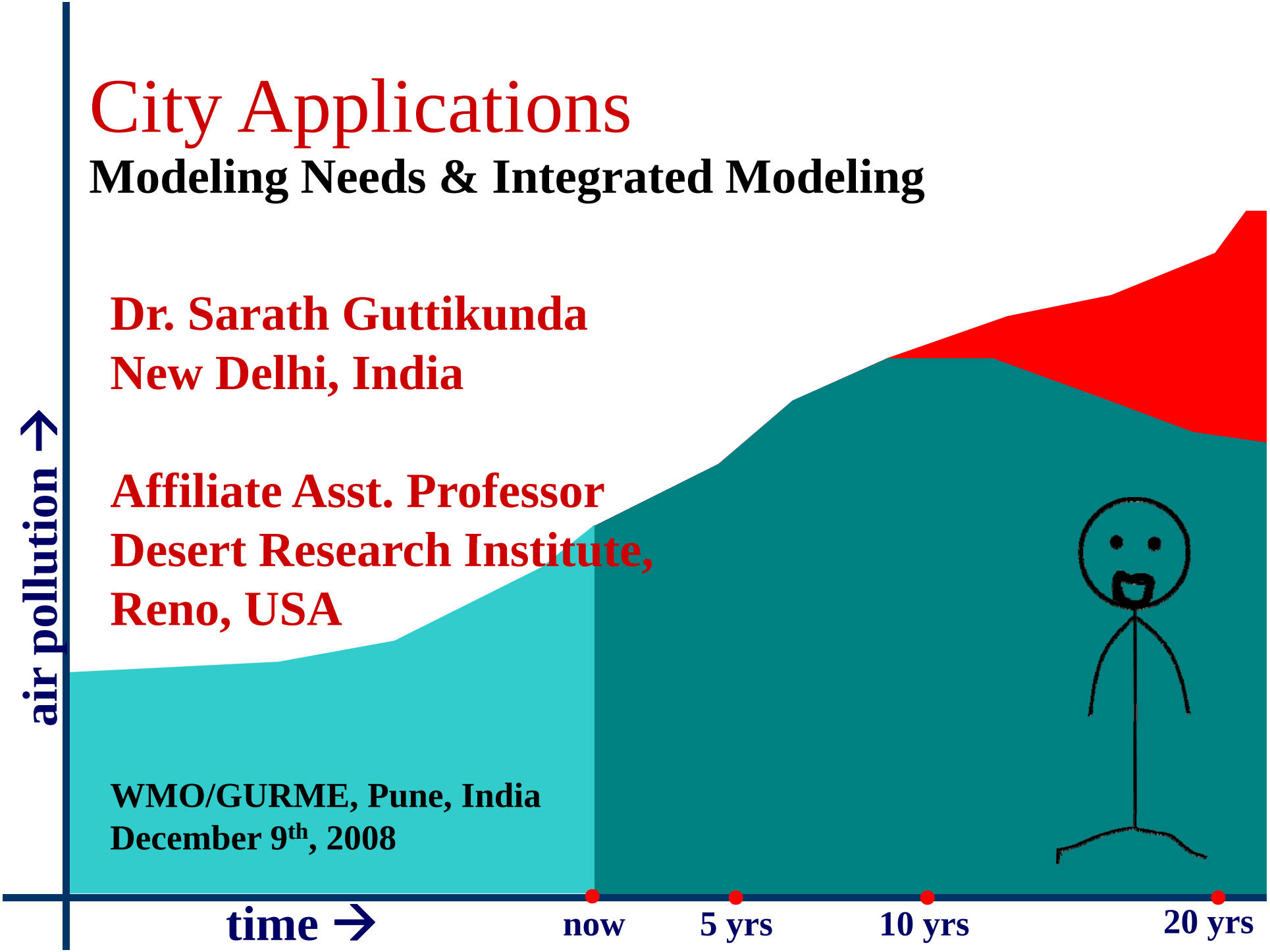
City Applications

Modeling Needs & Integrated Modeling

Dr. Sarath Guttikunda
New Delhi, India

Affiliate Asst. Professor
Desert Research Institute,
Reno, USA



WMO/GURME, Pune, India
December 9th, 2008

Topics Covered

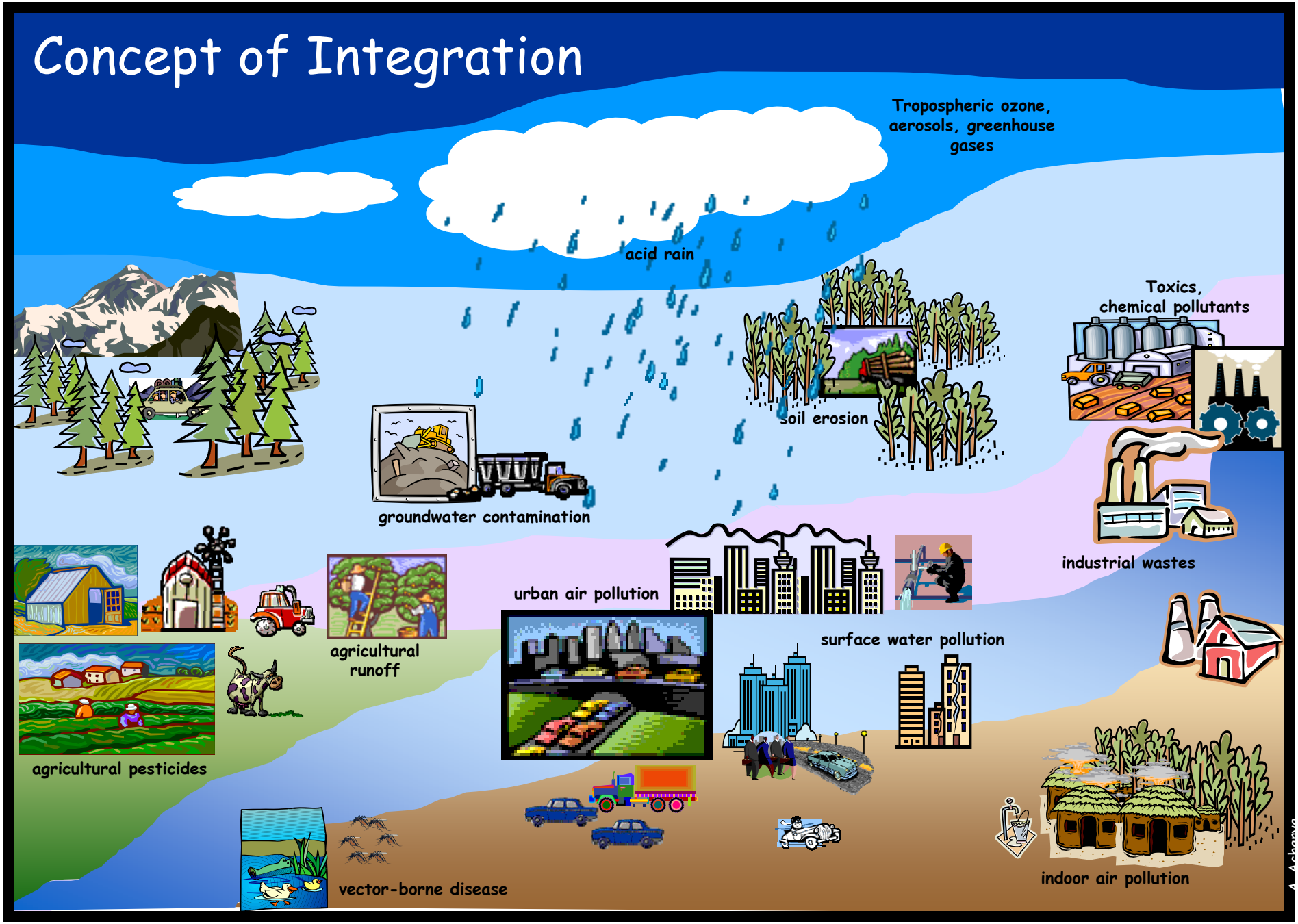
- Overview of Information required and available for an AQM
- Demonstration of tools
- Summary of applications
- Details from three cities
  - Hyderabad, Ulaanbaatar, Hanoi

Cinderella's Shoe ..

- Every city is different
  - Understand their sources & priorities
- One tool doesn’t fit all
  - Needs local customization
- Need stakeholders participation (a lot)
  - Sharing is caring !!
- Informed decision making is key

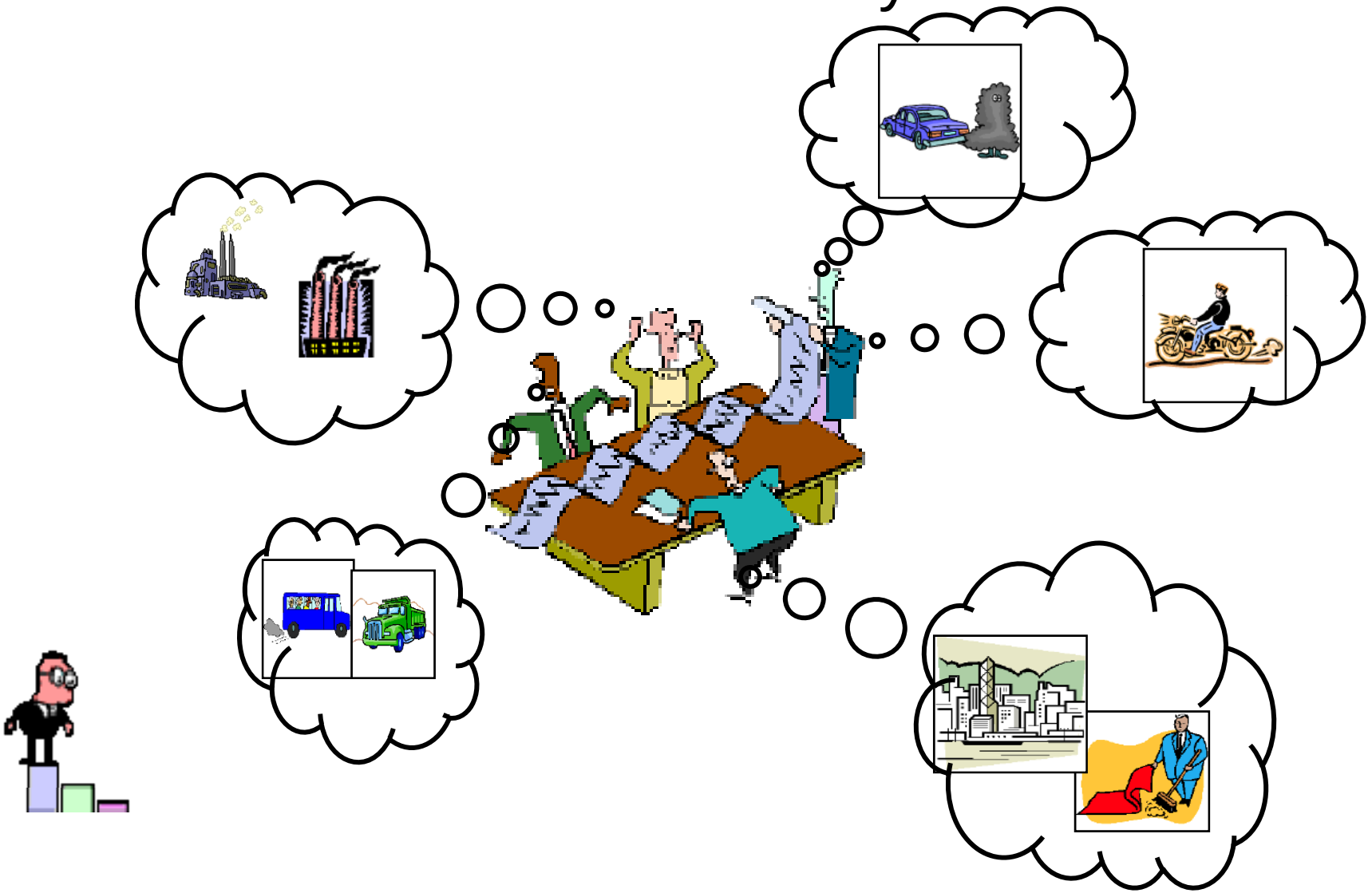
Why AQM

Concept of Integration



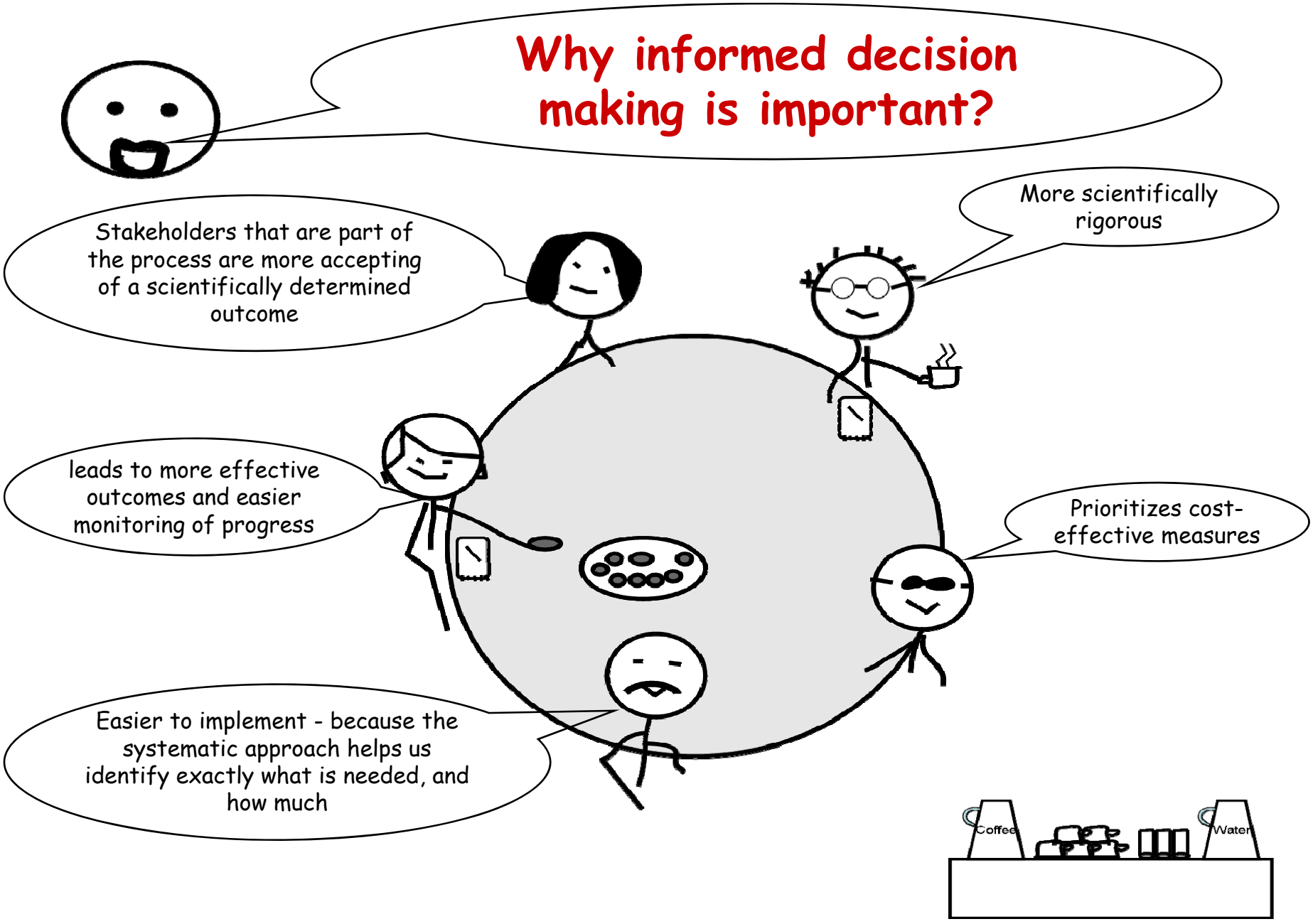
Let the “Blame Games” begin..

Sources are Many



.. making a decision is a decision

Why informed decision making is important?



Remember..

