Malé Declaration emissions inventory workshop

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Session 2 – Compiling emissions by sector: The energy sources (Sectors 1and 2)

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

Summary of 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

Other source sectors:

6   Industrial Processes
7   Solvent and Other Product Use
8   Agriculture
9   Vegetation Fires & Forestry
10   Waste

Emissions from combustion activities – Sector 1: Energy Industries

The energy industries are:

- **Public Electricity and Heat Production**

- **Petroleum Refining.**

    From the combustion of fuel for the refining of petroleum products.

- **Manufacture of Solid Fuels and Other Energy Industries.**

    From the combustion of fuels during the manufacture of:
    - coke
    - brown coal briquettes
    - patent fuel
    - charcoal
    - own use *

    * Mainly own (on-site) energy use in coal mining and in oil and gas extraction.

Emissions from combustion activities – *SO$_2$ emission factors*

SO$_2$ EFs for fuel combustion are calculated from:

- **the % sulphur (S) content of the fuel;**
- **the Net Calorific Value (NCV) of fuel;**
- **the % S retention in ash for solid fuels (defaults given)**

For most fuels, default values for the S content are offered in the Workbook. But (unless known precisely) user must choose from:
- **low S = 0.5 % medium S = 1.5 % high S = 3.0 % for *coal***
- **low S = 0.3 % high S = 1.0 % for *diesel (non-road use)***
- **low S = 1.0 %, medium S = 3.0 % , high S = 4.0 % for *heavy fuel oil***

Also, for Coal, Crude oil and Natural Gas Liquids, the NCVs can be found in the International Energy Agency (IEA) database (they vary from country to country.

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Emissions from combustion activities –
Fuel categories

Coal	Gas	Oil	Combustible renewables/ wastes
Coking Coal	Gas Works Gas (GWG)	Crude Oil	Solid Biomass and Animal Products:
Other Bituminous Coal & Anthracite	Natural Gas	Natural Gas Liquids (NGL)	Wood Vegetal materials and wastes
Sub-Bituminous Coal		Refinery Gas	Other (e.g. animal products/ wastes)
Lignite		Liquefied Petroleum Gases (LPG)	Gas/Liquids from Biomass + wastes
Patent Fuel		Motor Gasoline	Municipal Waste
Coke Oven Coke		Aviation Gasoline	Industrial Waste
Gas Coke		Gasoline type Jet Fuel	Charcoal
BKB (Brown coal briquettes)		Kerosene type Jet Fuel	
Coke Oven Gas (COG)		Kerosene	
Blast Furnace Gas (BFG)		Heavy Fuel Oil (HFO)	
		Petroleum coke	
		Other Petroleum Products	

Sheet: 1.1.1c Fuel consumption in kilotonnes (1000s of tonnes) per year (kt/year)

Sector:		Combustion in the Energy industries						
Sub-sector:				Manufacture of Solid Fuels and Other Energy				
Fuel type		Public Electricity and Heat Production[1]	Petroleum Refining[2]	Coke ovens[2]	Patent fuel, BKB[2]	Gas works[2]	Charcoal production	Other own use[3]
Coal	Coking Coal							
	Other Bituminous Coal & Anthracite							
	Sub-Bituminous Coal							
	Lignite							
	Patent Fuel							
	Coke Oven Coke							
	Gas Coke							
	BKB (Brown coal briquettes)							
	Coke Oven Gas							
	Blast Furnace Gas							
Gas	Gas Works Gas							
	Natural Gas							
Oil	Crude Oil							
	Natural Gas Liquids							
	Refinery Gas							
	Liquefied Petroleum Gases							
	Motor Gasoline							
	Aviation Gasoline							
	Gasoline type Jet Fuel							
	Kerosene type Jet Fuel							
	Kerosene							
	Gas/Diesel Oil							
	Heavy Fuel Oil							
	Petroleum coke							
	Other Petroleum Products							
Combustible renewables/ wastes	Primary Solid Biomass:							
	Wood[c]							
	Vegetal materials and wastes[c]							
	Other (e.g. animal products/wastes)[c]							
	Unspecified primary solid biomass							
	Gas/Liquids from Biomass + wastes							
	Municipal Waste							
	Industrial Waste							
	Charcoal							

