GLOBAL CLIMATE CHANGE:
WHAT DO WE KNOW?
WHAT SHOULD WE DO?

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Ecological Issues

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WHY DOES CLIMATE MATTER?

CLIMATE CONSISTS OF AVERAGES AND EXTREMES OF

- HOT & COLD
- WET & DRY
- SNOWPACK & SNOWMELT
- WINDS & STORM TRACKS
- OCEAN CURRENTS & UPWELLINGS

AND NOT JUST HOW MUCH & WHERE, BUT ALSO WHEN.

CLIMATE GOVERNS

- PRODUCTIVITY OF FARMS, FORESTS, & FISHERIES
- GEOGRAPHY OF DISEASE
- LIVABILITY OF CITIES IN SUMMER
- DAMAGES FROM STORMS, FLOODS, WILDFIRES
- PROPERTY LOSSES FROM SEA-LEVEL RISE
- EXPENDITURES ON ENGINEERED ENVIRONMENTS
- DISTRIBUTION & ABUNDANCE OF SPECIES

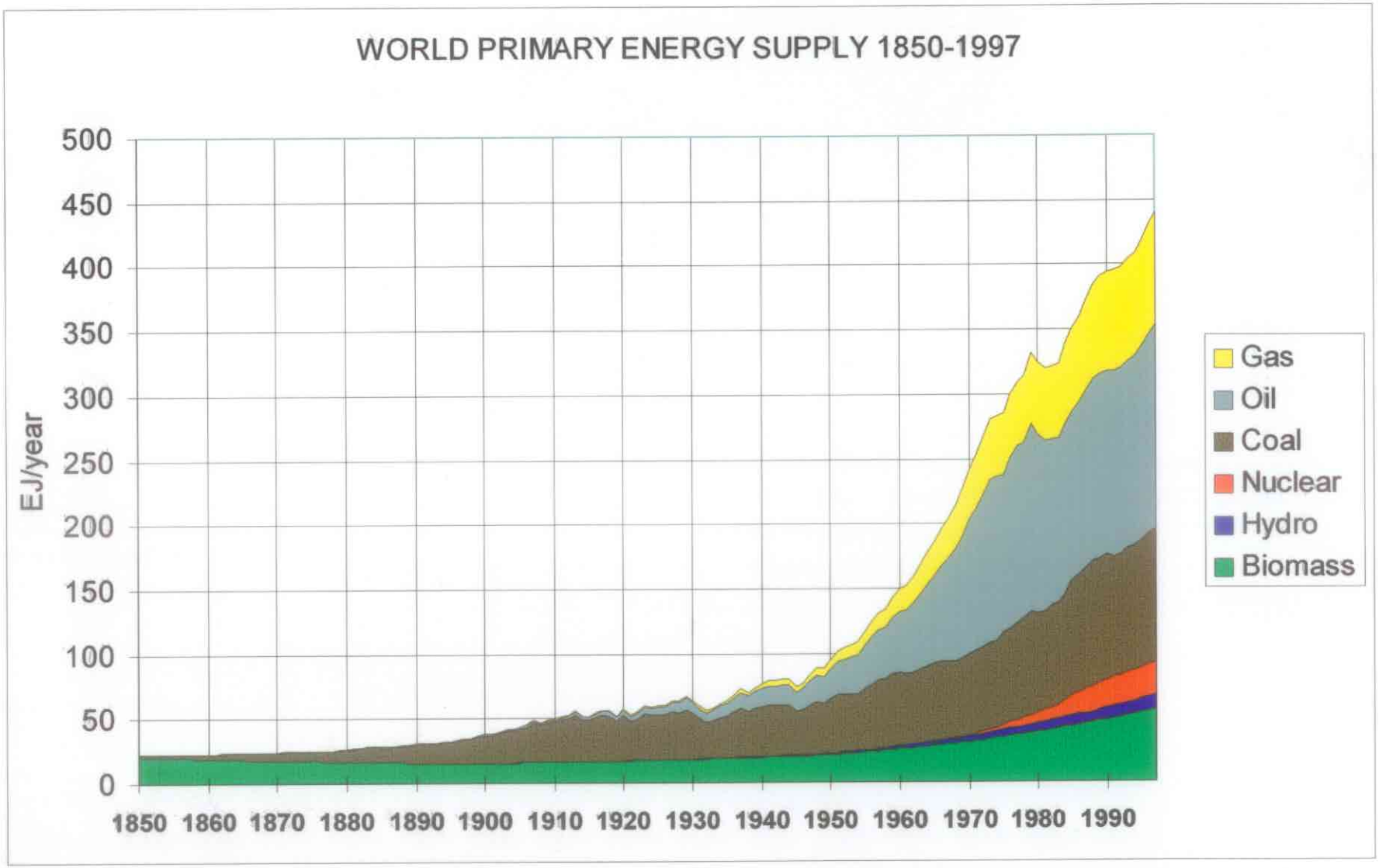
WHAT IS THE EVIDENCE THAT CLIMATE IS CHANGING?

THE AVERAGE TEMPERATURE OF THE EARTH IS RISING:

- UP 1.1 DEGREES F IN LAST 100 YEARS (INSTRUMENTAL RECORDS);
- 18 OF THE 20 WARMEST YEARS SINCE 1860 HAVE ALL OCCURRED SINCE 1980, THE 8 WARMEST SINCE 1990;
- 1998 WAS THE WARMEST YEAR IN THE INSTRUMENTAL RECORD AND PROBABLY THE WARMEST IN 1,000 YEARS; 2001 WAS THE 2nd WARMEST;
- THE LAST 50 YEARS APPEAR TO HAVE BEEN THE WARMEST HALF CENTURY IN 6,000 YEARS (ICE CORES).

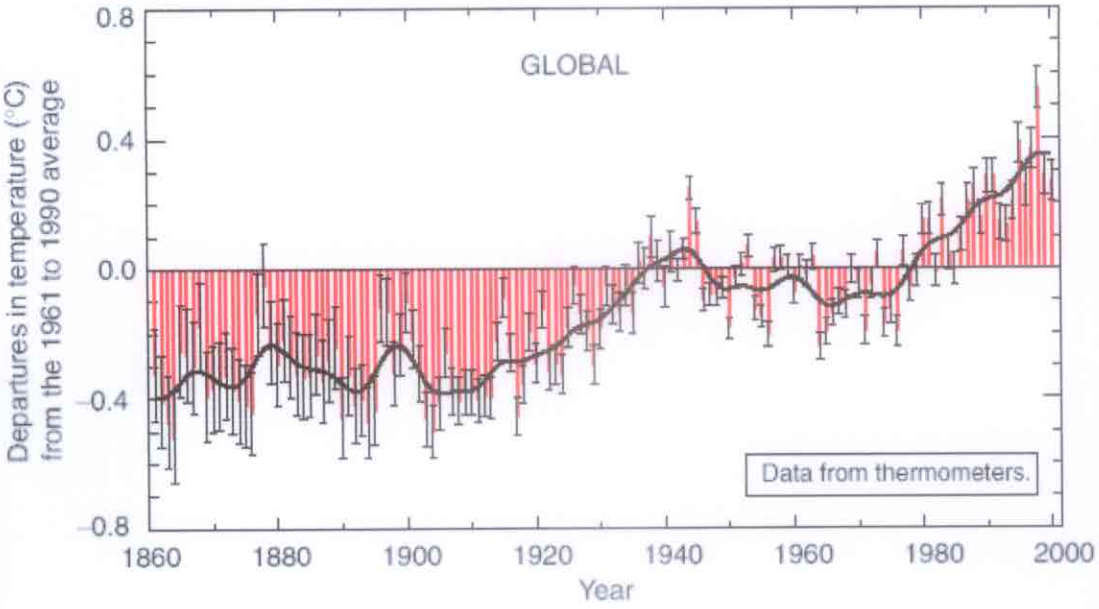
OBSERVATIONS OVER RECENT DECADES ALSO SHOW:

- EVAPORATION & RAINFALL ARE INCREASING;
- PERMAFROST IS MELTING;
- CORALS ARE BLEACHING;
- GLACIERS ARE RETREATING;
- SEA ICE IS SHRINKING;
- SEA LEVEL IS RISING.

