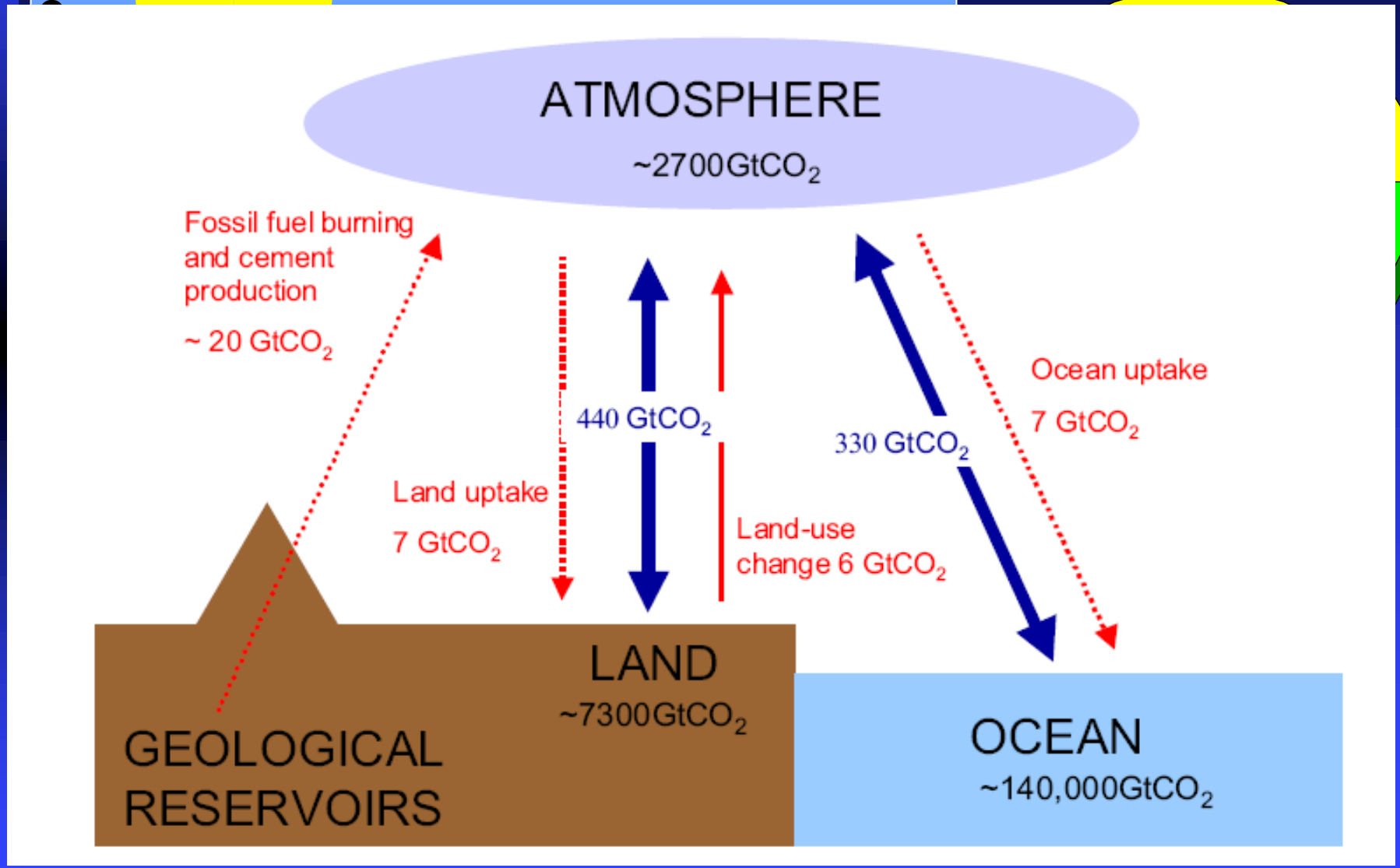
Climate change and the Greenhouse effect

