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Regional Air Pollution in Developing Countries

SEI STOCKHOLM ENVIRONMENT INSTITUTE

Malé Declaration emissions inventory workshop

Delhi, India 2010

Session 1 –

The basics of emission inventory compilation

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Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia

Presentation overview

Background

- The air pollution problem

General approach for calculation of emissions

- Emissions factors (EFs)
- Activity data

The Malé Declaration emission inventory manual and workbook

- Air pollutants included
- Emission source structure
- Looking at the Excel workbook (hands on)

General Steps in Inventory Development

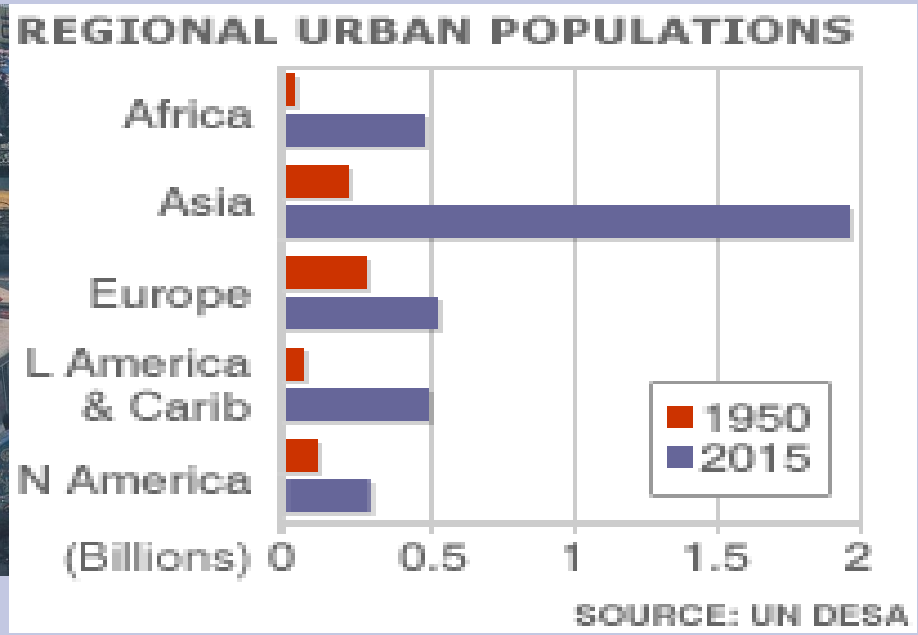
- Planning
- Data collection
- Calculations
- References/Documentation
- Quality assurance and quality control (QA/QC)

Units and conversions (+ exercises)

The problem

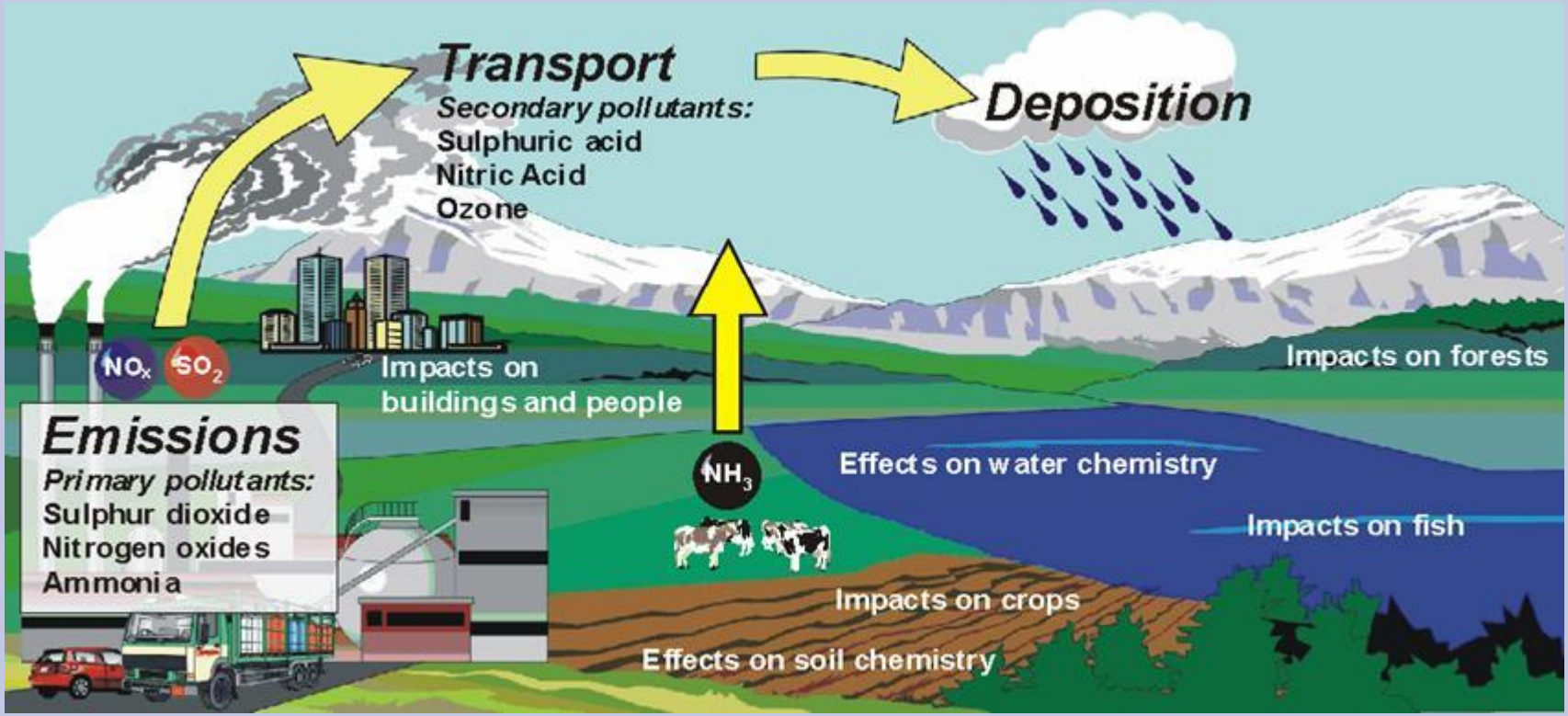
Driving Forces:

- Economic growth
- Urbanisation
- Motorisation
- Population growth
- Industrialisation
- Increasing energy demand



The problem:

Damage to crops, animals and ecosystems



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Impacts of Air Pollution at Different Scales

Household Urban Peri-urban Regional Global

What is an emissions inventory?

