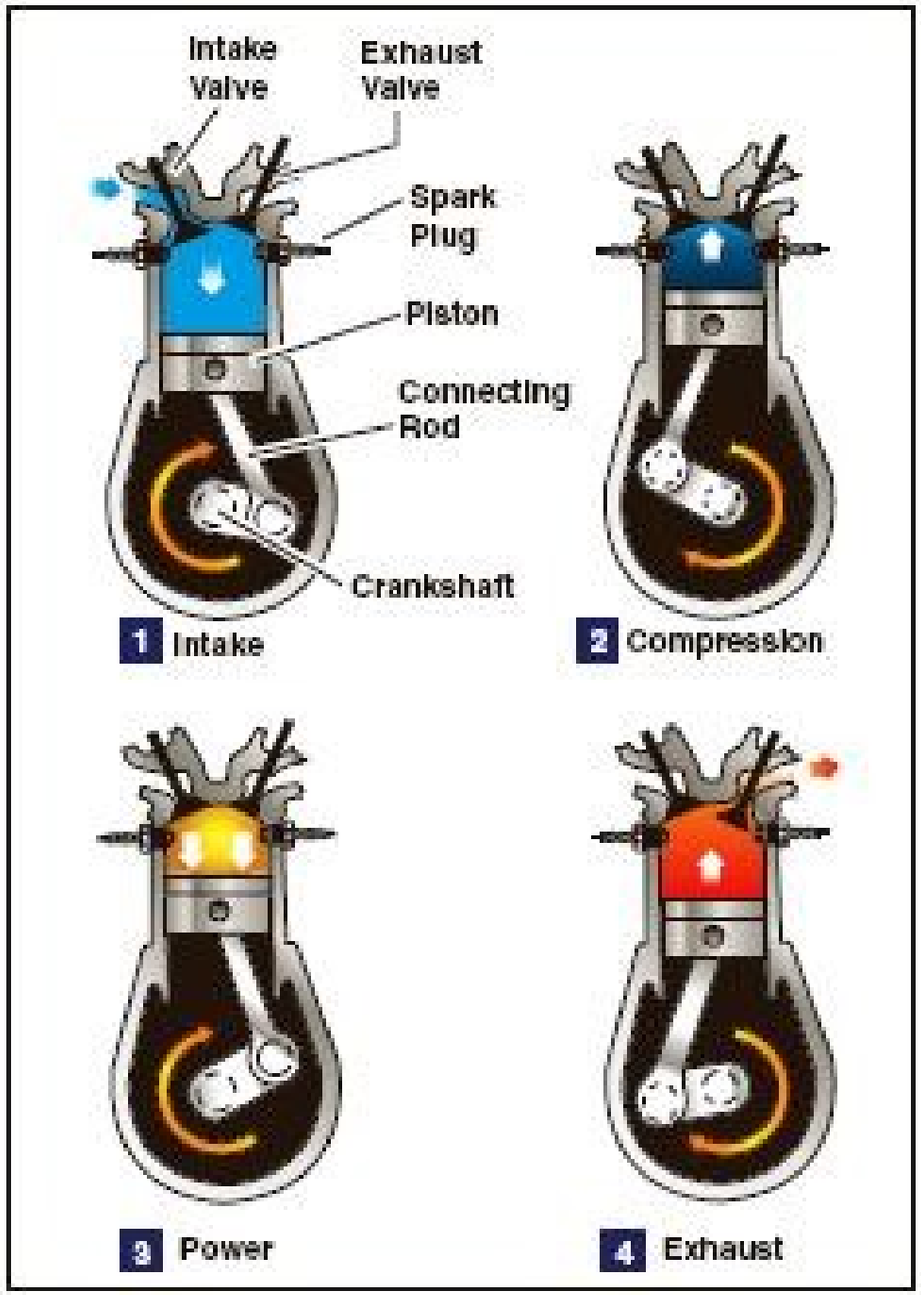
Topic 8: Energy production

What is the connection?

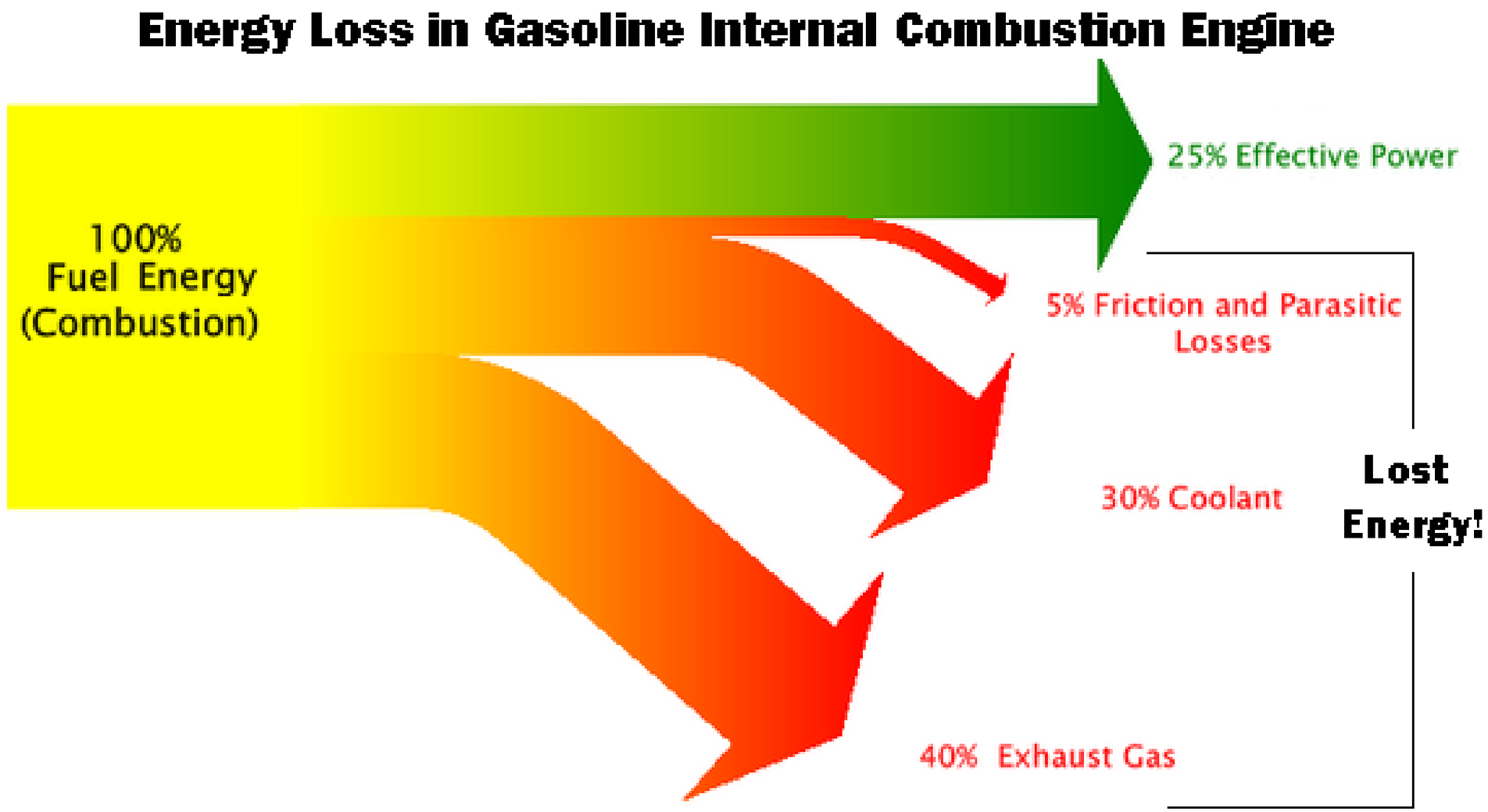
Energy degradation

- We can convert thermal energy to work
- However, the process must be cyclical to provide a steady output
- Also, some energy is "lost" to the surroundings



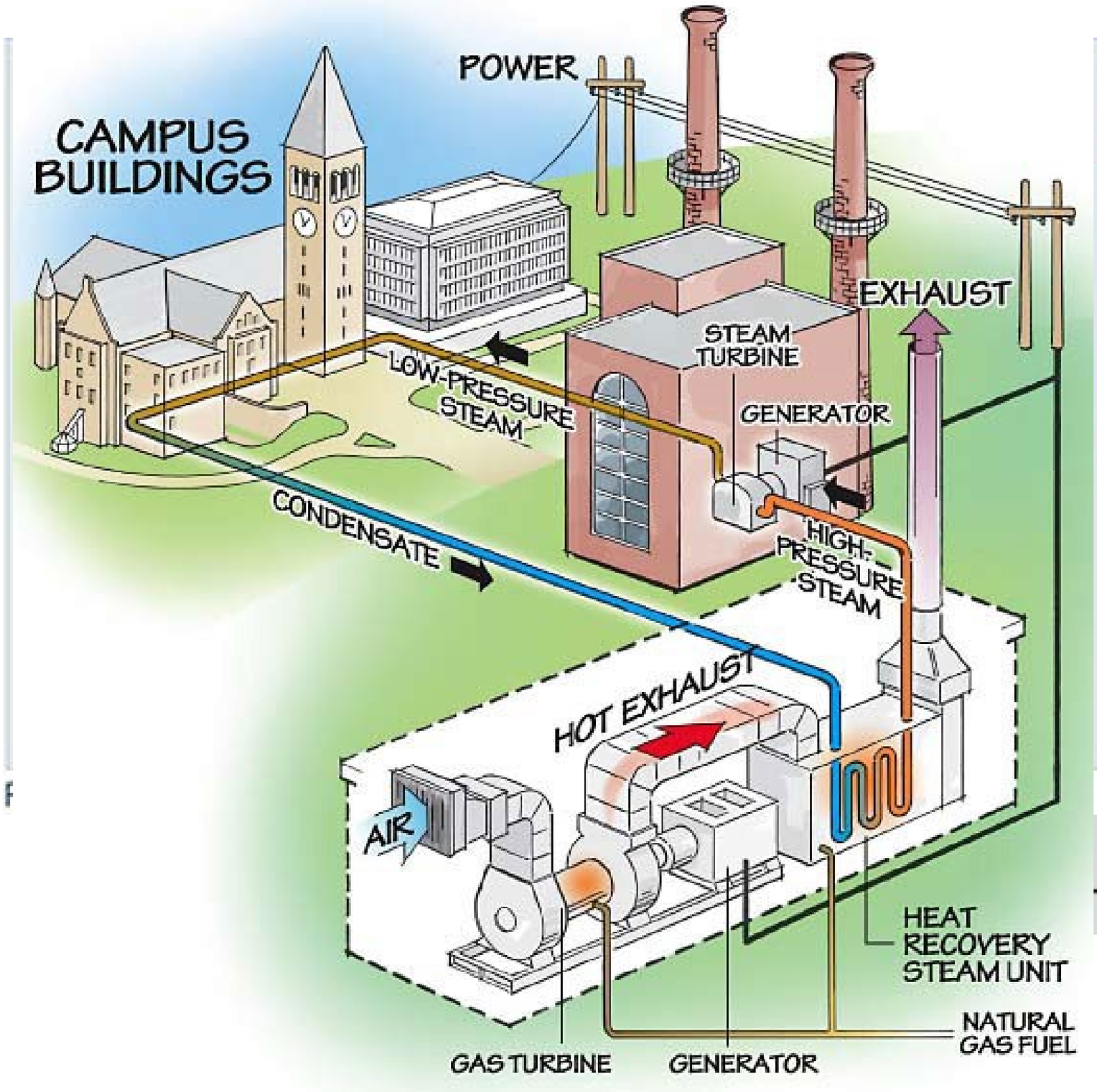
Sankey diagrams

- These show the how much energy is degraded

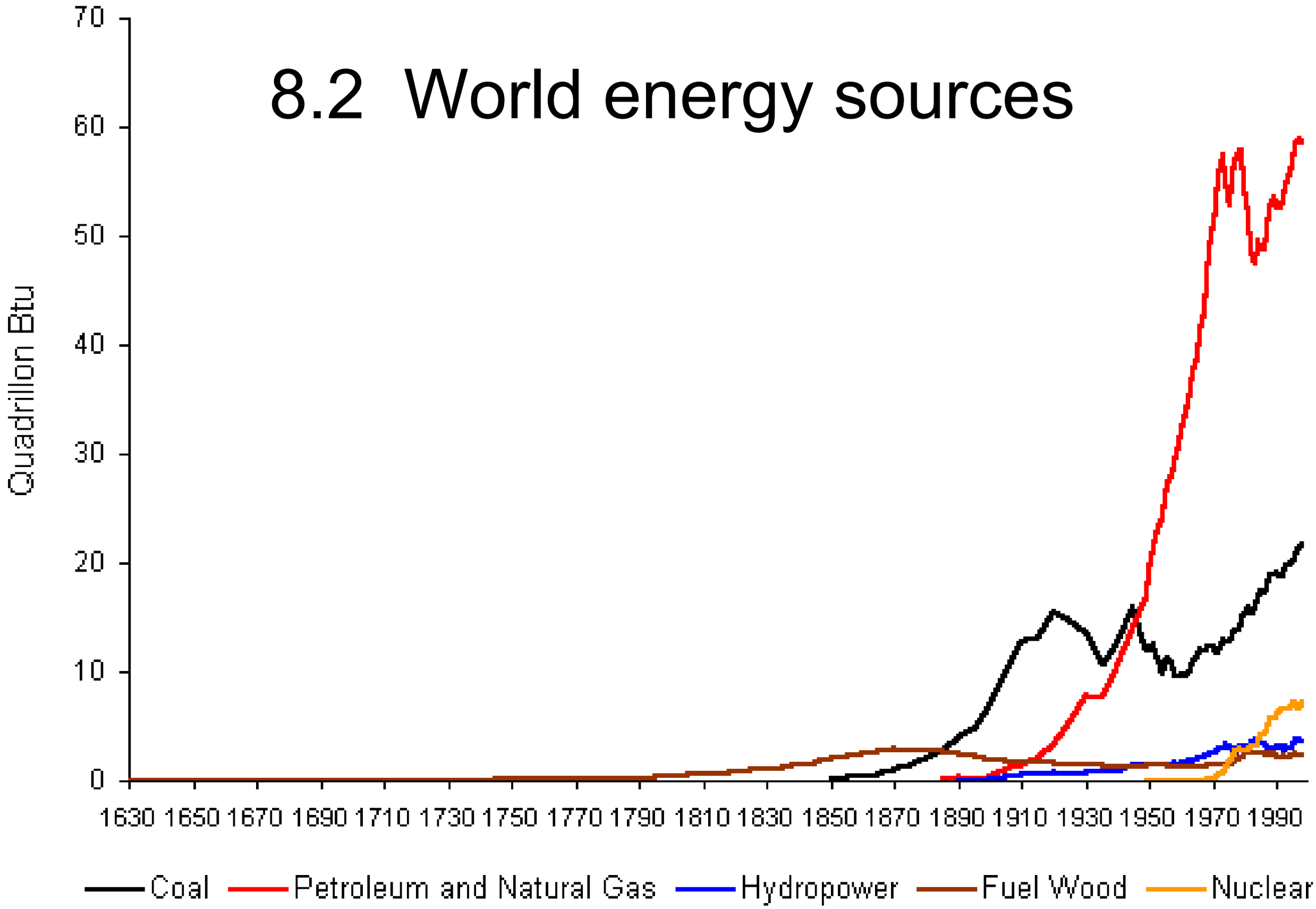


Power plant

- Most of the world's electricity is produced in this way:
- 1. Thermal Energy boils water
- 2. Steam drives turbines
- 3. Turbines spin generator
- 4. Generator sends electrical power to transmission lines



8.2 World energy sources



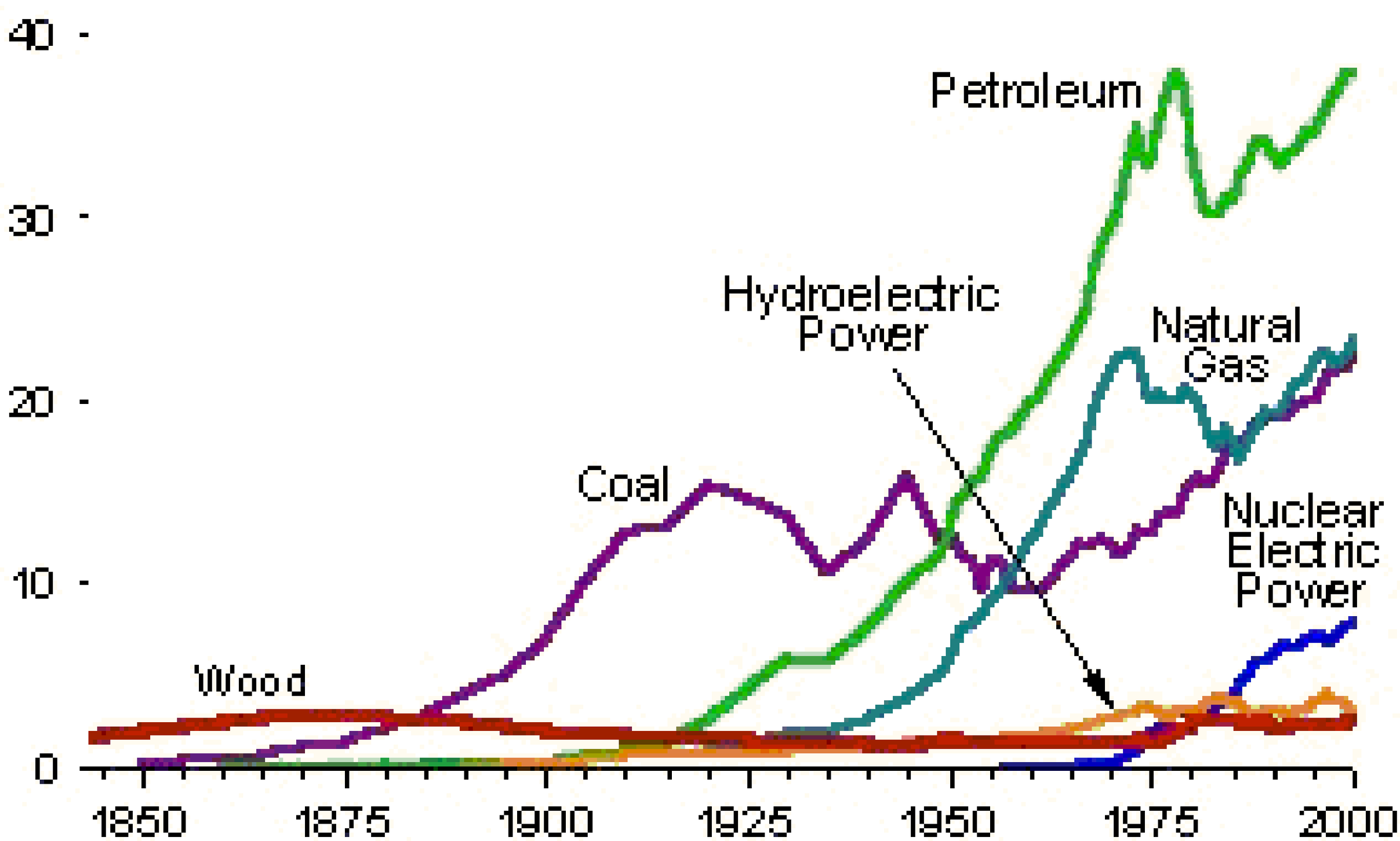
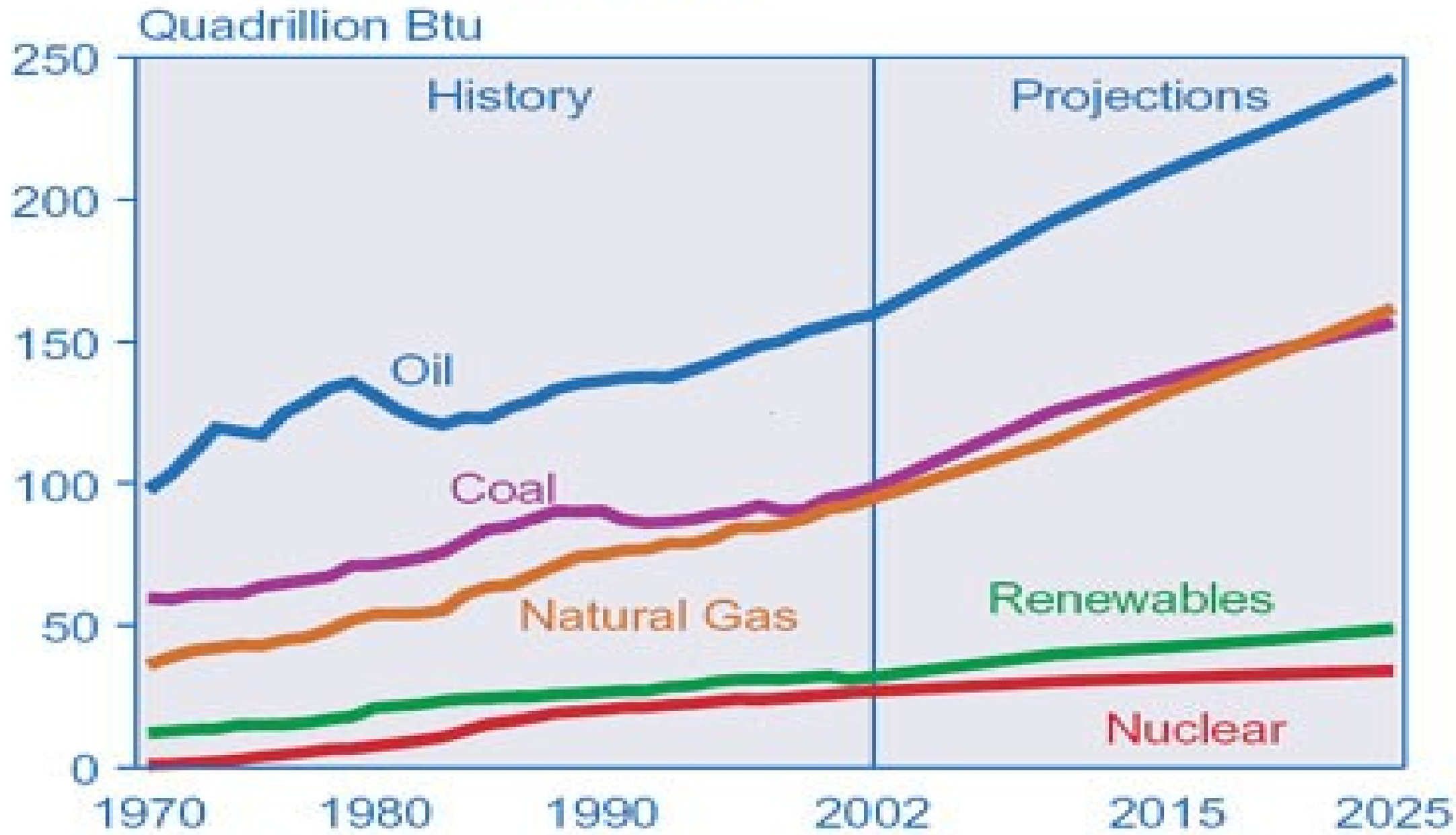
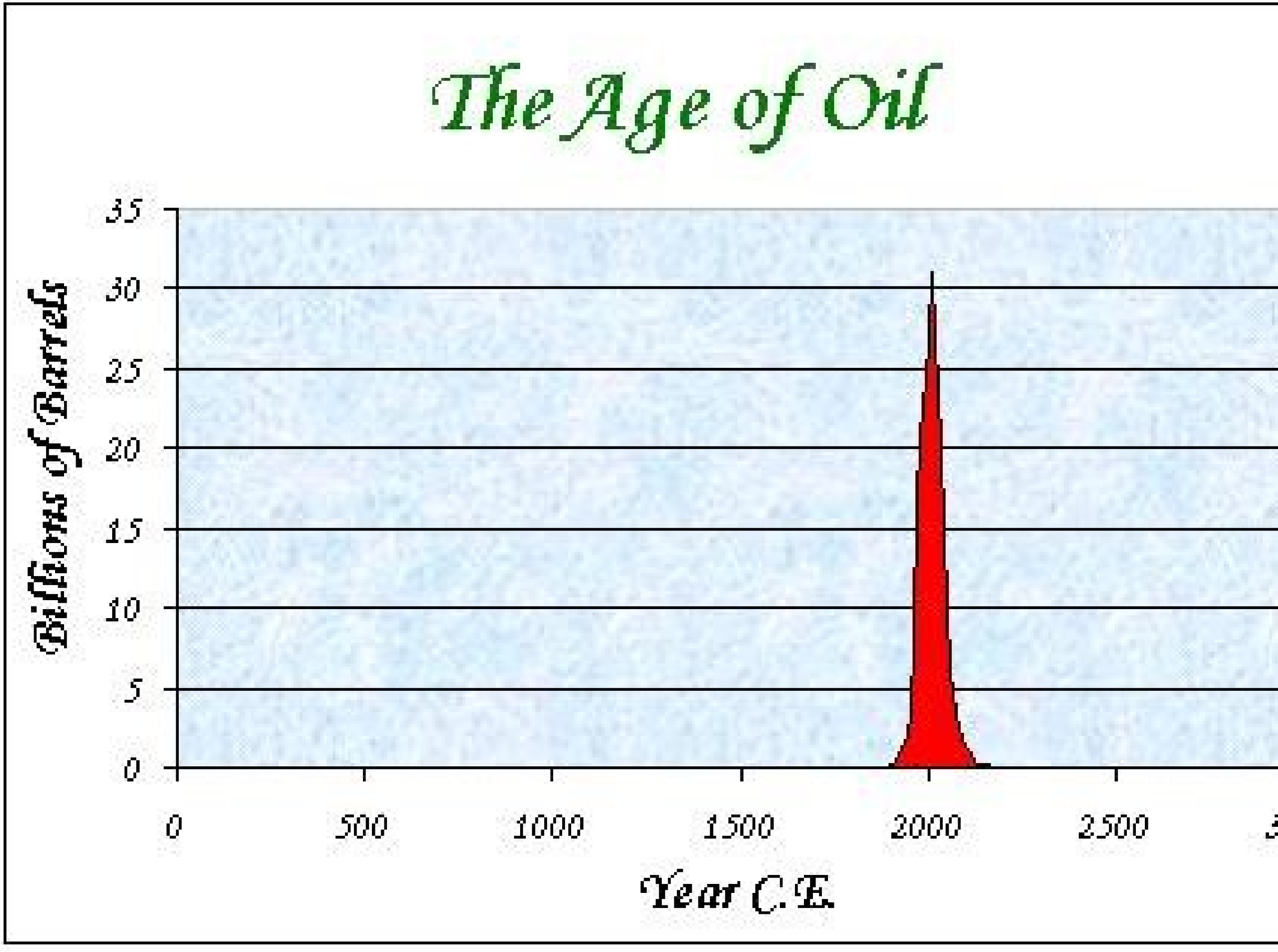

40
30
20
10
0
1850
1875
1900
1925
1950
1975
2000
Petroleum
Hydroelectric Power
Natural Gas
Coal
Nuclear Electric Power
Wood

Figure 10. World Marketed Energy Use by Fuel Type, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2002*, DOE/EIA-0219(2002) (Washington, DC, March 2004), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2005).

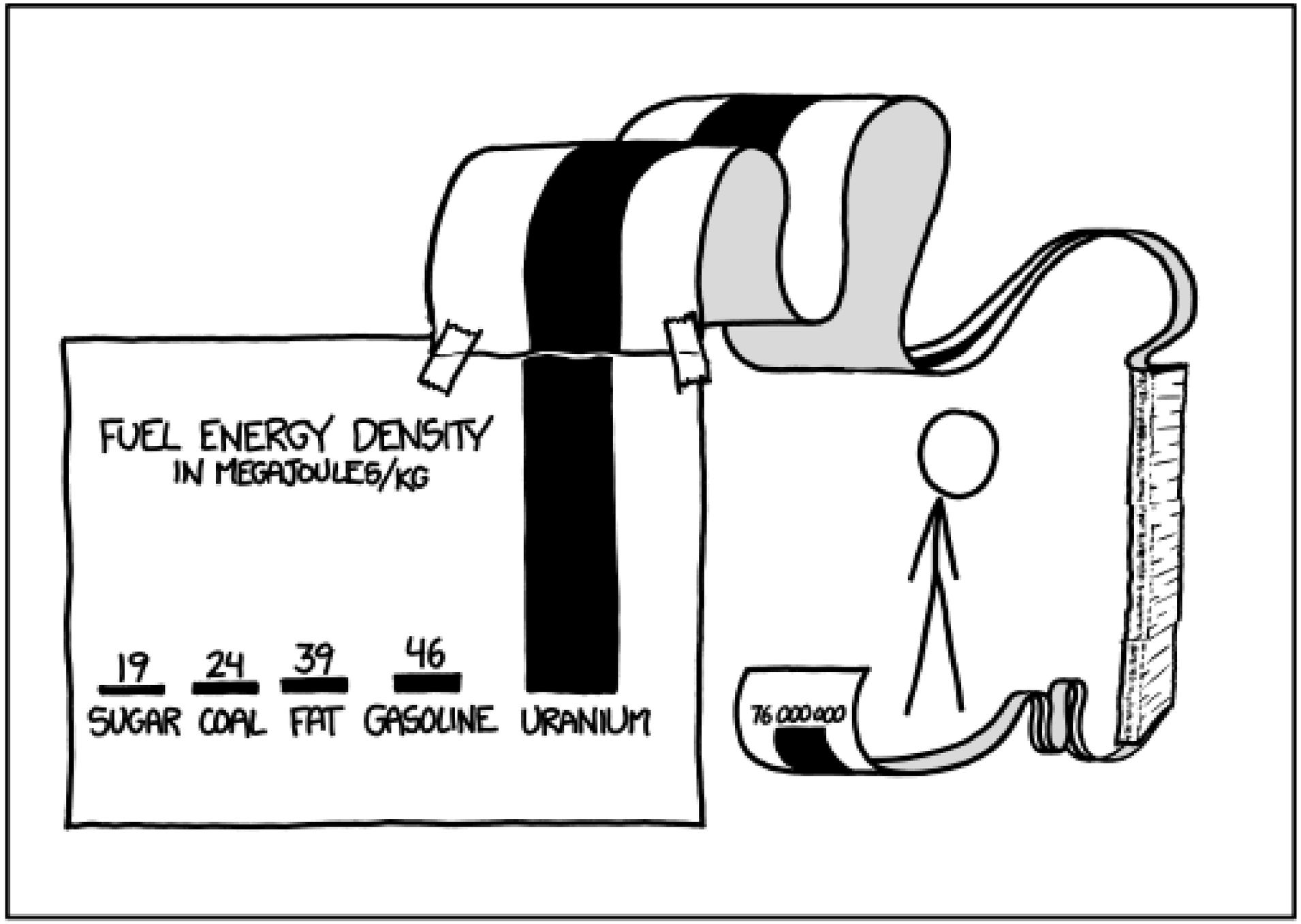

The Age of Oil
Billions of Barrels
35
30
25
20
15
10
5
0
0
500
1000
1500
2000
2500
Year C.E.

Why is oil so difficult to replace?

