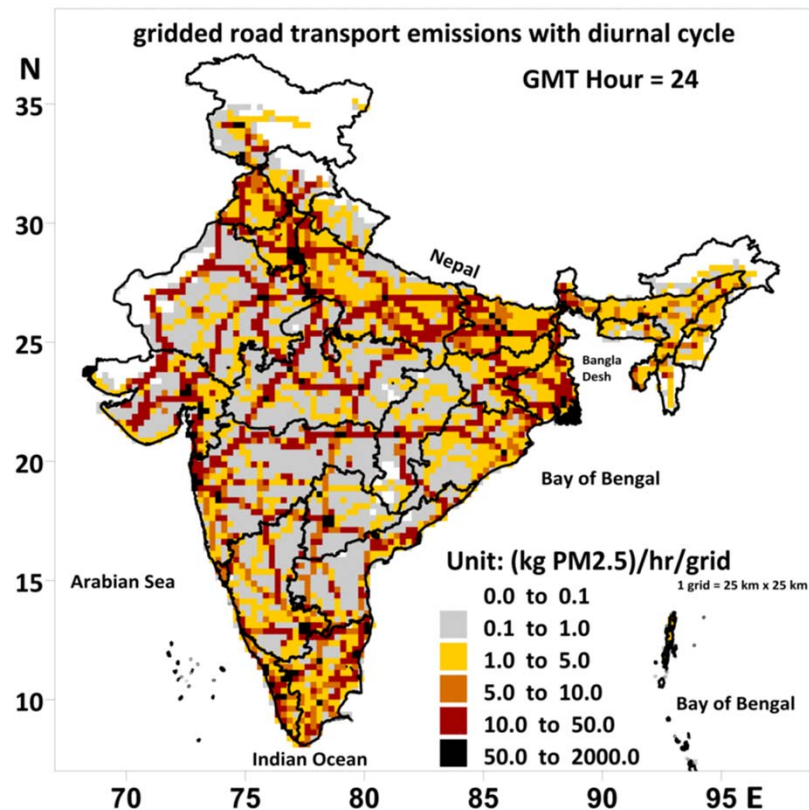


# GBD-MAPS - Emissions and Air Pollution Modeling in India

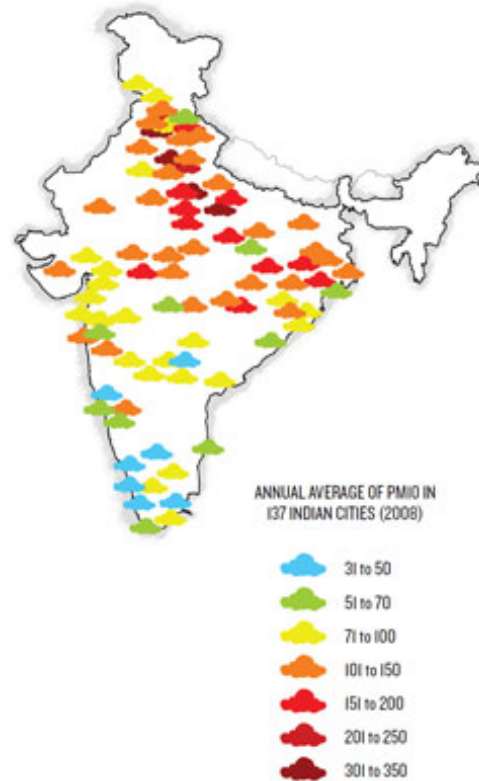


**Dr. Sarath Guttikunda**  
**UrbanEmissions.Info**

**Dr. Chandra Venkatraman**  
**and Team**

**@ Center for Climate Studies**  
**IIT, Mumbai, India**

# On-Ground Monitoring



All manual stations

30-40% collection

Limited CAMS

Limited PM<sub>2.5</sub>

Limited access

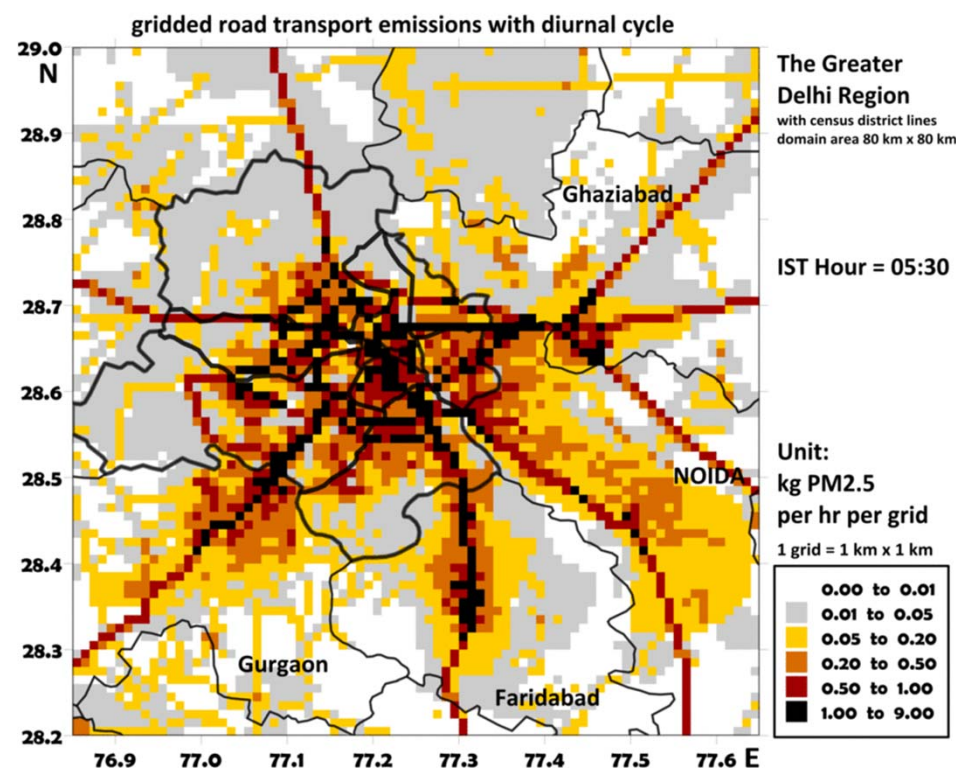
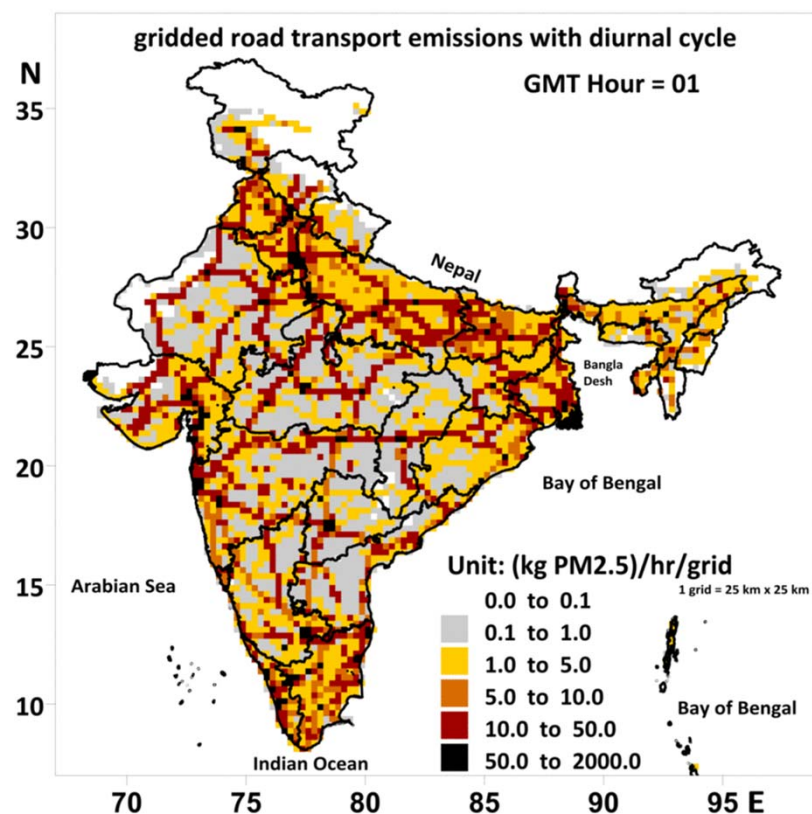
**550**

Manual Stations  
under the national  
ambient monitoring  
program (NAMP)