Definition:

"An air pollutant emissions inventory details the amounts and types of air pollutants released into the air by source category for a specific geographic area over a specific time period."

Emissions may be either:

- **Natural or**
- **Anthropogenic (man-made)**

Natural emissions include:

- Volcanic emissions (SO_2 & PM)
- Biogenic emissions from trees and other vegetation (VOCs & NH_3)
- Biogenic emissions from natural soils (NO_x)
- Wind-blown dust from deserts and disturbed areas
- Lightning (NO_x)

Anthropogenic (man-made) emissions

Large point sources (LPS) - large emitters that can be identified at a specific location:

- electrical power plants
- metal smelters
- large factories
- oil refineries

Air Pollution from stationary sources Azerbaijan
Source: HDR Azerbaijan, 1999

Anthropogenic (man-made) emissions

Other source categories are made up of many small, or diffuse sources:

- **domestic households**
- **small factories**
- **offices and public buildings**
- **cars and other mobile sources (line sources)**
- **vegetation fires**
- **crop residue burning**
- **application of fertilizers**

General approach for calculation of emissions

Emission = (emission factor) x (activity rate)

Emission factors are the rate of emission of a pollutant per unit of activity

Examples:

- **In power stations - kg NO_X per tonne coal burnt**
- **In copper smelters - kg SO_2 per tonne blister copper produced**

General approach for calculation of emissions

Emission = (emission factor) x (activity rate)

The activity rate is some measure of the annual level of the relevant activity e.g. :

- **For *fuel combustion* - the annual rate of consumption of a fuel (e.g. kilotonnes coal burnt per year in power stations)**
- **For *industrial process emissions* - the annual rate of production of the commodity (e.g. kilotonnes copper blister produced per year at copper smelters)**

Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia

The Malé Declaration Air Pollutant Emissions Inventory Manual

Version 2.5
October, 2010

UNEP RRC-AP

SACEP

SEI

Air pollutants included in the Malé Declaration emission inventory manual

- Sulphur dioxide (SO_2)
- Nitrogen oxides (NO_X)
- Particulate matter (PM_{10} and $PM_{2.5}$)
- Ammonia (NH_3)

The ozone (O_3) precursors (in addition to NO_X):

- Carbon monoxide (CO)
- Non-methane volatile organic compounds (NMVOCs)

Summary of anthropogenic emission source categories used in the manual

Energy sources:

1 Combustion in the Energy Industries

2 Combustion in Manufacturing Industries and Construction

3 Transport

4 Combustion in Other Sectors

5 Fugitive emissions from fuels

Summary of anthropogenic emission source categories used in the manual

Other source sectors:

6 Industrial Processes

7 Solvent and Other Product Use

8 Agriculture

9 Vegetation Fires & Forestry

10 Waste

Top-down or bottom up approach?

- Depends on data availability – flexibility crucial
- If national data only – then top-down
- If large point source (LPS) data – bottom-up
- National and LPS sources can be inventoried together – the workbook will automatically adjust national activity data to avoid ‘double-counting’.

Emission Factors (EFs) used in the manual

Currently, the default EFs in the Malé Manual are mostly taken from Europe (EMEP/Corinair), North America (US-EPA's AP-42) or UN (IPCC) source documents. But where possible, EFs specific to developing country regions, especially Asia, are suggested:

- **CO and PM EFs for household stoves in India**
- **NO_X EFs for household stoves in China**
- **NO_X, CO, NMVOC and NH_3 EFs from earthen charcoal kilns in Zambia**
- **EFs for road transport (detailed method) are from India (CPCB, Transport Fuel Quality for 2005)**

Input data required to compile an emissions inventory

International sources of activity data:

- ***Fuel consumption -*** International Energy Agency (IEA) Energy Statistics and Balances – data up to 2008 available on CD-ROM **(but Bhutan & Maldives are not covered)**
- ***Industrial processes -*** Annual production by country in: UN Industrial Commodity Statistics Database (online) **(but not for Maldives)**; Pig iron production (also called blast furnace iron or BFI): Worldsteel Association online statistics; for metals and minerals, the US Geological Survey (USGS) **(but not for Maldives)**; and for fertilizer production, Food and Agriculture Organisation's (FAO) online database FOASTAT.
- ***Agricultural activity -*** FOASTAT database (number of farm animals, crop production, fertilizer consumption, beer production)

Data required to compile an emissions inventory

National sources of data are better: from government departments, industry, research institutes, research publications, e.g.:

- **Areas of different natural vegetation types burnt in the relevant year**
- **Average levels of emission control in the various industrial sectors (e.g. sulphur recovery in copper smelters, SO_2 and NO_x controls on power stations)**
- **Point source emissions data for large facilities – if obtainable**

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The Malé Declaration emission inventory Excel workbook: main menu

User must enter inventory details here:

Inventory year:	2000
Region:	South Asia
Country:	Someland
Province:	Somestate (optional)

MENU OVERVIEW

GO	Menu1	Sectors 1. to 4. Fuel combustion activities
GO	Menu2	Sector 5. Fugitive emissions (non-combustion) for fuels
GO	Menu3	Sector 3. Fuel combustion activities. Sector: Transport (Detailed method)
GO	Menu4	Sector 6. Industrial processes (non-combustion) emissions
GO	Menu5	Sector 7. Solvent and other product use
GO	Menu6	Sector 8. Agriculture
GO	Menu7	Sector 9. Vegetation fires and Forestry.
GO	Menu8	Sector 10. Waste
GO	Menu9	Large Point sources
GO	Sheet 9	Summary sheet - Annual emissions of each pollutant by source sector
GO	References	