.. Waiting is futile

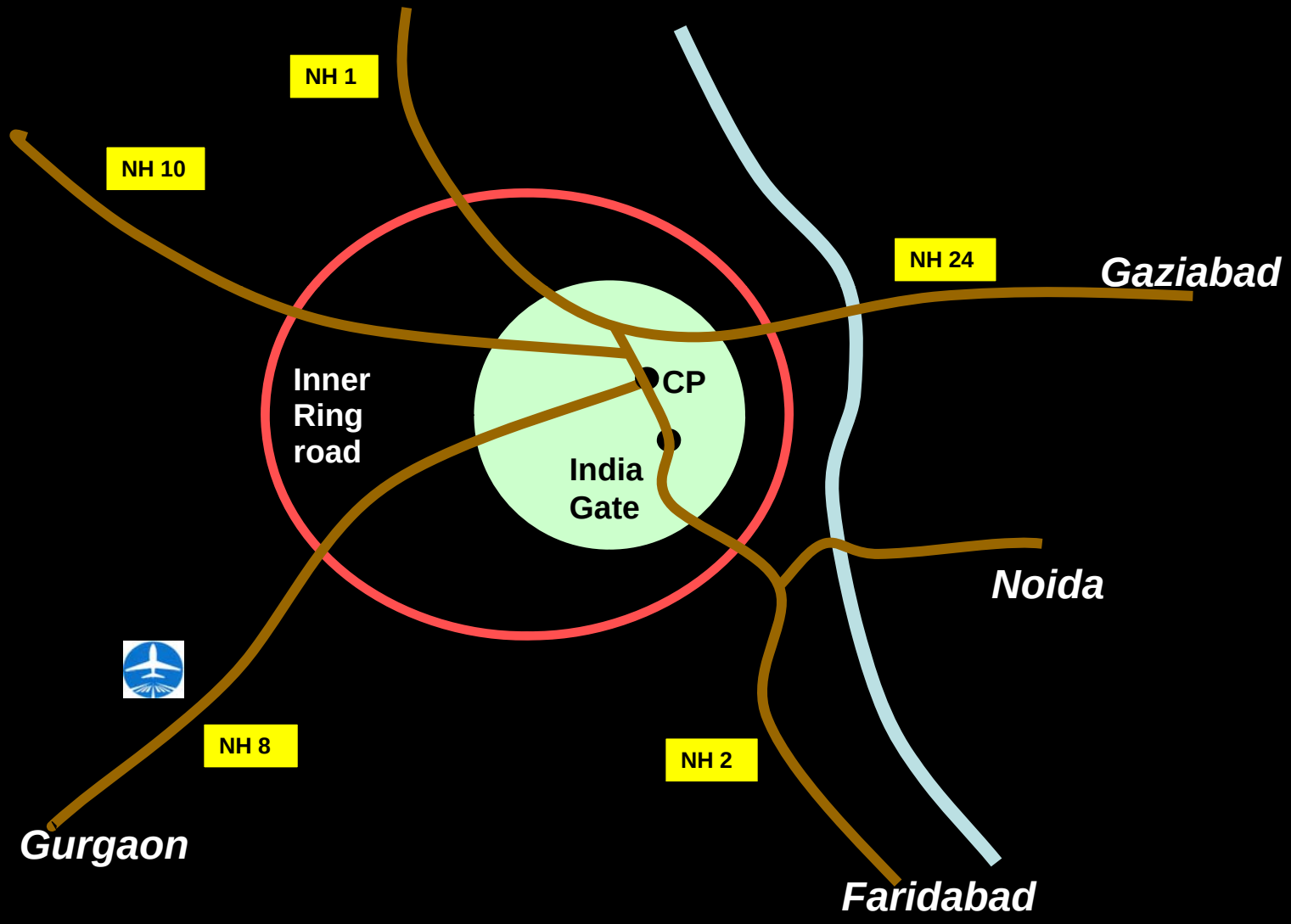
.. Check what’s done

.. Start doing something

Number of Cities

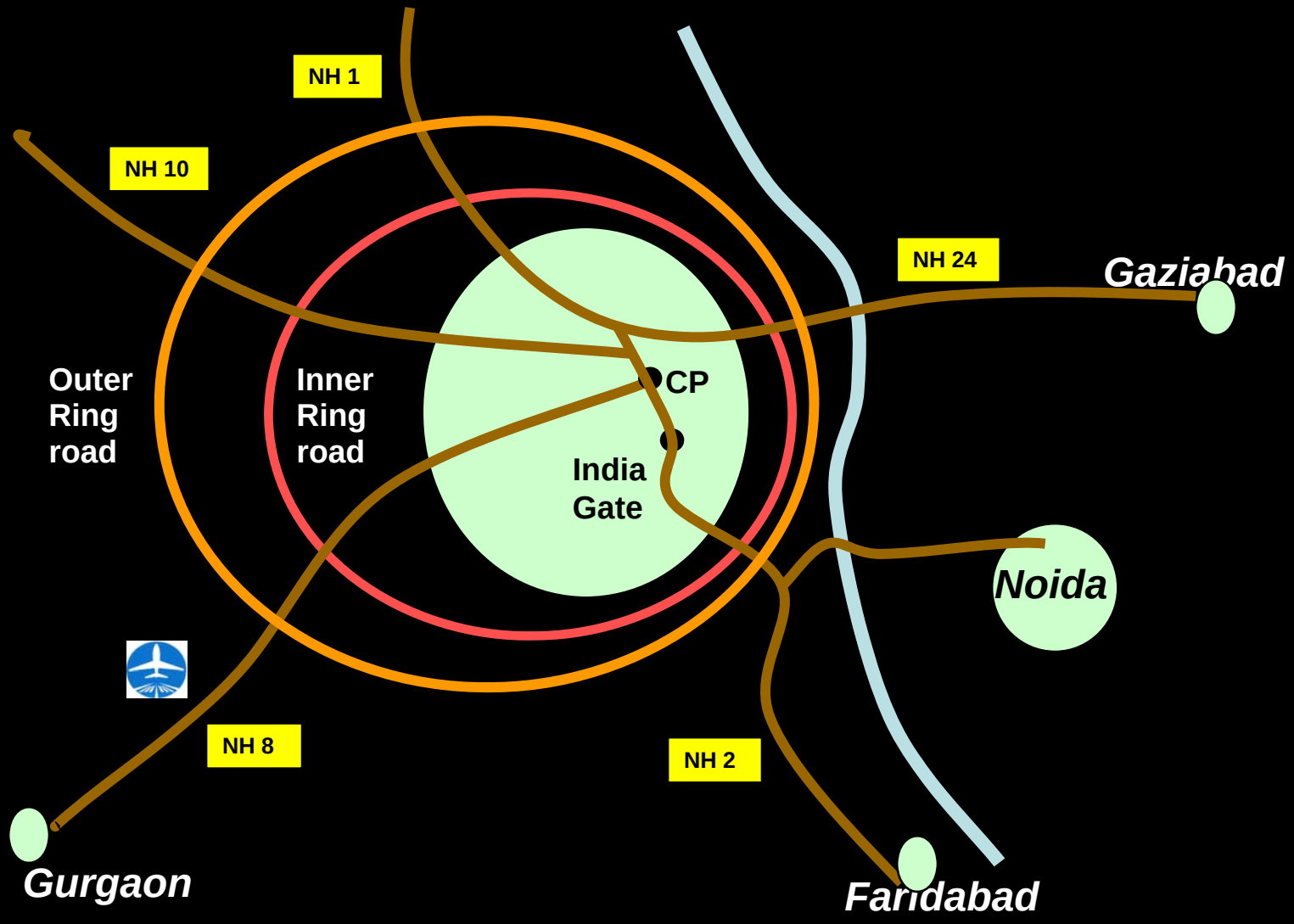
Google Earth

Delhi.. 1975



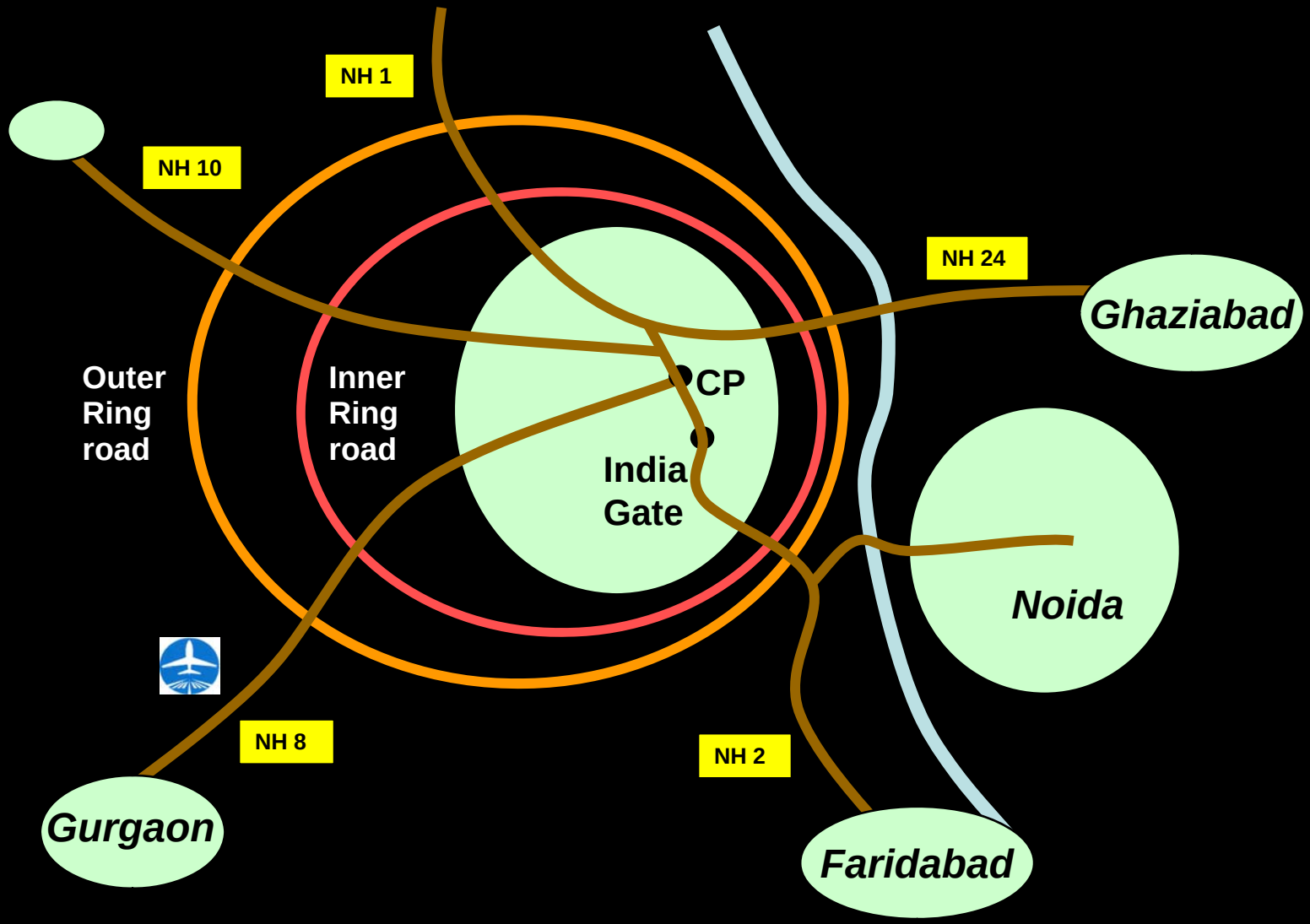
Source: Reproduced from Presentations by TheTIS & Harvard University

