EML 4450/EML 5451: Energy Conversion Systems I

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> *“The purpose of education is to bring out the best in you”*
> *Mahatma Gandhi*

Course Description

This course will present the challenge of changing the global energy system so that it addresses the objective of greatly reducing the dependence on the finite fossil energy sources and move to the environmentally sustainable energy sources. The emphasis will be on greenhouse gas emissions free energy production strategies, including renewable energy – solar, wind and biomass.*

** Sustainable development: ability of humanity to ensure that it meets the needs of the present without compromising the ability of future generation to meet their own needs*

Course Objectives

- *To provide an understanding of the concept of sustainable future.*
- *To provide critical and thorough introduction to the subject of energy, its use and its environmental effects, especially global warming.*
- *To provide an understanding of the role of thermodynamic principles in energy conversion.*
- *To introduce the major methods of direct energy conversion – thermoelectricity, photovoltaics, thermionics and fuel cells.*
- *To provide a survey of renewable energy systems, solar, wind and biomass.*

Course Outline

- Energy systems in sustainable future
- The science of global warming
- The solar strategy
- Solar radiation characteristics
- Thermodynamic fundamentals for energy conversion systems
- Essentials of quantum physics
- Thermoelectric generators
- Photovoltaic generators
- Thermionic generators
- Fuel cells
- Other modes of direct energy conversion
- Renewable energy sources
    - Solar energy
    - Wind energy
    - Other energy
- Socio-economic assessment of energy supply systems

Text Book and References

Text Book:

Renewable Energy by Brent Sorensen, Third edition, Academic Press, 2004, ISBN: 0-12-656153-2

References:

1. *Direct Energy Conversion, Stanley W. Angrist, Fourth Edition, Allyn and Bacon, 1982.*
2. *Energy and the Environment, James A. Fay & Dan S. Golomb, Oxford, 2002.*
3. *Renewable and Efficient Electric Power Systems, Gilbert M. Masters, Wiley Interscience, 2004. (used as a text book for the follow on spring semester class)*
4. *Fundamentals of Thermodynamics, Sonntag, Borgnakke & Van Wylen, 5th Edition, John Wiley & Sons, Inc,1998.*
5. *Solar Engineering of Thermal Processes, Duffie & Beckmann, 2nd Edition, Wiley Interscience, 1991*
6. *Wind Energy Explained, Manwell, McGowan & Rogers, Wiley, 2002*
7. *Fuel Cell Systems, Larminie & Dicks, 2nd edition, Wiley. 2003.*
8. *The Solar Economy, Hermann Scheer, Earthscan, 2002.*

What kind of a world would you like to live in?

Peaceful

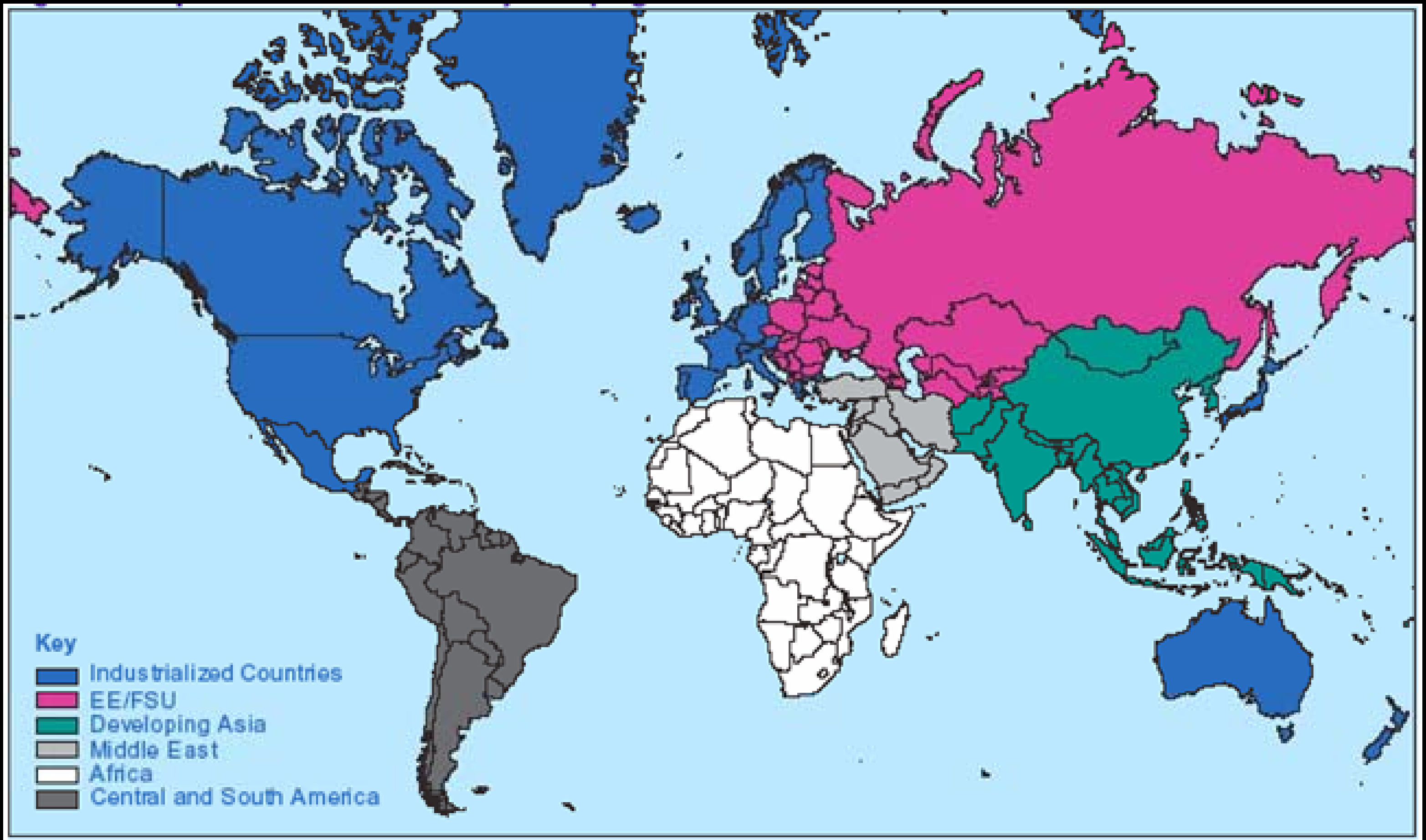
Joyful

Loving

If you think that the world is not this blissful - what are you doing about it?

your work towards sustainable energy will in some part help to achieve such a civilized world

Map of Six Basic Country Groupings



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

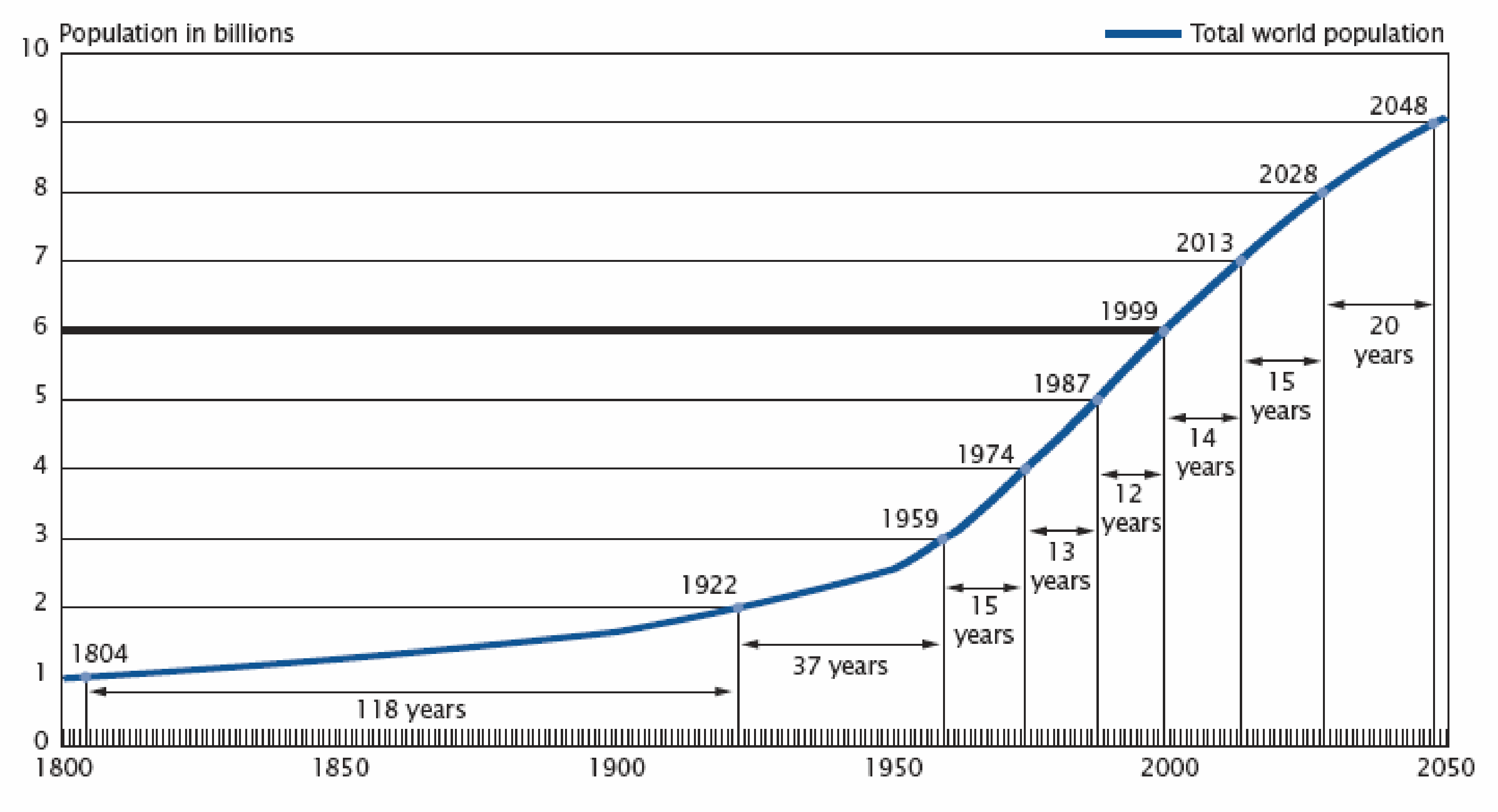
Source: EIA, *International Energy Outlook 2004*

Other Country Groupings

- **Annex I Countries** (countries participating in the Kyoto Climate Change Protocol on Greenhouse Gas Emissions): Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, European Community, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, and the United Kingdom.[1]
- **European Union (EU):** Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom.
- **G8:** Canada, France, Germany, Italy, Japan, Russia, United Kingdom, and the United States.
- **North American Free Trade Agreement (NAFTA) Member Countries:** Canada, Mexico, and the United States.
- **Organization for Economic Cooperation and Development (OECD):** Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, South Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.
- **Organization of Petroleum Exporting Countries (OPEC):** Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela.
- **Pacific Rim Developing Countries:** Hong Kong, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.
- **Persian Gulf:** Bahrain, Iran, Iraq, Kuwait, Qatar, Saudi Arabia, and the United Arab Emirates.

Source: EIA, *International Energy Outlook 2004*

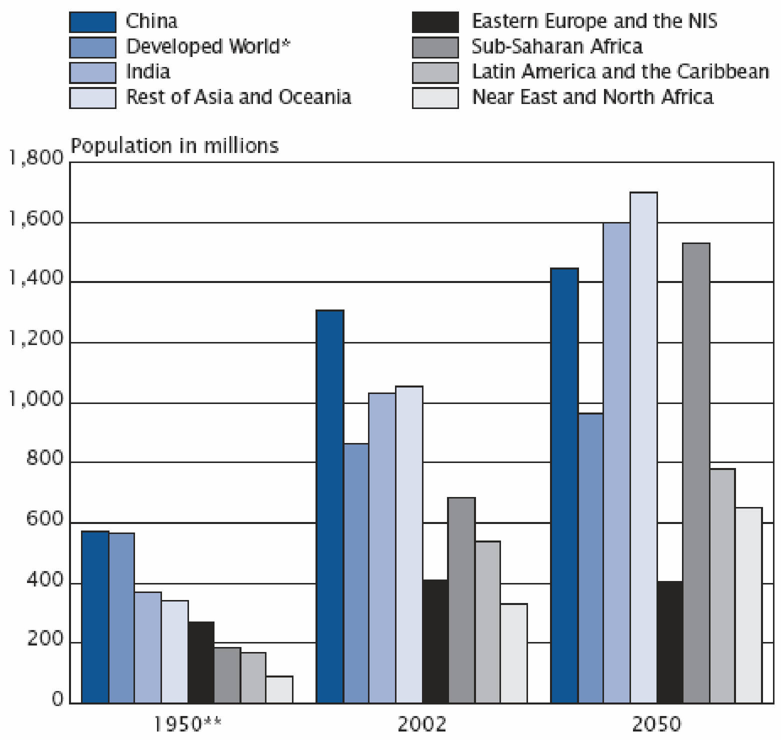
World Population



Source: United Nations (1995b); U.S. Census Bureau, International Programs Center, International Data Base and unpublished tables.

World Population

Population rankings of major world regions continue to shift in favor of developing regions



* "Developed World" refers to North America (excluding Latin America and the Caribbean), Western Europe, Japan, Australia, and New Zealand. Rest of Asia and Oceania refers to Asia excluding Japan, China, and India plus Oceania excluding Australia and New Zealand. NIS indicates the New Independent States of the former Soviet Union.
** Current boundaries.
Source: U.S. Census Bureau, International Programs Center, International Data Base.

The Top Ten Most Populous Countries: 1950, 2002, and 2050*

Less developed countries dominate the list of the world's ten most populous countries

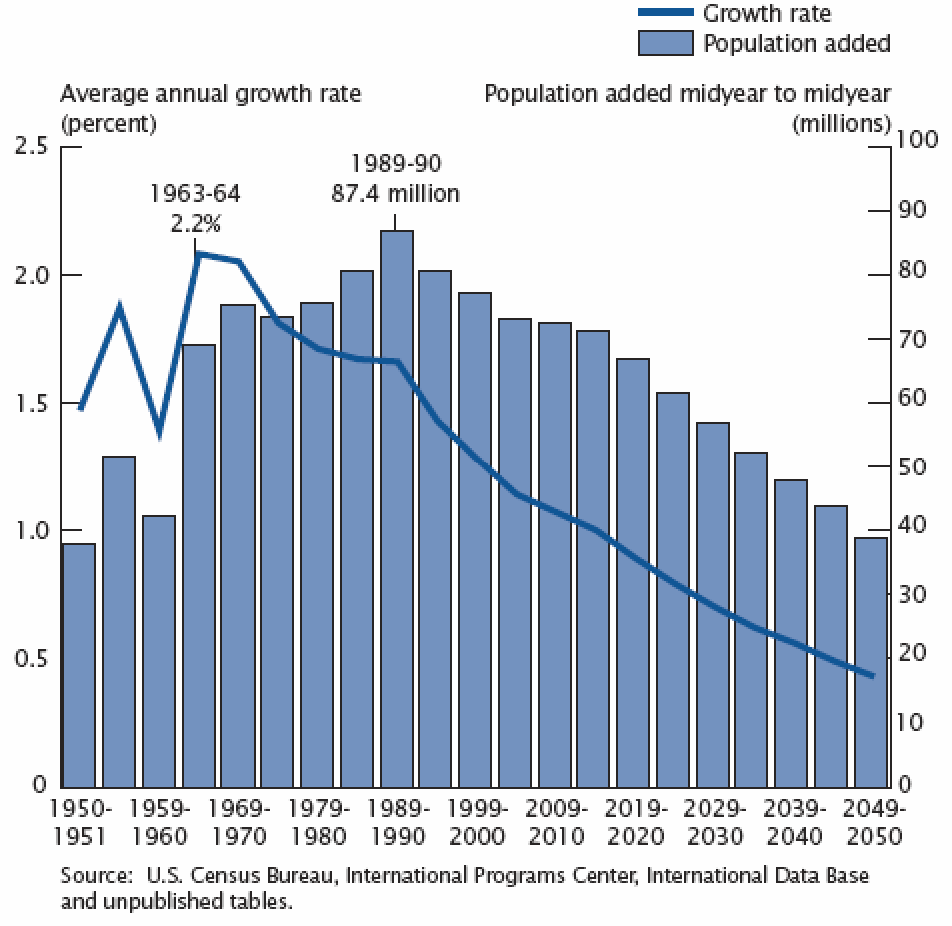
	1950**		2002		2050
1.	China	1.	China	1.	India
2.	India	2.	India	2.	China
3.	United States	3.	United States	3.	United States
4.	Russia	4.	Indonesia	4.	Indonesia
5.	Japan	5.	Brazil	5.	Nigeria
6.	Indonesia	6.	Pakistan	6.	Bangladesh
7.	Germany	7.	Russia	7.	Pakistan
8.	Brazil	8.	Bangladesh	8.	Brazil
9.	United Kingdom	9.	Nigeria	9.	Congo (Kinshasa)
10.	Italy	10.	Japan	10.	Mexico

Rankings of future or past top-ten countries

11.	Bangladesh	11.	Mexico	14.	Russia
13.	Pakistan	13.	Germany	16.	Japan
15.	Nigeria	21.	United Kingdom	24.	Germany
16.	Mexico	22.	Italy	29.	United Kingdom
32.	Congo (Kinshasa)	23.	Congo (Kinshasa)	35.	Italy

*More developed countries/less developed countries.
**Current boundaries.
Source: U.S. Census Bureau, International Programs Center, International Data Base and unpublished tables.

World Population



Source: U.S. Census Bureau, International Programs Center, International Data Base and unpublished tables.

Good News:

The pace of global population growth is on decline

To stabilize or reduce population:

Increase women's

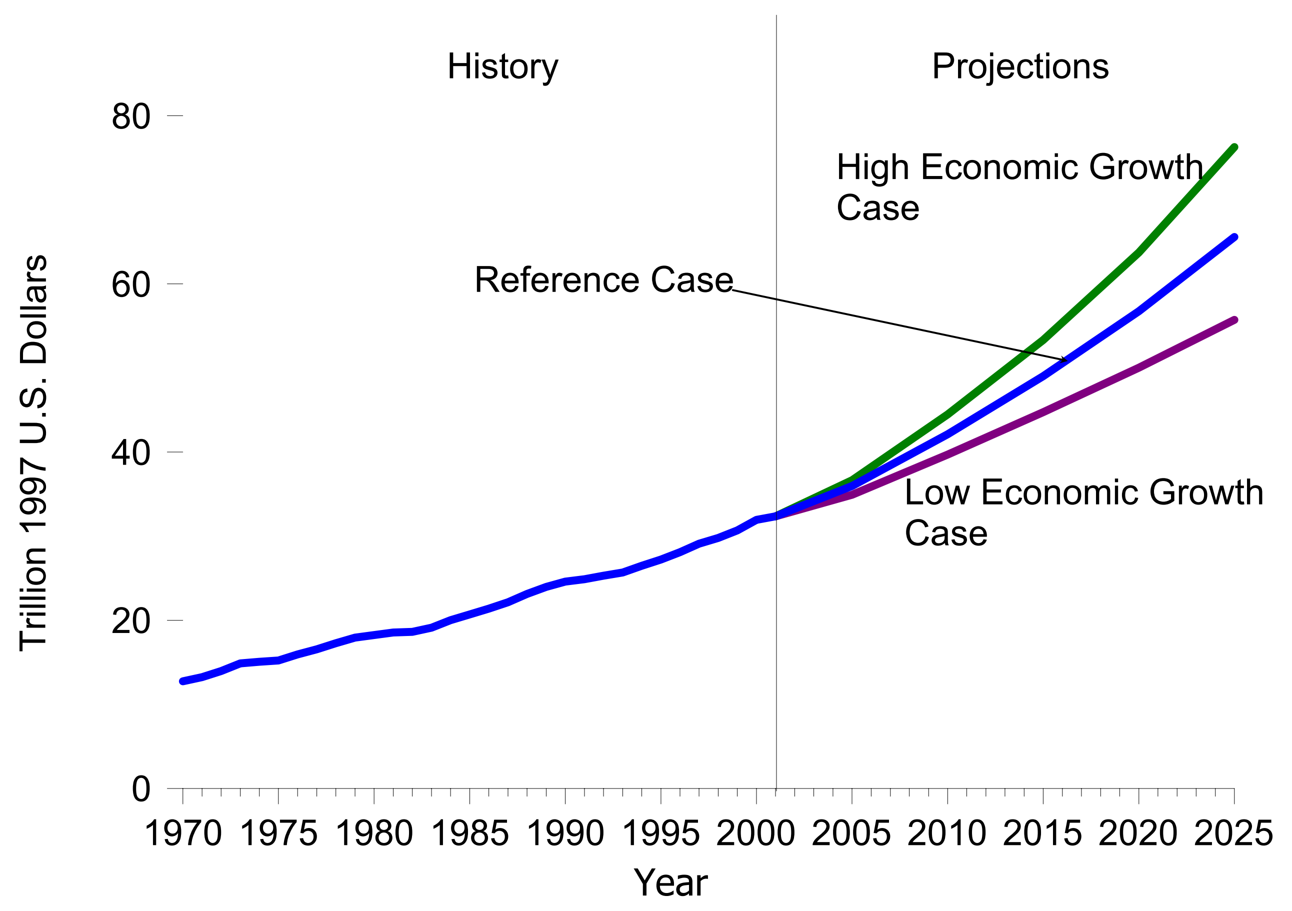
health

Education

employment

Women as equal participants in all aspects of society

World Gross Domestic Product



Source: EIA (Energy Information Administration), *International Energy Outlook 2004*

Top Ten GDP Countries

Table 1. Top ten GDP's in 2004

Ranking	*Economy*	*US dollars in millions*
1	United States	11,667,515
2	Japan	4,623,398
3	Germany	2,714,418
4	United Kingdom	2,140,898
5	France	2,002,582
6	Italy	1,672,302
7	China	1,649,329
8	Spain	991,442
9	Canada	979,764
10	India	691,876

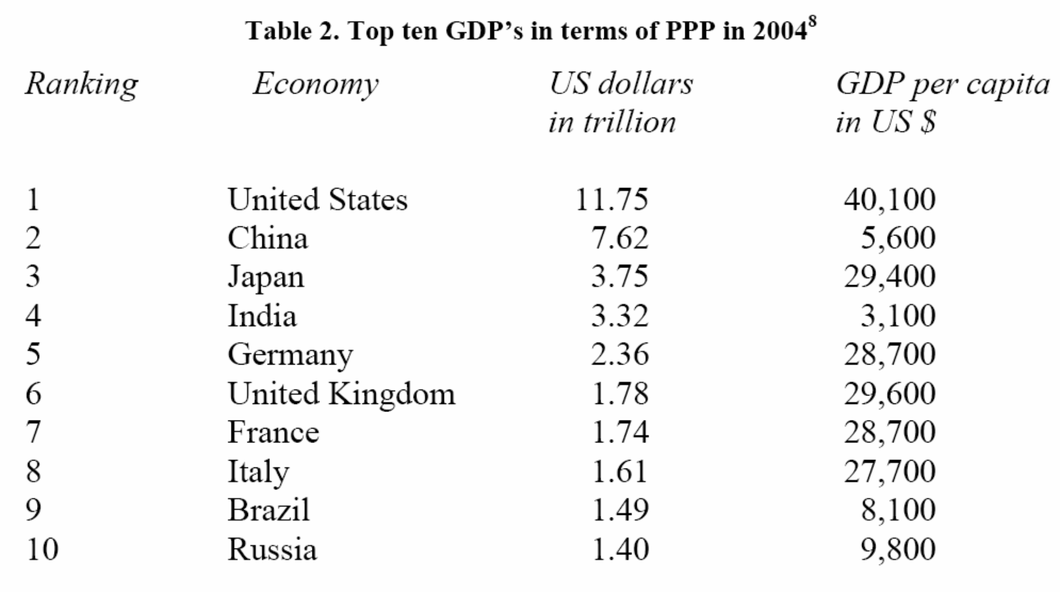
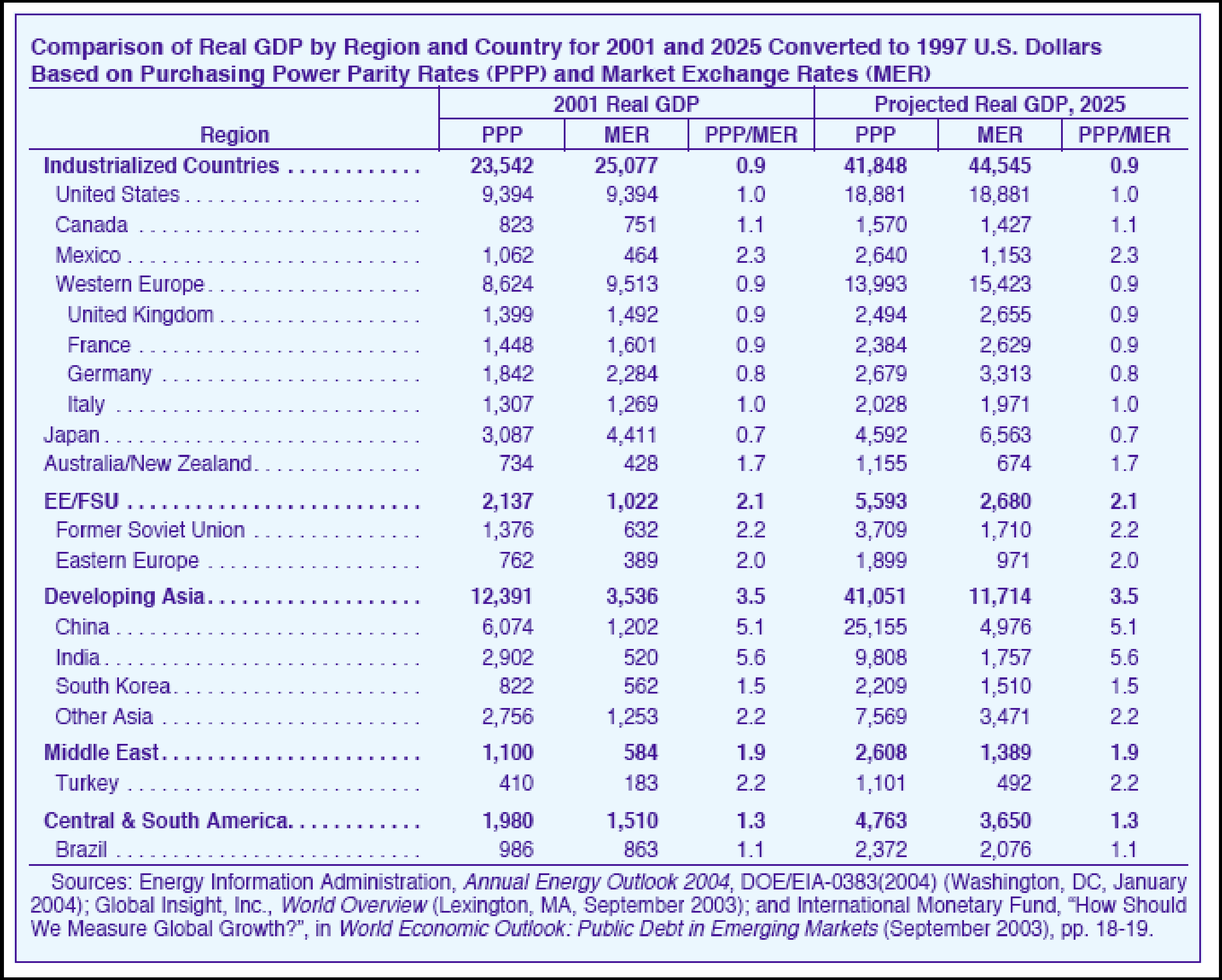


Table 2. Top ten GDP's in terms of PPP in 2004[8]

Ranking	*Economy*	*US dollars in trillion*	*GDP per capita in US $*
1	United States	11.75	40,100
2	China	7.62	5,600
3	Japan	3.75	29,400
4	India	3.32	3,100
5	Germany	2.36	28,700
6	United Kingdom	1.78	29,600
7	France	1.74	28,700
8	Italy	1.61	27,700
9	Brazil	1.49	8,100
10	Russia	1.40	9,800

World Gross Domestic Product



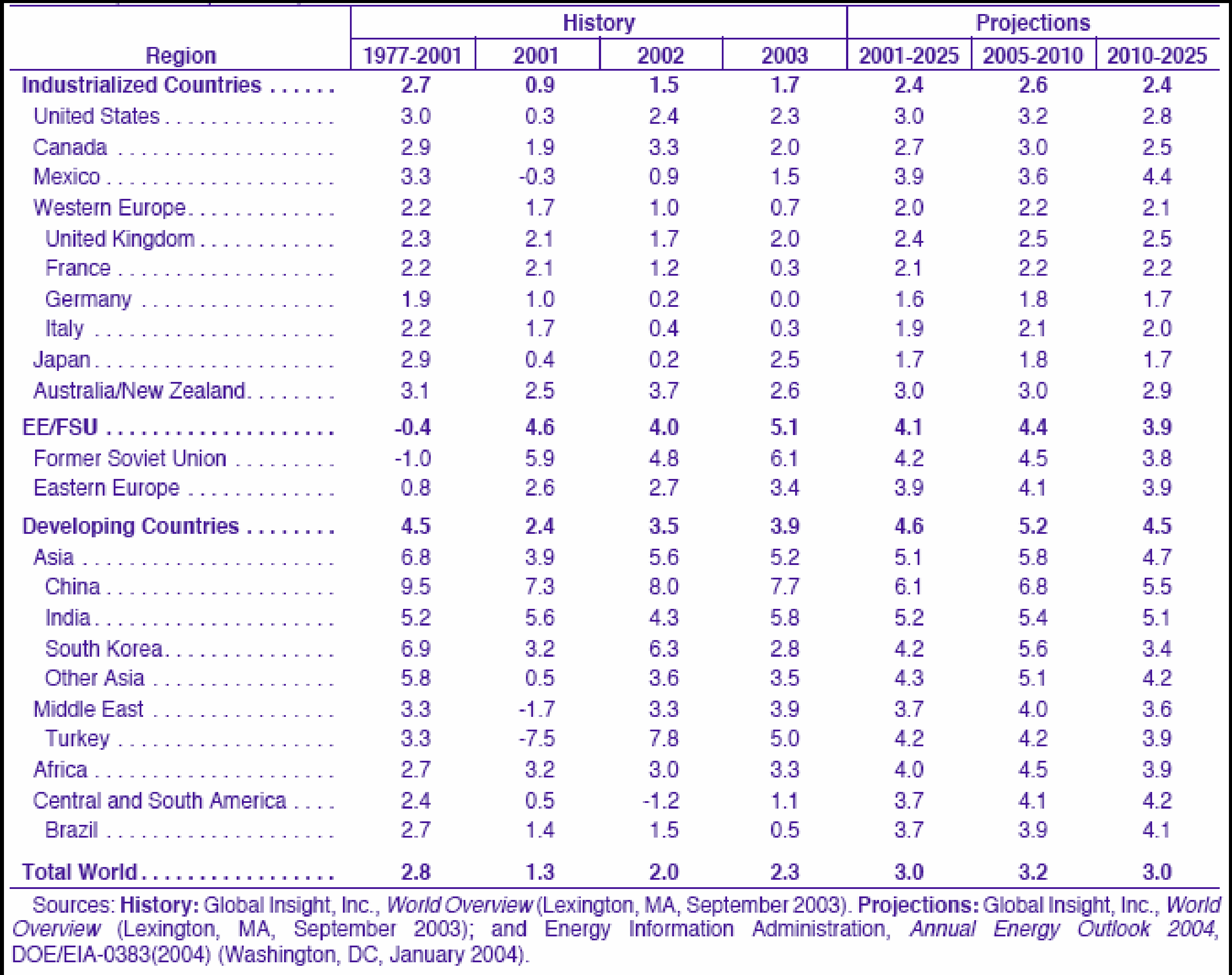
Comparison of Real GDP by Region and Country for 2001 and 2025 Converted to 1997 U.S. Dollars Based on Purchasing Power Parity Rates (PPP) and Market Exchange Rates (MER)

Region	2001 Real GDP			Projected Real GDP, 2025		
	PPP	MER	PPP/MER	PPP	MER	PPP/MER
Industrialized Countries	**23,542**	**25,077**	**0.9**	**41,848**	**44,545**	**0.9**
United States	9,394	9,394	1.0	18,881	18,881	1.0
Canada	823	751	1.1	1,570	1,427	1.1
Mexico	1,062	464	2.3	2,640	1,153	2.3
Western Europe	8,624	9,513	0.9	13,993	15,423	0.9
United Kingdom	1,399	1,492	0.9	2,494	2,655	0.9
France	1,448	1,601	0.9	2,384	2,629	0.9
Germany	1,842	2,284	0.8	2,679	3,313	0.8
Italy	1,307	1,269	1.0	2,028	1,971	1.0
Japan	3,087	4,411	0.7	4,592	6,563	0.7
Australia/New Zealand	734	428	1.7	1,155	674	1.7
EE/FSU	**2,137**	**1,022**	**2.1**	**5,593**	**2,680**	**2.1**
Former Soviet Union	1,376	632	2.2	3,709	1,710	2.2
Eastern Europe	762	389	2.0	1,899	971	2.0
Developing Asia	**12,391**	**3,536**	**3.5**	**41,051**	**11,714**	**3.5**
China	6,074	1,202	5.1	25,155	4,976	5.1
India	2,902	520	5.6	9,808	1,757	5.6
South Korea	822	562	1.5	2,209	1,510	1.5
Other Asia	2,756	1,253	2.2	7,569	3,471	2.2
Middle East	**1,100**	**584**	**1.9**	**2,608**	**1,389**	**1.9**
Turkey	410	183	2.2	1,101	492	2.2
Central & South America	**1,980**	**1,510**	**1.3**	**4,763**	**3,650**	**1.3**
Brazil	986	863	1.1	2,372	2,076	1.1

Sources: Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004); Global Insight, Inc., *World Overview* (Lexington, MA, September 2003); and International Monetary Fund, "How Should We Measure Global Growth?", in *World Economic Outlook: Public Debt in Emerging Markets* (September 2003), pp. 18-19.

Source: EIA (Energy Information Administration), *International Energy Outlook 2004*

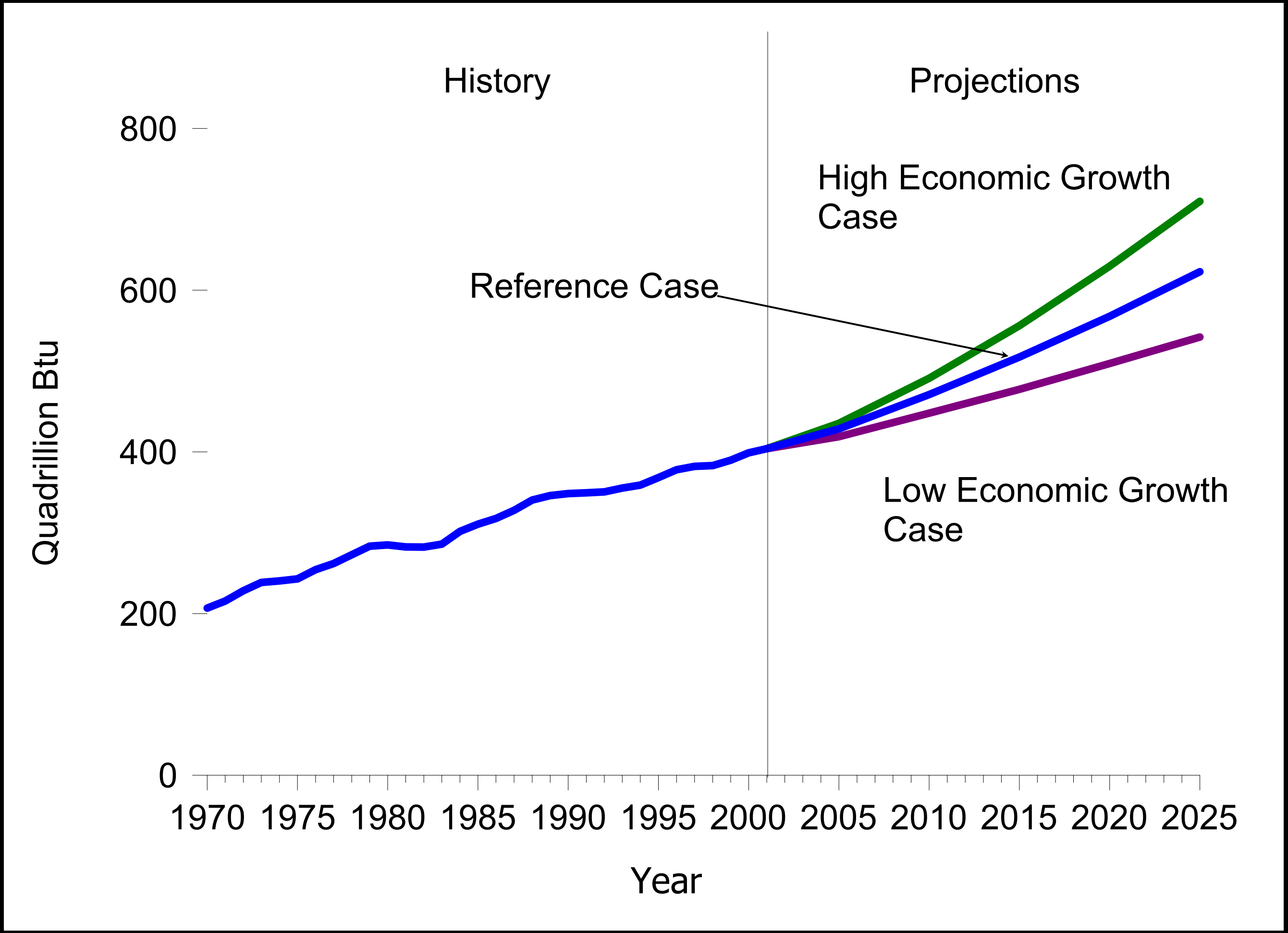
Annual Growth in World Gross Domestic Product (% per year)



Region	History				Projections		
	1977-2001	2001	2002	2003	2001-2025	2005-2010	2010-2025
Industrialized Countries	**2.7**	**0.9**	**1.5**	**1.7**	**2.4**	**2.6**	**2.4**
United States	3.0	0.3	2.4	2.3	3.0	3.2	2.8
Canada	2.9	1.9	3.3	2.0	2.7	3.0	2.5
Mexico	3.3	-0.3	0.9	1.5	3.9	3.6	4.4
Western Europe	2.2	1.7	1.0	0.7	2.0	2.2	2.1
United Kingdom	2.3	2.1	1.7	2.0	2.4	2.5	2.5
France	2.2	2.1	1.2	0.3	2.1	2.2	2.2
Germany	1.9	1.0	0.2	0.0	1.6	1.8	1.7
Italy	2.2	1.7	0.4	0.3	1.9	2.1	2.0
Japan	2.9	0.4	0.2	2.5	1.7	1.8	1.7
Australia/New Zealand	3.1	2.5	3.7	2.6	3.0	3.0	2.9
EE/FSU	**-0.4**	**4.6**	**4.0**	**5.1**	**4.1**	**4.4**	**3.9**
Former Soviet Union	-1.0	5.9	4.8	6.1	4.2	4.5	3.8
Eastern Europe	0.8	2.6	2.7	3.4	3.9	4.1	3.9
Developing Countries	**4.5**	**2.4**	**3.5**	**3.9**	**4.6**	**5.2**	**4.5**
Asia	6.8	3.9	5.6	5.2	5.1	5.8	4.7
China	9.5	7.3	8.0	7.7	6.1	6.8	5.5
India	5.2	5.6	4.3	5.8	5.2	5.4	5.1
South Korea	6.9	3.2	6.3	2.8	4.2	5.6	3.4
Other Asia	5.8	0.5	3.6	3.5	4.3	5.1	4.2
Middle East	3.3	-1.7	3.3	3.9	3.7	4.0	3.6
Turkey	3.3	-7.5	7.8	5.0	4.2	4.2	3.9
Africa	2.7	3.2	3.0	3.3	4.0	4.5	3.9
Central and South America	2.4	0.5	-1.2	1.1	3.7	4.1	4.2
Brazil	2.7	1.4	1.5	0.5	3.7	3.9	4.1
Total World	**2.8**	**1.3**	**2.0**	**2.3**	**3.0**	**3.2**	**3.0**

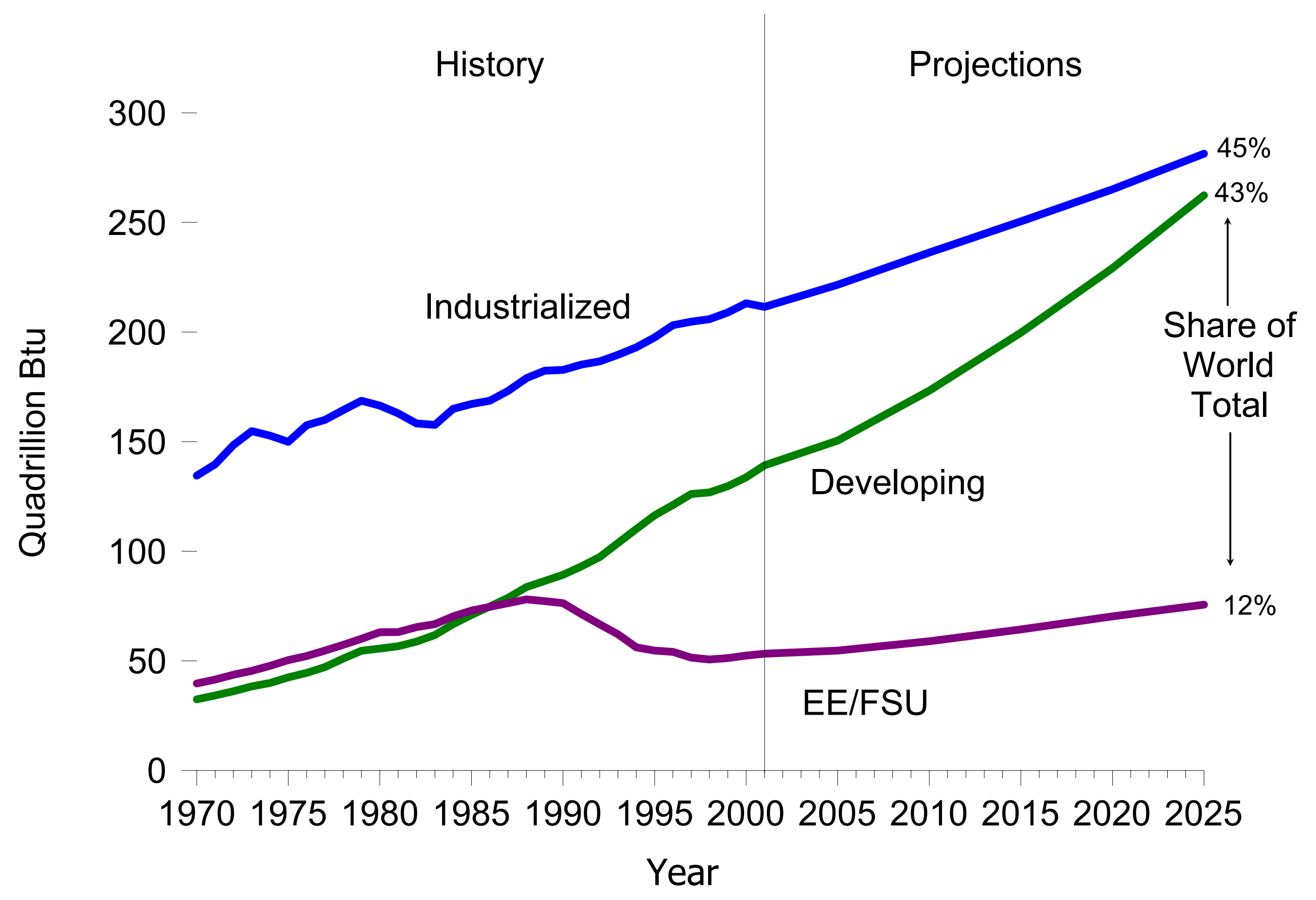
Sources: **History:** Global Insight, Inc., *World Overview* (Lexington, MA, September 2003). **Projections:** Global Insight, Inc., *World Overview* (Lexington, MA, September 2003); and Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004).