The Malé Declaration emission inventory Excel workbook: Menu 4

Sector 6. Industrial processes (non-combustion) emissions

Back to Back to Main

- GO Sheet: 2.1 Process (non-combustion) emissions from the production of mineral products.
- GO Sheet: 2.2 Process (non-combustion) emissions from the production of chemicals.
- GO Sheet: 2.3 Process (non-combustion) emissions from metal production.
- GO Sheet: 2.4 Process (non-combustion) emissions of SO_2, NOx and NMVOCs from pulp and paper production.
- GO Sheet: 2.5 Process (non-combustion) emissions of NMVOC from alcoholic beverage manufacture.
- GO Sheet: 2.6 Process (non-combustion) emissions of NMVOC, PM_{10}, and $PM_{2.5}$ from food production
- GO Sheet: 2.7 Fugitive emissions of particulate matter from major building construction activities.

Worksheet for *Process (non-combustion) emissions from metal production*

Process	A Activity rate (kt product/ year)	B SO_2 emission factor (kg SO_2/t)		C SO_2 emissions (Tonnes)	D NO_x emission factor (kg NO_x/t)		E NO_x emissions (Tonnes)
			Default	(A x B)		Default	(A x D)
Pig iron production			3[a]	0		0.076[d]	0
Aluminium production			15.1[e]	0		2.15[e]	0
Copper smelting (primary)			2120[f]	0			
Lead smelting (primary)			320[g]	0			
(secondary)			40[h]	0			
Zinc smelting (primary)			1000[g]	0			
Other (please specify)				0			0
Total emissions				0			0

Sheet 9 Summary sheet - Annual emissions of each pollutant by source sector

Sector	Sub-sector	Total emissions (kilotonnes pollutant per year (kt/yr))						
		SO_2	NO_x	CO	NMVOC	NH_3	PM_{10}	$PM_{2.5}$
1. Combustion in the Energy Industries	Public Electricity and Heat	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Petroleum Refining	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Manufacture of Solid Fuels and Other Energy	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2. Combustion in Manufacturing Industries and construction	Iron and Steel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Non-ferrous metals	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Non-metallic minerals	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pulp, Paper and print	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mining and Quarrying	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Other (Please specify in sheet 1.1.1a, 1.1.1b or 1.1.1c)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Autoproduction of electricity/heat	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Remainder (Non-specified)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3. Transport	Civil Aviation (Simple--not used if Detailed used)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Civil Aviation (Detailed)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Road transport (Simple--not used if Detailed used)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Road transport (Detailed)		0.00	0.00			0.00	0.00
	Railways	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Navigation	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pipeline transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Non-specified transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Combustion in Other Sectors	Commercial/Institutional	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Agriculture/Forestry/Fishing	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Non-specified "Other sectors"	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5. Fugitive emissions from fuels	Production of coke				0.00		0.00	0.00
	Oil exploration and crude oil production and transport				0.00			
	Oil refining	0.00	0.00	0.00	0.00			
	Distribution and handling of gasoline				0.00			
	Production and distribution of natural gas.				0.00			
	Flaring during oil and gas extraction		0.00	0.00	0.00			
6. Industrial processes	Mineral products	0.00		0.00	0.00		0.00	0.00
	Chemicals	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Metals	0.00	0.00	0.00	0.00		0.00	0.00
	Pulp and paper	0.00	0.00	0.00	0.00		0.00	0.00
	Food and drink				0.00		0.00	0.00
	Major construction site activities (Fugitive PM only)						0.00	0.00
7. Solvent and other product use					0.00			
8. Agriculture	Manure management					0.00		
	Application of N-containing fertilizers		0.00			0.00		
	Burning of agricultural crop residues	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9. Vegetation fires and Forestry	On-site burning of forests and grasslands	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10. Waste	Waste incineration	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Human excreta					0.00		
Total anthropogenic		0.00	0.00	0.00	0.00	0.00	0.00	0.00