- Each barrel contains over 6 GJ of "fossil energy"
- This would take a person 8.6 years to produce
- Each Canadian uses 24.7 barrels per year: this is like having 204 "energy slaves" in your household

Energy Density (GJ per ton)

- Wood: 16
- Coal: 29
- Oil: 45
- Gas: 54
- Uranium: 56,000



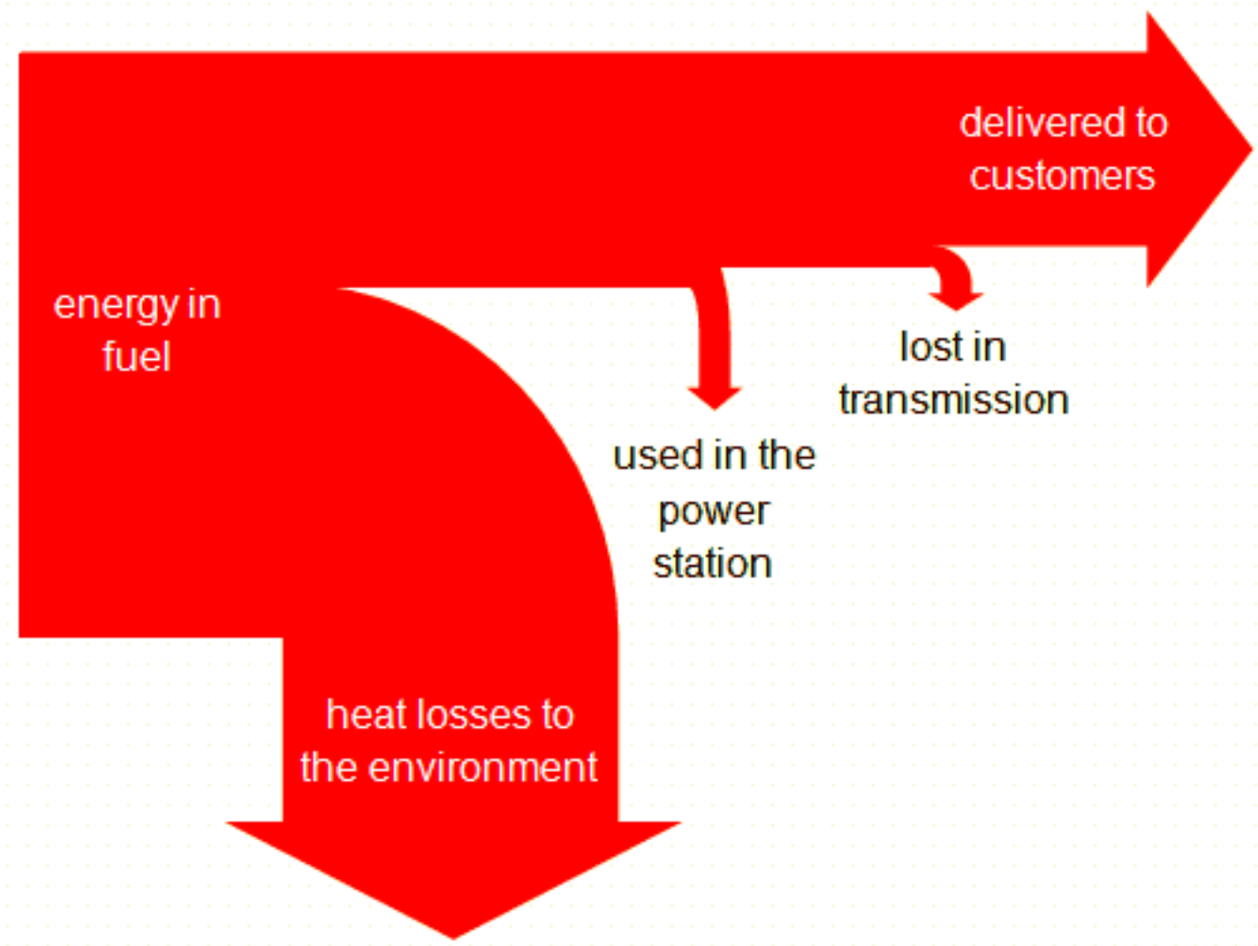
SCIENCE TIP: LOG SCALES ARE FOR QUITTERS WHO CAN'T FIND ENOUGH PAPER TO MAKE THEIR POINT *PROPERLY*.

Consequences of energy density

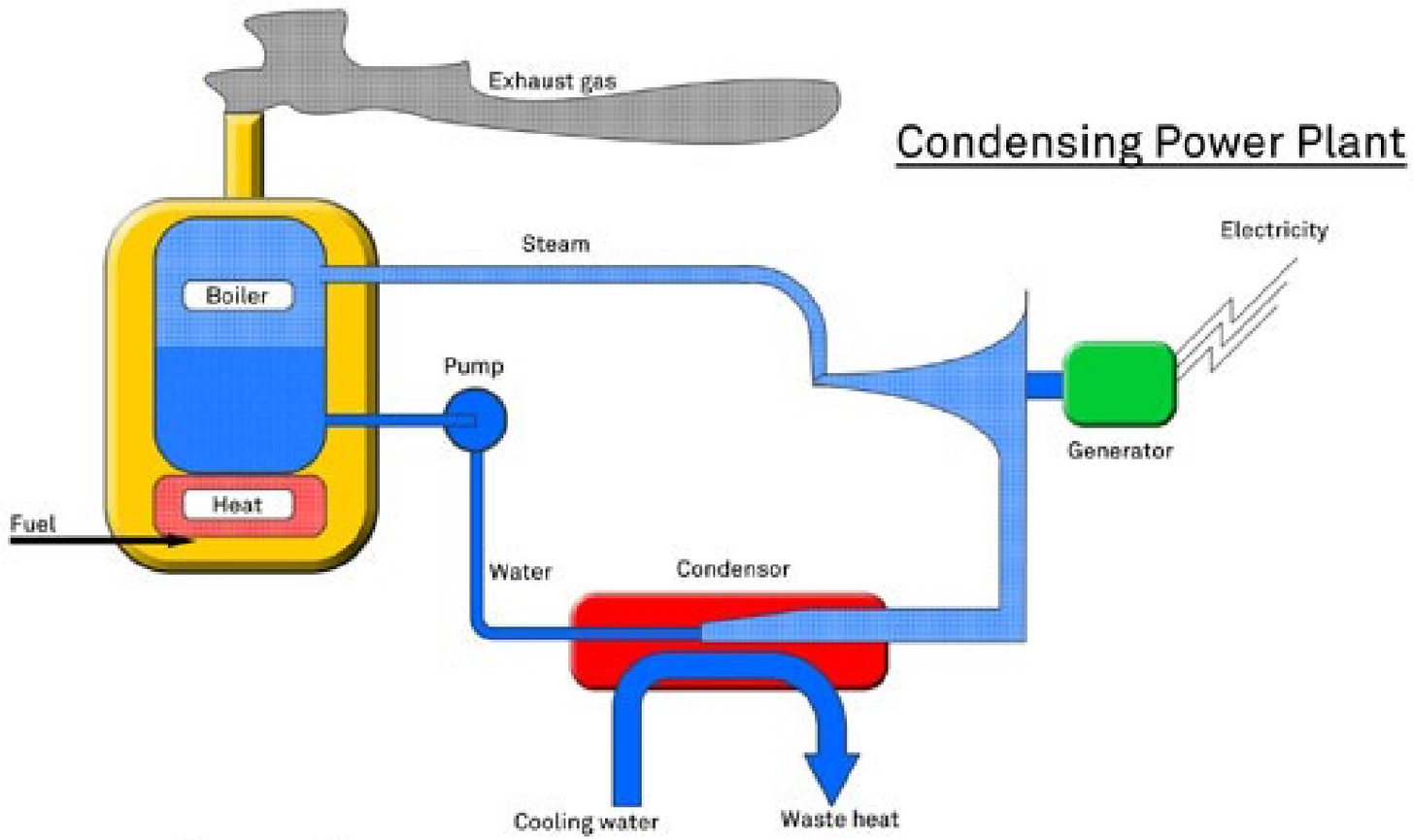
- Transport
- Storage
- Applications

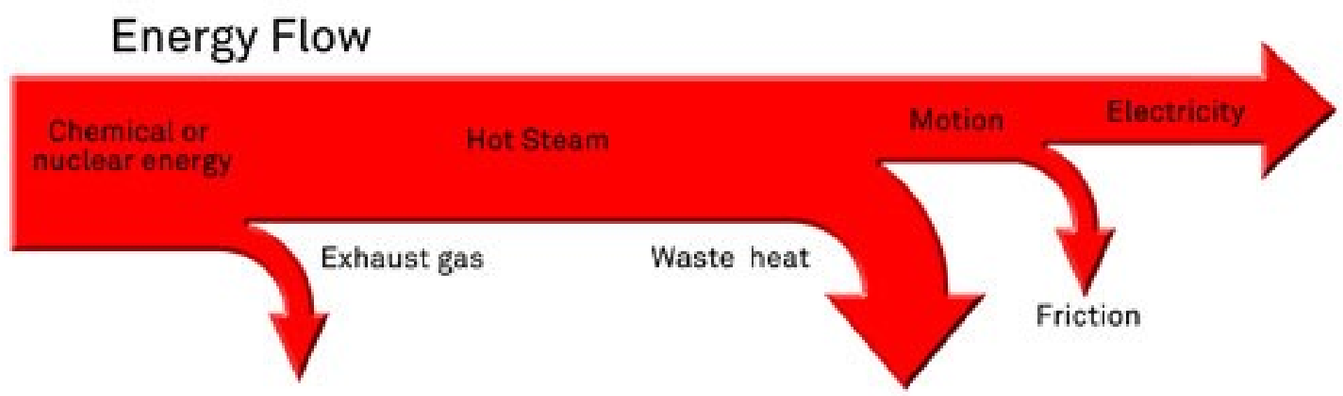
Efficiency of a power plant

- Coal 35-42%
- Natural gas 45-52%
- Oil 38-45%



Exercises p. 268 #1-2





Can we calculate the rate of coal use?

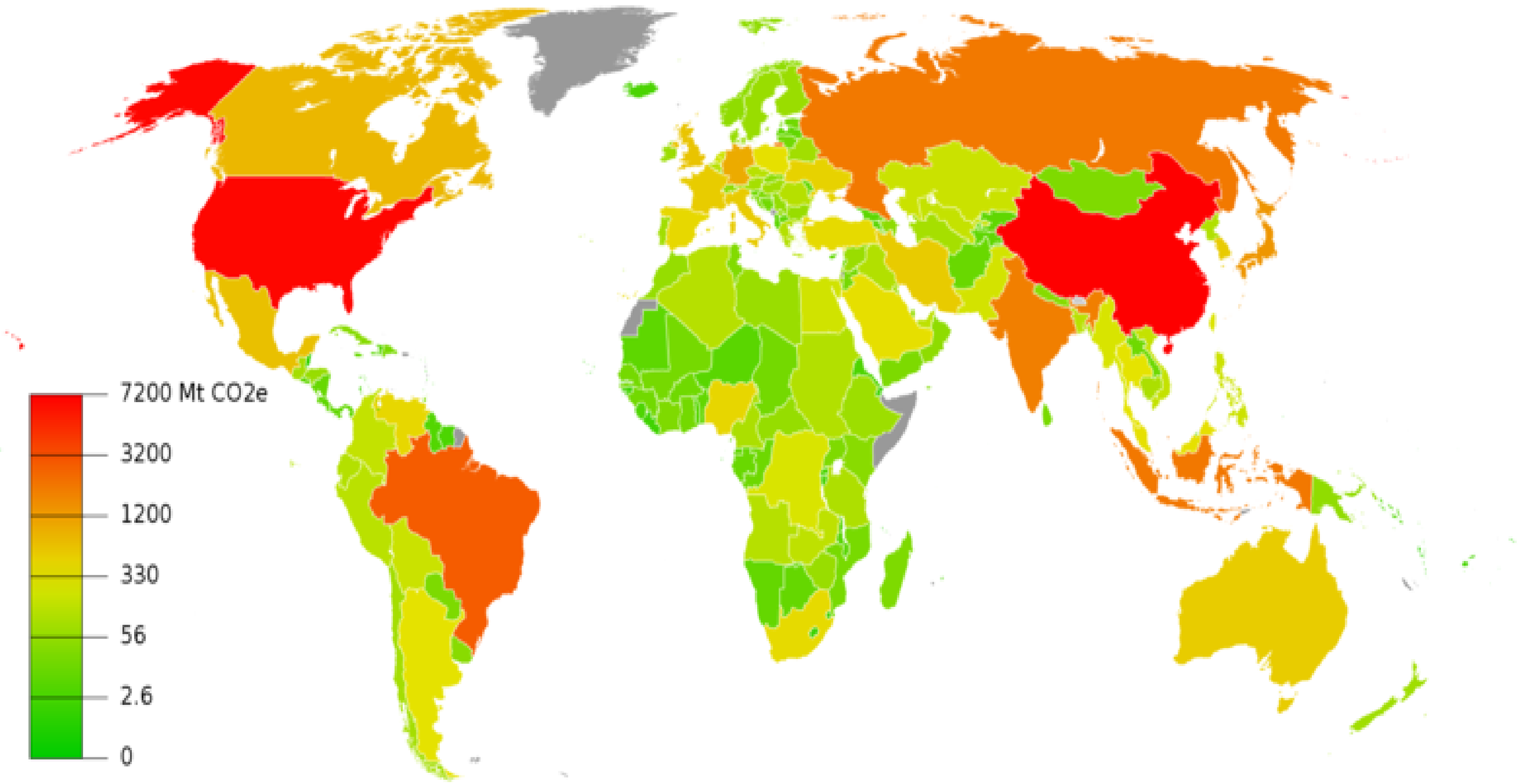
- Typical coal plant: 1 GW
- Average efficiency 40%
- How much coal is used in one year?

How much coal is used in one year?

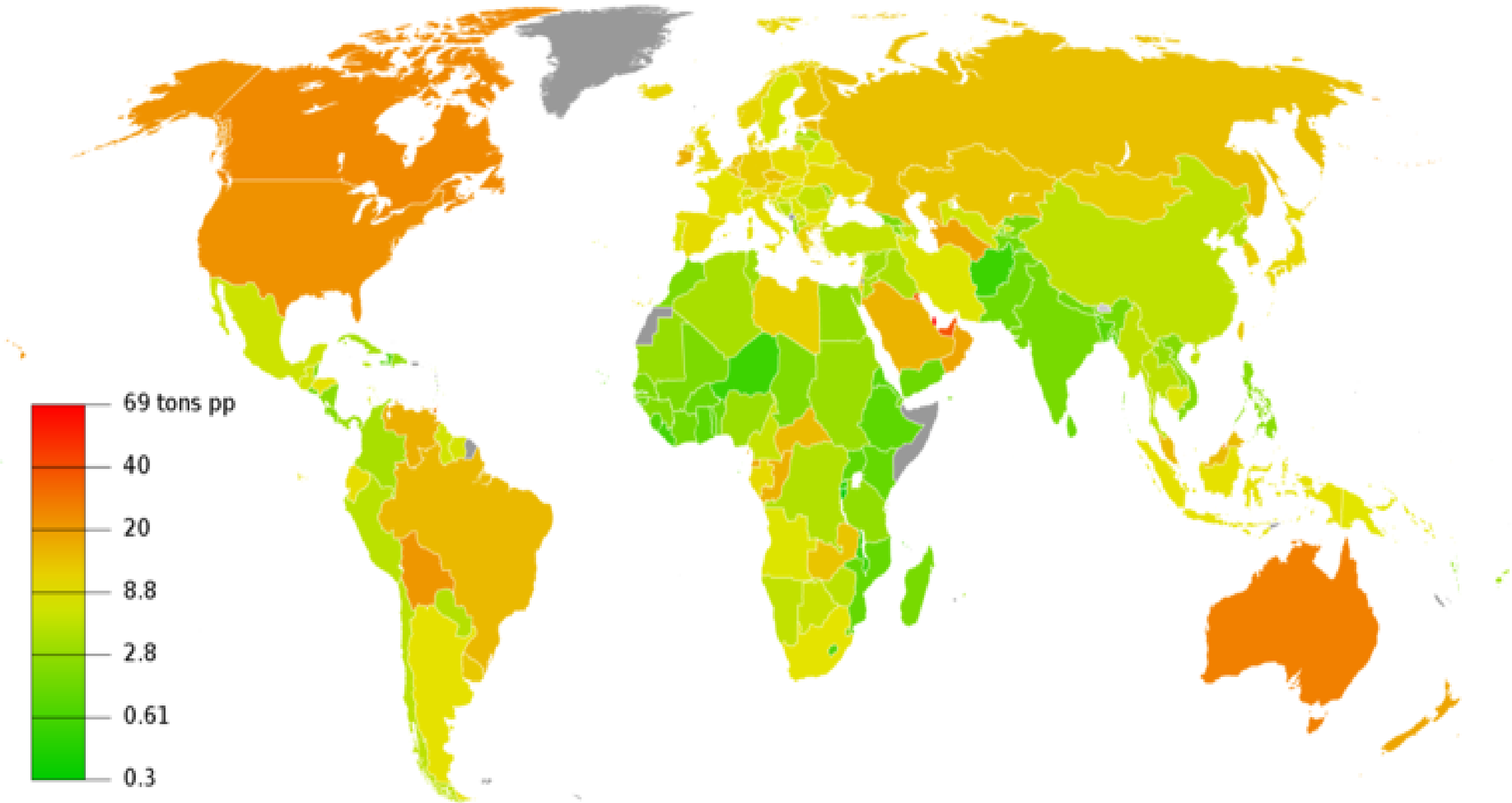
- Typical coal plant: 1 GW
- Divide by efficiency 40%= 2.5GJ per s
- Divide by 29 GJ per ton of coal = 0.086 ton per s
- Multiply by 3.16E7s in one year = 2.7 million tons
- 2.7 billion kg of coal per year

Who is burning the most fossil fuels?

GHG by country



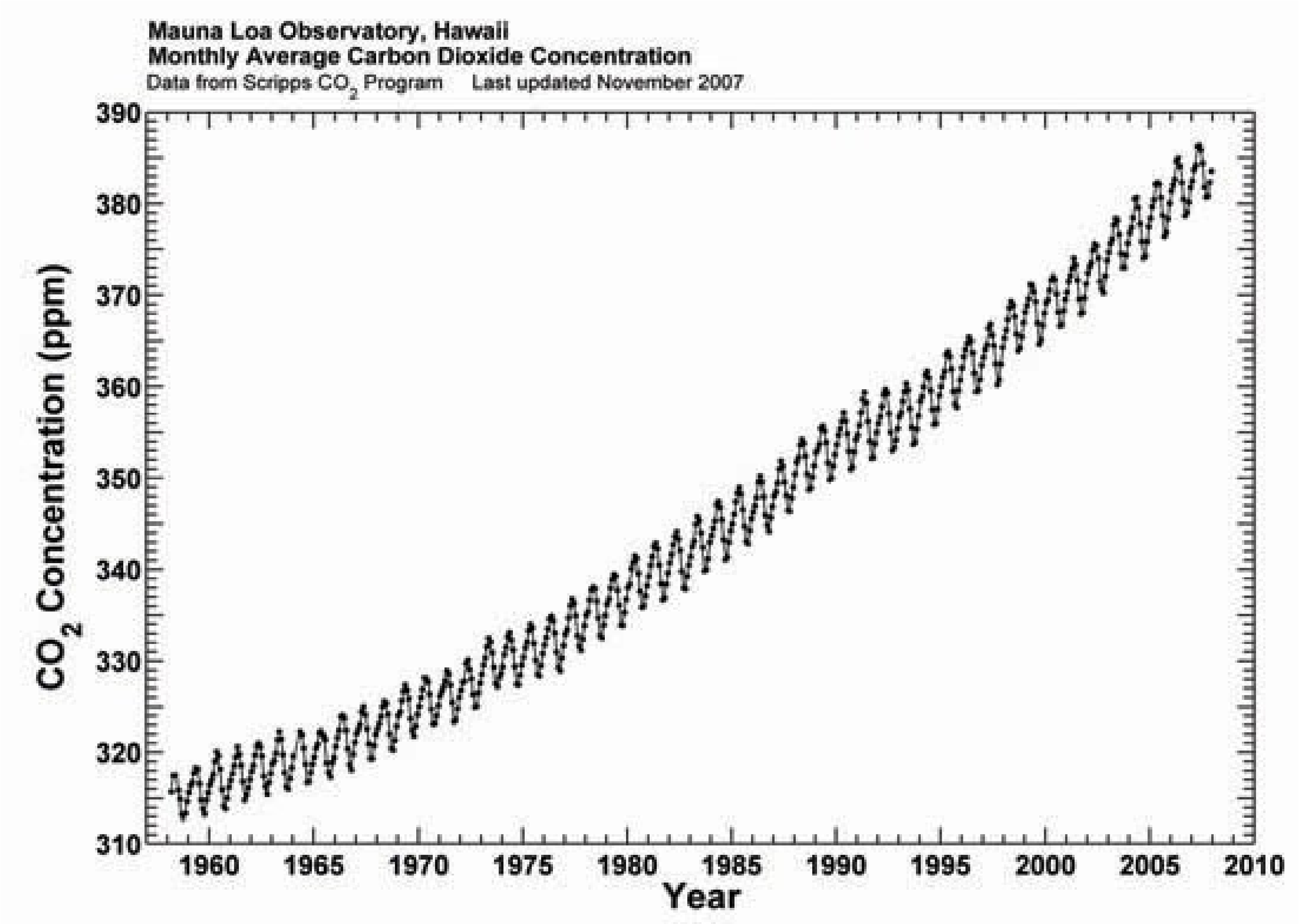
GHG per capita 2005



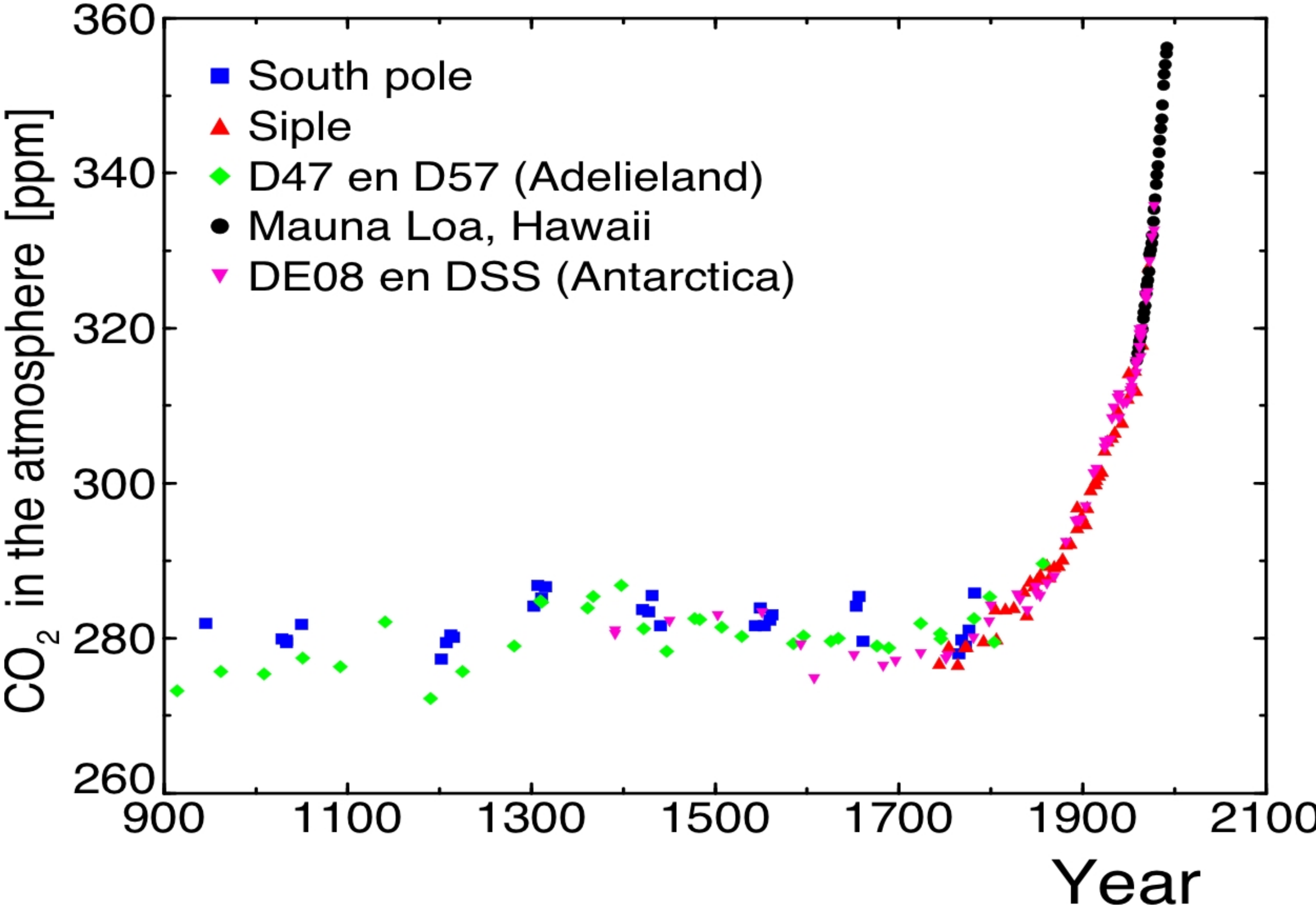
Fossil fuel CO2 emissions (kg per GJ)

- NaturalGas: 58
- LPG: 60
- CrudeOil: 76
- Coal(electricity): 290

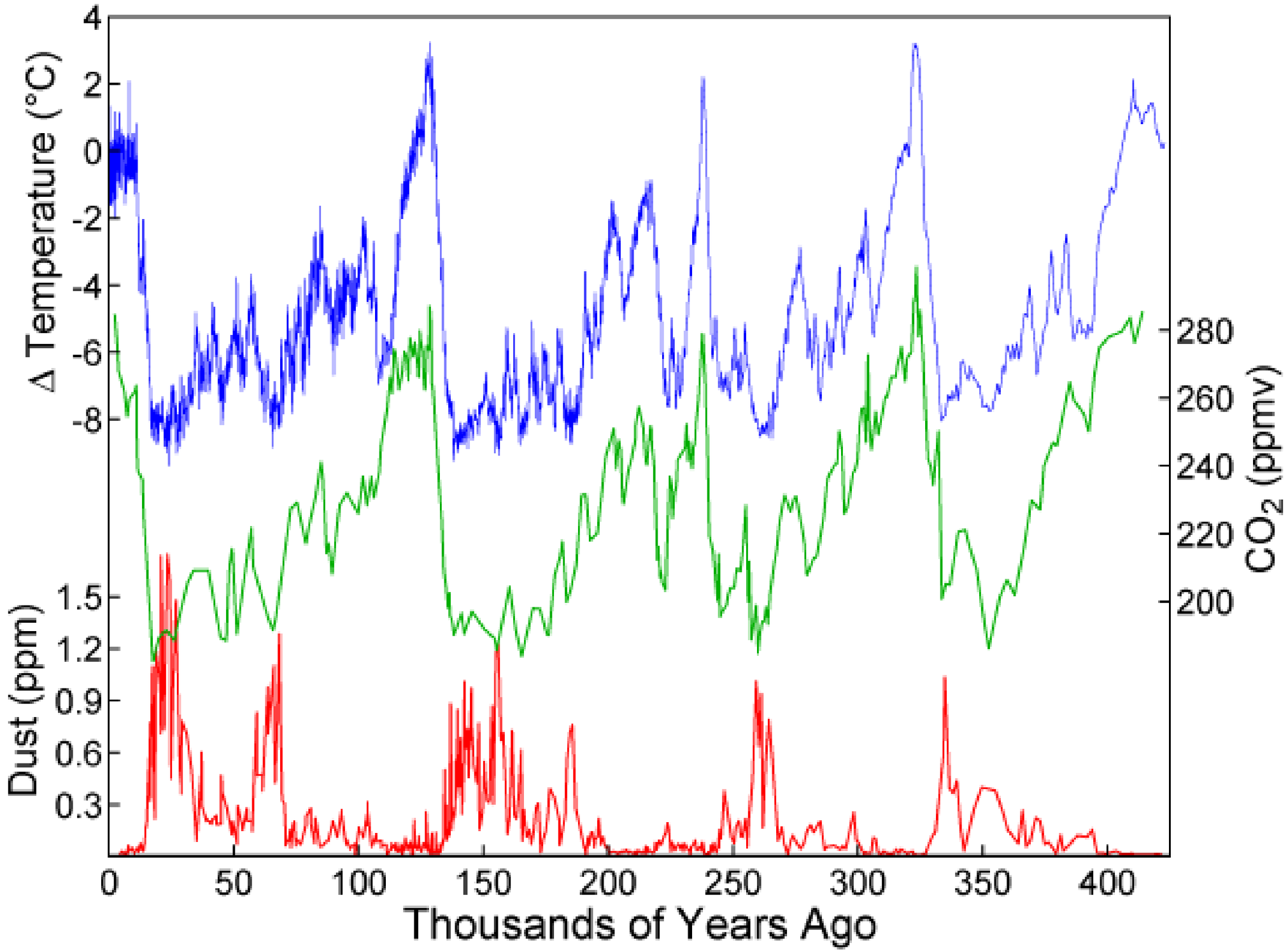
CO2 Concentration: weather balloons

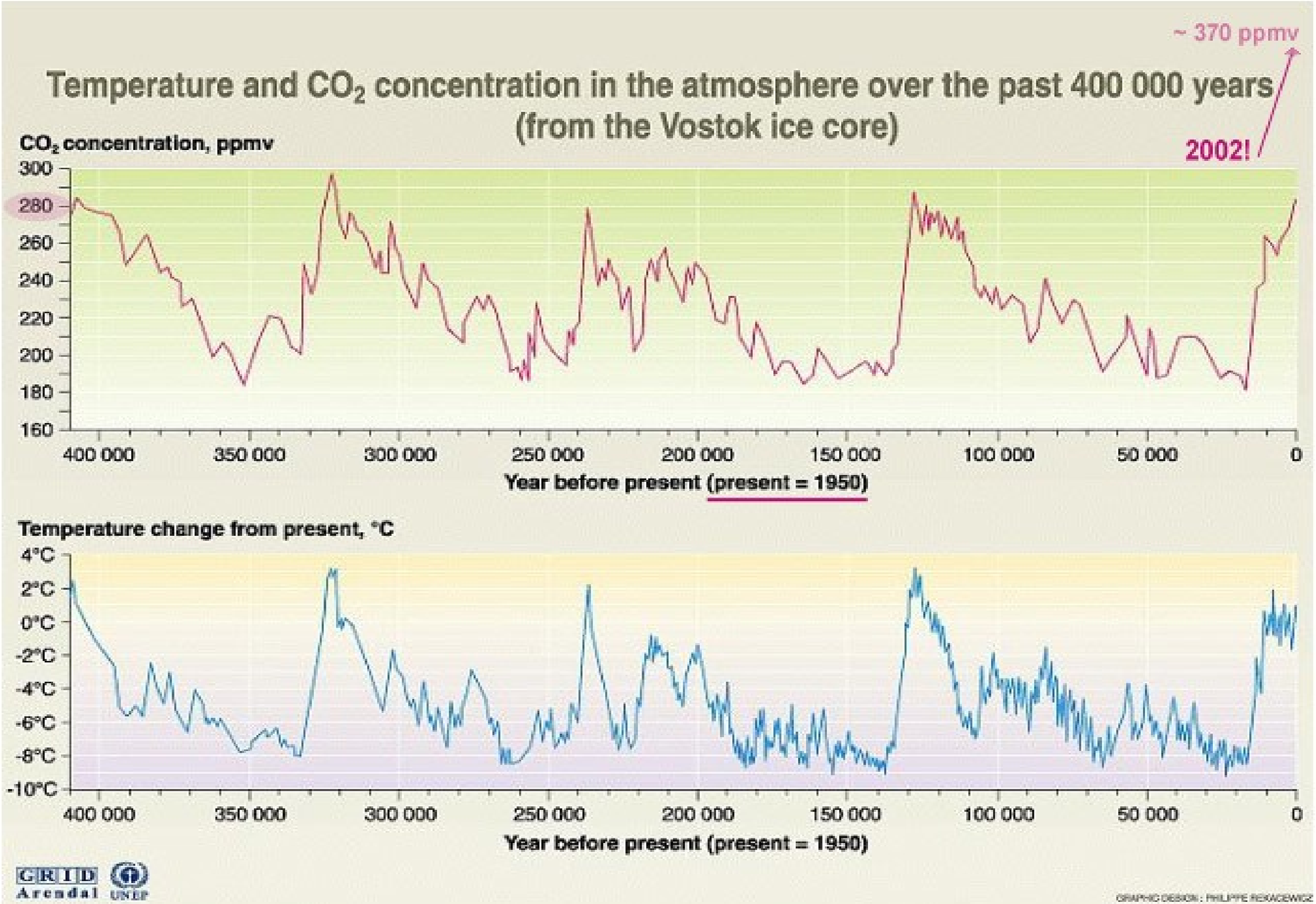


Ice cores


South pole
Siple
D47 en D57 (Adelieland)
Mauna Loa, Hawaii
DE08 en DSS (Antarctica)
CO_2 in the atmosphere [ppm]
360
340
320
300
280
260
900
1100
1300
1500
1700
1900
2100
Year