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Fuel type		Sector: Combustion in the Energy industries						
			Sub-sector: Manufacture of Solid Fuels and Other Energy					
		Public Electricity and Heat Production	Petroleum Refining	Coke ovens	Patent fuel, BKB	Gas works	Charcoal production	Other own use
Coal[a]	Coking Coal							
	Other Bituminous Coal & Anthracite							
	Sub-Bituminous Coal							
	Lignite							
	Patent Fuel							
	Coke Oven Coke							
	Gas Coke[e]							
	BKB (Brown coal briquettes)							
	Coke Oven Gas[b]	0.6688		0.6688		0.6688		0.6688
	Blast Furnace Gas[b]	0.0525		0.0525				
Gas	Gas Works Gas[d]	0.6688		0.6688		0.6688		
	Natural Gas[f]	1.2137	1.2137			1.2137		1.2137
Oil	Crude Oil[a]							
	Natural Gas Liquids[a]							
	Refinery Gas[c]	1.150	1.150					1.150
	Liquefied Petroleum Gases[c]	1.130	1.130					1.130
	Motor Gasoline[c]	1.070	1.070	1.070	1.070	1.070	1.070	1.070
	Aviation Gasoline[c]							
	Gasoline type Jet Fuel[c]							
	Kerosene type Jet Fuel[c]							
	Kerosene[c]	1.069	1.069					1.069
	Gas/Diesel Oil[c]	1.035	1.035					1.035
	Heavy Fuel Oil[c]	0.9599	0.9599					0.9599
	Petroleum coke							
	Other Petroleum Products[c]	0.9599	0.9599					0.9599
Combustible renewables/ wastes	Primary Solid Biomass:							
	Wood[c]	0.3583					0.3583	0.3583
	Vegetal materials and wastes[c]	0.2866						
	Other (e.g. animal products/wastes)[c]	0.3583						
	Unspecified primary solid biomass	0.3583						
	Gas/Liquids from Biomass + wastes							
	Municipal Waste[c]	0.2627						
	Industrial Waste[c]	0.2627						
	Charcoal							

Fuel type		Public Electricity and Heat Production	Petroleum Refining	Coke ovens	Patent fuel, BKB	Gas works	Charcoal production	Other own use
Sector:		Combustion in the Energy industries						
Sub-sector:				Manufacture of Solid Fuels and Other Energy				
Coal[a]	Coking Coal							
	Other Bituminous Coal & Anthracite	NCV needed		NCV needed		NCV needed		NCV needed
	Sub-Bituminous Coal	NCV needed						
	Lignite	NCV needed						
	Patent Fuel							
	Coke Oven Coke	NCV needed		OK	OK	OK		OK
	Gas Coke							
	BKB (Brown coal briquettes)							
	Coke Oven Gas	OK		OK		OK		OK
	Blast Furnace Gas	OK		OK				
Gas	Gas Works Gas	OK		OK		OK		
	Natural Gas	OK	OK			OK		OK
Oil	Crude Oil	OK	OK					OK
	Natural Gas Liquids	OK						
	Refinery Gas	OK	OK					OK
	Liquefied Petroleum Gases	OK	OK					OK
	Motor Gasoline	OK	OK	OK	OK	OK	OK	OK
	Aviation Gasoline							
	Gasoline type Jet Fuel							
	Kerosene type Jet Fuel							
	Kerosene	OK	OK					OK
	Gas/Diesel Oil	OK	OK					OK
	Heavy Fuel Oil	OK	OK					OK
	Petroleum coke	OK	OK					OK
	Other Petroleum Products	OK	OK					OK
Combustible renewables/wastes	Primary Solid Biomass:							
	Wood	OK					OK	
	Vegetal materials and wastes	OK						
	Other (e.g. animal products/wastes)	OK						
	Unspecified primary solid biomass	OK						
	Gas/Liquids from Biomass + wastes							
	Municipal Waste	OK						
	Industrial Waste	OK						
	Charcoal							

NOTE: "NCV needed" indicates that a value for fuel consumption has been entered but a net calorific value (NCV) has not.

Worksheet for calculating SO$_2$ emissions from energy industries.

