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Motorized Passenger Travel in Urban India

Emissions & Co-Benefits Analysis

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(UEinfo) was founded in 2007 with the vision to be a repository of information, research, and analysis related to air pollution. There is a need to scale-up research applications to the secondary and the tertiary cities which are following in the footsteps of the expanding mega-cities. Advances in information technology, open-data resources, and networking, offers a tremendous opportunity to establish such tools, to help city managers, regulators, academia, and citizen groups to develop a coordinated approach for integrated air quality management for a city.

UEinfo has four objectives: (1) sharing knowledge on air pollution (2) science-based air quality analysis (3) advocacy and awareness raising on air quality management and (4) building partnerships among local, national, and international airheads.

This report was conceptualized, drafted, and designed by the members of UEinfo.

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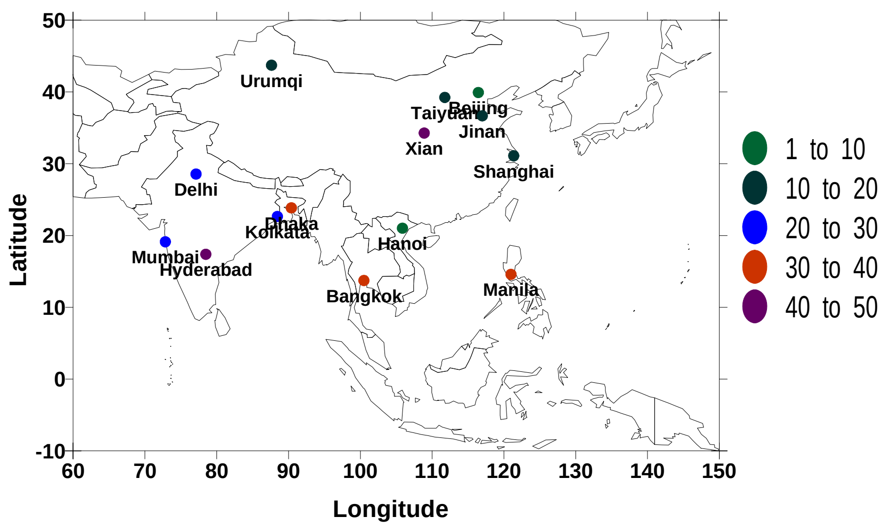
Motorized Passenger Travel in Urban India: Emissions & Co-Benefits Analysis

Among the many air pollution sources, the transport sector, the fastest growing contributor, is one of the main culprits (if not the primary) causing air pollution in the urban centers of the developed and developing countries. **Figure 1** presents a summary of the estimated share of transport sector to the local air pollution, based on a series of source apportionment studies in Asia. The numbers represent the direct vehicular emissions and do not include the fugitive dust from paved and unpaved roads due to the vehicular activity, which is a major part of the measured PM pollution, especially in the developing countries.

Figure 1: The share of transport emissions contributing to the measured ambient air quality in Asia[1]



The cities represented in **Figure 1** are centers of economic and industrial growth in their respective countries. In Asia, besides the economic hubs, the secondary cities, with population more than 2 million are increasing[2], the demand for personal transport is growing in all the cities, and these cities are increasingly facing the air pollution problems, especially from the transport sector. It is important to note that the results presented are based on monitoring data (operated at limited capacity), and in reality, the exposure levels (and times) of transport related pollution is expected to be much higher[3], especially when combined with the road resuspension dust.

In the transport sector, especially for the PM pollution, the diesel combustion dominates – in number and quantity, primarily from the buses and the goods vehicles. Among the

[1] SIM working paper series "SIM-10-2008: What is PM" and "SIM-16-2009: Urban Particulate Pollution Source Apportionment" and references within, @ http://urbanemissions.info/simair/simseries.html
[2] Demographia, 2008 @ http://www.demographia.com/
[3] Science Daily, may 28th, 2009, "Reducing Gasoline Emissions Will Benefit Human Health" @ http://www.sciencedaily.com/releases/2009/05/090528135250.htm

personal transport, the gasoline is the traditional fuel, but due to subsidy programs for diesel and the emerging engine technologies, the diesel component is increasing[4].

Scope of this Paper

This paper presents the emissions analysis of the motorized "**in-city**" passenger travel from twenty cities in India, covering the current trends in four modes of transport (passenger cars, motorcycles, 3 wheelers, and buses), estimated energy consumption for the assumed growth patterns, and possible co-benefits of three combined scenarios (public transport, policy reforms, and non-motorized transport)[5].

Passenger Travel in India

Burgeoning urbanization in India is leading the travel demand in not only the megacities (with population more than 10 million), but also in the growing number of secondary and tertiary cities (with population more than 1-2 million)[6].

The growing industrial conglomerations and information technology (IT) parks, under the Special Economic Zone (SEZ) schemes[7] have led the way. For example, in the Cochin city, the SEZ covers an estimated 103 acres of land and ~79 factories manufacturing ready-made garments, rubber gloves, electronic items, software, hardware, food items and jewellery. This combined with the increasing geographic size of the cities are changing the travel patterns across the country. For example, once the satellite cities to Delhi, the NOIDA and Gurgaon have since become part of the Delhi administration, forming the National Capital Region (**Figure 2**, **top right**). On a daily basis, the travel into and out of Delhi to these cities account for nearly 30-40 percent of the passenger trips[8]. Similarly, a large number of IT parks were sanctioned in the cities of Hyderabad, Bangalore, Pune, Bhopal, and others, resulting in increase of the urban development zones and local administrative responsibilities for infrastructure.

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[4] Global Subsidies Initiative @ http://www.globalsubsidies.org

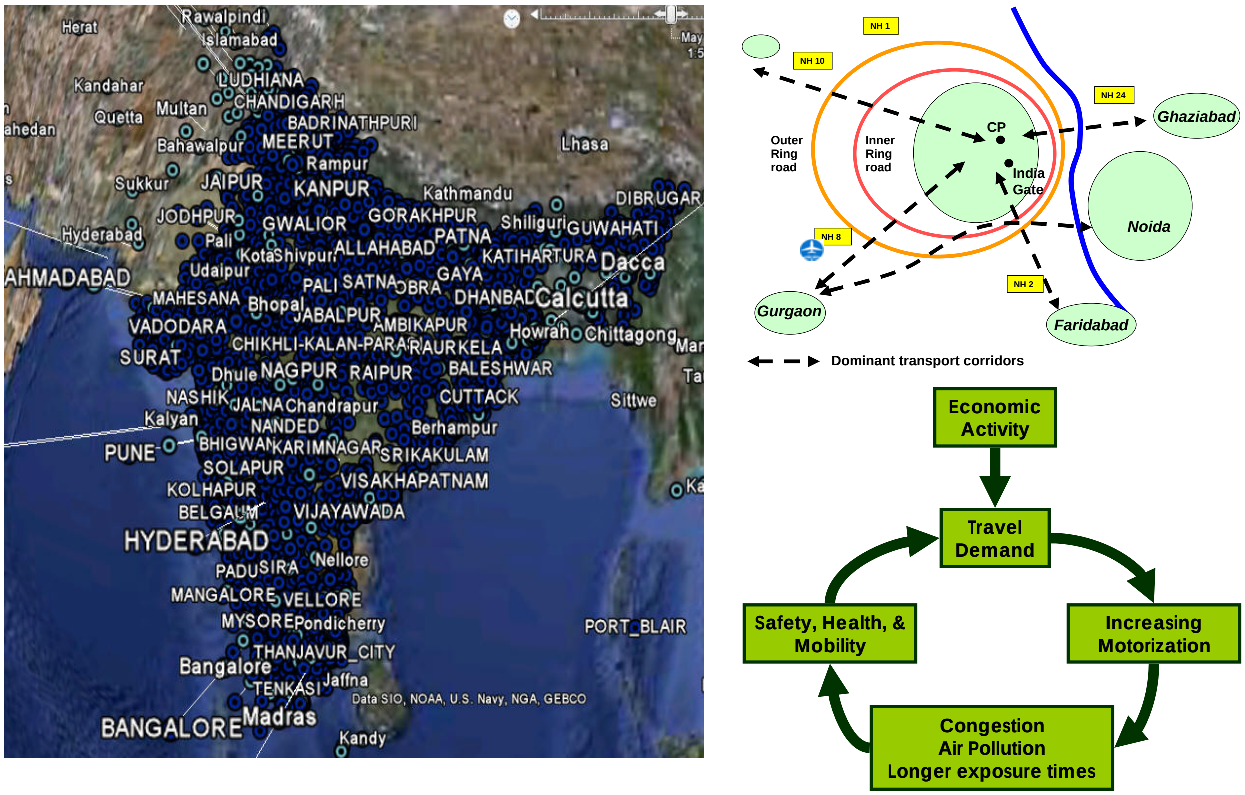
[5] An analysis of the "Emissions from India's Intercity and Intracity Road Transport" is presented by the Clean Air Initiative for Asian Cities (CAI-Asia). A draft report from May, 2009, is available @ http://www.cleanairnet.org/caiasia/1412/article-73353.html
A study of basic transport and air quality indicators was carried out by WRI/EMBARQ in 2009 @ http://www.embarq.org/en/book/export/html/427
ADB, 2006, "Energy Efficiency and Climate Change considerations for on-road transport in Asia" @ http://www.cleanairnet.org/caiasia/1412/articles-70656_finalreport.pdf
PEW Climate, May, 2001, "Transportation in Developing Countries: Greenhouse Gas Scenarios for Delhi, India" @ http://www.pewclimate.org/global-warming-in-depth/all_reports/transportation_in_india/
Badami, 2005, "Transport and urban air pollution in India" Environment Management @ http://www.ncbi.nlm.nih.gov/pubmed/15995891

[6] Wall Street Journal, May 13th, 2009, "Megacities threaten to choke to India" @ http://online.wsj.com/article/SB124216531392512435.html
SEMINAR Magazine, New Delhi, India, November, 2007, "Transport and Livable Cities" @ http://www.india-seminar.com/2007/579.htm
Institute of Urban Transport (IUT) India @ http://www.iutindia.org/aboutus.html
SIM-10-2008, "The Nano Car-nomics in India" @ http://urbanemissions.info/simair/simseries.html

[7] India Together, 2005 @ http://www.indiatogether.org/2005/aug/eco-sezone.htm

[8] Central Road Research Institute, Delhi, India @ http://www.crridom.gov.in

Figure 2: Growing number of mega, secondary, and tertiary cities in India[9]; Travel demand from the satellite cities in Delhi, India



The change in the geographical settings of the cities, the travel behavior and the mode of transport (transformed to motorized transport) is not only increasing the vehicle kilometers traveled per day, but also exerting pressure on the limited infrastructure, leading to traffic congestion, idling, and pollution. The rapid growth in the number of vehicles, increased fuel combustion, poor traffic management, and lack of sufficient public transport has led to deteriorating air quality, increased trip costs and substantially extended the commuting times[10] resulting in longer exposure times to increasing pollution and health impacts (**Figure 2**, **bottom right**). For example, the big cities are registering ~600 to ~1000 vehicles per day, mostly dominated by the 2 wheelers and passenger cars[11].

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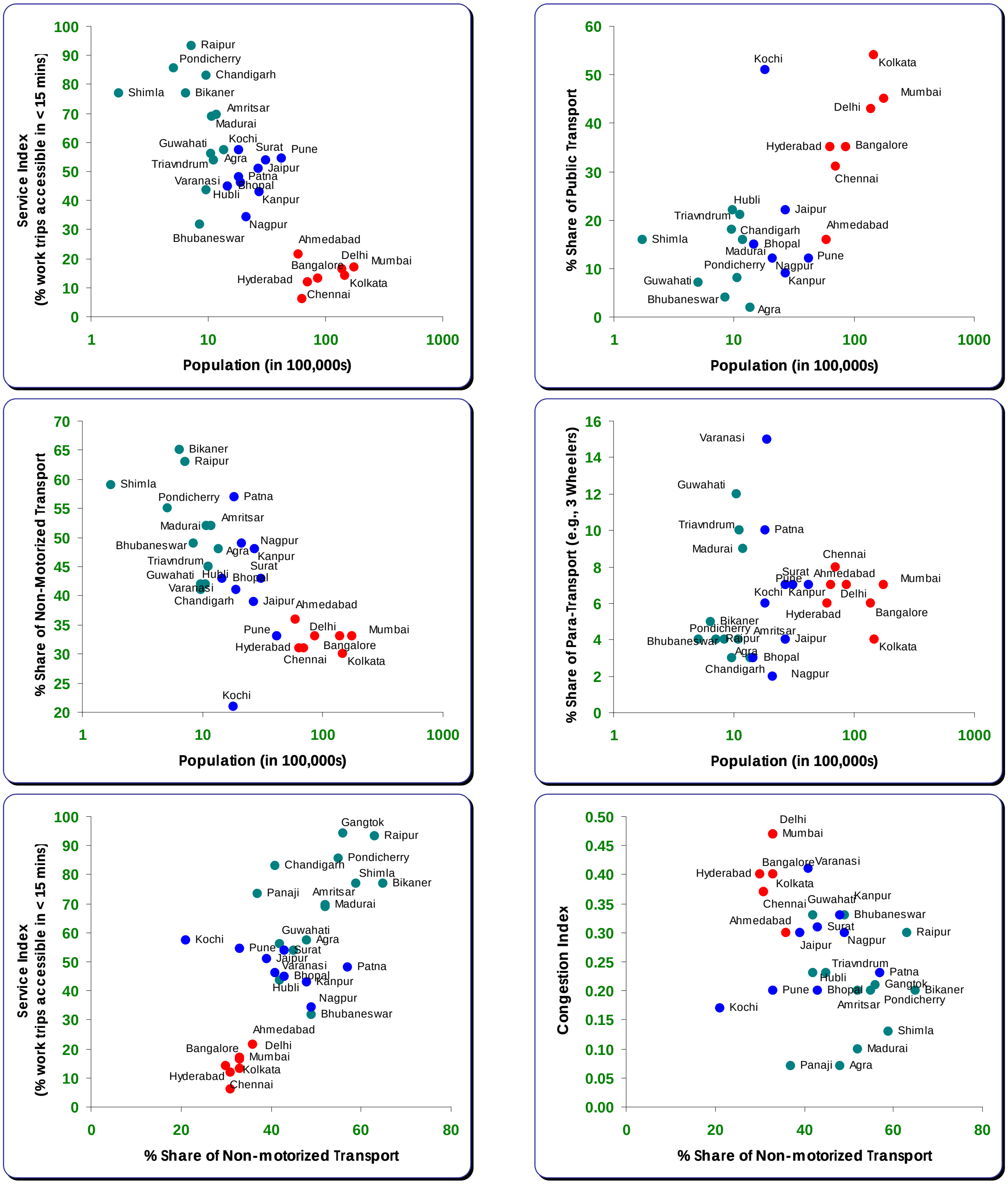
[9] Population map overlaid on Google Earth platform @ http://earth.google.com/

[10] See the SIM-18-2009, "Indicative Impacts of Vehicular Idling on Air Emissions" @ http://urbanemissions.info/simair/simseries.html

[11] Presentation by Ms. Anumita Roychoudary for IES India Program, December, 2007 @ http://www.epa.gov/ies/india/apportionment_documents.htm

Figure 3: Travel statistics in India[12]



Color code: red = mega cities; blue = secondary cities; light blue (ash) = tertiary cities

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[12] Data is sources from the report "Traffic and Transportation Policies and Strategies in Urban Areas in India" by Ministry of Urban Development, Government of India, May, 2008 @ http://urbanindia.nic.in/moud/theministry/ministryofurbandevelopment/main.htm

The big cities of India have at least doubled their administrative boundaries in the last decade. This, combined with increasing incomes, has been the impetus for transport demand to increase exponentially. **Figure 3**, **top left panel**, presents the relationship between the city population (on log scale) and city travel service index (defined as the percentage of work trips accessible in less than 15 minutes of travel time). The megacities (red dots) fair poorly compared to the medium size cities (blue dots) and then the tertiary cities (ash colored dots). As the cities are expanding geographically, the need for motorized (self or public) transport is becoming imminent.

Important messages in **Figure 3**:

- As the cities grew, access to the work places in less than 15 mins travel time decreases
- As the cities grew, the share of public transport in the form of buses (percent of passenger trips) increases
- As the cities grew, the share of non-motorized transport (NMT) in the form of walking and biking (percent of passenger trips) decreases
- As the cities grew, the share of para-transit remained constant
- Lower the share of non-motorized transport in the city, lower the service index (% trips accessible in less than 15 mins travel time)
- Lower the share of NMT in the city, higher the congestion index, primarily due increase in the personal transport

The access to public transport is growing, but not enough to support the travel demand growth in the big cities. **Figure 3**, **top right panel**, presents the share of passenger trips covered by the public transport against the population in the cities. The access to the public transport is high in the megacities, and expected to grow under the JNNURM funds[13]. However, the lack of infrastructure in the bus manufacturing sector to supply the necessary (currently standing at ~70,000 buses) is hindering the public transport promotion[14].

In India, the growth rate for the motor vehicles (passenger cars and 2 wheeler motorcycles) is approximately 10 to 12 percent[15]. While the personal transport is growing, it is important to focus on the NMT, the walking and cycling together, which forms a major portion of the passenger trips, especially the short trips less than 1-3 km. The **Figure 3**, **middle left panel**, presents a correlation between the percent of NMT trips to the population in the cities. The statistics clearly indicate that the access to the pedestrian walking and cycling has reduced drastically, and leading up to maximizing the space for motorized transport.

[13] Jawaharlal Nehru National Urban Renewal Mission (JNNURM) @ http://jnnurm.nic.in/

[14] Down to Earth, October, 2008, “City bus: In demand, out of supply” @ http://www.downtoearth.org.in/cover.asp?foldername=20081031&filename=news&sid=45&page=1&sec_id=9&p=1
Times of India, February 8th, 2009, “BRTS dreams may go bust” @ http://timesofindia.indiatimes.com/articleshow/msid-4096144,prtpage-1.cms
The Hindu, May 13th, 2009, “Delhi Govt. faces cancellation of bus funding under JNNURM” @ http://www.hindu.com/thehindu/holnus/004200905131452.htm

[15] Times of India, May 12th, 2009, “On growth track: Auto sales zoom 11% in April, 2009”, report from SIAM – Society of Indian Automobile Manufacturer @ http://timesofindia.indiatimes.com/Car-sales-up-420-bikes-jump-1211-in-April/articleshow/4508229.cms

The **Figure 3**, **bottom left panel**, presents the correlation between city travel service index the percent share of NMT. The correlation is very strong indicating a negative effect of the urban growth on the accessibility. As the cities grow the percent of the short trips, which are dominated by the NMT mode are reduced and replaced by the motorized transport. Also, the change in the geography of the cities, presented as an example in **Figure 2**, is altering the modal shares to lesser accessibility index.

The correlation between the congestion index and the percent share of NMT trips is presented in **Figure 3**, **bottom right panel**, which clearly indicates the need for prioritizing the NMT mode for reductions in the congestion problems.

It's all about choice

By Gordon Price, Director of the City Program, Simon Fraser University, Canada
http://www.pricetags.ca/

It has taken a century of building almost exclusively for the car to get us to our current dilemma. It will take some considerable time to achieve long-term solutions. Ultimately, they can only be found in the way we build our cities. We will have to establish virtuous cycles to offset the vicious ones, where success leads to more success.

There is no single solution. Top-down planning can never be comprehensive enough or flexible enough. Give people enough transportation options and they can by and large work out their own solutions. That in turn is dependent on the design and integration of land-use and transportation choices.

Ideally, people should have at least five choices - feet, bike, transit, taxi/car sharing and personal vehicle - and the ability to mix and match them appropriate to the kind of trip and the circumstances faced. The combinations and the mix make it all work.

The trip is only a few blocks? Walking is best. It's raining? Grab a taxi. The trip is around five kilometers? Cycling may be the faster alternative. Going to a town centre in the suburbs? Try transit.

Heading out of town? Train, perhaps - or car. Yes, the car is perfectly appropriate for many trips, but not all. Once the car is used less frequently, needs may be met more affordability by a car sharing or the occasional rental, with considerable savings.

Of course, the provision of alternatives assumes a city designed around more than the car - and a citizenry comfortable with the choices. In the end, the answers are found in the plans we have to implement. Concentrate growth. Build complete communities. Provide transportation choice.

But to do so, we will first have to be aware of the impediments to success, rooted in the unrealistic beliefs and assumptions we have associated with the success of the car.

The role of para-transit mode *aka* 3 Wheelers and taxi services, cannot be ignored. The **Figure 3**, **middle right panel**, indicates that the share of taxi services is fairly constant in all the cities.

The air quality, which is closely linked to the transport sector, is deteriorating in the cities, as the share of motorized transport is increasing. This is primarily due to the direct vehicular exhaust while driving, and during the idling and congestion periods. A secondary source of pollution, linked to the transport sector is the road dust, which contributes significantly to the ground level air pollution in most of these cities. The contribution of the road dust is enhanced during the resuspension of the dust due to constant vehicular movement and not allowing the dust to settle (which also depends on the local meteorological conditions).

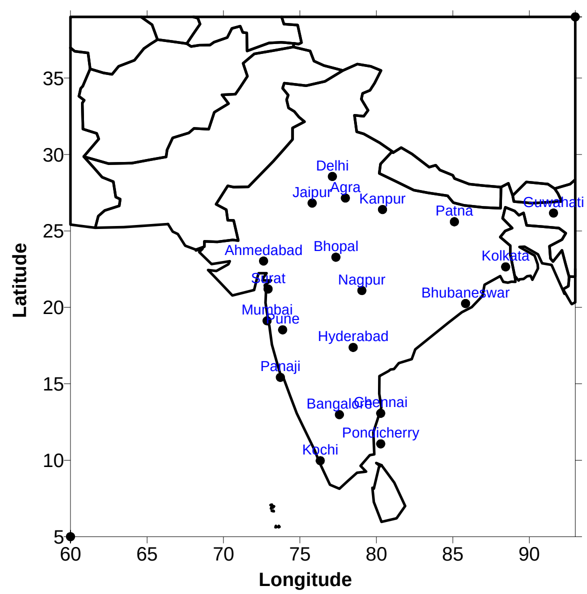
Urban Transport Emissions Analysis

The emissions from the transport sector play a vital role in the air quality management in the growing cities. Traditionally, the industries are considered the gross polluters, given the energy intensity and outdated pollution control equipment, but the emissions from the transport sector are increasingly considered the largest contributor to the air pollution related health impacts. One of the main reasons is the increasing amount of time spent outdoors and the related exposure times, which enhance the health impacts of the air pollution.

Why the Transport Emissions Analysis

While the mobility and the need for access to the private or public transportation has taken precedence, the growing air pollution levels and the interlinkages to health cannot be ignored[16]. Even if most people thought they would be better off with more roads instead of the better facilities for public transport or pedestrian walkways, it would still lack strong advocates, primarily because of the lack of information to support the otherwise. Before an intervention to become a policy, possible big gains need to be demonstrated and analyzed for various indicators. Specifically, the benefits of the policy must exceed both the costs of the policy and the costs of mobilizing and campaigning to adopt the policy. All this requires information. The goal of this paper is to estimate the trends in twenty cities (**Figure 4**) for emissions from passenger travel and analyze possible interventions for benefits. The twenty cities range from megacities (e.g. Delhi and Mumbai) to secondary (e.g. Pune and Bhopal) to tertiary (e.g. Panaji and Guwahati).

Figure 4: The 20 case study cities



[16] The Health and Environment Linkages Initiative (HELI) @ http://www.who.int/heli/risks/urban/urbanenv/en/index.html

Methodology

A methodology was developed to estimate the trends in the emissions with air quality and health as the primary indicator. The fundamental equation for calculating the emissions is based on the activity level, which for the transport sector is equivalent of "*Emissions = Number of Vehicles * Vehicle kilometers traveled (km)* Emission Factor(gm/km)*". A detailed mathematical representation of the methodology is presented in **Figure 5**. The emissions analysis is carried out for four pollutants – particulates, nitrogen oxides, carbon monoxide, and carbon dioxide. All the calculations are conducted for the period of 2008-2030.

Figure 5: Mathematical representation of emissions calculator

$$NV_{t+1} = NV_t * (1 + growth)$$

$$NV_{total} = \sum_{age=0}^{age=20} NV_{age}$$

$$EF_{age} = EF_{new} * (1 + drate)^{\wedge 2}$$

$$EF_{effective} = \sum_{age=0}^{age=20} EF_{age} * \frac{NV_{age}}{NV_{total}}$$

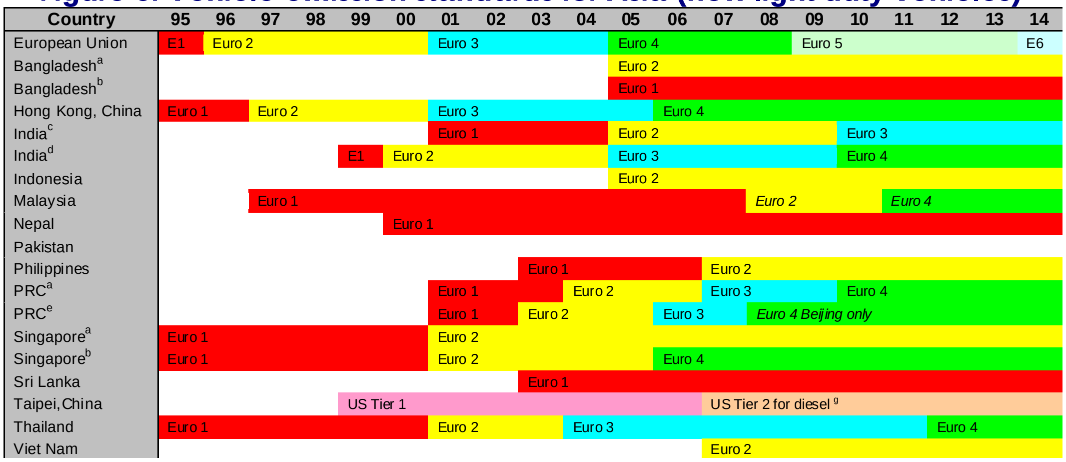
$$Emissions = NV_{total} * VKT * EF_{effective}$$

For each of the parameters, the assumptions and the resources of information are detailed in the following sections. For a given fleet, the total emissions depend on the mix of the vehicles on road, e.g., the make and the age of the vehicles. The age mix of the vehicles is considered to account for the deterioration of the vehicles, which impact the emission release levels, and to account for the average retirement of the vehicles. For all the cities, an average retirement age of 10 years for the passenger cars, 15 years for the buses, 10 years for the 3 wheelers, and 8 years for the motorcycles is assumed. The average retirement age doesn't mean that all the vehicles are retired instantaneously, but a fraction of the fleet is interchanged for a newer fleet to maintain the assumed age mix. However, the methodology assumes a 20 year cap on the vehicle age.

Based on the growth rates for the four categories, the fleet is progressively calculated at a two year interval. The methodology allows for varying growth rates for each fleet by fuel mix. For example, given the subsidies for the diesel, the growth rate for the diesel passenger cars is assumed higher than the gasoline based cars. For all the cities, it is assumed that the 2-stroke motorcycles will be phased out by 2012 and replaced by 4-stroke motorcycles. The growth rate for the 2 categories is adjusted to support the phase out program.

All the emissions are calculated using the emissions standards as the starting point, which is retained for the newer fleet for each year. **Figure 6** presents a summary of the prevalent emission standards in Asia. **Table 1** presents the assumed emission standards for the calculations in this study.

Figure 6: Vehicle emission standards for Asia (new light duty vehicles)



Note: a – gasoline; b – diesel; c – Entire country; d – Delhi, Chennai, Mumbai, Kolkata, Bangalore, Hydrabad, Agra, Surat, Pune, Kanpur, Ahmedabad, Sholapur, Lucknow; Other cities in India are in Euro 2; e – Beijing and Guangzhou (as of 01 September 2006) have adopted Euro 3 standards; Shanghai has requested the approval of the State Council for implementation of Euro 3; f – Euro 4 for gasoline vehicles and California ULEV standards for diesel vehicles; g – Gasoline vehicles under consideration
Source: Various sources, compiled by CAI-Asia @ http://www.cleanairnet.org/caiasia/

Table 1: Vehicular Emission Standards[17]

	Petrol	Diesel	CNG	LPG
$PM_{2.5}$ (gm/km)				
Passenger Cars	0.05[a]	0.15[b]	0.03	0.005
Buses	-	0.34[e]	0.02[e]	-
3 Wheelers	0.08[a]	-	0.03	0.005
2 Wheelers	0.05[a]	0.05[a]	-	-
NO_x (gm/km)				
Passenger Cars	0.2[a]	1.2[b]	0.7	0.7
Buses	-	17[e]	12.1[e]	-
3 Wheelers	1.5[b]	2.0	1.0	0.5
2 Wheelers	0.07[a]	0.3[a]	-	-
CO (gm/km)				
Passenger Cars	2.0[a]	1.0[b]	1.0	1.0
Buses	-	7.1[e]	5.3[e]	-
3 Wheelers	4.0[b]	4.3	1.5	1.0
2 Wheelers	2.2[a]	2.2[a]	-	-

[17] (a) http://cpcb.nic.in/Source_Apportionment_Studies.php
(b) http://www.dieselnet.com/standards/in/
(e) www.tec.org.au/index.php?option=com_docman&task=doc_download&gid=147

This study does not include the emissions analysis for SO_2, however the prevalent fuel quality standards in Asia for sulfur levels in diesel is presented in **Figure 7**.

