

Greenhouse Gases

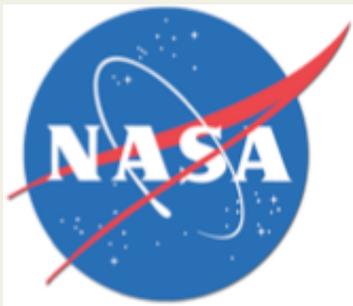
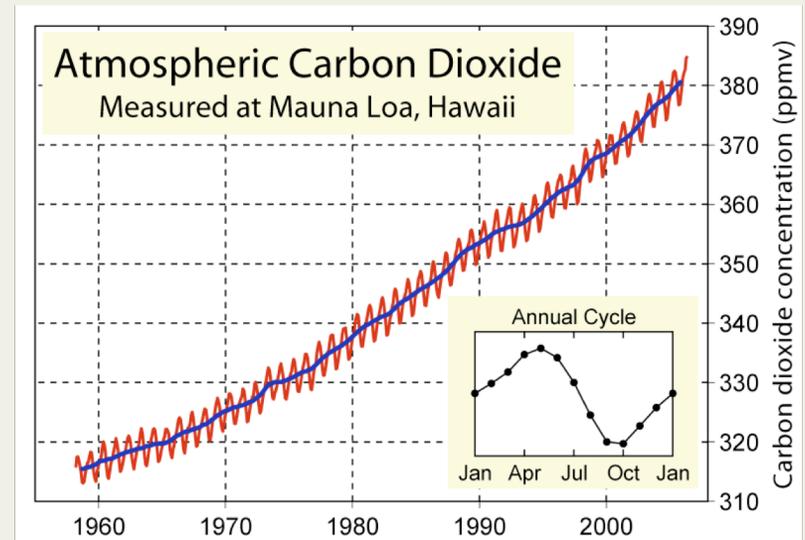
Past, Present and Future

Session 5

Neil Leary

Changing Planet Study Group

June 28 – July 1, 2011



Cooling the Liberal Arts Curriculum
A NASA-GCCE Funded Project



Objectives of the Session

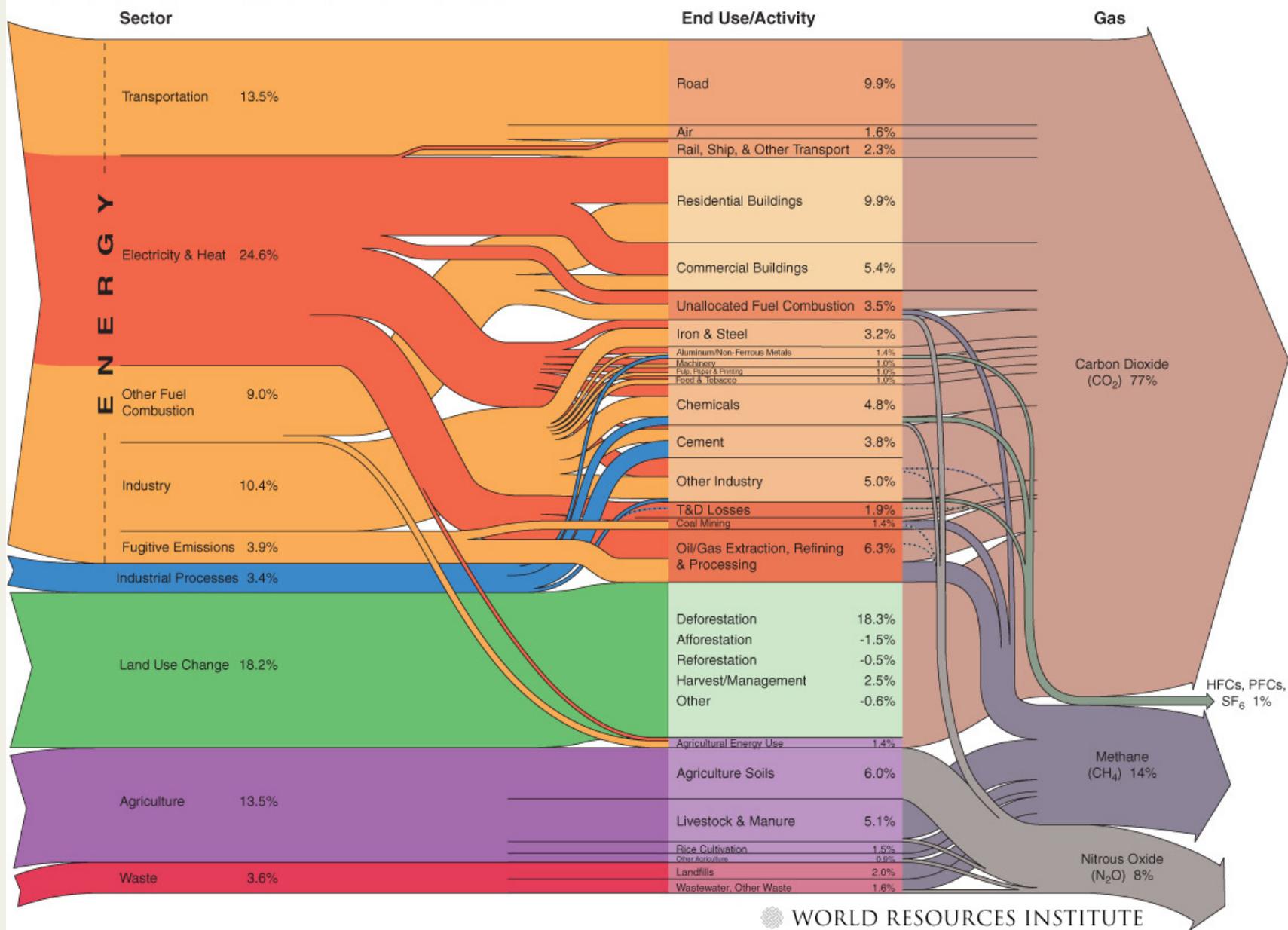
- Gain literacy about GHG emissions sources, trends, and future projections
 - Cross-country comparisons
 - Influences of changes in income, population, energy efficiency, and fuel mix on emissions trends
 - Policy implications
- Become familiar with the Climate Analysis Indicators Tool (CAIT)
 - Explore ways for students to use CAIT to develop quantitative literacy about GHG emissions.
- Identify ‘essential principles’ for students to learn about GHGs

The main greenhouse gases

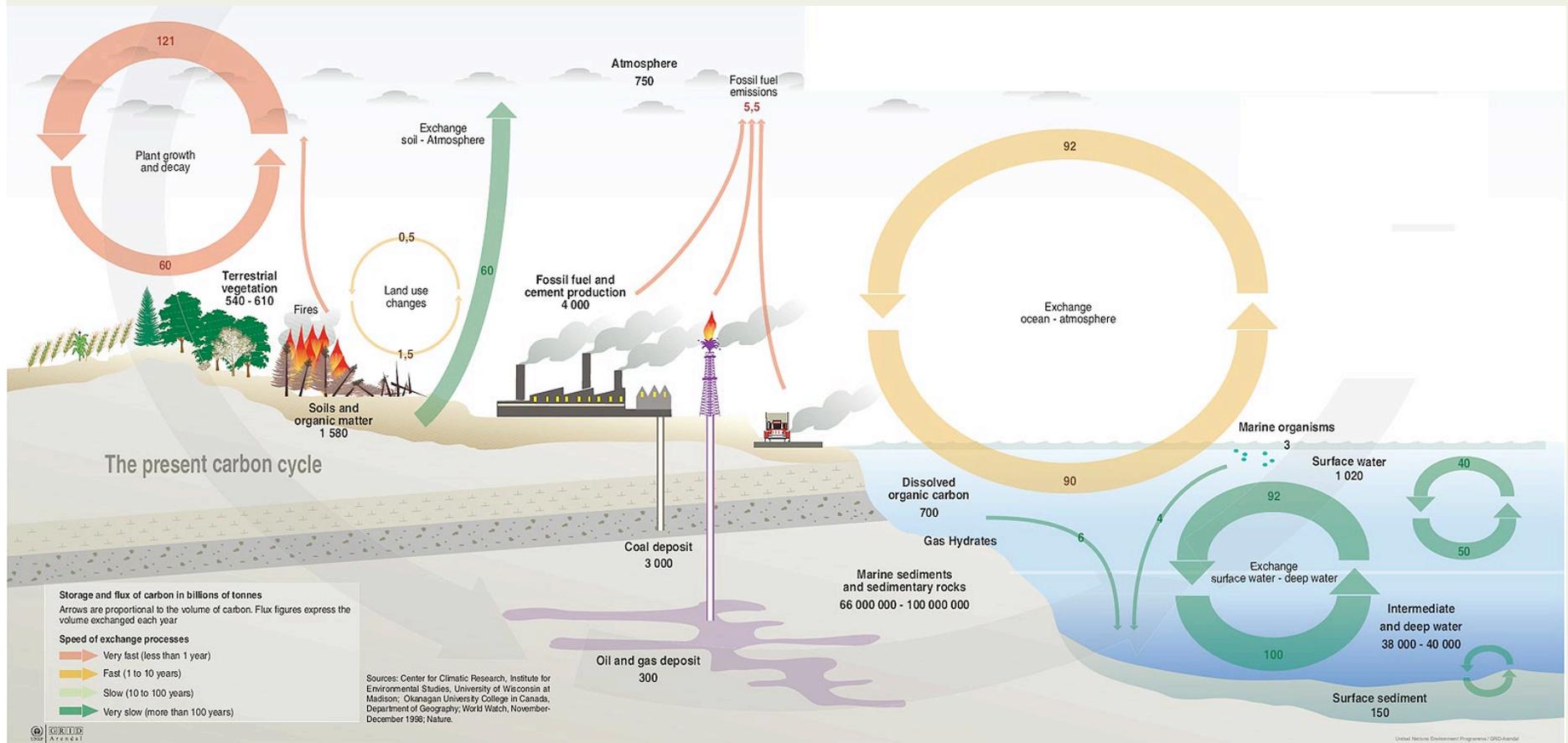
Name	Pre-industrial concentration (ppmv *)	Concentration in 1998 (ppmv)	Atmospheric lifetime (years)	Main human activity source	GWP **
Water vapour	1 to 3	1 to 3	a few days	-	-
Carbon dioxide (CO ₂)	280	365	variable	fossil fuels, cement production, land use change	1
Methane (CH ₄)	0,7	1,75	12	fossil fuels, rice paddies waste dumps, livestock	23
Nitrous oxide (N ₂ O)	0,27	0,31	114	fertilizers, combustion industrial processes	296
HFC 23 (CHF ₃)	0	0,000014	260	electronics, refrigerants	12 000
HFC 134 a (CF ₃ CH ₂ F)	0	0,0000075	13,8	refrigerants	1 300
HFC 152 a (CH ₃ CHF ₂)	0	0,0000005	1,4	industrial processes	120
Perfluoromethane (CF ₄)	0,00004	0,00008	> 50 000	aluminium production	5 700
Perfluoroethane (C ₂ F ₆)	0	0,000003	10 000	aluminium production	11 900
Sulphur hexafluoride (SF ₆)	0	0,0000042	3 200	dielectric fluid	22 200

* ppmv = parts per million by volume, ** GWP = Global warming potential (for 100 year time horizon).