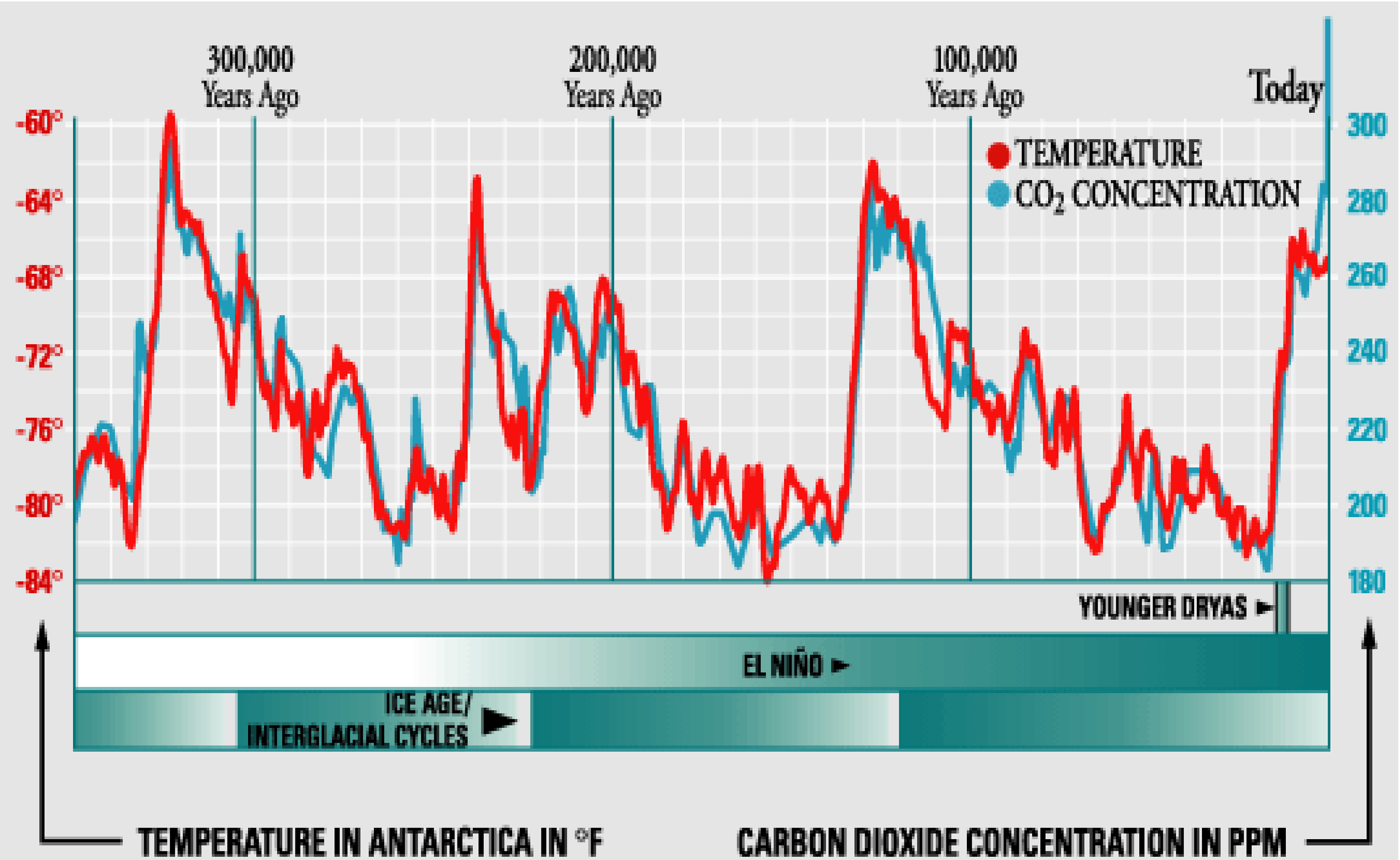
Vostok ice core data



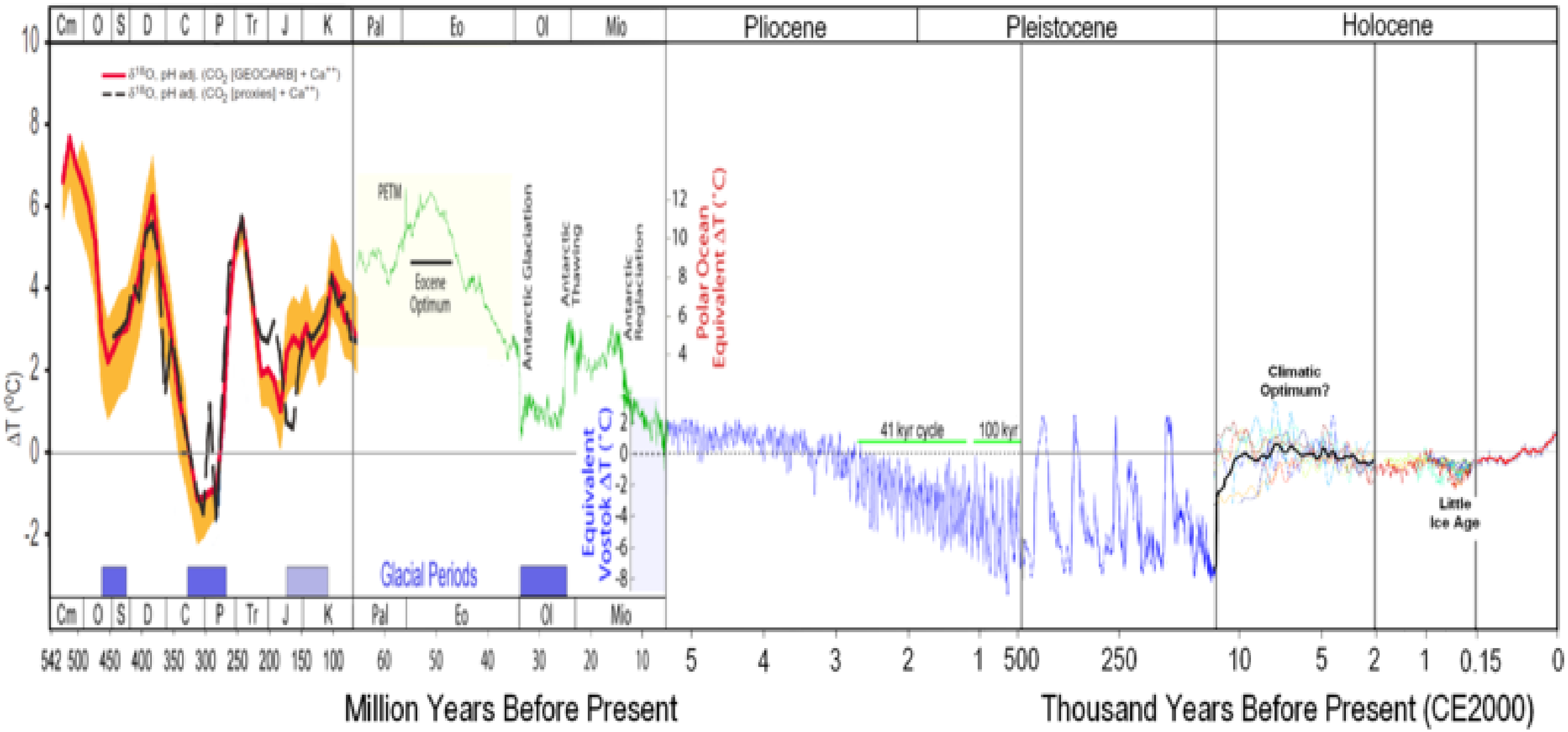


Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.

(Note: 2002 information added to diagram)


300,000 Years Ago
200,000 Years Ago
100,000 Years Ago
Today
-60°
-64°
-68°
-72°
-76°
-80°
-84°
300
280
260
240
220
200
180
TEMPERATURE
CO2 CONCENTRATION
YOUNGER DRYAS
EL NIÑO
ICE AGE/ INTERGLACIAL CYCLES
TEMPERATURE IN ANTARCTICA IN °F
CARBON DIOXIDE CONCENTRATION IN PPM

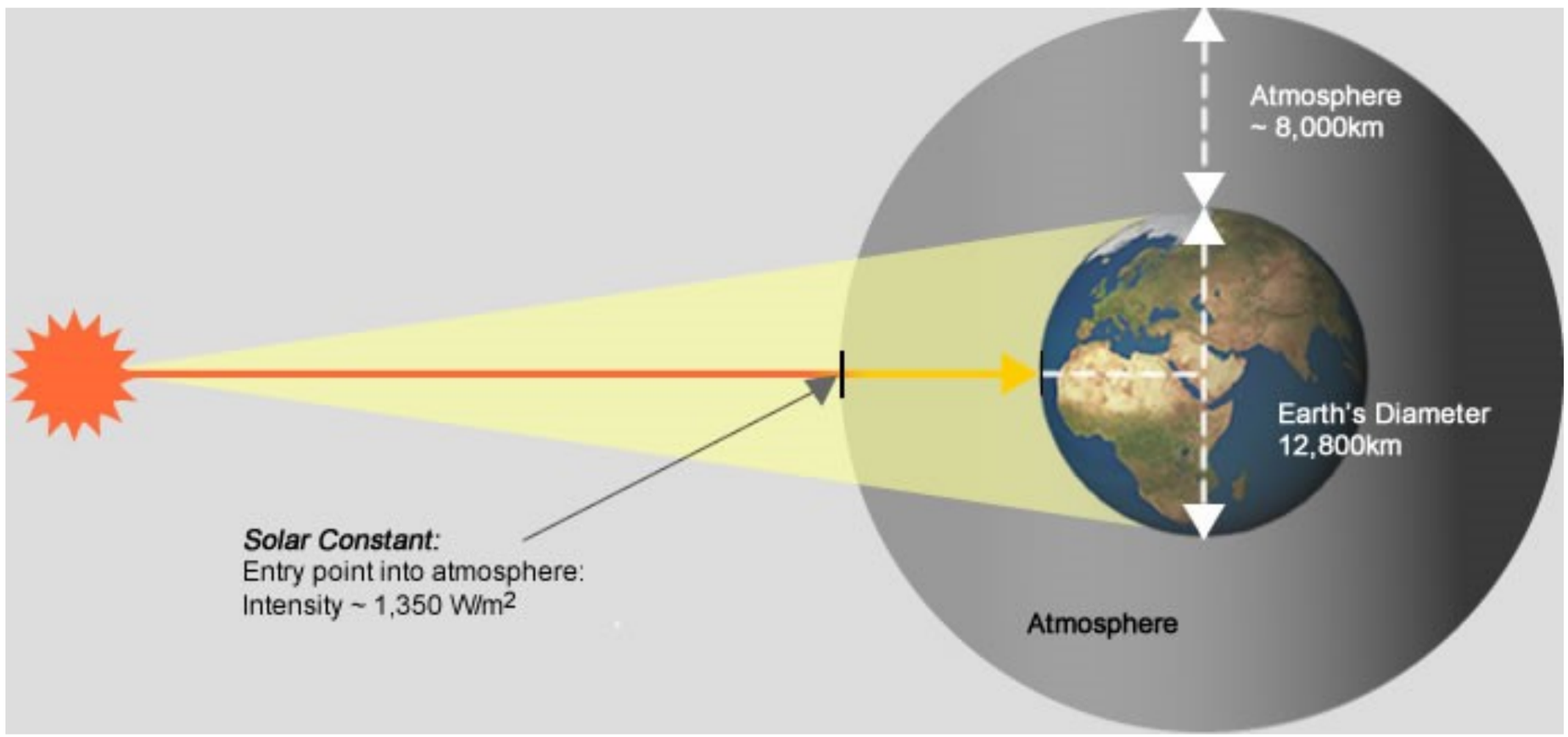
Temperature of Planet Earth



Start p. 327 #2-5

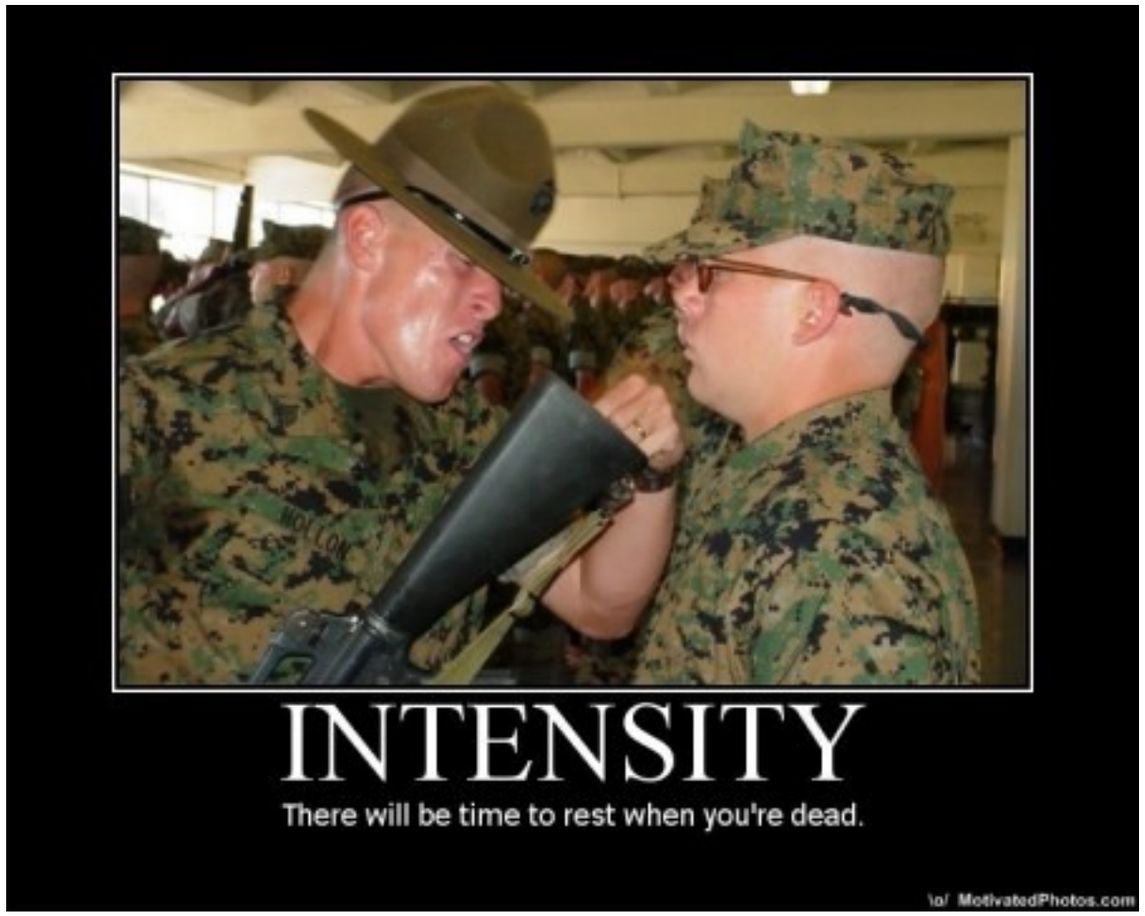
Solar Constant

- The sun radiates 3.9E26W



Intensity

$$I = \frac{power}{A}$$



Intensity

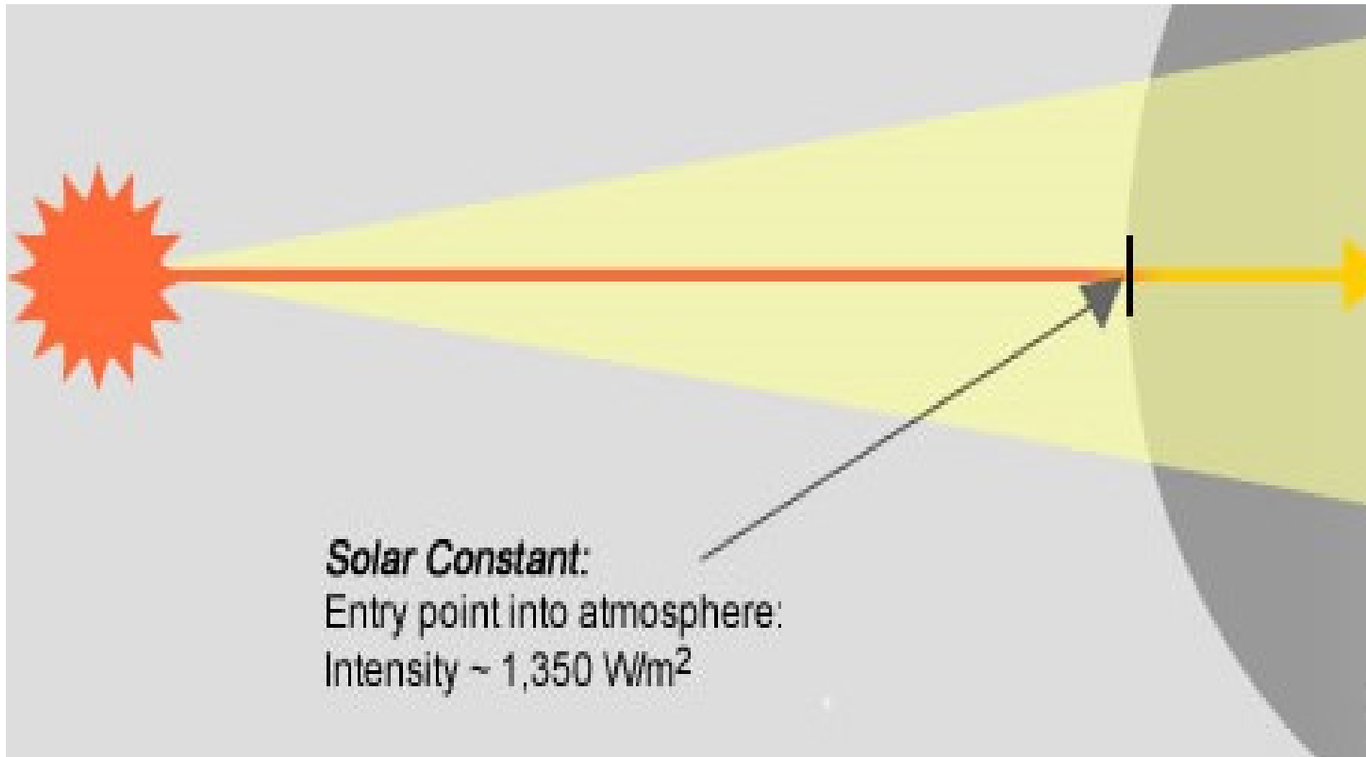
- The sun radiates 3.9E26W
- Calculate the light intensity at the Earth

$$I = \frac{power}{A}$$

$$I = 1.4 kW \cdot m^{-2}$$

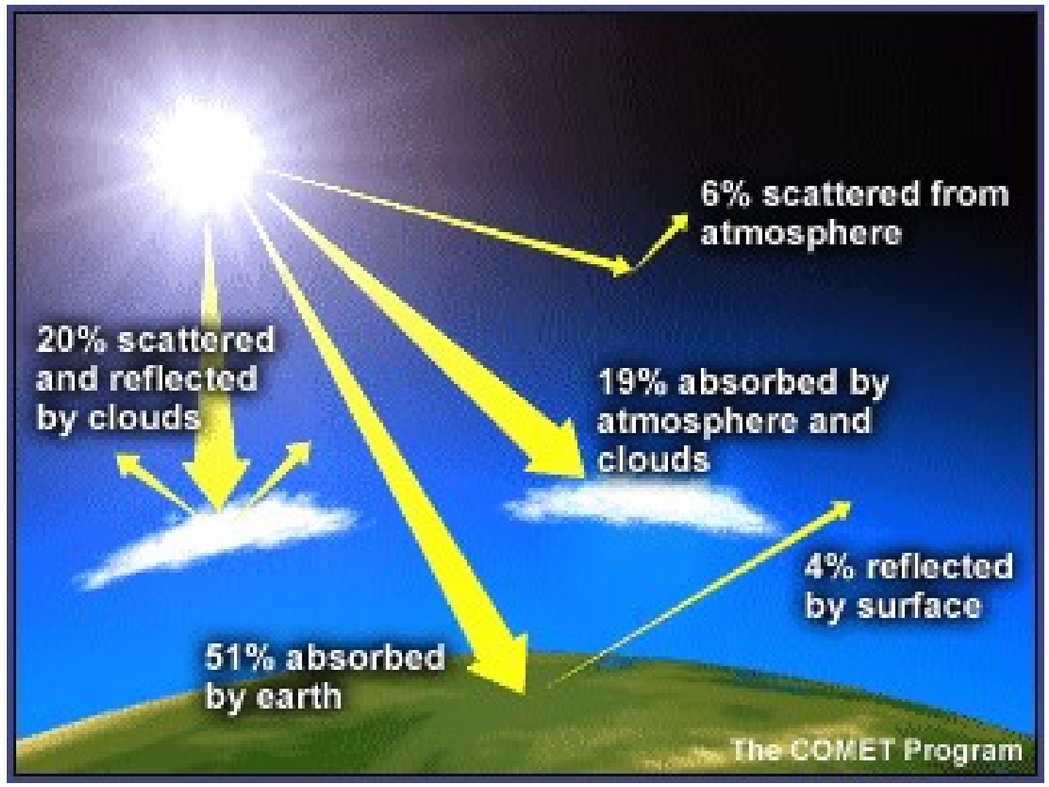
$$I = \frac{power}{4\pi r^2}$$

$$I = \frac{3.9 \times 10^{26} W}{4\pi (1AU)^2}$$

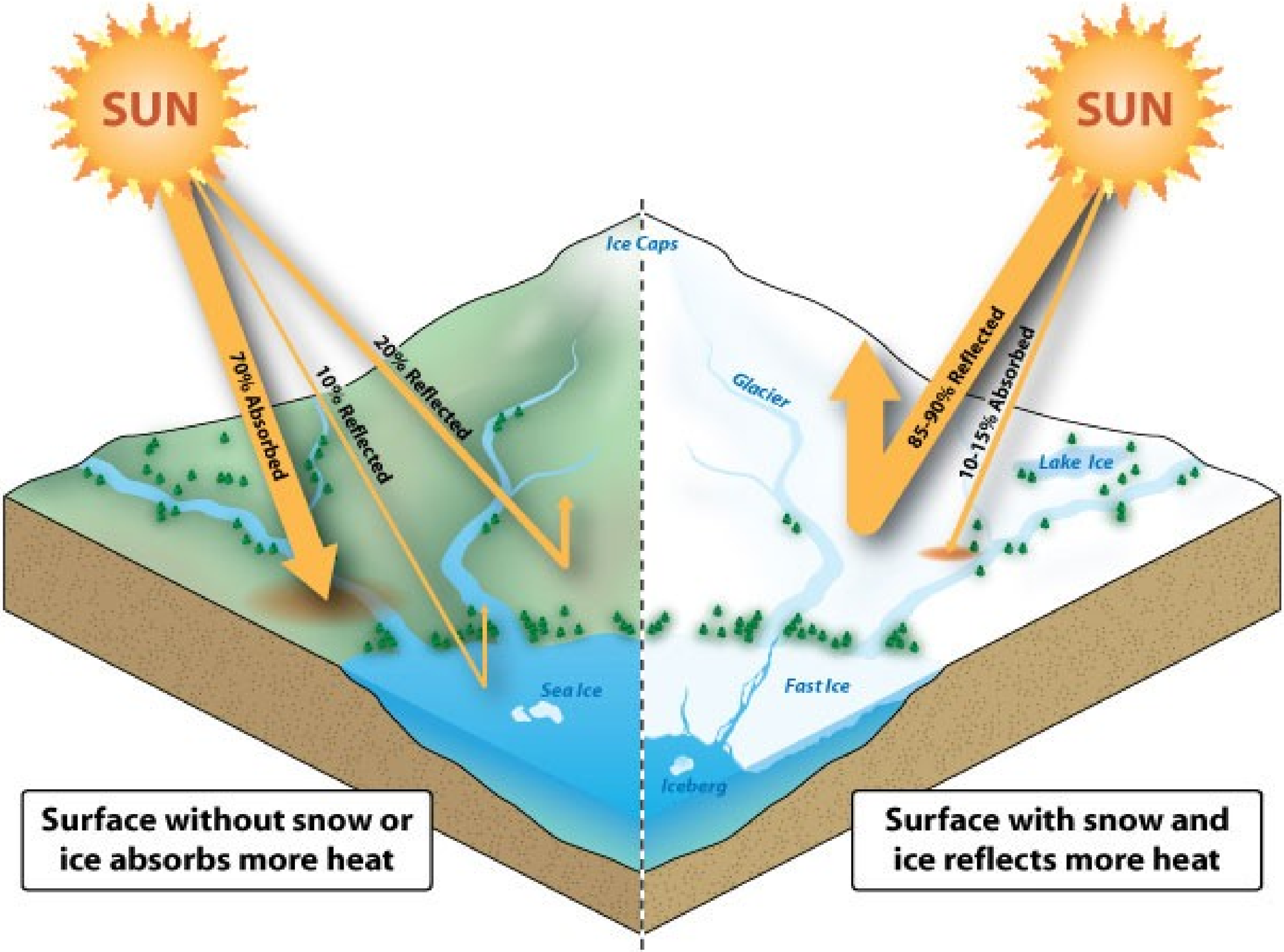


Albedo

How much of the sun's energy is reflected?



$$\text{Albedo} = \frac{\text{total scattered power}}{\text{total incident power}}$$

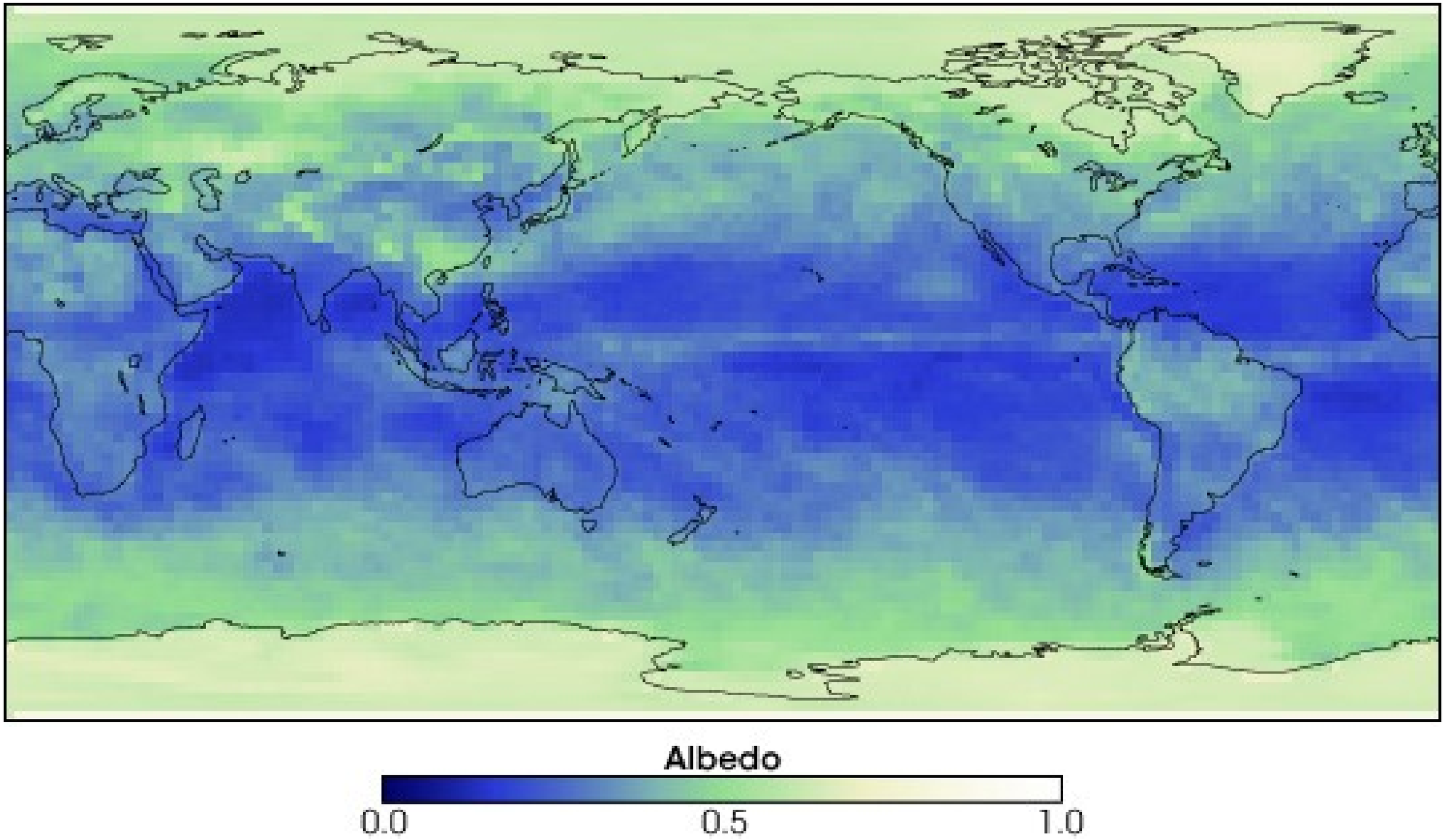


the-m-factory.com 410.420.8032

Albedo variations

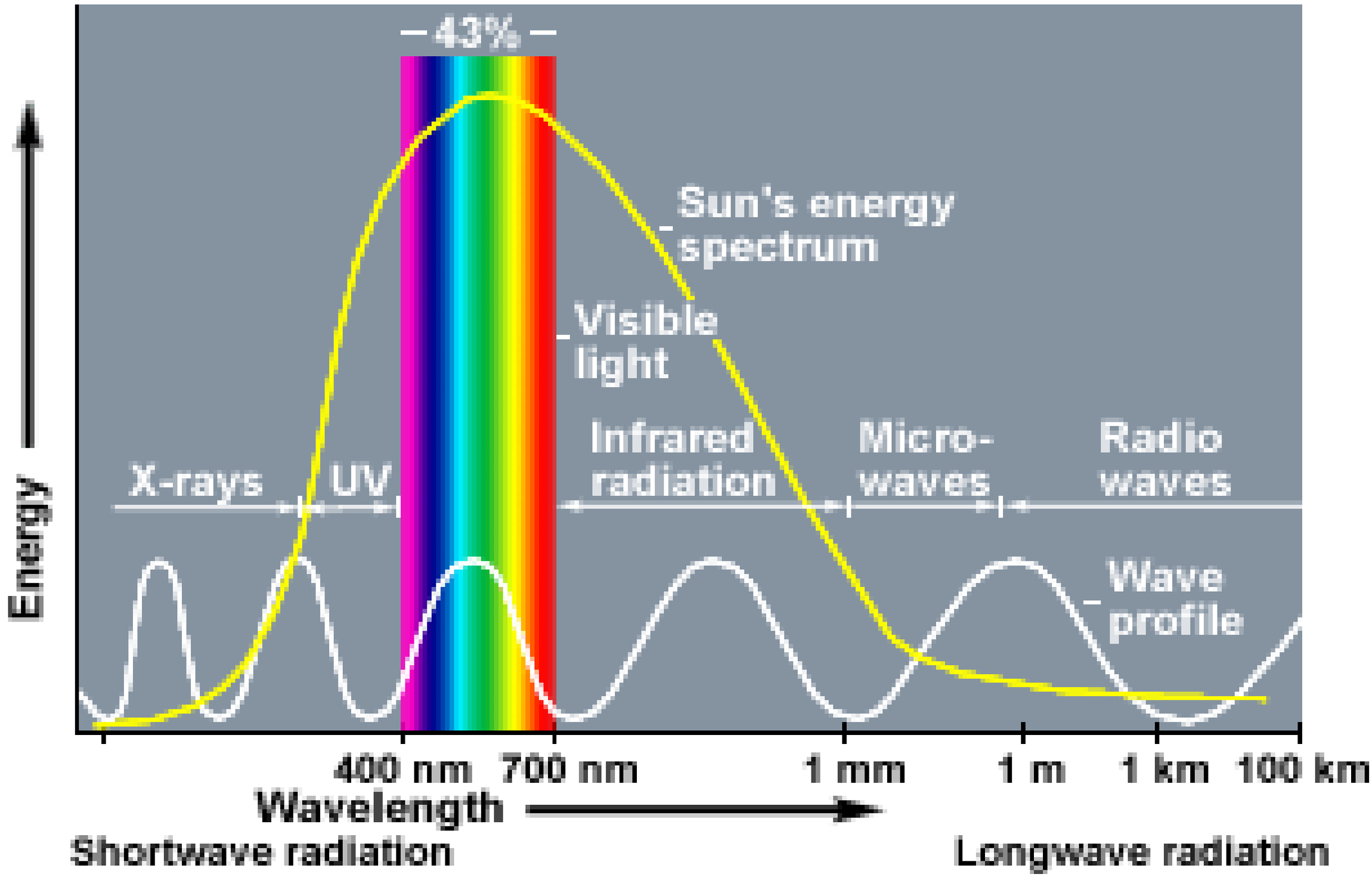
TABLE 2-3 Albedo (reflectivity) of various surfaces