Figure 7: Fuel standards for sulfur levels in diesel in Asia

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Bangladesh							5000									
Cambodia					2000				1500							
Hong Kong, China		500					50					*10 - under consideration*				
India (nationwide)	5000				2500					500					350	
India (metros)	5000				2500	500				*350*					*50*	
Indonesia	5000										2000				*350*	
Japan[a]	500									50		10				
Malaysia	5000		3000				*500 - marketed*			500					*50*	
Pakistan	10000						5000			*1000*						
Philippines	5000					2000			500						*50*	
PRC (nationwide)	5000						2000			*500 - widely used*					*50*	
PRC - Beijing	5000						2000		500	350			*50*			
Republic of Korea	500								100			*15/10*				
Singapore	3000		500								50					
Sri Lanka	10000							5000	3000/ 500		*500*					
Taipei,China	3000			500			350		100						50	
Thailand	2500			500					350		150				50	
Viet Nam	10000							2500			500				*150*	
European Union					500					50/ 10			10			
United States	500										15					

Source: Various sources, compiled by CAI-Asia @ http://www.cleanairnet.org/caiasia/

Increasing congestion in the cities is a leading cause for the "*stop and go*" driving patterns, combined with outdated traffic control systems and traffic management techniques, which compound the deterioration of the vehicles. For the older fleet, the emission factors are deteriorated (*drate* in the **Figure 5**) at an assumed rate of 2 percent per year. Similarly, the fuel consumption patterns, all the categories of the vehicles were deteriorated at the rate of 2 percent per year.

The vehicle kilometers traveled (VKT *per day*), which determine the activity level is based on local survey. In the general, for the

1. Public transport buses, operating on fixed or non-fixed routes, operating at an average speed of 30 km/hr for 8 hours a day, accounts for 240 km per day.
2. Public transport buses operating on long distance routes, travel in and out of the city, which means distance traveled in the city limits is the distance between the depots to the city limits.
3. Passenger vehicles, operate at 30-40 km/hr for 1-2 hours on the road. An average value of 40 km per day is assumed for the megacities and 30 km per day for the secondary and tertiary cities.
4. Motorcycles (2Ws) are assumed to travel at speeds higher than the other modes and for short time periods; most often for personal travel, unlike in the cities of the Bangkok, Hanoi, and Hoi Chi Minh City, where the motorcycles are effectively used as distance passenger taxi.

Results & Observations

It is important to note that the assumed numbers (theories) are for conditions observed in the developing countries (here in India), where the congestion levels are on the rise and doesn't allow the vehicles to operate at speeds observed in the developed countries.

The major challenge in this exercise is the number of vehicles, ***the database of which is developed utilizing multiple sources and assumptions***. All the cities do not have the necessary information of their fleet published periodically, nor presented using the same baseline, which makes the process difficult and uncertain. However, while a caution is requested, the vehicle numbers and the subsequent emissions analysis discussed in this report present an indication of the current. The resources used for collecting the fleet numbers are described in **Table 2**.

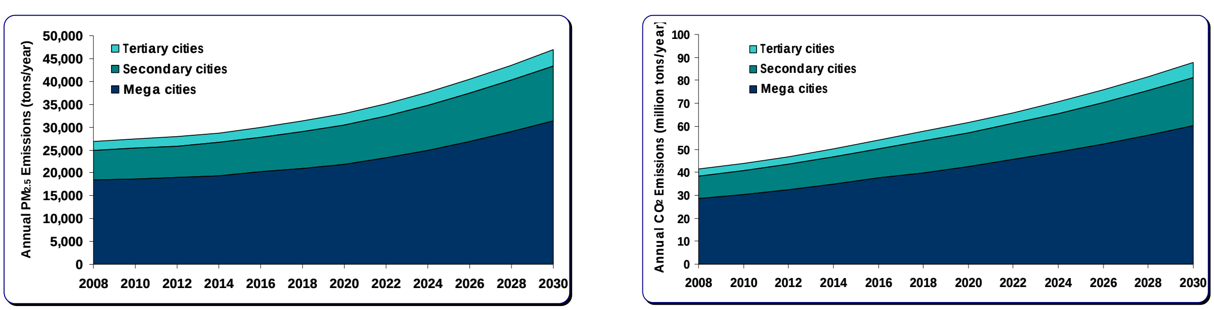
Based on the methodology presented in **Figure 5** and the estimated total emissions for the four vehicular categories are presented in **Figure 8** and **Table 3-6**. The city pages with detailed trend analysis through 2030 for vehicular number, share of passenger trips, energy consumption, and emissions of PM, NO_x, CO, and CO_2 are presented in **Annex 1** and the VAPIS calculator utilized for the analysis is available for download[18].

The emissions inventory presented in this study is an indicative analysis based on the information available in the public domain, plus author's interpretation of the same and comes with a set of limitations that should be noted, while taking the results into consideration further use.

Any further use of the material presented requires thorough investigation and detailed surveys to improve the parameters described and assumed in the earlier sections.

All the growth rates are speculative. The calculations do not include the trucks or non-road transport, such as metro rail or long distance railways.

Figure 8: Annual total emissions for $PM_{2.5}$ and CO_2 for all the cities combined



[18] The VAPIS – Vehicular Air Pollution Information System is available for download @ http://ww.urbanemissions.info/simair

Table 2: City vehicular fleet for year 2008, information source, and brief description

City	Passenger Cars	Buses	3 Wheelers	2 Wheelers	Source
Delhi	1,140,000	16,000	80,000	1,600,000	Ms. Anumita Roychoudary, CSE, New Delhi, India
Mumbai	507,400	47,600	108,800	865,450	Transport Statistics for Mumbai Metro Region by MMRDA
Kolkata	509,350	32,550	87,650	531,700	PICEE proceedings, March, 2009, Parti, et al.[19]
Chennai	335,150	5,100	183,100	1,110,550	PICEE proceedings, March, 2009, Parti, et al.
Hyderabad	303,000	14,500	96,800	1,730,300	AP Pollution Control Board, via IES program
Bangalore	347,100	11,350	221,150	1,341,450	PICEE proceedings, March, 2009, Parti, et al.
Kanpur	48,000	600	1,400	274,250	PICEE proceedings, March, 2009, Sharma, et al.
Agra	9,450	350	1,000	46,250	Regional Transport Office, via Dr. Ajay Taneja Dr. B. R. Ambedkar University, Agra
Pune	116,000	1,200	34,200	842,350	Pune Regional Emissions Inventory Study (PREIS)[20]
Ahmedabad	281,700	950	105,900	1,495,150	BRT System Plan, Ahmedabad Municipal Corporation, via ITDP office
Bhopal	118,100	270	2,450	284,300	Ministry of Urban Development, May 2008
Jaipur	163,150	18,200	163,200	823,450	Journal of Public Transportation, Vol No.1, 2005, Singh @ IIT K
Surat	173,500	170	6,250	829,650	Ministry of Urban Development, May 2008[21]
Pondicherry	25,000	60	800	42,800	Ministry of Urban Development, May 2008
Bhubaneswar	29,100	150	3,450	95,900	Ministry of Urban Development, May 2008
Panaji	79,700	4,220	3,100	302,300	Regional Transport Office, via Ms. Mehra, TERI, Goa
Patna	115,450	4,650	30,300	384,500	Ministry of Urban Development, May 2008
Kochi	77,100	4,400	36,400	158,100	Ministry of Urban Development, May 2008
Nagpur	63,000	1,300	13,850	415,250	Ministry of Urban Development, May 2008
Guwahati	51,200	400	7,500	75,000	Ministry of Urban Development, May 2008

Note:

- For the fleet where the baseline information was not available for 2008, the numbers were estimated based on the available information.
- The vehicle numbers are rounded for simplicity

[19] Proceedings of International Conference on Energy & Environment, March, 2009 @ http://waset.org/pwaset/v39/
[20] Pune Regional Emissions Inventory Study @ http://www.unipune.ernet.in/dept/env/pei/resources.html
[21] Data from the Annexure report "Traffic and Transportation Policies and Strategies in Urban Areas in India" by Ministry of Urban Development, Government of India, May, 2008 @ http://urbanindia.nic.in/moud/theministry/ministryofurbandevelopment/main.htm

Table 3: Total $PM_{2.5}$ emissions from the passenger travel in 2008 (tons/year)

City	Passenger Cars	Buses	3 Wheelers	2 Wheelers	Total
Delhi	1,405	235	142	929	**2,711**
Mumbai	481	3,087	306	503	**4,377**
Kolkata	563	1,932	415	329	**3,240**
Chennai	424	364	868	688	**2,343**
Hyderabad	335	979	244	1,072	**2,629**
Bangalore	439	808	1,048	831	**3,125**
Kanpur	39	18	4	133	**193**
Agra	7	16	4	27	**54**
Pune	80	63	93	326	**562**
Ahmedabad	312	60	502	724	**1,597**
Bhopal	131	15	12	165	**322**
Jaipur	180	981	774	478	**2,414**
Surat	192	9	30	482	**712**
Pondicherry	28	3	4	25	**60**
Bhubaneswar	32	7	16	56	**111**
Panaji	88	228	15	176	**506**
Patna	128	250	144	223	**744**
Kochi	85	238	172	92	**587**
Nagpur	70	69	66	241	**445**
Guwahati	57	22	36	44	**157**
Total	5,134	9,533	4,903	7,659	

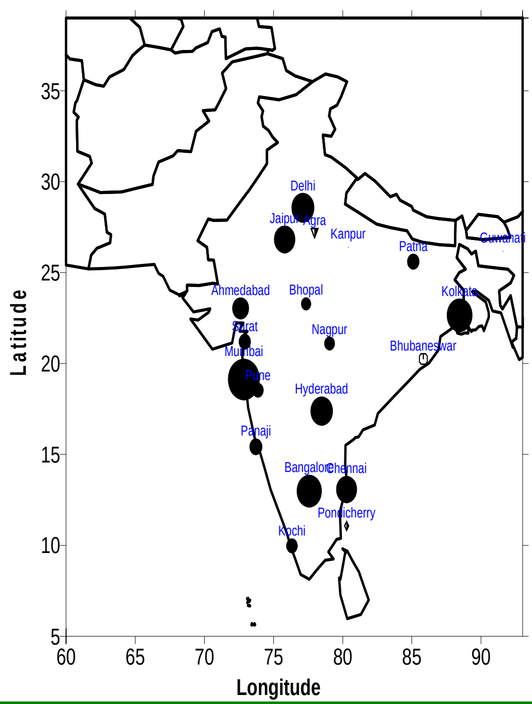


Table 4: Total NO_x emissions from the passenger travel in 2008 (tons/year)

City	Passenger Cars	Buses	3 Wheelers	2 Wheelers	Total
Delhi	9,907	20,883	4,740	2,156	**37,686**
Mumbai	3,006	80,729	7,092	1,629	**92,456**
Kolkata	3,219	46,655	7,790	1,067	**58,731**
Chennai	2,648	8,790	16,271	2,229	**29,937**
Hyderabad	1,915	24,887	5,735	3,966	**36,503**
Bangalore	2,742	19,506	19,654	2,692	**44,594**
Kanpur	256	815	83	430	**1,584**
Agra	47	441	68	87	**643**
Pune	458	1,691	1,945	1,057	**5,150**
Ahmedabad	1,780	1,558	9,412	2,677	**15,428**
Bhopal	746	381	217	611	**1,956**
Jaipur	1,031	25,672	14,504	1,769	**42,977**
Surat	1,097	240	554	1,783	**3,673**
Pondicherry	158	86	73	92	**409**
Bhubaneswar	184	182	305	206	**877**
Panaji	504	5,952	275	650	**7,380**
Patna	730	6,533	2,691	826	**10,780**
Kochi	487	6,226	3,232	340	**10,284**
Nagpur	398	1,796	1,230	892	**4,317**
Guwahati	324	567	667	161	**1,718**
Total	**31,972**	**257,556**	**96,724**	**25,753**	

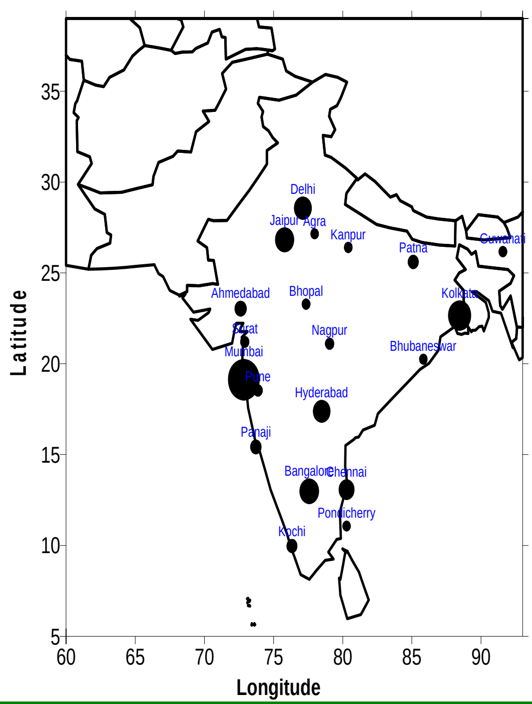


Table 5: Total CO emissions from the passenger travel in 2008 (tons/year)

City	Passenger Cars	Buses	3 Wheelers	2 Wheelers	Total
Delhi	28,820	9,092	7,110	40,886	**85,908**
Mumbai	10,222	33,716	16,763	22,116	**82,817**
Kolkata	14,486	19,485	20,773	14,492	**69,237**
Chennai	9,002	3,671	43,389	30,270	**86,332**
Hyderabad	8,618	10,394	14,339	47,163	**80,513**
Bangalore	9,323	8,147	52,411	36,564	**106,444**
Kanpur	967	348	184	5,840	**7,338**
Agra	159	184	182	1,181	**1,707**
Pune	2,061	706	5,024	14,350	**22,142**
Ahmedabad	8,011	651	25,100	31,839	**65,601**
Bhopal	3,359	159	579	7,264	**11,362**
Jaipur	4,640	10,722	38,679	21,042	**75,083**
Surat	4,935	100	1,477	21,200	**27,712**
Pondicherry	711	36	194	1,094	**2,034**
Bhubaneswar	827	76	813	2,450	**4,167**
Panaji	2,267	2,486	734	7,724	**13,211**
Patna	3,283	2,729	7,177	9,824	**23,013**
Kochi	2,192	2,600	8,618	4,040	**17,450**
Nagpur	1,791	750	3,280	10,611	**16,433**
Guwahati	1,456	237	1,778	1,916	**5,387**
Total	**118,640**	**107,946**	**249,094**	**337,018**	

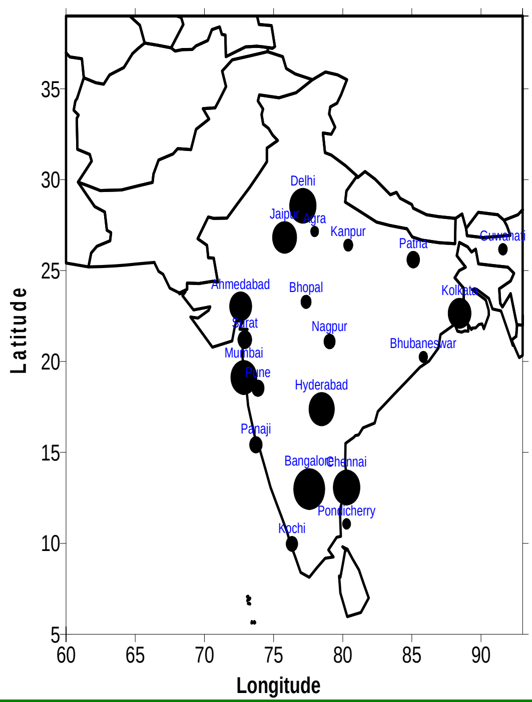
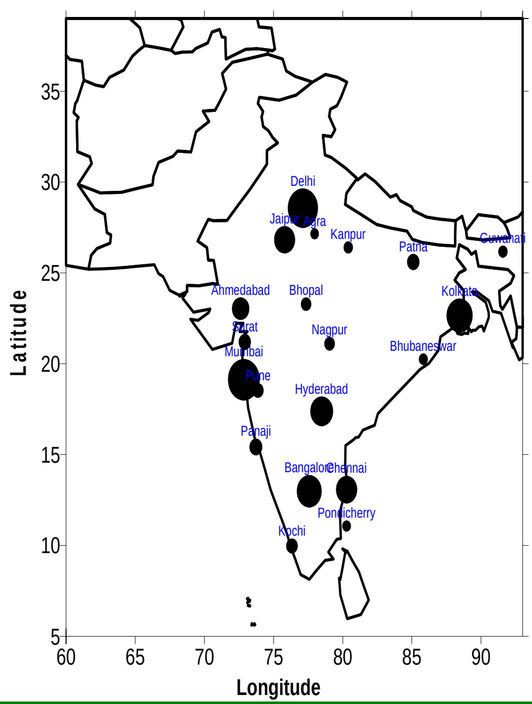


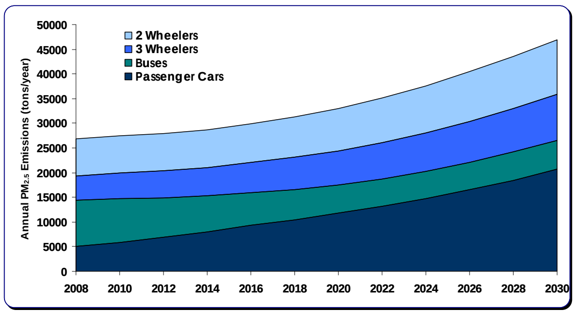
Table 6: Total CO_2 emissions from the passenger travel in 2008 (million tons/year)

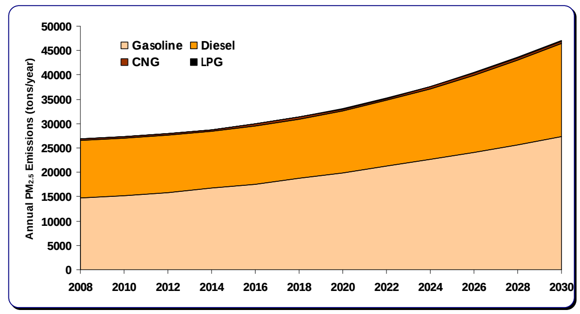
City	Passenger Cars	Buses	3 Wheelers	2 Wheelers	Total
Delhi	3,337,363	1,147,076	406,475	982,180	**5,873,094**
Mumbai	1,139,550	3,923,625	701,429	528,237	**6,292,841**
Kolkata	1,535,283	2,267,523	627,353	346,152	**4,776,312**
Chennai	1,003,528	427,210	1,310,350	723,007	**3,464,094**
Hyderabad	913,326	1,209,557	645,100	1,123,253	**3,891,236**
Bangalore	1,039,326	948,027	1,582,806	873,339	**4,443,498**
Kanpur	106,052	42,488	6,894	139,484	**294,918**
Agra	17,673	21,453	5,509	28,217	**72,852**
Pune	218,451	82,163	187,694	342,751	**831,059**
Ahmedabad	849,077	75,712	758,014	758,287	**2,441,090**
Bhopal	356,022	18,517	17,500	173,010	**565,048**
Jaipur	491,789	1,247,699	1,168,091	501,152	**3,408,731**
Surat	523,026	11,659	44,613	504,908	**1,084,206**
Pondicherry	75,356	4,183	5,848	26,044	**111,431**
Bhubaneswar	87,669	8,847	24,557	58,354	**179,428**
Panaji	240,257	289,270	22,174	183,969	**735,669**
Patna	347,980	317,525	216,751	233,982	**1,116,238**
Kochi	232,311	302,575	260,262	96,215	**891,362**
Nagpur	189,834	87,302	99,067	252,714	**628,918**
Guwahati	154,287	27,569	53,681	45,643	**281,180**
Total	**13,018,330**	**12,652,797**	**8,158,955**	**8,043,542**	



In the emissions inventory, the large cities stand out, because of the shear number of vehicles and the vehicle kilometers traveled. **Figure 9** presents the share of $PM_{2.5}$ emissions by vehicle category and fuel type. In case of Delhi, the total emissions, especially for the particulates is comparatively low, in spite of a large vehicular fleet, due to the extensive use of the compressed natural gas (CNG) for the bus, para transit, taxi, and a share of passenger car fleet. The use of liquefied petroleum gas (LPG) is included for the para transit fleets of Mumbai, Pune, and Hyderabad only[22].

Figure 9: Annual total emissions for $PM_{2.5}$ by vehicle category & fuel type for 20 cities





Note that the totals represent the passenger travel only. A major non-passenger source not included in this analysis is "trucks".

From **Annex 1**, the motorcycle transport is the dominant mode of transport for most of the secondary and tertiary cities and it is also reflected in the emissions inventory. For the motorcycles and cars, the gasoline remains the dominant fuel source. Diesel is the main fuel source for the buses for all the cities, except for Delhi, and a share of diesel based passenger cars is also increasing in the cities. In the mega cities of Delhi, Hyderabad, Chennai, Bangalore, the para transit plays a critical role for mobility and expected to continue through 2030.

Among the four vehicle categories, the highest growth rate is estimated for the passenger cars and hence the tripling in the respective emissions. For the public transport, the current

[22] Relevant references – most of the past studies have focused on national scale emissions analysis.
Bose, 1999, "Automotive energy use and emissions control: a simulation model to analyse transport strategies for Indian metropolises" Energy Policy @ http://dx.doi.org/10.1016/S0301-4215(98)00045-7
Garg et al., 2006, "The sectoral trends of multigas emissions inventory of India", Atmospheric Environment @ http://dx.doi.org/10.1016/j.atmosenv.2006.03.045
Reddy et al., 2002, "Inventory of aerosols and sulfur dioxide emissions in India, Atmospheric Environment @ http://dx.doi.org/10.1016/S1352-2310(01)00463-0

City level analysis exists for the cities Delhi, Mumbai, Kanpur, Pune, Ahmedabad, and Hyderabad
Gurjar et al., 2004, "Emission estimates and trends (1990–2000) for megacity Delhi and implications" Atmospheric Environment @ http://dx.doi.org/10.1016/j.atmosenv.2004.05.057
Venkatraman et al., 2002, "Aerosol size and chemical characteristics at Mumbai, India, during the INDOEX (1999)" Atmospheric Environment @ http://dx.doi.org/10.1016/S1352-2310(02)00167-X
Guttikunda et al., 2007, "Air pollution and Co-benefits analysis for Hyderabad, India" @ http://www.epa.gov/ies/india/apportionment_documents.htm
Pune Regional Emissions Inventory Study @ http://www.unipune.ernet.in/dept/env/pei/resources.html
Sharma et al., "Impact of CNG conversion on air quality in Kanpur", Proceedings of International Conference on Energy & Environment, March, 2009 @ http://waset.org/pwaset/v39/

bus fleet for most of the cities is old, with an average age of 6-8 years and in some cases more than 10 years. With the JNNURM funds promoting the public transport and supporting the new bus purchase for most of the cities, the newer bus fleet is expected to reduce the relative emissions in the coming decades. Overall, the emissions are expected increase and deteriorating the air quality under business as usual.

In Conclusion - Co-benefits & Challenges

A major challenge for effective implementation of transport interventions is the private motor vehicle ownership, which is expected to maintain their current share on the roads. Hence, in order to improve the travel times and speeds, the best are the modes most commonly used, especially public transport (bus and metro, where available) and NMT (walking and biking). In this study, three combined interventions are evaluated for the emissions co-benefits (particulates for the health concerns and CO_2 for the climate change concerns)

- Promotion of the public transport, resulting in at least 30 percent increase in the riders by 2030
- Introduction of stringent standards and better traffic management (improving the deterioration rates and resulting in better fuel efficiency), resulting in at least 38 percent improvement overall emission factors and fuel economy
- Promotion of NMT resulting in at least 20 percent reduction in the passenger car riders, and 10 percent each from buses, 2 wheelers, and 3 wheelers by 2030, primarily from the short trips

It is assumed that the expected 30 percent increase in the ridership can be supported by increase in the necessary number of buses and required infrastructure. Similarly, it is expected that provisions will be made to support the necessary shift to NMT. The second measure represents the policy reforms which will have the largest impact on the fuel demand (by better fuel economy standards for the manufacturers), on the emissions (via emission standards), and for better traffic management.

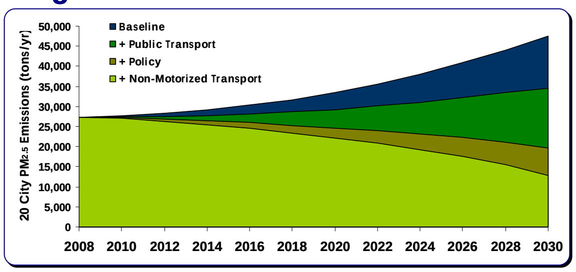
At the end, the analysis is expected to present a possible range of emission reductions, for a combination of the three measures, but not delve into the modalities of the implementation of the measures[23]. For example, in case of NMT and public transport, it is important to address the issue of public safety, where the accidents (walkers and cyclists), eve-teasing for women, and crime in the major cities is an issue.

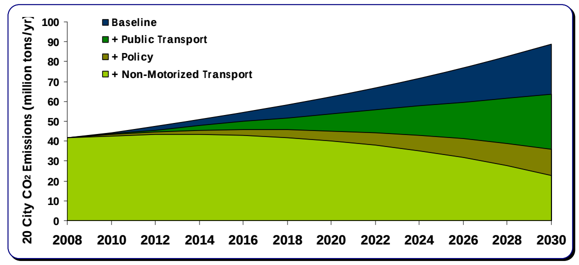
The **Figure 10** presents a summary of the estimated change in total emissions for the particulates and CO_2 through 2030, upon implementation of the three interventions for all the twenty cities combined. A combined reduction of at least 45 percent of the emissions compared to current 2008 emission levels is estimated, which represents a significant reduction in the exposure times and air pollution related health impacts.

[23] Ministry of Urban Development inaugurates a seminar on "Guidelines And Toolkits For Urban Transport Development in Medium Sized Cities in India", May 29th, 2009 @ http://pib.nic.in/release/release.asp?relid=48940

The uncertainties related to the emissions projections are large although there are potentially important unaddressed uncertainties (e.g., growth rates, emission factors of the in-use fleet, the vehicle kilometers traveled, and expected sales of various modes of transport – model and fuel), which need further scrutiny.

Figure 10: Annual total emissions for $PM_{2.5}$ & CO_2 for three interventions for 20 cities





However, the co-benefits of these interventions can be multi dimensional. The fact that major roads tend to support the neighborhoods around them also means that the poor tend to live in these neighborhoods. In the dense urban areas, this means that low-income people tend to be exposed to higher concentrations of urban transport air pollution[24].

Mr. Todd Litman of the Victoria Transport Policy Institute (Email: litman@vtpi.org), reports that a number of recent studies do show that high quality public transit service can improve public health by

- Increasing physical activity (people who use public transit on a particular are about 3 times more likely to achieve the basic amount of walking required for public health as people who drive and do not use public transit)
- Reducing per capita traffic fatalities (residents of cities with high quality public transit have about a quarter of the per-capita traffic fatality rates as residents of more automobile-dependent communities)
- Increased affordability and therefore less stress and more money left in the household budget for healthy food and other necessities (residents of cities with high quality public transportation spend about 20% small portion of household budgets on transportation, and this effect is probably larger for lower-income households)
- Improved accessibility for non-drivers, and therefore less difficulty reaching medical services and healthy food.

These factors cannot overcome other demographic and economic factors that reduce poor people's health, but it does suggest that everybody, particularly poor people, are much better off in a transit oriented community than in an automobile-dependent community.

Also see

Todd Litman (2003), "Economic Value of Walkability," Transportation Research Record 1828, pp. 3-11; @ www.vtpi.org/walkability.pdf

Todd Litman (2004), "Whose Roads? Evaluating Bicyclists' and Pedestrians' Right to Use Public Roadways", VTPI @ www.vtpi.org/whoserd.pdf

Todd Litman (2005), "Quantifying the Benefits of Non-Motorized Transport for Achieving TDM Objectives", VTPI @ www.vtpi.org/nmt-tdm.pdf

Todd Litman (2009), "Transportation Cost & Benefit Analysis" VTPI @ http://www.vtpi.org/tca

[24] The poor are over-represented among the estimated 1.2 million annual premature deaths caused by exposure to unhealthy levels of mobile-source air emissions (WHO)

Among an array of interventions available for the policy makers, the common practice has been to focus largely on infrastructure development[25]. In the transport sector, while building the roads is important, it is also important to focus on the prevention of the air pollution due to the impending exhaust emissions.

In the industrial sector, it is easier to consider capturing the emissions out of a furnace, because they cannot imagine changing their fuel source or an alternative for the manufacturing process. However, in the transport sector, a large share of environmental benefits can be achieved through a modal shift by providing for better and cleaner buses, and space for pedestrian walking and cycling[26].

In the name of mobility, the supply of the personal transport has become the key, which tend to put more importance on the products (roads) than the services (provisions for public transport and NMT). An informed decision would make the policy makers take a serious look at energy efficiency and cleaner energy sources (such as electric bikes[27]) which will benefit the economy[28] as well as the environment.

