Energy Sector

Regional African Workshops on REDD+ National Forest Monitoring Systems and Greenhouse Gas National Inventory Systems

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Livingstone, Zambia

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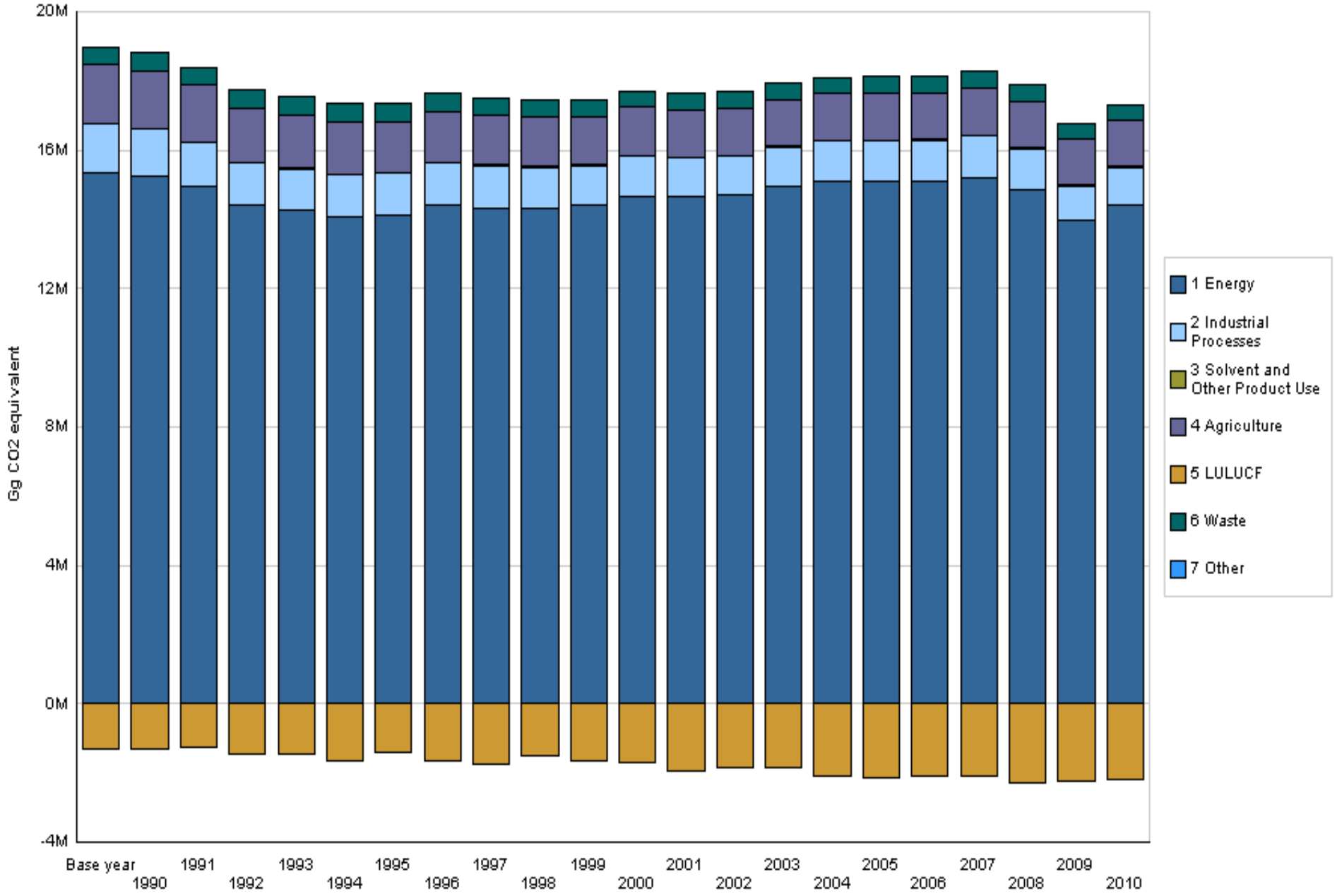
1. Who has worked on their national Energy GHG emissions?
2. What Gases are emitted in the Energy Sector?
3. What are the two most important sectors in your national GHG Inventory?
4. What fuels are most important in your country?
5. What fuels are produced in your country?

Some Questions…

Annual greenhouse gas (GHG) emissions for Annex I

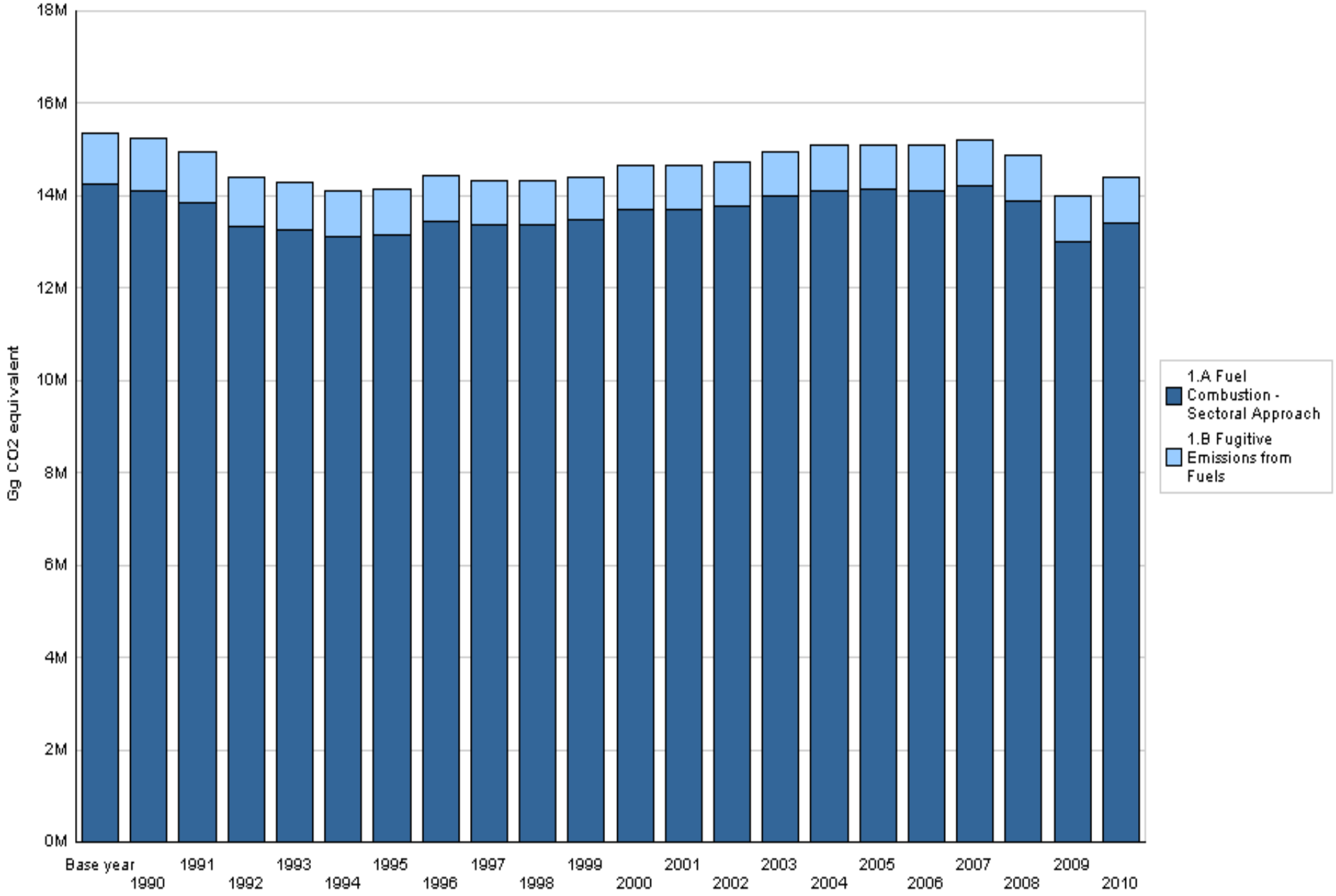
Query results for Party: Annex I - Years: All years - Category: Total GHG emissions including LULUCF/LUCF - Gas: Aggregate GHGs



