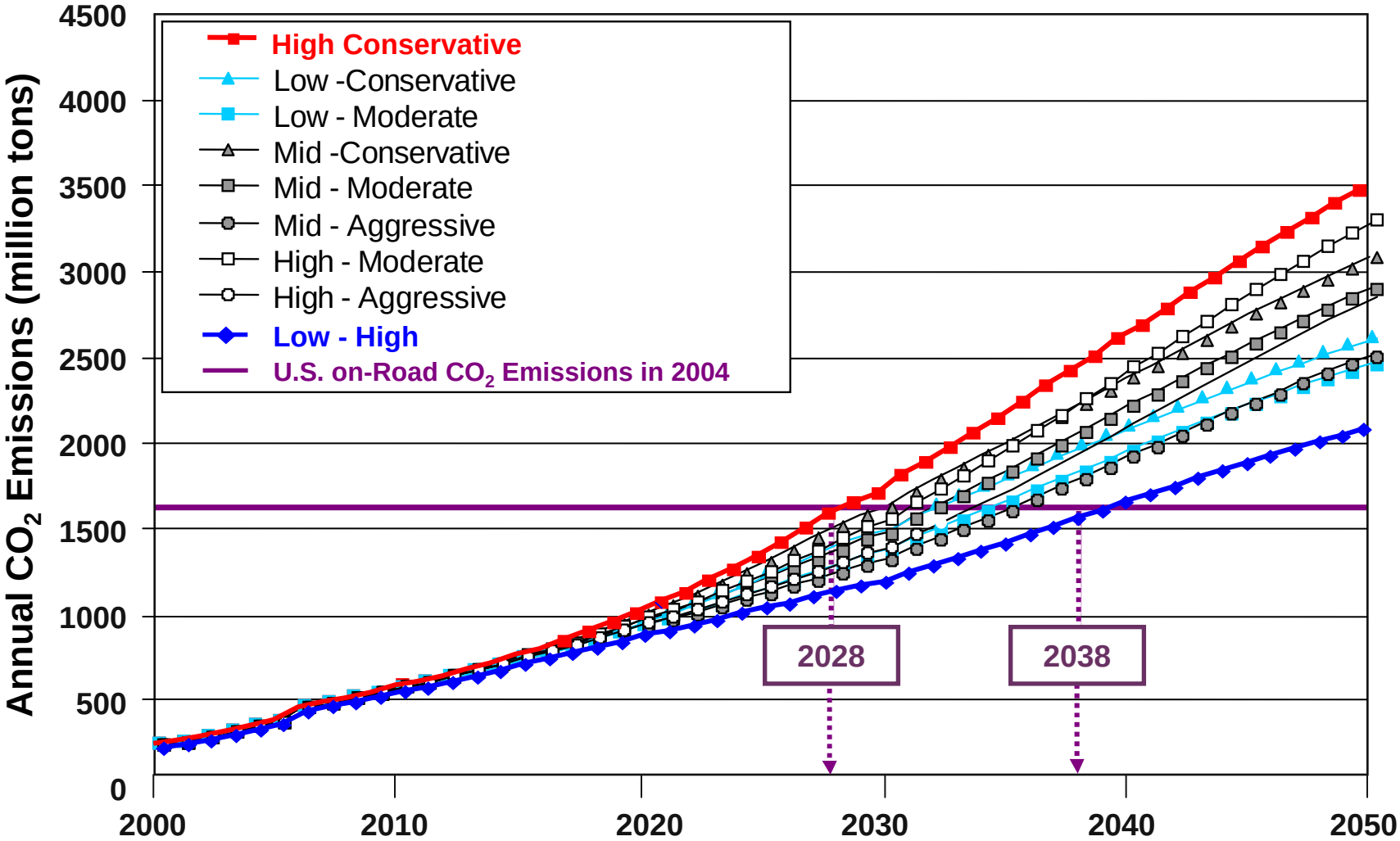
Oil Demand by Chinese Motor Vehicles Could Reach the Current U.S. Level by 2030-2040



The difference among the scenarios could be as high as 65%, indicating a great potential for reducing oil demand by both containing vehicle population growth and improving vehicle fuel economy

U.S. oil consumption data source: Davis et al, 2006

CO_2 Emissions from Chinese Motor Vehicles Could Equal the Current U.S. Level by 2030s