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[25] Down to Earth, May 31st, 2008, "Caravan to Disaster" @ http://www.downtoearth.org.in/full6.asp?foldername=20080531&filename=news&sec_id=9&sid=46

[26] Mr. Penolosa (former mayor of Bogota, Columbia) asks to choose people over cars, "NMT is the best" and the city authorities need to promote these more @ http://www.thejakartaglobe.com/news/article/18929.html

[27] Latest article in the Economist, praised the efforts of China in promoting the electric motor cycles, which provide 30-50 kilometers for a fraction of the cost of the fuel spent in the regular motorcycle. The charging takes 5-8 hours, depending on the battery power, but the travel is safer and faster than the regular bicycles, and the environment is clean @ http://www.economist.com/world/international/displayStory.cfm?story_id=13565800

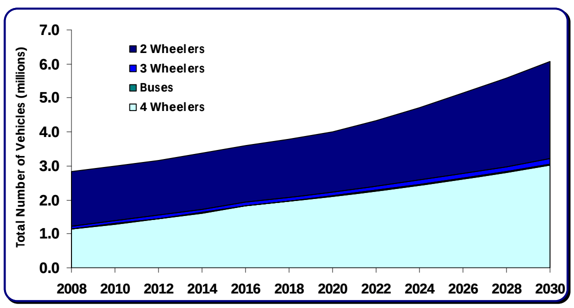
[28] New York Times, April 1st, 2009, "China vies to be world's leader in electric cars" @ http://www.nytimes.com/2009/04/02/business/global/02electric.html

Annex 1

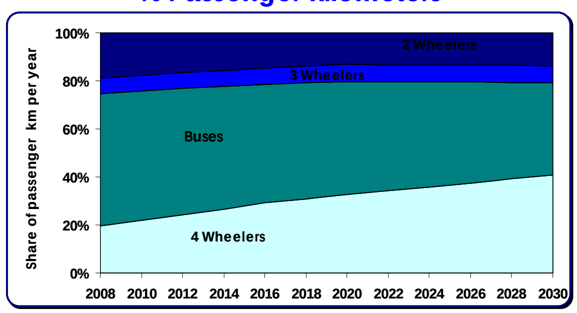
City Pages presenting the estimated trends in vehicular numbers, energy consumption, and emissions (PM, NO_x, CO, and CO_2)

Delhi, India

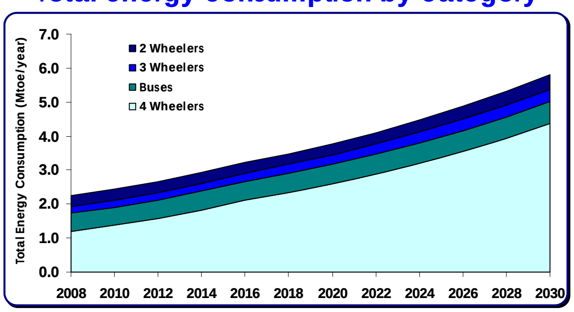
Number of Vehicles



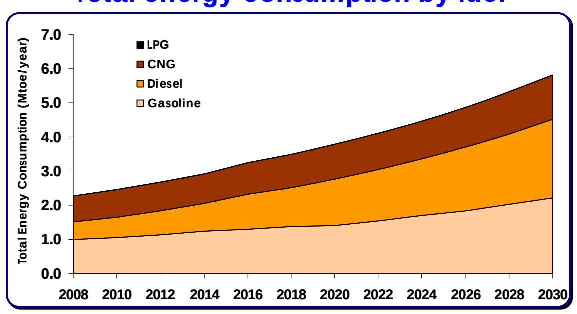
% Passenger kilometers



Total energy consumption by category



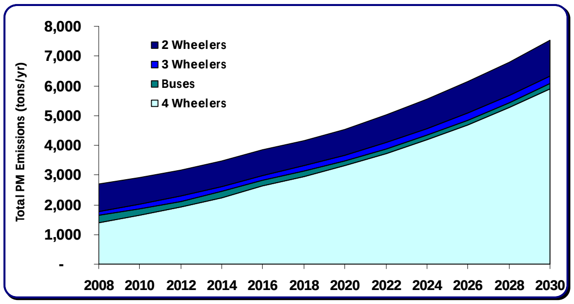
Total energy consumption by fuel

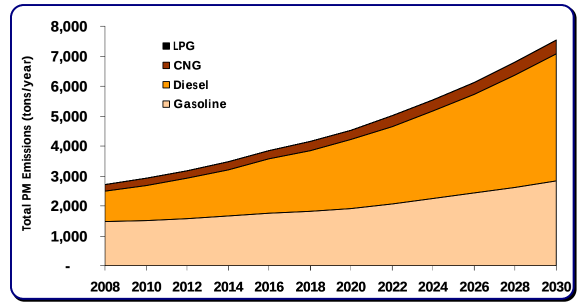


Delhi, India

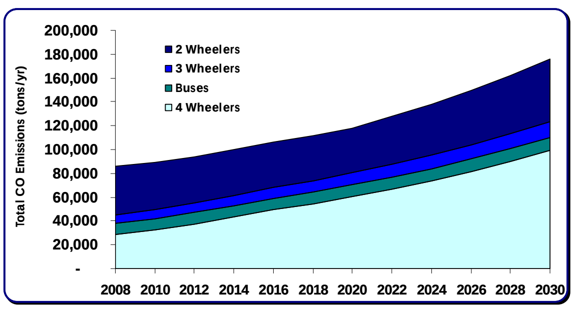
Total emissions by category	Total emissions by fuel

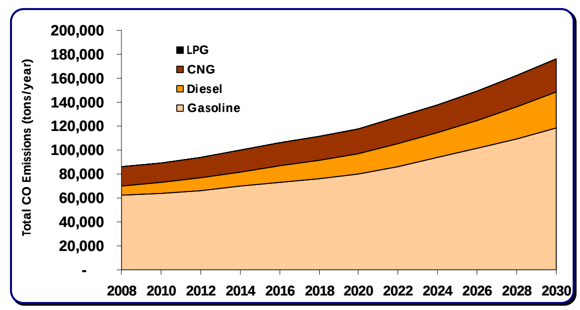
Particulate Matter < 2.5μm



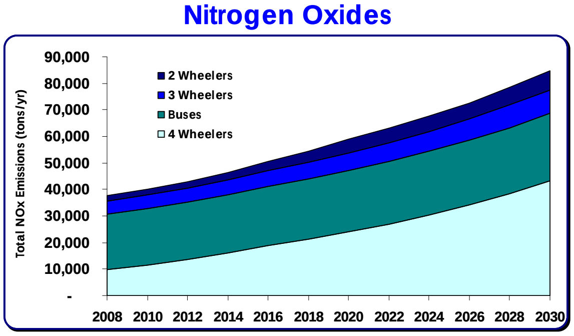


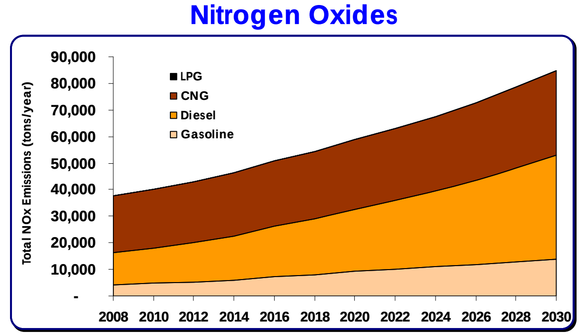
Carbon Monoxide



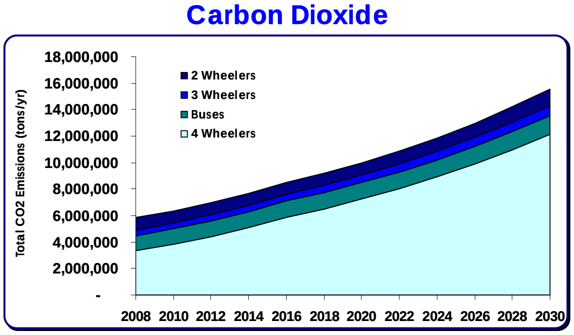


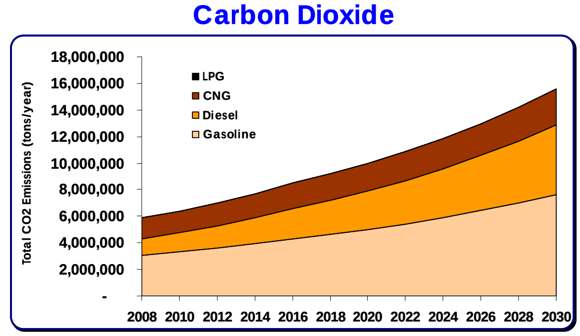
Nitrogen Oxides



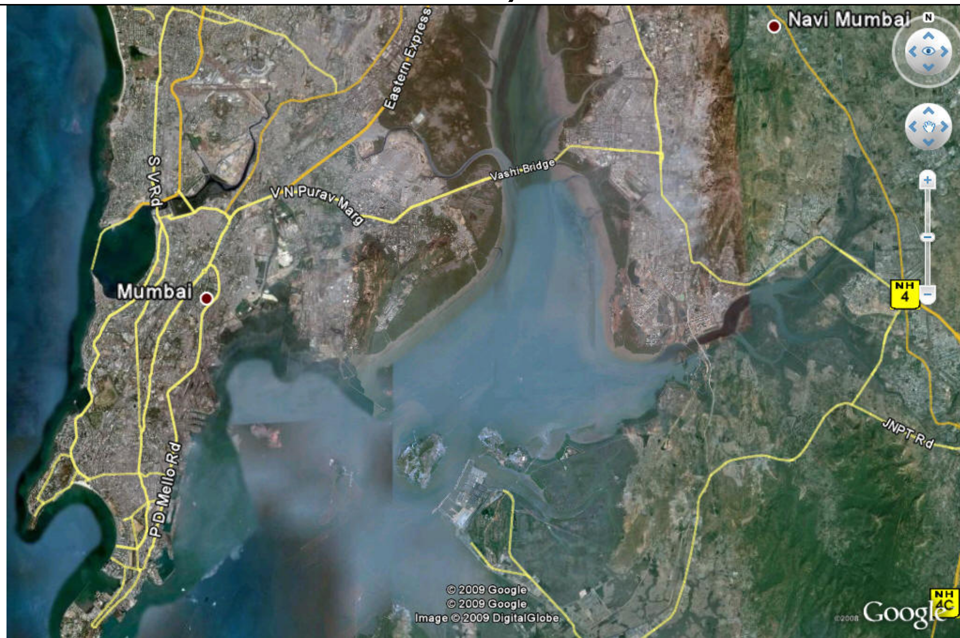


Carbon Dioxide

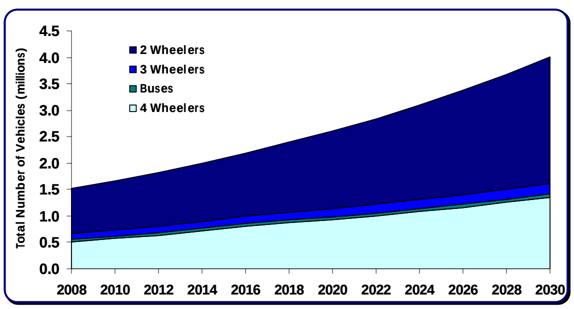




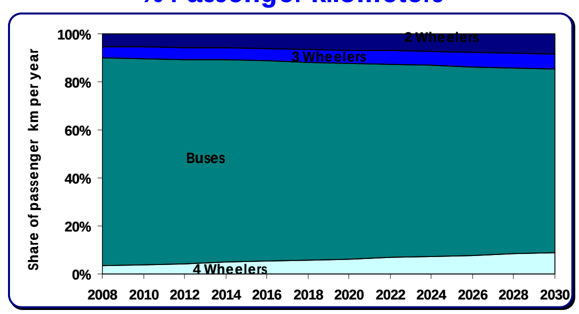
Mumbai, India



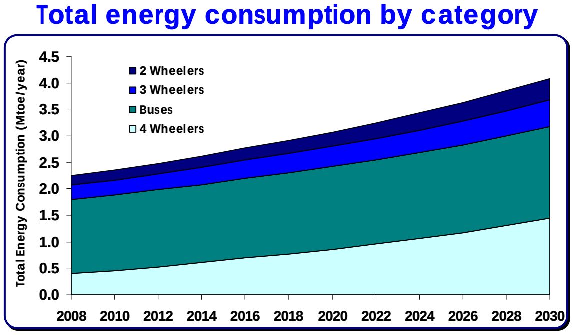
Number of Vehicles



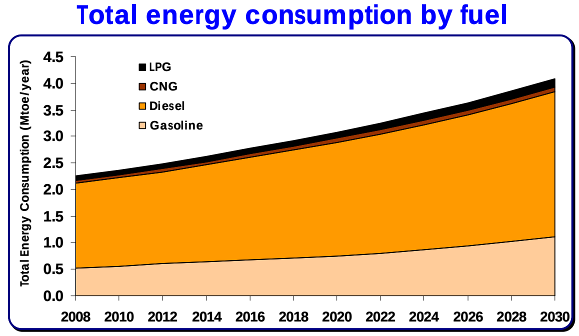
% Passenger kilometers



Total energy consumption by category



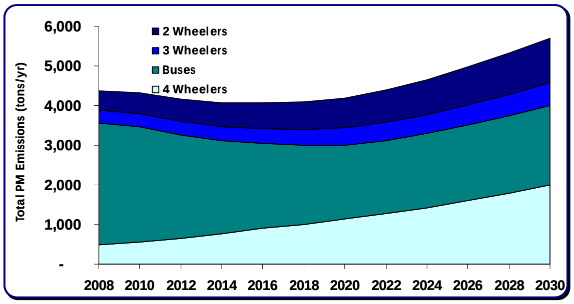
Total energy consumption by fuel



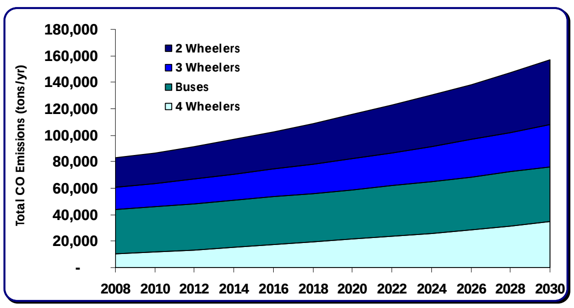
Mumbai, India

Total emissions by category

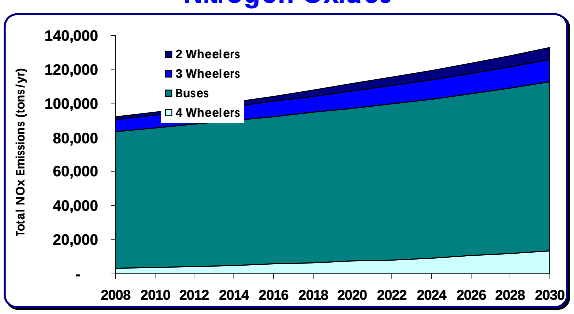
Particulate Matter < 2.5µm



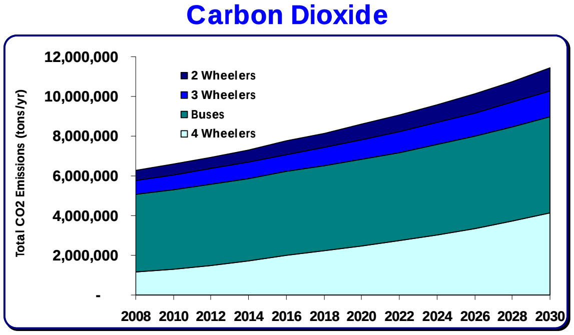
Carbon Monoxide



Nitrogen Oxides

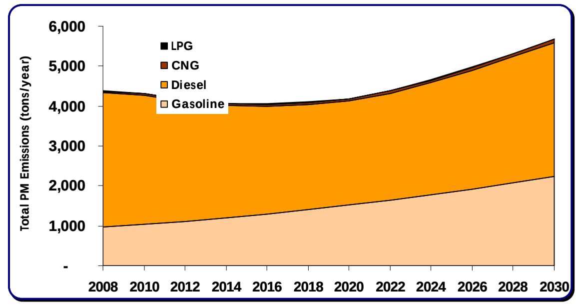


Carbon Dioxide

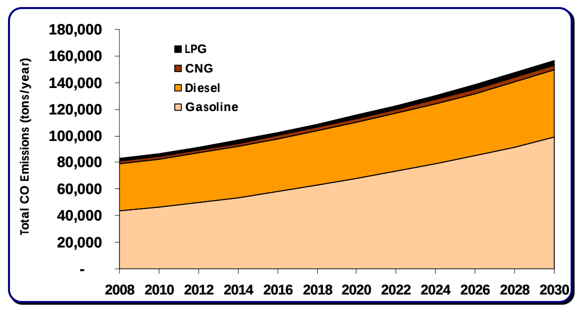


Total emissions by fuel

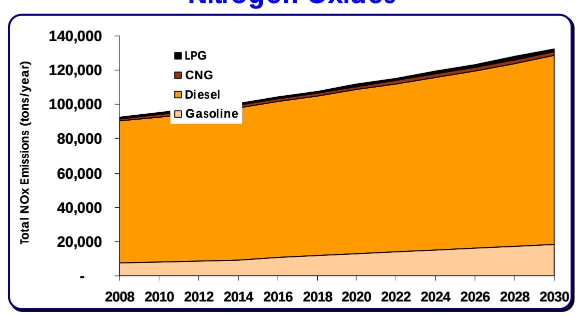
Particulate Matter < 2.5µm



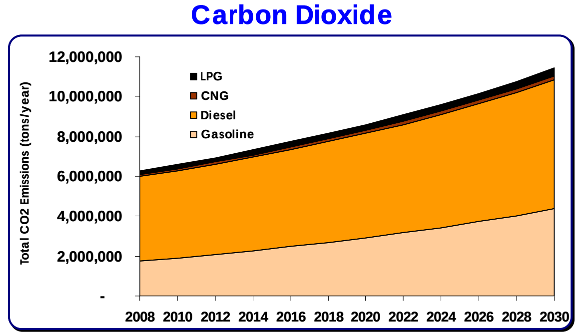
Carbon Monoxide



Nitrogen Oxides

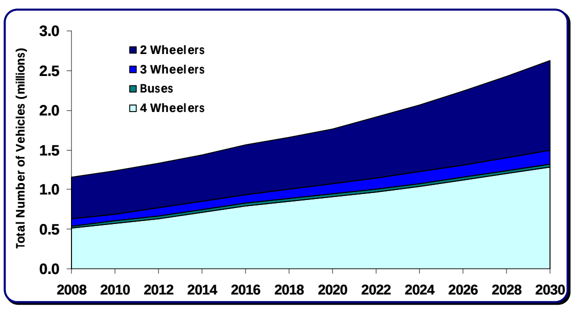


Carbon Dioxide

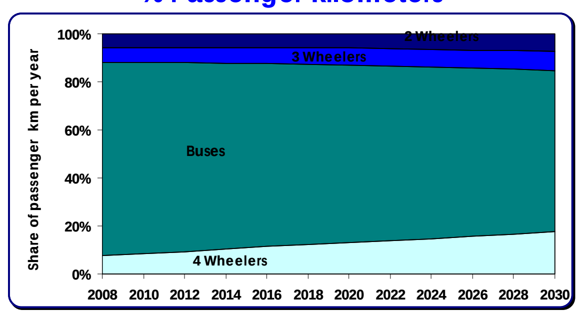


Kolkata, India

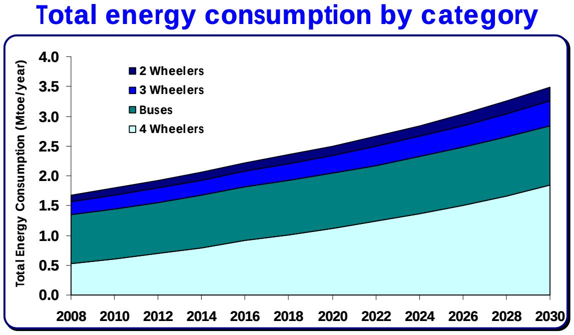
Number of Vehicles



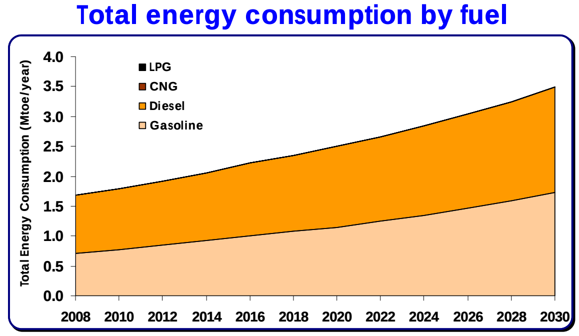
% Passenger kilometers



Total energy consumption by category



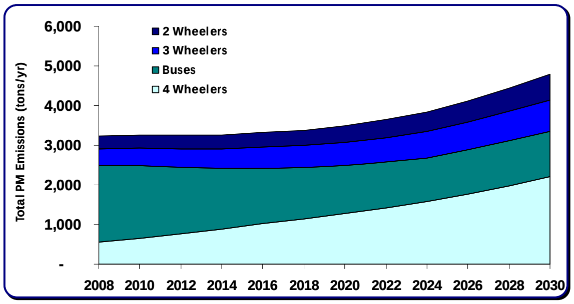
Total energy consumption by fuel



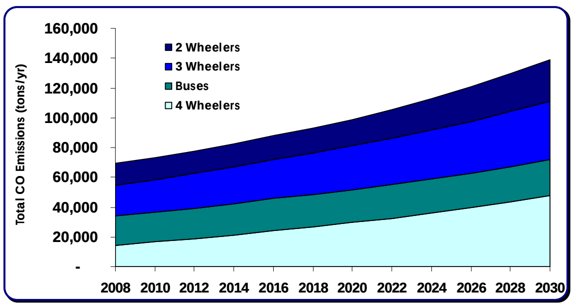
Kolkata, India

Total emissions by category	Total emissions by fuel

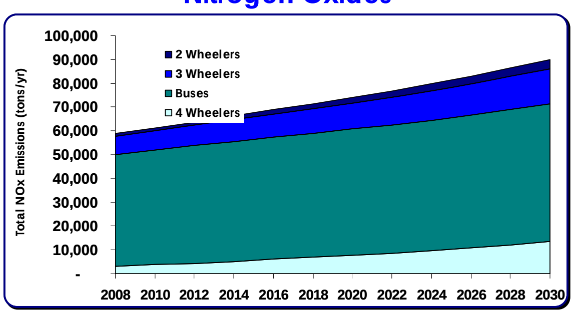
Particulate Matter < 2.5µm



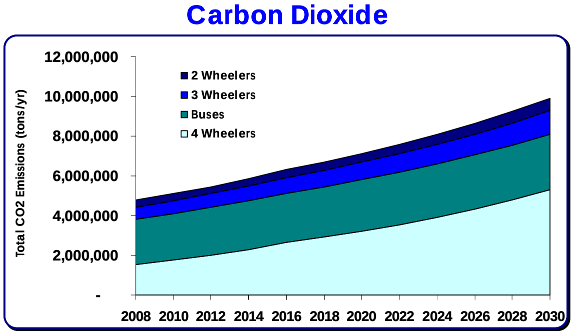
Carbon Monoxide



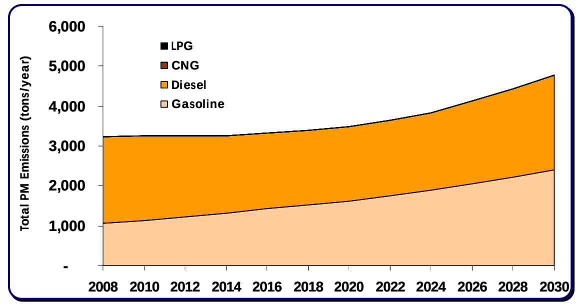
Nitrogen Oxides



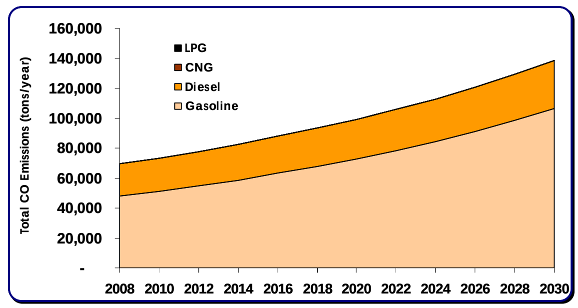
Carbon Dioxide



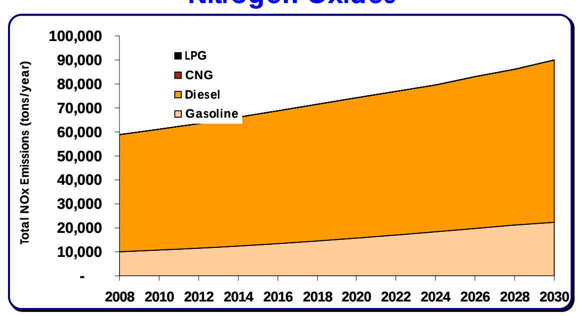
Particulate Matter < 2.5µm



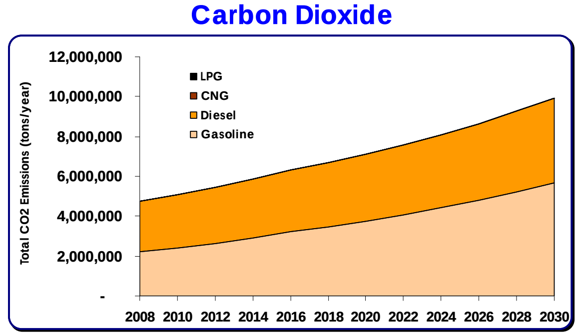
Carbon Monoxide



Nitrogen Oxides

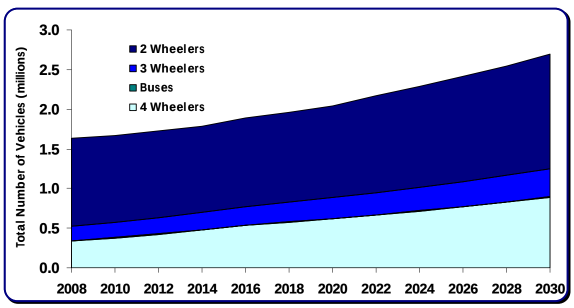


Carbon Dioxide

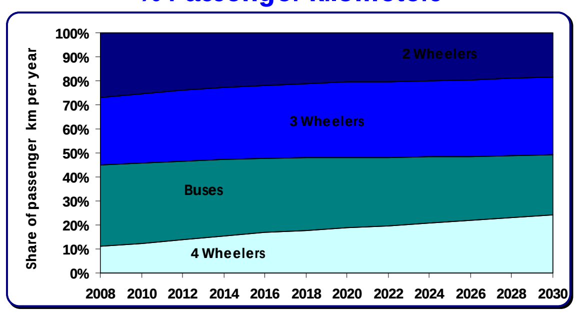


Chennai, India

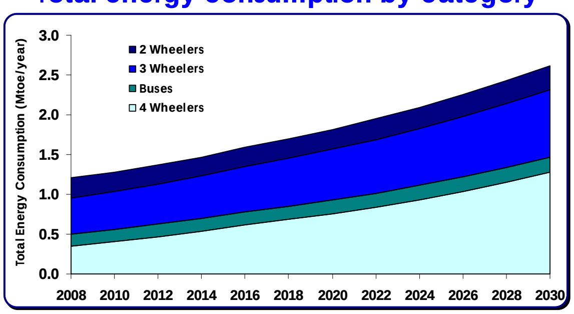
Number of Vehicles



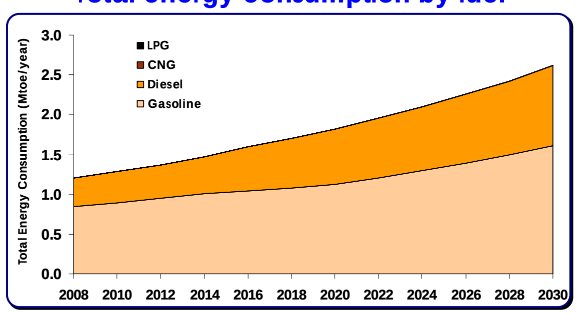
% Passenger kilometers



Total energy consumption by category



Total energy consumption by fuel

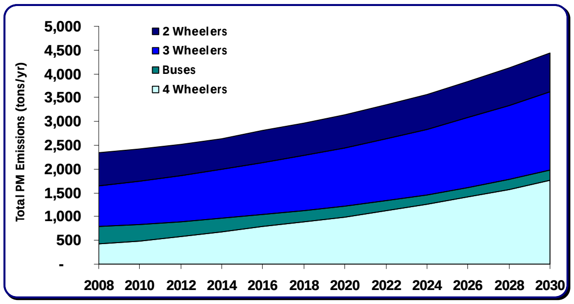


Chennai, India

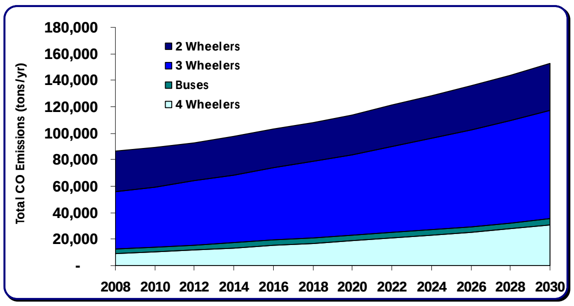
Total emissions by category	Total emissions by fuel