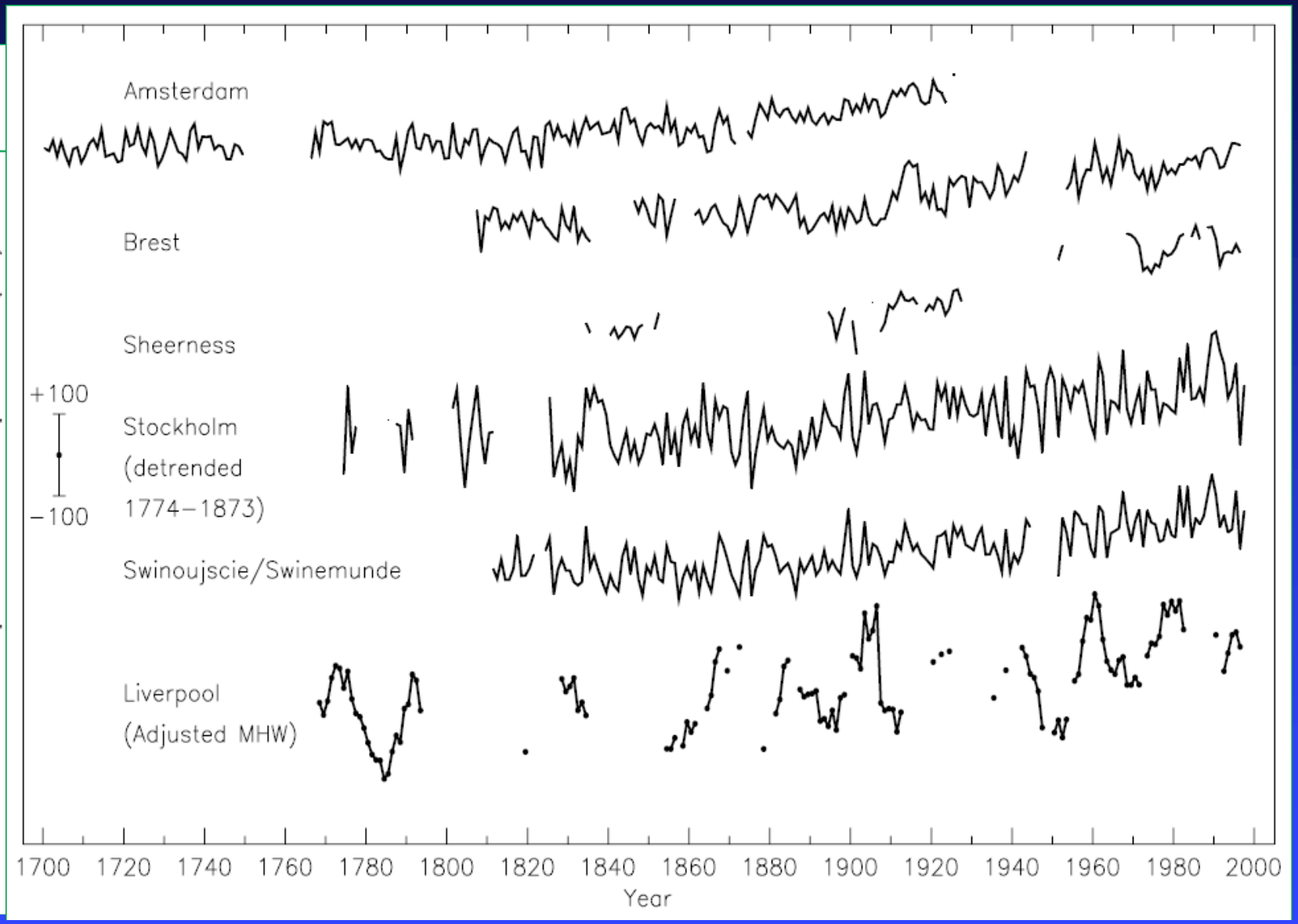
Umberto Desideri

What is the greenhouse effect

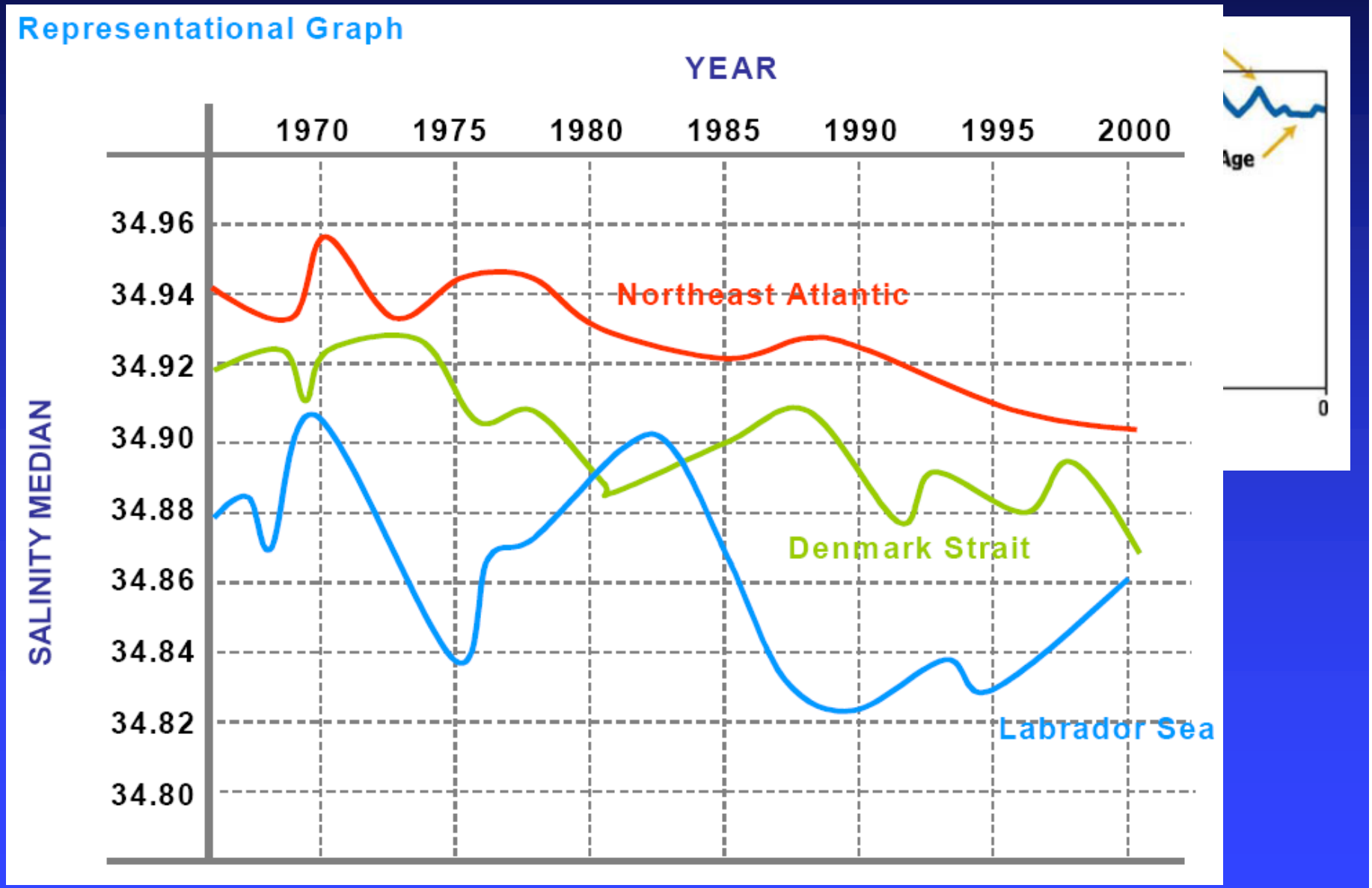
Heat Balance of the Earth [W/m^2]