World GHG Emissions Flow Chart

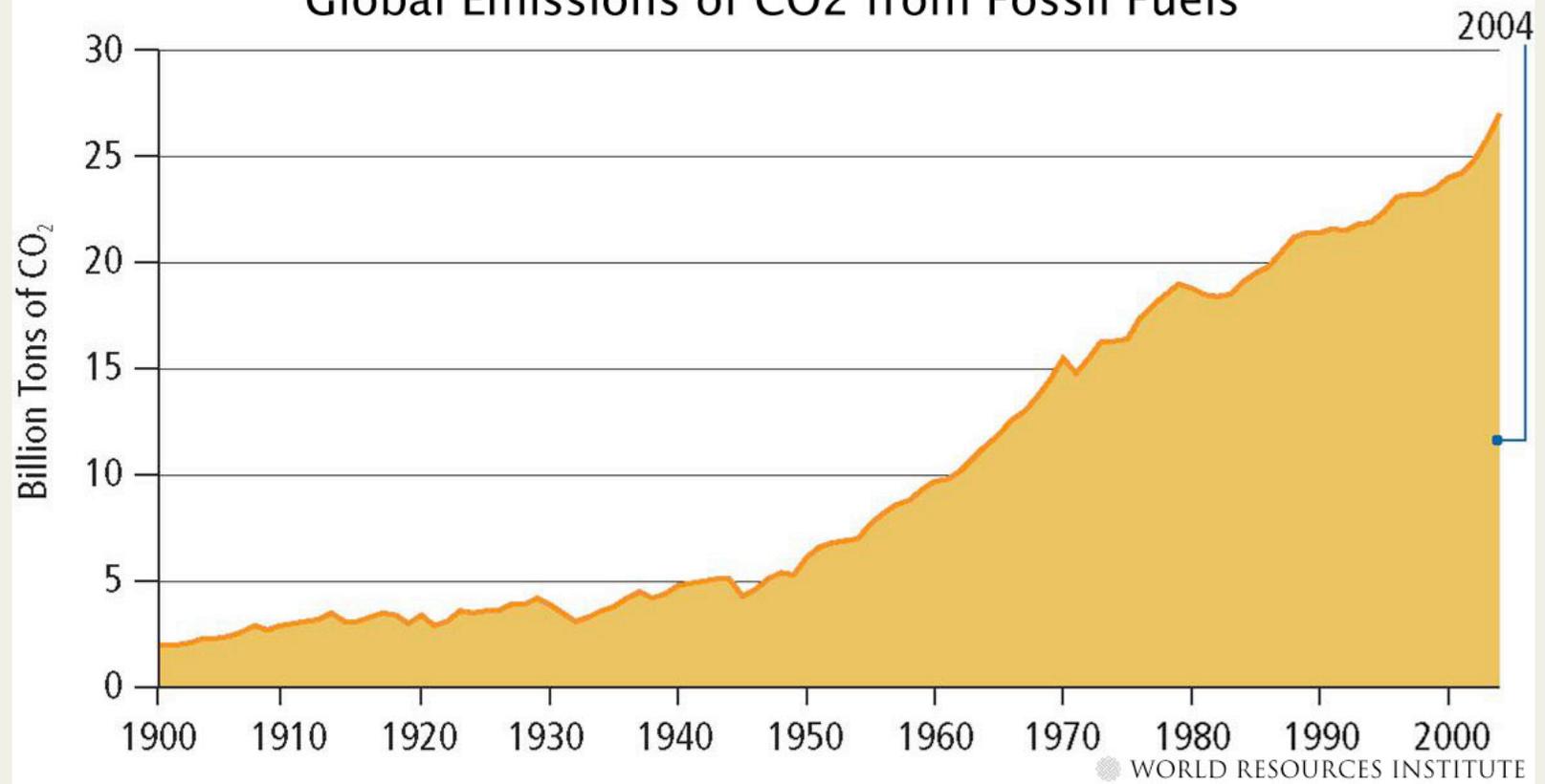


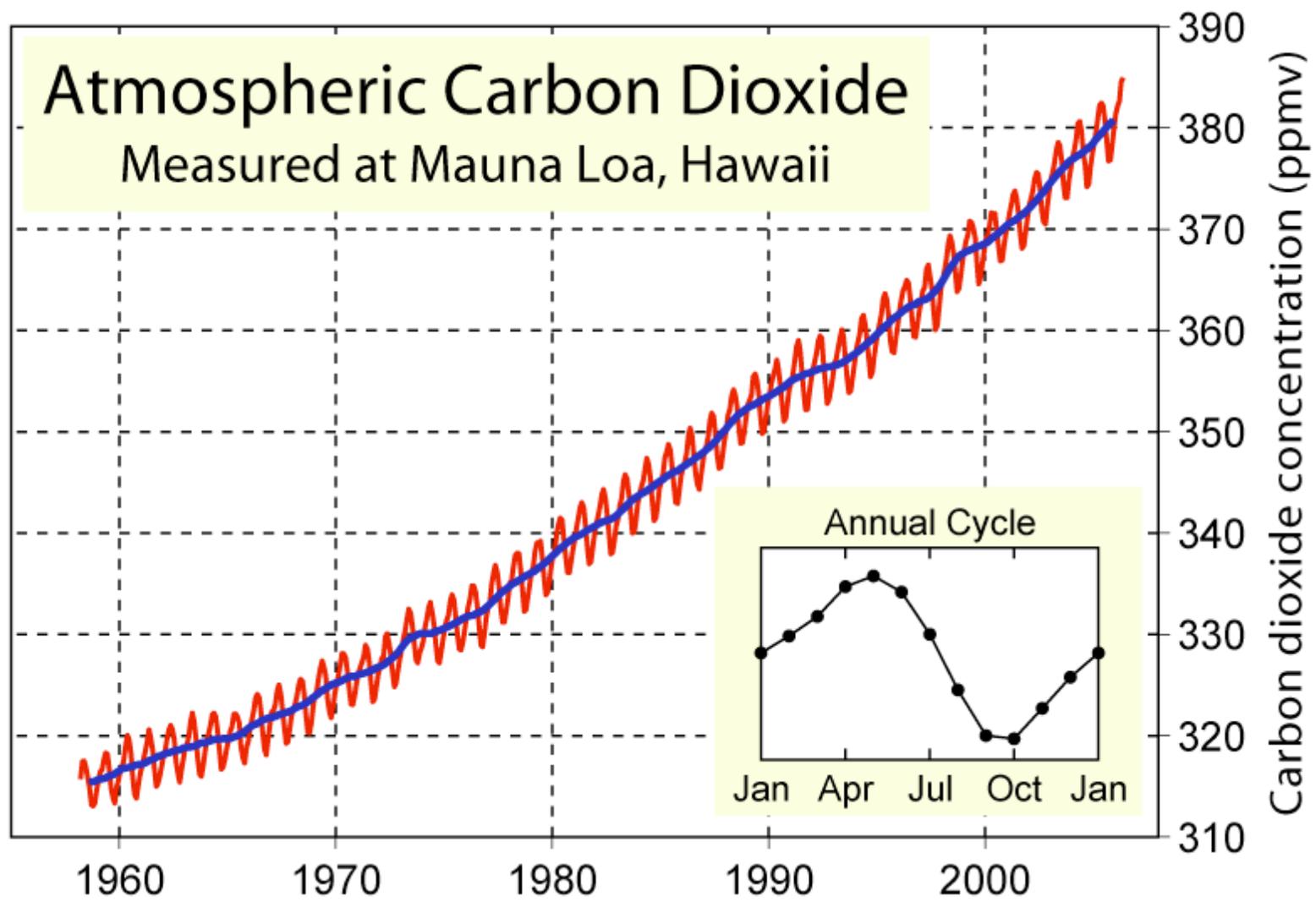
Carbon Cycle



Source: UNEP, GRID/Arendal, Vital Climate Graphics, <http://www.grida.no/publications/vg/climate/>

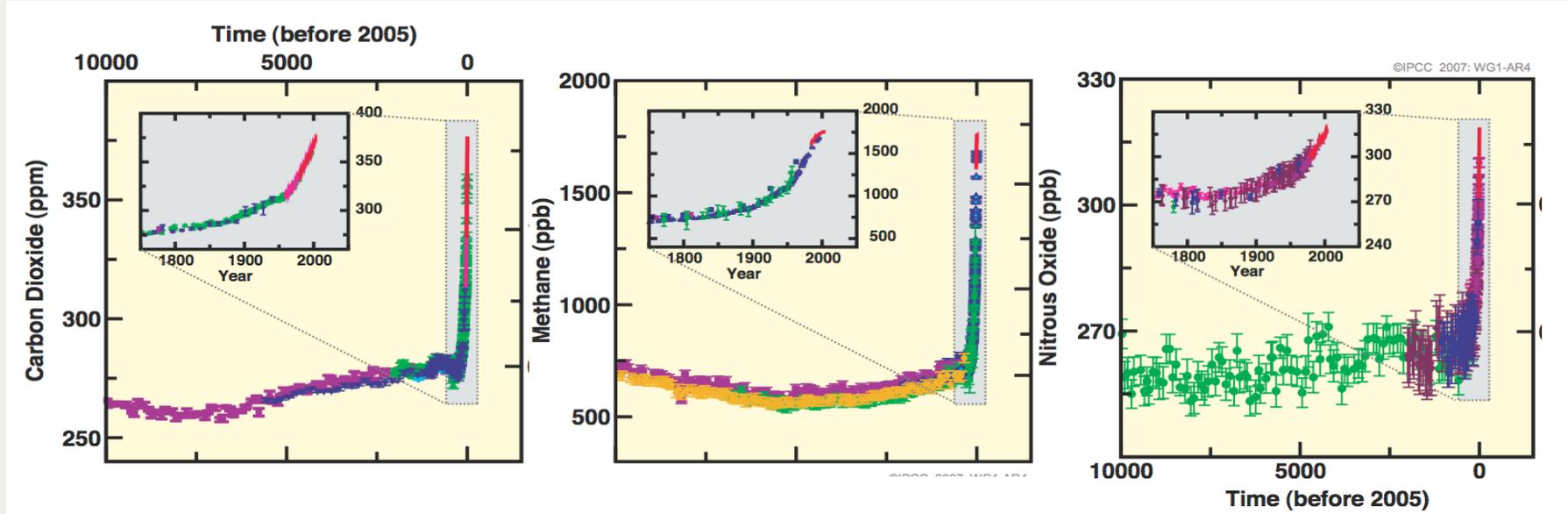
Global Emissions of CO₂ from Fossil Fuels





“Keeling Curve.” Average monthly CO₂ concentration (red) and 12 month moving average (blue). This figure was created by Robert Rohde from published data.

