Global Warming and Our Energy Future

Dennis Silverman
Physics and Astronomy
U C Irvine
www.physics.uci.edu/~silverma/
gwenergy.ppt

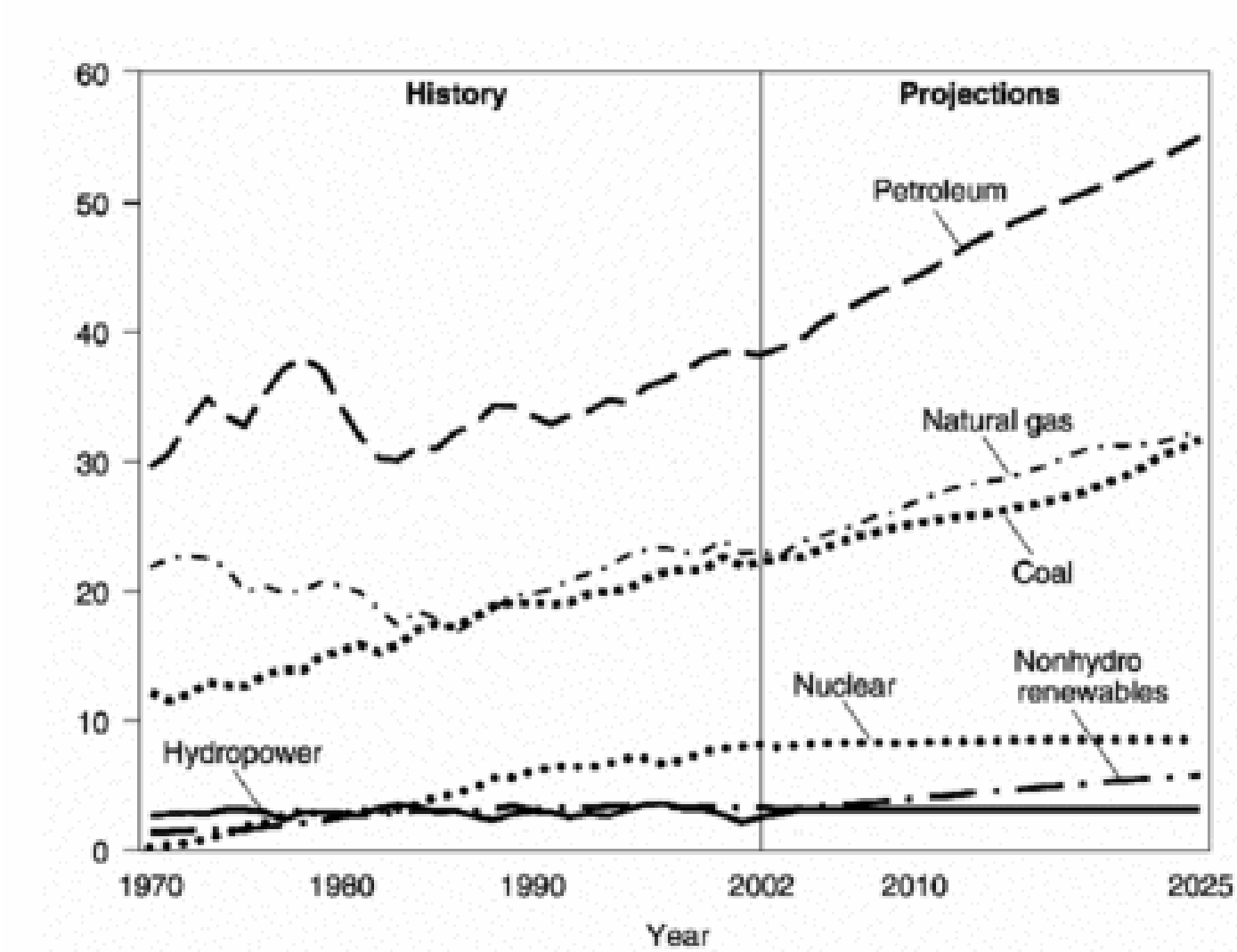
Global Warming and Energy Questions

- How will nations respond to Global Warming and energy predictions? This will determine what the actual greenhouse gas generation will be.
- What is the timescale for the eventual scarcity of oil and natural gas?
- What will be the price rises on fuels, and how will they feedback onto the generation of greenhouse gases?
- What will replacement fuels and their costs be?
- What will be the role of nuclear plants and alternative energy sources?
- How will the costs and taxes for holding back CO2 be assessed nationally and internationally?
- How will costs of severe dislocation and damages be weighed into prevention and international cost assessments?