World Marketed Energy Consumption



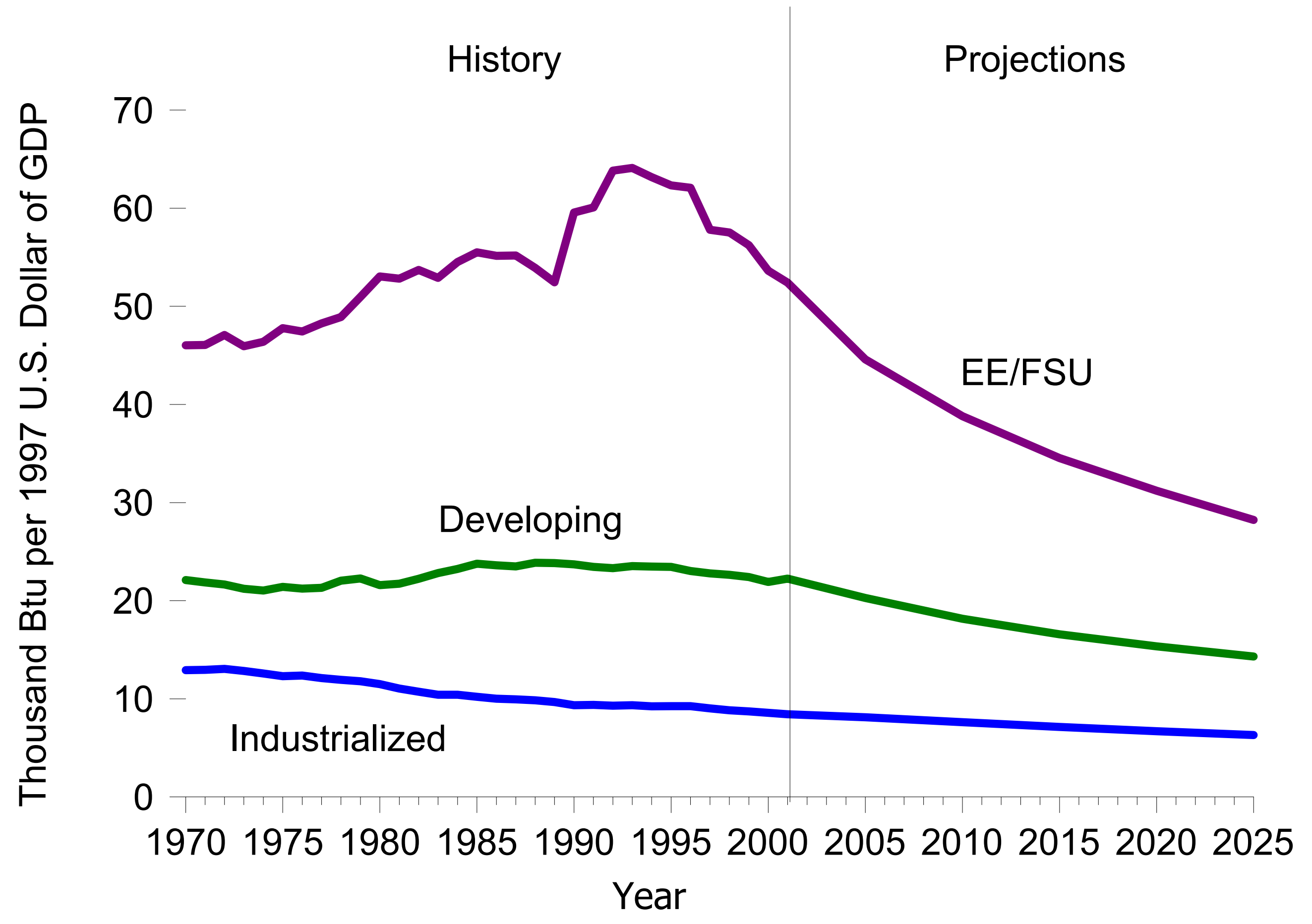
Source: EIA, *International Energy Outlook 2004*

World Marketed Energy Consumption by Region



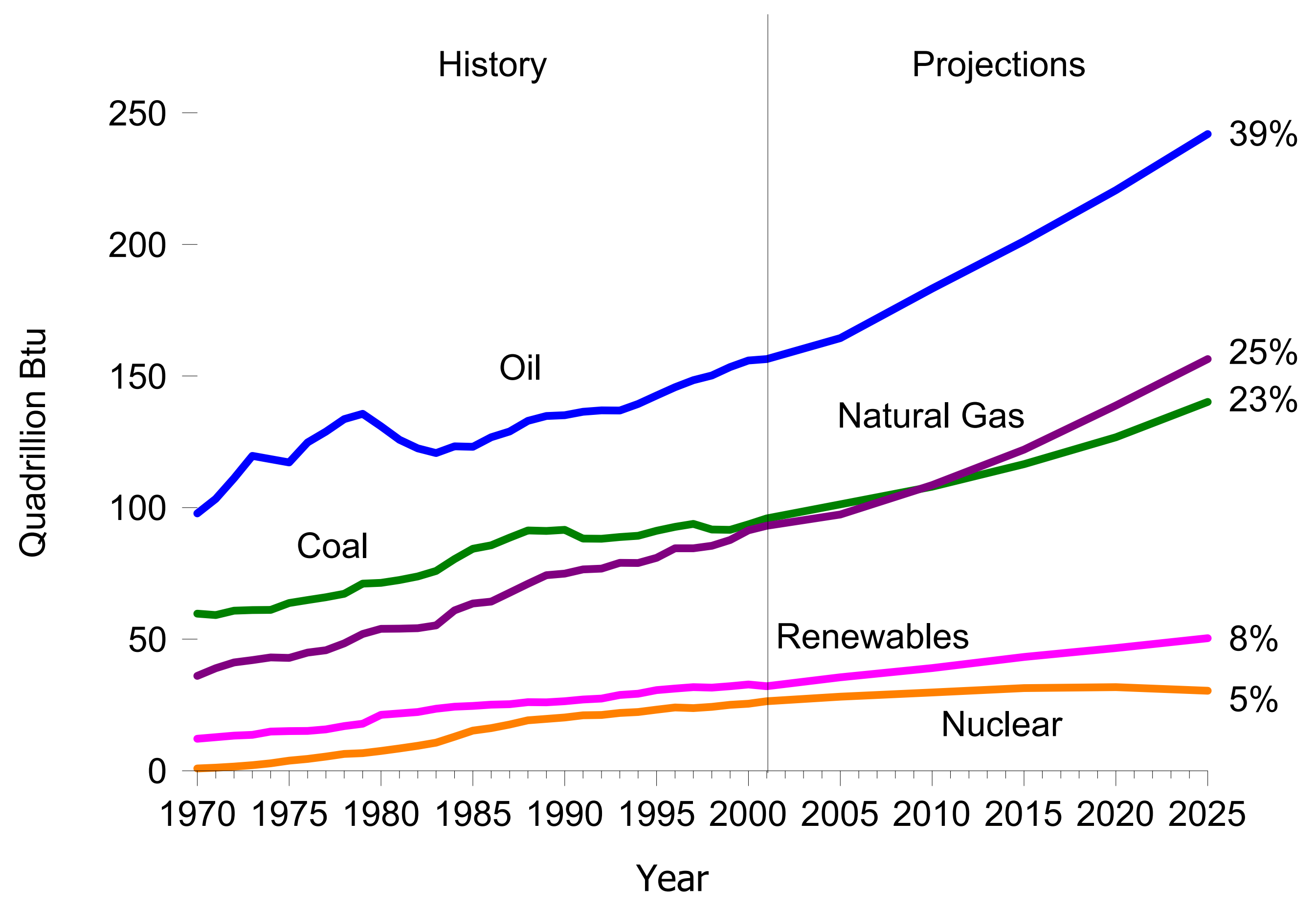
Source: EIA, *International Energy Outlook 2004*

Energy Intensity by Region



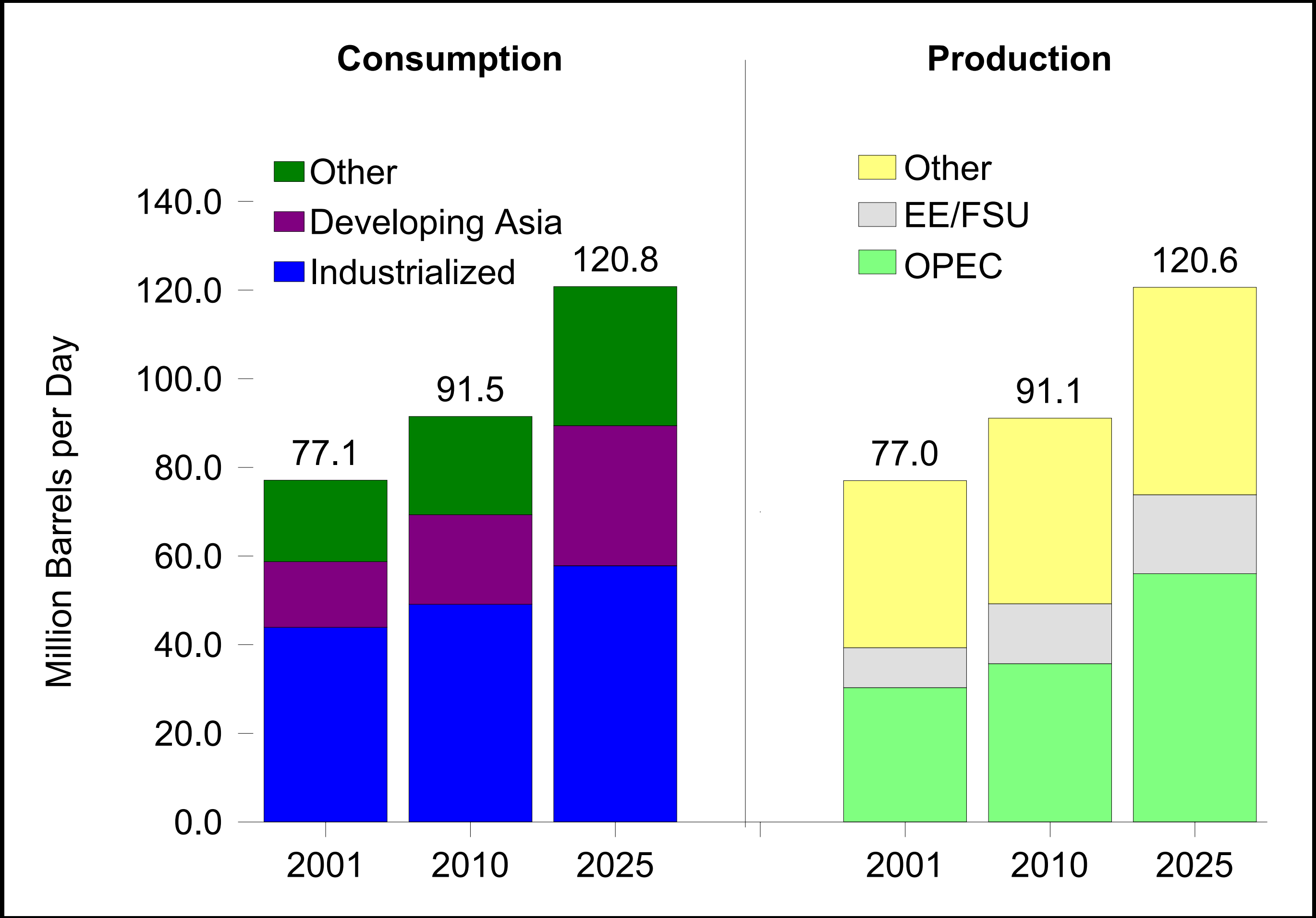
Source: EIA, *International Energy Outlook 2004*

World Primary Energy Consumption by Fuel Type



Source: EIA, *International Energy Outlook 2004*

World Oil Consumption and Production



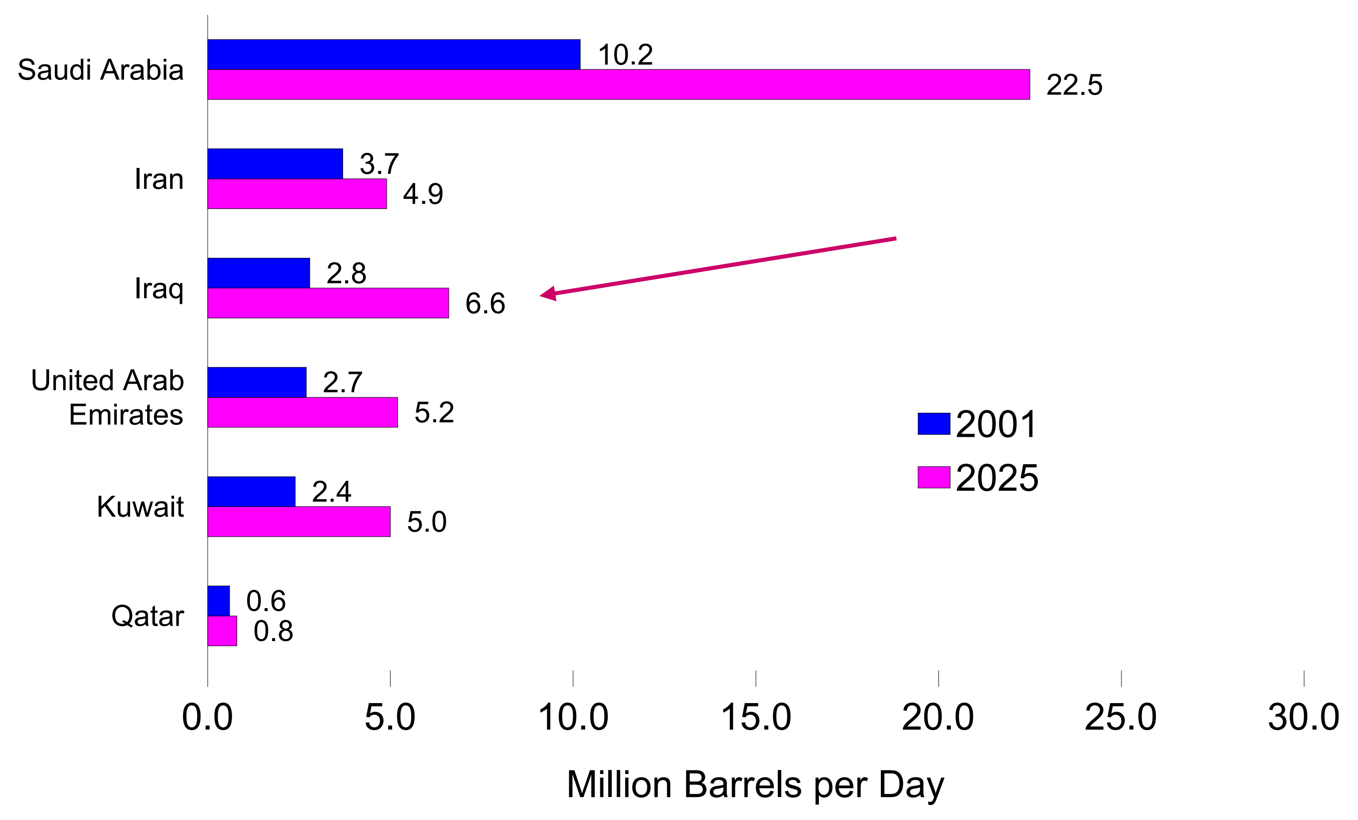
2004 Production:

NY Times, 8/15/04

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

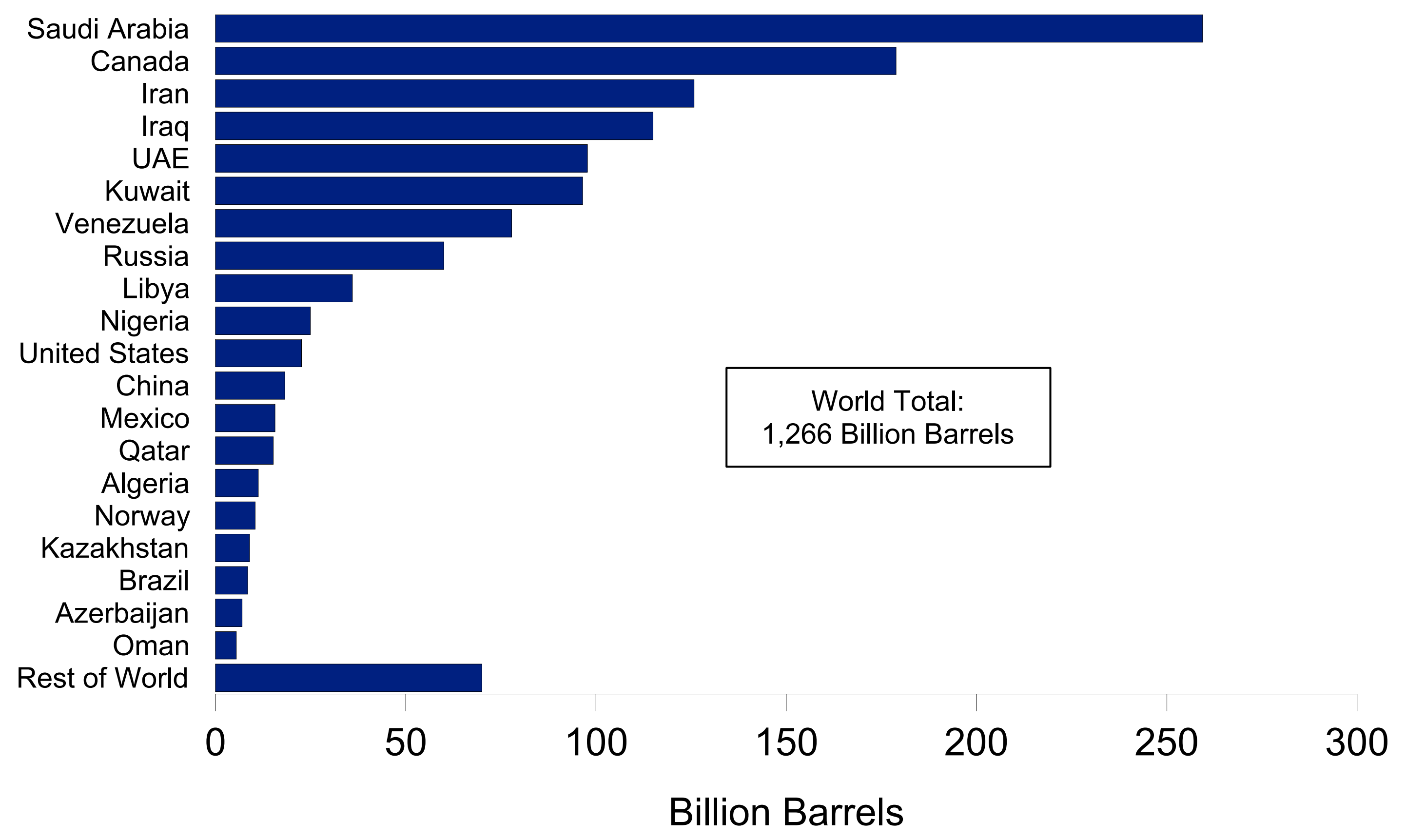
Source: EIA, *International Energy Outlook 2004*

Persian Gulf Oil Productive Capacity



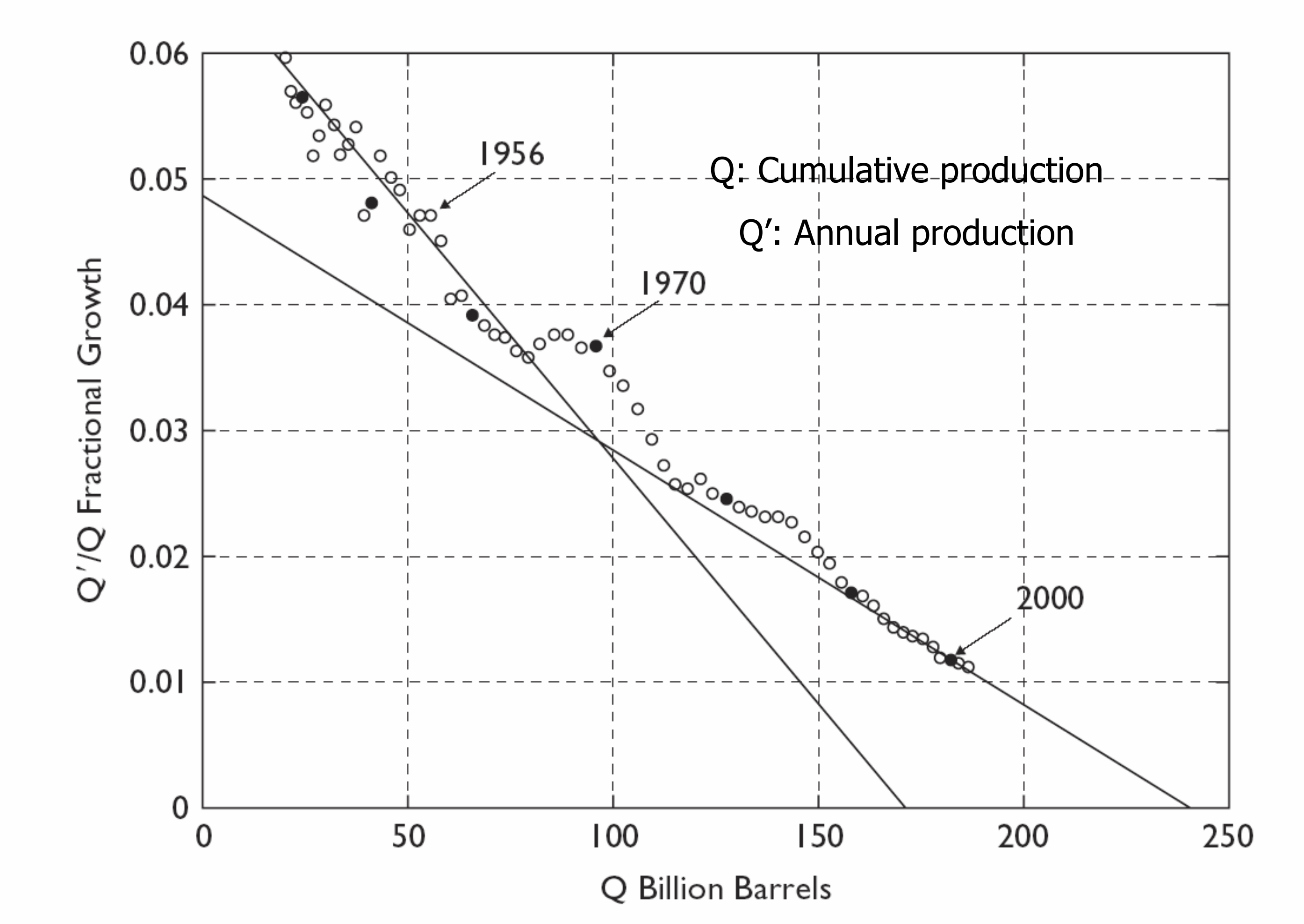
Source: EIA, *International Energy Outlook 2004*

World Oil Reserves by Country (1/1/04)



Source: "Worldwide Look at Reserves and Production."*Oil & Gas Journal*, Vol. 100, No. 49 (December 22, 2003), pp. 46-47.

Logistic Equation



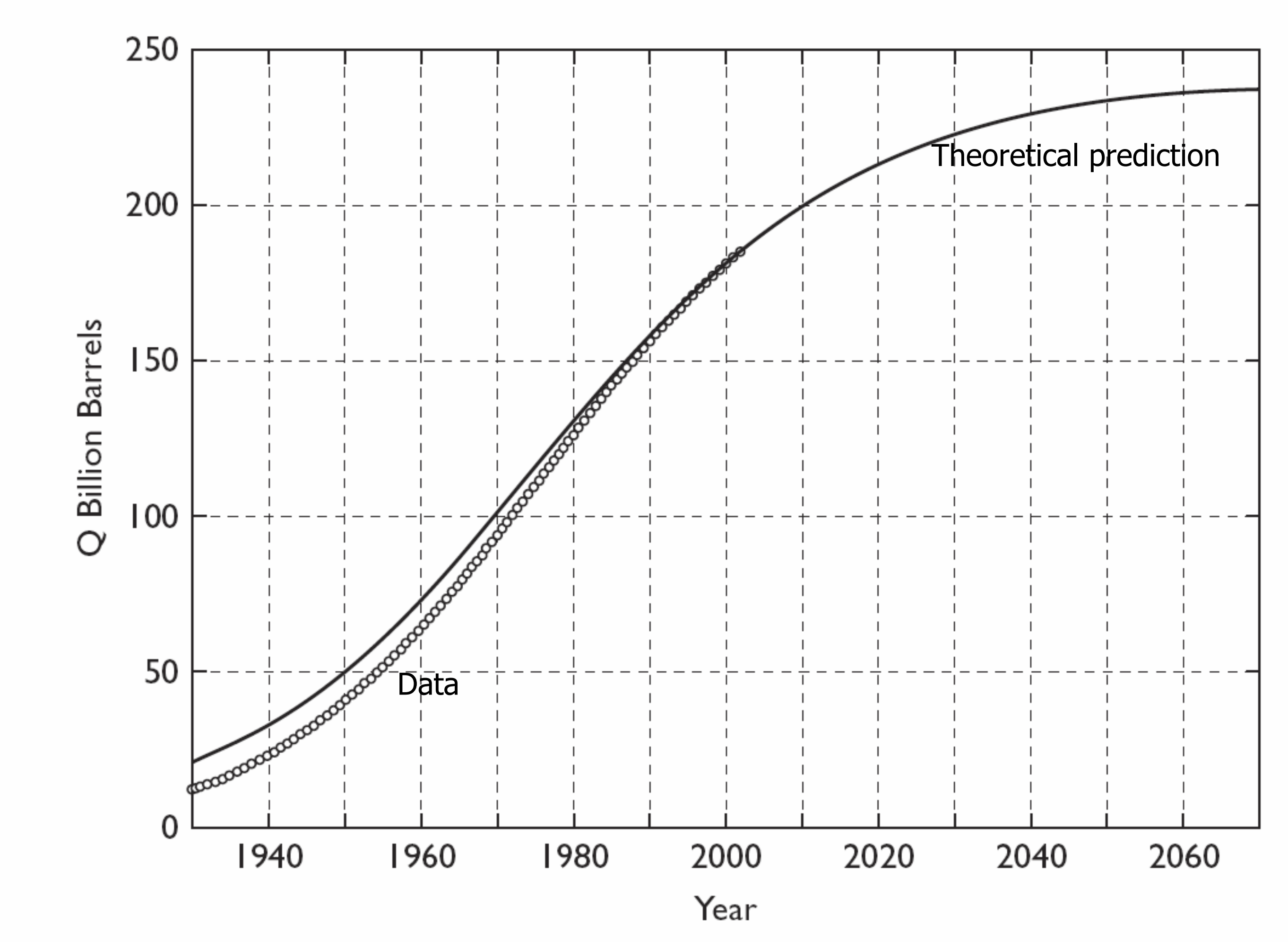
Q: Cumulative production

Q': Annual production

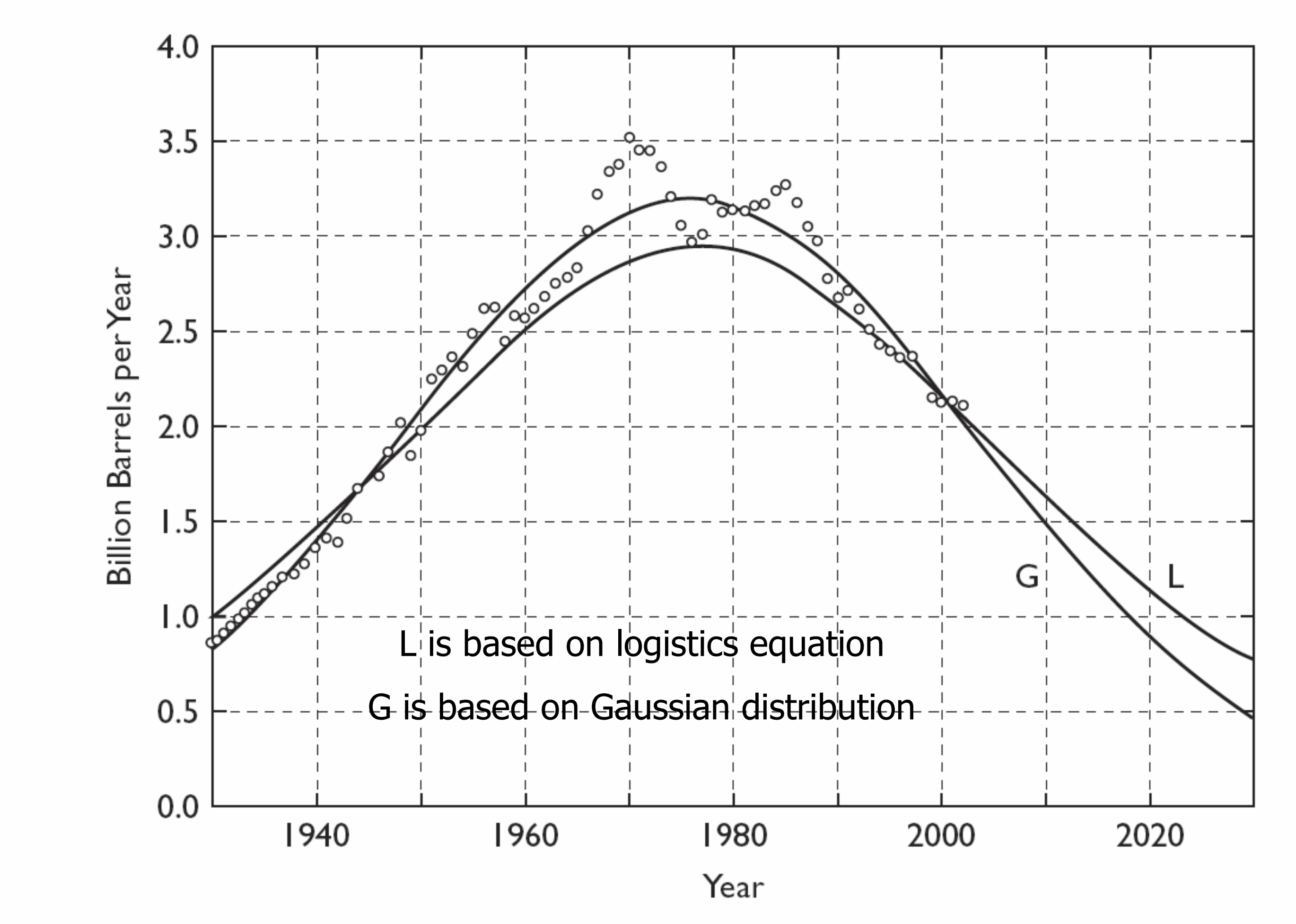
$Q = Q_0/(1+\exp[-a(t-t_m)])$

Q_o :Ultimate production; t_m: Year of peak production

US Cumulative Oil Production



US Annual Oil Production

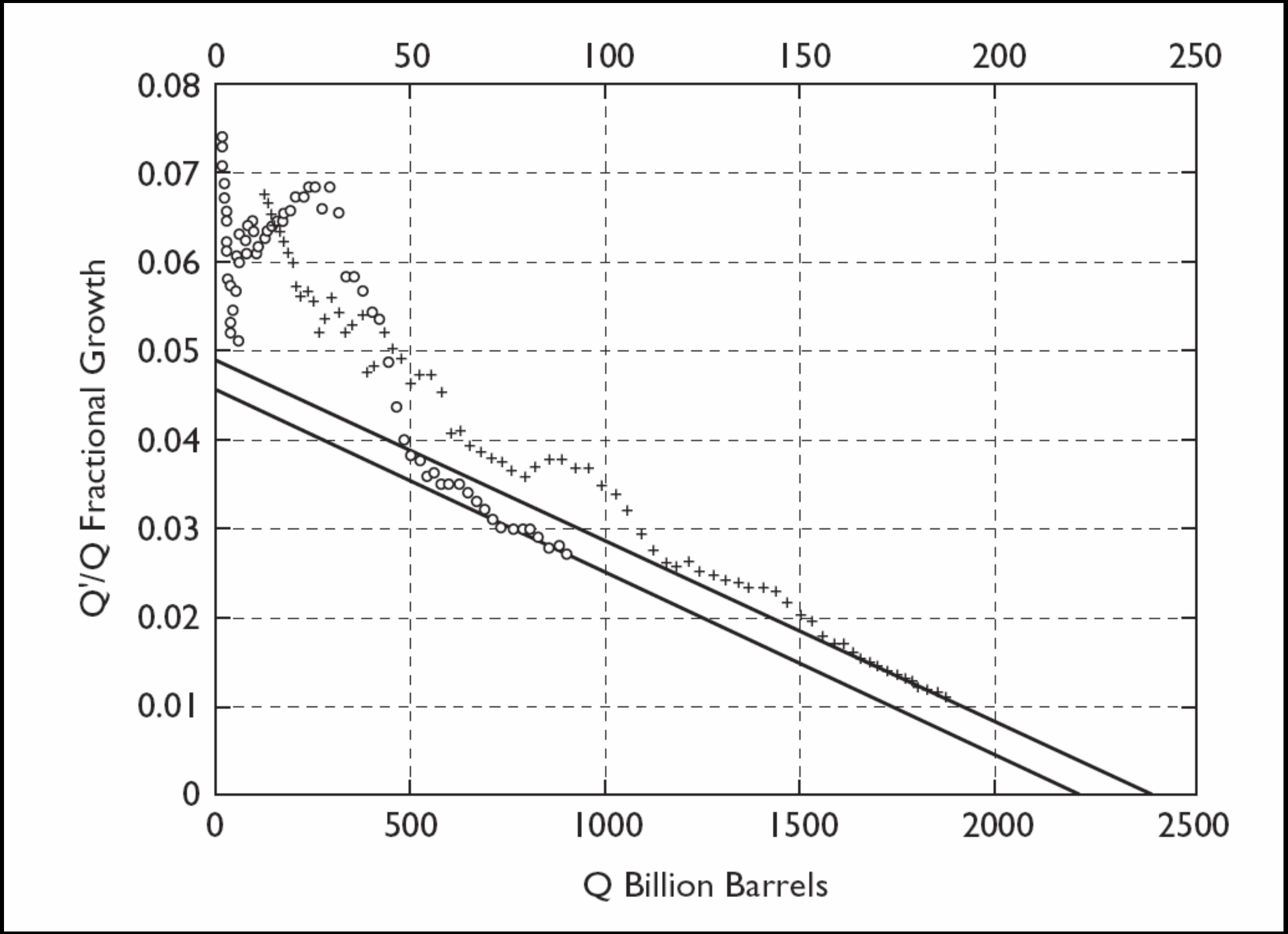


L is based on logistics equation

G is based on Gaussian distribution

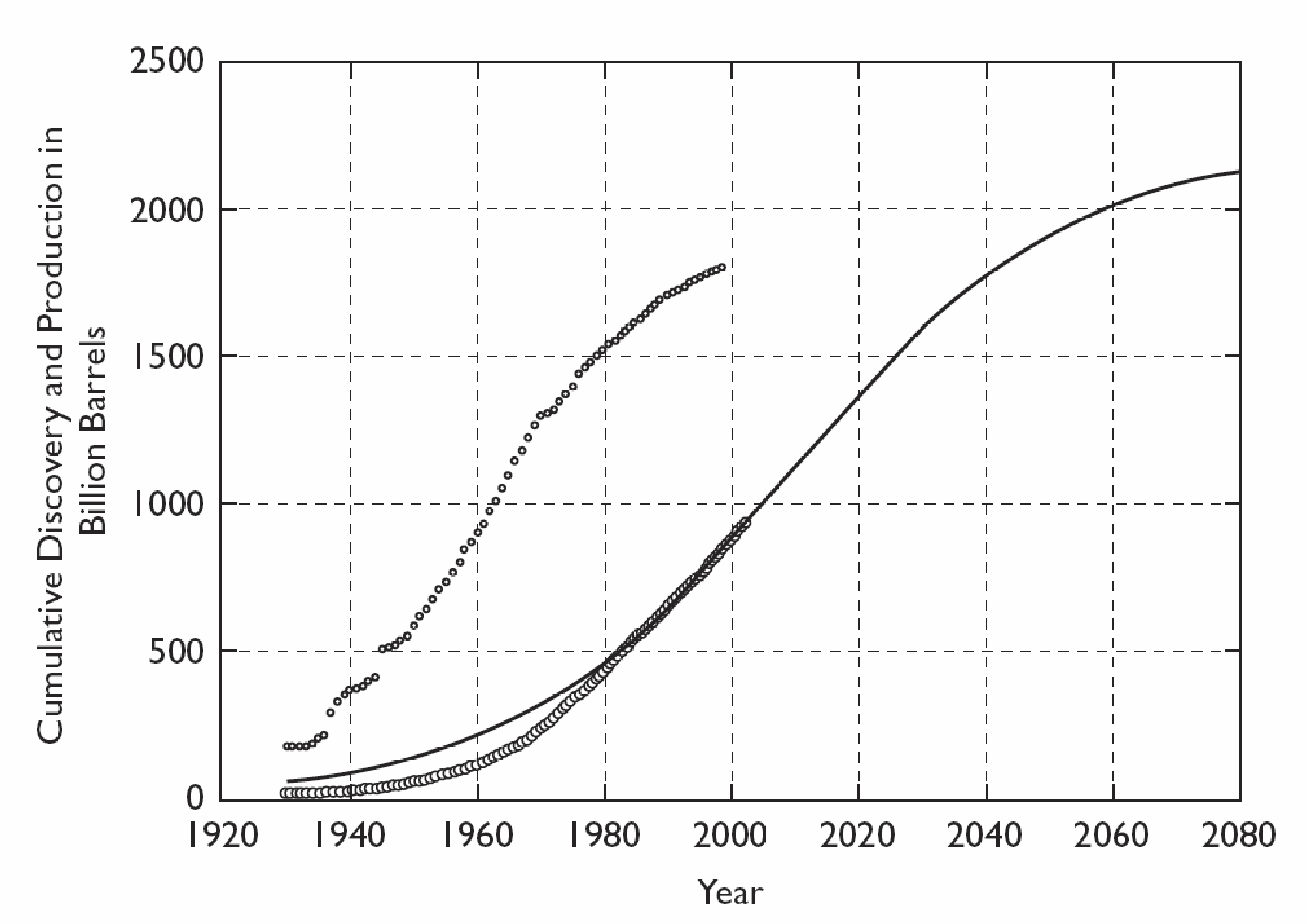
Source: Prediction of world peak oil production, Seppo A. Korpela, Ohio State University, 2003

