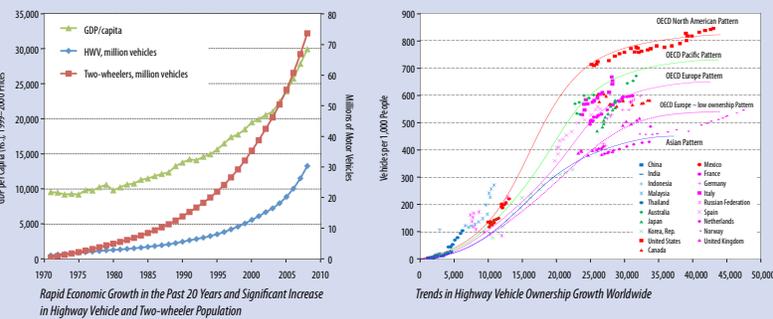


# Oil Demand and CO<sub>2</sub> Emissions in India by 2040 due to the Increase in Highway Vehicles: The Impact of Business-as-Usual Growth

## Overview

We have developed motor vehicle projections (highway vehicles and two-wheelers), related oil demand, and carbon dioxide (CO<sub>2</sub>) emissions for India until the year 2040 by analyzing:

- Historical vehicle stock and sales data for India
- Vehicle growth trends in developed and developing economies
- Trends in fuel mix of Indian vehicles
- Variation in vehicle use with increase in per capita GDP
- Policies of the Indian government on infrastructure development, growth in the number of personal vehicles, and regulation of the fuel economy of motor vehicles



### Highway vehicle (HWV) ownership saturation varies by the region

- OECD North America: 850 vehicles/1,000 people
- OECD Pacific: 750 vehicles/1,000 people
- OECD Europe: 550–650 vehicles/1,000 people

In the large developing Asian economies of India, China, and Indonesia, HWV ownership is expected to ultimately saturate at 450 vehicles/1,000 people, assuming (1) each household has a maximum of one car and (2) average household size is projected to be between 3 and 3.5 persons by 2040, compared to the 2001 Indian household size of 5.3 persons

Actual HWV ownership in India is hypothesized to not exceed 250 vehicles per 1000 people because of:

- Low urbanization rates in India (projected to be 40% urbanized by 2040)
- Low ownership for rural households

### Indian two-wheeler ownership will not reach saturation by 2040

- In 2004, there were 47 two-wheelers per 1,000 people in India.
- For the past five years (2005–2009), 7.1 million two-wheelers have been sold annually, on average.
- Two-wheeler ownership is expected to decrease for upper- and middle-income classes, but increase for the lower-middle income class.

## Highway Vehicle and Two-Wheeler Stock Projections

Projections developed by using Gompertz function:

$$V_i = \gamma \theta \alpha e^{\beta GDP_i} + (1 - \theta) V_{i-1}$$

Where:

$V_i$  = vehicle ownership in year  $i$  (vehicles per 1,000 people);

$\gamma$  = saturation level of vehicle ownership (vehicles per 1,000 people);

$GDP_i$  = GDP per capita in year  $i$ ;

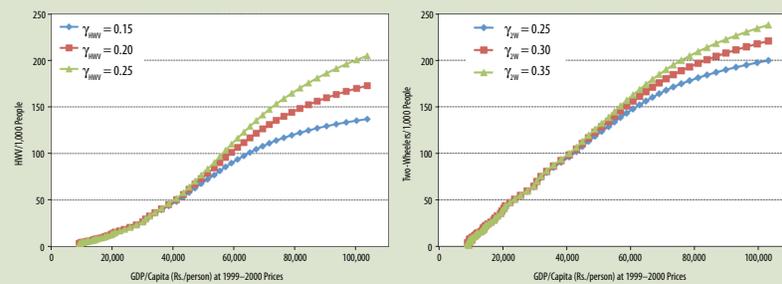
$\alpha$  and  $\beta$  = parameters that define the S-shape curve of vehicle ownership growth over economic growth;

$\theta$  = speed of adjustment for vehicle ownership, with respect to GDP growth ( $0 < \theta < 1$ ).

Vehicle ownership projected through 2040 is based on the following growth scenarios:

$$\gamma_{HWV} = 150, 200, 250 \text{ highway vehicles (HWVs) per 1,000 people;}$$

$$\gamma_{2W} = 250, 300, 350 \text{ two-wheelers (2Ws) per 1,000 people;}$$



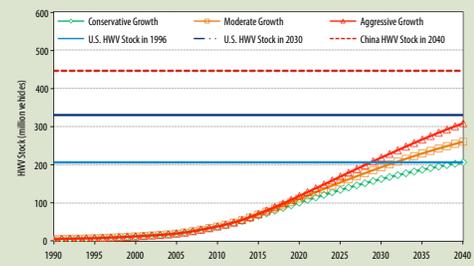
### Indian Vehicle Stock Projections

- India will have third largest HWV stock in the world by 2040, after China and the United States.

By 2040:

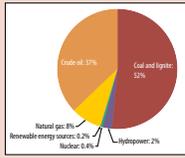
- The Indian car population will exceed the 2007 U.S. car population of 136 million and will be between 144 and 215 million.
- The commercial vehicle population will be between 38 and 57 million, with a majority of vehicles in the LCV segment (20–30 million).

- The Indian two-wheeler population will exceed China's two-wheeler population between 2010 and 2020, and it will have the largest two-wheeler stock in the world (between 301 and 359 million by 2040).

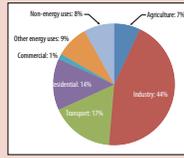


# Indian Transportation Energy Mix

India has abundant coal reserves and ranks third worldwide in coal production and consumption. India is also the sixth largest importer of oil. In 2008, 78% of crude oil consumed was imported. The transportation sector is the major consumer of oil; natural gas consumption by the transport sector is increasing.