Source: UNFCCC Data Interface, Thursday, 30 August 2012 09:02:52 CEST

Annual greenhouse gas (GHG) emissions for Annex I

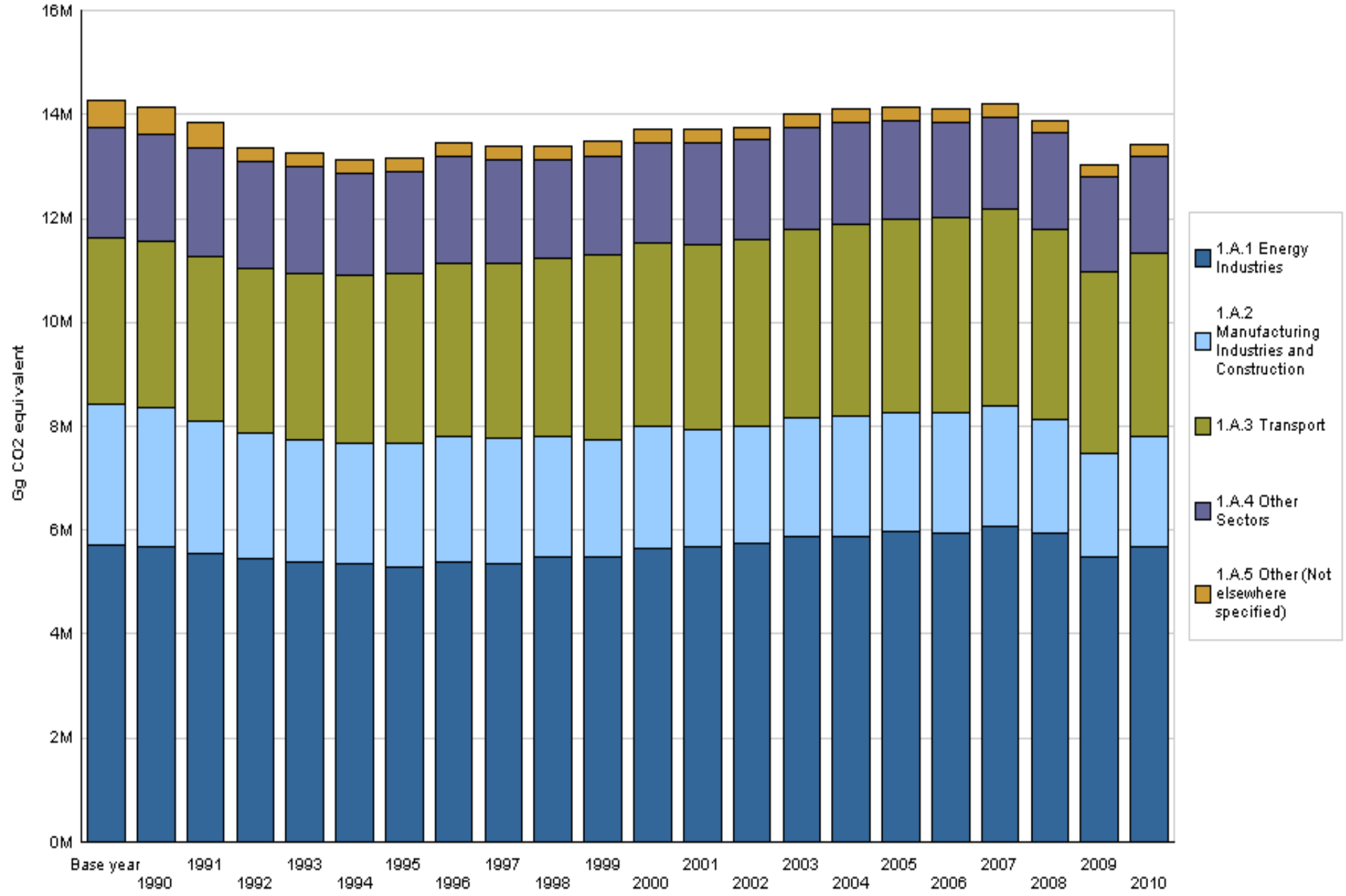
Query results for Party: Annex I - Years: All years - Category: 1 - Energy - Gas: Aggregate GHGs



Source: UNFCCC Data Interface, Thursday, 30 August 2012 09:07:18 CEST

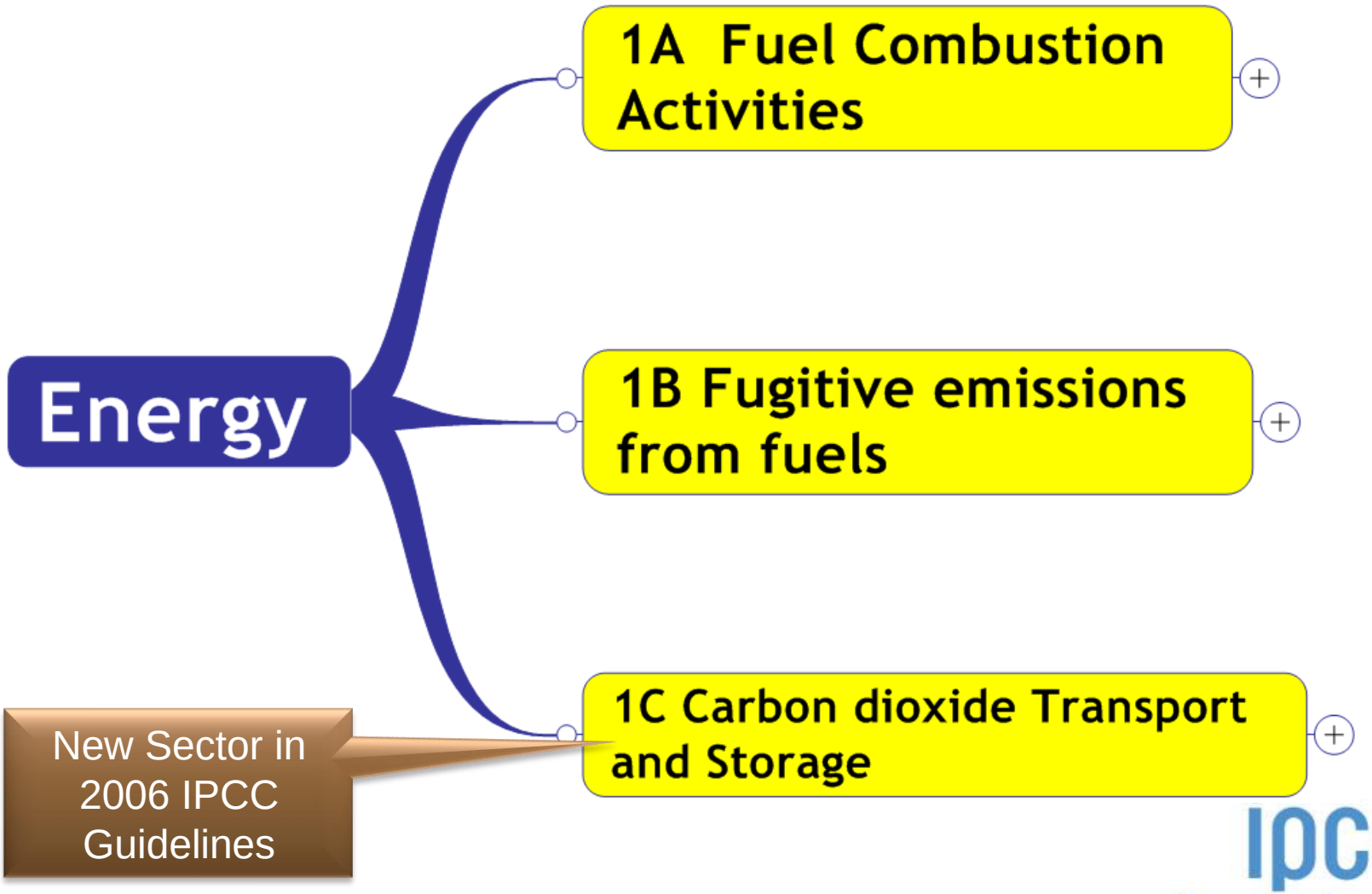
Annual greenhouse gas (GHG) emissions for Annex I

Query results for Party: Annex I - Years: All years - Category: 1.A - Fuel Combustion - Sectoral Approach - Gas: Aggregate GHGs



Source: UNFCCC Data Interface, Thursday, 30 August 2012 09:01:18 CEST

Energy Sector



Energy Emissions








Production

- Fugitive emissions from coal mining, oil wells and gas production
- Combustion for energy under stationary combustion

Processing

- Transformation
- Power Stations
- Refineries
- Production of Solid Smokeless Fuels
- Combustion for energy under stationary combustion

Storage

- Leaks form oil tanks and gas storage
- Emissions from Coal Piles

Transport

- Mainly fugitive emissions form pipelines, ships and road transport
- Pipeline compressors under mobile sources
- Combustion for energy under stationary combustion

Use

- Stationary Combustion: industry, commerce, agriculture, fishing etc.
- Mobile Sources: road vehicles, aviation and shipping