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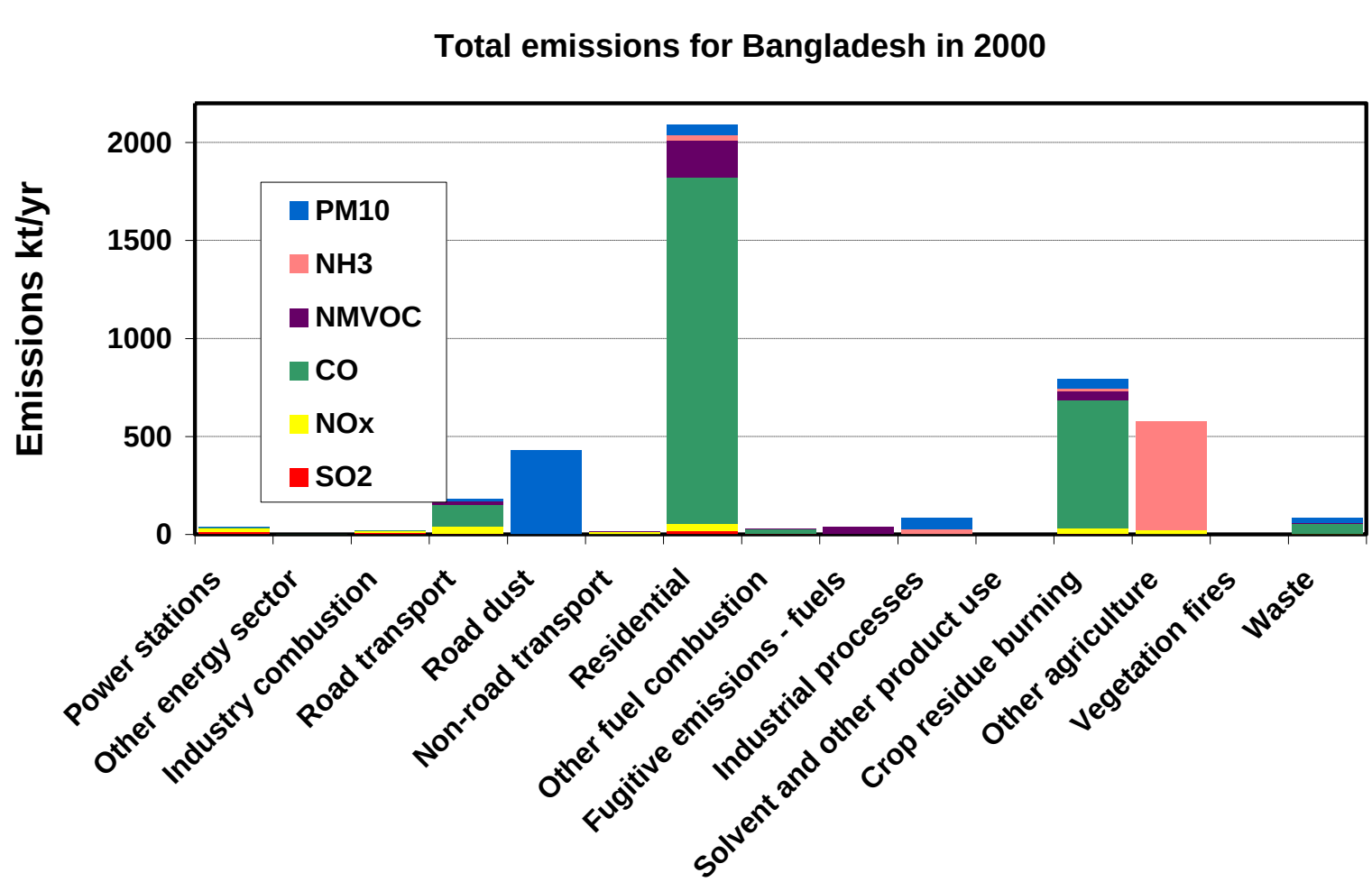