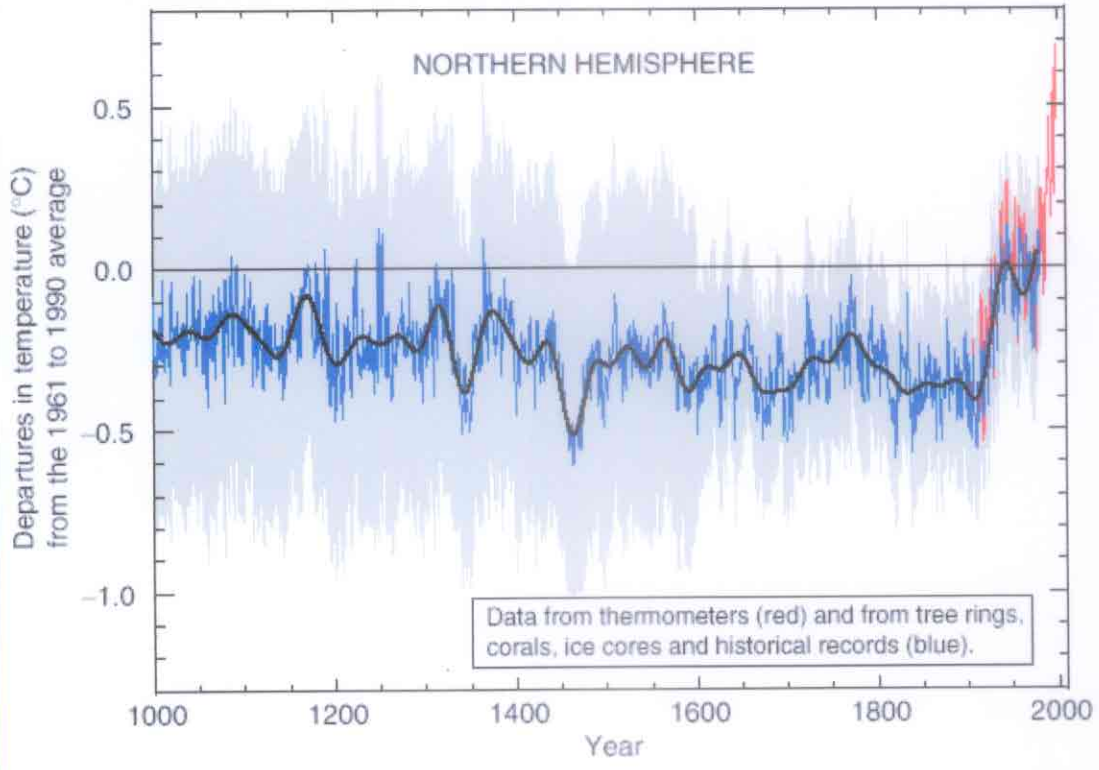

WORLD PRIMARY ENERGY SUPPLY 1850-1997
EJ/year
500
450
400
350
300
250
200
150
100
50
0
1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990
Gas
Oil
Coal
Nuclear
Hydro
Biomass

Variations of the Earth's surface temperature for:

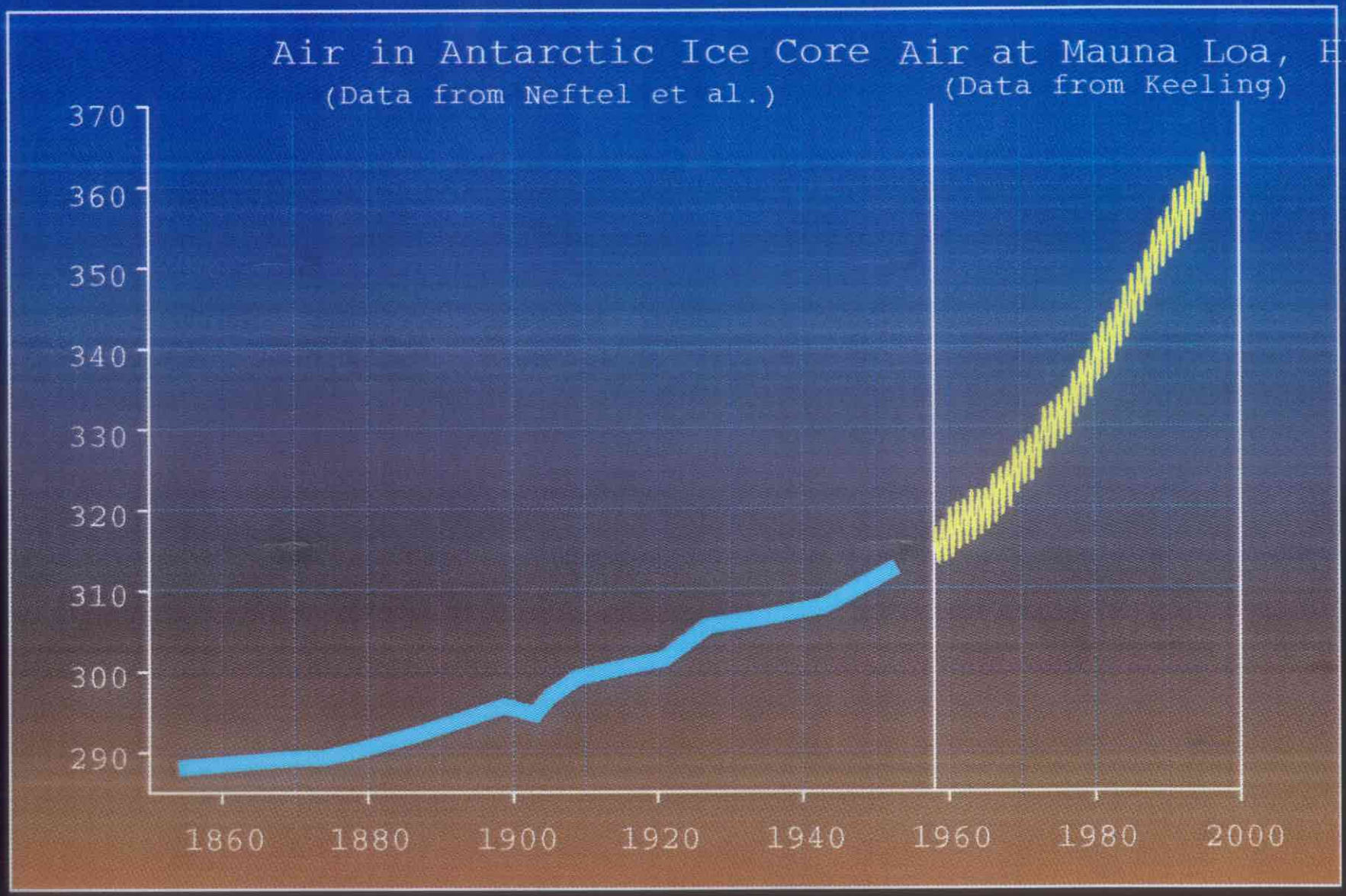
(a) the past 140 years



(b) the past 1,000 years



Carbon Dioxide Concentrations



EVIDENCE THAT HUMANS ARE THE MAIN CAUSE

THE PRINCIPAL CONTRIBUTOR TO THE INCREASED GREEN-HOUSE "FORCING" OF CLIMATE IN THE PAST 250 YEARS HAS BEEN THE INCREASE IN ATMOSPHERIC CARBON DIOXIDE. EVIDENCE THAT THIS 90 ppmv INCREASE IN CO2 HAS BEEN CAUSED BY HUMAN ACTIVITIES INCLUDES:

- THE OBSERVED INCREASES IN ATMOSPHERIC CONCEN-TRATION TRACK ALMOST PERFECTLY THE KNOWN INCREASES IN HUMAN ADDITIONS OF CO2 OVER THIS PERIOD, INITIALLY FROM DEFORESTATION AND SUBSE-QUENTLY AND MOST IMPORTANTLY FROM FOSSIL FUELS.