**60**

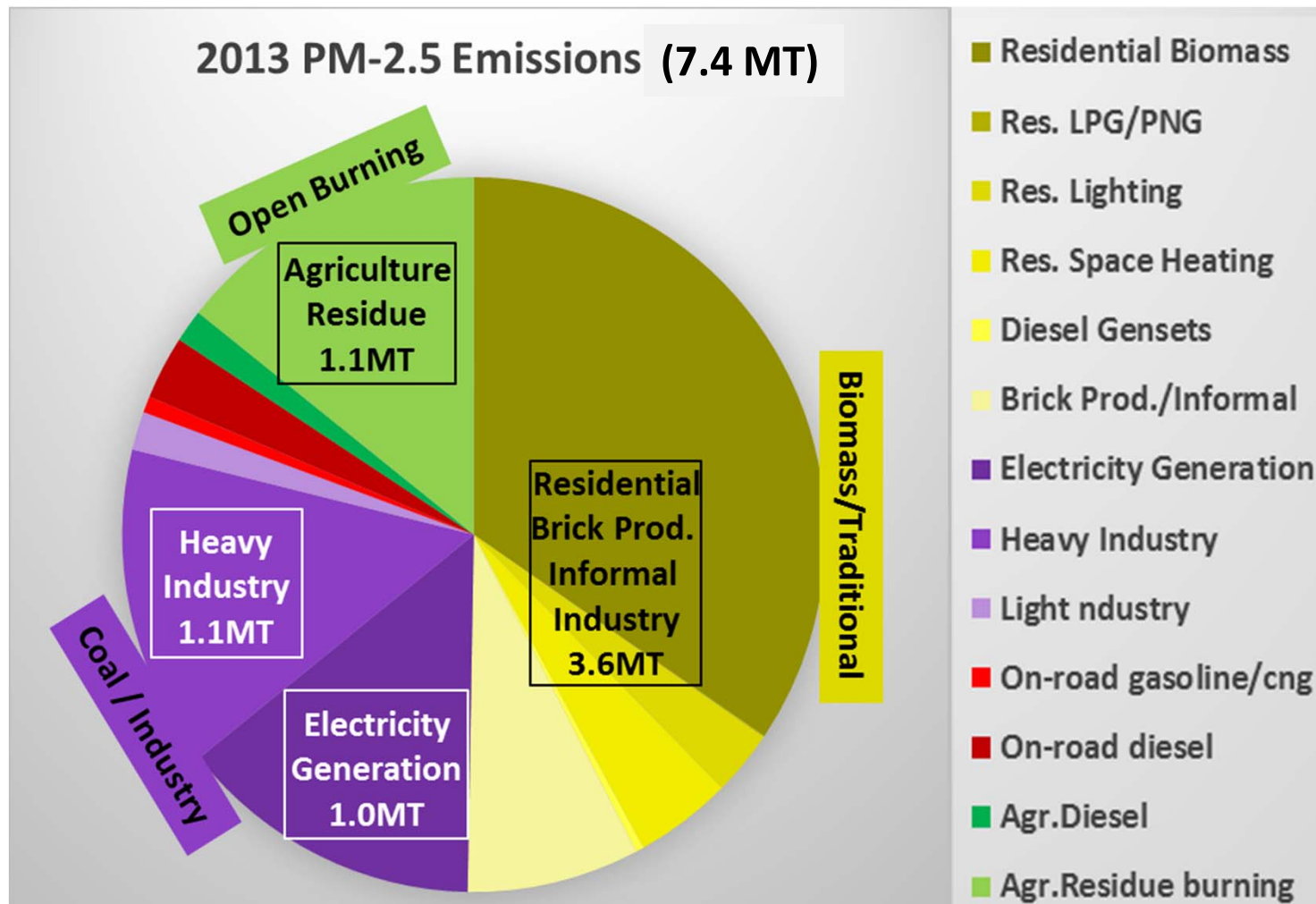
Continuous  
monitoring stations

# Modeling Emissions and Pollution is a Must



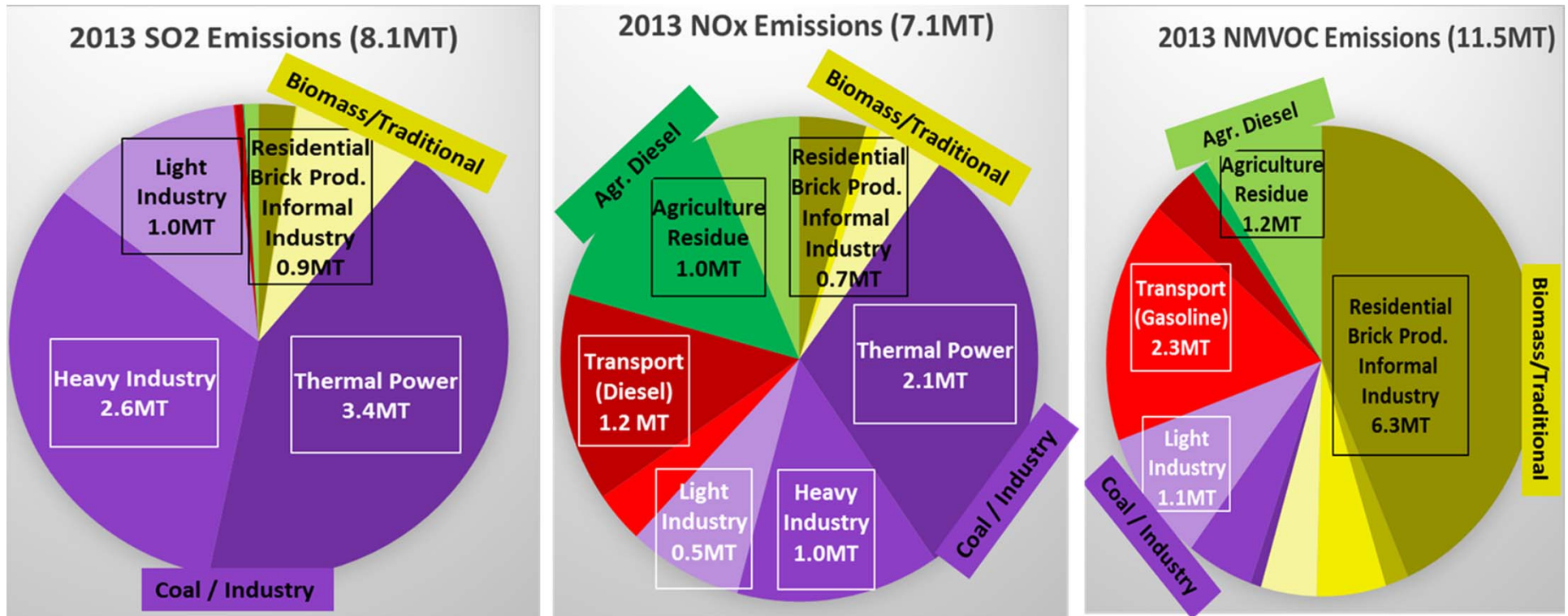
**New open data fields are helping us do this better and faster**

# Total PM2.5 Emissions in India



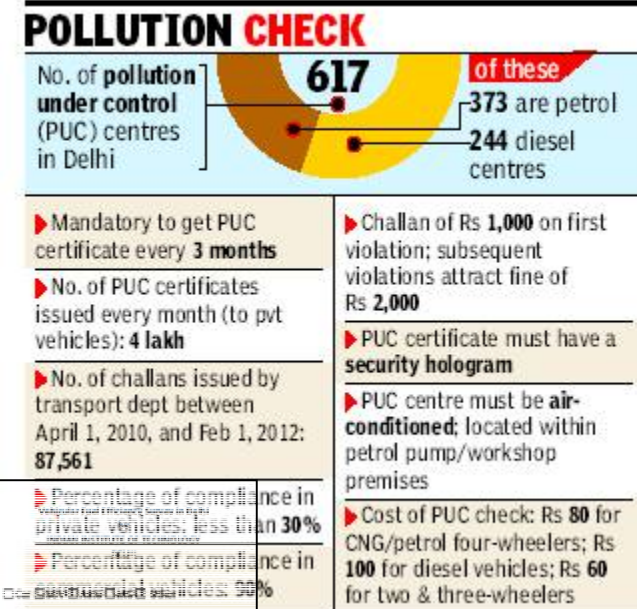
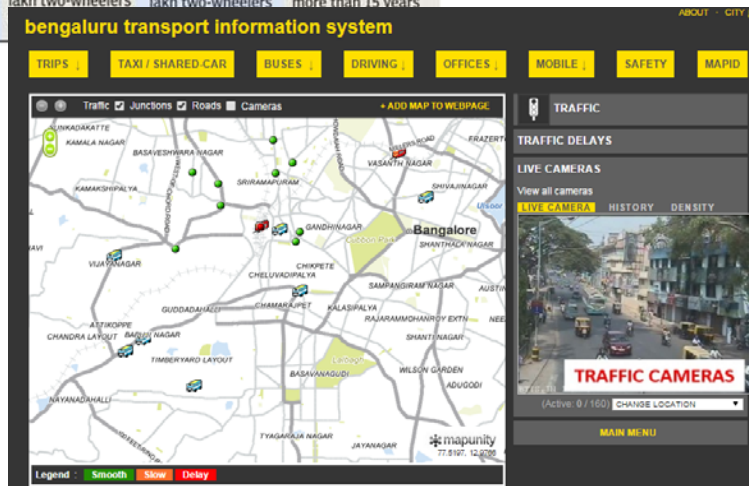
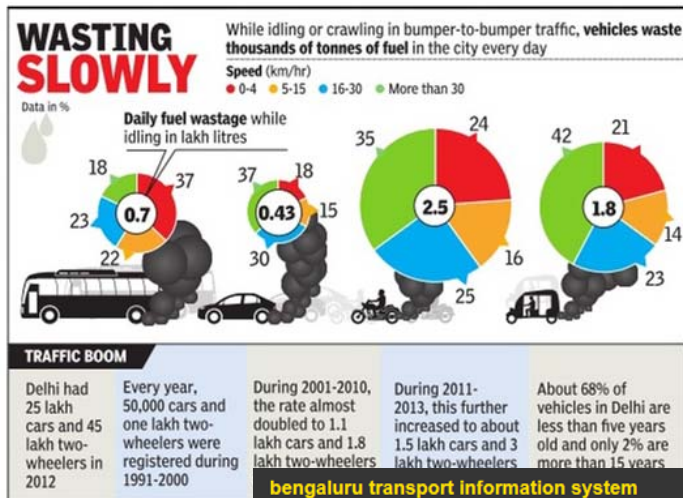


# Other Precursor Emissions in India



- **Multi-pollutant inventory includes anthropogenic and non-anthropogenic sources**
- **On-going surveys in multiple cities for various sectors**
- **Linkages to online data resources for better temporal and spatial resolution in the emissions**

# Data Support for Road Transport Emissions



Percentage of compliance in private vehicles: less than 30%

Percentage of compliance in commercial vehicles: 90%

Type of Vehicle: ☐ Car ☐ Two-wheeler ☐ Three-wheeler

Type of Fuel: ☐ Petrol ☐ Diesel ☐ CNG ☐ LPG

Make/Model/Year: \_\_\_\_\_

Mileage:  Km/Litre

Odometer Reading:

Type of Vehicle: ☐ Car ☐ Two-wheeler ☐ Three-wheeler

Type of Fuel: ☐ Petrol ☐ Diesel ☐ CNG ☐ LPG

Make/Model/Year: \_\_\_\_\_

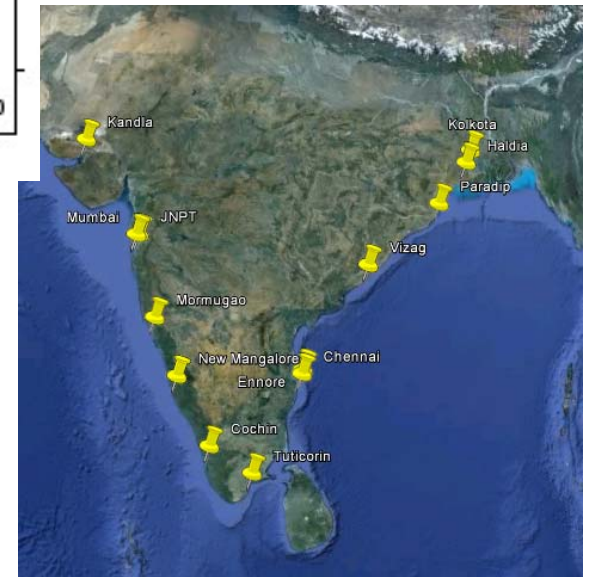
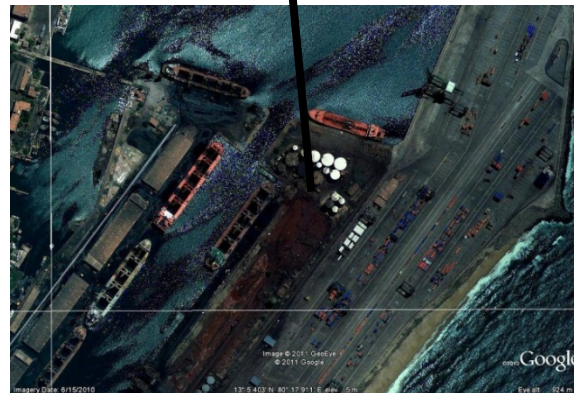
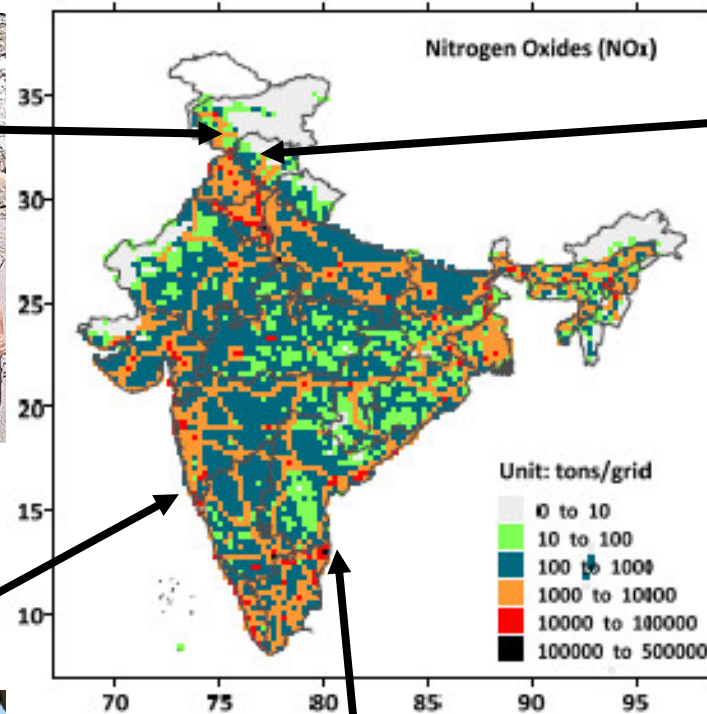
Mileage:  Km/Litre

Odometer Reading:

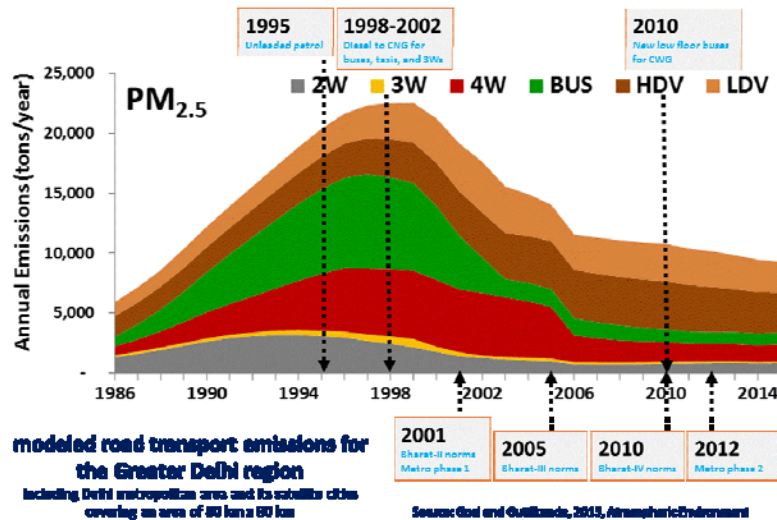
- congestion and speed mapping using google maps and on-road GPS runs for multiple runs
- data analysis of “PUC” (pollution under check program) and sample surveys at fueling stations
- road density maps, freight movement, landuse, and meteorology



# Freight Movement and Diesel PM2.5 Emissions



# Delhi On-road Emissions



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	
a) Do-nothing																						
4W	BS-4																					
2W	BS-3																					
3W	BS-3																					
LDV	BS-3																					
HDV	BS-3																					
b) Auto Fuel Policy - 2025																						
4W	BS-4							BS-5							BS-6							
2W	BS-3						BS-4				BS-5											
3W	BS-3						BS-4				BS-5											
LDV	BS-3							BS-4			BS-5					BS-6						
HDV	BS-3							BS-4			BS-5					BS-6						
c) B6-2017																						
4W	BS-4							BS-6														
2W	BS-3						BS-5															
3W	BS-3						BS-5															
LDV	BS-3							BS-6														
HDV	BS-3							BS-6														

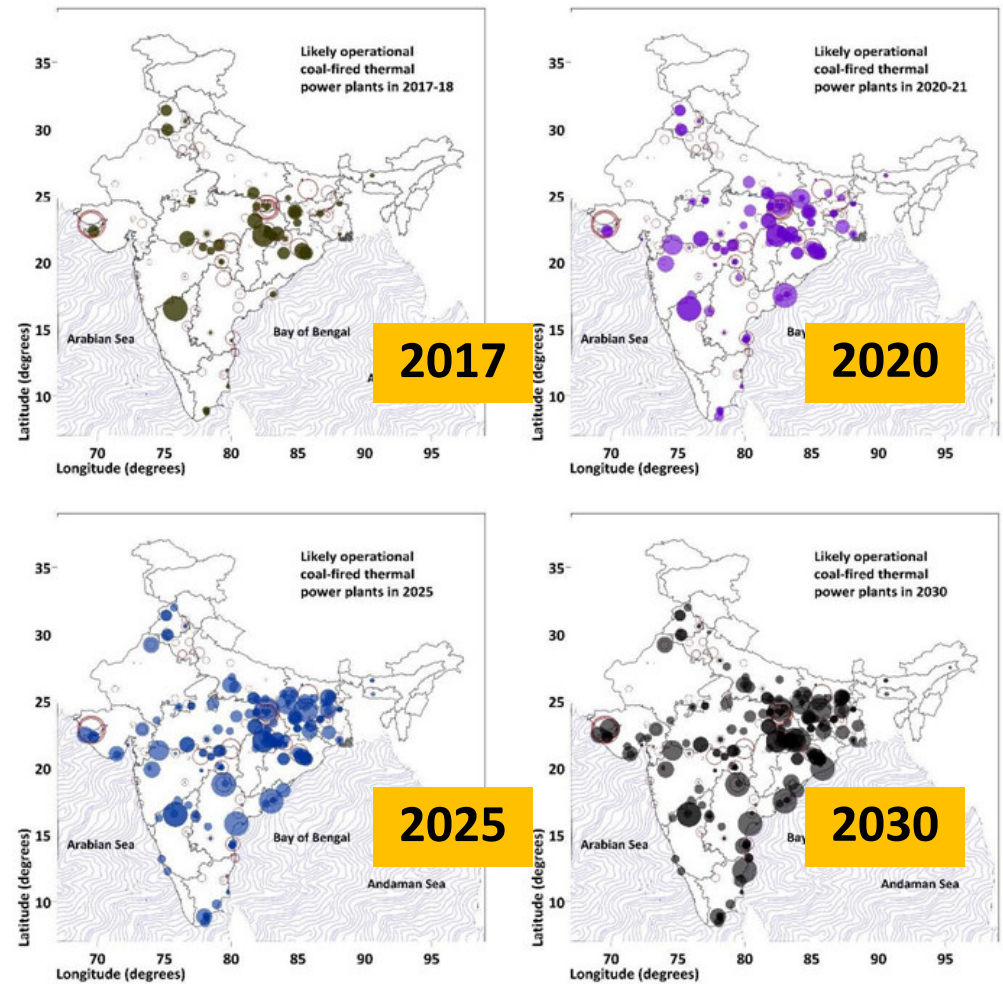
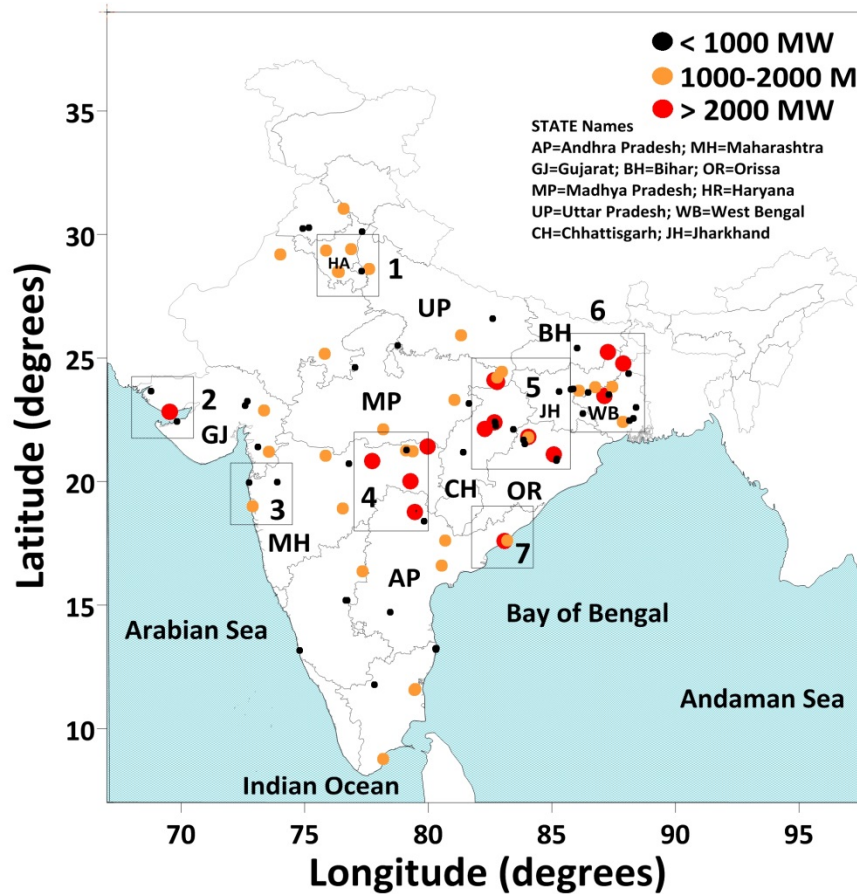
- Analysis of past fuel and emission standards
- On-road exposure assessments in multiple travel modes
- Impact assessments of transport policies (for example, odd-even)