Surface	Percent Reflected
Fresh snow	80–90
Old snow	50–60
Sand (beach, desert)	20–40
Grass	5–25
Dry soil (plowed field)	15–25
Wet earth (plowed field)	10
Forest	5–10
Water (Sun near horizon)	50–80
Water (Sun near zenith)	5–10
Thick cloud	70–85
Thin cloud	25–30
Earth and atmosphere (overall total)	30


Albedo
0.0
0.5
1.0

Albedo activity

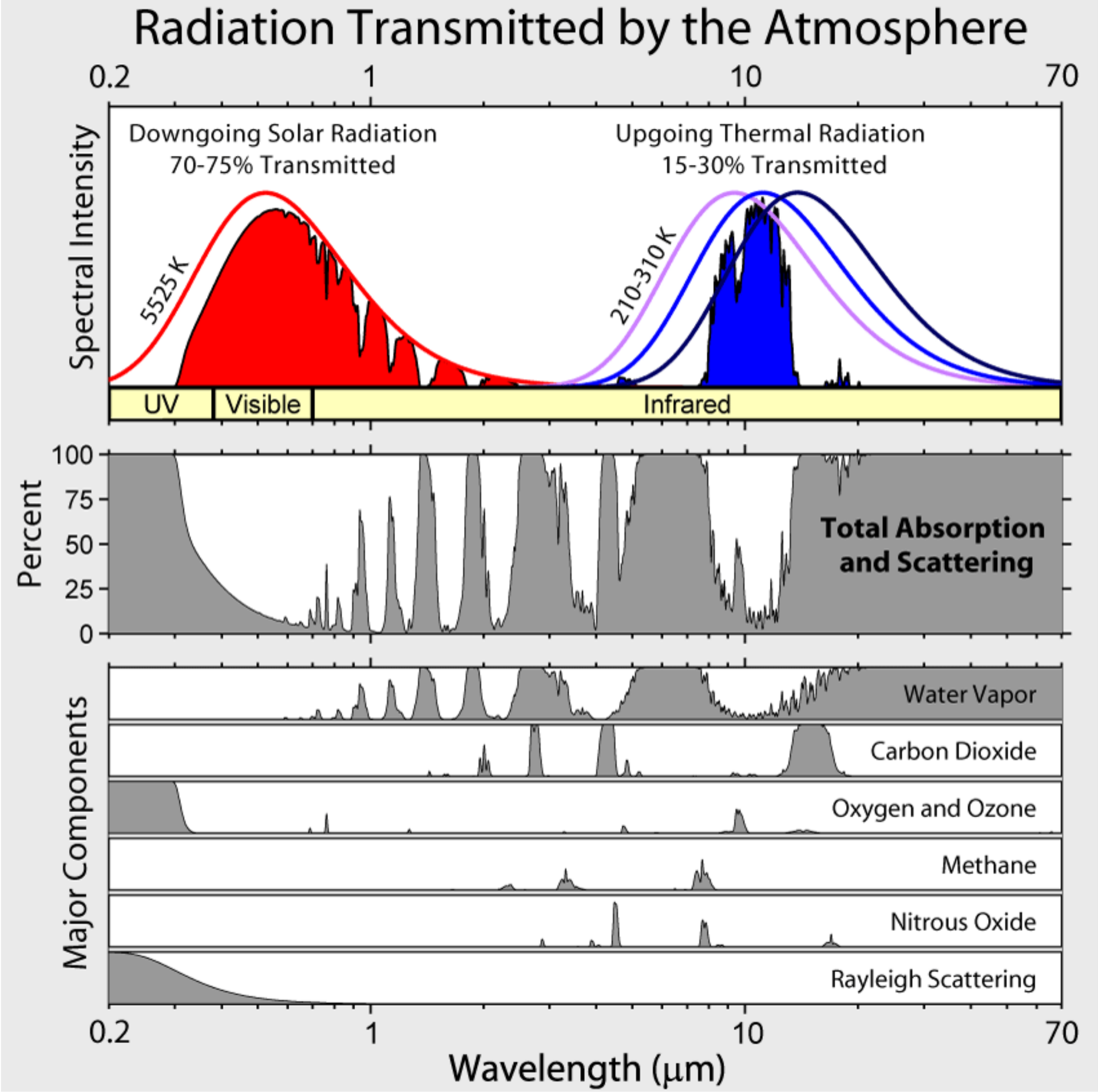
- Measure temperature rise using a heat lamp "star" and "planets" with different albedo
- The star must be 1.5×10^{11} pm away
- Graph the variation of temperature with time
- Calculate the slope including uncertainties



The COMET Program

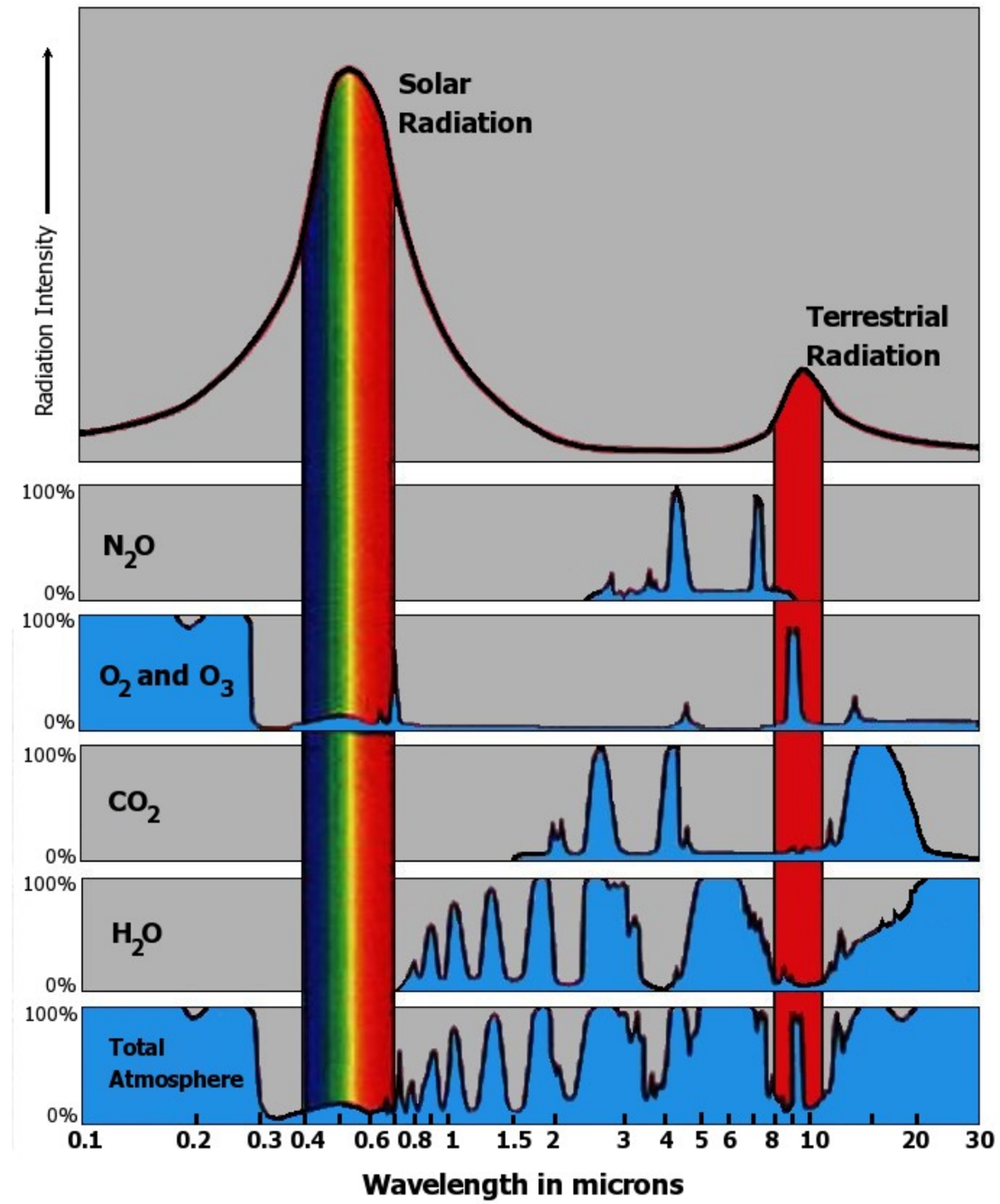
What is resonance?

- If vibrations match an objects natural oscillation, it resonates
- Greenhouse gases resonate in the infrared range and absorb those frequencies

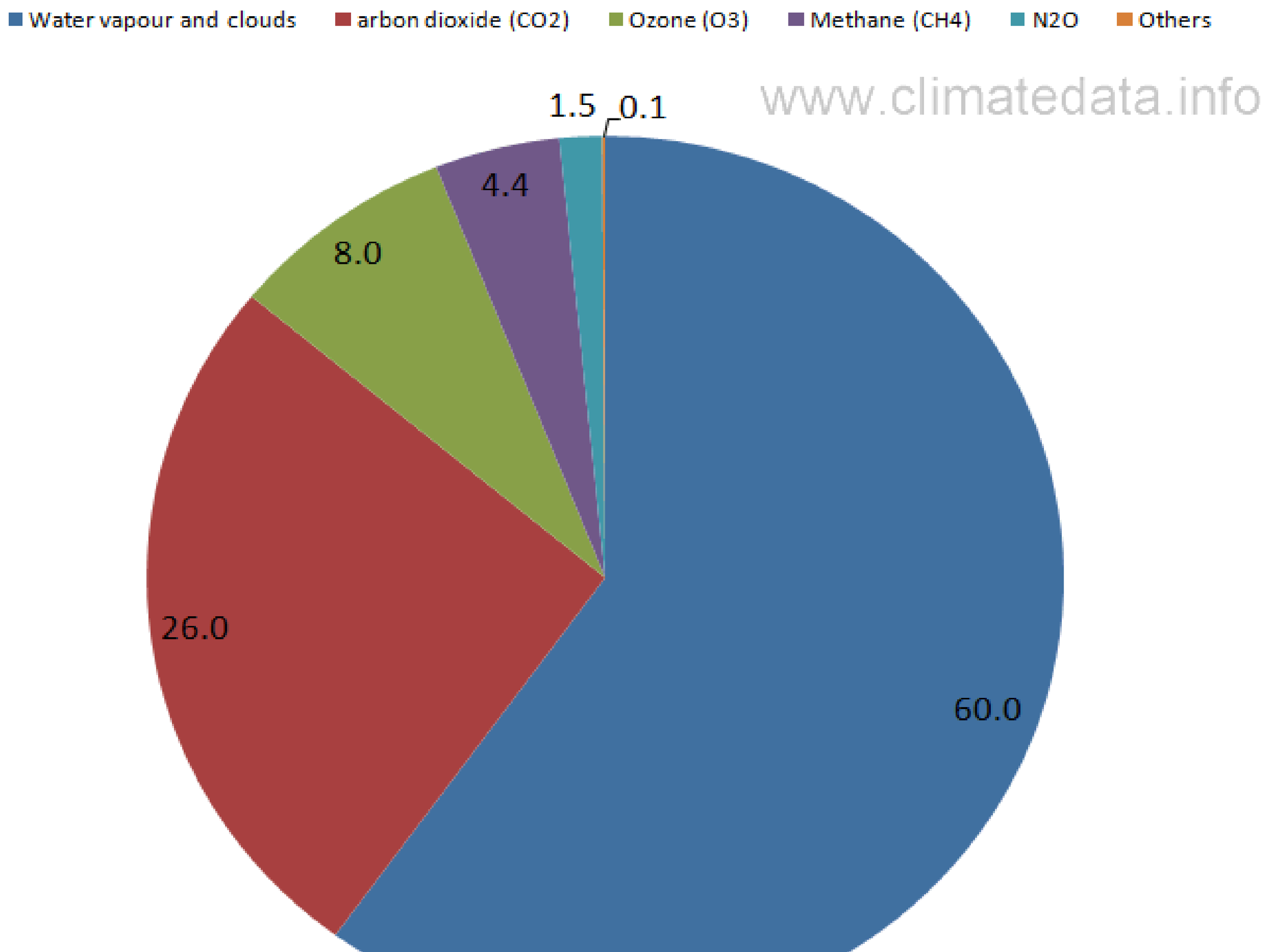

Radiation Transmitted by the Atmosphere
0.2
1
10
70
Spectral Intensity
Downgoing Solar Radiation
70-75% Transmitted
Upgoing Thermal Radiation
15-30% Transmitted
5525 K
210-310 K
UV
Visible
Infrared
Percent
100
75
50
25
0
Total Absorption
and Scattering
Major Components
Water Vapor
Carbon Dioxide
Oxygen and Ozone
Methane
Nitrous Oxide
Rayleigh Scattering
Wavelength (μm)

Greenhouse gas sources

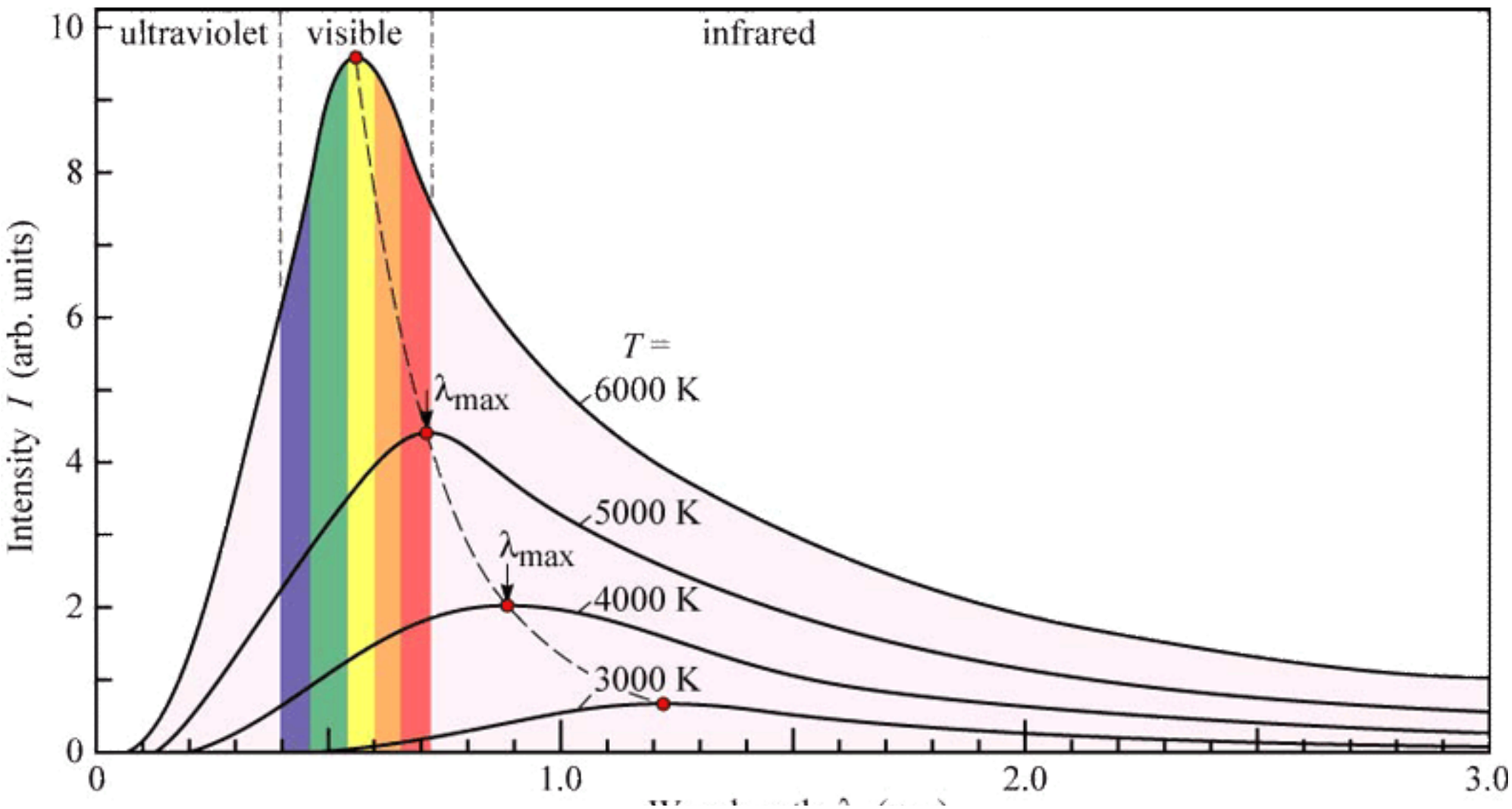
- Fossil fuel burning
- Deforestation
- Livestock CO_2 and CH_4
- Fertilizers N_2O
- CFCs: refrigerant, fire extinguishers



Percentage contribution to greenhouse effect



Black body radiation



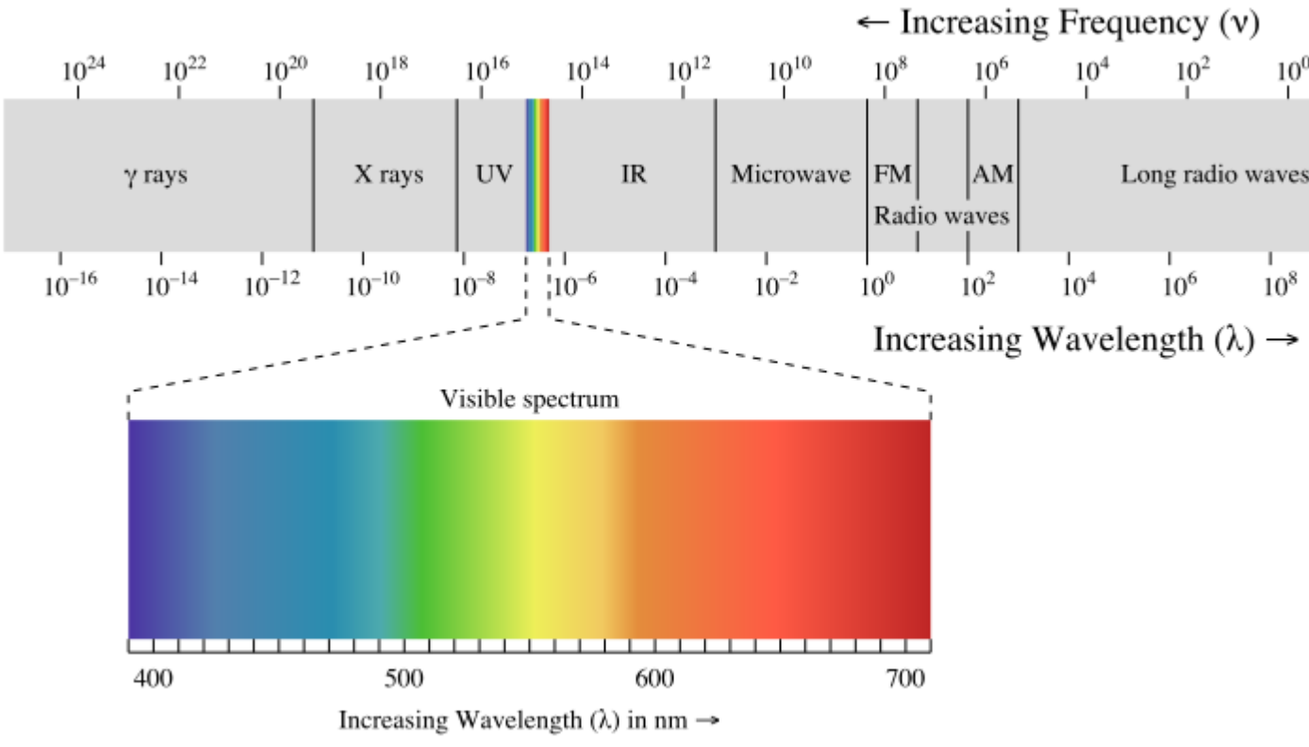
$$\lambda_{max\,(meters)} = {}^{b}/_{T}$$

λ_{max} = peak wavelength
b = Wien's displacement constant = .002898 m*K
T = temperature (K)

Ex: find the peak wavelength you are emitting right now according to Wien's displacement law

$$\lambda_{\max} = \frac{2.9\times10^{-3}}{T} = \frac{2.9\times10^{-3}}{303}$$

$$\lambda_{\max} = 9.6\,\mu m$$

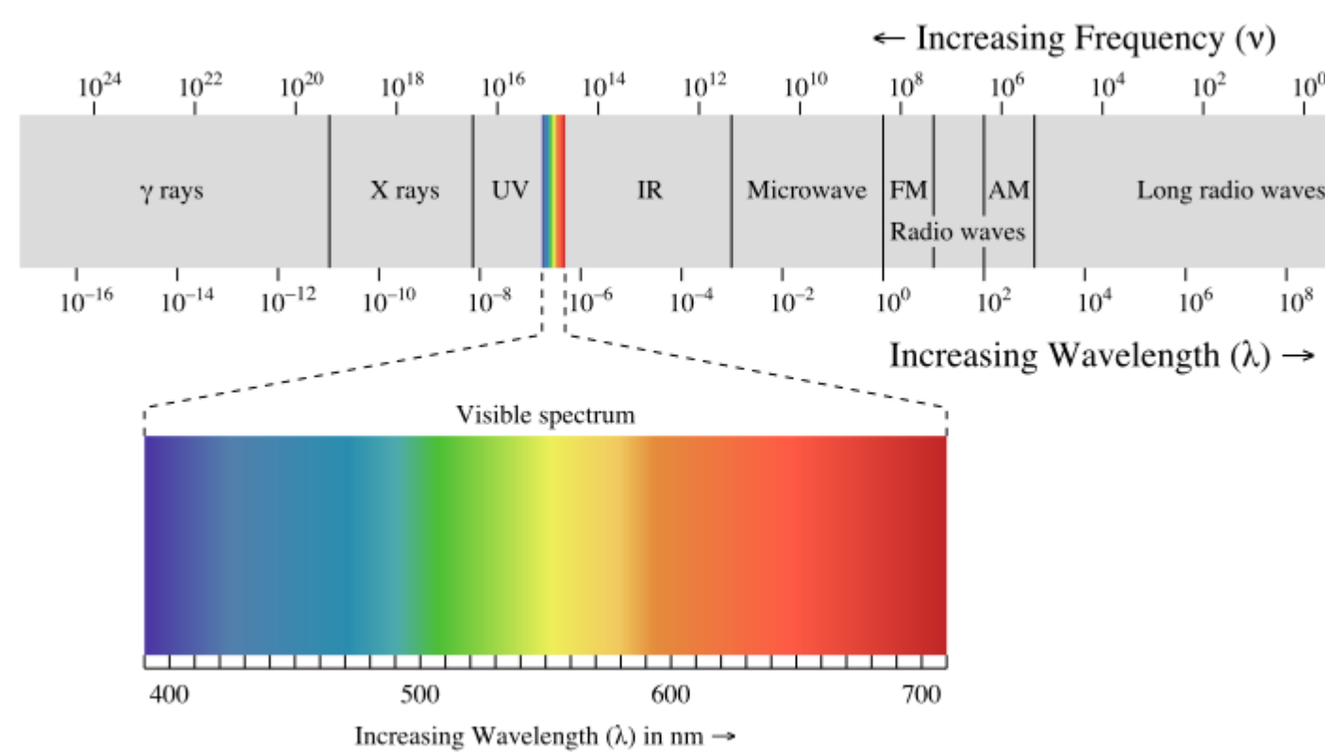


Ex: find the temperature of a “red hot” object

$$\lambda_{\max} = \frac{2.9\times10^{-3}}{T} \qquad T = \frac{2.9\times10^{-3}}{\lambda_{\max}}$$

$$T = \frac{2.9\times10^{-3}}{700\times10^{-9}}$$

$$T = 4100K$$



Stefan-Boltzmann law

$$P = \sigma A T^4$$

- Real objects don't have the emissivity of an idealized blackbody, so we have

$$P = e\sigma A T^4$$

$$\sigma = 5.67 \cdot 10^{-8} Wm^{-2} K^{-4}$$

Emissivity

Aluminum Foil	0.04
Asphalt	0.93
Black Body Matt	1.00
Brass Dull Plate	0.22
Brass Polished	0.03
Brick, red rough	0.93
Concrete	0.85
Ice smooth	0.97
Sand	0.76
Plant Leaves	0.96

Ex: what is the power of each square cm of your skin (e=0.98)?

$$P = e\sigma A T^4$$

$$P = 0.98\left(5.67\times10^{-8}\right)0.01^2\left(303\right)^4$$

$$P = 0.047W$$

Ex: what is your total power output?

$$P = e\sigma A T^4$$

$$P = 0.98\left(5.67\times10^{-8}\right)2\left(303\right)^4$$

$$P = 937W$$

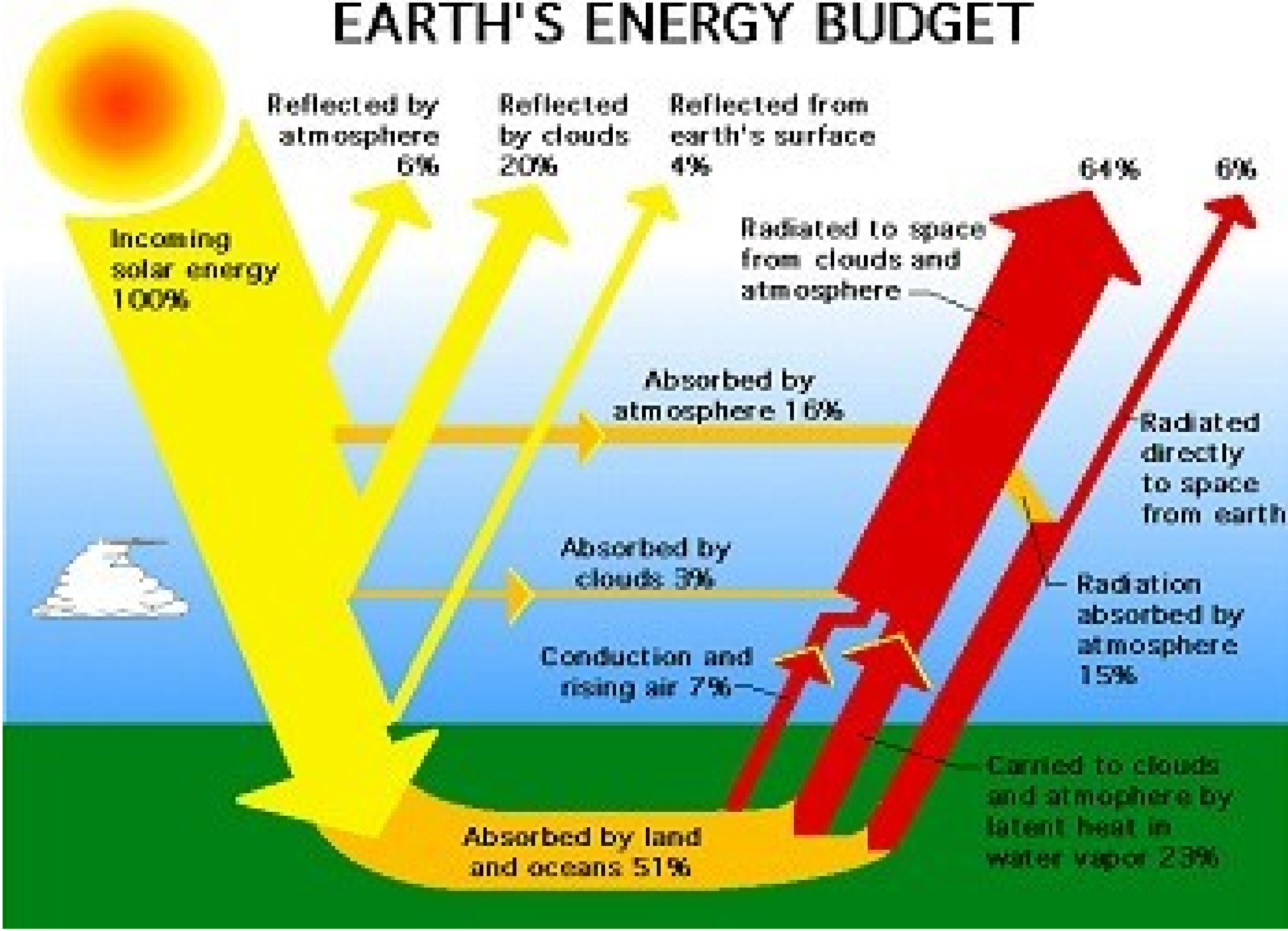
Ex: Assuming 2000 Calories per day, what is your maximum power output?