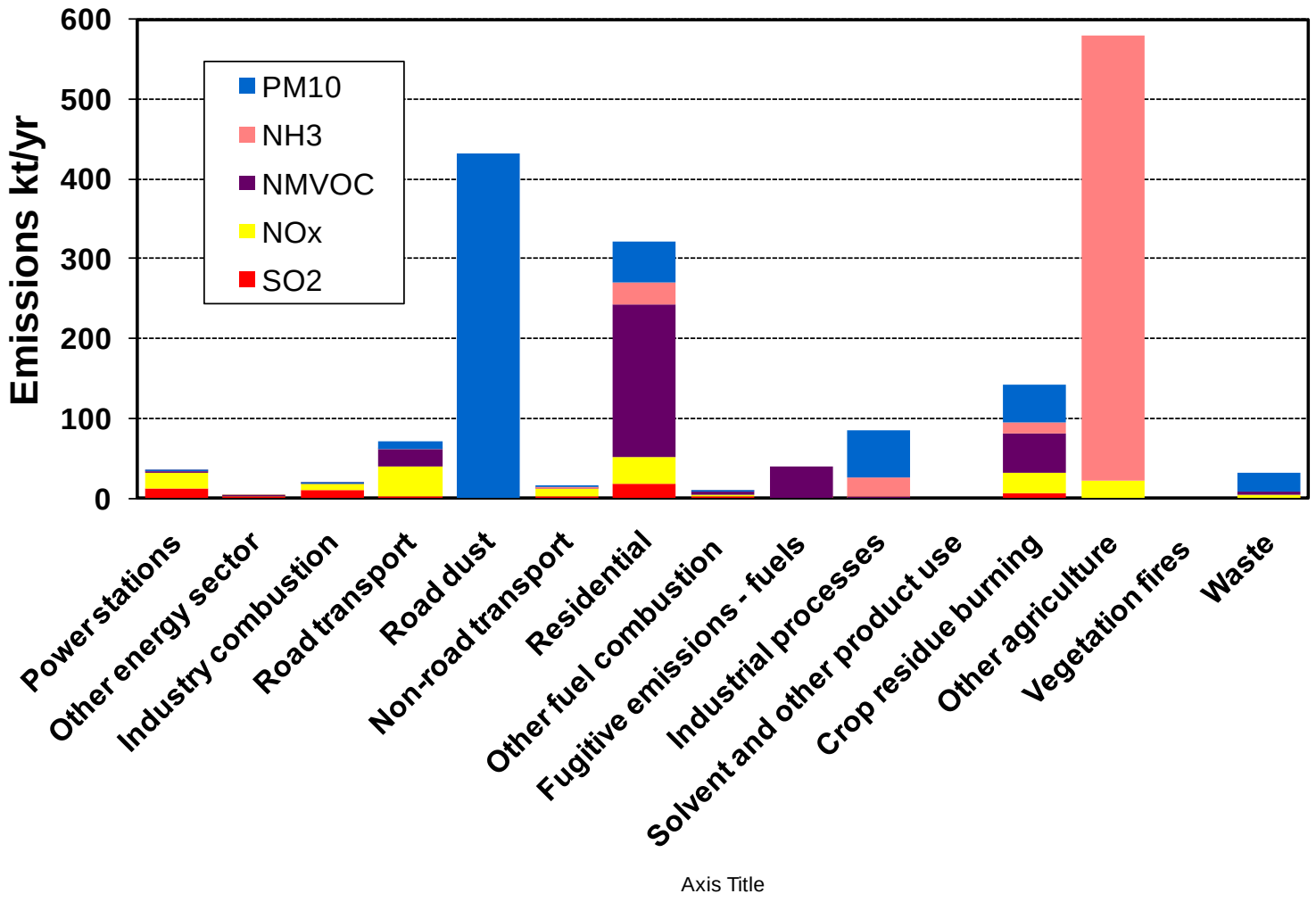
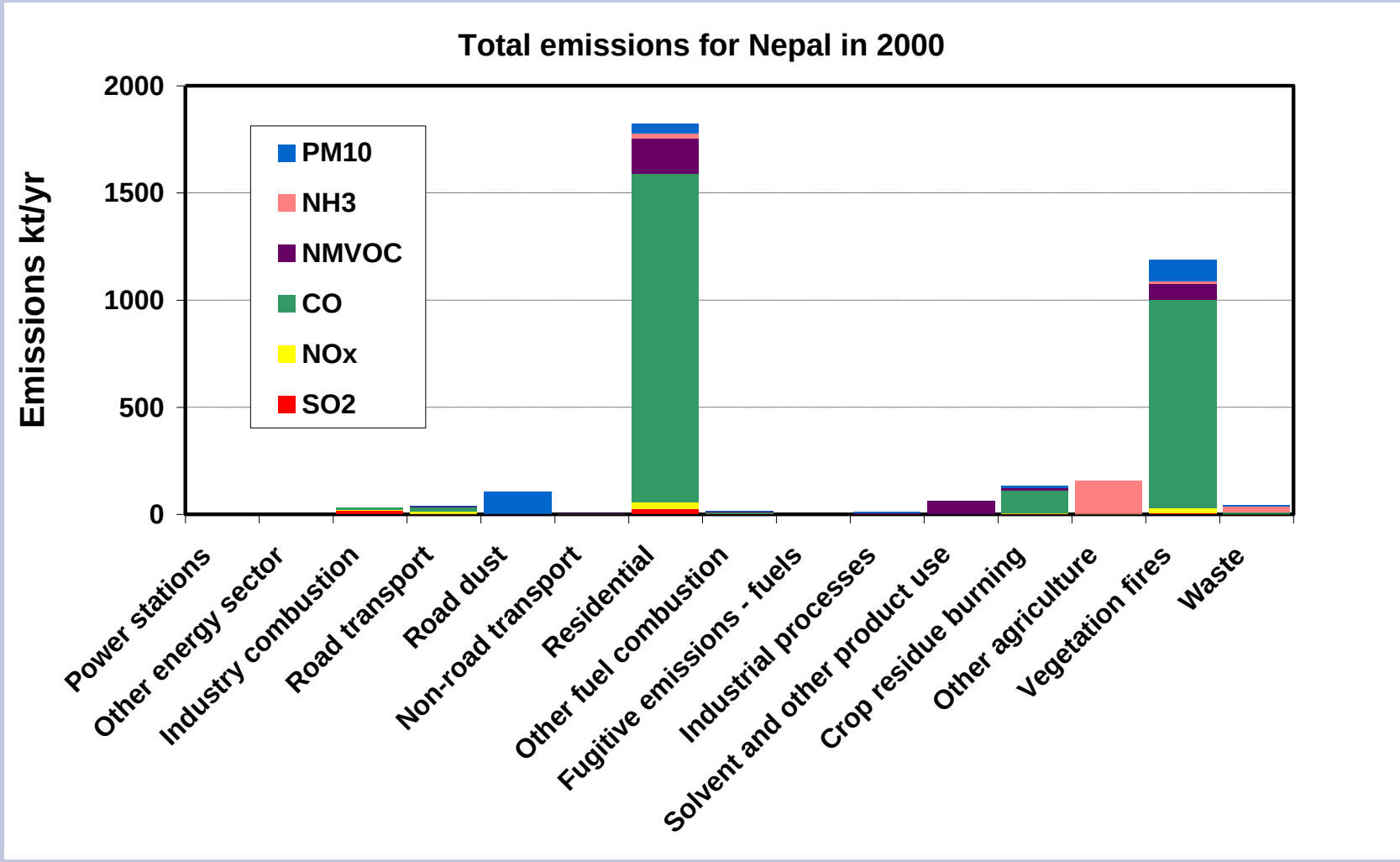
Bangladesh emission inventory for 2000