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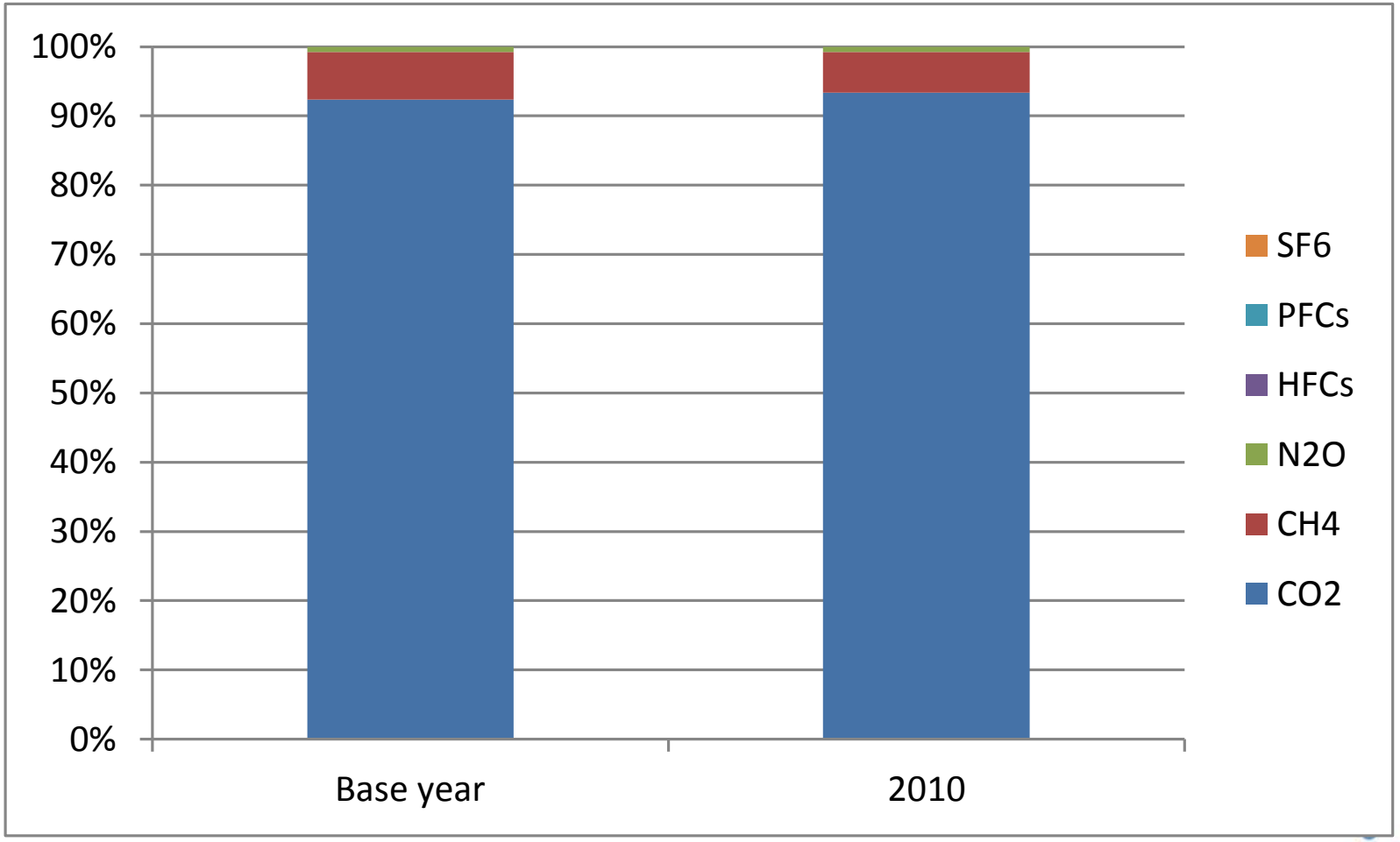
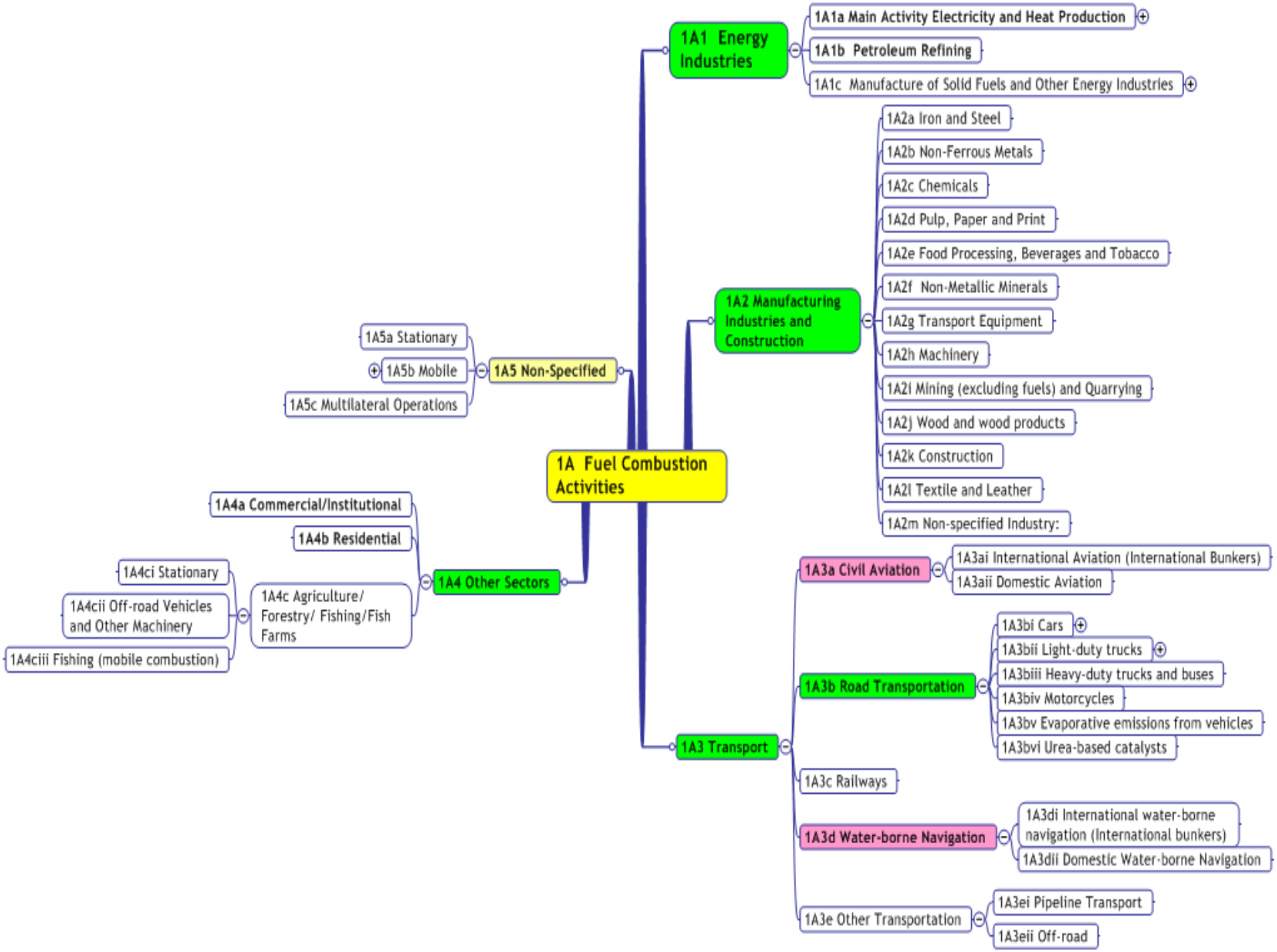
Annex 1 – Emissions from Energy sector by gas




1A Fuel Combustion Activities
1A1 Energy Industries
1A1a Main Activity Electricity and Heat Production
1A1b Petroleum Refining
1A1c Manufacture of Solid Fuels and Other Energy Industries
1A2 Manufacturing Industries and Construction
1A2a Iron and Steel
1A2b Non-Ferrous Metals
1A2c Chemicals
1A2d Pulp, Paper and Print
1A2e Food Processing, Beverages and Tobacco
1A2f Non-Metallic Minerals
1A2g Transport Equipment
1A2h Machinery
1A2i Mining (excluding fuels) and Quarrying
1A2j Wood and wood products
1A2k Construction
1A2l Textile and Leather
1A2m Non-specified Industry:
1A3 Transport
1A3a Civil Aviation
1A3ai International Aviation (International Bunkers)
1A3aii Domestic Aviation
1A3b Road Transportation
1A3bi Cars
1A3bii Light-duty trucks
1A3biii Heavy-duty trucks and buses
1A3biv Motorcycles
1A3bv Evaporative emissions from vehicles
1A3bvi Urea-based catalysts
1A3c Railways
1A3d Water-borne Navigation
1A3di International water-borne navigation (International bunkers)
1A3dii Domestic Water-borne Navigation
1A3e Other Transportation
1A3ei Pipeline Transport
1A3eii Off-road
1A4 Other Sectors
1A4a Commercial/Institutional
1A4b Residential
1A4c Agriculture/ Forestry/ Fishing/Fish Farms
1A4ci Stationary
1A4cii Off-road Vehicles and Other Machinery
1A4ciii Fishing (mobile combustion)
1A5 Non-Specified
1A5a Stationary
1A5b Mobile
1A5c Multilateral Operations

Combustion Emissions

- CO_2 emissions depend:
  - Almost entirely on the carbon content of the fuel
  - A small amount of carbon is un-oxidised (usually >1%)
- CH_4 and N_2O Emissions depend on
  - Type of fuel
  - Combustion technology
  - Operating conditions
  - Control technology
  - Quality of maintenance
  - Age of equipment

Calculating Emissions of CO_2

- Often simple calculations can be used. For example:
  - CO_2 from combustion comes for the carbon in the fuel
  - In efficient combustion nearly all (>>99%) of the carbon in the coal is converted into CO_2.

C emitted as CO_2
Also SO_2, NO_x etc.

Incomplete combustion leads to
CO, PM, CH_4, NMVOC etc.

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Fuel Combustion Example

- Emissions from fuel use, E (kTonne).
  - Fuel Burnt (GJ) (= Activity data) , A
  - Emission Factor, EF
    - Amount of carbon in fuel (Gg/GJ), C
    - Fraction carbon oxidised, U
    - $\frac{44}{12}$ Converts Carbon to CO_2 (= 3.667)

$$EF = \left[C \times U \times \frac{44}{12} \right]$$

$$Emission = EF \times A$$

1. A plant burns 1000 tonnes of coal.
2. The coal composition is:

	%
Carbon	85
Hydrogen	5.6
Oxygen	7.3
Sulphur	1.0

3. Assuming complete combustion how much CO2 is emitted?

Question

1. Emission Factor = 0.85 * 1 * 44/12 = 3.117
2. Emission = 1,000 * 3.117 = 3,117 tonnes

3. How would this differ if combustion not perfect but 99%...

   Emission Factor = 0.85 * .99 * 44/12 = 3.086

   Emission = 1,000 * 3.086 = 3,086 tonnes

Answer

	%
Carbon	85
Hydrogen	5.6
Oxygen	7.3
Sulphur	1.0

However

- EFs are often specified in Energy Units.
  - IPCC Guidelines give kg of GHG TJ on a net calorific basis
- If you have mass of fuel and carbon content in terms of mass use this data directly
  - E.g. tonnes of fuel and % Carbon
- If you need to use the EF default data you will need to convert the amount of fuel used to Energy (net CV).

Energy Units

- To convert these data to energy units, eg joules, requires calorific values.
- The IPCC Guidelines use net calorific values (NCVs), expressed in SI units.
- Some statistical offices use gross calorific values (GCV).
  - The difference between NCV and GCV is the latent heat of vaporisation of the water produced during combustion of the fuel.
  - for coal and oil, the NCV is about 5 % less than the GCV
  - For most natural and manufactured gas, the NCV is about 10 % less.
- Where fuel characteristics (moisture, hydrogen and oxygen contents) are known the 2006 Guidelines give a more precise method to convert GCV to NCV data

IPCC Default Data

	Default CO_2 EF (kg/TJ)	Lower	Upper	NCV (TJ/Gg)
Coke	107,000	95,700	119,000	*28.2*
Peat	106,000	100,000	108,000	*9.76*
Lignite	101,000	90,900	115,000	*8.9*
Anthracite	98,300	94,600	101,000	*26.7*
Coking Coal	94,600	87,300	101,000	*28.2*
Other Bituminous Coal	94,600	89,500	99,700	*25.8*
Residual Fuel Oil	77,400	75,500	78,800	*40.4*
Gas/Diesel Oil	74,100	72,600	74,800	*43.0*
Motor Gasoline	69,300	67,500	73,000	*44.3*
Liquefied Petroleum Gases	63,100	61,600	65,600	*47.3*
Natural Gas	56,100	54,300	58,300	*48.0*

Emission Factors (EF)

- This EF approach can be extended to other gases and sources
- Often emissions are proportion to some parameter associated with the process:
  - CO_2 from fuel depends on carbon in fuel
  - CH_4 proportional to amount of fuel burnt (for particular technologies)
  - CH_4 and N_2O from cars is proportional to the distance travelled (for each type and age class of vehicle)