World Oil Production

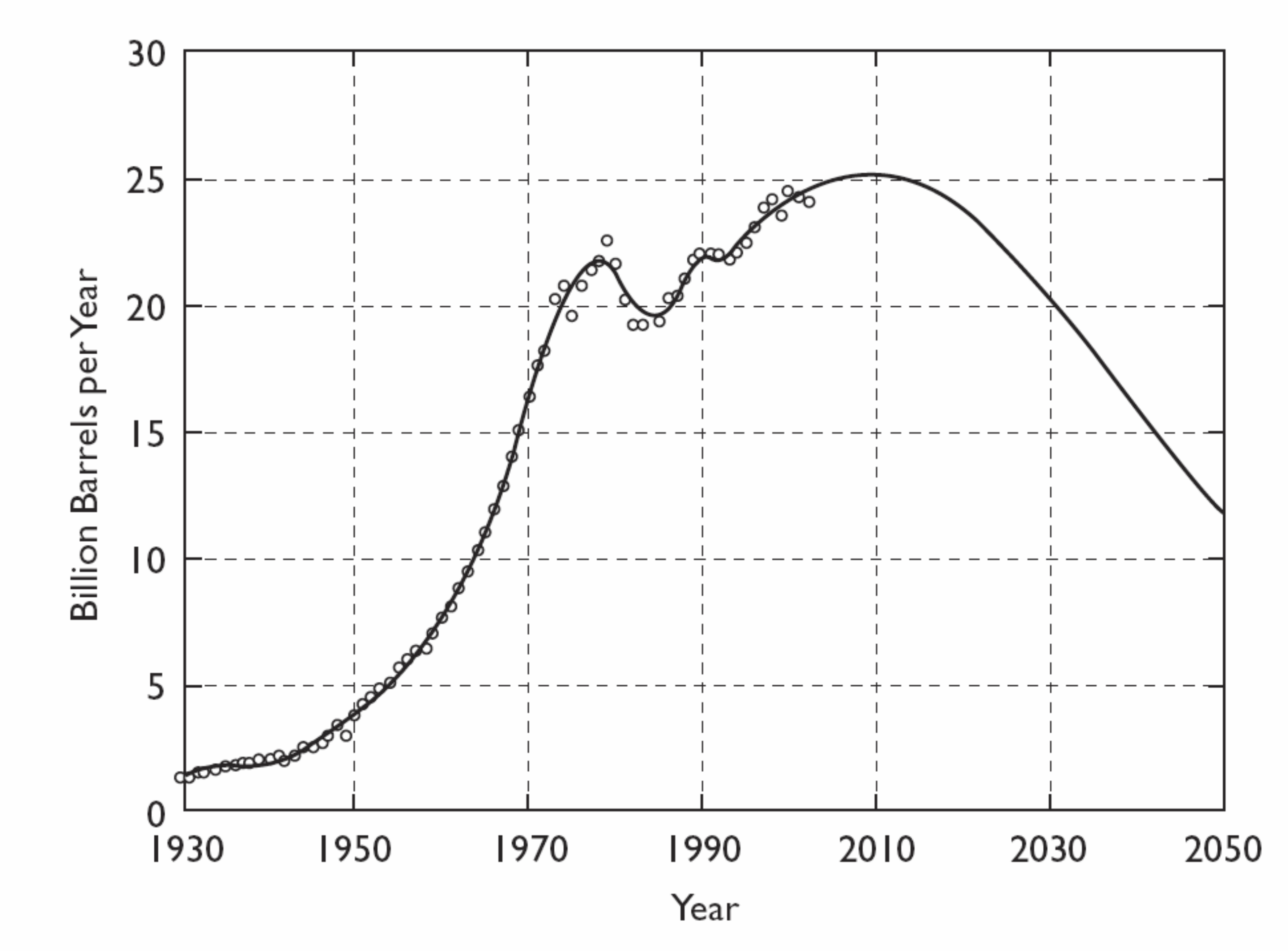


Source: Prediction of world peak oil production, Seppo A. Korpela, Ohio State University, 2003

World Oil Cumulative Discovery and Production

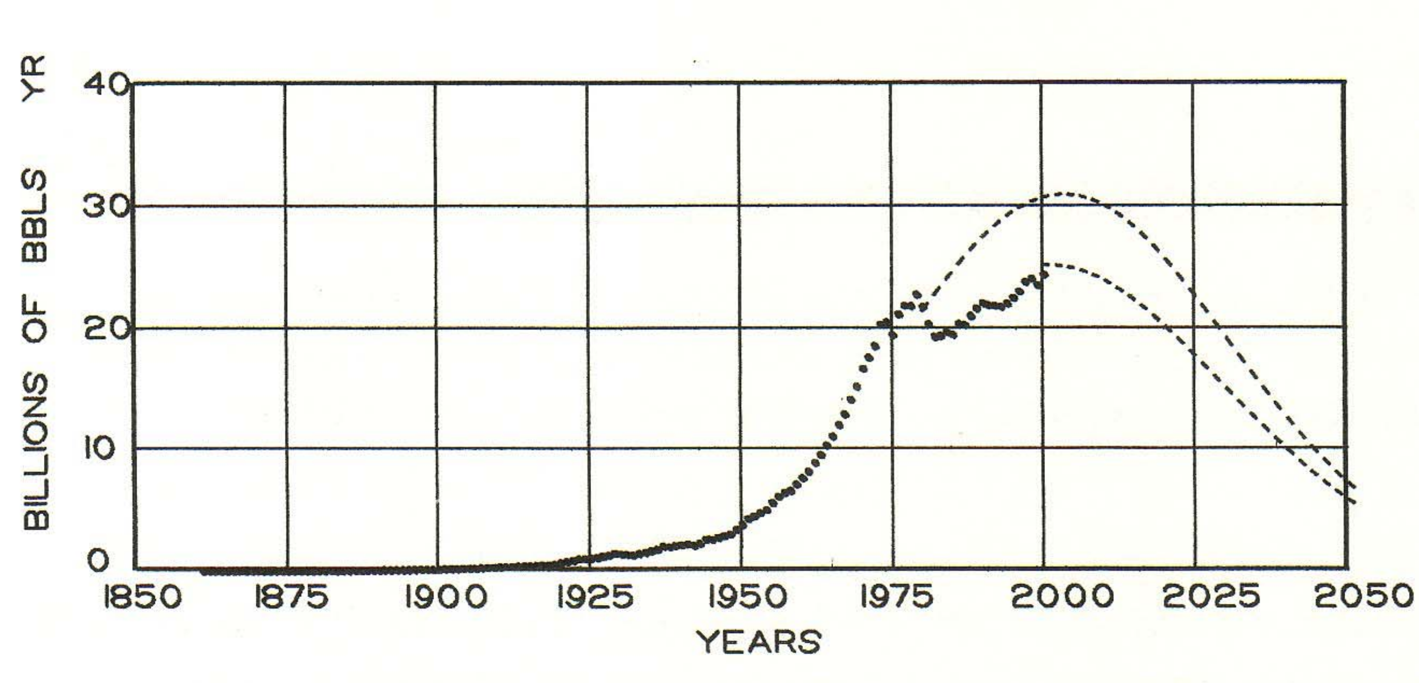


Annual World Oil Production



Source: Prediction of world peak oil production, Seppo A. Korpela, Ohio State University, 2003

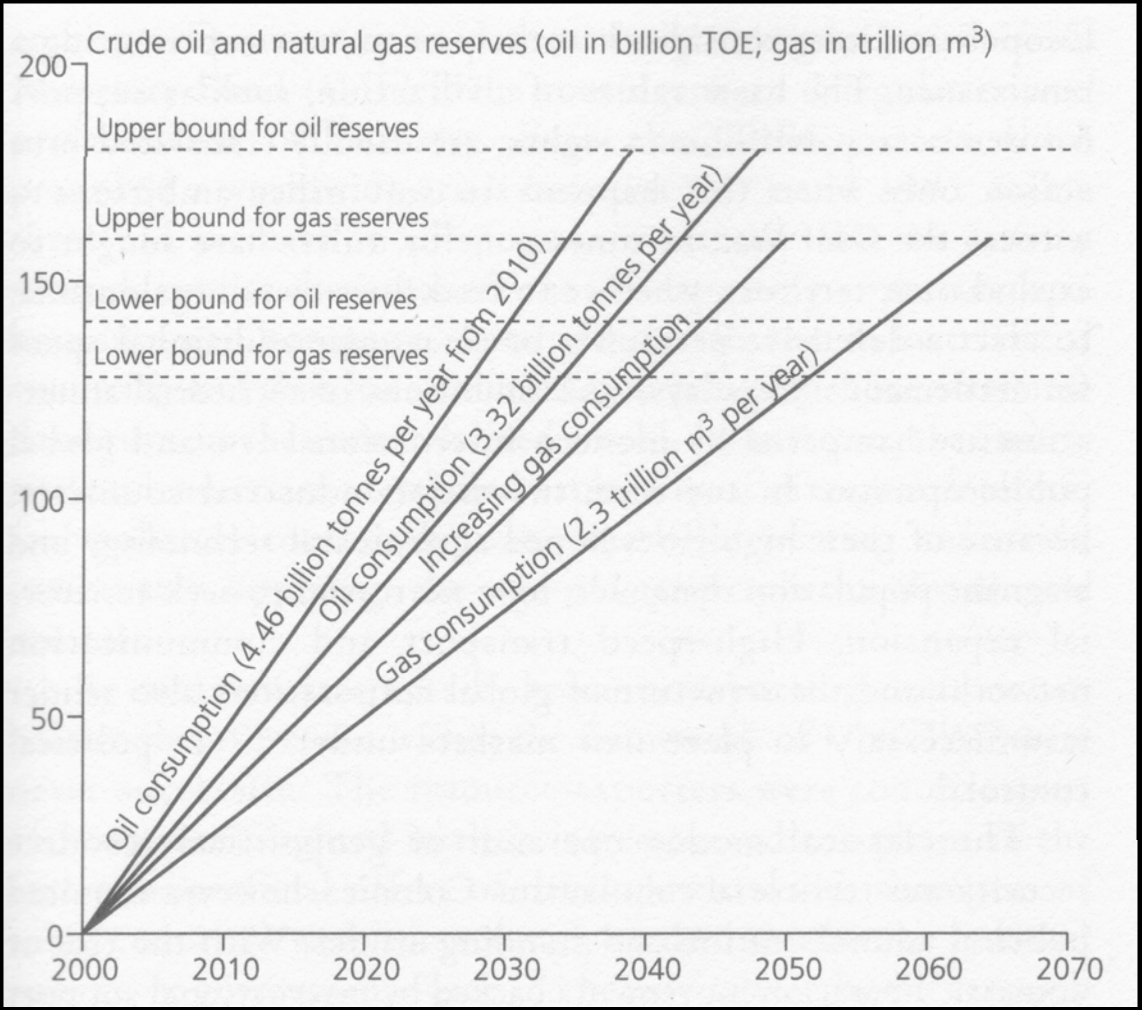
World Oil Production - Hubbert’s Method



World oil production through the year 2000 is shown as heavy dots. Hubbert’s method is used to obtain most likely future production. The dashed lines show the probable production rates if the ultimate discoverable oil is 1.8 trillion barrels - the lower curve or 2.1 trillion barrels - the upper curve

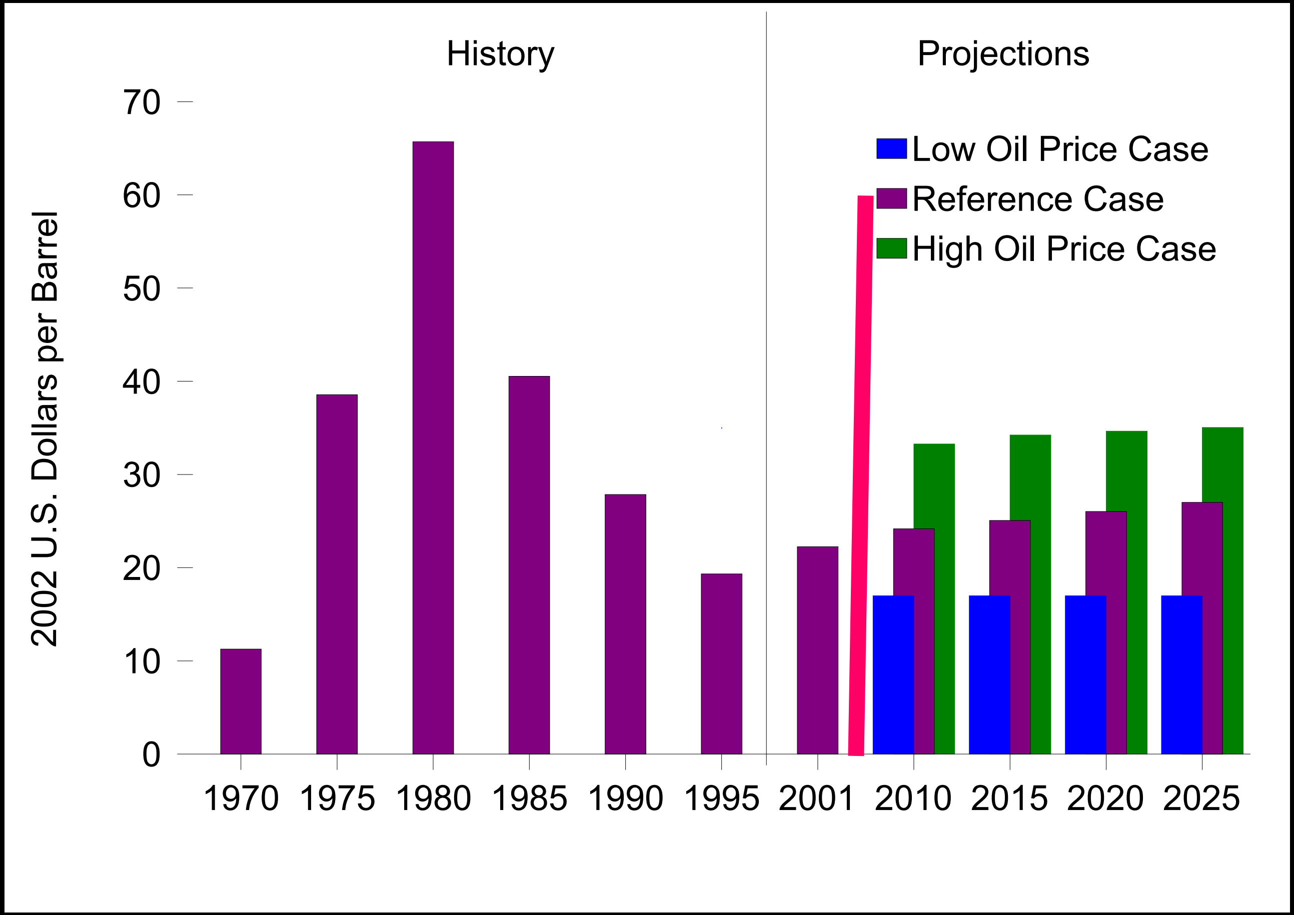
Source: Hubbert’s Peak: The Impending World Oil Shortage, Kenneth S. Deffeyes, Princeton Univ. Press, 2001.

Estimated Duration of Crude Oil and Natural Gas Reserves



Source: The Solar Economy by Hermann Scheer, Earthscan, 2002.

World Oil Prices



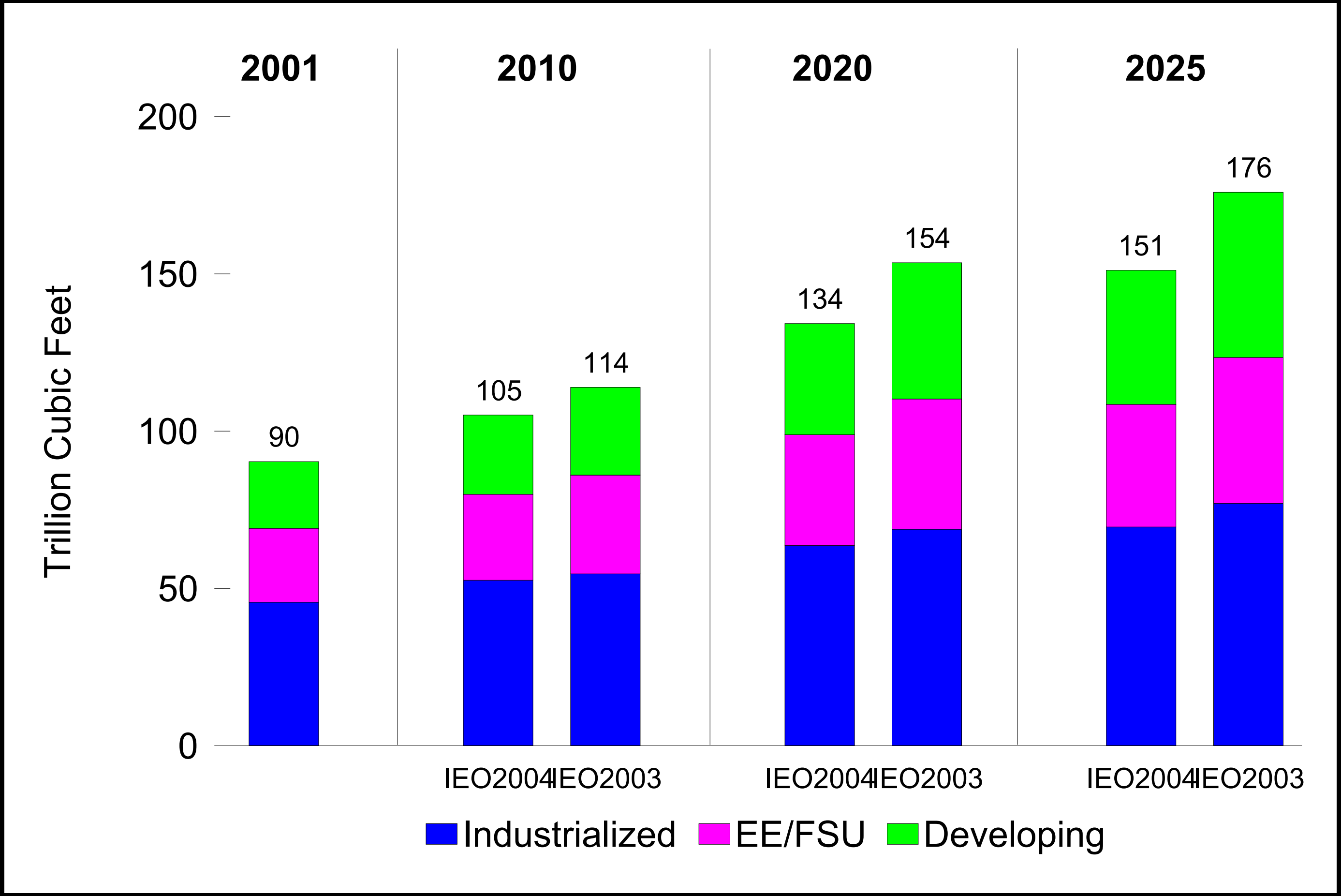
"International Energy Agency warned that if oil prices remained at $35 a barrel, or $10 above their 2001 levels, that would slash at least half a percentage point from world G.D.P. the next year"

NY times - August 11, 2004 - Global oil demand expected to exceed forecasts, Report says

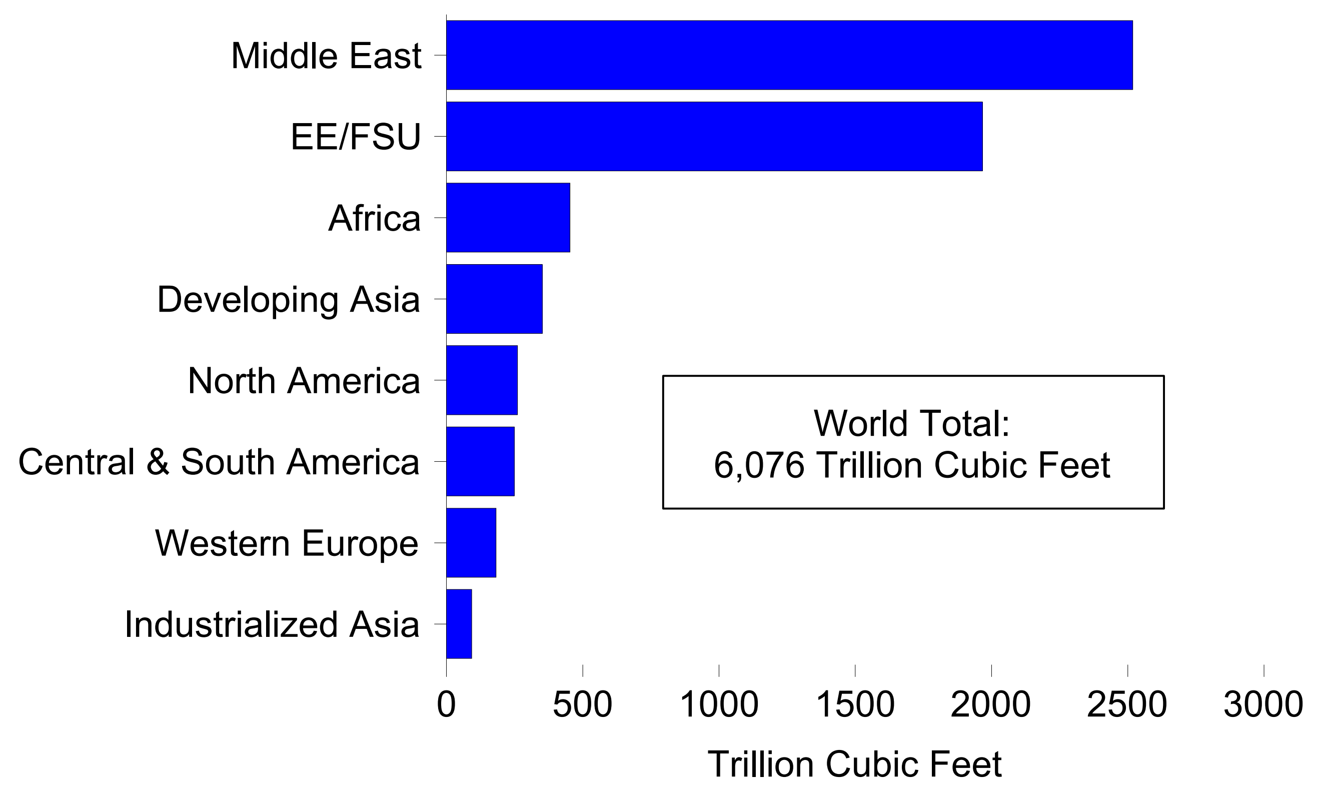
$45 a Barrel will reduce the world GDP by 1% from 2001 levels (~ $450 Billion)

Source: EIA, *International Energy Outlook 2004*

Natural Gas Consumption by Region



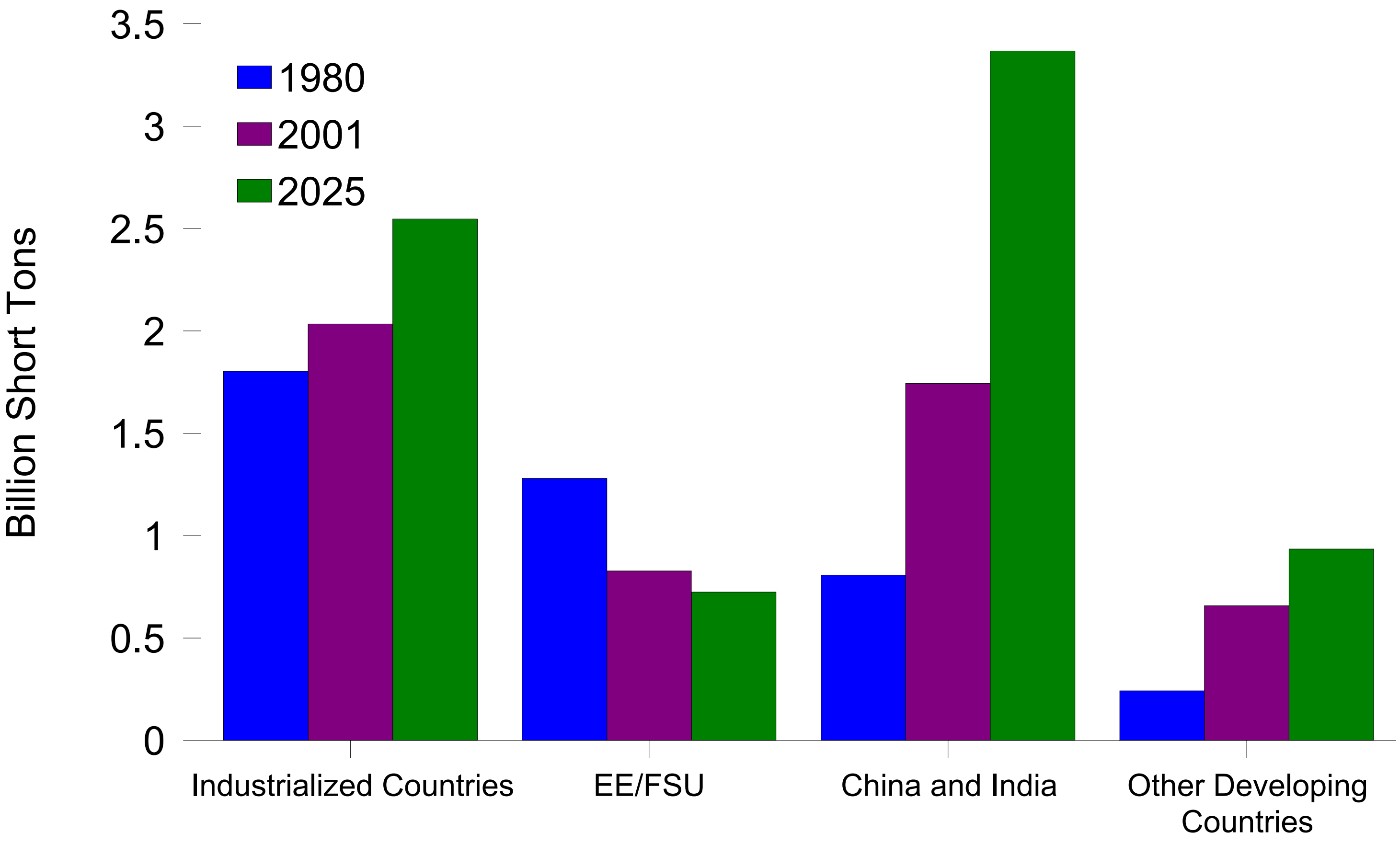
World Natural Gas Reserves by Region (1/1/04)



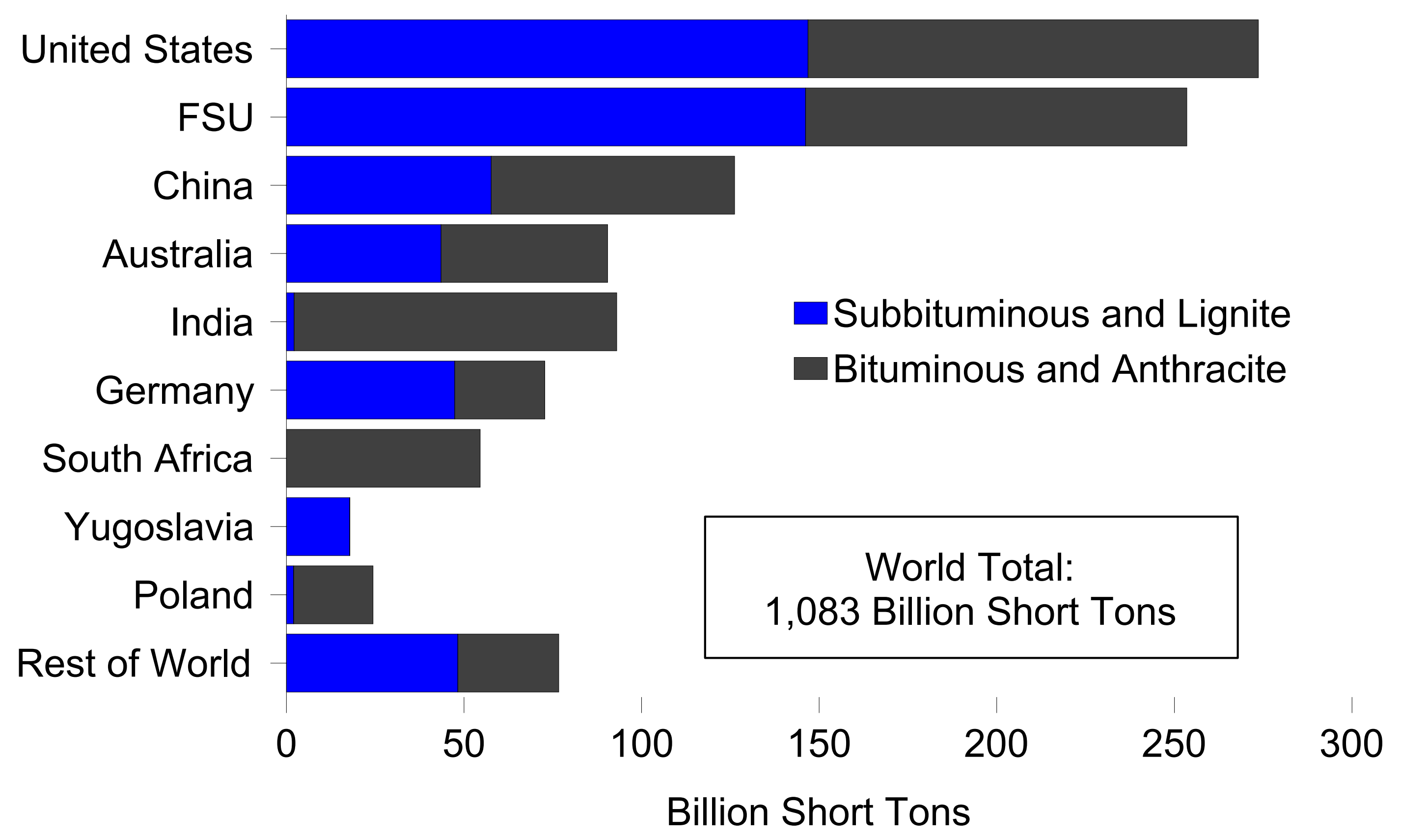
World Total:
6,076 Trillion Cubic Feet

Source: "Worldwide Look at Reserves and Production," Oil & Gas Journal, Vol. 100, No. 49, December 22, 2003, pp. 46-47

World Coal Consumption by Region



World Recoverable Coal Reserves in 2001



World 2025 Consumption ~ 7 billion short tones/year

Coal will last at least 150 years

Summary - Fossil Fuel Future

Dwindling reserves versus worldwide growth in demand will lead to energy prices beyond consumer’s ability to pay - leads to political tension and violence.

Conventional oil and gas reserves will probably be exhausted between 2030 and 2050.

Coal is the worst possible fossil fuel (most polluting of the fossil fuels and the one that produces the greatest amount of the greenhouse gas CO_2 per unit energy), but the world has at least a 150 year supply of coal.

Conclusion: Sustainable future is not possible if we continue to rely on fossil fuel for energy. Therefore, a massive and immediate shift towards renewable sources is inevitable.

Not a New Idea

“Within a few generations at most, some other energy than that of combustion of fuel must be relied upon to do a fair share of the work of the civilized world.”

Robert H. Thurston - 1901 in the Smithsonian Institution annual report.

Energy Systems in Sustainable Future

Summary from Lecture 1 - Fossil Fuel Future

Dwindling reserves versus worldwide growth in demand will lead to energy prices beyond consumer’s ability to pay - leads to political tension and violence.

Conventional oil and gas reserves will probably be exhausted between 2030 and 2050.

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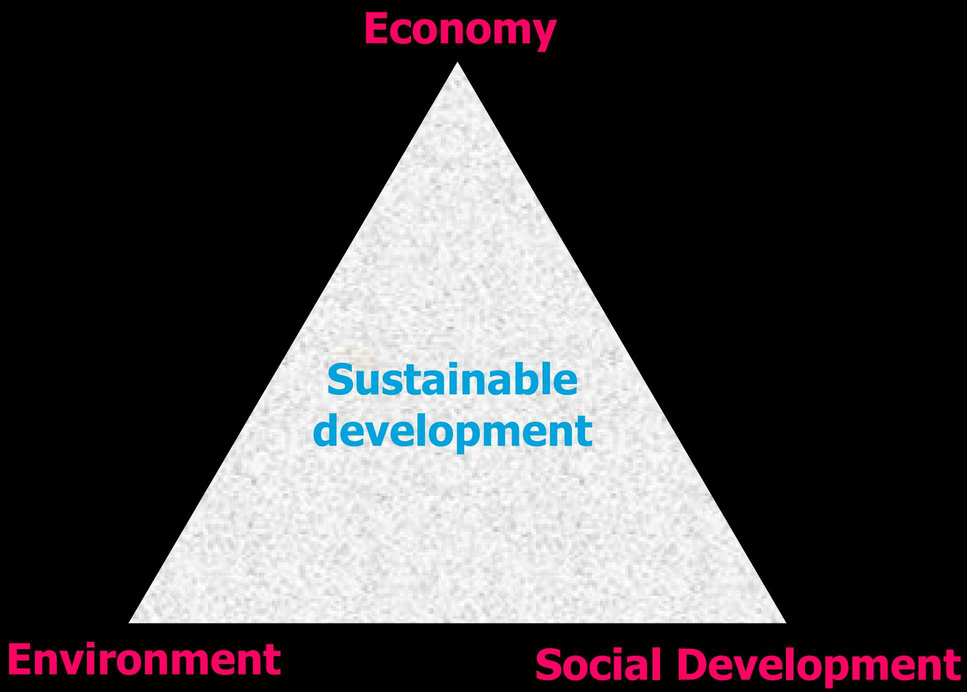
Conclusion: Sustainable future is not possible if we continue to rely on fossil fuel for energy. Therefore, a massive and immediate shift towards renewable sources is inevitable.

Energy and Sustainability



Economy

Sustainable development

Environment

Social Development

Energy has strong relationship with three pillars of sustainable development.

Sustainability requires secure, reliable and affordable supply of energy.

Sustainable energy future is not static - it must be continuously redefined and rebalanced with new technical solutions and technologies.

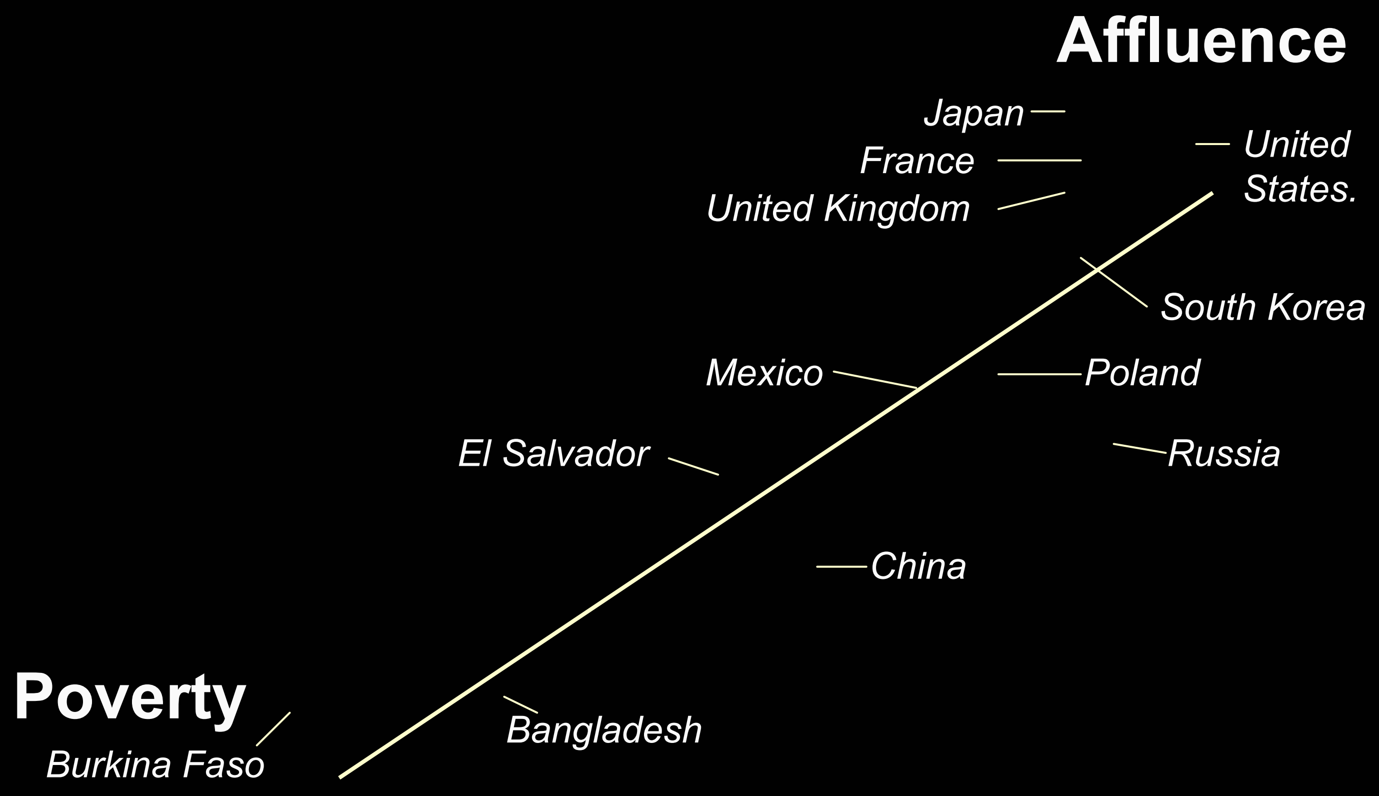
Sustainability demands that we seek to change present trends.

Change the structure of energy sector, behavior in our societies and economics

Challenge: *To fuel worldwide economic growth with secure and reliable energy supply without despoiling our environment*

Source: IEA statement on sustainable development at the world summit on sustainable development, Johannesburg, 2002

Per Capita Energy Consumption and GDP



Affluence

Japan

France

United Kingdom

United States.

