ENERGY STATISTICS

The Use of Energy Statistics to Estimate CO_2 Emissions

Joint IEA, ESCWA and RCREEE National Workshop on Energy Statistics

Cairo, Egypt

27 April – 01 May 2014

International Energy Agency

Outline

- International context
- Trends in emissions over time
- IPCC methodology
- Estimation of CO_2 emissions by the IEA
- Comparison of Reference and Sectoral approaches
- Conclusions

International Context

International Context

Stabilisation of greenhouse gas concentrations in the atmosphere.

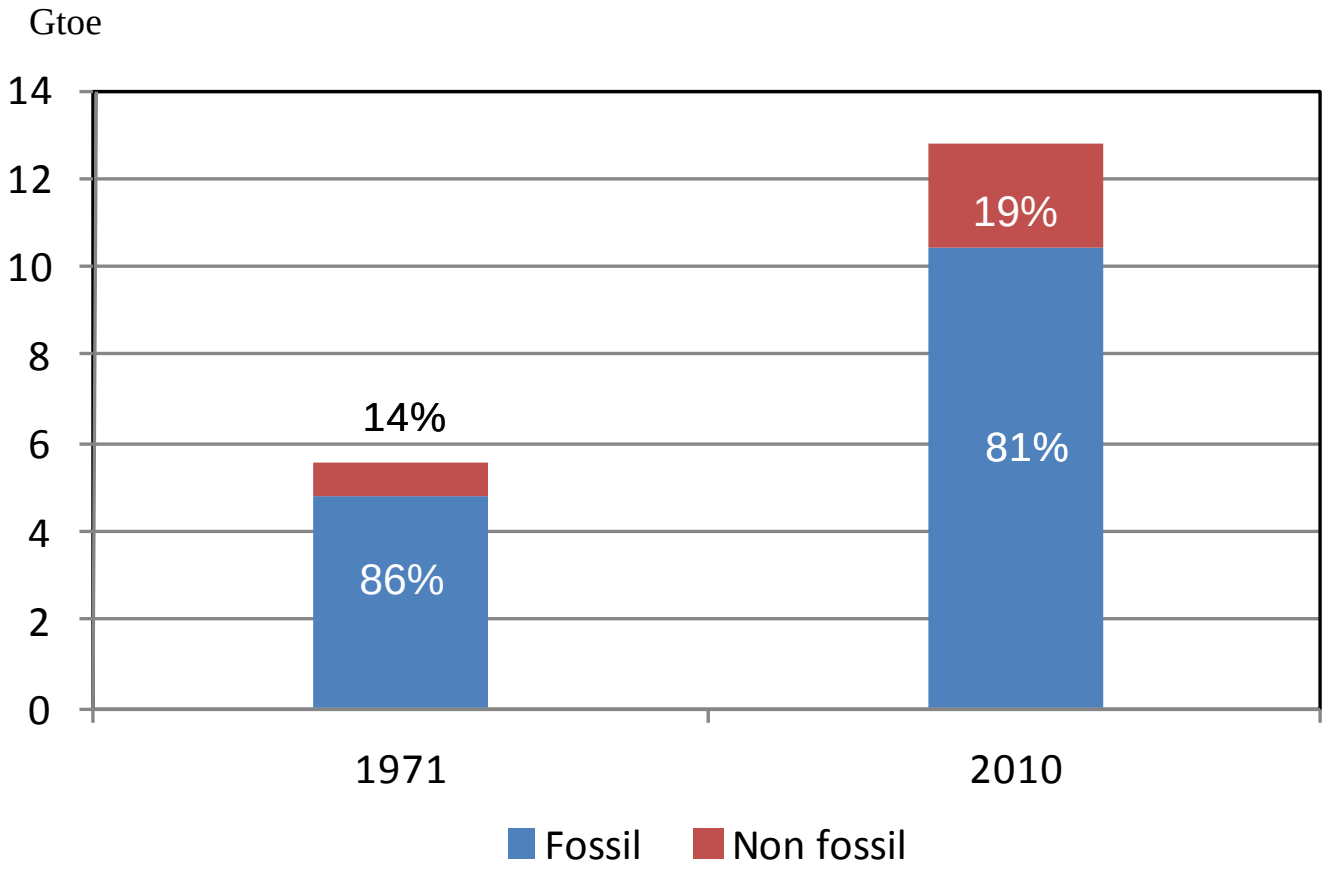
- **1992:** United Nations Framework Convention on Climate Change (UNFCCC) at negotiated at the Earth Summit Conference, Rio de Janeiro.
- **1997:** Kyoto Protocol negotiated (entered into force in 2005).
- **2008-2012:** First commitment period of the Kyoto Protocol.

  38 developed countries agreed to reduce anthropogenic greenhouse gas emissions over this period by about 5% compared to 1990.
- **Ongoing:** Since 1995, the parties to the Convention have met once a year at the Conference of the Parties (COP) to discuss progress.

  COP19 is being held from 11-22 November in Warsaw, Poland.

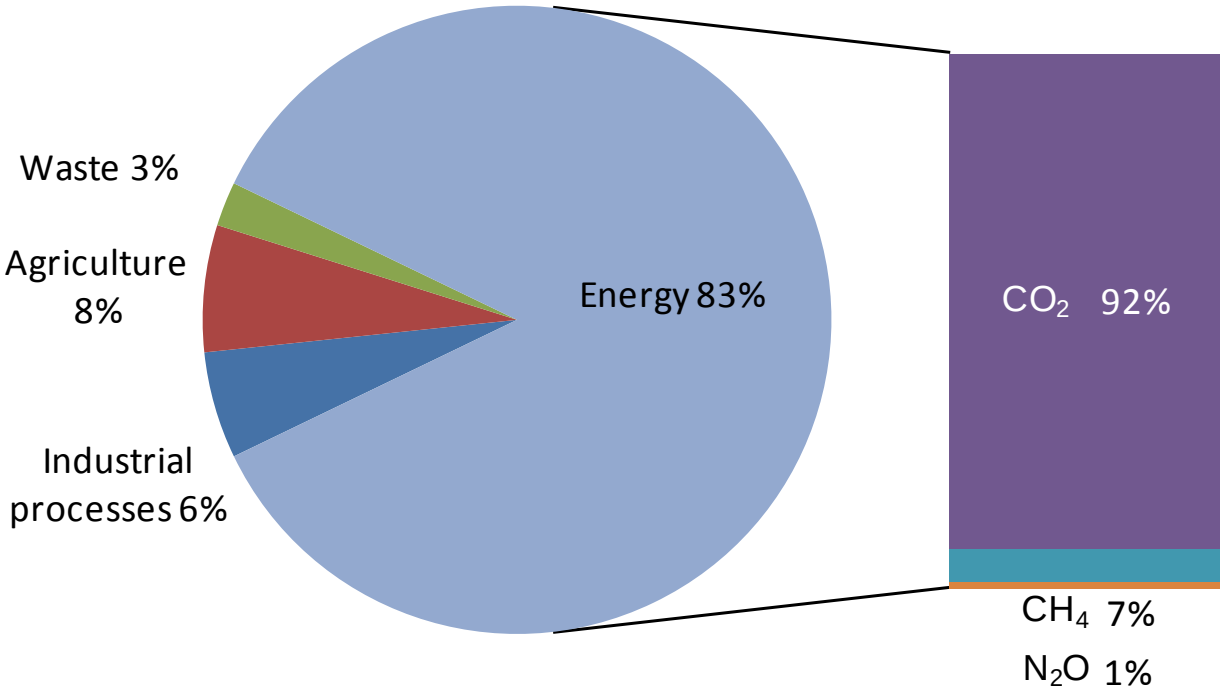
Trends in emissions over time

World primary energy supply



Despite growth in renewable energy, fossil fuels still satisfy most of the world's energy supply.

