Planet Earth

(Avoiding a Venus Disaster)

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Outline

Earth and Venus

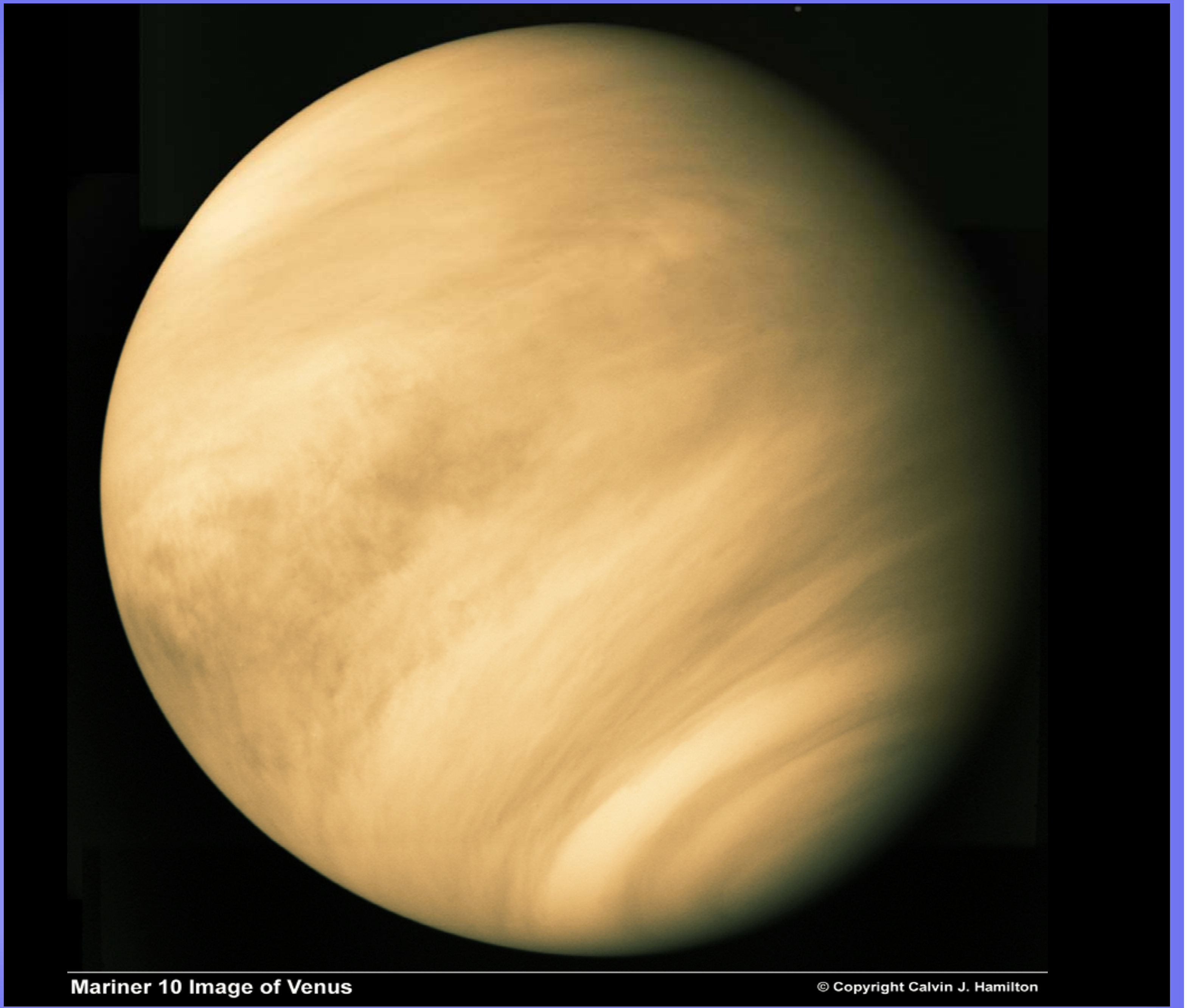
Evolution of Earth's Atmosphere

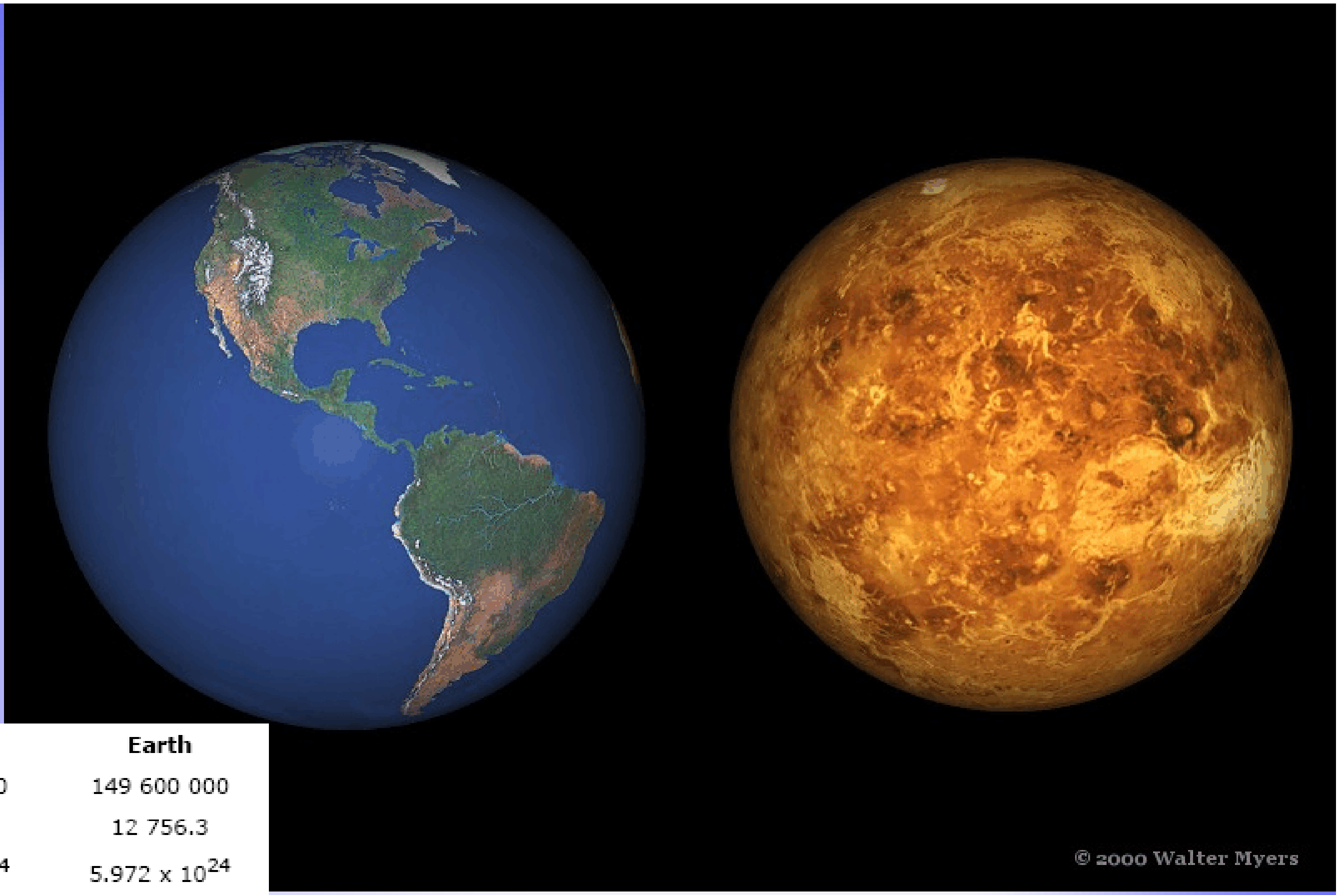
Life Sustaining Qualities

Current Status

A Plan for the Future

Outline


Mariner 10 Image of Venus
© Copyright Calvin J. Hamilton

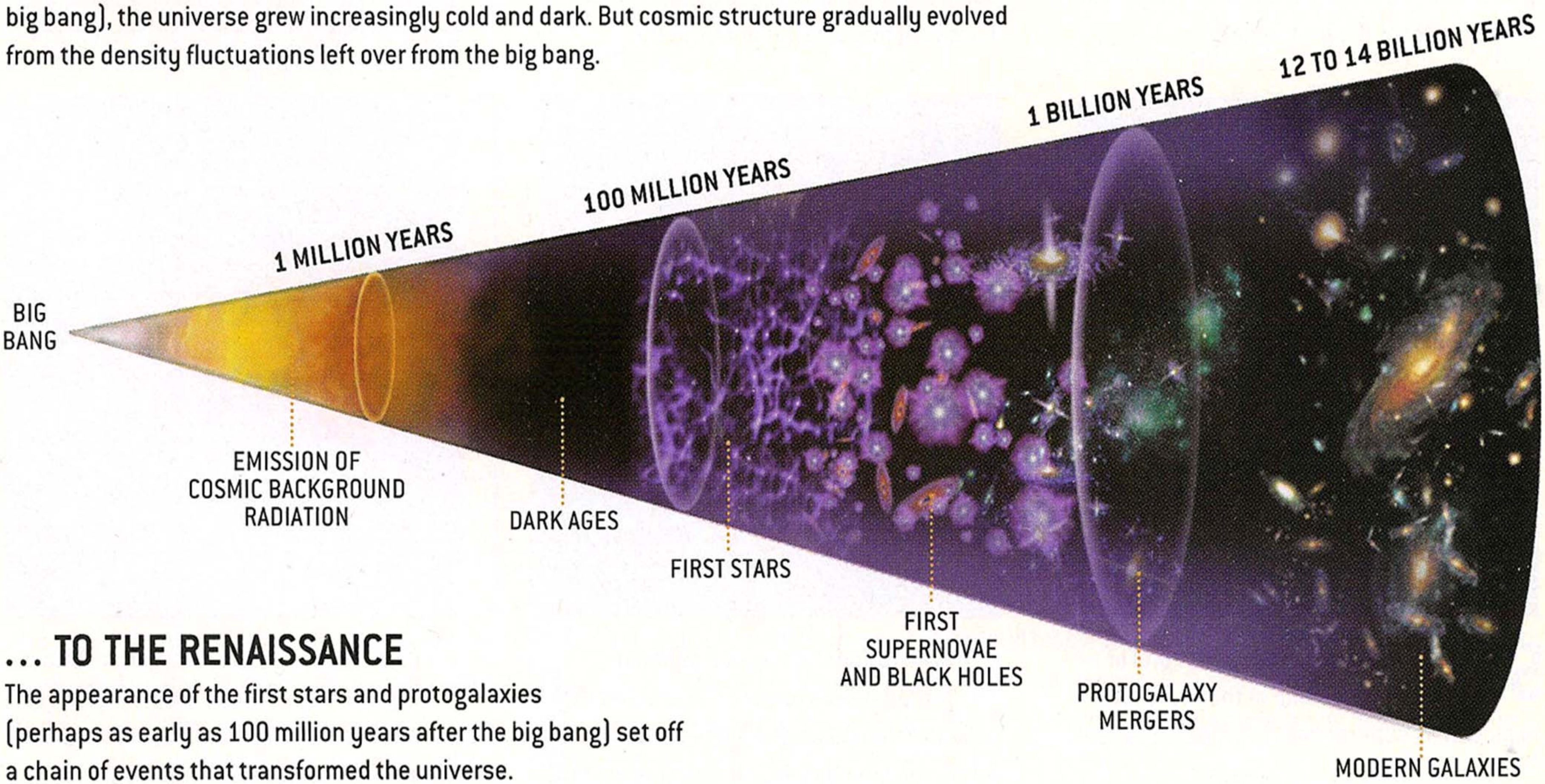


Parameter	Venus	Earth
Orbital Distance (km)	108 200 000	149 600 000
Diameter (km)	12 103.6	12 756.3
Mass (kg)	4.869×10^{24}	5.972×10^{24}
Density (kgm^{-3})	5.24	5.52
1 Day	243 Earth days	23h 56m
1 Year	224.7 Earth days	365.25 days
Atmosphere	96% CO_2 3% N	77% N 21% O
Escape Velocity (kms^{-1})	10.36	11.18
Surface Gravity (ms^{-2})	8.87	9.81
Axial Tilt (°)	177.36	23.5

COSMIC TIMELINE

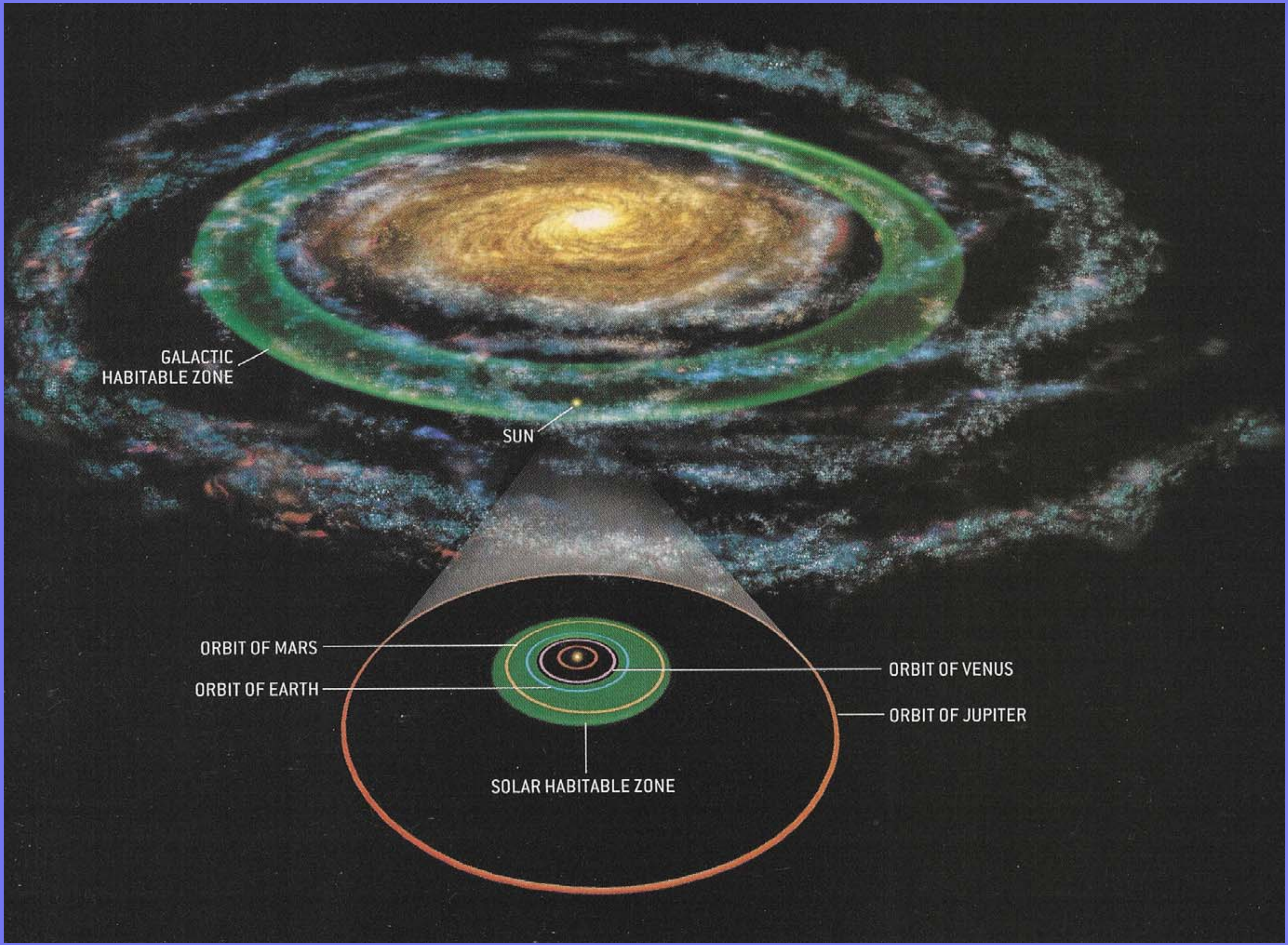
FROM THE DARK AGES ...

After the emission of the cosmic microwave background radiation (about 400,000 years after the big bang), the universe grew increasingly cold and dark. But cosmic structure gradually evolved from the density fluctuations left over from the big bang.