Reports and infographics @  
<http://www.delhiarquality.info>



# Thermal Power Plants

**Figure 8: Proposed locations of the coal-fired TPPs in India through 2030.** The brown circles represent the TPPs operational in 2014 (details in Figure 6) and the second colour in each map represents all the new plants and expansions expected after 2014 and likely to be operational in the representative year. The largest circle is 4620MW. Note that many of these circles are overlapping due their close proximity to other TPPs



# Diesel Generator Sets



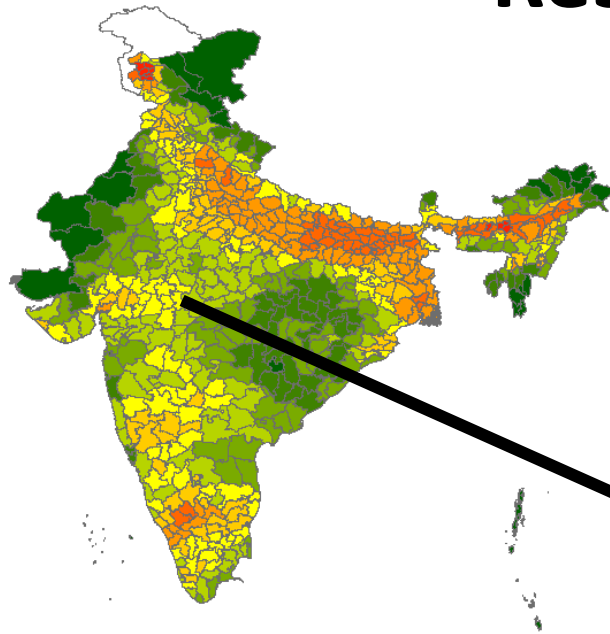
## Telecom Towers

40% power from grid  
60% from diesel

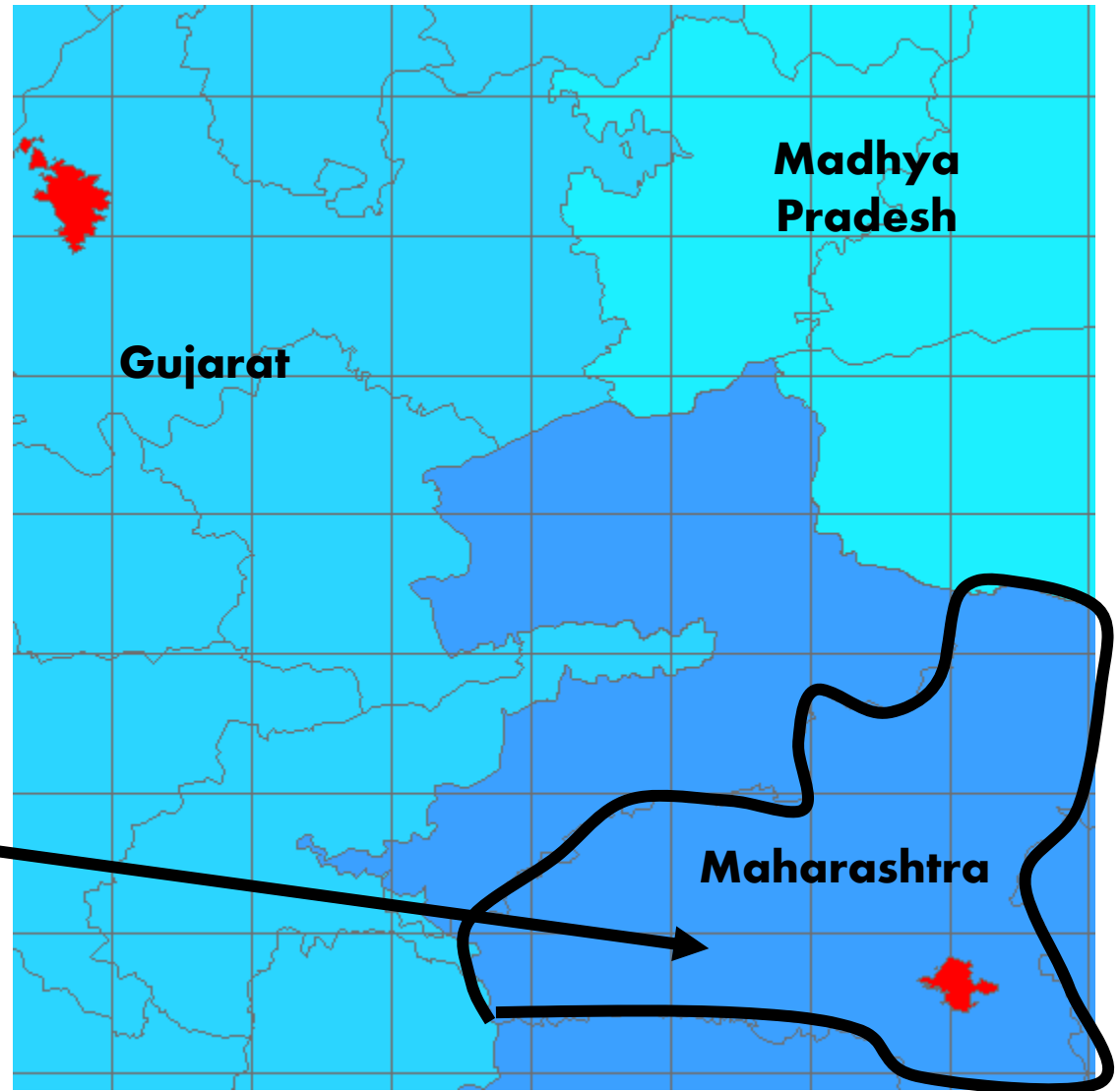
Estimates 2 billion  
litres of annual  
diesel consumption

**Other sectors using diesel generators include hotels, hospitals, malls and markets, apartment complexes, institutions, cinema halls, metro stations**

# Residential Emissions



**For each district,  
CENSUS provides  
share of HH's using  
different fuels –  
segregated into  
urban/rural areas and  
inside/outside cooking  
Grids @ 0.25°**





# Household Energy Consumption, Emissions, Pollution, and Health Impacts in India

STATE	<b>NCT of Delhi</b>
	(state and district as of census-India, 2011)
DISTRICT	<b>New_Delhi</b>

## %Households Primary Cooking Fuel

gas+elec

78.8%

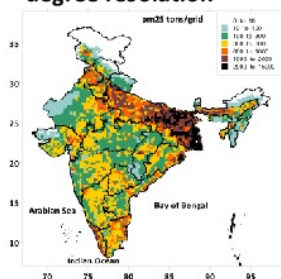
others

21.2%

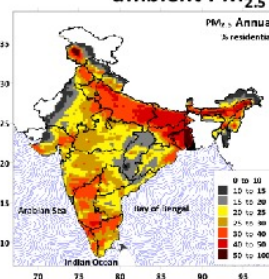
## Estimated district annual HEC emissions

Particulates (2.5µm)	500 tons
Sulfur dioxide	80 tons
Nitrogen oxides	20 tons
Carbon monoxide	6,400 tons
Hydrocarbons	1,560 tons
Black carbon (BC)	100 tons
Organic carbon	220 tons
Carbon dioxide (CO <sub>2</sub> )	0.19 mil tons

Estimated PM<sub>2.5</sub> emissions @ 0.25 degree resolution

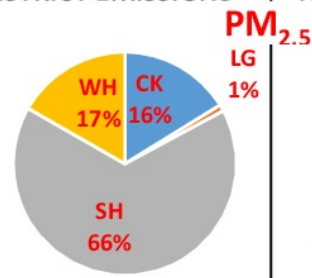


Modeled share of HEC emissions to ambient PM<sub>2.5</sub>

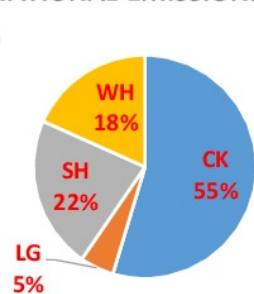


Household energy consumption (HEC) emissions were calculated in four classes - cooking (CK), lighting (LG), space heating (SH), and water heating (WH). Bottom-up emissions for the four classes are available @ 0.25 degree spatial resolution, and further aggregated to district and state level. A sub-classification is available by fuel - biomass, coal, kerosene, liquified petroleum gas (LPG), and others.