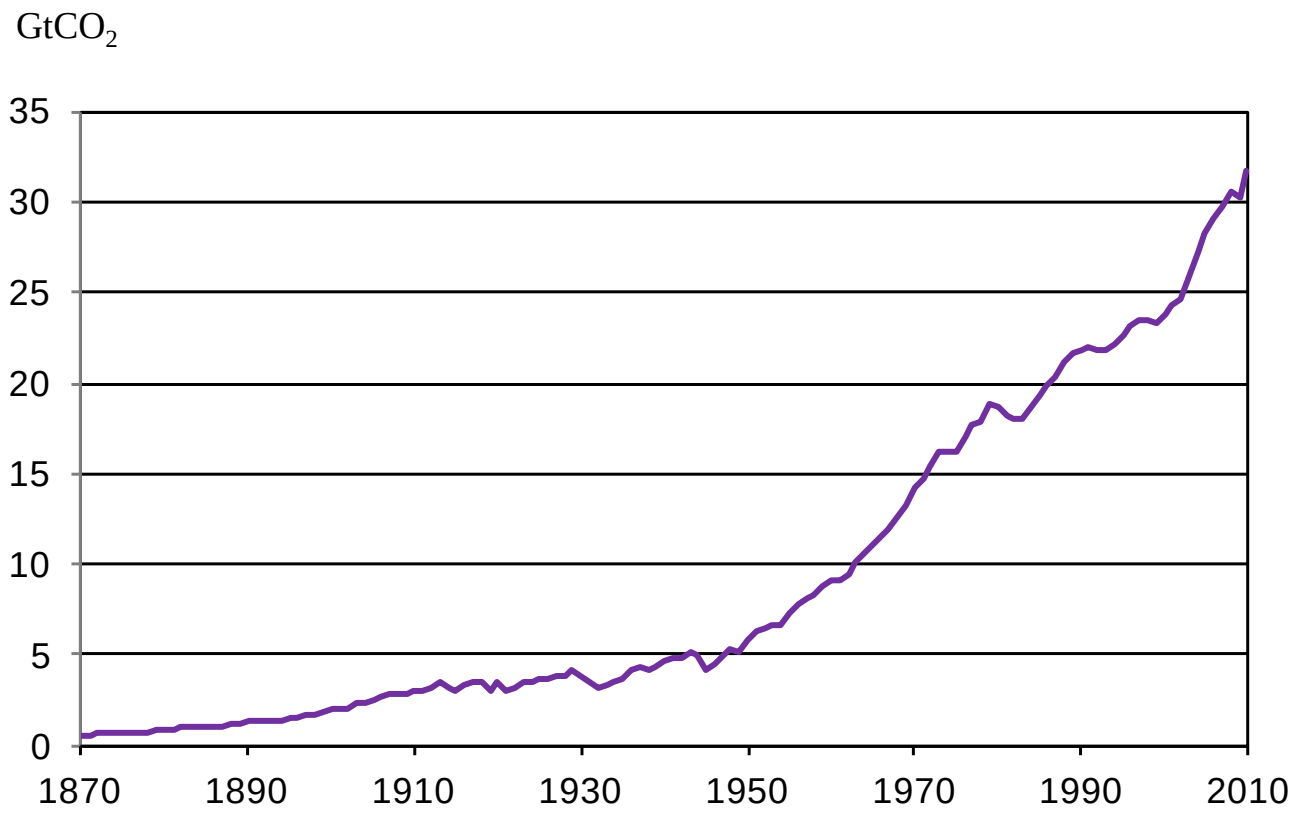
Share of energy in GHG emissions



Source: UNFCCC - based on Annex I countries for 2010

Energy sector emissions, which are predominantly CO_2, account for the largest share of global greenhouse gas (GHG) emissions.

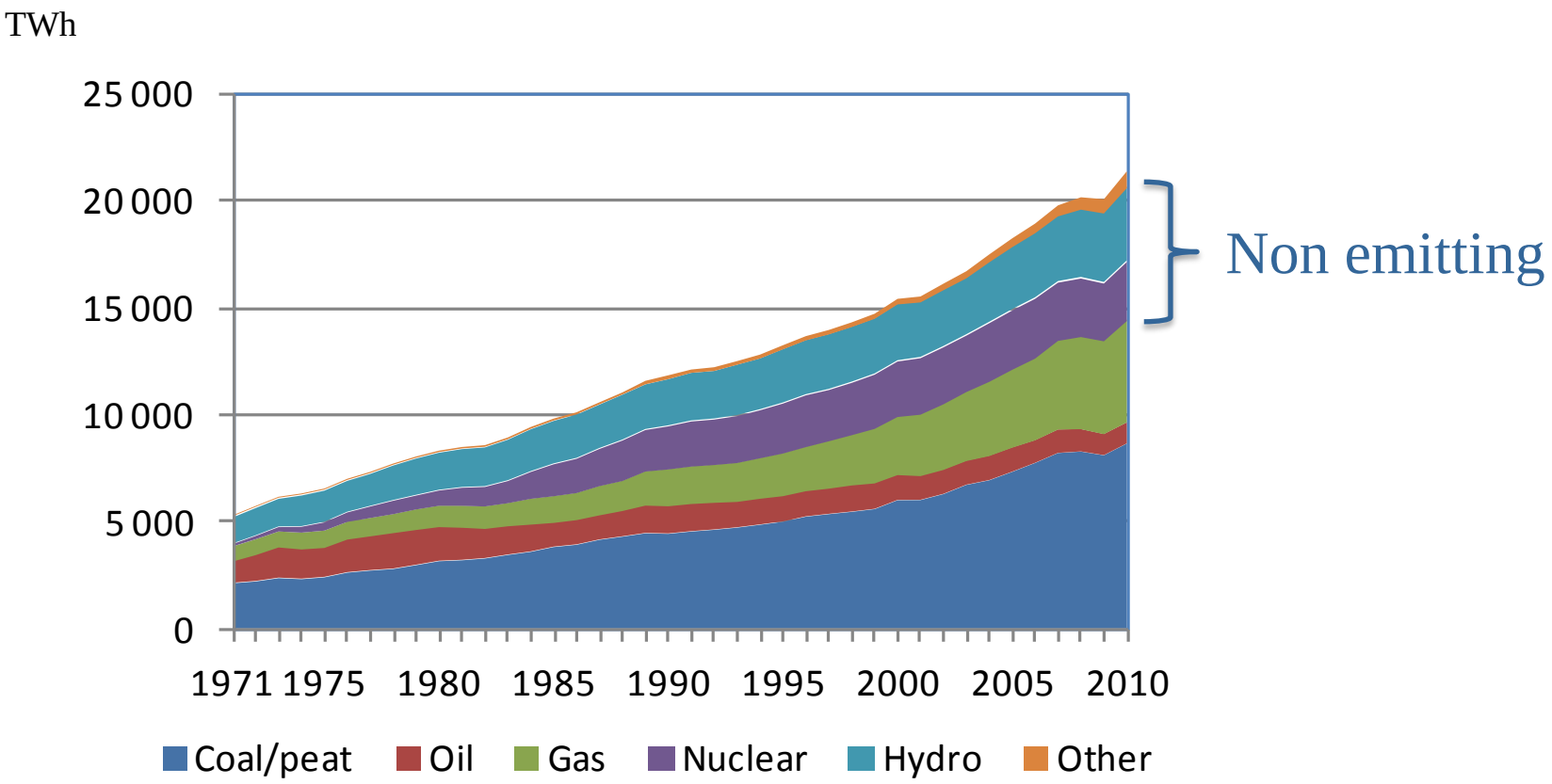
Trend in CO_2 emissions from fossil fuel combustion



