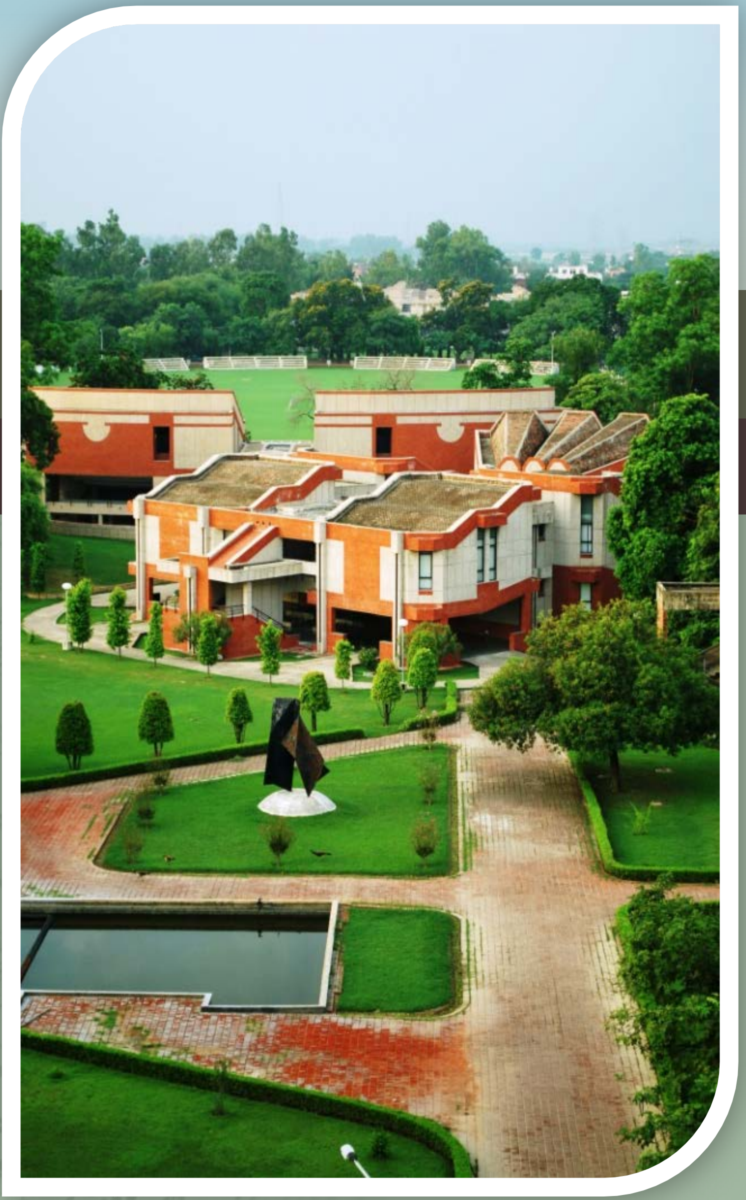
HyCAMP

National Emission Inventory of Black Carbon ; Uncertainty Analyses



Dr. Mukesh Sharma
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Anil Agarwal Dialogue 2015

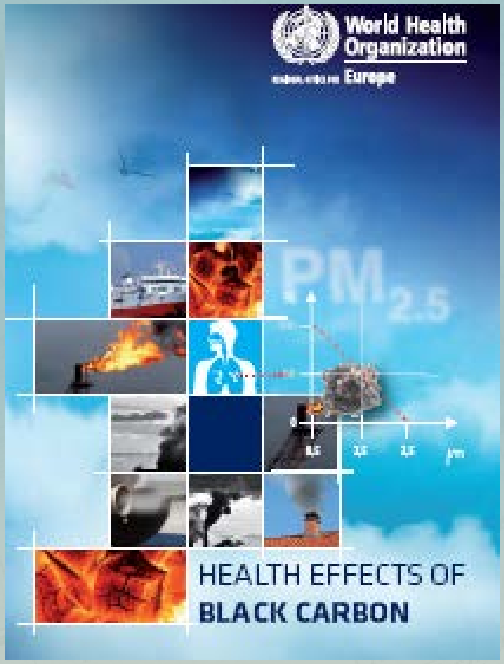
Importance

- Deposition of light absorbing pollutants(eg. Black Carbon) enhance the rate of melting of glaciers
- Himalayan glaciers are central to India's water needs, they supply water to large river systems that support millions of people inhibiting the surrounding areas

Himalayan Snow covered with Black Carbon

Health Importance

The systematic review of the available time-series studies, as well as information from panel studies, provides sufficient evidence of an association of short-term (daily) variations in BC concentrations with short-term changes in health (all-cause and cardiovascular mortality, and cardiopulmonary hospital admissions). Cohort studies provide sufficient evidence of associations of all-cause and cardiopulmonary mortality with long-term average BC exposure.



Why Emission Inventory

Analysis, Impact, Exposure, Strategy, Control need Emission Inventory: Challenges?

Resolution:

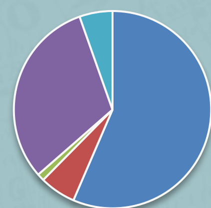
Climate Impact: Coarse (40 km x 40 km)
Health Impact: Fine (2km x 2km)

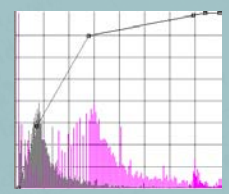
Challenges: Many
Uncertainty in Activity data and Emission Factors

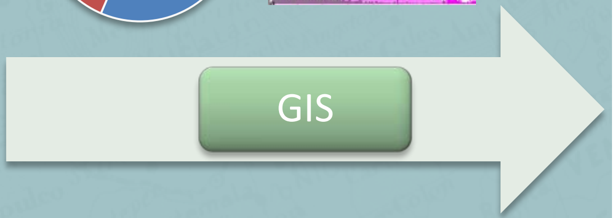
EMISSION INVENTORY, WHY GIS ?

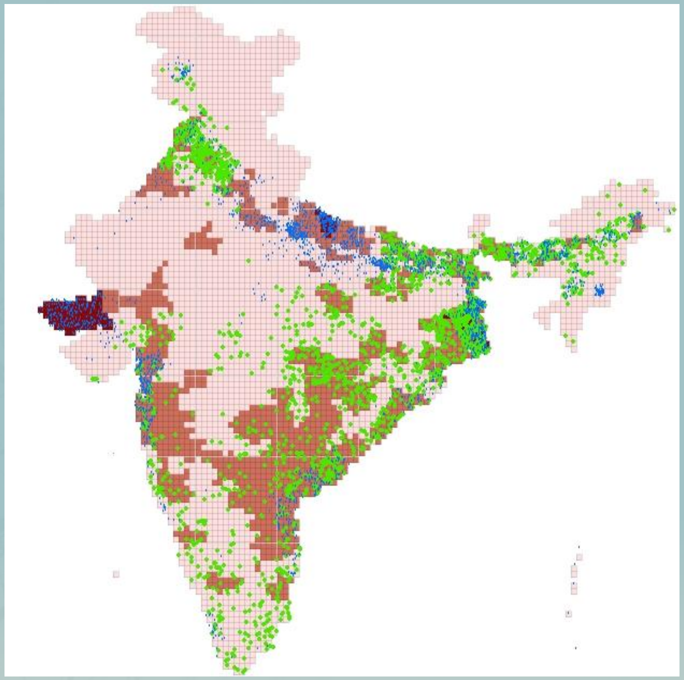
Often our Inventories are 'Tables'……

PM10	CO	SO2	NOx
961.41	5047.42	60.09	360.53
1406.75	7385.45	87.92	527.53
1447.48	7599.27	90.47	542.80
1005.39	5278.27	62.84	377.02
1894.00	9943.53	118.38	710.25
1725.42	9058.45	107.84	647.03



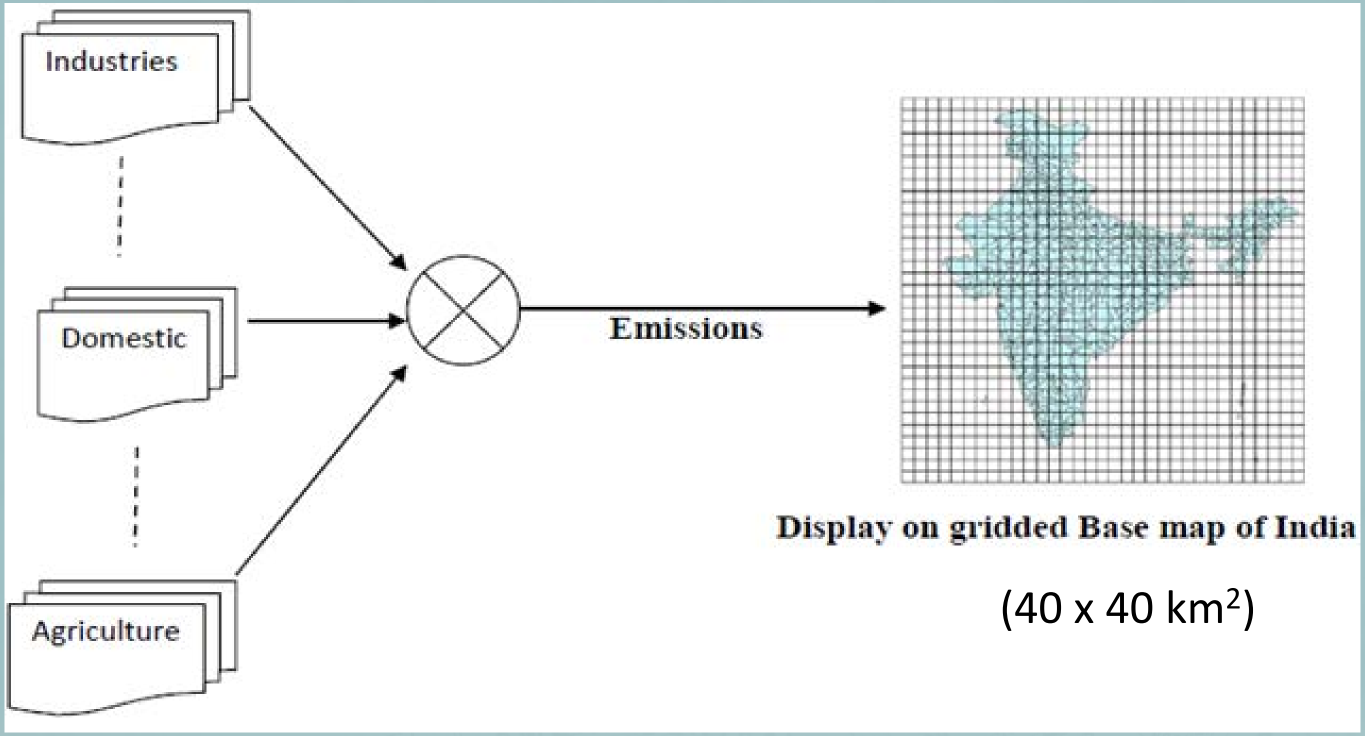






- **Advantages** -
  - More understandable and accessible
  - Increase integration and consistency
  - Provide various analytical tool for database
  - Visualization, Mapping and Modeling