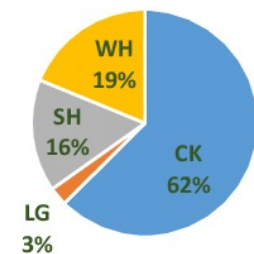
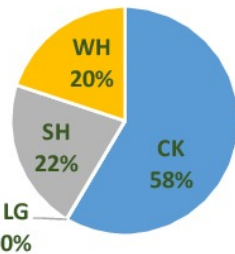
## DISTRICT EMISSIONS



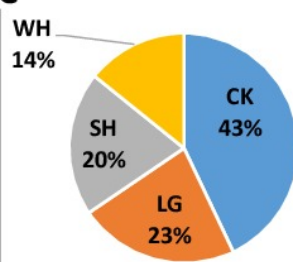
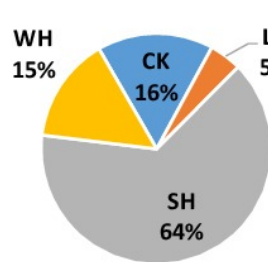
## NATIONAL EMISSIONS



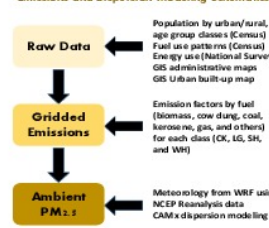
CO<sub>2</sub>



BC



## Emissions and Dispersion Modeling Schematics



% contribution of HEC emissions to modeled ambient PM<sub>2.5</sub> concentrations

(concentrations were conducted using the WRF-CAMx models)

National	29.6%
District	32.7%

The health impacts of outdoor air pollution as ischemic heart diseases (which can lead to heart attacks), cerebrovascular disease (which can lead to strokes), chronic obstructive pulmonary diseases, lower respiratory infections, and cancers (in trachea, lungs, and bronchitis) were estimated using the age-dependent relative risk functions detailed in the Global Burden of Disease study (2013) and dispersion modeling results from this study. The final calculations were conducted at the district level using the population distribution by age presented in

Estimated premature mortality of outdoor air pollution per year - apportioned to HEC emissions

National	59,000 - 72,000
District	10 - 13

Emission and dispersion modeling results, pollution animations, and summary sheets by district and state are hosted @ <http://www.urbanemissions.info>  
Send your comments and questions to [sim-air@urbanemissions.info](mailto:sim-air@urbanemissions.info)

# Household Energy Consumption, Emissions, Pollution, and Health Impacts in India

STATE	<b>Chhattisgarh</b>
(state and district as of census-India, 2011)	
DISTRICT	<b>Korba</b>

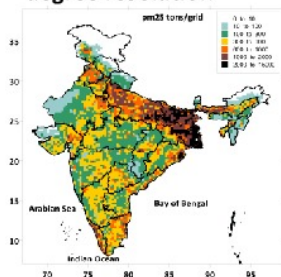
## %Households Primary Cooking Fuel

gas+elec	others
16.6%	83.4%

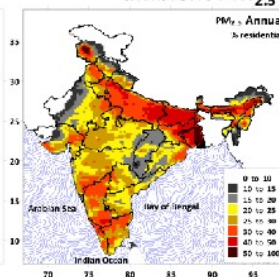
## Estimated district annual HEC emissions

Particulates (2.5µm)	4,700 tons
Sulfur dioxide	910 tons
Nitrogen oxides	60 tons
Carbon monoxide	84,900 tons
Hydrocarbons	7,460 tons
Black carbon (BC)	1,170 tons
Organic carbon	1,940 tons
Carbon dioxide (CO <sub>2</sub> )	0.34 mil tons

## Estimated PM<sub>2.5</sub> emissions @ 0.25 degree resolution

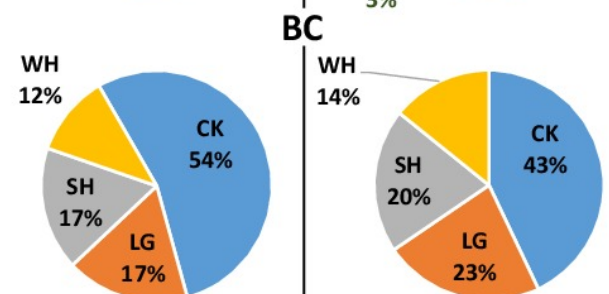
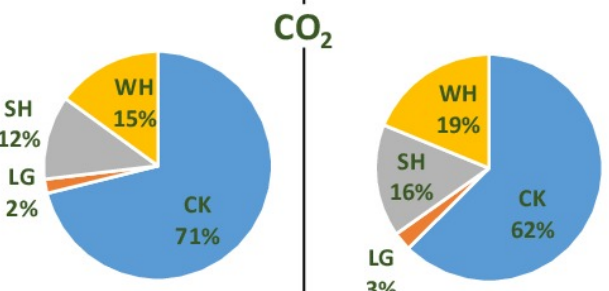
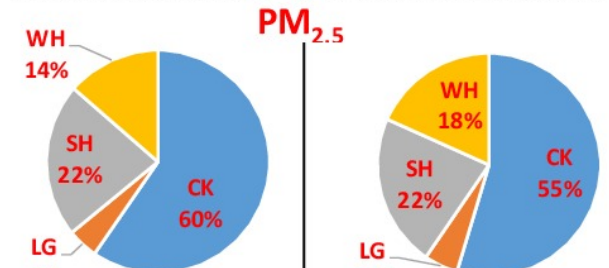


## Modeled share of HEC emissions to ambient PM<sub>2.5</sub>

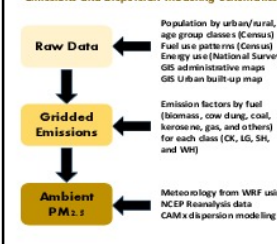


Household energy consumption (HEC) emissions were calculated in four classes - cooking (CK), lighting (LG), space heating (SH), and water heating (WH). Bottom-up emissions for the four classes are available @ 0.25 degree spatial resolution, and further aggregated to district and state level. A sub-classification is available by fuel - biomass, coal, kerosene, liquified petroleum gas (LPG), and others.

## DISTRICT EMISSIONS NATIONAL EMISSIONS



## Emissions and Dispersion Modeling Schematics



## % contribution of HEC emissions to modeled ambient PM<sub>2.5</sub> concentrations

(concentrations were conducted using the WRF-CAMx models)

National	29.6%
District	16.2%

The health impacts of outdoor air pollution as ischemic heart diseases (which can lead to heart attacks), cerebrovascular disease (which can lead to strokes), chronic obstructive pulmonary diseases, lower respiratory infections, and cancers (in trachea, lungs, and bronchitis) were estimated using the age-dependent relative risk functions detailed in the Global Burden of Disease study (2013) and dispersion modeling results from this study. The final calculations were conducted at the district level using the population distribution by age presented in

## Estimated premature mortality of outdoor air pollution per year - apportioned to HEC emissions

National	59,000 - 72,000
District	28 - 31

Emission and dispersion modeling results, pollution animations, and summary sheets by district and state are hosted @ <http://www.urbanemissions.info>  
Send your comments and questions to [sim-air@urbanemissions.info](mailto:sim-air@urbanemissions.info)



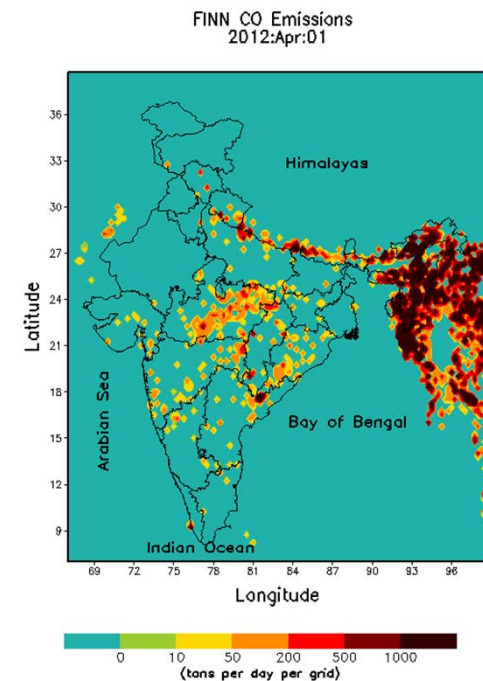
# Trash Burning and Open Fires



**March, 2016, Mumbai**

**Urban India generates 188,500 tonnes per day (68.8 million tonnes per year) of municipal solid waste – with at least 30% burning @ landfills, residential areas, and road sides**