Source: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, US

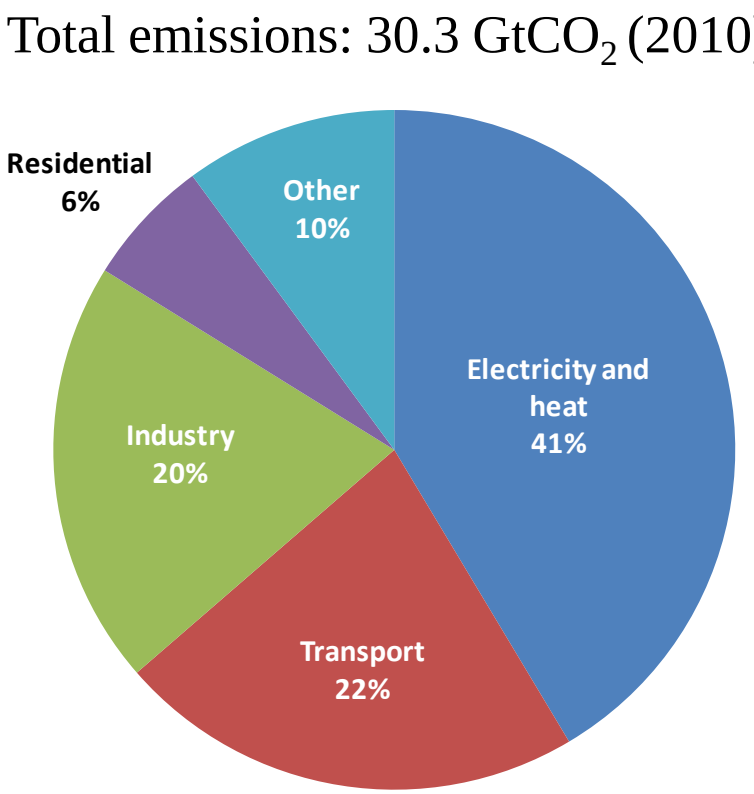
Since 1870, CO_2 emissions from fuel combustion have risen exponentially.

World electricity generation by fuel



Although non- and low-emitting sources of electricity are growing, electricity generation remains CO_2-intensive due to the increasing share of coal.

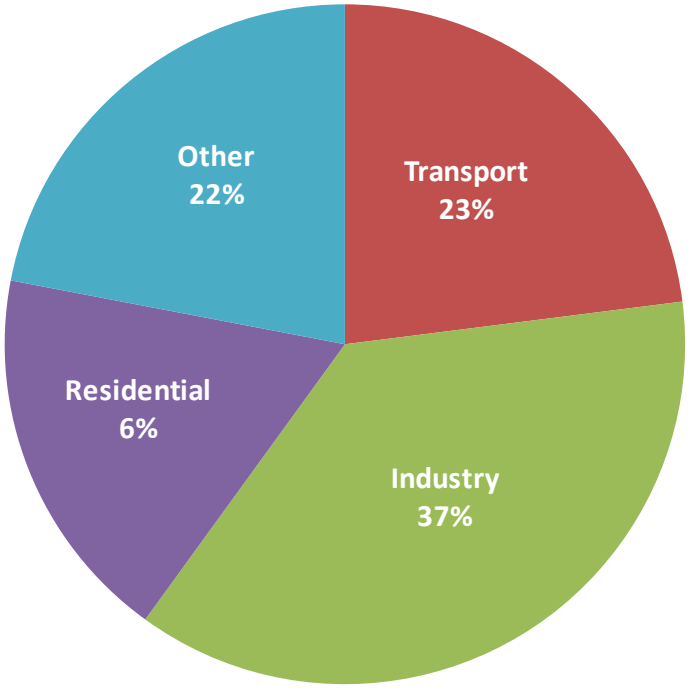
World CO_2 emissions by sector



Electricity / heat generation and transport make up almost 2/3 of global emissions. This has increased from 1/2 in 1971.

World CO_2 emissions by sector in with electricity and heat re-allocated

Total emissions: 30.3 $GtCO_2$ (2010)



When electricity / heat emissions are allocated to their consuming sectors, Industry becomes the largest emitting sector.