MAPPING AND GRID EXTRACTION



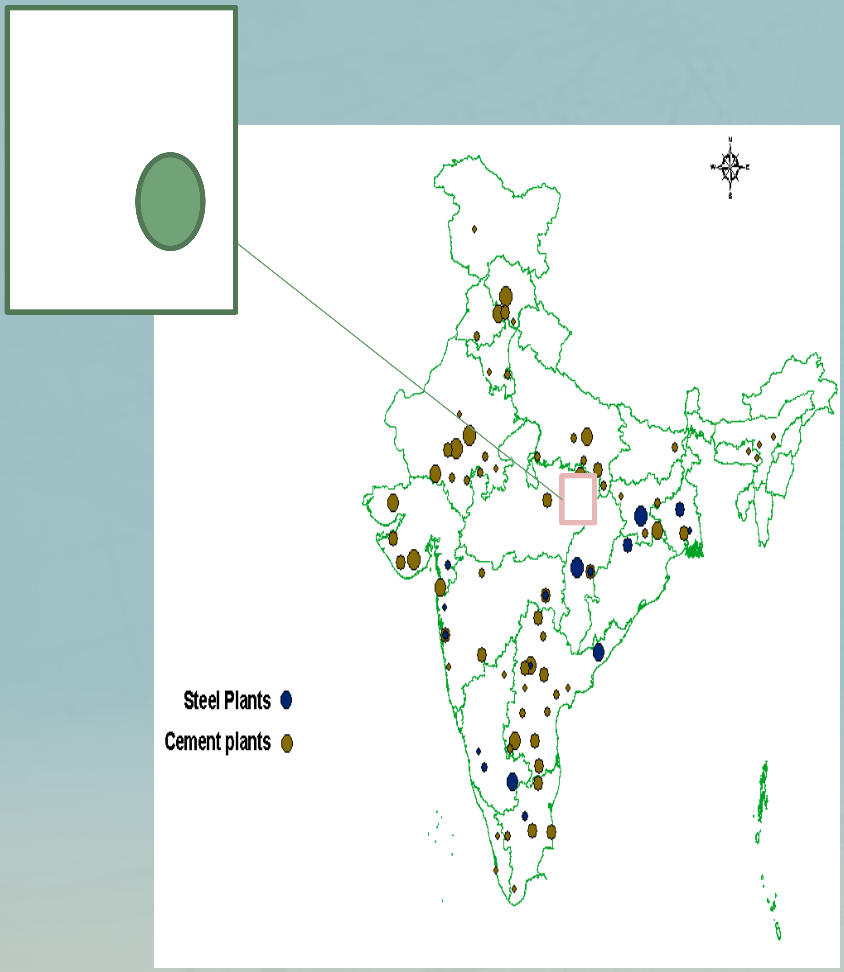
$Activity_{projected} = f\ (Activity_{baseyear}, \text{Growth rate})$

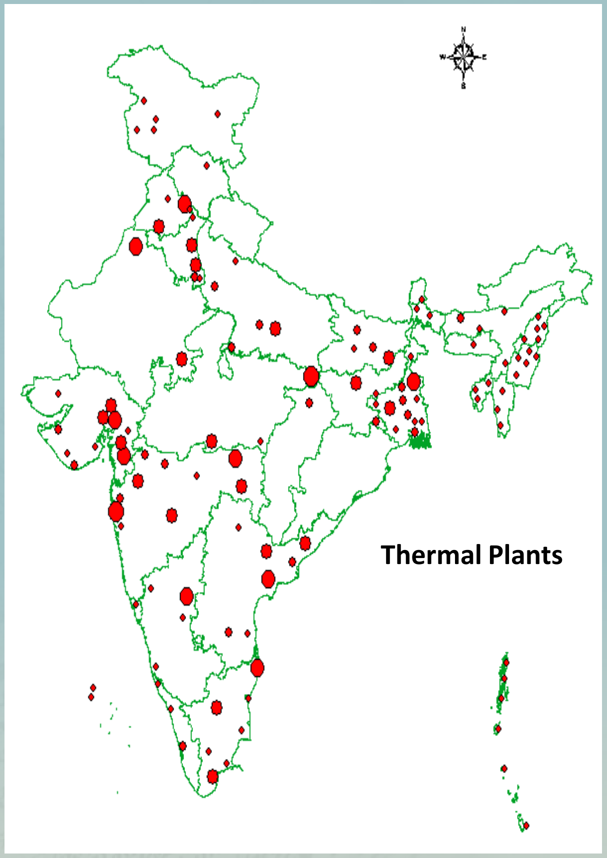
$PEC_{ij} = f\ (Activity_{ij}, \text{Emission Factor}_i)$

$\text{Total Emission}_j = \sum_{i=1} PEC_{ij}$

i=Source
j=Location
PEC_{ij}= Projected Emissions of BC

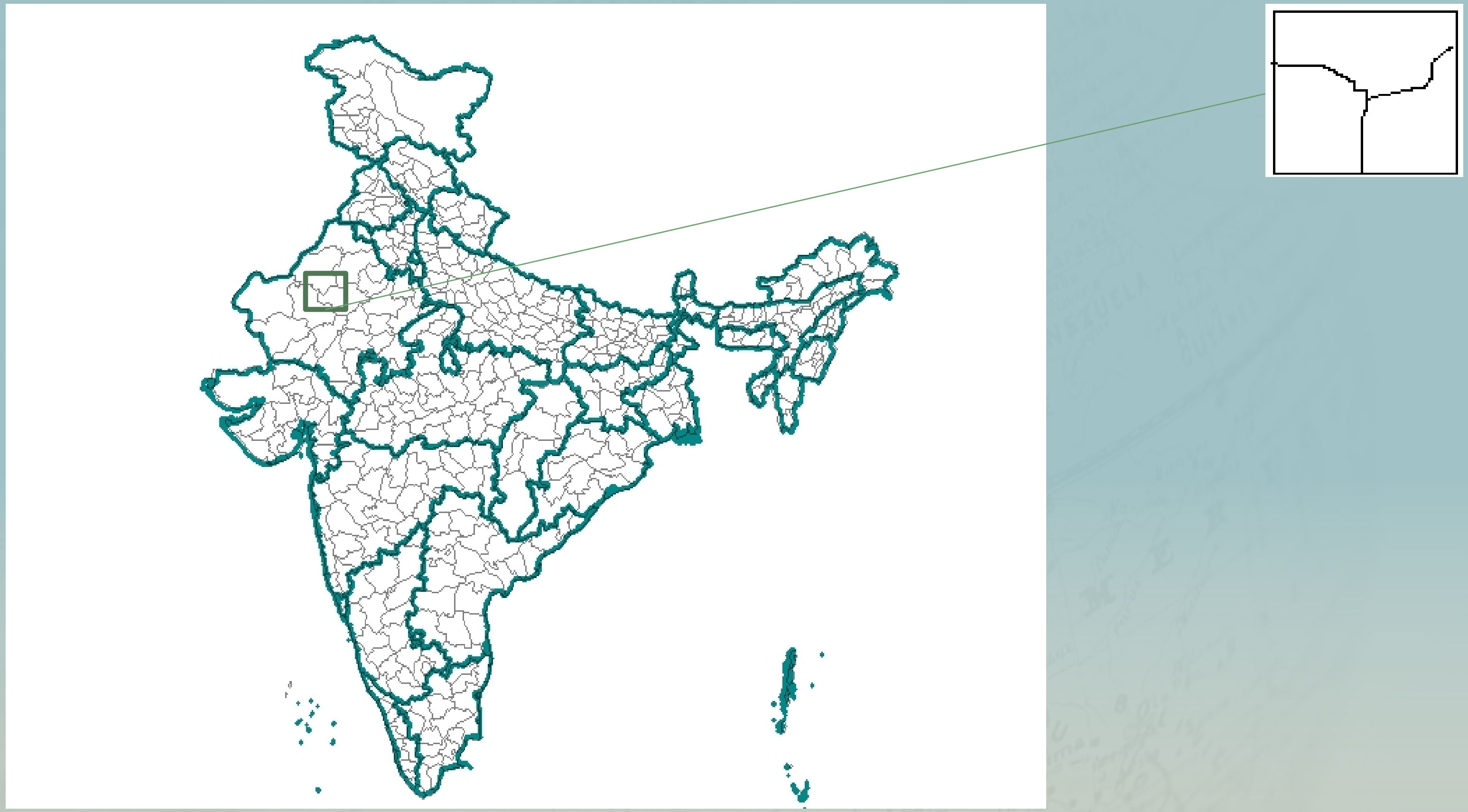
POINT SOURCES





AREA SOURCES

District wise Emission Density (ED) = Emission / District Area(km^2)
Grid wise Emission = ∑ (Intersected district area X ED)



SOURCES

Sector	Sub Sector
Domestic Fuel	Firewood
	Agriculture Residue
	Coal
	LPG
	Kerosene
	Dung Cake
Open Burning	Waste Burning
	Crop Residue Burning
	Forest Fire
Industry	Brick
	Cement
	Steel
	Sugar

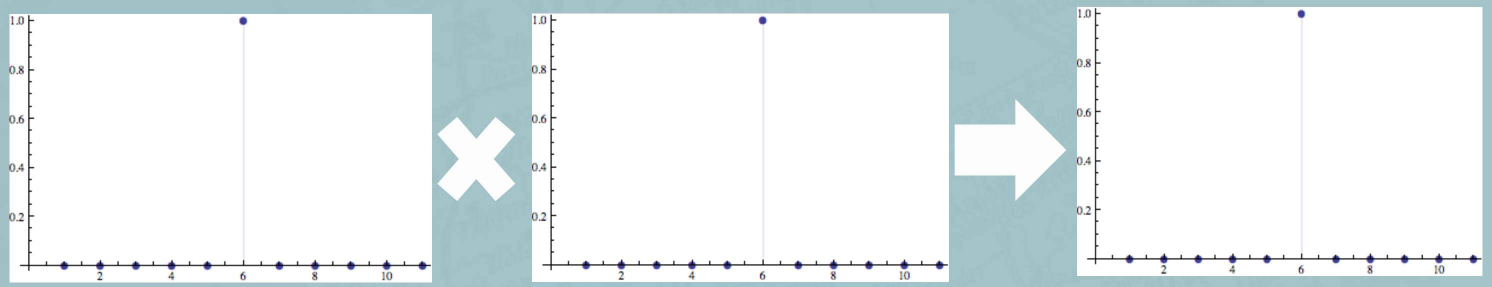
Sector	Sub Sector
Transport	Two Wheeler
	Trucks
	LMV Passenger
	LCV
	Car
	Taxi
	Bus
	Tractors & Trailers
	Railways
Power Plants	Diesel & Coal

Comprehensive source selection

EMISSION INVENTORY, CHALLENGES

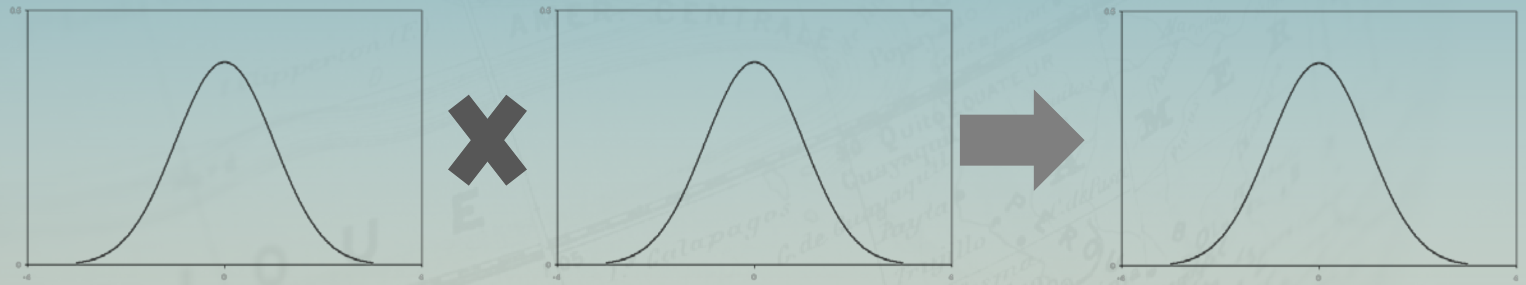
- Large variation in Activity data and Emission factors
- No point estimate is better or worse than other