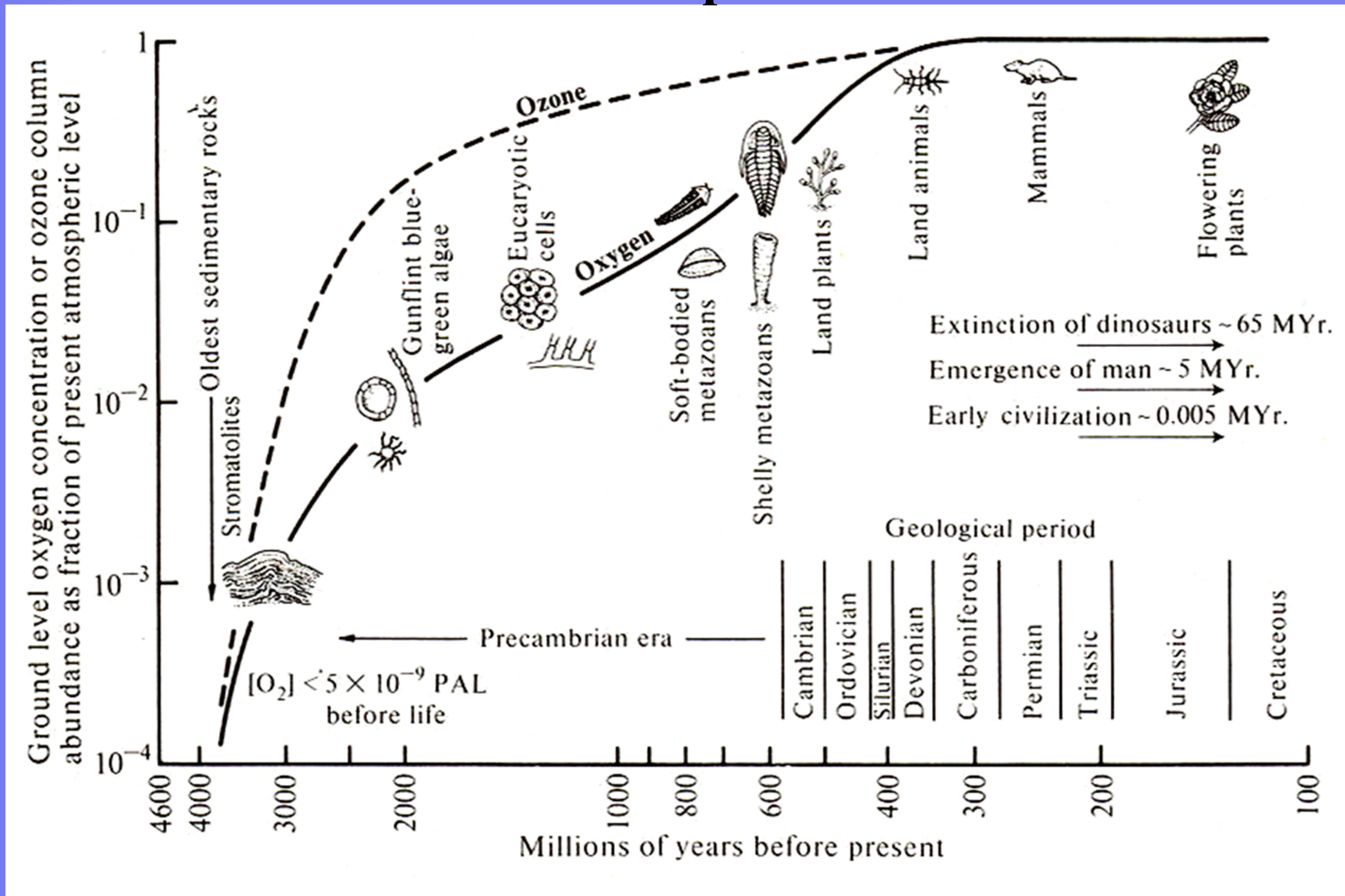


... TO THE RENAISSANCE

The appearance of the first stars and protogalaxies (perhaps as early as 100 million years after the big bang) set off a chain of events that transformed the universe.

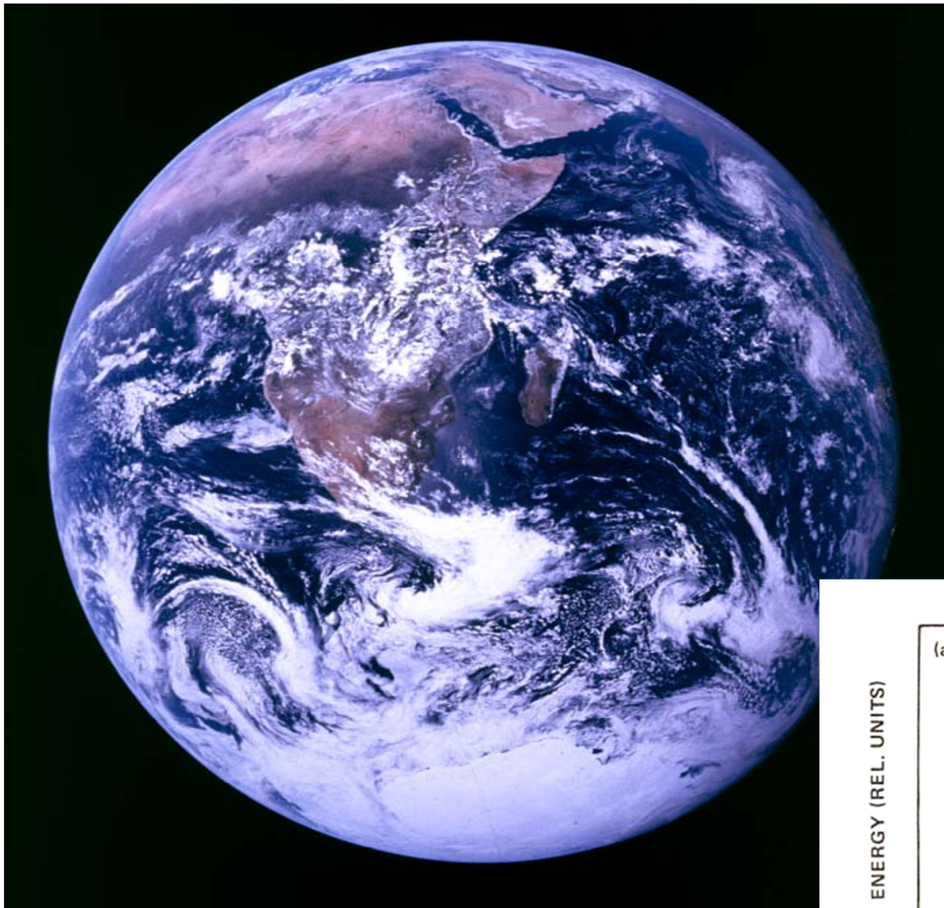

GALACTIC
HABITABLE ZONE
SUN
ORBIT OF MARS
ORBIT OF EARTH
ORBIT OF VENUS
ORBIT OF JUPITER
SOLAR HABITABLE ZONE

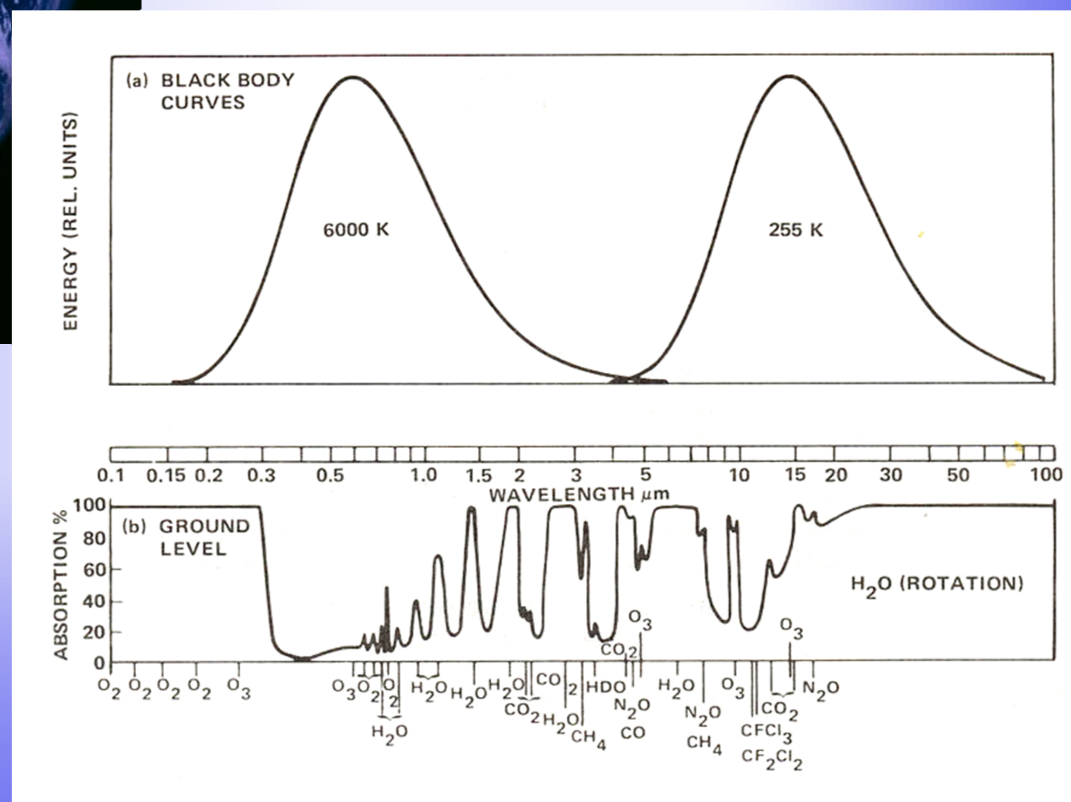
Evolution of Earth's Atmosphere



From a gaseous nebula atmosphere of H_2, He, CH_4, H_2O, NH_3, N_2, H_2S, HCl …

H_2 loss and chemistry transformed the planetary atmosphere to H_2O, CO_2, CO, N_2, COS, SO_2 …





(a) BLACK BODY CURVES
ENERGY (REL. UNITS)
6000 K
255 K
0.1 0.15 0.2 0.3 0.5 1.0 1.5 2 3 5 10 15 20 30 50 100
WAVELENGTH μm
(b) GROUND LEVEL
ABSORPTION %
100 80 60 40 20 0
H2O (ROTATION)
O3
CO2
O2 O2 O2 O2 O3
H2O
HDO
N2O
CO
CH4
CFCl3
CF2Cl2

Life Supporting and Sustaining Conditions

Long-lifetime solar system (late development of our galaxy)

Close enough to galaxy center to have heavy isotopic masses

Far enough from galaxy center to have low energetic radiation levels

Distance from Sun in life sustaining region

Atmosphere that supports life forms

Atmosphere removes threatening radiation, ionizing flux and ozone shield (CR, γ-radiation, x-ray, UV)

Atmosphere slows and protects against dust, particles, and meteors

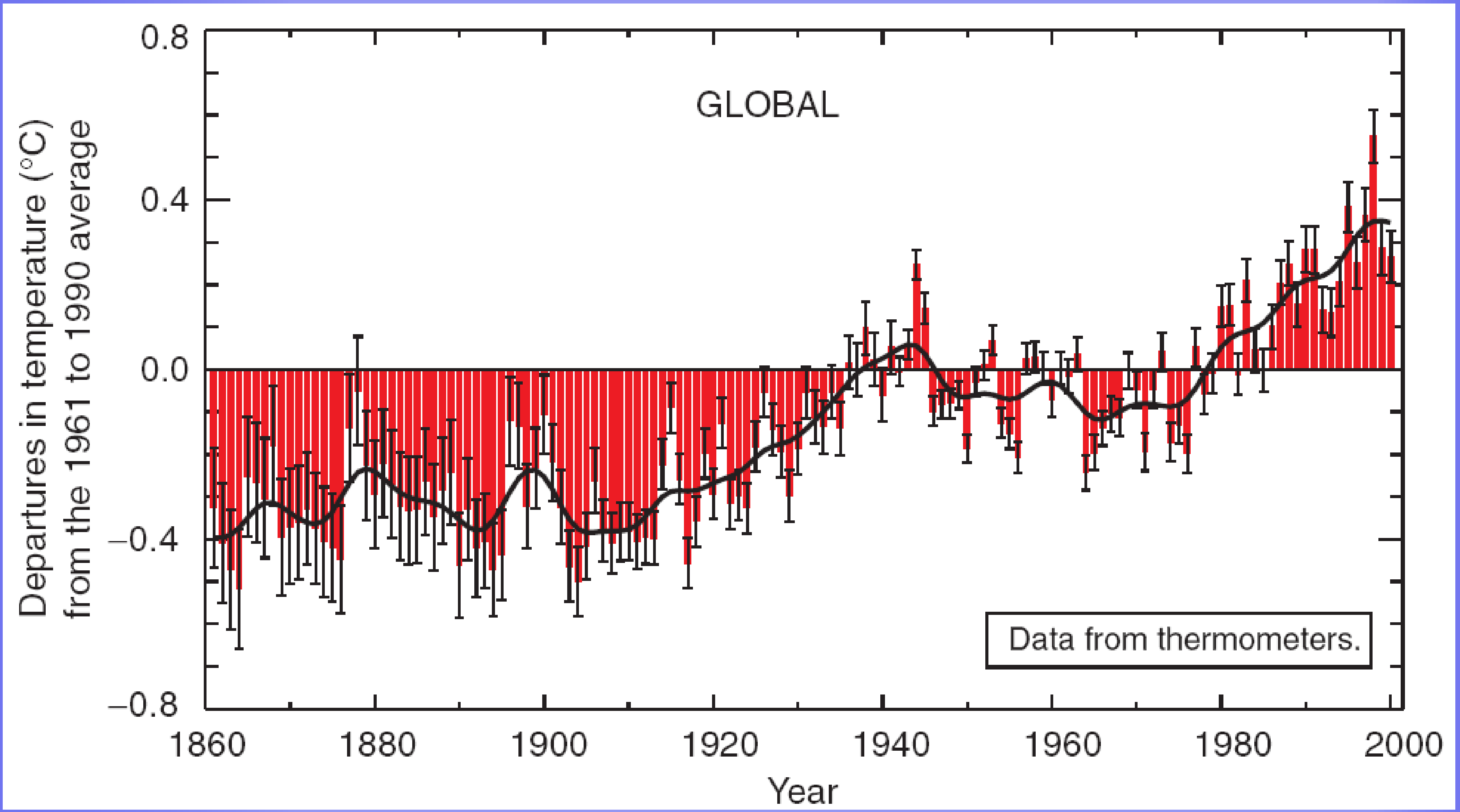
Magnetic field rigidity protects against high energy ionized particles

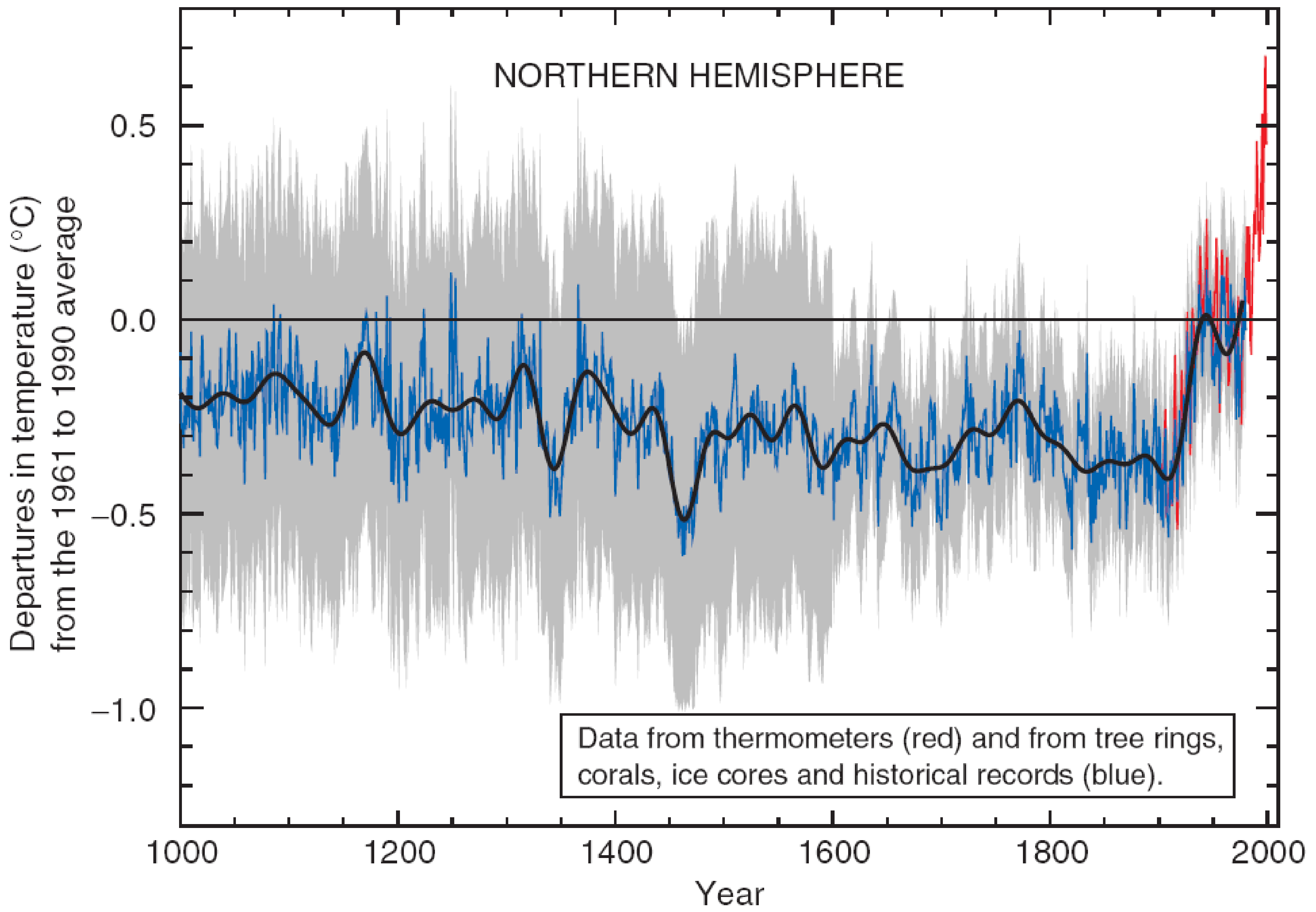
Atmosphere distributes heat energy – water vapor latent heat transports energy to polar regions