## Open fires from FINN fields



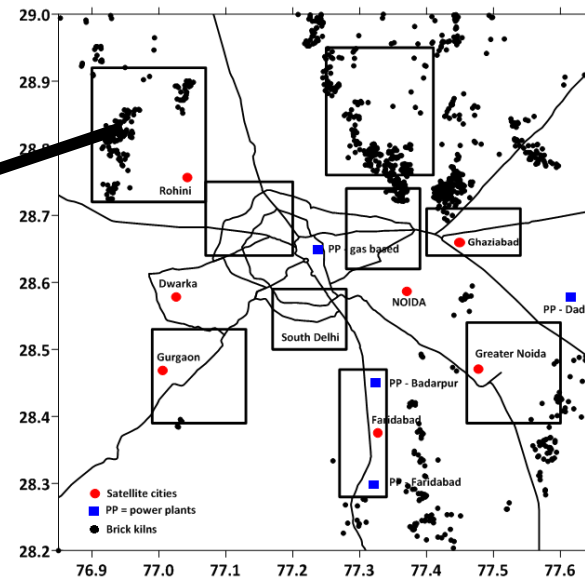
(c) UrbanEmissions.info

Extract from UCAR FINN files



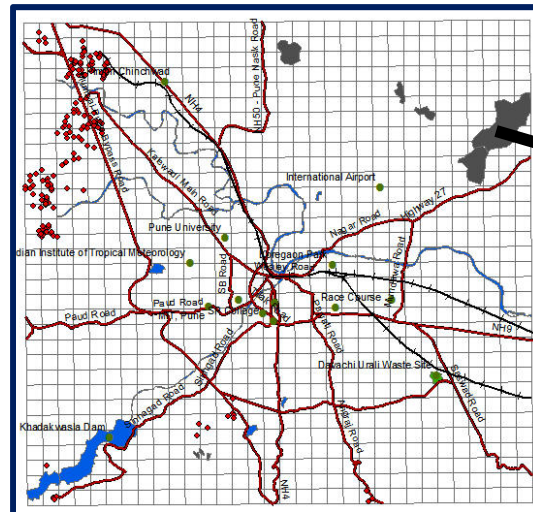
# Brick Kilns and Rock Quarries

## Delhi

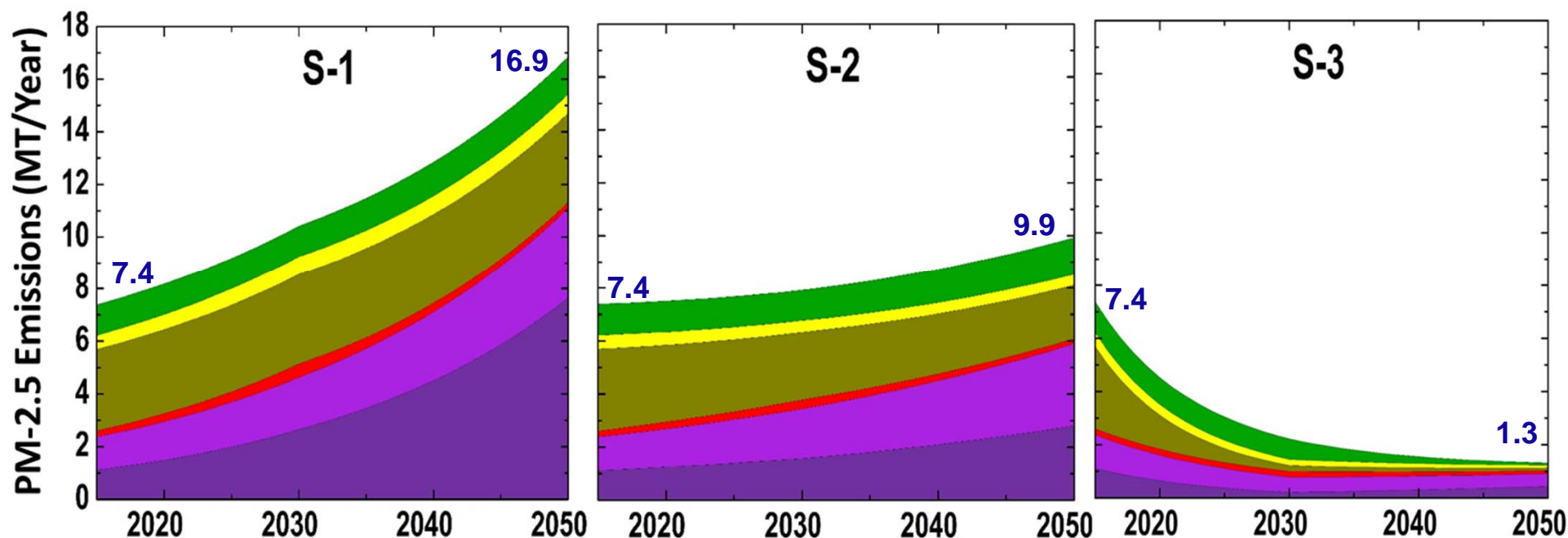


## Pune

- **Mixed and dirty fuel sources.**
- **Mostly supported by old diesel vehicles**
- **Most of quarries are at off-grid locations**



# Projected evolution of Indian PM-2.5 emissions



Projected growth in PM-2.5 emissions from 7.4 Tgy<sup>-1</sup> (2015):

**S1:** Current legislation in Elec, IND, TRN. Current rates (past 20y) of cleaner technology diffusion in RES, BRK, no control on field burning.

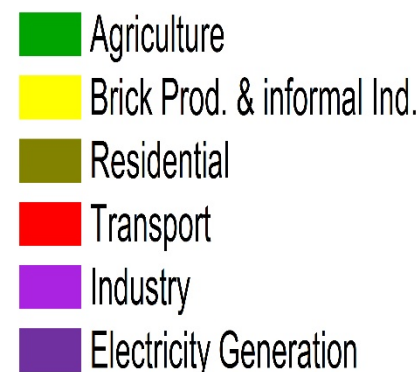
▪ **10.4 Tg (2030) and 16.9 Tg (2050)**

**S2:** Aspirational policies in Elec, IND, TRN. Higher (10% > current) rates of cleaner technology diffusion, in RES, BRK, no control on field burning.

▪ **7.9 Tg (2030) and 9.9 Tg (2050)**

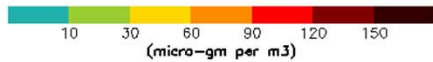
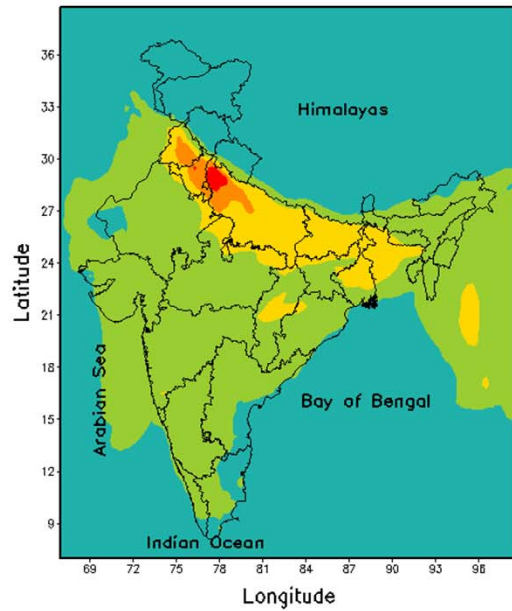
**S3:** Low-carbon scenario assumptions for Elec, IND; BS-VI (2020) TRN; complete phase out of traditional technologies in residential, bricks and informal industry, field burning controlled by 2030.

▪ **2.2 Tg (2030) and 1.3 Tg (2050)**

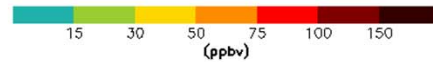
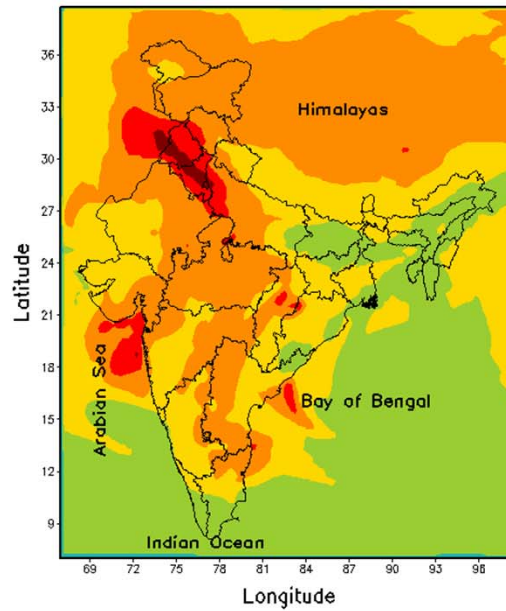


# regional WRF-CAMx simulations

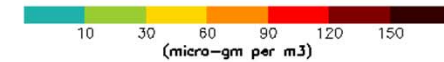
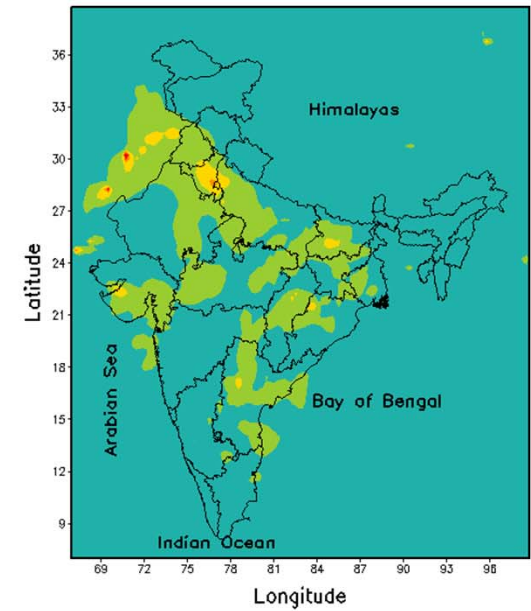
Ground Level PM10 Concentrations  
24hr Average for 06Apr2010