Previous studies



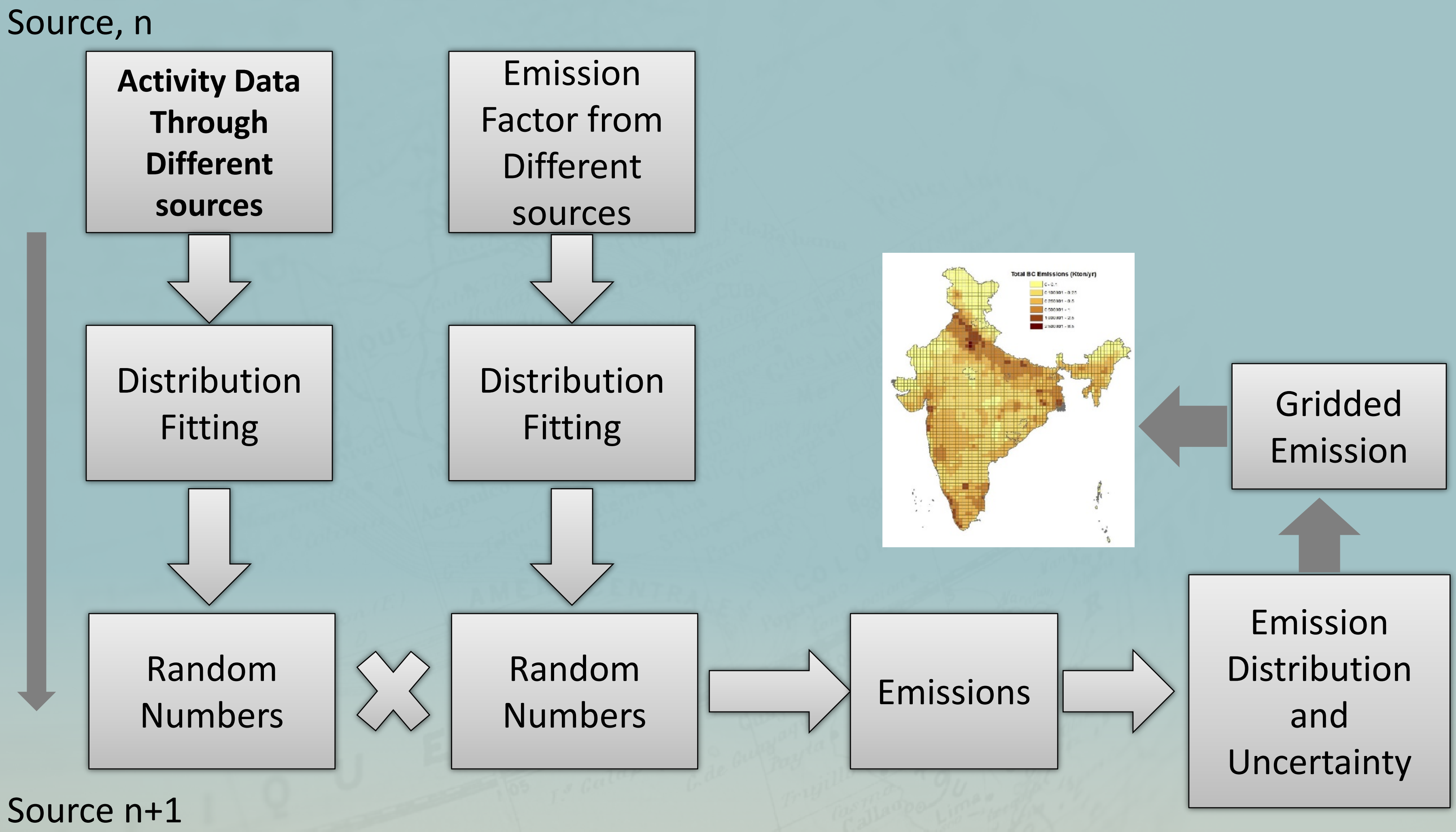
Activity　　Emission Factor　　Emissions

This study



Activity　　Emission Factor　　Emissions

METHODOLOGY - MONTE CARLO SIMULATION



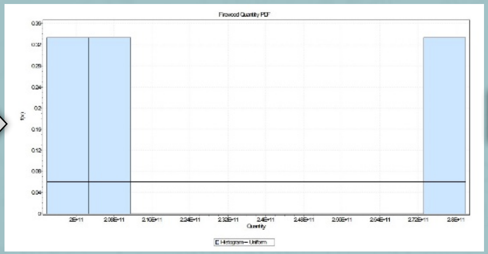
EMISSION FACTORS

Source	EF (g/kg)
Brick	0.16±0.09
Cement	0.45±0.51
Crop Burning	0.69±0.19
Forest Fire	0.76±0.21
Garbage Burning	0.51±0.15
Railway Coal	1.67±1.25
Railway Diesel	0.78±0.59
Steel	0.45±0.51
Sugar	0.95±0.27
Power Coal	0.03±0.03
Power Diesel	0.15±0.08

Source	EF(g/km)
Bus	0.70±0.51
Two wheeler	0.02±0.01
Car	0.09±0.06
LCV	0.34±0.44
LMV Passenger	0.15±0.01
Taxi	0.05±0.02
Tractor &Trailer	0.63±0.67
Truck	0.52±0.43