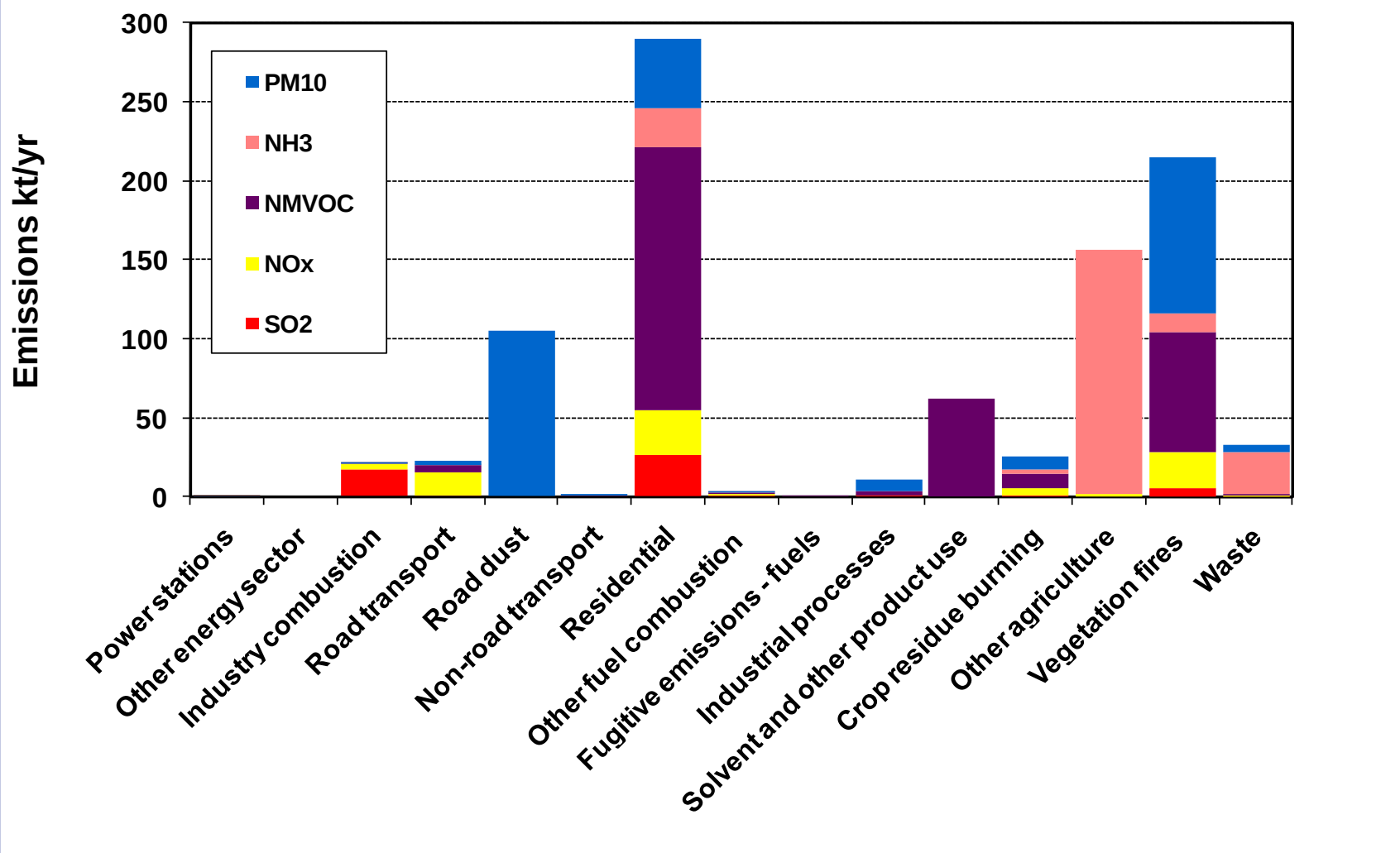
Bangladesh emission inventory for 2000 (no CO)