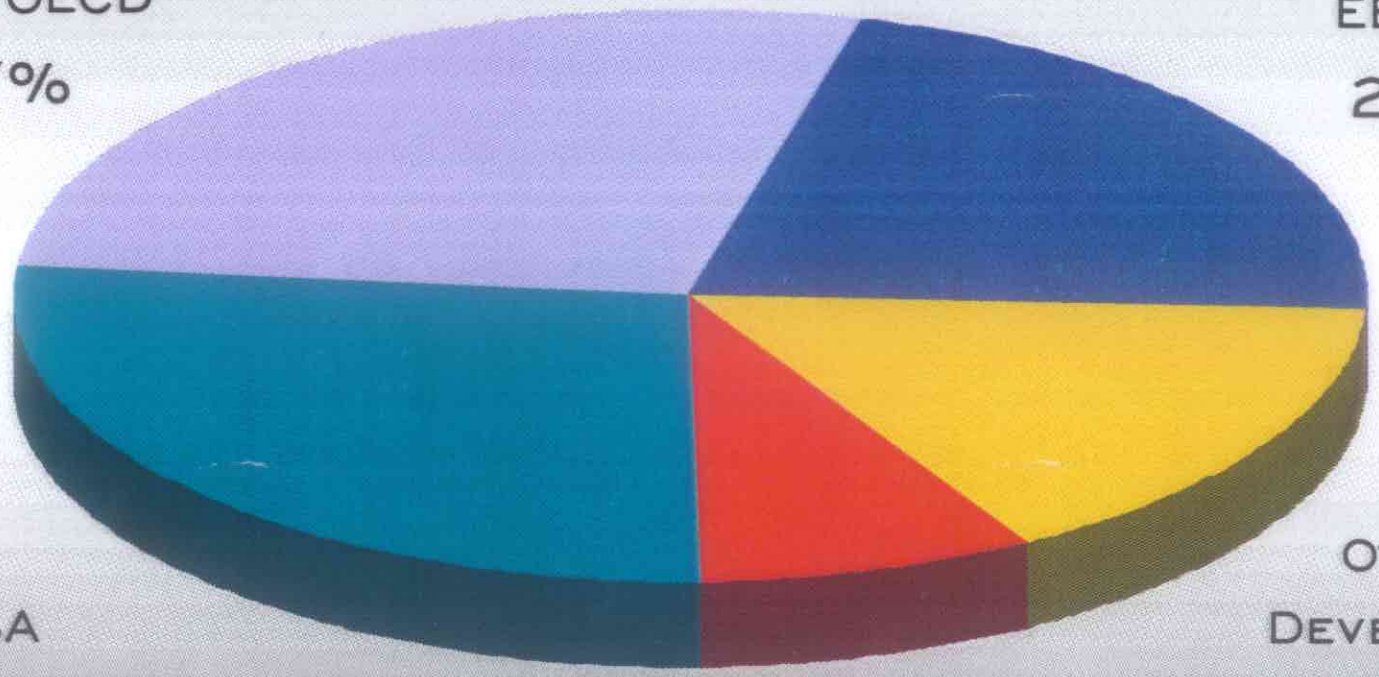
- ICE-CORE DATA SHOW THAT NATURAL FLUCTUATIONS IN ATMOSPHERIC CO2 OVER THE PAST 10,000 YEARS HAVE BEEN ONLY ±10 ppmv.

- CARBON-14 ANALYSIS OF TREE RINGS BACK TO 1800 CONFIRMS THE FOSSIL-FUEL CONTRIBUTION TO THE ATMOSPHERIC CO2 BURDEN IN THE LAST 200 YEARS.

THE PATTERN OF CLIMATIC CHANGE DISCERNIBLE IN GLOBAL MEASUREMENTS & OBSERVATIONS CORRESPONDS CLOSELY TO WHAT BASIC CLIMATE SCIENCE AND SOPHISTICATED COMPUTER MODELS ALIKE PREDICT TO RESULT FROM THE OBSERVED GREENHOUSE-GAS INCREASES. NO ONE HAS PUT FORWARD AN ALTERNATIVE CAUSE WITH EFFECTS THAT WOULD MATCH THE OBSERVED PATTERN.