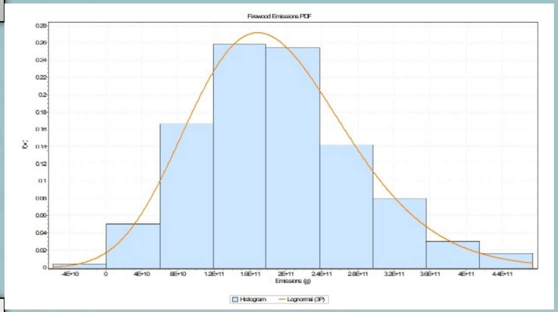
EMISSIONS FROM DOMESTIC FIREWOOD

Total Fuelwood Consumption from 3 sources

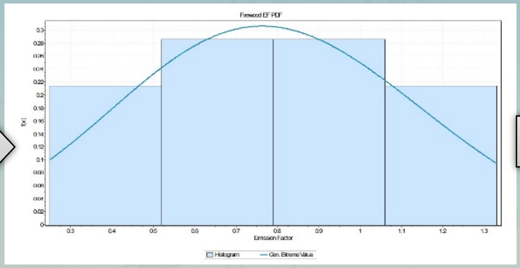


Random Numbers from fitted distribution

×



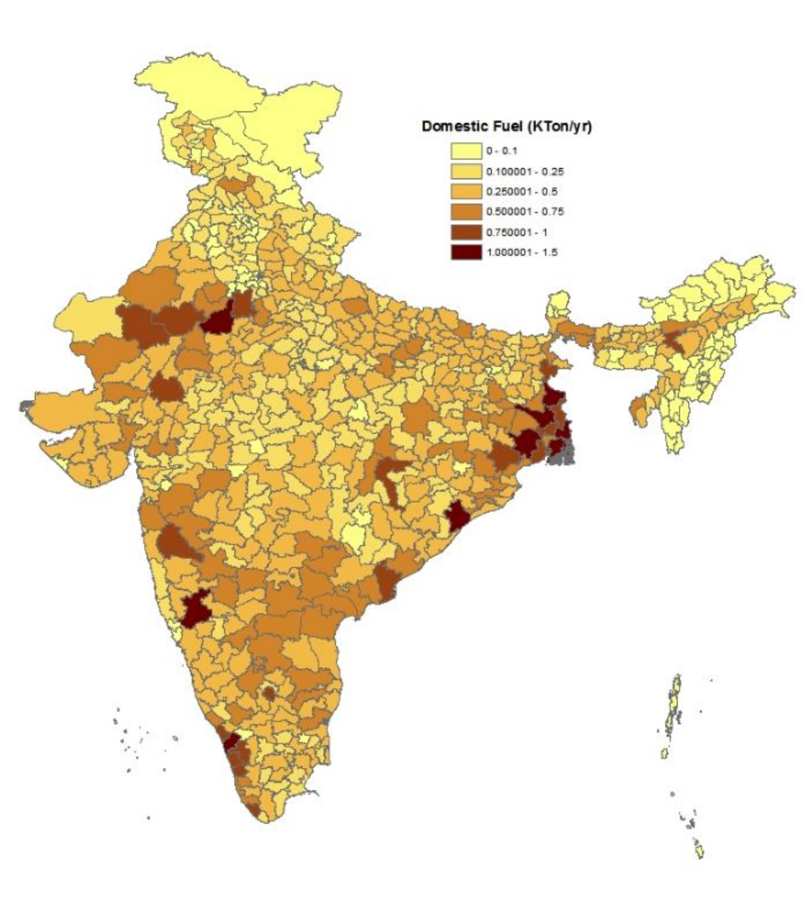
Firewood EF
14 sources

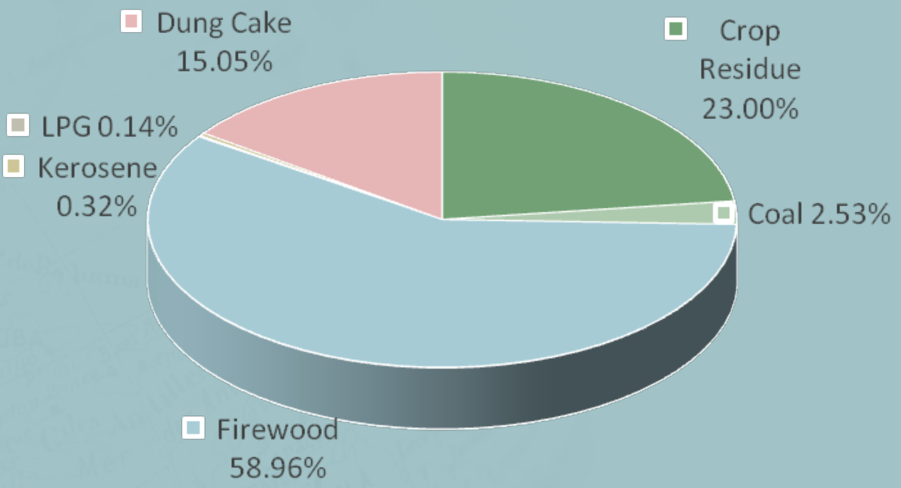


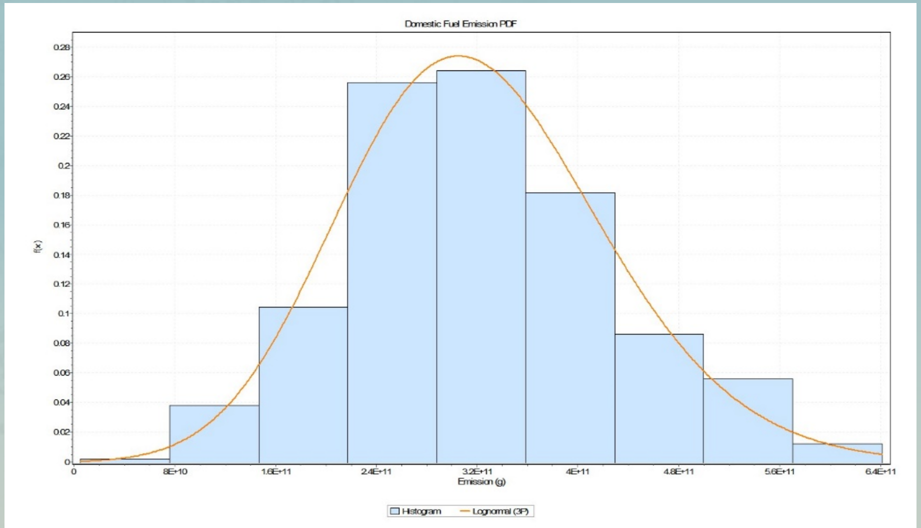
Random Numbers from fitted distribution

DOMESTIC COMBUSTION

BC Emission 321.75 KTon/yr

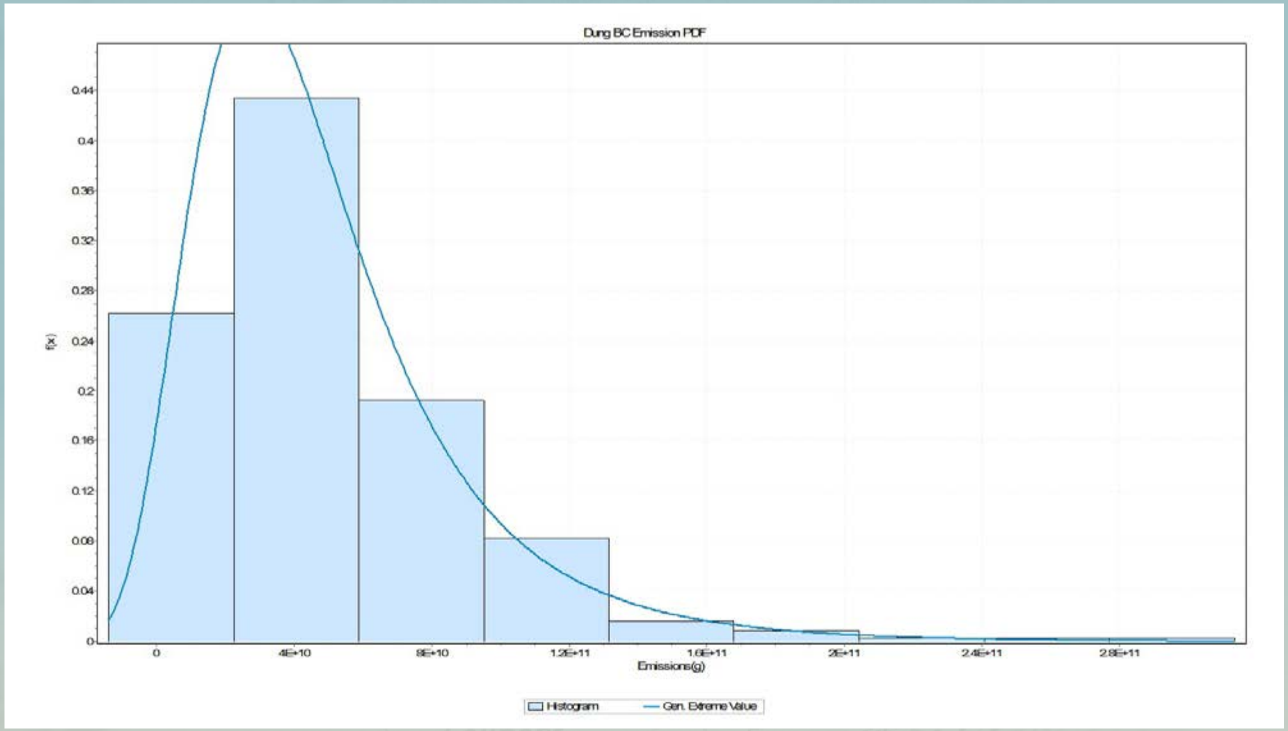






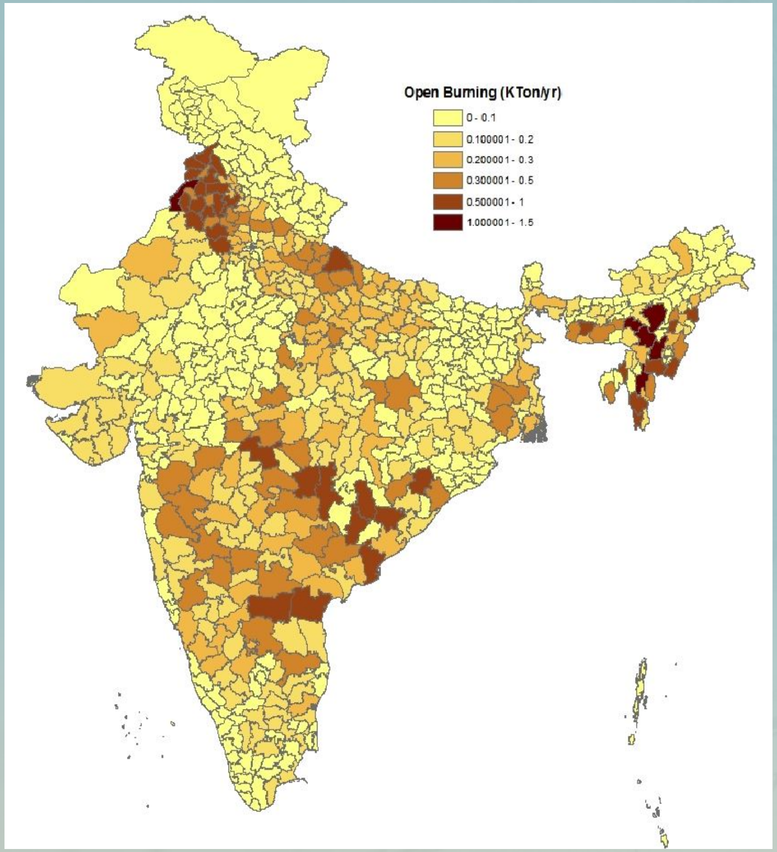
DOMESTIC COMBUSTION

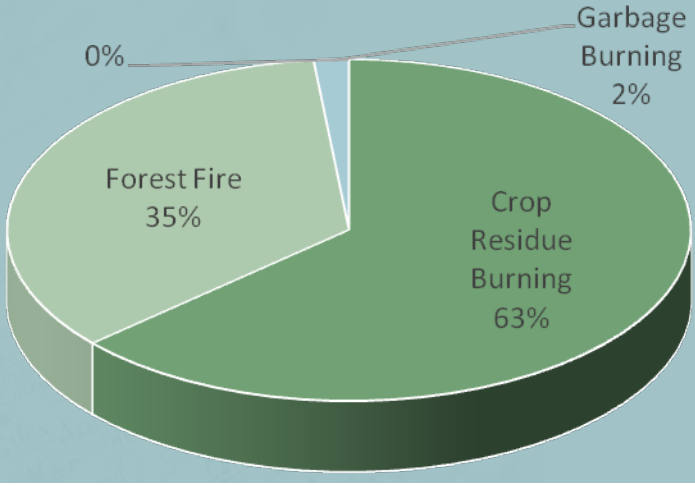
Source	Distribution	Parameters
Firewood	Lognormal 3P	σ = 0.15857 μ = 27.043 ϒ = -3.725E+11
Dung Cake	General Extreme Value	K = 0.10209 σ = 2.609E+10 μ = 3.046E+10
Coal	Gen. Gamma	K = 0.37 α = 4.37 β = 9.911E+7 γ = 1.28E+8