Delhi.. 2000



Source: Reproduced from Presentations by TheTIS & Harvard University

Delhi.. Today.. NCR



Source: Reproduced from Presentations by TheTIS & Harvard University

300 cities >2 m pop by 2025 +
thousands of Secondary Cities

Source: Google Earth & www.demographia.org

Cities: A Problem & Solution

Energy Demand

Industries

Waste

Transport

Domestic

– – – – – – – – – – – 3 D's – – – – – – – – – – –

Renewables

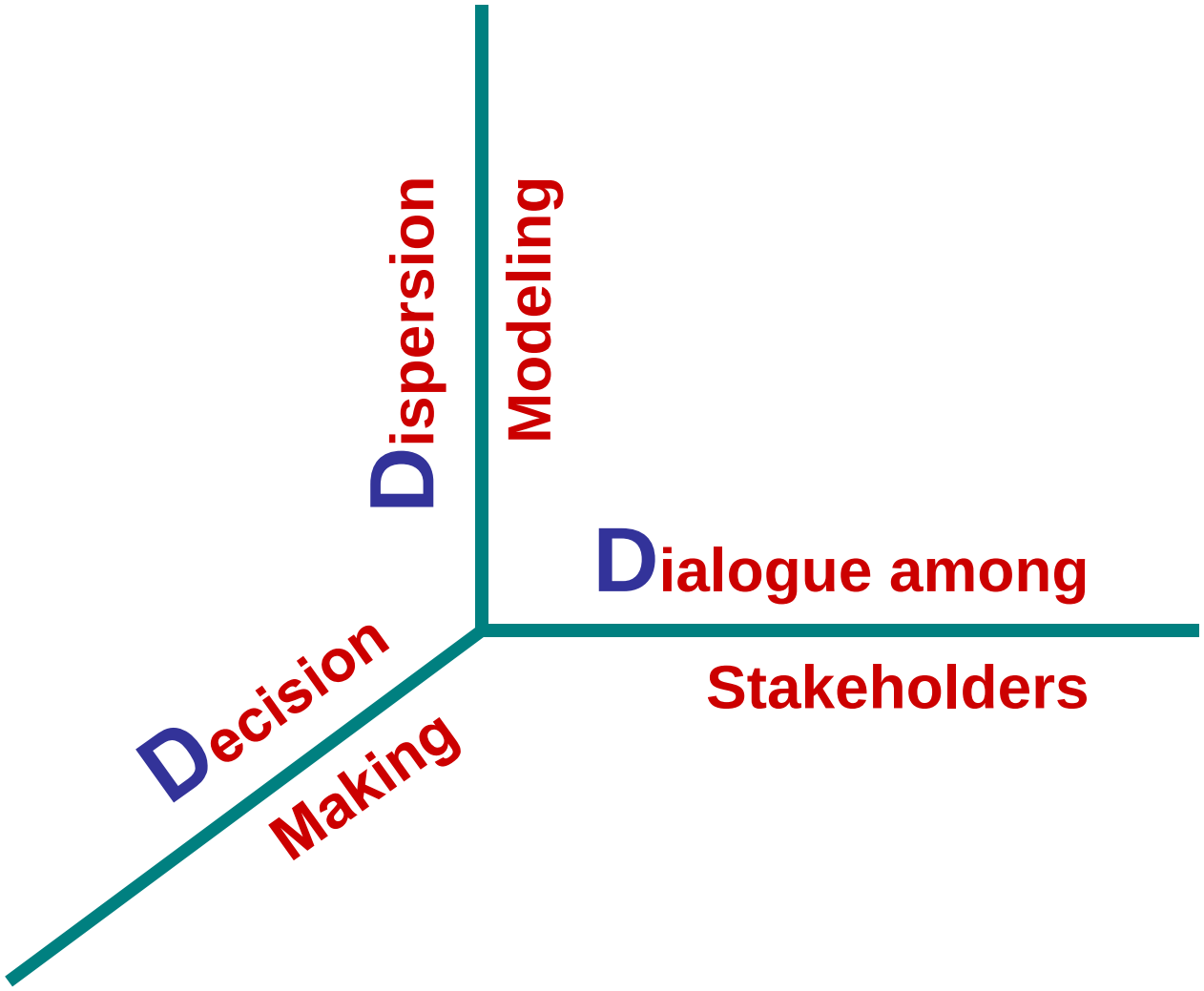
Efficiency

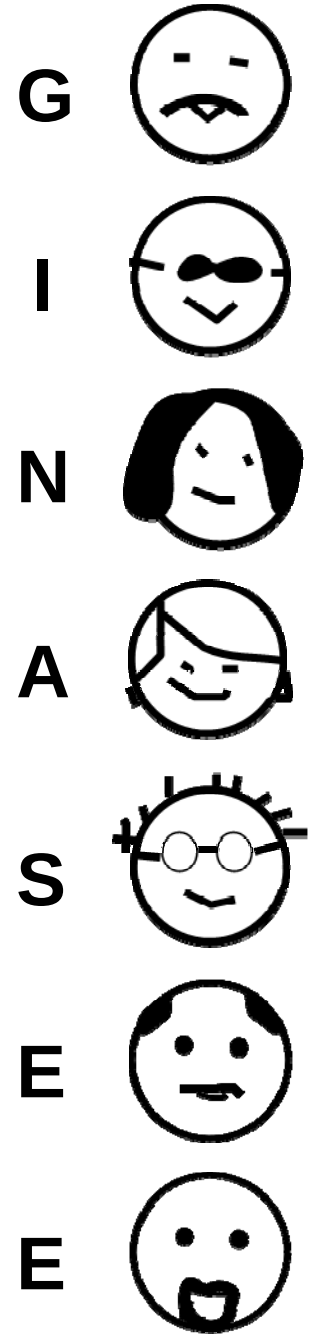
Management

Buses/NMT

Cleaner Fuels

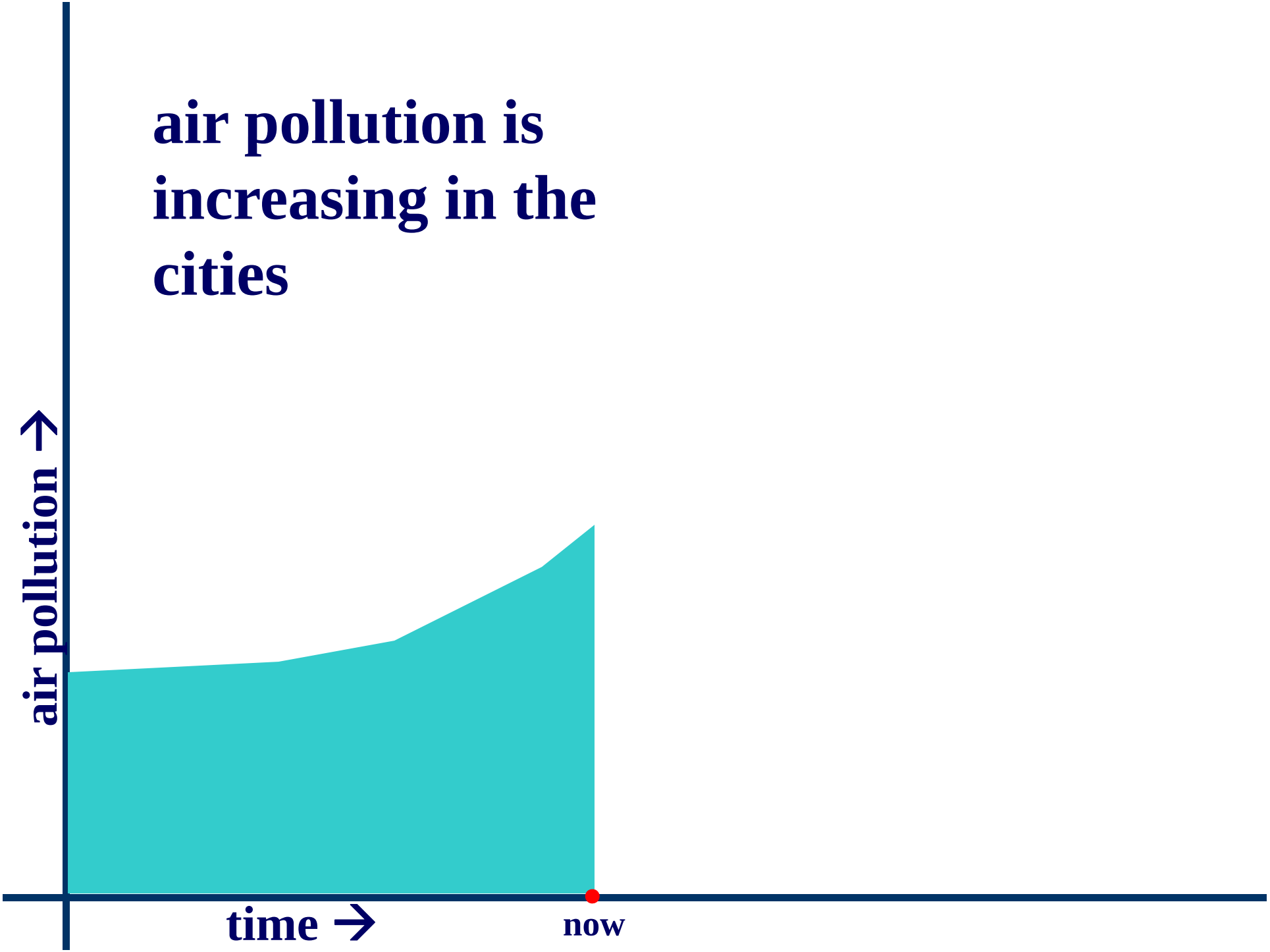
3 D Effect

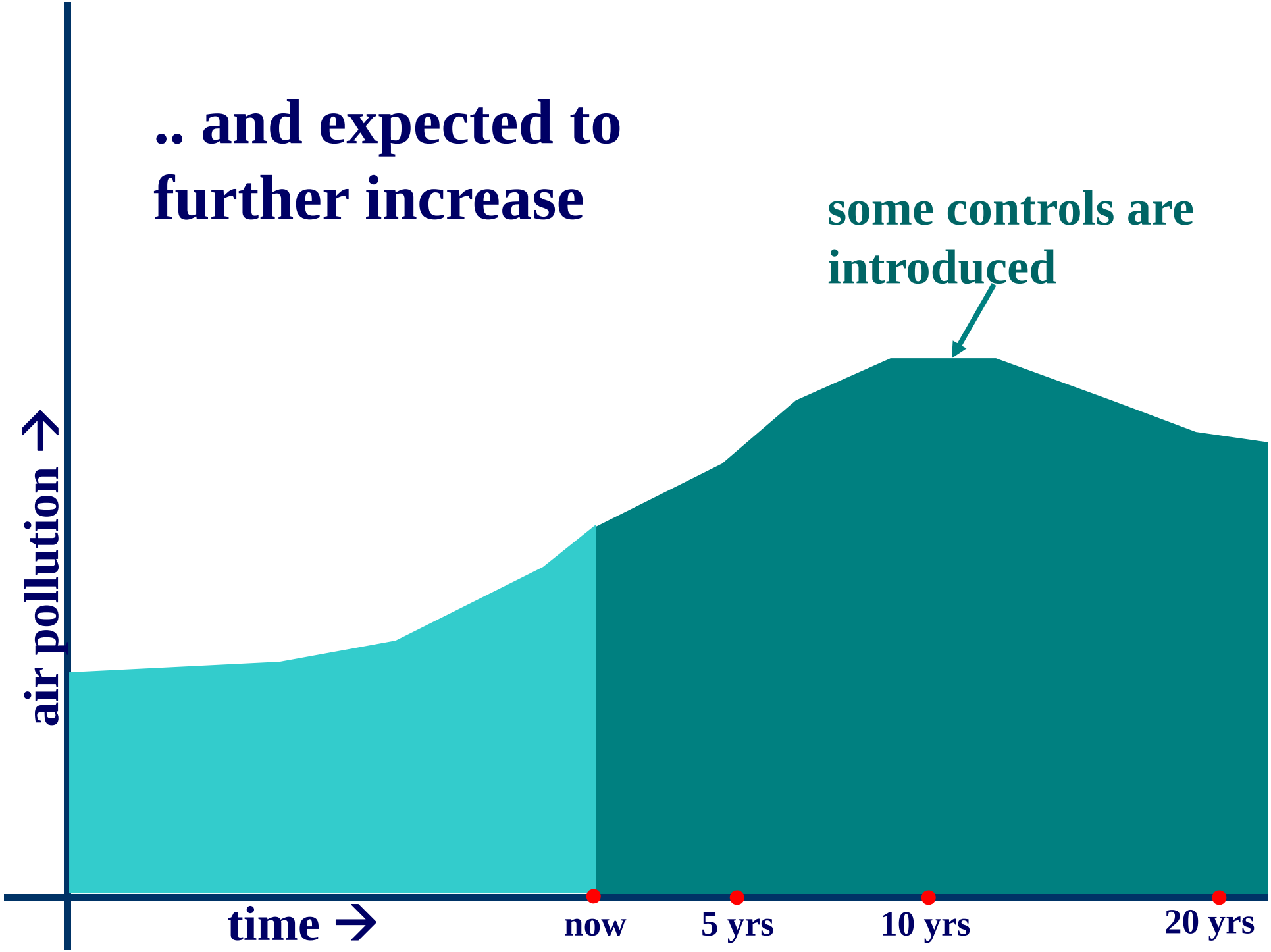


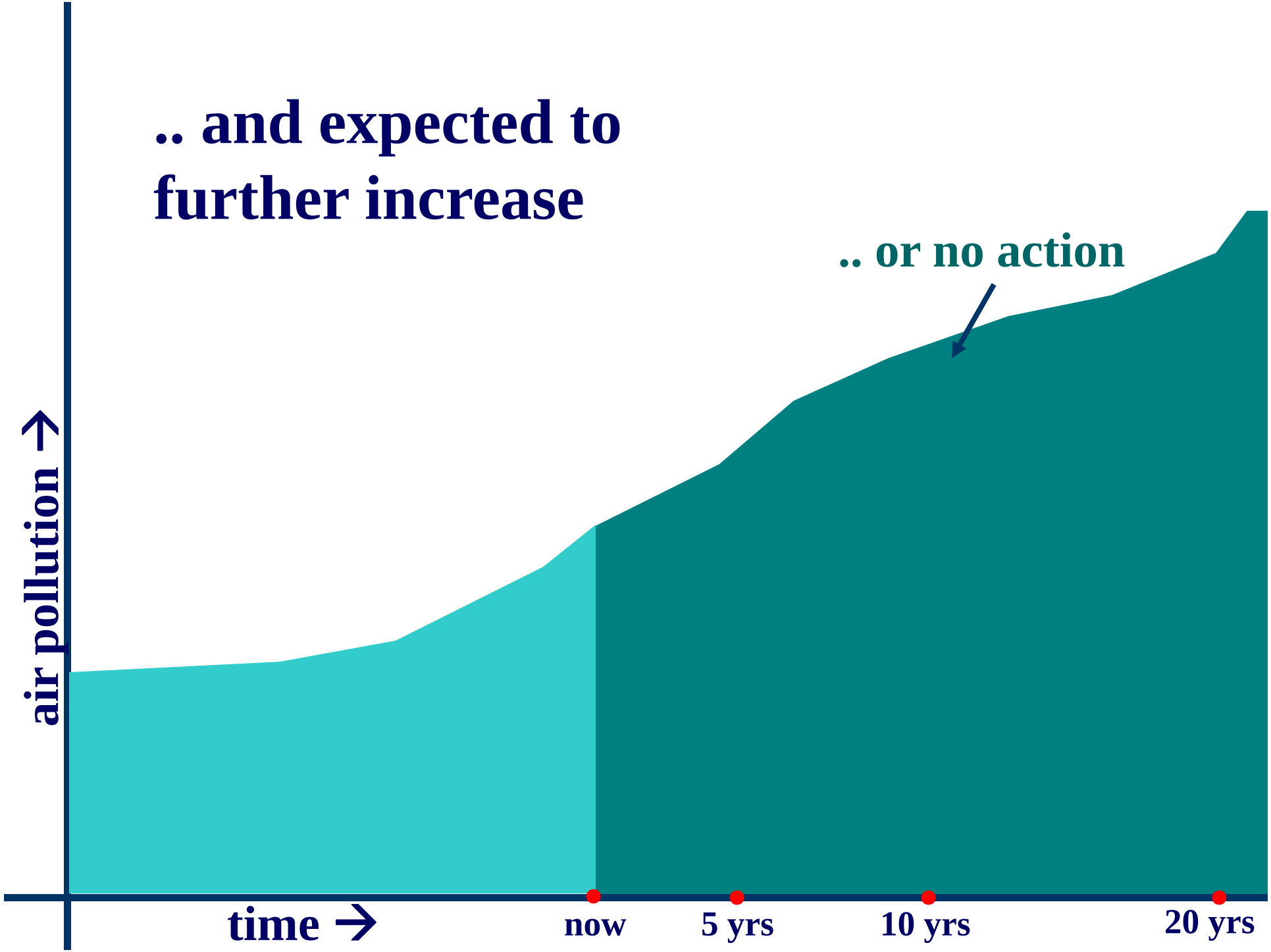


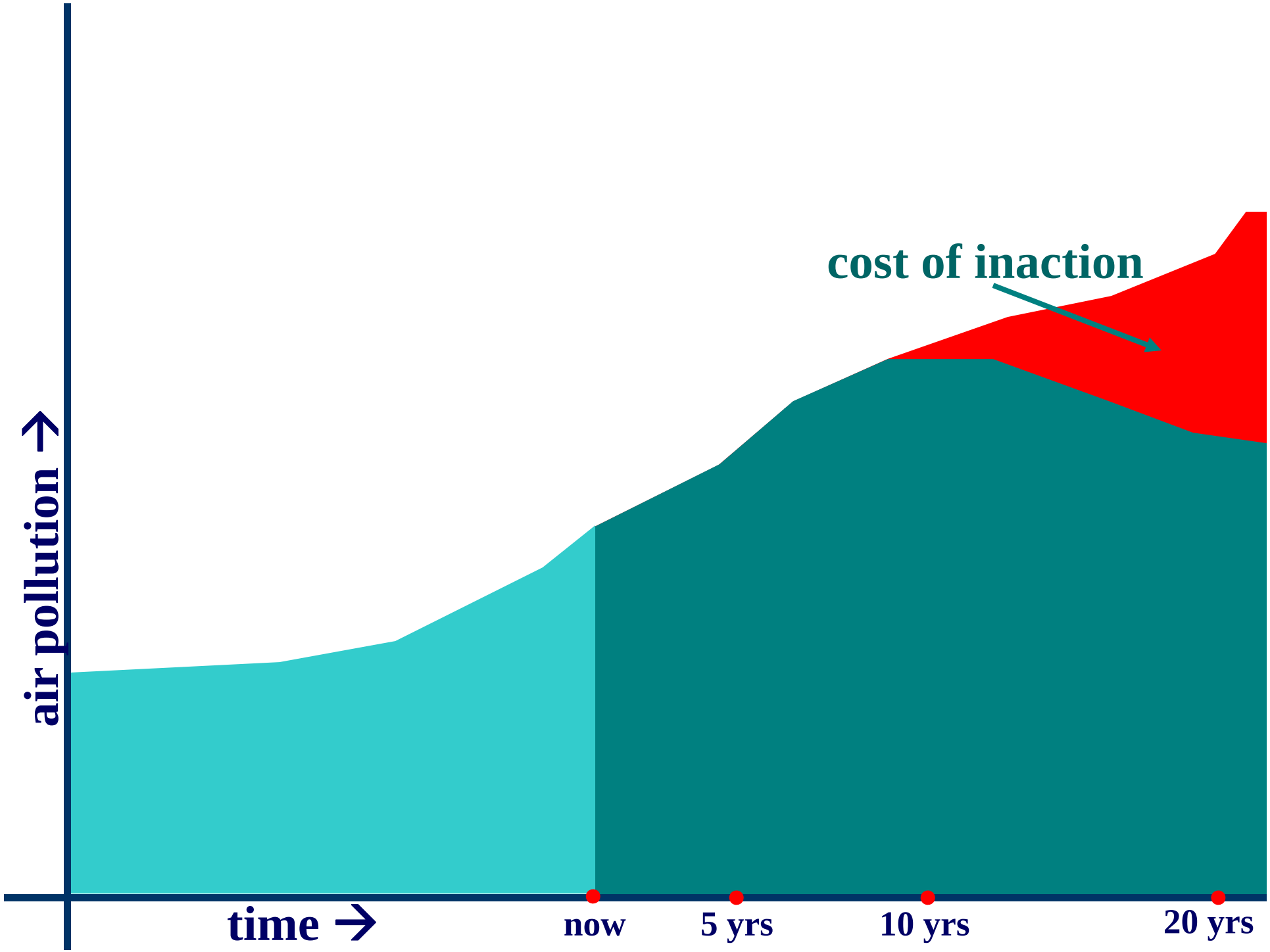
Disclaimer: All characters are fictional ☺

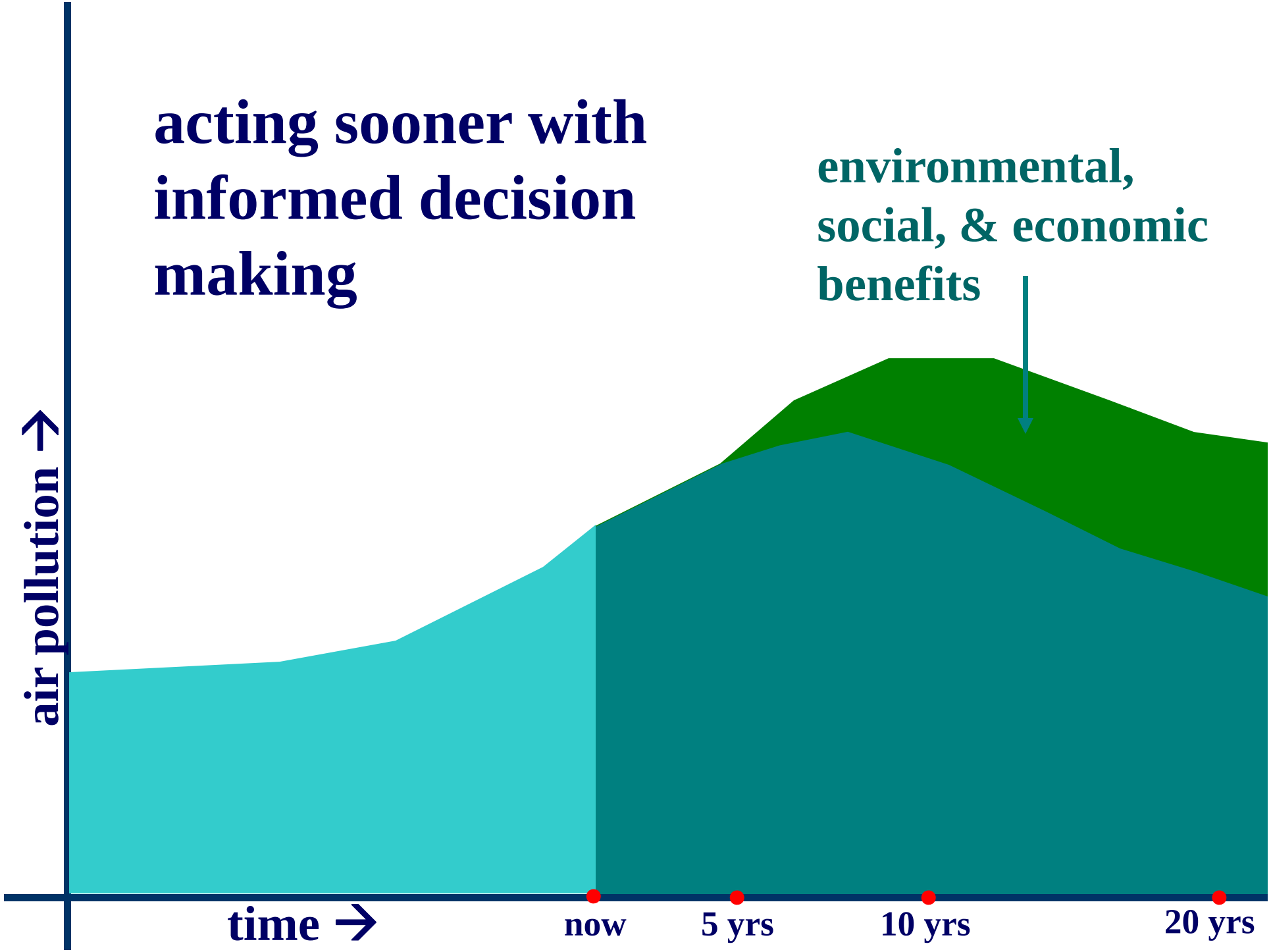
air pollution is increasing in the cities

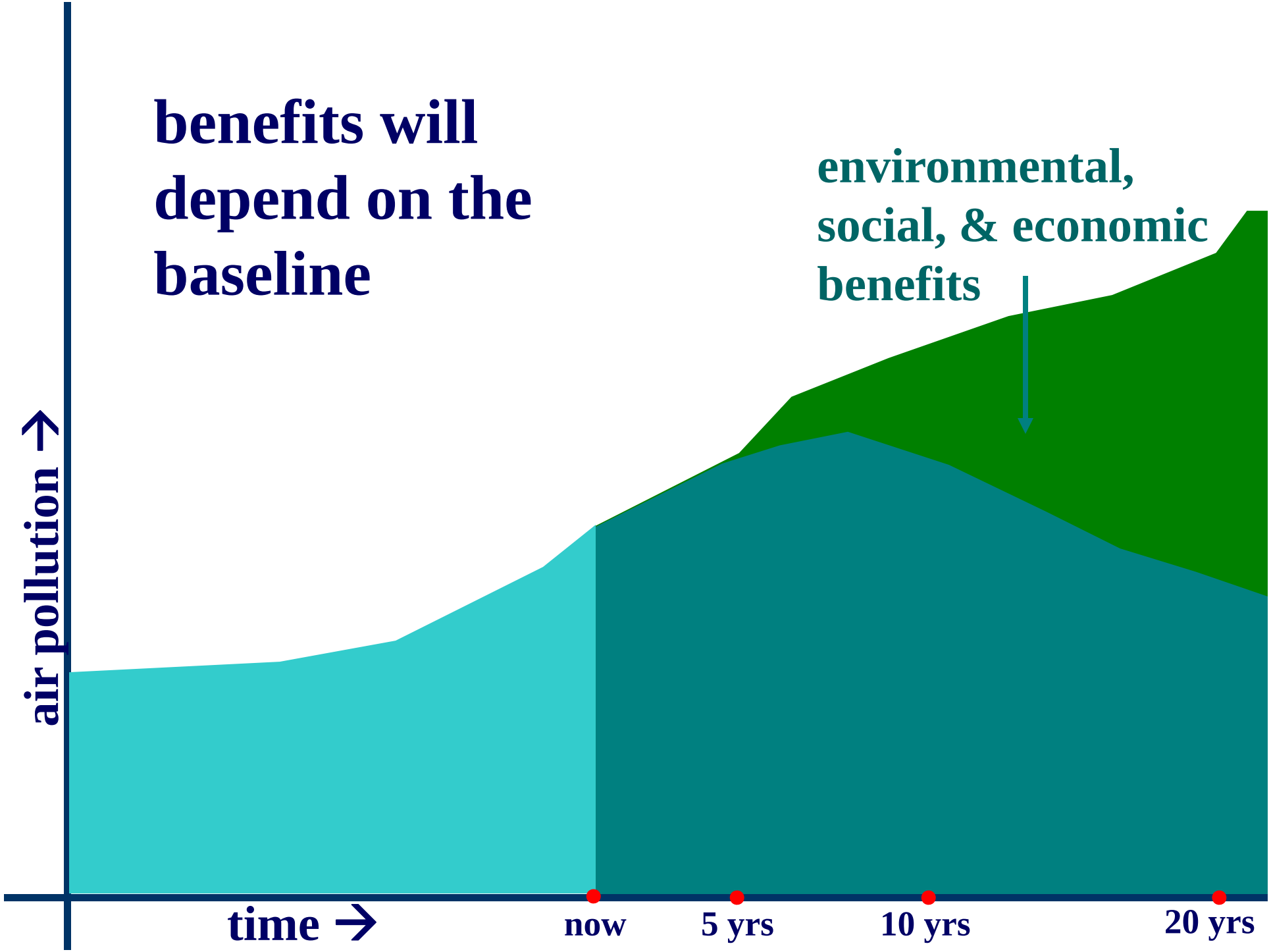


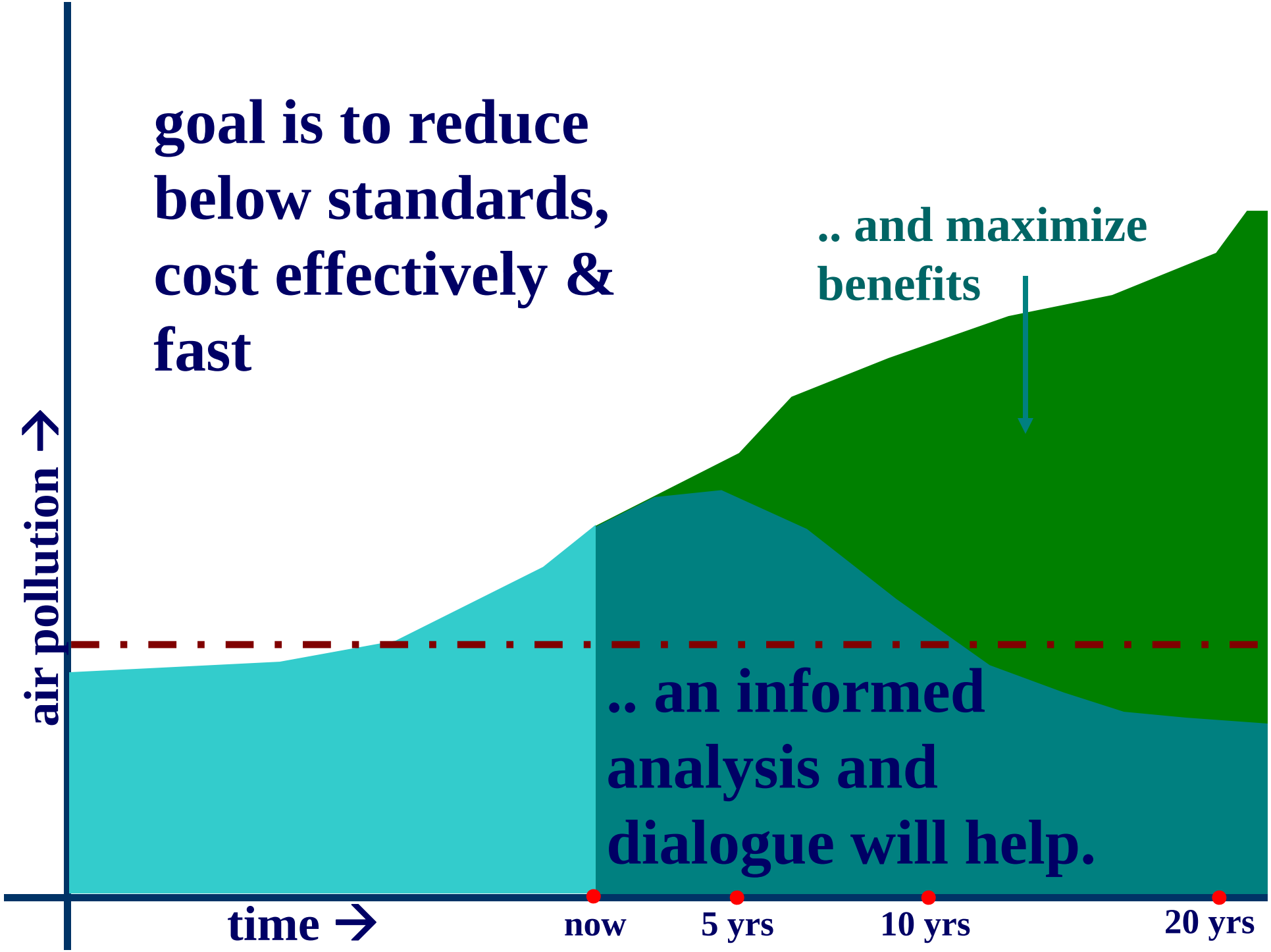

.. and expected to further increase
some controls are introduced
air pollution →
time →
now
5 yrs
10 yrs
20 yrs


.. and expected to further increase
.. or no action
air pollution →
time →
now
5 yrs
10 yrs
20 yrs

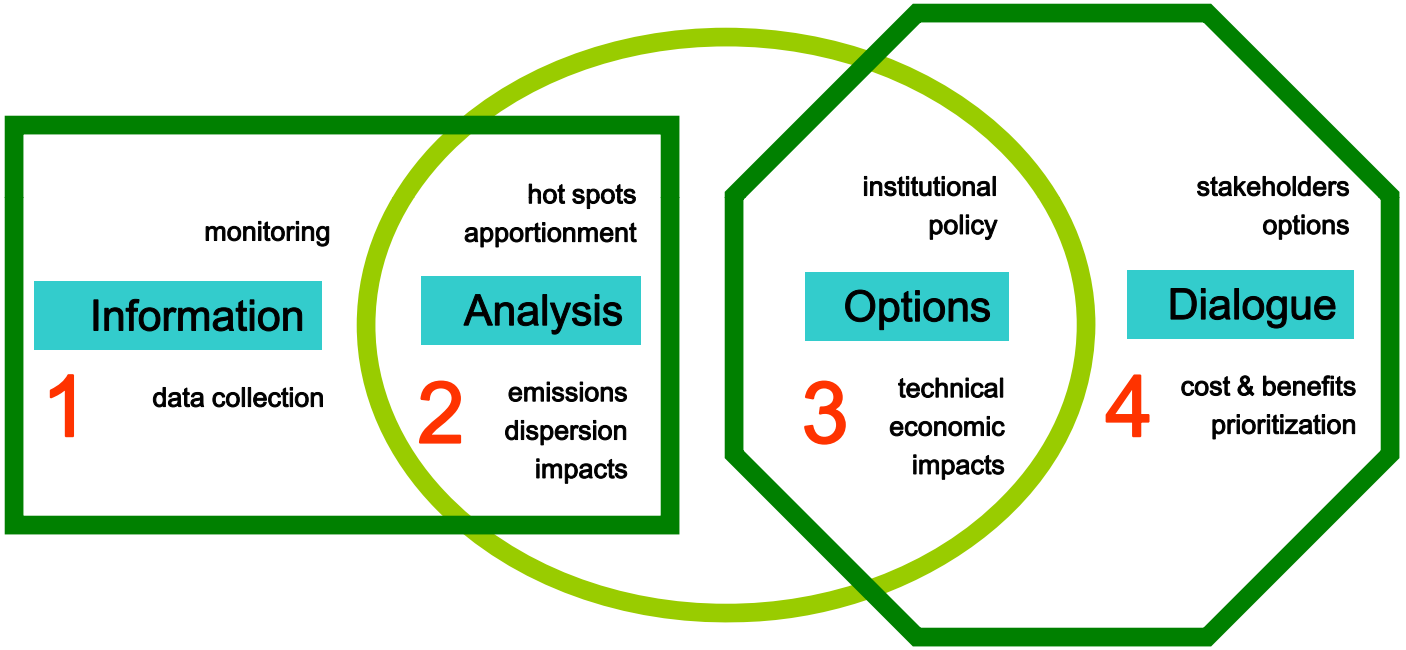

cost of inaction
air pollution →
time →
now
5 yrs
10 yrs
20 yrs


acting sooner with informed decision making
environmental, social, & economic benefits
air pollution →
time →
now
5 yrs
10 yrs
20 yrs


benefits will depend on the baseline
environmental, social, & economic benefits
air pollution →
time →
now
5 yrs
10 yrs
20 yrs

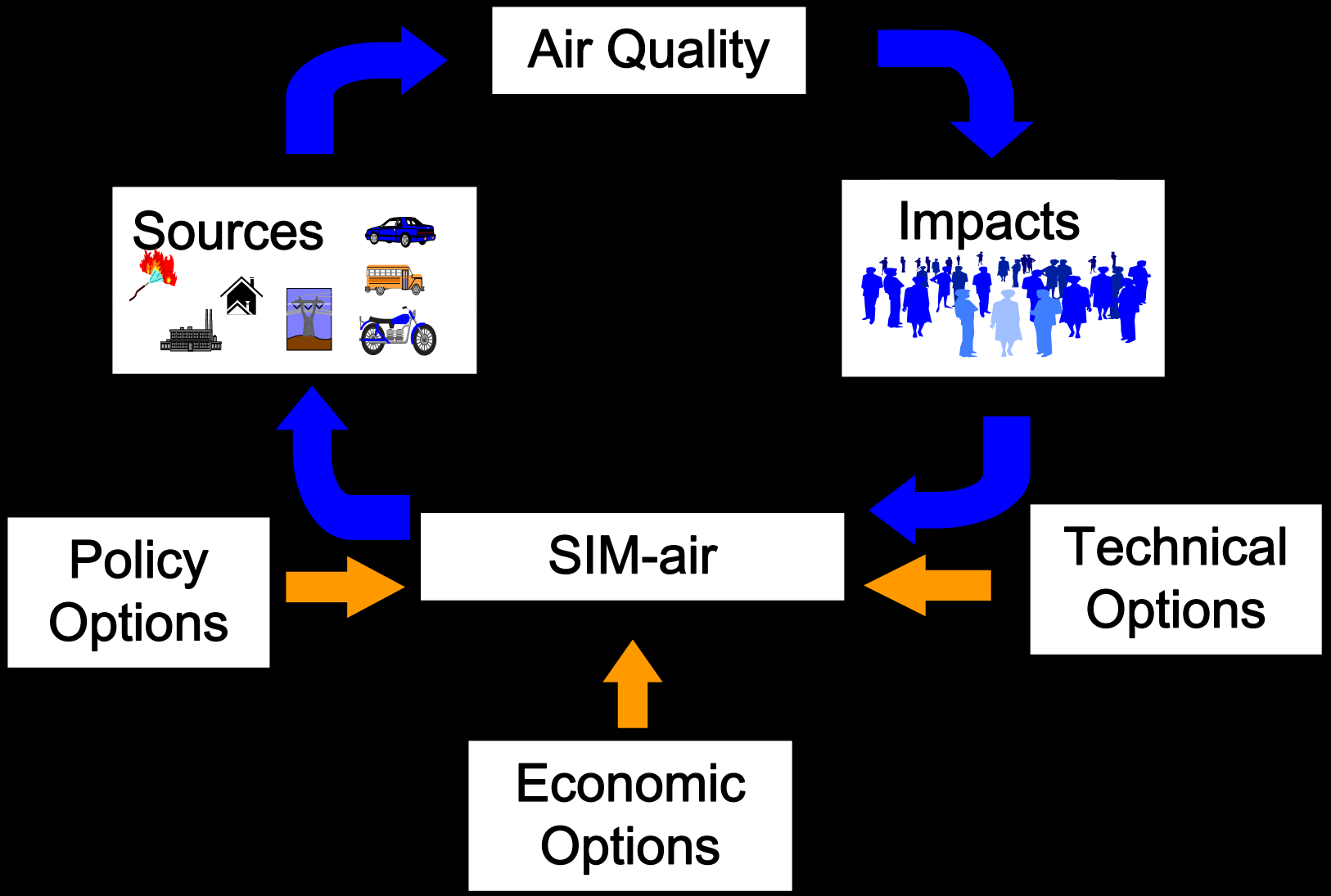

goal is to reduce below standards, cost effectively & fast
.. and maximize benefits
air pollution →
.. an informed analysis and dialogue will help.
time →
now
5 yrs
10 yrs
20 yrs

Small steps..