1950-1995: Cumulative Emissions of CO_2

Global Total: 183 billion tonnes Carbon



Source: Gregg Marland and Tom Boden, CDIAC

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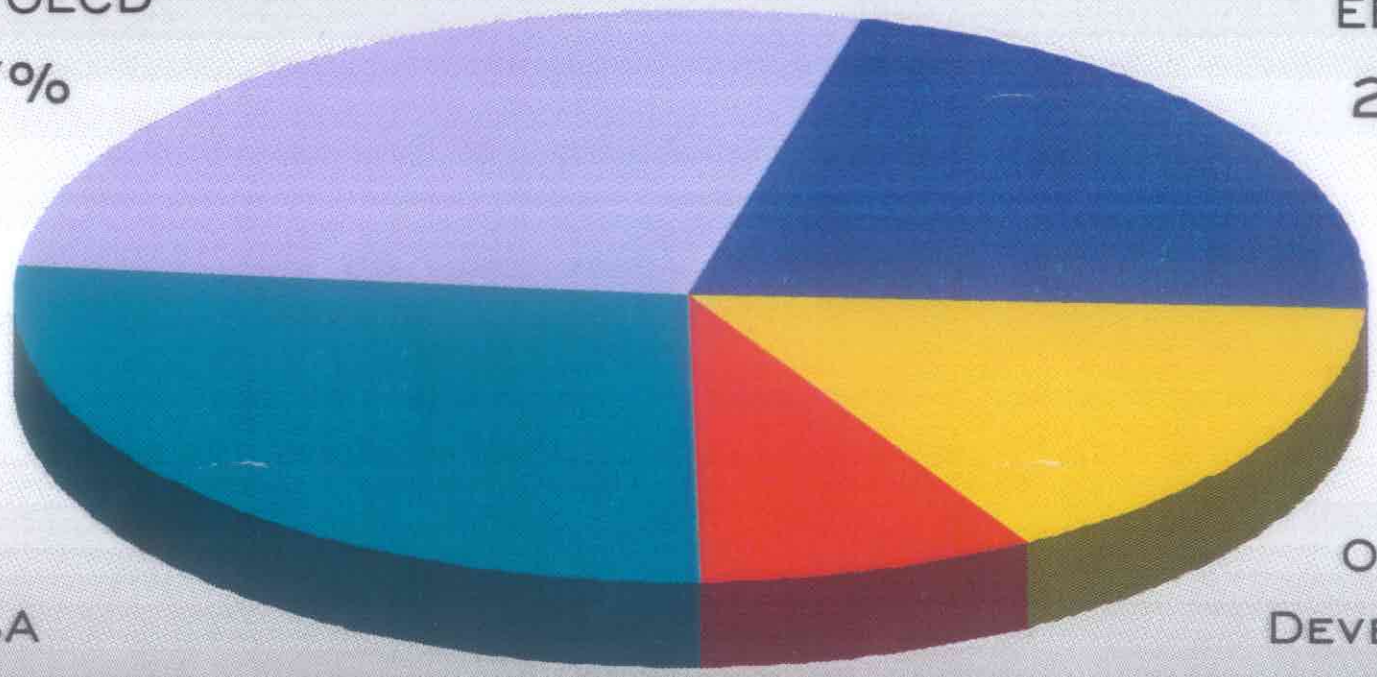
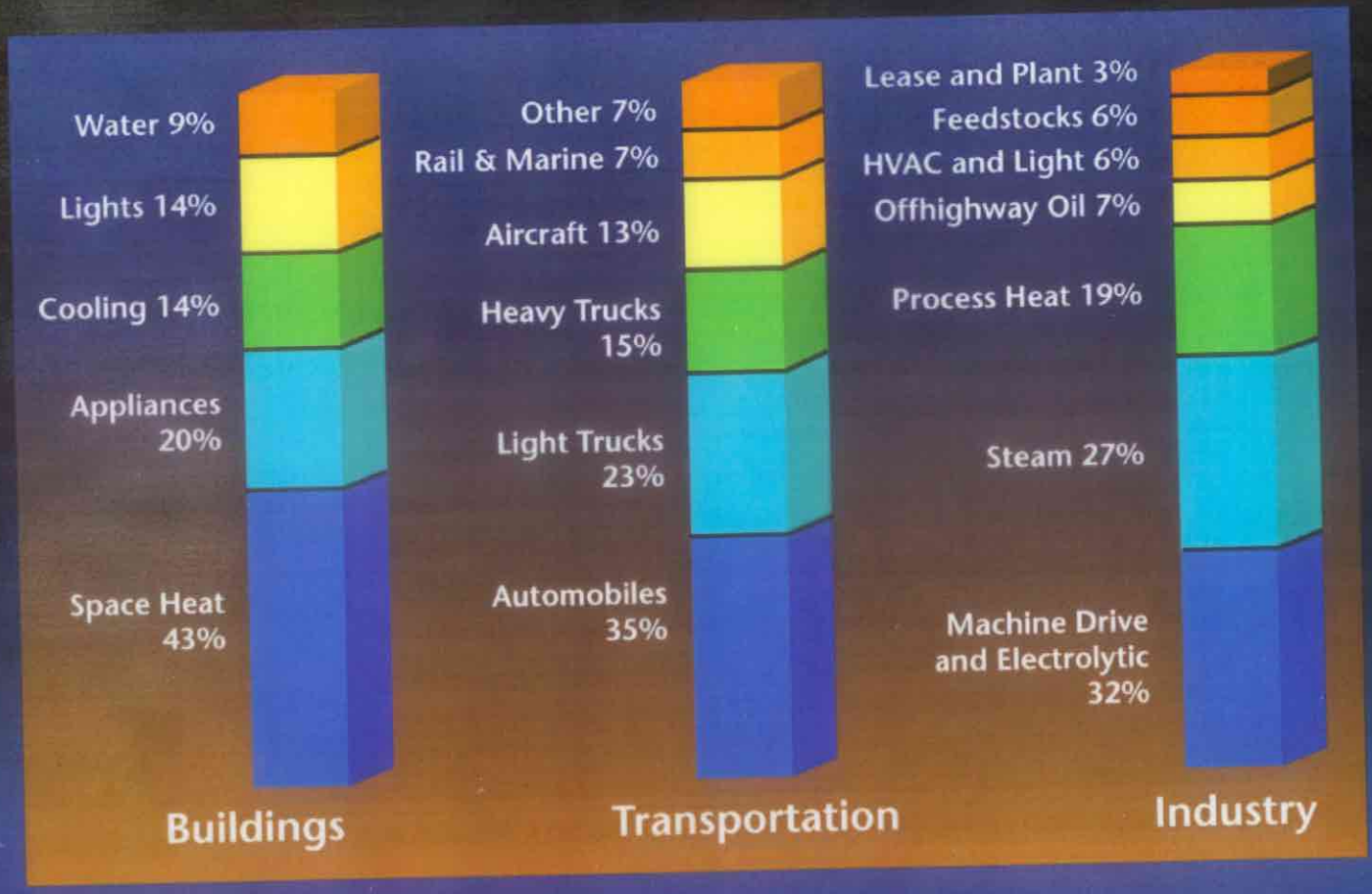


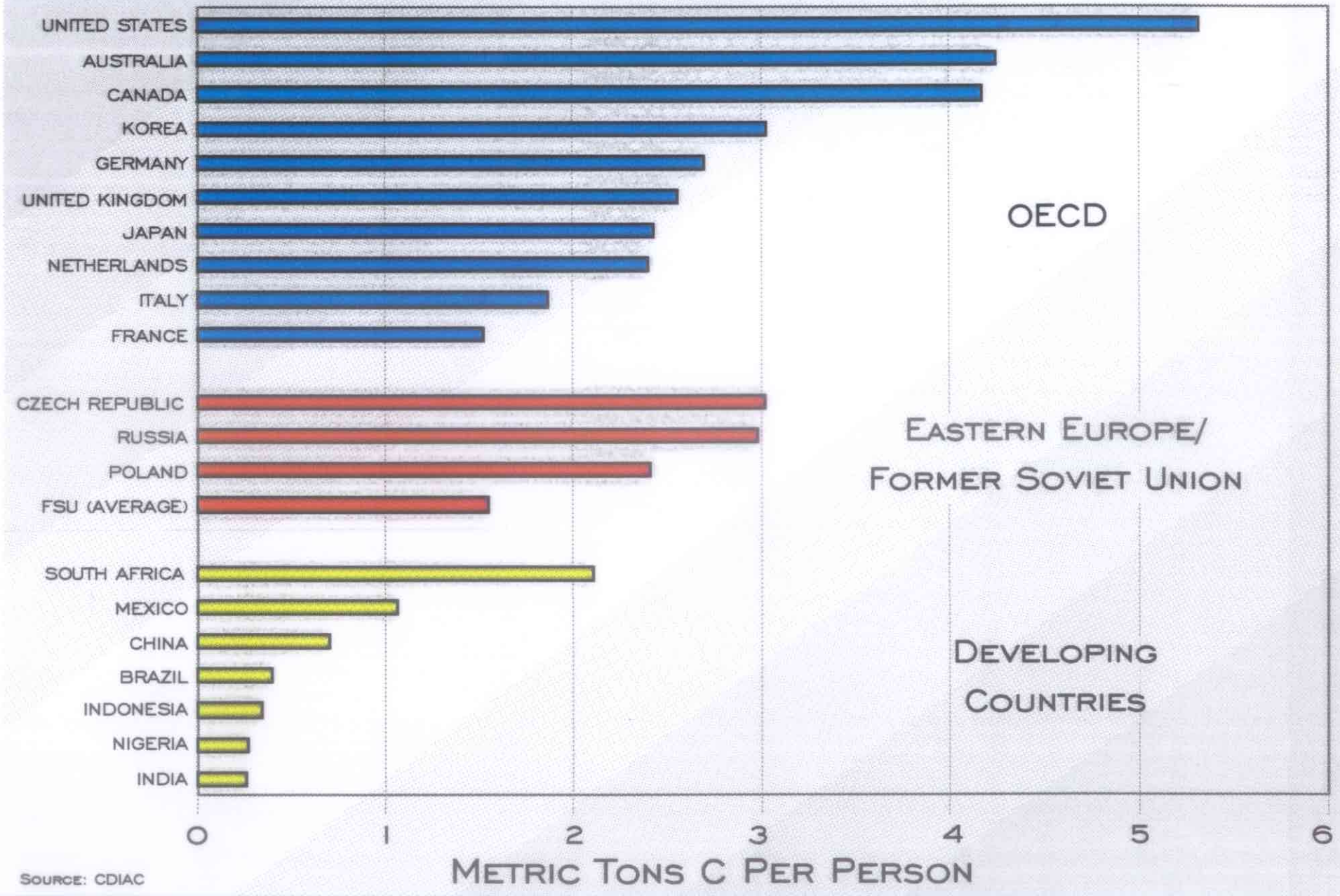
Source: Gregg Marland and Tom Boden, CDIAC