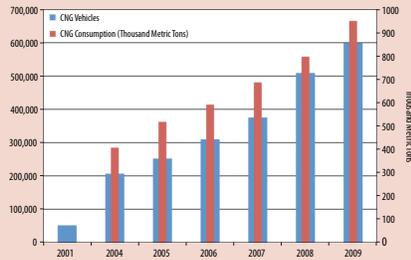
India – Primary Energy Consumption, by Type (2006)



India – Primary Energy Consumption, by Sector (2006)

## Increased Use of CNG- and LPG-Fueled-Vehicles in India

- CNG and LPG fuels were introduced in the early 2000s to reduce air pollution from on-road transport in urban areas. As of 2005, India had approximately 0.25 million LPG-fueled vehicles.
- Delhi has the largest CNG fueled bus fleet in the world, and India has significant natural gas reserves of 1.06 trillion cubic meters.
- By 2040, we project that 15–20% of commercial vehicles (trucks, buses, three-wheelers) and 10% of cars will be fueled by CNG.

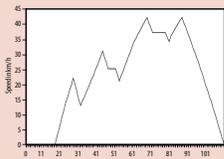


## Fuel Economy of Indian Vehicles

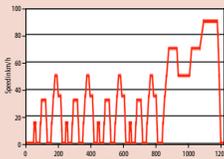
- The Indian light-duty passenger vehicle fleet consists of smaller cars (majority Mini and Compact segments). The market share of the Mini segment (e.g., TATA Nano) is projected to increase significantly.
- Currently, there are no government regulations mandating improvements in fuel economy for the Indian vehicle fleet.

### Drive cycle

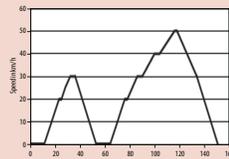
- The current driving cycles are too simplistic, especially for two-wheelers, three-wheelers, and heavy commercial vehicles, and so new driving cycles are required to account for real-world driving conditions.



Indian Driving Cycle (IDC): Used for Reporting Fuel Economy of Two- and Three-Wheelers



Modified Indian Driving Cycle (MIDC, based on EU-NEDC): Fuel economy of Light-Duty Vehicles (Cars, Utility Vehicles, Light Commercial Vehicles)



Overall Bus Driving Cycle (MIDC): Fuel Economy of Heavy Commercial Vehicles (Buses and Trucks)

## Indian Biofuels Consumption

### Ethanol

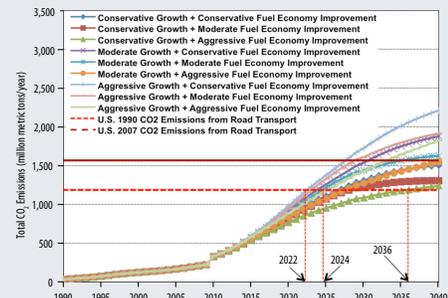
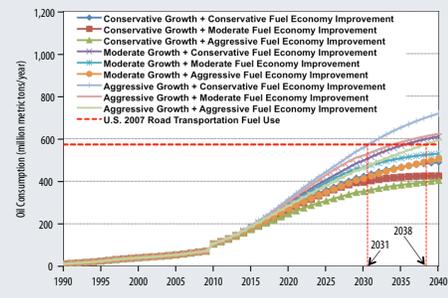
- The Indian government mandated 5% ethanol-gasoline blend since 2005, but current ethanol blend levels are still below the mandated 5% level. Ethanol in India is produced from molasses, a by-product of sugar production from sugarcane.
- India expects to introduce 10% ethanol-gasoline blends during the 11th five-year plan (2007–2012).

### Biodiesel

- India plans to produce biodiesel from non-edible oil seeds, like Jatropha, but it lacks sufficient land to produce biodiesel from Jatropha at large volumes required for commercial blending.
- India expects to introduce 5% biodiesel blended diesel by the end of 11th five-year plan.

# Annual Oil Demand and CO<sub>2</sub> Emission Projections for Indian Vehicles

- Increased Dieselization:** The demand for diesel is expected to grow faster than the demand for gasoline because of price incentives for diesel and better fuel efficiency for diesel-fueled vehicles.
- Commercial Vehicles:** At present, commercial vehicles (light- and heavy-duty trucks) consume 52% of total fuel consumed by the road transport sector. By 2040, commercial vehicles will account for 64–69% of total oil demand.
- Personal Vehicles:** The share of oil demand by personal vehicles (cars, utility vehicles, two-wheelers) will drop from the 2008 level of 27% to 21–22% by 2040.
- CO<sub>2</sub> Emissions:** Annual CO<sub>2</sub> emissions from Indian motor vehicles will exceed 1990 U.S. motor vehicle CO<sub>2</sub> emissions between 2020 and 2030s.



## Concluding Remarks

- The Indian road transport sector will grow rapidly in next 30 years, with significant impact on:
  - Crude oil imports
  - Air pollution in urban areas
- Related oil demand and CO<sub>2</sub> emissions will depend on:
  - Government policies to regulate fuel economy, especially for commercial vehicles, which will account for 64–69% of total fuel consumption
  - Investments in public transport infrastructure
  - Switch to gaseous fuels and increased use of biofuels
- Market penetration of alternative vehicle technologies (HEVs, EVs) will be limited:
  - Expensive compared to conventional vehicles
  - Significant electric supply deficits, power supplies fall short of peak demand by 17%
- Uncertainties in oil demand and CO<sub>2</sub> emission projections can be reduced by:
  - Obtaining accurate data regarding survival/scrappage rate, annual utilization, and fuel economy of Indian vehicles
  - Exploring the impact of road congestion and government policies on future vehicle growth