Global radiation balance is controlled by the "greenhouse" gasses and the planetary albedo

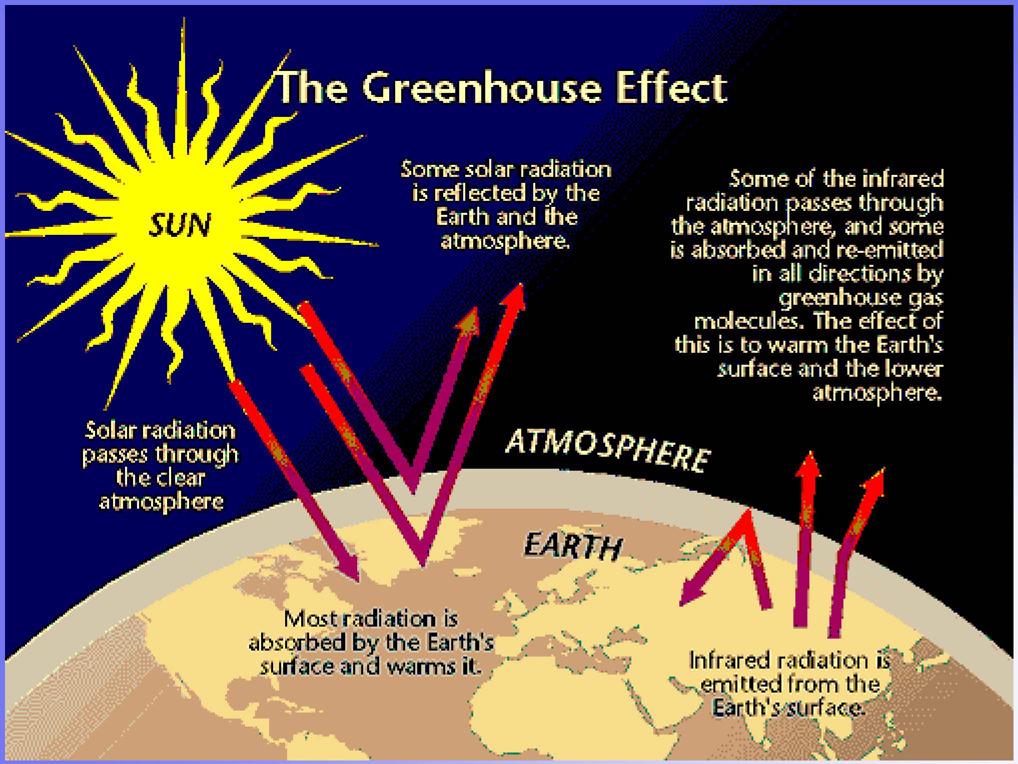
The Issues:

(1) Present CO_2 levels are approaching 400 ppm (>500 ppm by 2050)
(2) Most scientists that have studied the problem agree that unacceptable climate changes will have occurred by the time CO_2 reaches 450 ppm
(3) Fossil fuels account for 80% of the world's energy use
(4) A definite temperature increase is measured during the past 50 years (20 of the hottest years on record occurred since 1980)
(5) US did not sign the Kyoto Protocol
(reduce emission to 7% below 1990 level)
(6) US produces 25% of carbon emission with 5% of population
(7) Today the global input is ~ 7×10^9 tons per year and at present rate of growth that will be 14 billion tons per year by 2056
(8) Residential and commercial buildings account for > 60% of electric use
(9) Coal based synfuels add as much or more CO_2 as a gasoline car
(10) Corn based biofuels add as much CO_2 and may do more ecological damage because of fertilizers
(11) Today energy relies on digging or pumping 7 billion tons of carbon each year that is mostly input to the atmosphere
(12) No simple single fix will avert an eventual "run-away greenhouse"


GLOBAL
Data from thermometers.
0.8
0.4
0.0
−0.4
−0.8
Departures in temperature (°C) from the 1961 to 1990 average
1860
1880
1900
1920
1940
1960
1980
2000
Year



NORTHERN HEMISPHERE
0.5
0.0
–0.5
–1.0
Departures in temperature (°C) from the 1961 to 1990 average
Data from thermometers (red) and from tree rings, corals, ice cores and historical records (blue).
1000
1200
1400
1600
1800
2000
Year

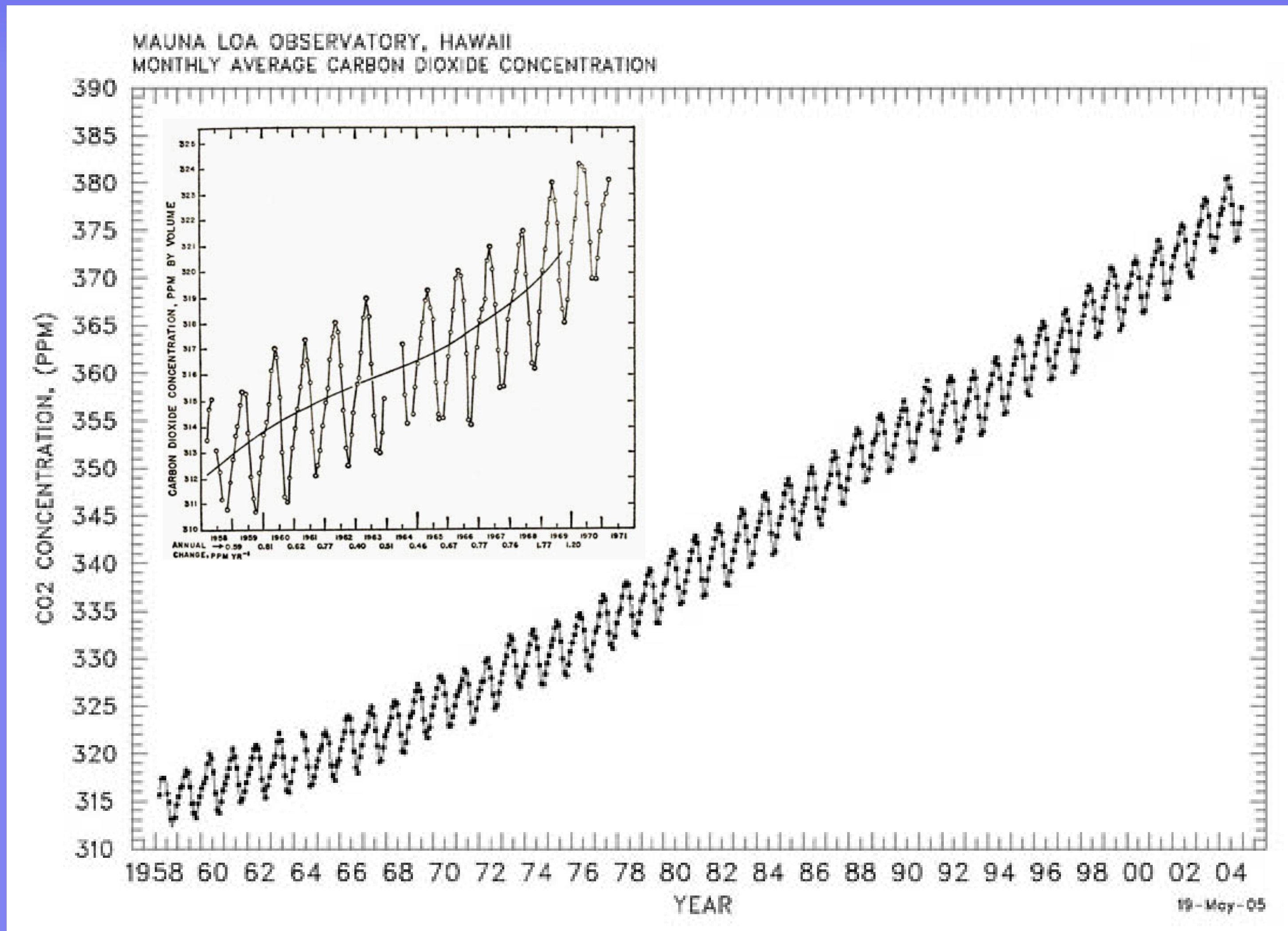


CO_2 keeps the atmosphere warms Earth enough to sustain life

CO_2 sustains the plants through photosynthesis

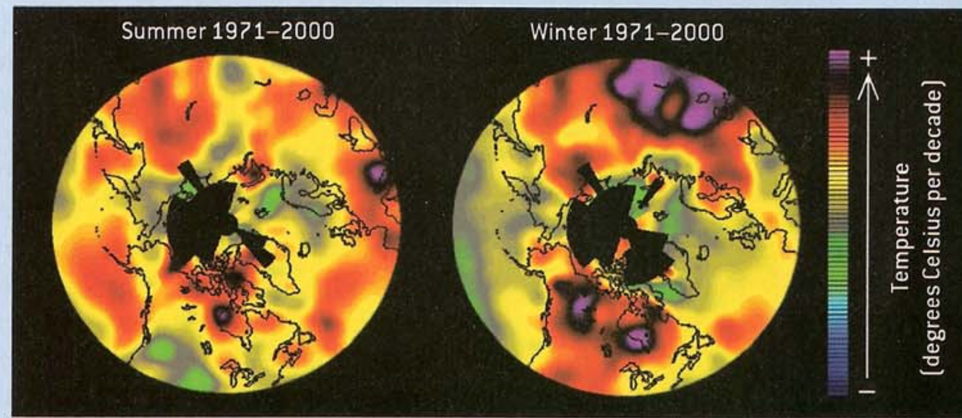
65% of the primary energy is lost in the process of conversion to the energy we use

85% of the primary energy comes from carbon emitting fossil fuel

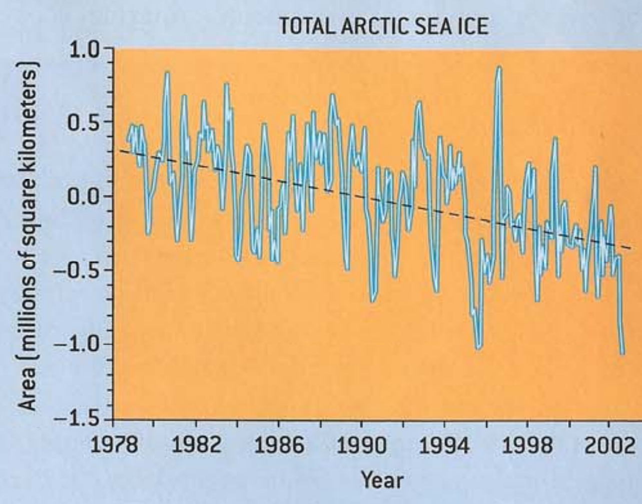


CO_2 → Chlorophyll → O_2

MELTING on the Greenland ice sheet set a record during the summer of 2002. The brown color shows where the ice sheet (*light-colored area*) underwent melt during the summer. The green indicates ice-free areas. Near the Dye-2 site, summer melting, usually confined to the edges of the ice sheet, extended all the way to the summit.



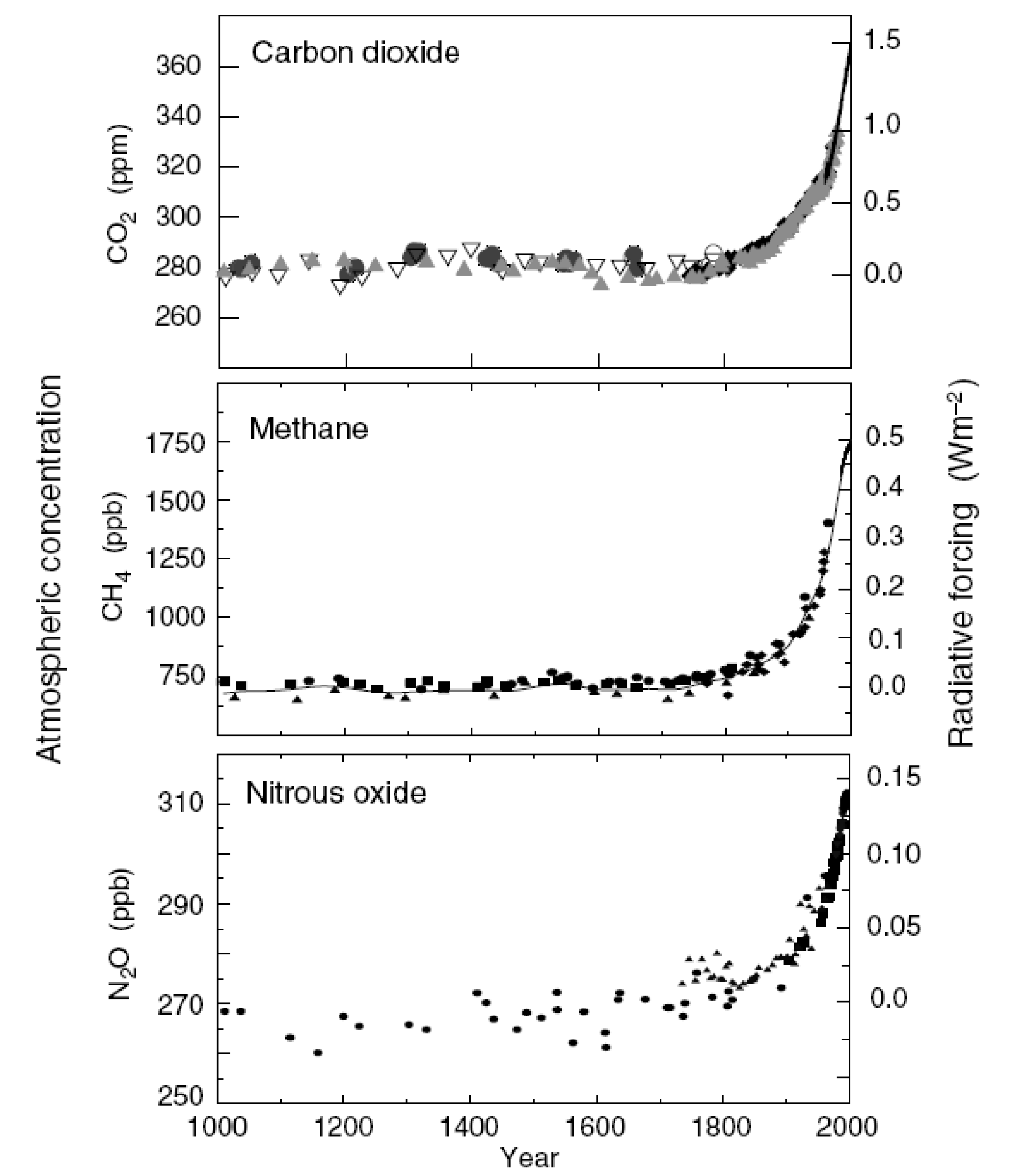
RATE AT WHICH Arctic air temperatures have been warming is shown for the past three decades. Warming has been greater in winter. Greens and blues indicate cooling; yellows and reds, warming. The scale bar runs from –1 to +1 degree Celsius per decade.



STRIKING REDUCTIONS in the extent of Arctic sea ice have been recorded since 1978.