South Korea

Mexico

Poland

El Salvador

Russia

China

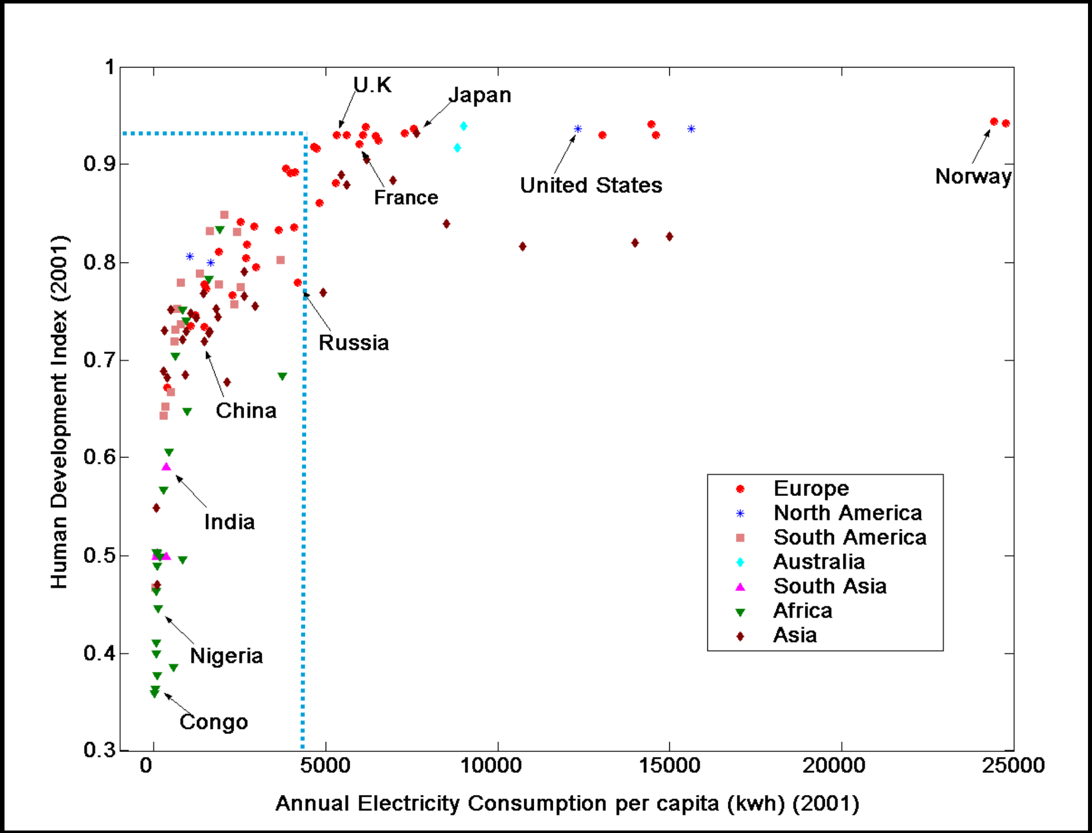
Poverty

Burkina Faso

Bangladesh

Source: Energy Information Administration, International Energy Annual 2000 Tables E1, B1, B2;
Gross Domestic Product per capita is for 2000 in 1995 dollars.

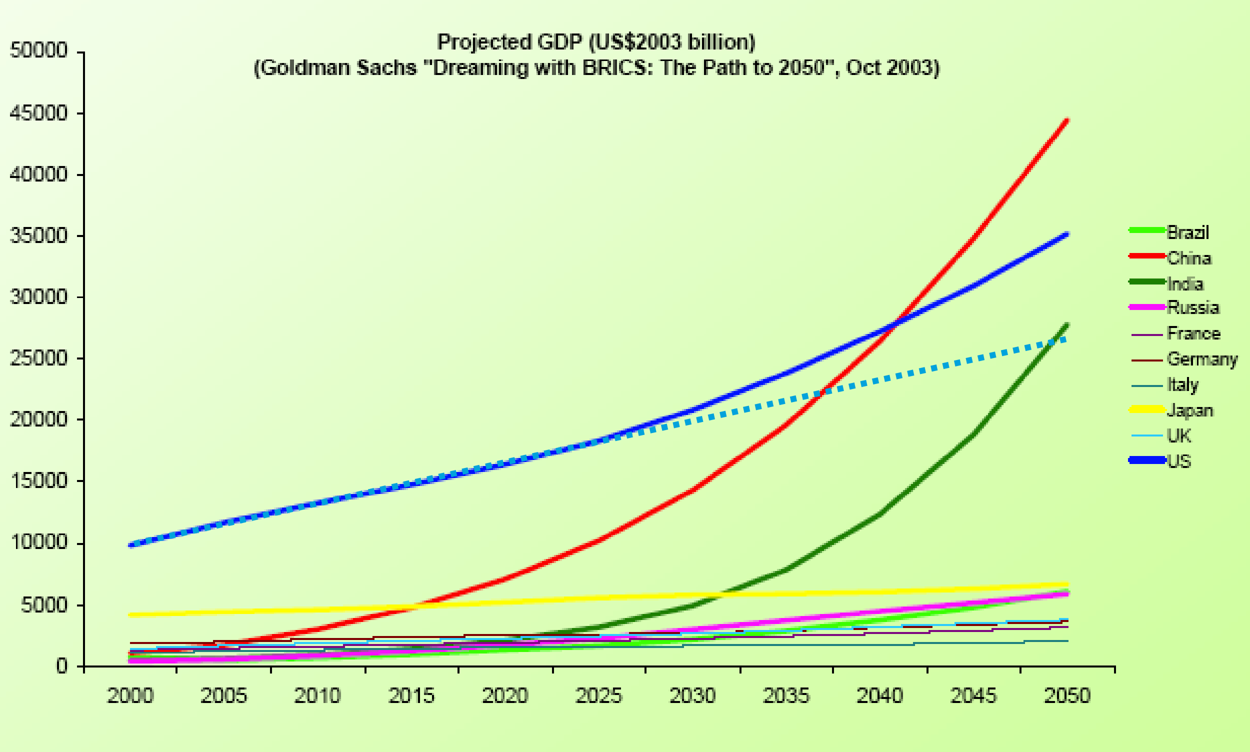
Per Capita Energy Consumption and HDI



HDI: Human development index - a composite measure of development based indicators: life expectancy, educational level and per capita gross domestic product. Each data point corresponds to a country. Modest increase in PCEC can lead to marked improvements in the quality of life in the developing nations.

Source: Alan D. Pasternak, Global energy futures and human development: A frame work for analysis, UCRL-ID-140773, Lawrence Livermore National Laboratory, U.S. DOE, 2003

GDP Growth for Selected Countries



GDP growth will bring urban shift in population

India: 28% in 2000

41% in 2035

Energy Units and Conversions

BTU : the amount of heat necessary to raise one pound of water by one degree F

Joule: the force of one Newton acting through one meter

1 BTU=1055 J

1 kWh = 3.6 x10^6 J

1 calorie = 4.184 J

1 Quad = 10^{15} BTU

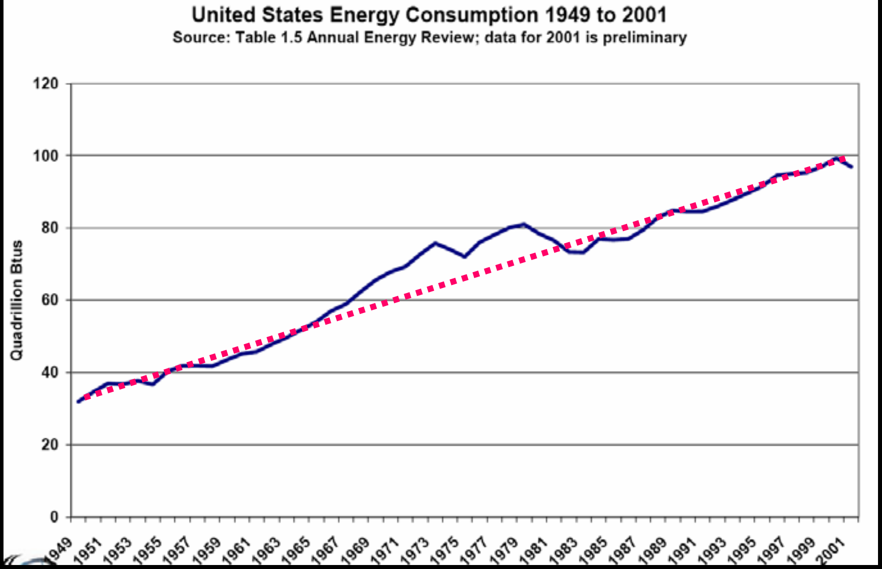
1 hp = 745.7 watts

Energy Content of Fuels:

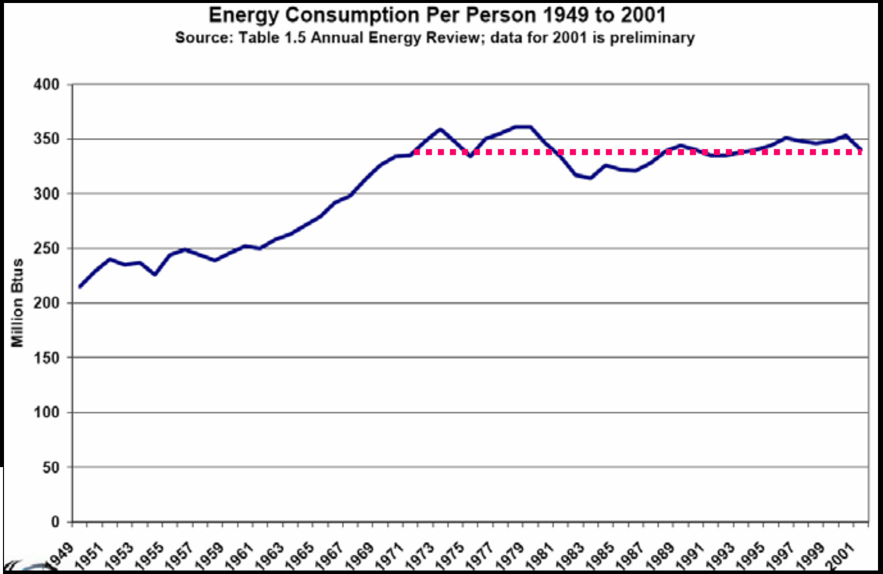
Coal	25 x10^6 BTU/ton
Crude oil	5.6 x10^6 BTU/barrel
Oil	5.78 x10^6 BTU/barrel = 1700 kWh
Gasoline	5.6 x10^6 BTU/barrel (a barrel is 42 gallons)
Liquid Natural Gas	4.2 x10^6 BTU/barrel
Natural Gas	1030 BTU/ft^3

terra, T: 10^{12}; giga, G = 10^9

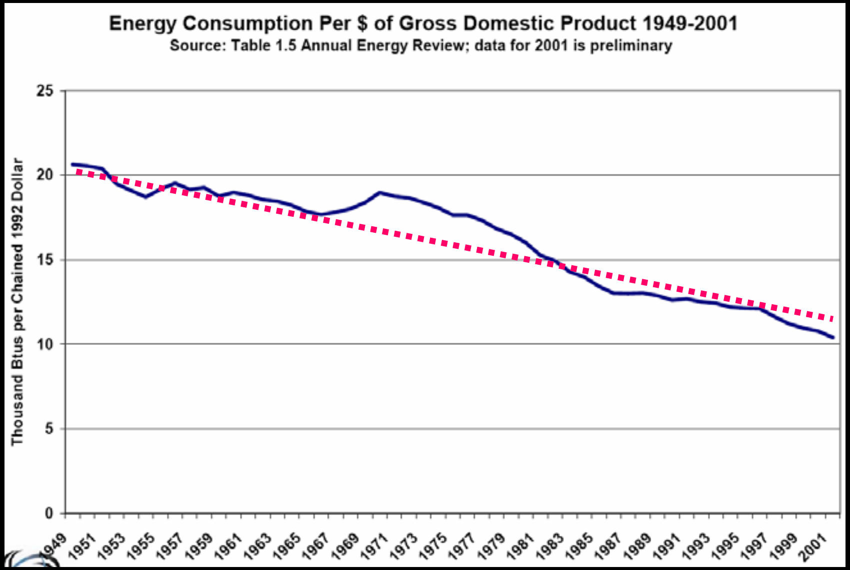
US Energy Consumption


United States Energy Consumption 1949 to 2001

Source: Table 1.5 Annual Energy Review; data for 2001 is preliminary


Energy Consumption Per Person 1949 to 2001

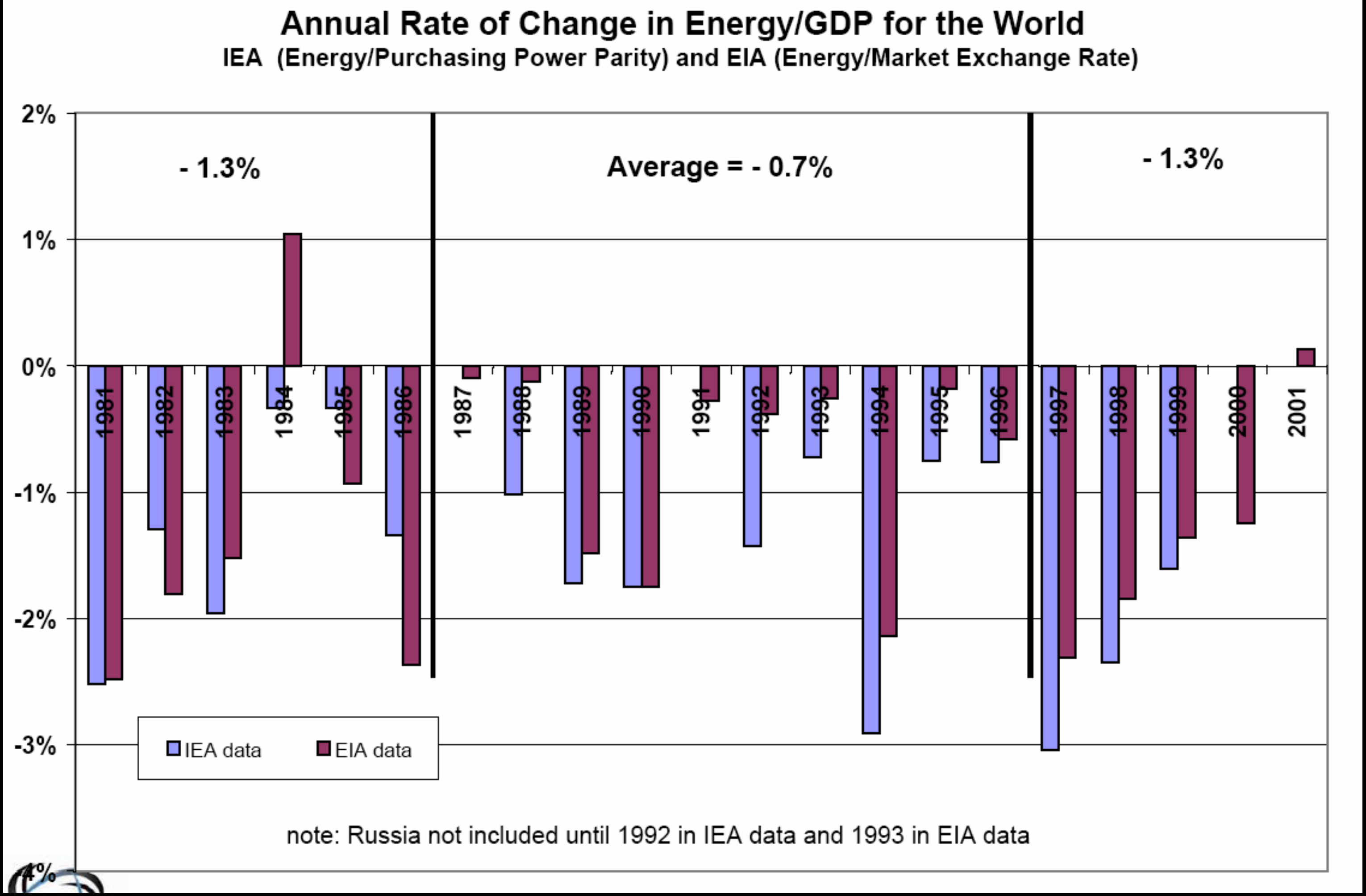
Source: Table 1.5 Annual Energy Review; data for 2001 is preliminary


Energy Consumption Per $ of Gross Domestic Product 1949-2001

Source: Table 1.5 Annual Energy Review; data for 2001 is preliminary

Effects of conservation and improvements in energy efficient consumer and industrial and transportation sectors

Rate of Change in World Energy

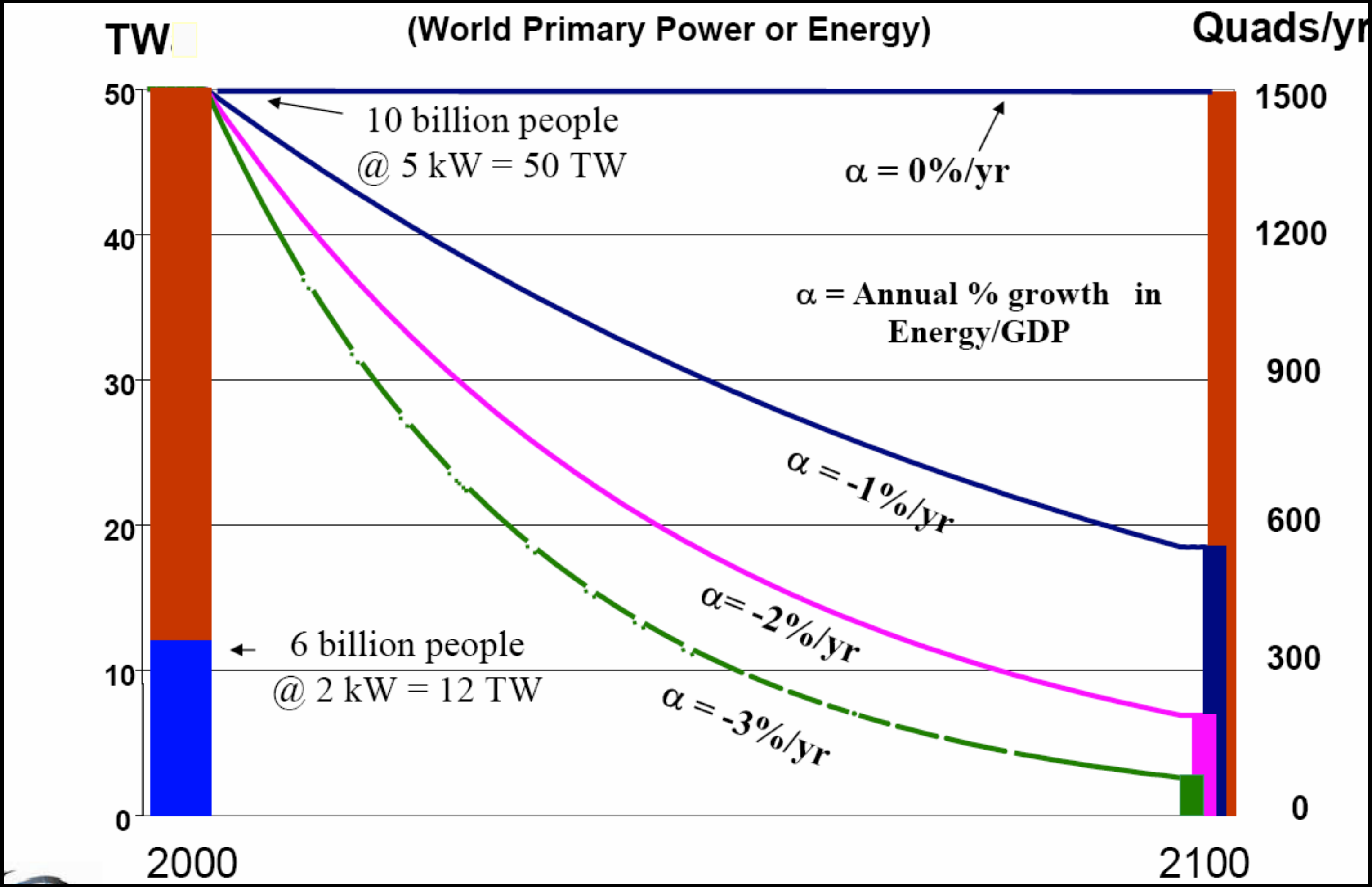


Annual Rate of Change in Energy/GDP for the World

IEA (Energy/Purchasing Power Parity) and EIA (Energy/Market Exchange Rate)

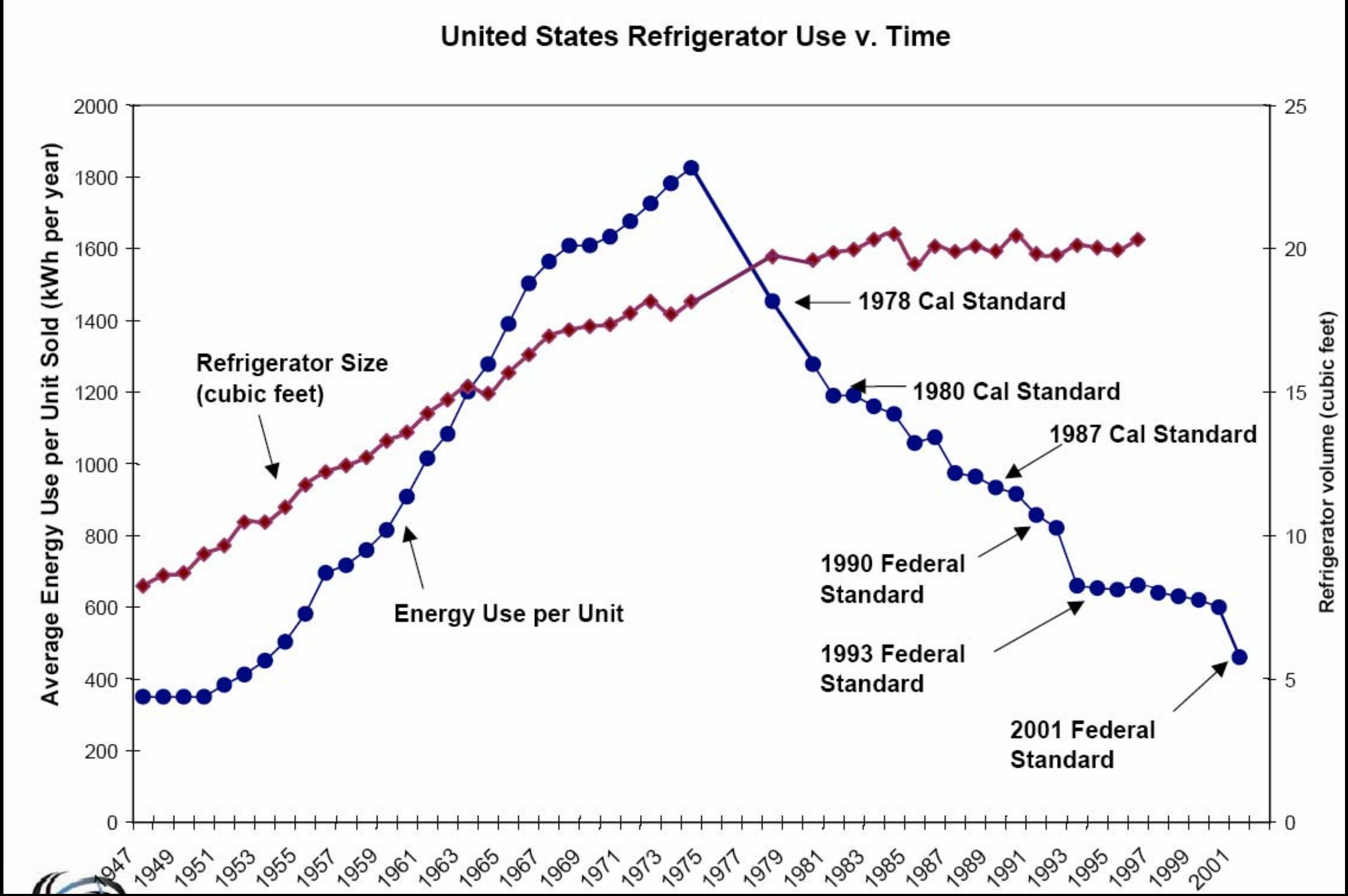
note: Russia not included until 1992 in IEA data and 1993 in EIA data

World Primary Energy



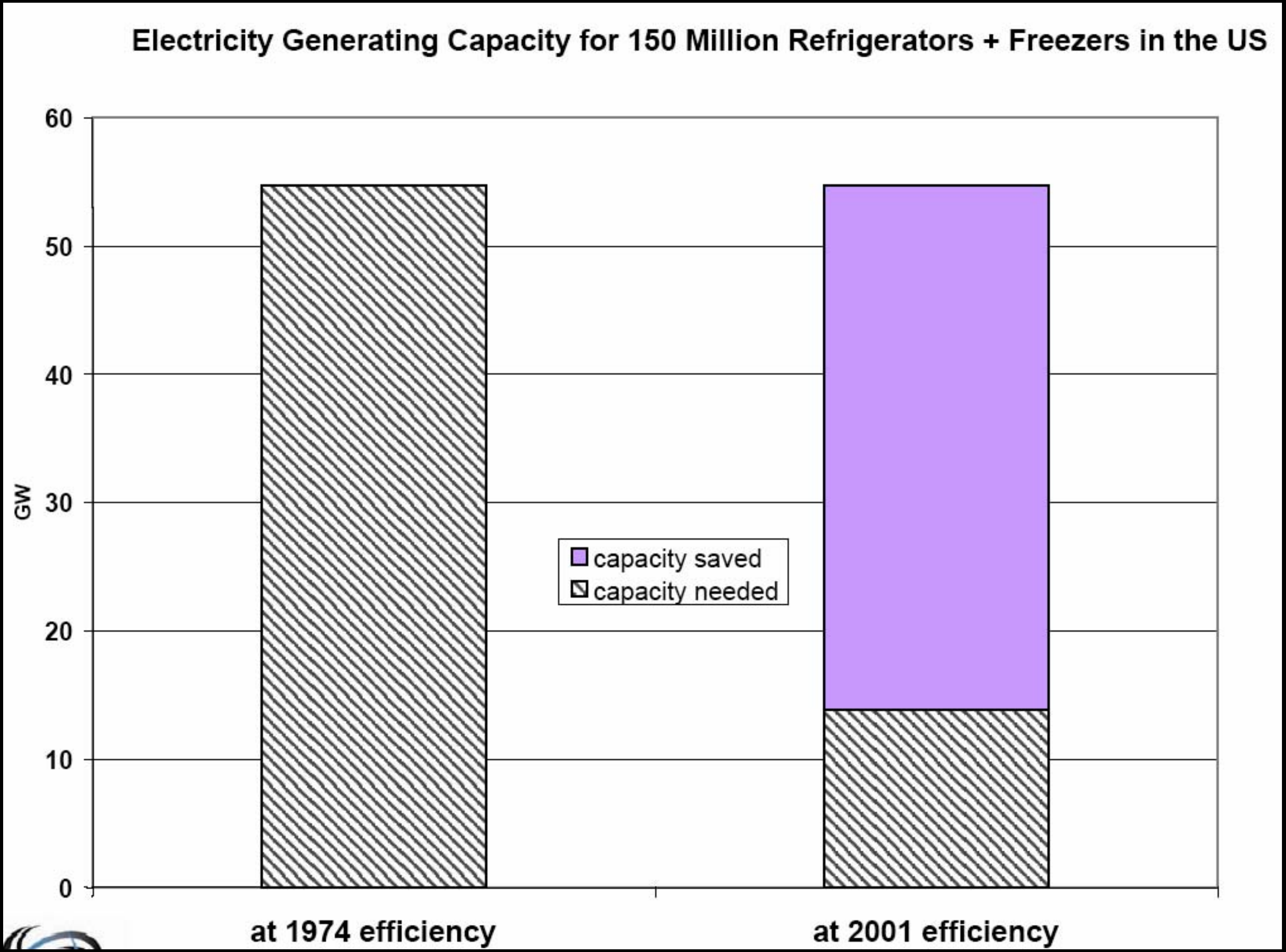
Source: Arthur Rosenfeld, commissioner, California Energy Commission

Role of Technology



Source: Arthur Rosenfeld, commissioner, California Energy Commission

Role of Technology



Source: Arthur Rosenfeld, commissioner, California Energy Commission

Energy Usage Sectors

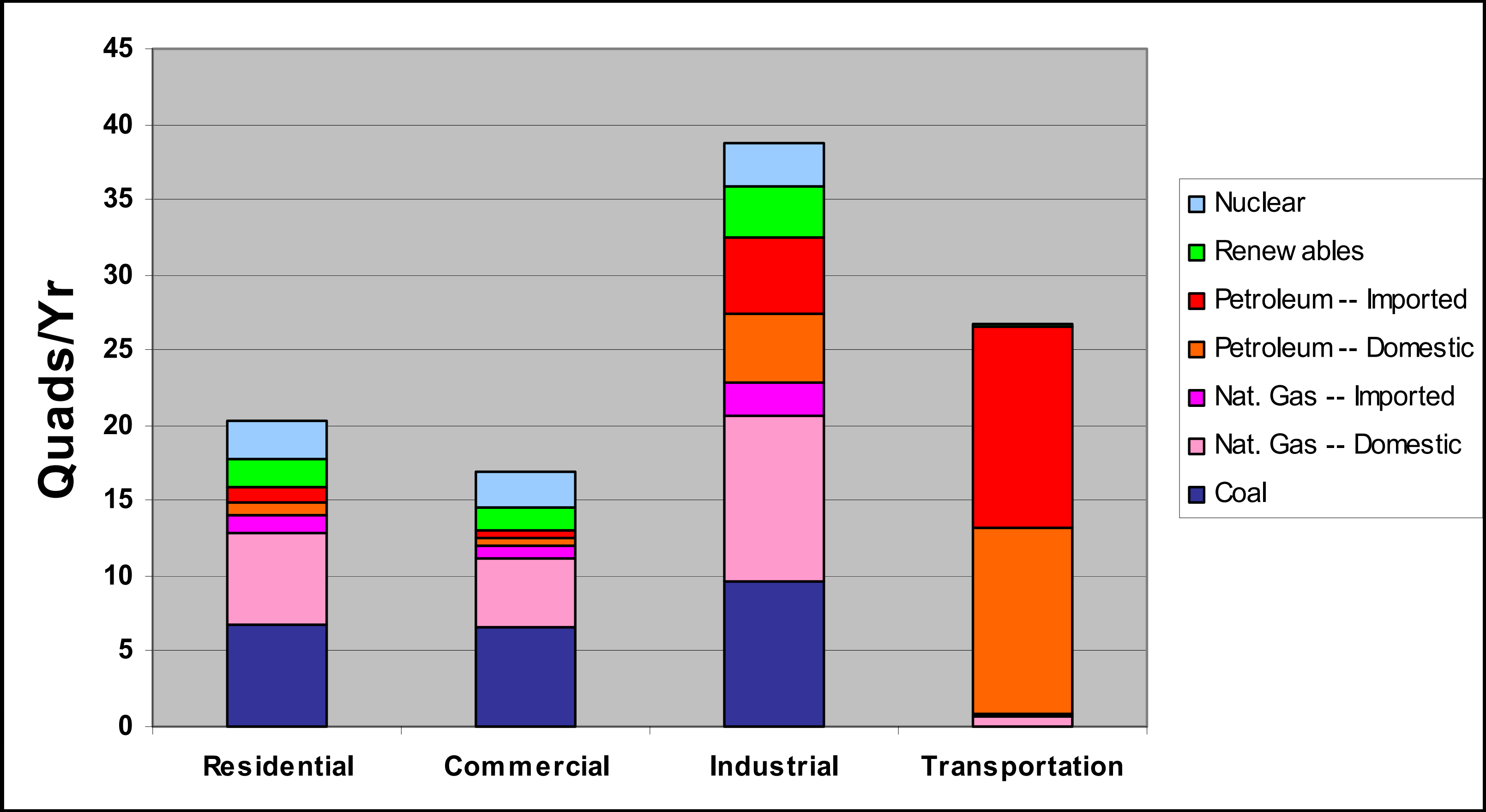
- Residential
- Commercial
- Industry
  - Iron and steel, Chemicals and petrochemicals,
  - Cement and other industries
- Transportation
  - Road, Rail and aviation

Energy Sources

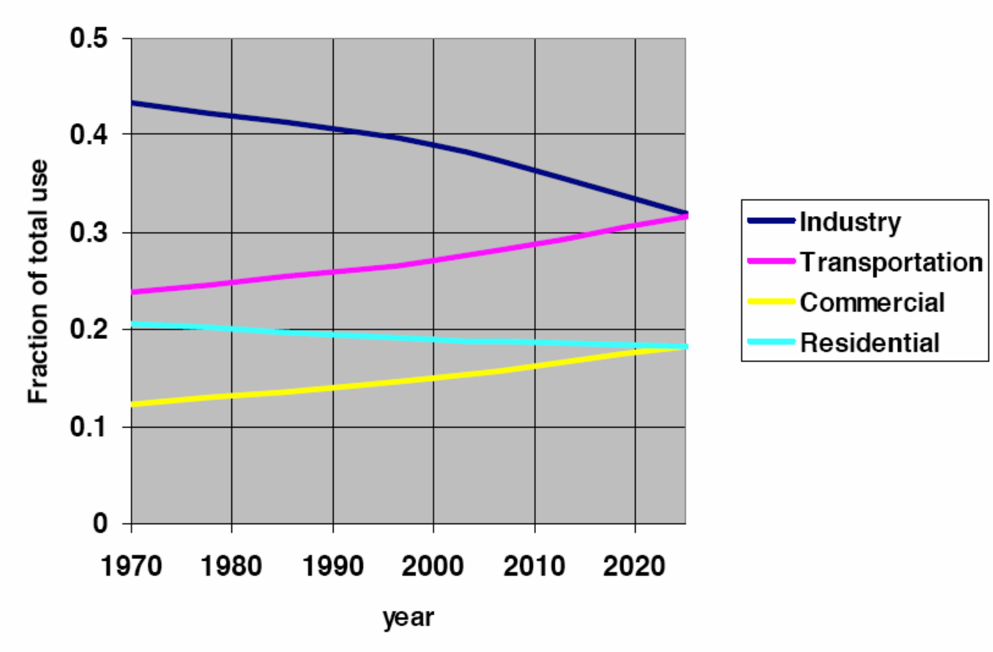
- Oil
- Coal
- Natural Gas
- Nuclear
- Biomass
- Renewable Energy

  Wind, Hydro, Solar Etc.

US Primary Energy Consumption by Sector - 1999

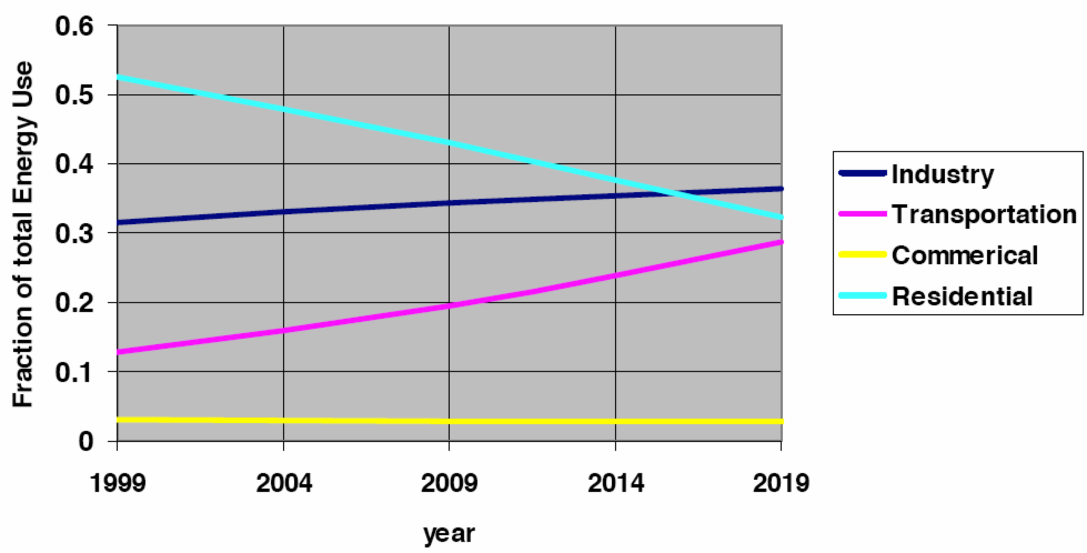


Energy Use by Sector



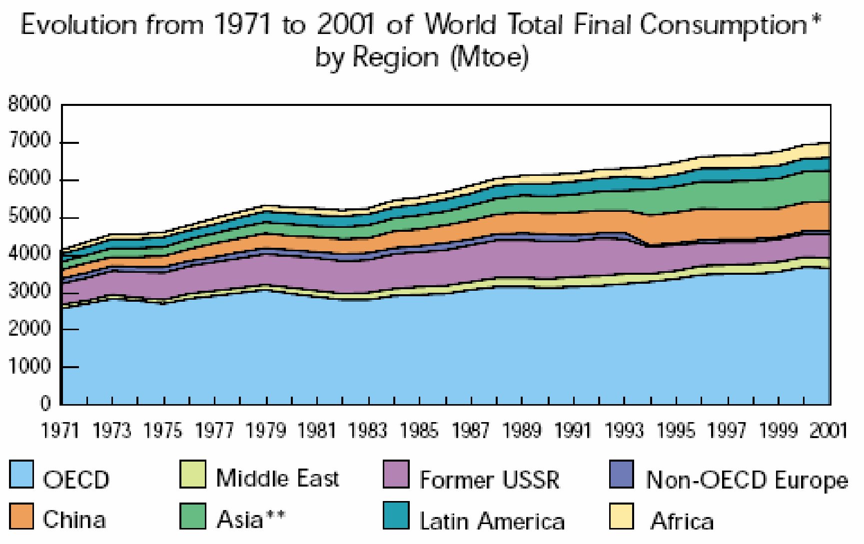
← USA

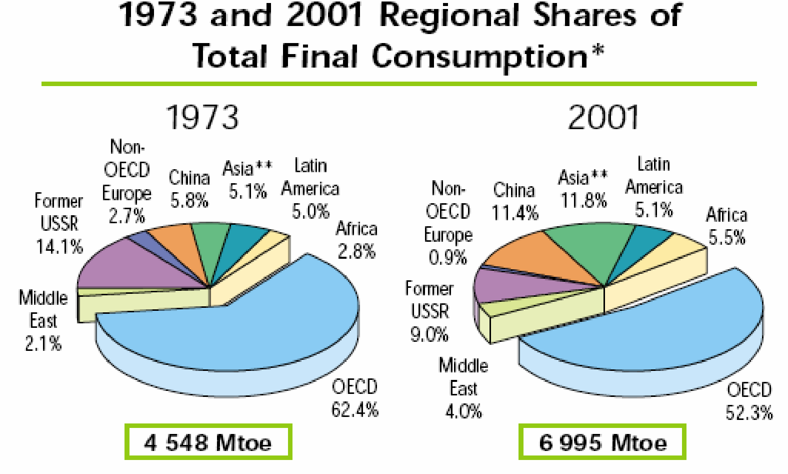
India →



Energy Consumption by Sector

Sector	China (%)	United States (%)	India (%)
Industry	*40*	*25*	*27*
Transportation	*11*	*40*	*9*
Agriculture	*3*	*1*	*2*
Commercial & public services	*14*	*13*	*1*
Residential	*29*	*17*	*58*
Non energy use	*3*	*4*	*3*

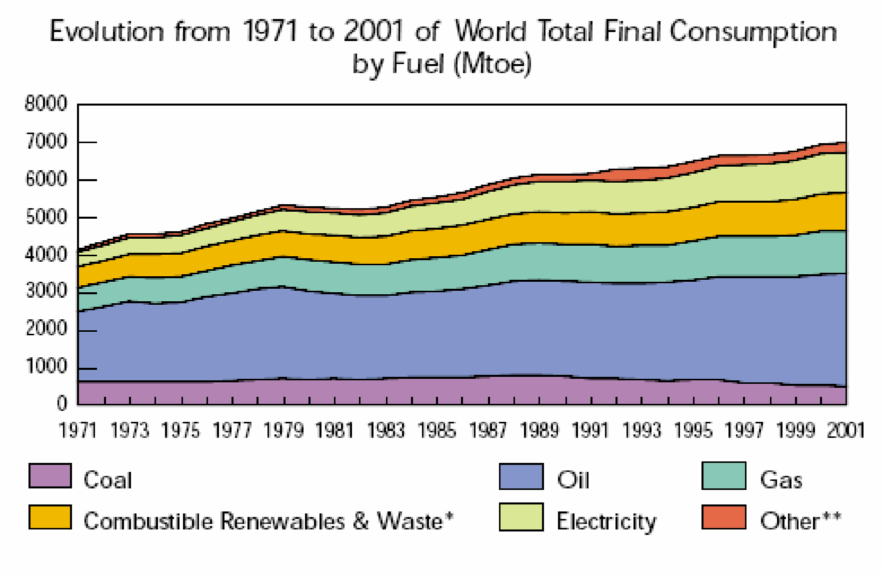

Evolution from 1971 to 2001 of World Total Final Consumption* by Region (Mtoe)