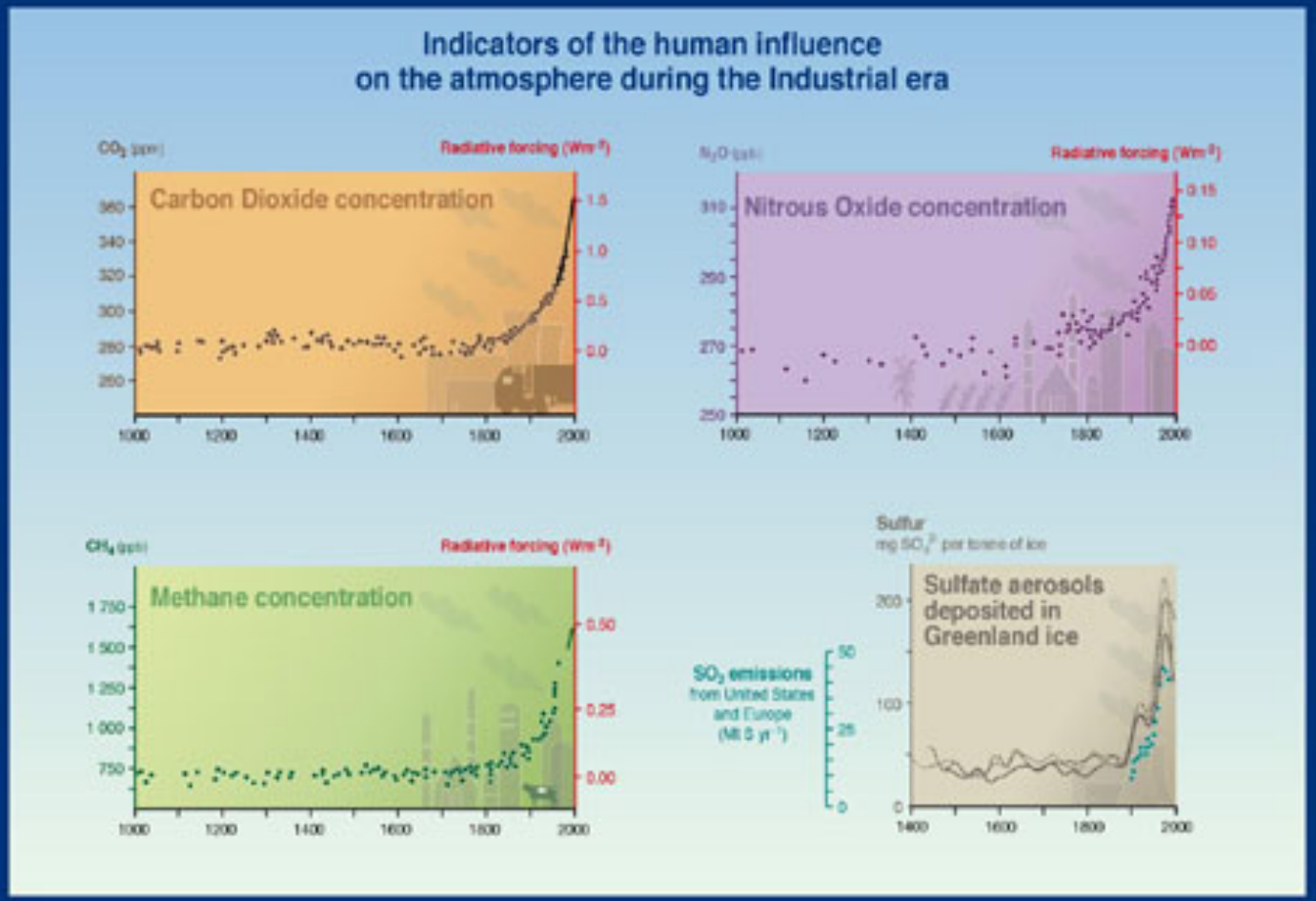
How to measure climate change



How to measure climate change



How the atmosphere changed

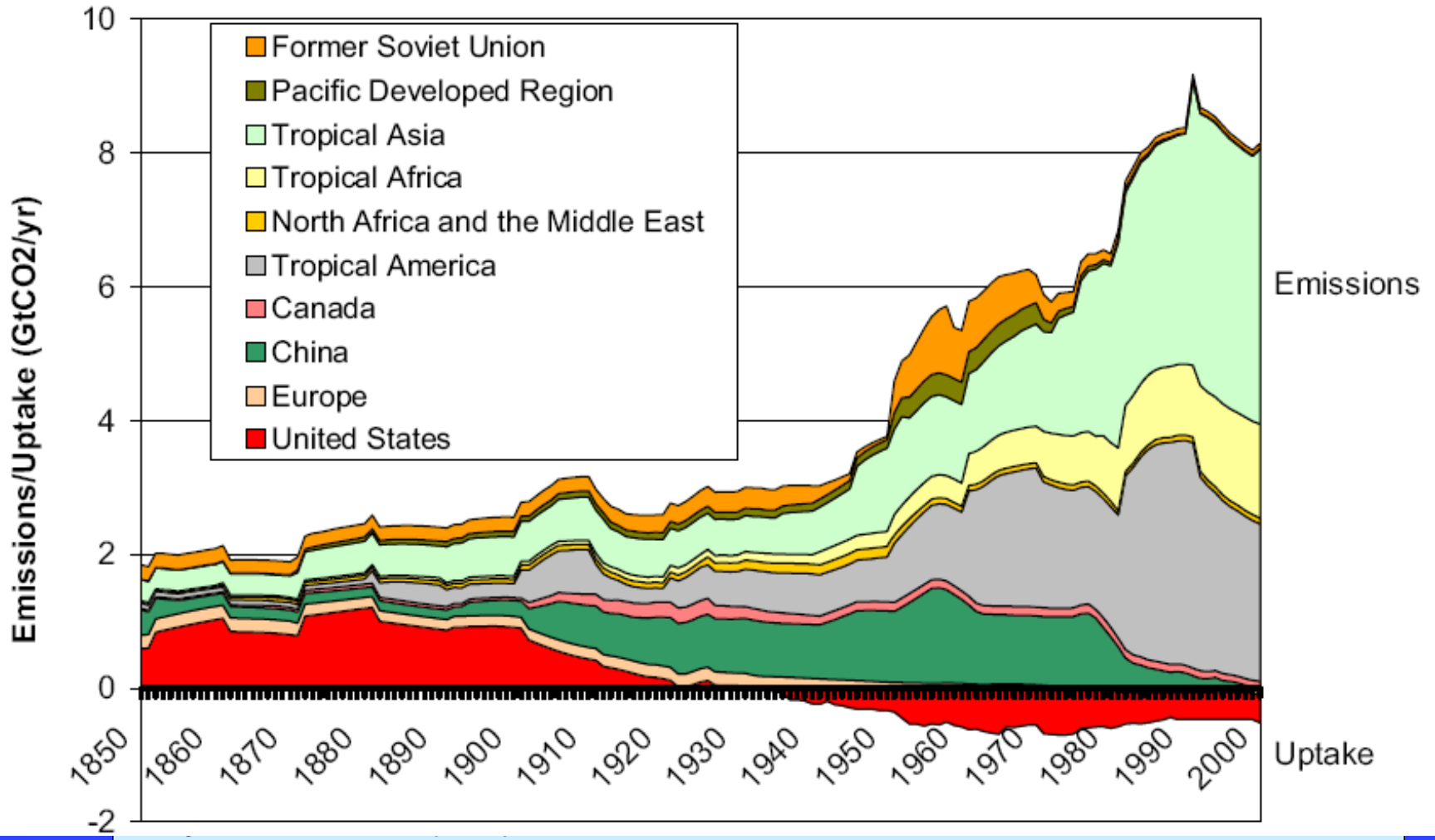


SYR - FIGURE 2-1
WG1 FIGURE SPM-2

Wha

Temp rise (°C)	Water	Food	Health	Land	Environment	Abrupt and Large-Scale Impacts
1°C	Small glaciers in the Andes disappear completely, threatening water supplies for 50 million people	Modest increases in cereal yields in temperate regions	At least 300,000 people each year die from climate-related diseases (predominantly diarrhoea, malaria, and malnutrition) Reduction in winter mortality in higher latitudes (Northern Europe, USA)	Permafrost thawing damages buildings and roads in parts of Canada and Russia	At least 10% of land species facing extinction (according to one estimate) 80% bleaching of coral reefs, including Great Barrier Reef	Atlantic Thermohaline Circulation starts to weaken
2°C	Potentially 20 - 30% decrease in water availability in some vulnerable regions, e.g. Southern Africa and Mediterranean	Sharp declines in crop yield in tropical regions (5 - 10% in Africa)	40 – 60 million more people exposed to malaria in Africa	Up to 10 million more people affected by coastal flooding each year	15 – 40% of species facing extinction (according to one estimate) High risk of extinction of Arctic species, including polar bear and caribou	Potential for Greenland ice sheet to begin melting irreversibly, accelerating sea level rise and committing world to an eventual 7 m sea level rise Rising risk of abrupt changes to atmospheric circulations, e.g. the monsoon Rising risk of collapse of West Antarctic Ice Sheet Rising risk of collapse of Atlantic Thermohaline Circulation
3°C	In Southern Europe, serious droughts occur once every 10 years 1 - 4 billion more people suffer water shortages, while 1 – 5 billion gain water, which may increase flood risk	150 - 550 additional millions at risk of hunger (if carbon fertilisation weak) Agricultural yields in higher latitudes likely to peak	1 – 3 million more people die from malnutrition (if carbon fertilisation weak)	1 – 170 million more people affected by coastal flooding each year	20 – 50% of species facing extinction (according to one estimate), including 25 – 60% mammals, 30 – 40% birds and 15 – 70% butterflies in South Africa Onset of Amazon forest collapse (some models only)	
4°C	Potentially 30 – 50% decrease in water availability in Southern Africa and Mediterranean	Agricultural yields decline by 15 – 35% in Africa, and entire regions out of production (e.g. parts of Australia)	Up to 80 million more people exposed to malaria in Africa	7 – 300 million more people affected by coastal flooding each year	Loss of around half Arctic tundra Around half of all the world's nature reserves cannot fulfill objectives	
5°C	Possible disappearance of large glaciers in Himalayas, affecting one-quarter of China's population and hundreds of millions in India	Continued increase in ocean acidity seriously disrupting marine ecosystems and possibly fish stocks		Sea level rise threatens small islands, low-lying coastal areas (Florida) and major world cities such as New York, London, and Tokyo		
More than 5°C	The latest science suggests that the Earth's average temperature will rise by even more than 5 or 6°C if emissions continue to grow and positive feedbacks amplify the warming effect of greenhouse gases (e.g. release of carbon dioxide from soils or methane from permafrost). This level of global temperature rise would be equivalent to the amount of warming that occurred between the last age and today – and is likely to lead to major disruption and large-scale movement of population. Such "socially contingent" effects could be catastrophic, but are currently very hard to capture with current models as temperatures would be so far outside human experience.					

Figure 3[9] Uptake and emissions from land-use changes between 1850 and 2000. The negative emissions (uptake) post-1940 are largely due to increasing forest area in the US (0.4$GtCO_2$/yr in 2000) and Europe (0.07$GtCO_2$/yr in 2000). The peak in 1990 linked to forest fires in Indonesia.