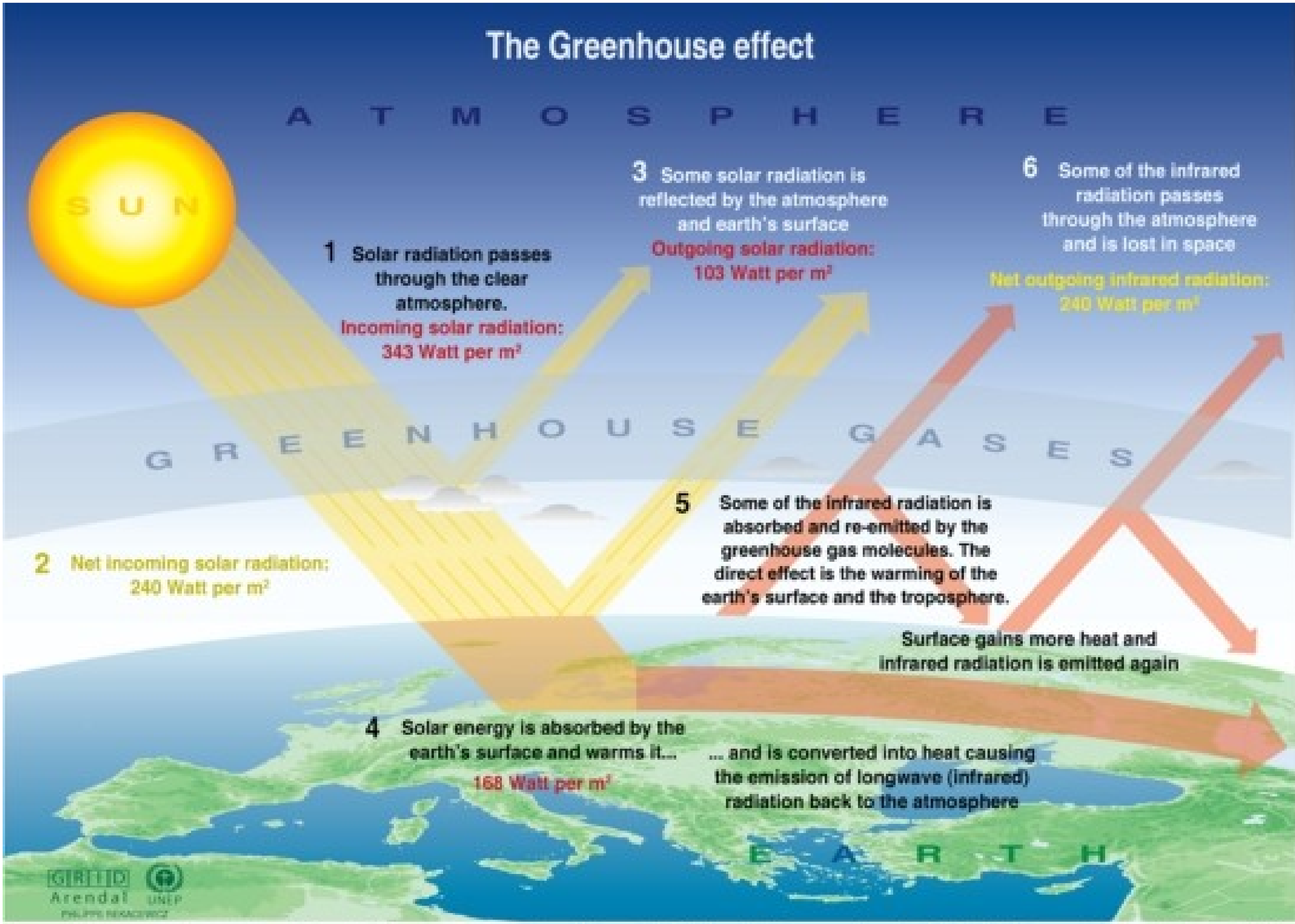
$$P = \frac{\Delta E}{t} = \frac{2000 \cdot 4200 J}{24 \cdot 60 \cdot 60}$$

$$= 97W$$

$$P = 937W$$

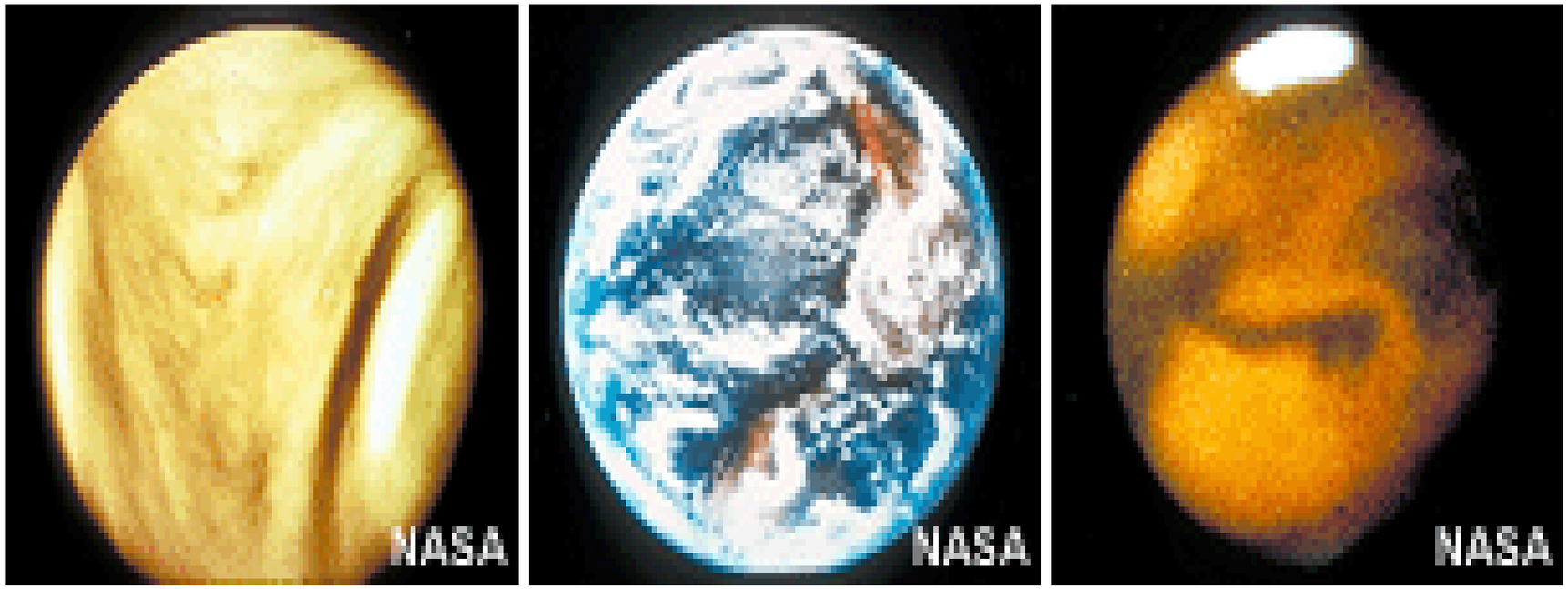
EARTH'S ENERGY BUDGET





Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

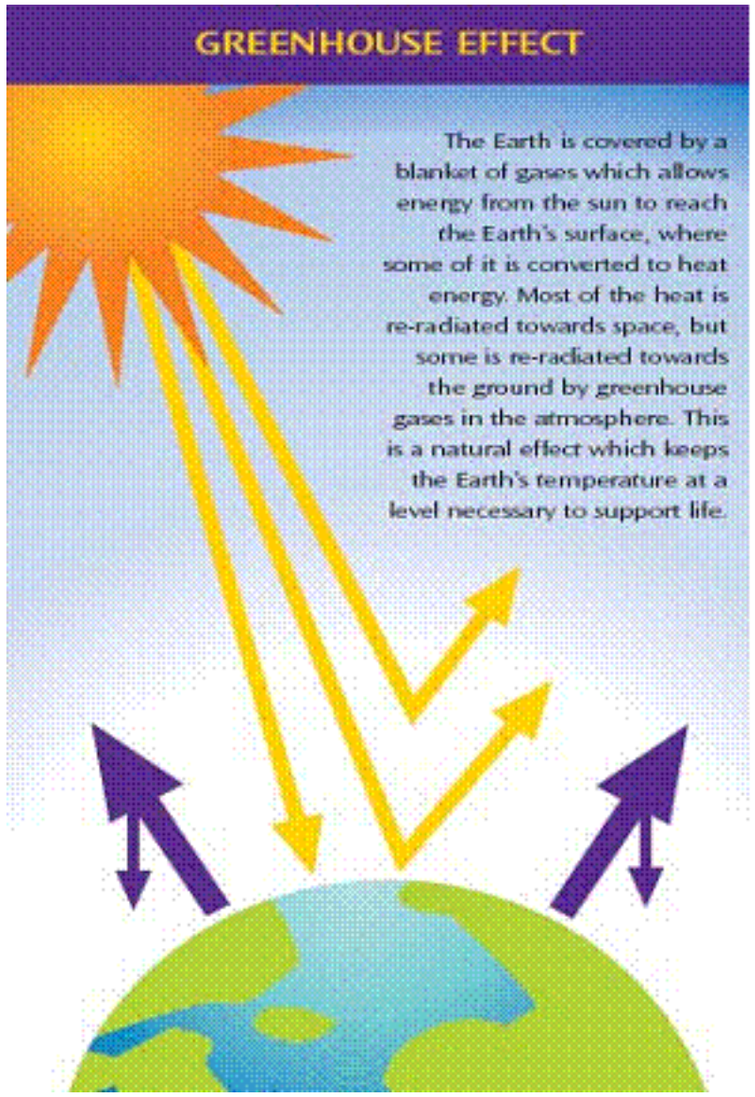
The “Goldilocks” planet?

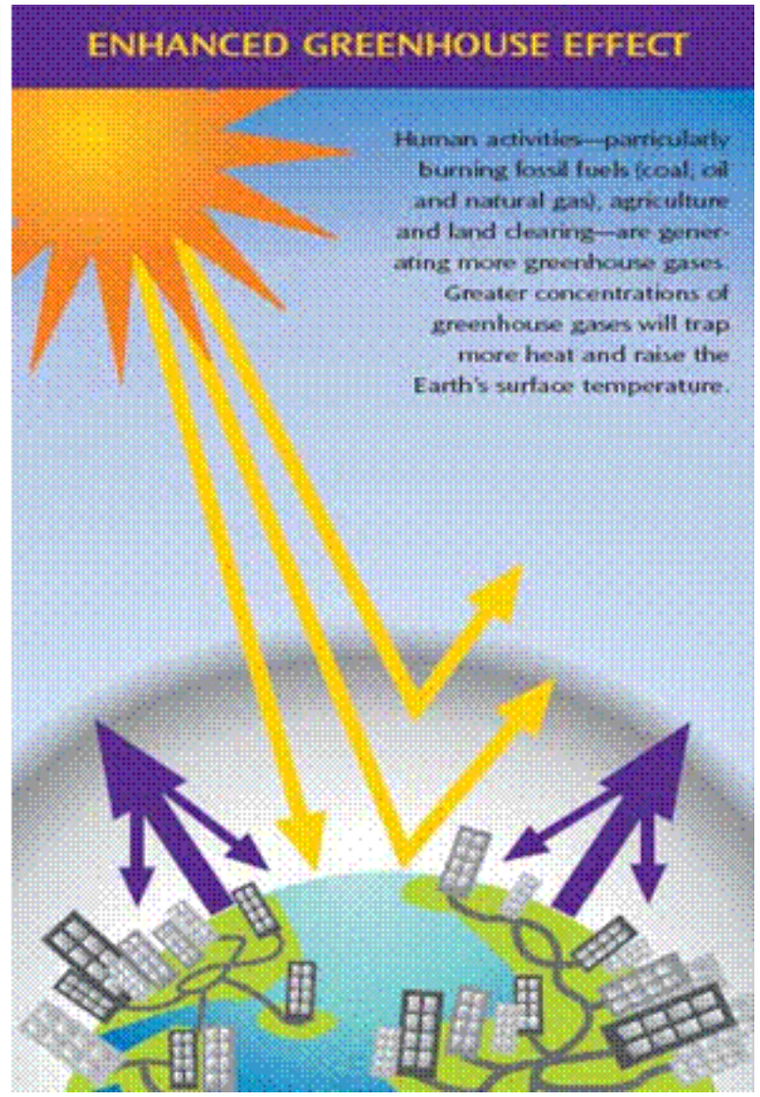


	Venus	Earth	Mars
Surface temperature	450°C	13°C	-53°C

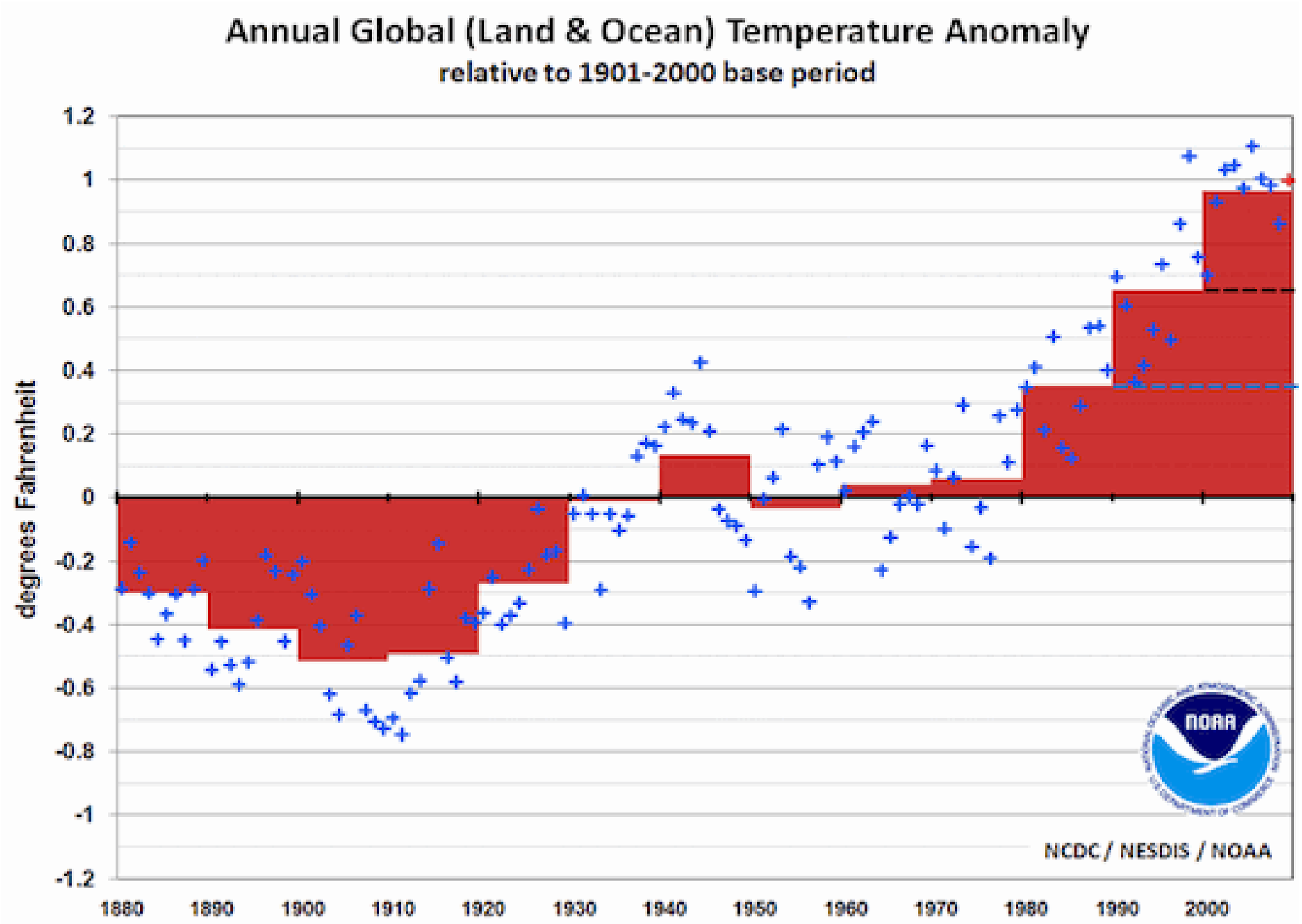
"Enhanced" greenhouse effect

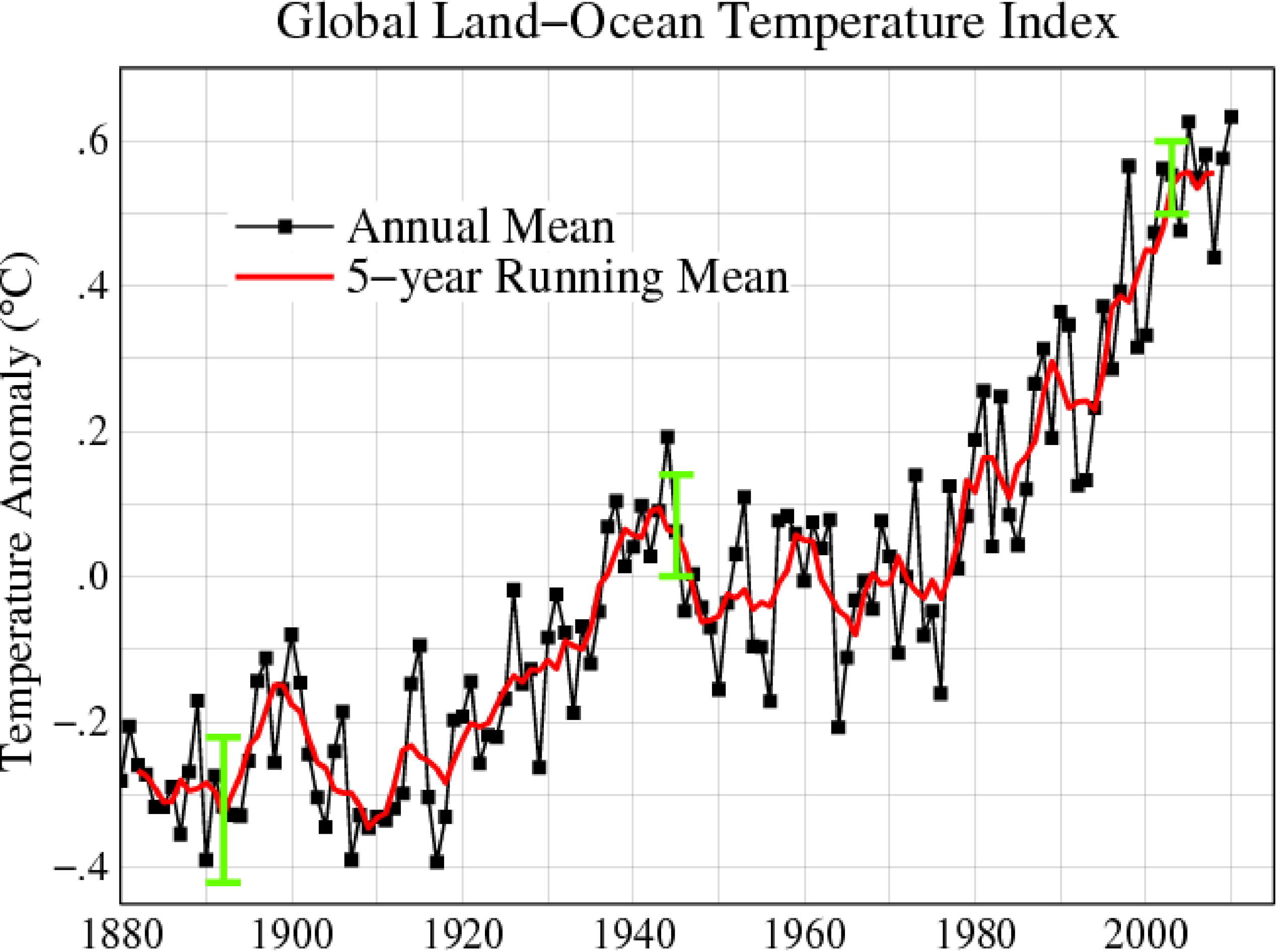
- Due to GHG added to the atmosphere by human activities

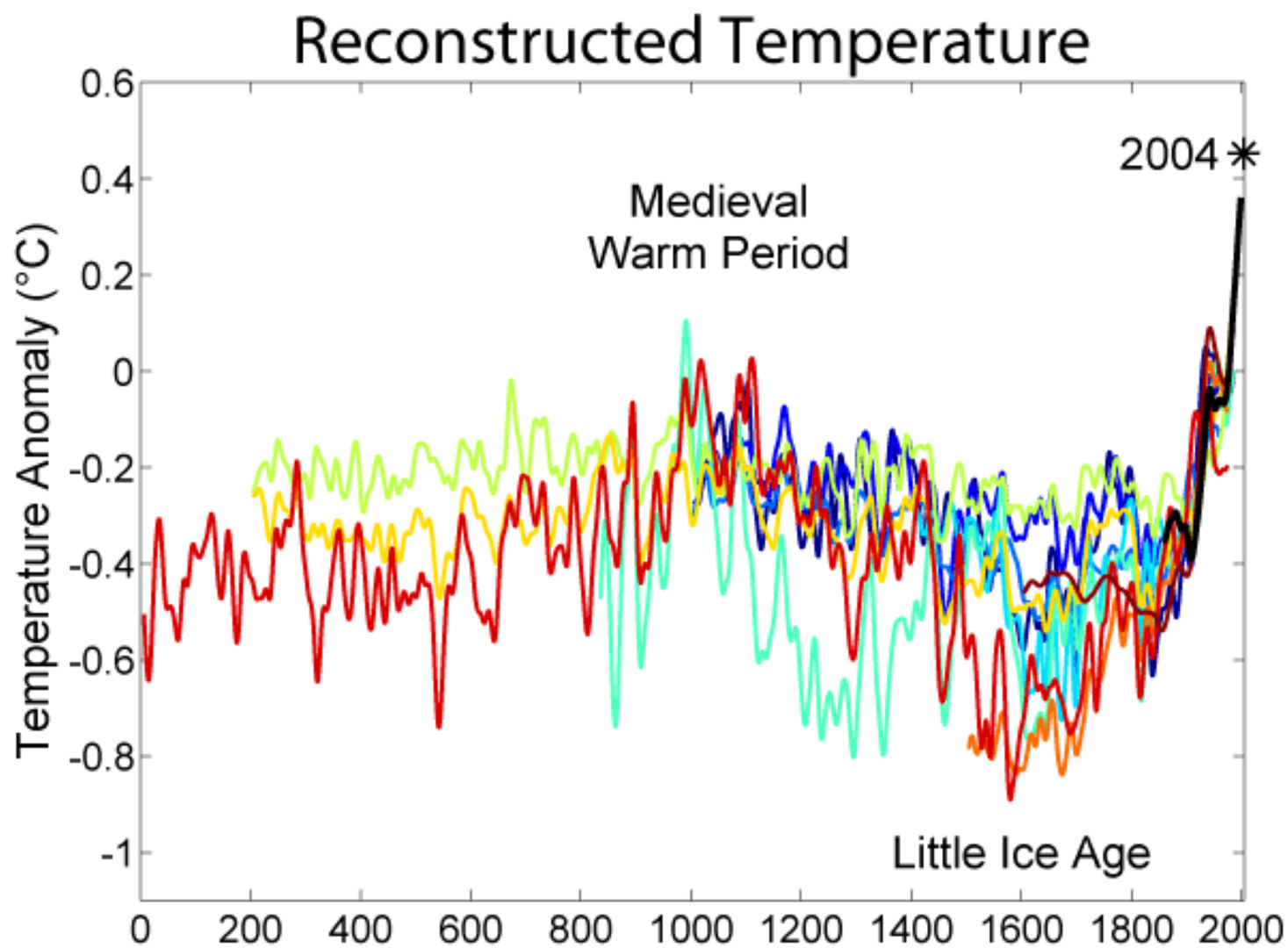




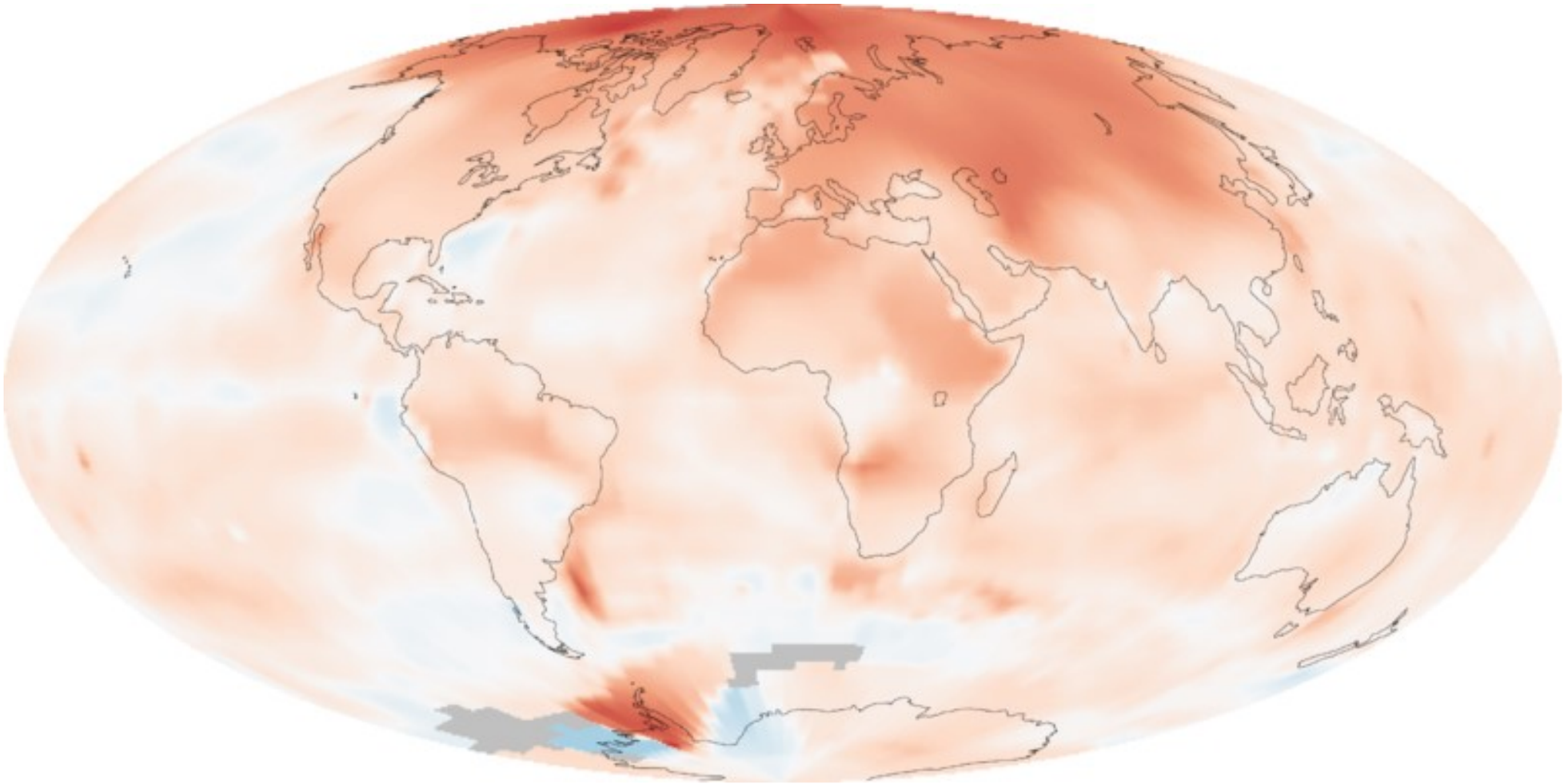
Temperature



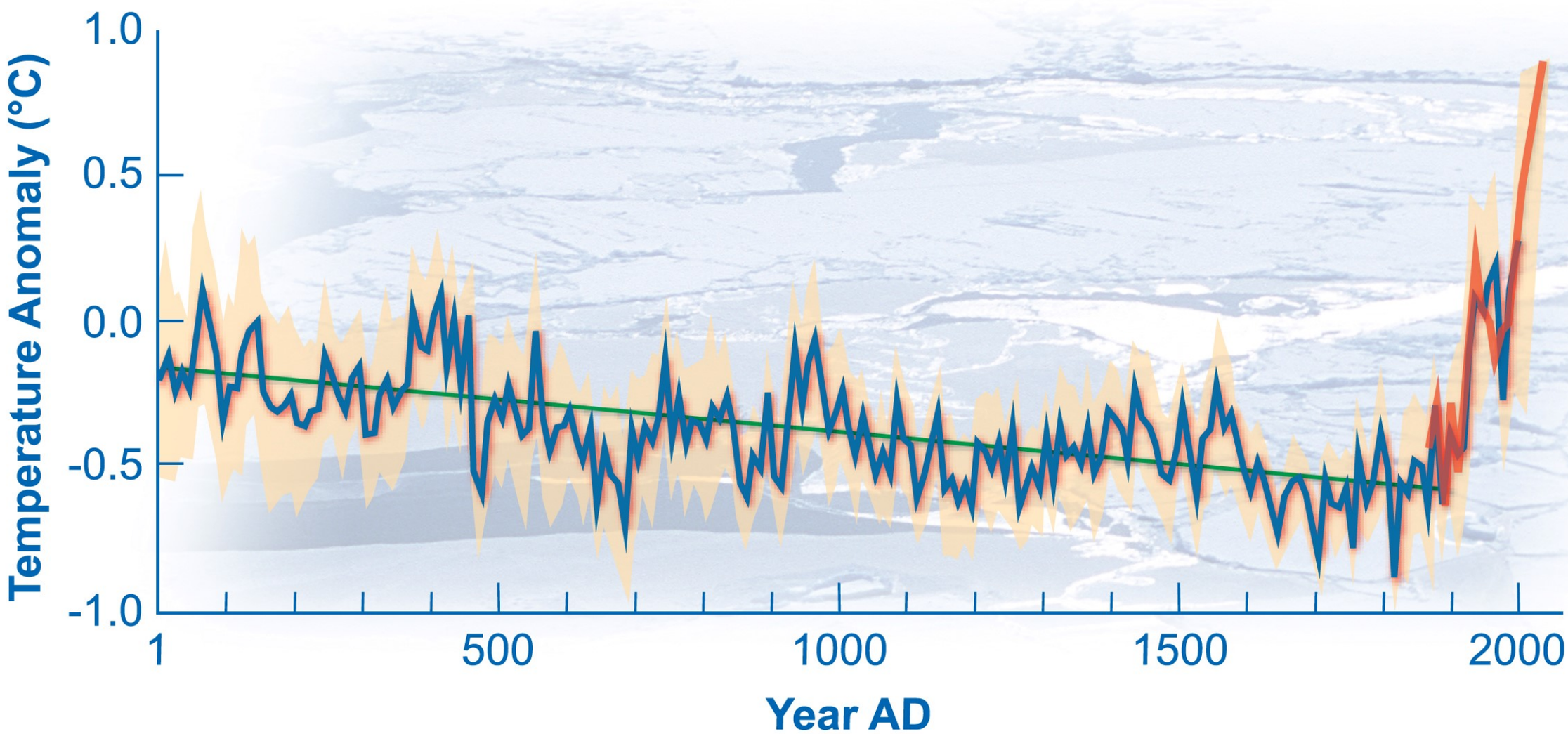

Global Land–Ocean Temperature Index
Annual Mean
5–year Running Mean
Temperature Anomaly (°C)
.6
.4
.2
.0
−.2
−.4
1880
1900
1920
1940
1960
1980
2000


Reconstructed Temperature
Temperature Anomaly (°C)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Medieval
Warm Period
2004
Little Ice Age