Industrial revolution and the atmosphere



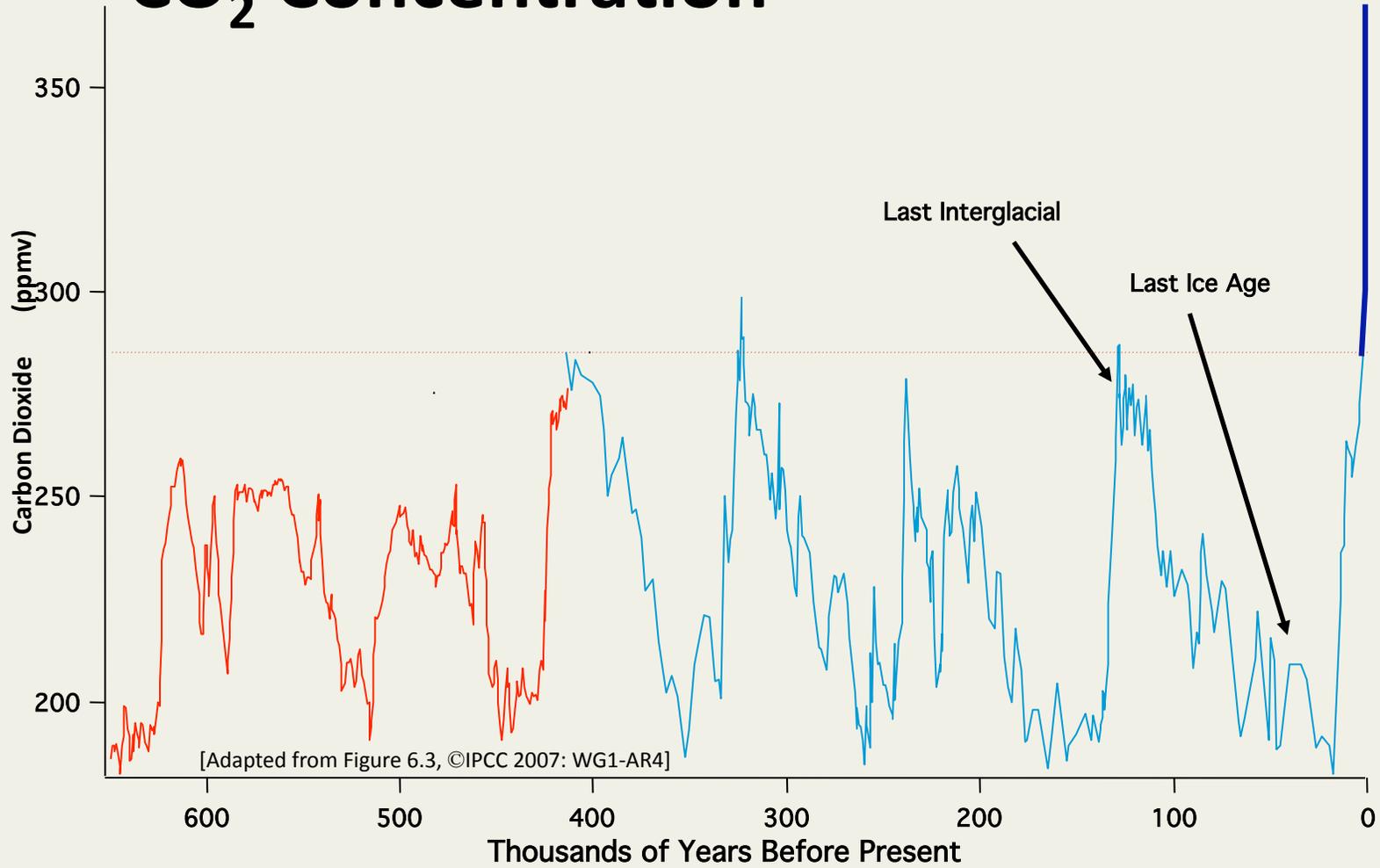
Carbon dioxide

Methane

Nitrous Oxide

Source: IPCC 2007, WGI, Figure SPM-1.

CO₂ Concentration



CAIT/WRI

Climate Analysis Indicators Tool

Login to CAIT:

<http://cait.wri.org/>

Tool for exploring and analyzing GHG and related social and economic data

The screenshot shows the CAIT/WRI website in a browser window. The browser title is "Climate Analysis Indicators Tool (CAIT)" and the address bar shows "http://cait.wri.org/". The website header includes the World Resources Institute logo and navigation links like "Most Visited", "Getting Started", "Latest Headlines", "Apple", "Yahoo!", "Google Maps", "YouTube", "Wikipedia", and "News". Below the header, there are links for "CAIT Home", "Register", and "Login". The main content area features a "Welcome!" message and a description of the tool. A "What's New" section highlights updates like "CAIT-US 4.0 Now Online", "CAIT 7.0 Now Online", and "CAIT-V&A 3.0 Now Online". A "Related Publications" section lists "Charting the Midwest", "Navigating the Numbers", "Target: Intensity", and "Growing in the Greenhouse". The footer contains copyright information for 2010 and contact details for the World Resources Institute.

Climate Analysis Indicators Tool (CAIT)

http://cait.wri.org/

World Resources Institute

CAIT Home

CAIT Home

Register | Login

CAIT Products

CAIT

CAIT-UNFCCC

CAIT-U.S.

CAIT-V&A

(About CAIT)

Feedback & Discussion Forum

Charts & Figures

FAQ

Acknowledgements

Resources & Links

Welcome!

The Climate Analysis Indicators Tool (CAIT) is an information and analysis tool on global climate change developed by the World Resources Institute. CAIT provides a comprehensive and comparable database of greenhouse gas emissions data (including all major sources and sinks) and other climate-relevant indicators. CAIT can be used to analyze a wide range of climate-related data questions and to help support future policy decisions made under the Climate Convention and in other fora.

- Register and Access CAIT.
- Already registered? Login.
- CAIT News and FAQ.

What's New

CAIT-US 4.0 Now Online.
CAIT-US 4.0 includes completely revised emissions data through 2007 as well as revised socio-economic data.

CAIT 7.0 Now Online.
CAIT 7.0 features international GHG emissions data through 2006 and updated CO2 projection data. Where applicable, socioeconomic and natural factor indicators have been updated as well.

In addition, download our COP15 brochure (8 pages) with CAIT-based graphics.

CAIT-V&A 3.0 Now Online.
CAIT-V&A 3.0 features a revised set of indicators on vulnerability and adaptive capacity, updated documentation, and improved mapping functionality.

Related Publications:

- Charting the Midwest
- Navigating the Numbers
- Target: Intensity
- Growing in the Greenhouse

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Done

Countries w/ largest GHG emissions

Select "GHG Emissions"

Select "Yearly Emissions"

Select:

- 2005
- National Total
- All GHGs
- Include Land-Use Change & Forestry

Select "Update"

Sort by MtCO2e in descending order

Select "Table Info" to view information about the data

Select "Map" to generate a global map of the data

Select "Download" to download data to spreadsheet.

Repeat for CO2 w/ LUCF and CO2 w/o LUCF

The screenshot shows the CAIT - Yearly Emissions website interface. The browser address bar displays the URL: <http://cait.wri.org/cait.php?page=yearly&mode=view&sort=val-desc&pHints>. The page title is "CAIT - Yearly Emissions". The website header includes "WORLD RESOURCES INSTITUTE" and "CAIT". The main content area shows a navigation menu on the left with categories like "Introduction", "Indicators", "Analysis", "Customize", "Notes & Definitions", "Questions and Comments", and "Credits". The "Indicators" section is expanded to show "GHG Emissions" and "Yearly Emissions". The "Yearly Emissions" section is further expanded to show "Cumulative Emissions", "Emissions Intensities", and "Projections". The "Analysis" section is expanded to show "Compare Gases", "Compare Sectors", "Compare Indicators", "Compare Countries", "Calculate Trends", and "Graph Trends". The "Customize" section is expanded to show "Countries & Regions", "User-Defined Regions", and "Display". The "Notes & Definitions" section is expanded to show "Questions and Comments" and "Credits". The "Questions and Comments" section is expanded to show "Questions and Comments". The "Credits" section is expanded to show "Credits".