Emissions and wealth

$$C = P \times GNP/P \times E/GNP \times C/E$$

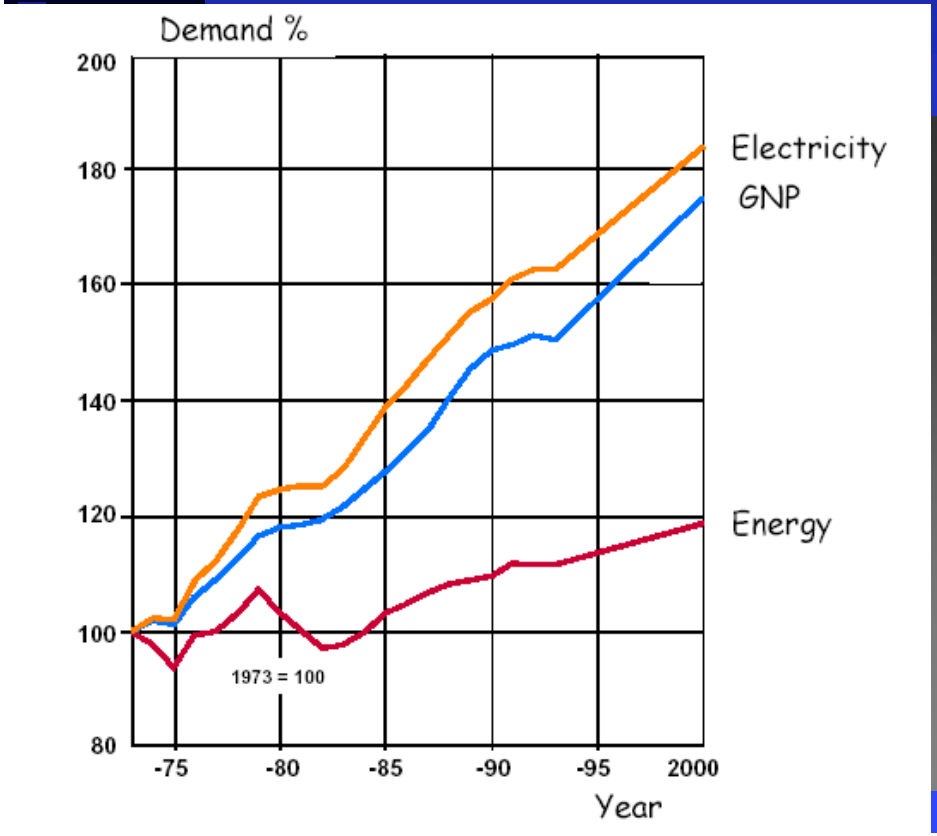
C = Carbon content in emitted CO2, tons

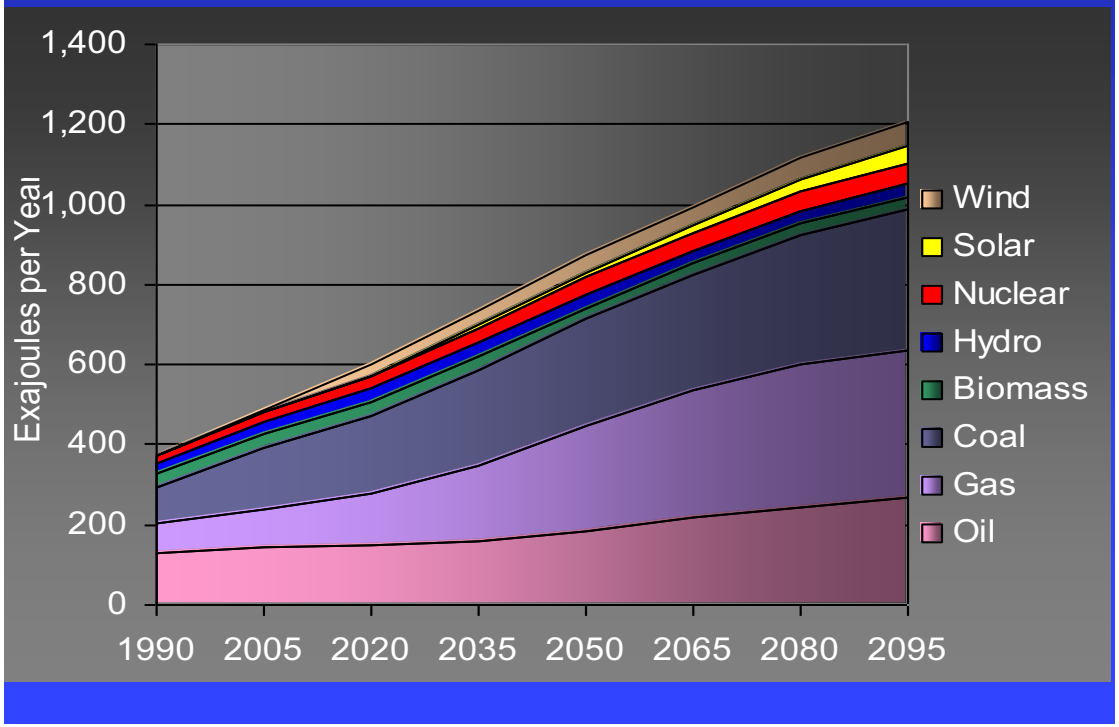
P = World population

GNP / P = per capita GNP, $/pers

E / GNP = Energy intensity, GJ/$

C / E = Specific emissions of carbon, kg/GJ





Political measures

- Kyoto Protocol
  - Emission Trading
  - Flexible Mechanism
  - Voluntary emission offset
- Asia Pacific Partnership
  - Specific measures with strong incentives

Kyoto Protocol

- The United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol provide the only international framework for combating climate change. The UNFCCC, was adopted in May 1992 and came into force in March 1994. It obliges all its signatories to establish national programmes for reducing greenhouse gas emissions and to submit regular reports, and demands that the industrialised signatory countries, as opposed to developing countries, stabilise their greenhouse gas emissions at 1990 levels by the year 2000. This goal, however, is non-binding.
- By differentiating between industrialised and developing countries, the UNFCCC recognises that industrialised countries are responsible for most of the global greenhouse gas emissions and also have the institutional and financial capacities for reducing them.
- On 11 December 1997, governments took a further step and adopted a protocol to the UNFCCC in the Japanese town of Kyoto. The Kyoto Protocol sets legally binding limits on greenhouse gas emissions in industrialised countries and envisages innovative market-based implementation mechanisms aimed at keeping the cost of curbing emissions low.
- Under the Kyoto Protocol, industrialised countries are required to reduce the emissions of six greenhouse gases (CO_2, which is the most important one, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) on average by 5.2 % below the 1990 levels during the first “commitment period” from 2008 to 2012. There are no emission targets for developing countries.
- The UNFCCC divides countries into two main groups: As of 1 July 2002, 186 countries were Parties to the Convention, out of which 40 industrialised countries were listed in the Convention’s Annex I, and the remaining 146 were known as non-Annex I countries. Annex I countries include the 24 relatively wealthy industrialised countries that were members of the organisation for Economic Co-operation and Development (OECD) in 1992, the 15 EU Member States and 11 countries with economies in transition to a market economy, including Russia.

Kyoto Protocol

- A five-year commitment period was chosen rather than a single target year to smooth out annual fluctuations in emissions due to uncontrollable factors such as weather. International negotiations on a second commitment period under the Kyoto Protocol after 2012 are to start in 2005.
- The commitments will become legally binding once the Kyoto Protocol enters into force. The rules for entry into force demand that at least 55 Parties to the UNFCCC ratify the Protocol and that those include industrialised countries (Annex I countries) accounting for at least 55% of the CO_2 emissions in 1990.
- There is one Annex I county that has not ratified yet: the United States..
- After the Kyoto Protocol was adopted, negotiations on the details of the mechanisms that it envisages and on the rules of implementation continued. The final negotiations were concluded with the Marrakech Accords in 2001. The EU played a major role in bringing the negotiations on the Kyoto Protocol to a successful conclusion, in particular after the US withdrawal.

Kyoto Protocol mechanisms

- The Kyoto Protocol envisages three market-based “flexible mechanisms”: emissions trading, Joint Implementation and the Clean Development Mechanism. These are to allow industrialised countries to meet their targets through trading emission allowances between themselves and gaining credits for emission-curbing projects abroad. Joint Implementation refers to projects in countries that, too, have emission targets, and the Clean Development Mechanism refers to projects in developing countries with no targets.
- The rationale behind these three mechanisms is that greenhouse gas emissions are a global problem and that the place where reductions are achieved is of less importance. In this way, reductions can be made where costs are lowest, at least in the initial phase of combating climate change.

Emission trading scheme

- Under the EU emissions trading scheme, the EU Member States will set limits on CO_2 emissions from energy-intensive companies (approximately 10,000 steel factories, power plants, oil refineries, paper mills, and glass and cement installations) by issuing allowances as to how much CO_2 these companies are allowed to emit. Reductions below the limits will be tradable.
- Companies that achieve reductions can sell them to companies that have problems staying within their limits or for which emissions reduction measures are too expensive in comparison with what the allowances will cost. Any company may also increase its emissions above the level of allowance it is issued by acquiring more allowances from the market.
- This scheme will induce companies to make emission cuts where they are cheapest, thereby ensuring that reductions are made at the lowest possible cost to the economy and that innovation is fostered.
- It is estimated that the companies currently participating in the scheme account for almost half of the EU's total CO_2 emissions. Other sectors, such as aluminium producers, the chemicals industry and the transport sector, might be brought in later.
- The EU Member States have prepared their National Allocation Plans setting out the allowances that each sector and company will be issued.

CDM and JI

- Building on these provisions and the EU emissions trading system, the Commission on 23 July 2003 adopted a proposal that links credits from JI and CDM projects with the emissions trading system. Under this proposal, European companies covered by the EU emissions trading system will be allowed to convert credits from JI and CDM projects for use towards meeting their commitments under the trading system.
- The reasoning behind JI and CDM is similar to the one behind emissions trading: It does not matter where emissions reductions are achieved as climate change is a global problem. The important thing is that they take place and are achieved in the most cost-effective way. It is estimated that the linking of project credits to the emissions trading system will lower the annual compliance costs for companies covered by the scheme, which include companies in the ten accession countries, by about a quarter. JI and CDM will also transfer environmentally sound technology to countries with economies in transition (JI) and developing countries (CDM), which will help them move onto a sustainable path of development.
- A condition for the issue of credits in respect of the reductions achieved is that the projects result in real, measurable and long-term climate change benefits.
- Uncertainty remains about the effects of emission removal by carbon sinks: projects concerning land use.