Total emissions by category

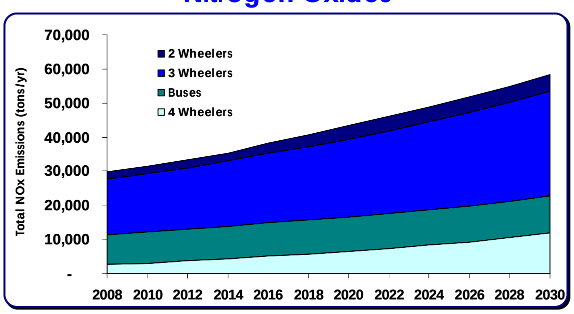
Particulate Matter < 2.5µm



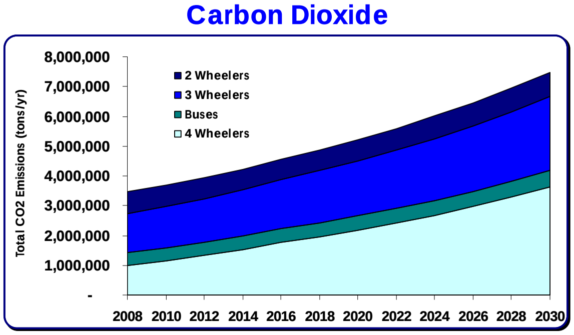
Carbon Monoxide



Nitrogen Oxides

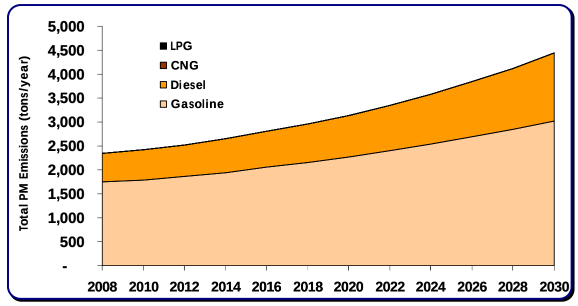


Carbon Dioxide

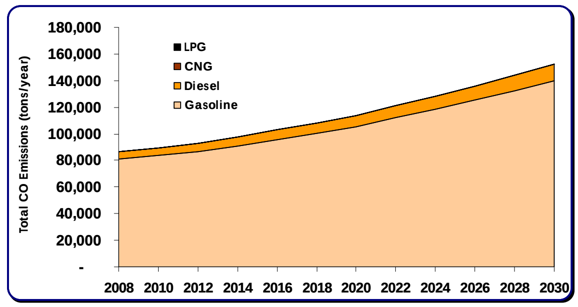


Total emissions by fuel

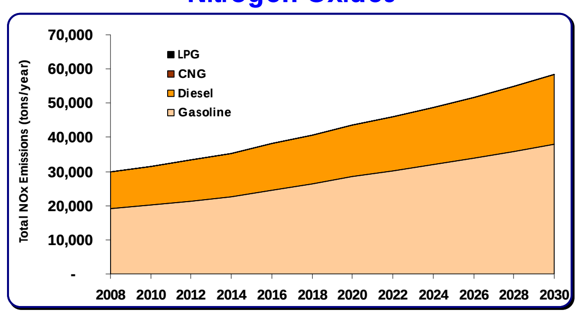
Particulate Matter < 2.5µm



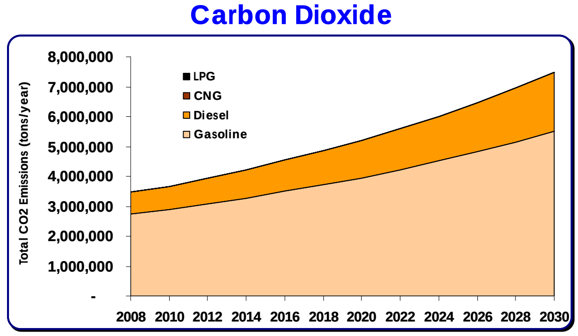
Carbon Monoxide



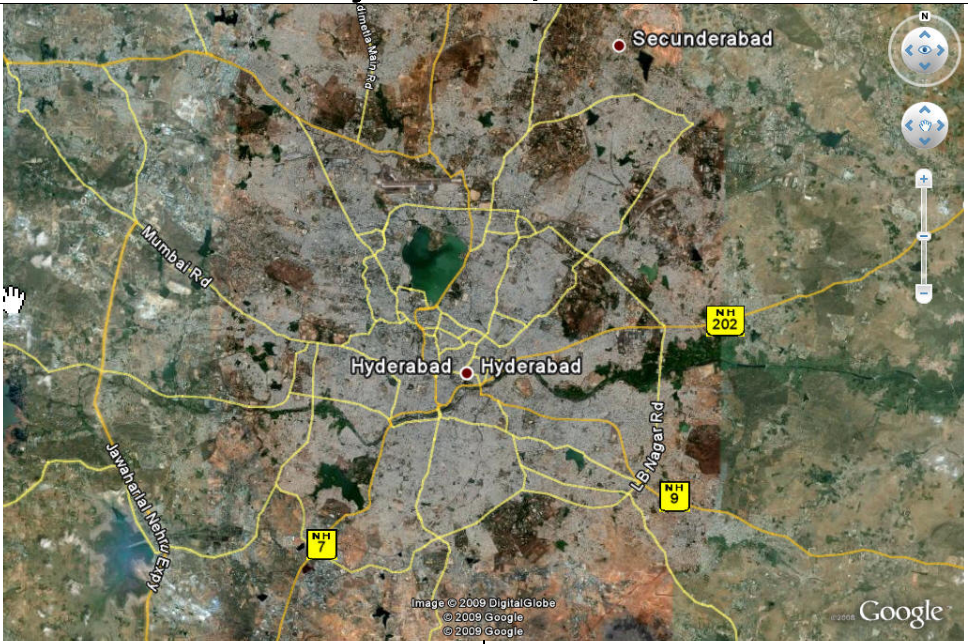
Nitrogen Oxides



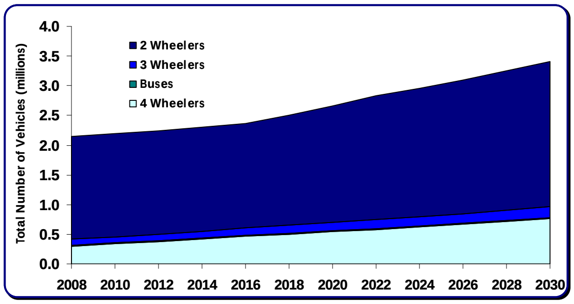
Carbon Dioxide



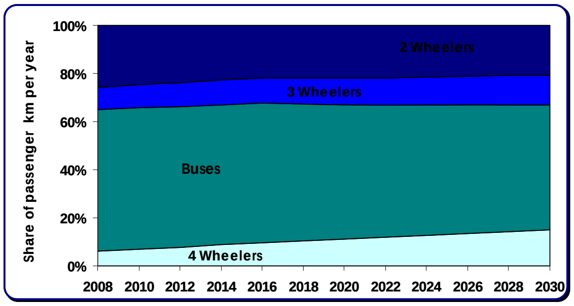
Hyderabad, India



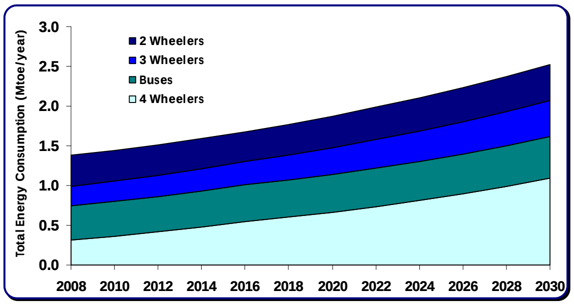
Number of Vehicles



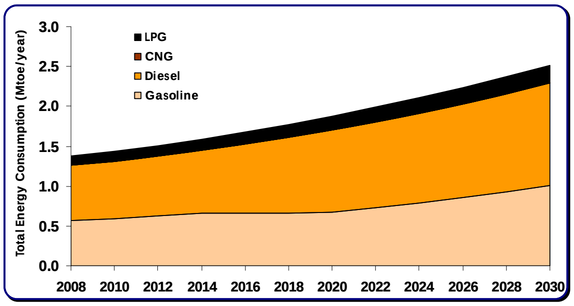
% Passenger kilometers



Total energy consumption by category



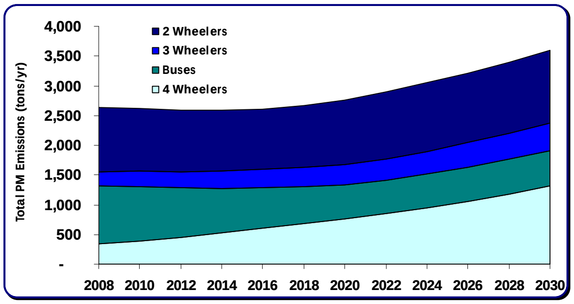
Total energy consumption by fuel



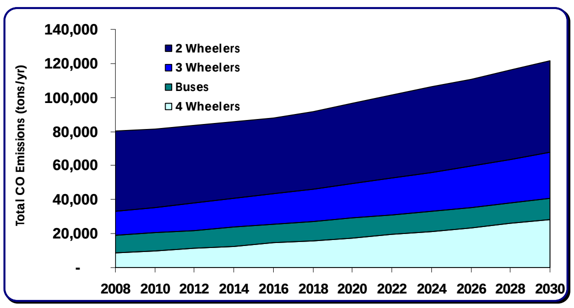
Hyderabad, India

Total emissions by category

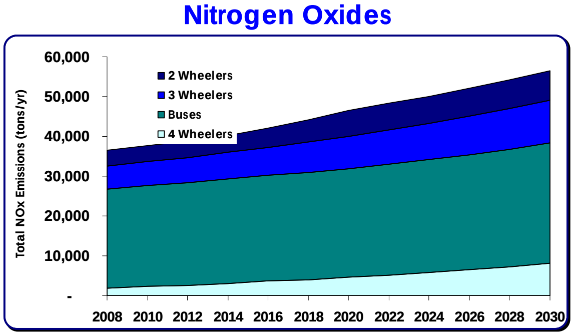
Particulate Matter < 2.5µm



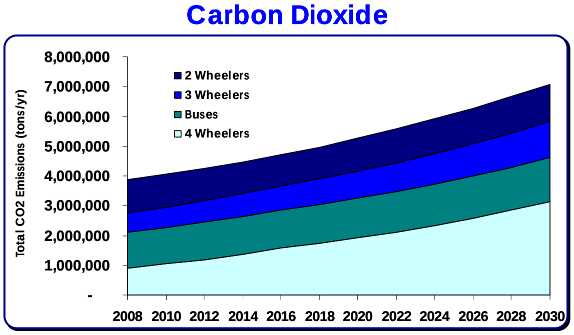
Carbon Monoxide



Nitrogen Oxides

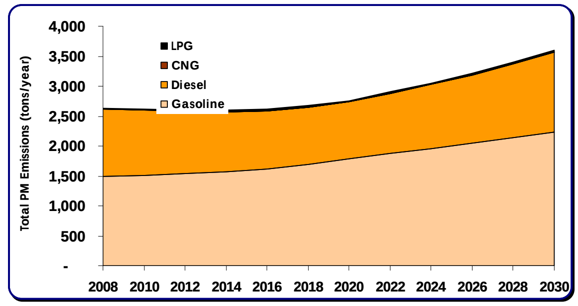


Carbon Dioxide

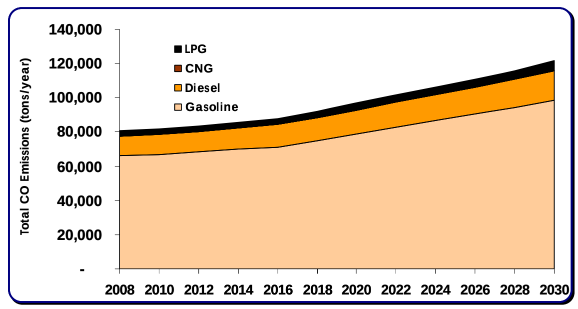


Total emissions by fuel

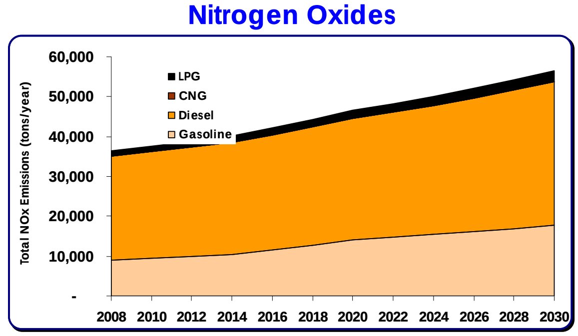
Particulate Matter < 2.5µm



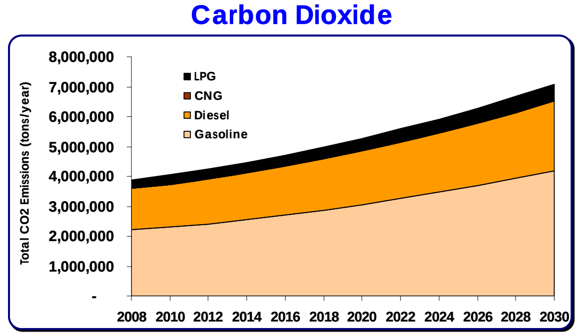
Carbon Monoxide



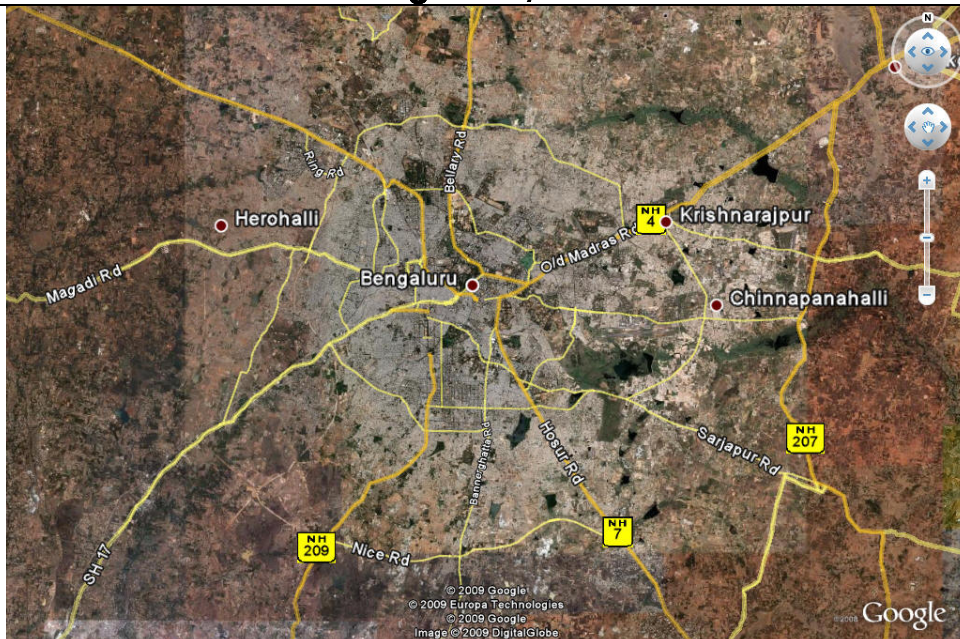
Nitrogen Oxides



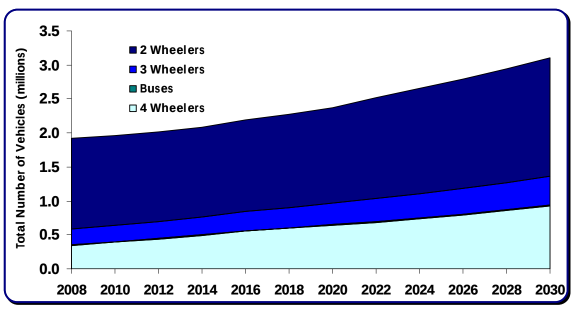
Carbon Dioxide



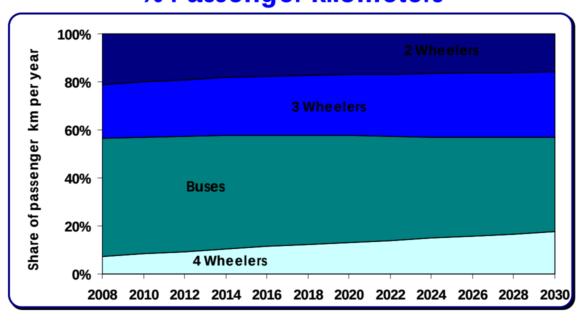
Bangalore, India



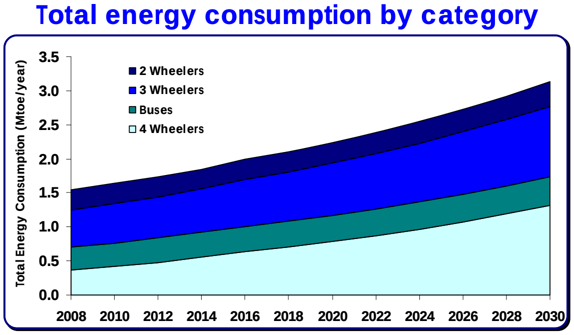
Number of Vehicles



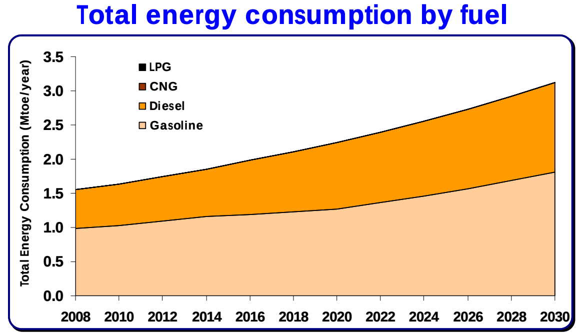
% Passenger kilometers



Total energy consumption by category



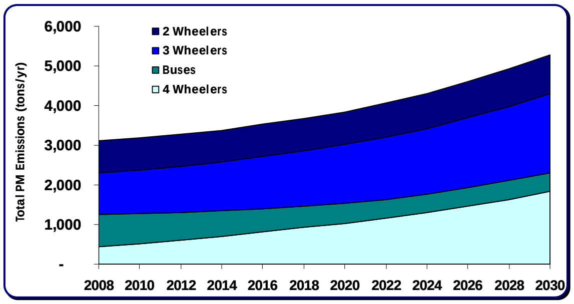
Total energy consumption by fuel



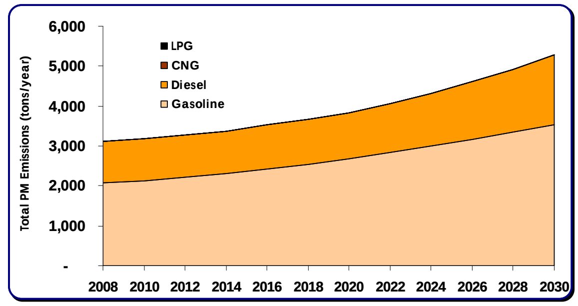
Bangalore, India

Total emissions by category	Total emissions by fuel

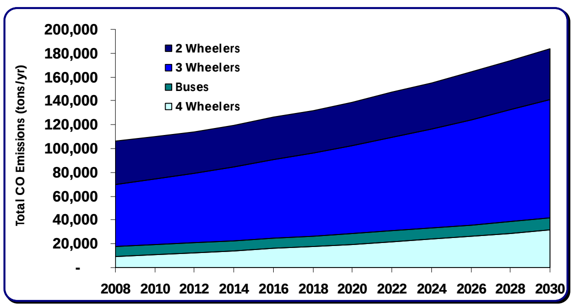
Particulate Matter < 2.5μm



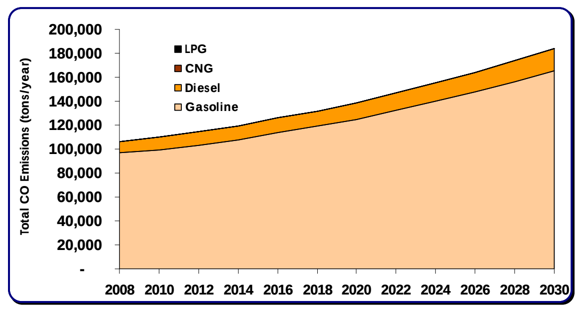
Particulate Matter < 2.5μm



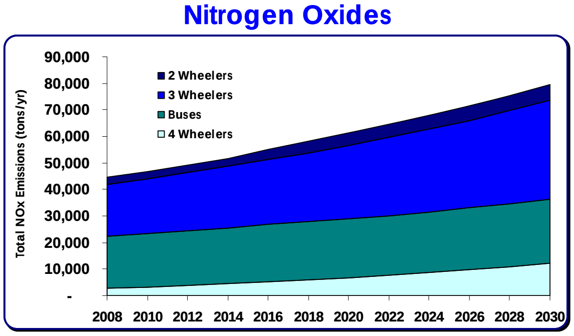
Carbon Monoxide



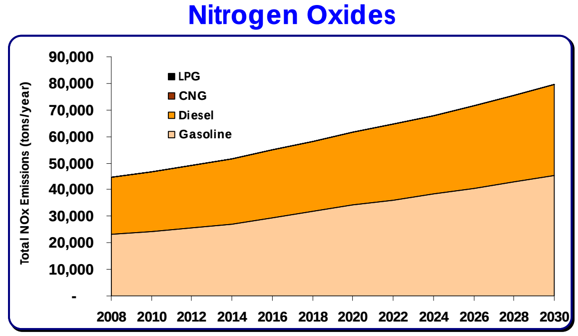
Carbon Monoxide



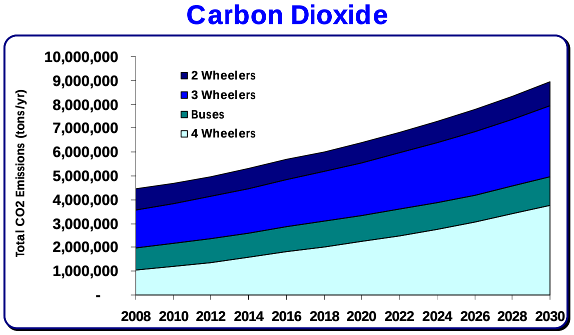
Nitrogen Oxides



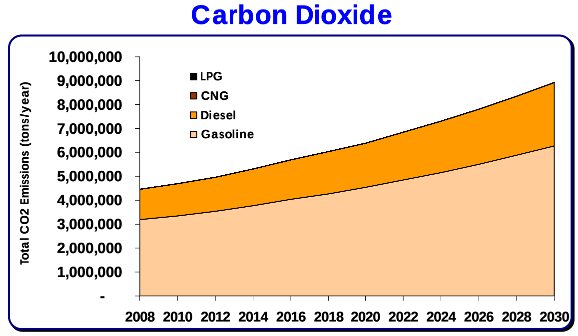
Nitrogen Oxides



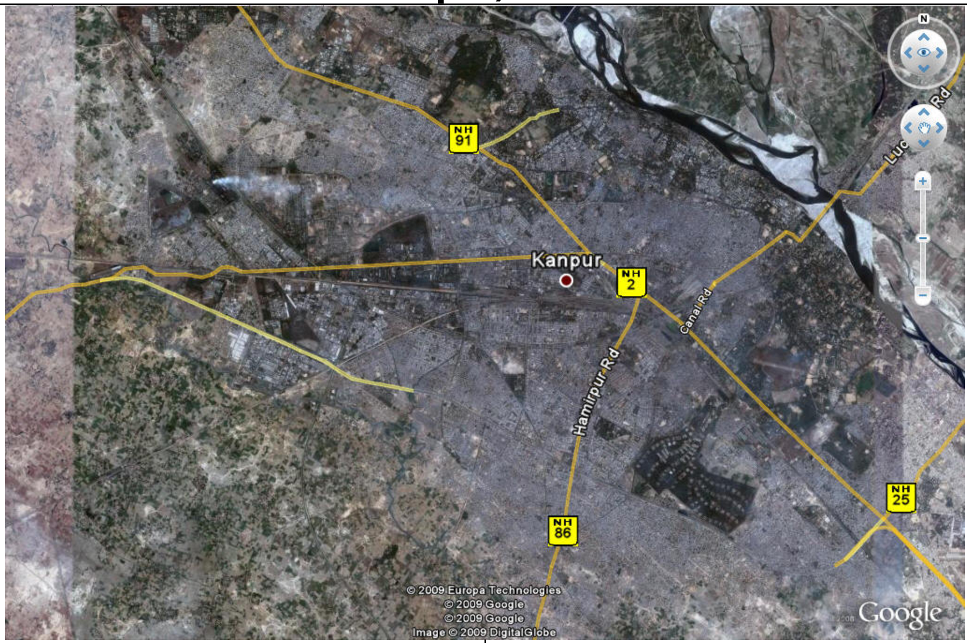
Carbon Dioxide



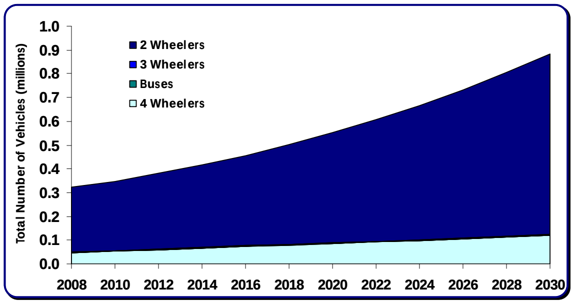
Carbon Dioxide



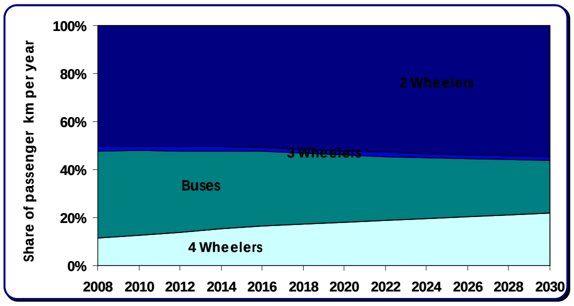
Kanpur, India



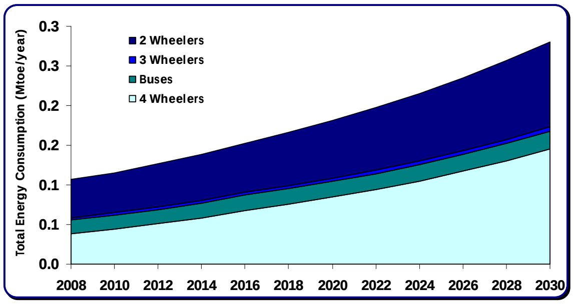
Number of Vehicles



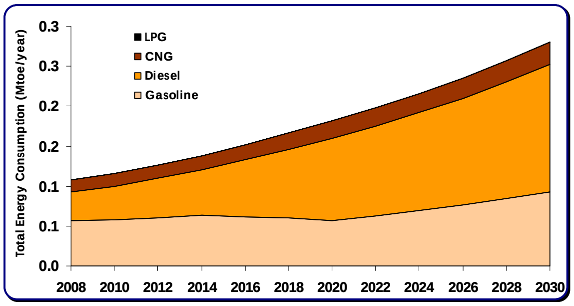
% Passenger kilometers



Total energy consumption by category



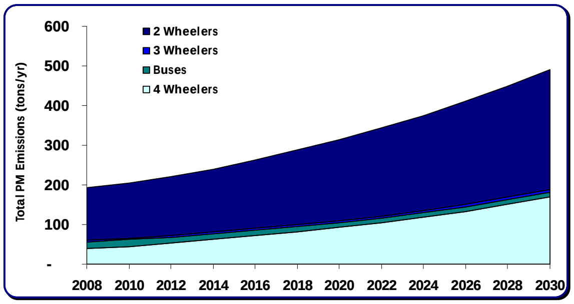
Total energy consumption by fuel



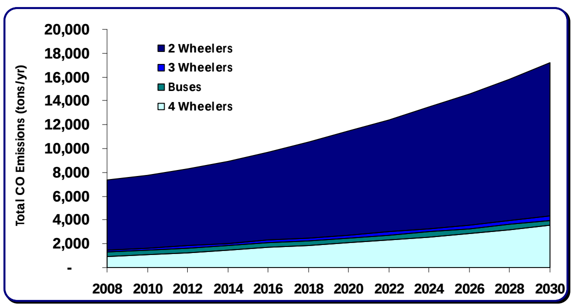
Kanpur, India