Ground Level O3 Concentrations  
Daytime Average for 06Oct2010



Ground Level SO2 Concentrations  
24hr Average for 06Oct2010



24hr Standard 100

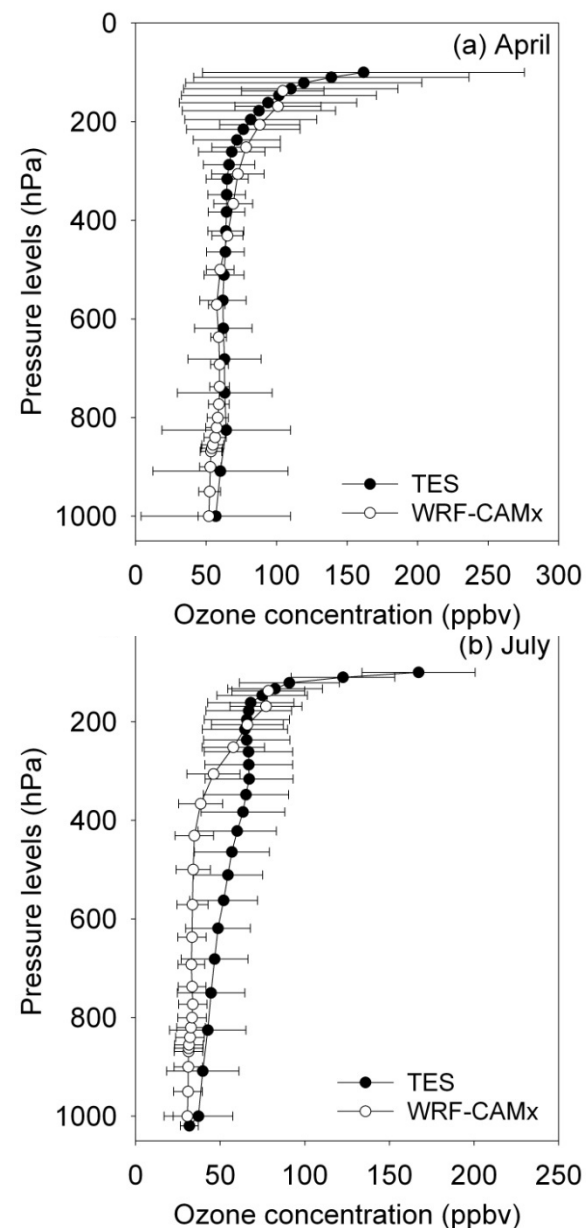
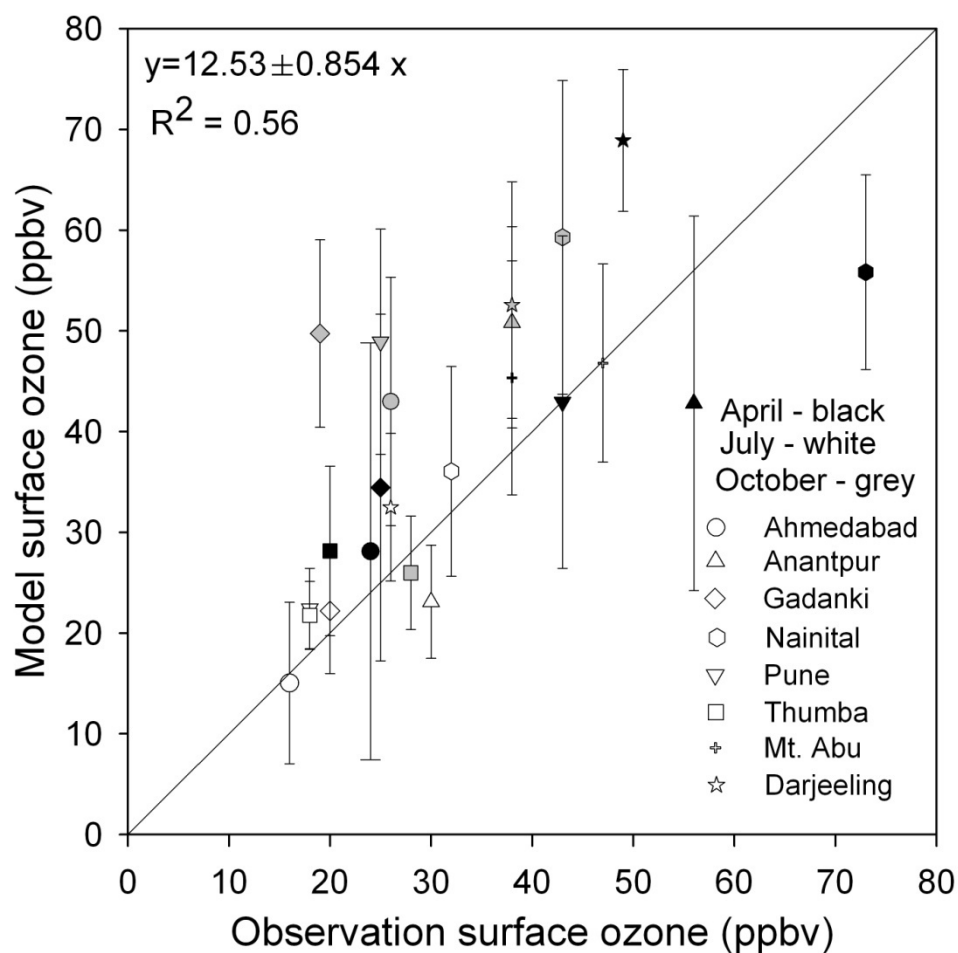
Output of CAMx Dispersion Model 8hr Standard 51