Targets of the KP in the EU

MEMBER STATE	Base year [1] (million tonnes)	2001 (million tonnes)	Change 2000–2001 (%)	Change base year–2001 (%)	Targets 2008–12 under Kyoto Protocol and "EU burden sharing" (%)
Austria	78,3	85,9	4,8%	9,6%	-13,0%
Belgium	141,2	150,2	0,2%	6,3%	-7,5%
Denmark [2]	69,5	69,4	1,8%	-0,2% (-10,7%)	-21,0%
Finland	77,2	80,9	7,3%	4,7%	0,0%
France	558,4	560,8	0,5%	0,4%	0,0%
Germany	1216,2	993,5	1,2%	-18,3%	-21,0%
Greece	107,0	132,2	1,9%	23,5%	25,0%
Ireland	53,4	70,0	2,7%	31,1%	13,0%
Italy	509,3	545,4	0,3%	7,1%	-6,5%
Luxembourg	10,9	6,1	1,3%	-44,2%	-28,0%
Netherlands	211,1	219,7	1,3%	4,1%	-6,0%
Portugal	61,4	83,8	1,9%	36,4%	27,0%
Spain	289,9	382,8	-1,1%	32,1%	15,0%
Sweden	72,9	70,5	2,2%	-3,3%	4,0%
United Kingdom	747,2	657,2	1,3%	-12,0%	-12,5%
EU-15	**4204,0**	**4108,3**	**1,0%**	**-2,3%**	**-8,0%**

[1] Base year for CO_2, CH_4 and N_2O is 1990; for fluorinated gases 1995 is used as the base year, as allowed for under the Kyoto Protocol. This reflects the preference of most Member States.

[2] For Denmark, data that reflect adjustments in 1990 for electricity trade (import and export) and for temperature variations are given in brackets. This methodology is used by Denmark to monitor progress towards its national target under the EU "burden sharing" agreement. For the EU emissions total non-adjusted Danish data have been used.

Strategies to mitigate CO_2 emissions in atmosphere

- *Increase in the efficiency of production and utilization of energy: rational and economically interesting*
- *Transition to fossil fuels with a high H/C ratio (from coal to natural gas): easy but the trends is opposite*
- *Renewable energy: may produce an impact in some sectors and users but it still needs economic support*
- *Nuclear energy: political and social issues*
- *CO_2 capture and storage: difficult, expensive but may be used in large new and existing power plants, guaranteeing security of large scale energy production*

Non renewable energy sources speeding to the end

Oil reserves

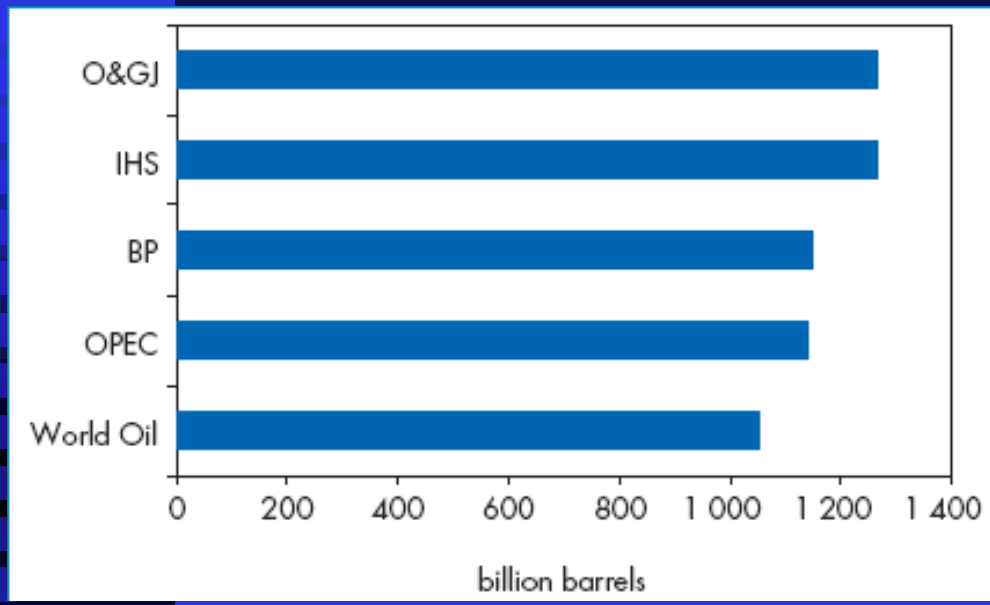


Table 3.1: **World Oil Demand** (million barrels per day)

	2002	2010	2020	2030	2002-2030*
OECD North America	22.6	25.5	28.7	31.0	1.1
United States and Canada	*20.7*	*23.2*	*25.8*	*27.6*	*1.0*
Mexico	*2.0*	*2.3*	*2.9*	*3.4*	*2.0*
OECD Europe	14.5	15.3	16.3	16.6	0.5
OECD Pacific	8.4	8.9	9.4	9.5	0.5
OECD Asia	*7.5*	*7.9*	*8.3*	*8.3*	*0.4*
OECD Oceania	*0.9*	*1.0*	*1.1*	*1.2*	*1.2*
OECD	**45.4**	**49.7**	**54.4**	**57.1**	**0.8**
Transition economies	4.7	5.5	6.5	7.6	1.8
Russia	*2.7*	*3.1*	*3.6*	*4.2*	*1.6*
Other transition economies	*2.0*	*2.4*	*3.0*	*3.4*	*2.0*
China	5.2	7.9	10.6	13.3	3.4
Indonesia	1.2	1.6	2.1	2.6	2.9
India	2.5	3.4	4.5	5.6	2.9
Other Asia	3.9	5.1	7.0	8.8	3.0
Latin America	4.5	5.4	6.8	8.4	2.3
Brazil	*1.8*	*2.3*	*2.9*	*3.6*	*2.4*
Other Latin America	*2.7*	*3.2*	*3.9*	*4.8*	*2.1*
Africa	2.4	3.1	4.4	6.1	3.4
Middle East	4.3	5.4	6.8	7.8	2.1
Non-OECD	**28.6**	**37.5**	**48.8**	**60.4**	**2.7**
Miscellaneous**	3.0	3.2	3.5	3.8	0.9
World	**77.0**	**90.4**	**106.7**	**121.3**	**1.6**
European Union	*13.6*	*14.4*	*15.3*	*15.6*	*0.5*

In 2002, 77 million barrels per day were consumed: 28 billion barrels per year

In 2030, 121,3 million barrels per day will be consumed: 44 billion barrels per year

In the first 30 years of the third millennium an average of 36 billion barrels of oil per year will be consumed

Dividing the proven reserves by the average consumption: 1400/36 oil will be available for 38 years

Additional or unexplored reserves are estimated at 2600 billion barrels for 72 years more

Gas reserves

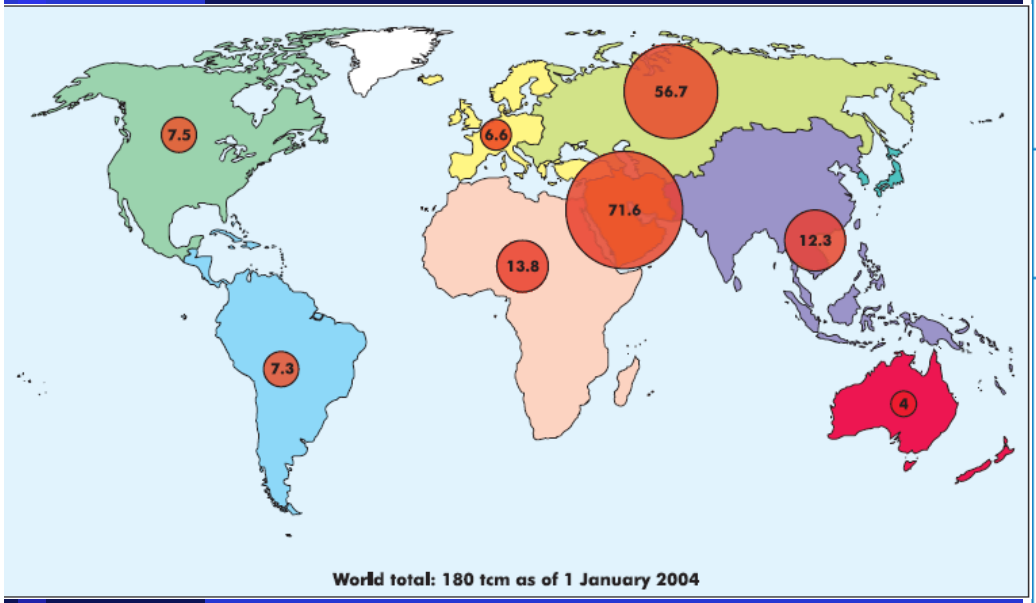


Table 4.1: **World Natural Gas Primary Demand** (bcm)