The main content area displays a table titled "Total GHG Emissions in 2005 (Includes land use change)". The table columns are "Country", "MtCO2e", "Rank", "% of World Total", and "Metric tons CO2e Per Person". The table lists 33 countries and their emissions data for 2005. The data is as follows:

Country	MtCO2e	Rank	% of World Total	Metric tons CO2e Per Person
China	7,185.5	(1)	16.64%	5.5 (94)
United States of America	6,797.2	(2)	15.74%	23.0 (10)
European Union (27) [1]	5,043.1	(3)	11.68%	10.3 (48)
Brazil	2,841.6	(4)	6.58%	15.3 (19)
Indonesia	2,042.2	(5)	4.73%	9.3 (56)
Russian Federation	2,012.6	(6)	4.66%	14.1 (23)
India [1]	1,859.0	(7)	4.30%	1.7 (154)
Japan [1]	1,346.3	(8)	3.12%	10.5 (45)
Germany [1]	977.5	(9)	2.26%	11.9 (33)
Canada	803.9	(10)	1.86%	24.9 (9)
Mexico	685.0	(11)	1.59%	6.6 (82)
United Kingdom [1]	644.1	(12)	1.49%	10.7 (44)
Korea (South) [1]	568.9	(13)	1.32%	11.8 (34)
Italy [1]	562.4	(14)	1.30%	9.6 (55)
Iran [1]	559.2	(15)	1.29%	8.1 (68)
Australia [1]	557.6	(16)	1.29%	27.3 (7)
France [1]	550.4	(17)	1.27%	9.0 (60)
Ukraine [1]	493.9	(18)	1.14%	10.5 (46)
Nigeria	455.3	(19)	1.05%	3.2 (118)
Venezuela	447.4	(20)	1.04%	16.8 (16)
Spain [1]	436.7	(21)	1.01%	10.1 (51)
Turkey	424.6	(22)	0.98%	6.0 (86)
South Africa [1]	422.2	(23)	0.98%	9.0 (61)
Saudi Arabia [1]	376.6	(24)	0.87%	16.3 (18)
Malaysia [2]	374.9	(25)	0.87%	14.6 (21)
Poland [1]	372.8	(26)	0.86%	9.8 (53)
Argentina	359.6	(27)	0.83%	9.3 (58)
Thailand [1]	351.1	(28)	0.81%	5.3 (97)
Taiwan* [1,2]	283.8	(29)	0.66%	12.4 (31)
Congo, Dem. Republic	269.3	(30)	0.62%	4.6 (107)
Myanmar	265.0	(31)	0.61%	5.5 (95)
Pakistan [1]	239.7	(32)	0.55%	1.5 (156)
Egypt [1]	227.2	(33)	0.53%	2.9 (124)

Countries with largest GHG emissions, 2005

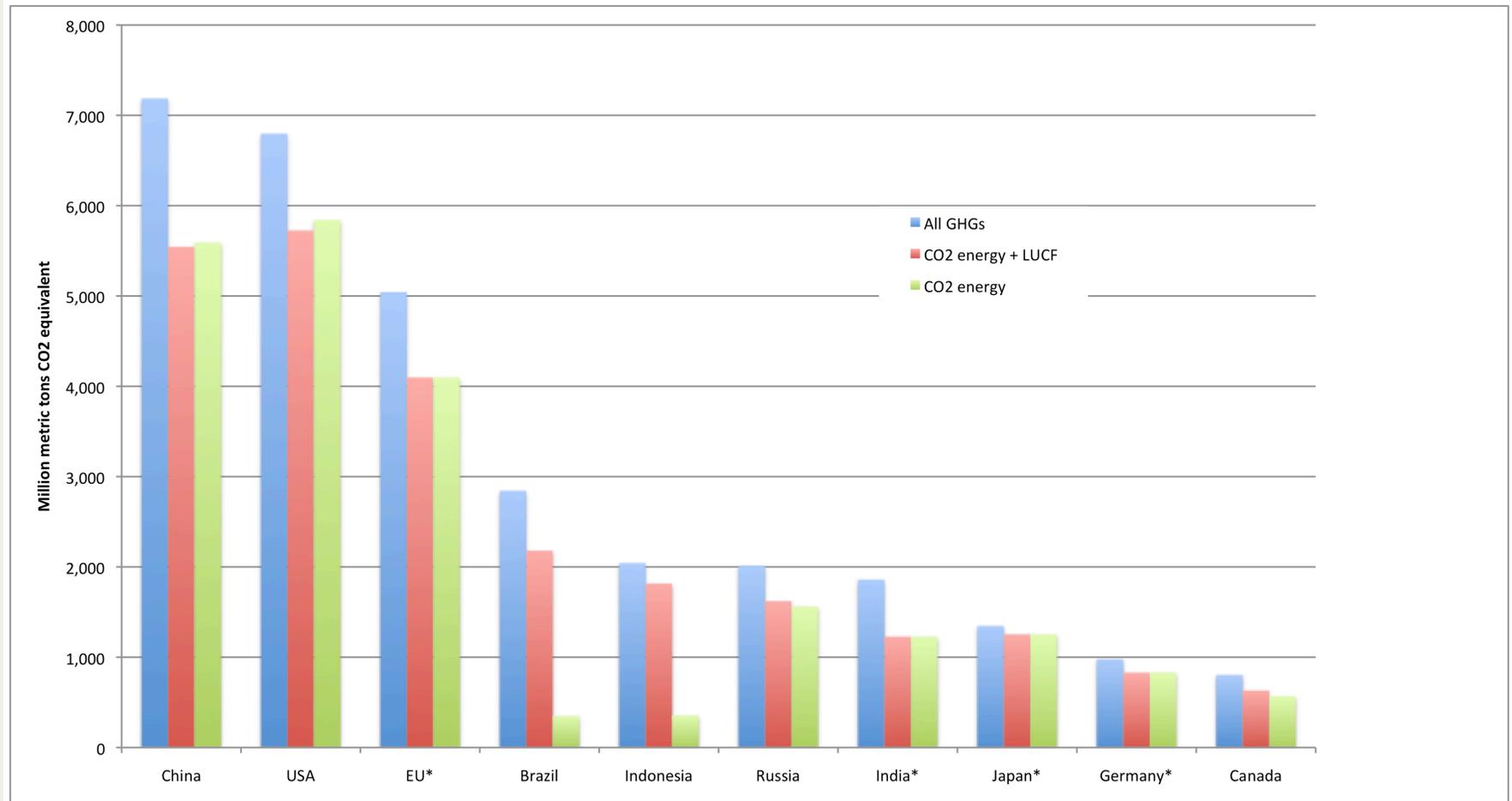
(Source: WRI, CAIT, Version 8)

All GHGs from Energy & Land Use Change			CO2 from Energy & Land Use Change			CO2 from Energy Only		
Rank	Country	MtCO2e	Rank	Country	MtCO2e	Rank	Country	MtCO2e
1	China	7,186	1	USA	5,725	1	USA	5,842
2	USA	6,797	2	China	5,544	2	China	5,591
3	EU*	5,043	3	EU*	4,097	3	EU*	4,097
4	Brazil	2,842	4	Brazil	2,180	4	Russia	1,563
5	Indonesia	2,042	5	Indonesia	1,815	5	Japan	1,253
6	Russia	2,013	6	Russia	1,621	6	India*	1,228
7	India*	1,859	7	Japan*	1,253	7	Germany*	829
8	Japan*	1,346	8	India*	1,228	8	Canada	567
9	Germany*	978	9	Germany*	829	9	UK*	543
10	Canada	804	10	Canada	631	10	S. Korea*	495

*Data not available for emissions from land use change.

GHG Emissions Selected Countries, 2005

Data source: WRI, CAIT, version 8.0



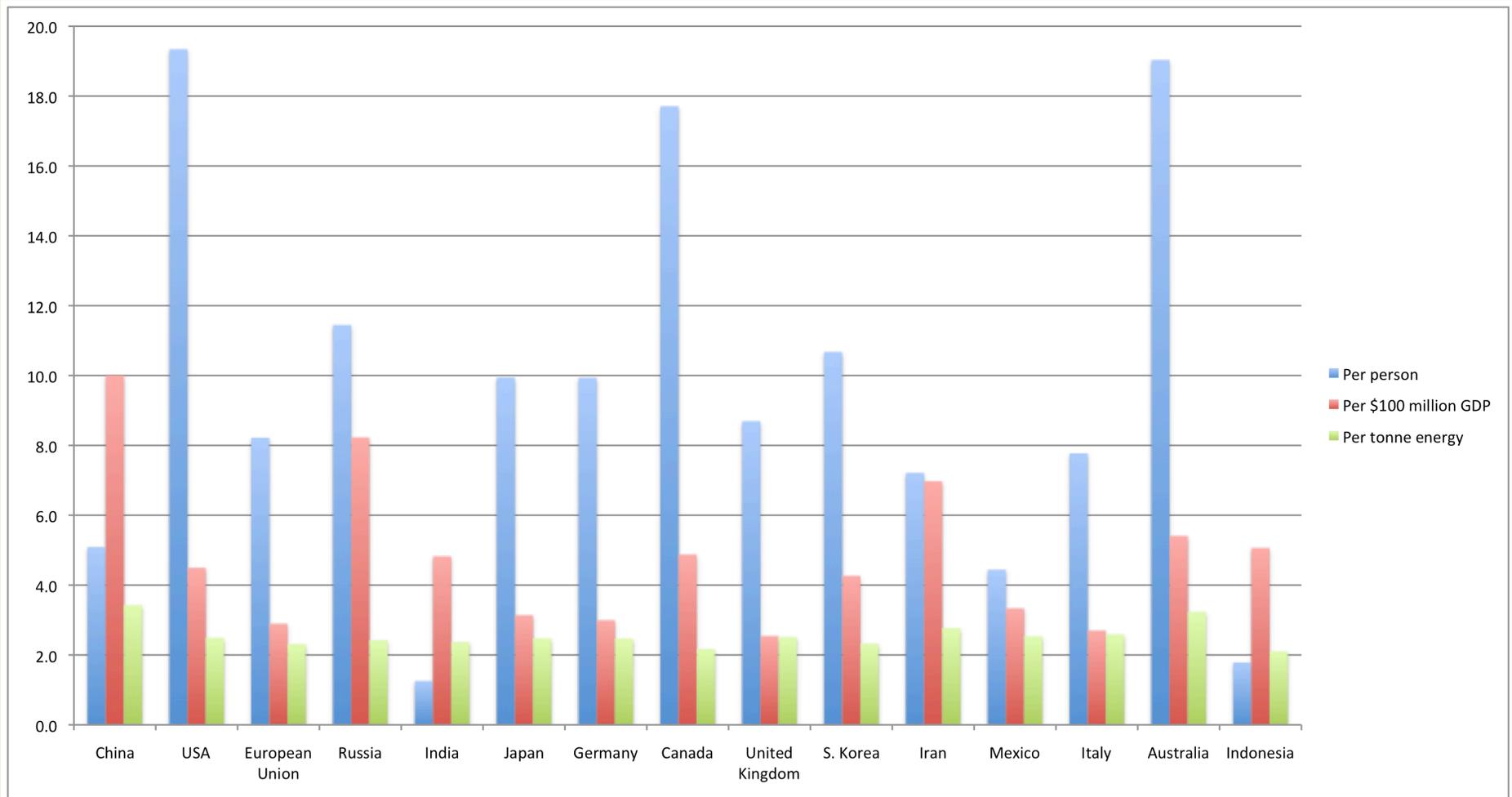
*Data not available for emissions from land use change.