Sheet 1.2.1 Sulphur dioxide (SO2) - Calculation of emission factors and emissions for Energy Industries

Sector: Combustion in the En **BACK TO MENU** ▢ =S content needed ▢ = S retention needed

Sub-sector	Fuel type	A Fuel consumption (TJ/year)	B Sulphur content of fuel (%) Default		C Sulphur retention in ash (%) Default [i]	D SO$_2$ emission control efficiency (%)	E Net Calorific Value (NCV)[j] (TJ/kt)	F SO$_2$ emission factor (kg/TJ) [2 x B/100 x 10^6/E x (100 - C)/100 x (100 - D)/100]	G SO$_2$ emissions (Tonnes) [(A x F)/1000]
Public Electricity and	Coking coal	41868	1.0	[0.5-3.0]^b	5	5	0.0	25.12	756	31667
Heat Production	Other Bituminous Coal/Anthracite	209340		[0.5-3.0]^b		5	0.0	25.12	0	0
	Sub-Bituminous Coal	0		[0.5-3.0]^b		25	0.0	0.00	#DIV/0!	#DIV/0!
	Lignite	0		[0.5-3.0]^b		25	0.0	0.00	#DIV/0!	#DIV/0!
	Coke Oven Gas	0		[1.35 x coal S%]^h		0		28.00	0	0
	Blast Furnace Gas	0		0.00064^k		0		2.20	0	0
	Gas Works Gas	0		0.00064^k		0		28.00	0	0
	Natural Gas	0		0.00064^h		0		50.82	0	0
	Crude Oil	0		1.2^d		0		0.00	#DIV/0!	#DIV/0!
	Natural Gas Liquids	0		0.00064^k		0		0.00	#DIV/0!	#DIV/0!
	Refinery Gas	0		0.00064^k		0		48.15	0	0
	Liquefied Petroleum Gases	0		0.00064^k		0		47.31	0	0

Note: If fuel consumption is carried forward from Sheet 1.1.1 into column A, then coloured cells will indicate where the user must enter S content (yellow) and S retention (blue) before SO$_2$ emissions can be calculated.

Sheet: 1.3.1 Nitrogen oxides (NOx) - emission factors (kg/TJ)

▢ = Emission factor needed

Sector:		Combustion in the Energy industries													
Sub-sector:		Public Electricity		Petroleum refining[a]		Manufacture of Solid Fuels and Other Energy[a]									
		and Heat Production[a]				Coke ovens		Patent fuel, BKB		Gas works		Charcoal production		Other own use	
Fuel type			Default		Default		Default		Default		Default		Default		Default
Coal	Coking Coal	▢	300^C												300^C
	Other Bituminous Coal & Anthracite	300	300^C				300^C				300^C				300^C
	Sub-Bituminous Coal		300^C												
	Lignite		300^C						300^C						
	Patent Fuel														
	Coke Oven Coke						300^C		300^C		300^C				300^C
	Gas Coke														
	BKB								300^C						
	Coke Oven Gas		77.8^b				55^b				55^b				55^b
	Blast Furnace Gas		10.5^b				7.4^b								
Gas	Gas Works Gas		10.5^b		7.4^b		7.4^b				7.4^b				
	Natural Gas		105^b		53^b						53^b				53^b
Oil	Crude Oil		200^c		200^c										200^c
	Natural Gas Liquids		200^c												
	Refinery Gas		16^b		11^b										11^b
	Liquefied Petroleum Gases		79^b		56^b										56^b

Emissions from combustion activities in the energy industries –

SO$_2$ emission controls

SO$_2$ emission controls are only significant in the "*Public Electricity and Heat Production*" sector

For top-down estimates:
The % national power plant generation capacity (by fuel type) that has SO$_2$ emission control is entered into the calculator at the bottom the worksheet.

For Large Point Sources:
SO$_2$ control efficiencies for each plant will be required if stack emissions are not measured directly.

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Emissions from combustion activities in the energy industries –

SO_2 emission controls

Emission control calculator for hard coal (Other Bituminous Coal, Anthracite and subituminous coal) combustion in public electricity

Air pollution control device (APCD)	% emission control for SO2	% time APCD in use (assume 50% by default)	Average % emission control achieved over a year	% hard coal fired generation capacity subject to the APCD	Average % emission control achieved in this sector
Flue Gas Desulphurization (Wet scrubber)	90	50	45		0
Flue Gas Desulphurization (Spray dry)	80	50	40		0
Flue Gas Desulphurization (Type unknown)	85	50	42.5		0
Atmospheric Fluidized Bed Combustion (AFBC) with sorbent injection	80	50	40		0
Furnace injection	38	50	19.0		0
					0.0

Emissions from combustion activities in the energy industries – *NO$_x$ emission controls*

Several types of NO$_x$ control technologies of varying efficiency are used in power stations (and industrial boilers).