	2002	2010	2020	2030	2002-2030*
OECD North America	759	866	1 002	1 100	1.3%
OECD Europe	491	585	705	807	1.8%
OECD Pacific	130	173	216	246	2.3%
OECD	**1 380**	**1 624**	**1 924**	**2 154**	**1.6%**
Russia	415	473	552	624	1.5%
Other transition economies	220	254	311	360	1.8%
Transition economies	**635**	**728**	**863**	**984**	**1.6%**
China	36	59	107	157	5.4%
Indonesia	36	53	75	93	3.5%
India	28	45	78	110	5.0%
Other Asia	109	166	242	313	3.8%
Brazil	13	20	38	64	5.8%
Other Latin America	89	130	191	272	4.1%
Africa	69	102	171	276	5.1%
Middle East	219	290	405	470	2.8%
Developing countries	**597**	**864**	**1 307**	**1 753**	**3.9%**
World**	**2 622**	**3 225**	**4 104**	**4 900**	**2.3%**
European Union	*471*	*567*	*684*	*786*	*1.8%*

In 2002, 2,622 billion cubic meters of natural gas were consumed every year

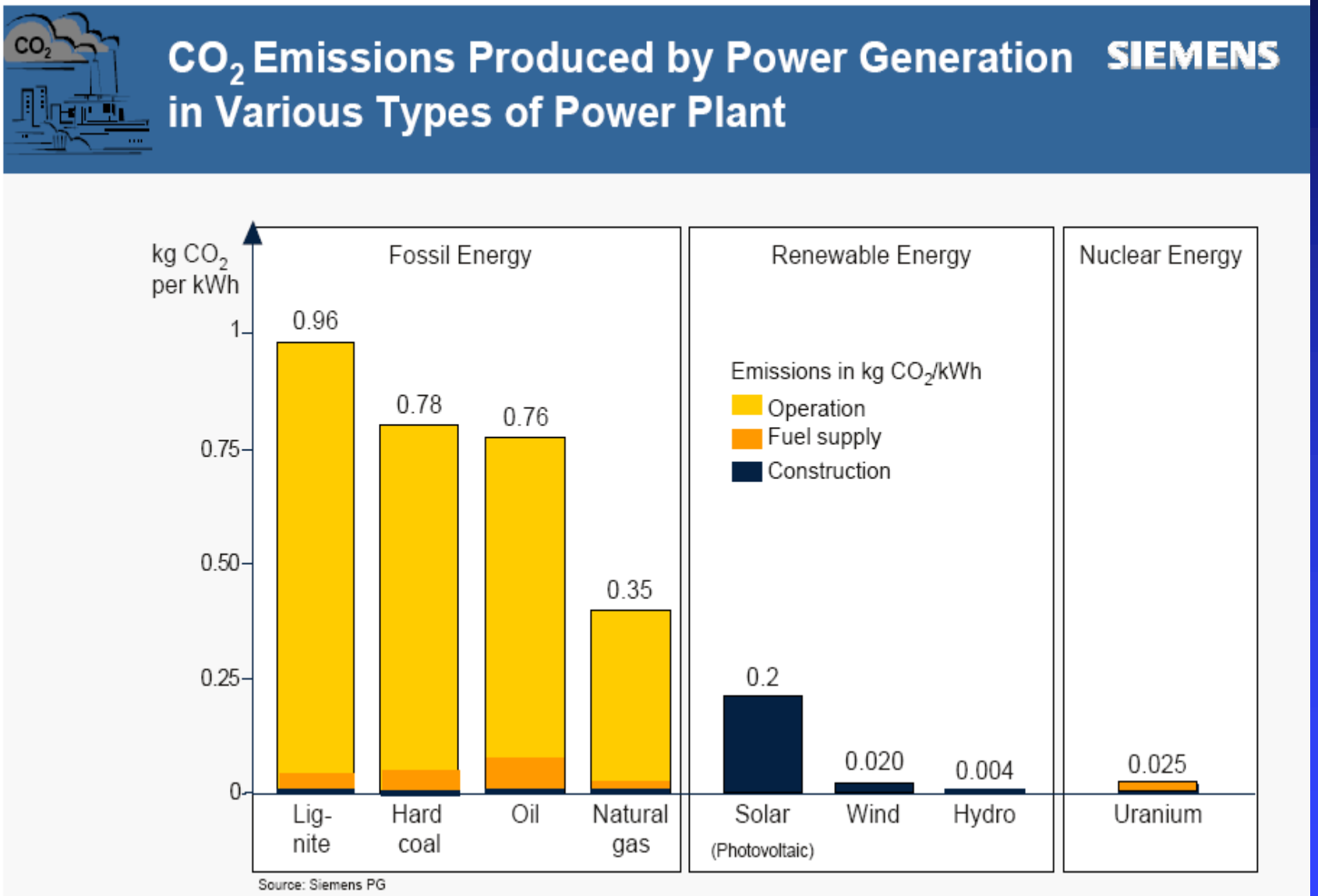
In 2030 4,900 billion cubic meters per year will be consumed

In the first 30 years of the thir millenium 3,761 billion cubic meters will be consumed every year

Dividing the proven reserves by the average consumption: 180,000/3,761 Natural gas will be available for 47 years

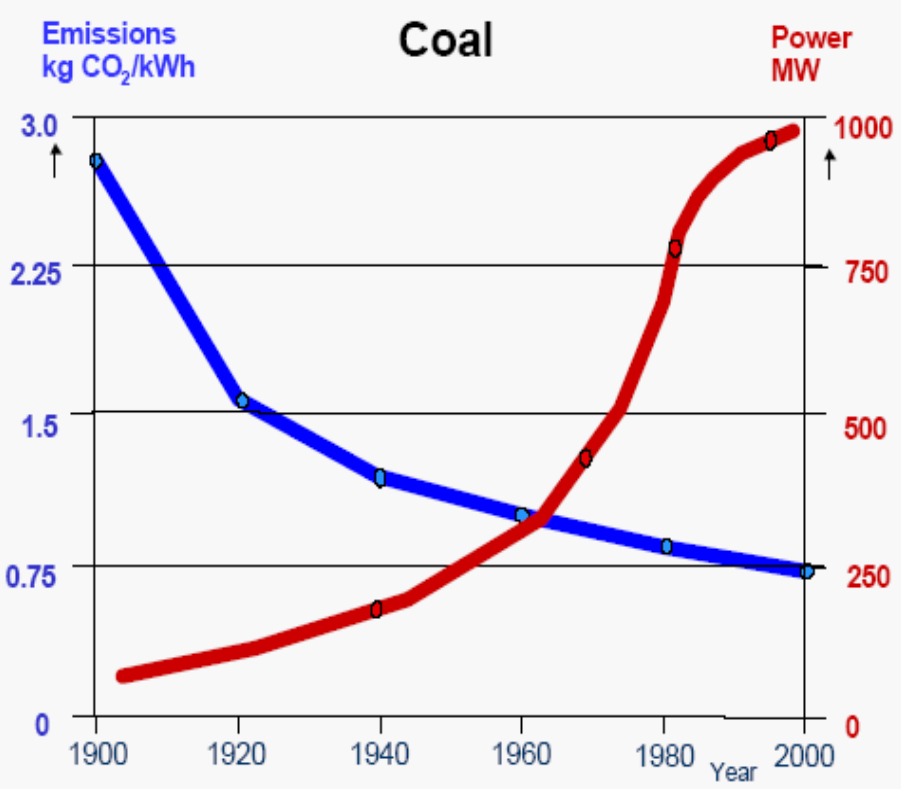
Additional and unexplored reserves are estimated at 147,000 billion cubic meters for 40 years more