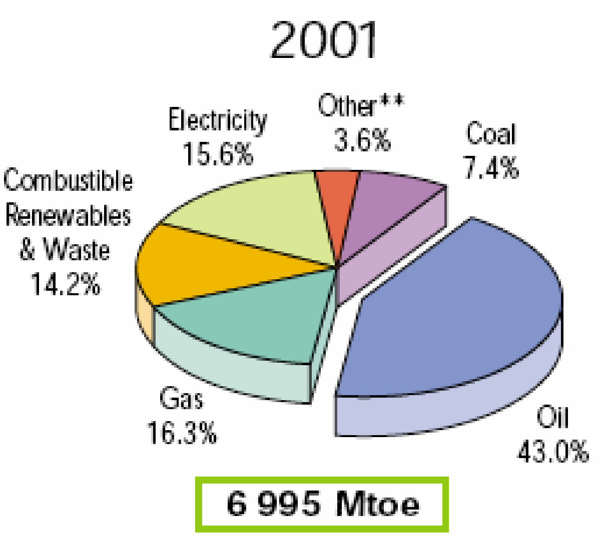

1973 and 2001 Regional Shares of Total Final Consumption*

1 Mtoe: amount of energy released when one million tones of crude oil is burnt=41.868x10^{15} J

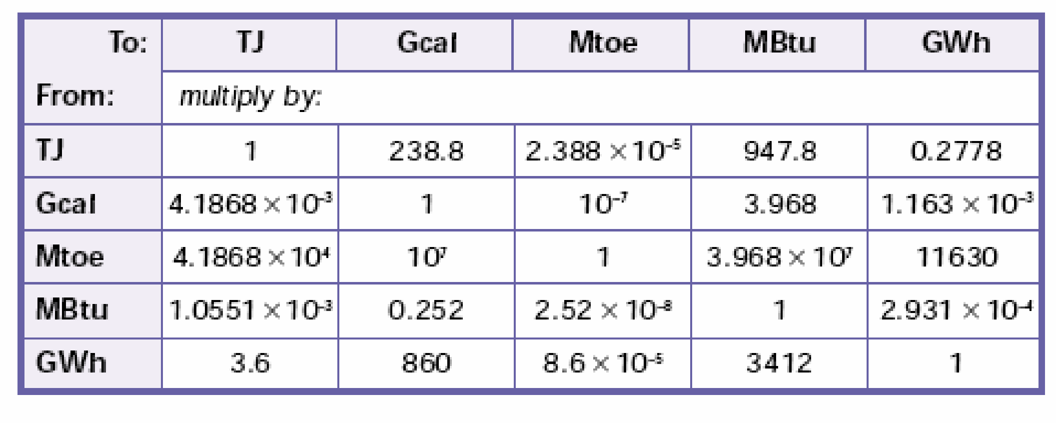
Source: IEA Key World Statistics - 2003

Energy Consumption by Fuel Type


Evolution from 1971 to 2001 of World Total Final Consumption by Fuel (Mtoe)


2001

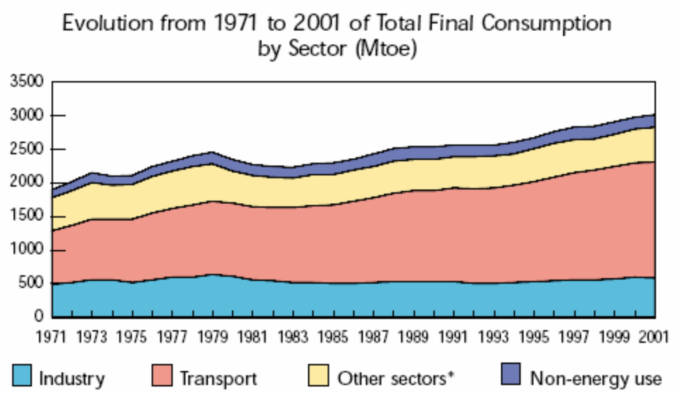
6 995 Mtoe

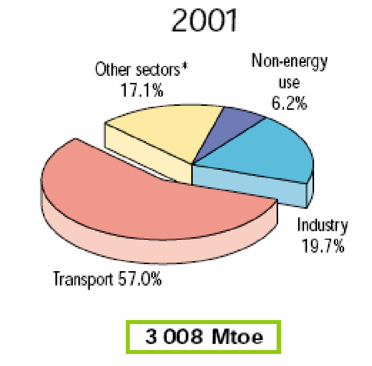


To:	TJ	Gcal	Mtoe	MBtu	GWh
From:	*multiply by:*				
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	10^{-7}	3.968	1.163×10^{-3}
Mtoe	4.1868×10^{4}	10^{7}	1	3.968×10^{7}	11630
MBtu	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	860	8.6×10^{-5}	3412	1

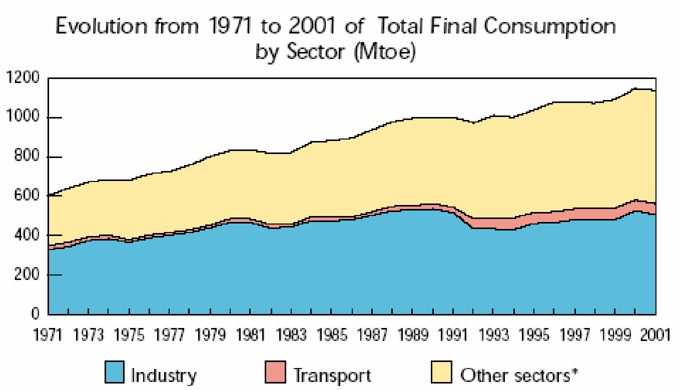
Sustainable Energy Science and Engineering Center

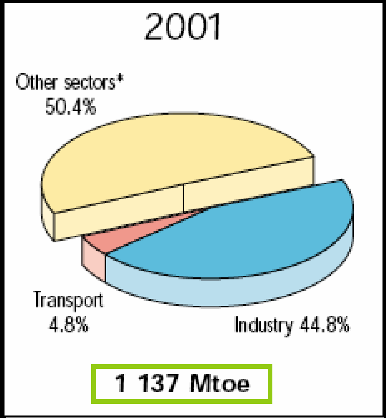
Fuel Consumption by Sector



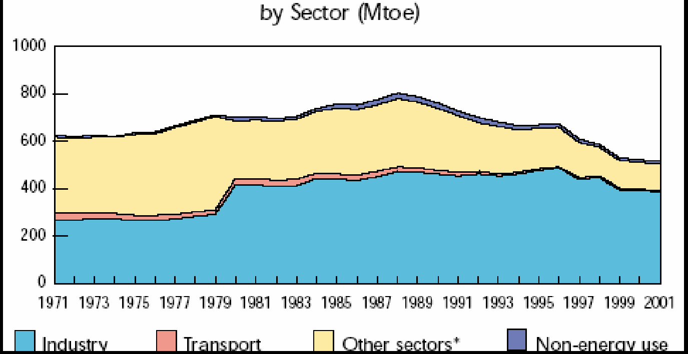


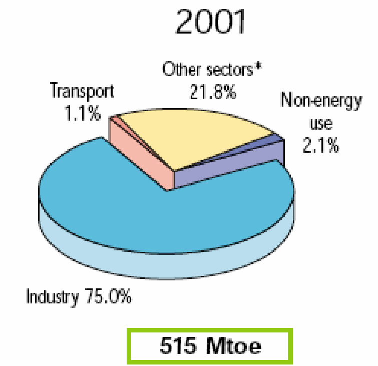
Oil





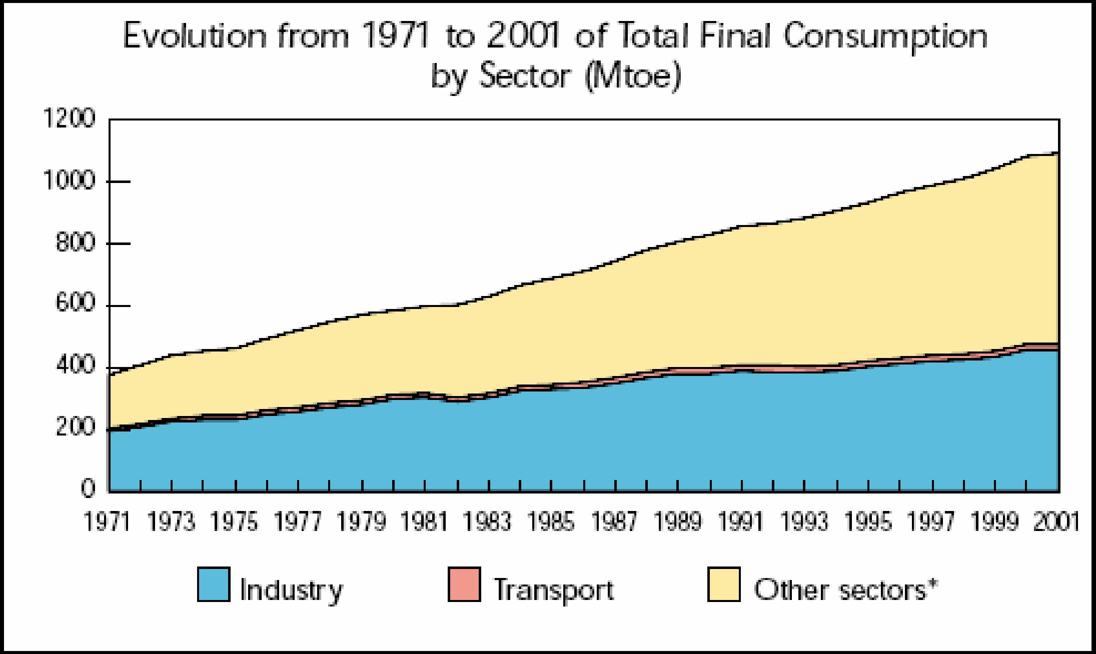
Gas

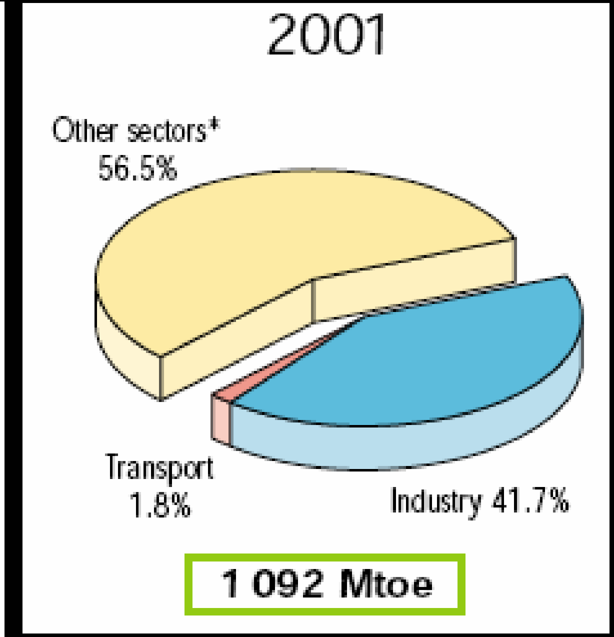




Coal

World Electricity Consumption by Sector



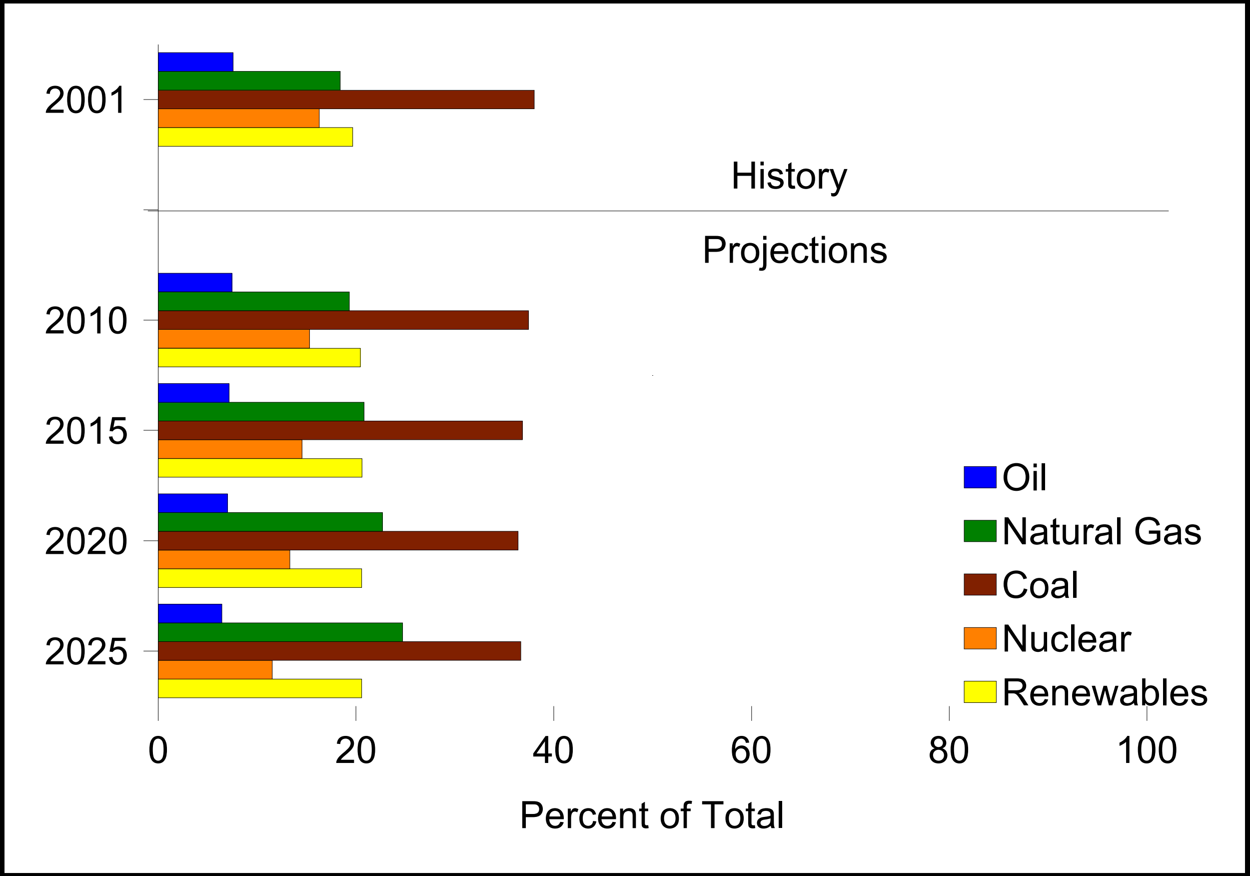


Retail Prices ($) in selected Countries

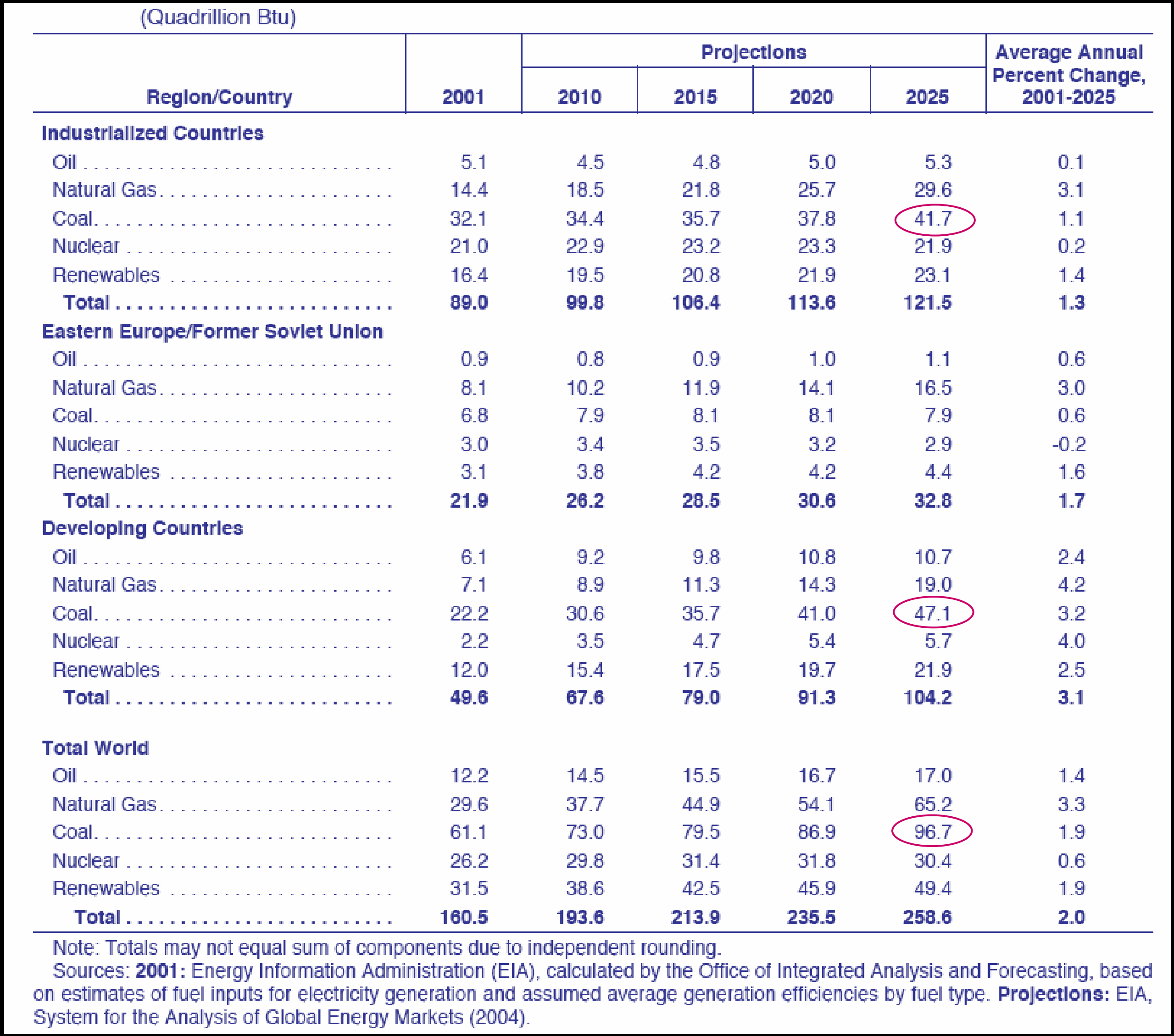
Country	Heavy Fuel Oil for Industry (tonne)	Automotive Diesel oil (liter)	Unleaded premium (liter)	Electricity For Industry (kWh)	Electricity For Households (kWh)	Natural gas for Industry (10^7 kcal GCV*)
USA	174.48	0.380	0.381	0.0470	0.0830	176.27
France	189.70	0.665	1.033	0.0368	0.1045	187.27
Japan	219.42	0.518	0.829	0.1426	0.2144	406.4
India	309.58	0.416	0.613	0.0801	0.0388	------

*GCV: Gross Caloric Value

Energy Use for Electricity Generation



Energy Consumption for Electricity Generation



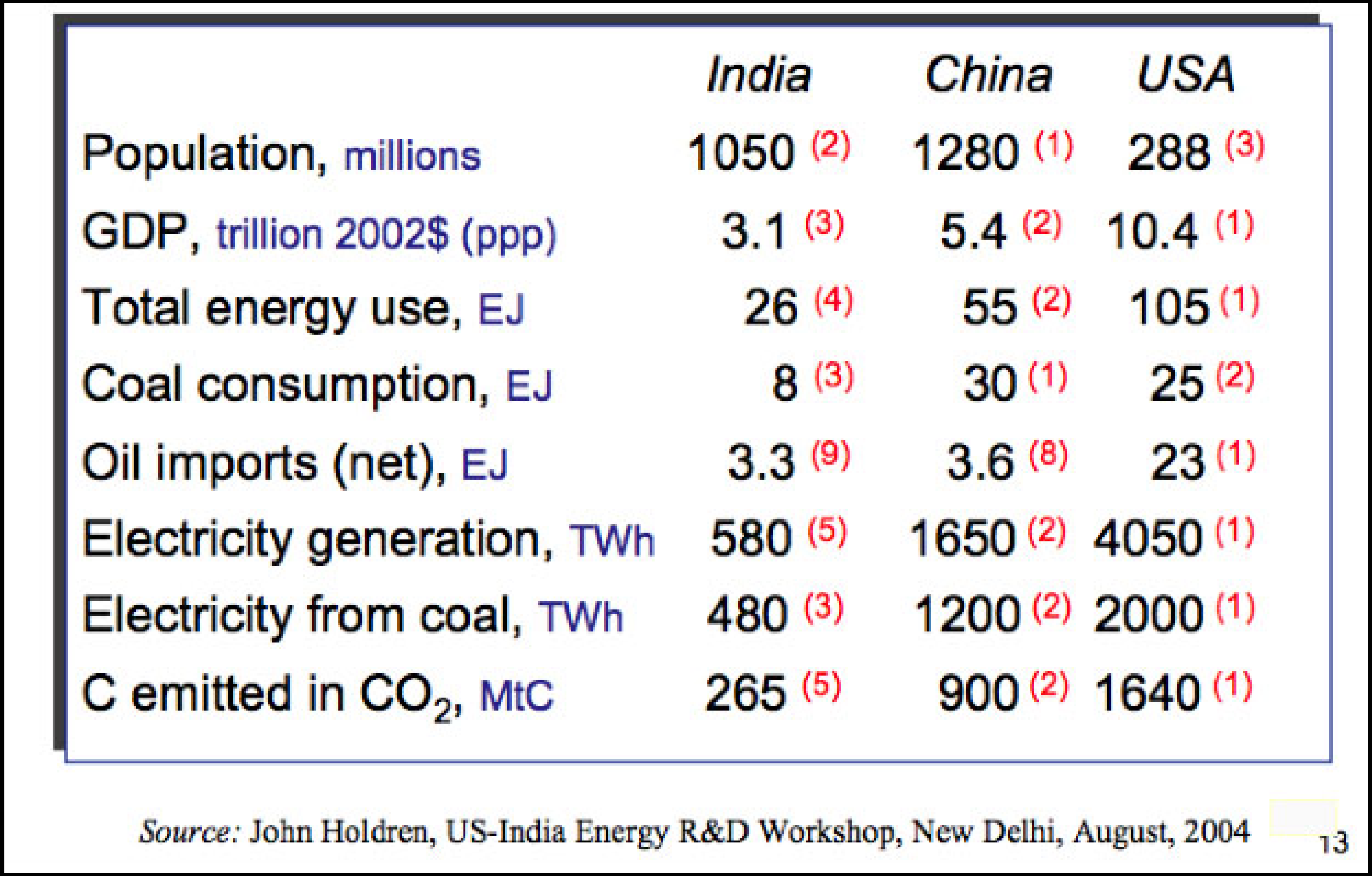
(Quadrillion Btu)

Region/Country	2001	Projections				Average Annual Percent Change, 2001-2025
		2010	2015	2020	2025	
Industrialized Countries						
Oil	5.1	4.5	4.8	5.0	5.3	0.1
Natural Gas	14.4	18.5	21.8	25.7	29.6	3.1
Coal	32.1	34.4	35.7	37.8	41.7	1.1
Nuclear	21.0	22.9	23.2	23.3	21.9	0.2
Renewables	16.4	19.5	20.8	21.9	23.1	1.4
Total	**89.0**	**99.8**	**106.4**	**113.6**	**121.5**	**1.3**
Eastern Europe/Former Soviet Union						
Oil	0.9	0.8	0.9	1.0	1.1	0.6
Natural Gas	8.1	10.2	11.9	14.1	16.5	3.0
Coal	6.8	7.9	8.1	8.1	7.9	0.6
Nuclear	3.0	3.4	3.5	3.2	2.9	-0.2
Renewables	3.1	3.8	4.2	4.2	4.4	1.6
Total	**21.9**	**26.2**	**28.5**	**30.6**	**32.8**	**1.7**
Developing Countries						
Oil	6.1	9.2	9.8	10.8	10.7	2.4
Natural Gas	7.1	8.9	11.3	14.3	19.0	4.2
Coal	22.2	30.6	35.7	41.0	47.1	3.2
Nuclear	2.2	3.5	4.7	5.4	5.7	4.0
Renewables	12.0	15.4	17.5	19.7	21.9	2.5
Total	**49.6**	**67.6**	**79.0**	**91.3**	**104.2**	**3.1**
Total World						
Oil	12.2	14.5	15.5	16.7	17.0	1.4
Natural Gas	29.6	37.7	44.9	54.1	65.2	3.3
Coal	61.1	73.0	79.5	86.9	96.7	1.9
Nuclear	26.2	29.8	31.4	31.8	30.4	0.6
Renewables	31.5	38.6	42.5	45.9	49.4	1.9
Total	**160.5**	**193.6**	**213.9**	**235.5**	**258.6**	**2.0**

Note: Totals may not equal sum of components due to independent rounding.

Sources: **2001:** Energy Information Administration (EIA), calculated by the Office of Integrated Analysis and Forecasting, based on estimates of fuel inputs for electricity generation and assumed average generation efficiencies by fuel type. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

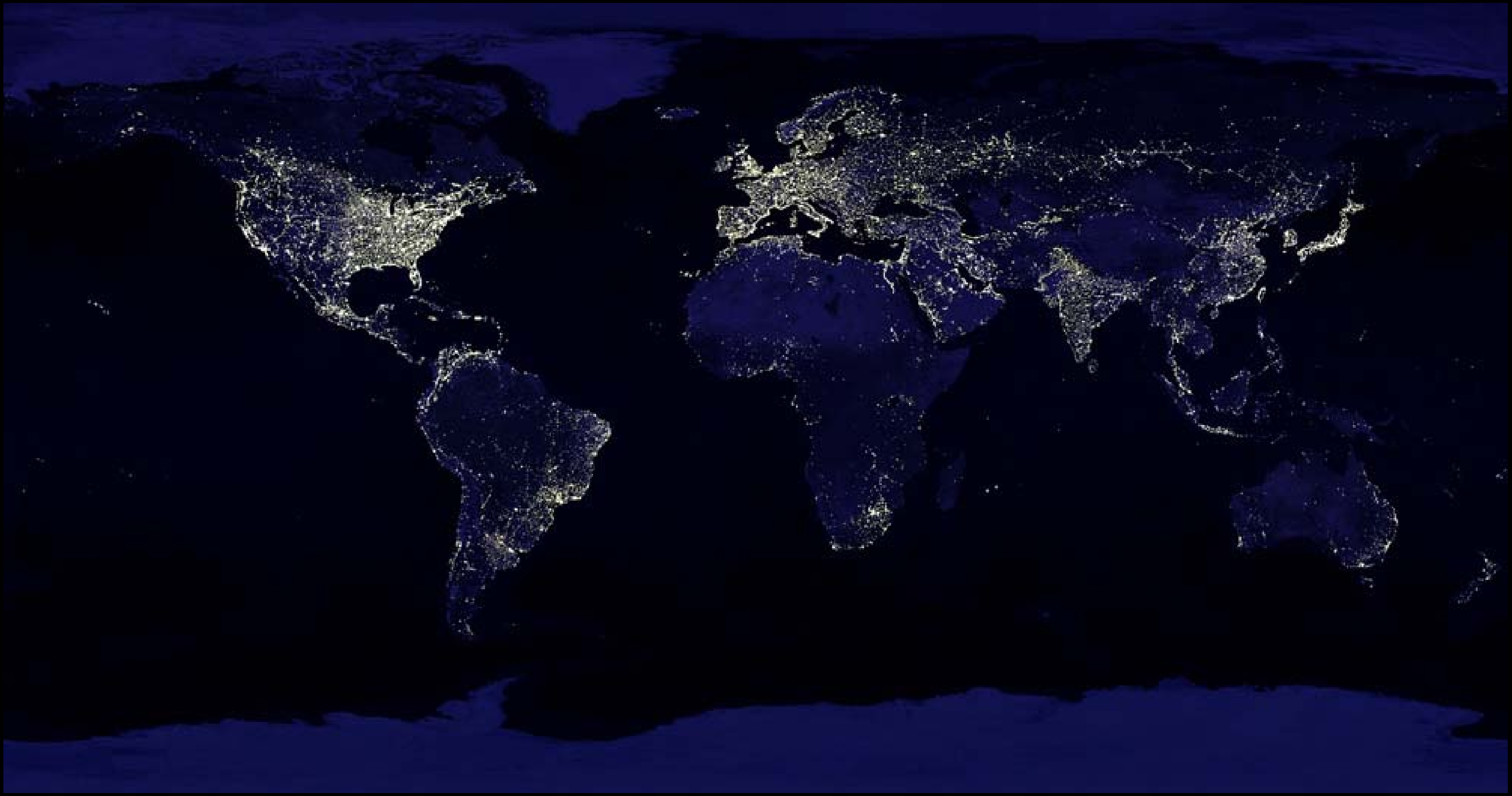
Energy Consumption and Generation



	India	China	USA
Population, millions	1050 (2)	1280 (1)	288 (3)
GDP, trillion 2002$ (ppp)	3.1 (3)	5.4 (2)	10.4 (1)
Total energy use, EJ	26 (4)	55 (2)	105 (1)
Coal consumption, EJ	8 (3)	30 (1)	25 (2)
Oil imports (net), EJ	3.3 (9)	3.6 (8)	23 (1)
Electricity generation, TWh	580 (5)	1650 (2)	4050 (1)
Electricity from coal, TWh	480 (3)	1200 (2)	2000 (1)
C emitted in CO_2, MtC	265 (5)	900 (2)	1640 (1)

Source: John Holdren, US-India Energy R&D Workshop, New Delhi, August, 2004

World at Night from Space



Urban Population Growth

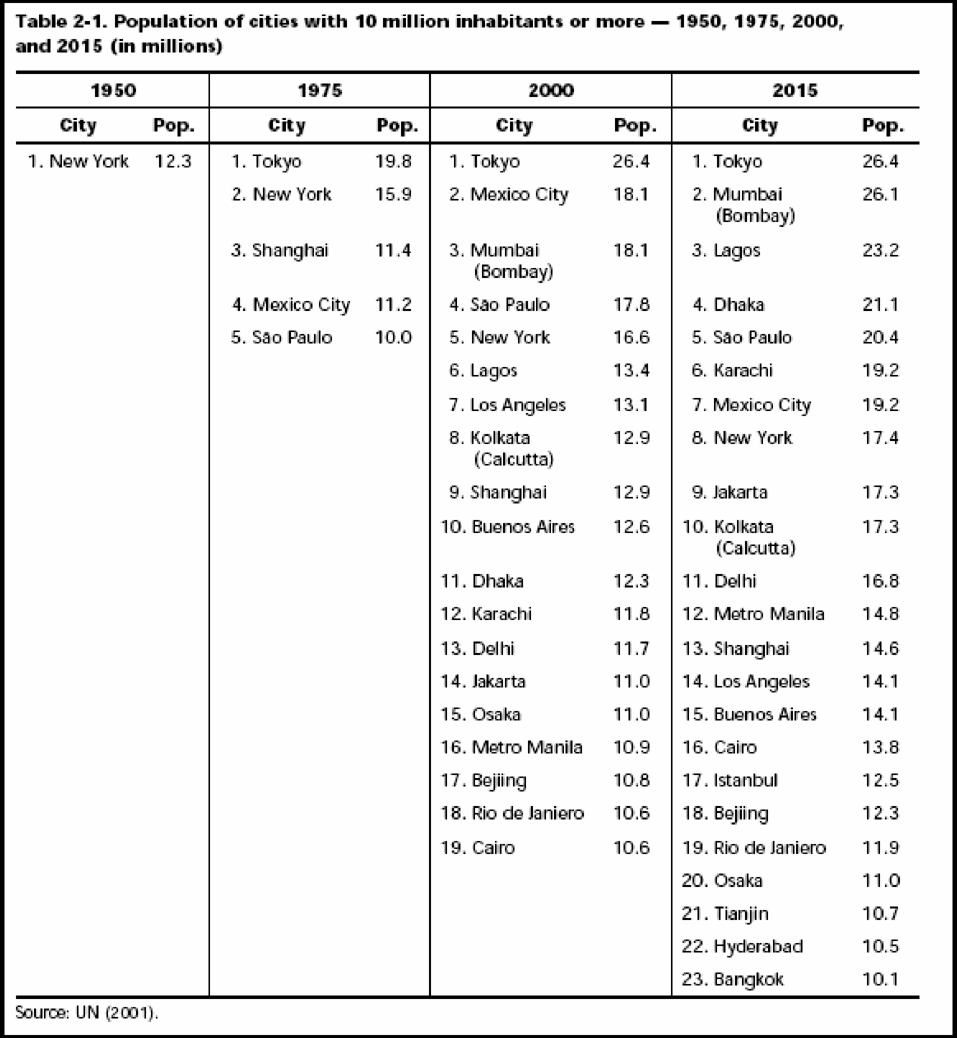
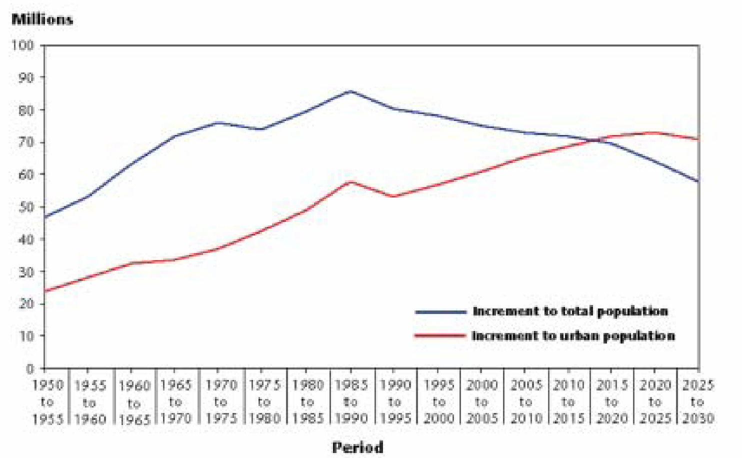


Table 2-1. Population of cities with 10 million inhabitants or more — 1950, 1975, 2000, and 2015 (in millions)

1950		1975		2000		2015	
City	**Pop.**	**City**	**Pop.**	**City**	**Pop.**	**City**	**Pop.**
1. New York	12.3	1. Tokyo	19.8	1. Tokyo	26.4	1. Tokyo	26.4
		2. New York	15.9	2. Mexico City	18.1	2. Mumbai (Bombay)	26.1
		3. Shanghai	11.4	3. Mumbai (Bombay)	18.1	3. Lagos	23.2
		4. Mexico City	11.2	4. São Paulo	17.8	4. Dhaka	21.1
		5. São Paulo	10.0	5. New York	16.6	5. São Paulo	20.4
				6. Lagos	13.4	6. Karachi	19.2
				7. Los Angeles	13.1	7. Mexico City	19.2
				8. Kolkata (Calcutta)	12.9	8. New York	17.4
				9. Shanghai	12.9	9. Jakarta	17.3
				10. Buenos Aires	12.6	10. Kolkata (Calcutta)	17.3
				11. Dhaka	12.3	11. Delhi	16.8
				12. Karachi	11.8	12. Metro Manila	14.8
				13. Delhi	11.7	13. Shanghai	14.6
				14. Jakarta	11.0	14. Los Angeles	14.1
				15. Osaka	11.0	15. Buenos Aires	14.1
				16. Metro Manila	10.9	16. Cairo	13.8
				17. Bejiing	10.8	17. Istanbul	12.5
				18. Rio de Janiero	10.6	18. Bejiing	12.3
				19. Cairo	10.6	19. Rio de Janiero	11.9
						20. Osaka	11.0
						21. Tianjin	10.7
						22. Hyderabad	10.5
						23. Bangkok	10.1

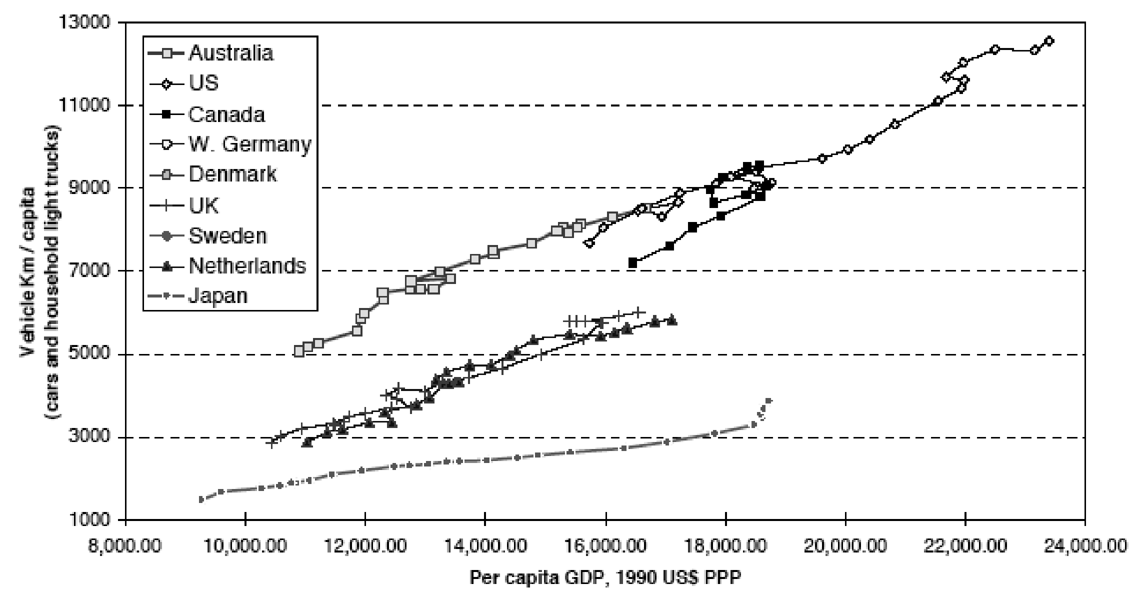
Source: UN (2001).