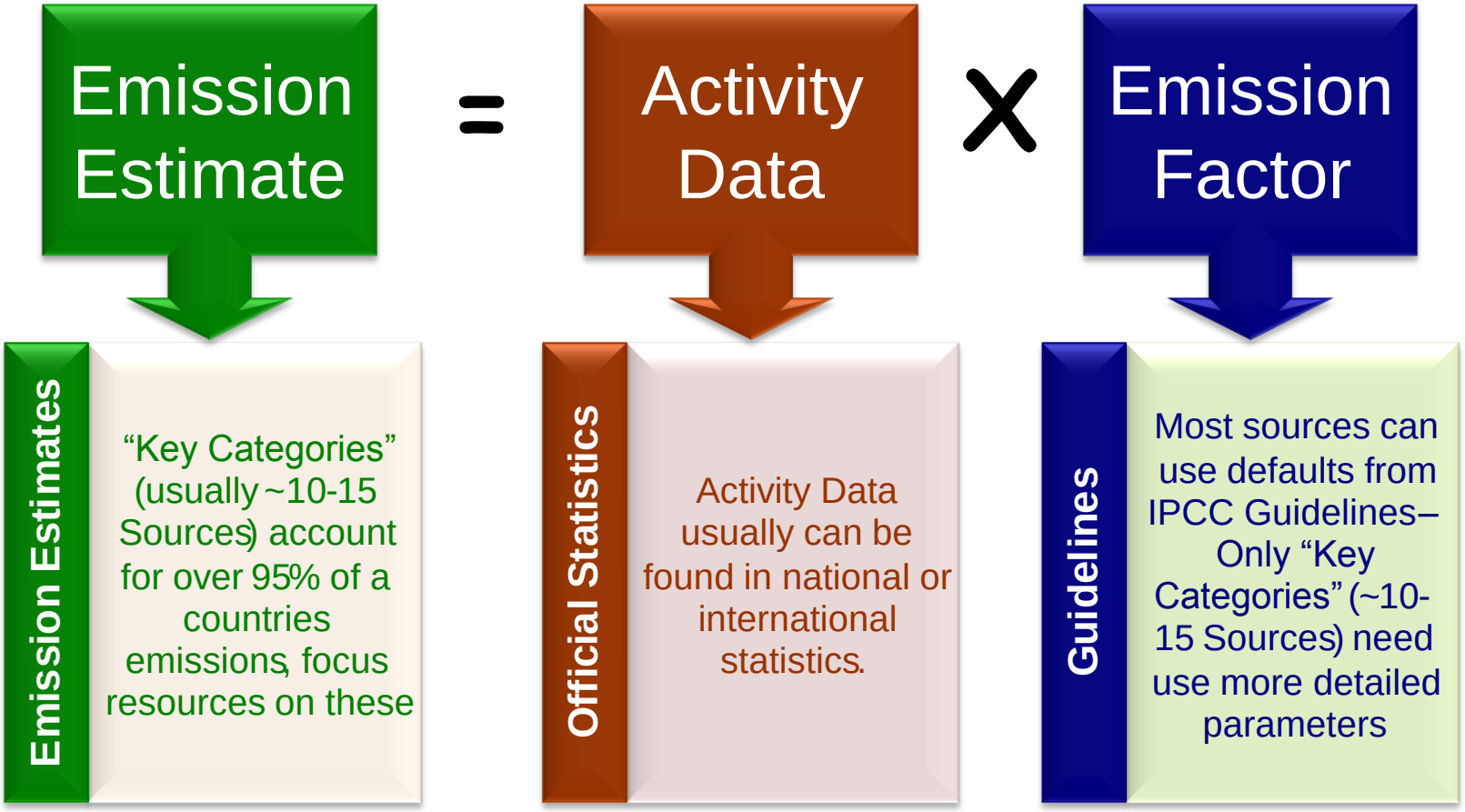
Fuels

- SOLID (Coal and Coal Products)
  - Inc. coal, coke and derived gases.
- LIQUID (Crude Oil and Petroleum Products)
  - Fuel Oil, Gasoline, LPG, Ethane and Petroleum Coke
- GAS (Natural Gas)
- OTHER FOSSIL FUELS
  - Non-biomass municipal & Industrial wastes, waste oils
- PEAT (treated as fossil fuel)
- BIOMASS
  - Wood, Charcoal, Biofuels, Biomass fraction of MSW
    - CO_2 Emissions not included in total Energy Emissions

Biomass

- CO_2 emissions from biomass combustion are not included in the national total
  - Although they are reported separately
  - Non-CO_2 emissions are reported in the national total
- Net carbon emissions are accounted for in the LULUCF/AFOLU sector
- Peat is treated as a fossil fuel

Basic Method



Coal Use – Africa – IEA data 2006 (Original Units)

Data: IEA 2009 (http://www.iea.org/Textbase/stats/index.asp)

,	Coking Coal	Other Bituminous Coal	Peat	Patent Fuel	Coke Oven gas	Gas Coke	Gas Works Gas	Coke Oven Gas	Blast Furnace Gas
Unit	*kT*						*TJ*		
Electricity Plants		*124764*							
Energy Sector					*18*				
Industry	*14*	*12,921*			*841*	*55*	*86,586*	*16,763*	*32,341*
Transport		*8*							
Residential		*4,942*	*4*	*104*			*380*		
Commercial and Public Services		*2,589*					*326*		
Agriculture / Forestry		*265*							
Fishing									
Other Non-Specified		*397*							
Non-Energy Use		*2,220*							
cv (TJ/Gg)	*28.2*	*25.8*	*9.76*	*20.7*	*28.2*	*28.2*			

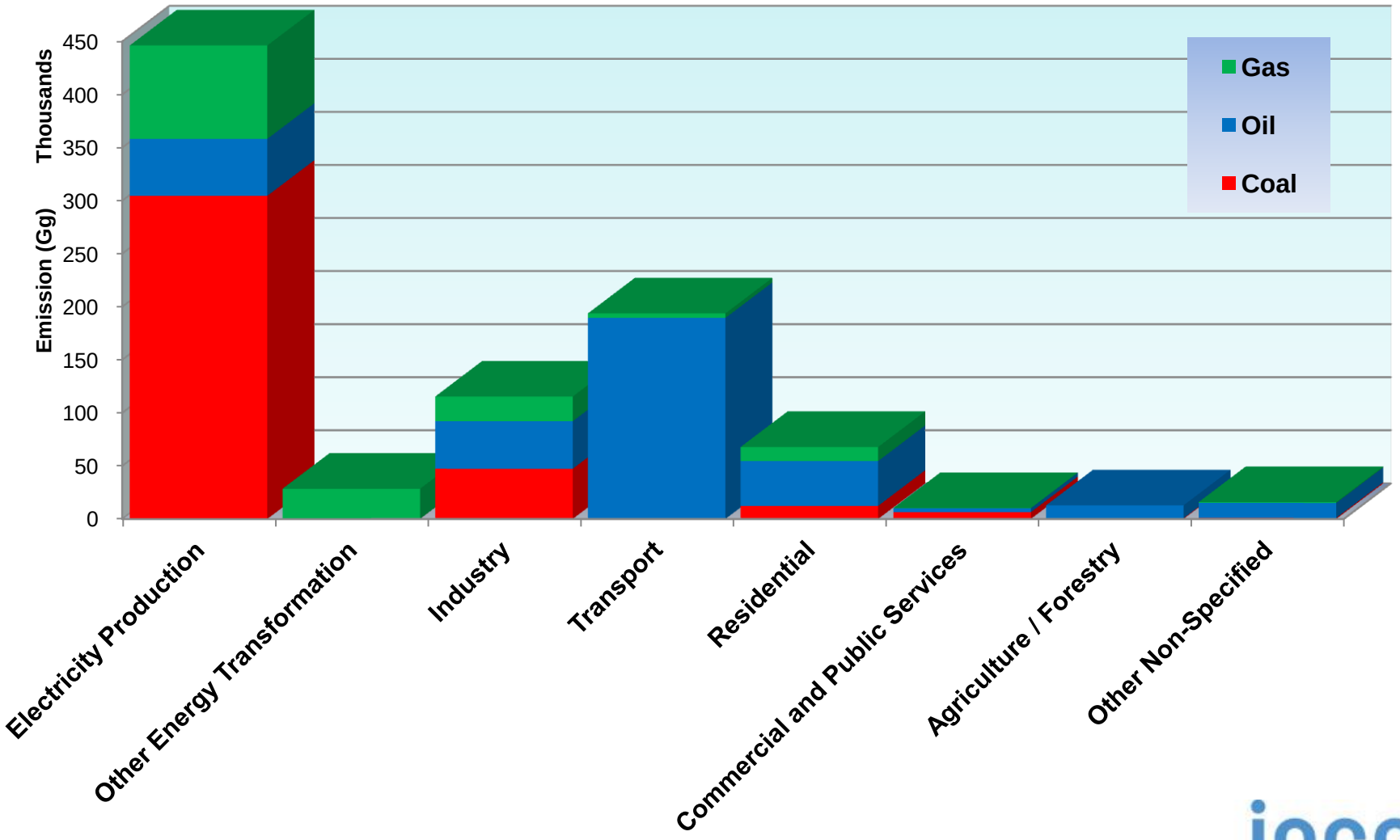
Coal Use – Africa – IEA data 2006 (Energy)

,	Coking Coal	Other Bituminous Coal	Peat	Patent Fuel	Coke Oven gas	Gas Coke	Gas Works Gas	Coke Oven Gas	Blast Furnace Gas
Unit			TJ					TJ	
Electricity Plants	-	3,218,911	-	-	-	-	-	-	-
Energy Sector	-	-	-	-	508	-	-	-	-
Industry	395	333,362	-	-	23,716	1,551	86,586	16,763	32,341
Transport	-	206	-	-	-	-	-	-	-
Residential	-	127,504	39	2,153	-	-	380	-	-
Commercial and Public Services	-	66,796	-	-	-	-	326	-	-
Agriculture / Forestry	-	6,837	-	-	-	-	-	-	-
Fishing	-	-	-	-	-	-	-	-	-
Other Non-Specified	-	10,243	-	-	-	-	-	-	-
Non-Energy Use	-	57,276	-	-	-	-	-	-	-
Emission Factors kg/TJ	**94,600**	**94,600**	**106,000**	**97,500**	**107,000**	**107,000**	**44,400**	**44,400**	**260,000**