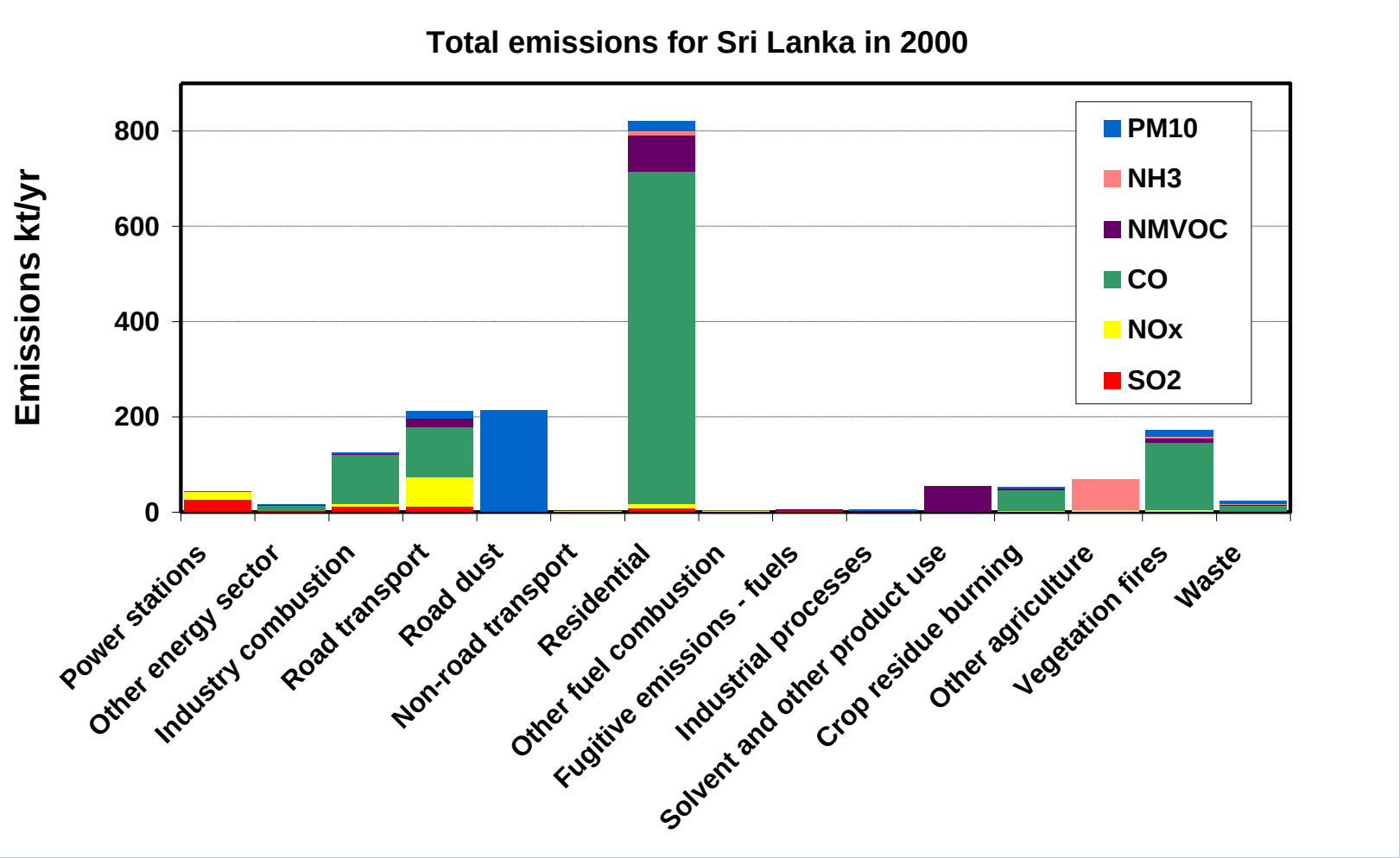
Nepal emission inventory for 2000



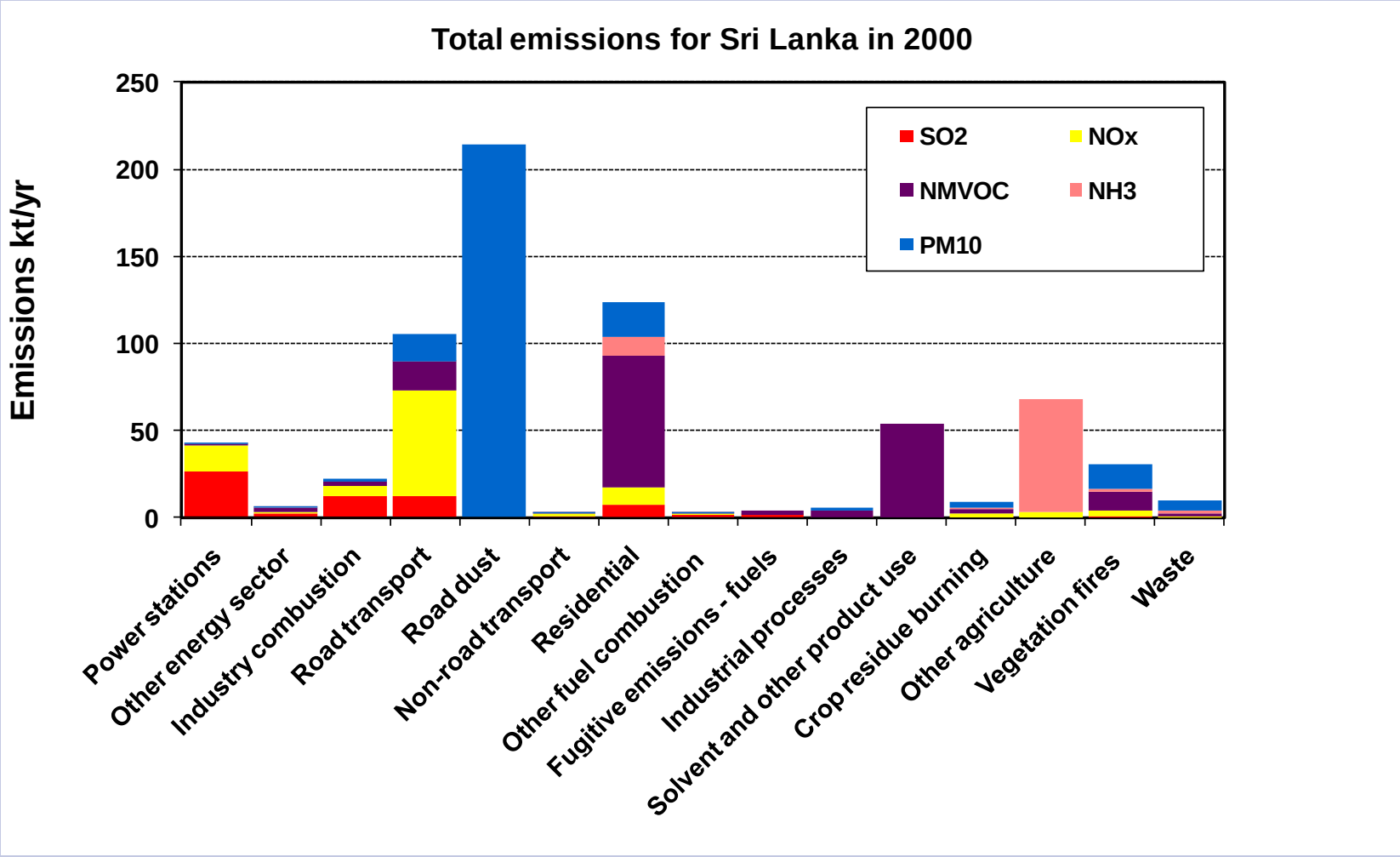
Nepal emission inventory for 2000 (no CO)



Sri Lanka emission inventory for 2000

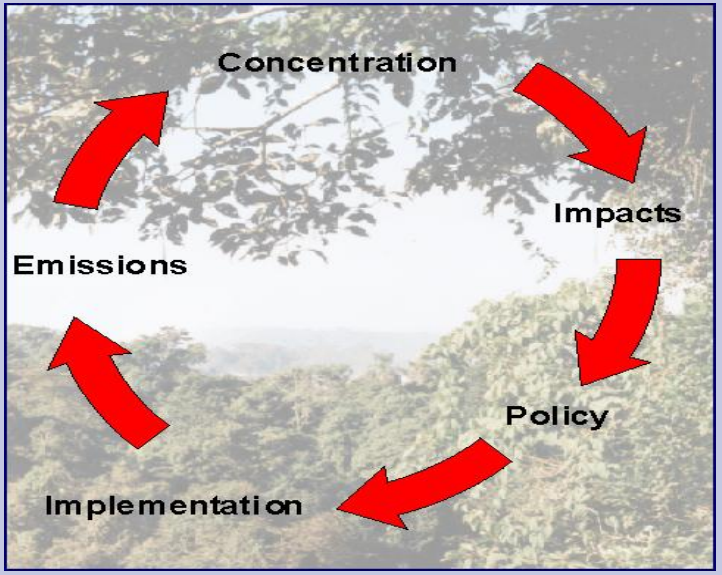


Sri Lanka emission inventory for 2000 (no CO)



Why produce an emissions inventory?

- provide input data for modelling the movement, concentrations, deposition and effects of air pollutants
- help inform the policy makers and the public
- help define priorities and set objectives for reducing emissions
- assess the potential impacts of different reduction strategies on current levels of emissions
- forecast future emission levels to determine which emission sources might require further controls



Getting to know the workbook

- Using an Excel spread sheet
- Structure of Malé emissions inventory preparation workbook:

  division into worksheets,

  navigation menus,

  freeze panes and scrolling in worksheets

  general data input areas (white),

  general data output areas (green),

  understanding the formulae used,

  final summary sheet & graphs for reporting

  recording tables for reference source(s) of activity data and emission factors if defaults not used (transparency of data)

General Steps in Inventory Development

- Planning
- Data collection
- Calculations
- References/Documentation
- Quality assurance and quality control (QA/QC) throughout

General Steps in Inventory development

Planning:

- who has overall responsibility and who is in the compilation team?
- which geographic area is to be covered (city, province, country, region)?
- which pollutants will be included?
- which emission source categories will be included?
- what time period or year will the inventory cover?
- to whom will the results be communicated and by when?