Annual increments of the world population and the urban population



Developing World

Rising net income will propel consumer demand for automobiles - Effects oil consumption

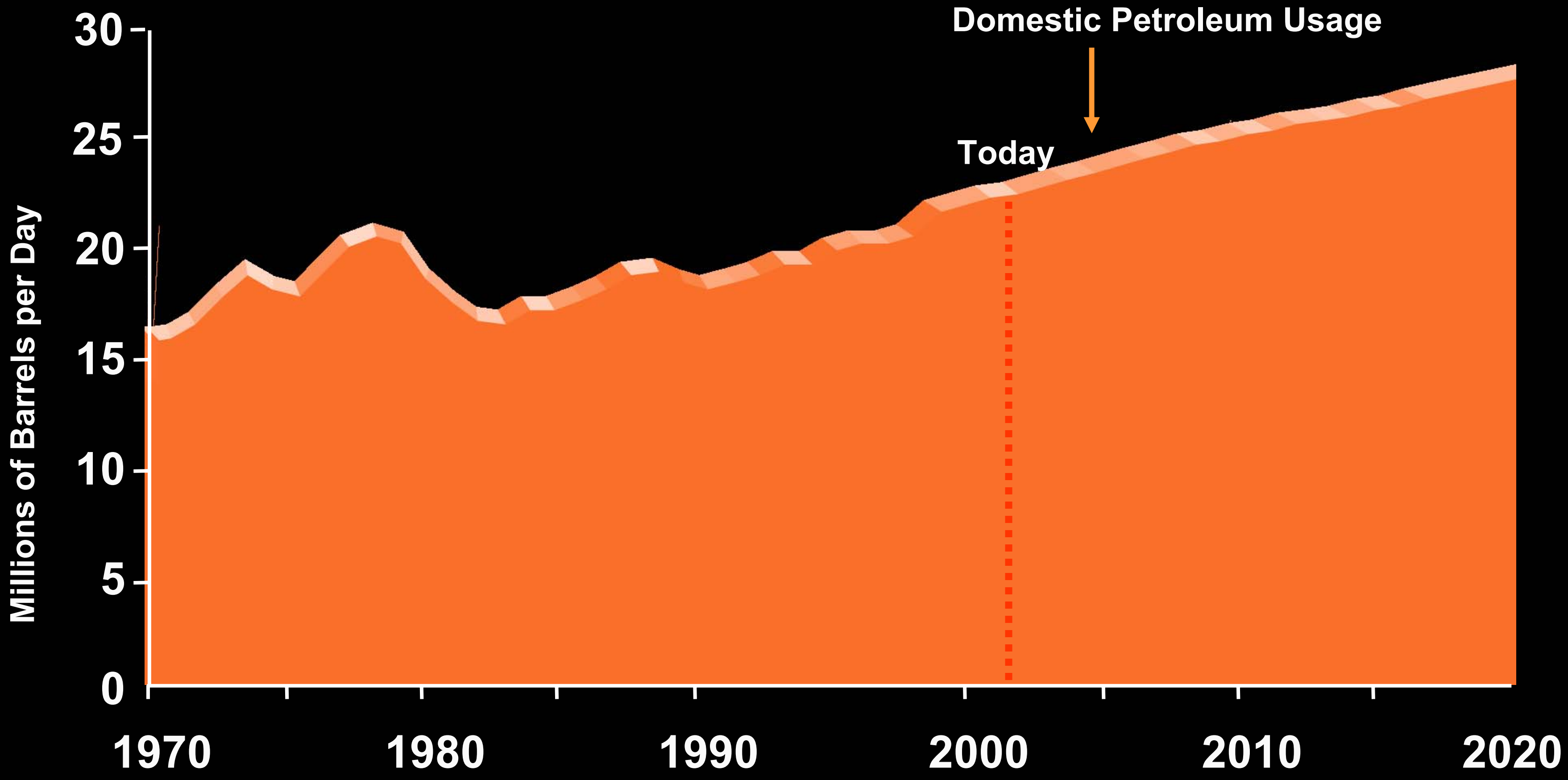


More money - more travel everywhere

Only 50% rural households have access in India

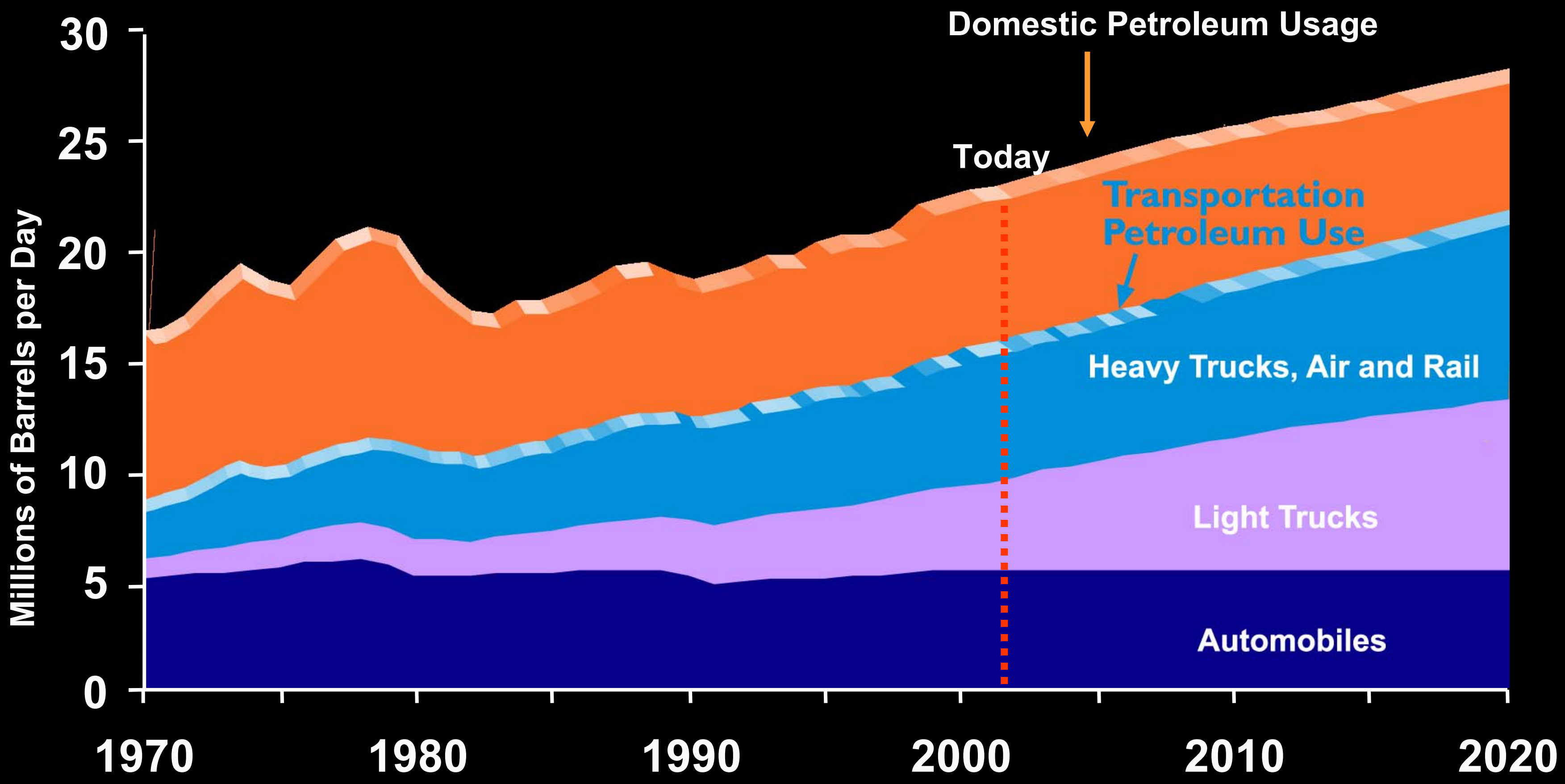
Power for all by 2012 in India

US Petroleum use in Transportation

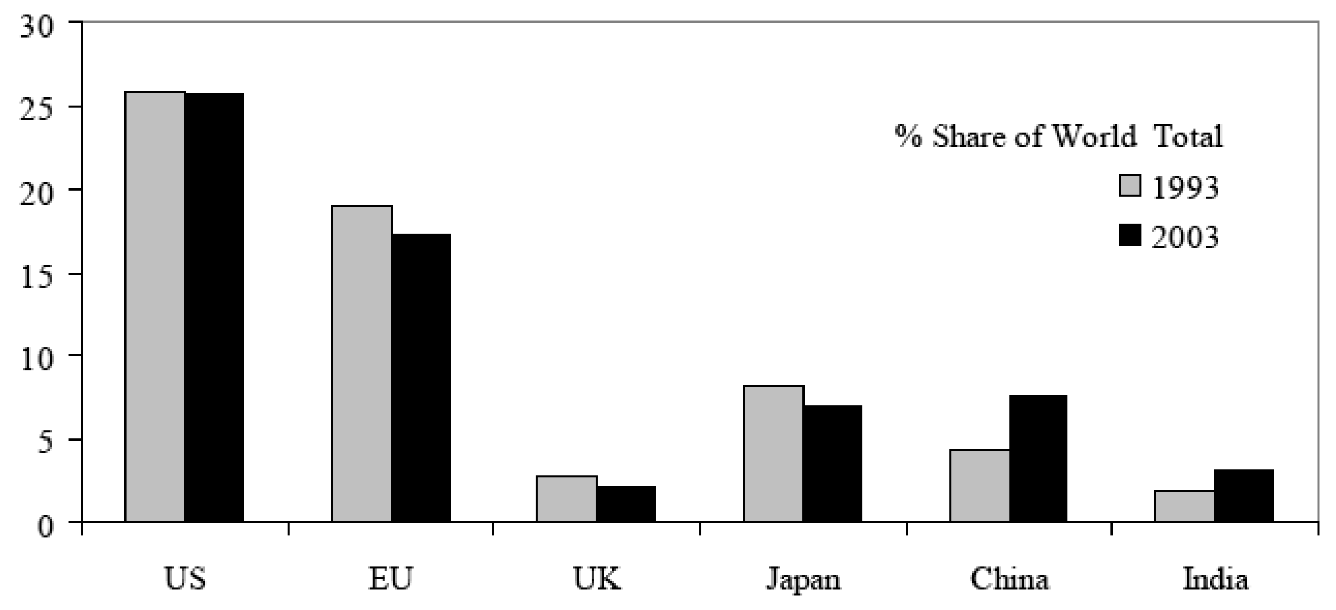


Actual: Annual Energy Review 2000 Tbls 1.2, 5.1 and 5.12
Forecast: Annual Energy Outlook 2002 Tbls 7 and 11
Split between Autos and Lt Truck: Transportation Energy Data Book Edition 21 Tbl 2.6

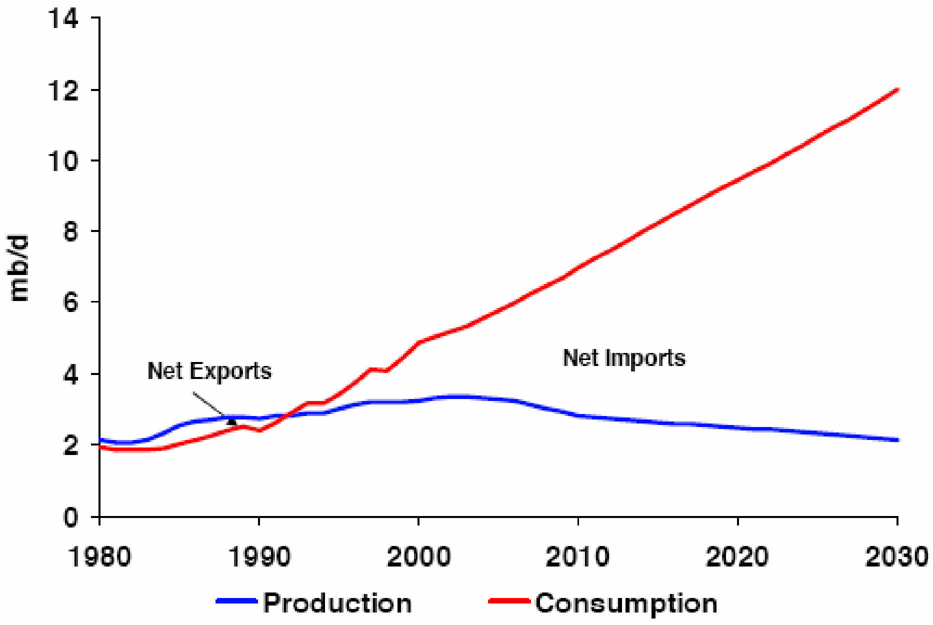
US Petroleum use in Transportation Sector



World Oil Consumption



Demand for Oil in China



Rapid motorisation underpins strong oil demand growth. Net oil imports will rise from 1.7mb/d in 2001 to 9.8mb/d in 2030.

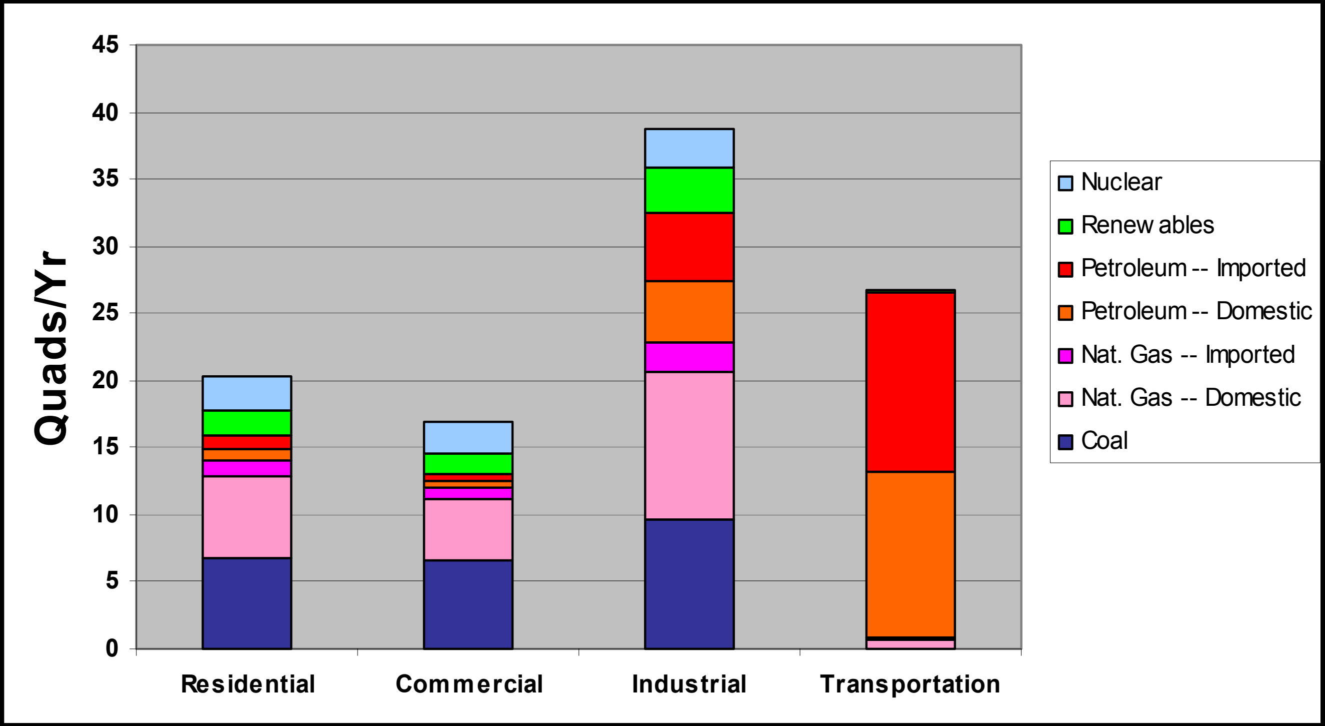
Oil imports will reach almost 10 mb/d in 2030, equivalent to US imports today.

Oil Dependency

Have Oil		Use Oil	
Saudi Arabia	26%	U.S.	26%
Iraq	11%	Japan	7%
Kuwait	10%	China	6%
Iran	9%	Germany	4%
UAE	8%	Russia	3%
Venezuela	6%	S. Korea	3%
Russia	5%	France	3%
Mexico	3%	Italy	3%
Libya	3%	Mexico	3%
China	3%	Brazil	3%
Nigeria	2%	Canada	3%
U.S.	2%	India	3%

Source: International Energy Annual 1999 (EIA), August 2002

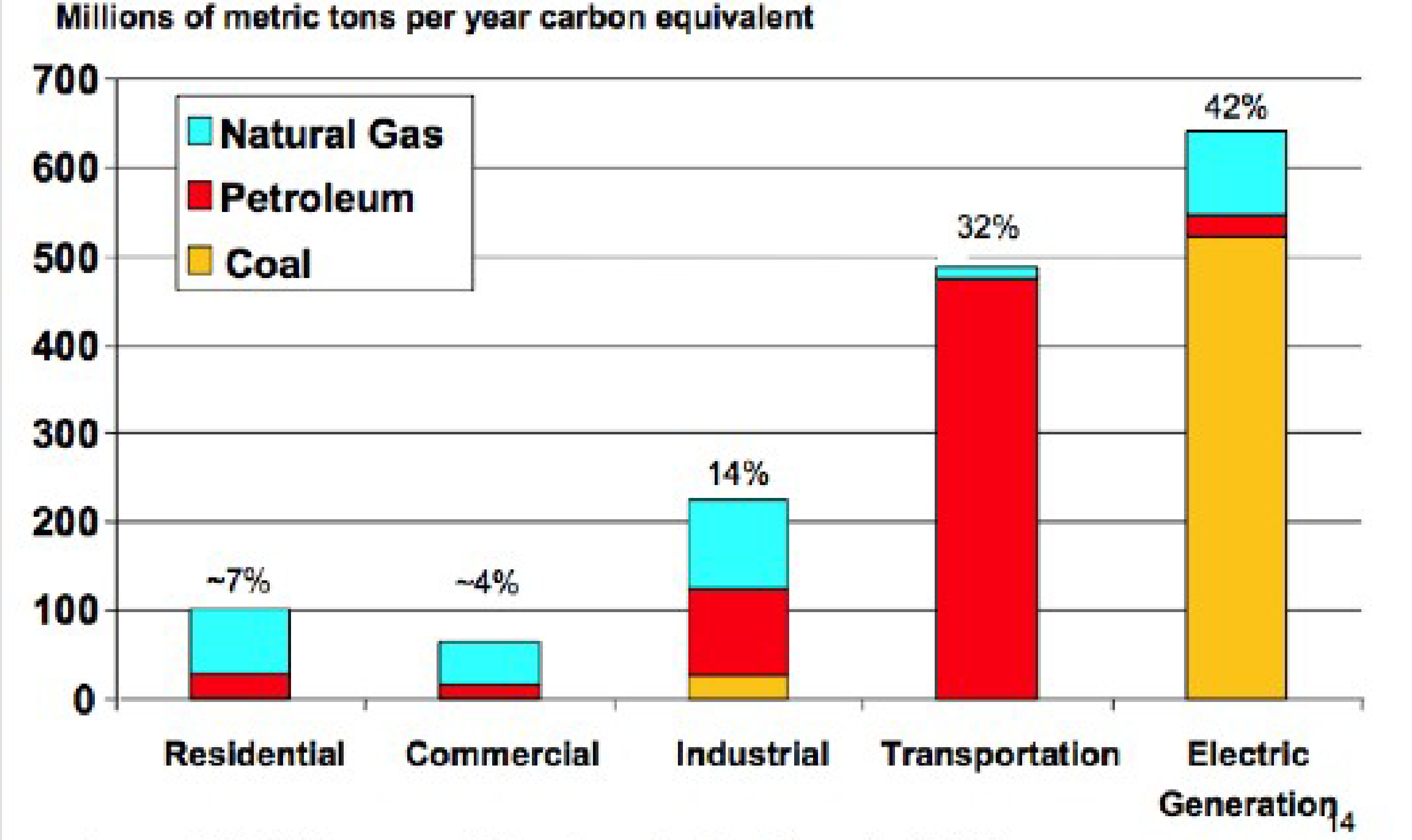
Summary



Immediate shift in ways to generate electricity and fuel type for transportation

Lead to reductions in coal and petroleum use

CO_2 Emissions



Source: U.S. EPA Inventory of Greenhouse Gas Emissions, April 2002

Energy Demand Scenarios

Transportation and Commercial energy usage are expected to increase around the world.

Transportation (especially personal) is expected to grow rapidly in developing countries and the proportion of energy in the residential sector will fall.

Electricity usage is expected to grow world wide with developing nations taking the lead.

Technology, economic conditions, energy prices and government legislation will affect the long term predictions.

Climate Change & Global Warming

Reference Books:

1. Global Warming by *L.D. Danny Harvey*, Prentice Hall, 2000.
2. Atmospheric Pollution by *Mark Z. Jacobson*, Cambridge University Press, 2002
3. Climate Change, 2001

Homework

- Consider a typical 2000 sq.ft home in Florida with major appliances such as 25 cu.ft refrigerator, washer, drier, air-conditioning unit along with the traditional lighting system. Estimate the annual electricity consumption in terms of kWh.
- Suggest means by which you can reduce the electricity consumption by half with out significant life style changes.

The Climate System

Components of the climate system:

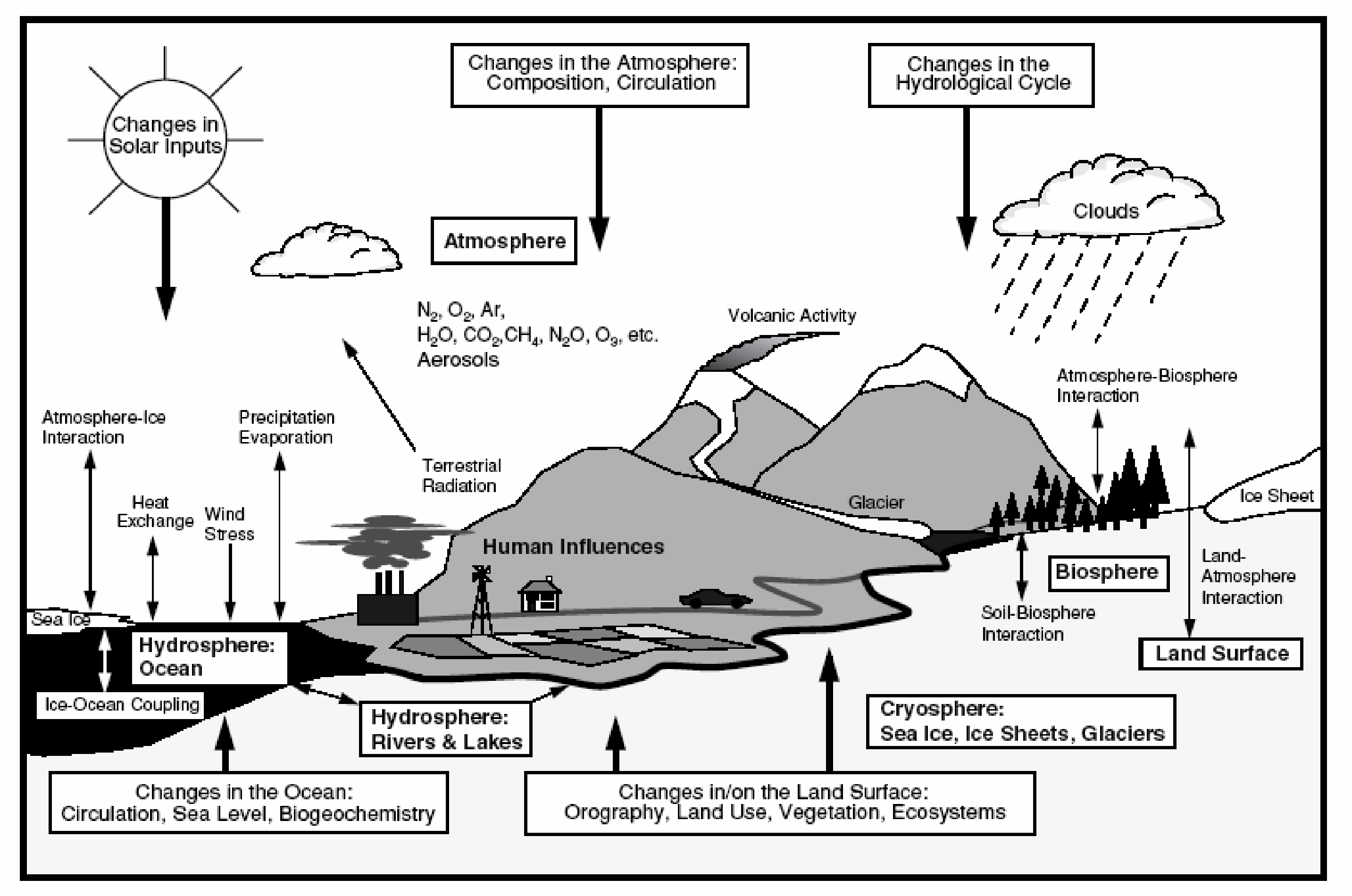
- The atmosphere
- Oceans
- Biosphere
- Cryosphere (ice & snow)
- Lithosphere (Earth’s crust)

External forcing:

- Sun
- Volcanic eruptions

Originating from inside the earth but they are external in a system sense - they influence but are not influenced by the climate system. They influence climate system through the injection of sulphur gases into the stratosphere which are transformed chemically into sulphate aerosols that have cooling effect on climate and through the emissions of CO_2

Global Climate System Components



The Climate System: Energy and Mass Flows

Energy and matter links the different components of the climate system.

Energy flows : Solar and infrared radiation

Sensible heat

Latent heat (related to the evaporation and condensation of water vapor or freezing and melting of ice)

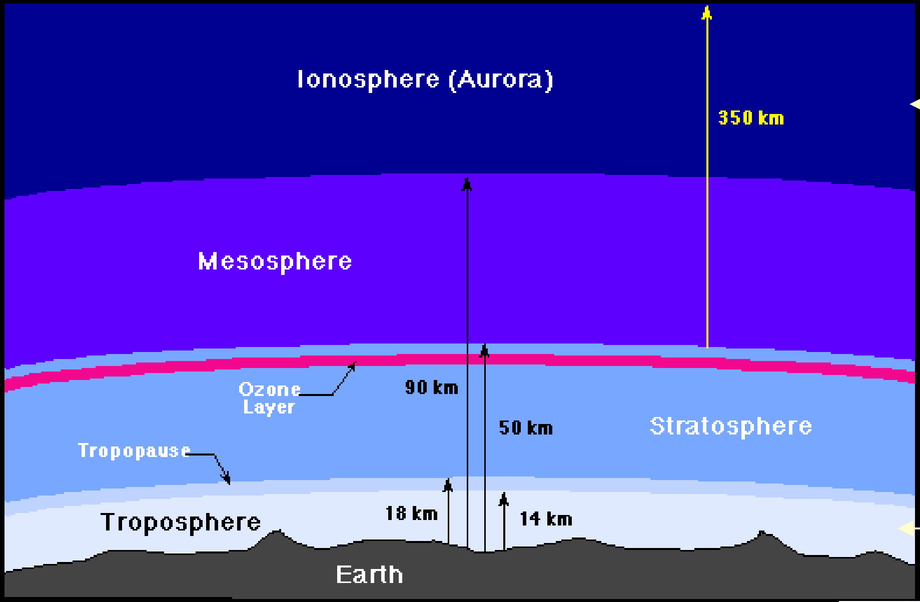
Transfer of momentum between the ocean and atmosphere

Mass flows: Water, carbon, sulphur and nutrients such as phosphorus and nitrate (NO_3^-)

The behavior of the climate system depends on the nature of the energy flow and mass flows change as the system changes and vice versa.

The time scales with which the system responds to changes in the mass and energy flows are important.

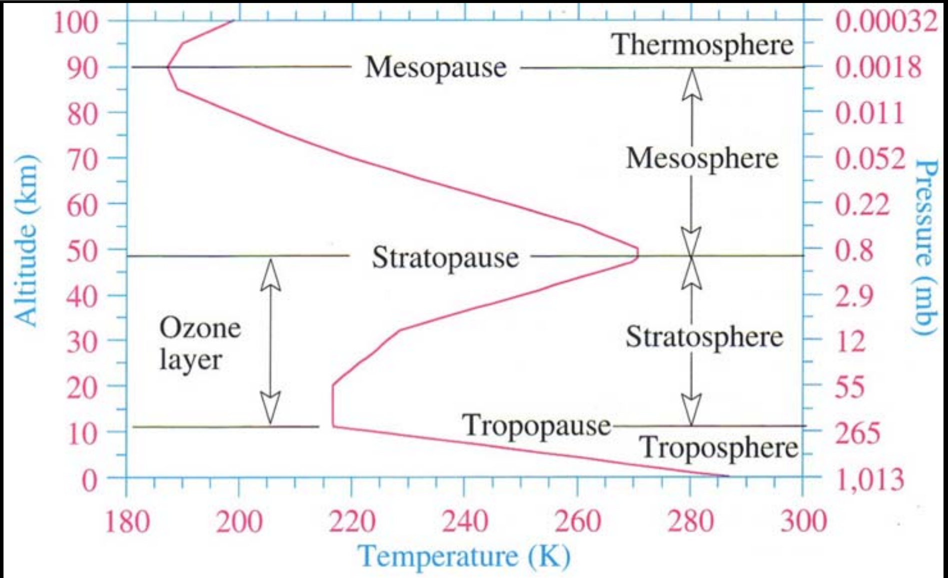
Layers of the Atmosphere



Most energetic photons from the Sun are absorbed

Responsible for absorbing ultraviolet radiation from Sun

All weather takes place



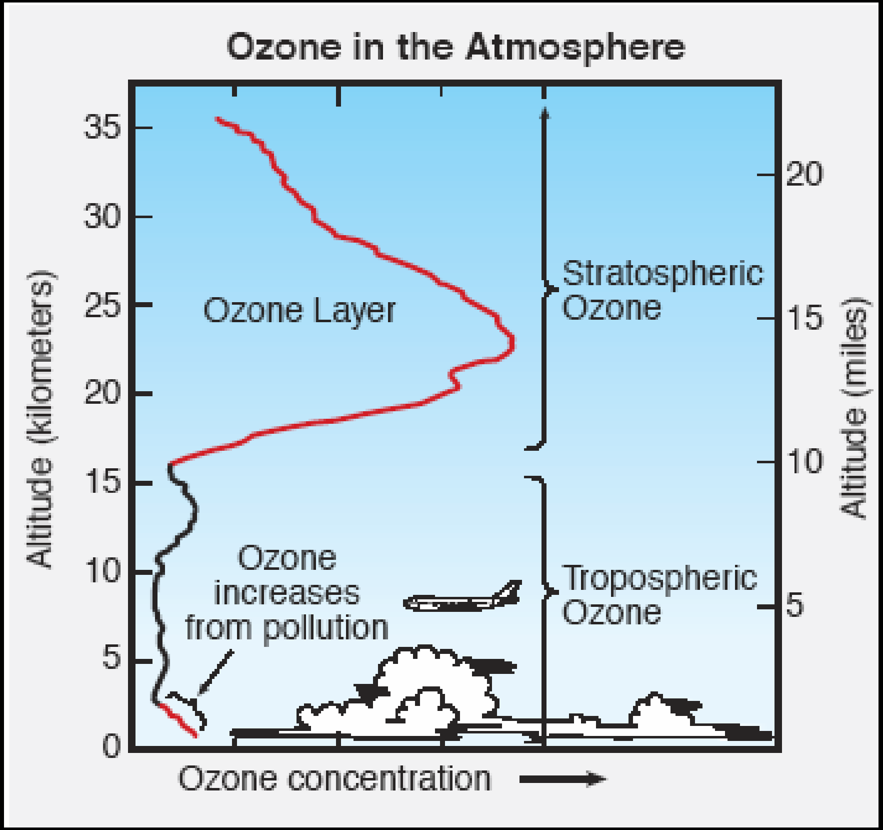
Major Global Environmental issues

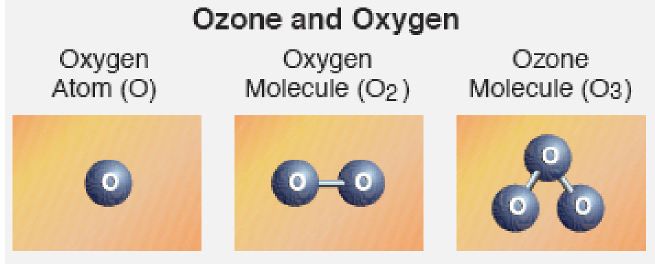
- Global stratospheric ozone (O_3) Reduction

  (Reference: D.W. Fahey, http://www.epa.gov/ozone/science/index.html)

- Global warming

Global stratospheric ozone (O_3) Reduction





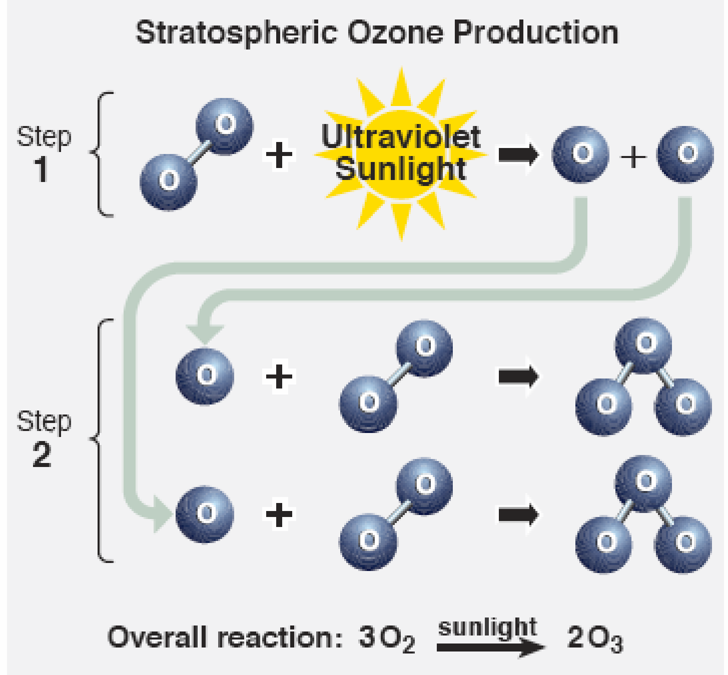
Ozone is a gas that is naturally present in our atmosphere at a concentration of 12,000 ozone molecules for every billion air molecules. About 90% of all ozone molecules in the atmosphere reside in the stratosphere and the rest reside in troposphere.

While ozone molecules near the earth's surface are quite harmful to life, they however, shield the earth from harmful ultraviolet (UV) radiation. Hence, absorption of ultraviolet (UV) radiation (UV portion of the solar spectrum) by ozone is critical for sustainable life on earth.

Oxides of nitrogen (NO and NO_2) destroy ozone, primarily in the upper stratosphere.

Between 1979 and 2000, the global stratospheric ozone decreased approximately by 3.5%. These reductions are well correlated with increase in anthropogenic chlorine compounds (chlorofluorocarbons (CFCs)) in the stratosphere – hence the current ban on their utilization.

Ozone Formation in the Atmosphere



Green plants produce oxygen using sunlight via photosynthesis

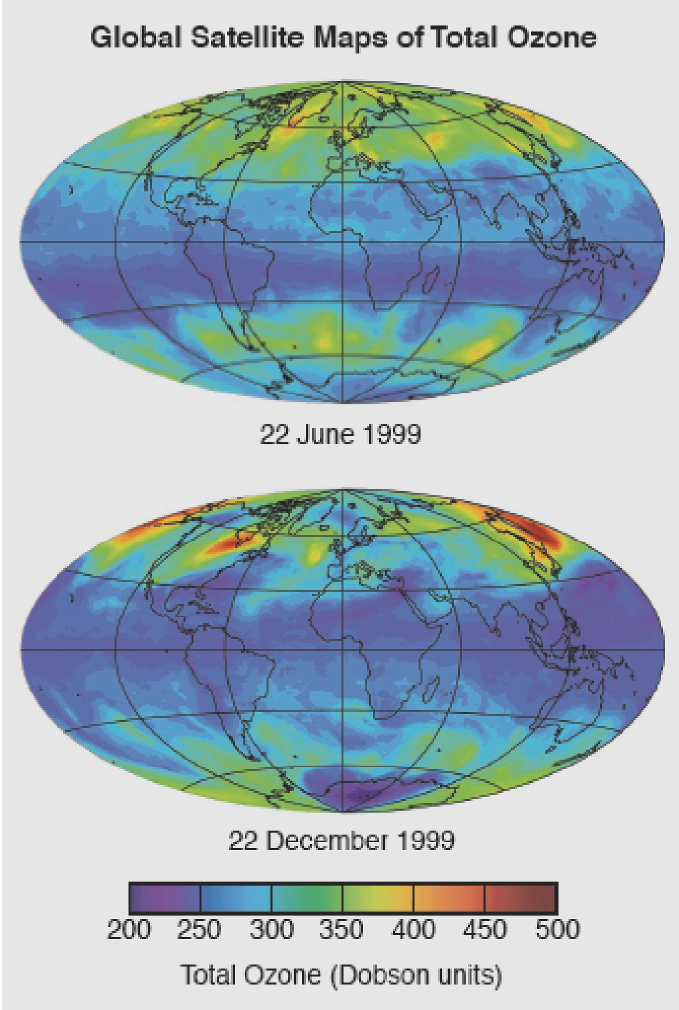
Break apart of an oxygen molecule (O_2) by ultraviolet radiation from the Sun

In the lower atmosphere (troposphere) ozone is formed in a different set of chemical reactions involving hydrocarbons and nitrogen oxide gases. Fossil fuel combustion is a primary pollution source for tropospheric ozone (bad ozone) production. It is too small and the surface production ozone does not significantly contribute to the abundance of stratospheric ozone (good ozone). In humans. Ozone exposure can reduce lung capacity.

Reduction of ozone in the lower atmosphere is desirable

Increasing ozone in stratosphere is necessary for sustainable future

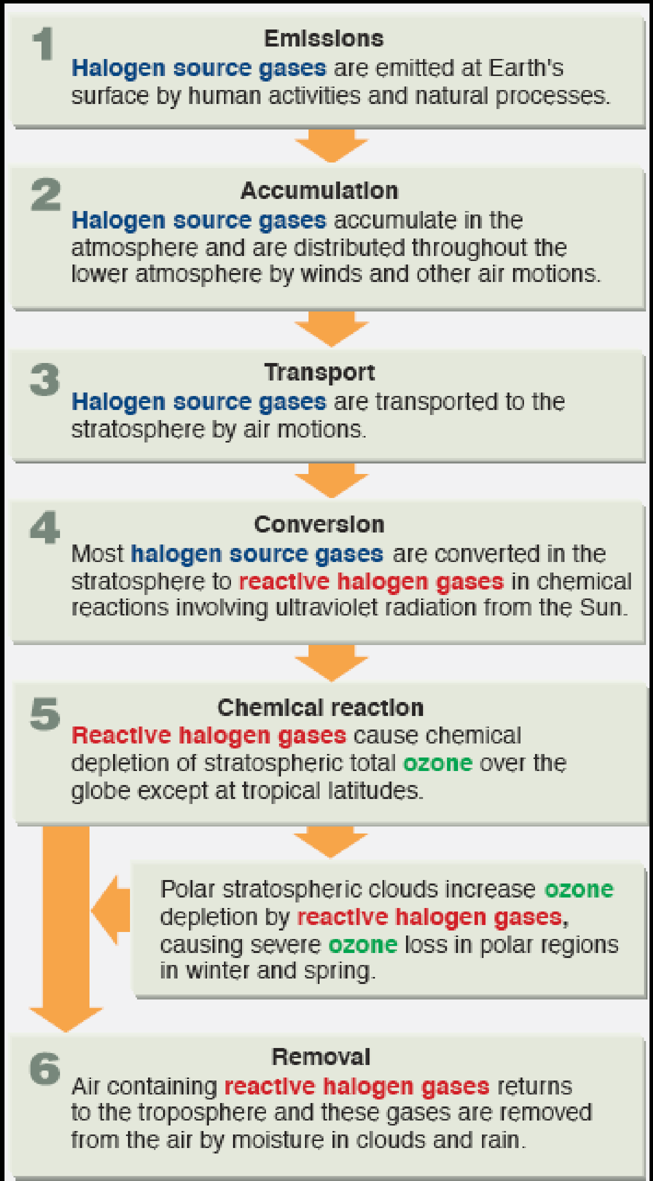
Ozone Distribution over the Globe



Total amount of ozone above the surface of Earth varies with location on time scales that range from daily to seasonal. The variations are caused by stratospheric winds and the chemical production and destruction of ozone. Total ozone is generally lowest at the equator and highest near the poles because of seasonal wind patterns in the stratosphere.

Ozone values are reported in Dobson units (DU). Typical values vary from 200 and 500 DU. A total ozone value of 500 DU is equivalent to a layer of pure ozone gas on earth's surface having a thickness of 5 mm.

Principle Steps in the Depletion of Stratospheric Ozone



1 **Emissions**
Halogen source gases are emitted at Earth's surface by human activities and natural processes.

2 **Accumulation**
Halogen source gases accumulate in the atmosphere and are distributed throughout the lower atmosphere by winds and other air motions.

3 **Transport**
Halogen source gases are transported to the stratosphere by air motions.

4 **Conversion**
Most **halogen source gases** are converted in the stratosphere to **reactive halogen gases** in chemical reactions involving ultraviolet radiation from the Sun.

5 **Chemical reaction**
Reactive halogen gases cause chemical depletion of stratospheric total **ozone** over the globe except at tropical latitudes.

Polar stratospheric clouds increase **ozone** depletion by **reactive halogen gases**, causing severe **ozone** loss in polar regions in winter and spring.

6 **Removal**
Air containing **reactive halogen gases** returns to the troposphere and these gases are removed from the air by moisture in clouds and rain.