.. for BIG reductions

Simple Interactive Models



Details @ www.sim-air.org

Simple objectives..

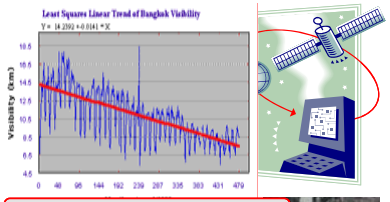
Collate first, complicate later

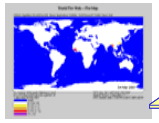
Apply tools for analysis

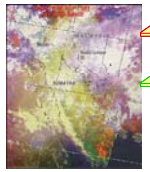
Evaluate C&B of options

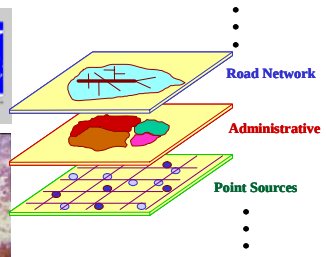
Support stakeholder dialogue

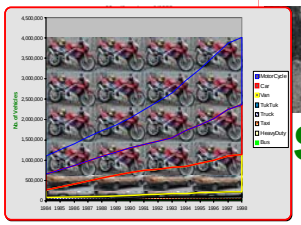
Details @ www.sim-air.org

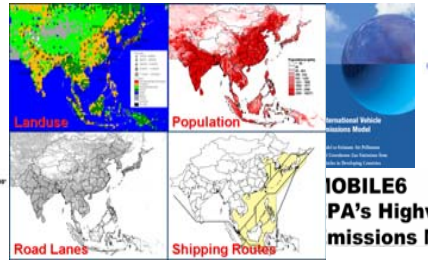












APHEBA

ISC3
UAM
ATMOS
CMAQ
WARF
HYSPLIT
RAMS/MM5

IDEAS

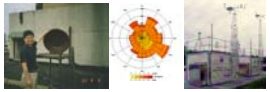
OBILE6
PA's Highway Vehicle
missions Model

Statistics, Remote Sensing, GIS, Databases

Models

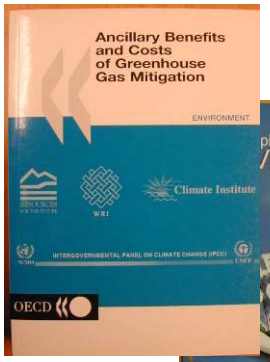
Knowledge Base

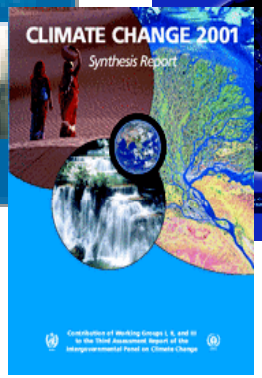
Analysis

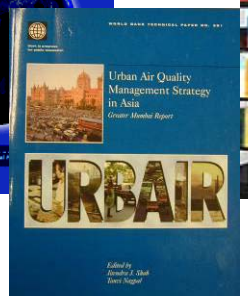


Monitoring

Stakeholders





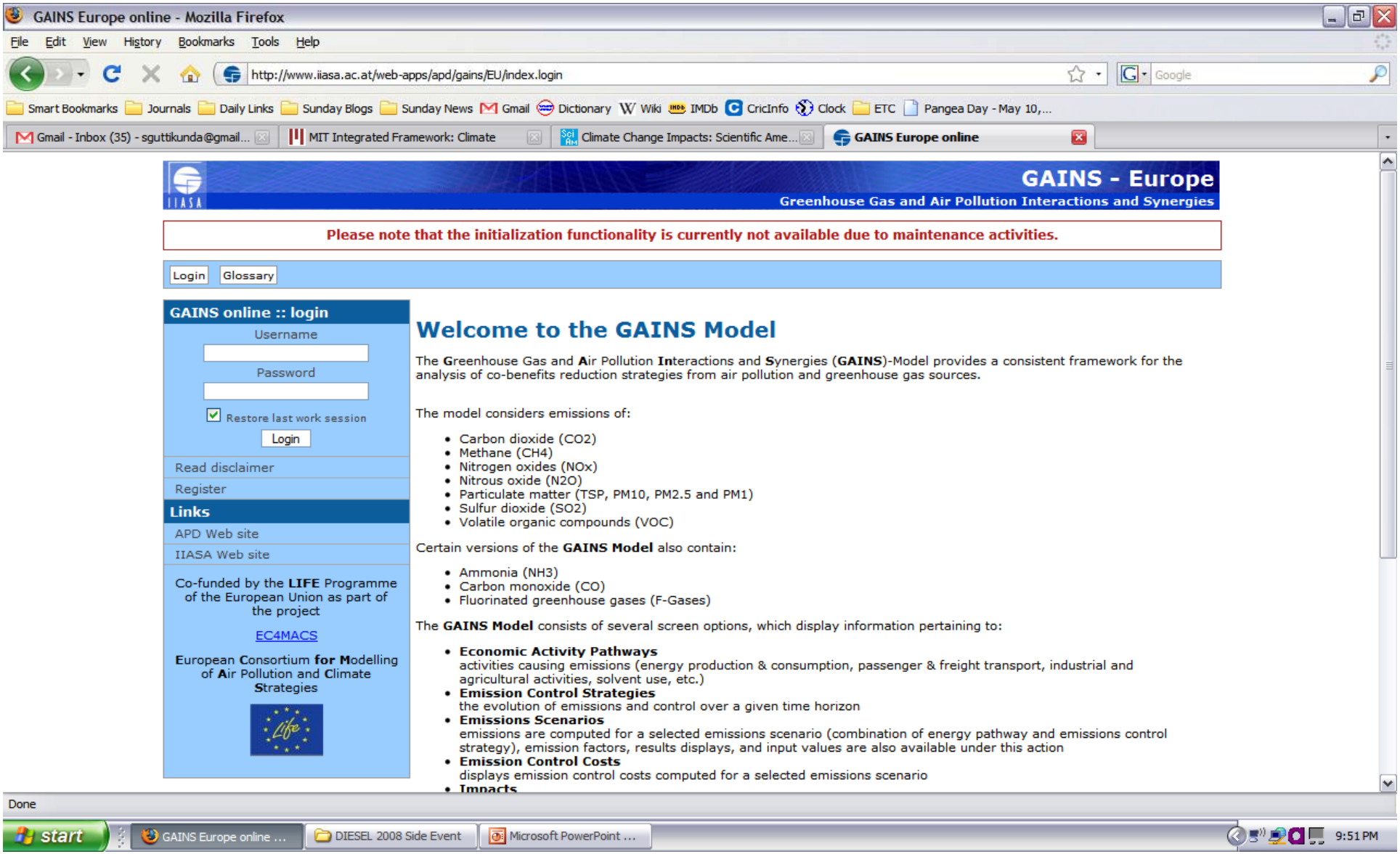


Reports

Environmental Agencies

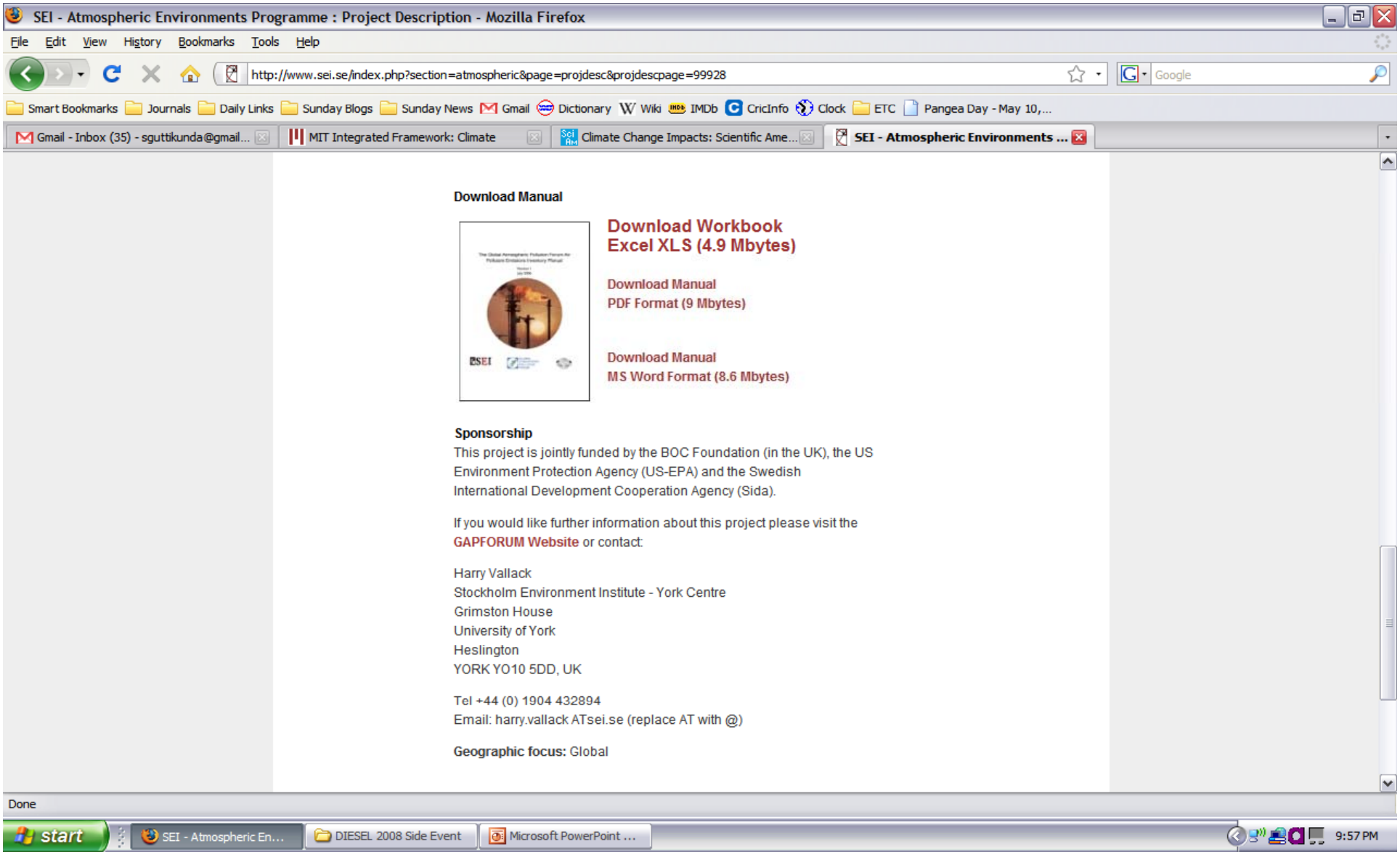
GAINS/RAINS Model

@ http://www.iiasa.ac.at/~rains



SEI Emissions Handbook

Email: harry.vallack@sei.se



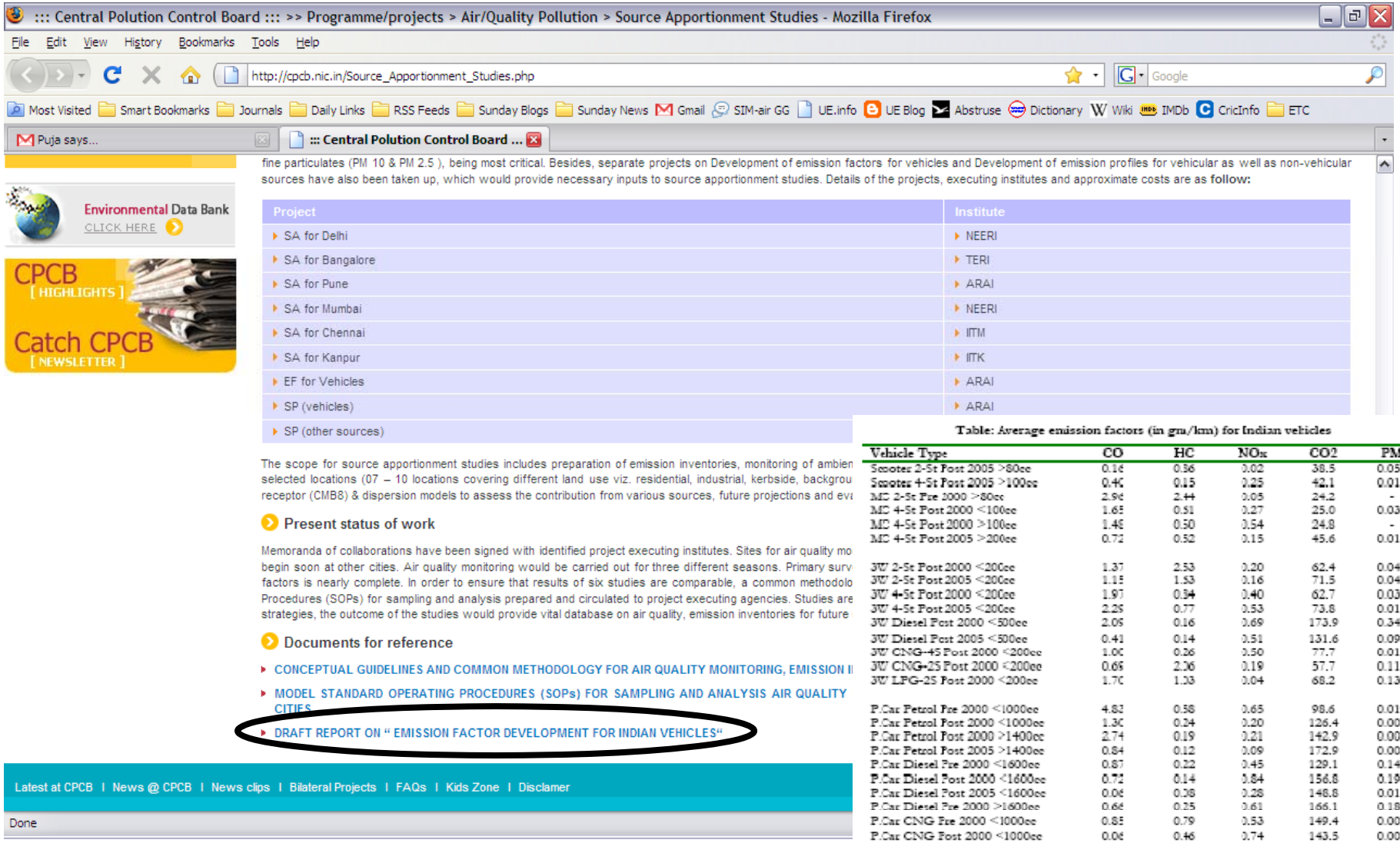
HEAT Emissions Database

@ http://www.iclei.org/heat

Bangkok, Thailand, 2008

		Average Speed				Average Speed				Average Speed		
		10	20	30		10	20	30		10	20	30
		Light Duty Vehicles				Heavy Duty Buses				Heavy Duty Trucks		
HC	Pre-1994	0.52	0.32	0.25	Pre-1995	2.35	1.31	0.93	Pre-1995	1.46	0.93	0.71
CO		1.88	1.32	1.07		10.17	6.59	5.11		13.12	10.35	9.02
NOx		2.97	2.34	2.03		19.68	12.00	8.98		15.02	10.44	8.44
CO2		414.74	317.95	272.17		1299.06	843.09	654.71		1163.51	921.26	803.67
PM		216.18	187.54	172.59		1319.11	962.30	800.18		2445.90	1859.44	1583.94
HC	1994-96	0.36	0.24	0.20	1996-97	1.81	1.10	0.82	1996-97	1.65	1.18	0.96
CO		1.51	1.09	0.90		17.40	16.02	15.26		4.24	3.46	3.08
NOx		3.37	2.60	2.24		22.45	13.30	9.80		14.24	10.88	9.30
CO2		409.56	322.43	280.32		1317.69	999.87	850.79		1185.70	980.67	877.59
PM		153.14	155.50	156.90		1928.59	1759.84	1668.06		933.68	880.38	850.62
HC	1997-99	0.34	0.21	0.16	1997-2000	0.85	0.46	0.32	1997-2000	1.83	1.22	0.97
CO		1.83	1.08	0.79		18.21	15.42	13.99		4.24	3.46	3.08
NOx		2.87	2.23	1.93		19.68	12.00	8.98		15.02	10.44	8.44
CO2		437.58	342.34	296.56		1789.18	1154.76	893.83		1401.33	1127.40	992.71
PM		169.94	166.20	164.05		835.09	620.84	522.00		1283.03	925.60	764.66
HC	after 2000	0.27	0.19	0.16	after 2001	1.83	1.05	0.76	after 2001	0.83	0.55	0.43
CO		1.70	1.37	1.21		6.36	3.72	2.72		5.40	3.61	2.85
NOx		1.45	1.14	0.98		13.50	9.47	7.70		15.07	10.03	7.91
CO2		420.66	342.25	303.35		1474.90	1038.44	845.75		1438.36	1009.98	821.27
PM		138.24	145.44	149.83		1116.67	982.14	911.09		447.67	410.40	390.06

CPCB, India, 2008



::: Central Polution Control Board ::: >> Programme/projects > Air/Quality Pollution > Source Apportionment Studies - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://cpcb.nic.in/Source_Apportionment_Studies.php

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Puja says... | ::: Central Polution Control Board ...

Environmental Data Bank
CLICK HERE

CPCB [HIGHLIGHTS]
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fine particulates (PM 10 & PM 2.5), being most critical. Besides, separate projects on Development of emission factors for vehicles and Development of emission profiles for vehicular as well as non-vehicular sources have also been taken up, which would provide necessary inputs to source apportionment studies. Details of the projects, executing institutes and approximate costs are as **follow:**

Project	Institute
SA for Delhi	NEERI
SA for Bangalore	TERI
SA for Pune	ARAI
SA for Mumbai	NEERI
SA for Chennai	IITM
SA for Kanpur	IITK
EF for Vehicles	ARAI
SP (vehicles)	ARAI
SP (other sources)	

The scope for source apportionment studies includes preparation of emission inventories, monitoring of ambien selected locations (07 – 10 locations covering different land use viz. residential, industrial, kerbside, backgrou receptor (CMB8) & dispersion models to assess the contribution from various sources, future projections and eva

Present status of work

Memoranda of collaborations have been signed with identified project executing institutes. Sites for air quality mo begin soon at other cities. Air quality monitoring would be carried out for three different seasons. Primary surv factors is nearly complete. In order to ensure that results of six studies are comparable, a common methodolo Procedures (SOPs) for sampling and analysis prepared and circulated to project executing agencies. Studies are strategies, the outcome of the studies would provide vital database on air quality, emission inventories for future

Documents for reference

- CONCEPTUAL GUIDELINES AND COMMON METHODOLOGY FOR AIR QUALITY MONITORING, EMISSION I
- MODEL STANDARD OPERATING PROCEDURES (SOPs) FOR SAMPLING AND ANALYSIS AIR QUALITY CITIES
- DRAFT REPORT ON " EMISSION FACTOR DEVELOPMENT FOR INDIAN VEHICLES"

Latest at CPCB | News @ CPCB | News clips | Bilateral Projects | FAQs | Kids Zone | Disclamer

Done

Table: Average emission factors (in gm/km) for Indian vehicles

Vehicle Type	CO	HC	NOx	CO2	PM
Scooter 2-St Post 2005 >80cc	0.16	0.36	0.02	38.5	0.057
Scooter 4-St Post 2005 >100cc	0.40	0.15	0.25	42.1	0.015
MC 2-St Pre 2000 >80cc	2.90	2.44	0.05	24.2	-
MC 4-St Post 2000 <100cc	1.65	0.51	0.27	25.0	0.035
MC 4-St Post 2000 >100cc	1.48	0.50	0.54	24.8	-
MC 4-St Post 2005 >200cc	0.72	0.52	0.15	45.6	0.013
3W 2-St Post 2000 <200cc	1.37	2.53	0.20	62.4	0.045
3W 2-St Post 2005 <200cc	1.15	1.53	0.16	71.5	0.043
3W 4-St Post 2000 <200cc	1.97	0.34	0.40	62.7	0.030
3W 4-St Post 2005 <200cc	2.25	0.77	0.53	73.8	0.015
3W Diesel Post 2000 <500cc	2.05	0.16	0.69	173.9	0.347
3W Diesel Post 2005 <500cc	0.41	0.14	0.51	131.6	0.091
3W CNG-4S Post 2000 <200cc	1.00	0.26	0.50	77.7	0.015
3W CNG-2S Post 2000 <200cc	0.65	2.26	0.19	57.7	0.118
3W LPG-2S Post 2000 <200cc	1.70	1.33	0.04	68.2	0.130
P.Car Petrol Pre 2000 <1000cc	4.83	0.58	0.65	98.6	0.019
P.Car Petrol Post 2000 <1000cc	1.30	0.24	0.20	126.4	0.004
P.Car Petrol Post 2000 >1400cc	2.74	0.19	0.21	142.9	0.006
P.Car Petrol Post 2005 >1400cc	0.84	0.12	0.09	172.9	0.002
P.Car Diesel Pre 2000 <1600cc	0.87	0.22	0.45	129.1	0.145
P.Car Diesel Post 2000 <1600cc	0.72	0.14	0.84	156.8	0.190
P.Car Diesel Post 2005 <1600cc	0.06	0.08	0.28	148.8	0.015
P.Car Diesel Pre 2000 >1600cc	0.66	0.25	0.61	166.1	0.180
P.Car CNG Pre 2000 <1000cc	0.85	0.79	0.53	149.4	0.001
P.Car CNG Post 2000 <1000cc	0.06	0.46	0.74	143.5	0.006
P.Car LPG Pre 2000 >1000cc	6.78	0.35	0.50	130.9	0.001
P.Car LPG Post 2000 >1400cc	2.72	0.23	0.20	140.0	0.002

Average EF's in VAPIS

	Gasoline			Diesel				CNG			
	2Ws	3Ws	Cars	Cars	LDV	HDT	Bus	3Ws	Cars	LDV	Bus
PM_{10}	0.10	0.20	0.10	1.00	1.25	2.00	1.50	0.10	0.05	0.02	0.02
$PM_{2.5}$	0.05	0.08	0.03	0.60	0.50	1.00	0.80	0.05	0.02	0.01	0.01
SO_2	0.02	0.02	0.07	0.40	0.30	1.00	1.00	0.00	0.00	0.00	0.00
NO_x	0.15	0.10	0.20	1.25	2.00	10.0	10.0	0.35	0.20	3.50	2.50
CO	2.50	8.00	5.00	2.00	2.50	3.50	3.50	3.50	1.00	3.50	3.50
CO_2	40	80	200	250	500	850	850	70	100	450	450
HC	1.50	5.00	1.00	0.40	0.20	1.00	1.00	0.15	0.02	0.10	0.10