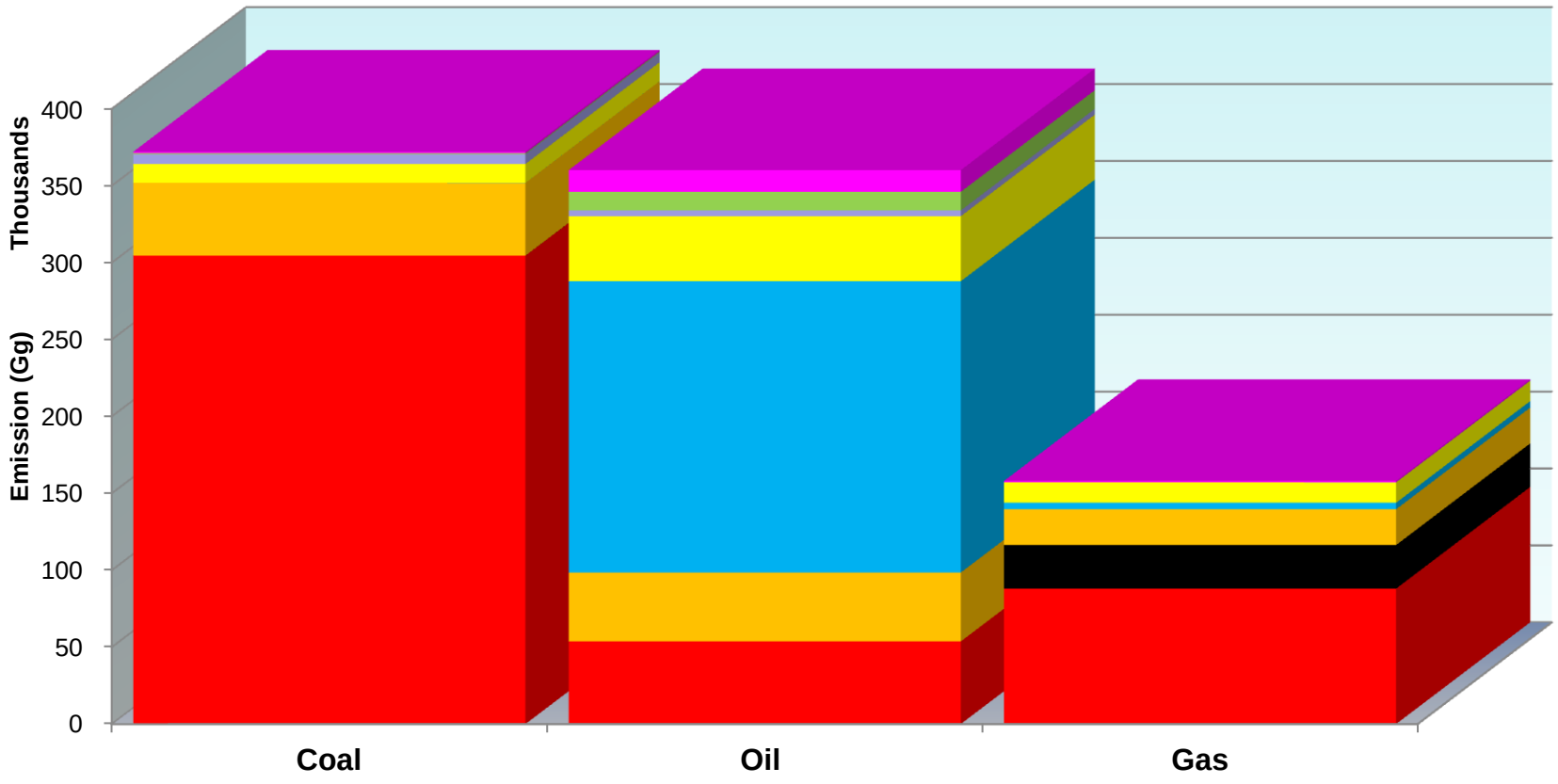
Coal Use – Africa – IEA data 2006

	Coking Coal	Other Bituminous Coal	Peat	Patent Fuel	Coke Oven gas	Gas Coke	Gas Works Gas	Coke Oven Gas	Blast Furnace Gas
Unit	*Gg (ktonne)*								
Electricity Plants	-	304,509	-	-	-	-	-	-	-
Energy Sector	-	-	-	-	54	-	-	-	-
Industry	37	31,536	-	-	2,538	166	3,844	744	8,409
Transport	-	20	-	-	-	-	-	-	-
Residential	-	12,062	4	210	-	-	17	-	-
Commercial and Public Services	-	6,319	-	-	-	-	14	-	-
Agriculture / Forestry	-	647	-	-	-	-	-	-	-
Fishing	-	-	-	-	-	-	-	-	-
Other Non-Specified	-	969	-	-	-	-	-	-	-
Non-Energy Use	-	5,418	-	-	-	-	-	-	-
Total Emissions	**37**	**356,061**	**4**	**210**	**2,592**	**166**	**3,876**	**744**	**8,409**

African CO_2 Emissions -2006



African CO_2 Emissions -2006



- Other Non-Specified
- Agriculture / Forestry
- Commercial and Public Services
- Residential
- Transport
- Industry
- Other Energy Transformation
- Electricity Production

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Combustion Emissions – Higher Tiers

- Country Specific emission factors – carbon contents – are needed
- Need to consider oxidation rates
- Any abatement needs to be taken into account
- May need to stratify fuel use by abatement type and oxidation rate (technology)
- Non-CO_2 emissions technology dependent
- Measurements are a Tier 3 approach – can be combined with emission factor tier 1/2 approaches if sufficient data available

Reference Approach

- A simple basic method based on imports, production and exports.
- Essentially:

$$Emission = Production + Imports - Exports - NonEnergyUse$$

- CO_2 only!
- Used as a check on the sectoral approach described above
  - Differences due to non-energy use of fuel, as well as differing quality data sets

Non-Energy Use of Fuels

Types of use and examples of fuels used for non-energy applications			
Use	**Example of fuel types**	**Product/process**	**Ch**
Feedstock	natural gas, oils, coal	ammonia	3.2
	naphtha, natural gas, ethane, propane, butane, gas oil, fuel oils	methanol, olefins (ethylene, propylene), carbon black	3.9
Reductant	petroleum coke	carbides	3.6
	coal, petroleum coke	titanium dioxide	3.7
	metallurgical cokes, pulverised coal, natural gas	iron and steel (primary)	4.2
	metallurgical cokes	ferroalloys	4.3
	petroleum coke, pitch (anodes)	aluminium [1]	4.4
	metallurgical coke, coal	lead	4.6
	metallurgical coke, coal	zinc	4.7
Non-energy Product	lubricants	lubricating properties	5.2
	paraffin waxes	misc. (e.g., candles, coating)	5.3
	bitumen (asphalt)	road paving and roofing	5.4
	white spirit[2], some aromatics	as solvent (paint, dry cleaning)	5.5

1. Also used in secondary steel production (in electric arc furnaces) (see Chapter 4.2).
2. Also known as mineral turpentine, petroleum spirits, industrial spirit ('SBP').

African Energy Use – Energy Balance

ktonne oil equivalent (ktoe)

SUPPLY and CONSUMPTION	Coal and Peat	Crude Oil	Petroleum Products	Gas
Production	141,801	495,846	0	169,668
Imports	7,698	42,879	45,214	4,030
Exports	-46,879	-401,357	-43,524	-96,473
International Marine Bunkers**	0	0	-6,035	0
Stock Changes	-39	-336	-1,113	0

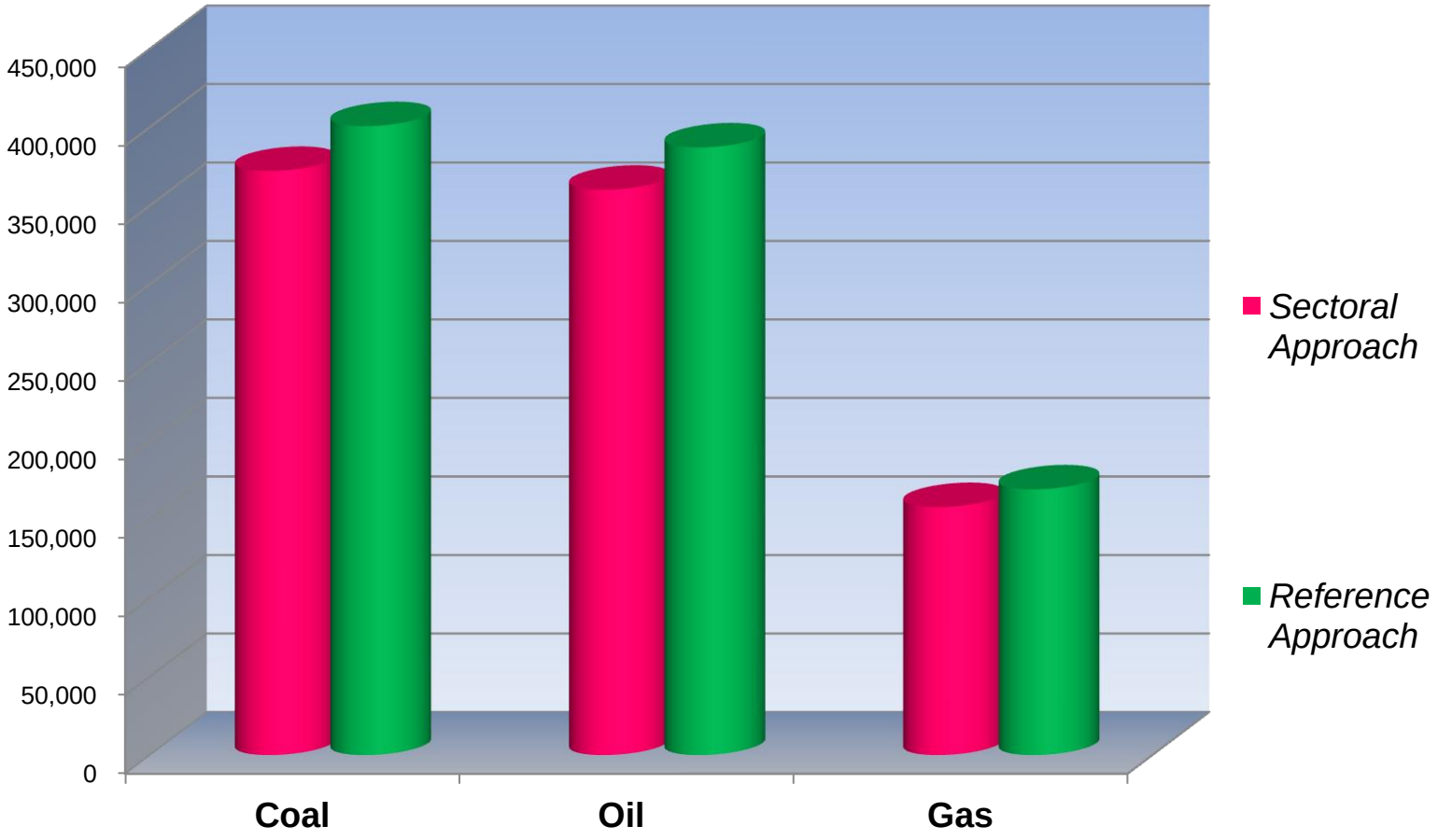
African Energy Emissions

SUPPLY and CONSUMPTION	Coal and Peat	Crude Oil	Petroleum Products	Gas
Production	5,936,924	20,760,080	0	7,103,660
Imports	322,300	1,795,258	1,893,020	168,728
Exports	-1,962,730	-16,804,015	-1,822,263	-4,039,132
International Marine Bunkers**	0	0	-252,673	0
Stock Changes	-1,633	-14,068	-46,599	0