Asymmetrical warming: 2000-2009 anomaly

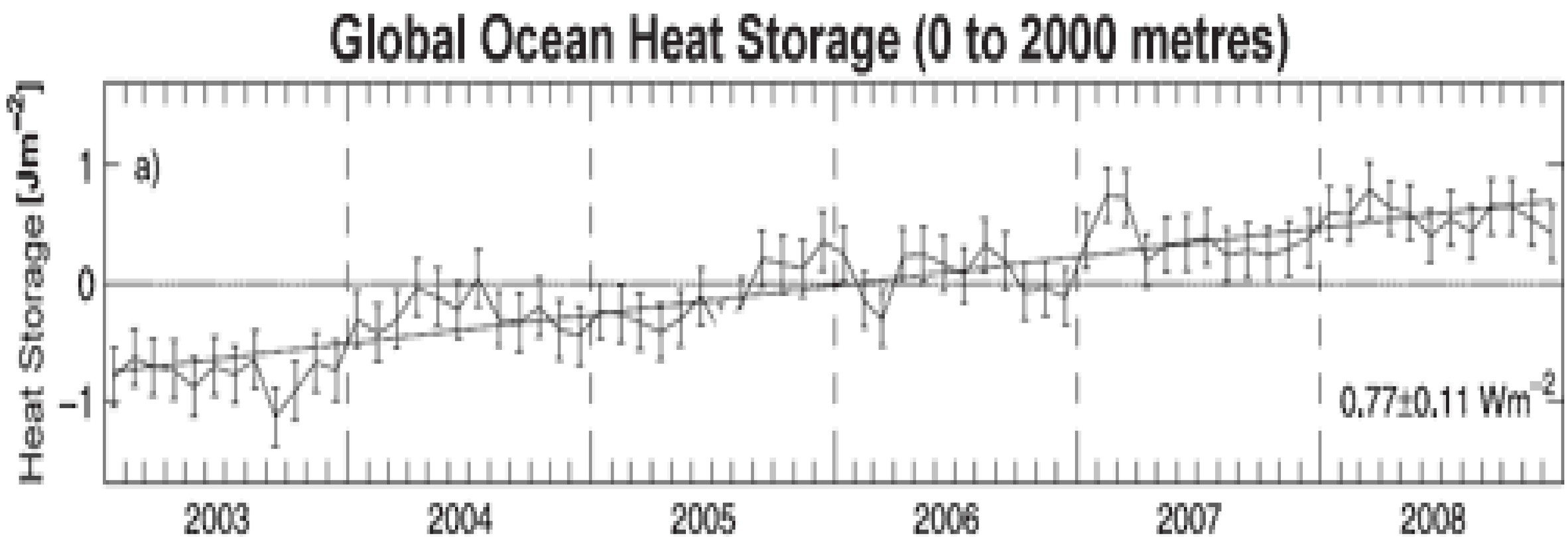


The “hockey stick”



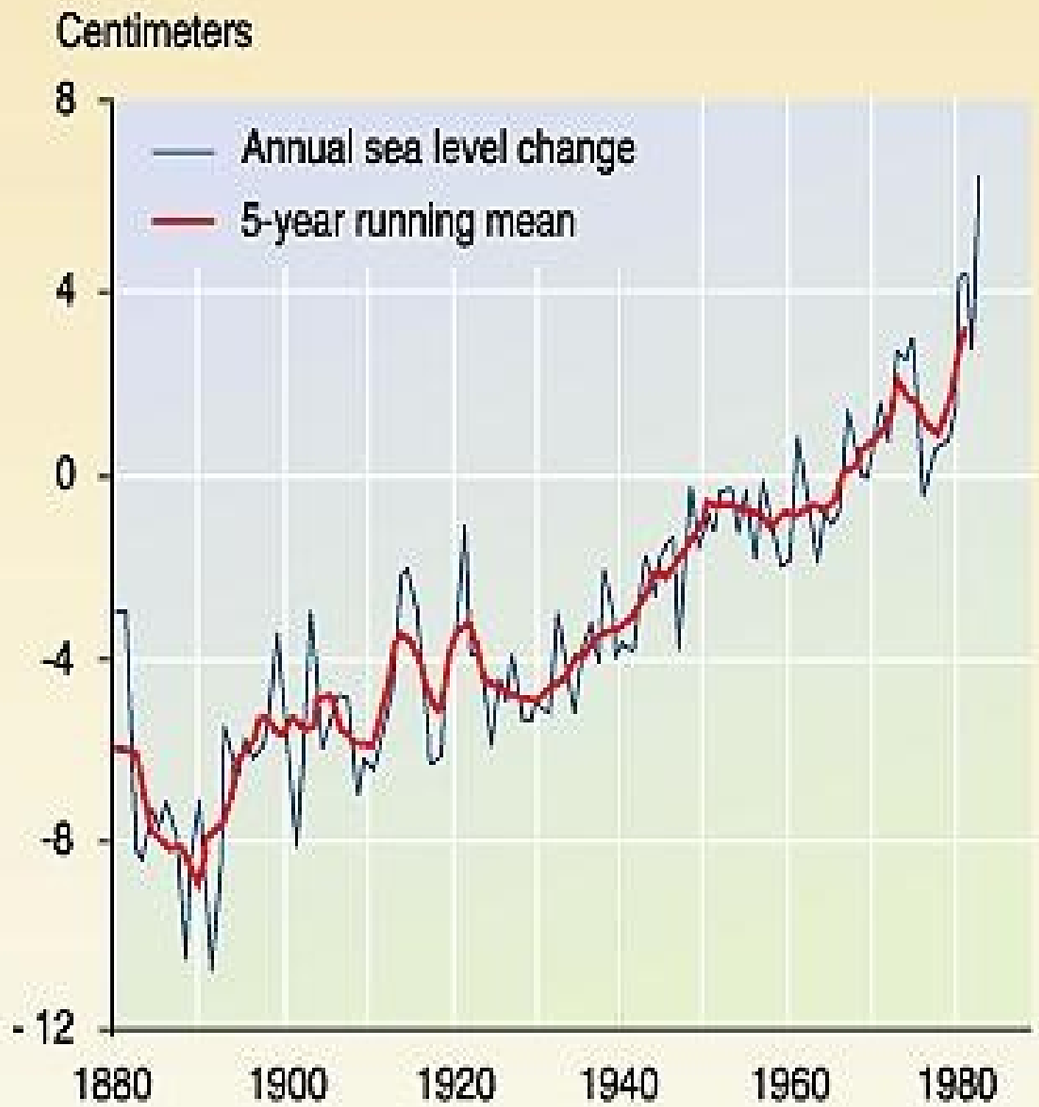
Only 1 degree?

- Where did the rest of the extra heat go?

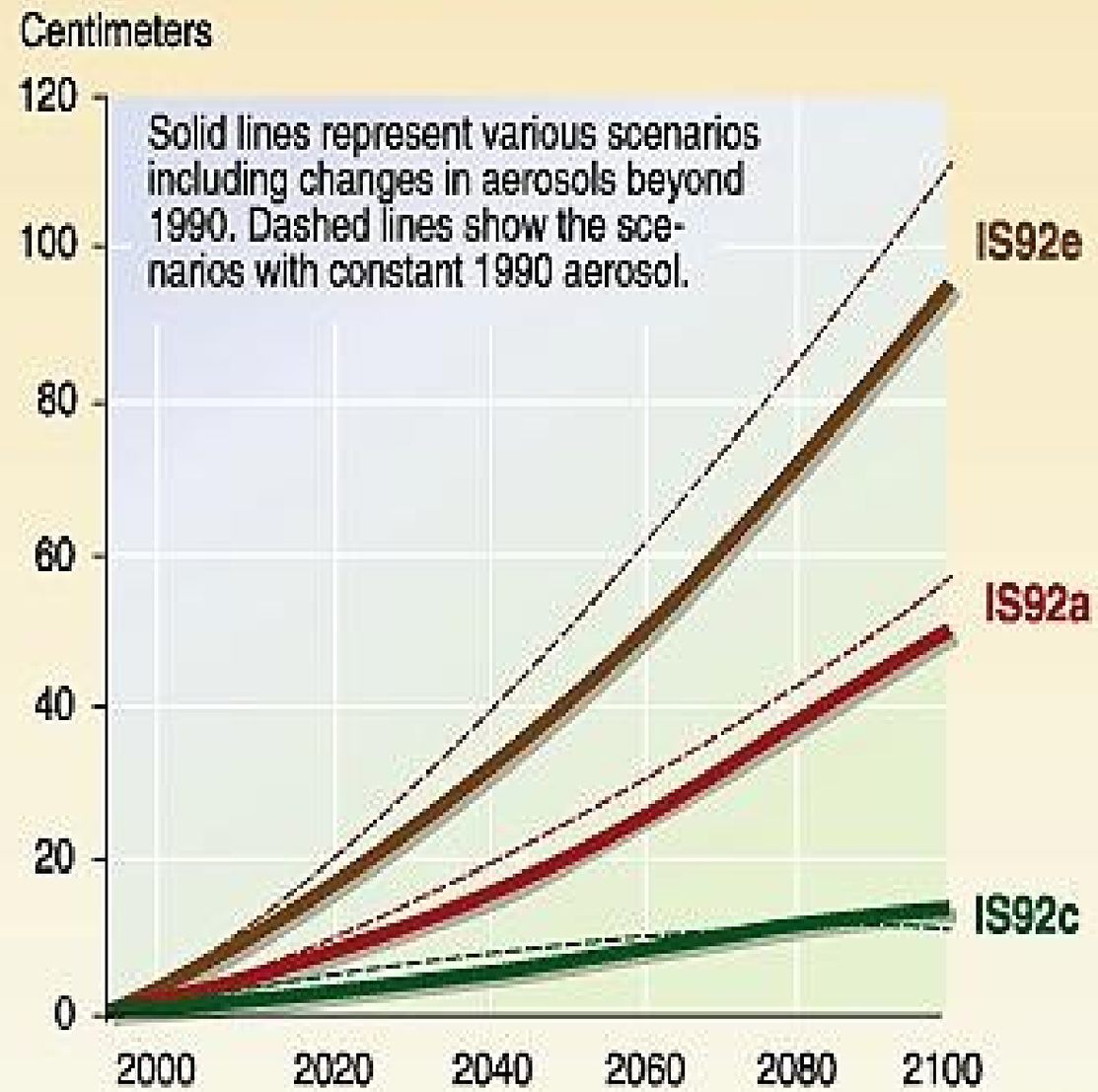


Sea level rise due to global warming

Sea level rise over the last century



Sea level rise scenarios for 2100



GRID Arendal UNEP

GRAPHIC DESIGN : PHILIPPE REMACEWICZ

Source: Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996; Sea level rise over the last century, adapted from Gornitz and Lebedeff, 1987.

Land ice melting

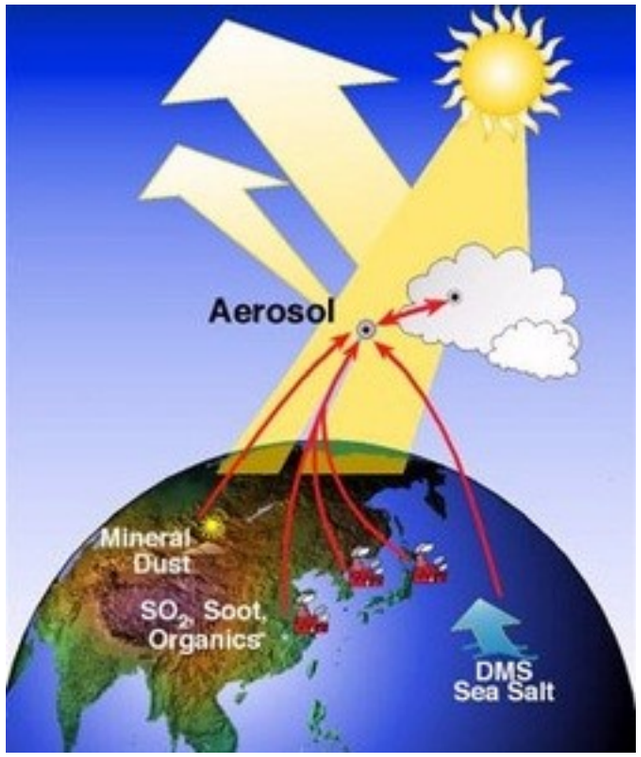
Video

- Latoc 17:00

Feedbacks

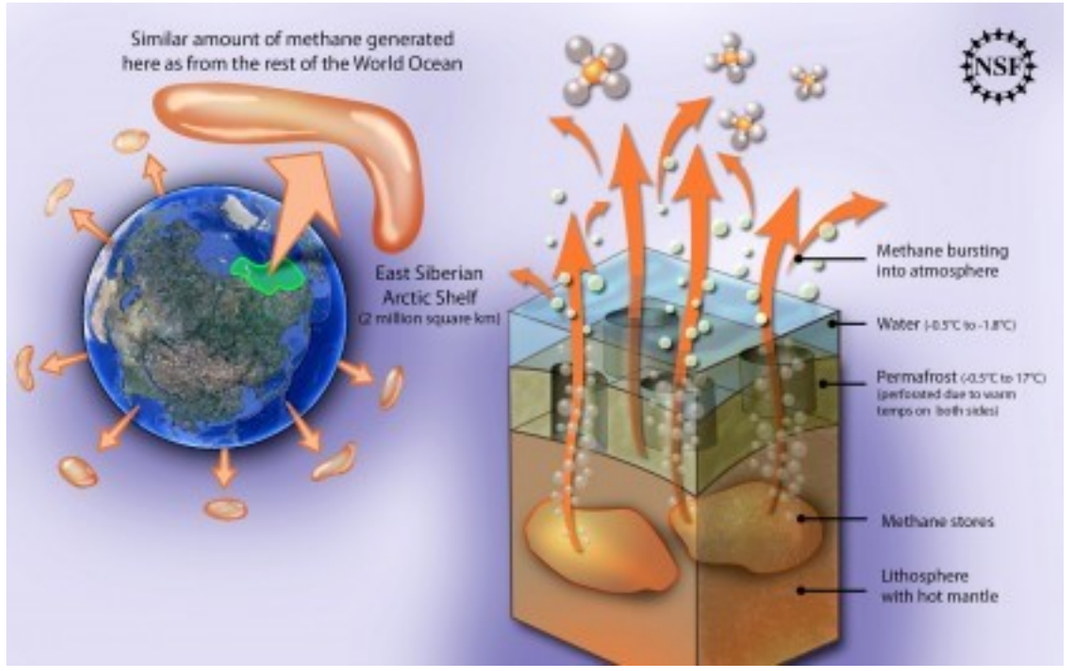
Negative feedbacks:

- Cloud cover?
- Aerosol release
- Heat radiation

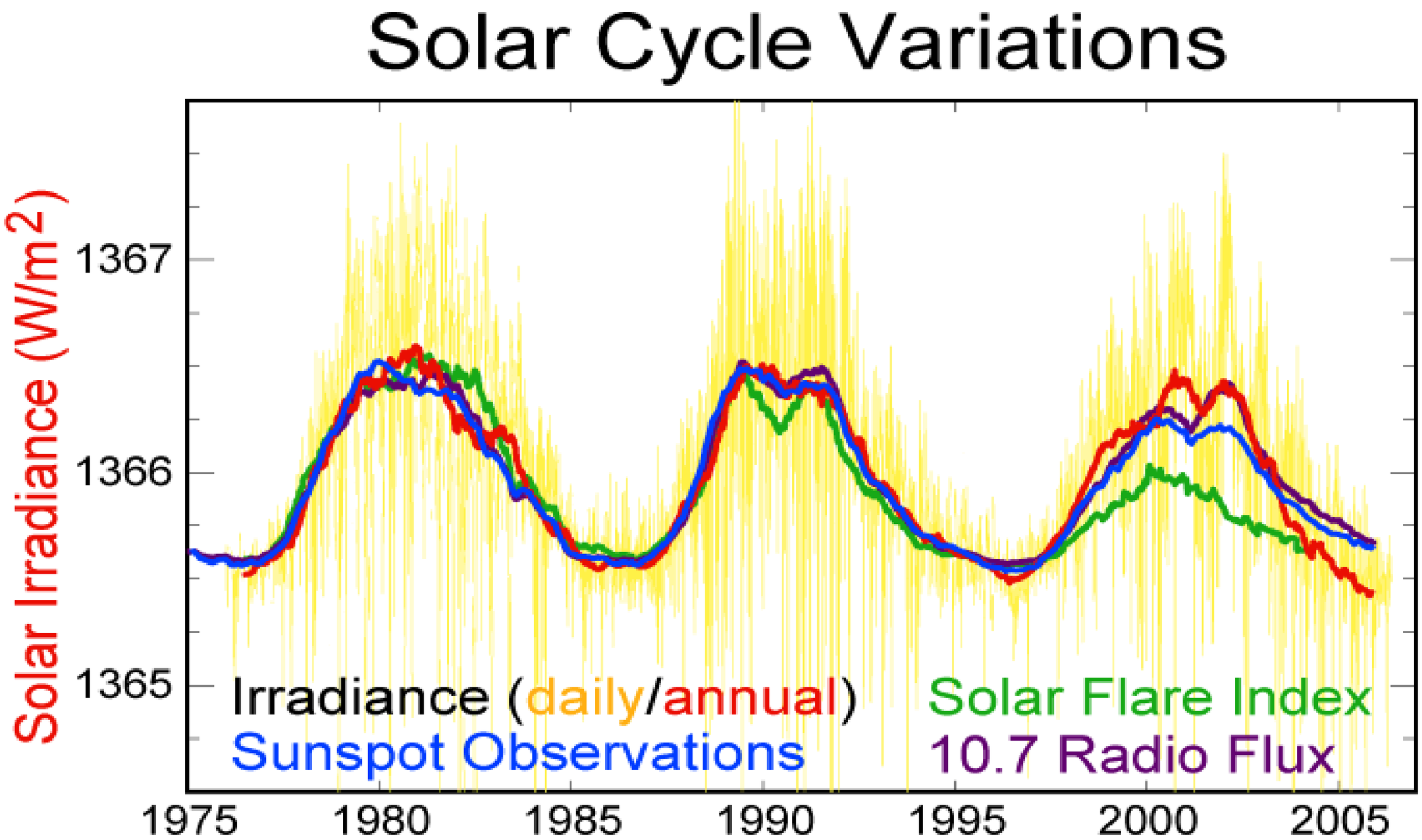


Positive feedbacks

- Albedo change: melting ice and snow
- Methane release from permafrost

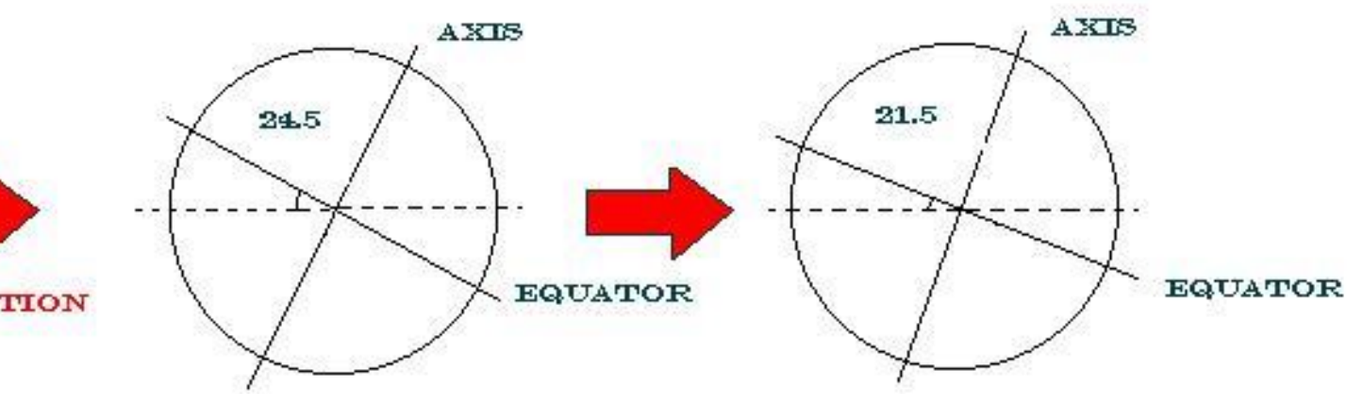


Other factors



Milankovich cycles: ice ages

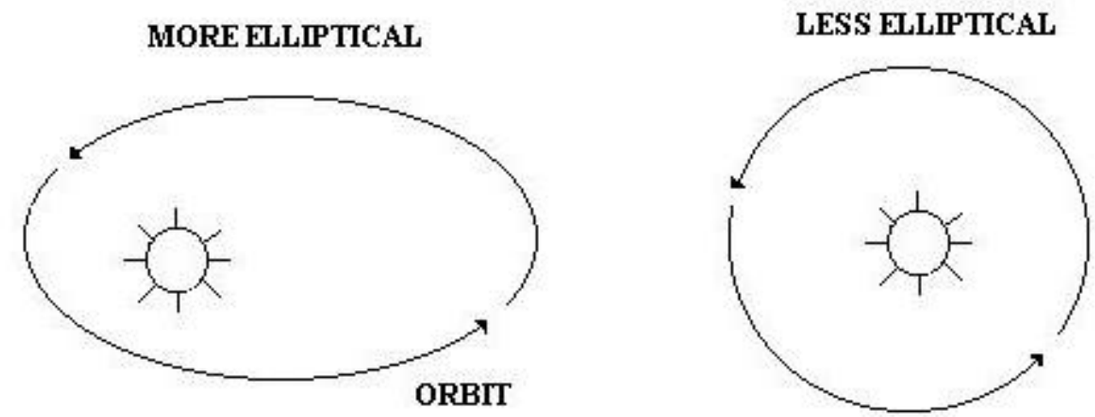
AXIAL TILT



PERIODICITY:

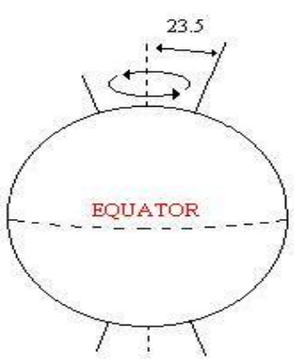
41,000 YEARS

ECCENTRICITY



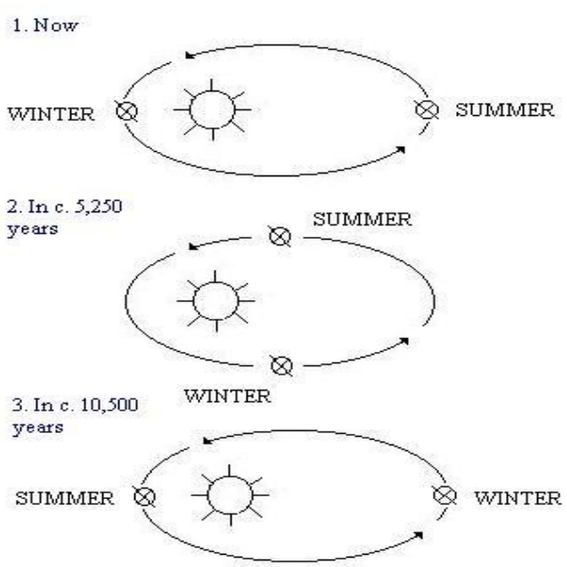
PERIODICITY:

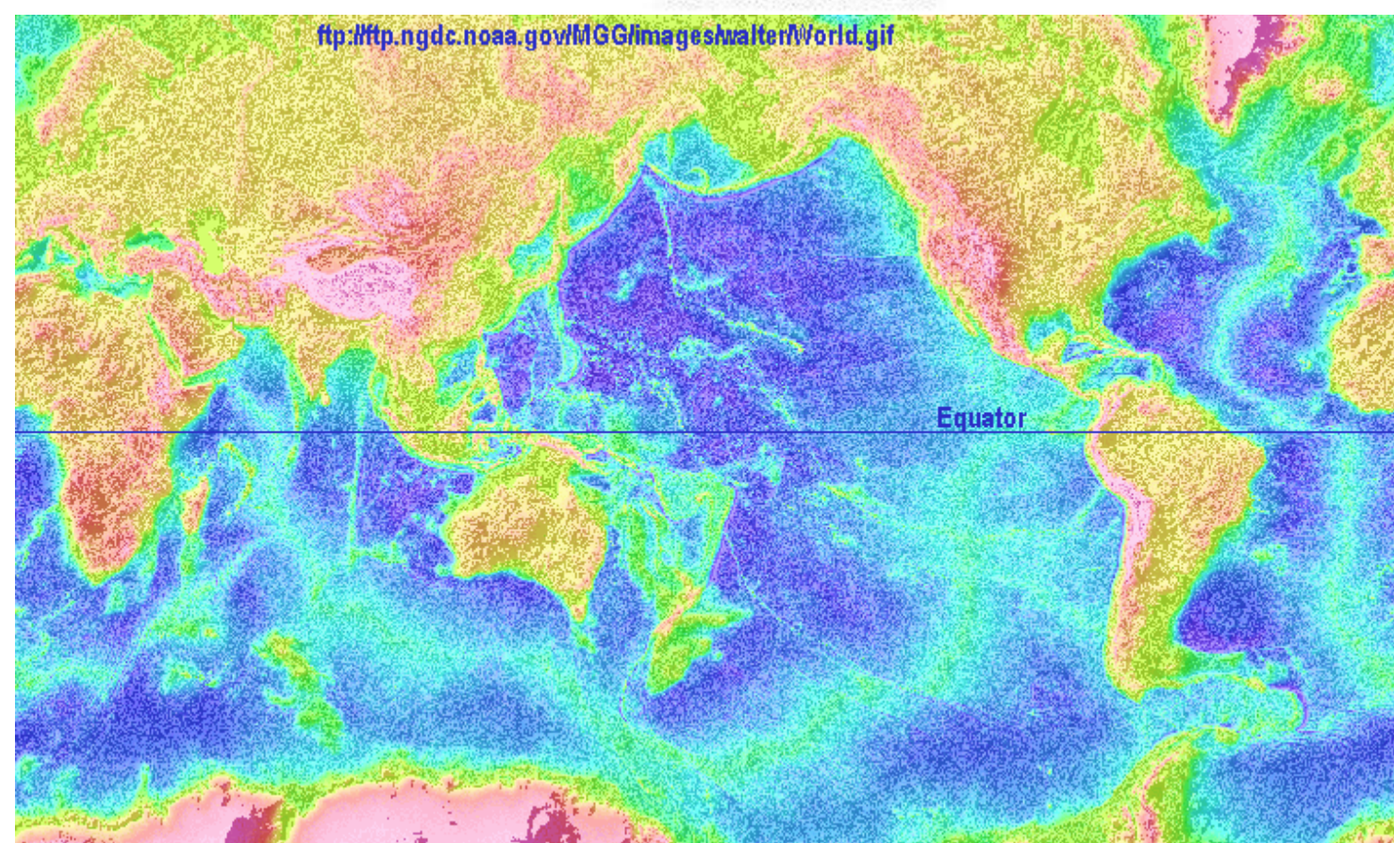
PRECESSION



PERIODICITY:

C. 23,000 YEARS

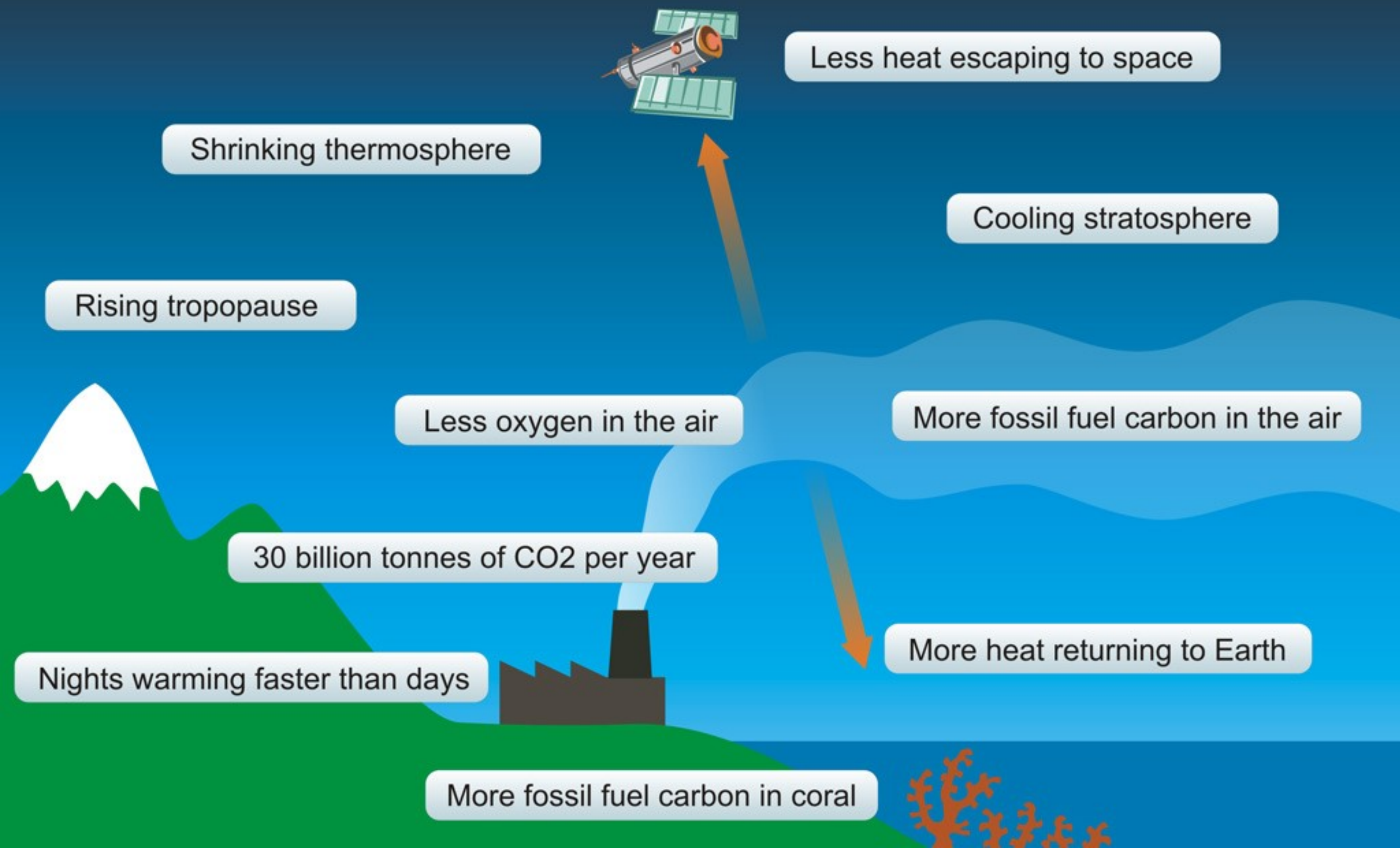




Warming Fingerprint

- If we are causing the warming, where are the fingerprints?