Sources of U.S. Emissions of CO_2



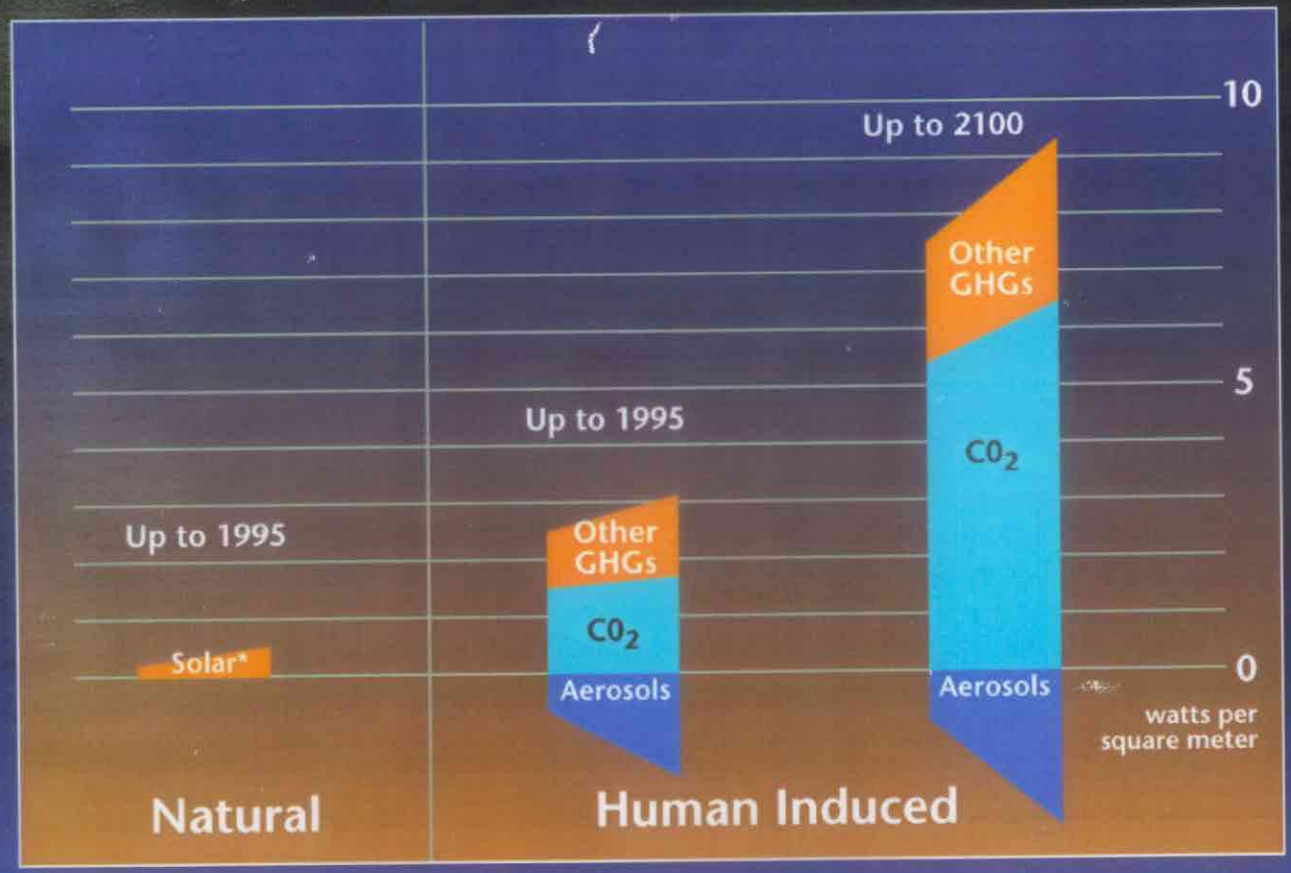
Office of Science and Technology Policy

Per Capita Carbon Emissions



Source: CDIAC

Radiative Forcing from Pre-Industrial Times



Source: Estimated forcings cited in IPCC, 1995.

Office of Science and Technology Policy

THE "BUSINESS AS USUAL" ENERGY FUTURE

	2000	2050	2100
Population, 10^9			
Industrial countries	1.3	1.4	1.4
Developing countries	4.8	8.4	9.7
GDP/person, 10^3 ppp 2000$			
Industrial countries	23	45	80
Developing countries	3.2	14	40
Energy/person, kW			
Industrial countries	6.4	8.0	8.1
Developing countries	1.2	3.0	4.8
GWP, 10^{12} ppp 2000$	45	180	510
World energy, TW	14	35	59
Fossil carbon, GtC/yr	6.4	13.9	21.4

CONSEQUENCES OF "BUSINESS AS USUAL"

THE SCIENTIFIC-CONSENSUS **"BEST ESTIMATES"** ARE THAT:

CONTINUING "BUSINESS AS USUAL" GHG EMISSIONS WILL LEAD TO INCREASES OF 0.2-0.4 °C PER DECADE IN GLOBAL-AVERAGE SURFACE TEMPERATURE, OR 2-4 °C WARMER THAN NOW BY 2100.

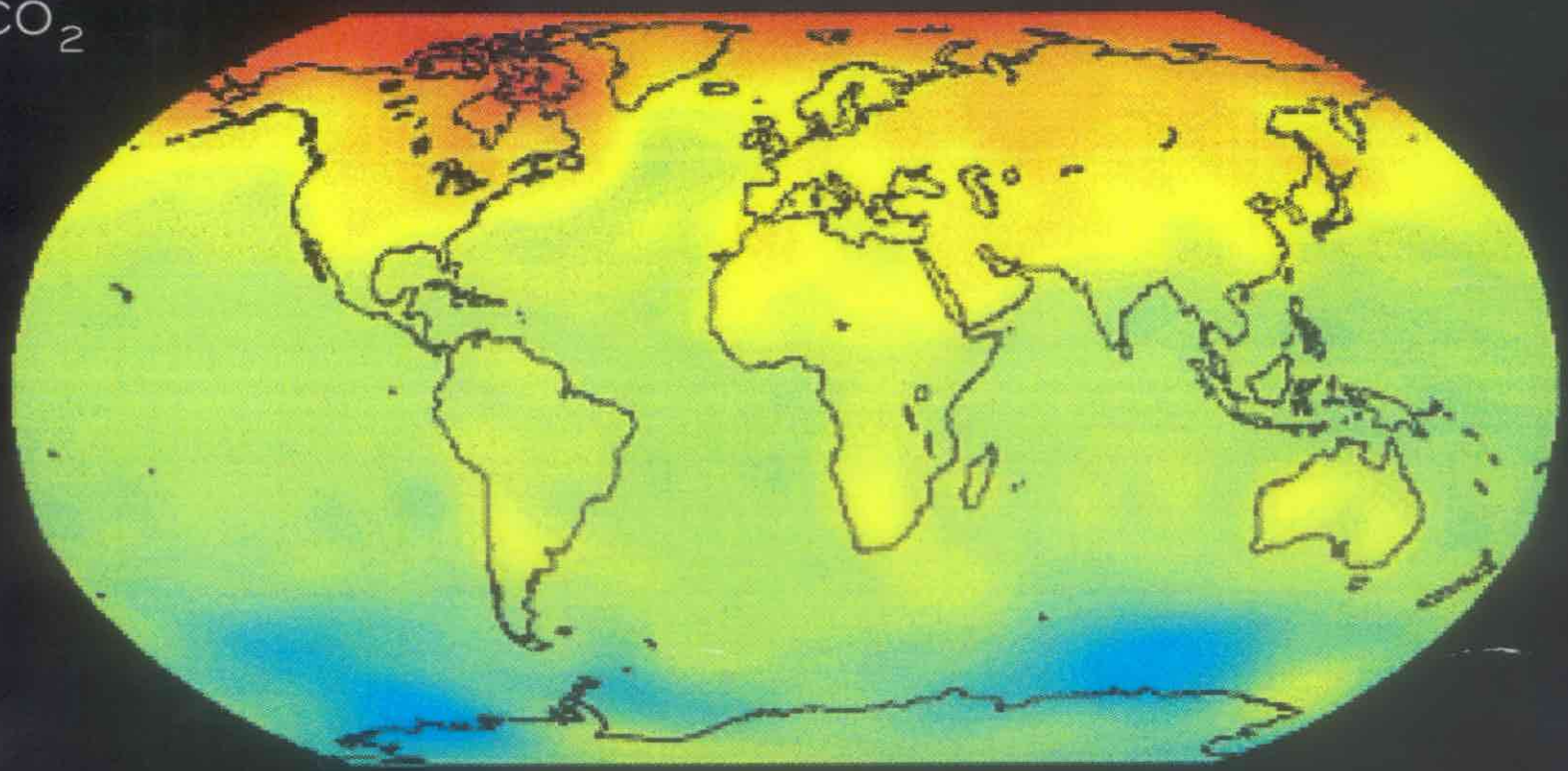
THE EARTH WILL THEN BE WARMER THAN AT ANY TIME IN THE LAST 160,000 YEARS. SEA LEVEL WILL BE 10-90 CM HIGHER THAN TODAY (BEST ESTIMATE 50 CM).