Top 10 emitters: total, per person, per \$ gdp, per ton energy consumed

Rank	Total CO2 from Energy	CO2 per person	CO2 per \$ GDP	CO2 per tonne energy consumed
1	USA	Qatar	Nauru	Congo
2	China	Kuwait	Uzbekistan	Mongolia
3	European Union	UAE	N Korea	Korea (North)
4	Russia	Bahrain	Turkmenistan	Lebanon
5	Japan	Luxembourg	Serbia & Mont	China
6	India	USA	Mongolia	Cyprus
7	Germany	Trinidad & Tobago	Kazakhstan	Bosnia & Herzegovina
8	Canada	Australia	Ukraine	Greece
9	United Kingdom	Canada	China	Estonia
10	Korea (South)	Saudi Arabia	Iraq*	Australia

Data source: WRI, CAIT, Version 8.0

CO₂ Emissions from Energy, 2007



Data source: WRI, CAIT, version 8.0

Responsibility for Climate Change

Contributions to annual CO2 emissions from energy and to CO2 concentration in the atmosphere

	Annex I	Non-Annex I
CO2 Emissions 2007	49.4%	49.1%
CO2 Concentration: 1990 - 2007	57.4%	41.1%
CO2 Concentration: 1950 - 2007	66.4%	32.6%
CO2 Concentration: 1900 - 2007	69.1%	29.9

Data source: WRI, CAIT, Version 8.0

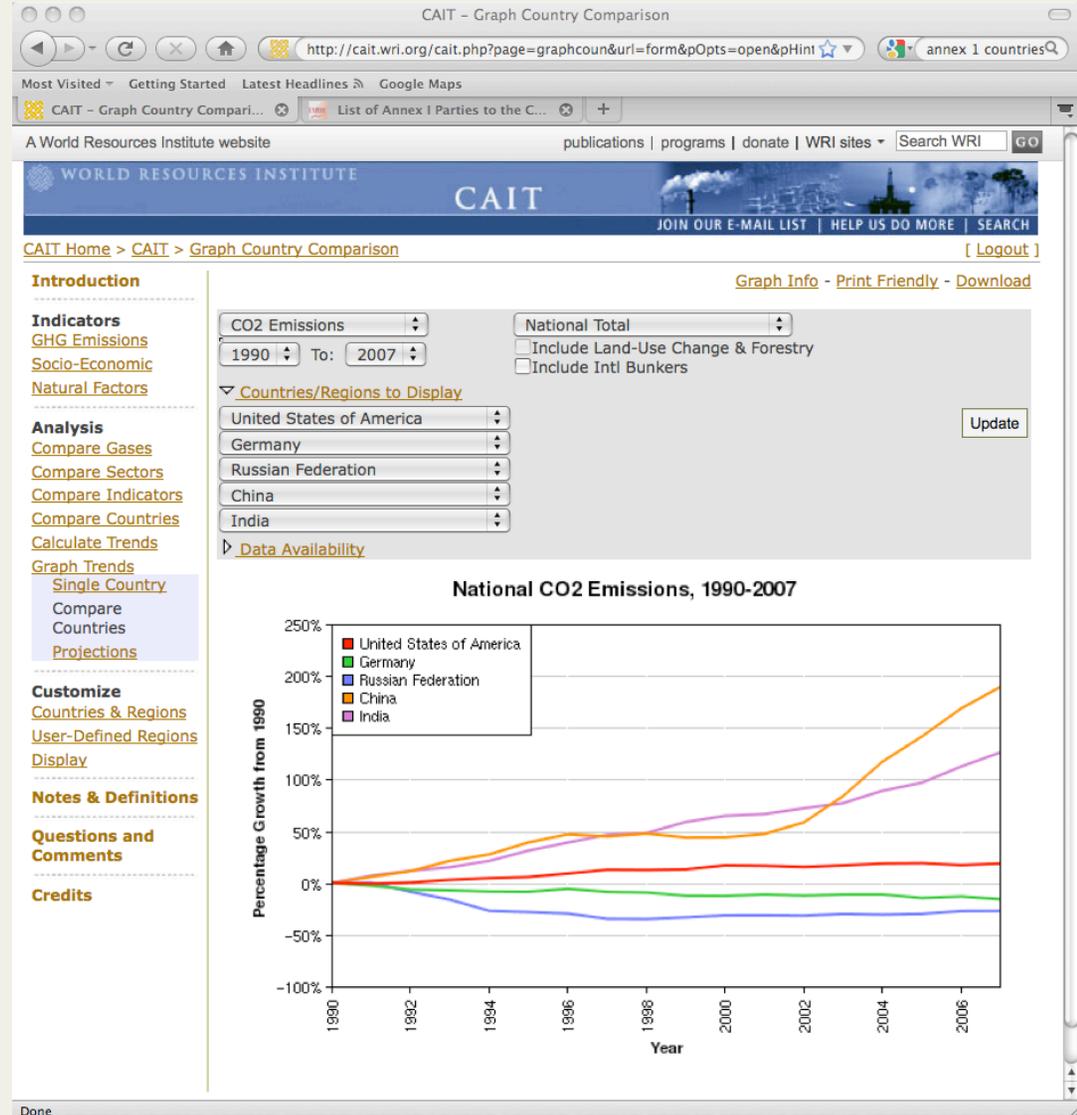
CO2 emission trends

Select:

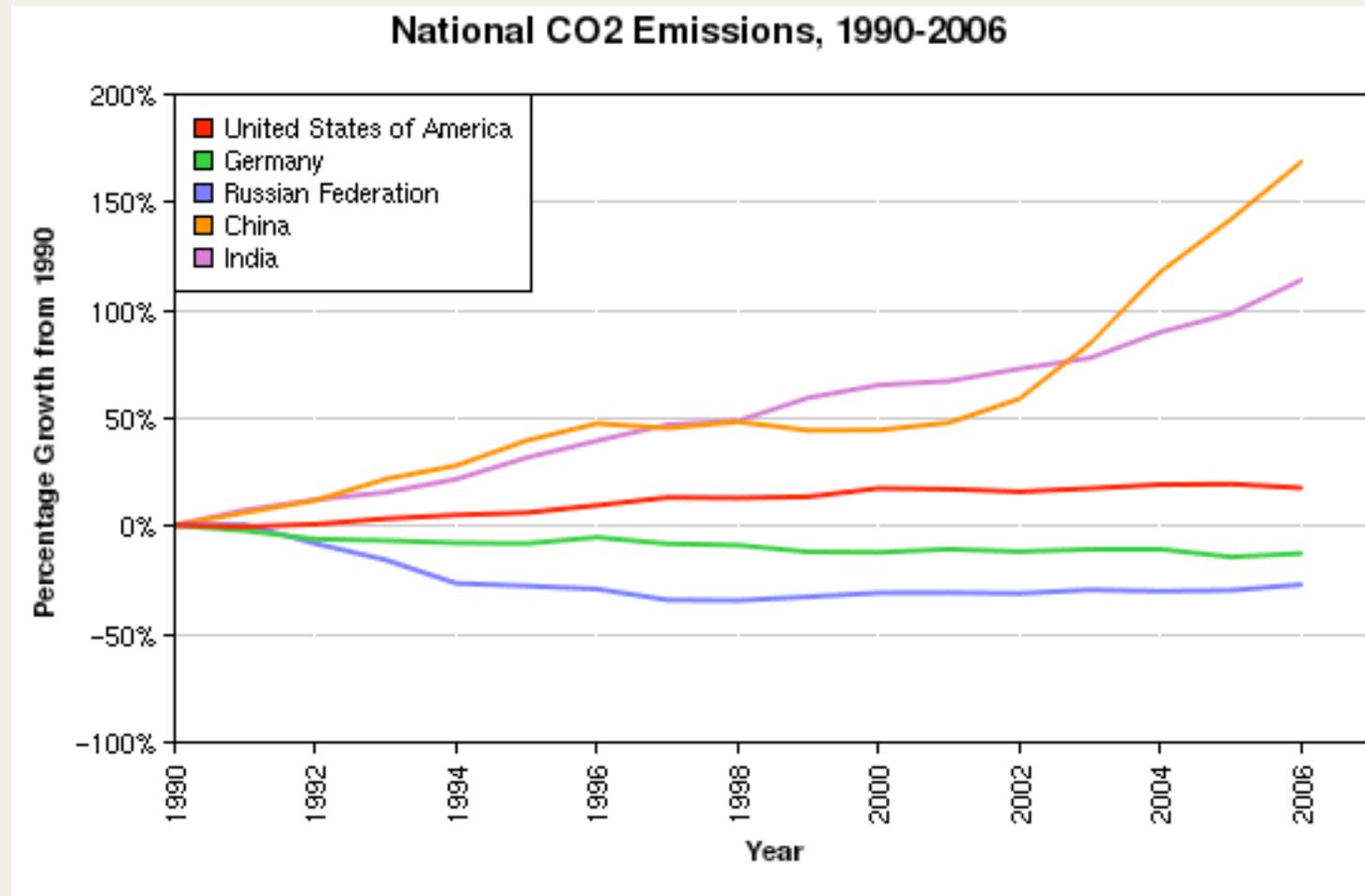
- “Graph Trends”
- “Compare Countries”
- CO2 emissions
- Time period
- Countries

Select “Update”

Can save image by right clicking over graph



CO₂ emission trends: 5 country comparison



Emissions of CO₂ from energy use and industrial sources.
Graph generated from CAIT, July 2010: <http://cait.wri.org/>