Output of CAMx Dispersion Model 24hr Standard 80

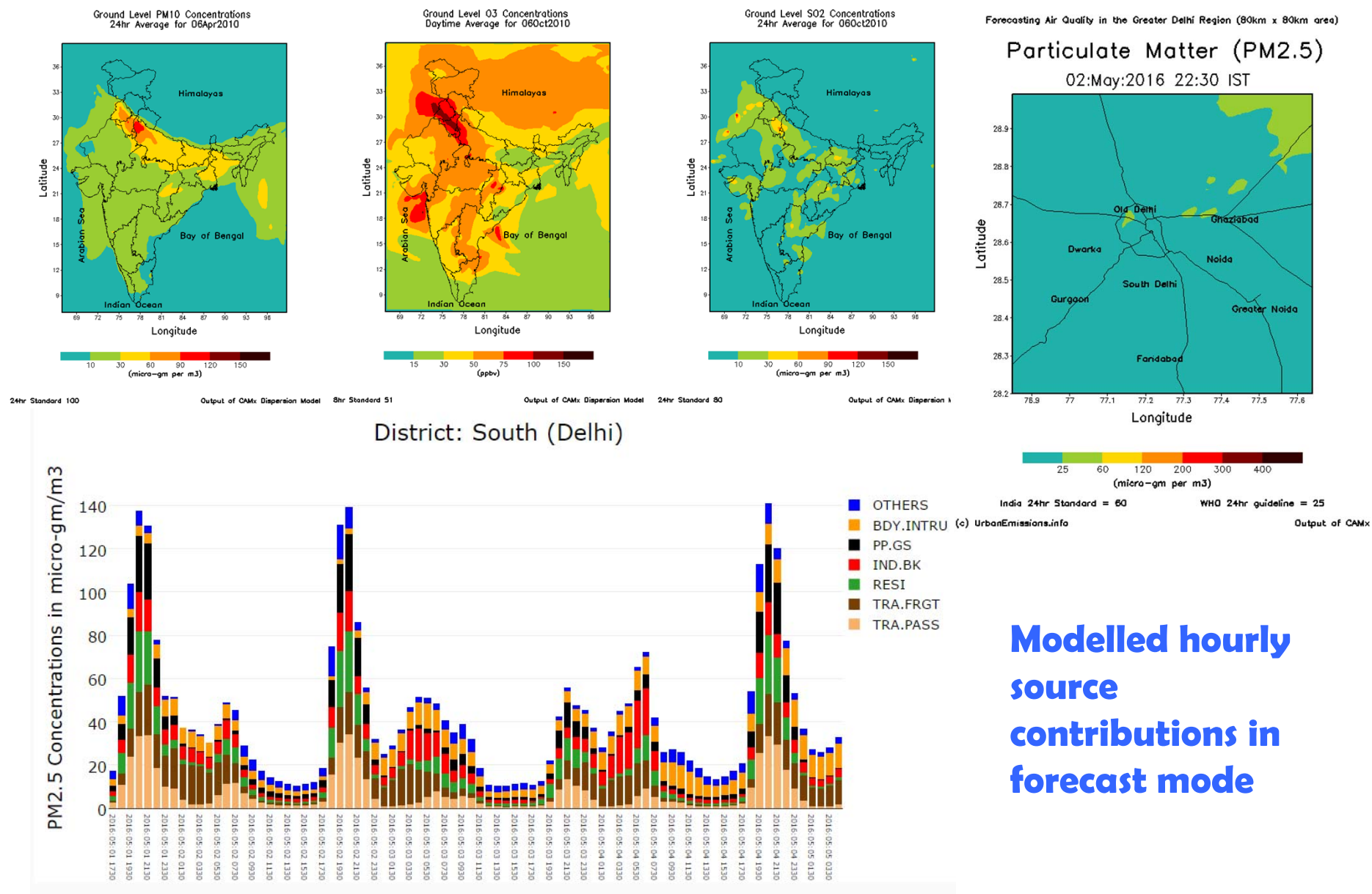
Output of CAMx Dispersion Model



# regional WRF-CAMx simulations

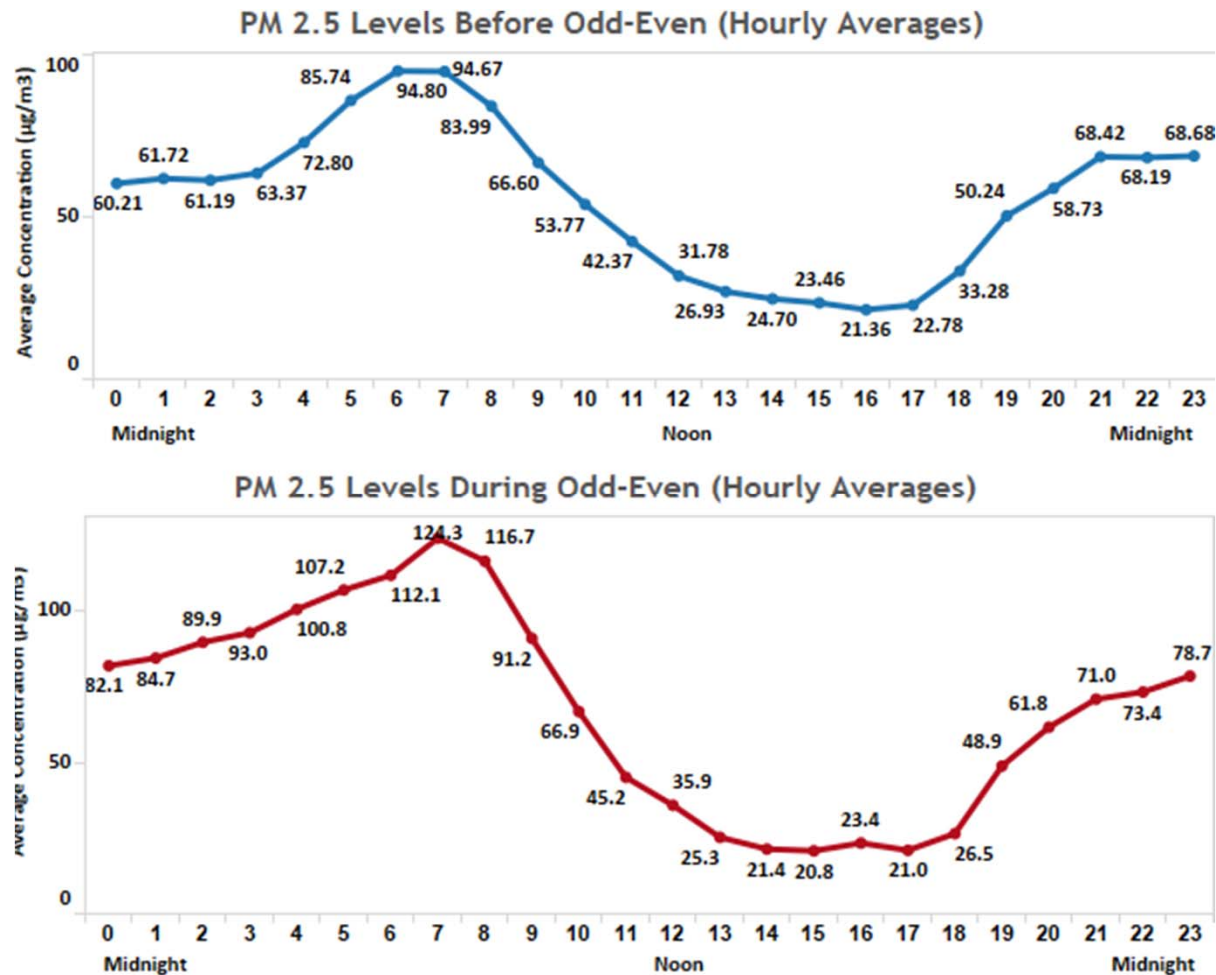


# regional WRF-CAMx simulations to support health and air quality alerts



**Modelled hourly source contributions in forecast mode**

# Delhi Odd/Even Experiment 2

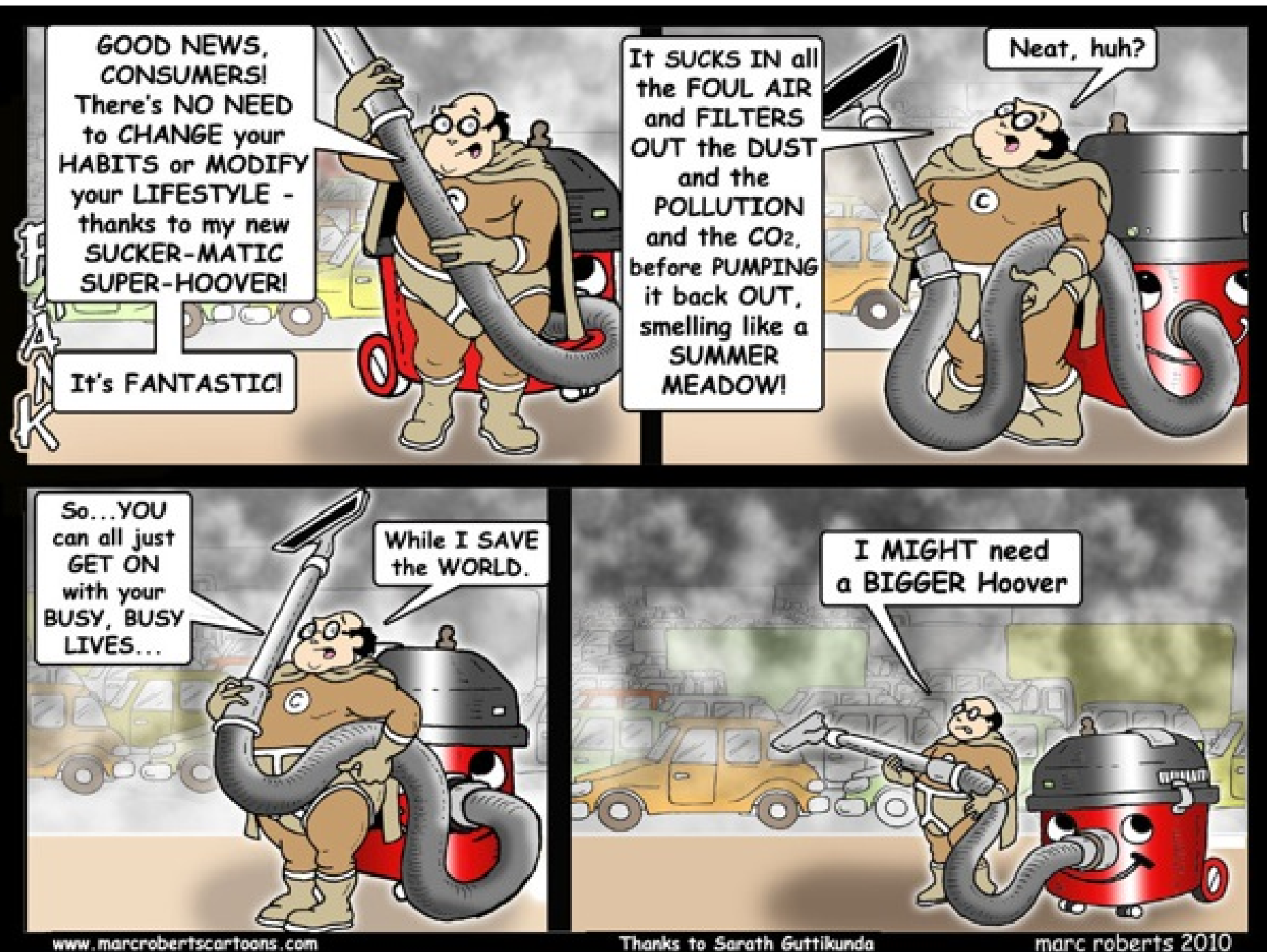


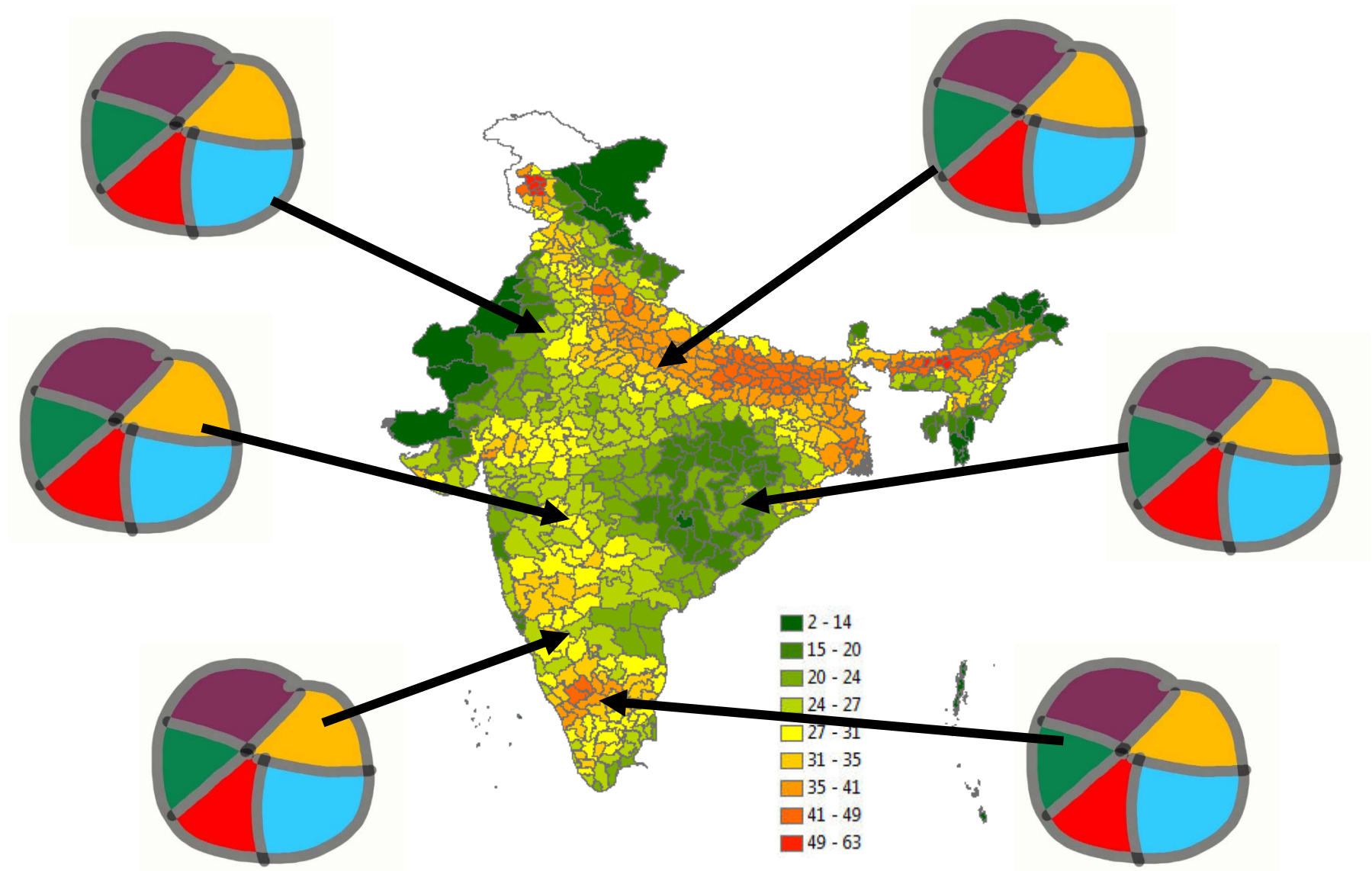
Data source : India Spend



# Giant vacuum cleaner?







<http://www.indiaairquality.info>

<http://www.delhiairquality.info>