THIS GLOBAL-AVERAGE WARMING WILL ENTAIL MAJOR CHANGES IN CLIMATIC PATTERNS: STORM TRACKS, DISTRIBUTION OF PRECIPITATION & SOIL MOISTURE, EXTREMES OF HOT & COLD.

IN PART BECAUSE OF THE PACE OF THE CHANGES IN CLIMATIC PATTERNS, THE RESULTING EFFECTS ON HUMAN WELL-BEING ARE LIKELY TO BE MORE NEGATIVE THAN POSITIVE.

Surface Air Warming (°F)

$2xCO_2$

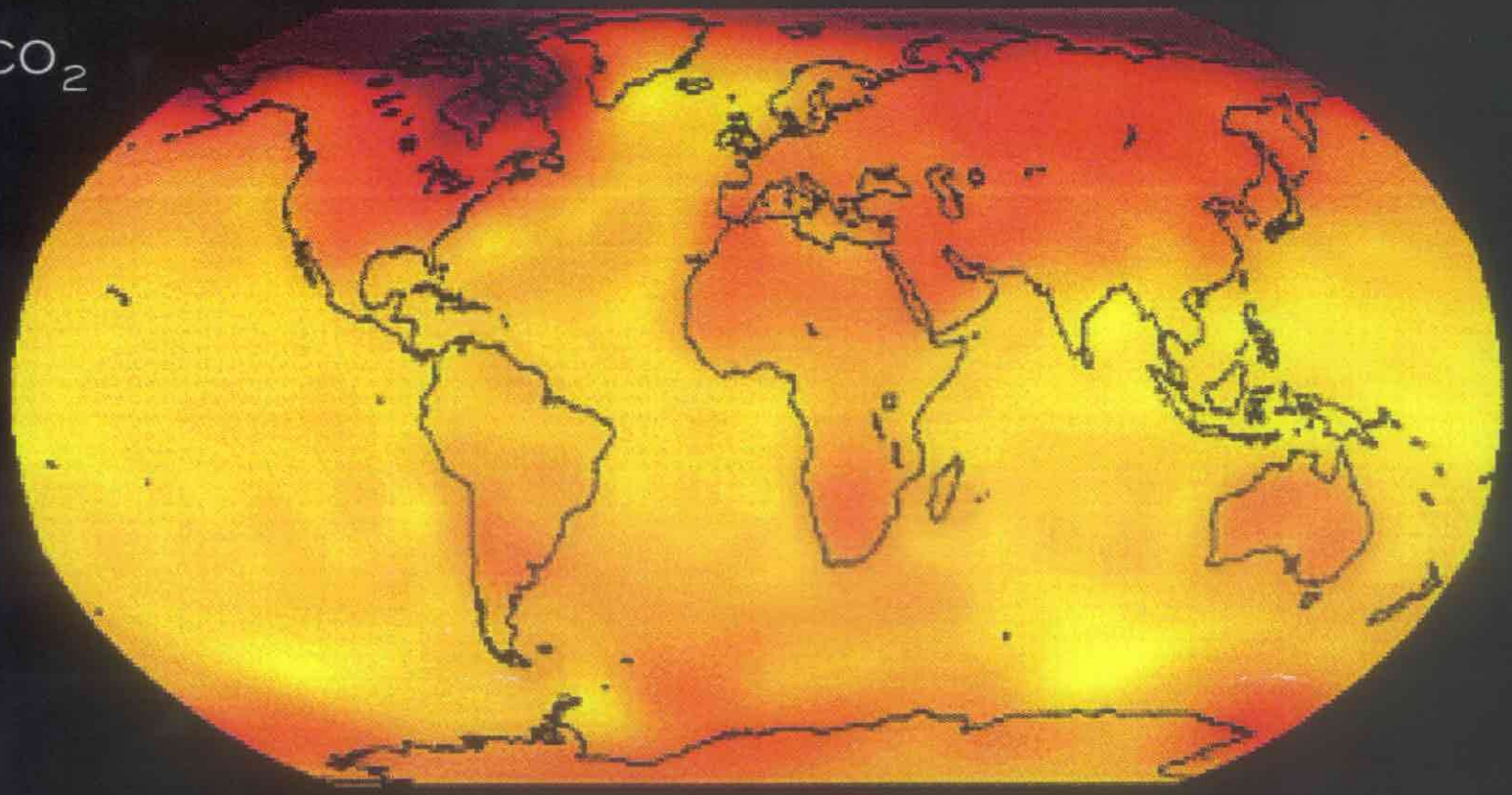


-5 0 5 10 15 20 25

Source: GFDL R15 Climate Model, CO_2 transient experiments, years 401-500

Surface Air Warming (°F)

$4xCO_2$



Source GFDL R15 Climate Model, Co. transient experiments, years 401-500

Confidence in observed changes (latter half of the 20th century)	Changes in Phenomenon	Confidence in projected changes (during the 21st century)
Likely[7]	**Higher maximum temperatures and more hot days over nearly all land areas**	Very likely[7]
Very likely[7]	**Higher minimum temperatures, fewer cold days and frost days over nearly all land areas**	Very likely[7]
Very likely[7]	**Reduced diurnal temperature range over most land areas**	Very likely[7]
Likely[7], over many areas	**Increase of heat index[12] over land areas**	Very likely[7], over most areas
Likely[7], over many Northern Hemisphere mid- to high latitude land areas	**More intense precipitation events[13]**	Very likely[7], over many areas
Likely[7], in a few areas	**Increased summer continental drying and associated risk of drought**	Likely[7], over most mid-latitude continental interiors. (Lack of consistent projections in other areas)
Not observed in the few analyses available	**Increase in tropical cyclone peak wind intensities[14]**	Likely[7], over some areas
Insufficient data for assessment	**Increase in tropical cyclone mean and peak precipitation intensities[15]**	Likely[7], over some areas