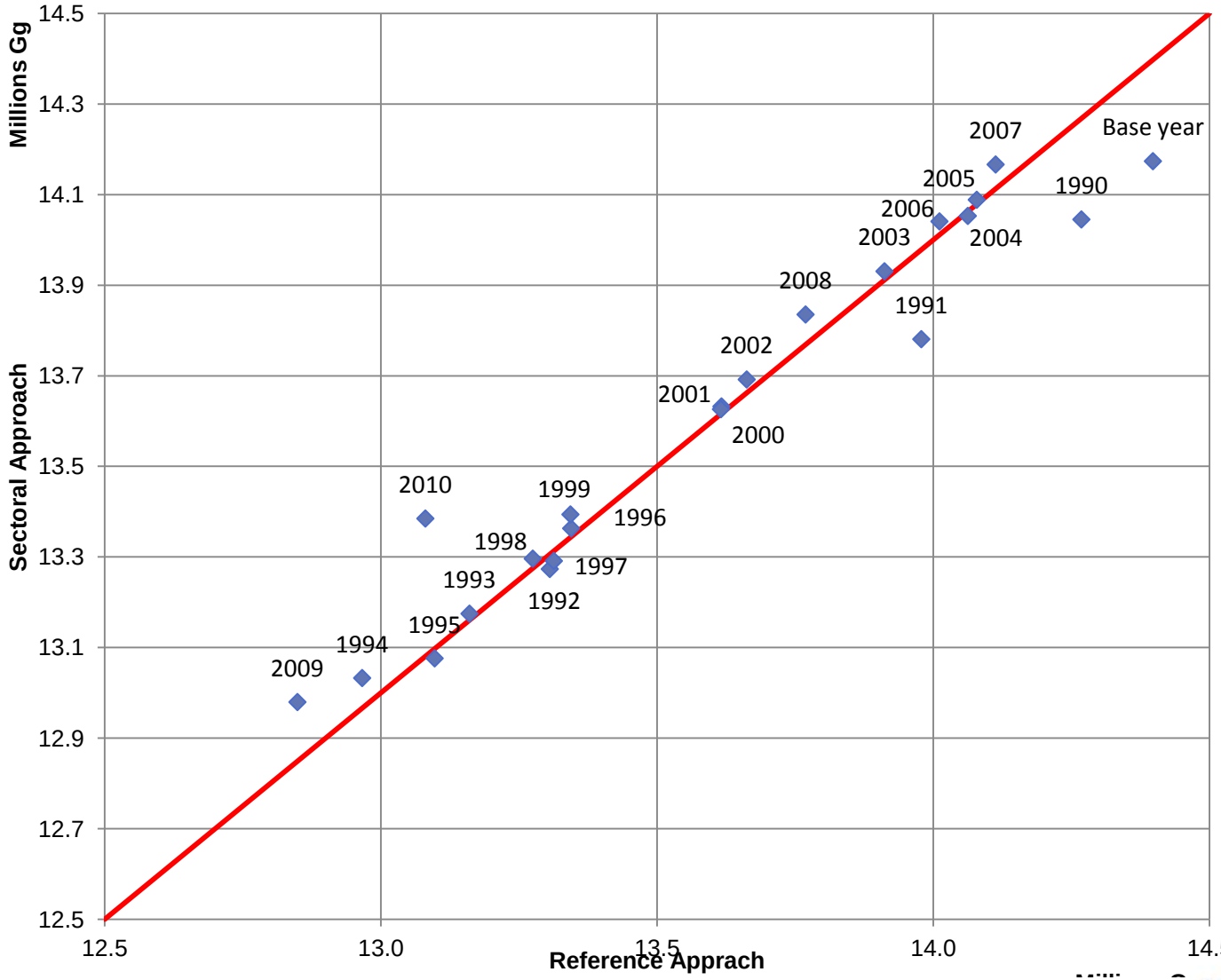
Total Emission = 978,092 Gg

Data: IEA 2009 (http://www.iea.org/Textbase/stats/index.asp)

African CO_2 Emissions – Sectoral and Reference Emission Estimates



Comparison of Reference and Sectoral Approaches – all Annex I



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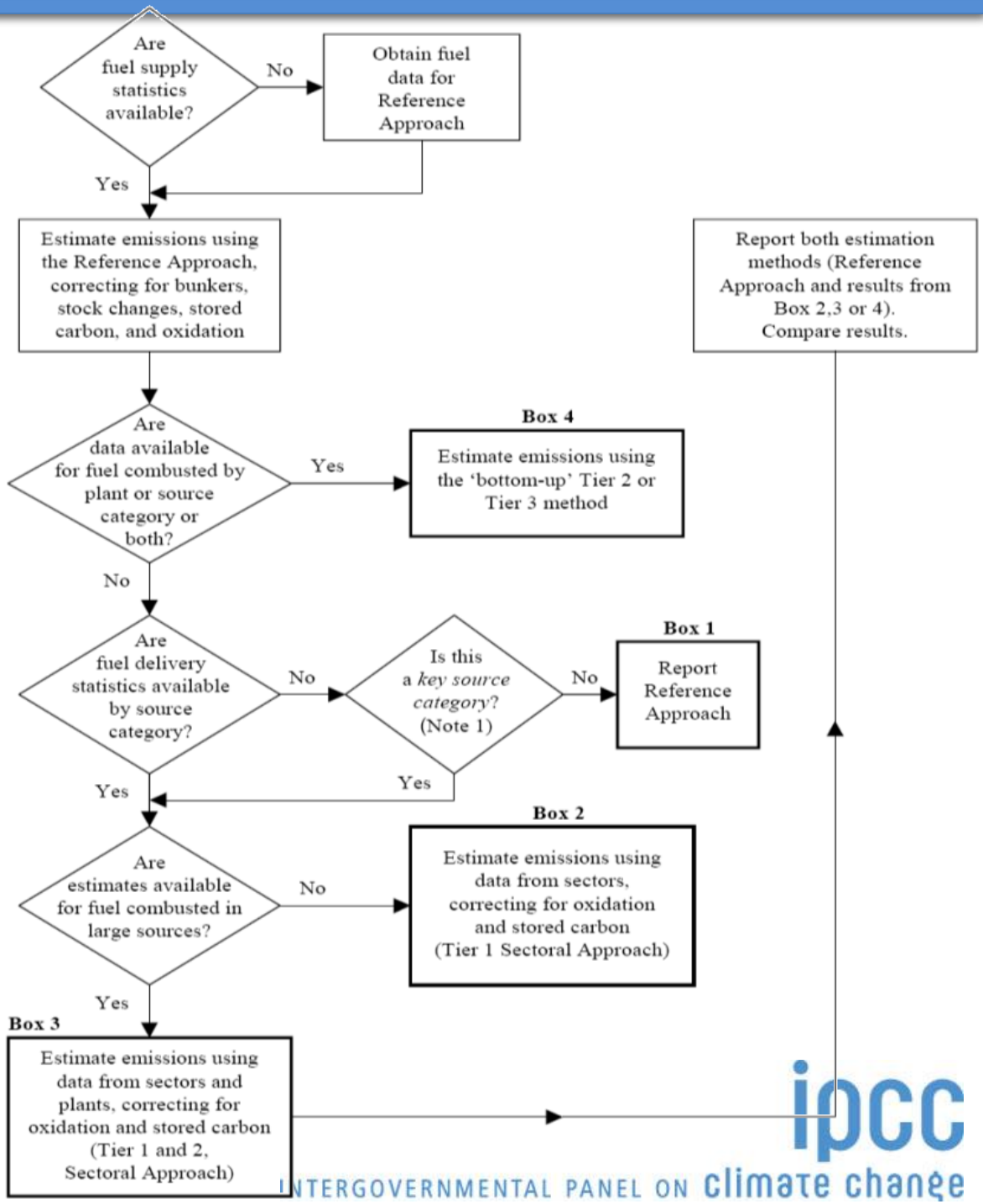
2000 GPG Decision Tree

- If not a key category can use reference approach
- Only estimation methods considered