Technology	Representative NO$_x$ reduction (%)
Low Excess Air (LEA)	15
Overfire Air (OFA) - Coal	25
OFA - Gas	40
OFA - Oil	30
Low NOx Burner (LNB) - Coal	45
LNB - Tangentially Fired	35
LNB - Oil	35
LNB - Gas	50
LNB with OFA - coal	50
Cyclone Combustion Modification (in power stations)	40
Flue Gas Recirculation (in industrial boilers)	40
Ammonia Injection	60
Selective Catalytic Reduction (SCR) - Coal	80
SCR - Oil	80
SCR - Gas	80
Water Injection - Gas Turbine Simple Cycle	70
SCR - Gas Turbine	80

Emissions from combustion activities in the energy industries – *NO_x emission controls*

For top-down inventories:
For each type of fuel (hard coal, lignite, heavy fuel oil (HFO) or natural gas) the % national power plant generation with each type of NOx control must be entered into the emission control calculator at the bottom the worksheet.

For Large Point Sources (LPS):
NOx control efficiencies for each individual power plants will be required if stack emissions are not measured directly.

Emissions from combustion activities in the energy industries – NO_x emission controls

NOx emission control calculator for coal combustion in *public electricity*

Air pollution control device (APCD)	% emission control for NO_x[a]	% time APCD in use (assume 50% by default)	Average % emission control achieved for APCD	% coal fired generation capacity subject to the APCD	Average % emission control achieved in public electricity sector
Low Excess Air (LEA)	15	50	7.5		
Overfire air (OFA)	25	50	12.5		
Low NOx burner (LNB)	45	50	22.5		
LNB with OFA	50	50	25		
Reburn	55	50	27.5		
SNCR	45	50	22.5		
SCR	80	50	40		
Cyclone combustion modification	40	50	20		
LBN with SNCR	65	50	32.5		
LNB with OFA and SCR	90	50	45		
[a] Mean value from AP-42 (EPA, 1995).					0

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Emissions from combustion activities in the energy industries – *PM emission controls*

Particulate matter (PM) emissions from power stations and industry can be controlled by a variety of technologies :

Technology	Reduction range (%)
Multiple Cyclone	50 - 75
Scrubber	82 - 92
Electrostatic Precipitator (ESP)	98 - 99
Fabric Filtration (in "baghouses")	99

The % coal and heavy fuel oil (HFO) fuel consumption subject to PM control must be estimated and entered into the emission control calculator provided at the bottom the relevant worksheet.

There are no significant combustion emission controls for CO, NMVOC and NH$_3$

Emissions from combustion activities – *Manufacturing Industry and Construction*

The major fuel-consuming activities in this sub-sector are:

- iron and steel manufacture

- non-ferrous metal smelting

- non-metallic minerals

- manufacture of chemicals

- pulp and paper industry

- mining and quarrying

- Construction

- Auto-production of electricity for own use

  (within manufacturing industry as a whole)

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Emission controls from combustion activities in – *Manufacturing Industry and Construction*

NOx emission control calculator for coal combustion in *industry*

Air pollution control device (APCD)	% emission control for NO_x[a]	% time APCD in use (assume 50% by default)	Average % emission control achieved for APCD	% capacity subject to the APCD	Average % emission control achieved in industrial sector
Low Excess Air (LEA)	15	50	7.5		
Overfire air (OFA)	25	50	12.5		
Low NOx burner (LNB)	45	50	22.5		
LNB with OFA	50	50	25		
Reburn	55	50	27.5		
SNCR	45	50	22.5		
SCR	80	50	40		
Cyclone combustion modification	40	50	20		
LBN with SNCR	65	51	33.15		
LNB with OFA and SCR	90	50	45		

[a] Mean value from AP-42 (EPA, 1995). **0**

PM_{10} emission control calculator for oil combustion in *industry*

Air pollution control device (APCD)	% emission control for PM_{10}[a]	% time APCD in use (assume 50% by default)	Average % emission control achieved for APCD	% oil-fired generation capacity subject to the APCD	Average % emission control achieved in industrial sector
Electrostatic precipitators (ESP)	99.2	50	49.6		
Multiple cyclones	80	51	40.8		
Baghouse	99	52	51.5		
Scrubber	55	50	27.5		

[a] From AP-42 (EPA, 1995). **0.0**

Emissions from combustion activities in the energy sources (Sectors 1 & 2)

Practical session:

1. Filling in workbook with dummy data:

   Exercise 3 for ***Energy industries*** and

   Exercise 4 for ***Manufacturing Industry and Construction***

1. Plenary session – *sharing problems etc.*

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