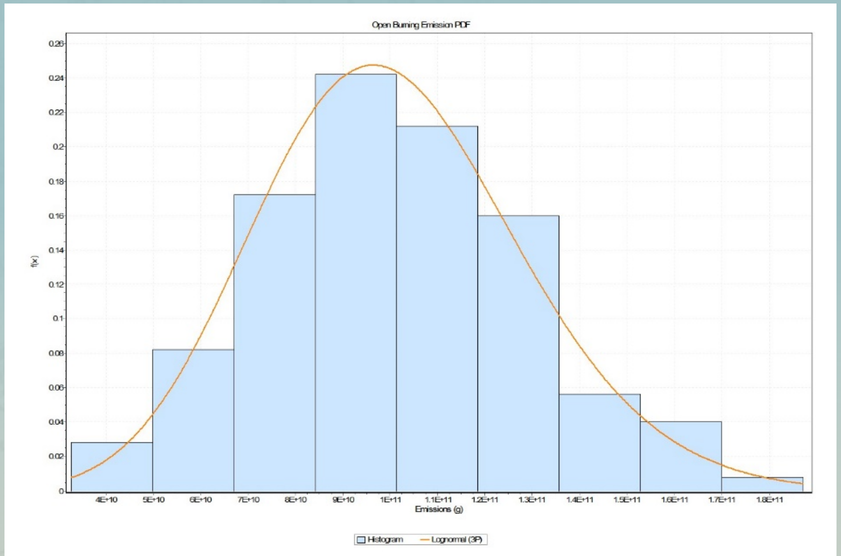


OPEN BURNING

BC Emissions 100.6 Kton/yr

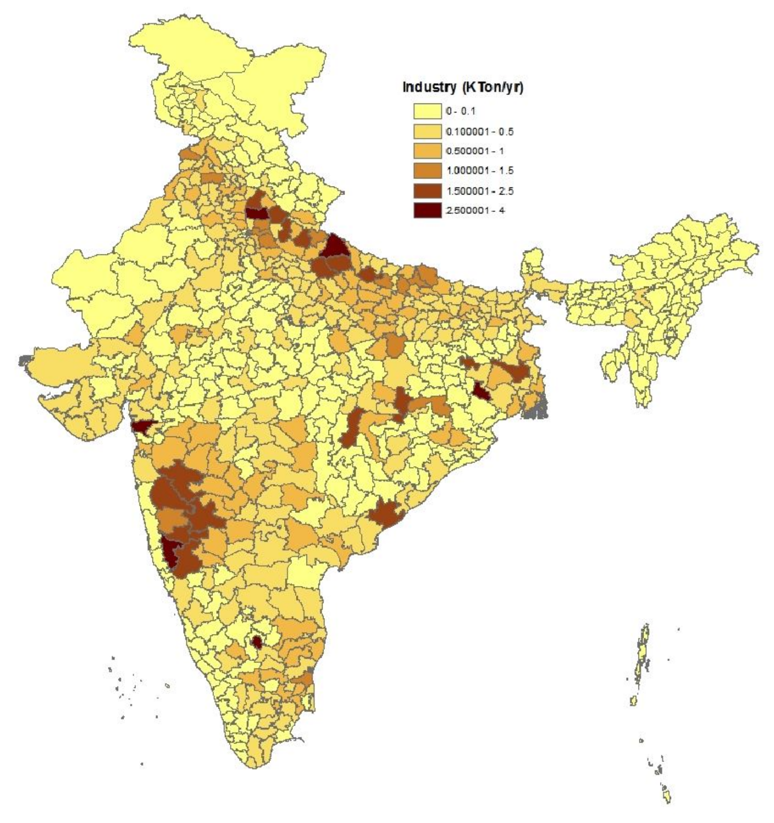


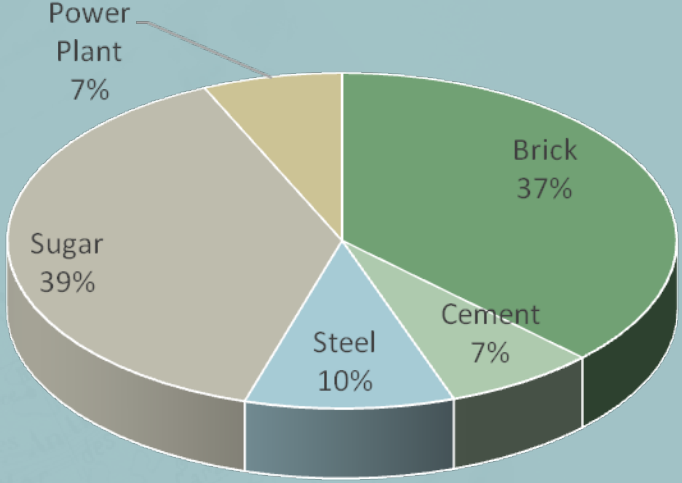


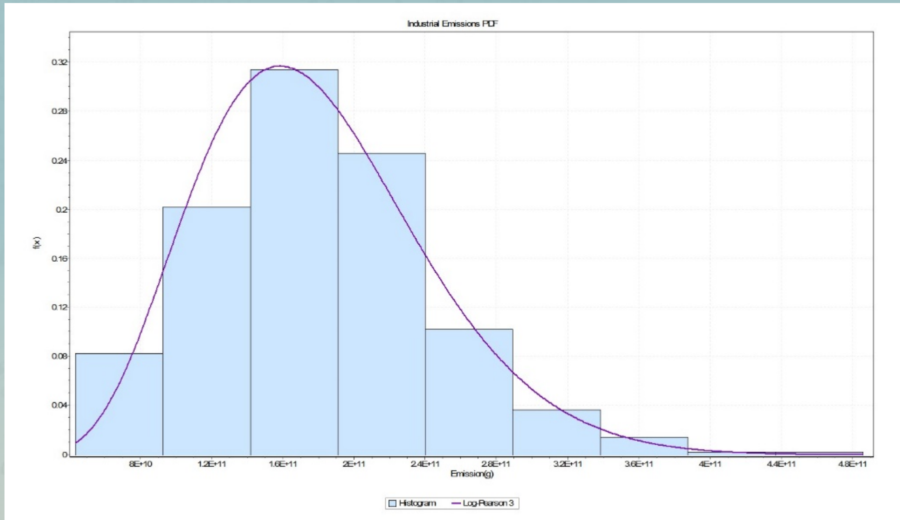


INDUSTRIAL EMISSIONS

BC Emissions 191.7 Kton/yr

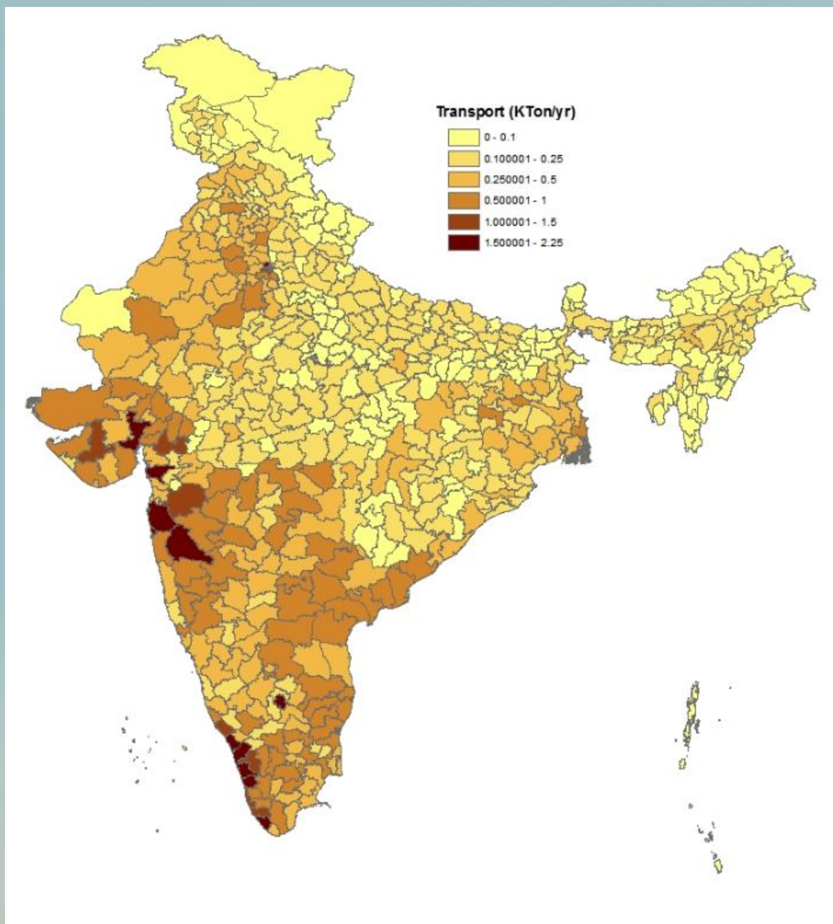


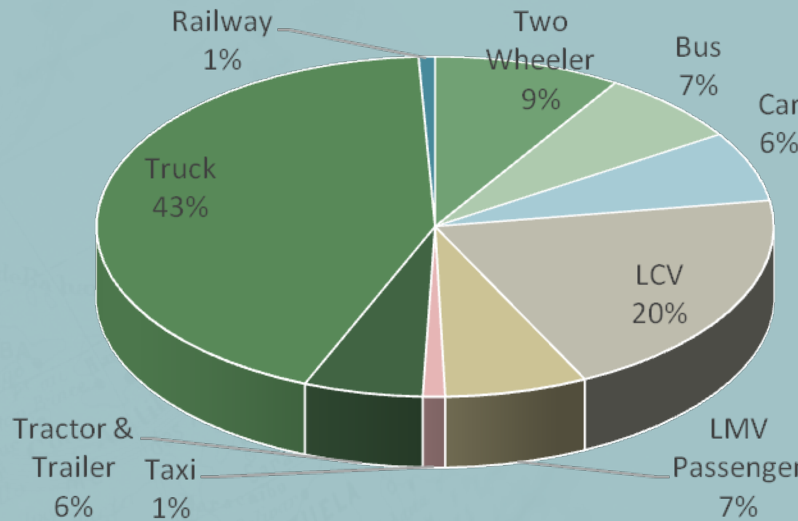


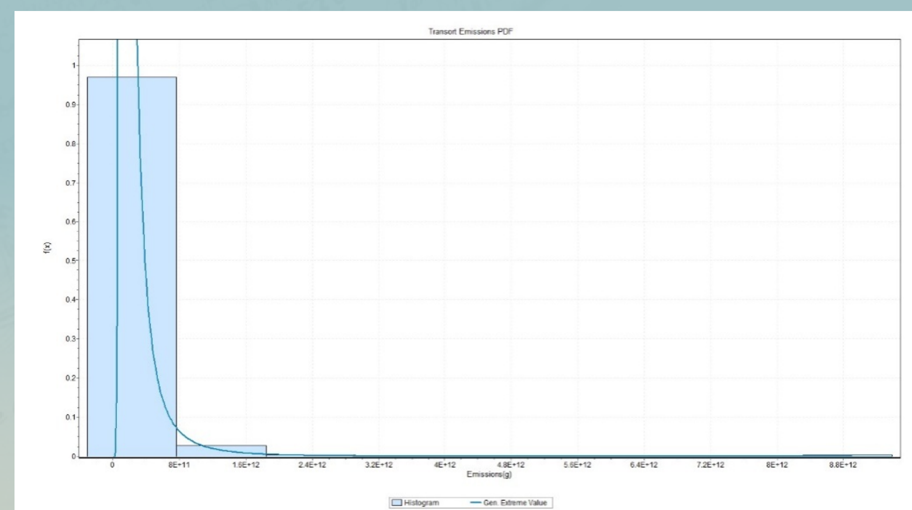


TRANSPORTATION

BC Emission 209.12 KTon/yr







TRUCK EMISSIONS

Emission from Trucks = Σ(N x AKT x EF)

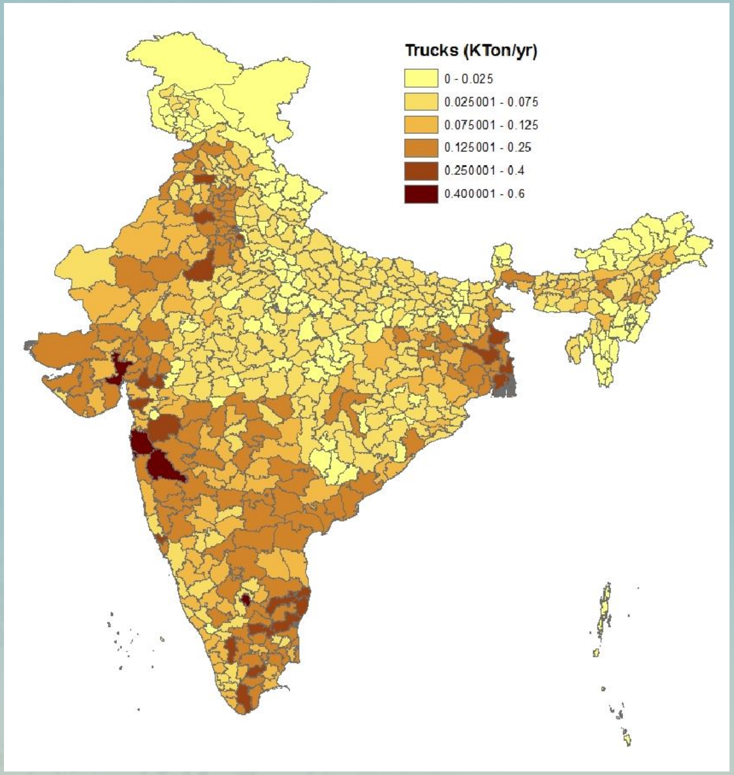
N – Number of vehicles on road determined using survival function from 1971-2011

AKT – Annual km Travelled

EF – Emission factor (g/km)

The standard deviation in emissions from truck is high because of highly variable emission factors and annual distance travelled by a truck

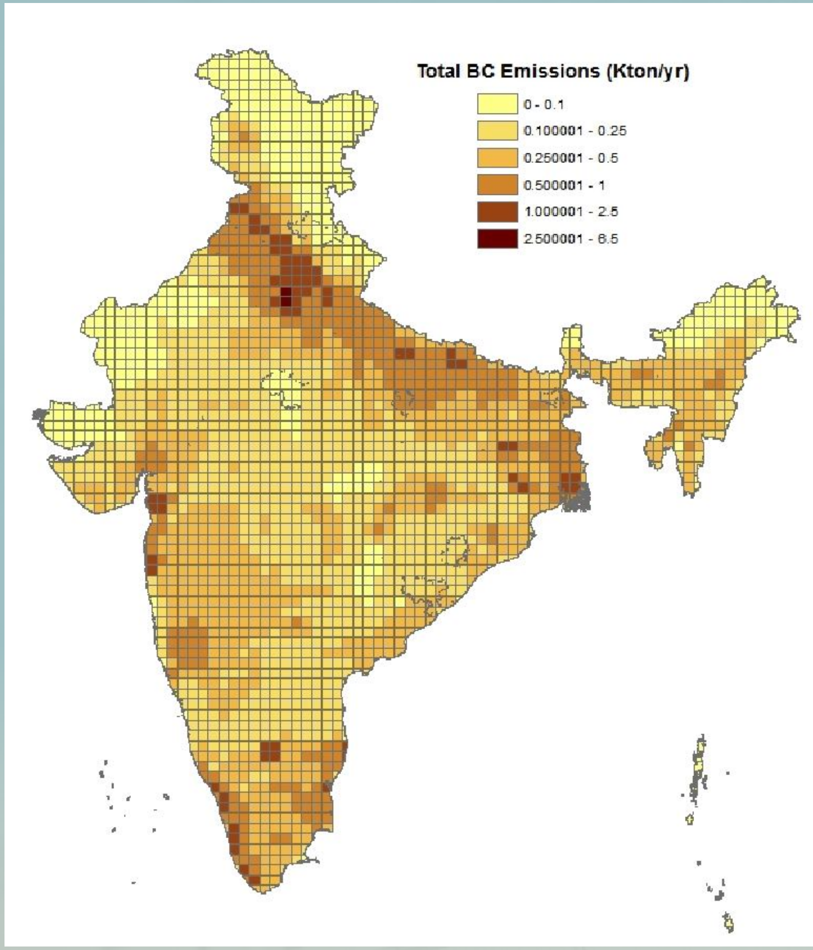
Annual km. Travelled	EF(g/km)
56350	1.24
30000	0.61
40000	0.26
57500	0.18
47000	0.304



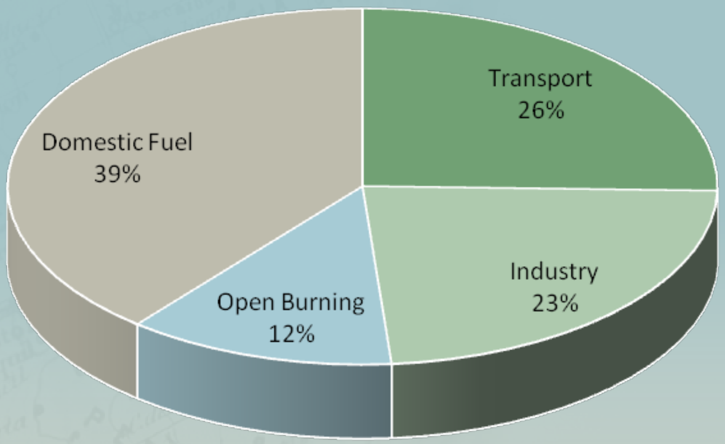
SOURCE-WISE BC EMISSIONS (2011)

Source	Mean BC Emission(Kton/yr)
Bricks	71.46 ± 44.29
Cement Industry	14±17.60
Crop Residue	63.84±16.92
Domestic Fuel	321.75±104.49
Garbage Burning	1.66±0.64
Sugar Industry	73.92±26.12
Transport	209.12±535.73
Forest Fire	35.10±21.59
Power Plants	12.94±20.04
Steel Industry	19.38±31.74
Total	823.17±555.44