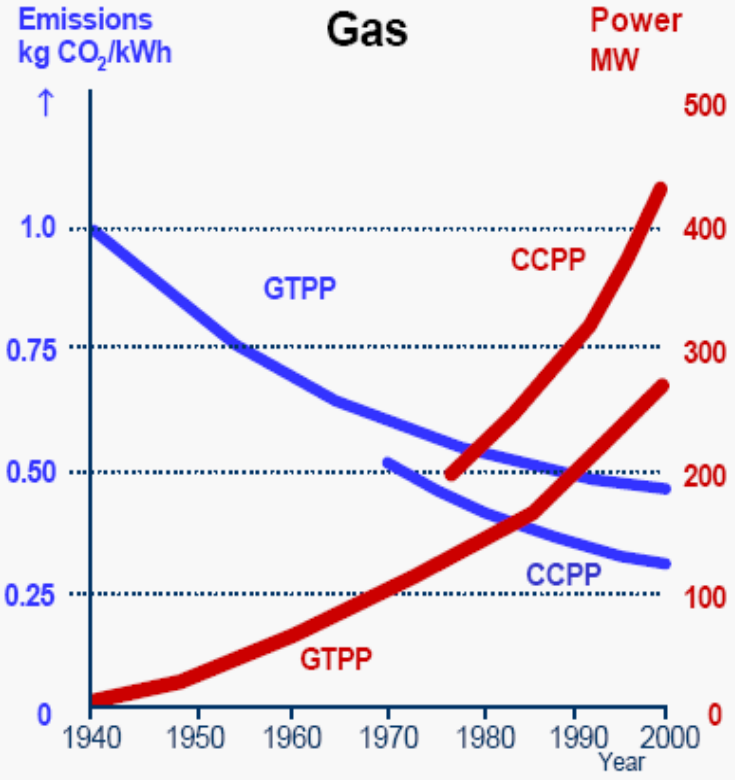
CO_2 emissions from different power plants



Development of Gas and Steam Cycles
CO_2 Emissions, Power Output

SIEMENS



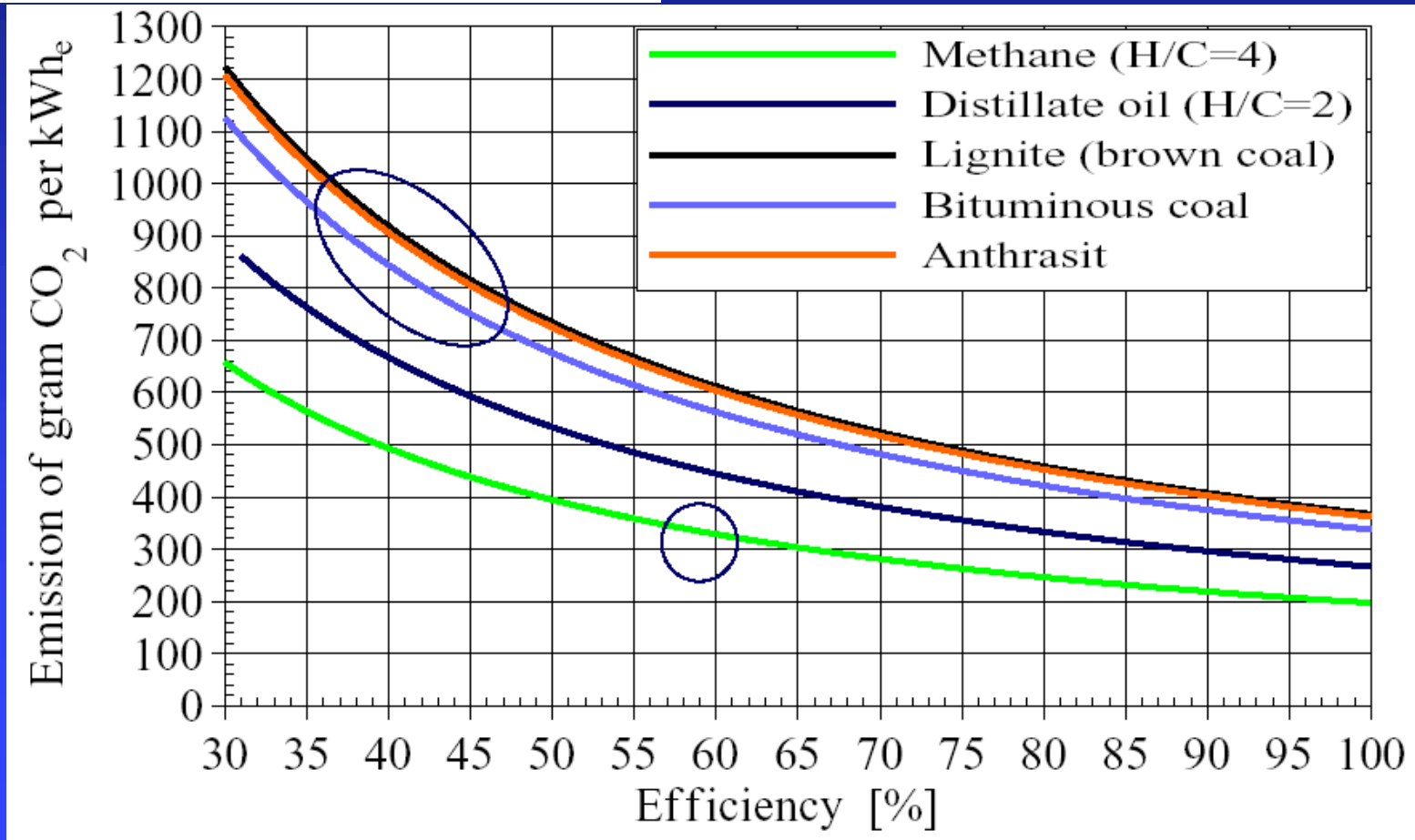


Specific emissions of CO_2 for different types of fuel

$$C_m H_n + \left(m + \frac{n}{4}\right) O_2 \Rightarrow m\,CO_2 + \frac{n}{2} H_2O$$

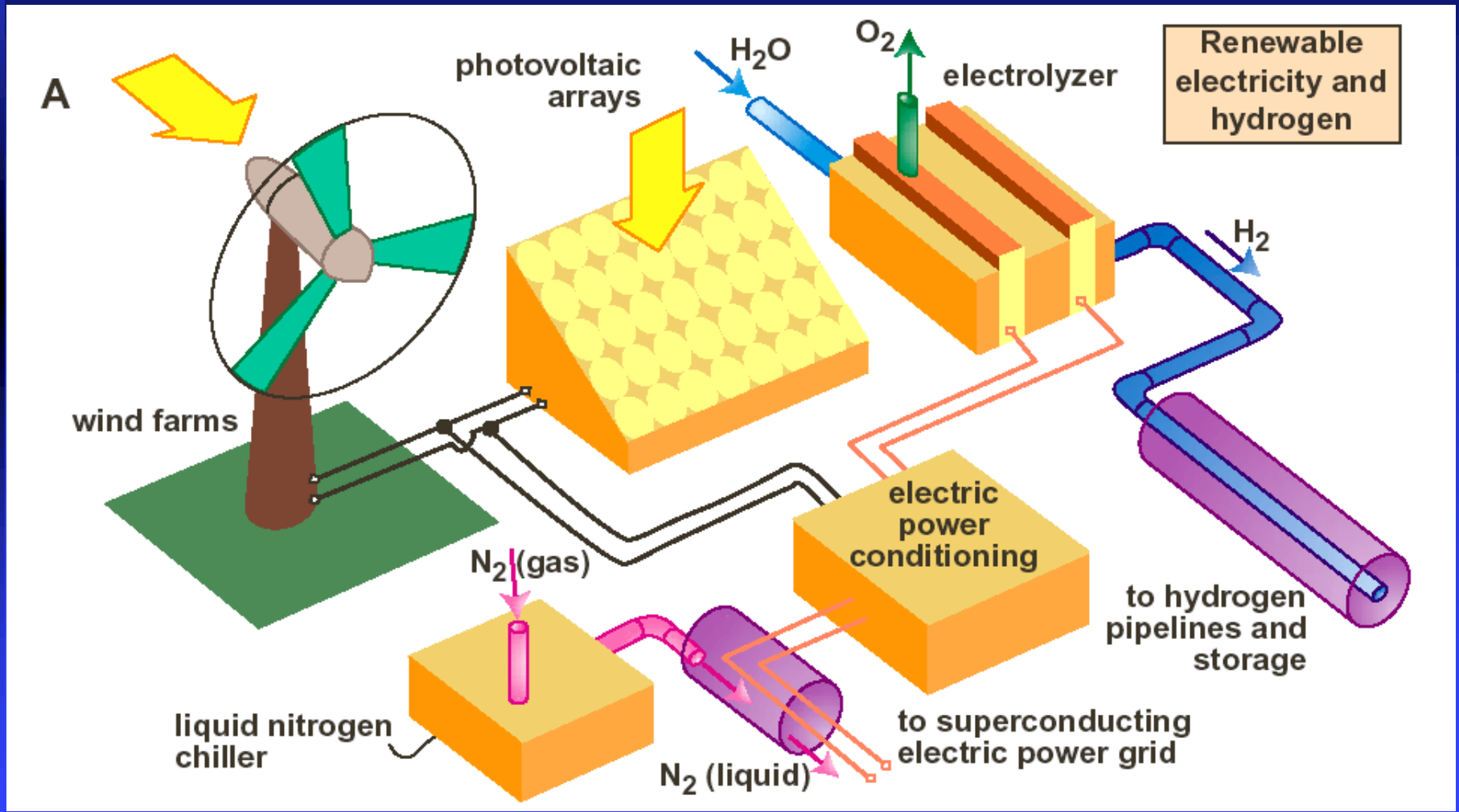
$$\left(\frac{m}{n}\right)_{coal} > \left(\frac{m}{n}\right)_{oil} > \left(\frac{m}{n}\right)_{natural\ gas}$$