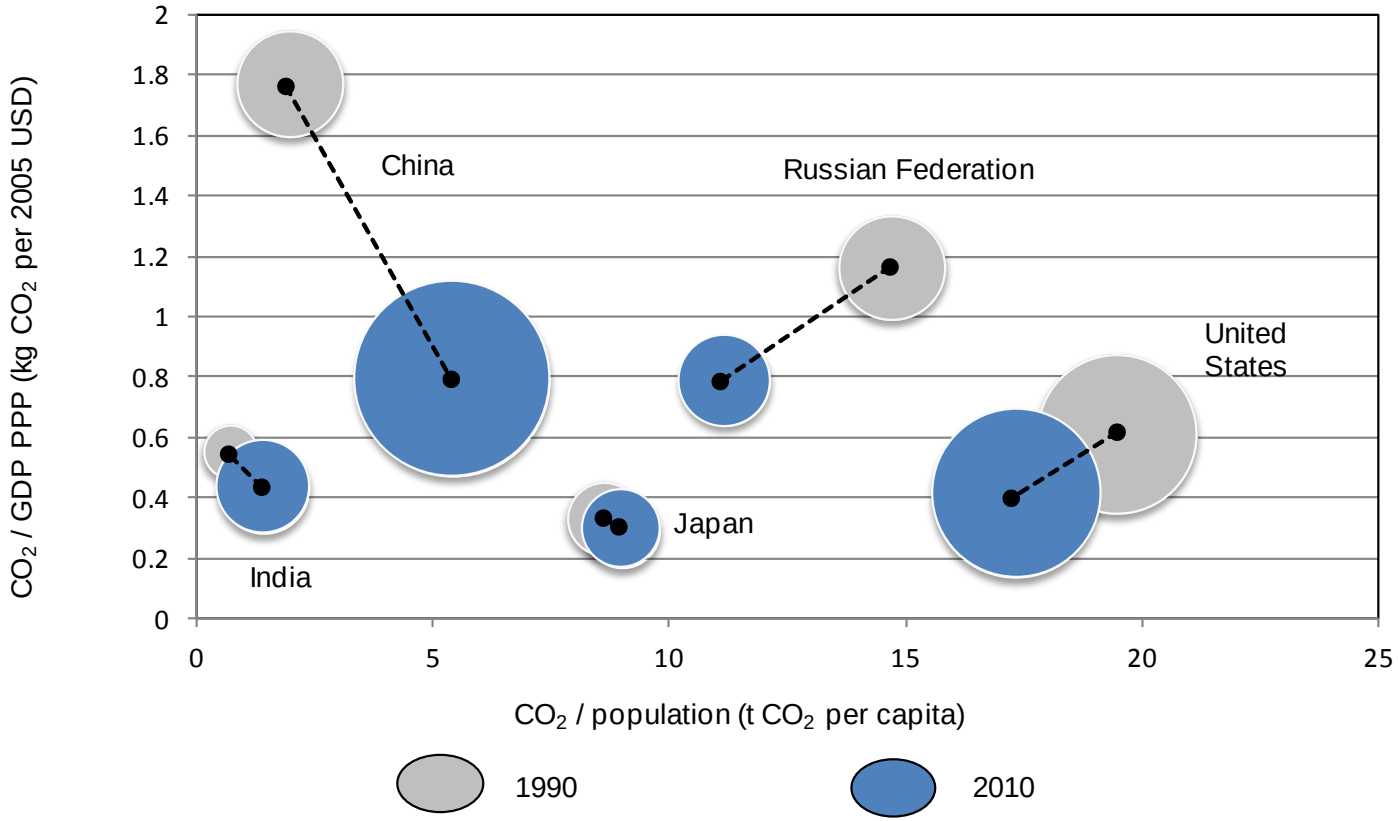
CO_2 intensity indicators

Emissions estimates can be combined with energy data and other socio-economic figures to produce useful indicators such as:

- CO_2 / population
- CO_2 / GDP

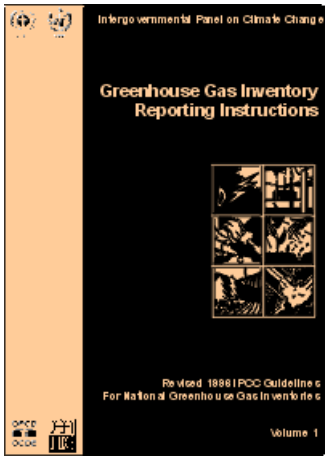
- CO_2 / TPES
- CO_2 / kWh

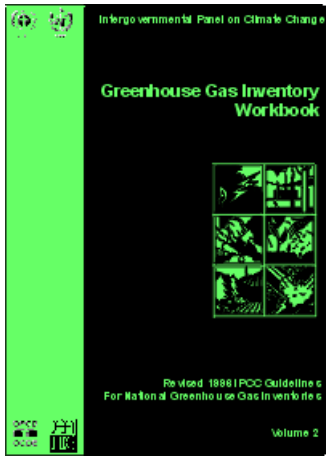
CO_2 intensities of major countries

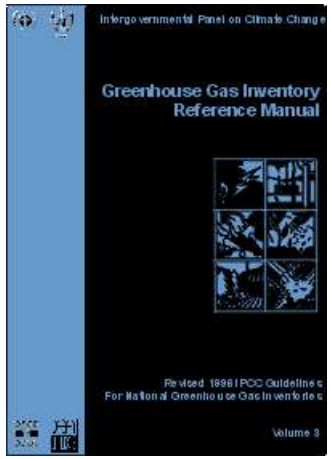


CO_2 indicators can be used to compare emissions in countries with differing economic circumstances.

IPCC Methodologies







IPCC methodologies: overview

- Allow a complete inventory of emissions across countries to be calculated in a consistent, accurate, comparable and transparent manner.

- Two sets of Guidelines were published:

  Revised 1996 IPCC Guidelines
  2006 IPCC Guidelines

- Kyoto Protocol is based on the *Revised 1996 IPCC Guidelines*

Therefore, IEA CO_2 estimates are also calculated using the *Revised 1996 IPCC Guidelines*.

IPCC methodologies: tiered approach

Tier 1

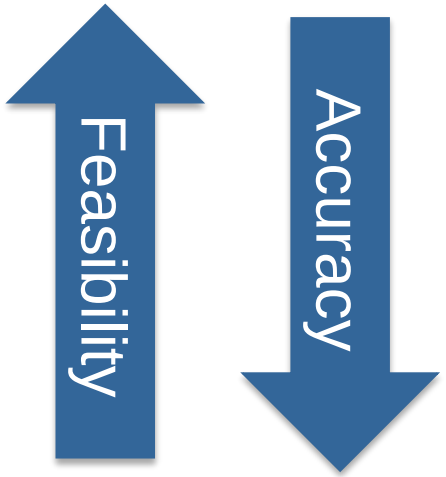
- Simplest method
- Use fuel consumption (activity) data available to all countries

Tier 2

- Country or technology-specific emission factor

Tier 3

- More detailed or country-specific methods



Although Tier 2 and 3 are more accurate in general, in the case of CO_2 from fuel combustion, the Tier 1 approach produces accurate results, as emissions are based on the carbon content of the fuels (conservation of carbon).

IPCC methodologies: basic computation

Basic computation for CO_2 emissions using the *1996 Guidelines*:

- CO_2 emissions by product: **Fuel Quantity x Emission Factor** (with corrections for stored and unoxidised carbon)
- Sum over all different products

Can be done from two independent sets of data:

Supply of fuels to the country **Reference Approach**	**Consumption** by end-use sectors **Sectoral Approach**

IPCC methodologies: what is not included?

IPCC Guidelines: Biomass is **not included** in national totals for CO_2 emissions from **fuel combustion**.