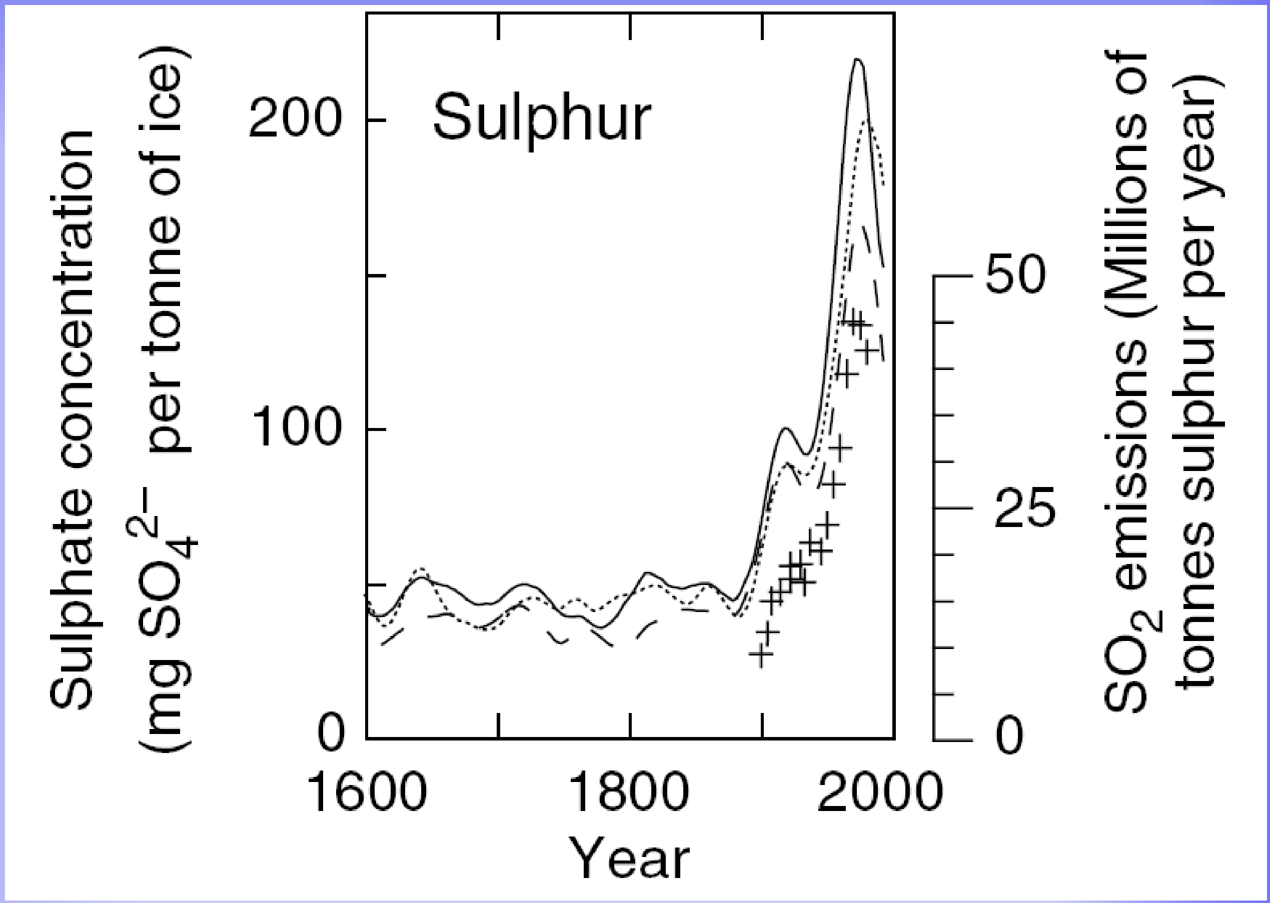
Meltdown in the North, Scientific American, Oct 2003

Global Concentrations of Three Well Mixed Greenhouse Gases Showing Human Influence on the Atmosphere



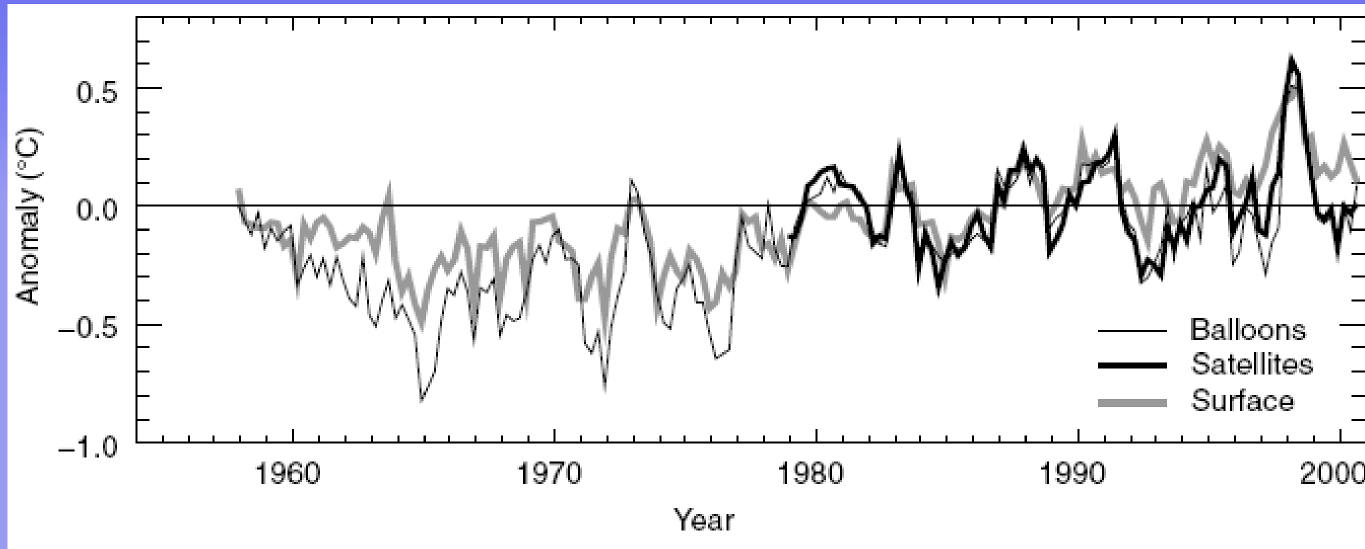
Climate Change 2001:
Impacts, Adaptation, and Vulnerability
(Intergovernmental Panel on Climate Change)

Sulfate from Greenland ice cores, US, and European station averages compared with total sulphur emission inventories.

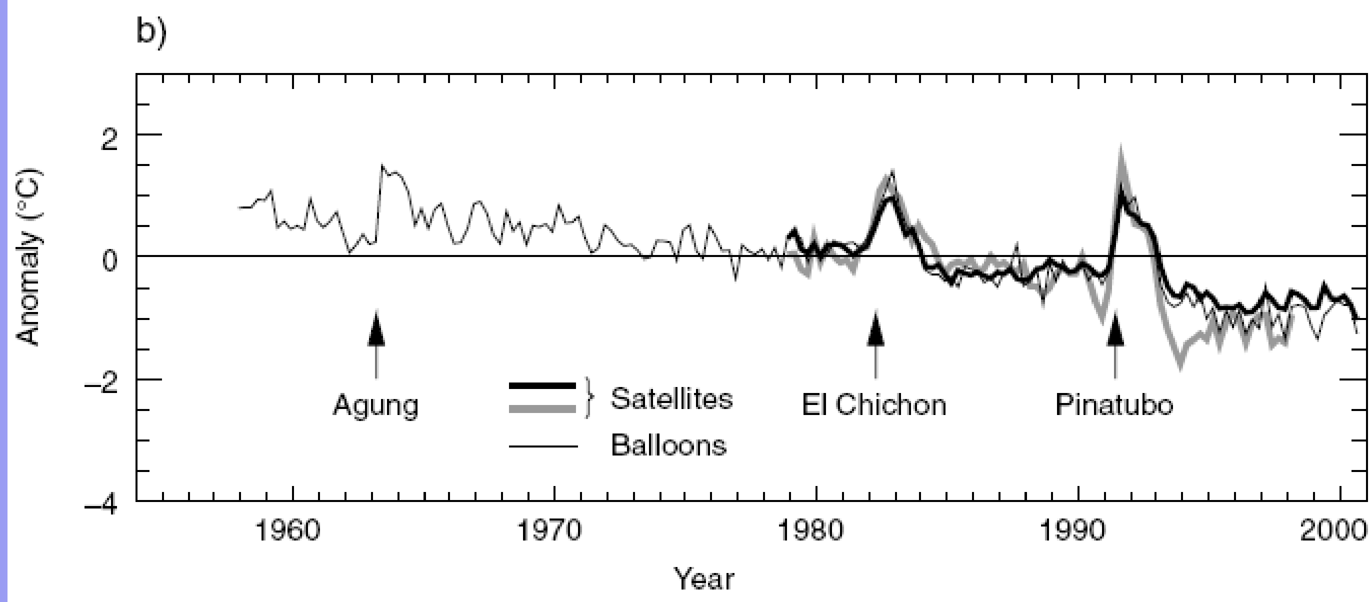


Climate Change 2001: Impacts, Adaptation, and Vulnerability (Intergovernmental Panel on Climate Change)

Surface



Stratosphere



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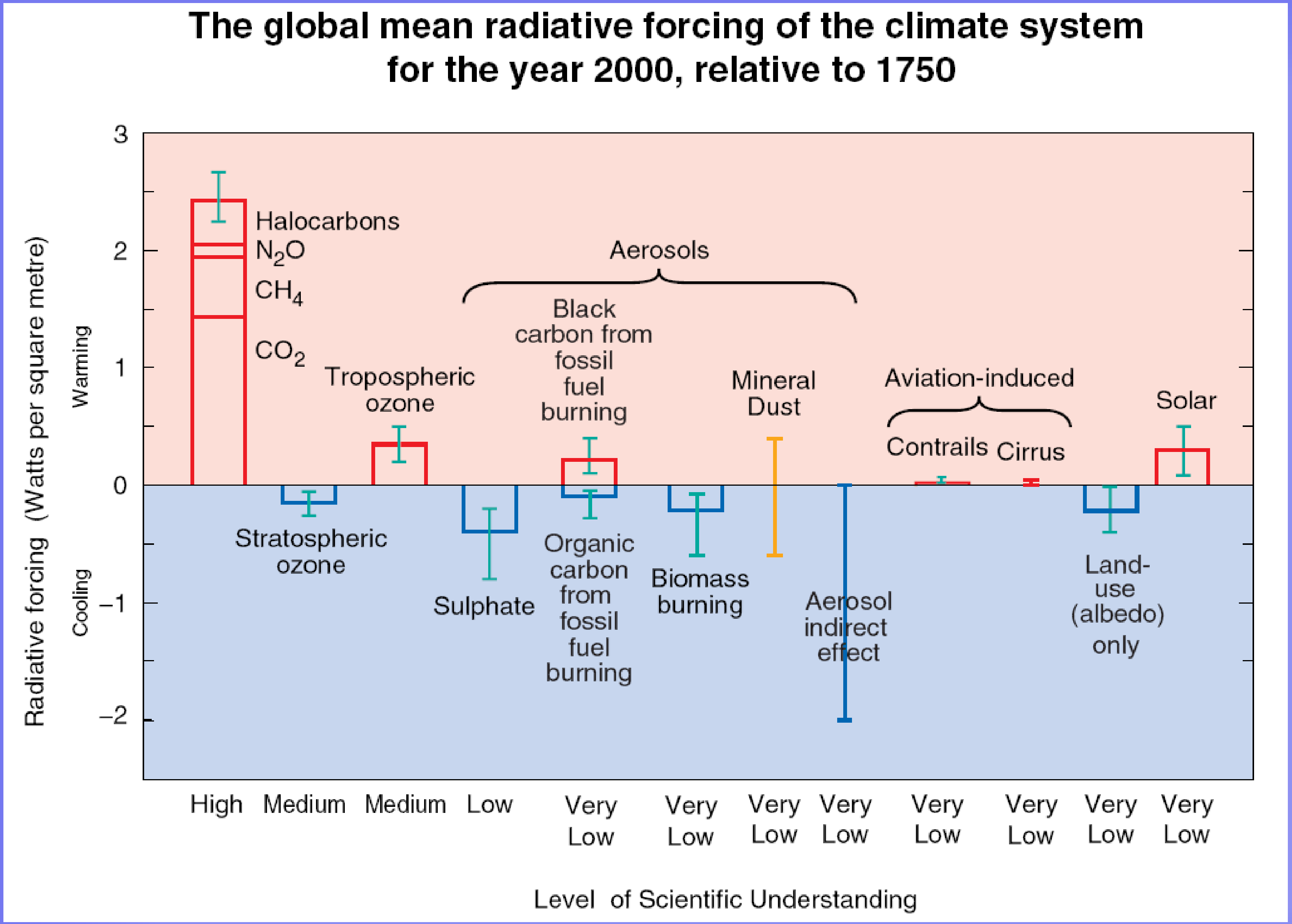
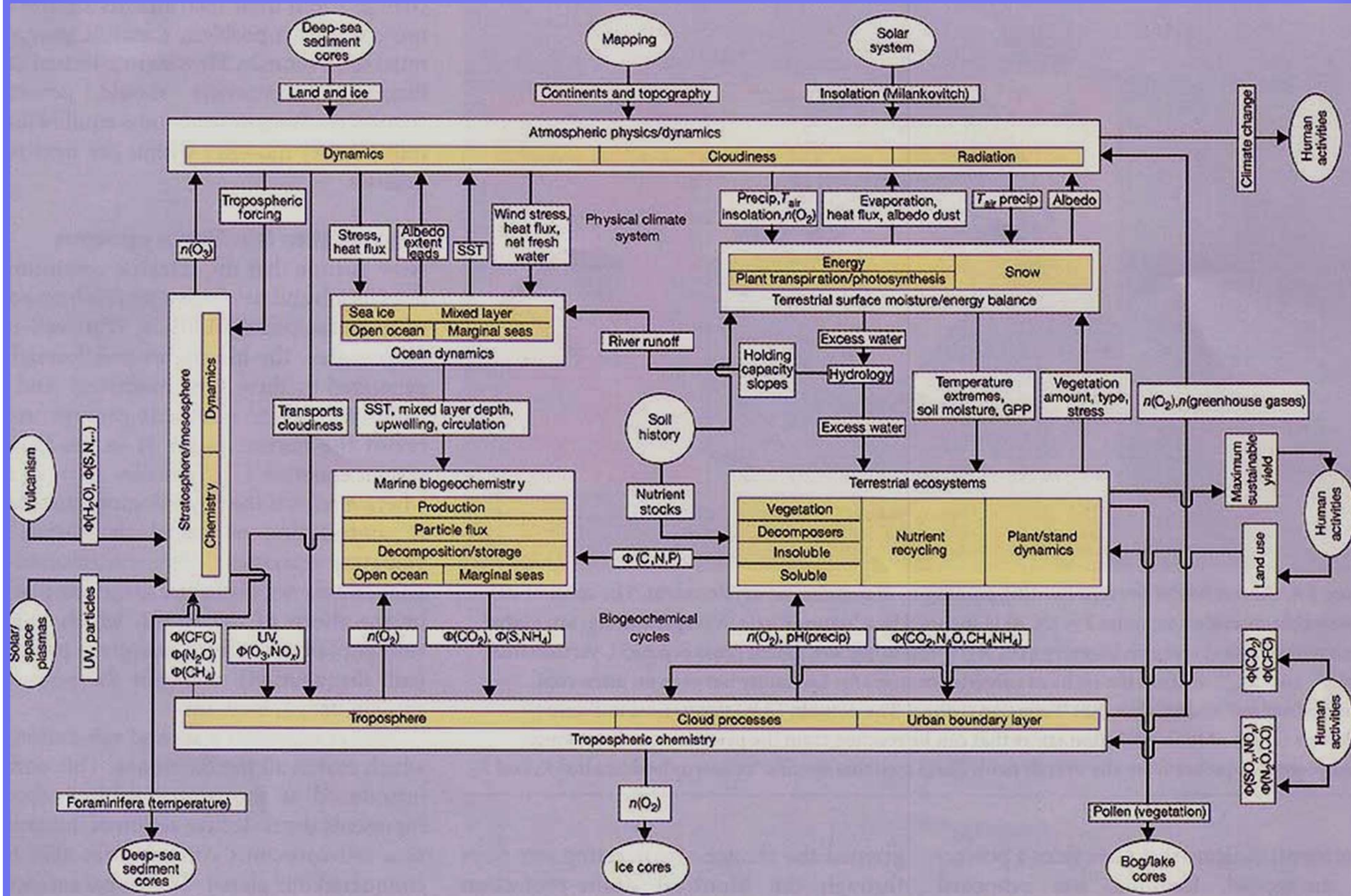
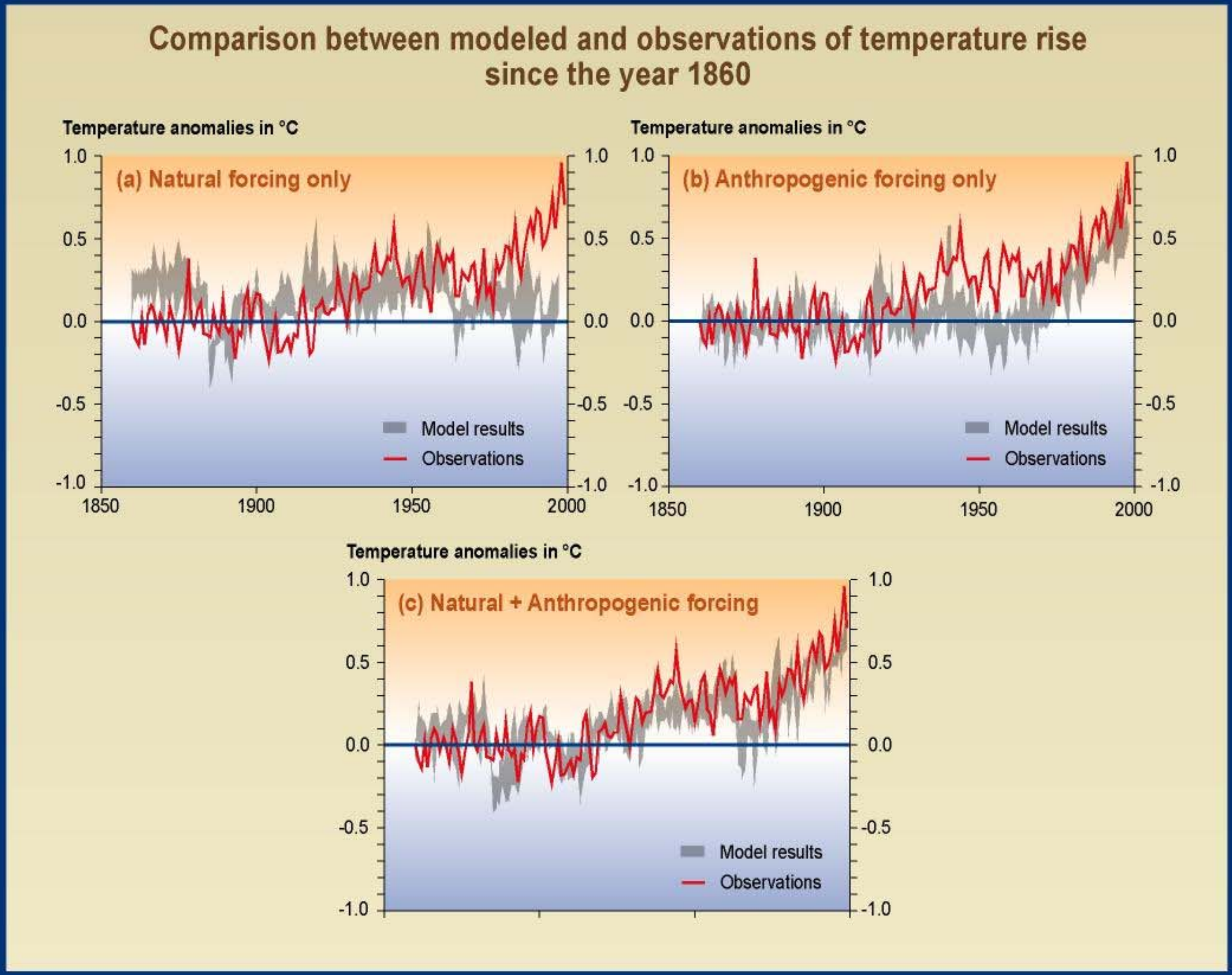