Halogen source gases: Manufactured gases containing chlorine (CFC's) or bromine

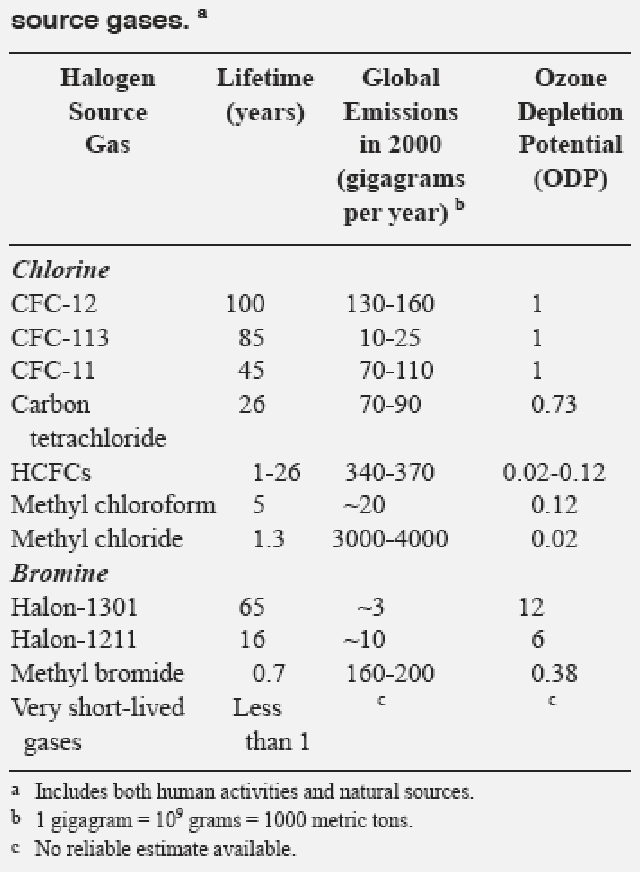


Table Q7-1. Atmospheric lifetimes, emissions, and Ozone Depletion Potentials of halogen source gases. [a]

Halogen Source Gas	Lifetime (years)	Global Emissions in 2000 (gigagrams per year) [b]	Ozone Depletion Potential (ODP)
Chlorine			
CFC-12	100	130-160	1
CFC-113	85	10-25	1
CFC-11	45	70-110	1
Carbon tetrachloride	26	70-90	0.73
HCFCs	1-26	340-370	0.02-0.12
Methyl chloroform	5	~20	0.12
Methyl chloride	1.3	3000-4000	0.02
Bromine			
Halon-1301	65	~3	12
Halon-1211	16	~10	6
Methyl bromide	0.7	160-200	0.38
Very short-lived gases	Less than 1	[c]	[c]

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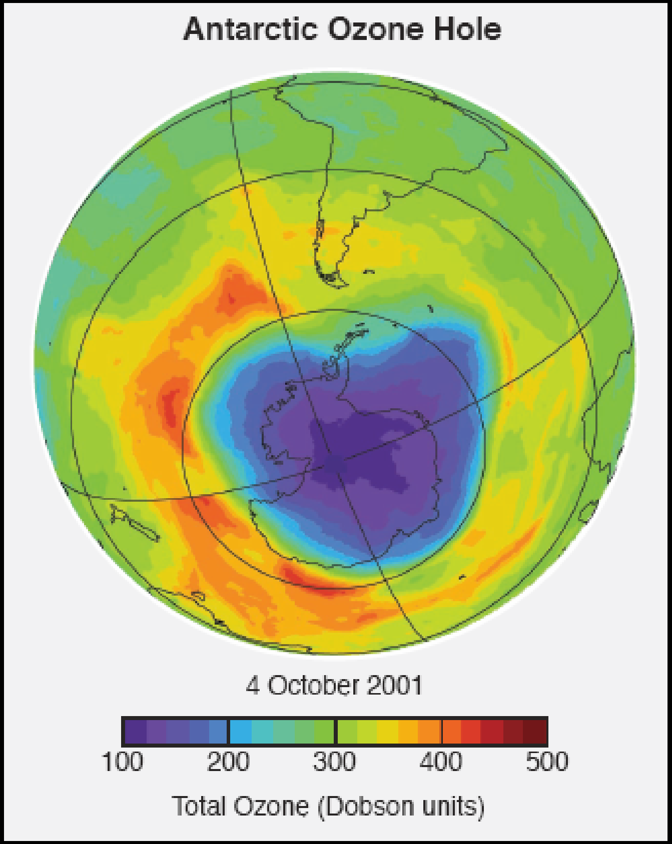
[a] Includes both human activities and natural sources.
[b] 1 gigagram = 10^9 grams = 1000 metric tons.
[c] No reliable estimate available.

Ozone Hole



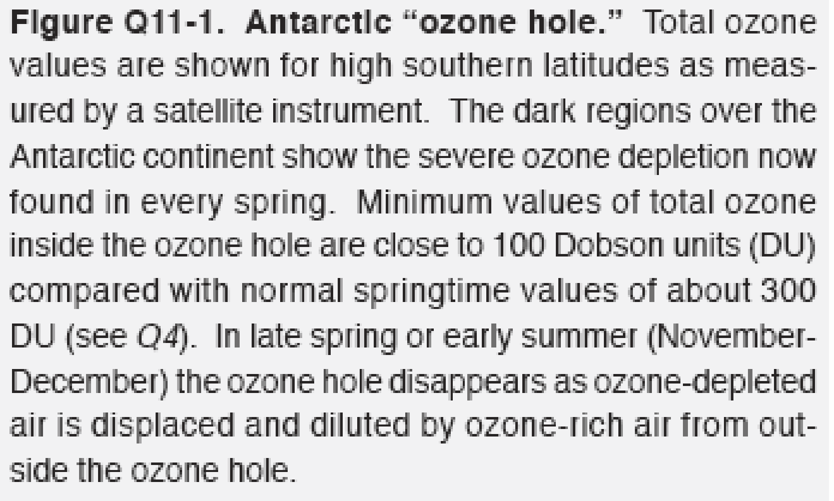


Figure Q11-1. Antarctic "ozone hole." Total ozone values are shown for high southern latitudes as measured by a satellite instrument. The dark regions over the Antarctic continent show the severe ozone depletion now found in every spring. Minimum values of total ozone inside the ozone hole are close to 100 Dobson units (DU) compared with normal springtime values of about 300 DU (see *Q4*). In late spring or early summer (November-December) the ozone hole disappears as ozone-depleted air is displaced and diluted by ozone-rich air from outside the ozone hole.

2003 Ozone Hole

A polar stratospheric cloud appears above Australia's Mawson Antarctic base in this undated handout picture. Australian scientists warn the ozone hole over the ice continent could grow to a record size in 2003 due to colder stratospheric temperatures, which result in the formation of clouds, that convert inert man-made gases into ozone destroying chemicals. (Reuters - Handout - August 22,2003)

Ozone is a protective layer in the atmosphere that shields the Earth from the sun's rays, in particular ultraviolet-B radiation that can cause skin cancer, cataracts and can harm marine life. In 2000, NASA said the ozone hole expanded to a record 10.9 million square miles, three times the size of Australia or the United States, excluding Alaska.

Past and Future of Atmospheric Halogen Source Gases

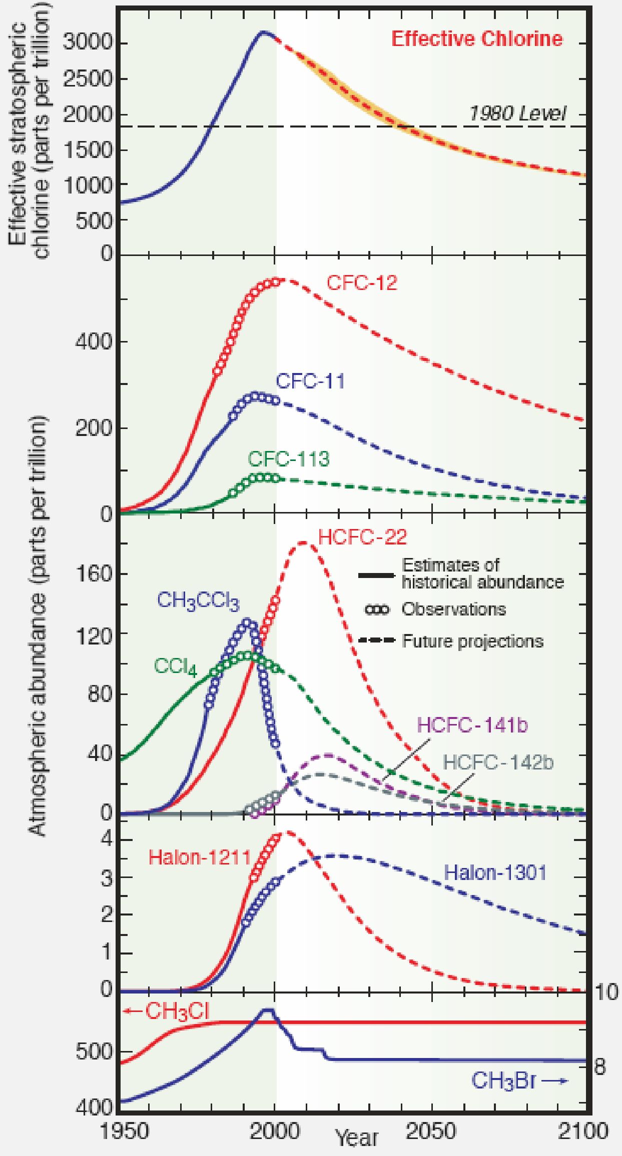
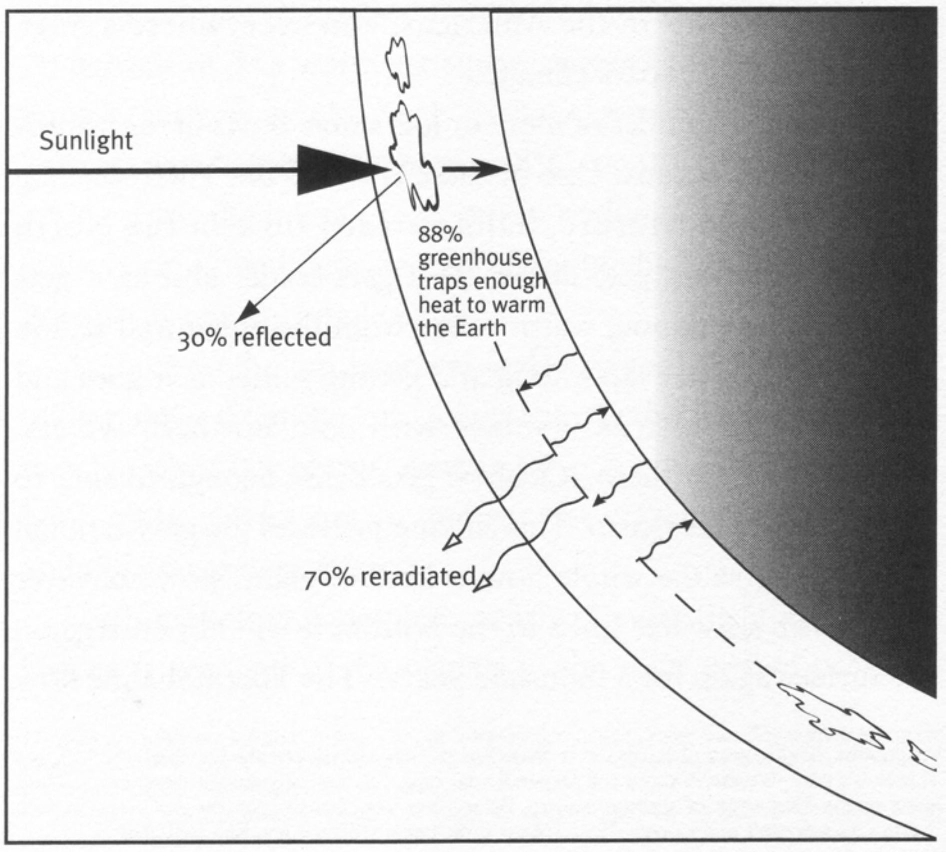


Figure Q16-1. Halogen source gas changes. The rise in effective stratospheric chlorine values in the 20th century has slowed and reversed in the last decade (top panel). Effective chlorine values combine the measured or projected abundances of chlorine-containing gases with those of bromine-containing gases in a way that properly accounts for the greater effectiveness of bromine in depleting stratospheric ozone. As effective chlorine decreases in the 21st century, the potential for ozone depletion from halogen gases will also decrease. The decrease in effective chlorine values is a result of reductions in individual halogen source gas emissions. The emissions decreased because of the Montreal Protocol, which restricts production and consumption of manufactured halogen gases. The changes in the atmospheric abundance of individual gases are shown in the lower panels using a combination of direct atmospheric measurements, estimates of historical abundance, and future projections of abundance. The increases of CFCs, along with those of CCl_4 and CH_3CCl_3, have either slowed significantly or reversed in the last decade. HCFCs, which are being used as CFC substitutes, will continue to increase in the coming decades. Some halon abundances will also grow in the future while current halon reserves are being depleted. Smaller relative decreases are expected for CH_3Br in response to restrictions because it has substantial natural sources. CH_3Cl has large natural sources and is not regulated under the Montreal Protocol. (See ***Figure Q7-1*** for chemical names and formulas. The unit "parts per trillion" is defined in the caption of ***Figure Q7-1***.)

Ozone Depletion & Climate Change

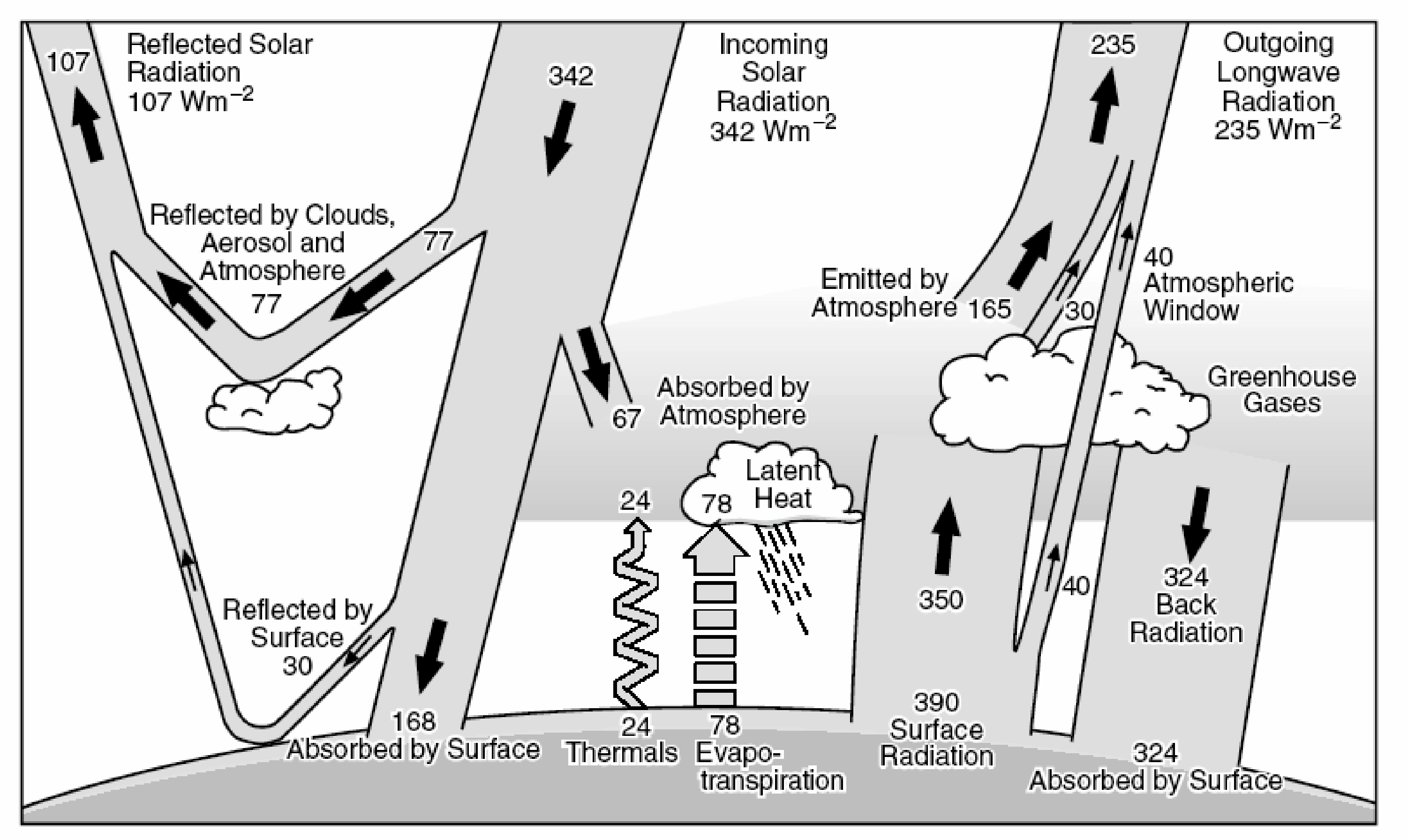


Ozone is a “greenhouse gas” along with carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) . The accumulation of these gases changes the radiative balance (between the incoming solar radiation and outgoing infrared radiation) of Earth’s atmosphere.

Greenhouse gases generally change the balance by absorbing outgoing radiation, leading to a warming at Earth’s surface.

The change in earth’s radiative balance is called radiative forcing of climate change.

Global Mean Energy Balance



Ozone Depletion & Climate Change

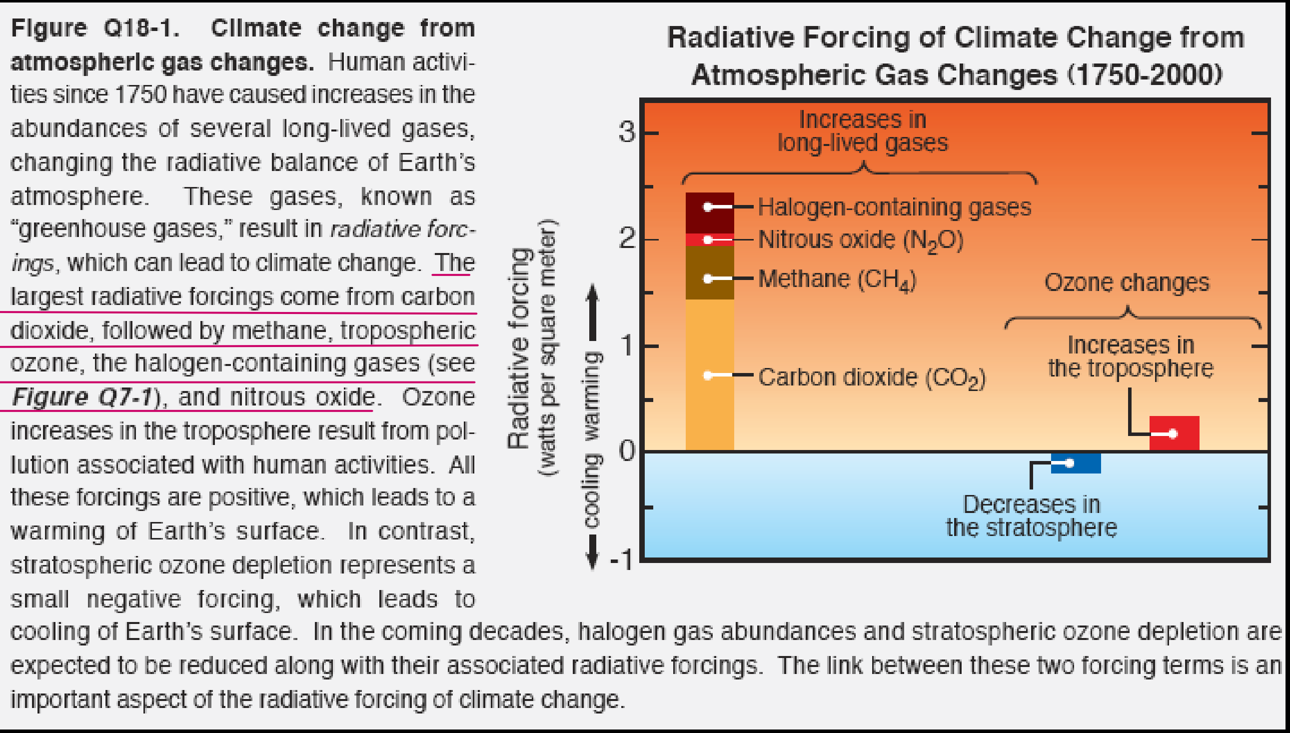
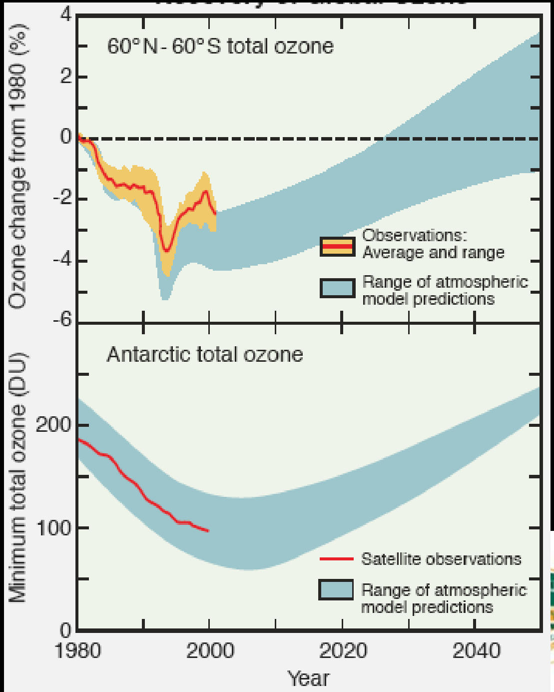


Figure Q18-1. Climate change from atmospheric gas changes. Human activities since 1750 have caused increases in the abundances of several long-lived gases, changing the radiative balance of Earth's atmosphere. These gases, known as "greenhouse gases," result in *radiative forcings*, which can lead to climate change. The largest radiative forcings come from carbon dioxide, followed by methane, tropospheric ozone, the halogen-containing gases (see ***Figure Q7-1***), and nitrous oxide. Ozone increases in the troposphere result from pollution associated with human activities. All these forcings are positive, which leads to a warming of Earth's surface. In contrast, stratospheric ozone depletion represents a small negative forcing, which leads to cooling of Earth's surface. In the coming decades, halogen gas abundances and stratospheric ozone depletion are expected to be reduced along with their associated radiative forcings. The link between these two forcing terms is an important aspect of the radiative forcing of climate change.

Changes in stratospheric and tropospheric ozone represent radiative forcing of climate change.

Certain changes in Earth's climate could affect the future of the ozone layer.

Recovery of global ozone →



Natural Greenhouse Effect

Warming of the Earth’s lower atmosphere due to natural gases that transmit the Sun’s visible radiation, but absorb and reemit the Earth’s thermal-IR radiation.

The atmosphere allows a large percentage of the rays of visible light from the Sun to reach the Earth's surface and heat it.

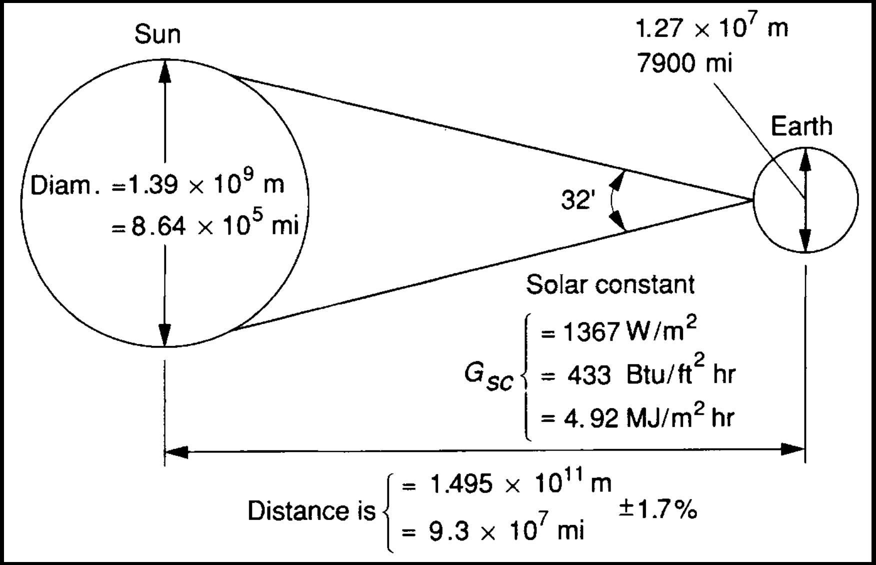
A part of this energy is reradiated by the Earth's surface in the form of long-wave infrared radiation, much of which is absorbed by molecules of carbon dioxide and water vapor in the atmosphere and which is reflected back to the surface as heat.

The trapping of this infrared radiation causes the Earth's surface and lower atmospheric layers to warm to a higher temperature than would otherwise be the case.

Without this greenhouse heating, the Earth's average temperature would be only about 255 K, about 18K below the freezing temperature of water and would not support most life on Earth.

Owing to the rise in atmospheric carbon dioxide caused by modern industrial societies' widespread combustion of fossil fuels (coal, oil, and natural gas), the greenhouse effect on Earth may be intensified and long-term climatic changes may result.

Incoming Solar Radiation



Sun emits radiation with an effective temperature of about $T_P = 5785$ K (photosphere temperature)

The energy flux (watts/ m^2) emitted by the Sun (Stefan-Boltzmann law):

$$F_P = \varepsilon_P \sigma_B T_P^4$$

The emissivity = 1

5.67×10^{-8} W m^{-2} K^{-4}

Total energy emitted by the Sun: $4\pi R_P^2 F_P$

Total energy emitted by the Sun per unit time passing through a sphere of radius R_{es} (Earth-Sun distance):

$$4\pi R_{es}^2 F_s = 4\pi R_P^2 F_P$$

$$F_s = \left(\frac{R_P}{R_S}\right)^2 \sigma_B T_P^4$$

$$F_S = 1{,}365 \text{ W/m}^2$$

Solar constant

Incoming Solar Radiation

Taking into account the cross-sectional area of the Earth and the Earth's albedo (A_e), the total energy per unit time absorbed by the Earth in a simple energy balance model:

$$E_{in} = F_S(1 - A_e)(\pi R_e^2)$$

$$R_e = 6.378 \times 10^6 m$$

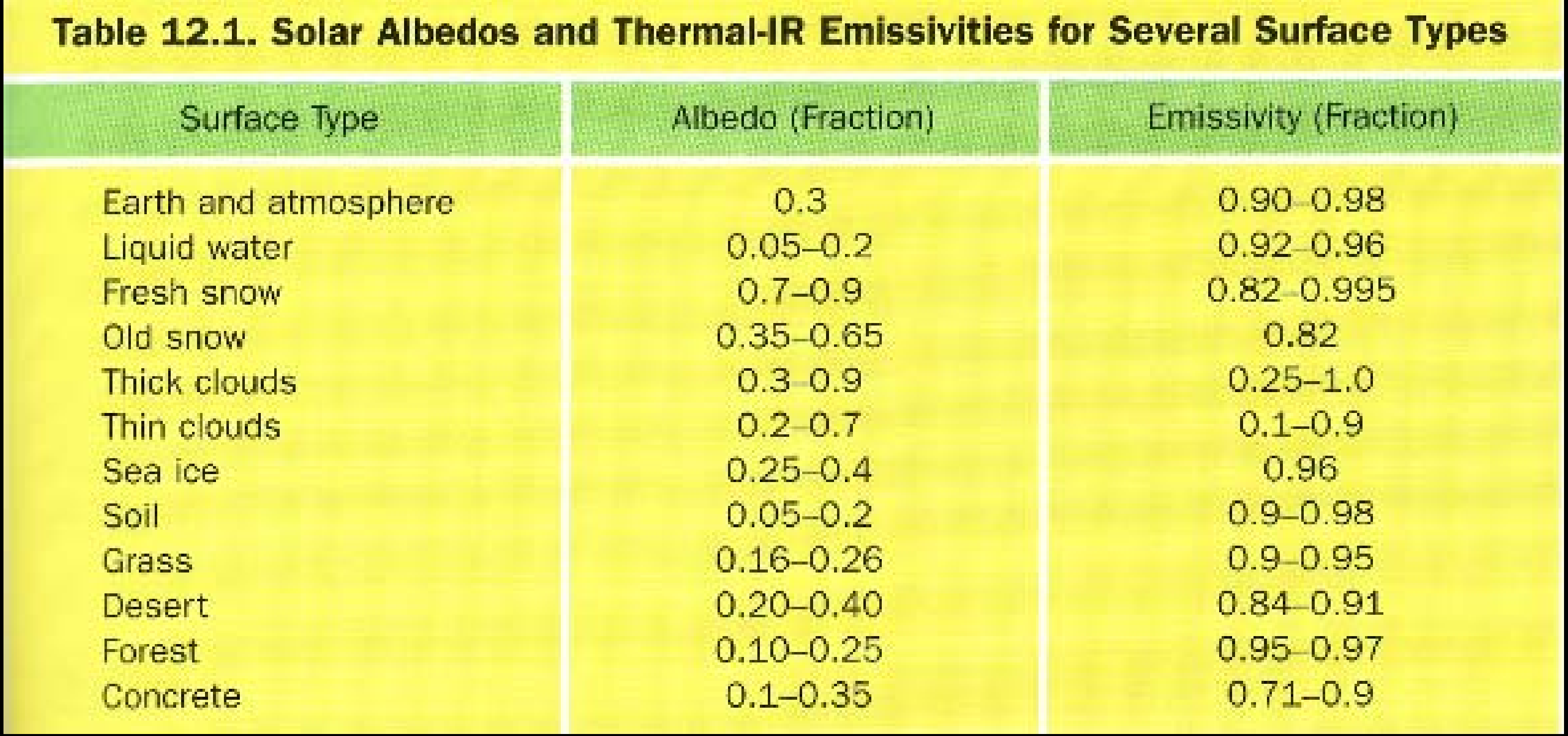


Table 12.1. Solar Albedos and Thermal-IR Emissivities for Several Surface Types

Surface Type	Albedo (Fraction)	Emissivity (Fraction)
Earth and atmosphere	0.3	0.90–0.98
Liquid water	0.05–0.2	0.92–0.96
Fresh snow	0.7–0.9	0.82–0.995
Old snow	0.35–0.65	0.82
Thick clouds	0.3–0.9	0.25–1.0
Thin clouds	0.2–0.7	0.1–0.9
Sea ice	0.25–0.4	0.96
Soil	0.05–0.2	0.9–0.98
Grass	0.16–0.26	0.9–0.95
Desert	0.20–0.40	0.84–0.91
Forest	0.10–0.25	0.95–0.97
Concrete	0.1–0.35	0.71–0.9

Outgoing Thermal-IR Radiation

The energy flux emitted by the earth: $E_{out} = \varepsilon_e \sigma_B T_e^4 (4\pi R_e^2)$

The globally averaged emissivity of Earth = 0.9 ~ 0.98 (assumed as one)

Equilibrium temperature of the Earth's surface = T_e

Equilibrium Temperature of the Earth:

Incoming solar radiation = outgoing thermal-IR radiation

$$T_e = \left[\frac{F_S(1 - A_e)}{4\varepsilon_e \sigma_B}\right]^{\frac{1}{4}}$$

$F_S = 1365\ W/m^2;\ A_e = 0.3$

$T_e = 254.8\ K$

Natural Greenhouse Effect & Global warming

Equilibrium temperature of the Earth = 255 K

Actual globally averaged near-surface air temperature: 288 K

The difference of 33 K is attributed to the presence of atmosphere that is transparent to most incoming solar radiation but selectively absorbs a portion of the outgoing thermal-IR radiation.

Some of the absorbed radiation is reemitted back to the surface, warming the surface.

The resulting 33 K increase over the equilibrium temperature of the earth is called the *natural greenhouse effect*

Global warming is the increase in Earth's temperature above the natural greenhouse effect temperature as a result of the emission of anthropogenic greenhouse gases and particulate black carbon.

Natural Greenhouse Effect & Global warming

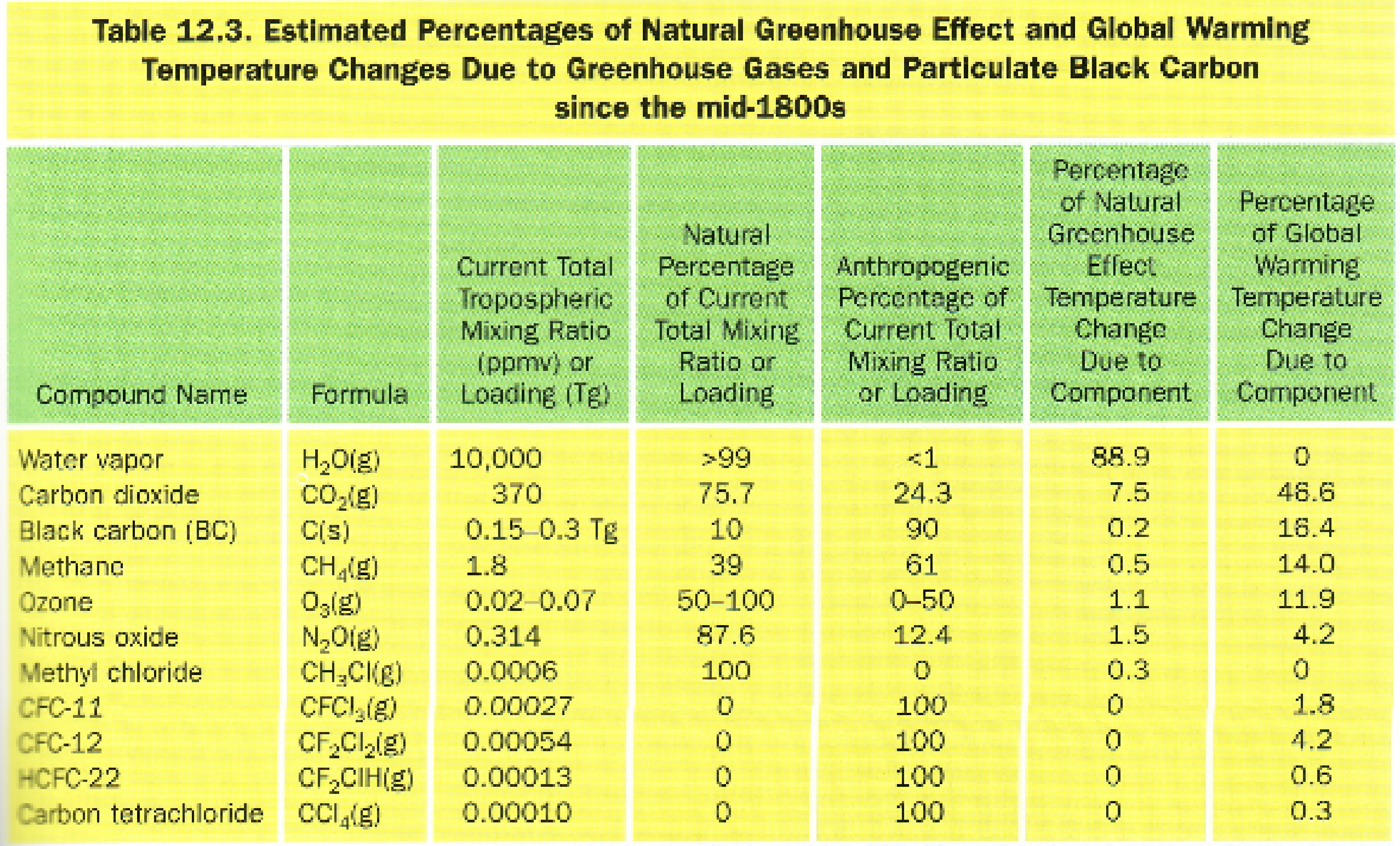
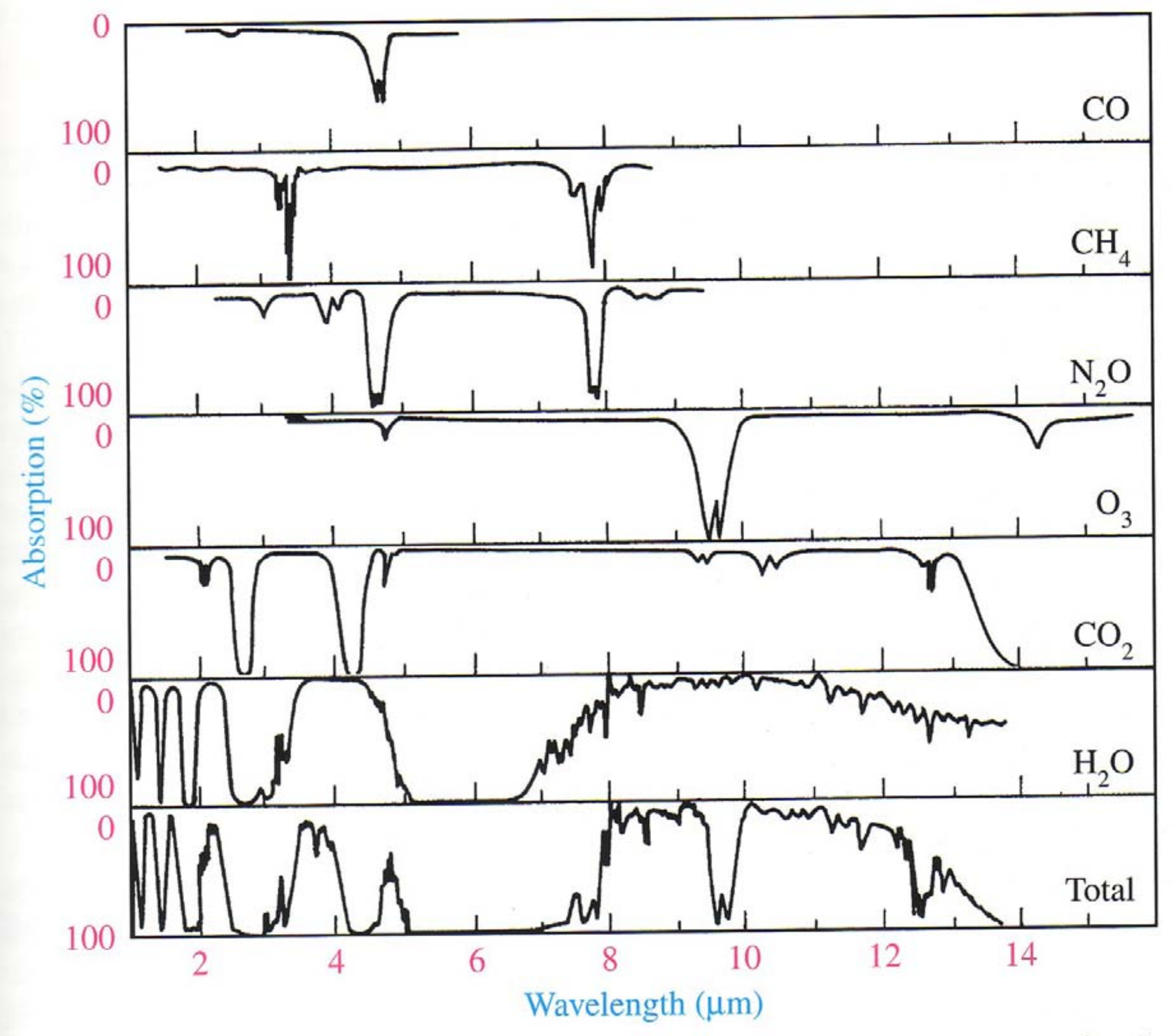


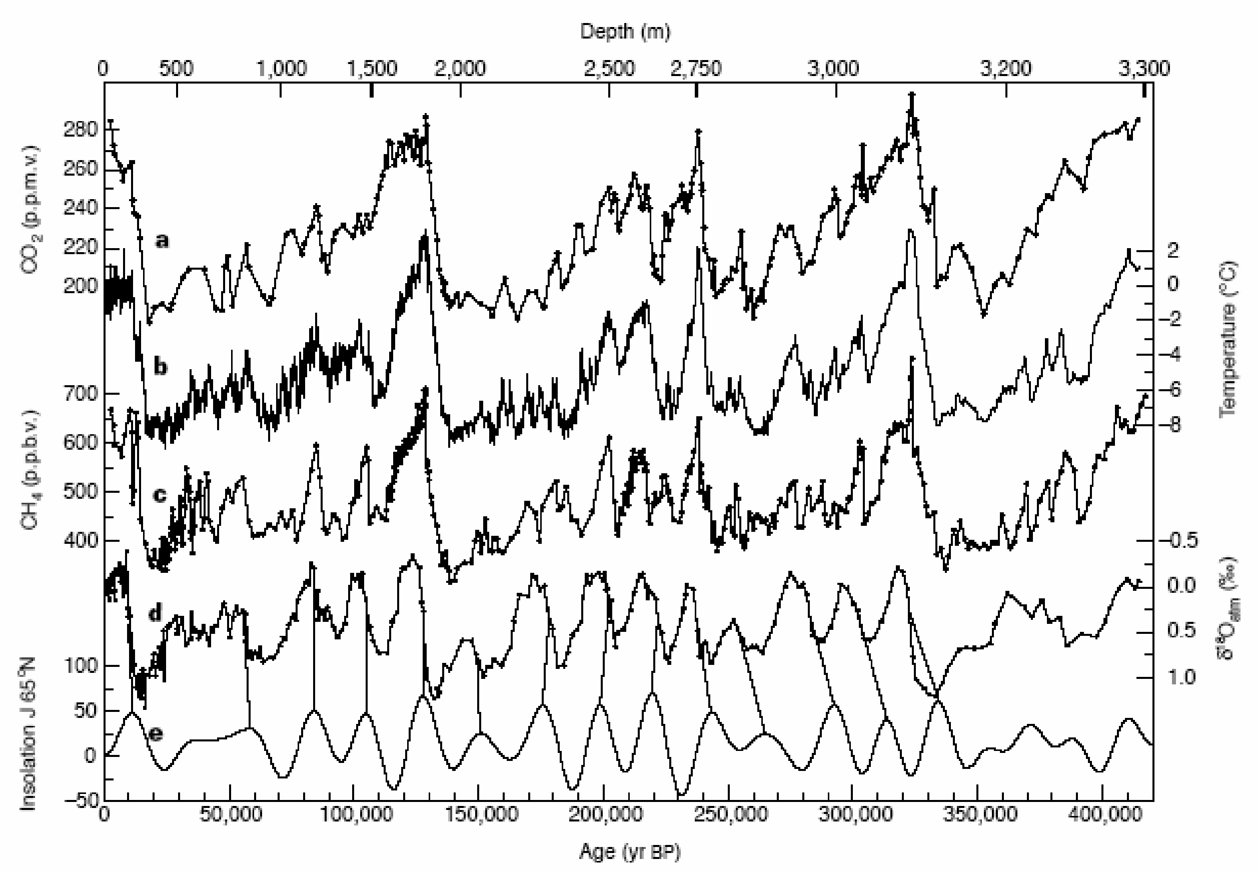
Table 12.3. Estimated Percentages of Natural Greenhouse Effect and Global Warming Temperature Changes Due to Greenhouse Gases and Particulate Black Carbon since the mid-1800s

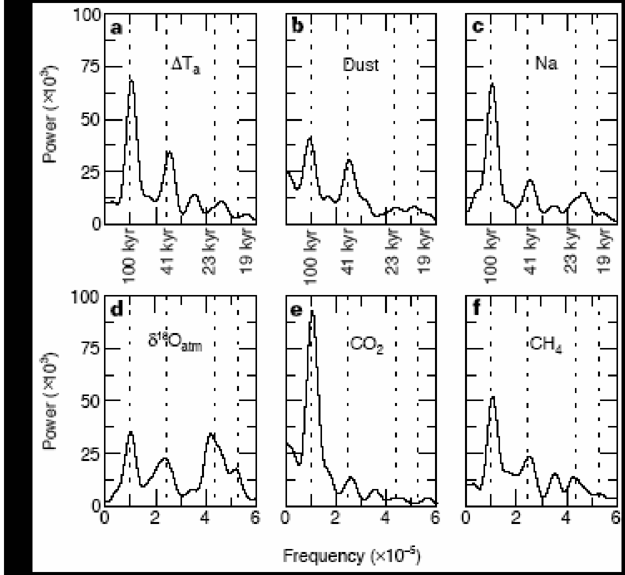
Compound Name	Formula	Current Total Tropospheric Mixing Ratio (ppmv) or Loading (Tg)	Natural Percentage of Current Total Mixing Ratio or Loading	Anthropogenic Percentage of Current Total Mixing Ratio or Loading	Percentage of Natural Greenhouse Effect Temperature Change Due to Component	Percentage of Global Warming Temperature Change Due to Component
Water vapor	$H_2O(g)$	10,000	>99	<1	88.9	0
Carbon dioxide	$CO_2(g)$	370	75.7	24.3	7.5	46.6
Black carbon (BC)	$C(s)$	0.15–0.3 Tg	10	90	0.2	16.4
Methane	$CH_4(g)$	1.8	39	61	0.5	14.0
Ozone	$O_3(g)$	0.02–0.07	50–100	0–50	1.1	11.9
Nitrous oxide	$N_2O(g)$	0.314	87.6	12.4	1.5	4.2
Methyl chloride	$CH_3Cl(g)$	0.0006	100	0	0.3	0
CFC-11	$CFCl_3(g)$	0.00027	0	100	0	1.8
CFC-12	$CF_2Cl_2(g)$	0.00054	0	100	0	4.2
HCFC-22	$CF_2ClH(g)$	0.00013	0	100	0	0.6
Carbon tetrachloride	$CCl_4(g)$	0.00010	0	100	0	0.3

Absorption of Radiation by GHG's



Climate & Atmospheric History of the Past 420,000 years





Spectral properties

Ref: Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica, J.R. Petit et.al, Nature, 399, 3, June 1999, 429 - 436.