10 Indicators of a Human Fingerprint on Climate Change



Particulates: aerosols

Volcanic explosions

Contrails: cloud cover

Black carbon

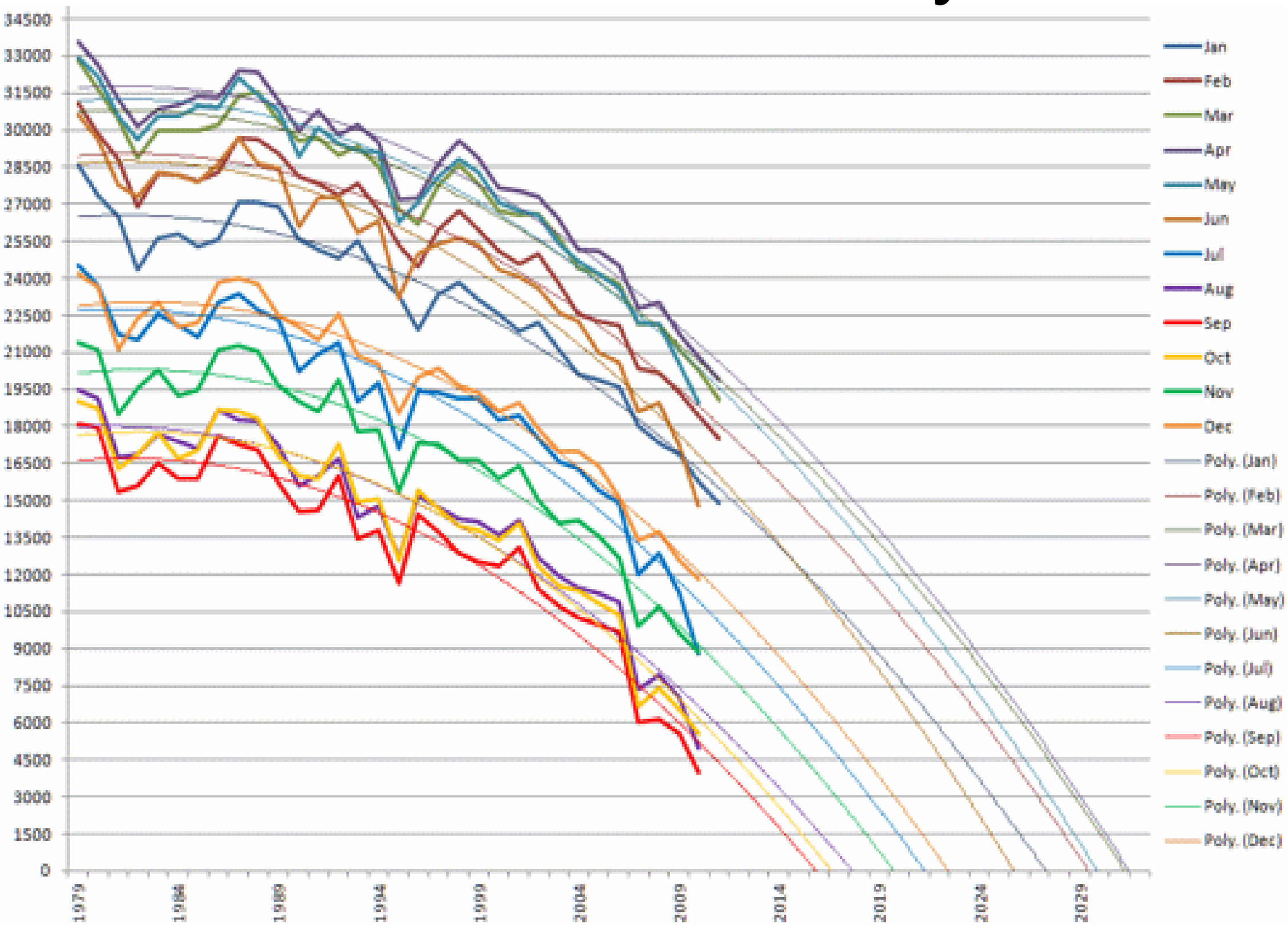
Other greenhouse gases

Water Vapor

Methane

Nitrous oxides

Arctic sea ice volume by month

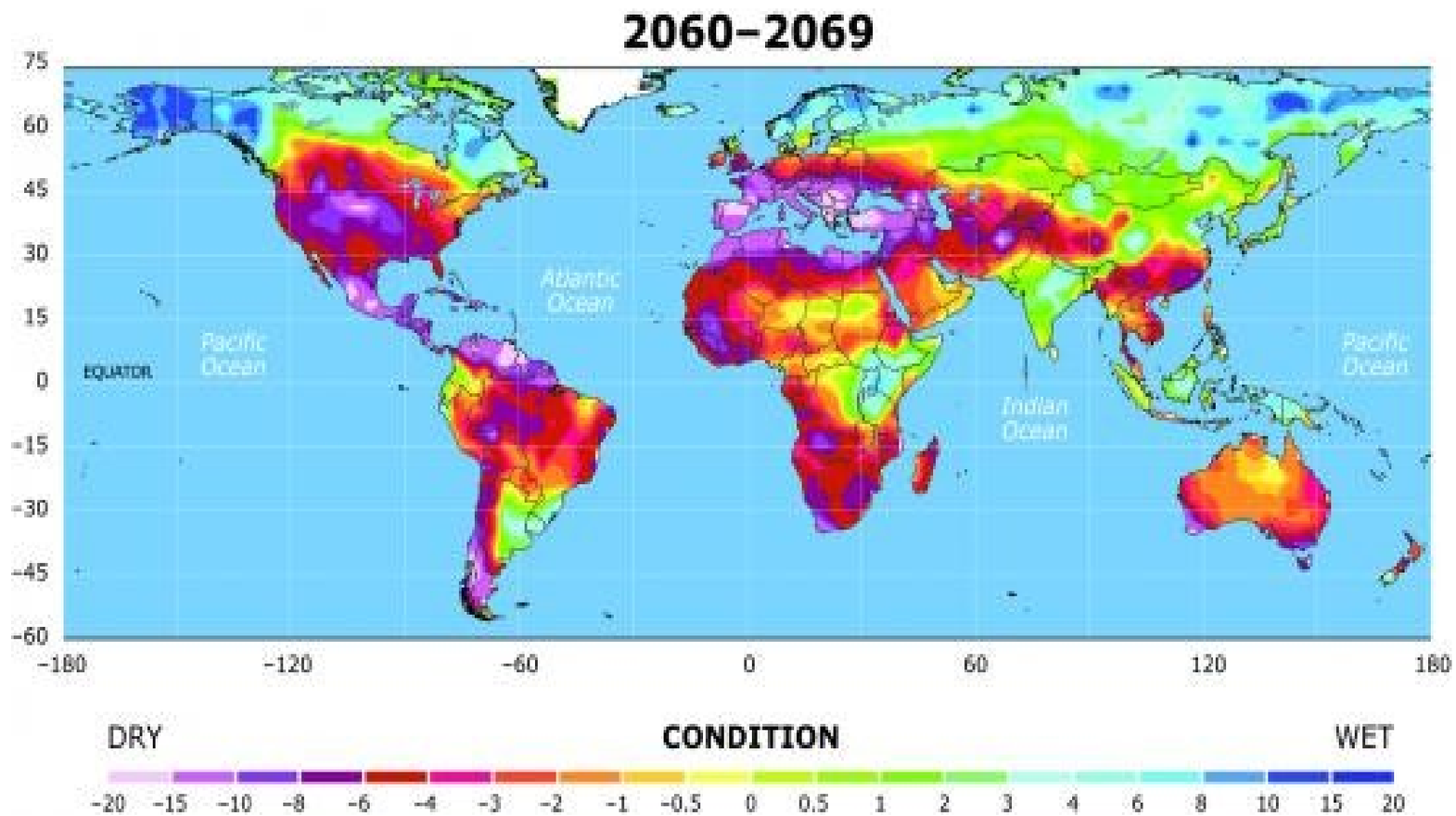


Maldives

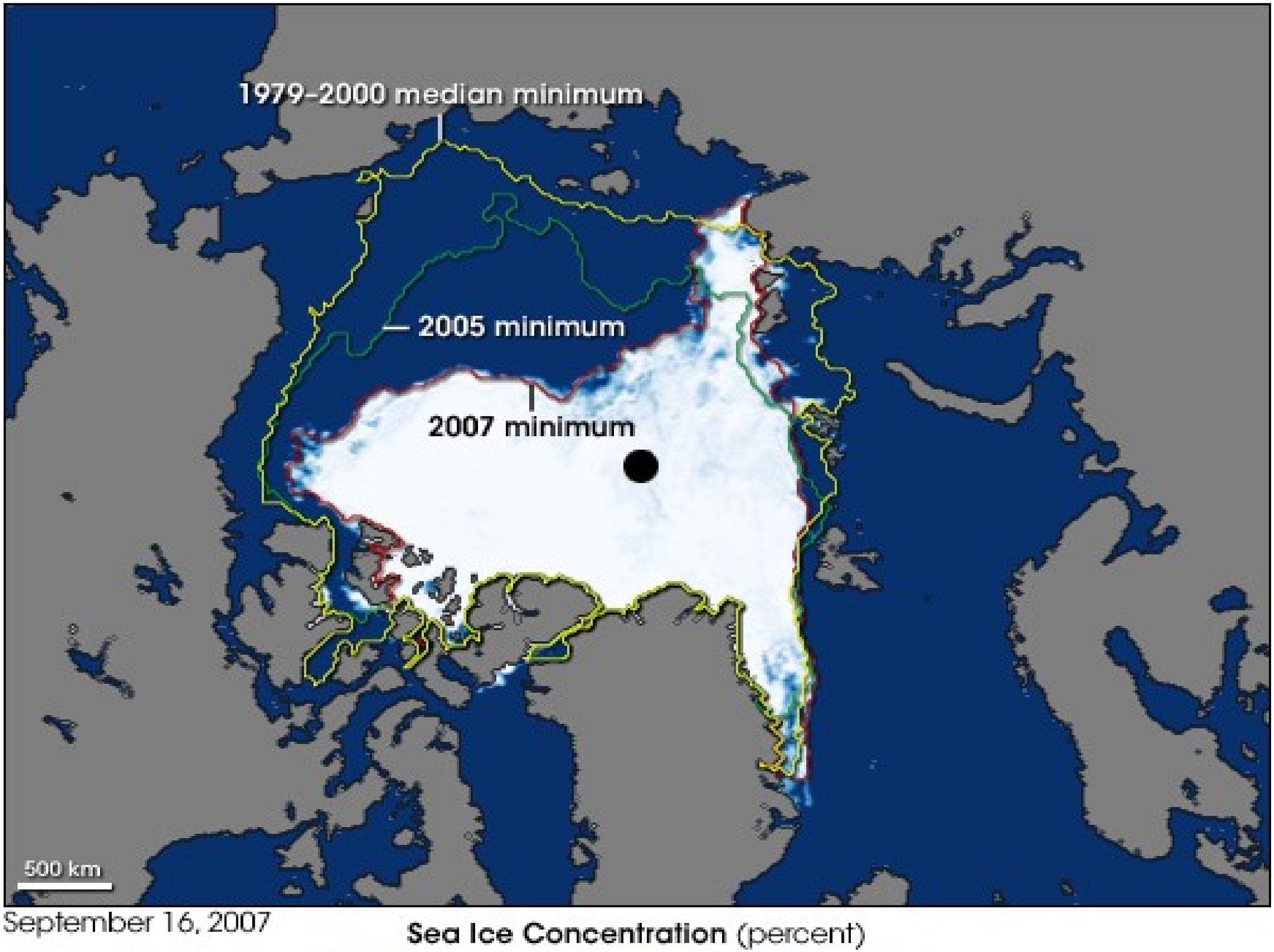
- Could we lose an entire country?

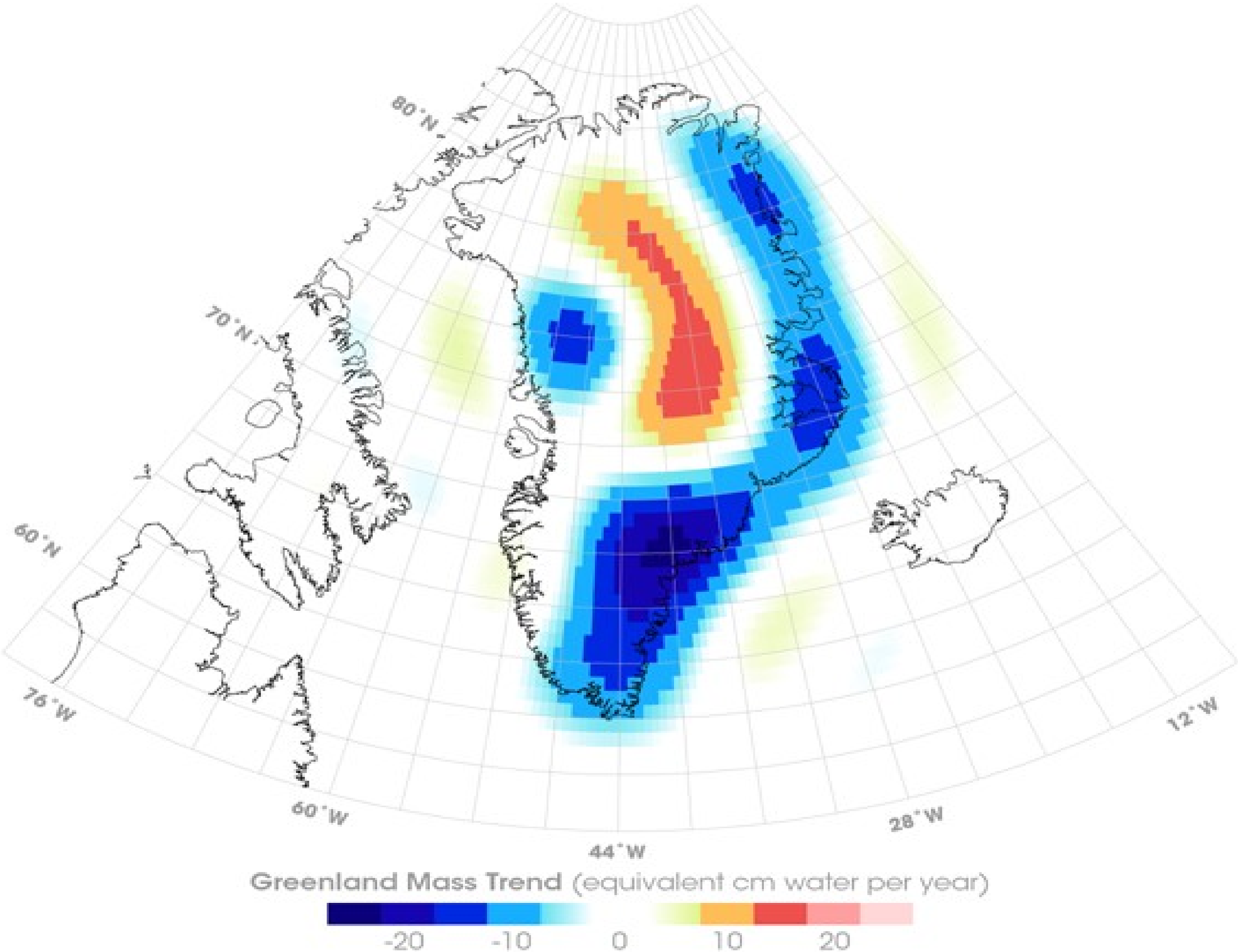
Drought

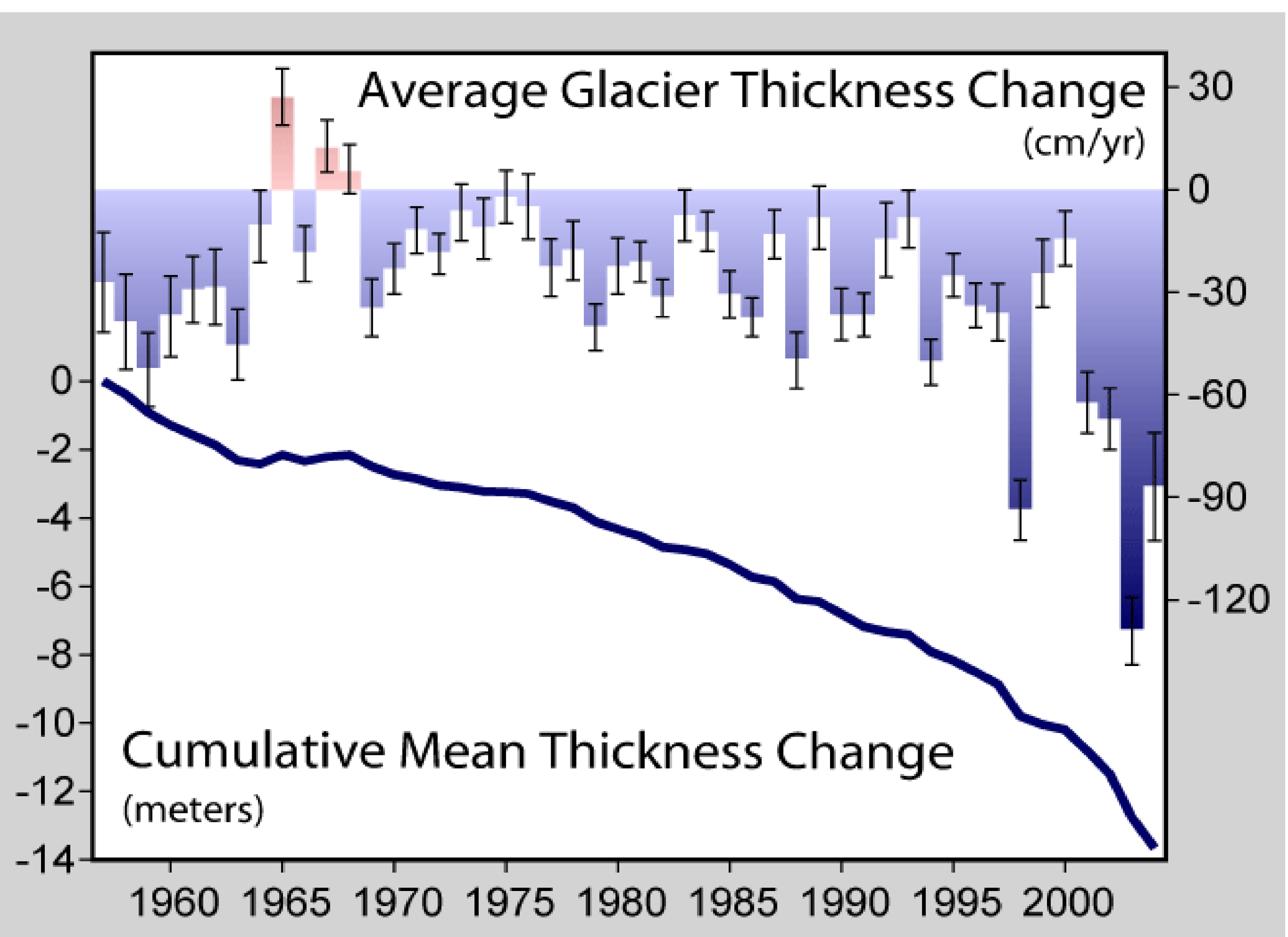
Mid-latitudes get increased drought due to more convection



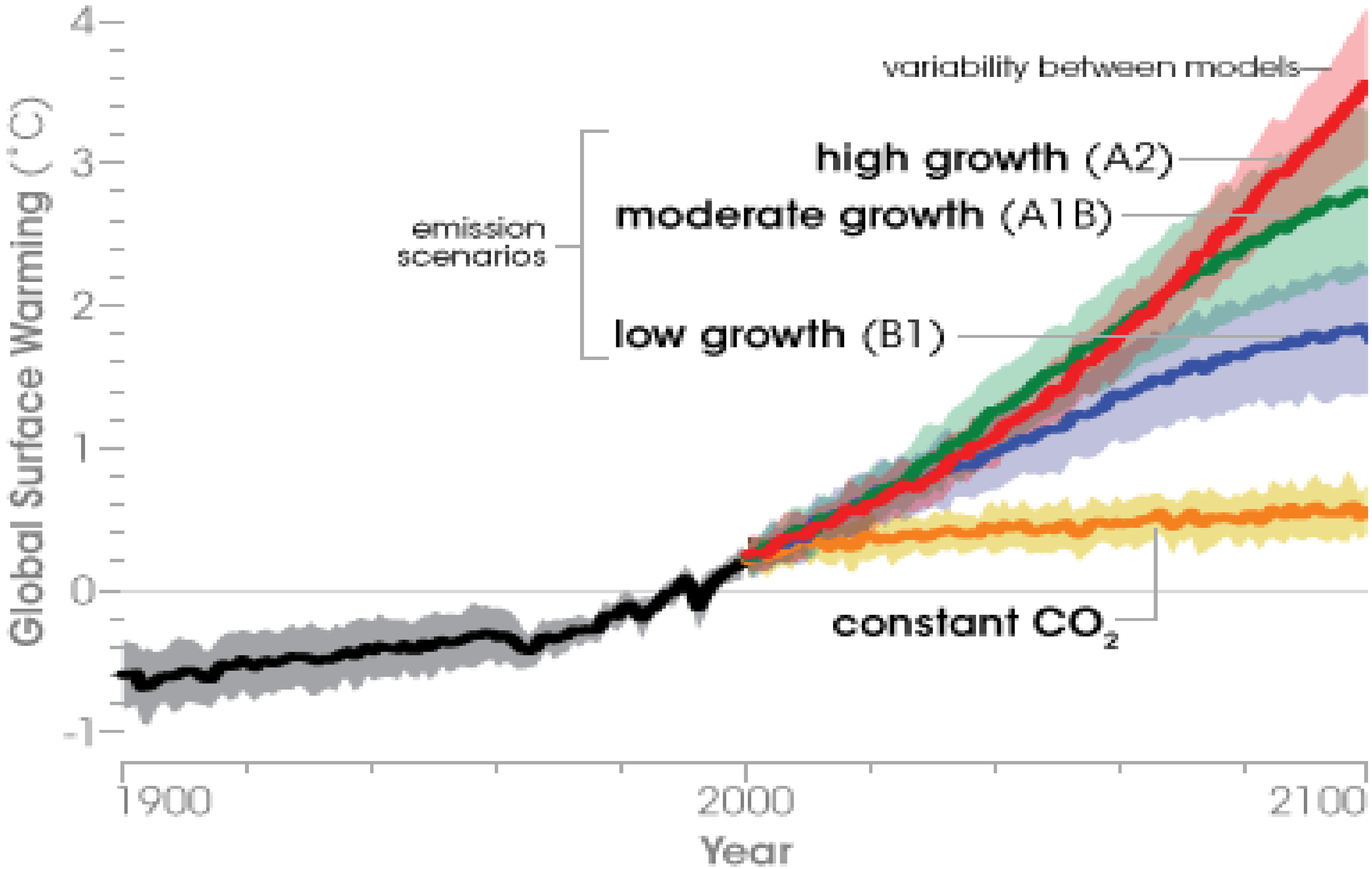
Arctic sea ice minimum



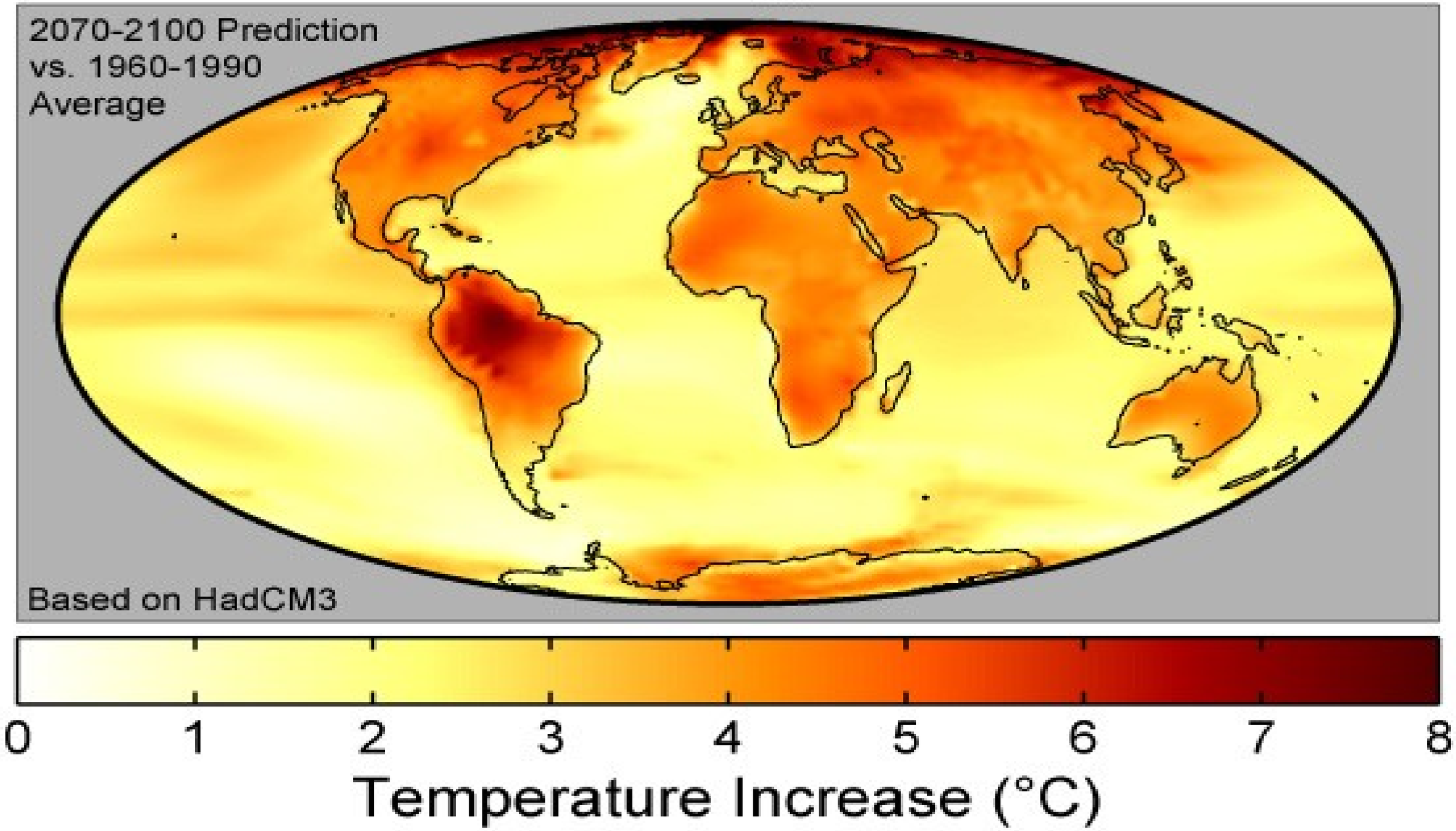

80°N
70°N
60°N
76°W
60°W
44°W
28°W
12°W
Greenland Mass Trend (equivalent cm water per year)
-20
-10
0
10
20

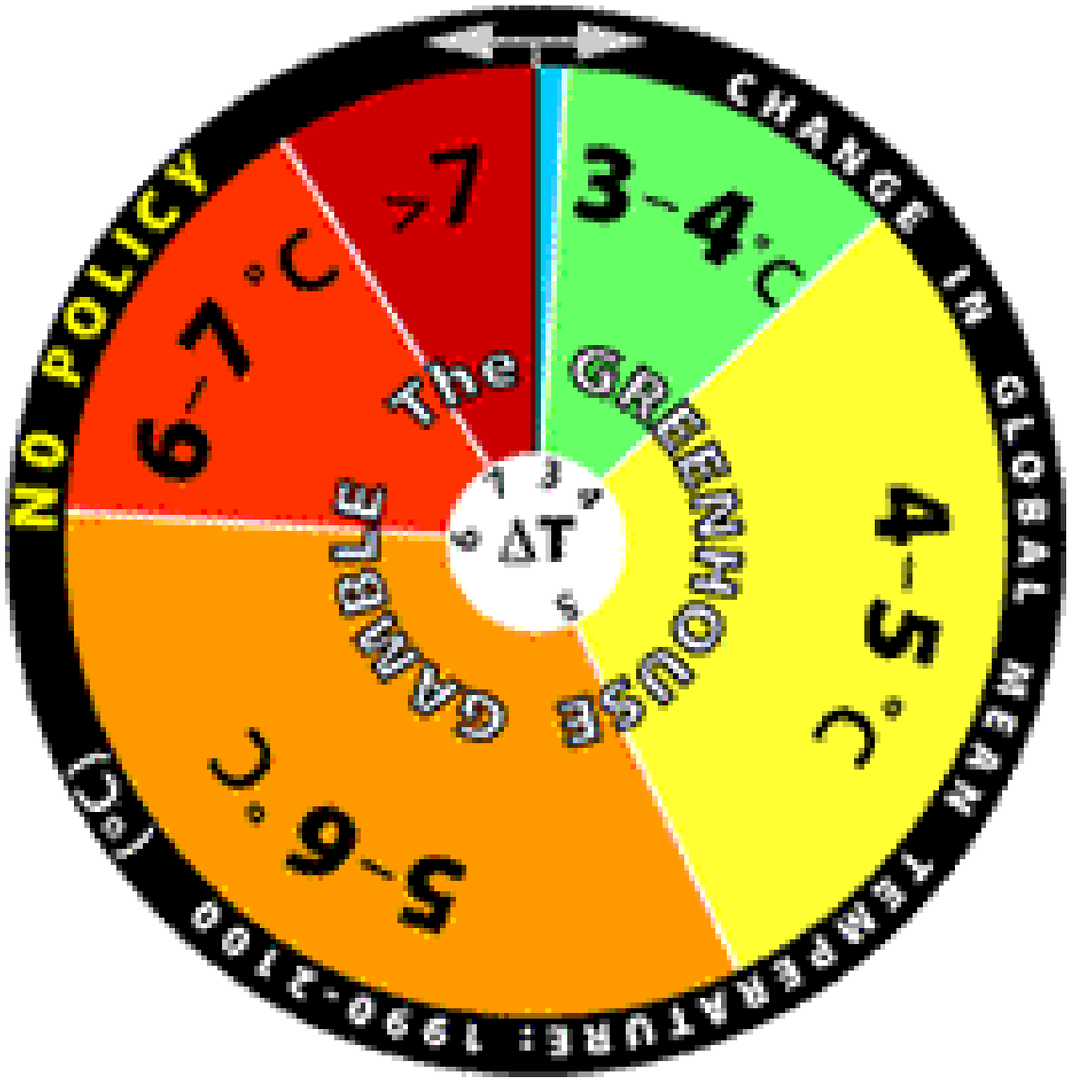

Average Glacier Thickness Change
(cm/yr)
30
0
-30
-60
-90
-120
Cumulative Mean Thickness Change
(meters)
0
-2
-4
-6
-8
-10
-12
-14
1960
1965
1970
1975
1980
1985
1990
1995
2000