Kaya Identity & decomposition

$$C = \text{Pop} \times \text{GDP/Pop} \times \text{E/GDP} \times \text{C/E}$$

Emissions = population x per capita income x energy intensity x carbon intensity

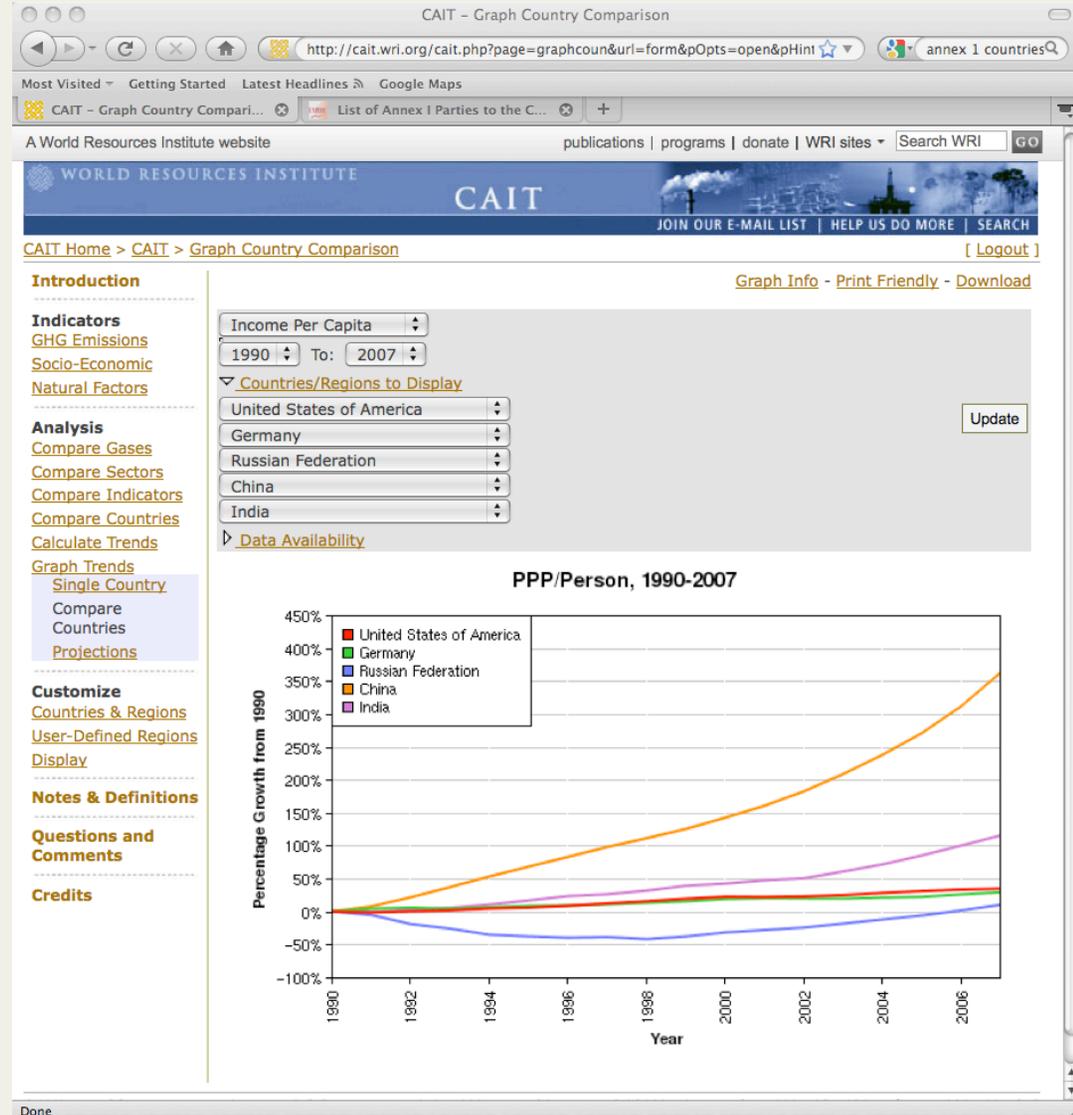
For small changes:

$$\begin{aligned} \% \Delta \text{CO}_2 = & \% \Delta \text{population} \\ & + \% \Delta \text{per capita income} \\ & + \% \Delta \text{energy intensity} \\ & + \% \Delta \text{carbon intensity} \end{aligned}$$

Graph trends in Kaya identity factors

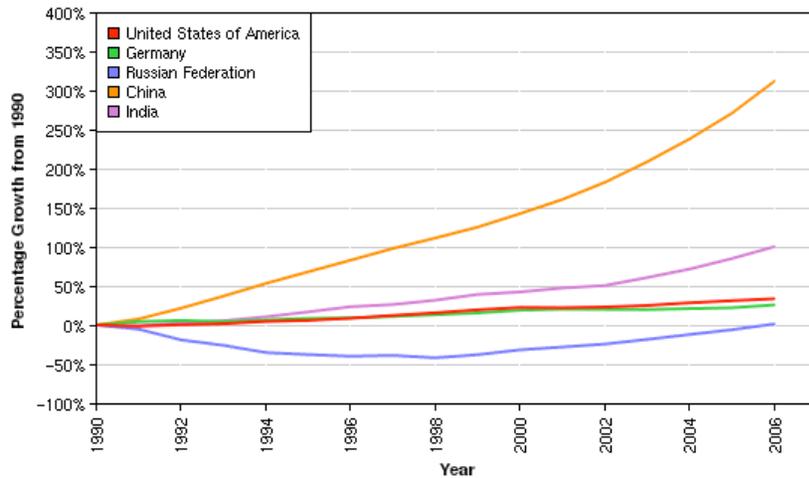
Under “Graph Trends”, “Compare Countries” select:

- Income per capita
- Population
- Carbon intensity of economy
- Carbon intensity of energy use