Climate & Atmospheric History of the Past 420,000 years

Salient Observations:

Climate has almost always been in state of change with stable bounds.

CO_2 and CH_4 concentrations changes are similar for each 100 kyr glacial cycle. They are strongly correlated with Antarctic temperatures.

The bounds (lowest and highest values) of major transitions are associated with glacial and interglacial transitions. *(Milankovitch cycles - caused by gravitational attraction between planets of the solar system and Earth due to changes in the eccentricity of the Earth's orbit, obliquity of the Earth's axis and precession of the Earth's axis of rotation.)*

Bounds of CO_2 : 180 to 280 - 300 ppmv

Bounds of CH_4: 350 to 650-770 ppbv

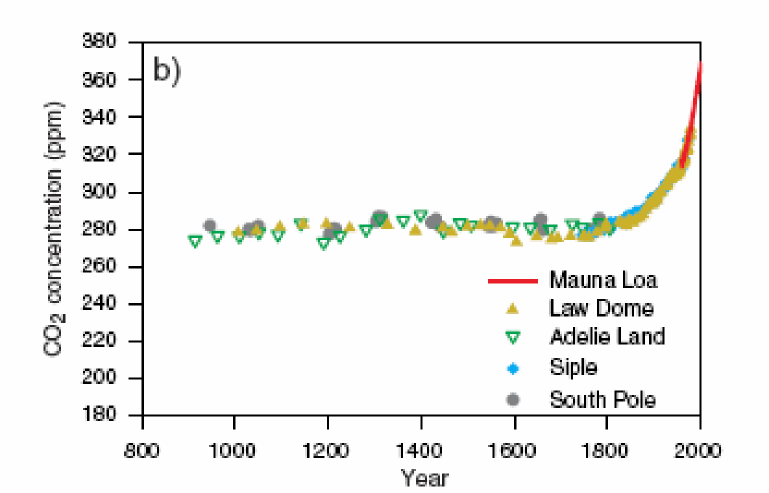
Present day levels:

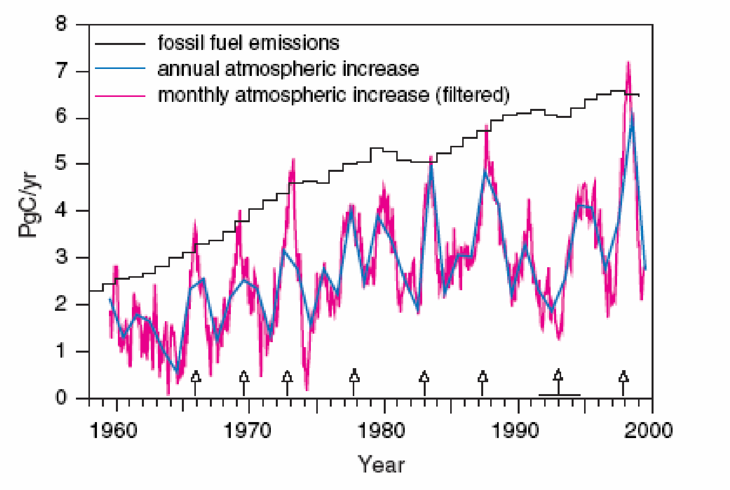
CO_2 : ~ 365 - 385* ppmv; CH_4 : ~1,700 ppbv

The data supports the idea that greenhouse gases have contributed significantly to the glacial-interglacial change.

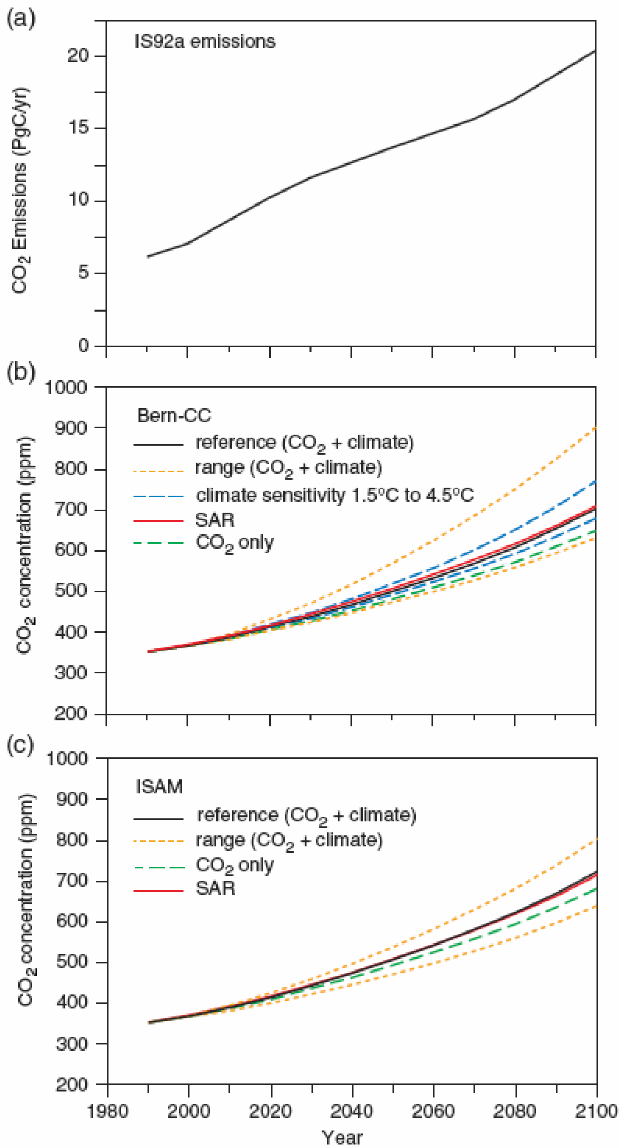
* 2004 data, Greenhouse gas jumps spurs global warming fears. Reuters, October 11, 2004; 2ppm per year for the last two years as opposed to 1.5 ppm per year recent trend.

CO_2 Concentrations



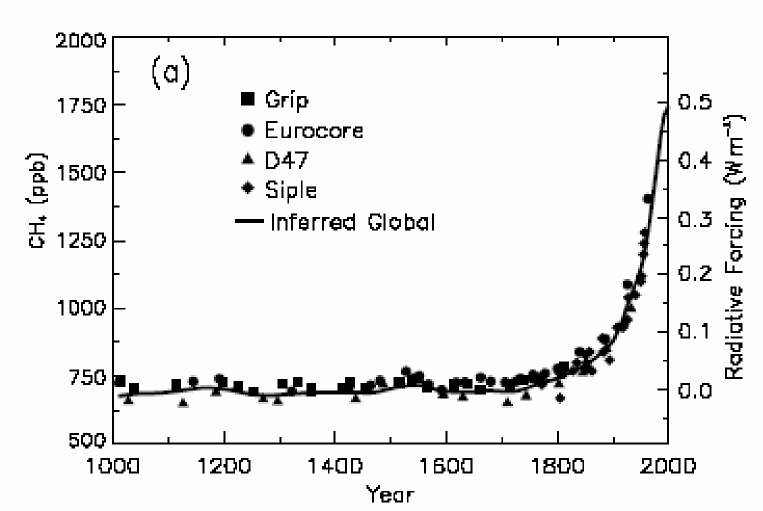


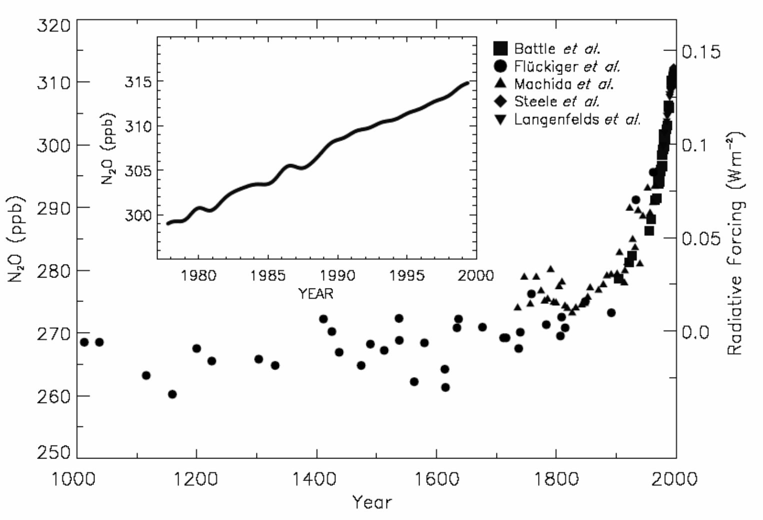
Fossil fuel burning and cement production

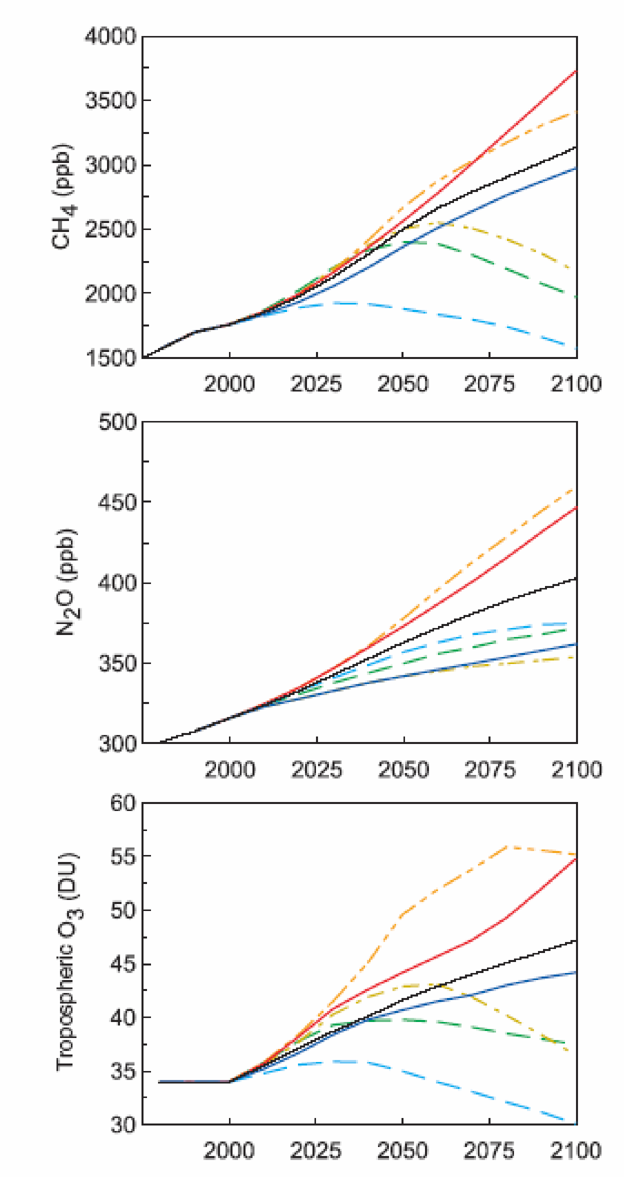


Projected CO_2 concentrations

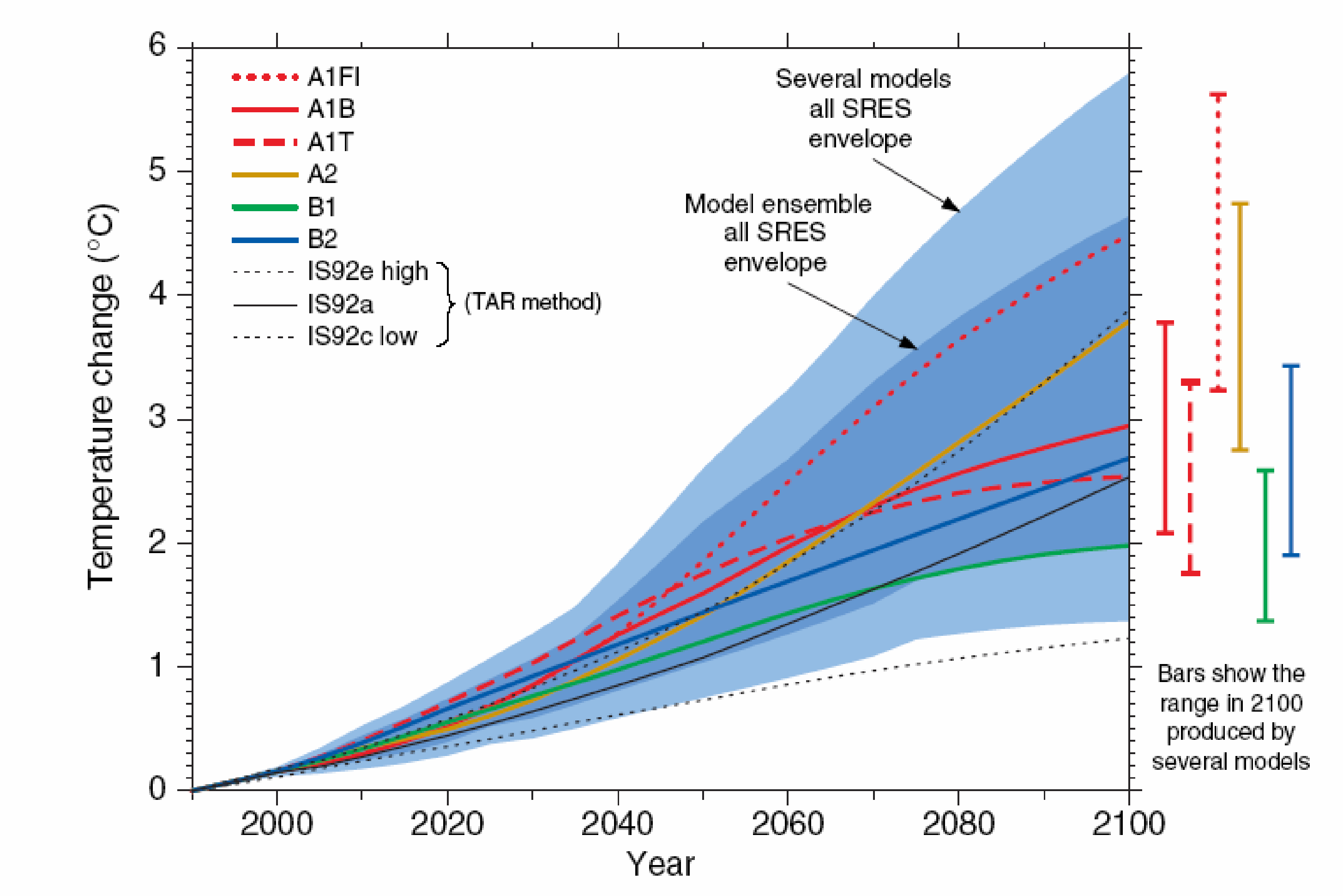
GHG’s Concentrations



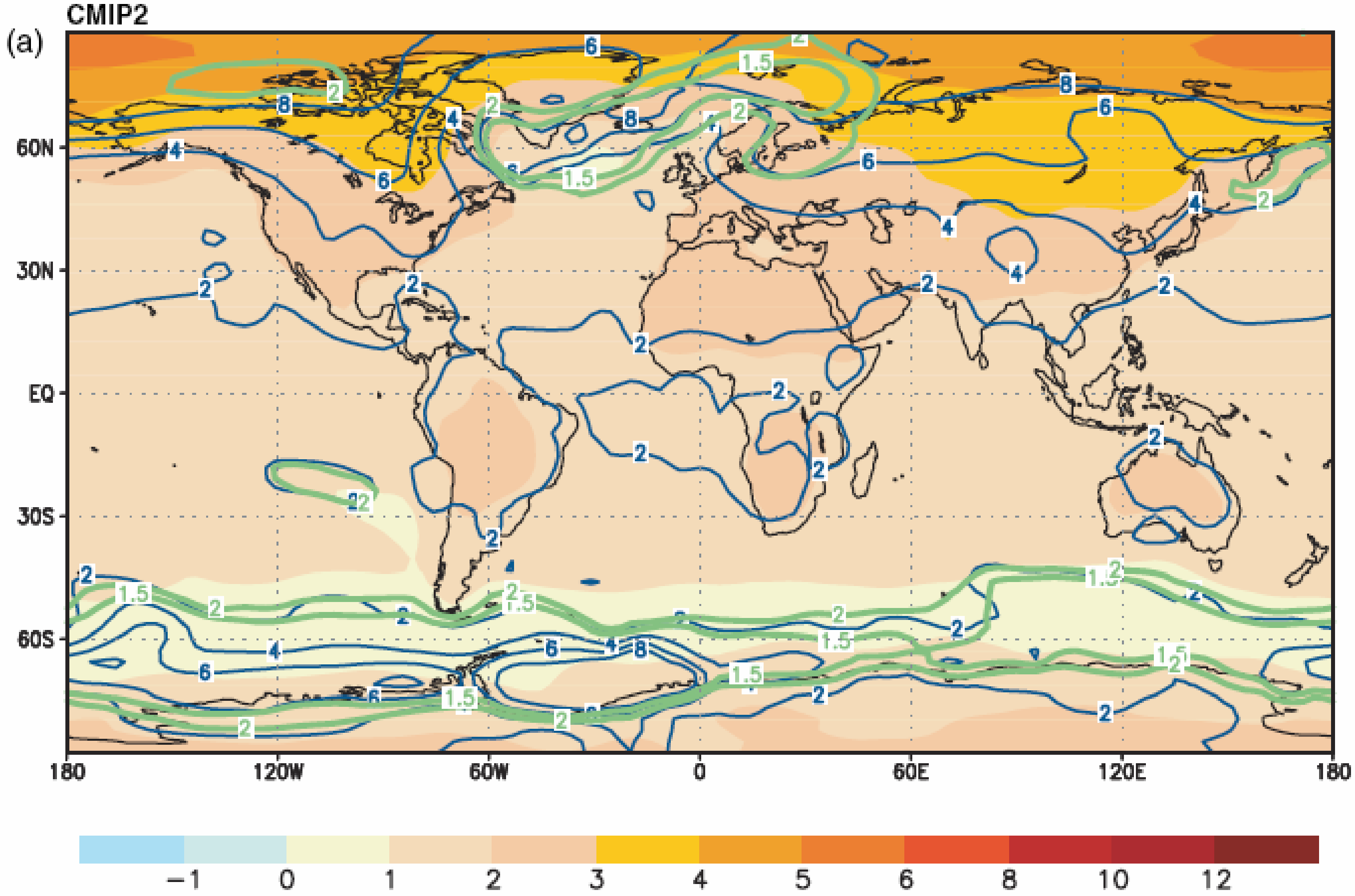




Global Temperature Change

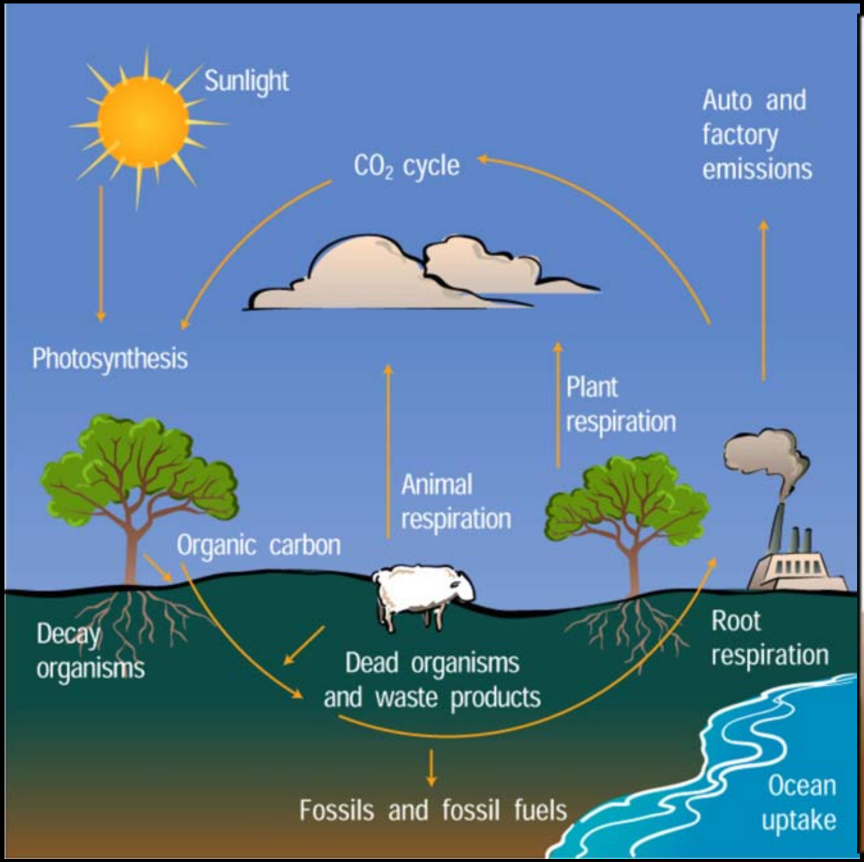


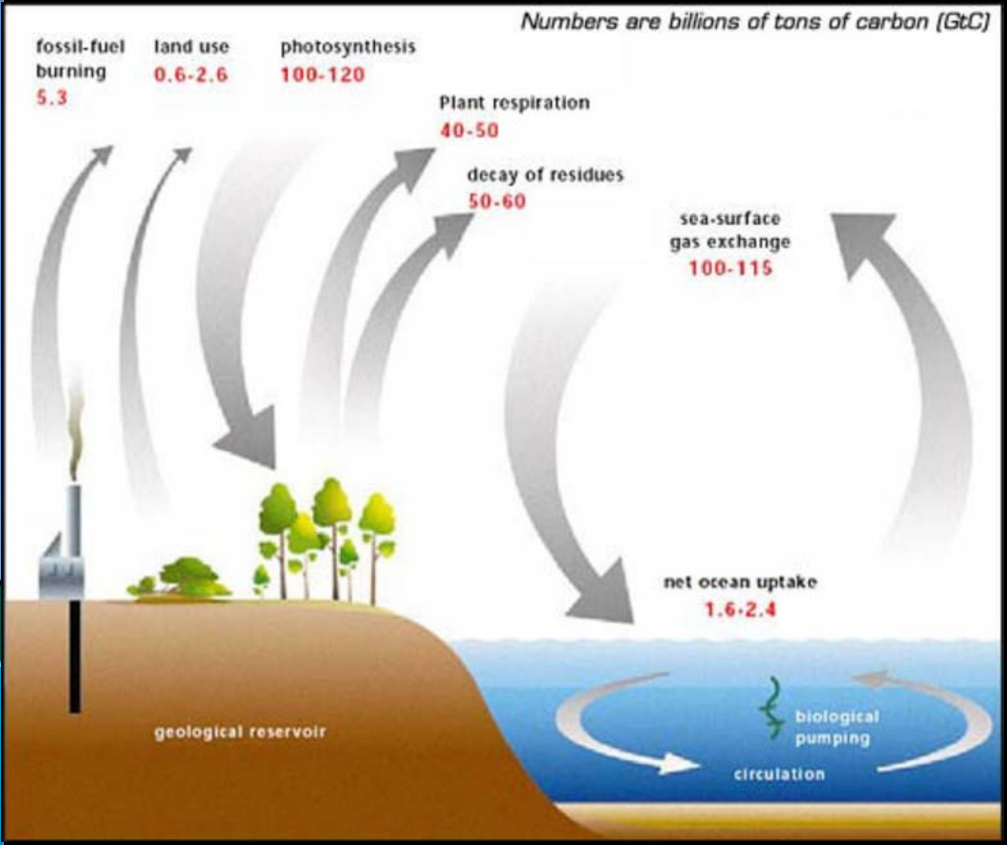
Annual Mean Change of the Temperature



At the time of CO_2 doubling

Global Carbon Cycle



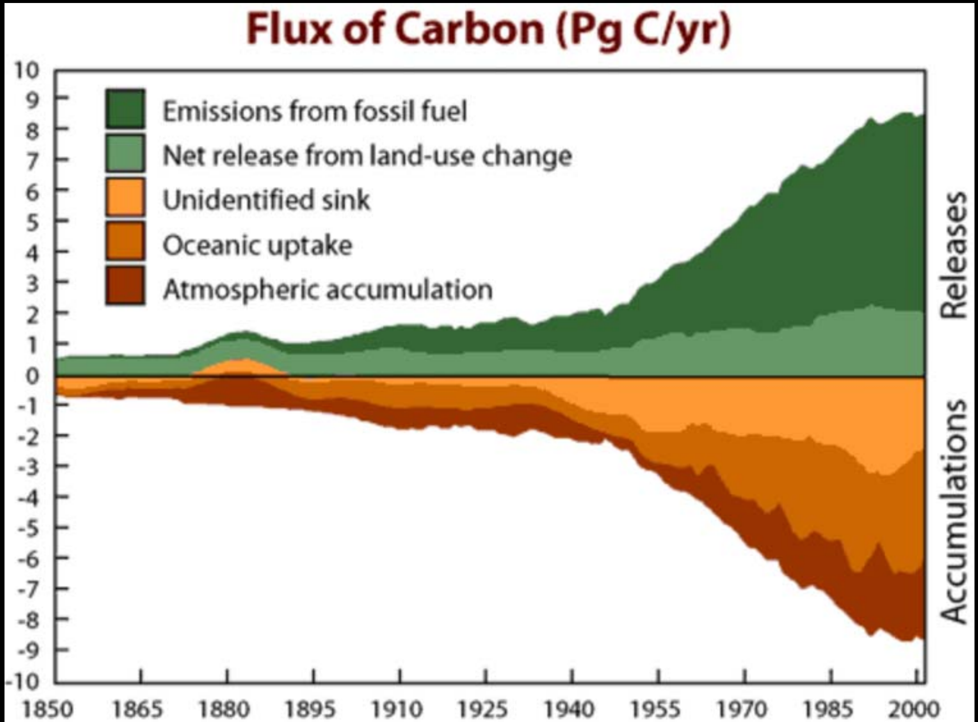


Global Carbon Equation

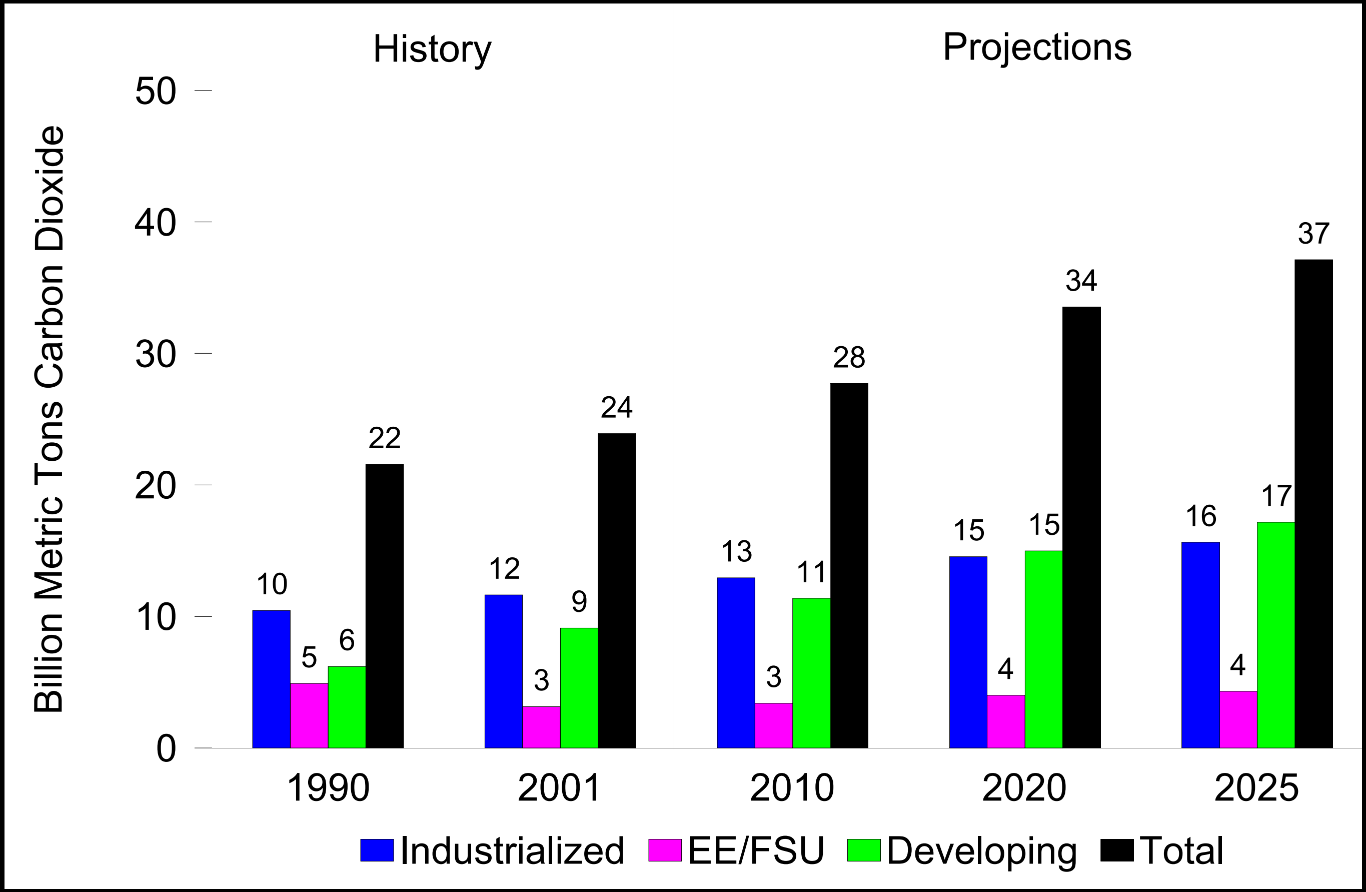
Atmospheric increase = Emissions from fossil fuels+Net emissions from changes in land use-Oceanic uptake-Missing carbon sink

3.2 (±0.2)=6.3 (±0.4)+2.2 (±0.8)-2.4 (±0.7)-2.9 (±1.1) in PgC

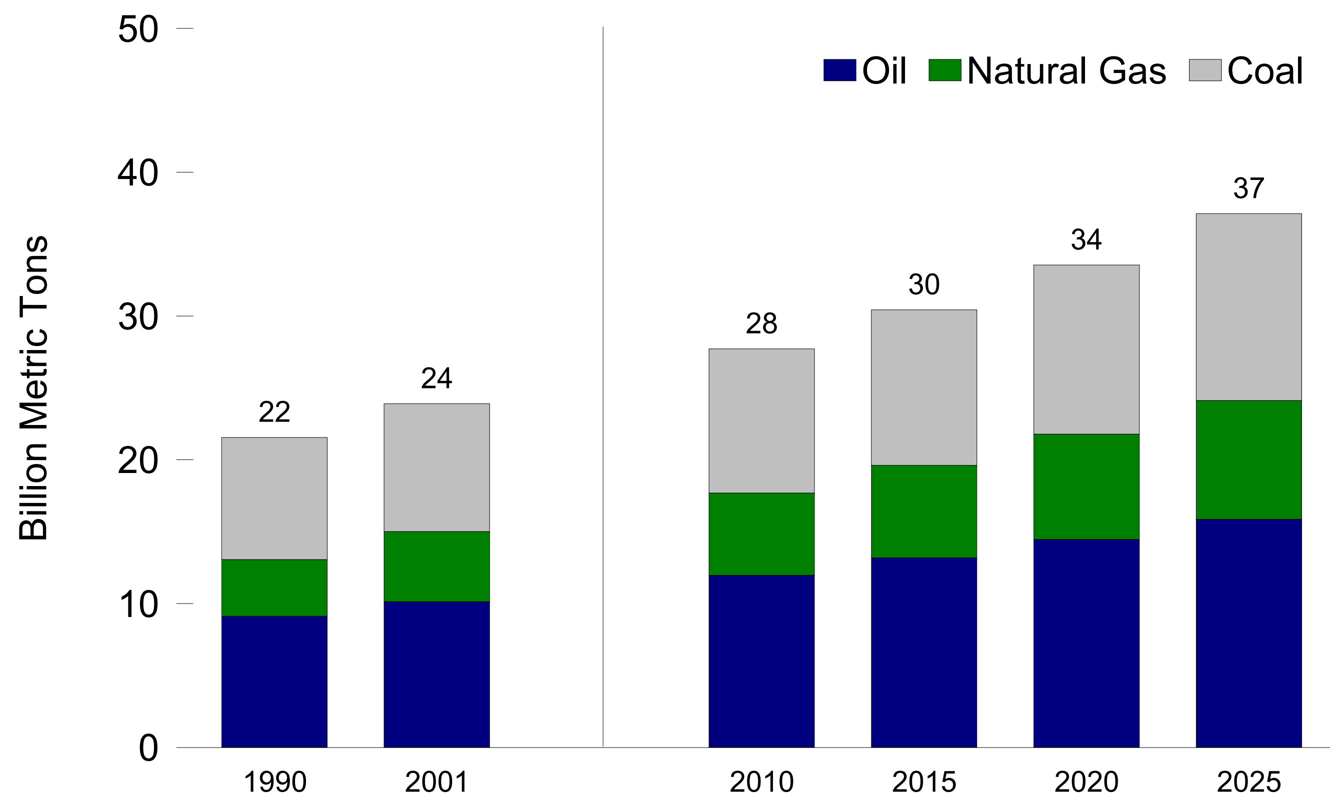
One Pg (pentagram) = one billion metric tones= 10^{12} kg



World Energy-Related CO_2 Emissions

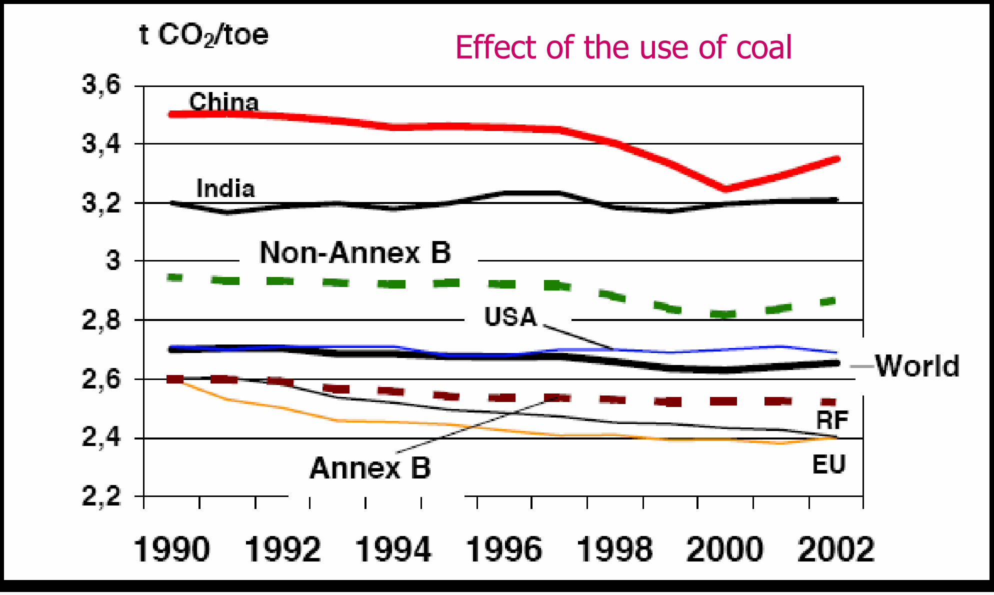


World Energy-Related CO_2 Emissions by Fossil Fuel Type



World CO_2 Emissions

Average CO_2 emissions per unit primary energy consumed



In 1998, the US released 5.4 tonnes of carbon per capita, European countries averaged around 1.9 tonnes and Africa emitted 0.3 tonnes.

CO_2 Emissions from Fossil fuel combustion (Gg) - 2002

		% Change from 1990
USA	6,175,900	16%
Germany	875,600	-13%
China	334,200	39%
India	104,000	72%

BBC News: September 1, 2004

Governments should consider setting lower targets for levels of CO2 in the atmosphere and investigate ways to extract surplus amounts of the greenhouse gas from circulation, say climate scientists.

Before the industrial revolution, the level of CO2 in the atmosphere was around 280 parts per million by volume (ppmv) but that has risen to around 380ppmv due to our burning of fossil fuels.

The Intergovernmental Panel on Climate Change is focusing its efforts on emission scenarios that lead to concentrations of no less than 450ppmv while the UK government is working towards a concentration target of around double pre-industrial levels, at 550ppmv.

If concentrations stabilize at 550ppmv, the corresponding global average temperature rise brought about by the greenhouse effect could still be as high as 5.5C, sufficient to melt the Greenland Ice Sheet and prompt a rise in sea level of six meters.

Scientists have watched as the melting of Greenland's ice has accelerated

Summary

The renewed look at the Sustainable Energy results from two irrefutable reasons:

The supplies of fossil and mineral resources are limited.

The process in which these resources are used in energy services damage and even destroy those limited planetary resources on which our lives depend: water, land and atmosphere.

We are becoming a culture of amnesia and strategically dependent on fossil energy.

Strategy: Energy from solar sources - Solar Strategy

Signs from Earth*

"Carbon Dioxide Levels Rise; Oceans Warm; Glaciers Melt; sea Level Rises,; Ice Shelves Collapse; Droughts Linger; Precipitation Increases; Winter looses its Bite; Spring Arrives Earlier; Autumn Comes Later; Habitats Change; Birds Nest Earlier; Coral Reefs Bleach; Snowpacks Decline; Coastline Erode: Temperatures Spike at High Altitudes"

Not a belief but a scientific Fact

Source: National Geographic, September 6-10, 2004