CLIMATE-CHANGE IMPACTS, ADAPTATION, AND VULNERABILITY

Quotations from *Summary for Policy Makers* of IPCC Working Group II, 3rd Assessment Report, 2001

"Natural systems can be especially vulnerable to climate change because of limited adaptive capacity, and some of these systems may undergo significant and irreversible damage. Natural systems at risk include glaciers, coral reefs and atolls, mangroves, boreal and tropical forests, polar and alpine ecosystems, prairie wetlands, and remnant native grasslands. While some species may increase in abundance or range, climate change will increase existing risks of extinction of some more vulnerable species and loss of biodiversity." (p 3)

IMPACTS, ADAPTATION, VULNERABILITY (cont)

"Human systems that are sensitive to climate change include mainly water resources; agriculture (especially food security) and forestry; coastal zones and marine systems (fisheries); human settlements, energy, and industry; insurance and other financial services; and human health. The vulnerability of these systems varies with geographic location, time, and social, economic, and environmental conditions." (pp 3-4)

IMPACTS, ADAPTATION, VULNERABILITY (cont)

"Projected adverse impacts based on models and other studies include:

- A general reduction in potential crop yields in most tropical and sub-tropical regions for most projected increases in temperature;

- A general reduction, with some variation, in potential crop yields in most regions in mid-latitudes for increases in average-annual temperature of more than a few degrees C;

- Decreased water availability for populations in many water-scarce regions, particularly in the sub-tropics;

- An increase in the number of people exposed to vector-borne diseases (e.g. malaria) and water-borne diseases (e.g. cholera) and an increase in heat-stress mortality;

- A widespread increase in the risk of flooding for many human settlements (tens of millions of inhabitants in settlements studied) from both increased heavy precipitation events and sea-level rise;

- Increased energy demand for space cooling due to higher summer temperatures." (p 4)

IMPACTS, ADAPTATION, VULNERABILITY (cont)

"Projected beneficial impacts based on models and other studies include:

- Increased potential crop yields in some regions at mid-latitudes for increases in temperature of less than a few degrees C;

- A potential increase in global timber supply from appropriately managed forests;

- Increased water availability for populations in some water-scarce regions, for example in parts of South East Asia;

- Reduced winter mortality in mid- and high-latitudes;

- Reduced energy demand for space heating due to higher winter temperatures." (p 4)

IMPACTS, ADAPTATION, VULNERABILITY (cont)

"Adaptation has the potential to reduce adverse impacts of climate change and to enhance beneficial impacts, but will incur costs and will not prevent all damages." (p 5)

DISTRIBUTIONAL ASPECTS OF CLIMATE CHANGE

THERE WILL BE MORE LOSERS THAN WINNERS BECAUSE

- AGRICULTURE IS TUNED TO CURRENT CLIMATE
- PESTS ADJUST FASTER THAN PREDATORS
- SOILS NEED CENTURIES TO ADJUST
- DISEASES MOVE FASTER THAN DEFENSES

THE POOR WILL BE BIGGER LOSERS THAN THE RICH, BECAUSE THE POOR HAVE

- WORSE NUTRITION & HEALTH CARE
- LESS CAPITAL & INFRASTRUCTURE
- LESS MOBILITY
- MORE EXTENSIVE DEPENDENCE ON THE BIOTA

POSSIBILITIES FOR UNPLEASANT "SURPRISES"

- LARGE INCREASES IN THE FREQUENCY AND INTENSITY OF HIGHLY DESTRUCTIVE STORMS

- DRASTIC SHIFTS IN OCEAN CURRENT SYSTEMS THAT CONTROL REGIONAL CLIMATES (e.g., GULF STREAM / WESTERN EUROPE)

- MULTI-METER SEA-LEVEL RISE FROM DISIN-TEGRATION OF WEST-ANTARCTIC ICE SHEET

- RUNAWAY GREENHOUSE EFFECT FROM DECOMPOSITION OF METHANE CLATHRATES, AMPLIFYING PROSPECTS FOR ALL OF THE ABOVE

WHAT ARE THE OPTIONS FOR CORRECTIVE ACTION?

POSSIBLE APPROACHES

- **REDUCE** EMISSIONS OF GREENHOUSE GASES (GHGs)
- **REMOVE** GHGs FROM THE ATMOSPHERE
- **COUNTERACT** THEIR CLIMATIC EFFECTS
- **ADAPT** TO GHG-INDUCED CLIMATE CHANGE

DETERMINANTS OF CARBON DIOXIDE EMISSIONS

- **POPULATION**
- **GDP** PER PERSON
- **ENERGY INTENSITY** OF GDP
- **CARBON INTENSITY** OF ENERGY SUPPLY

POLICIES TO AFFECT ENERGY & CARBON INTENSITIES

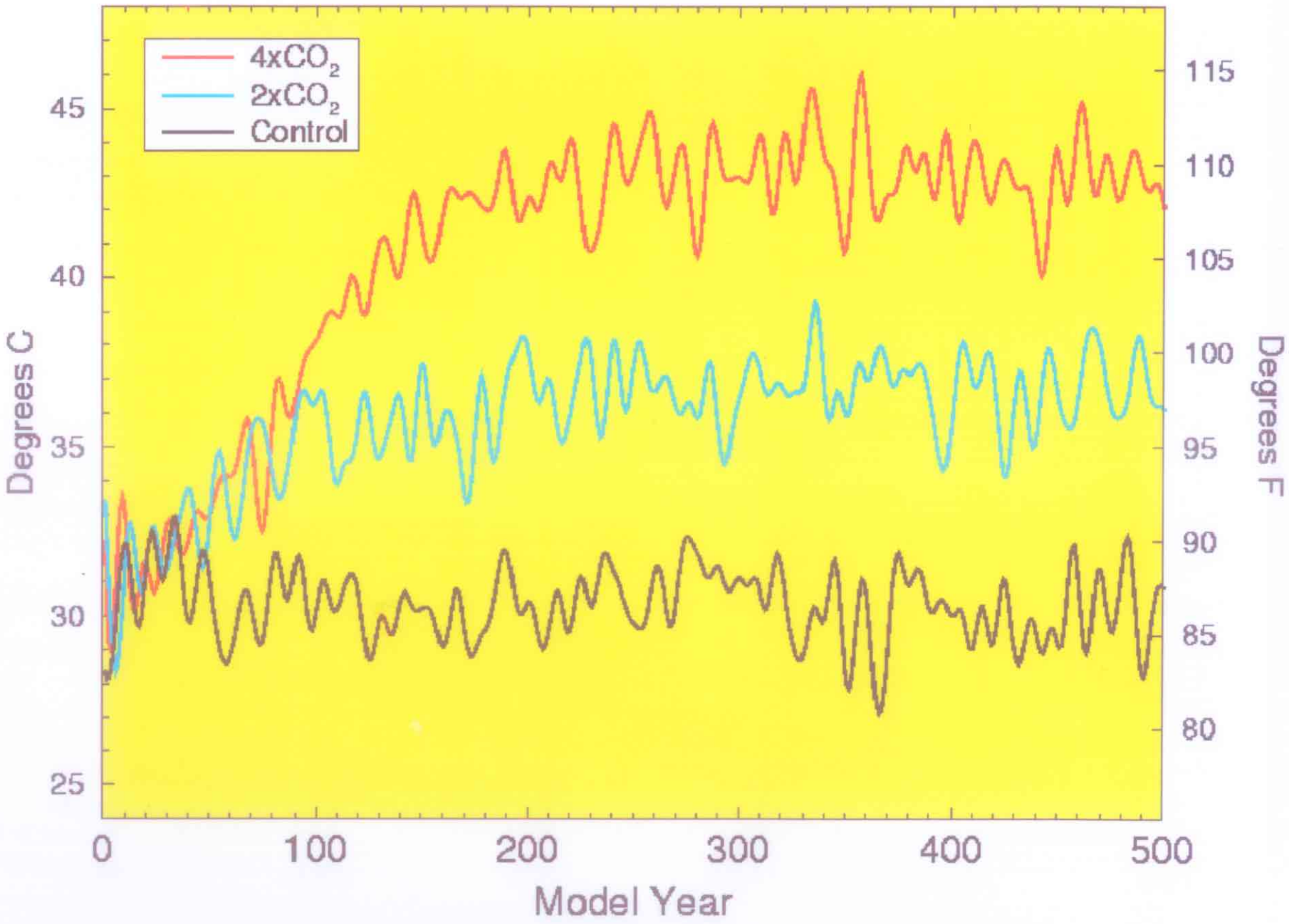
...by affecting choices from the available mix of technologies