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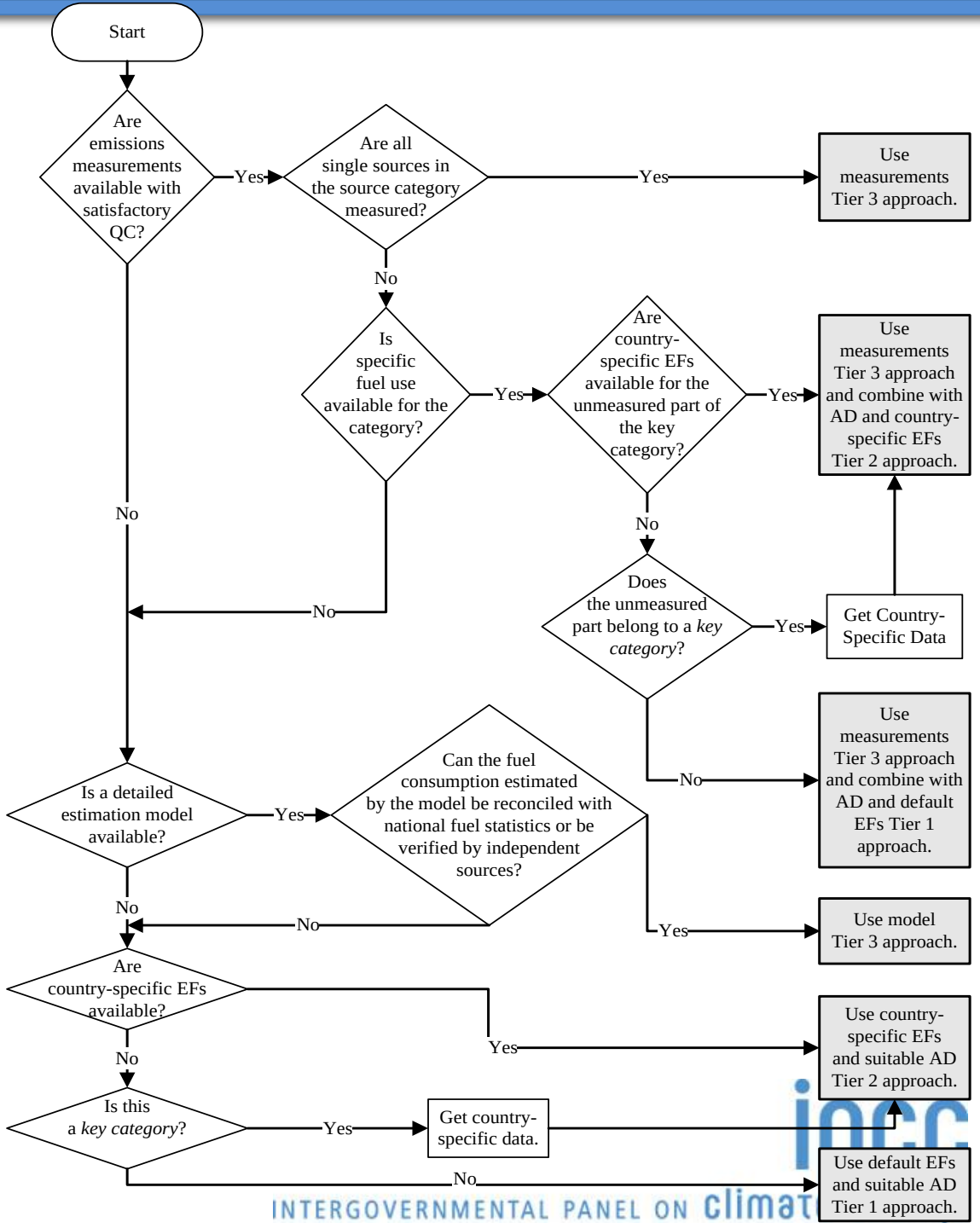
2006 IPCC Guidelines Decision Tree

- Use Sectorial approach for all Tiers.
- Reference approach for QA/QC
- Deals with measurements



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Road Transport

- CO_2 Emissions from C in fuel used
  - Bio-fuels carbon removed form total and reported separately
  - Carbon is also emitted from urea based catalysts and included here (not strictly combustion?)

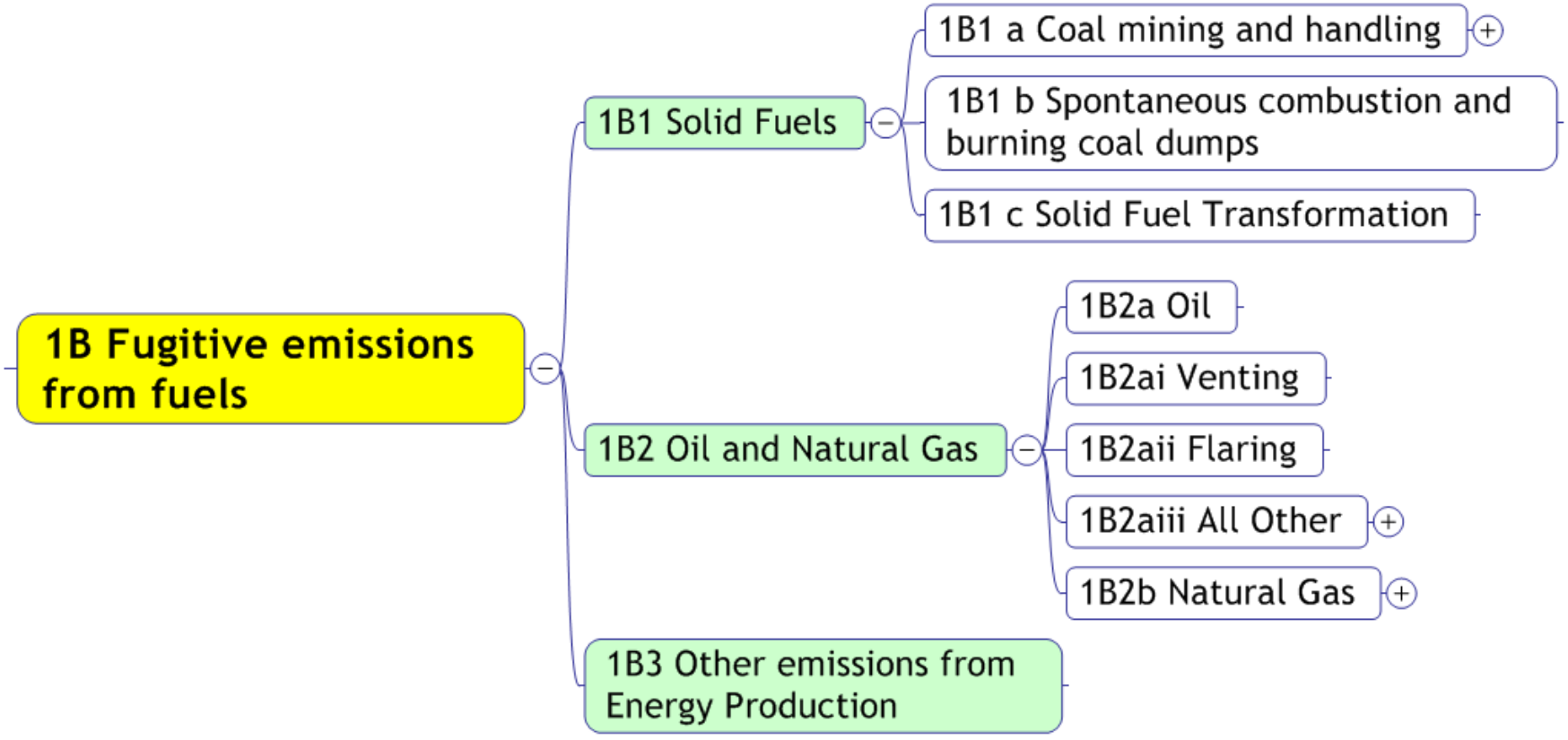
$$Emission = Activity \bullet \frac{12}{60} \bullet Purity \bullet \frac{44}{12}$$

  - CH_4 and N_2O strongly technology related. At higher tiers need to know technologies in fleet (especially type and proportion of catalysts)
- Caution with "fuel sold" data
  - overlaps with off-road and potentially other sectors (e.g. agriculture)
  - Blended fuels (e.g. with bio-ethanol and lubricants)
  - Smuggling
- All fuel sold in country included – even if fuel exported in fuel tanks of vehicles and used elsewhere

Aviation and Shipping

- Aviation and Shipping
  - Domestic Emissions included in National Total
  - International Emissions Reported separately "*Bunker Fuels*"
  - Domestic trips are legs of journeys between points in one country
  - International are trips between countries

Fugitive Emissions



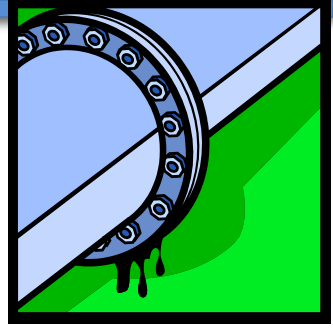
Fugitive Emissions

- ***Fugitive emissions*** are emissions of gases or vapour from equipment due to leaks and other unintended or irregular releases of gases, mostly from activities associated with the production and distribution of fossil fuels
  - Includes leaks form pressurised equipment, evaporation and displacement of vapour, and accidental releases
- Significant CH_4 Emissions from
  - Coal Mines
  - Refinery leaks
  - Gas Distribution pipelines
- Simple Emission Factor methods at Tier 1
- Higher Tiers need more detail on technologies and age of plant/mines etc.

Coal Mines

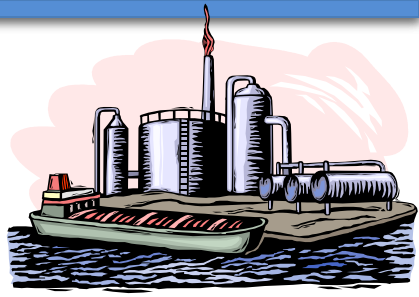
- Emissions from
  - Mining Emissions, gas liberated by fracturing coal during mining. This may be collected (for safety) and flared or used for energy. Emission can continue after mine closure.
  - Post-mining emissions, emissions during processing, handling and distribution
  - Low temperature oxidation, coal slowly oxidises to CO_2 when exposed to the air
  - Uncontrolled Combustion, oxidation may lead to an active fire in coal storage or exposed coal seams. This can occur naturally.
- Mining emissions differ in underground and surface mines.
- Simple emission factors are provided for Tier 1 but this is very site specific so country-specific data is required for better estimates.

Oil and Gas



- Fugitive emissions include all emissions from oil and gas systems EXCEPT those for the use of oil and gas for energy or as a feedstock.
- It covers everything from the oil well to the consumer:
  - Exploration
  - Production
  - Collection
  - Processing and Refining
  - Distribution and Delivery
- Includes equipment leaks, evaporation loses, venting, flaring and accidental releases.