Total emissions by category	Total emissions by fuel

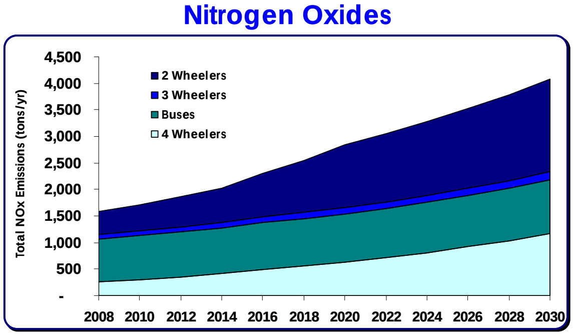
Particulate Matter < 2.5μm



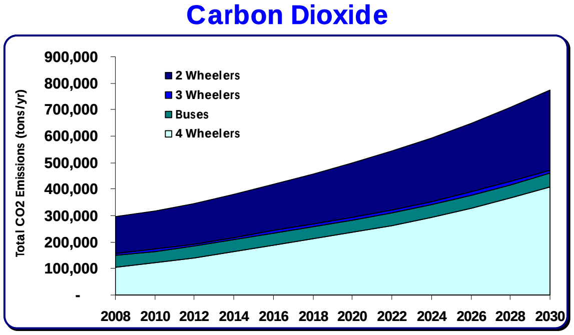
Carbon Monoxide



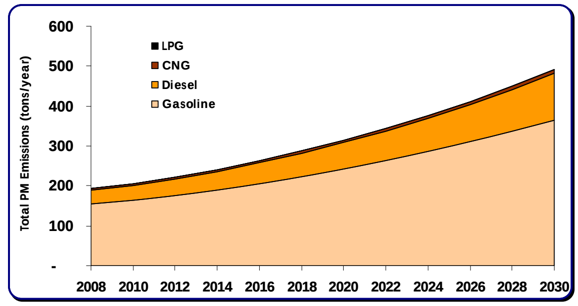
Nitrogen Oxides



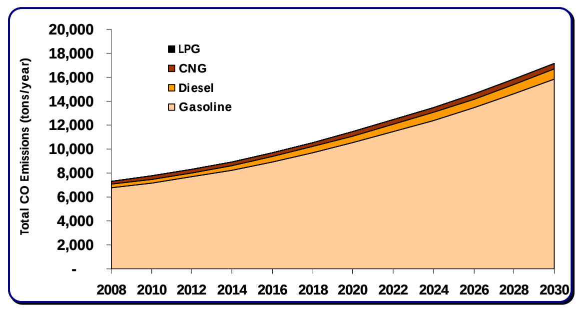
Carbon Dioxide



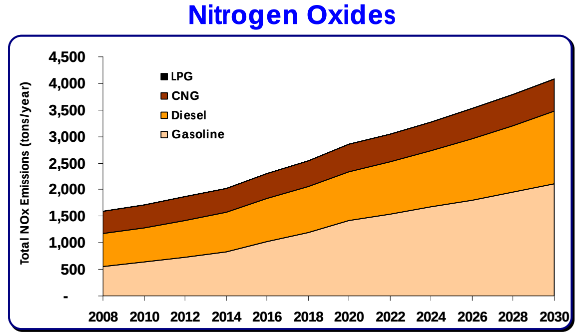
Particulate Matter < 2.5μm



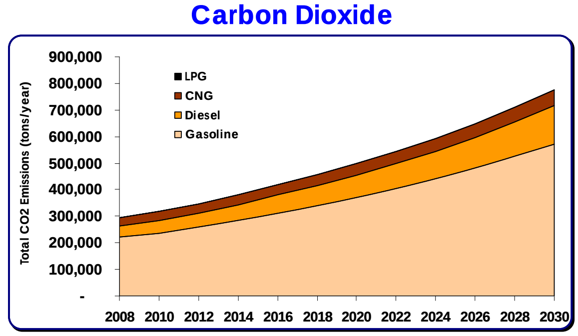
Carbon Monoxide



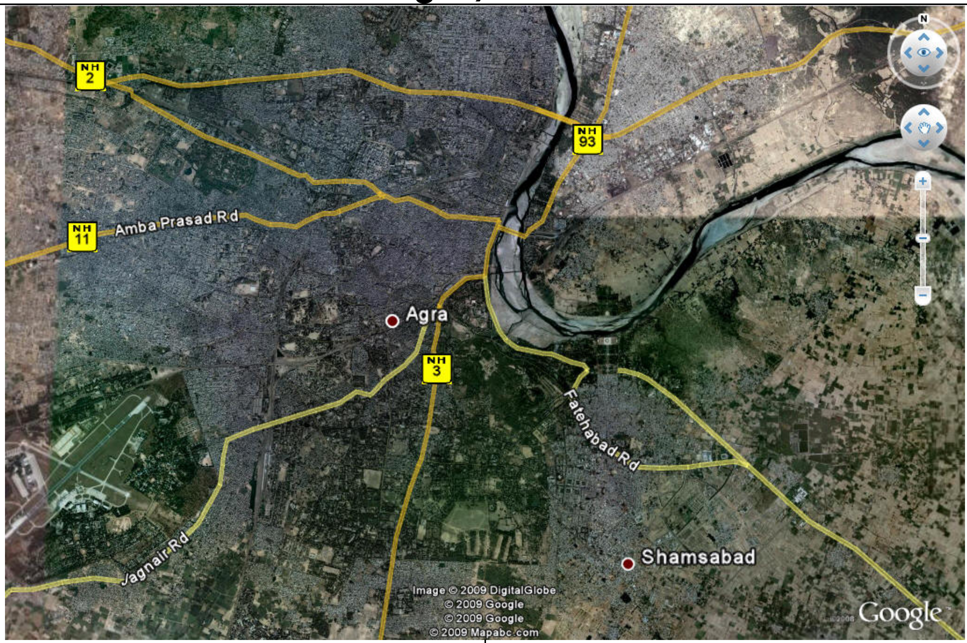
Nitrogen Oxides



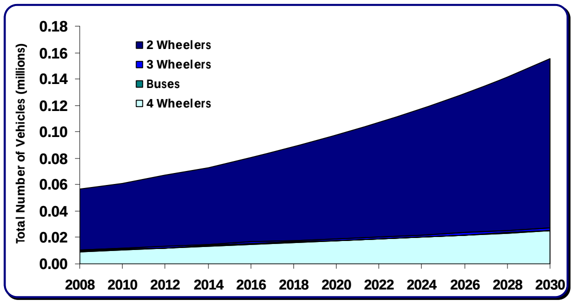
Carbon Dioxide



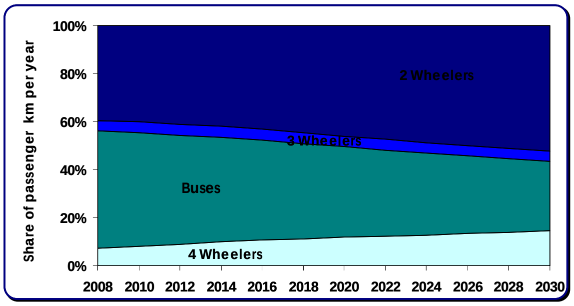
Agra, India



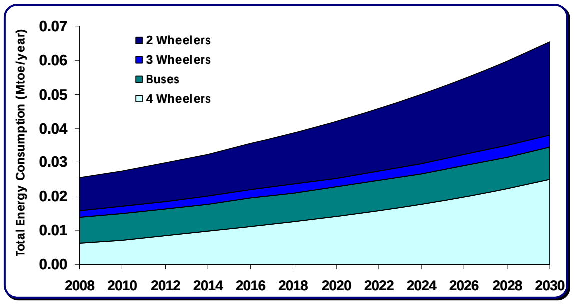
Number of Vehicles



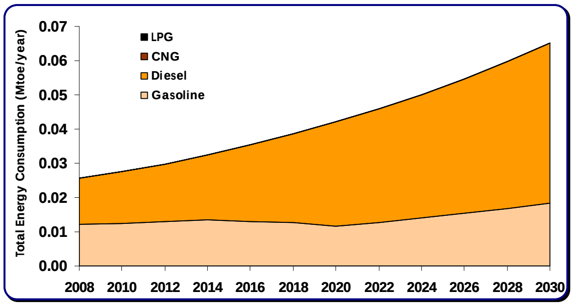
% Passenger kilometers



Total energy consumption by category



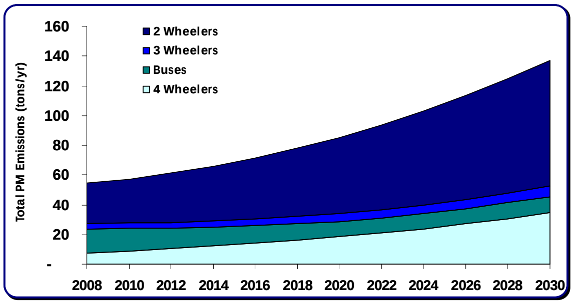
Total energy consumption by fuel



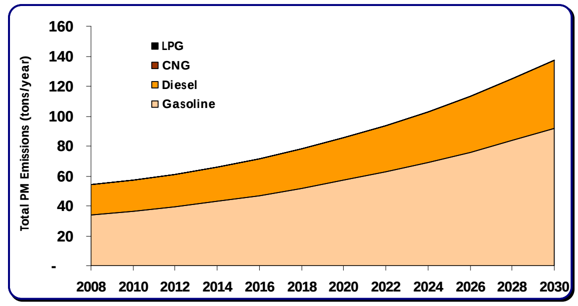
Agra, India

Total emissions by category	Total emissions by fuel

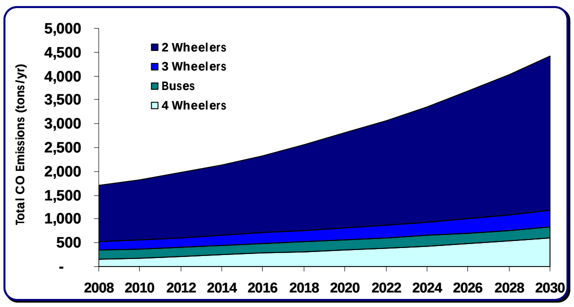
Particulate Matter < 2.5μm



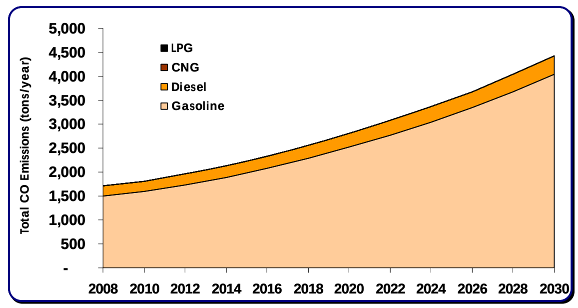
Particulate Matter < 2.5μm



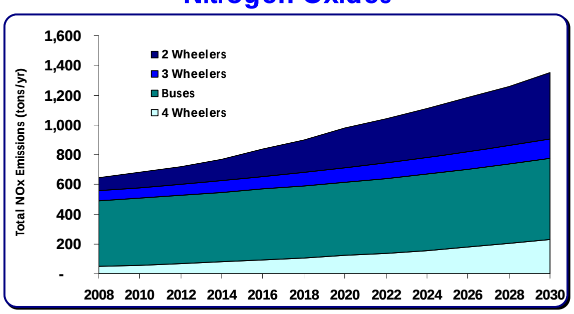
Carbon Monoxide



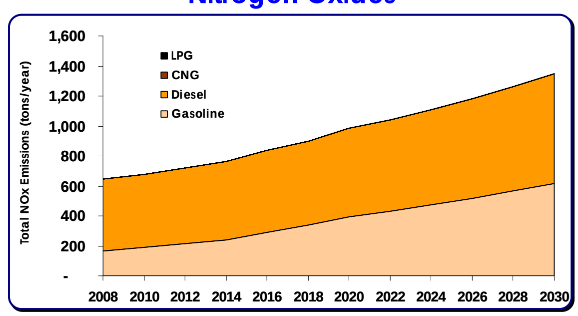
Carbon Monoxide



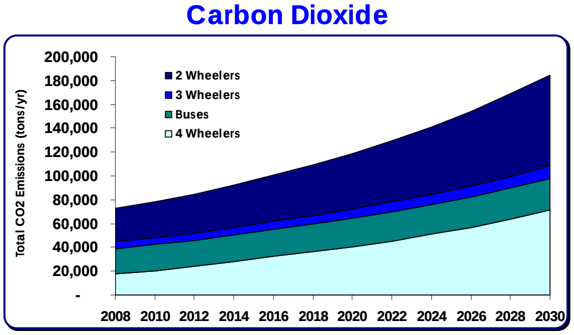
Nitrogen Oxides



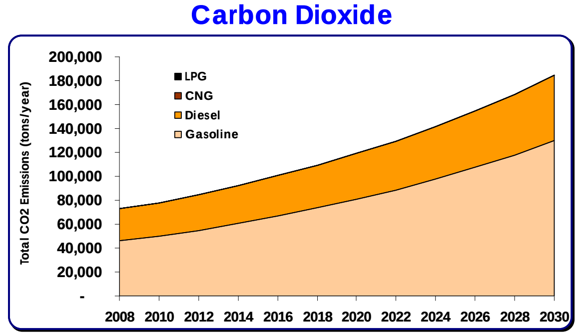
Nitrogen Oxides



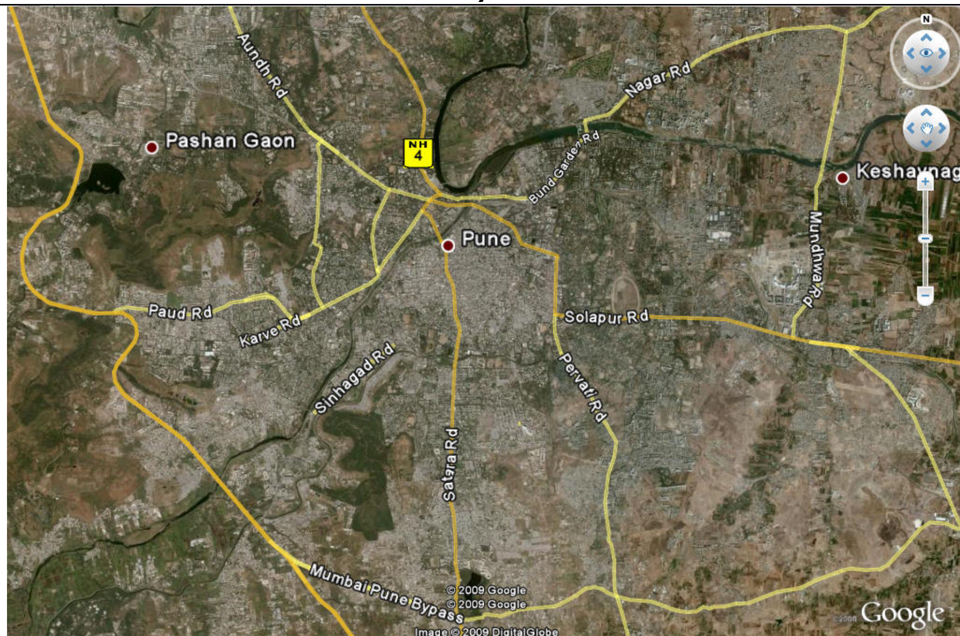
Carbon Dioxide



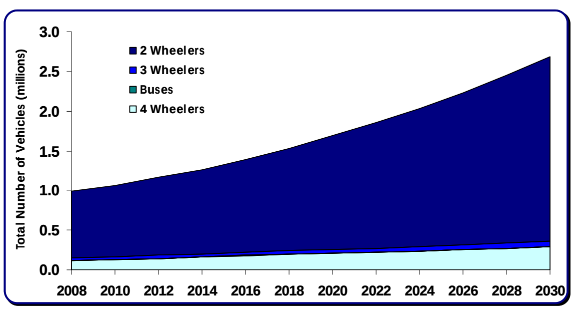
Carbon Dioxide



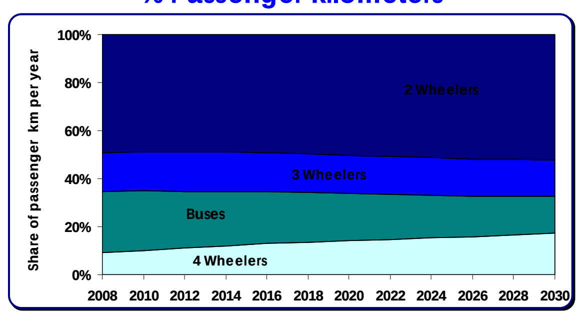
Pune, India



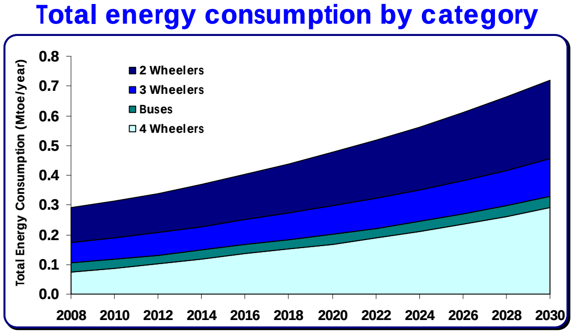
Number of Vehicles



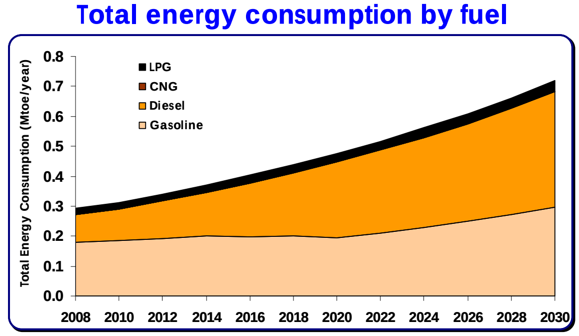
% Passenger kilometers



Total energy consumption by category



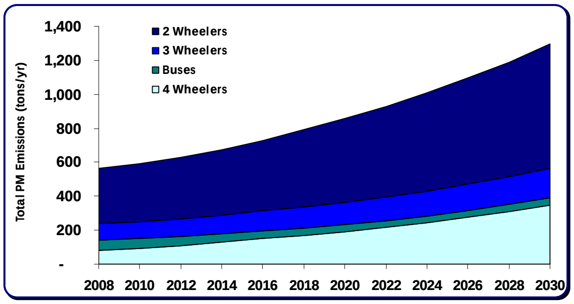
Total energy consumption by fuel



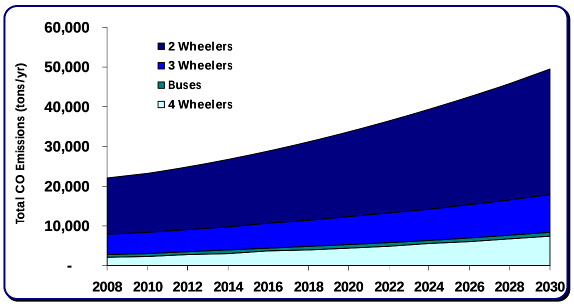
Pune, India

Total emissions by category	Total emissions by fuel

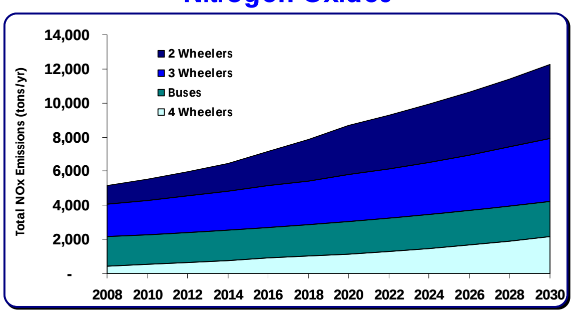
Particulate Matter < 2.5μm



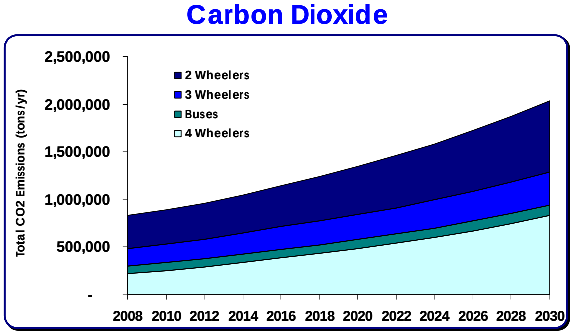
Carbon Monoxide



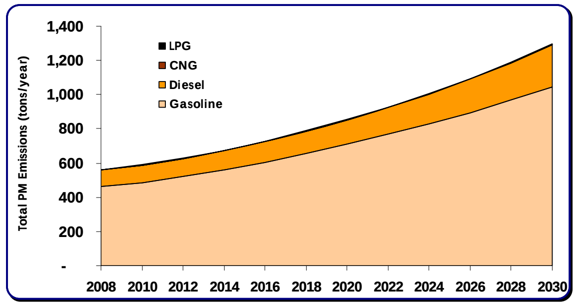
Nitrogen Oxides



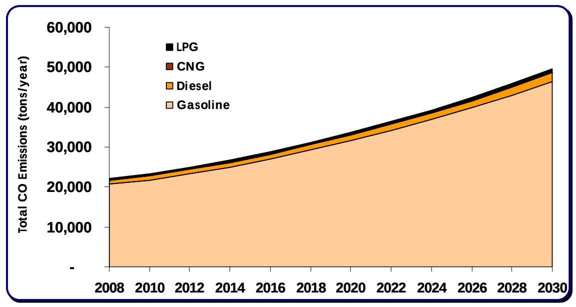
Carbon Dioxide



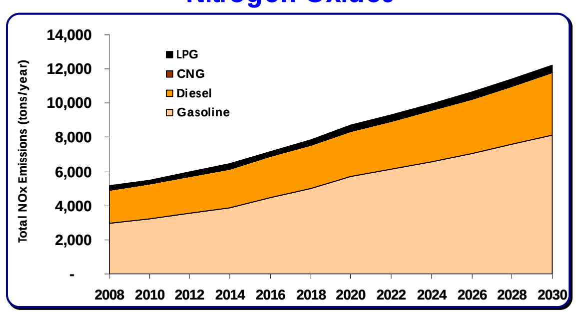
Particulate Matter < 2.5μm



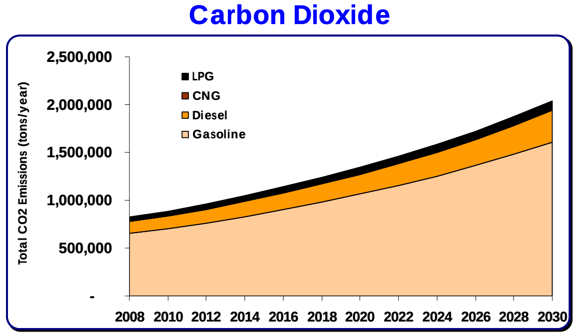
Carbon Monoxide



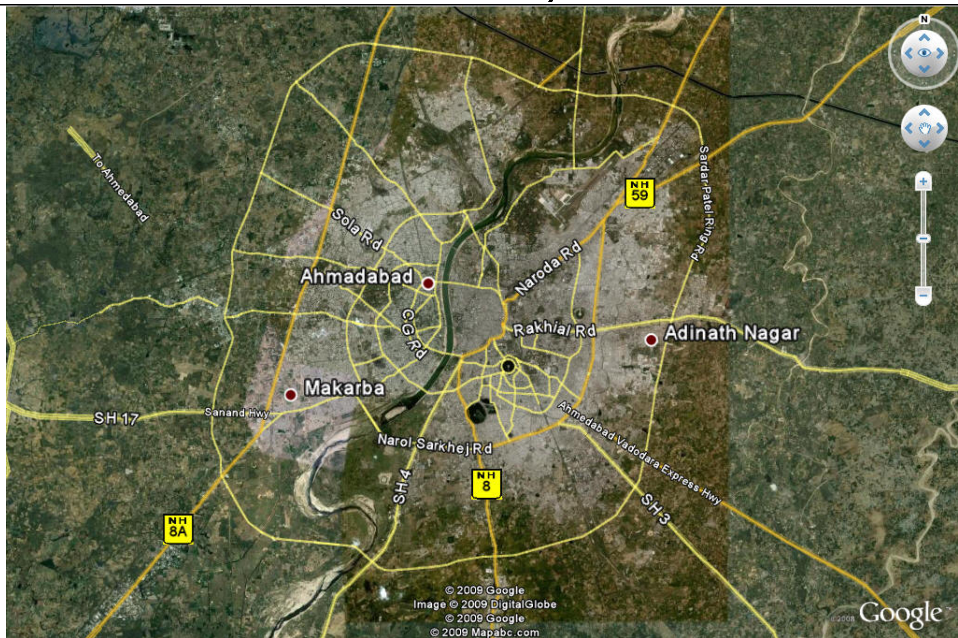
Nitrogen Oxides



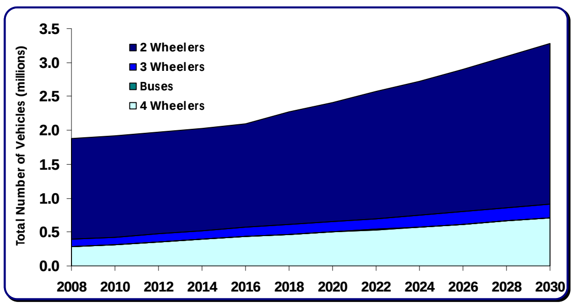
Carbon Dioxide



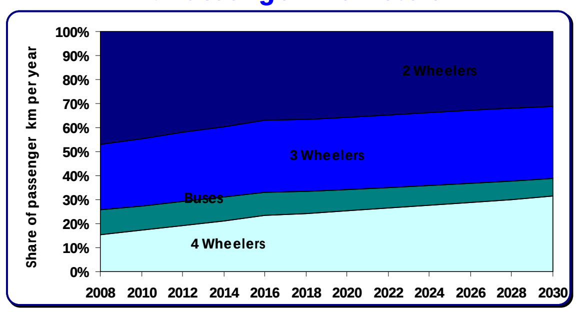
Ahmedabad, India



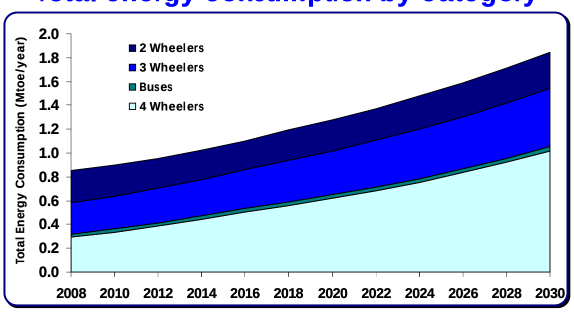
Number of Vehicles



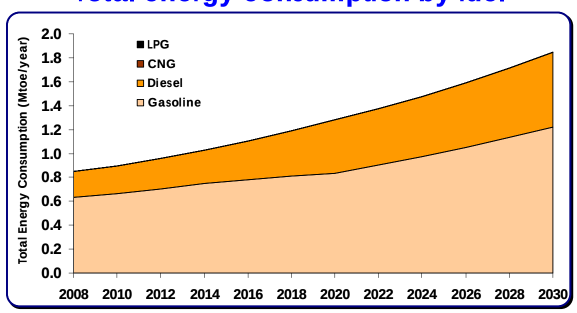
% Passenger kilometers



Total energy consumption by category



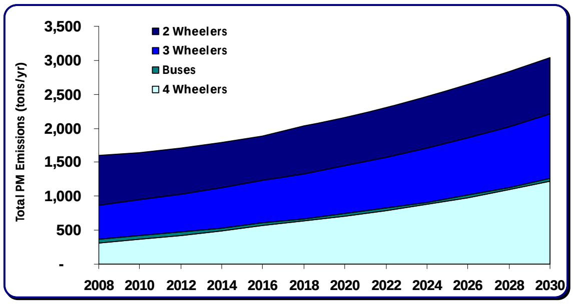
Total energy consumption by fuel



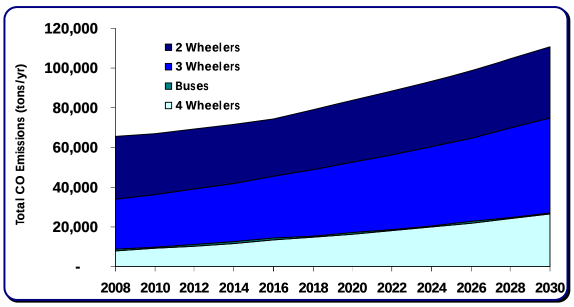
Ahmedabad, India	
Total emissions by category	Total emissions by fuel