VAPIS: Vehicular Air Pollution Information System
@ www.sim-air.org

SIM-air Working Paper Series

In 2008

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Details @ www.sim-air.org

SIM 06-2008 – Health

SIM-air

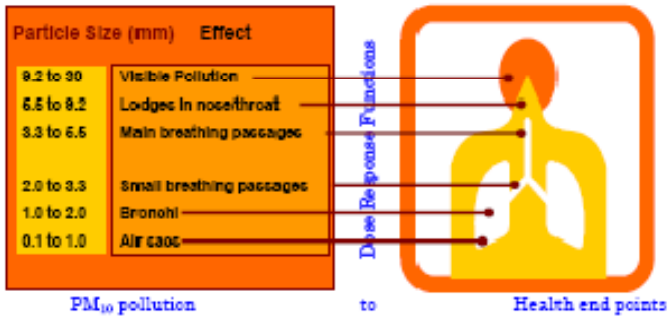
Simple Interactive Models for Better Air Quality

www.sim-air.org

Estimating Health Impacts of Urban Air Pollution

Dr. Sarath Guttikunda
New Delhi, India
October 2008

SIM-06-2008

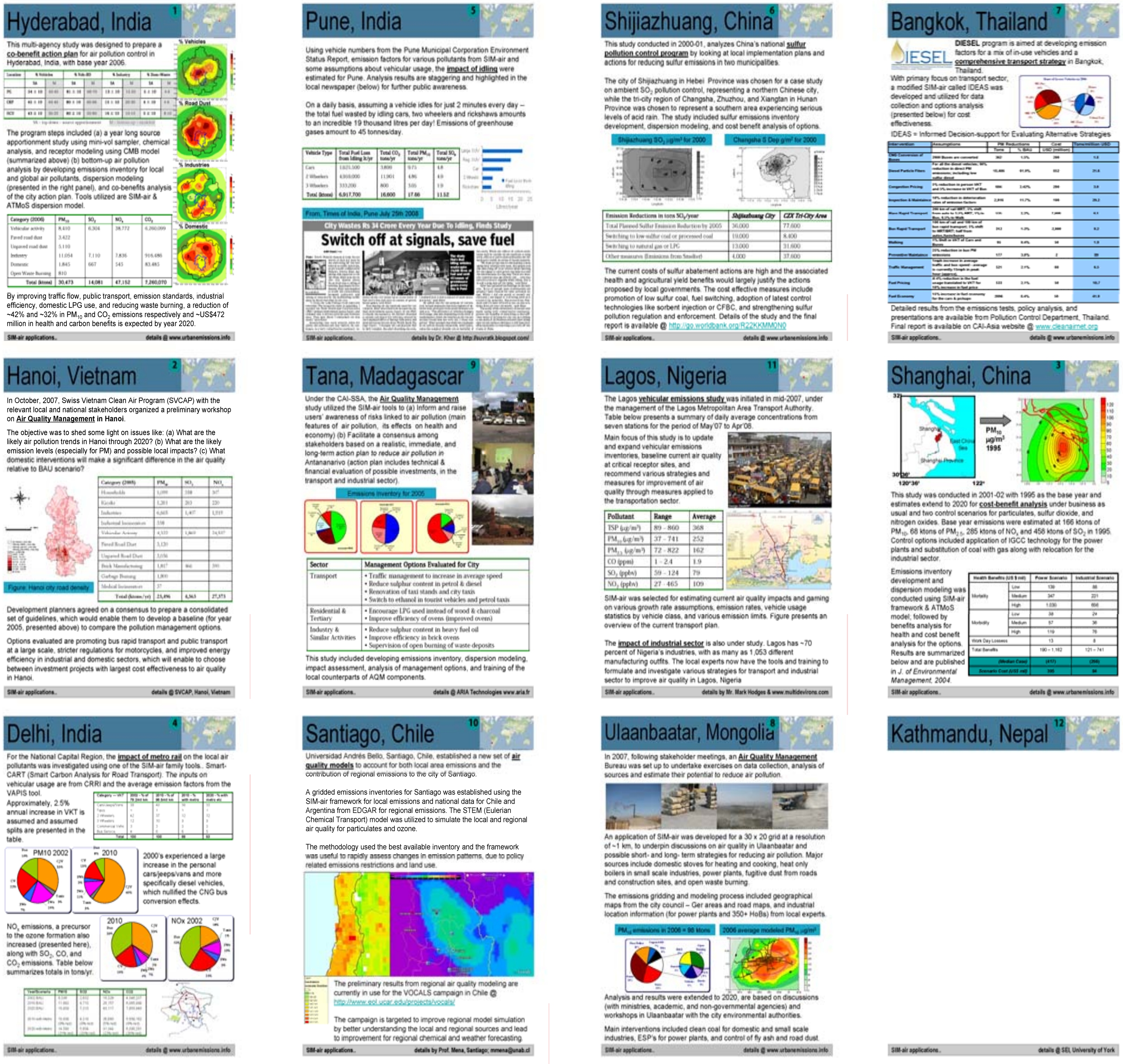


SIM-air Cities 2008

Details @ www.sim-air.org

SIM-air Cities

Case Studies



Pune, India

Times of India, July 25th, 2008

City Wastes Rs 34 Crore Every Year Due To Idling, Finds Study

Switch off at signals, save fuel

Aditi Tilpat | TNN

Pune: Every Punekar wastes at least Rs 800 worth of fuel per year by not switching off his/her vehicle at traffic junctions, as per a study conducted by Punekar, Suvrat Kher. Applying this equation to entire Pune, Kher says the entire city wastes about Rs 34 crore due to idling of vehicles. A geologist by profession, Kher was inspired to study the relationship between pollution and idling of vehicles by the maddening traffic jams he faced everyday in the city.

Suvrat Kher

"I cross the Law College road junction everyday. The situation there is appalling. I studied the Pune Municipal Corporation's (PMC) annual environment status report, and realised that it did not provide any relevant data. That was when I embarked on this study" said Kher.

Assuming that each vehicle idles for about two minutes per day (which, he confesses, is a very conservative estimate), vehicles in the city waste up to 19,000 litres of fuel every day and emit 45 tonnes of greenhouse gases, said Kher.

The study finds that idling vehicles waste upto 19,000 litres of fuel and emit 45 tonnes of greenhouse gases every day in Pune

Elucidating on the methods used for calculation, Kher described how he used the annual environment status report of the PMC to obtain the statistics. He further obtained a carbon calculator for vehicles created by the Canadian Office of Energy Efficiency and multiplication factors from World Bank Energy reports. "I thought the calculations will be very complex. But after obtaining the tools, I realised that it was a matter of mere multiplication," said Kher.

He added that for the purpose of calculation, he had estimated that most engines of vehicles were produced in the years between 1996 and 2005. "The efficiency of vehicles changes with usage, and also depending on the level of maintenance. Since the vehicles in the city are neither brand new nor very old, I chose this period." Kher stressed that while the emphasis is on carbon dioxide emissions, other pollutants like sulphur dioxide are as harmful, if not more. While the effects of carbon emissions will be visible in the medium to long term, effects of particulate pollutants are immediately visible in terms of health hazards.

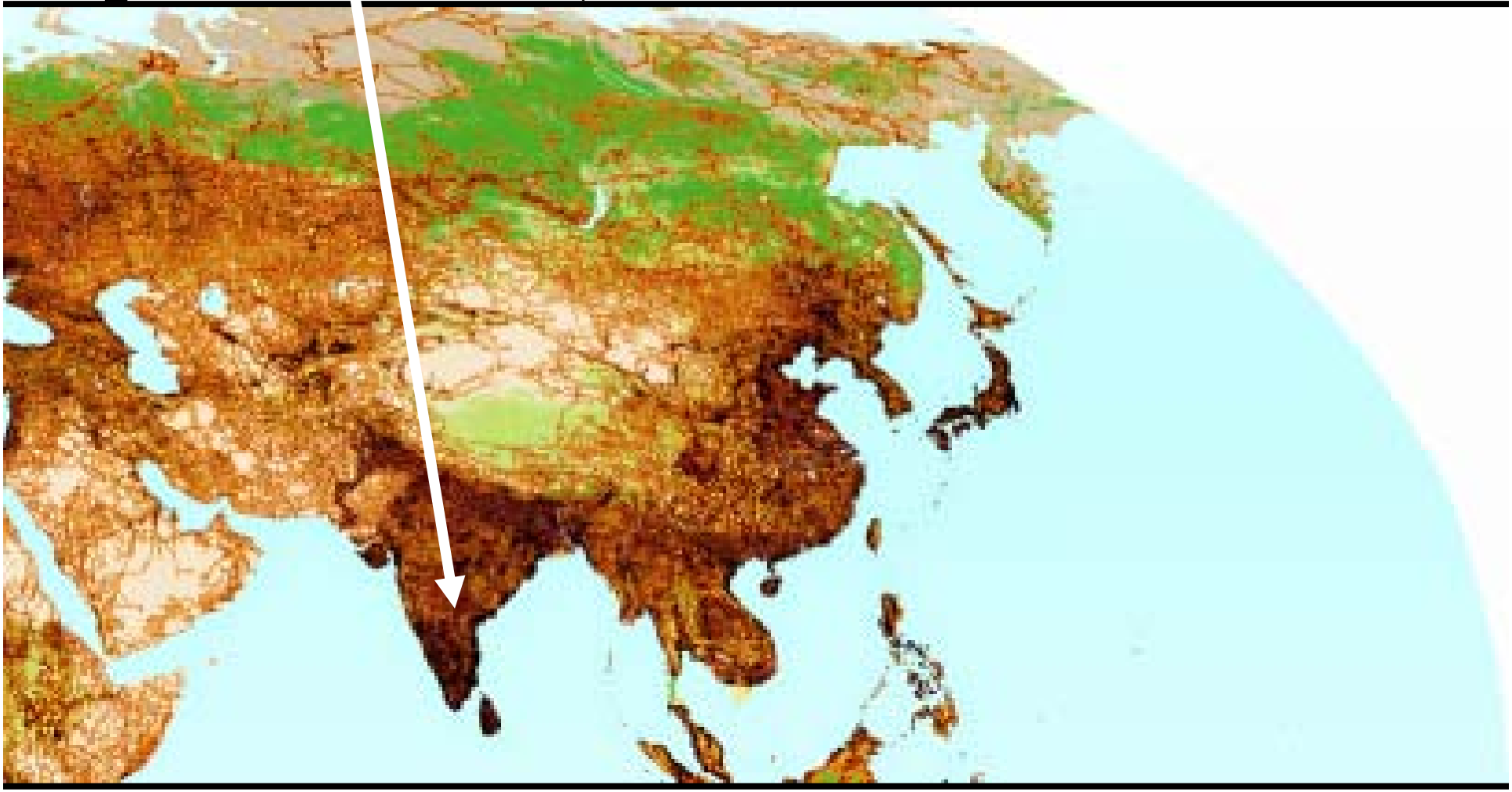
"We must accept that no one is going to stop using their vehicles very soon. But simple acts like switching off your vehicle while waiting for the signal to turn green can help you and the environment in a big way. There are western countries that use hybrid cars — cars that switch to electric engines while idling. But it is still a long way off for India," said Kher.

Kher has uploaded his findings on his website. "A lot of people have downloaded the graphs I have created for their personal usage. While I did the study to satisfy my curiosity, I am happy if it is being used as a resource by someone. Reporters from Pakistan and US have written to me, as also students from all over the world," said Kher.

The study, while elementary in nature and made using very conservative estimates, proves the benefits of switching to fuel-efficient ways of driving for the city. According to the study if all Punekars reduced their idling time by one minute everyday it will have benefits equivalent to removing 9,000 cars off the roads of Pune.

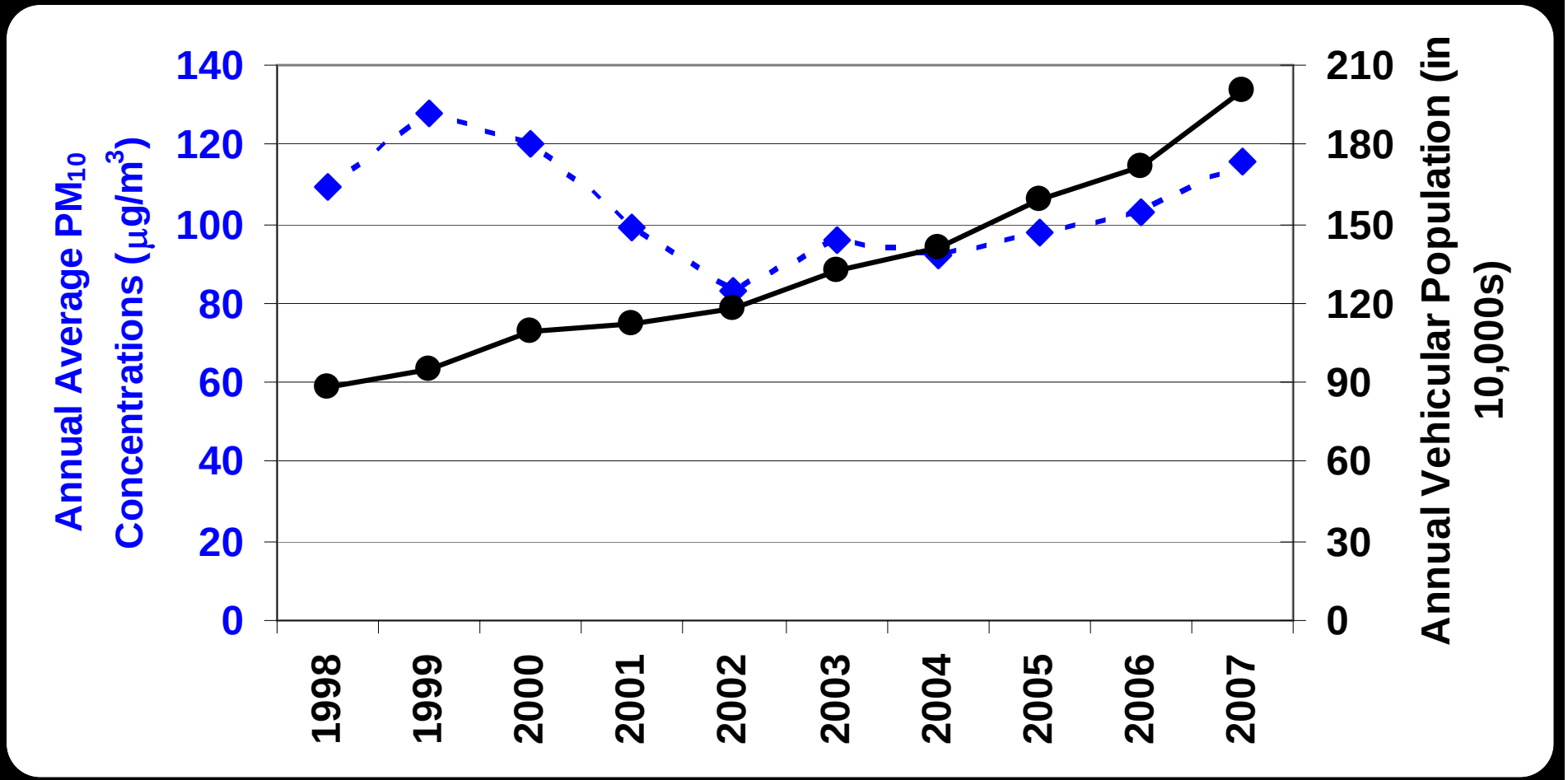
City Applications

Hyderabad, India



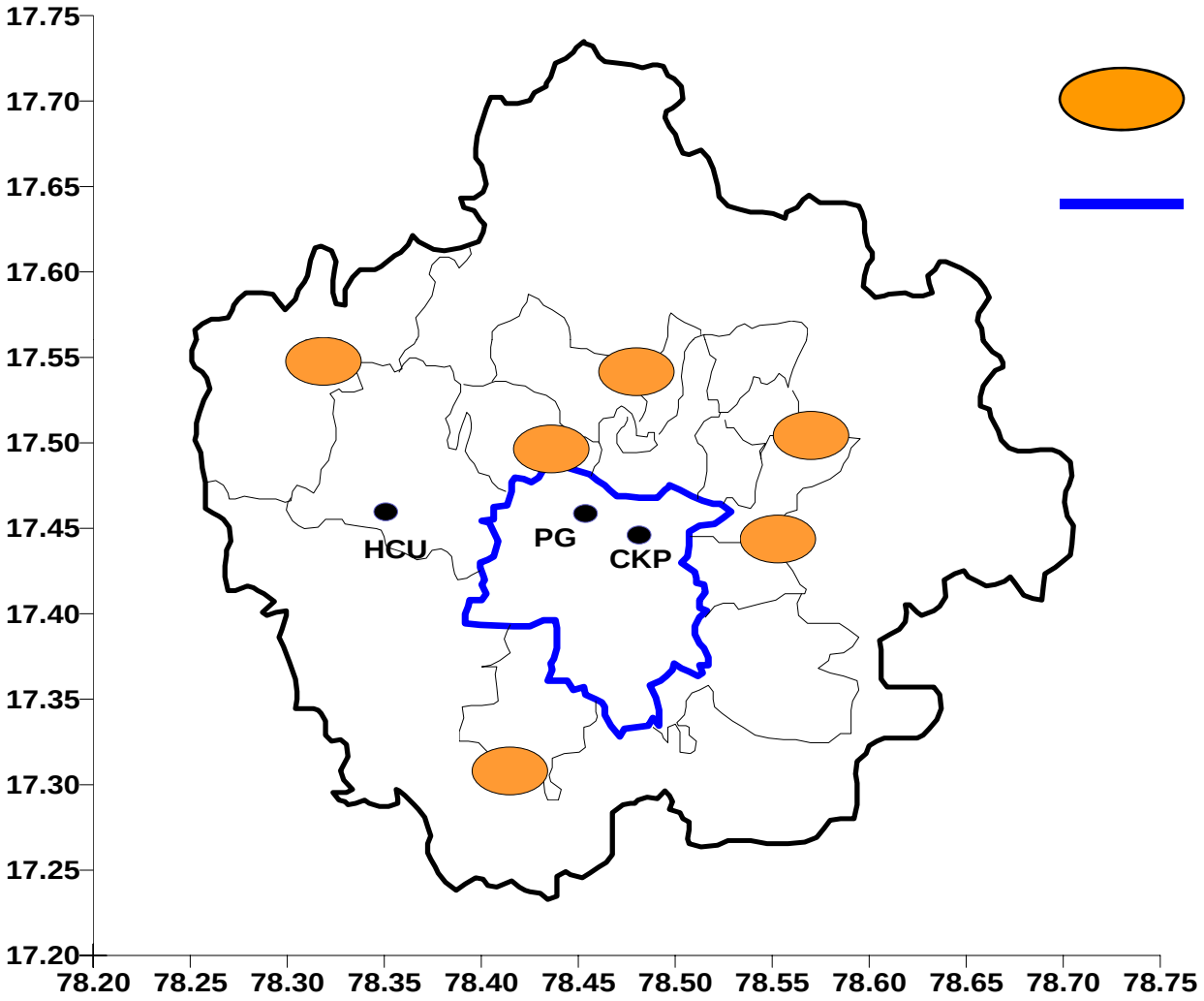
2006-08

Transport vs. Air Quality



Total Vehicles; 2002 = 14.5 L; 2006 = 18.0 L; 2007 = 20.0 L

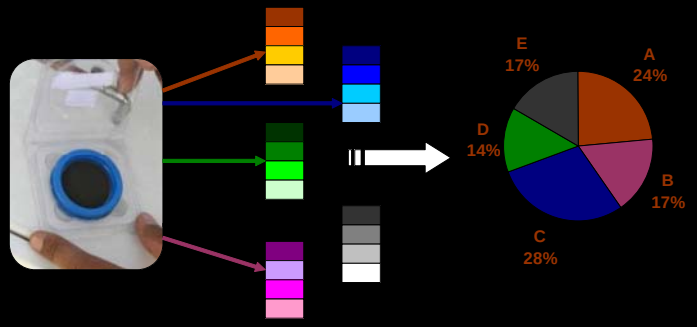
Hyderabad Urban Development Area



Source Apportionment Study

- Three seasons in 2005-06
- Three sites (PG, CKP, HCU)
- Airmetrics MiniVol samplers
- 24-hour sampling periods
- Filters
  - PM_{10} and $PM_{2.5}$
  - Teflon/quartz fiber filters

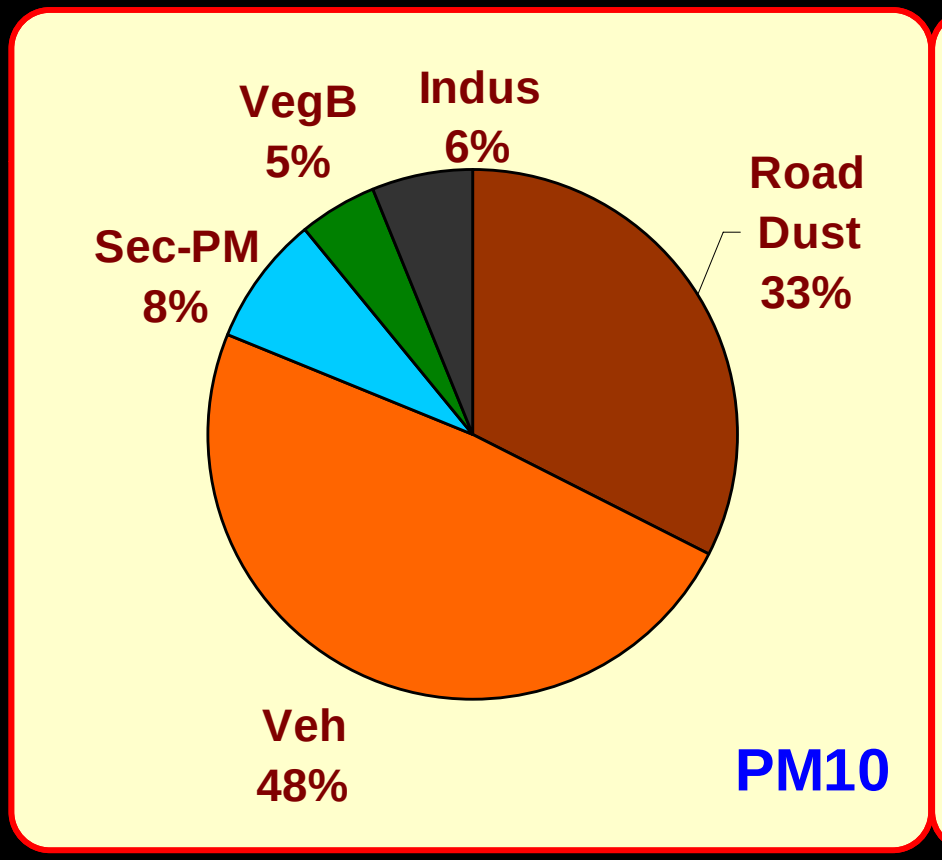
- Averages
  - PM_{10} ranged 59 to 160 $\mu g/m^3$
  - $PM_{2.5}$ ranged 26 to 86 $\mu g/m^3$