Fugitive Gases Emitted

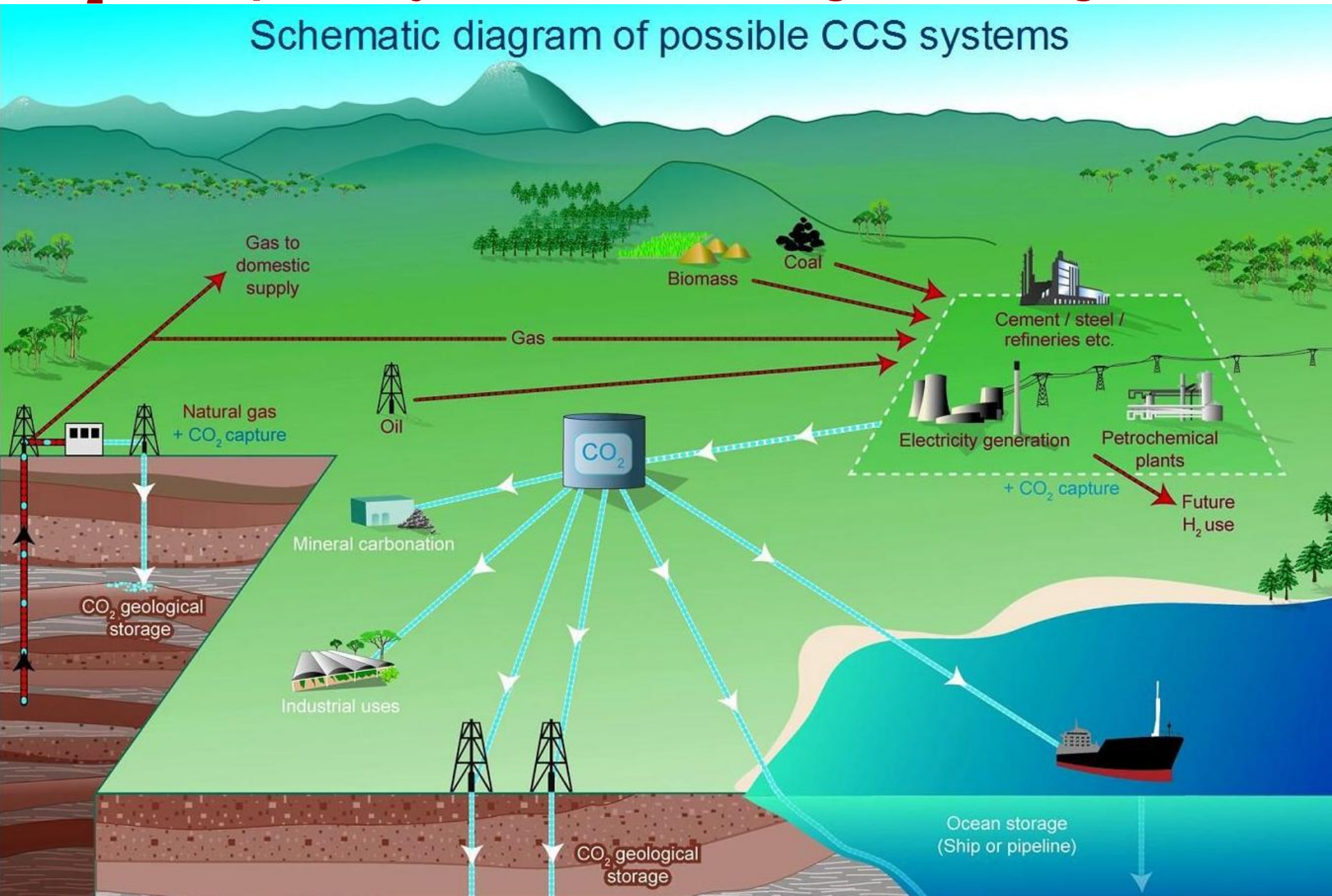


- CO_2 may be contained in the oil or gas as extracted from the reservoir
- CH_4 can be released directly
  - e.g. leaks of natural gas
- CO_2 may be formed from releases of CH_4
  - e.g. some CH_4 leaking from distribution pipelines is converted to CO_2 before it reaches the atmosphere
- CO_2, CH_4 and N_2O can also be formed in non-useful energy combustion
  - e.g. flaring
- General Tier 1 EFs (for developing and developed countries) are available,
  - These are based on amounts produced, processed or distributed
- At higher tiers detailed knowledge of the system is needed.
  - Country-specific EFs will need to be developed based on measurements

Sources Considered

- Well Drilling and Testing, Well Servicing, Gas Production
- Gas Processing (Sweet Gas Plants, Sour Gas Plants, Deep-cut Extraction Plants (Straddle Plants))
- Gas Transmission & Storage Transmission (Storage
  - Gas Distribution, Natural Gas Liquids Transport (Condensate, Liquefied Petroleum Gas, Conventional Oil, Heavy Oil/Cold Bitumen)
- Thermal Oil Production (Default, Synthetic Crude from Oil sands and from Oil Shale)
- Oil Transport (Pipelines, Tanker Trucks and Rail Cars, Loading of Off-shore Production on Tanker Ships)
- Oil Refining and Upgrading
- Refined Product Distribution (Gasoline, Diesel, Aviation Fuel, Jet Kerosene)

CO_2 Transport, Injection and Geological Storage



CCS

No CCS

- Emissions depend on carbon in fuel burnt

With CCS

- Emissions equal carbon n fuel burnt minus measure C in CO2 captured
- Additional fuel may be burnt to power capture

Transport

- By pipeline or ship etc.
- Include intermediate storage.
- Leaks may occur

Injection

- Leaks while CO2 is injection into final storage location

Storage

- Monitor any potential leaks
- Measurement, monitoring and modelling before and during storage to ensure no leaks.
- On-going monitoring to detect any leaks

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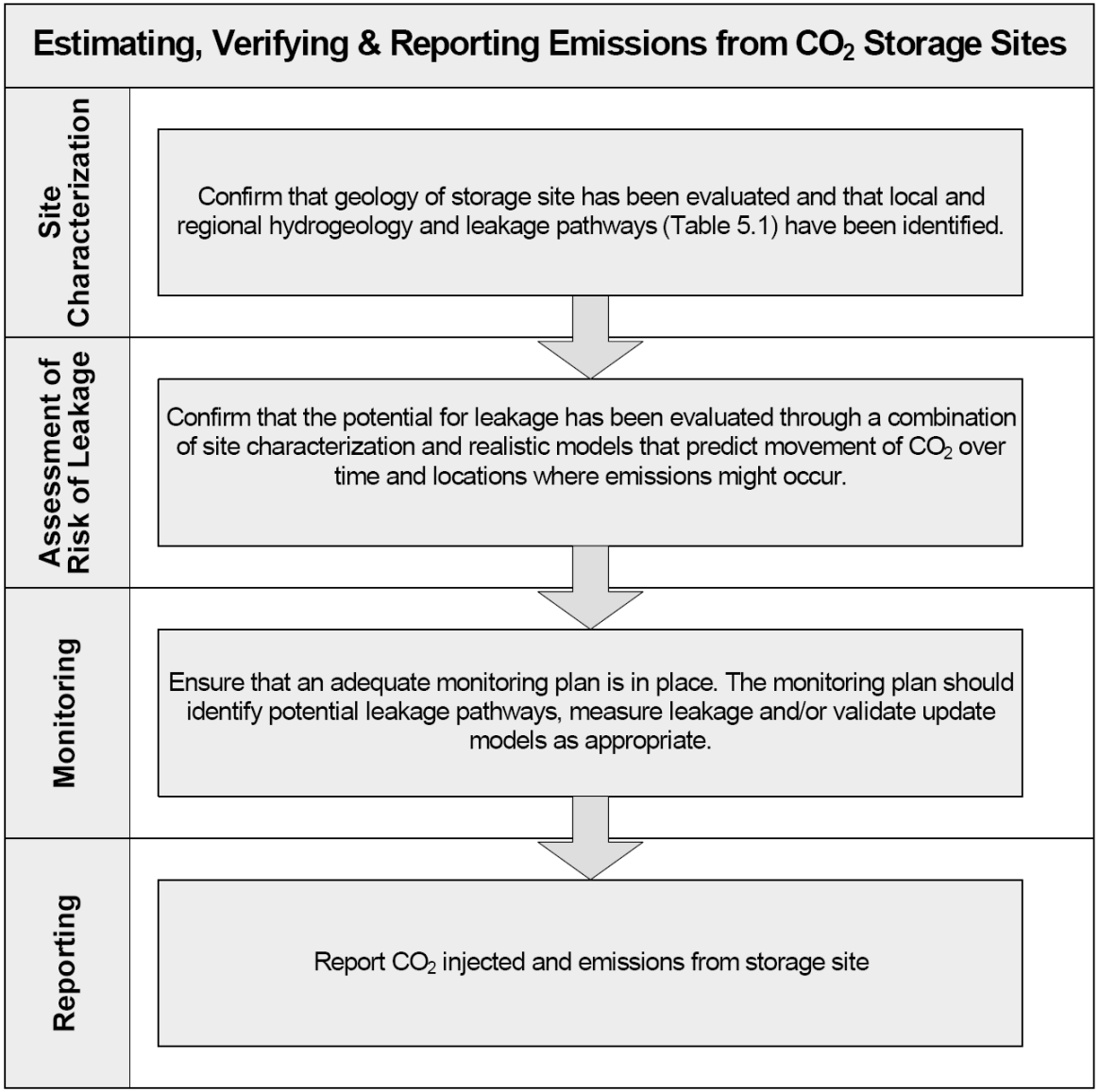
CO_2 – Leakage from storage site



1. Which gases are emitted from the *Energy Sector*?
2. What is the major GHG from the energy sector?
3. What is the major gas emitted through *fugitive emissions*?
4. What is the main parameter required for CO_2 emission estimates?
5. How is the CO_2 Emission Factor estimated?
6. What are "*fugitive emissions*"?
7. What is an "*oxidation factor*"
8. What is the difference between the *Sectoral* and *Reference Approaches*?
9. Can the *Reference Approach* be used for all GHGs?
10. Can you give fugitive emission sources of CO_2?

Review

Summary

- Energy Emissions are usually the most important
  - CO_2 from fuel combustion is major source
  - CH_4 mainly comes from fugitive emissions
- CO_2 emission factor depends on carbon content of fuel.
- Reference approach used for checking

Thank you

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