Total emissions by category

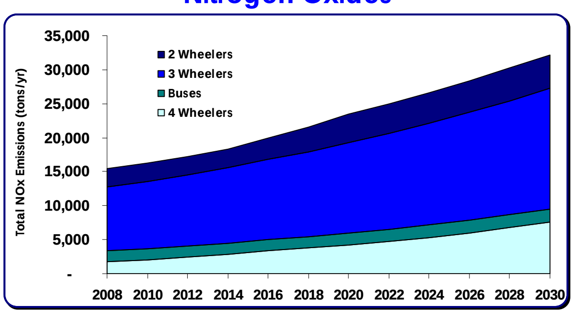
Particulate Matter < 2.5µm



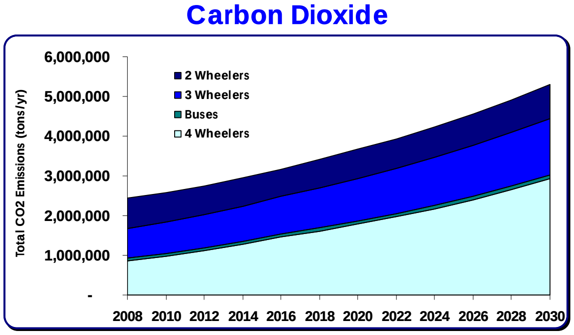
Carbon Monoxide



Nitrogen Oxides

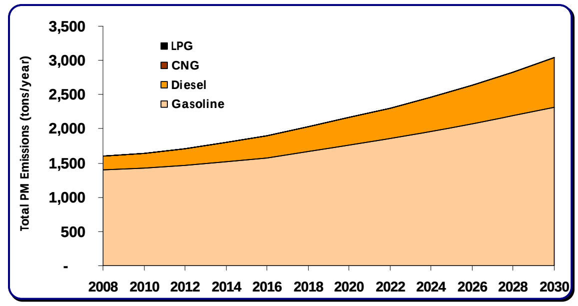


Carbon Dioxide

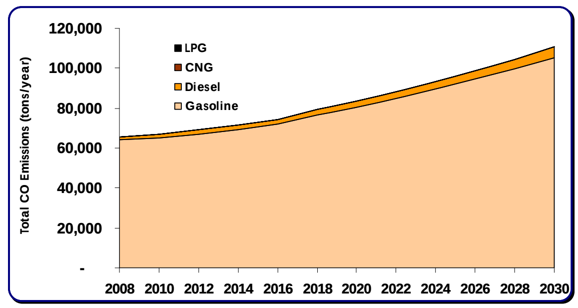


Total emissions by fuel

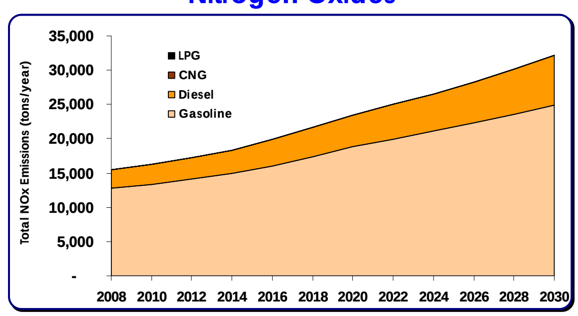
Particulate Matter < 2.5µm



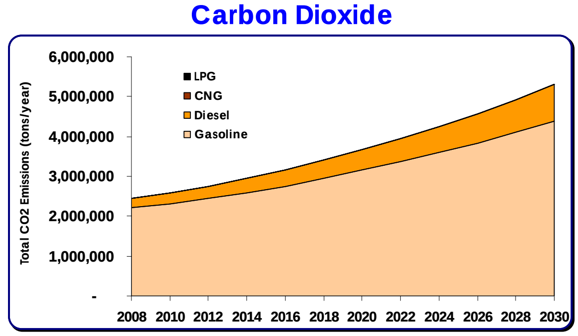
Carbon Monoxide



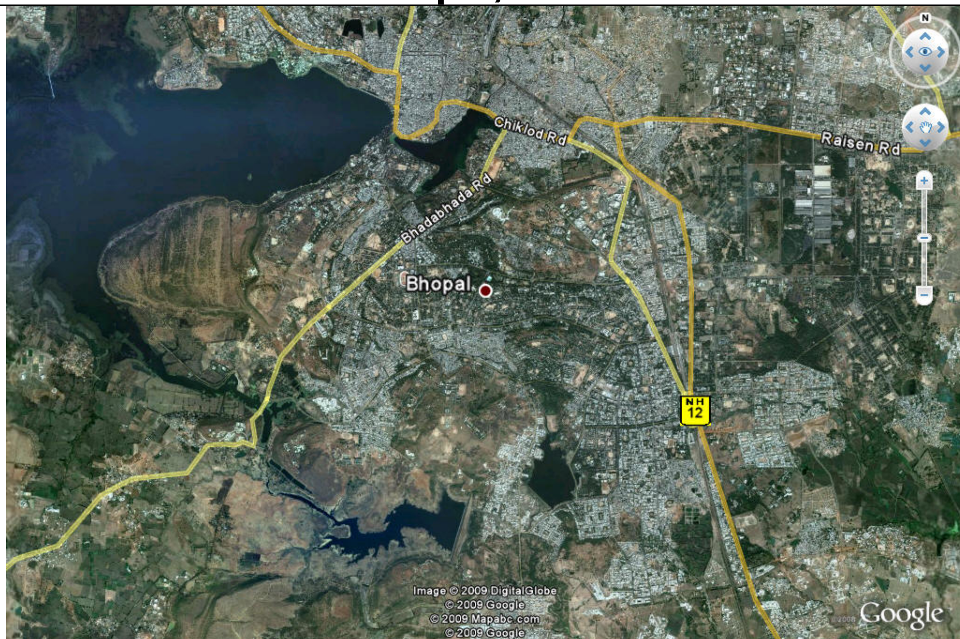
Nitrogen Oxides



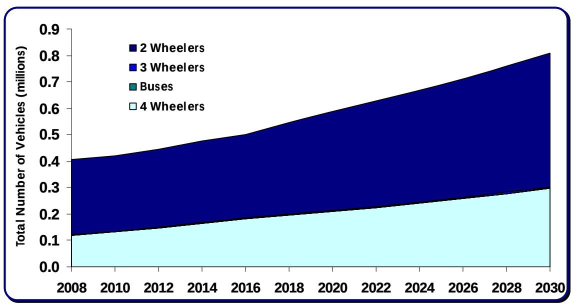
Carbon Dioxide



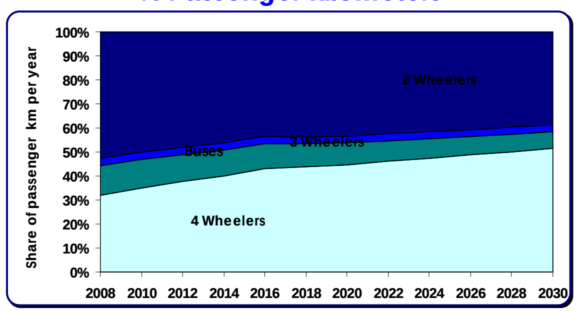
Bhopal, India



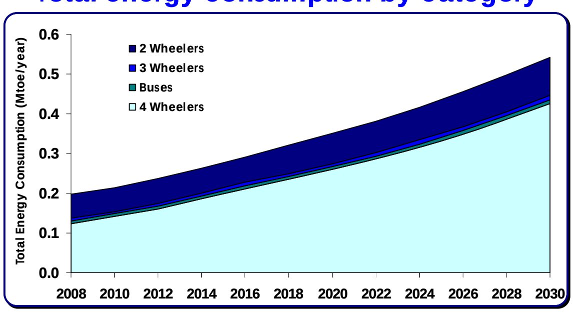
Number of Vehicles



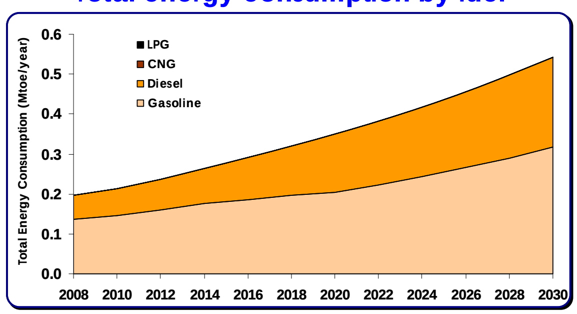
% Passenger kilometers



Total energy consumption by category



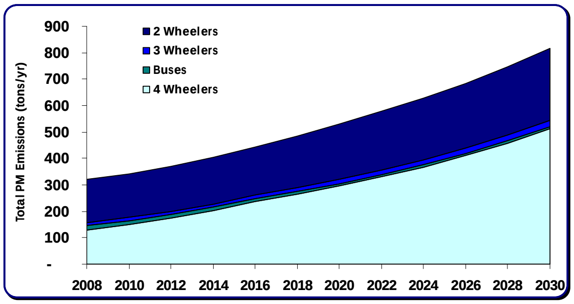
Total energy consumption by fuel



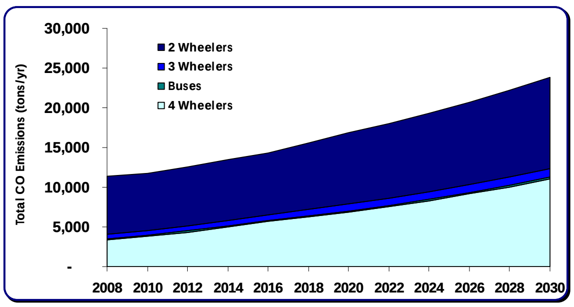
Bhopal, India

Total emissions by category	Total emissions by fuel

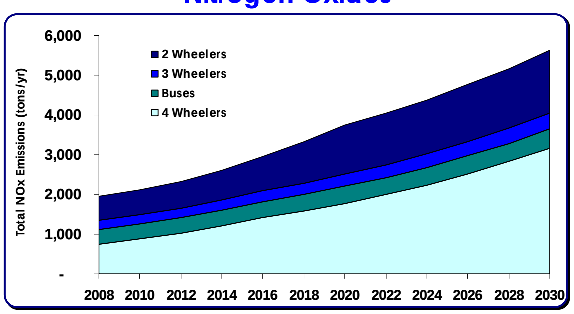
Particulate Matter < 2.5µm



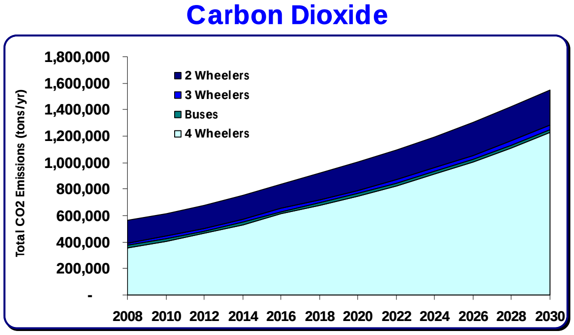
Carbon Monoxide



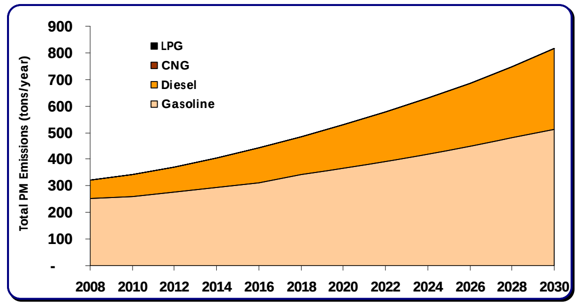
Nitrogen Oxides



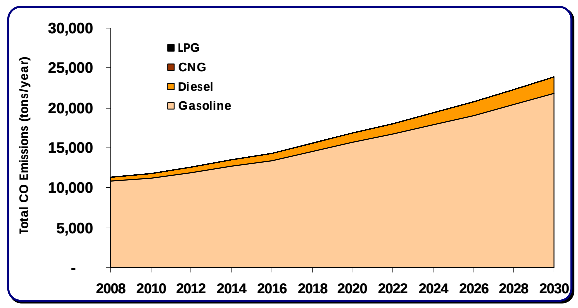
Carbon Dioxide



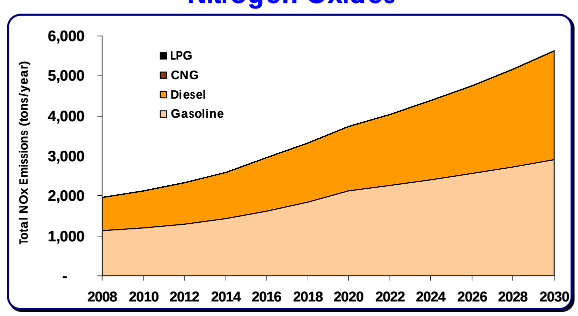
Particulate Matter < 2.5µm



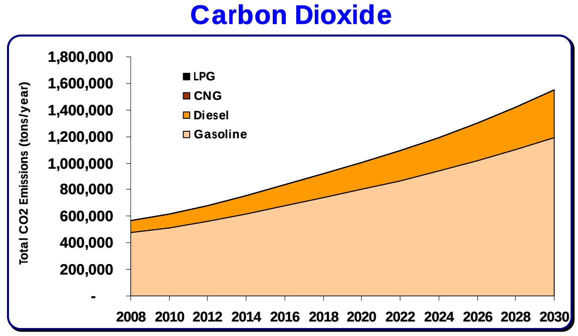
Carbon Monoxide



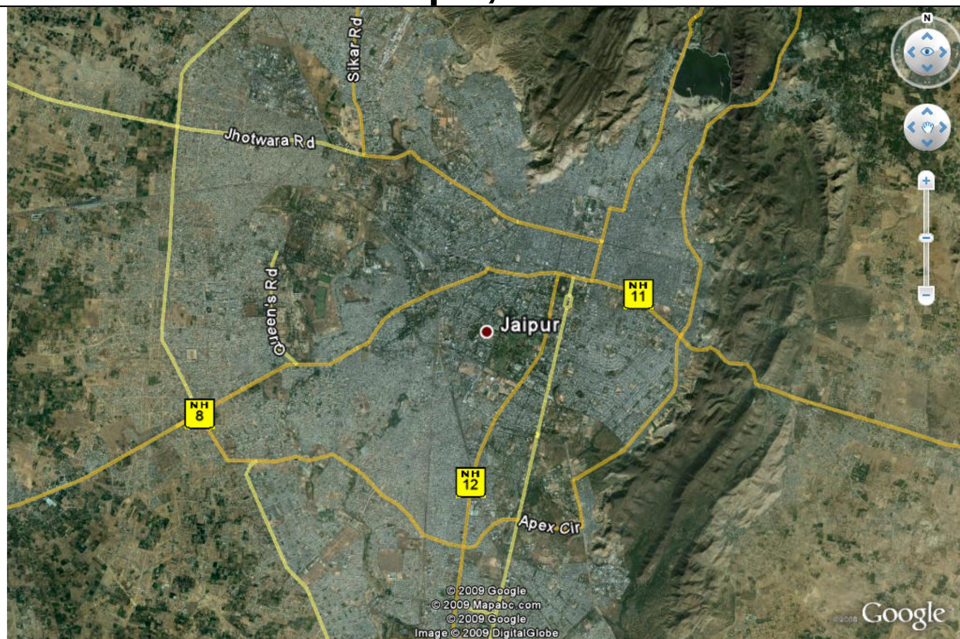
Nitrogen Oxides



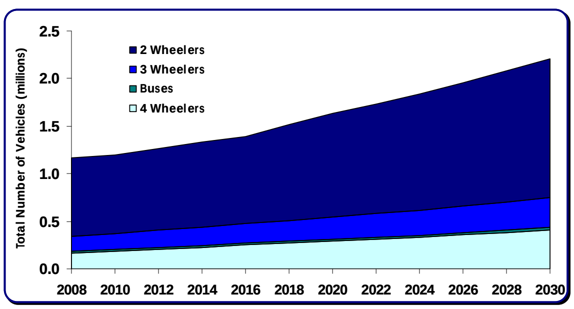
Carbon Dioxide



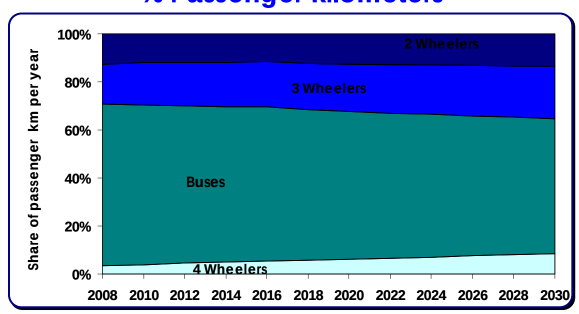
Jaipur, India



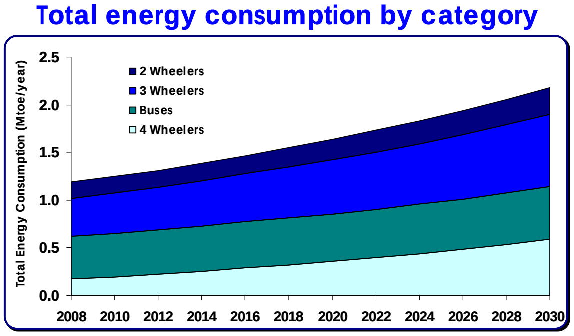
Number of Vehicles



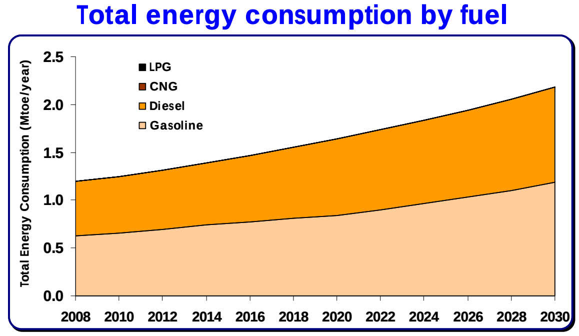
% Passenger kilometers



Total energy consumption by category



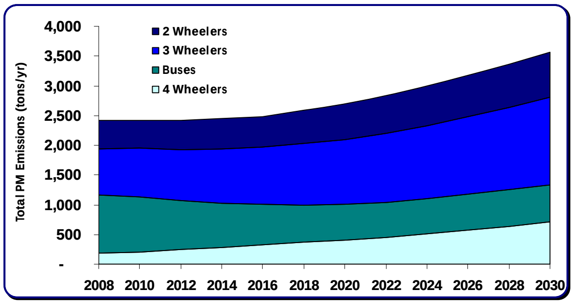
Total energy consumption by fuel



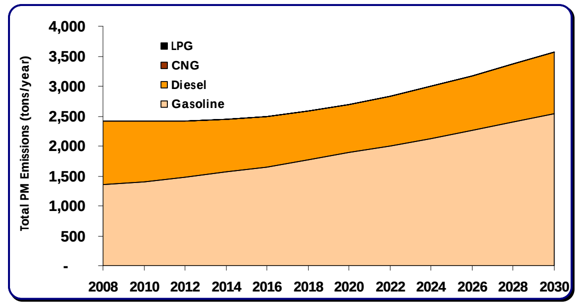
Jaipur, India

Total emissions by category	Total emissions by fuel

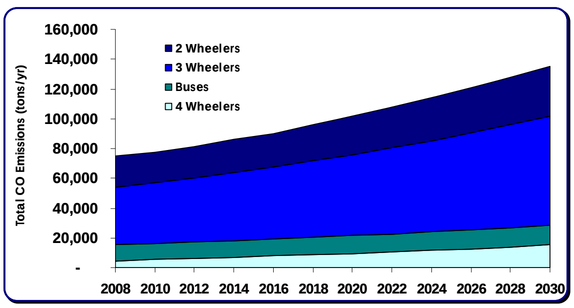
Particulate Matter < 2.5µm



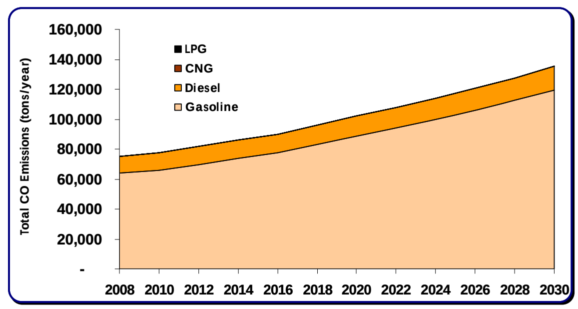
Particulate Matter < 2.5µm



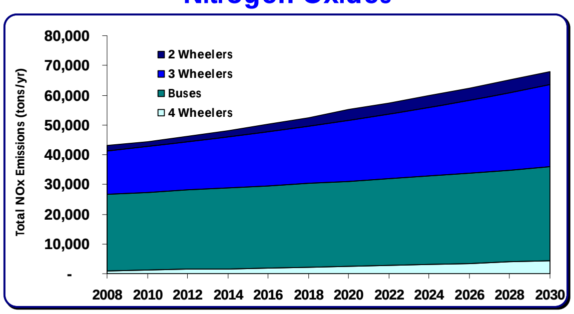
Carbon Monoxide



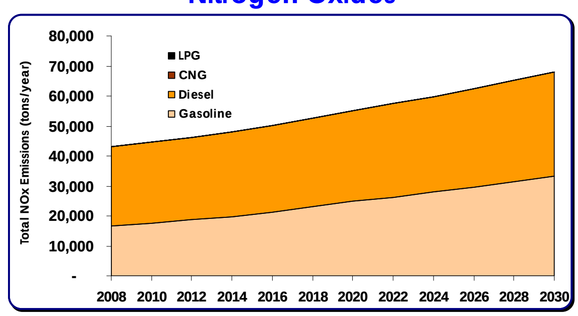
Carbon Monoxide



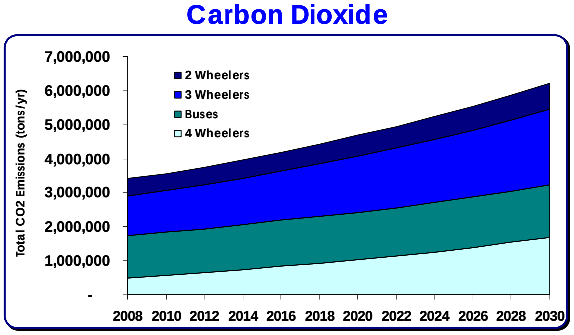
Nitrogen Oxides



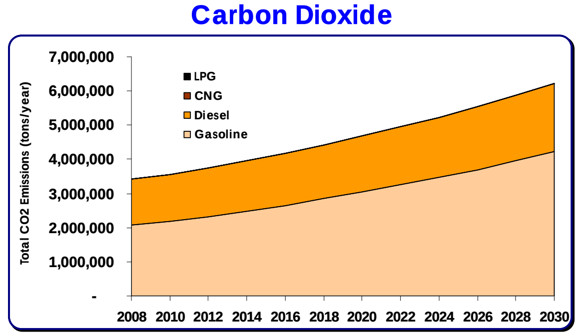
Nitrogen Oxides



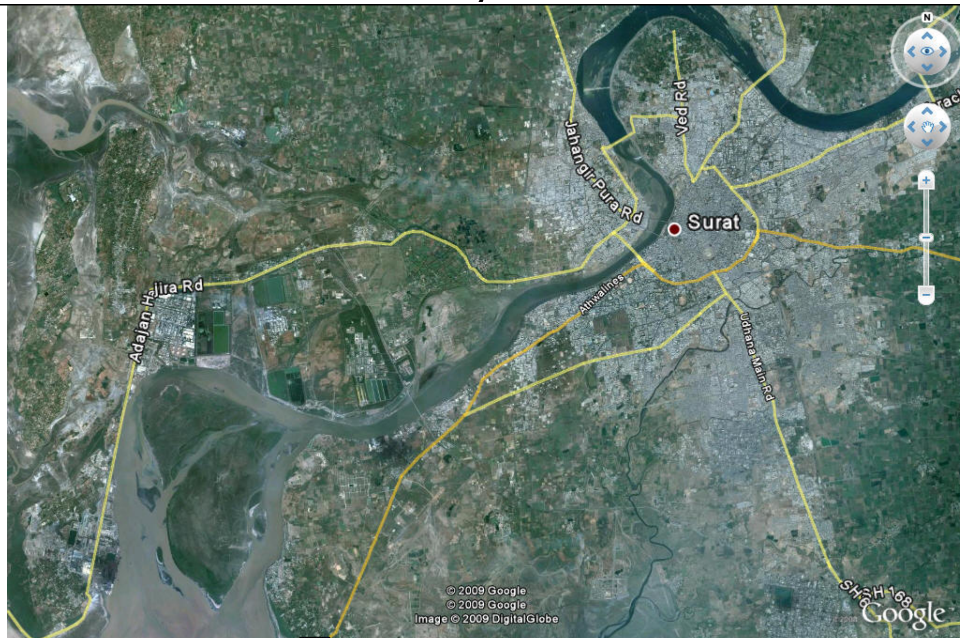
Carbon Dioxide



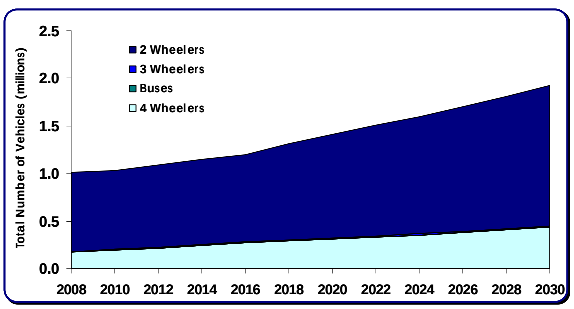
Carbon Dioxide



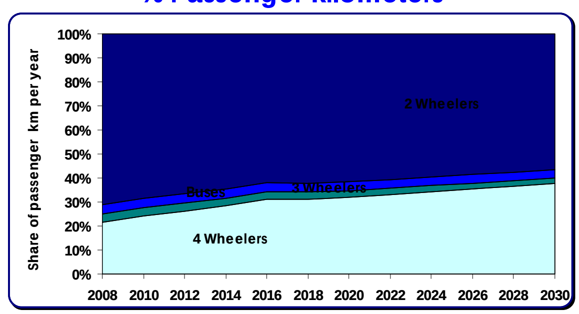
Surat, India



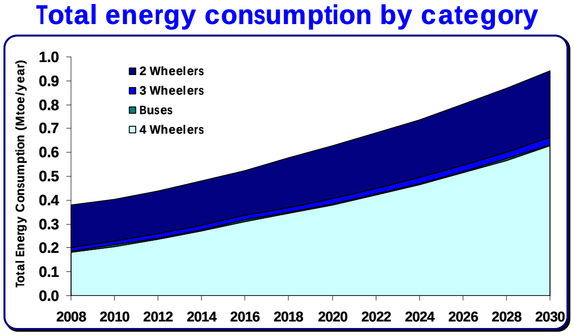
Number of Vehicles



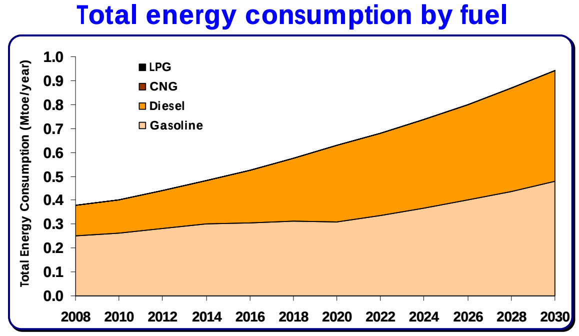
% Passenger kilometers



Total energy consumption by category



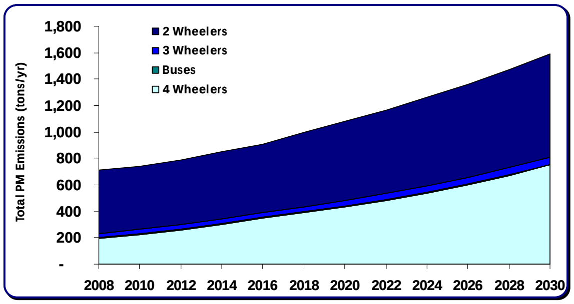
Total energy consumption by fuel



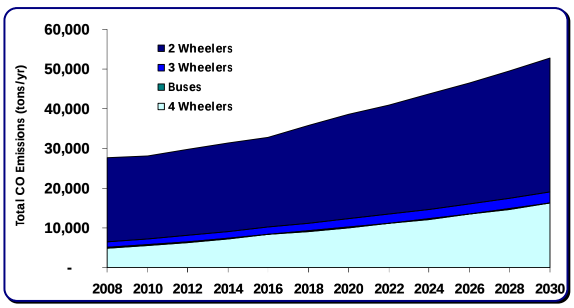
Surat, India

Total emissions by category

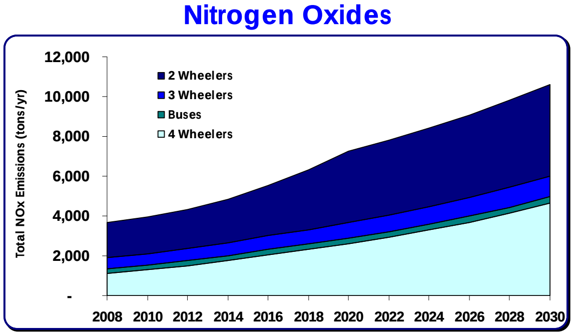
Particulate Matter < 2.5μm



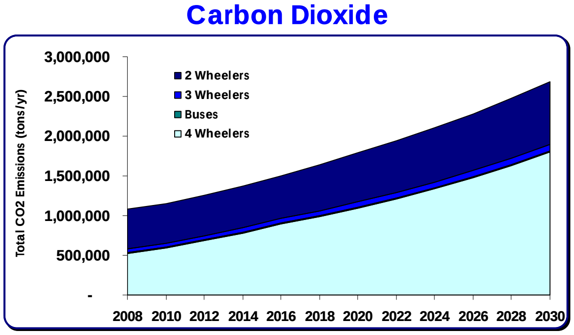
Carbon Monoxide



Nitrogen Oxides

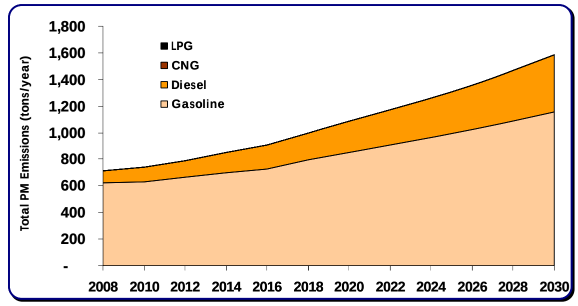


Carbon Dioxide

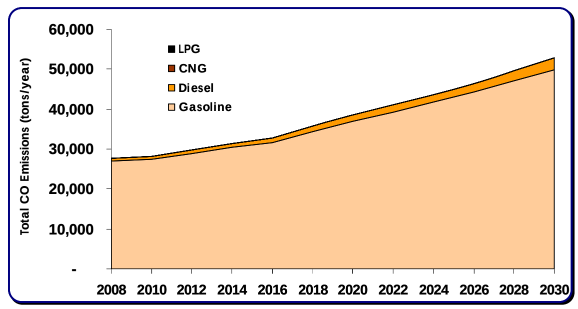


Total emissions by fuel

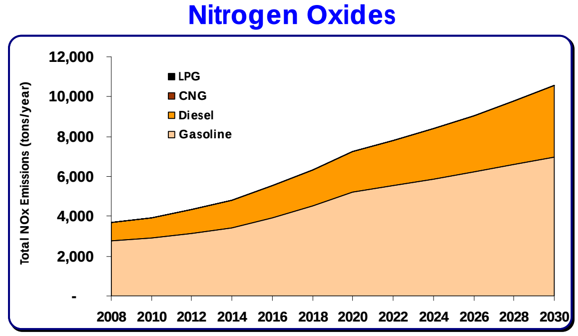
Particulate Matter < 2.5μm



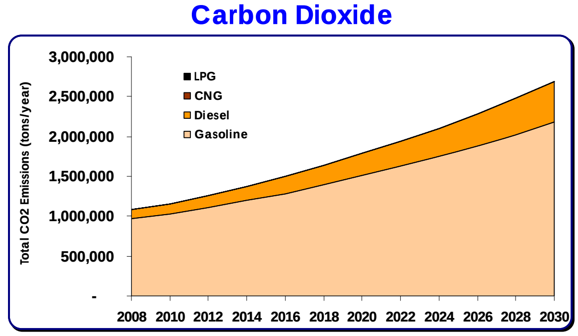
Carbon Monoxide