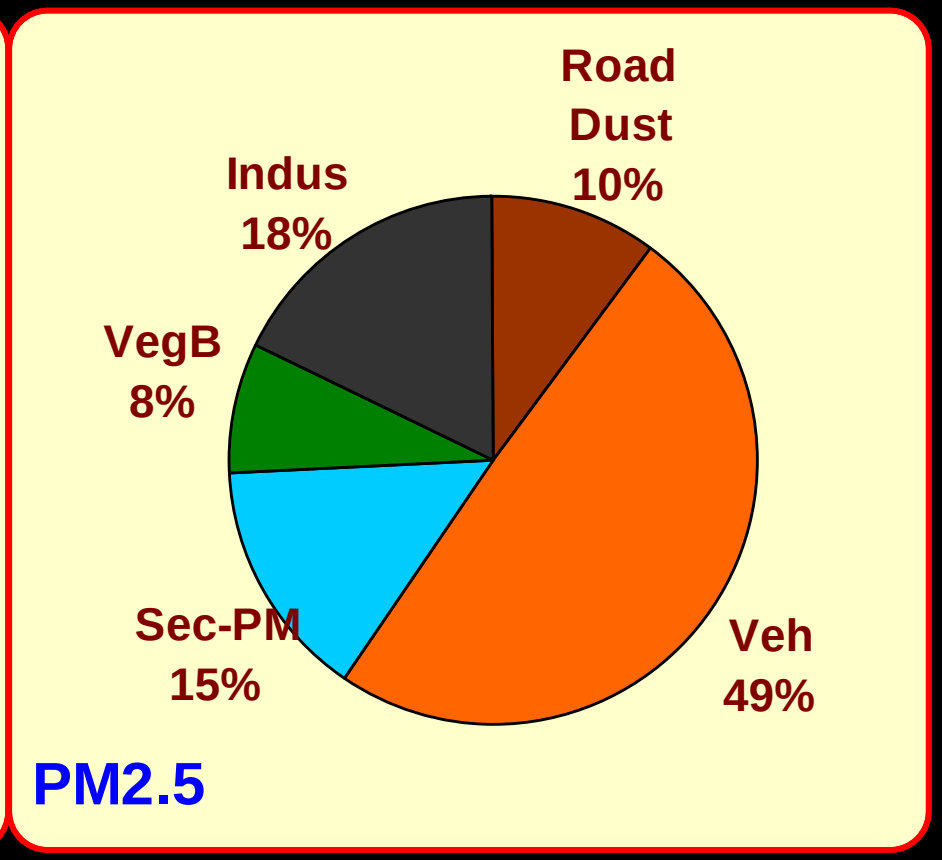


Receptor Model: CMB 8.2

Detailed report @ www.urbanemissions.info

CMB Results:
Average Sectoral Contributions





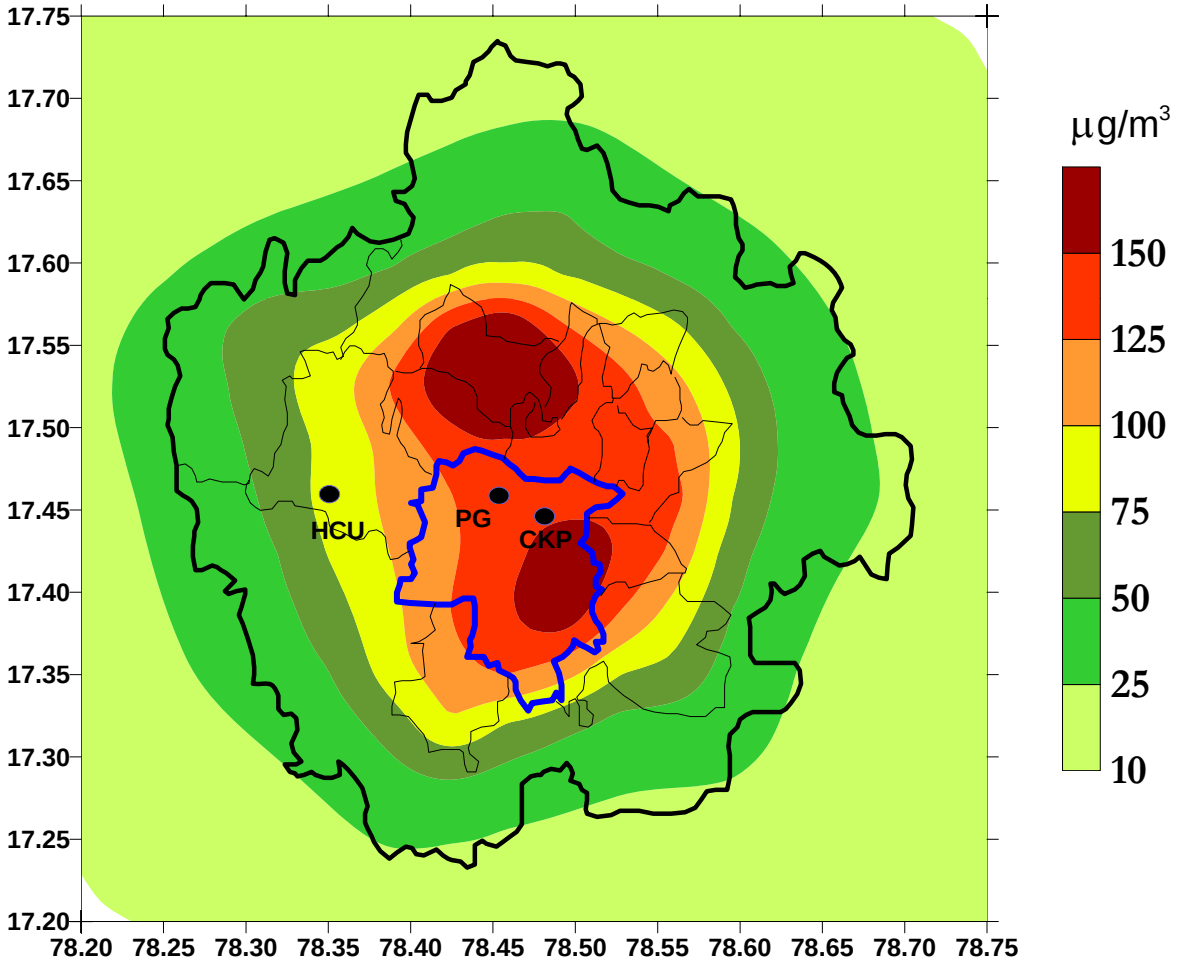
Emission Inventory (yr 2006)

Category	PM_{10}	SO_2	NO_x	CO_2
Vehicular activity	8,410	6,304	38,772	6,260,099
Paved road dust	3,422			
Unpaved road dust	5,110			
Industry	11,054	7,110	7,836	916,486
Domestic	1,845	667	545	83,485
Open Waste Burning	810			
Total	30,473	14,081	47,152	7,260,070

in tons/yr

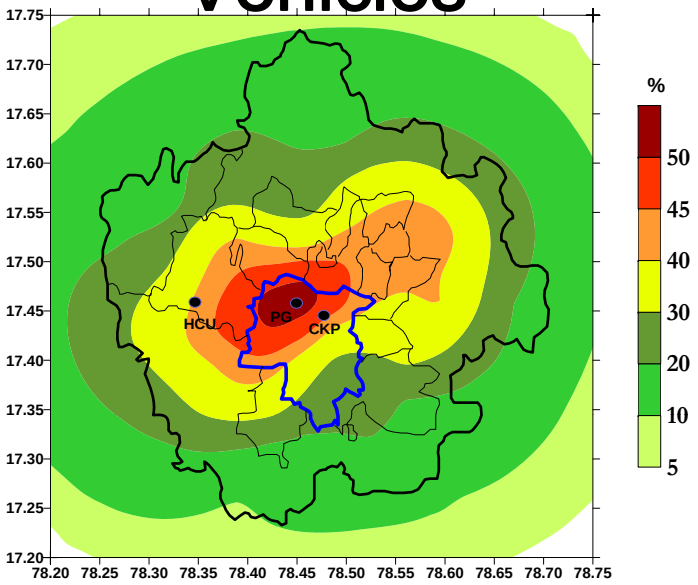
Detailed report @ www.urbanemissions.info

Modeled Annual Average PM_{10}

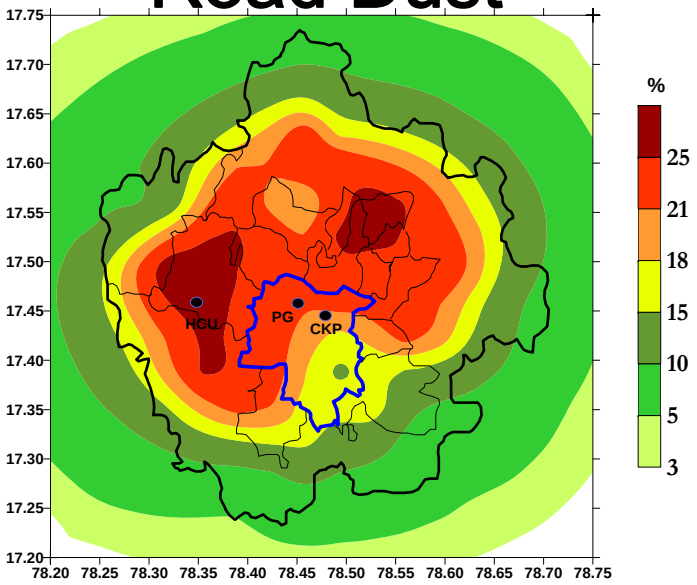


% Estimated Contribution of Sectors

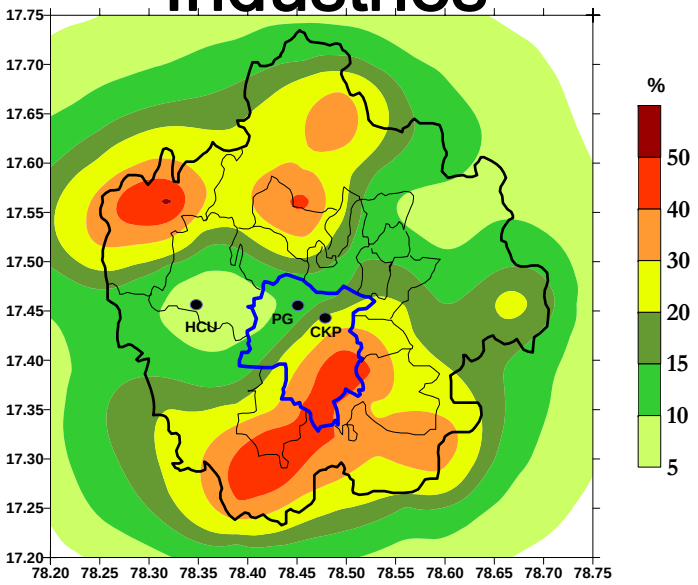
Vehicles



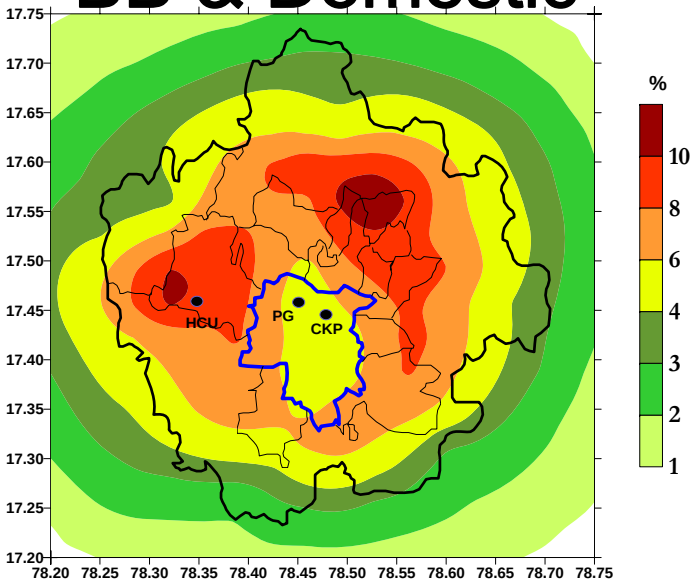
Road Dust



Industries



BB & Domestic



Top-Down vs. Bottom-Up

Location	Vehicles		Veh+RD		Industry		Dom+OWB	
	SA	M	SA	M	SA	M	SA	M
Punjagutta	54 ± 10	40-45	81 ± 10	66-70	13 ± 10	15-20	5 ± 10	4-6
Chikkadpally	45 ± 10	40-45	80 ± 10	60-66	15 ± 10	20-30	4 ± 10	4-6
HCU	43 ± 10	30-35	80 ± 10	50-60	16 ± 10	10-15	5 ± 10	8-10

SA = top-down = source apportionment

M = bottom-up = modeled

Detailed report @ www.urbanemissions.info

Action Plan for Air Pollution Reduction

Co-Benefits Analysis

Hyderabad: Proposed Action Plan

- Road maintenance
- LPG for 3 W's
- Public transport
- New emissions standards
- Phase-out for old 2 W's, 3 W's, & Cars
- Industrial energy efficiency
- Garbage management

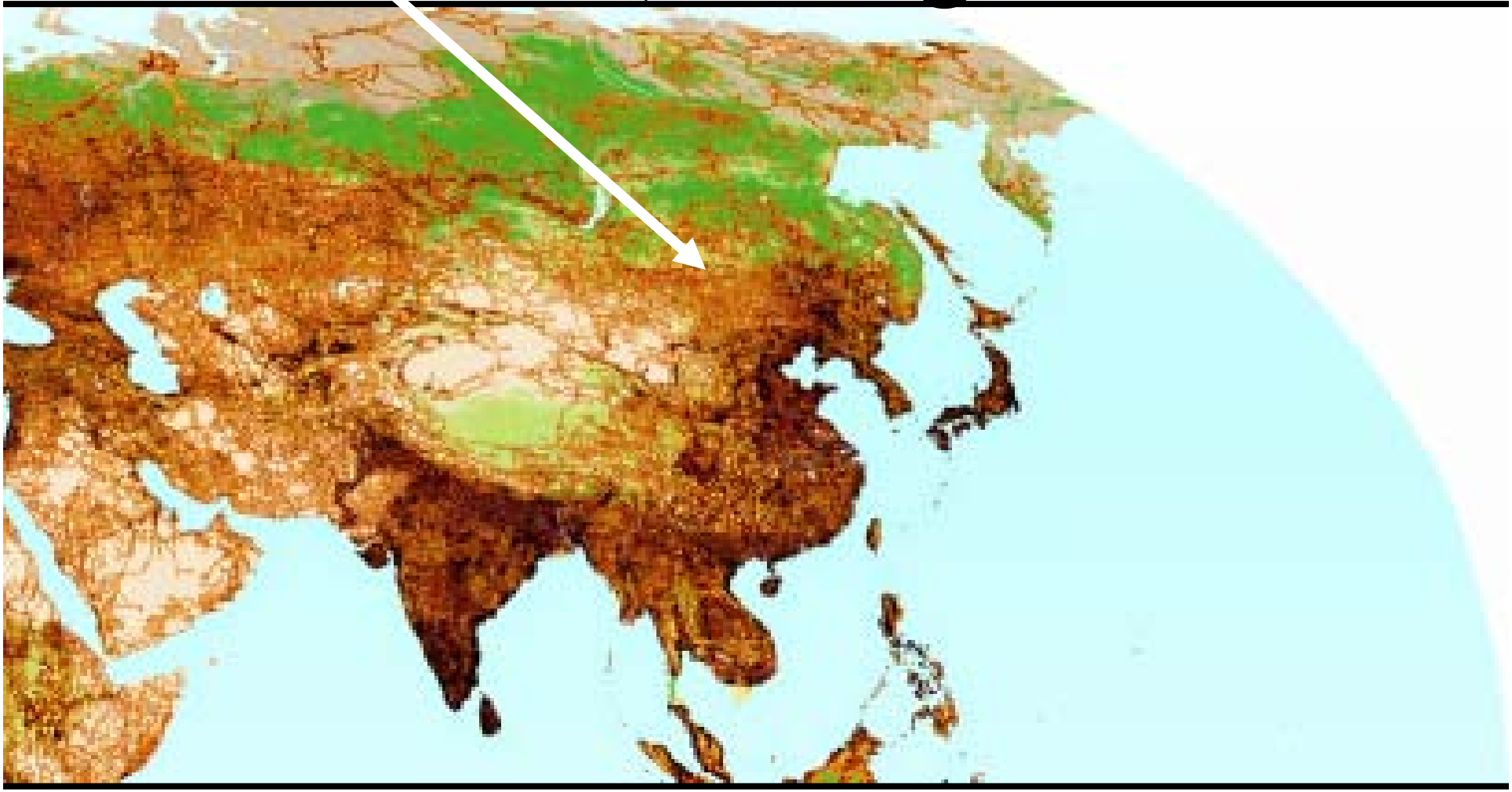
Co-Benefits for 2020

Estimated Overall Percent Reductions

Intervention	PM_{10} (%)	CO_2 (%)
100% buses to CNG	11.6	16.2
Public transport	6.1	9.8
Wet & vacuum sweeping	6.9	
I & M	1.2	3.8
Abolish diesel gen sets & biomass	14.2	2.0
Control illegal garbage burning	1.6	
Coal use in domestic sector	3.1	0.6

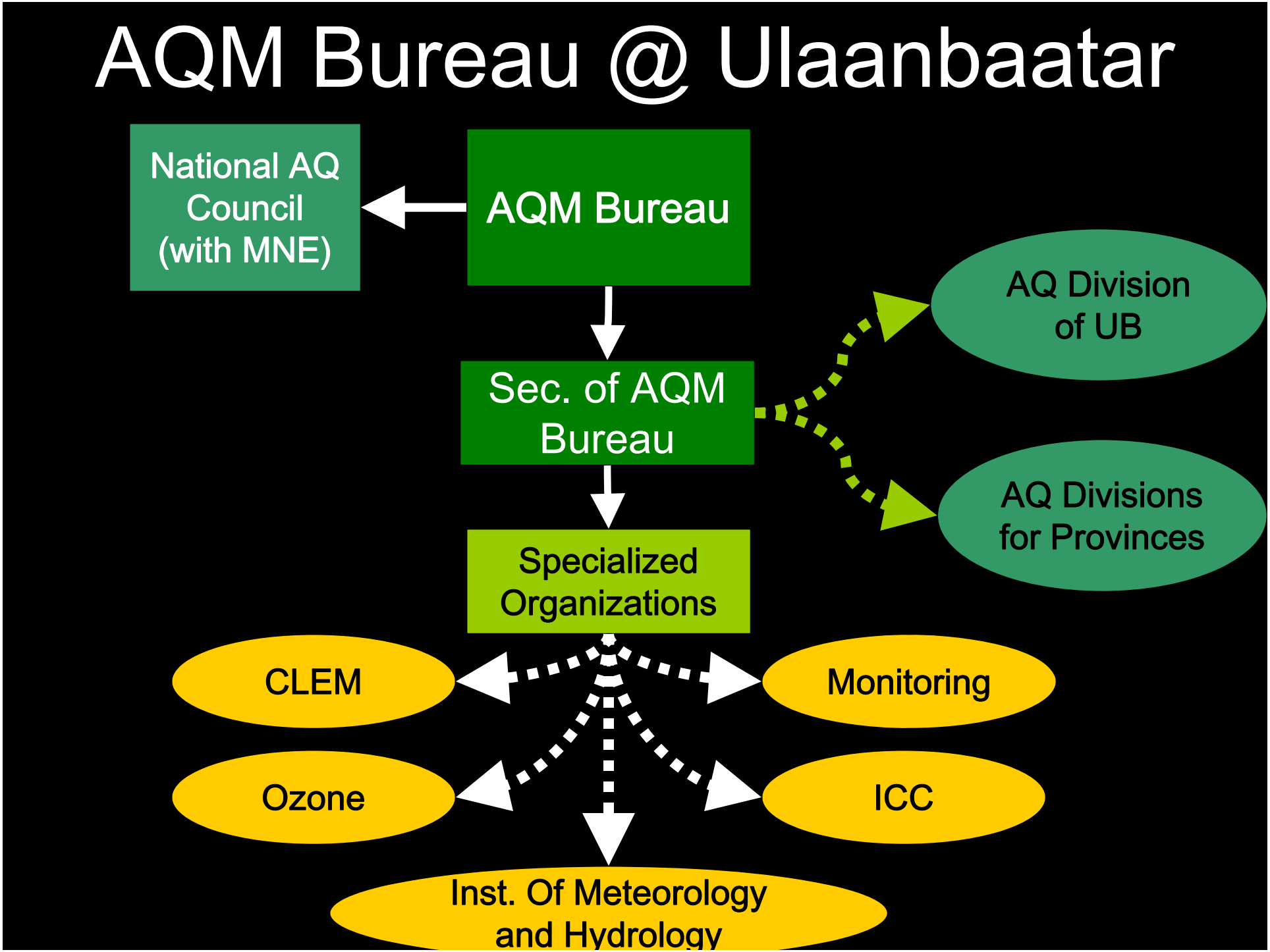
Detailed report @ www.urbanemissions.info