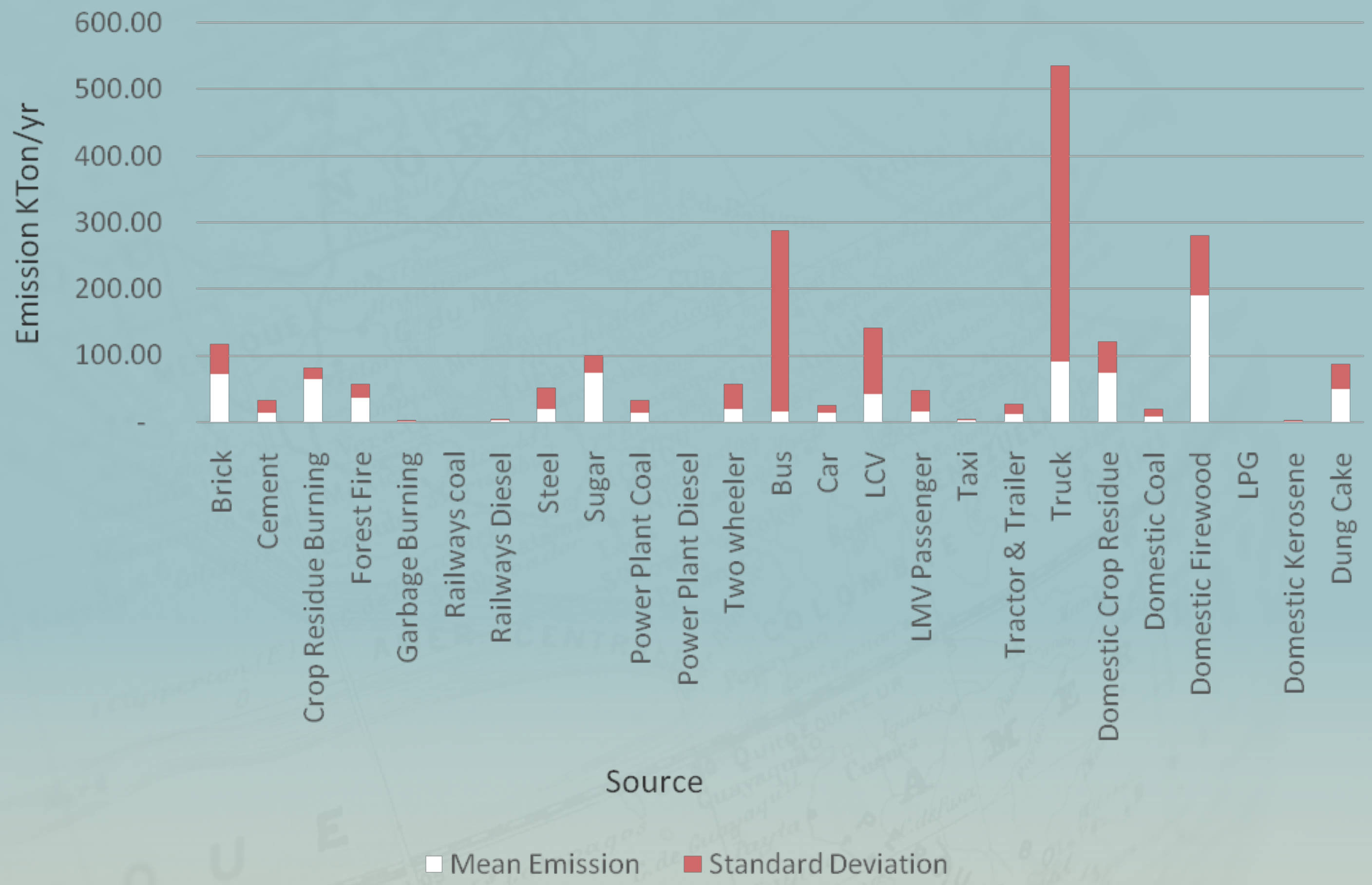
ANNUAL BC EMISSIONS IN INDIA - 2011



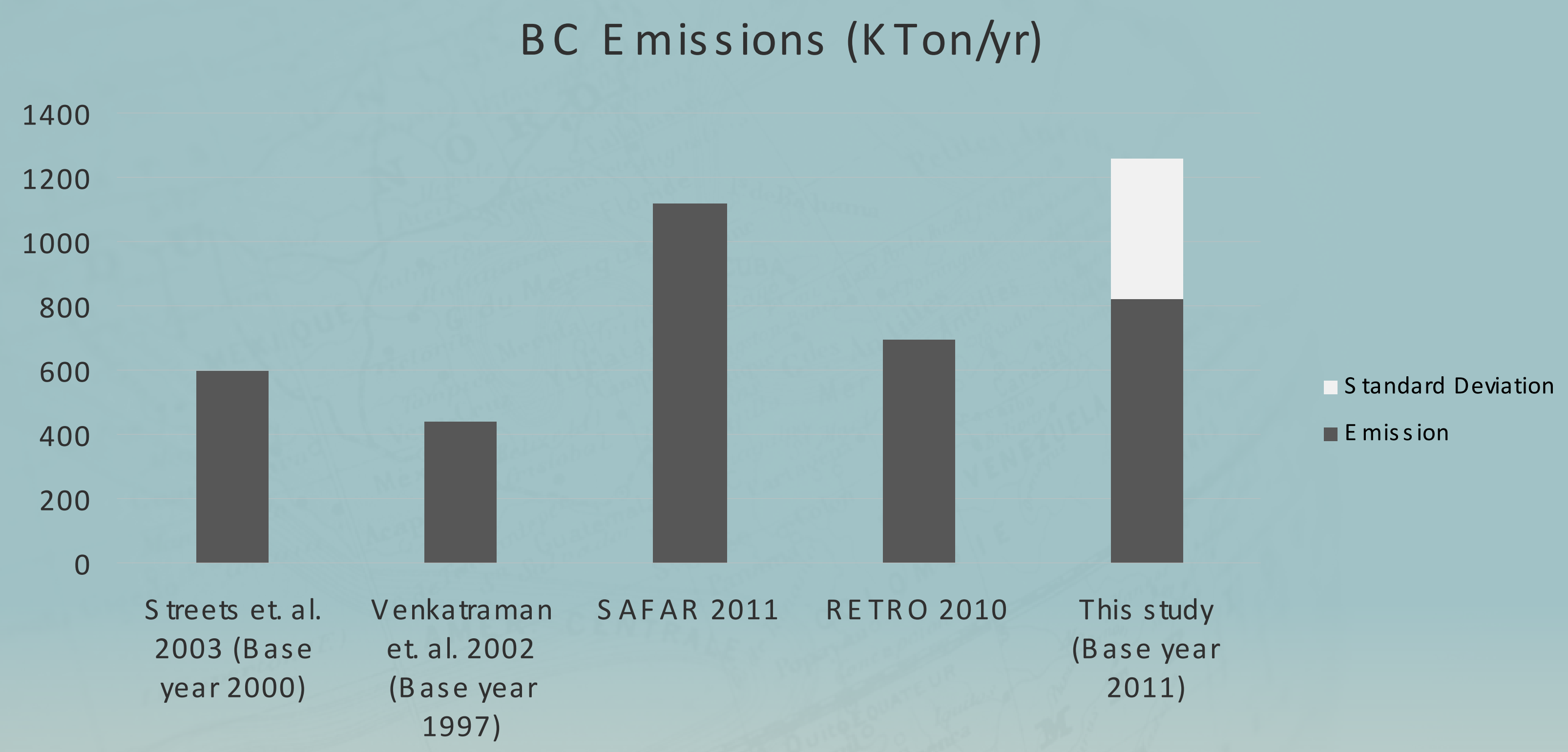
Total BC Emission 823.17 KTon/yr



SOURCE WISE EMISSION AND STANDARD DEVIATION



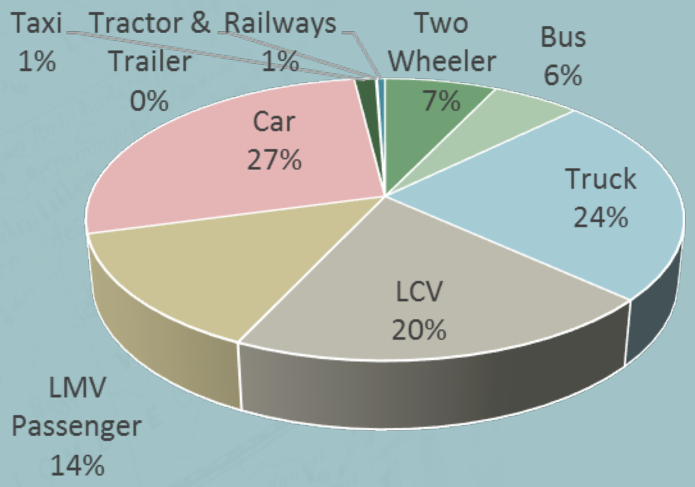
COMPARISON WITH PREVIOUS STUDIES

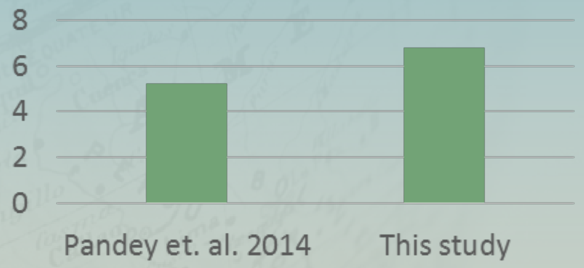


DELHI

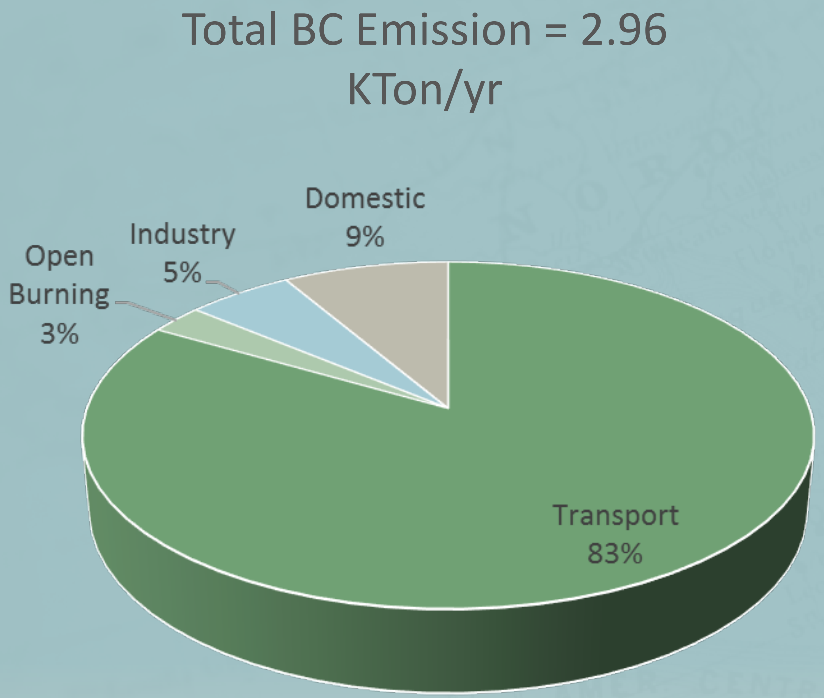
Total BC Emission = 7.12 KTon/yr

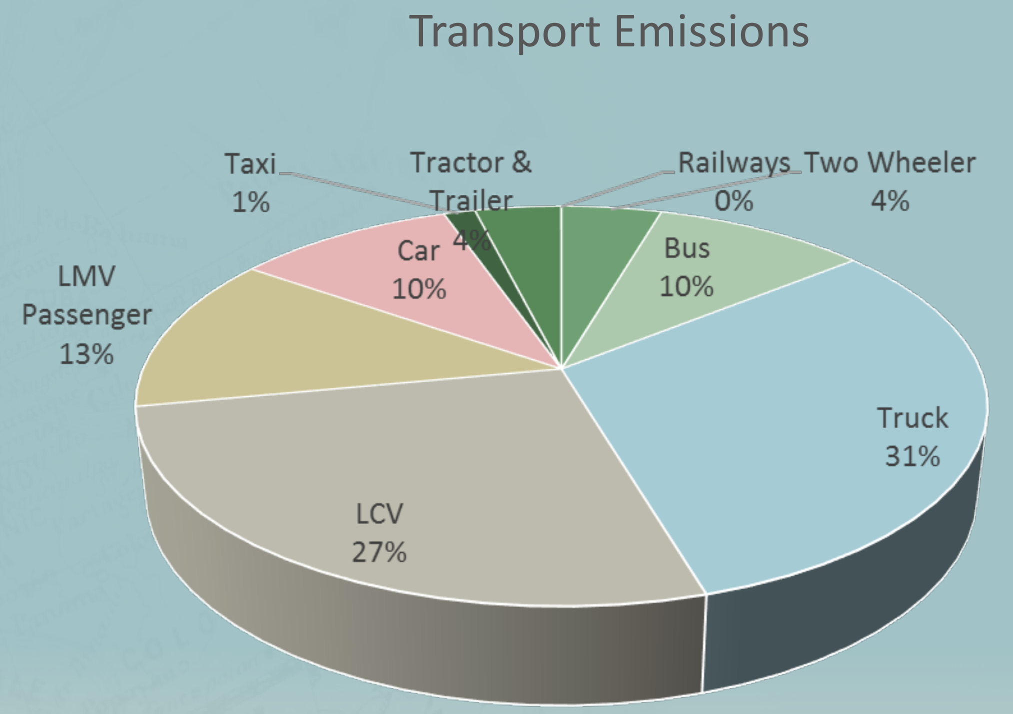
Transport Emissions





MUMBAI


Total BC Emission = 2.96 KTon/yr
Domestic 9%
Industry 5%
Open Burning 3%
Transport 83%

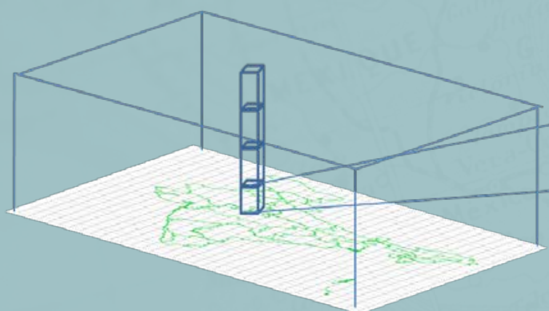

Transport Emissions
Taxi 1%
Tractor & Trailer 4%
Railways 0%
Two Wheeler 4%
Bus 10%
Car 10%
LMV Passenger 13%
Truck 31%
LCV 27%

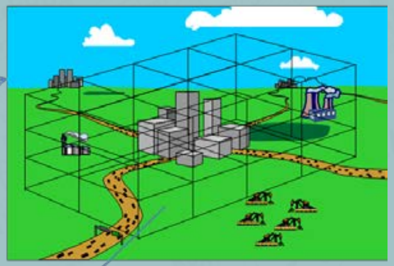
WAY AHEAD: Model and Strategy

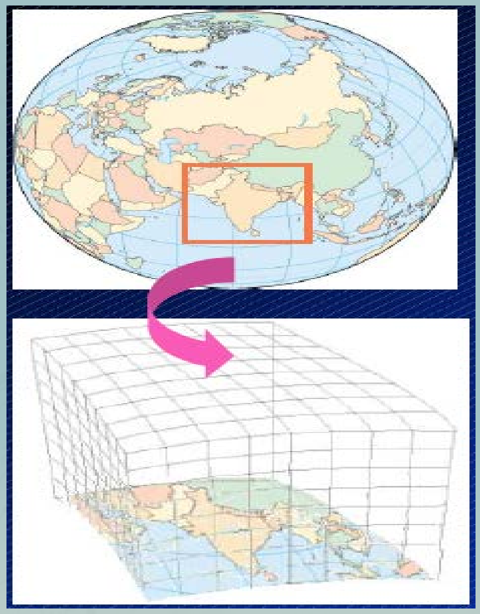