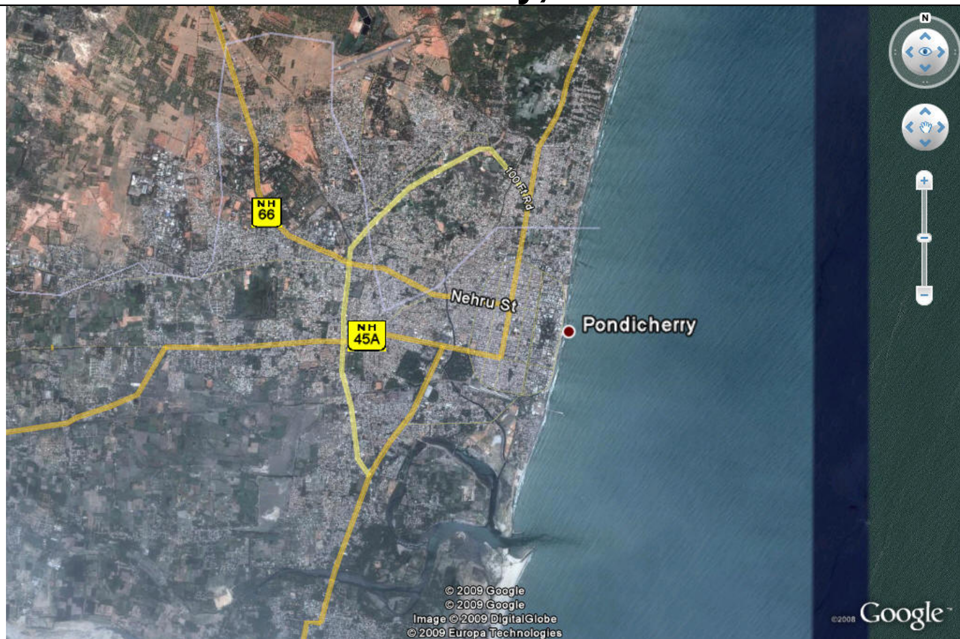
Nitrogen Oxides



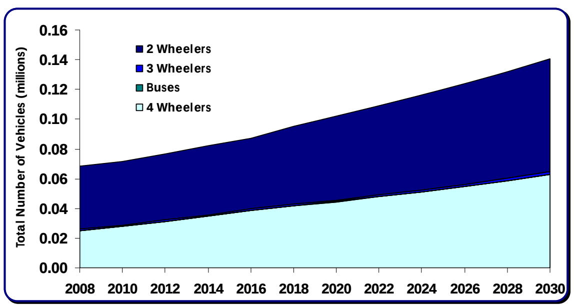
Carbon Dioxide



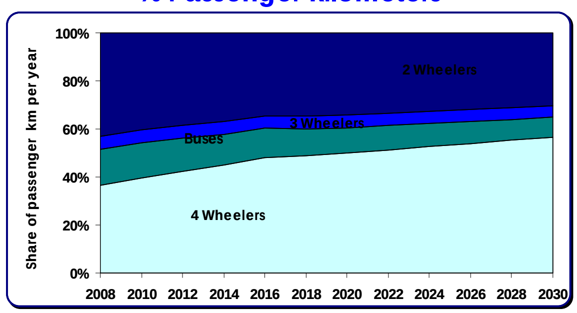
Pondicherry, India



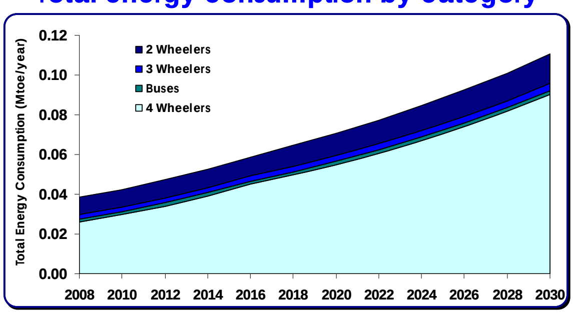
Number of Vehicles



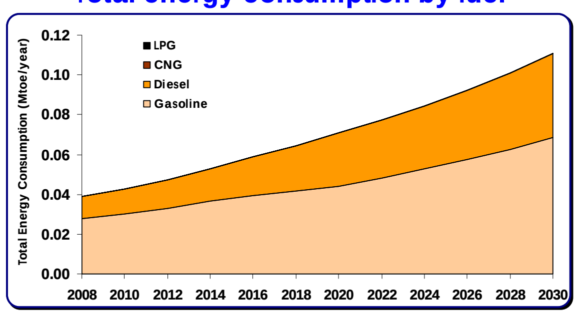
% Passenger kilometers



Total energy consumption by category



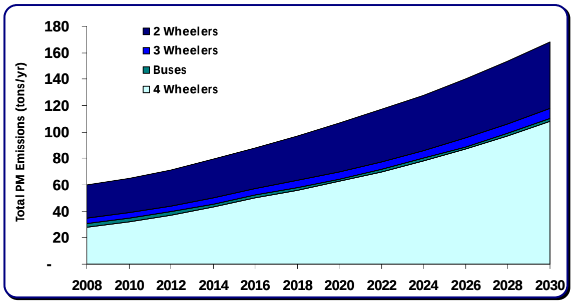
Total energy consumption by fuel



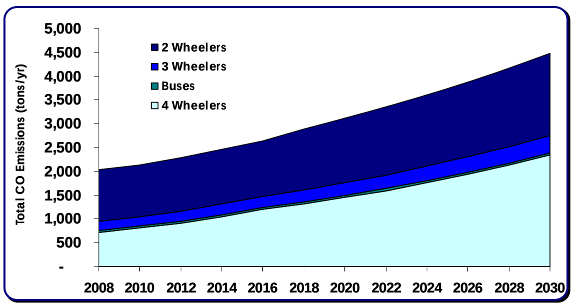
Pondicherry, India

Total emissions by category

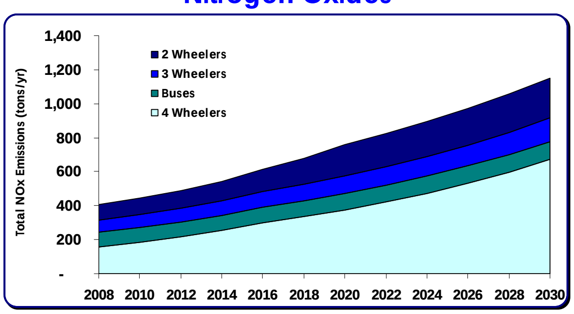
Particulate Matter < 2.5µm



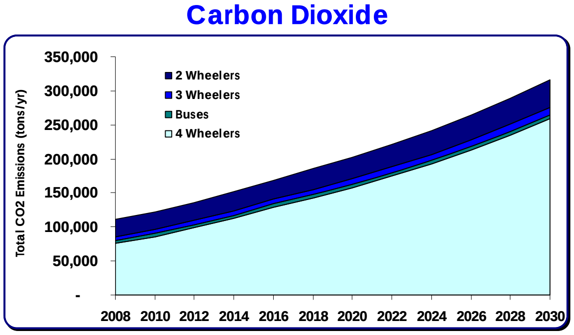
Carbon Monoxide



Nitrogen Oxides

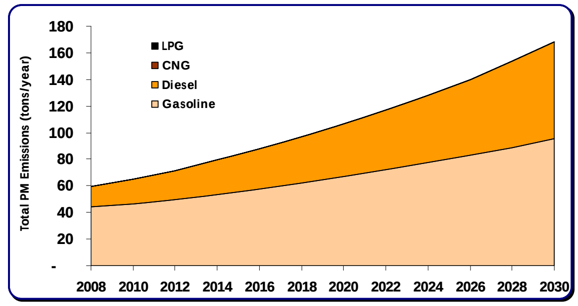


Carbon Dioxide

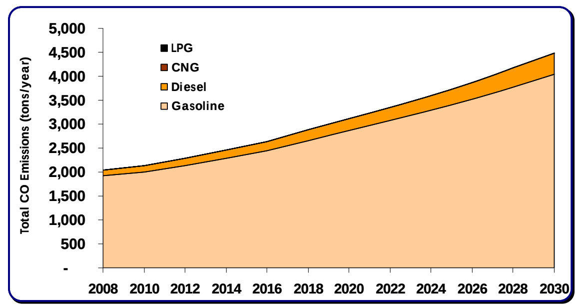


Total emissions by fuel

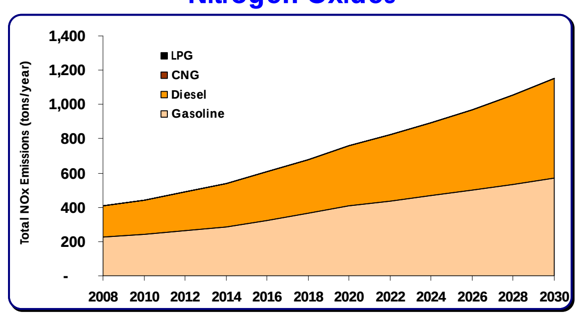
Particulate Matter < 2.5µm



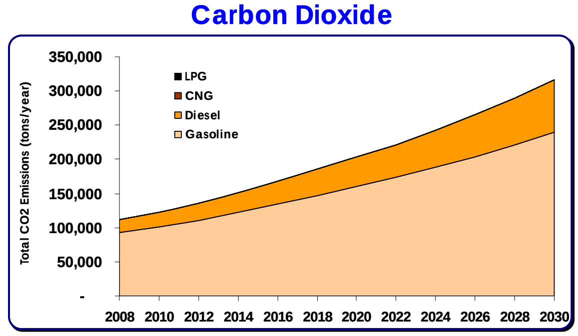
Carbon Monoxide



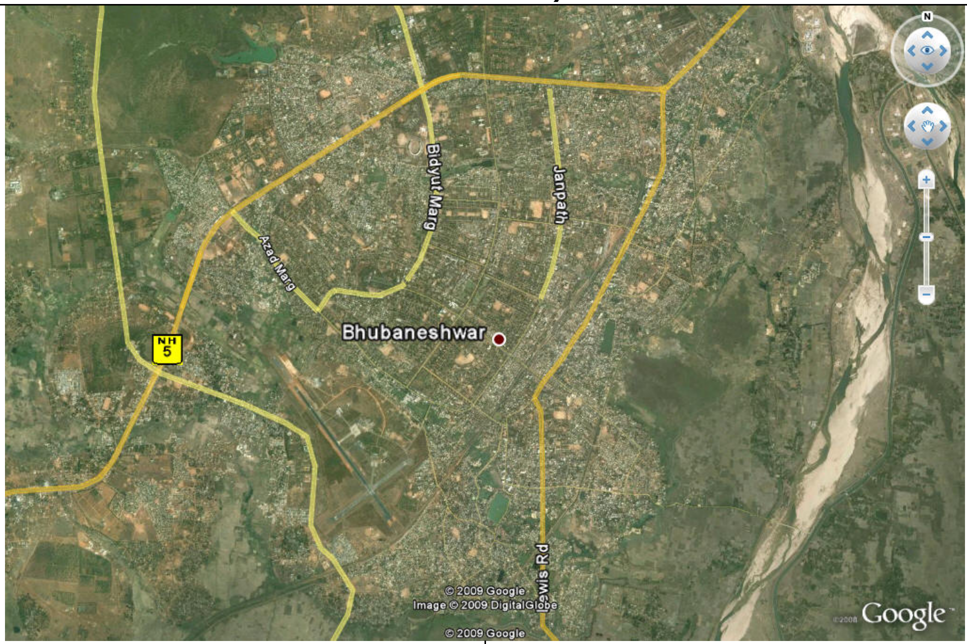
Nitrogen Oxides



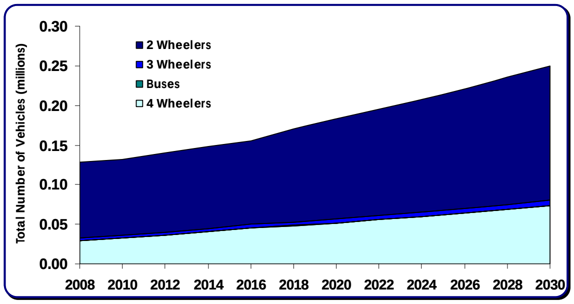
Carbon Dioxide



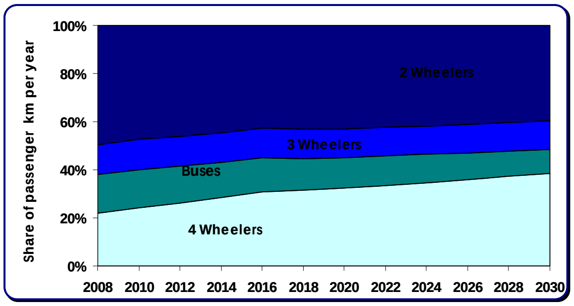
Bhubaneswar, India



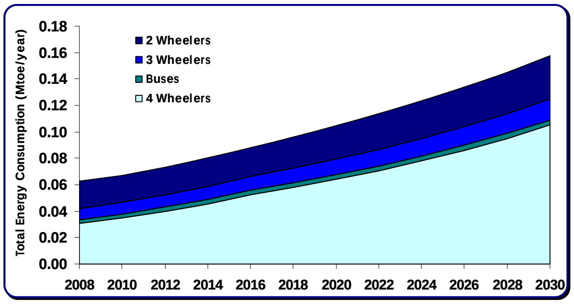
Number of Vehicles



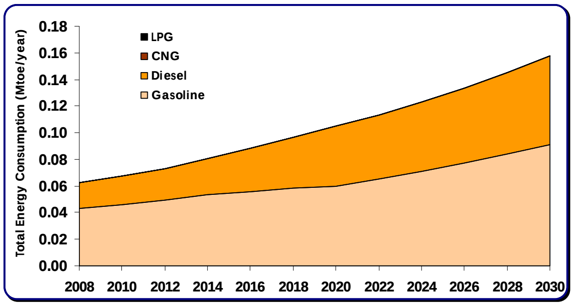
% Passenger kilometers



Total energy consumption by category



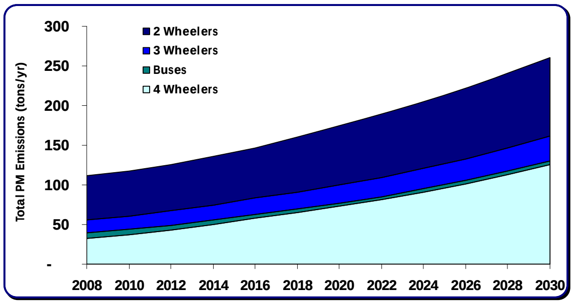
Total energy consumption by fuel



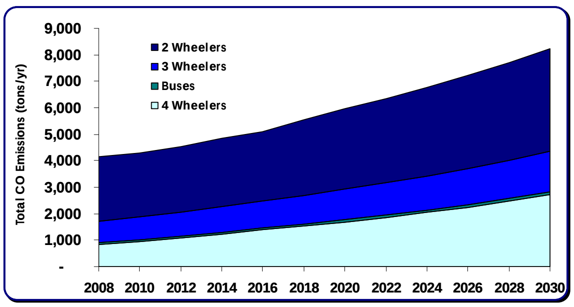
Bhubaneswar, India

Total emissions by category

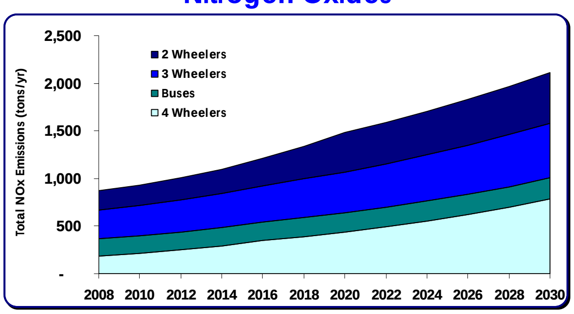
Particulate Matter < 2.5µm



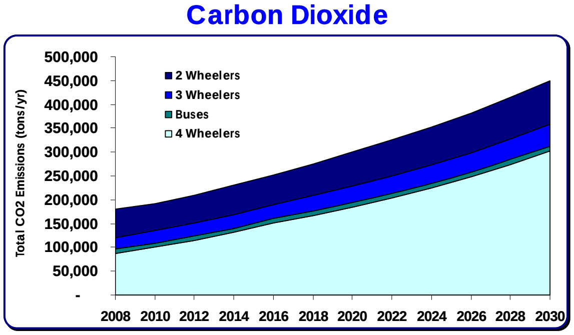
Carbon Monoxide



Nitrogen Oxides

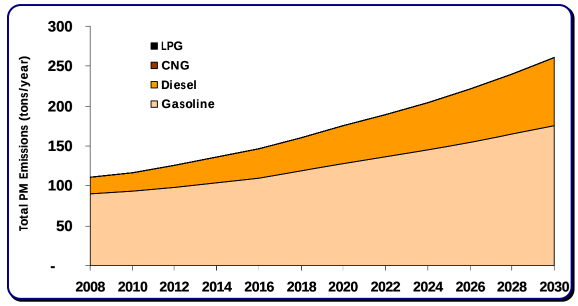


Carbon Dioxide

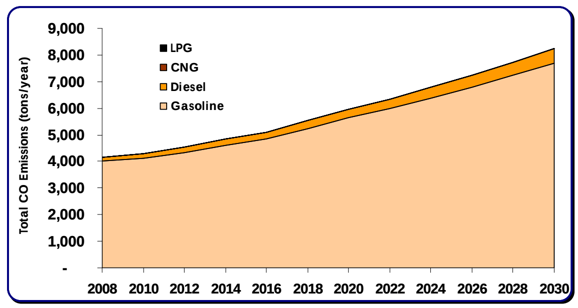


Total emissions by fuel

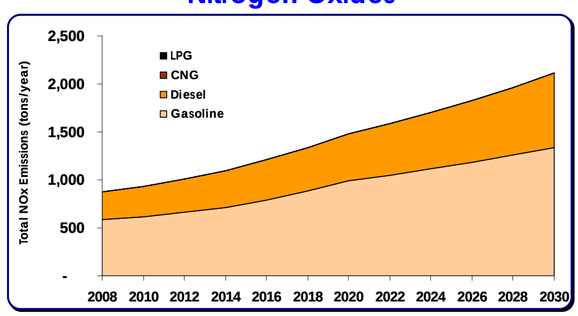
Particulate Matter < 2.5µm



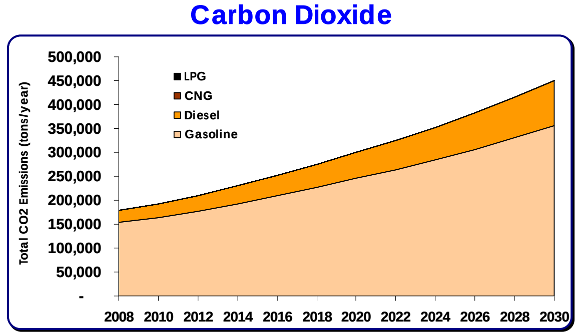
Carbon Monoxide



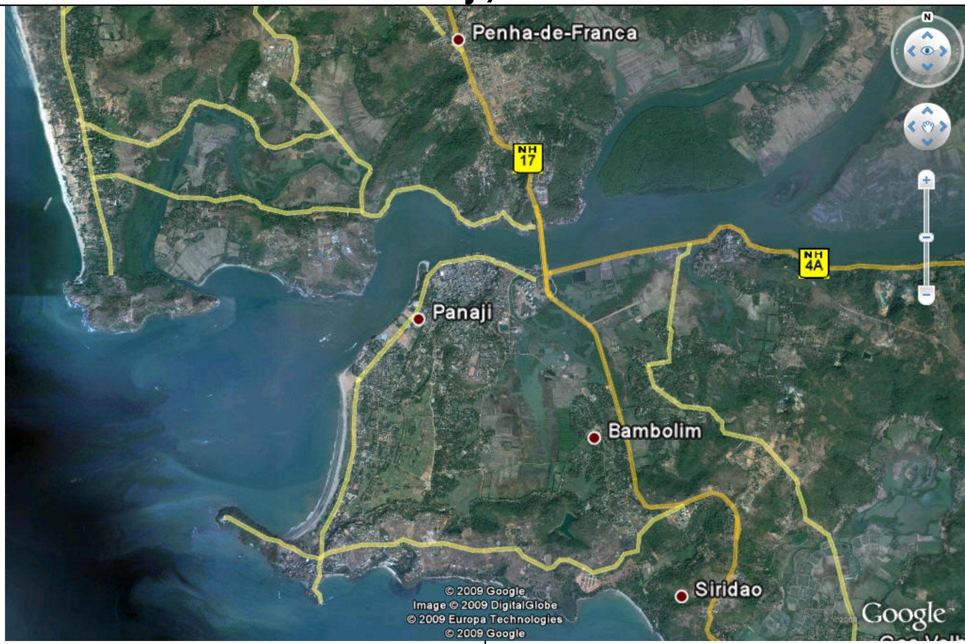
Nitrogen Oxides



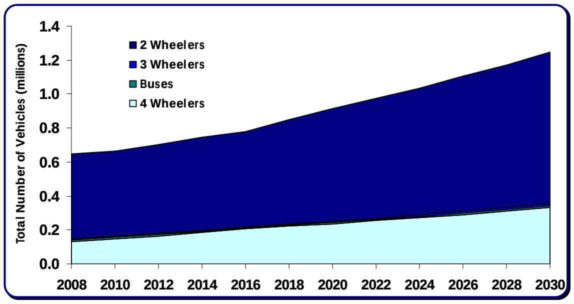
Carbon Dioxide



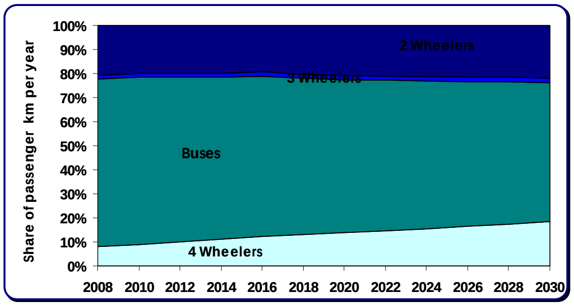
Panaji, India



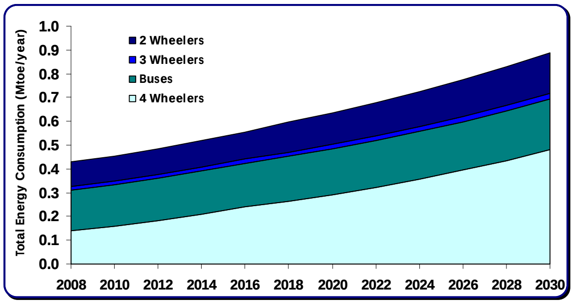
Number of Vehicles



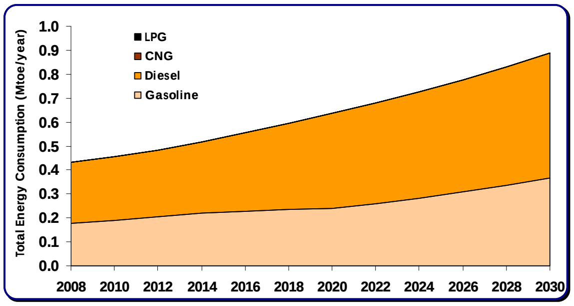
% Passenger kilometers



Total energy consumption by category



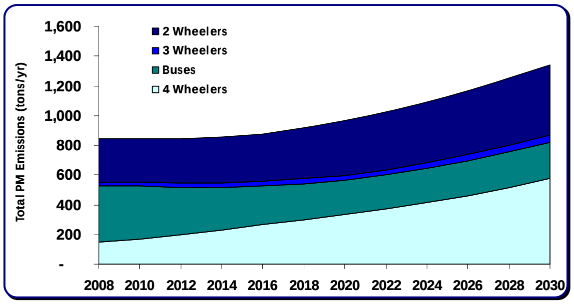
Total energy consumption by fuel



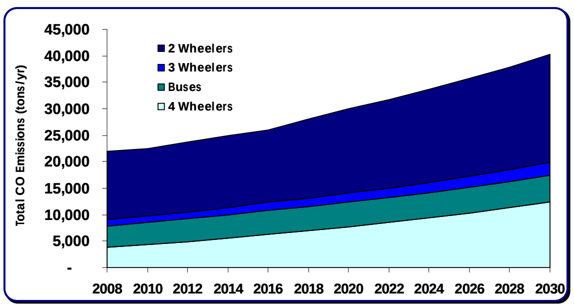
Panaji, India

Total emissions by category

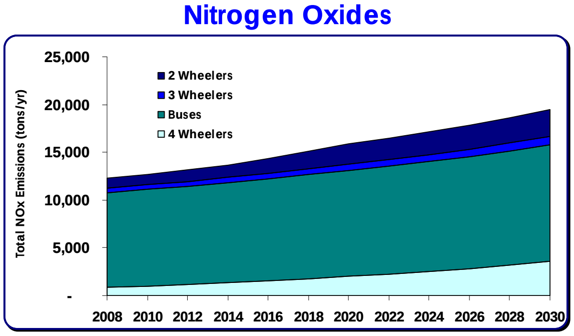
Particulate Matter < 2.5µm



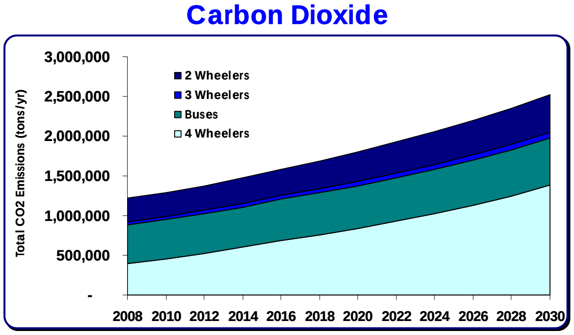
Carbon Monoxide



Nitrogen Oxides

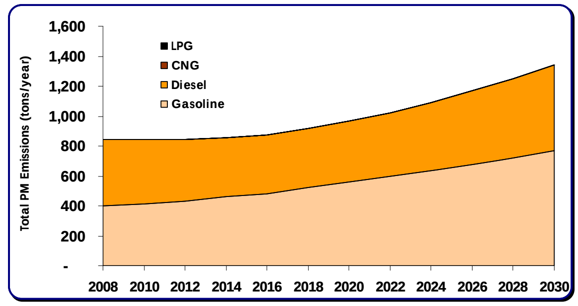


Carbon Dioxide

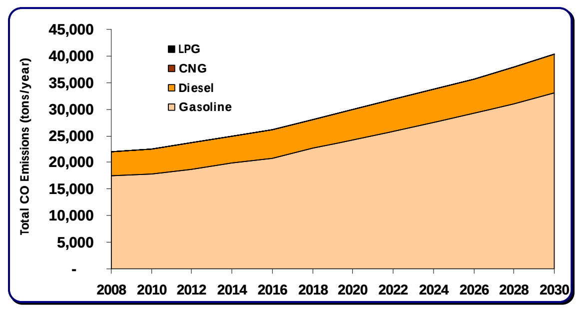


Total emissions by fuel

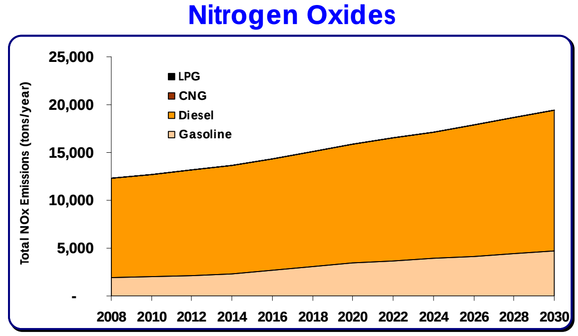
Particulate Matter < 2.5µm



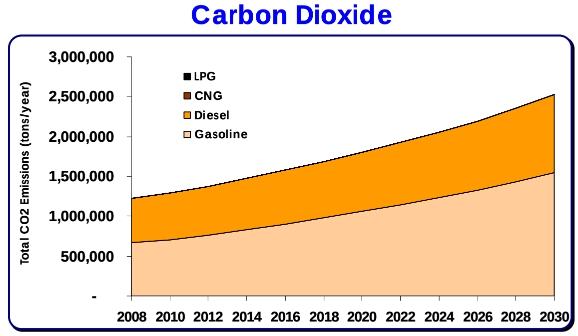
Carbon Monoxide



Nitrogen Oxides

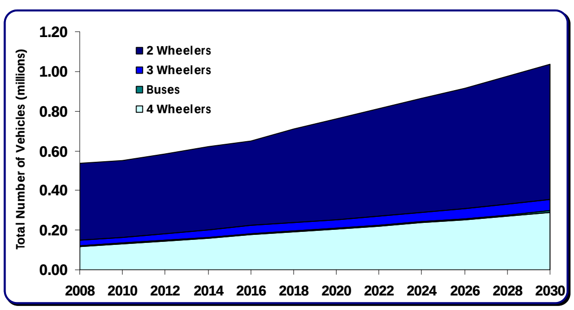


Carbon Dioxide

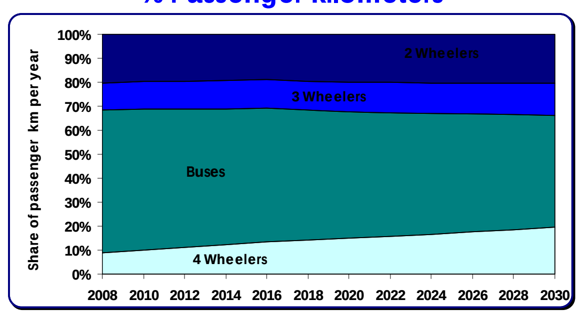


Patna, India

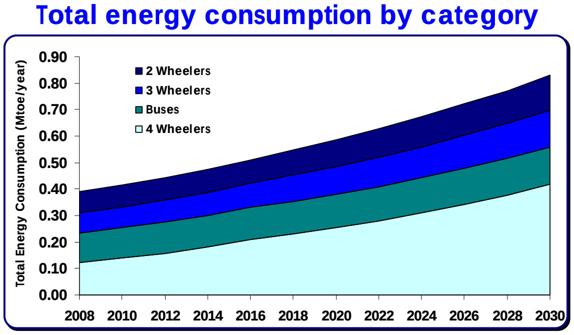
Number of Vehicles



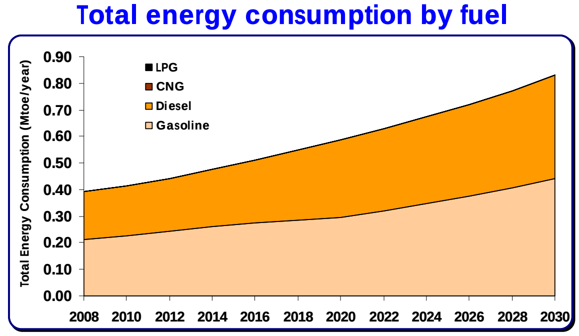
% Passenger kilometers



Total energy consumption by category



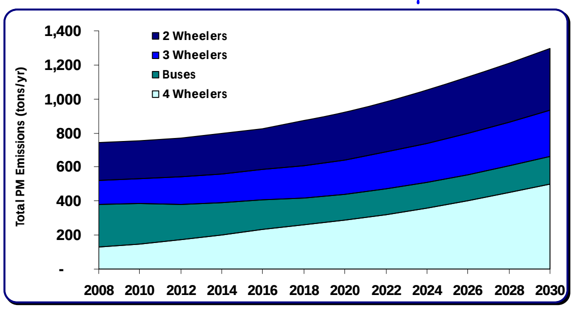
Total energy consumption by fuel



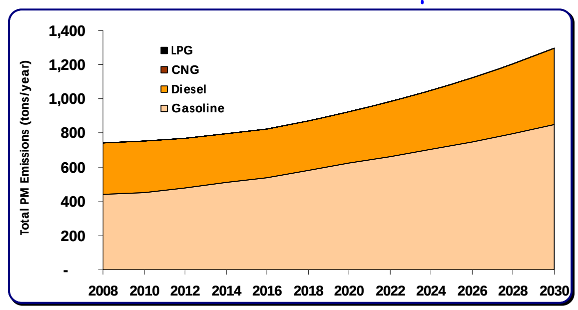
Patna, India