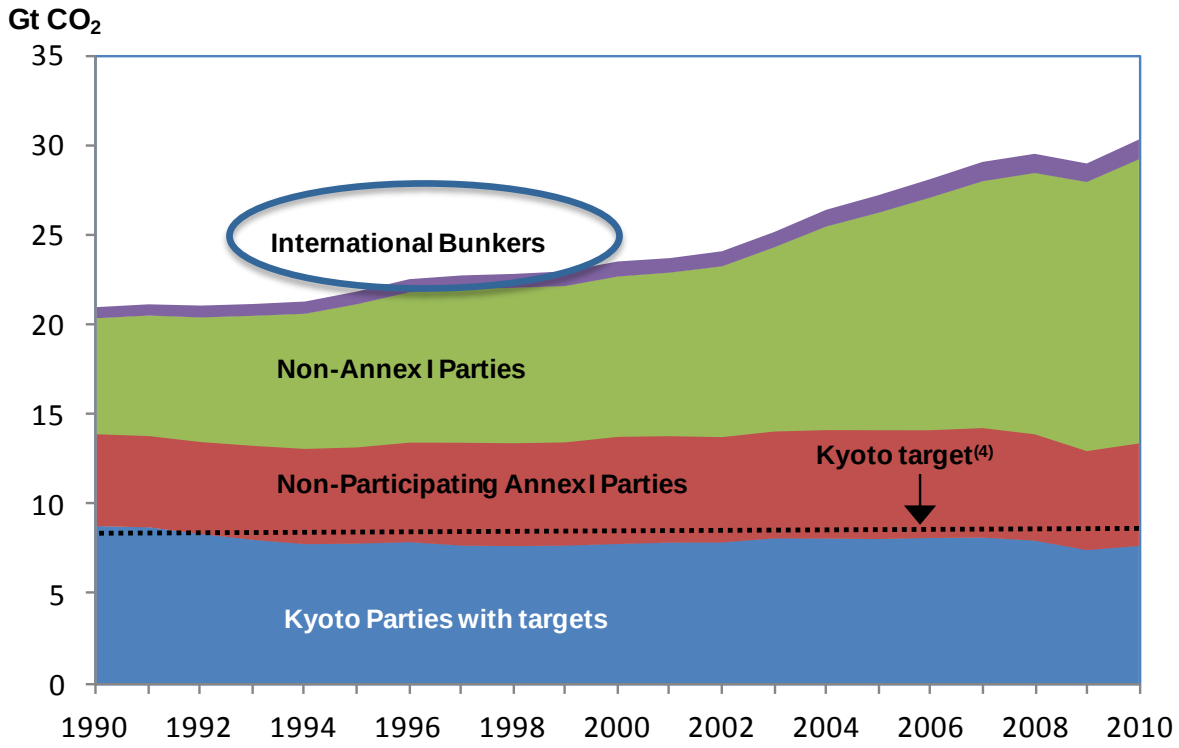
Biomass contains carbon, absorbed by plants through photosynthesis.

However, if biomass is sustainably grown, no additional CO_2 is considered as emitted into the atmosphere.

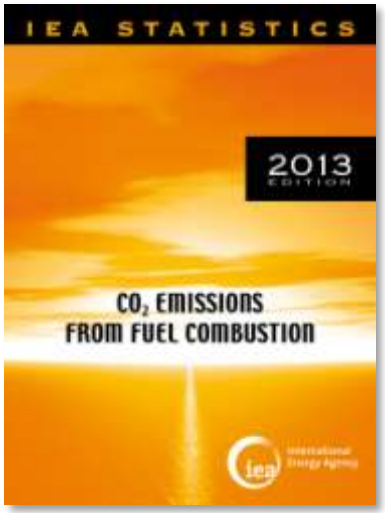
If there is a change in the biomass stocks, then the CO_2 is accounted for in *land-use, land-use change and forestry (LULUCF).*

IPCC methodologies: what is not included?

IPCC Guidelines: international aviation and international marine bunkers are **not included** in national totals.



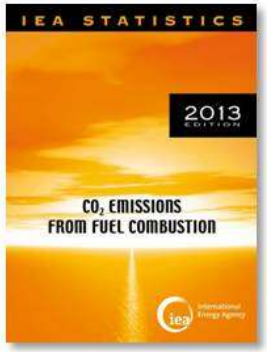
IEA CO_2 Emissions Estimates



How IEA estimates CO_2 emissions from fuel combustion

Energy Statistics

Energy Balances



CO_2 Emissions

IPCC Methodologies (Revised 1996 GLs)

Step 1: Estimating sectoral fuel consumption

Revised 1996 Guidelines

MODULE	**ENERGY**
SUBMODULE	**CO_2 FROM FUEL COMBUSTION (TIER I SECTORAL APPROACH)**
WORKSHEET	**STEP BY STEP CALCULATIONS**
SHEET	**MANUFACTURING INDUSTRIES AND CONSTRUCTION**

	STEP 1	STEP 2				
Manufacturing Industries and Construction	A Consumption					
Crude Oil						
Natural Gas Liquids						
Gasoline						
Jet Kerosene						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG						

Separate sheet filled out for each sector:

Main activity producer electricity and heat
Unallocated autoproducers
Other energy industries
Manufacturing industries and construction
Transport
of which: road
Other sectors
of which: residential

Units:
Could be in natural units (e.g. 1000 tonnes) or in energy units (e.g. TJ)

Step 2: Converting to a common energy unit

Revised 1996 Guidelines

MODULE	**ENERGY**
SUBMODULE	**CO_2 FROM FUEL COMBUSTION (TIER I SECTORAL APPR**
WORKSHEET	**STEP BY STEP CALCULATIONS**
SHEET	**MANUFACTURING INDUSTRIES AND CONSTRUCTION**

	STEP 1	STEP 2		
Manufacturing Industries and Construction		B Conversion Factor (TJ/unit)	C Consumption (TJ)	
			C=(AxB)	
Crude Oil				
Natural Gas Liquids				
Gasoline				
Jet Kerosene				
Other Kerosene				
Gas/Diesel Oil				
Residual Fuel Oil				
LPG				

Country-specific NCVs for natural gas and coal are given explicitly in the *Revised 1996 IPCC Guidelines*

SELECTED NET CALORIFIC VALUES FROM THE 1996 GLS	
	Factors ($TJ/10^3$ tonnes)
Refined petroleum products	
Gasoline	44.80
Jet kerosene	44.59
Other kerosene	44.75
Shale oil	36.00
Gas/diesel oil	43.33
Residual fuel oil	40.19
LPG	47.31
Ethane	47.49
Naphtha	45.01
Bitumen	40.19
Lubricants	40.19
Petroleum coke	31.00
Refinery feedstocks	44.80
Refinery gas	48.15
Other oil products	40.19
Other products	
Coal oils and tars derived from coking coals	28.00
Oil shale	9.40
Orimulsion	27.50

Step 3: Multiplying by carbon emission factors

Revised 1996 Guidelines

MODULE	ENERGY
SUBM	I SECTORAL APPROACH)
WORK	
	ONSTRUCTION

CARBON EMISSION FACTORS (CEF)	
Fuel	*Carbon emission factor (t C/TJ)*
LIQUID FOSSIL	
Primary fuels	
Crude oil	20.0
Orimulsion	22.0
Natural gas liquids	17.2
Secondary fuels/products	
Gasoline	18.9
Jet kerosene	19.5
Other kerosene	19.6
Shale oil	20.0
Gas/diesel oil	20.2
Residual fuel oil	21.1
LPG	17.2
Ethane	16.8
Naphtha	(20.0)
Bitumen	22.0
Lubricants	(20.0)
Petroleum coke	27.5
Refinery feedstocks	(20.0)
Refinery gas	18.2
Other oil	(20.0)