CAMx simulates the dispersion , chemical reactions, and removal of the pollutants in lower troposphere by solving the pollutant continuity equation on a system of nested three dimensional grids

$$\frac{\partial C}{\partial t} = -\nabla_H . VHC + \left[\frac{\partial (C\eta)}{\partial z} - C\frac{\partial}{\partial z}\left(\frac{\partial h}{\partial t}\right)\right] + \nabla . \rho K \nabla \left(\frac{C}{\rho}\right) + \frac{\partial C}{\partial t}_{Emiss} + \frac{\partial C}{\partial t}_{Chem} + \frac{\partial C}{\partial t}_{Remov}$$

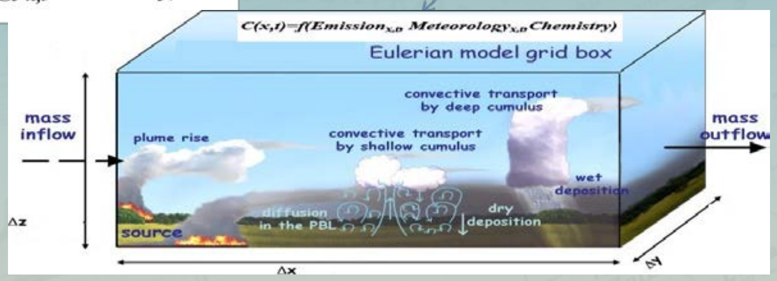
CAMx (Comprehensive Air Quality Model)– Chemical Transport Model



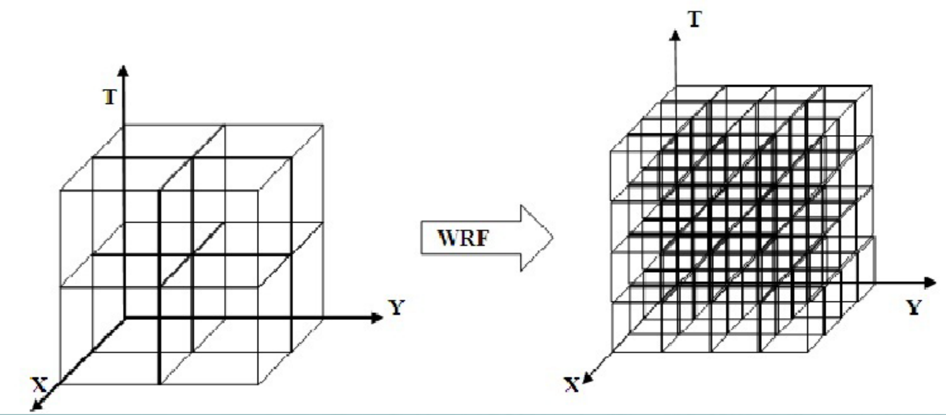


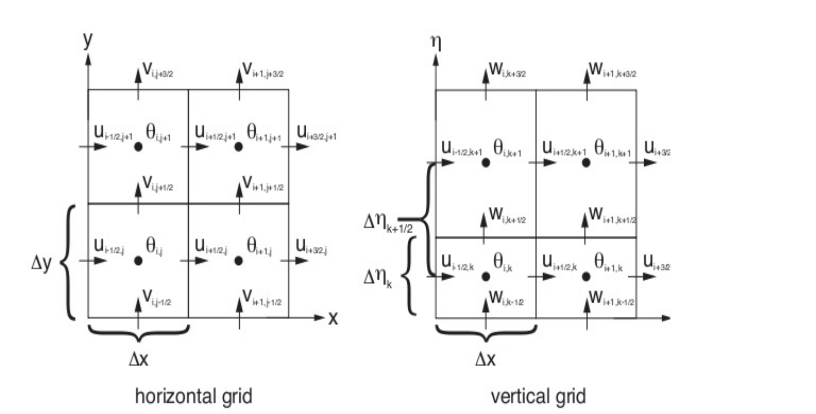


$C(x,t)=f(Emission_{x,t}, Meteorology_{x,t}, Chemistry)$



WRF





The WRF model takes input of meteorological parameters for a given geographical domain and can predict the values of these parameters at finer space and time resolution