Total emissions by category	Total emissions by fuel

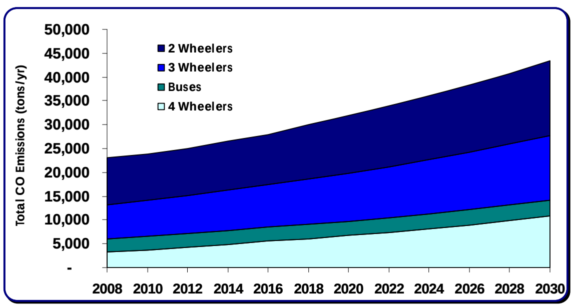
Particulate Matter < 2.5µm



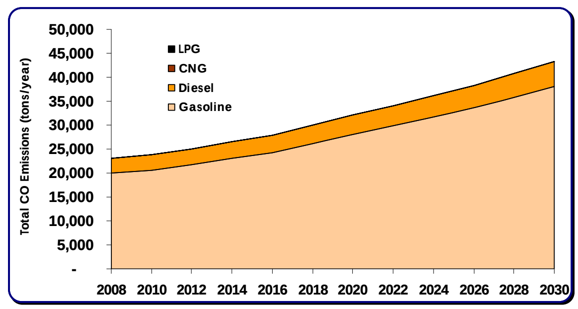
Particulate Matter < 2.5µm



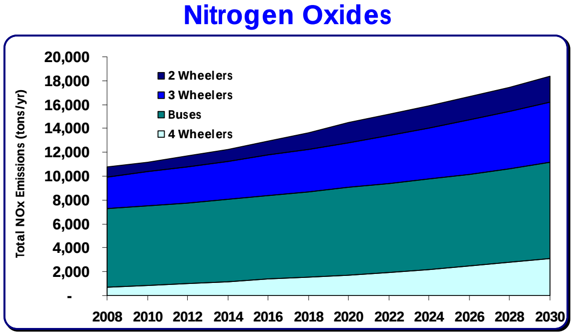
Carbon Monoxide



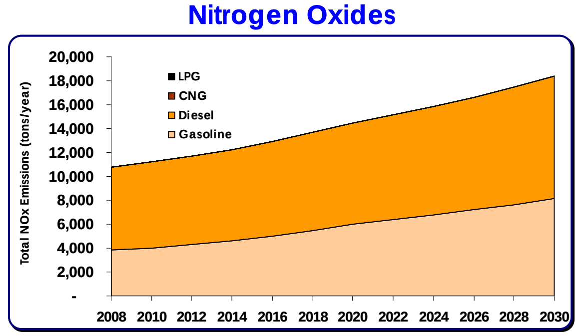
Carbon Monoxide



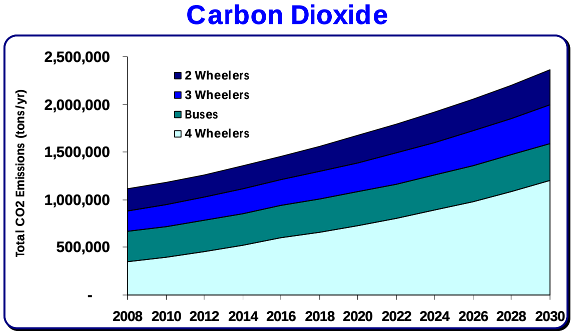
Nitrogen Oxides



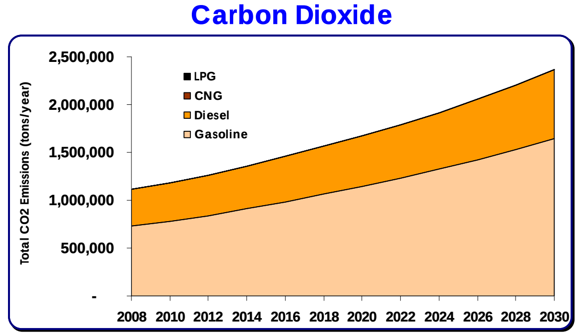
Nitrogen Oxides



Carbon Dioxide

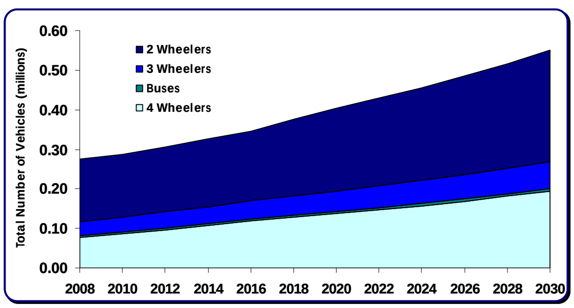


Carbon Dioxide

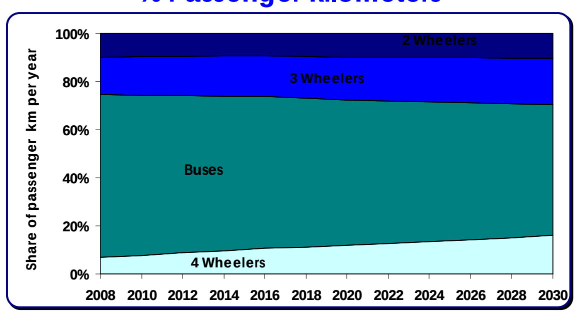


Kochi, India

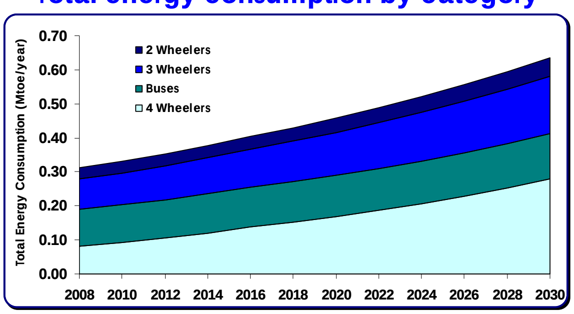
Number of Vehicles



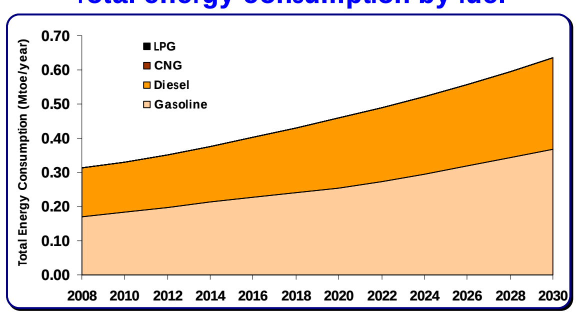
% Passenger kilometers



Total energy consumption by category



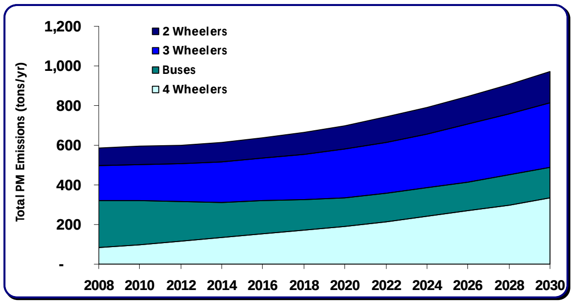
Total energy consumption by fuel



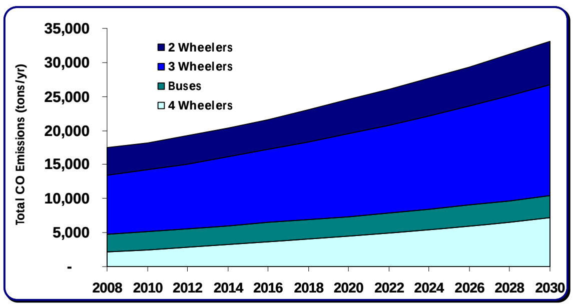
Kochi, India

Total emissions by category

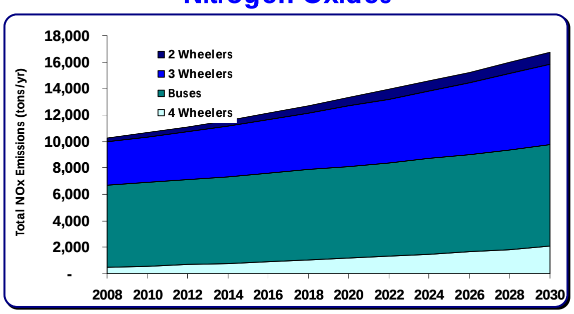
Particulate Matter < 2.5µm



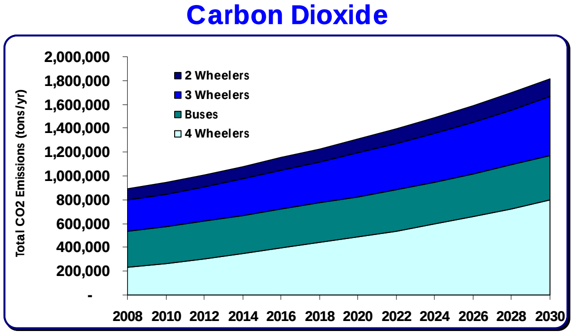
Carbon Monoxide



Nitrogen Oxides

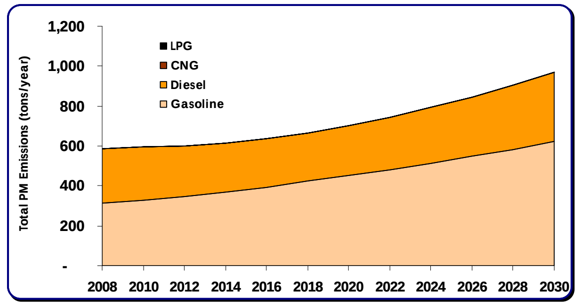


Carbon Dioxide

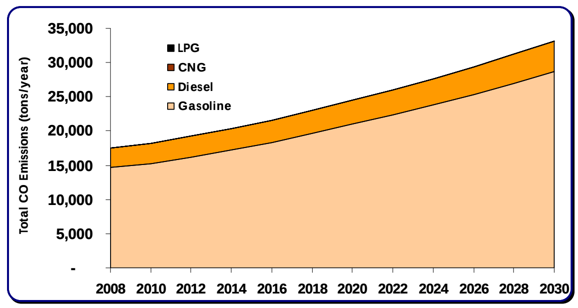


Total emissions by fuel

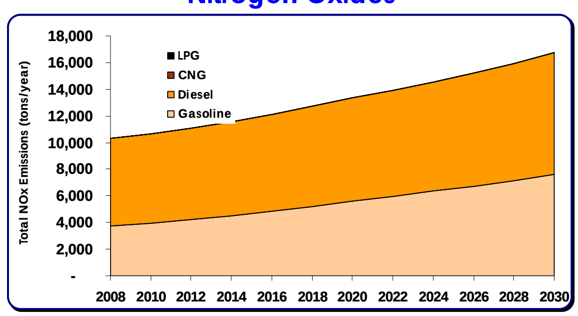
Particulate Matter < 2.5µm



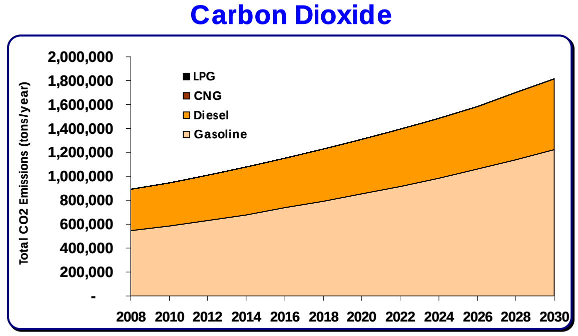
Carbon Monoxide



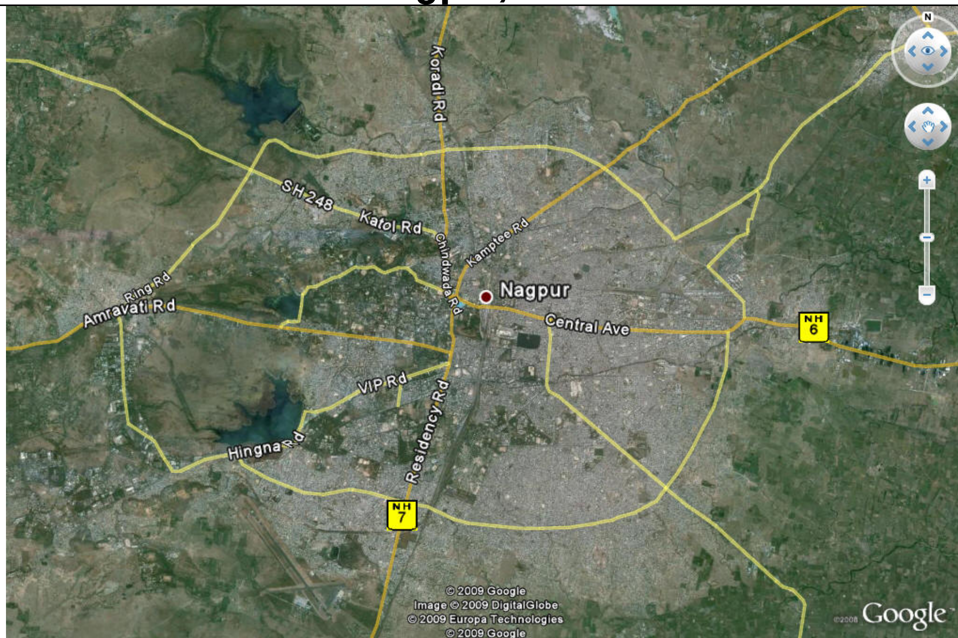
Nitrogen Oxides



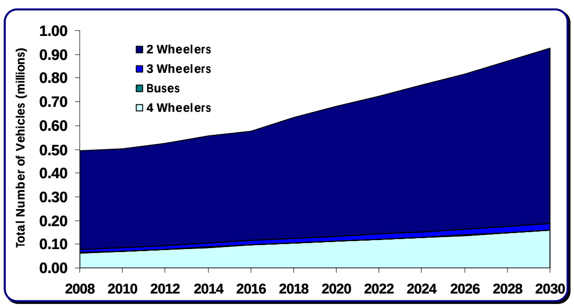
Carbon Dioxide



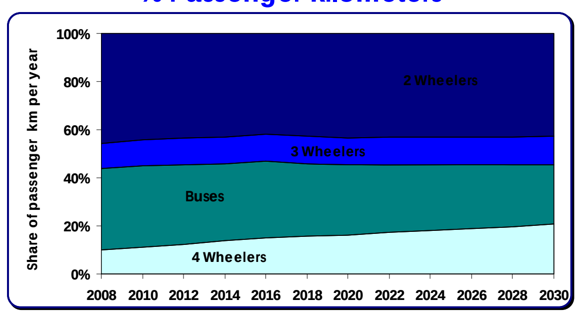
Nagpur, India



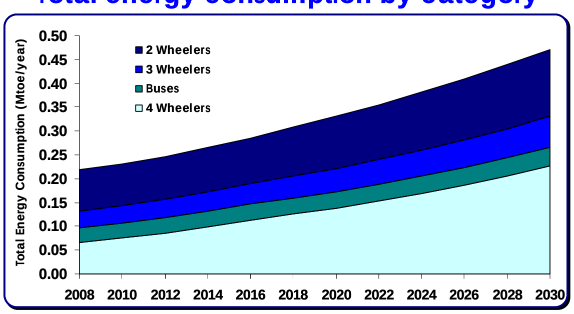
Number of Vehicles



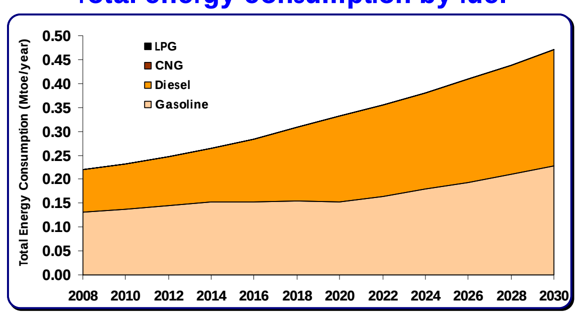
% Passenger kilometers



Total energy consumption by category



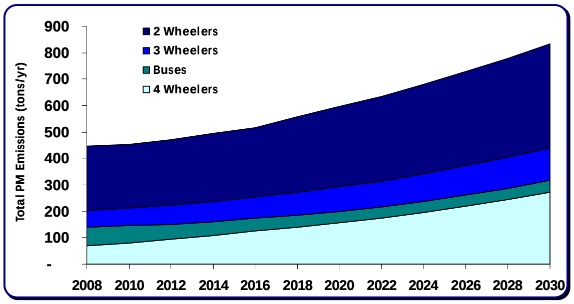
Total energy consumption by fuel



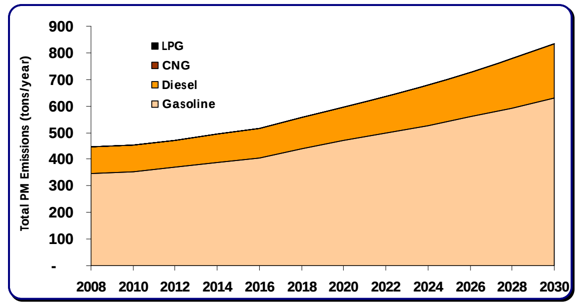
Nagpur, India

Total emissions by category	Total emissions by fuel

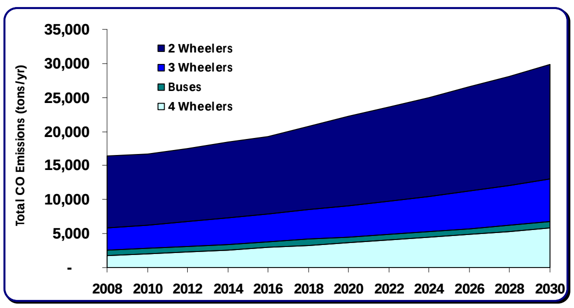
Particulate Matter < 2.5µm



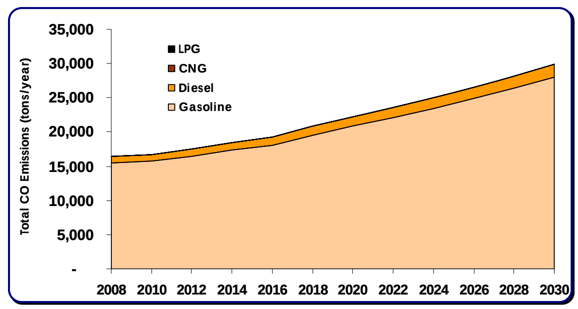
Particulate Matter < 2.5µm



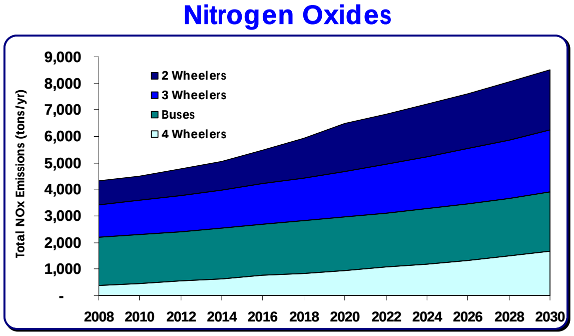
Carbon Monoxide



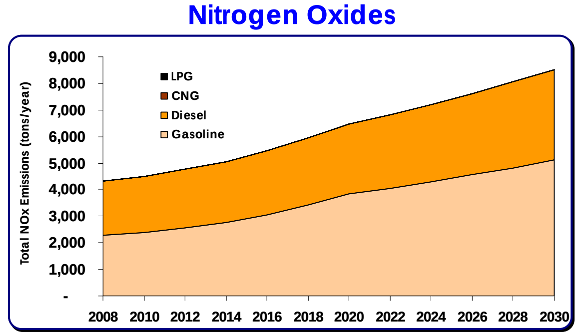
Carbon Monoxide



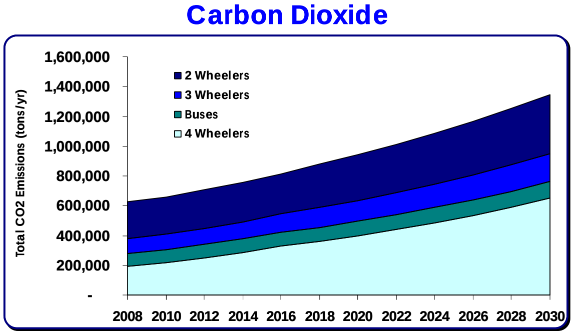
Nitrogen Oxides



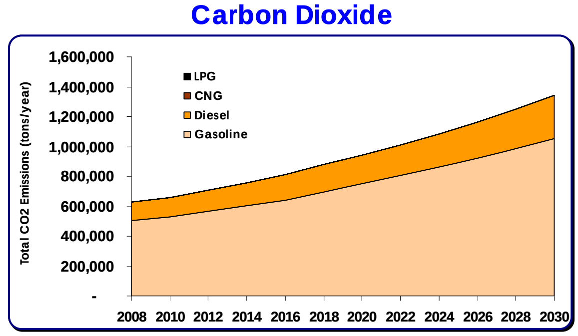
Nitrogen Oxides



Carbon Dioxide

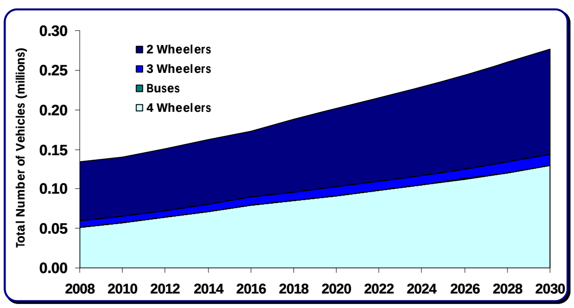


Carbon Dioxide

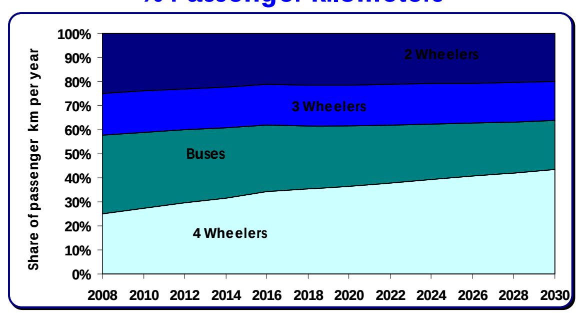


Guwahati, India

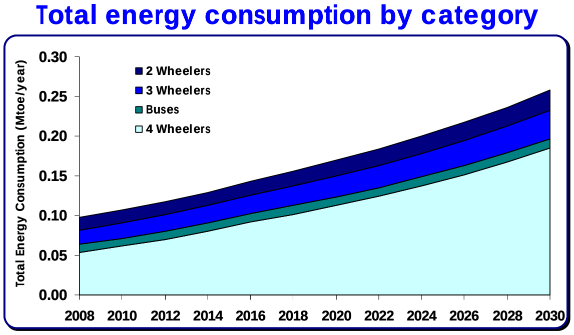
Number of Vehicles



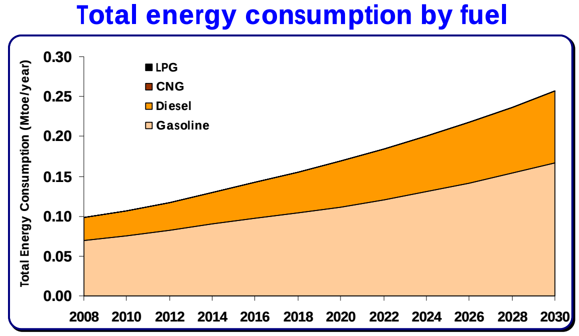
% Passenger kilometers



Total energy consumption by category



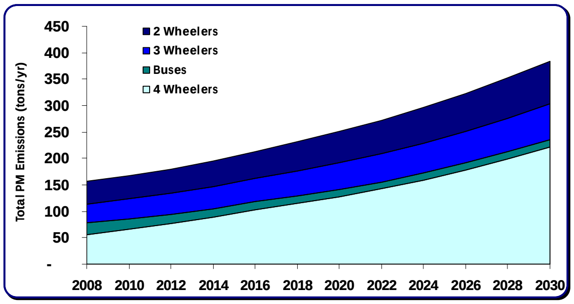
Total energy consumption by fuel



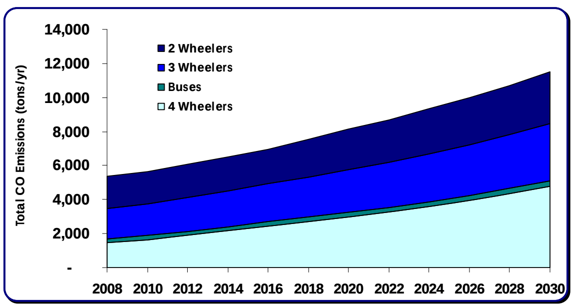
Guwahati, India

Total emissions by category

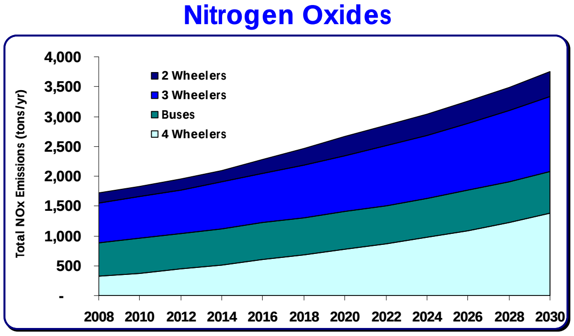
Particulate Matter < 2.5μm



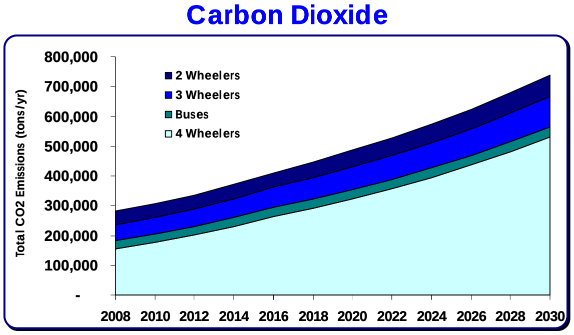
Carbon Monoxide



Nitrogen Oxides

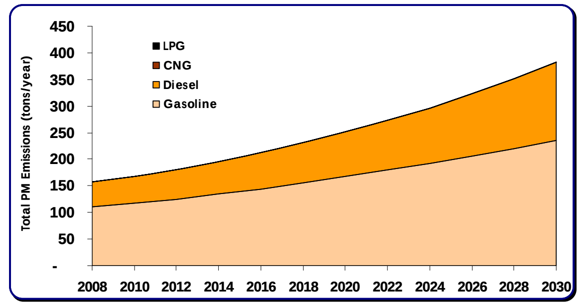


Carbon Dioxide

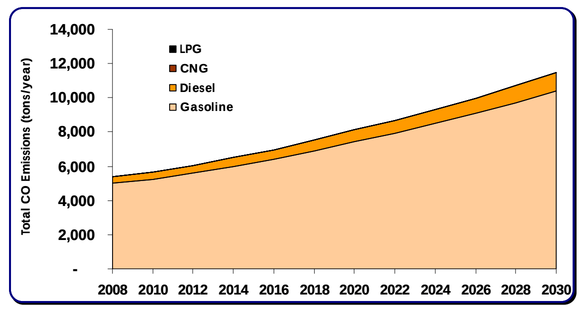


Total emissions by fuel

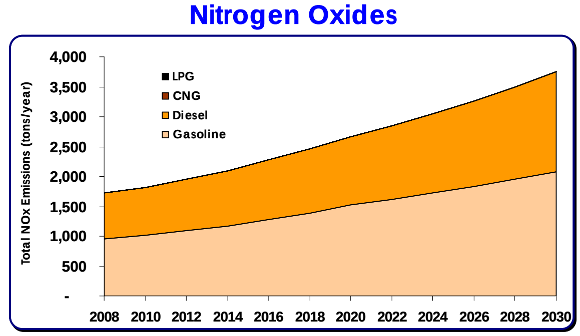
Particulate Matter < 2.5μm



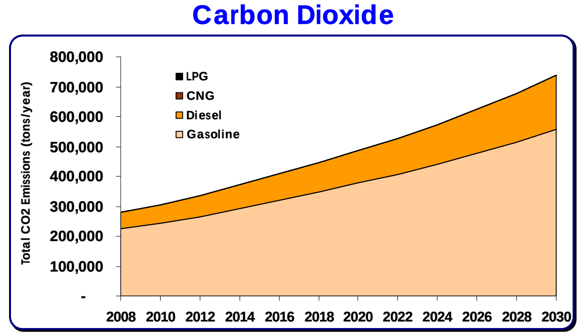
Carbon Monoxide



Nitrogen Oxides



Carbon Dioxide



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