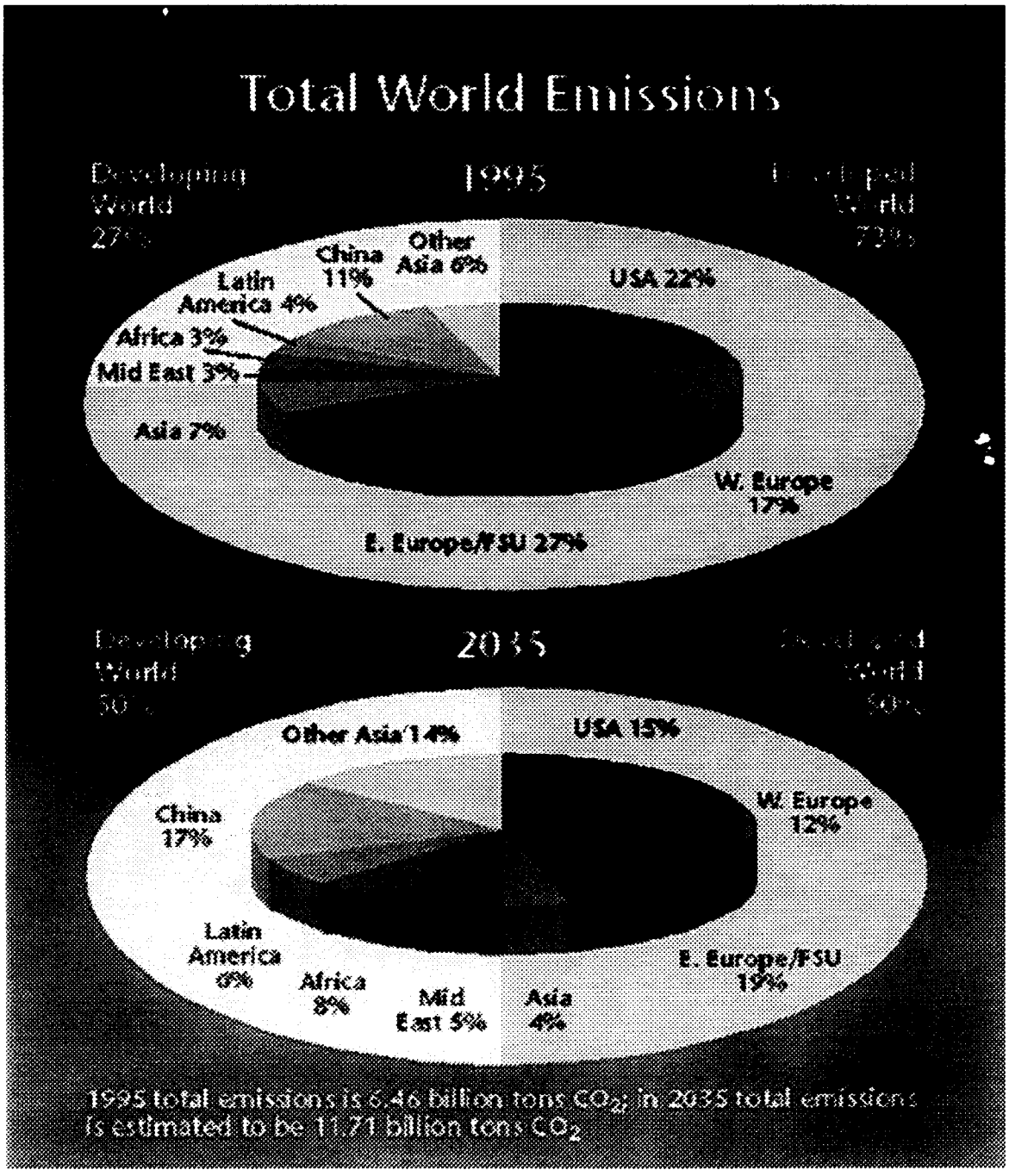
- ANALYSIS OF AND EDUCATION ABOUT THE OPTIONS
- CORRECTION OF PERVERSE INCENTIVES
- LOWERING BUREAUCRATIC BARRIERS
- FINANCING FOR TARGETED OPTIONS
- PERFORMANCE & PORTFOLIO STANDARDS
- SUBSIDIES FOR TARGETED OPTIONS
- EMISSION CAP & TRADE PROGRAMS
- TAXES ON CARBON OR ENERGY

...by improving the mix of technologies available

- IMPROVING CAPABILITIES FOR R&D
- ENCOURAGING R&D WITH TAX POLICY & OTHER POLICIES
- FUNDING THE CONDUCT OF RD&D
- PROMOTING NICHE & PRECOMMERCIAL DEPLOYMENT
- INTERNATIONAL TRANSFER OF RESULTING TECHNOLOGIES

July Heat Index for Southeastern U.S.




Total World Emissions
1995
China 11%
Other Asia 6%
USA 22%
Latin America 4%
Africa 3%
Mid East 3%
Asia 7%
W. Europe 17%
E. Europe/FSU 27%
2035
Other Asia 14%
USA 15%
China 17%
W. Europe 12%
Latin America 6%
Africa 8%
Mid East 5%
Asia 4%
E. Europe/FSU 19%
1995 total emissions is 6.46 billion tons CO_2; in 2035 total emissions is estimated to be 11.71 billion tons CO_2

A SIX-POINT ACTION PROGRAM ON ENERGY & CLIMATE

1. Expanded research on: science of climate change; climate-change impacts; enhancement of terrestrial & oceanic carbon sinks; geotechnical engineering to offset effects of GHG increases; and adaption to climate change. Increased invest-ments to exploit opportunities uncovered by this research.

2. Increased national & international support for the education, development, social-welfare, and family planning measures known to be most effective in reducing population growth.

3. Incentives and other help for firms and consumers to make low- and no-CO_2 choices from menu of energy-supply & end-use- efficiency options available at any given time.

4. Accelerated research, development, and demonstration to improve this menu.

5. Increased international cooperation to facilitate applying the results of climate research, low/no-CO_2 energy research, development, & demonstration, and insights about promoting low/no-CO_2 choices in the South as well as the North.

6. Development of a global framework of commitments to long-term restraints on GHG emissions designed for sufficiency, equity, and feasibility.


CAN WE APPEAL THIS TO THE SUPREME COURT?
NATIONAL ACADEMY OF SCIENCES REPORT: GLOBAL WARMING EXISTS
YALE
DOCTOR
PHD

THE ARITHMETIC OF THE BUSH CLIMATE PLAN

	REAL GDP (Bn 2001 $)	GHG (Mt CE)	GHG/GDP (tCE / M$)
1990	7379	1678	227
2000	10146	1906	188
change	*+37.5%*	*+13.6%*	*-17.4%*
2002	10475	1917	183
2012	14483	2187	151
change	*+38.3%*	*+14.1%*	*-17.5%*
change 1990-2012	*+96.3%*	*+30.3%*	*-33.5%*
avg Kyoto target for 1990-2012		-5.0%	