WRF Validation-Qualitative

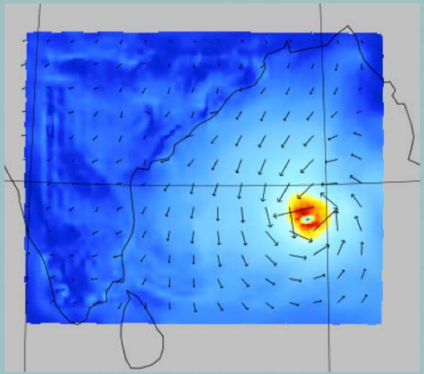
Lehar Cyclone 2013

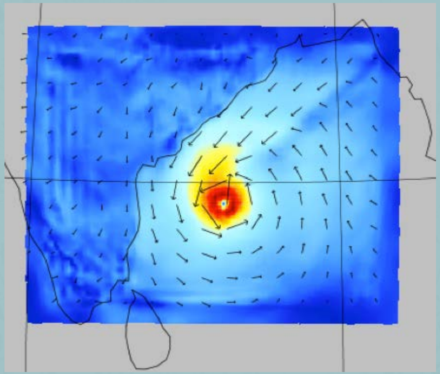
26.11.2013 0900 HRS

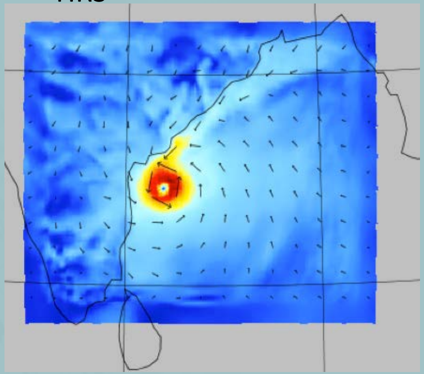
26.11.2013 2100 HRS

27.11.2013 0430HRS HRS

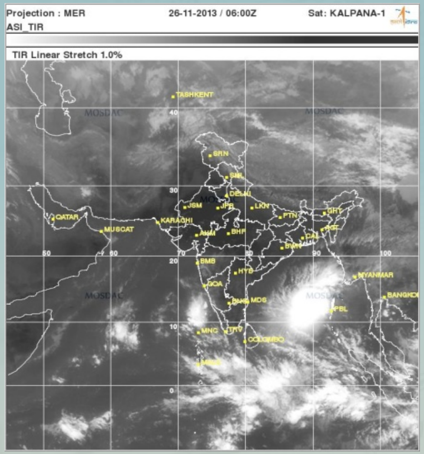
Model Output

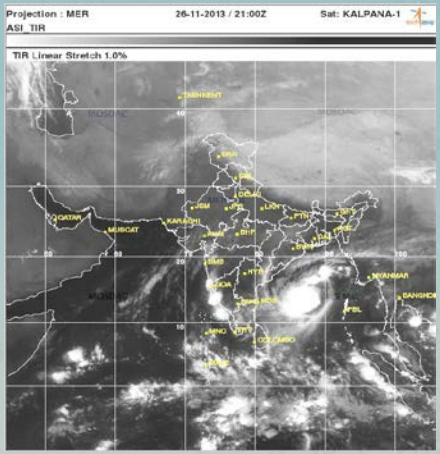


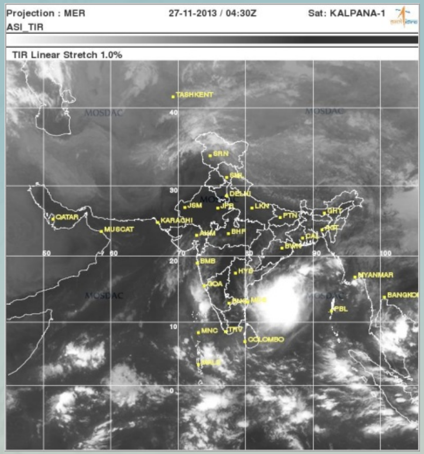




Kalpana Satellite Images





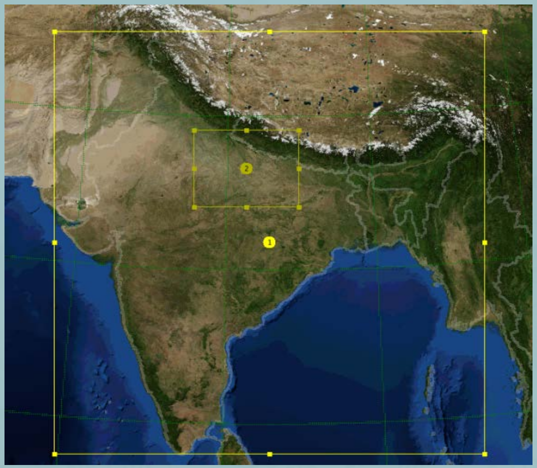


WRF Validation-Quantitative

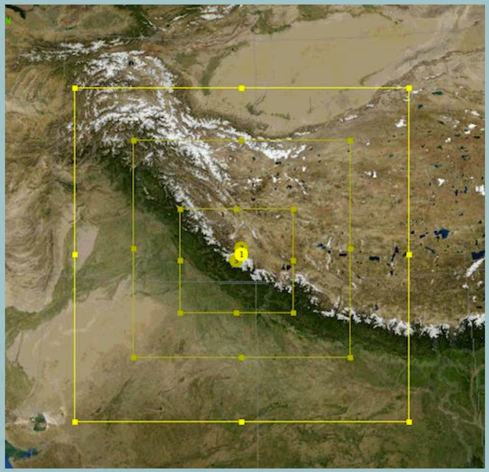
IIT Kanpur

IMD Station, Joshimath, Uttrakhand

Domain

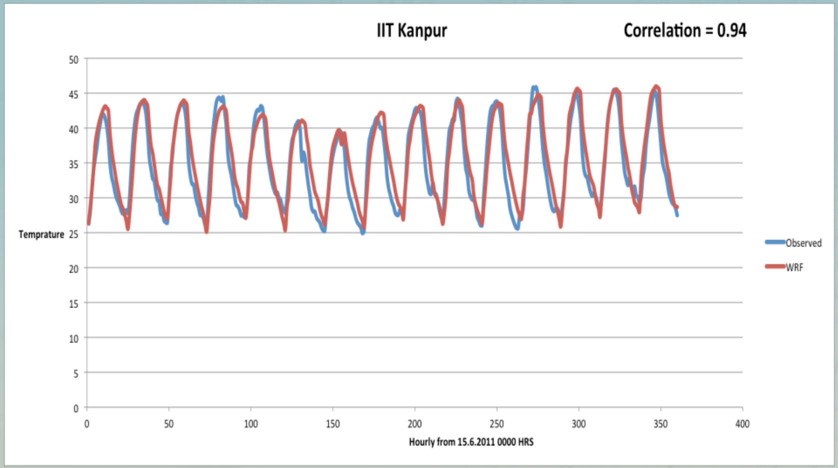


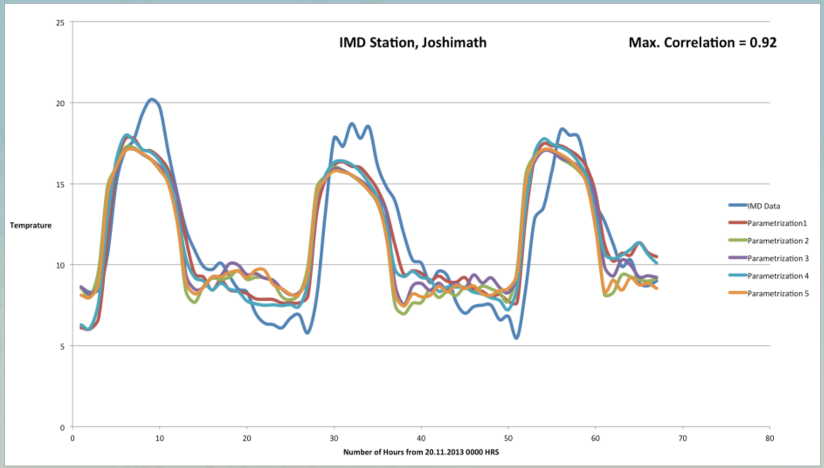
Grid Size –
40 km
13.33 km



Grid Size –
27 km
9 km
3 km

Results

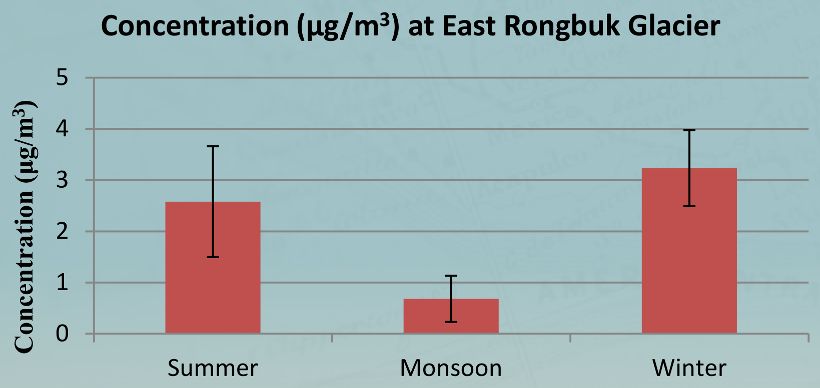


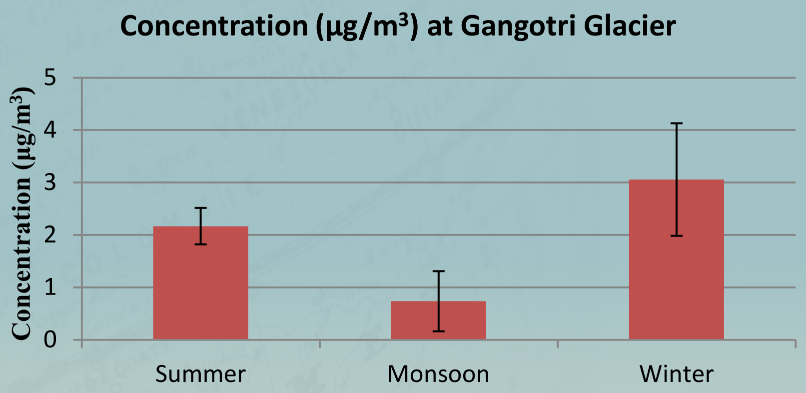


2008 STUDY

CONCENTRATIONS AT RECEPTOR SITES DUE TO EMISSIONS FROM INDIA

INDIA	Concentration in µg/m^3		
Receptor Location	**Summer**	**Monsoon**	**Winter**
Gangotri Glacier	2.17±0.35	0.74±0.57	3.06±1.07
East Rongbuk Glacier	2.58±1.08	0.68±0.45	3.23±0.74

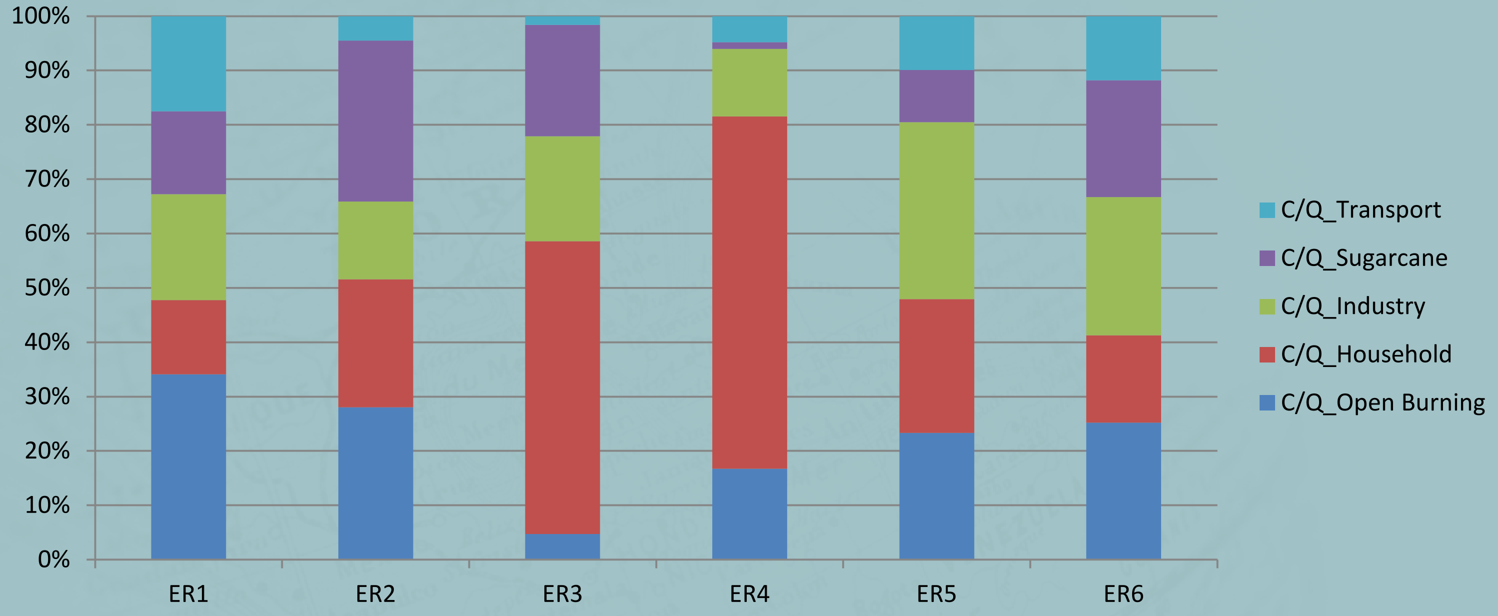




Maximum concentration values are during the summer and winter months, with very little concentration during the monsoon season.

Control Strategies

- **Sector Wise Contribution to EC concentration on the Receptor Sites**



Here, we have segregated sugarcane industry because emissions from bagasse Burning were considerably high. As could be observed, transport sector doesn't feature among the top emitters in any of the Emissions Regions.

Control Strategies… continued

- Order of preference for BC control over the Himalayas

Emission Region	1st preference	2nd preference
ER1	Open Burning	Industry
ER2	Sugarcane Industry	Open Burning + Household
ER3	Household	Industry
ER4	Household	Open Burning

Based on a control in household sector, we consider two change/demand scenarios (based on Antonette and Murthy, 2005). We assume that LPG replaces dung-cake and wood consumption in domestic sector

Control Strategies… continued

Demand Scenario 1- Business as usual (current growth & usage rates are used) (The study used 2005-06 as base year)

Year	Number of households using LPG (millions)			Proportion of total households using LPG (%)		
	Rural	**Urban**	**Total**	**Rural**	**Urban**	**Total**
2005-06	10.91	44.87	55.78	7.27	72.97	26.36
2010-11	15.17	63.38	78.56	9.30	90.00	33.64
2015-16	21.10	72.59	93.69	11.91	90.00	36.35

Under this scenario, a nominal increase in households using LPG will be observed. The observed impacts will not be so prominent.

Control Strategies… continued

Demand Scenario 2: Here we consider the case of promoting the use of LPG in rural India (growth of rural users is doubled but current growth is considered for the urban sector.)

Year	Number of households using LPG (millions)			Proportion of total households using LPG (%)		
	Rural	Urban	Total	Rural	Urban	Total
2010-11	20.67	63.38	84.06	12.68	90.00	36.00
2015-16	39.17	72.59	111.76	22.12	90.00	43.36

Under this scenario, a significant increase in rural LPG users will be observed. If this increase is taken as a mean to offset emissions from dung-cake and wood burning, we can observe large EC emission reductions from ER2, ER3 and ER4

Thank You