General Steps in Inventory Development

Data collection:

- Source of activity data (international, national statistical office)?
- Source of fuel quality data e.g. NCV, S-content, ash content of coal (IEA, national sources)?
- Source of emission factors (defaults, national, regional)?
- Source of information on emission control technologies in place?
- Source of LPS data (questionnaires, surveys, industry bodies, site visits)?

General Steps in Inventory Development

Calculations:

- most calculations are performed automatically by the Malé Declaration inventory workbook after activity data, emission factors and other data (fuel characteristics NCV, S-content, % ash of coal) have been entered into the workbook.

- workbook is transparent, calculations are shown, check them and *please* let someone know if you think you have found an error!

General Steps in Inventory Development

References/Documentation:

Present the inventory results within a final written report which should :

- **accurately reflect the inventory effort**
- **ensure reproducibility of the inventory estimates**
- **enable an inventory user or reviewer to assess the quality of the emission estimates and identify all the data references**
- **provide a good foundation for future inventories**
- **support QA/QC assessments of the inventory**

General Steps in Inventory Development

Quality assurance and quality control (QA/QC):

- *Quality Assurance (QA)*: external review and audit procedures by a third party (e.g. experienced emissions colleagues from other Malé Declaration countries)

- *Quality Control (QC):* accuracy checks (e.g. use of correct units), reality check (do totals make sense?), completeness checks (where are the gaps and how will they filled?), double counting (has a source been included under two different categories?)

Units and conversions

Positive numeric superscripts indicate a '*raising to the power* of the preceding number, that is, *multiplying* the previous number by itself the number of time shown by the superscript :

10^{6} = 10 x 10 x 10 x 10 x 10 x 10 = 1,000,000 (i.e. a million)

Negative numeric superscripts indicate 1 divided by the positive equivalent:

10^{-2} = $1/(10^{2})$ = 1/100 = 0.01 (i.e. one-hundredth)

10^{-3} = $1/(10^{3})$ = 1/1000 = 0.001 (i.e. one-thousandth)

For units, negative superscripts can also be used instead of the solidus or forward slash (/) to mean 'per':

kilogrammes per kilojoule can be shown as **kg kJ^{-1}** or **kg/kJ**

grams per cubic metre can be shown as **g m^{-3} or g/m^{3}**

Units and conversions

The International System of Units (SI system) generally used in the manual:

- **SI basic unit of mass is the gram (g)**
- **SI basic unit of energy is the joule (J)**
- **SI basic unit of length is the metre (m)**
- **SI basic unit of time is the second (s)**
- **SI basic unit of power is the watt (W) [= 1 J/s]**

The following units are also recognised for use in the SI system

- **metric tonne (t) [= 1,000,000 g]**
- **kilogramme (kg) [=1,000 g]**
- **hectare (ha) [= 10,000 square metres (m^2)]**
- **minute (min) [= 60 s]**
- **hour (h) [= 3600 s]**
- **litre (L or sometimes l) [= 1,000 cm^3]**

Units and conversions

Exceptions to use of SI units in the Malé manual:

- Fuel consumption activity data as reported by the International Energy Agency (IEA) Balances are expressed as **kilotonnes oil equivalent (ktoe)** where 1 toe = 10^7 kcal (kilocalories). The Malé workbook therefore allows for fuel consumption data to be input as ktoe (as well as in tonnes (t) or terajoules (TJ)).

- Similarly, Net Calorific Values (NCVs) for fuels given by the IEA are expressed as **tonnes oil equivalent per tonne (toe/t).** Therefore the Malé workbook is also set up to allow NCVs to be input in these units.

Units and conversions

- Units of greater magnitude denoted thus:

Symbol	*Prefix*	*Multiple*	
P	peta	1,000,000,000,000,000	10^{15}
T	tera	1,000,000,000,000	10^{12}
G	giga	1,000,000,000	10^{9}
M	mega	1,000,000	10^{6}
k	kilo	1,000	10^{3}
h	hecto	100	10^{2}
c	centi	0.01	10^{-2}
m	milli	0.001	10^{-3}

Therefore one kilogram (kg) equals one thousand (10^3) grams, and one megagram (Mg) equals 10^6 grams.

Units and conversions

Note that the comma (,) is used to separate large numbers into multiples of a thousand (10^3) whereas the full stop (.) is used to indicate the decimal place.

Symbol	*Prefix*	*Multiple*	
P	peta	1,000,000,000,000,000	10^{15}
T	tera	1,000,000,000,000	10^{12}
G	giga	1,000,000,000	10^{9}
M	mega	1,000,000	10^{6}
k	kilo	1,000	10^{3}
h	hecto	100	10^{2}
c	centi	0.01	10^{-2}
m	milli	0.001	10^{-3}

Beware: In some countries the comma **(,)** may be used to indicate the decimal place but this is unusual and not the case in the Malé manual !

Units and conversions

Exercise 1:

1. 2,000 kg = …… t
2. 356,000 Mg = ……. kt
3. 65,000 mg = …… kg
4. 10^6 g = …….. kg
5. 10^{12} m = …… km
6. 6 million tonnes = …… kt
7. 25,000,000 MJ = …… PJ
8. 0.0025 TJ = …… MJ
9. 10,000,000 m^2 = …… km^2
10. 0.250 Mtoe = …… ktoe

Units and conversions

Exercise 2:

1. 1 ha = …… m^2
2. 0.75 km^2 = …… ha
3. 250 kg/kt = …… g/kg
4. 50 g/kg = …….. %
5. 45 t/TJ = …….. kg MJ^{-1}
6. 150 ktoe = …… TJ (Note: 1 Mtoe = 4.1868 x 10^4 TJ)
7. 150 toe t^{-1} = …….. TJ t^{-1}
8. 80 g SO_2 /kg = …… kg SO_2 t^{-1}
9. 50 g NMVOC per litre = …….kg NMVOC /hl (Note: hl = hectolitre)
10. 2,000,000 m^3 /week = …….. x 10^6 m^3 yr^{-1}