The global mean radiative forcing of the climate system
for the year 2000, relative to 1750
Radiative forcing (Watts per square metre)
Warming
Cooling
3
2
1
0
−1
−2
Halocarbons
N2O
CH4
CO2
Tropospheric ozone
Stratospheric ozone
Aerosols
Black carbon from fossil fuel burning
Mineral Dust
Sulphate
Organic carbon from fossil fuel burning
Biomass burning
Aerosol indirect effect
Aviation-induced
Contrails
Cirrus
Land-use (albedo) only
Solar
High
Medium
Medium
Low
Very Low
Very Low
Very Low
Very Low
Very Low
Very Low
Very Low
Very Low
Level of Scientific Understanding



Deep-sea sediment cores
Land and ice
Mapping
Continents and topography
Solar system
Insolation (Milankovitch)
Atmospheric physics/dynamics
Dynamics
Cloudiness
Radiation
Climate change
Human activities
Tropospheric forcing
$n(O_3)$
Stress, heat flux
Albedo extent leads
SST
Wind stress, heat flux, net fresh water
Physical climate system
Precip, T_{air} insolation, $n(O_2)$
Evaporation, heat flux, albedo dust
T_{air} precip
Albedo
Energy
Plant transpiration/photosynthesis
Snow
Terrestrial surface moisture/energy balance
Sea ice
Mixed layer
Open ocean
Marginal seas
Ocean dynamics
River runoff
Holding capacity slopes
Excess water
Hydrology
Excess water
Temperature extremes, soil moisture, GPP
Vegetation amount, type, stress
$n(O_2)$, n(greenhouse gases)
Stratosphere/mesosphere
Dynamics
Chemistry
Transports cloudiness
SST, mixed layer depth, upwelling, circulation
Soil history
Vulcanism
$\Phi(H_2O)$, $\Phi(S,N,..)$
Maximum sustainable yield
Human activities
Marine biogeochemistry
Production
Particle flux
Decomposition/storage
Open ocean
Marginal seas
Nutrient stocks
Φ(C,N,P)
Terrestrial ecosystems
Vegetation
Decomposers
Insoluble
Soluble
Nutrient recycling
Plant/stand dynamics
Land use
Solar/space plasmas
UV, particles
$\Phi(CFC)$
$\Phi(N_2O)$
$\Phi(CH_4)$
UV, $\Phi(O_3,NO_x)$
$n(O_2)$
$\Phi(CO_2)$, $\Phi(S,NH_4)$
Biogeochemical cycles
$n(O_2)$, pH(precip)
$\Phi(CO_2,N_2O,CH_4NH_4)$
$\Phi(CO_2)$
$\Phi(CFC)$
Human activities
Troposphere
Cloud processes
Urban boundary layer
Tropospheric chemistry
$\Phi(SO_x,NO_x)$
$\Phi(N_2O,CO)$
Foraminifera (temperature)
$n(O_2)$
Pollen (vegetation)
Deep-sea sediment cores
Ice cores
Bog/lake cores



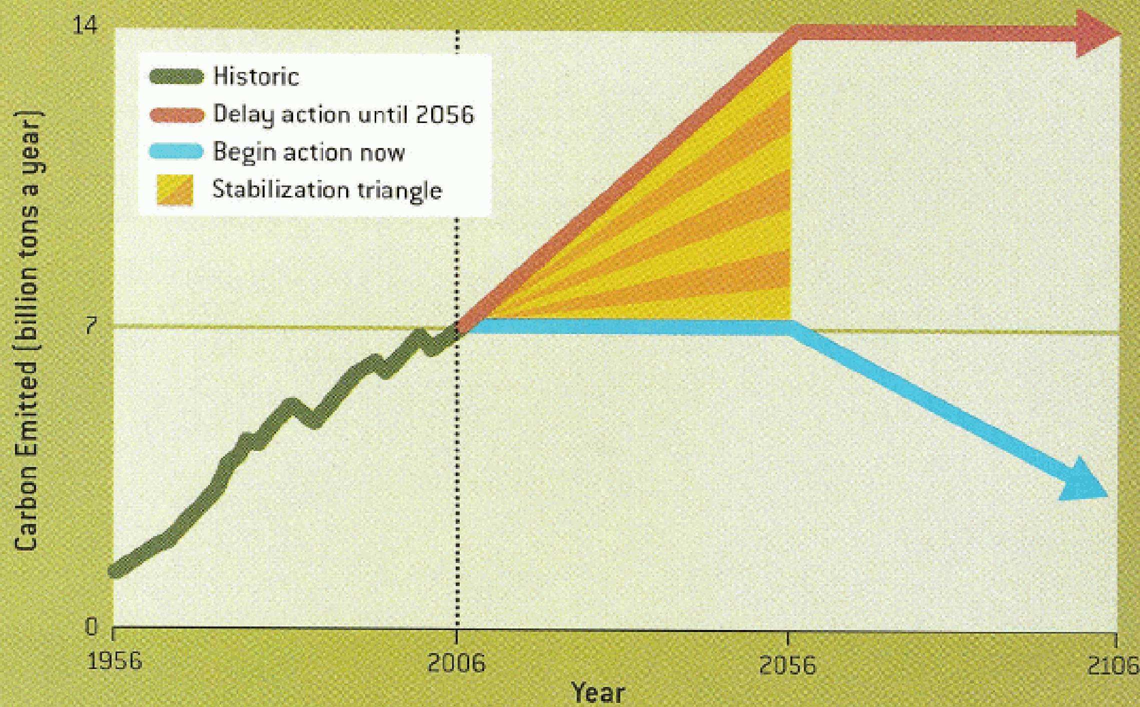
SYR - FIGURE 2-4

IPCC
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

WMO UNEP

ANNUAL EMISSIONS

In between the two emissions paths is the "stabilization triangle." It represents the total emissions cut that climate-friendly technologies must achieve in the coming 50 years.

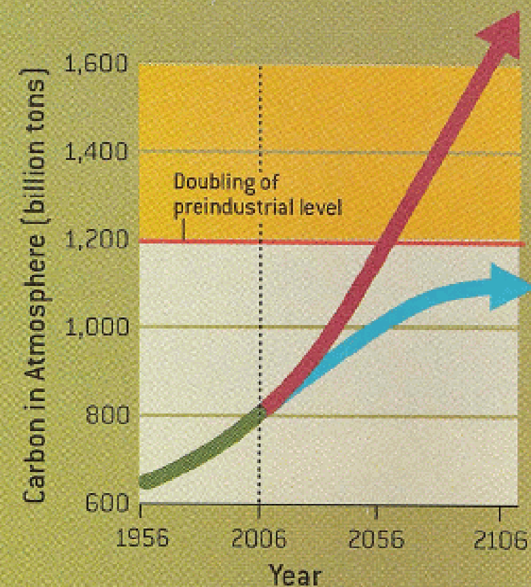


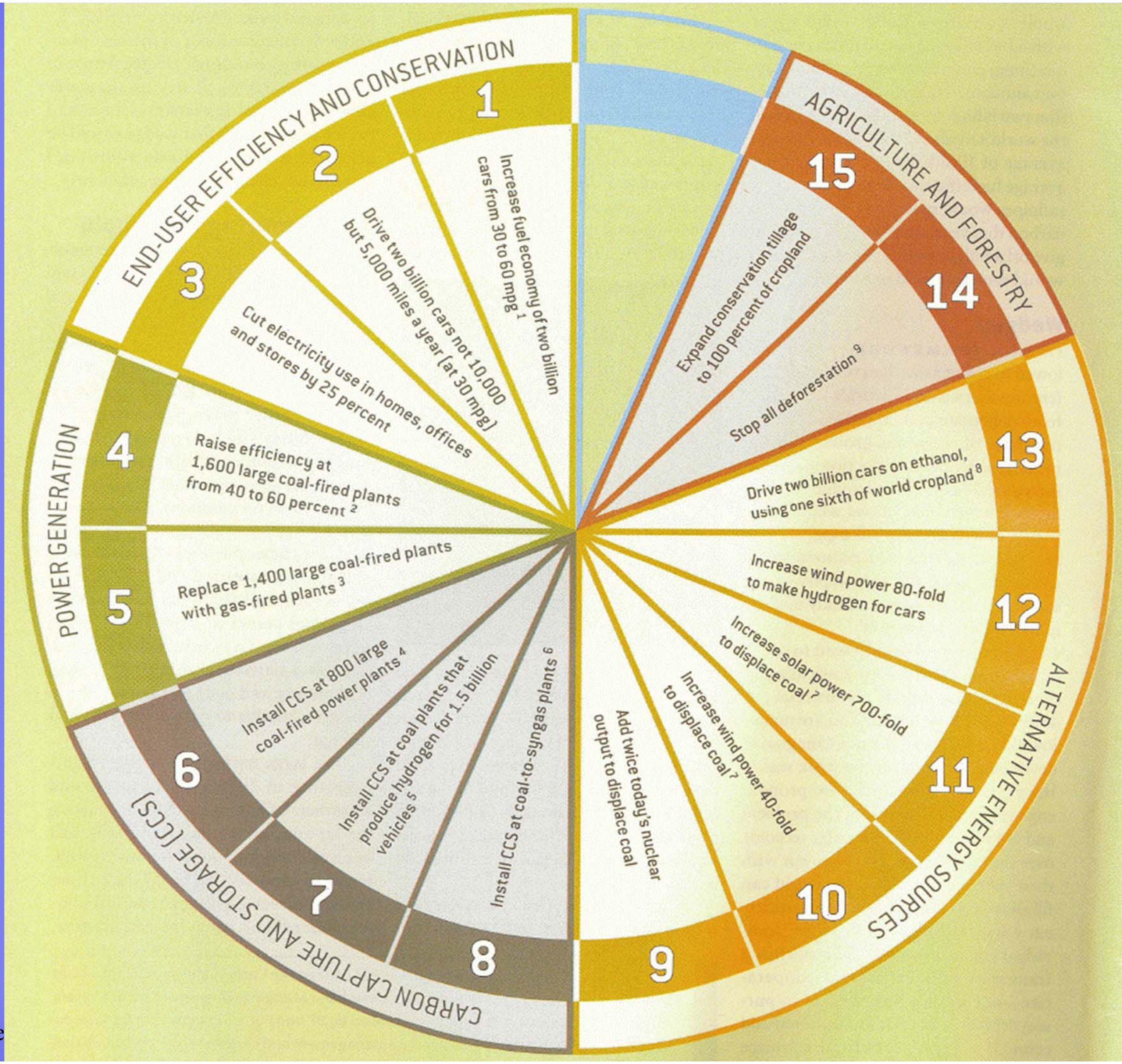
THE WEDGE CONCEPT

The stabilization triangle can be divided into seven "wedges," each a reduction of 25 billion tons of carbon emissions over 50 years. The wedge has proved to be a useful unit because its size and time frame match what specific technologies can achieve. Many combinations of technologies can fill the seven wedges.

CUMULATIVE AMOUNT

Each part per million of CO_2 corresponds to a total of 2.1 billion tons of atmospheric carbon. Therefore, the 560-ppm level would mean about 1,200 billion tons, up from the current 800 billion tons. The difference of 400 billion tons actually allows for roughly 800 billion tons of emissions, because half the CO_2 emitted into the atmosphere enters the planet's oceans and forests. The two concentration trajectories shown here match the two emissions paths at the left.




END-USER EFFICIENCY AND CONSERVATION
1
Increase fuel economy of two billion cars from 30 to 60 mpg [1]
2
Drive two billion cars not 10,000 but 5,000 miles a year (at 30 mpg)
3
Cut electricity use in homes, offices and stores by 25 percent
POWER GENERATION
4
Raise efficiency at 1,600 large coal-fired plants from 40 to 60 percent [2]
5
Replace 1,400 large coal-fired plants with gas-fired plants [3]
CARBON CAPTURE AND STORAGE (CCS)
6
Install CCS at 800 large coal-fired power plants [4]
7
Install CCS at coal plants that produce hydrogen for 1.5 billion vehicles [5]
8
Install CCS at coal-to-syngas plants [6]
ALTERNATIVE ENERGY SOURCES
9
Add twice today's nuclear output to displace coal
10
Increase wind power 40-fold to displace coal [7]
11
Increase solar power 700-fold to displace coal [7]
12
Increase wind power 80-fold to make hydrogen for cars
13
Drive two billion cars on ethanol, using one sixth of world cropland [8]
AGRICULTURE AND FORESTRY
14
Stop all deforestation [9]
15
Expand conservation tillage to 100 percent of cropland

Require a minimum of seven wedges to limit the CO_2 at a survival level

(wedges only count if added use of technologies that have already been demonstrated)

1 Wedge – Lower birth rate to hold global population below 8 billion people in 2056
1 Wedge – Curtail the emissions of methane (CH_4)
2 Wedges – Eliminate deforestation
1 Wedge – Wide spread use of synfuels with capture and storage of CO_2
2 Wedges – Expand the number of nuclear power plants by factor of five to displace conventional coal power plants
2 Wedges – Cut electricity use in building by half through use of super-efficient lighting and appliances
1 Wedge – Industrial use of electricity more efficiently
1 Wedge – Increased efficiency of automobiles
1 Wedge – Efficiency in transportation (other than automobile)
1 Wedge – Capture and store the carbon emissions from the present coal power plants
1 Wedge – capture and store carbon from large natural gas power plants
-1 to -3 Wedges – 700 coal power plants (1000 MW) emit one wedge (a few thousand such plants are presently expected to be built – natural gas plants burn half as much carbon per unit of electricity)

What is the level that we will experience irreversible changes?