				STEP 3		
Manufacturing Industries and Construction				D Carbon Emission Factor (t C/TJ)	E Carbon Content (t C)	F Carbon Content (Gg C)
					E=(CxD)	F=(E x 10-3)
Crude Oil						
Natural Gas Liquids						
Gasoline						
Jet Kerosene						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG						

Step 4: Calculating carbon stored

Revised 1996 Guidelines

MODULE	**ENERGY**
SUBMODULE	**CO_2 FROM FUEL COMBUSTION (TIER I SECTORAL APPROACH)**
WORKSHEET	**2 STEP BY STEP CALCULATIONS**
SHEET	**MANUFACTURING INDUSTRIES AND CONSTRUCTION**

	STEP 4			STEP 5		STEP 6
Manufacturing Industries and Construction	G Fraction of Carbon Stored	H Carbon Stored (Gg C)	I Net Carbon Emissions (Gg C)			
		H=(FxG)	I=(F-H)			
Crude Oil						
Natural Gas Liquids						
Gasoline						
Jet Kerosene						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG						

Default values: fraction of carbon stored

Naphtha*	0.8
Lubricants	0.5
Bitumen	1.0
Coal Oils and Tars	0.75
Natural Gas*	0.33
Gas/Diesel Oil*	0.5
LPG*	0.8
Ethane*	0.8

*When used as feedstocks

Step 5: Correcting for carbon unoxidised

Revised 1996 Guidelines

MODULE	**ENERGY**					
SUBMODULE	**CO_2 FROM FUEL COMBUSTION (TIER I SECTORAL APPROACH)**					
WORKSHEET	**2 STEP BY STEP CALCULATIONS**					
SHEET	**MANUFACTURING INDUSTRIES AND CONSTRUCTION**					
	STEP 4			**STEP 5**		**STEP 6**
Manufacturing Industries and Construction				J Fraction of Carbon Oxidised	K Actual Carbon Emissions (Gg C)	
					K=(IxJ)	
Crude Oil						
Natural Gas Liquids						
Gasoline						
Jet Kerosene						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG						

Default values: fraction of carbon oxidised

Coal	0.98
Oil and oil products	0.99
Gas	0.995
Peat for elec. Generation	0.99

Step 6: Converting to CO_2 emissions

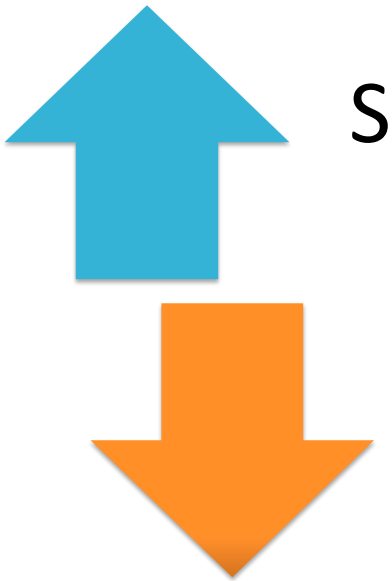
Revised 1996 Guidelines

MODULE	ENERGY					
SUBMODULE	CO_2 FROM FUEL COMBUSTION (TIER I SECTORAL APPROACH)					
WORKSHEET	2 STEP BY STEP CALCULATIONS					
SHEET	MANUFACTURING INDUSTRIES AND CONSTRUCTION					
	STEP 4			STEP 5		STEP 6
Manufacturing Industries and Construction						L Actual CO2 Emissions (Gg CO2)
						L=(K x [44/12])
Crude Oil						
Natural Gas Liquids						
Gasoline						
Jet Kerosene						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG						

Multiply by 44/12

(the molecular weight ratio of CO_2 to C)

Reference vs. Sectoral Approach

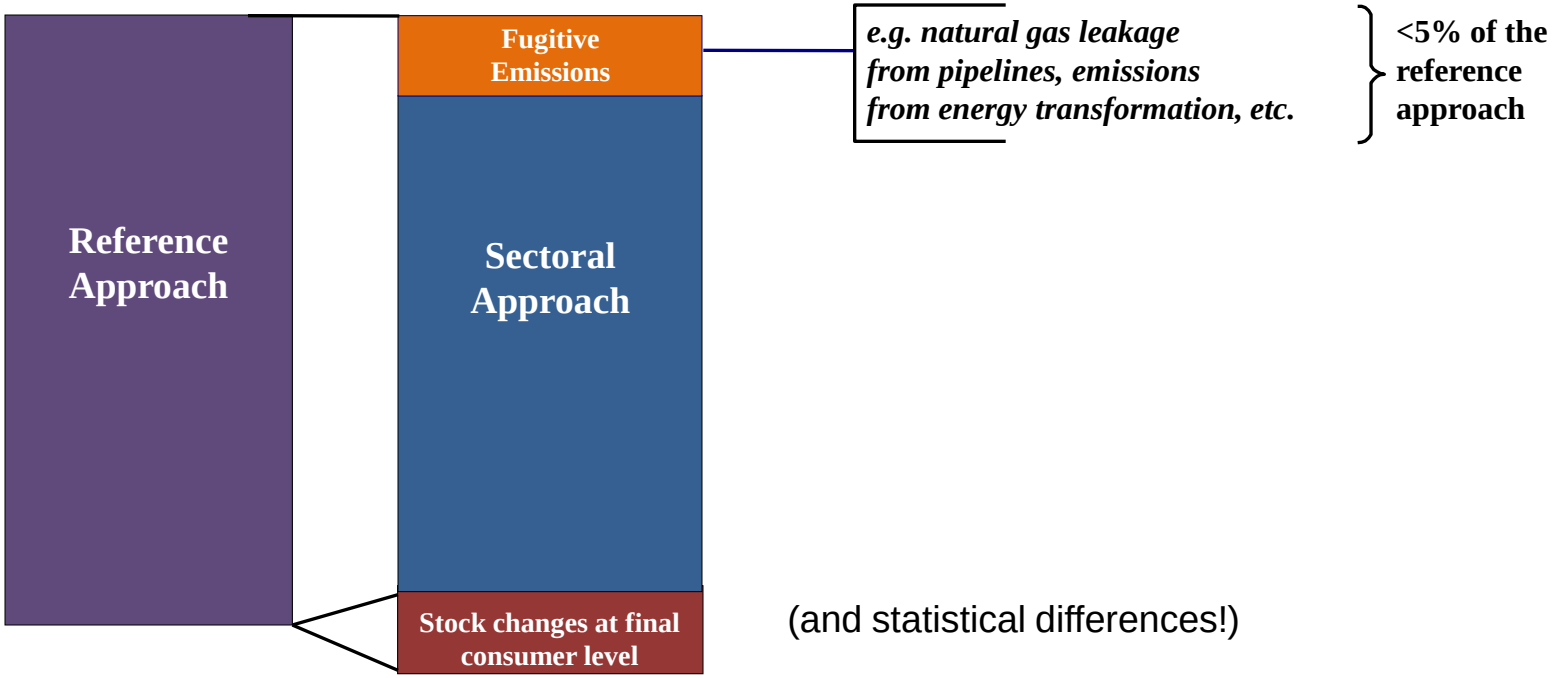


Sectoral

Reference

Data Quality: Reference vs. Sectoral Approach

Reference Approach is generally an **upper limit** for **Sectoral Approach**



(and statistical differences!)