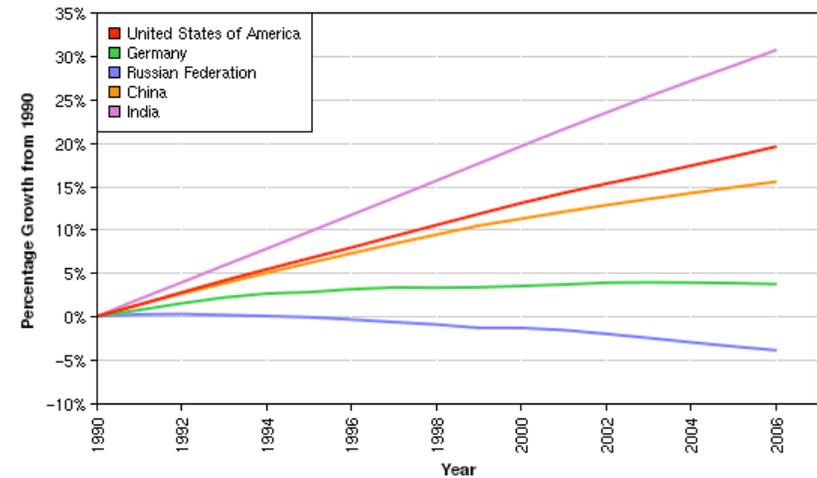


Five Country Comparison

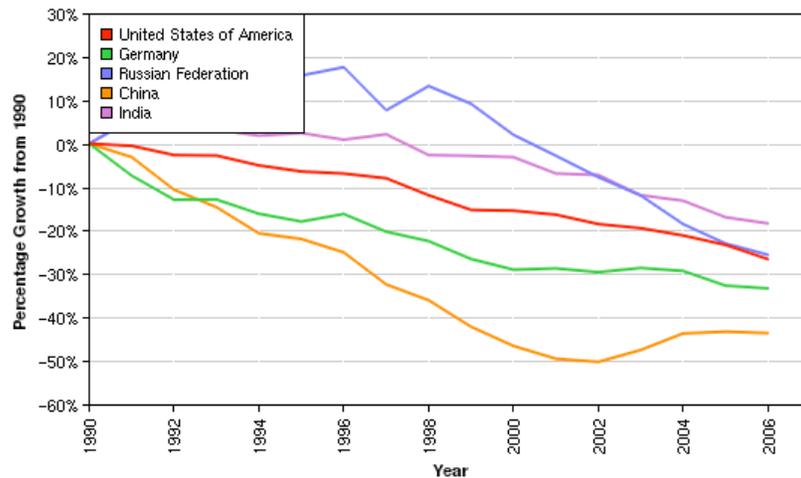
PPP/Person, 1990-2006



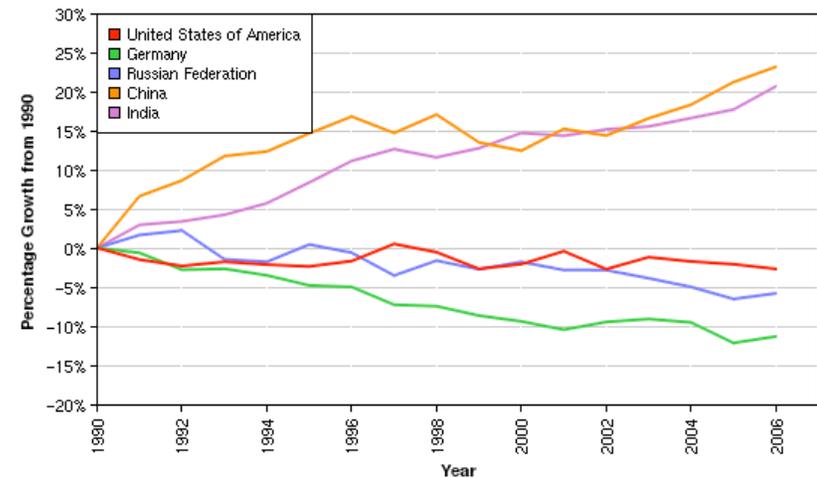
Population, 1990-2006



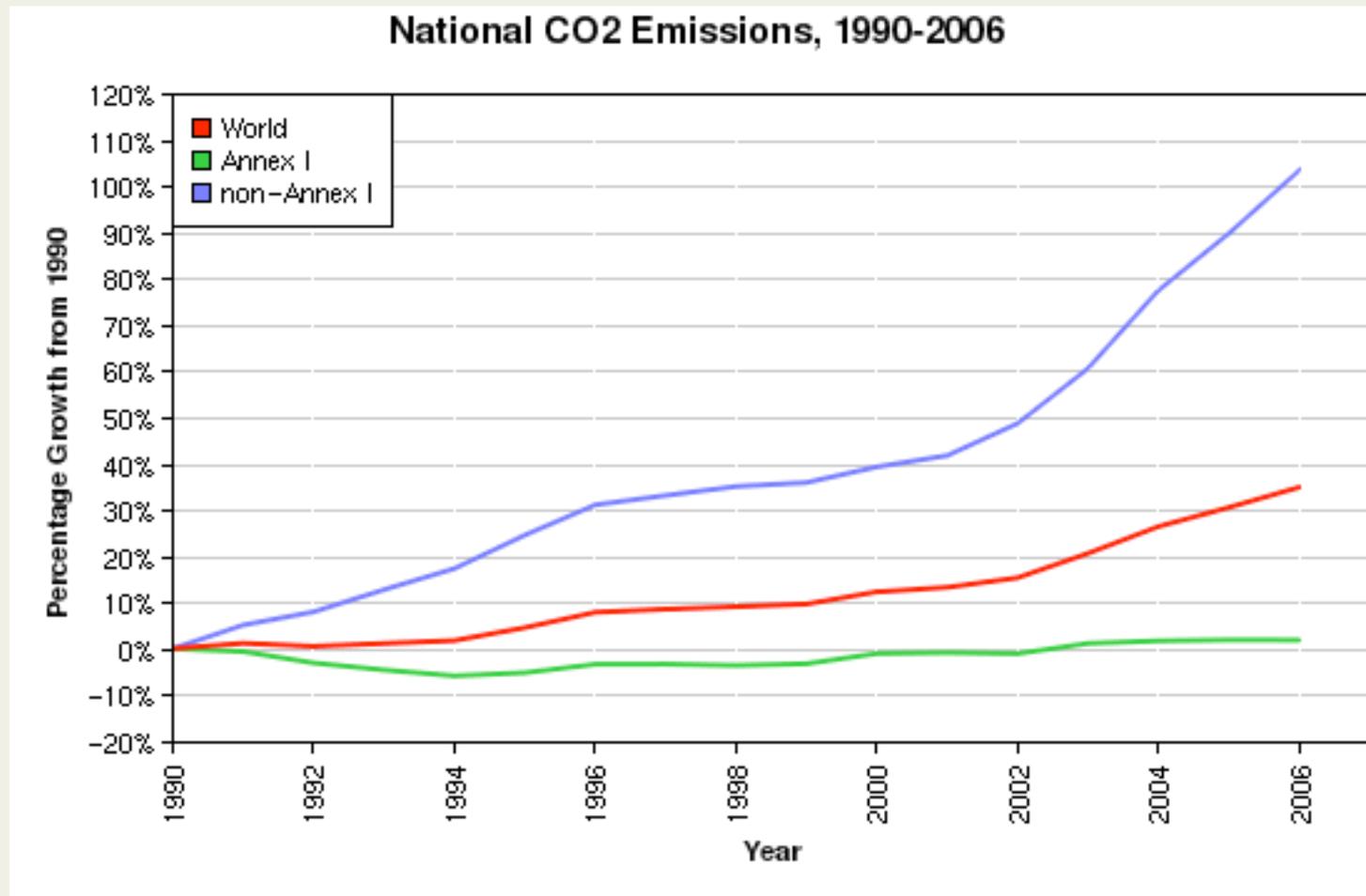
CO2 Intensity of Economy, 1990-2006



Carbon Intensity of Energy Use, 1990-2006



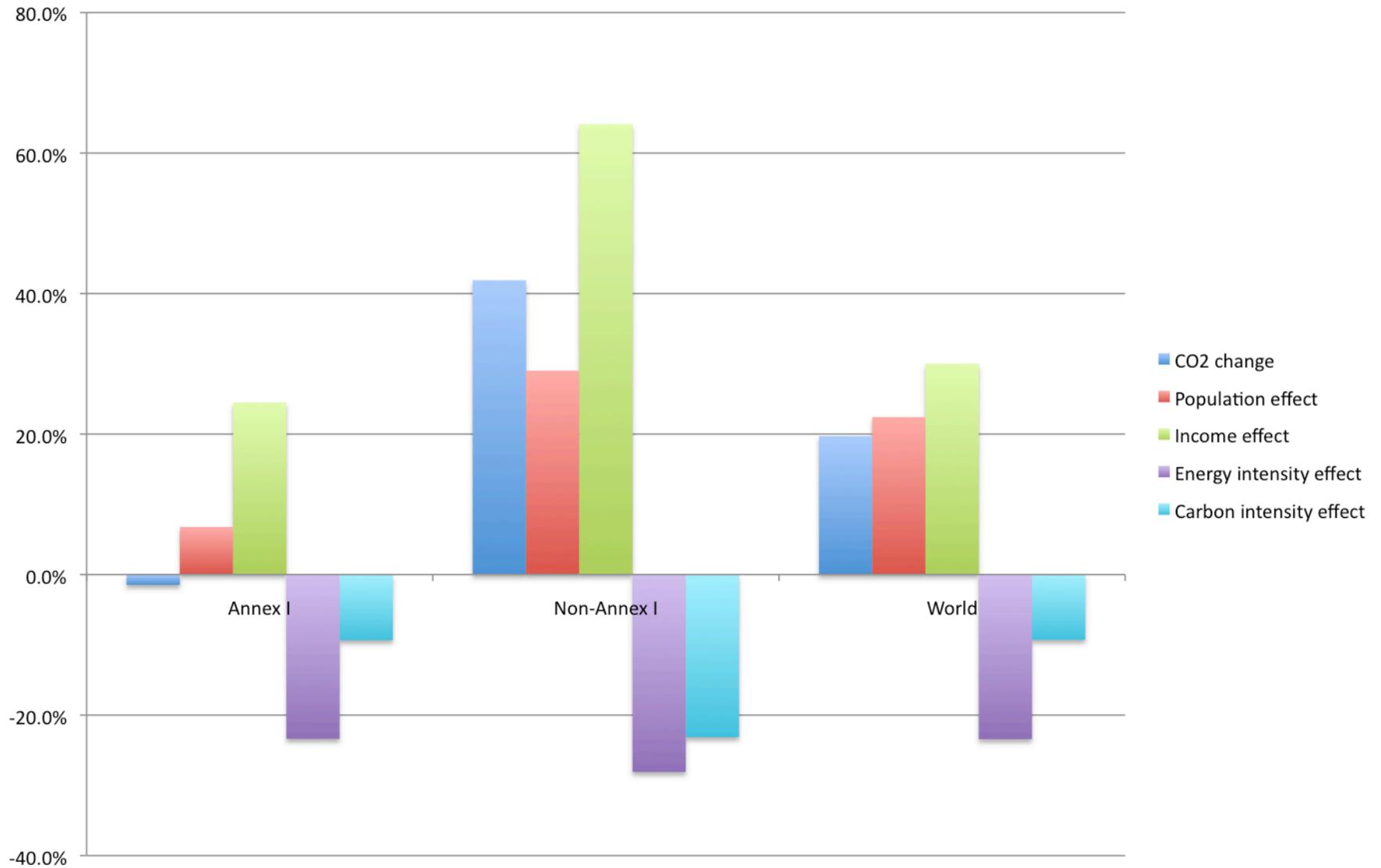
North-South Comparison



Emissions of CO2 from energy use and industrial sources.

Graph generated from CAIT, July 2010: <http://cait.wri.org/>

Decomposition Growth of CO₂ Emissions from Energy, 1990-2005



Data source: CAIT, July 2010: <http://cait.wri.org/>

Essential principles of GHGs (1)

(Or: what should our students learn?)

- CO_2 , CH_4 , N_2O have natural & human sources
 - Human sources: mostly burning fossil energy, clearing land, agriculture
- Emissions have grown rapidly since mid-19th century
 - Have exceeded capacity of Earth systems to process
- Concentrations growing
 - CO_2 concentration higher now than past 800k+ years
- It's not just about CO_2
 - Other gases responsible for >20% of the annual additions to warming potential

Essential principles of GHGs (2)

(Or: what should our students learn?)

- 25 countries responsible for 80% of emissions
- Developed countries account for majority of past & current emissions
 - Per capita emissions several times higher than in developing countries
 - Developed countries responsible for >60% of increase in CO₂ concentration in the atmosphere
- Emissions growth most rapid in developing world
 - Driven by income and population growth
 - Reductions in energy/\$gdp have offset some of the emissions growth
 - Changes in C/energy consumed has had mixed but mostly offsetting effects

Essential principles of GHGs (3)

(Or: what should our students learn?)

- Globally, emissions of GHGs continue to rise
 - Concentrations are rising too
- Projected trends in GHG emissions would warm the planet an estimated 1-6°C by 2100
- Halting the rise in GHG concentrations would require **deep** reductions in annual emissions
 - Stabilizing emissions near present level would **not** stabilize GHG concentrations

Useful Resources

- WRI website: www.wri.org
 - CAIT and CAIT-US databases & tools
 - Baumert, Herzog, Pershing (2005)
 - EarthTrends database
- USEPA website: www.epa.gov/climatechange/
 - Official inventories of US GHG emissions
 - Lots of other information about climate change

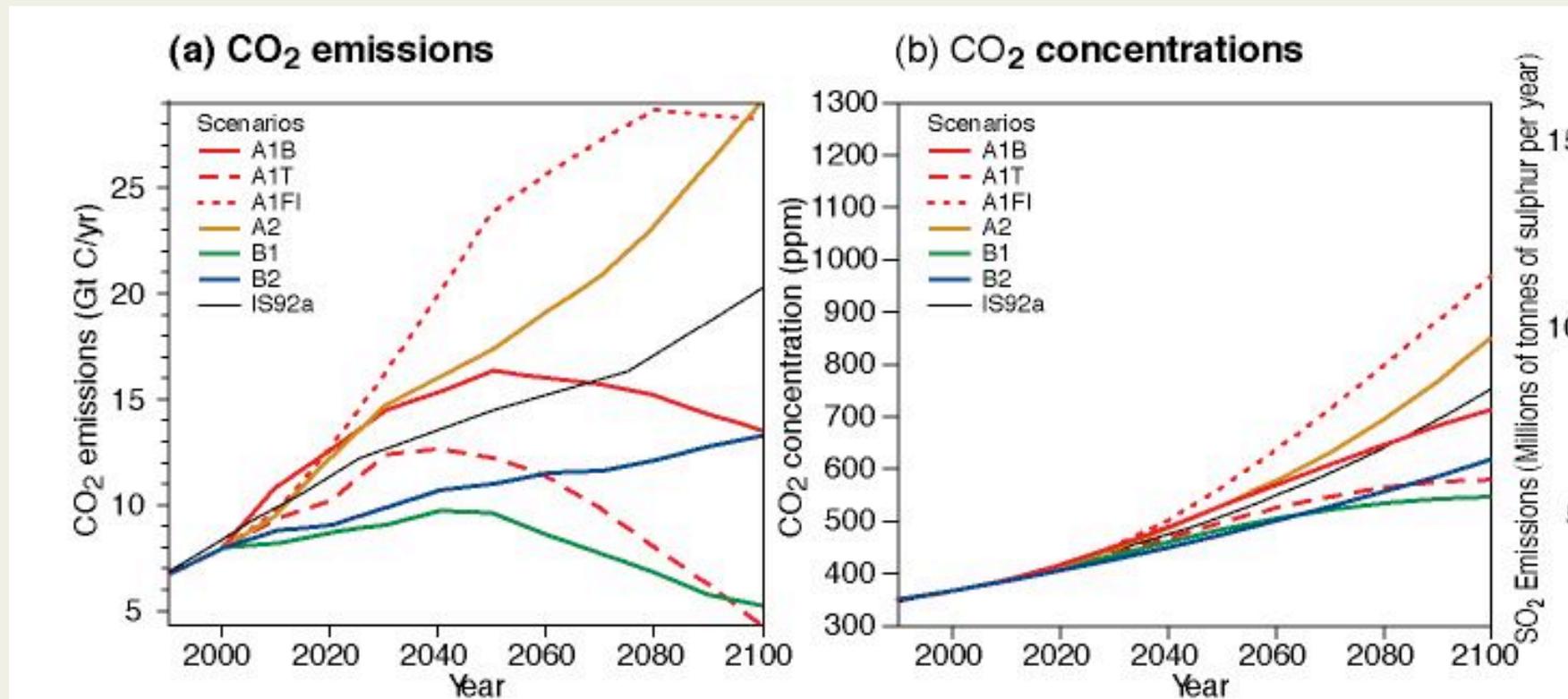
Extra Slides

IPCC Scenario Storylines

	Economic Goals		Ecological Goals	
Global Integration	A1		B1	
	Strong economic growth Convergence Developed & Developing Country incomes Rapid innovation Improvements energy intensity Low population growth	Year 2100 Population: 7.1 billion GDP/person: \$75,000 Energy/GDP: 3.29 million joules	Moderate economic growth Convergence Developed & Developing country incomes Strong improvements energy intensity Low population growth	Year 2100 Population: 7.1 billion GDP/person: \$46,500 Energy/GDP: 1.39 million joules
Regional Fragmentation	A2		B2	
	Weak economic growth Greater regional disparities Slower innovation Limited improvements energy intensity High population growth	Year 2100 Population: 15.1 billion GDP/person: \$16,100 Energy/GDP: 5.89 million joules	Low economic growth Regional disparities Moderate improvements energy intensity Low carbon energy Moderate population growth	Year 2100 Population: 10.4 billion GDP/person: \$22,500 Energy/GDP: 4.05 million joules