Projections

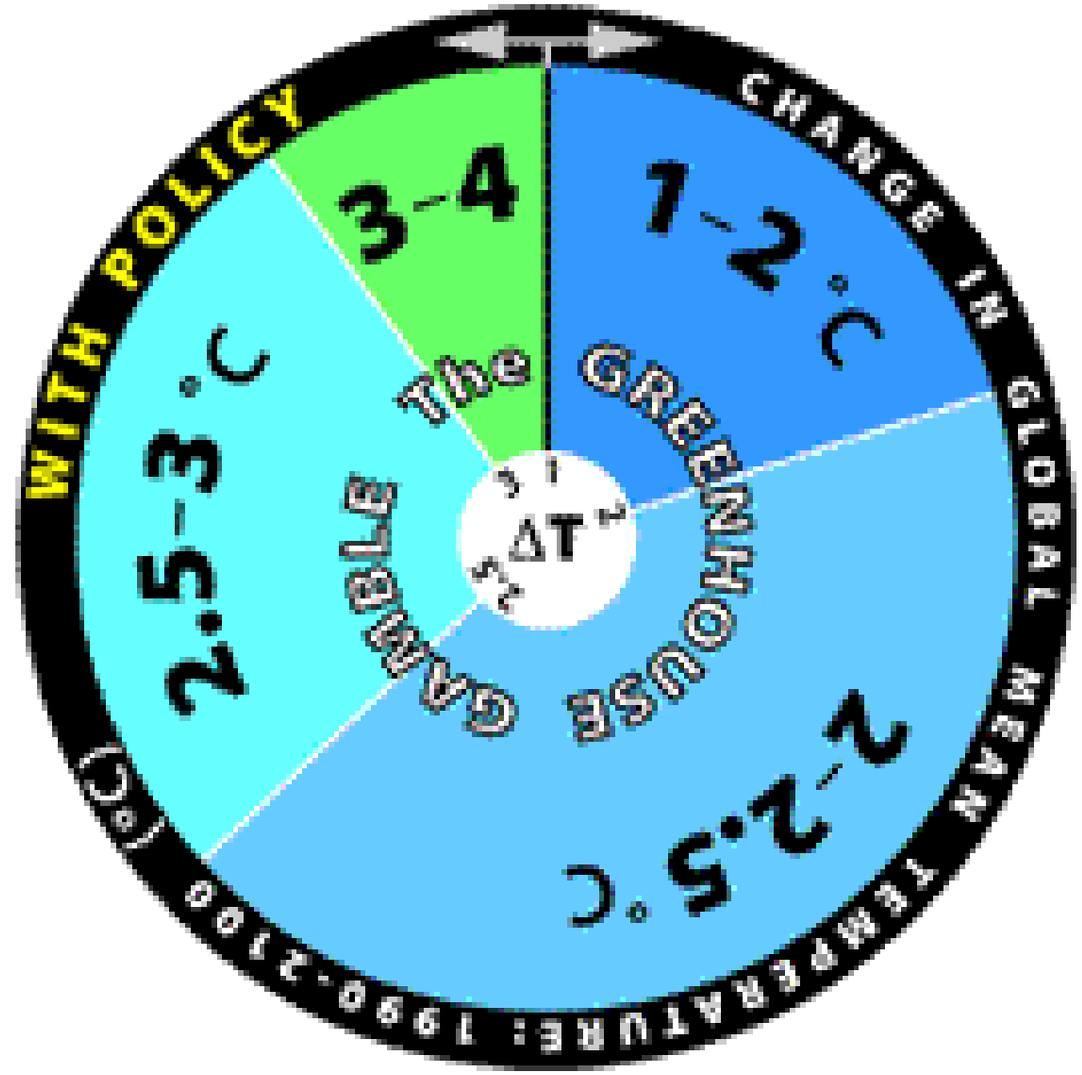


Global Warming Predictions

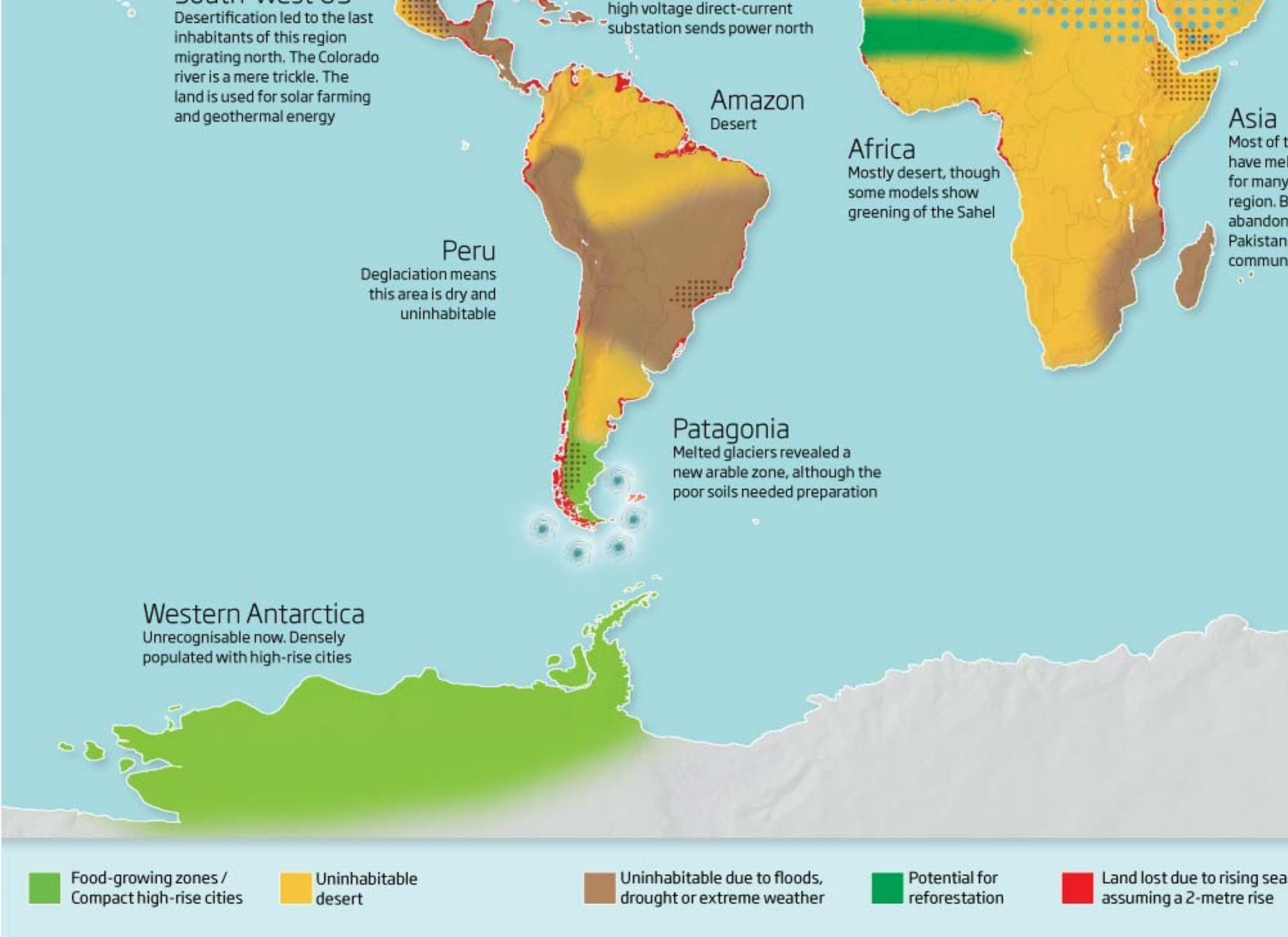




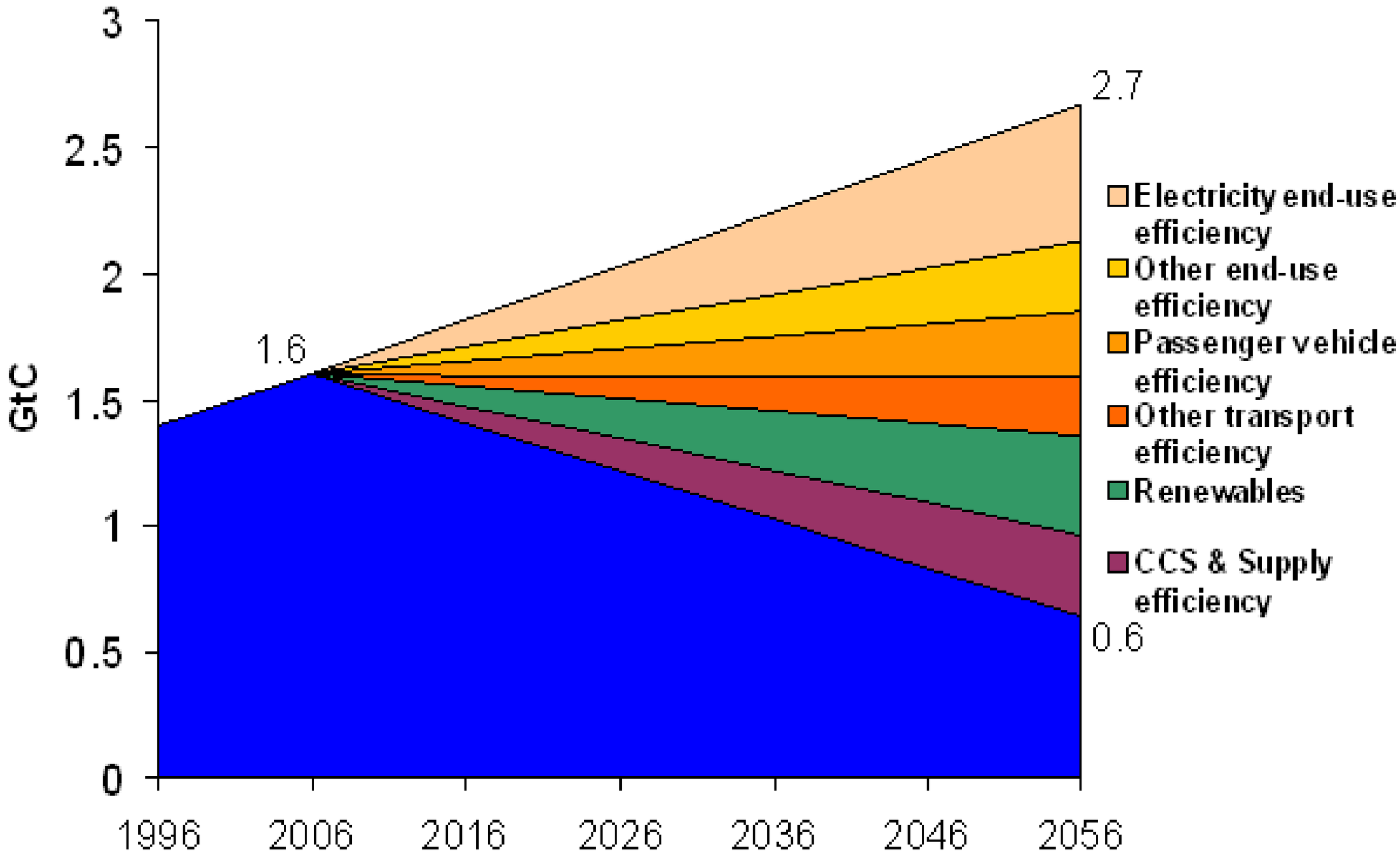
Warming Possibilities in 2100
Under No Policy Scenario

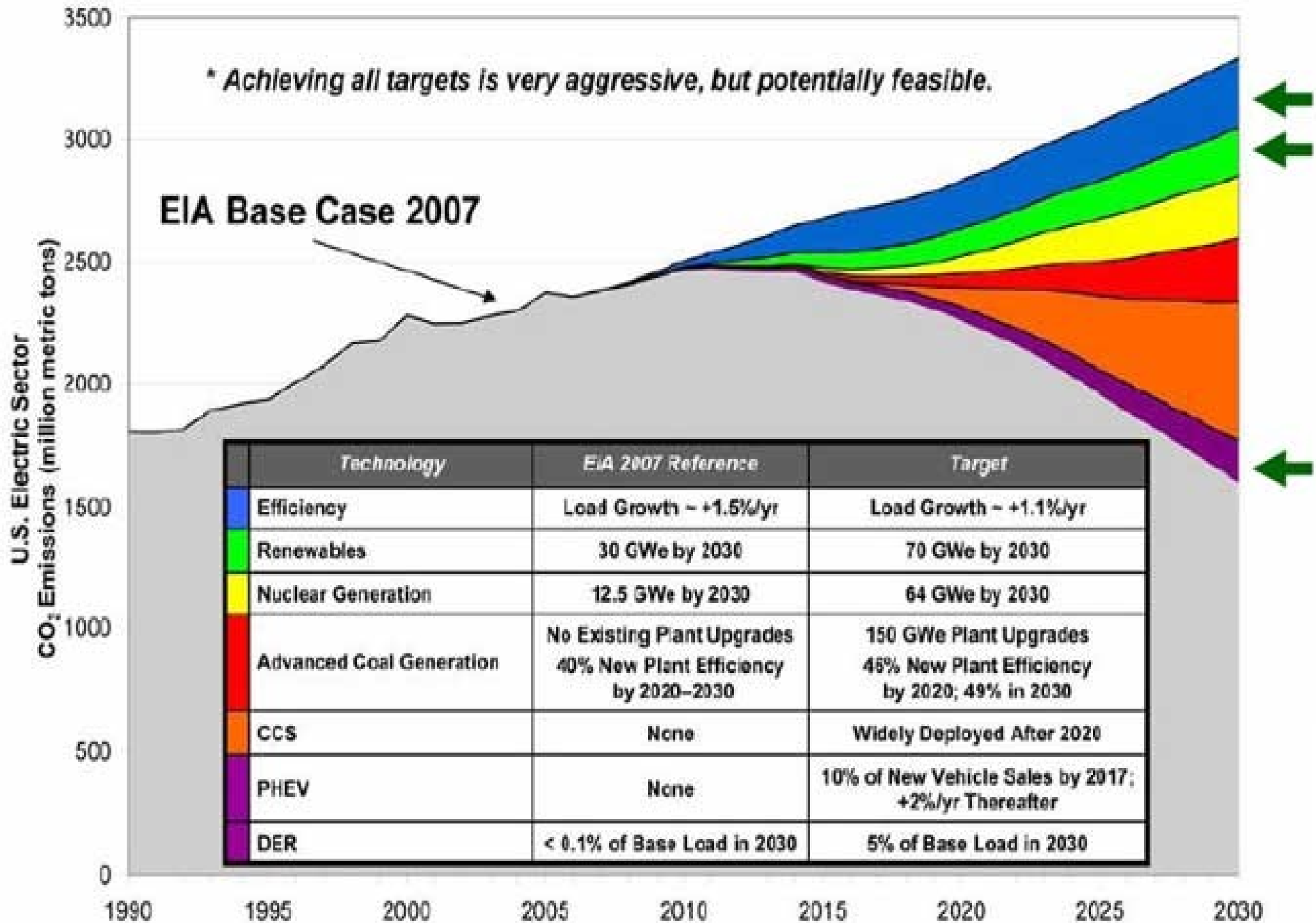


Warming Possibilities in 2100
Under Policy Scenario


Desertification led to the last inhabitants of this region migrating north. The Colorado river is a mere trickle. The land is used for solar farming and geothermal energy
high voltage direct-current substation sends power north
Amazon
Desert
Africa
Mostly desert, though some models show greening of the Sahel
Asia
Most of t
have mel
for many
region. B
abandon
Pakistan
commun
Peru
Deglaciation means this area is dry and uninhabitable
Patagonia
Melted glaciers revealed a new arable zone, although the poor soils needed preparation
Western Antarctica
Unrecognisable now. Densely populated with high-rise cities
Food-growing zones / Compact high-rise cities
Uninhabitable desert
Uninhabitable due to floods, drought or extreme weather
Potential for reforestation
Land lost due to rising sea
assuming a 2-metre rise

Wedges


3
2.5
2
1.5
1
0.5
0
GtC
1.6
2.7
0.6
1996
2006
2016
2026
2036
2046
2056
Electricity end-use efficiency
Other end-use efficiency
Passenger vehicle efficiency
Other transport efficiency
Renewables
CCS & Supply efficiency



Technology	EIA 2007 Reference	Target
Efficiency	Load Growth ~ +1.5%/yr	Load Growth ~ +1.1%/yr
Renewables	30 GWe by 2030	70 GWe by 2030
Nuclear Generation	12.5 GWe by 2030	64 GWe by 2030
Advanced Coal Generation	No Existing Plant Upgrades 40% New Plant Efficiency by 2020–2030	150 GWe Plant Upgrades 46% New Plant Efficiency by 2020; 49% in 2030
CCS	None	Widely Deployed After 2020
PHEV	None	10% of New Vehicle Sales by 2017; +2%/yr Thereafter
DER	< 0.1% of Base Load in 2030	5% of Base Load in 2030

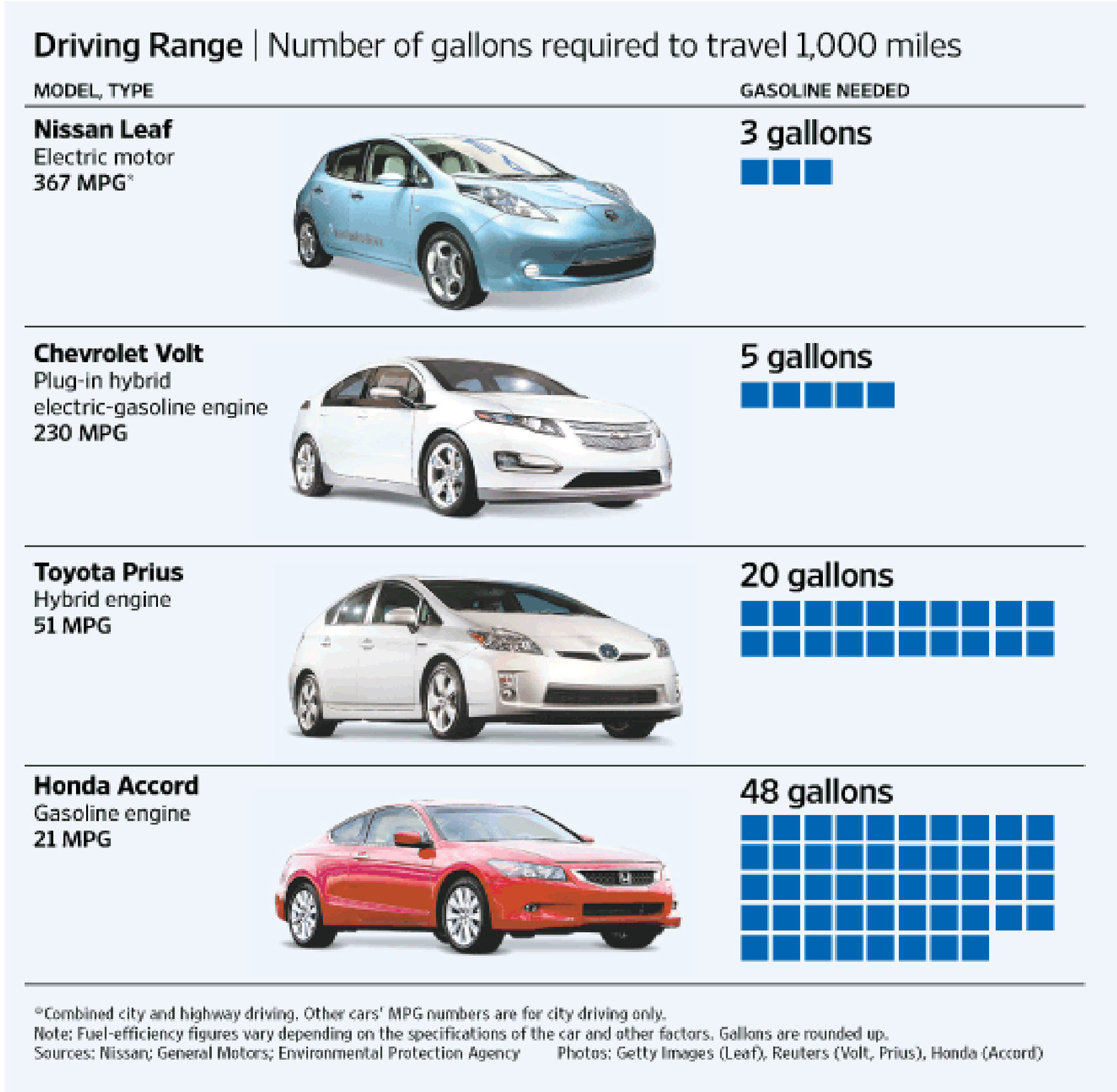
Short Term Wedges:

- 1 wedge of albedo change through white roofs and pavement (aka “soft geoengineering")
- 1 wedge of vehicle efficiency: all cars 60 mpg, with no increase in miles traveled per vehicle.
- 1 of wind for power: one million large (2 MW peak) wind turbines
- 1 of wind for electric vehicles: another 2000 GW wind.
- 3 of concentrated solar thermal (aka solar baseload): 5000 GW peak.
- 3 of efficiency: one each for buildings, industry, and cogeneration/heat-recovery for a total of 15 to 20 million GWh
- 1 of solar photovoltaics: 2000 GW peak
- 1 wedge of nuclear power: 700 GW
- 2 of forestry: End all tropical deforestation, plant new trees over an area the size of Canada

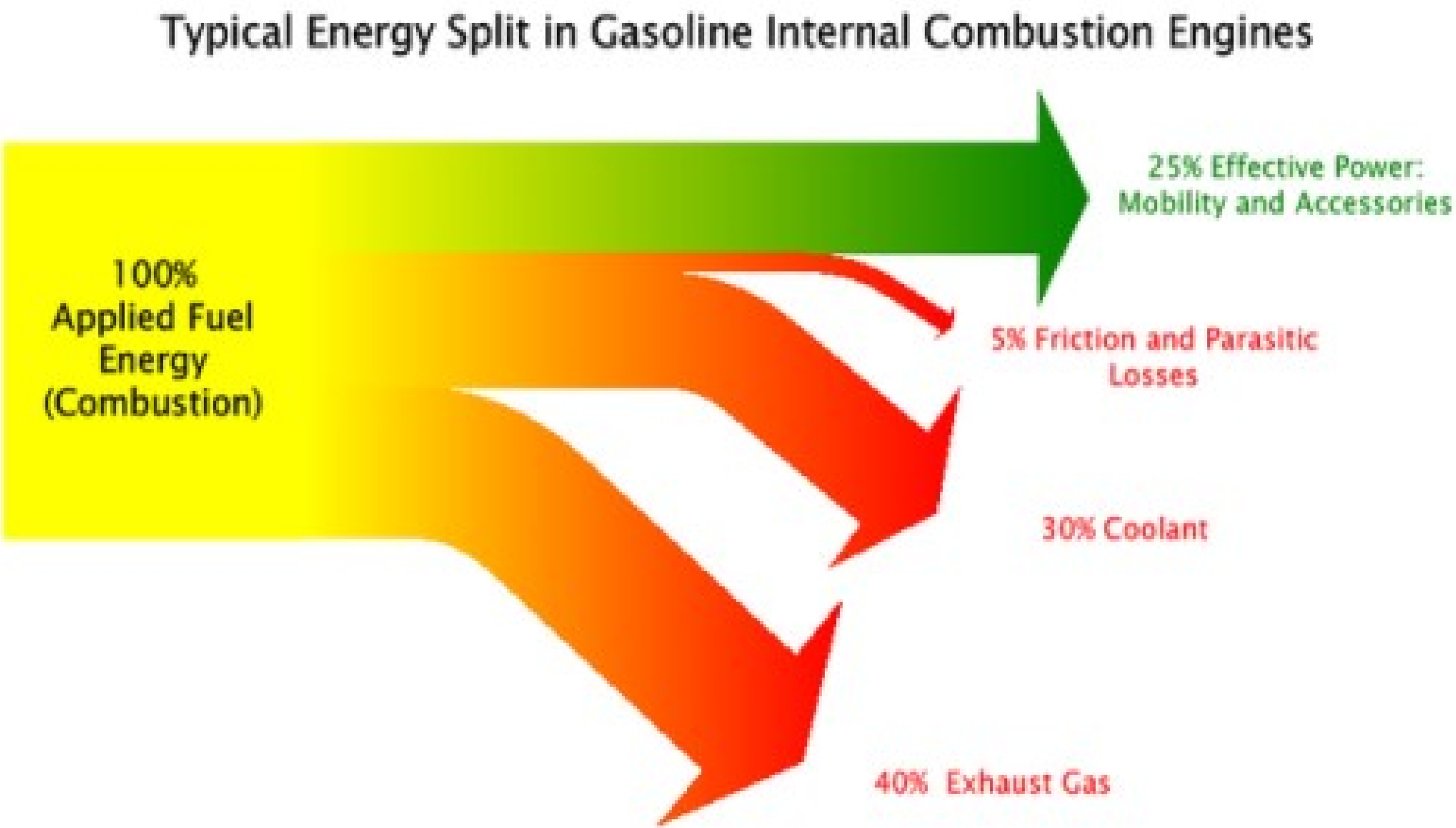
Longer-term Wedges?

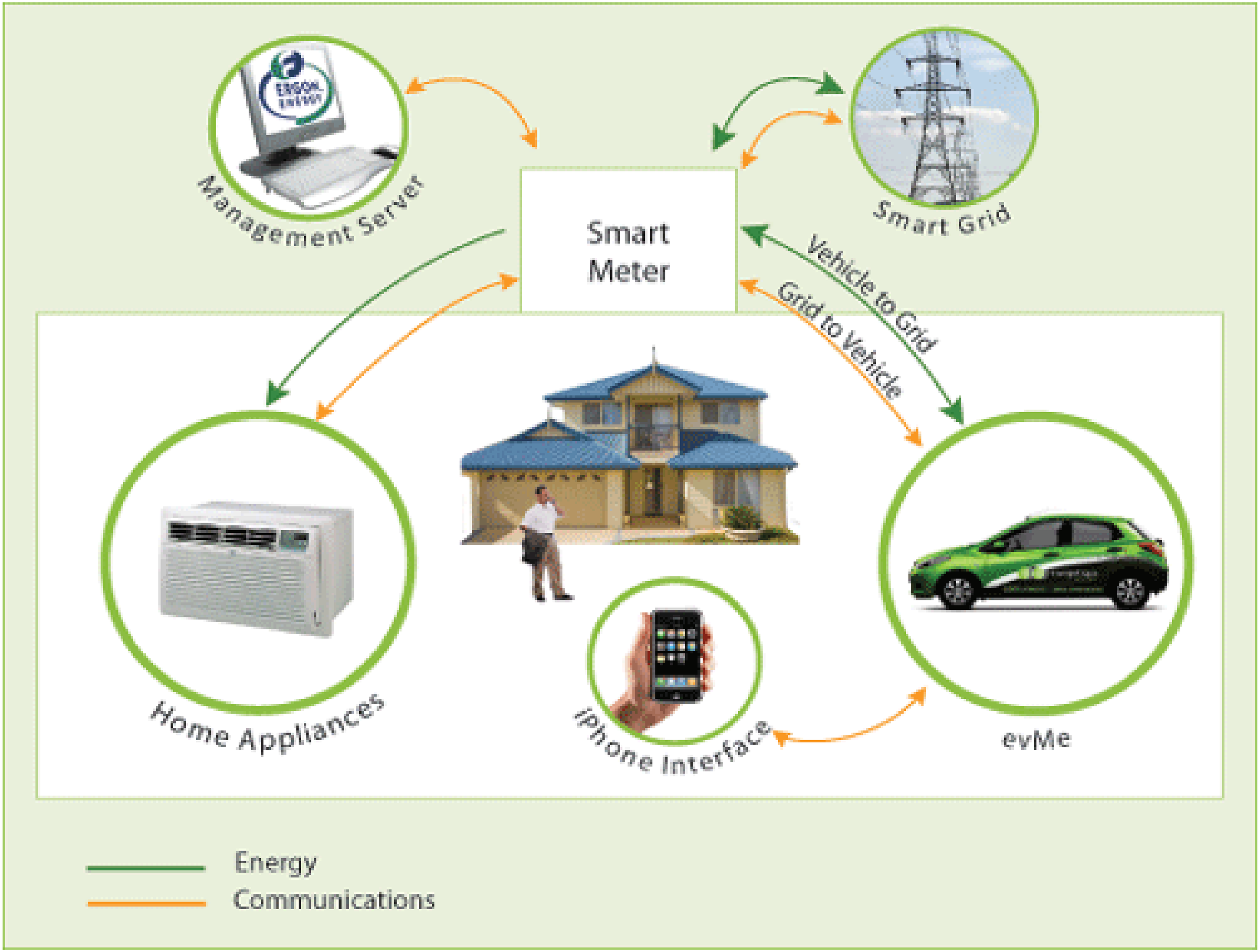
- 1 of geothermal plus ocean-based renewables (i.e. tidal, wave, and/or ocean thermal)
- 1 of coal with biomass cofiring plus carbon capture and storage: 400 GW of coal plus 200 GW biomass with CCS
- 1/2 to 1 wedge of cellulosic biofuels for long-distance transport and aviation using 8% of the world's cropland
- 1 of soils and/or biochar: apply improved agricultural practices to all existing croplands
- 1 wedge of WWII-style conservation, post-2030 [this could well include dietary changes]

Electric Vehicles



Why so much more efficient?



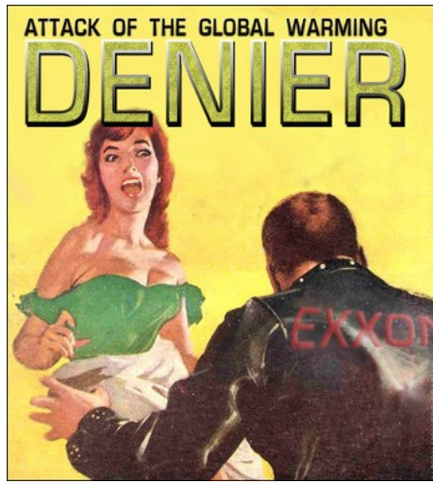

Management Server
Smart Grid
Smart Meter
Vehicle to Grid
Grid to Vehicle
Home Appliances
iPhone Interface
evMe
Energy
Communications

International efforts

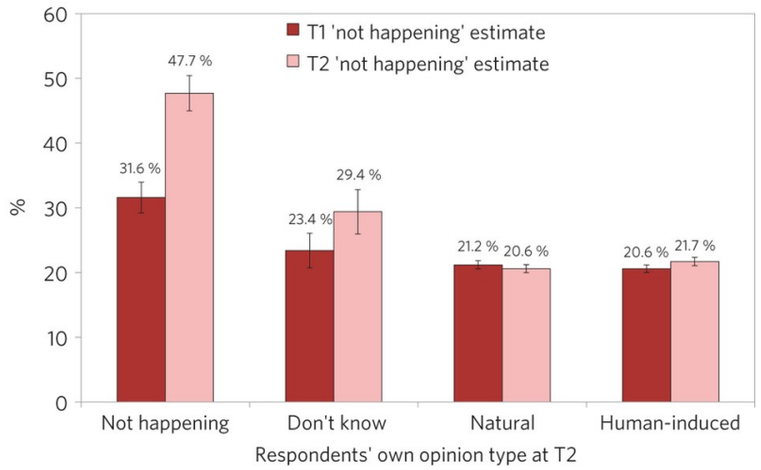
- IPCC
- Kyoto Protocol
- APPCDC

Quizlet!

Why do people still have doubts?



- Psychology: who wants to think humans are destroying our climate and that we are some of the biggest culprits?



- Professional misinformers: PR campaigns a la tobacco-cancer debate

- Illusion of debate in the media

"AstroTurf" groups

Earn Quick and Easy $20 for an hour or less of work (Midtown East)

Our firm needs 100 volunteers to attend and participate in a rally in front of the British Consulate/Embassy in Midtown Manhattan on the East Side on Wednesday, January 30, 2013 at 12 noon. The event is being held in order to protest wind turbines that are being built in Scotland and England. Your participation will be to ONLY stand next to or behind the speakers and elected officials/celebrities that will be speaking at the rally.

It is a really simple job and easy money for anyone who is around Manhattan at the time. We need all of our volunteers to RSVP for this event. It is VERY important that you RSVP because we have had people confirm spots and fill spots on the first day of the advertisement in the past. If you have participated in one of our events in the past (Ovation) please make a note of that in your RSVP email and we will email EVERYONE back to confirm your attendance.

We look forward to hearing from you all and again, the money is quick, the job is easy and we pay in CASH at the end of the event.

Looking forward to seeing you next Wednesday!

- Compensation: $20 dollars cash
- This is a part-time job.
- Principals only. Recruiters, please don't contact this job poster.
- Please, no phone calls about this job!
- Please do not contact job poster about other services, products or commercial interests.

Posting ID: 3566741544 Posted: 2013-01-23, 4:55PM EST email to a friend

Ebscohost: search scientific journals

- Find an article from a peer-reviewed journal
- Summarize the study and describe it to the class

Summary of my article

- Name of the article, journal, date
- What they were trying to find out
- What did they conclude?

- Liska, Adam J., et al. "Improvements In Life Cycle Energy Efficiency And Greenhouse Gas Emissions Of Corn-Ethanol." *Journal Of Industrial Ecology* 13.1 (2009): 58-74. *Academic Search Premier*. Web. 17 Oct. 2016.