Comparing the Reference Approach and the Sectoral Approach is one way to control data quality.

World CO_2 emissions

2010 CO_2 emissi

million	Coal/peat	C	gas	Other		change 90-10
Secto	**13 065.9**	**10 890.5**	**6 179.1**	**140.6**	**30 276.1**	**44.4%**
Main a	8 449.2	702.2	2 169.2	40.9	11 361.4	71.5%
Unallo				61.5	1 119.1	26.3%
Other				0.9	1 570.8	55.4%
Manufacturing industries and construc				32.5	6 186.4	36.6%
Transport **				-	6 755.8	47.0%
of which: road				-	*4 972.1*	51.1%
Other				4.9	3 282.6	-1.3%
of which: residential						3.2%
Reference Approach **						**44.4%**
Diff. due to losses and/or transformation						
Statistical differences	326.8	17.4	- 6.6			
Memo: international marine bunkers	-	*64*				*77.6%*
Memo: international aviation bunkers	-	*45*				*78.3%*

* Other includes industrial waste and non-renewable municipal waste.
** World includes international marine bunkers and international aviation bu

Other only includes industrial waste and non-renewable municipal waste (not biofuels)

Residential only includes emissions from fuels actually combusted in households (hence its relatively small share), not electricity or heat consumption

We show both the reference approach and sectoral approach emissions (the difference coming from statistical differences, and losses and transformation)

nker fuels are
luded in transport
for the world total (but

We show emissions for main activity and autoproducer plants separately (we don't have the required data to allocate autoproducers to their consuming sectors)

Conclusions

Dealing with energy-climate change challenges

- Emit less (be more efficient)
- Emit differently (switch fuels or processes to deliver same outcome)
- New technologies (CO_2 capture and storage,…)
- Change behaviour
- Adapt (learn to live with it)

A need for energy statistics to be able to monitor progress of the various policies

Concluding remarks

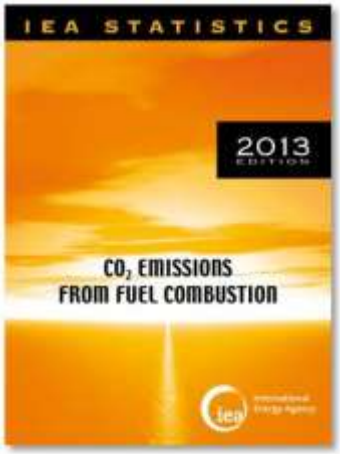
- Human influence on the climate system is clear. This is evident from the increasing GHG concentrations in the atmosphere…
  - IPCC 5th Assessment Report, Working Group I

- Effective emissions mitigation will require all countries, regardless of energy demand and infrastructure, to use energy in a sustainable manner.

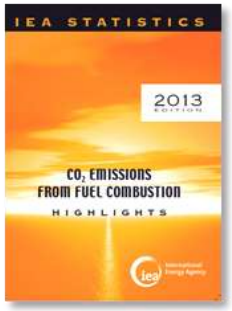
- Up-to-date and accurate information on energy use and GHG emissions is essential for countries to monitor their progress in reducing GHG emissions.

Good energy statistics are crucial for estimating GHG emissions

The *CO_2 Emissions from Fuel Combustion (2013 Edition)* will be available shortly.



PDF



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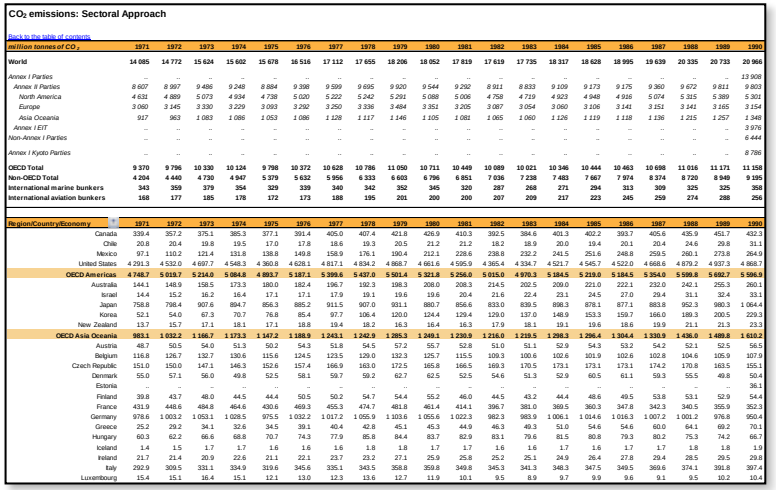

CO_2 emissions: Sectoral Approach

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million tonnes of CO_2	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
World	**14 085**	**14 772**	**15 624**	**15 602**	**15 678**	**16 516**	**17 112**	**17 655**	**18 206**	**18 052**	**17 819**	**17 619**	**17 735**	**18 317**	**18 628**	**18 995**	**19 639**	**20 335**	**20 733**	**20 966**
Annex I Parties	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	*13 908*
Annex II Parties	*8 607*	*8 997*	*9 496*	*9 248*	*8 884*	*9 398*	*9 599*	*9 695*	*9 920*	*9 544*	*9 292*	*8 911*	*8 833*	*9 109*	*9 173*	*9 175*	*9 360*	*9 672*	*9 811*	*9 803*
North America	*4 631*	*4 889*	*5 073*	*4 934*	*4 738*	*5 020*	*5 222*	*5 240*	*5 291*	*5 088*	*5 006*	*4 758*	*4 719*	*4 923*	*4 948*	*4 916*	*5 074*	*5 315*	*5 389*	*5 301*
Europe	*3 060*	*3 145*	*3 330*	*3 229*	*3 093*	*3 292*	*3 250*	*3 336*	*3 484*	*3 351*	*3 205*	*3 087*	*3 054*	*3 060*	*3 106*	*3 141*	*3 151*	*3 141*	*3 165*	*3 154*
Asia Oceania	*917*	*963*	*1 083*	*1 086*	*1 053*	*1 086*	*1 128*	*1 117*	*1 146*	*1 105*	*1 081*	*1 065*	*1 060*	*1 126*	*1 119*	*1 118*	*1 136*	*1 215*	*1 257*	*1 348*
Annex I EIT	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	*3 976*
Non-Annex I Parties	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	*6 444*
Annex I Kyoto Parties	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	*8 786*
OECD Total	**9 370**	**9 796**	**10 330**	**10 124**	**9 798**	**10 372**	**10 628**	**10 786**	**11 050**	**10 711**	**10 449**	**10 089**	**10 021**	**10 346**	**10 444**	**10 463**	**10 698**	**11 016**	**11 171**	**11 158**
Non-OECD Total	**4 204**	**4 440**	**4 730**	**4 947**	**5 379**	**5 632**	**5 956**	**6 333**	**6 603**	**6 796**	**6 851**	**7 036**	**7 238**	**7 483**	**7 667**	**7 974**	**8 374**	**8 720**	**8 949**	**9 195**
International marine bunkers	**343**	**359**	**379**	**354**	**329**	**339**	**340**	**342**	**352**	**345**	**320**	**287**	**268**	**271**	**294**	**313**	**309**	**325**	**325**	**358**
International aviation bunkers	**168**	**177**	**185**	**178**	**172**	**173**	**188**	**195**	**201**	**200**	**200**	**207**	**209**	**217**	**223**	**245**	**259**	**274**	**288**	**256**