U.S. CO_2 emission data source: EPA, 2006

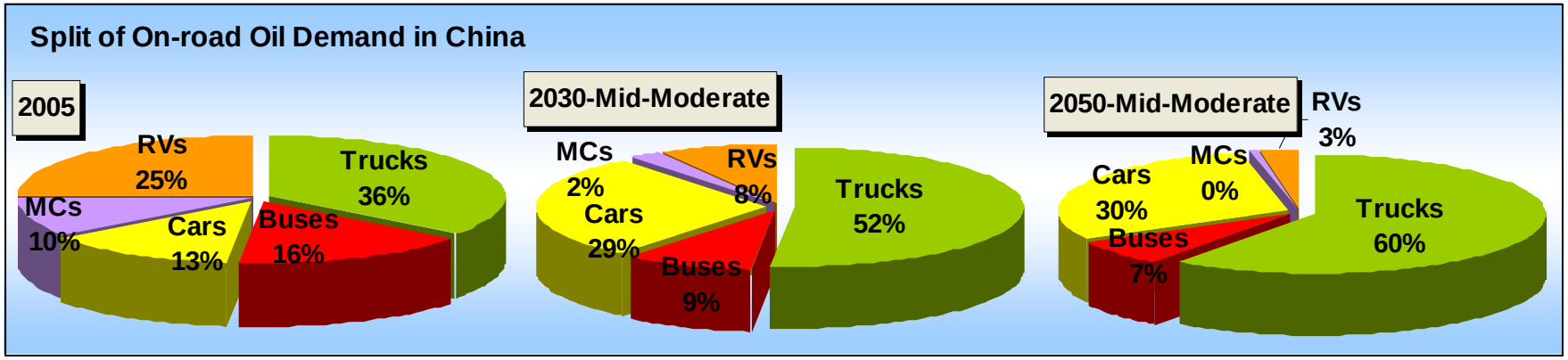
Conclusions and Discussion Issues

- Chinese highway vehicle stock could equal the current U.S. stock around 2027, and exceed the U.S. with the largest number of highway vehicles in the world by 2035
- Oil use and CO_2 emissions by Chinese on-road vehicles could reach the current U.S. oil demand between in the 2030s
- These conclusions are for a business-as-usual case of unconstrained vehicle growth and moderate fuel economy improvements
- The difference of 65% in oil demand by Chinese motor vehicles between the low and high scenarios indicates a great potential for reducing oil demand by
  - Containing both vehicle growth
  - Improving vehicle fuel economy
- Other opportunities such as introduction of advanced vehicle technologies and use of low-carbon fuels could offer additional reductions

Backup Slides

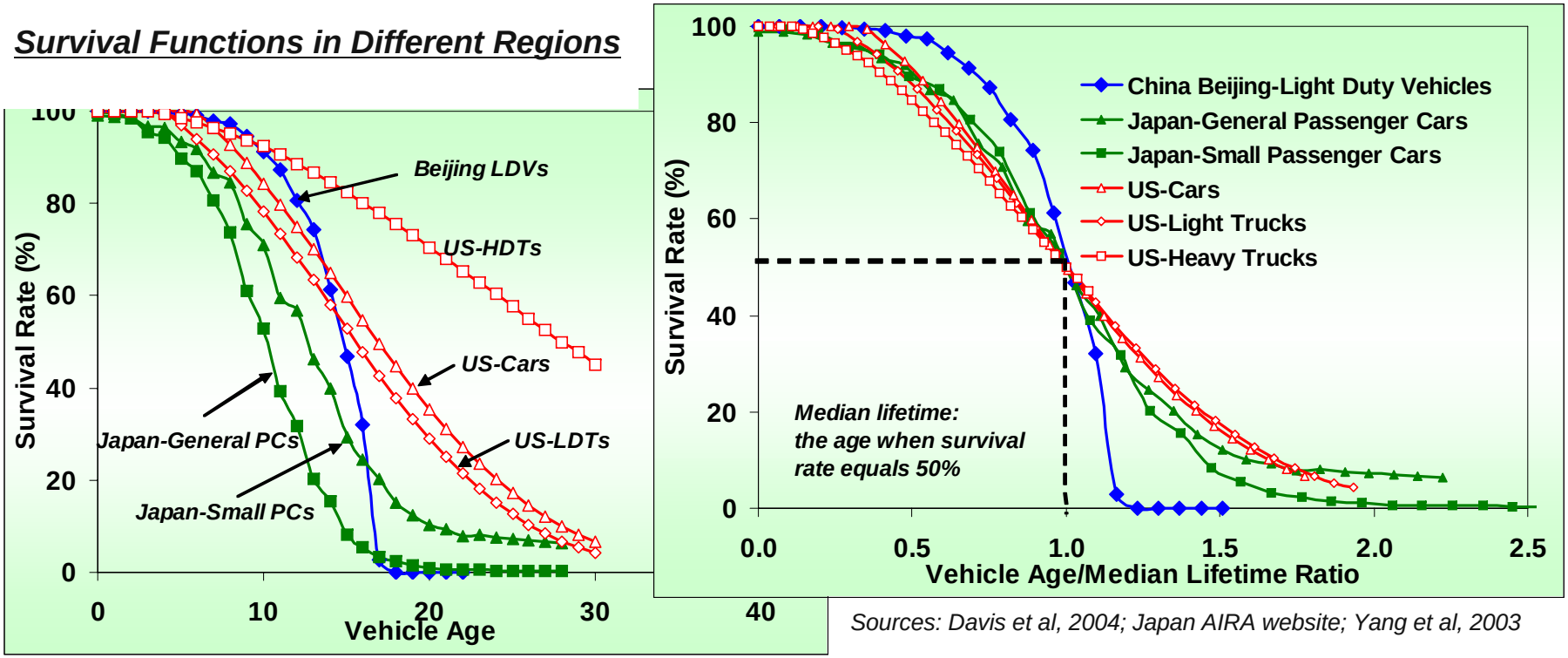
Trucks and Cars Will Dominate Motor Vehicle Oil Use in China

- Cars and trucks will become the largest oil consumers in the next 50 years
- Although the share of truck population will decrease to below 25% by around 2015, they will be the single largest oil consumer through 2050



At Present, Chinese Vehicles Retire Early; But They Could Gradually Increase Their Service Life

Survival Functions in Different Regions



Sources: Davis et al, 2004; Japan AIRA website; Yang et al, 2003

Scrappage rates of vehicles are significantly different from the US practice