Concept of several wedges to arrive at a solution.
Hold CO_2 constant without choking economic growth.

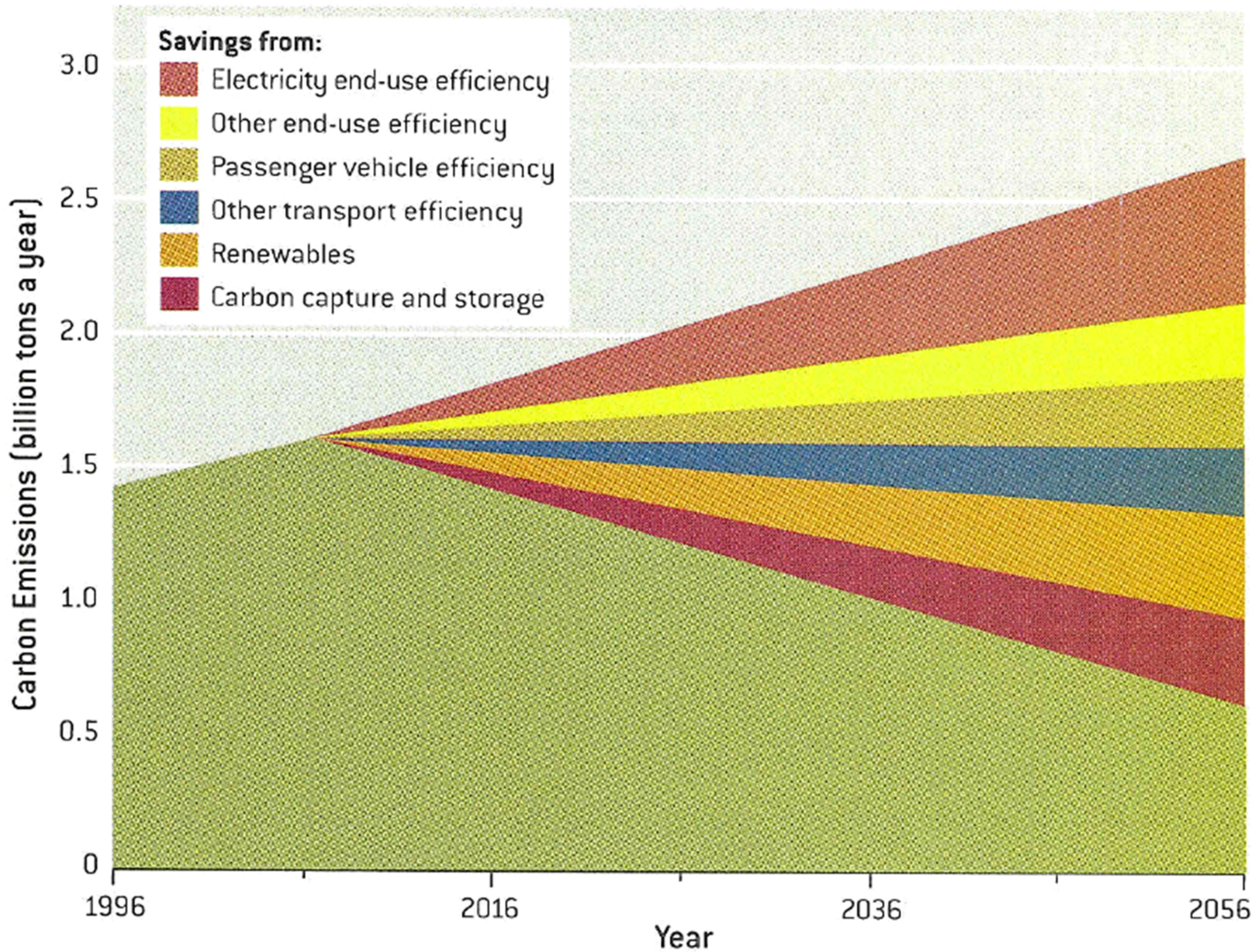
2056 Goals

- 60 mpg car
- cut electricity use in homes and buildings by half
- carbon sequestering (capture and storage)
- increased nuclear power (but hostage to the world's least well-run plant)
- increased alternative sources (solar cells, wind, waves)

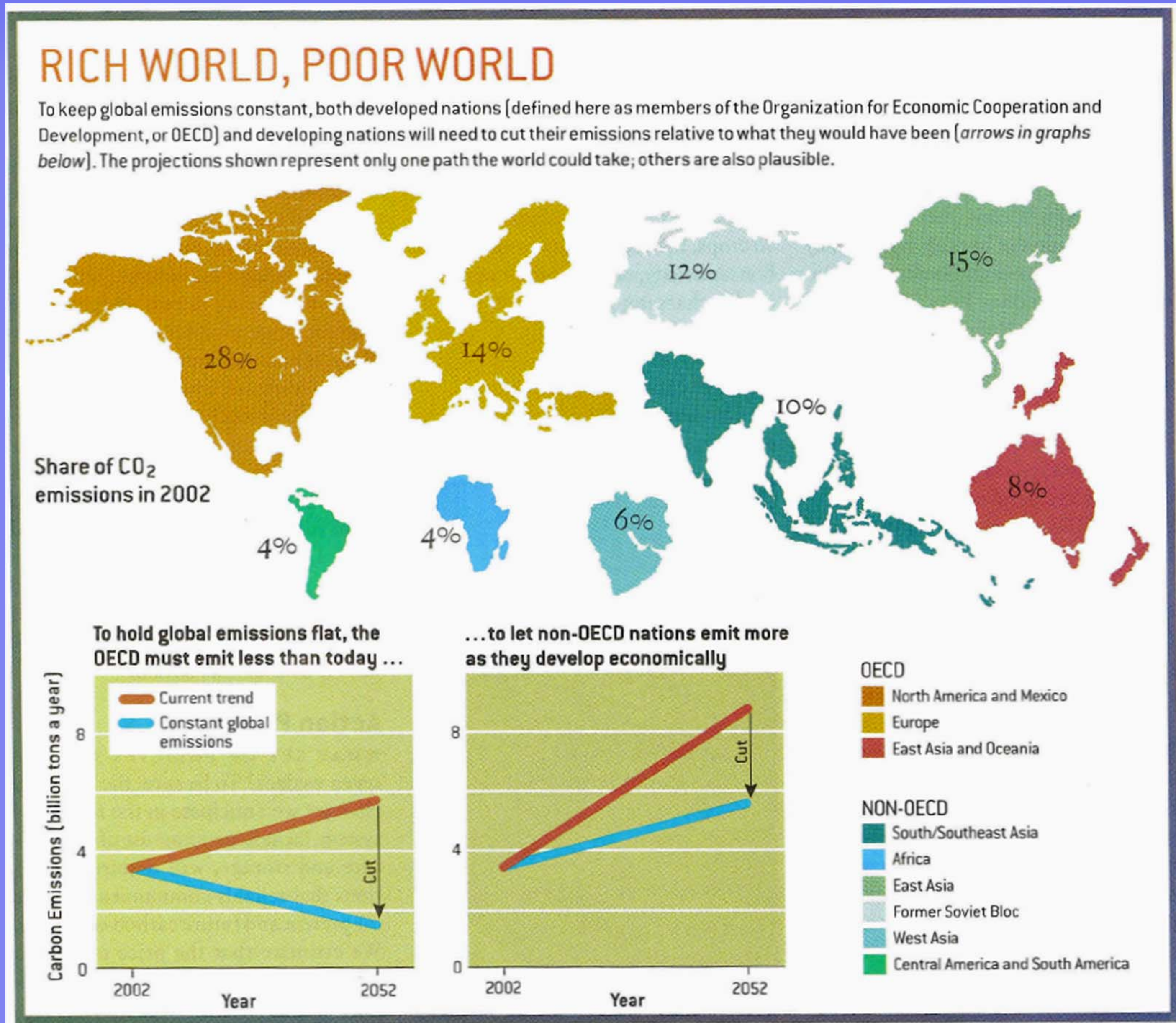
What set of polices will result in saving seven wedges?

(a wedge represents 1 billion tons of carbon per year)

ONE PLAN FOR THE U.S.



▲ U.S. share of emissions reductions could, in this Natural Resources Defense Council scenario, be achieved by efficiency gains, renewable energy and clean coal.



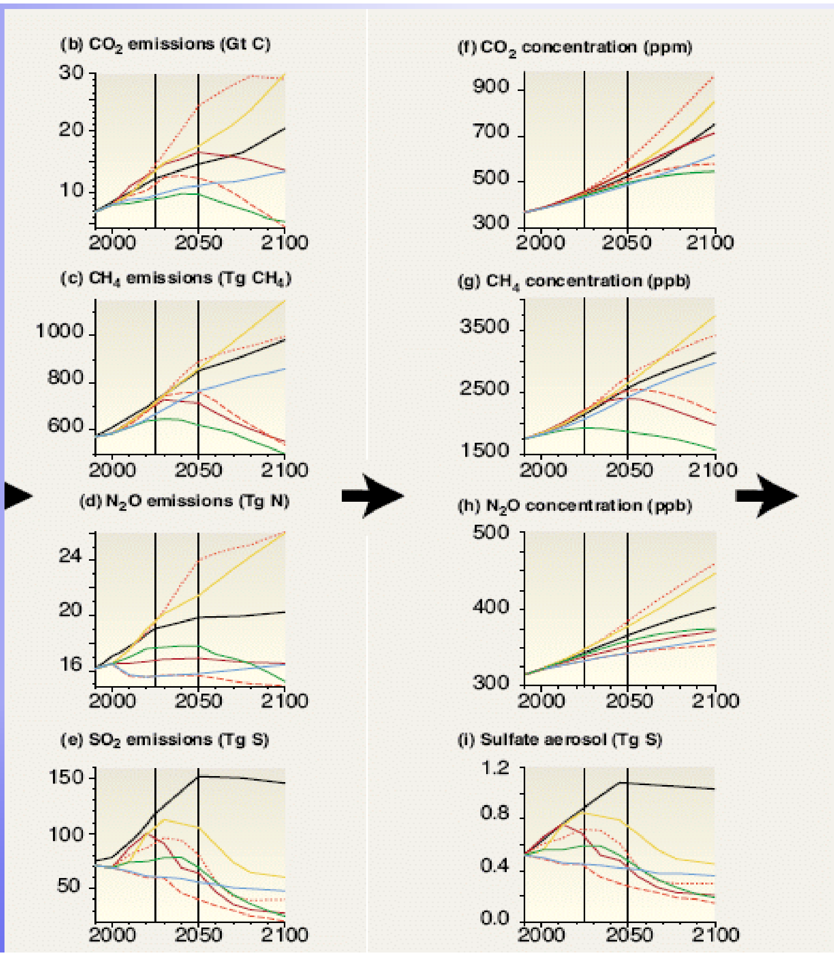
US share of global CO_2 was 39% in 1952 and 23 % in 2002

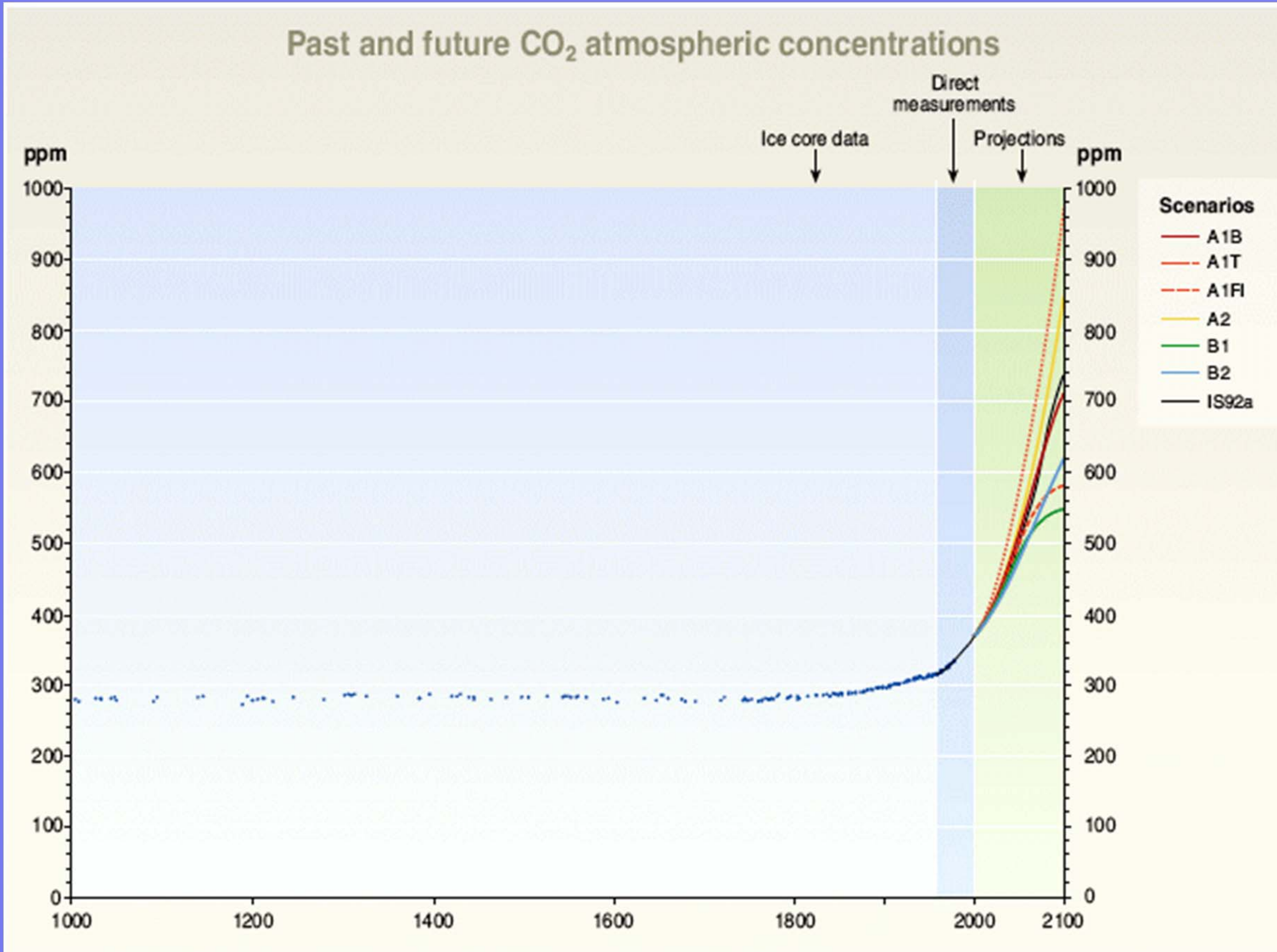
OECD – Organization for Economic Cooperation and Development

Things we are doing right:

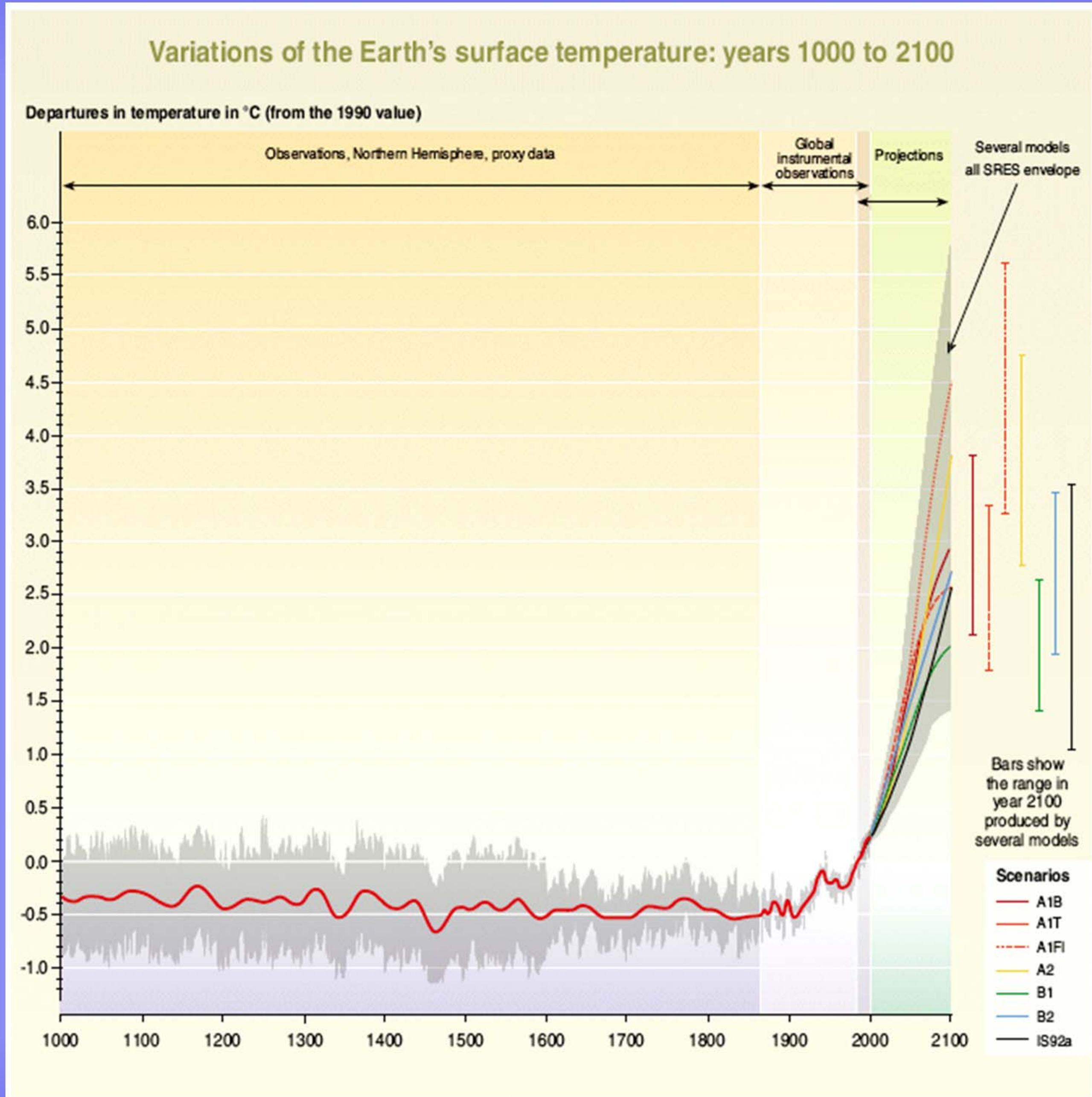
- Air-conditioning more efficient and safer refrigerants
- Refrigerators and freezers – one-fourth power, reduced 40GW demand 1974 and 2001
- Power generation more efficient
- Home insulation and building practice improvements
- Fluorescent bulbs replace incadecent - 40% less power and 10X longer life
- Improved transportation efficiency (cars and aircraft)

	CO_2 (Carbon Dioxide)	CH_4 (Methane)	N_2O (Nitrous Oxide)	CFC-11 (Chlorofluoro-carbon-11)	HFC-23 (Hydrofluoro-carbon-23)	CF_4 (Perfluoro-methane)
Pre-industrial concentration	about 280 ppm	about 700 ppb	about 270 ppb	zero	zero	40 ppt
Concentration in 1998	365 ppm	1745 ppb	314 ppb	268 ppt	14 ppt	80 ppt
Rate of concentration change [b]	1.5 ppm/yr [a]	7.0 ppb/yr [a]	0.8 ppb/yr	−1.4 ppt/yr	0.55 ppt/yr	1 ppt/yr
Atmospheric lifetime	5 to 200 yr [c]	12 yr [d]	114 yr [d]	45 yr	260 yr	>50,000 yr



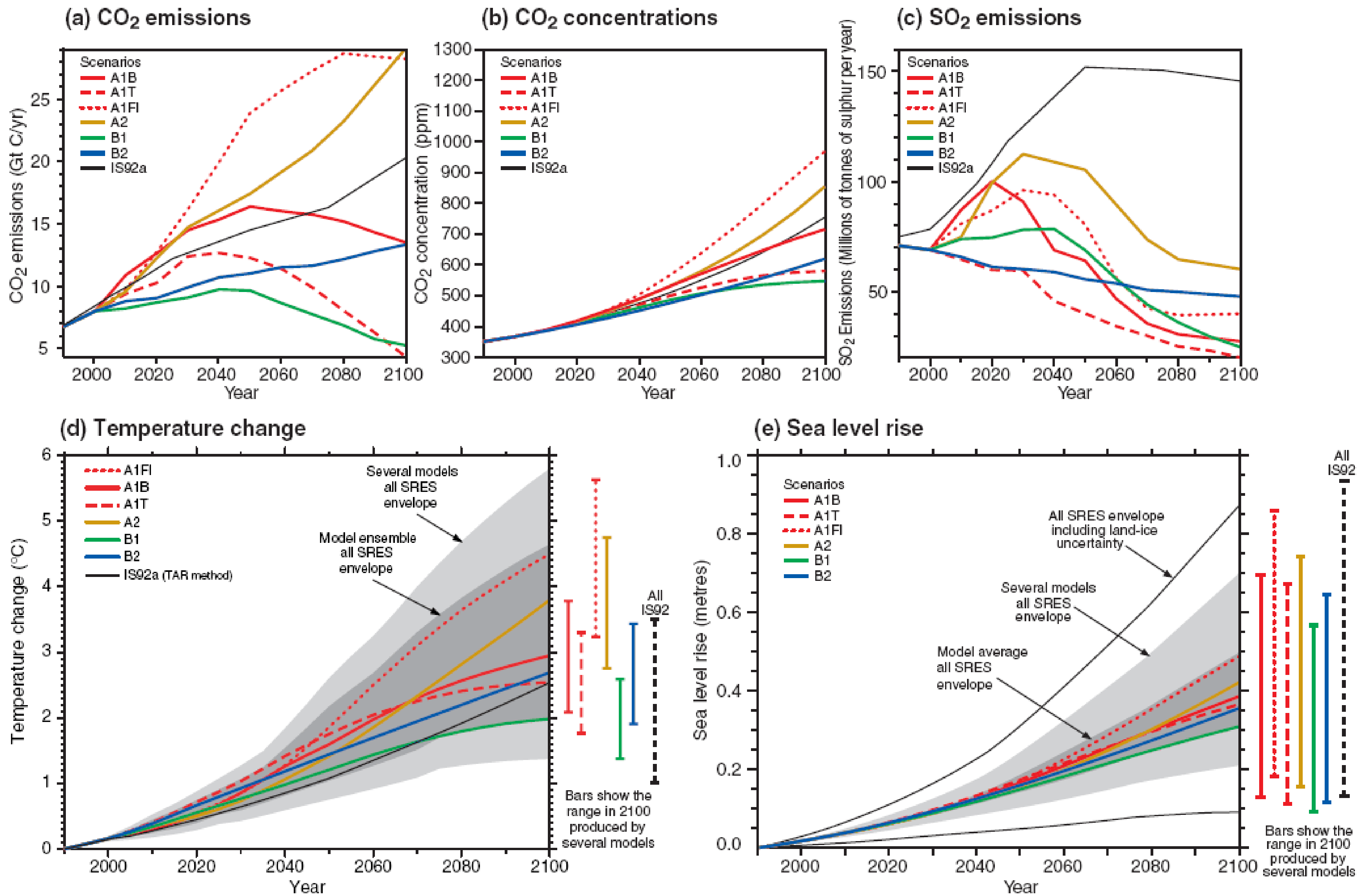


Past and future CO_2 atmospheric concentrations
Direct measurements
Ice core data
Projections
ppm
ppm
1000
900
800
700
600
500
400
300
200
100
0
1000
1200
1400
1600
1800
2000
2100
Scenarios
A1B
A1T
A1FI
A2
B1
B2
IS92a



Variations of the Earth's surface temperature: years 1000 to 2100
Departures in temperature in °C (from the 1990 value)
Observations, Northern Hemisphere, proxy data
Global instrumental observations
Projections
Several models all SRES envelope
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
Bars show the range in year 2100 produced by several models
Scenarios
A1B
A1T
A1FI
A2
B1
B2
IS92a

The global climate of the 21st century



Petroleum

We are using 80 million barrels per day (MBD)

2/3 of this is used for transportation

	MBD
People transportation	29
Freight movement	19
Air travel	5
Total	53

Automobiles

Need to average 60 mpg for cars within 50 years

Volkswagon is testing a two-person prototype

640 lbs

1 liter per 100 km (240 mpg)

	IMPLEMENTATION PHASE			
VEHICLE TECHNOLOGY	Market competitive vehicle	Penetration across new vehicle production*	Major fleet penetration†	Total time for impact
Turbocharged gasoline engine	5 years	10 years	10 years	20 years
Low-emissions diesel	5 years	15 years	10–15 years	30 years
Gasoline hybrid	5 years	20 years	10–15 years	35 years
Hydrogen fuel-cell hybrid	15 years	25 years	20 years	55 years

** More than one third of new vehicle production* † *More than one third of mileage driven*

Incentives

Estimate $200 per ton to initially capture and store carbon

Technology advances should reduce to $100 per ton

Translates to $27 per ton of CO_2

At $100 per ton, the cost for capture and storage corresponds to adding:

$12/barrel of oil

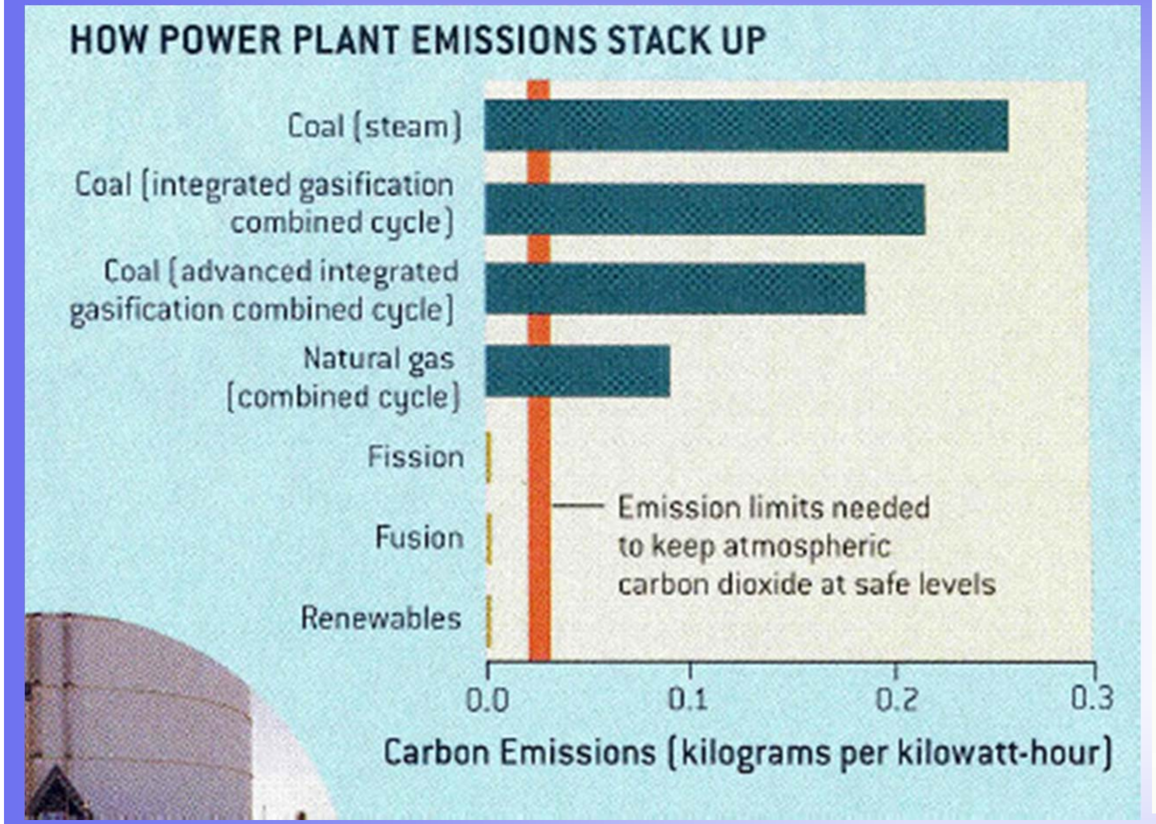
$60 per ton of coal

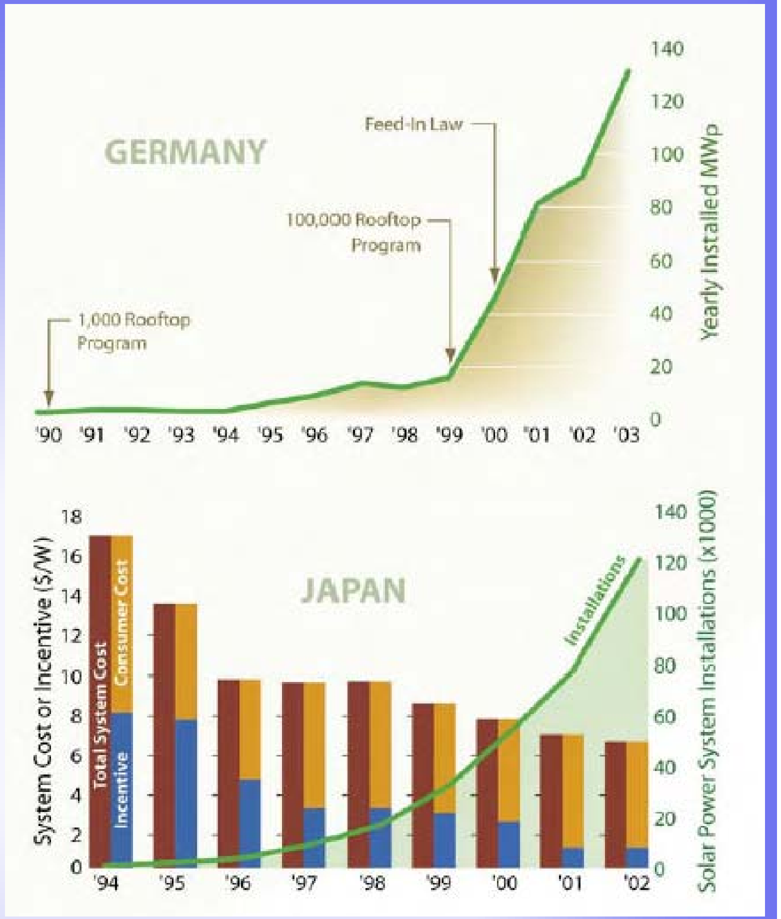
25¢ per gallon of gasoline

Perspectives – a car with 30 mpg fuel efficiency that is driven 10,000 miles emits ~ 1 ton of carbon

Hydrogen is an energy carrier rather than an energy source

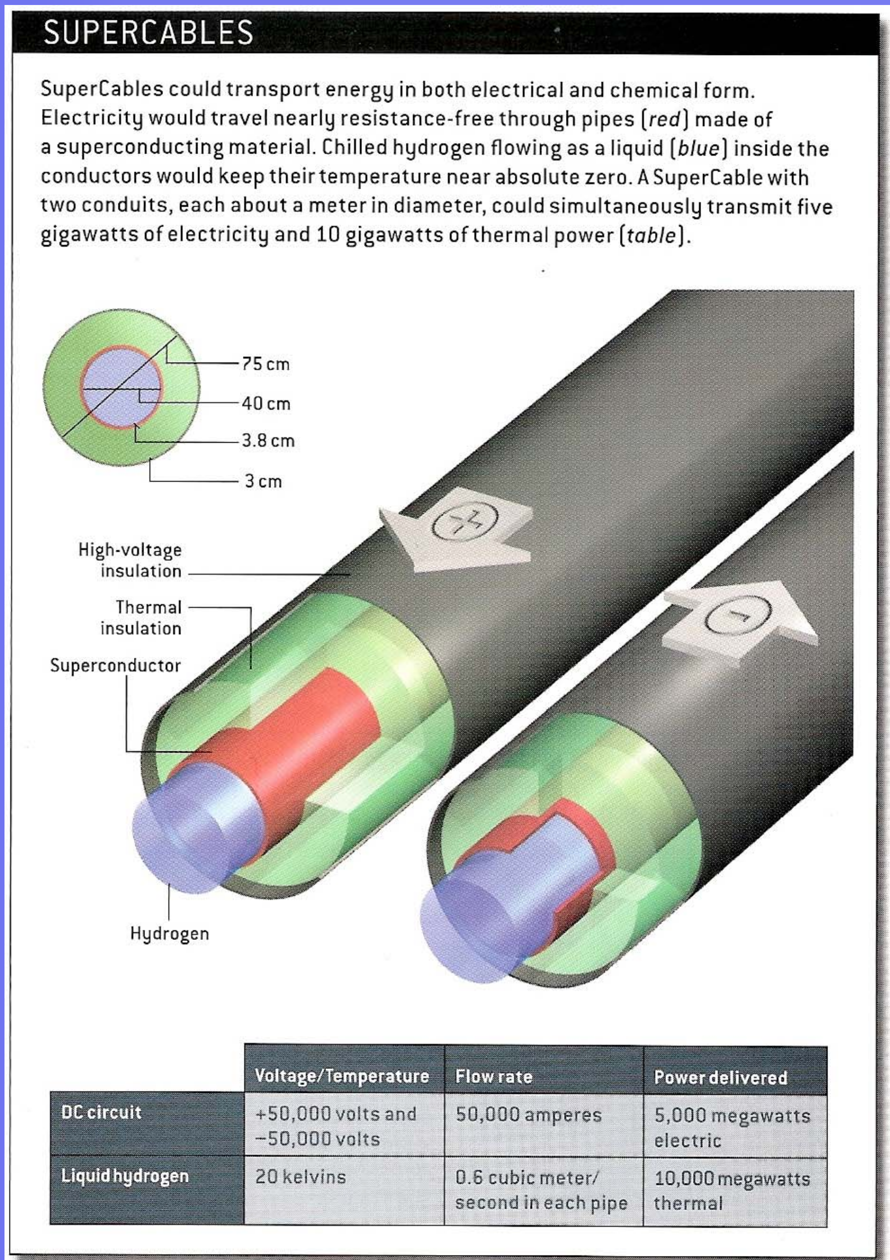
Electricity is an energy carrier (improved batteries are needed for transportation)