Ulaanbaatar, Mongolia

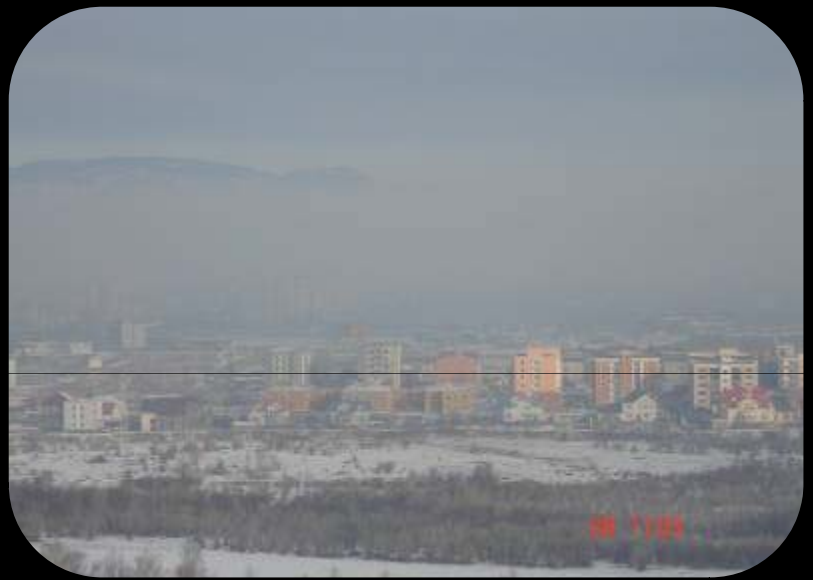


2007

AQM Bureau @ Ulaanbaatar



Dispersion in Winter…



In Migration of Population

Stoves: cooking & heating

… fly ash from power plants

Garbage Burning

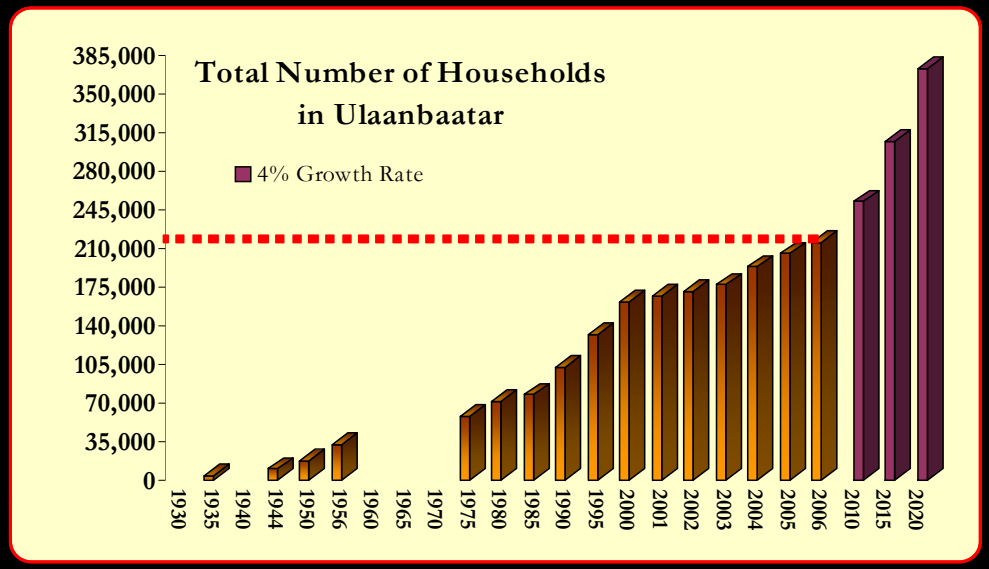
Brick Industry

Fugitive Dust… May 7th 2007

Traffic

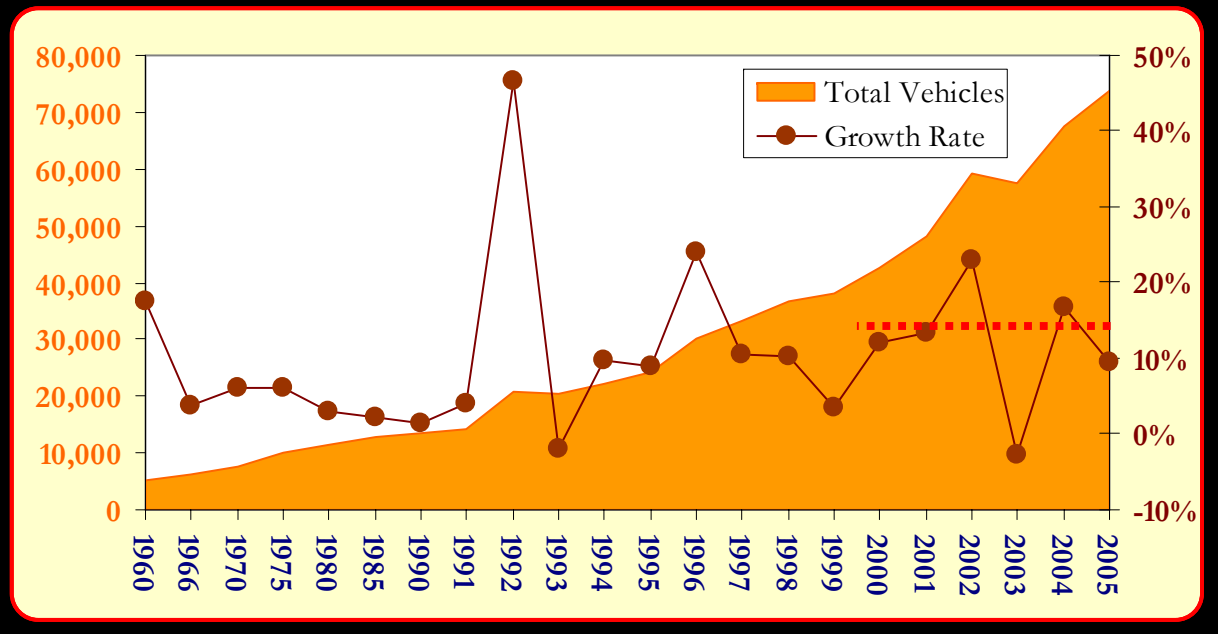
(image from google earth)

Fugitive Dust from Vehicles

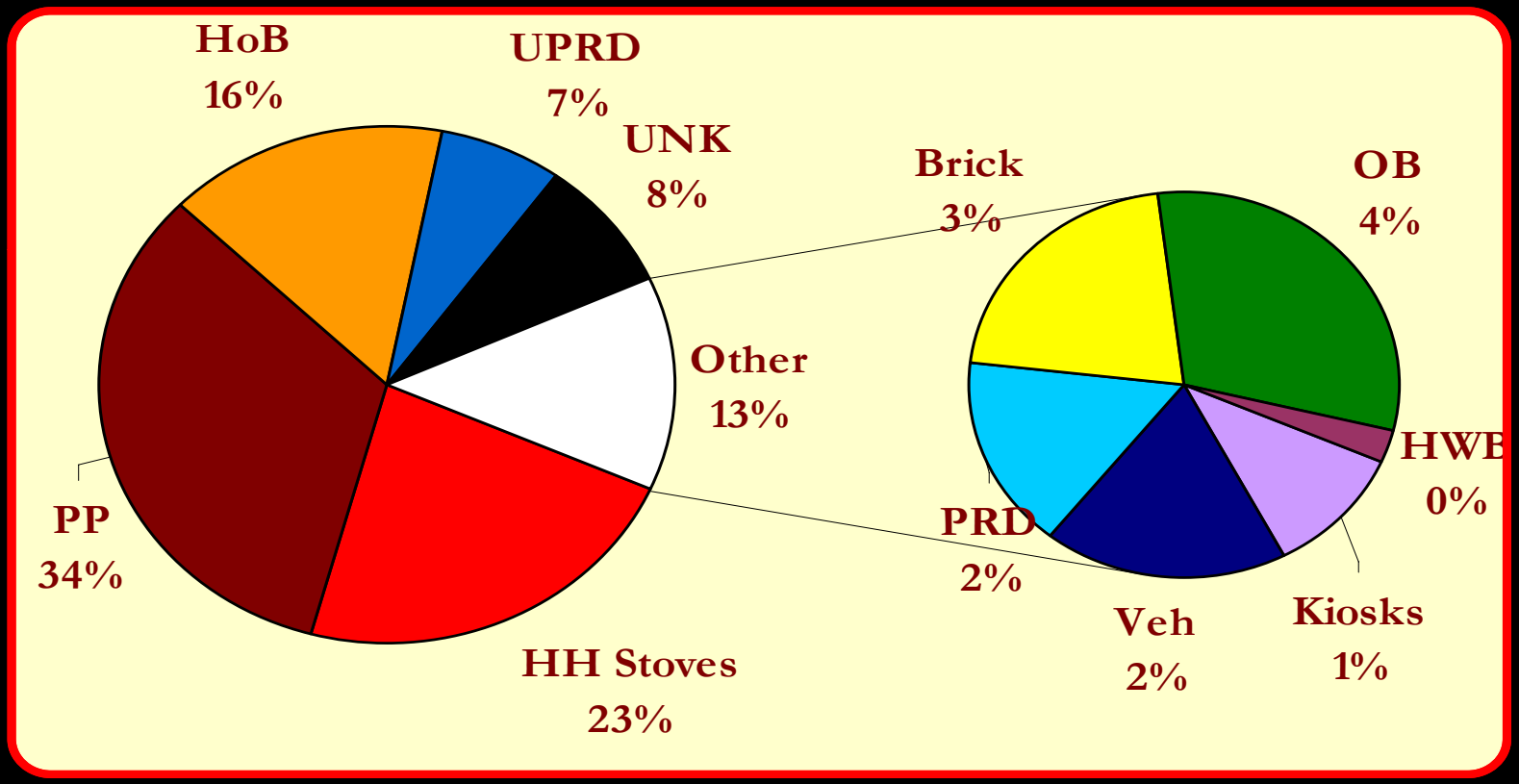


Households = Cooking & Heating

Transport, A Growing Sector



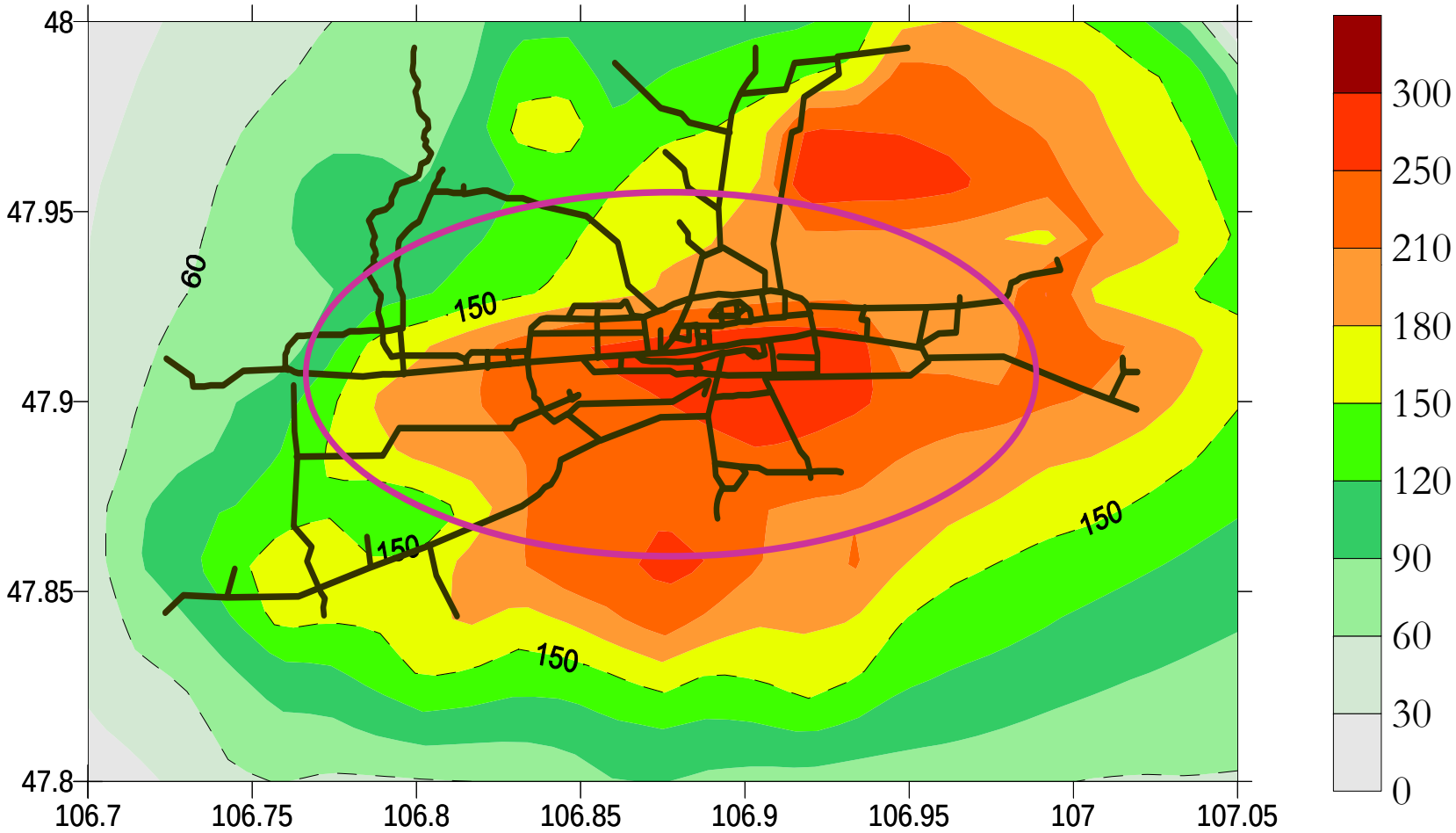
PM_{10} Emissions (2006)



Estimated @ 98.5 ktons (annual)

Detailed report @ www.urbanemissions.info

Modeled PM_{10} Concentrations

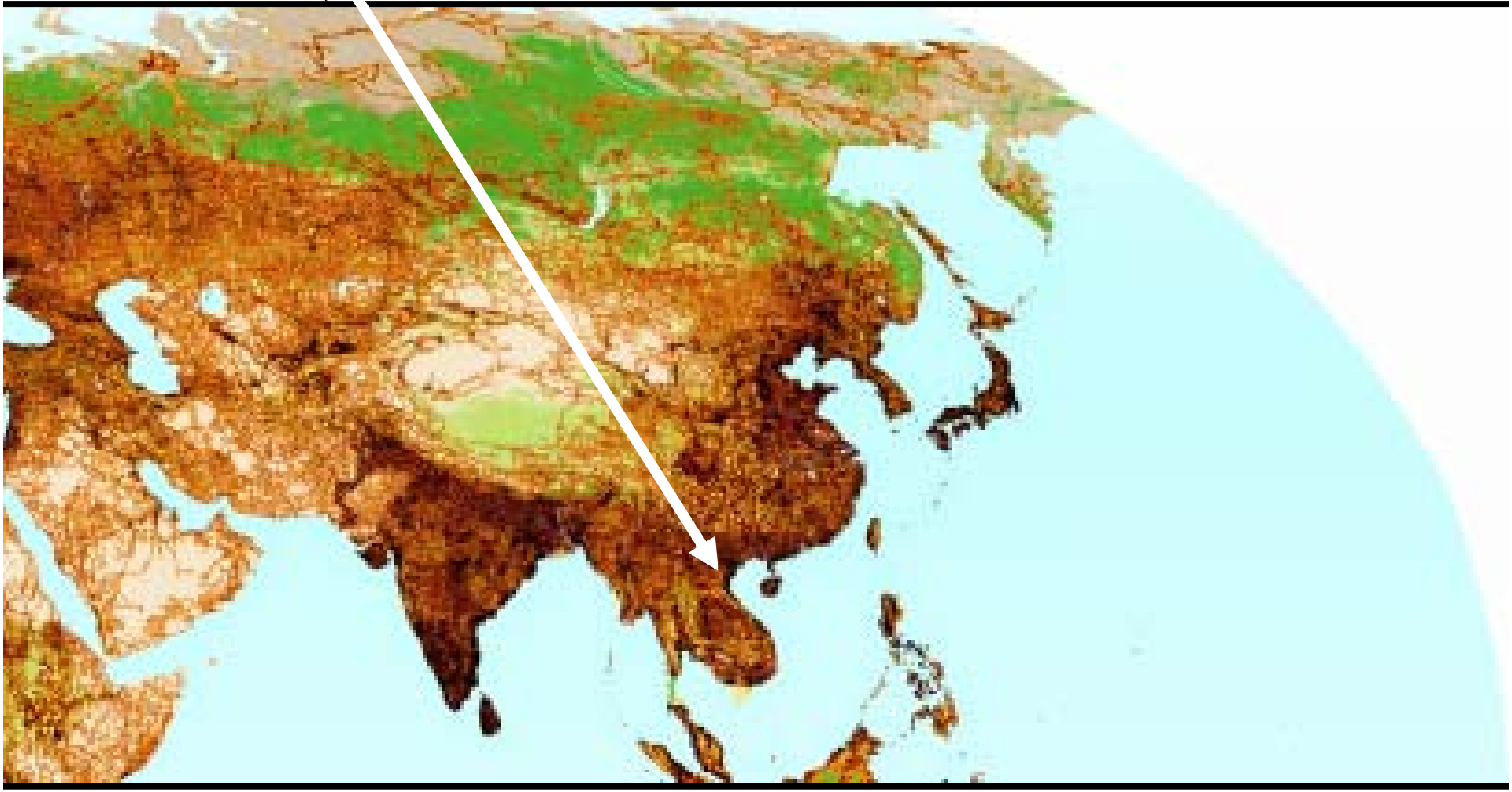


Plan of Action 2008-20

- Monitoring
- Clean coal for domestic sector ****
- Heating only boilers to central heating
- New combustion technologies for PP's
- ESP's for PP's & larger industries
- Fly ash control to brick making
- Energy efficiency at brick & cement