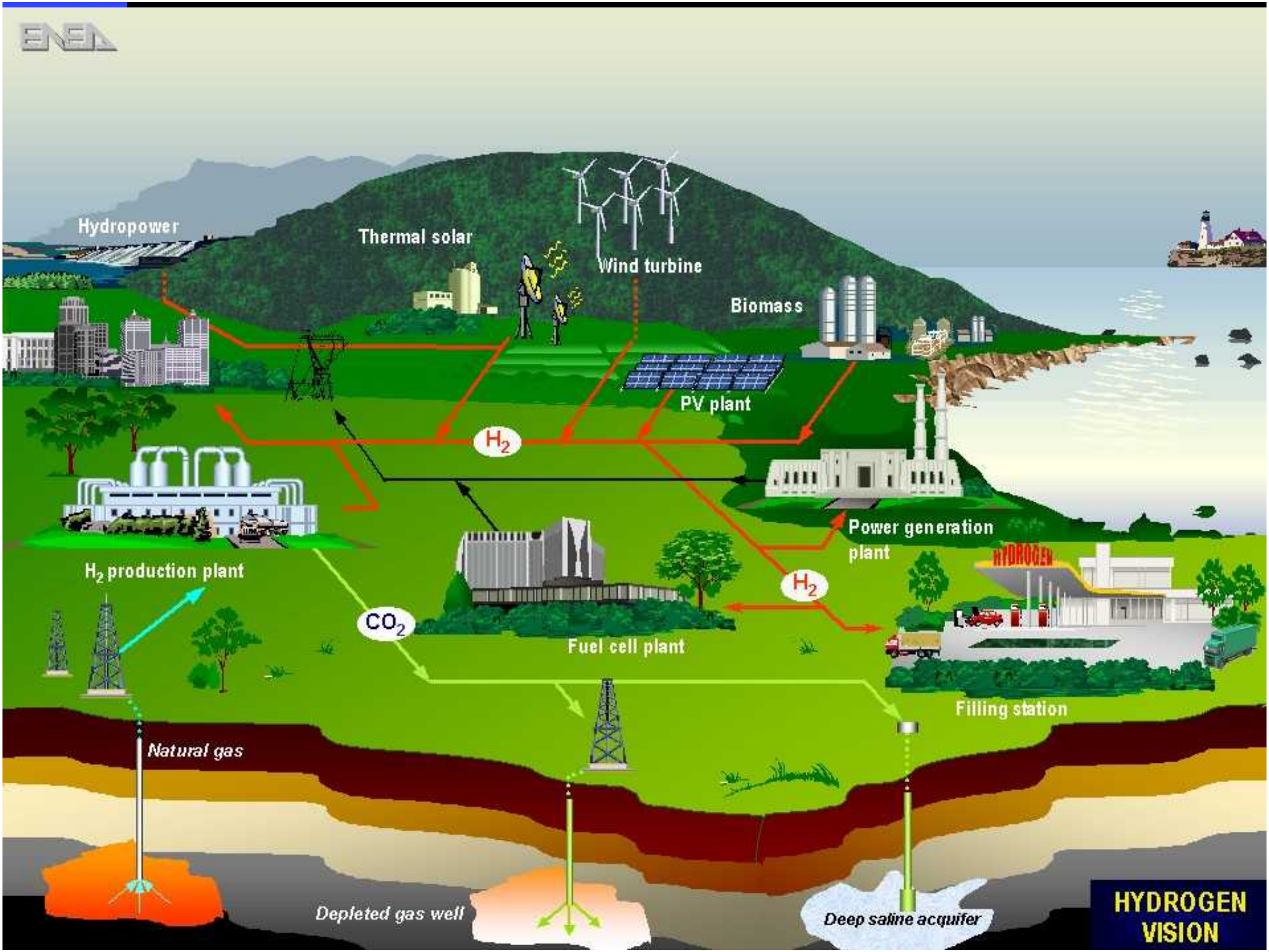
$$(\approx 1.1)_{coal} > (\approx 0.5)_{oil} > (\approx 0.25)_{natural\ gas}$$



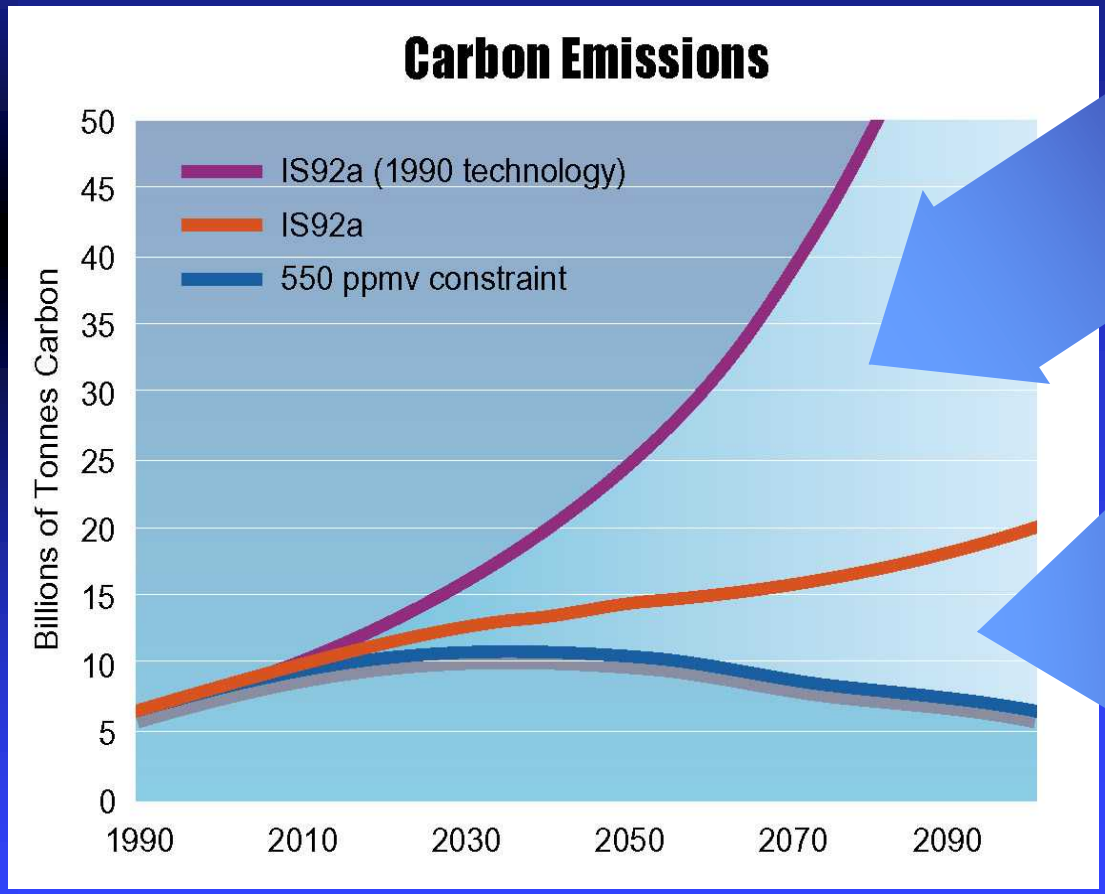
RENEWABLES

- Storage and distribution remain challenges
  - Hydrogen energy storage and distribution?
  - Superconducting long-distance electricity transmission?




Hydropower
Thermal solar
Wind turbine
Biomass
PV plant
H_2
Power generation plant
H_2 production plant
CO_2
Fuel cell plant
H_2
HYDROGEN
Filling station
Natural gas
Depleted gas well
Deep saline acquifer
HYDROGEN VISION

Stabilizing CO2
Base Case and "Gap" Technologies



Even lowering CO2 emissions by these strategies

- Fossil Fuels
- Energy intensity
- Nuclear
- Renewables

We have to fill a large gap

Possible technologies:

- Carbon capture & disposal
  Adv. fossil
- H2 and Adv. Transportation
- Biotechnologies
  Soils, Bioenergy, adv. Biological energy

Thanks for your attention