Region/Country/Economy	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Canada	339.4	357.2	375.1	385.3	377.1	391.4	405.0	407.4	421.8	426.9	410.3	392.5	384.6	401.3	402.2	393.7	405.6	435.9	451.7	432.3
Chile	20.8	20.4	19.8	19.5	17.0	17.8	18.6	19.3	20.5	21.2	21.2	18.2	18.9	20.0	19.4	20.1	20.4	24.6	29.8	31.1
Mexico	97.1	110.2	121.4	131.8	138.8	149.8	158.9	176.1	190.4	212.1	228.6	238.8	232.2	241.5	251.6	248.8	259.5	260.1	273.8	264.9
United States	4 291.3	4 532.0	4 697.7	4 548.3	4 360.8	4 626.1	4 817.1	4 834.2	4 868.7	4 661.6	4 595.9	4 365.4	4 334.7	4 521.7	4 545.7	4 522.0	4 668.6	4 879.2	4 937.3	4 868.7
OECD Americas	**4 748.7**	**5 019.7**	**5 214.0**	**5 084.8**	**4 893.7**	**5 187.1**	**5 399.6**	**5 437.0**	**5 501.4**	**5 321.8**	**5 256.0**	**5 015.0**	**4 970.3**	**5 184.5**	**5 219.0**	**5 184.5**	**5 354.0**	**5 599.8**	**5 692.7**	**5 596.9**
Australia	144.1	148.9	158.5	173.3	180.0	182.4	196.7	192.3	198.3	208.0	208.3	214.5	202.5	209.0	221.0	222.1	232.0	242.1	255.3	260.1
Israel	14.4	15.2	16.2	16.4	17.1	17.1	17.9	19.1	19.6	19.6	20.4	21.6	22.4	23.1	24.5	27.0	29.4	31.1	32.4	33.1
Japan	758.8	798.4	907.6	894.7	856.3	885.2	911.5	907.0	931.1	880.7	856.6	833.0	839.5	898.3	878.1	877.1	883.8	952.3	980.3	1 064.4
Korea	52.1	54.0	67.3	70.7	76.8	85.4	97.7	106.4	120.0	124.4	129.4	129.0	137.0	148.9	153.3	159.7	166.0	189.3	200.5	229.3
New Zealand	13.7	15.7	17.1	18.1	17.1	18.8	19.4	18.2	16.3	16.4	16.3	17.9	18.1	19.1	19.6	18.6	19.9	21.1	21.3	23.3
OECD Asia Oceania	**983.1**	**1 032.2**	**1 166.7**	**1 173.3**	**1 147.2**	**1 188.9**	**1 243.1**	**1 242.9**	**1 285.3**	**1 249.1**	**1 230.8**	**1 216.0**	**1 219.5**	**1 298.3**	**1 296.4**	**1 304.4**	**1 330.9**	**1 436.0**	**1 489.8**	**1 610.2**
Austria	48.7	50.5	54.0	51.3	50.2	54.3	51.8	54.5	57.2	55.7	52.8	51.0	51.1	52.9	54.3	53.2	54.2	52.1	52.5	56.5
Belgium	116.8	126.7	132.7	130.6	115.6	124.5	123.5	129.0	132.3	125.7	115.5	109.3	100.6	102.6	101.9	102.6	102.8	104.6	105.9	107.9
Czech Republic	151.0	150.0	147.1	146.3	152.6	157.4	166.9	163.0	172.5	165.8	166.5	169.3	170.5	173.1	173.1	173.1	174.2	170.8	163.5	155.1
Denmark	55.0	57.1	56.0	49.8	52.5	58.1	59.7	59.2	62.7	62.5	52.5	54.6	51.3	52.9	60.5	61.1	59.3	55.5	49.8	50.4
Estonia	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	36.1
Finland	39.8	43.7	48.0	44.5	44.4	50.5	50.2	54.7	54.4	55.2	46.0	44.5	43.2	44.4	48.6	49.5	53.8	53.1	52.9	54.4
France	431.9	448.6	484.8	464.6	430.6	469.3	455.3	474.7	481.8	461.4	414.1	396.7	381.0	369.5	360.3	347.8	342.3	340.5	355.9	352.3
Germany	978.6	1 003.2	1 053.1	1 039.5	975.5	1 032.2	1 017.2	1 055.9	1 103.6	1 055.6	1 022.3	982.3	983.9	1 006.1	1 014.6	1 016.3	1 007.2	1 001.2	976.8	950.4
Greece	25.2	29.2	34.1	32.6	34.5	39.1	40.4	42.8	45.1	45.3	44.9	46.3	49.3	51.0	54.6	54.6	60.0	64.1	69.2	70.1
Hungary	60.3	62.2	66.6	68.8	70.7	74.3	77.9	85.8	84.4	83.7	82.9	83.1	79.6	81.5	80.8	79.3	80.2	75.3	74.2	66.7
Iceland	1.4	1.5	1.7	1.7	1.6	1.6	1.6	1.8	1.8	1.7	1.7	1.6	1.6	1.7	1.6	1.7	1.7	1.8	1.8	1.9
Ireland	21.7	21.4	20.9	22.6	21.1	22.1	23.7	23.2	27.1	25.9	25.8	25.2	25.1	24.9	26.4	27.8	29.4	28.5	29.5	29.8
Italy	292.9	309.5	331.1	334.9	319.6	345.6	335.1	343.5	358.8	359.8	349.8	345.3	341.3	348.3	347.5	349.5	369.6	374.1	391.8	397.4
Luxembourg	15.4	15.1	16.4	15.1	12.1	13.0	12.3	13.6	12.7	11.9	10.1	9.5	8.9	9.7	9.9	9.6	9.1	9.5	10.2	10.4

A large amount of data is available online for free at:
http://www.iea.org/statistics/topics/CO2emissions

Thank you. emissions@iea.org

Exercises – things to remember

- Sectoral approach estimates CO_2 emissions using the consumption of fuels, not the supply
- Consumption of fuels includes Own Use in the Energy Sector and Transformation of fossil fuels in the Electricity Sector
- Certain fuels can be used for both energy and non-energy purposes – only estimate CO_2 emissions from energy use of these fuels
- CO_2 from biomass use is not added to emissions totals (reported as memo items) but emissions of other greenhouse gases from biomass are added to totals
- Emissions from consumption of bunker fuels are not included in totals for individual countries