All of the fossil fuel sources will require CCS (Carbon Capture and Storage)
Added cost for CCS is about 30% for coal (this should be regulated now)
(Issue is safe long term storage)

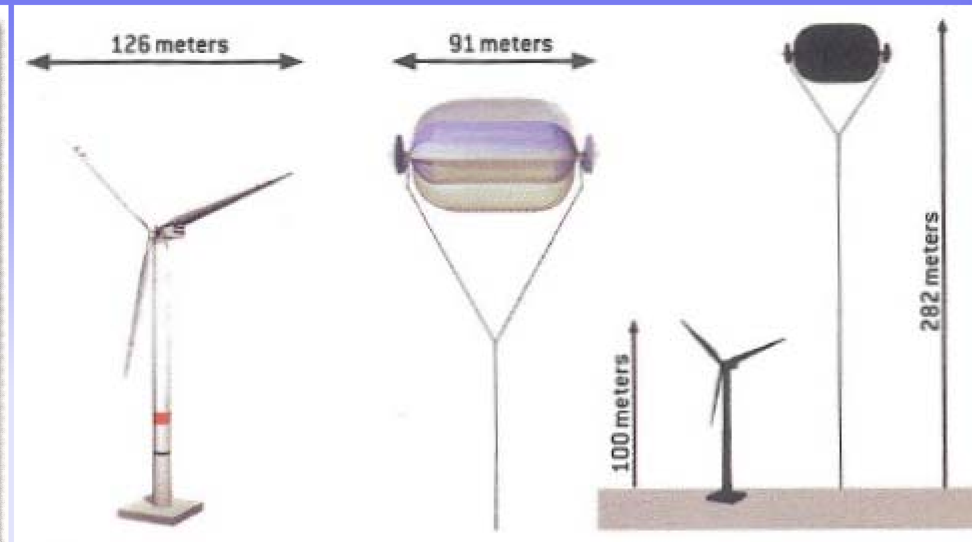
What does the future hold?



SUPERCABLES

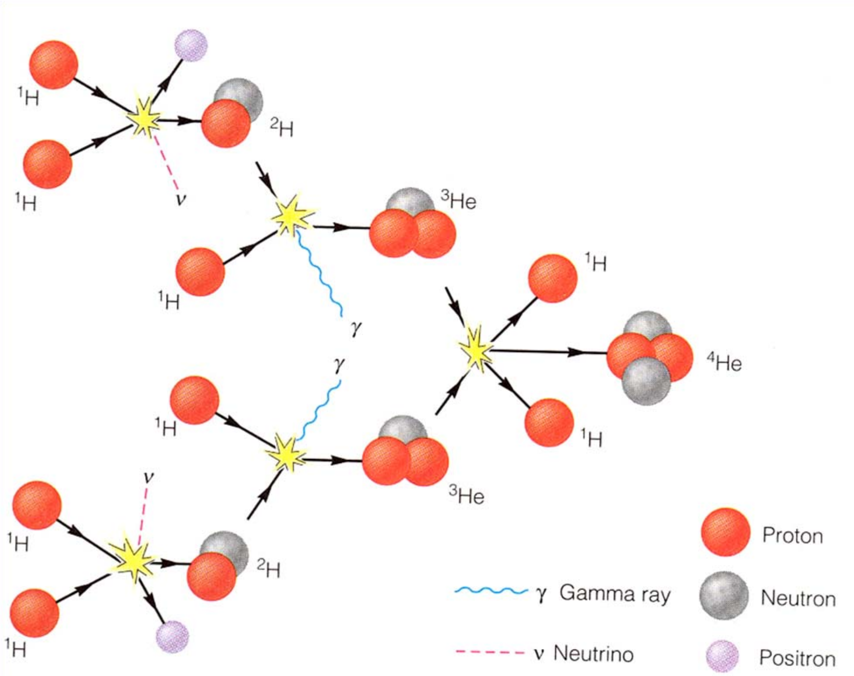
SuperCables could transport energy in both electrical and chemical form. Electricity would travel nearly resistance-free through pipes (*red*) made of a superconducting material. Chilled hydrogen flowing as a liquid (*blue*) inside the conductors would keep their temperature near absolute zero. A SuperCable with two conduits, each about a meter in diameter, could simultaneously transmit five gigawatts of electricity and 10 gigawatts of thermal power (*table*).

	Voltage/Temperature	Flow rate	Power delivered
DC circuit	+50,000 volts and −50,000 volts	50,000 amperes	5,000 megawatts electric
Liquid hydrogen	20 kelvins	0.6 cubic meter/ second in each pipe	10,000 megawatts thermal

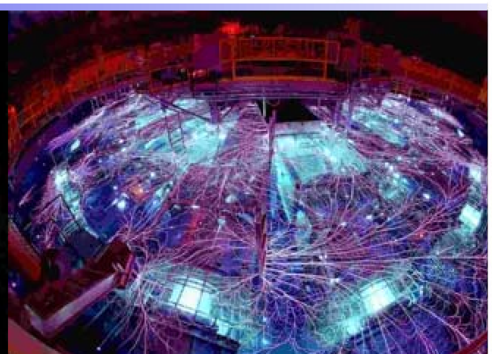


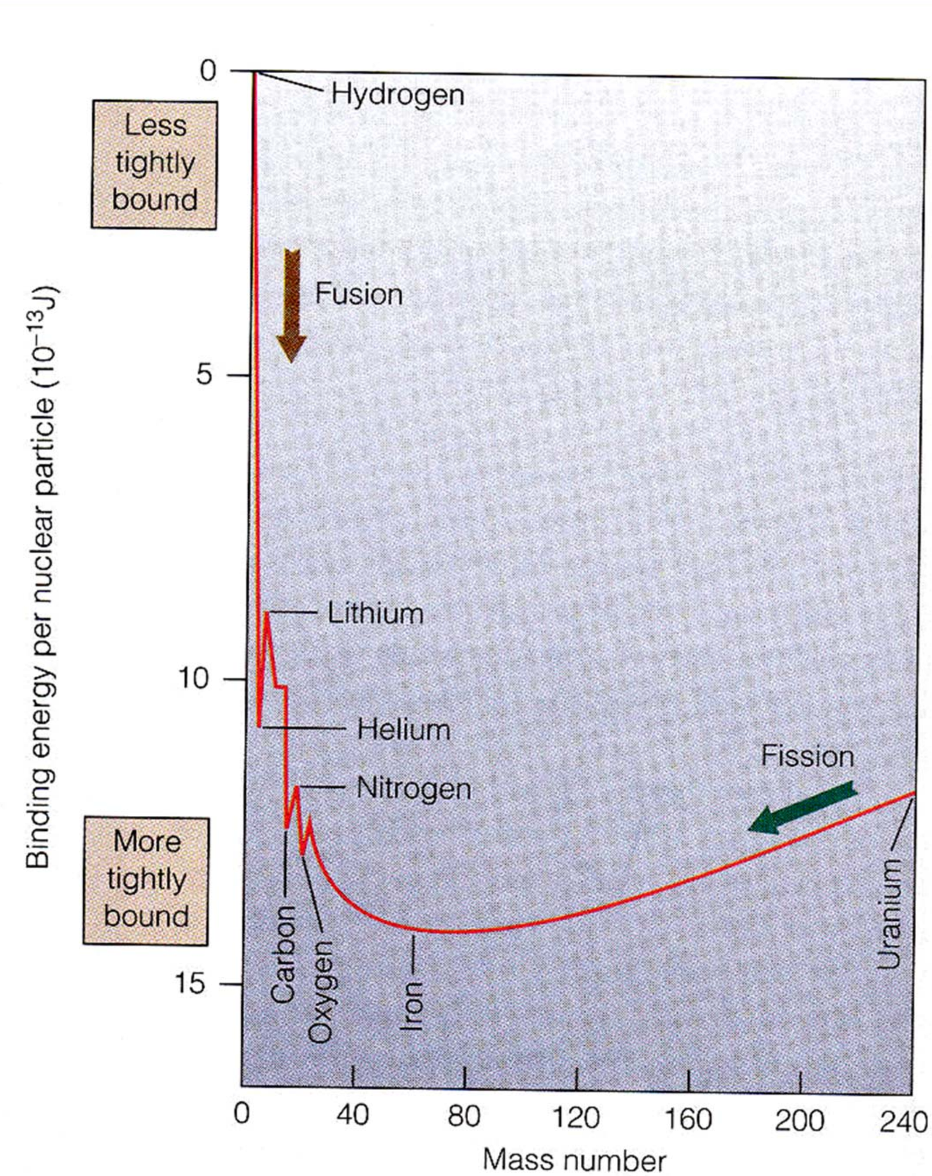
Wind Generators

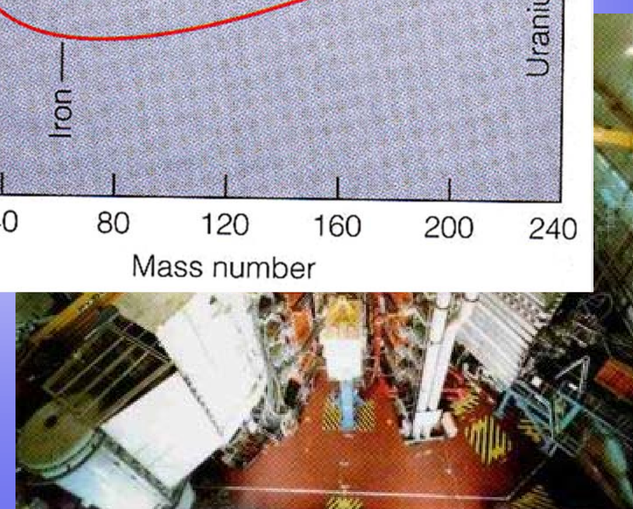
Wave Generators




Tokamak Plasma - Princeton


Z-Machine - Sandia

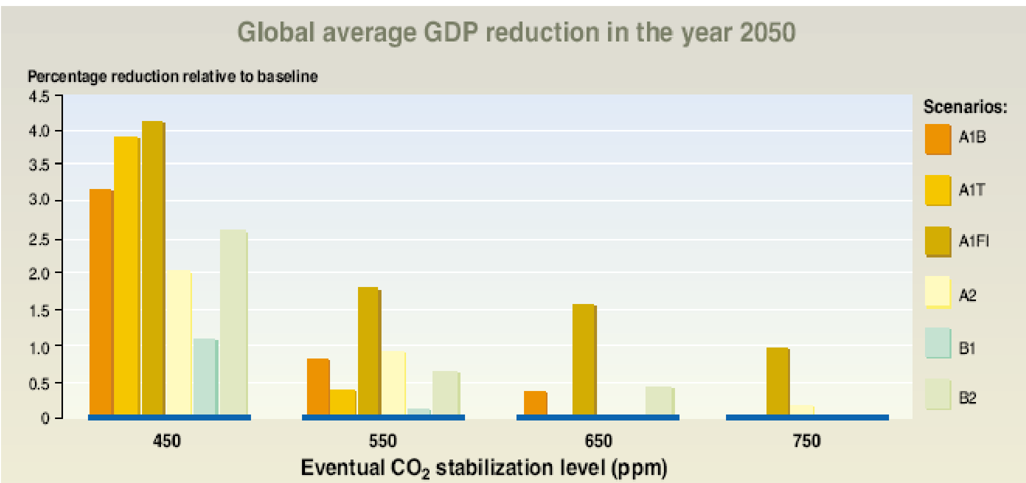


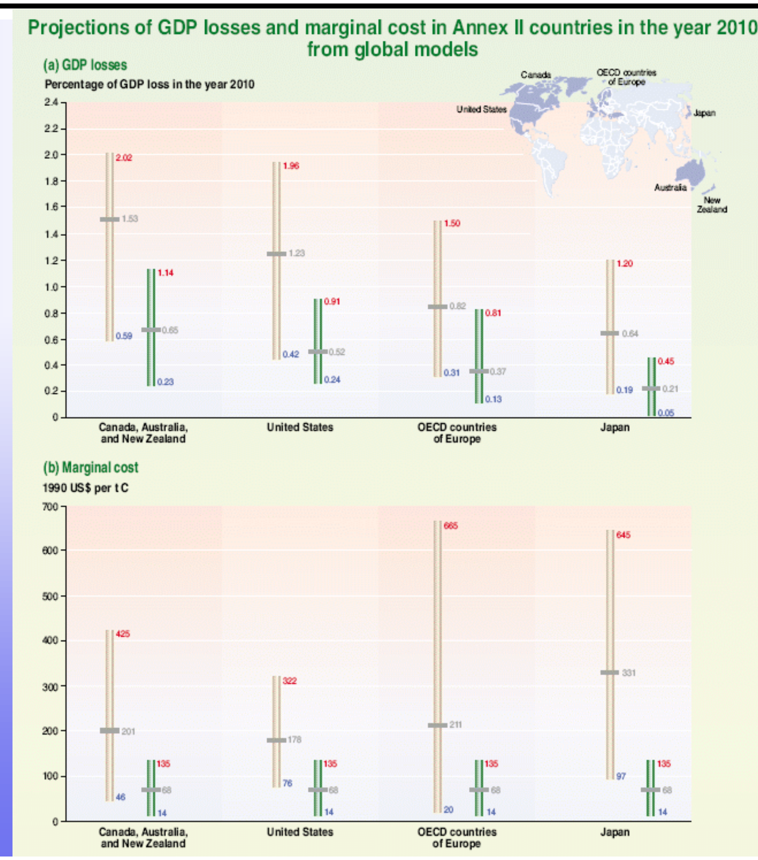


Plasma Fusion Reactors for the Future

Table TS-1: The SRES scenarios and their implications for atmospheric composition, climate, and sea level. Values of population, GDP, and per capita income ratio (a measure of regional equity) are those applied in integrated assessment models used to estimate emissions (based on Tables 3-2 and 3-9).

Date	Global Population (billions)[a]	Global GDP (10^{12} US$ yr^{-1})[b]	Per Capita Income Ratio[c]	Ground-Level O_3 Concentration (ppm)[d]	CO_2 Concentration (ppm)[e]	Global Temperature Change (°C)[f]	Global Sea-Level Rise (cm)[g]
1990	5.3	21	16.1	—	354	0	0
2000	6.1–6.2	25–28	12.3–14.2	40	367	0.2	2
2050	8.4–11.3	59–187	2.4–8.2	~60	463–623	0.8–2.6	5–32
2100	7.0–15.1	197–550	1.4–6.3	>70	478–1099	1.4–5.8	9–88





Climate Change 2001: Impacts, Adaptation, and Vulnerability

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Climate Change 2001: Impacts, Adaptation, and Vulnerability (Intergovernmental Panel on Climate Change)
http://www.grida.no/climate/ipcc_tar/

Planets and Their Atmospheres: Origin and Evolution, J.S. Lewis and R.G. Prinn,Academic Press, 1984.

The Bottom Line:
Study these issues and get involved!

A commitment will be required for mankind to keep this planet as a home for our children!

You have an individual responsibility to keep this planet clean and habitable – it is your home!

We all have a collective responsibility to conserve natural resources and protect the environment!

Man's quest should be to explore the universe and inhabit other worlds! Become a citizen of the universe!