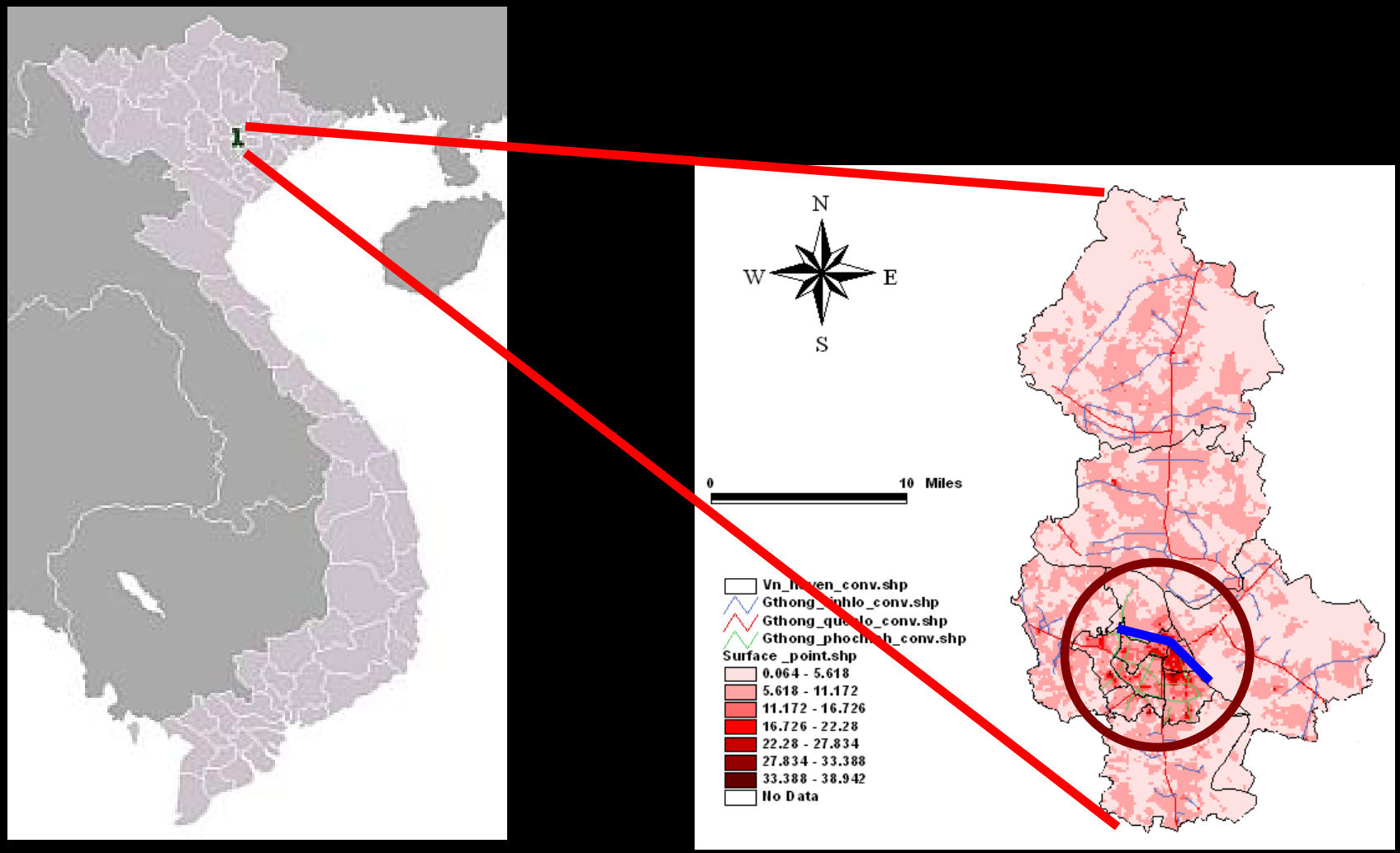
Briquette Technology

Hanoi, Vietnam



2008

Hanoi, Vietnam



In City Pollution Sources

Non-Transport

~ a large industry

~ domestic

~ coal mining

~ & related transport

~ power plant

In City Pollution Sources

Transport

~1.6 million in 2006

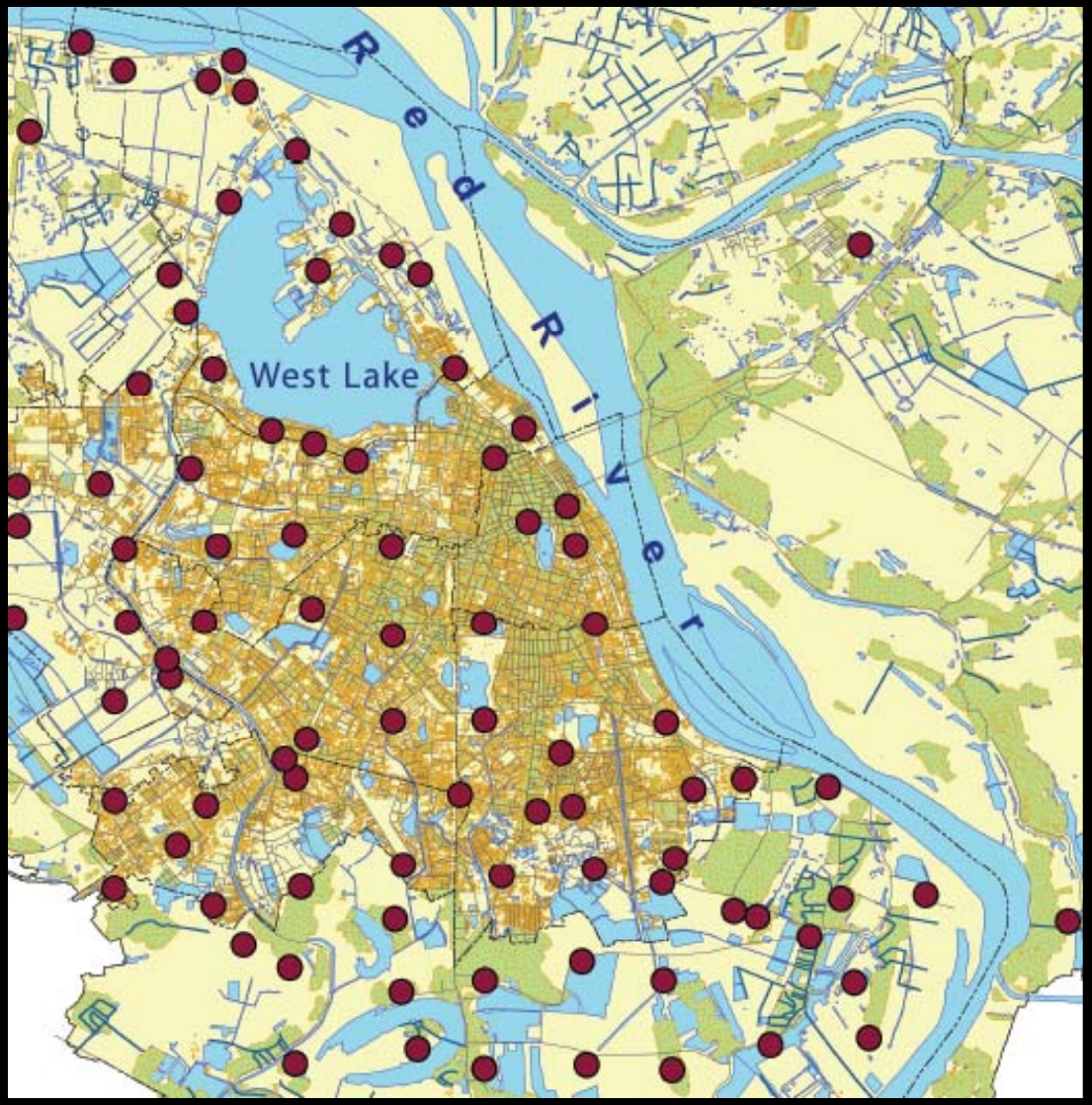
~ 90% are motorcycles

~ Dust levels are high

~ Cars are increasing

~ low public transport

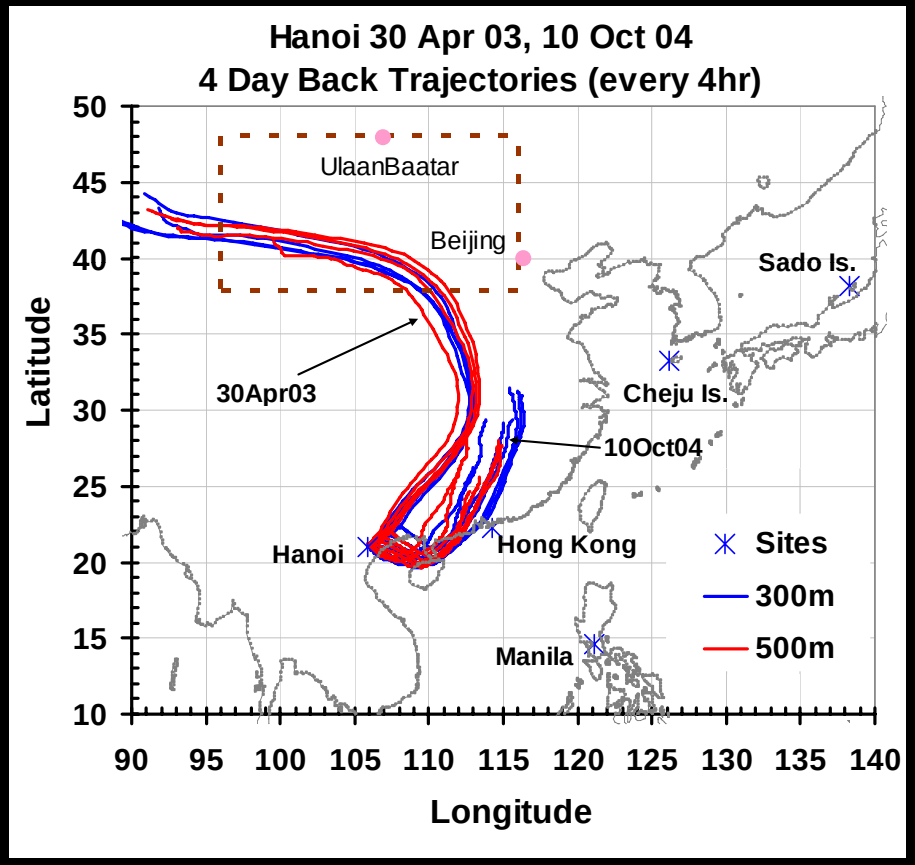
Passive Samplers – 2006-07

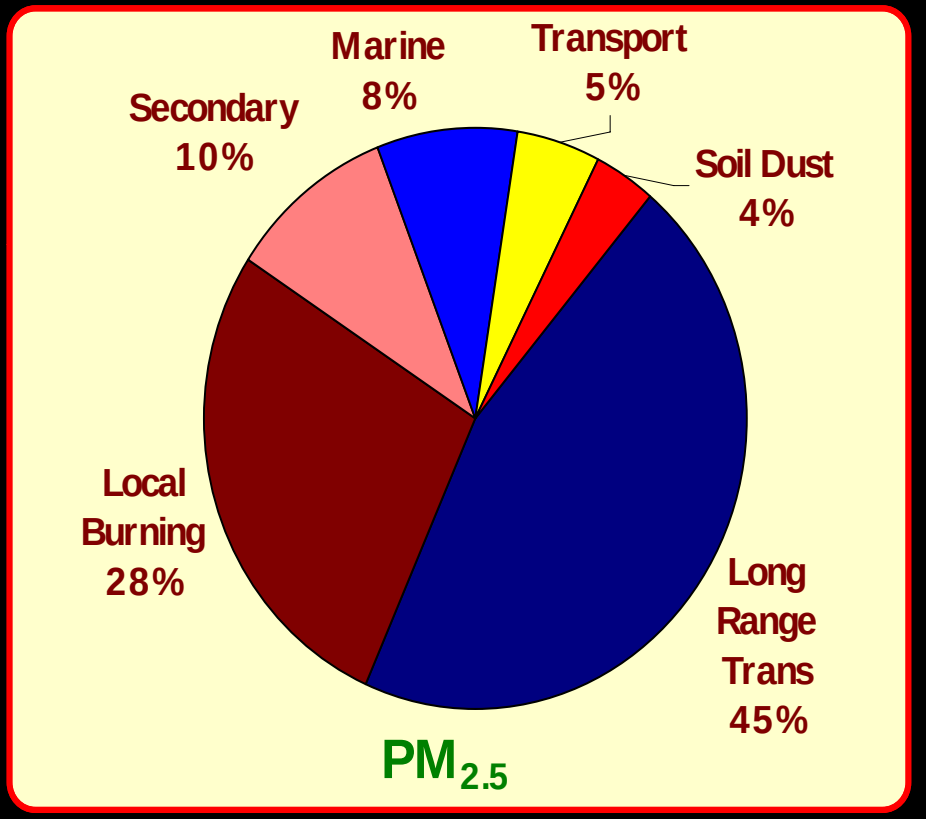


NO_x & SO_2

Averages are ~2 times the standards

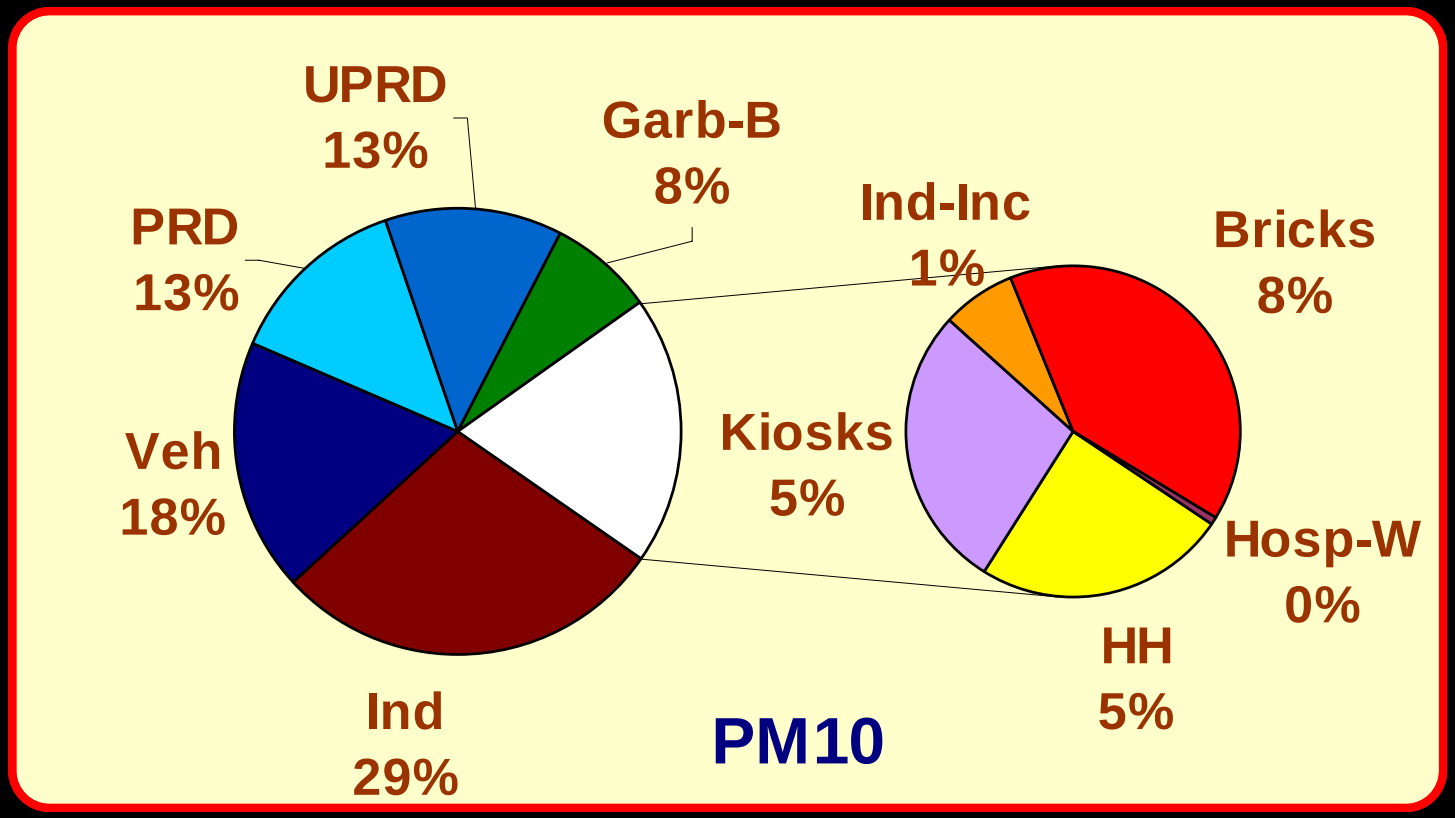
Source Apportionment for PM





Cohen et al., 2006 using back trajectories; Hien et al., 2004 using receptor modeling

PM_{10} Emissions (2005)



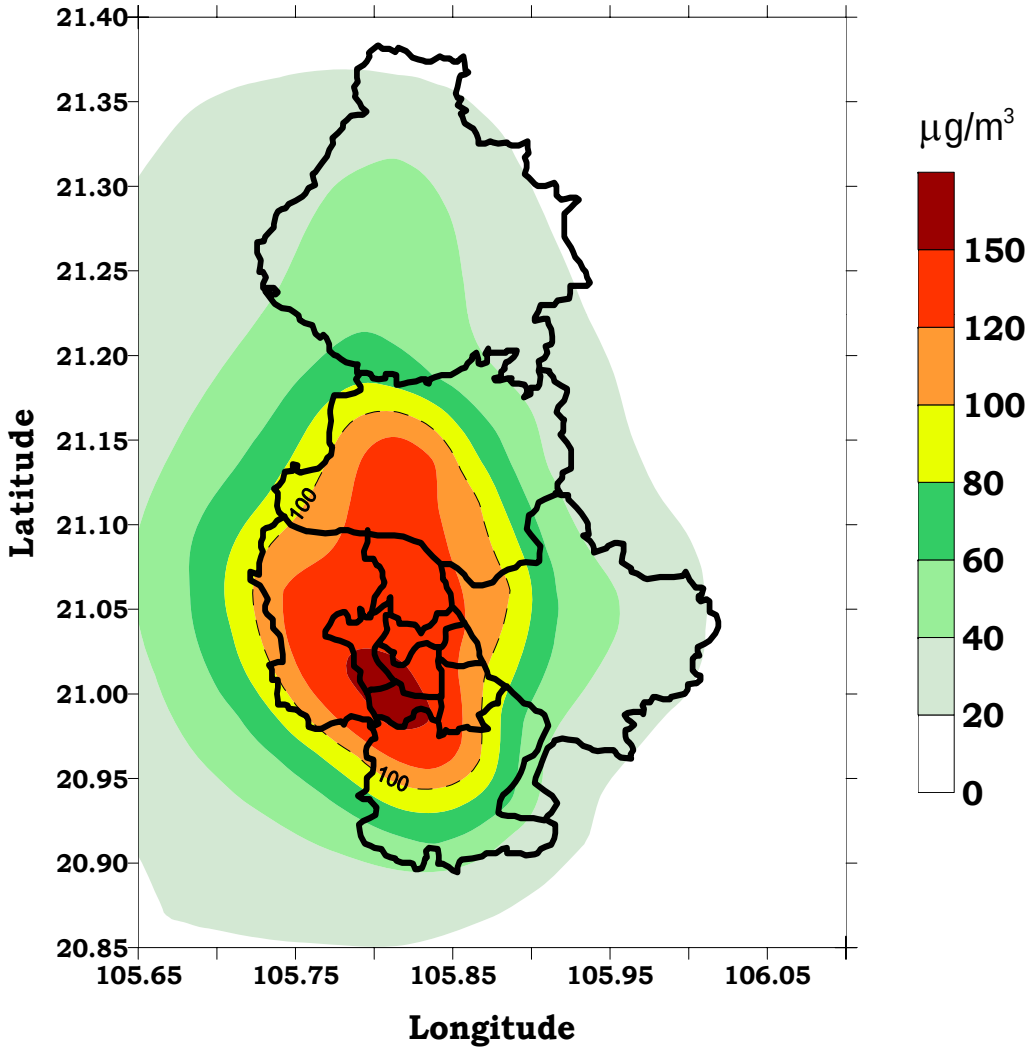
other pollutants

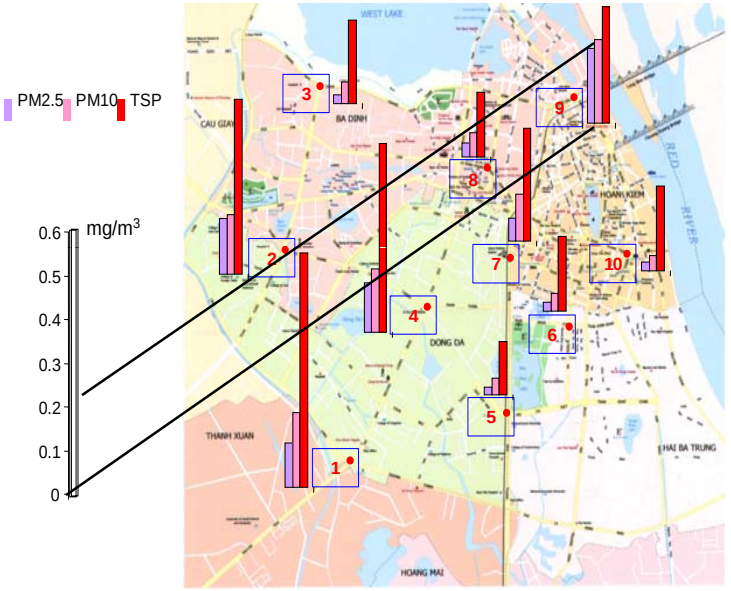
NO_x, SO_2, & CO_2

Estimated @ 23.5 ktons (annual)

Details @ Guttikunda & SVCAP, 2008

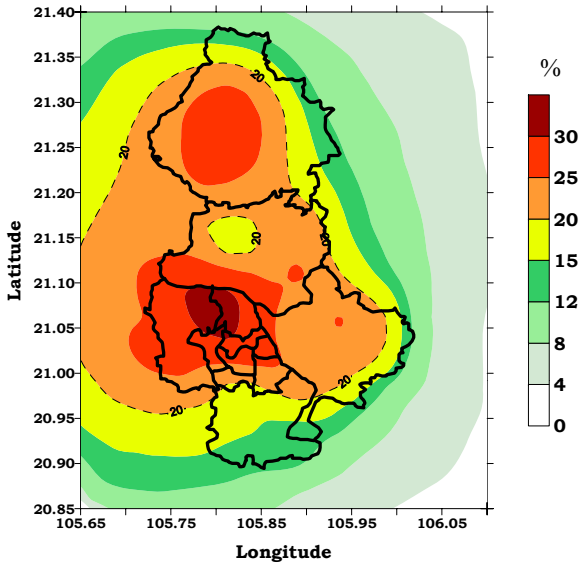
Modeled PM_{10} Concentrations



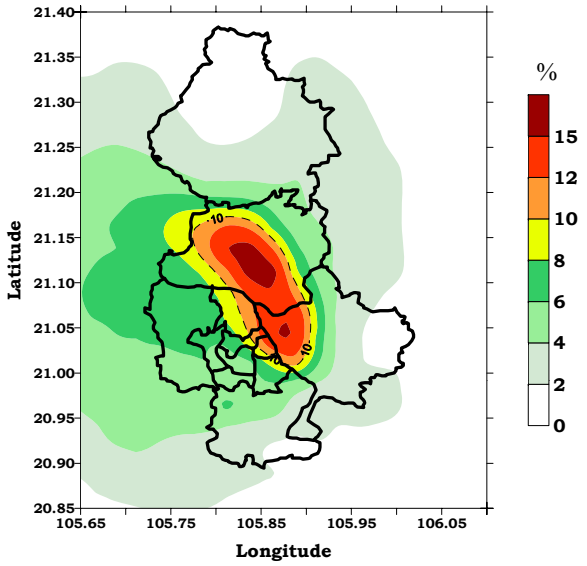


% Estimated Contribution of Sectors

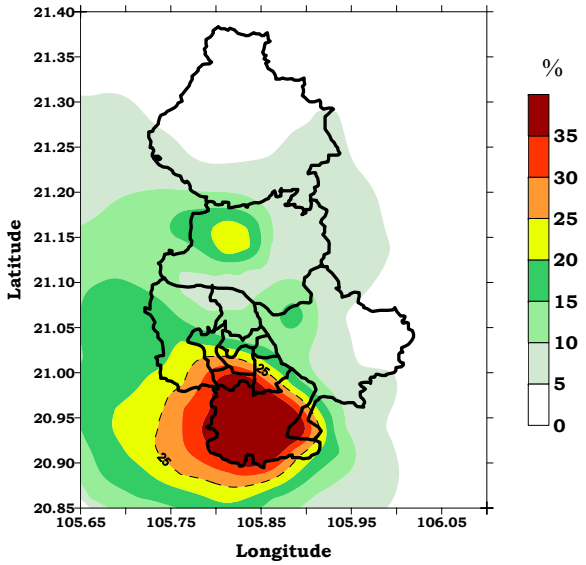
Vehicles



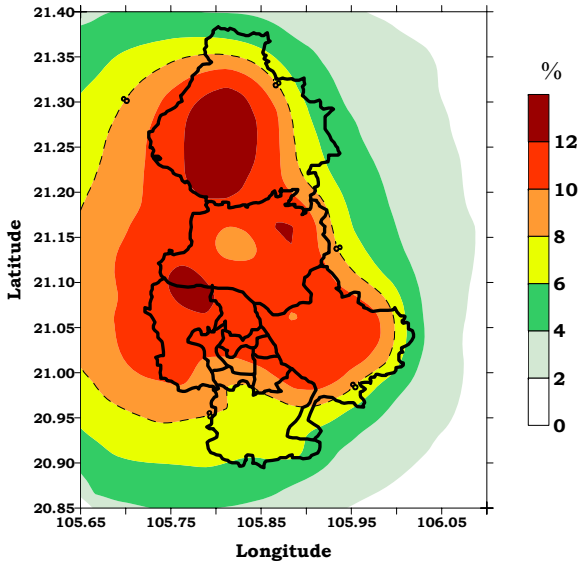
Road Dust



Ind - Bricks



BB & Domestic



Hanoi: AQM Plan 2020

- Road maintenance
- Mass transport – road & rail
- New emissions standards for 2W's & cars
- Industrial zoning & energy efficiency
- ESP's for larger industries
- Alternative fuels for domestic
- Landfill management

Details @ Guttikunda & SVCAP, 2008

Challenges ahead..

What goes in.. Comes out

Tools are plenty

Need more collaborative action

Informed decision making is key

To join SIM-air mailing list, send email to simair@urbanemissions.info

Thank you

Dr. Sarath Guttikunda
@ www.urbanemissions.info

December 2008