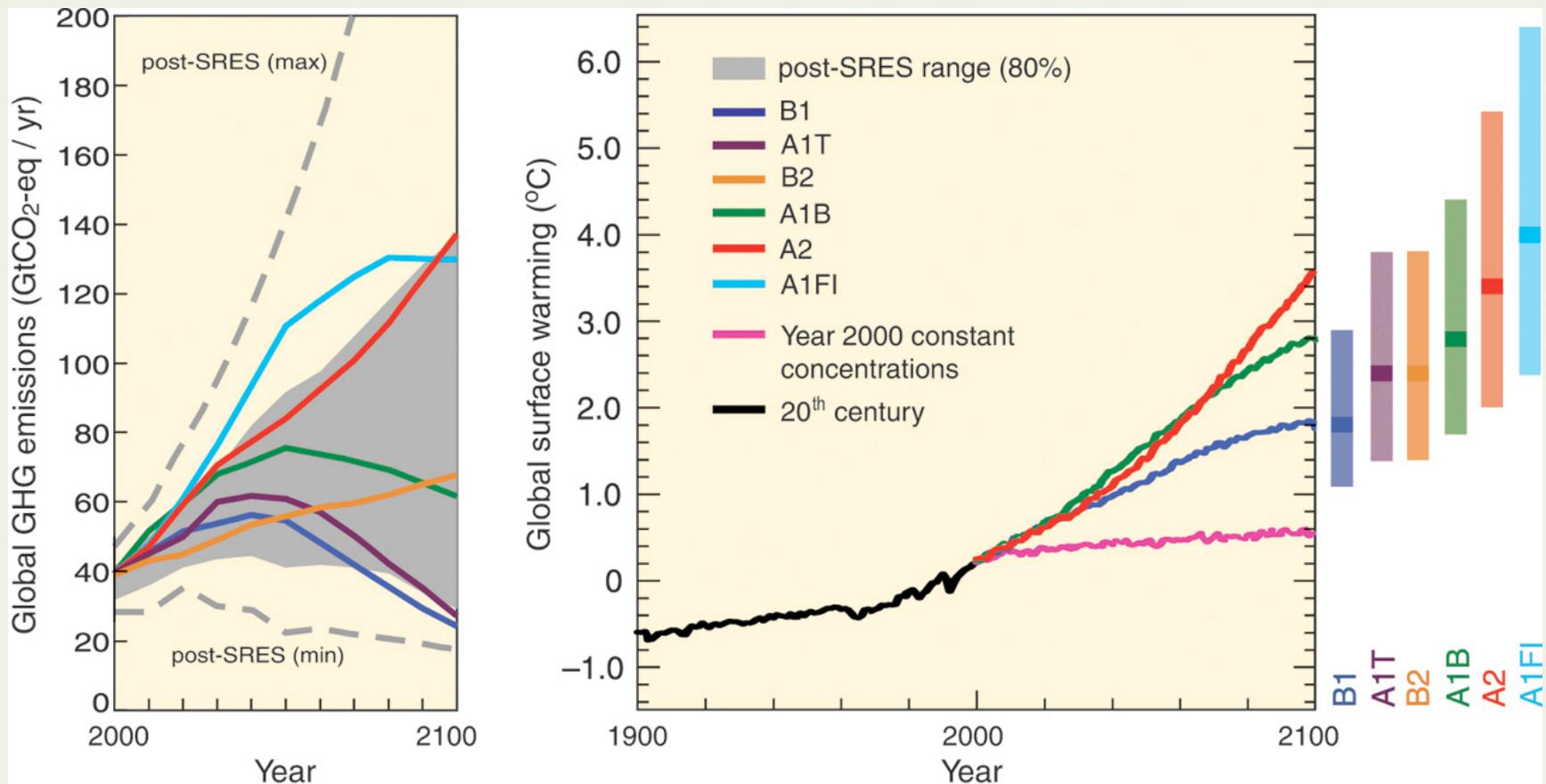
Source: derived from IPCC SRES, 2000.

Projections of CO₂ Emissions and Concentrations



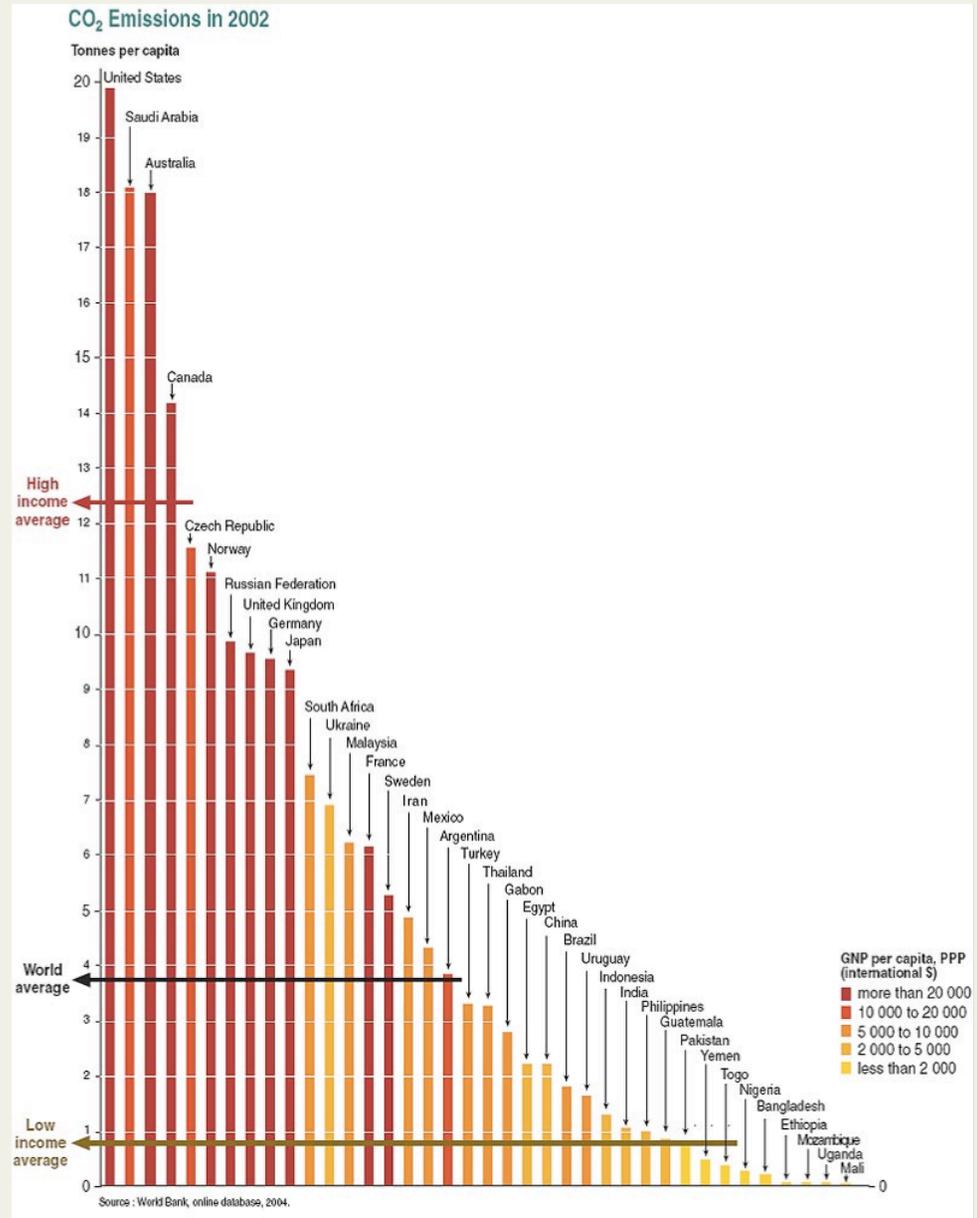
Source: IPCC, 2001, WGI Report, Figure 5

Projections of GHG Emissions and Changes in Global Mean Surface Temperature



Source: IPCC, 2007, Synthesis Report, Figure SPM-5

Per Capita CO₂ Emissions



Source: World Bank online database, 2004

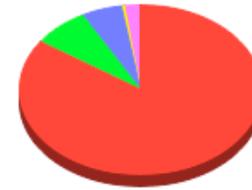
GHG Emission Profiles, 2005

Excludes land use change

Source: WRI, CAIT, version 8.0

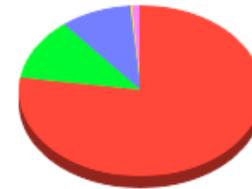
United States of America

Gas	MtCO2e	%
CO2	5,842.0	84.5
CH4	521.0	7.5
N2O	375.8	5.4
PFC	25.5	0.4
HFC	130.7	1.9
SF6	19.2	0.3
Total	6,914.2	



China

Gas	MtCO2e	%
CO2	5,590.9	77.3
CH4	853.3	11.8
N2O	684.1	9.5
PFC	16.1	0.2
HFC	80.1	1.1
SF6	8.3	0.1
Total	7,232.8	



India

Gas	MtCO2e	%
CO2	1,227.7	66.0
CH4	547.7	29.5
N2O	71.3	3.8
PFC	2.8	0.1
HFC	7.5	0.4
SF6	2.1	0.1
Total	1,859.0	



Tanzania

Gas	MtCO2e	%
CO2	5.8	9.8
CH4	30.2	50.8
N2O	23.4	39.4
PFC	--	--
HFC	--	--
SF6	--	--
Total	59.5	