I. Future of Fossil Fuels

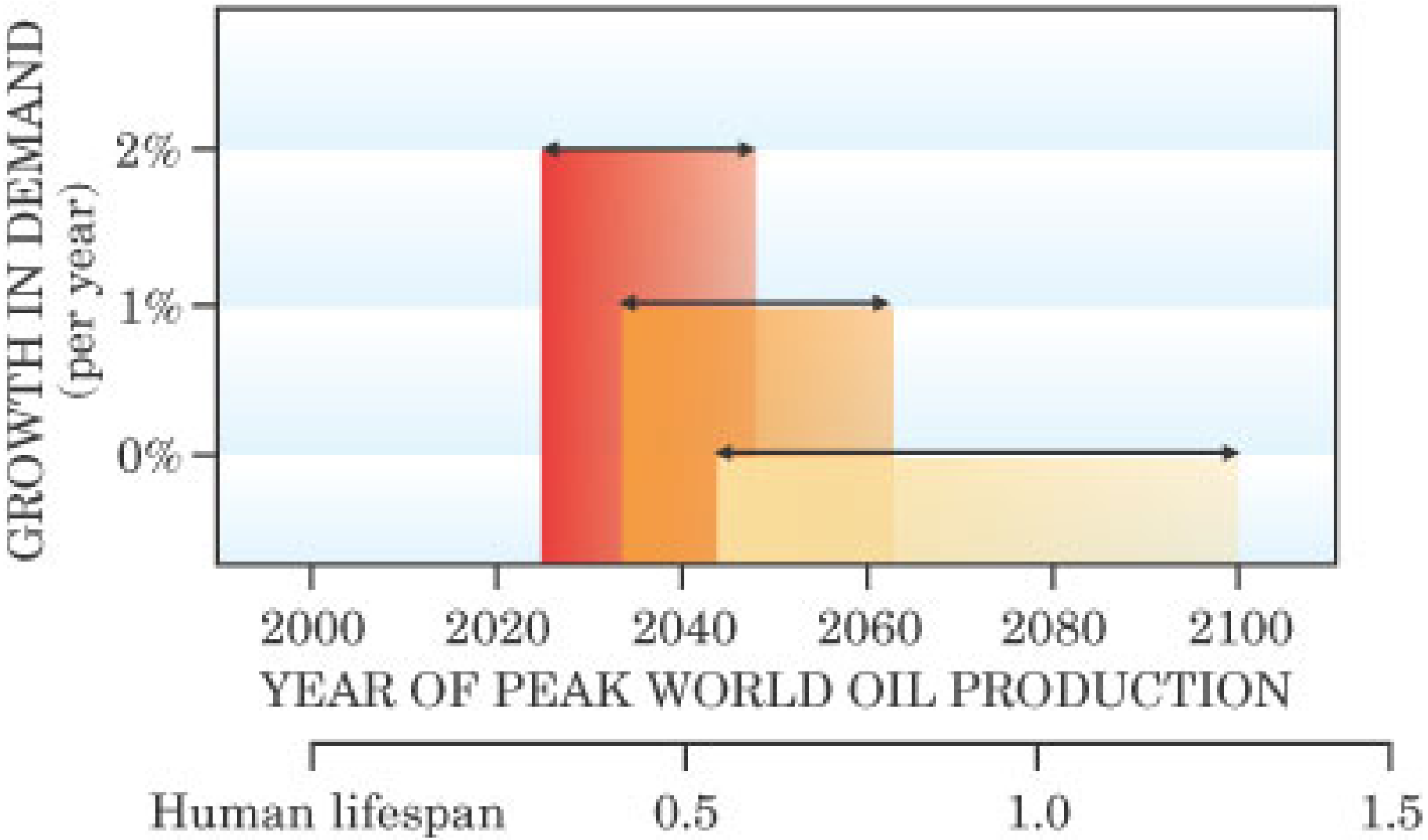
- Petroleum
- Natural Gas
- Coal
- Oil Shale and Tar Sands
- CO_2 Emissions

U.S. 20 Year Projections of Energy Use in Quadrillions of BTUs (Quads)



Petroleum Fuel Future

- The fossil fuel supply is expected to follow a bell shaped curve as developed by M. King Hubbert. The peak in the curve of yearly supply is the important point.
- US oil production peaked around 1970.
- World population growth is expected at 1% a year.
- US energy consumption is increasing at 1.5% a year.
- The US imports 60% of its oil.
- Proven world oil reserves are about 2,000 billion barrels.
- Unproven reserves may boost this to 3,000-4,000 billion barrels.
- For world oil demand growing in the range between 0-2 percent a year, the projected peak is shown in the next slide.
- (A lifetime here is 75 years.)
- The mean assessment of the reserves of the Artic National Wildlife Refuge (ANWR) is 6 billion barrels (if the price is greater than $25/barrel).


GROWTH IN DEMAND
(per year)
2%
1%
0%
2000
2020
2040
2060
2080
2100
YEAR OF PEAK WORLD OIL PRODUCTION
Human lifespan
0.5
1.0
1.5

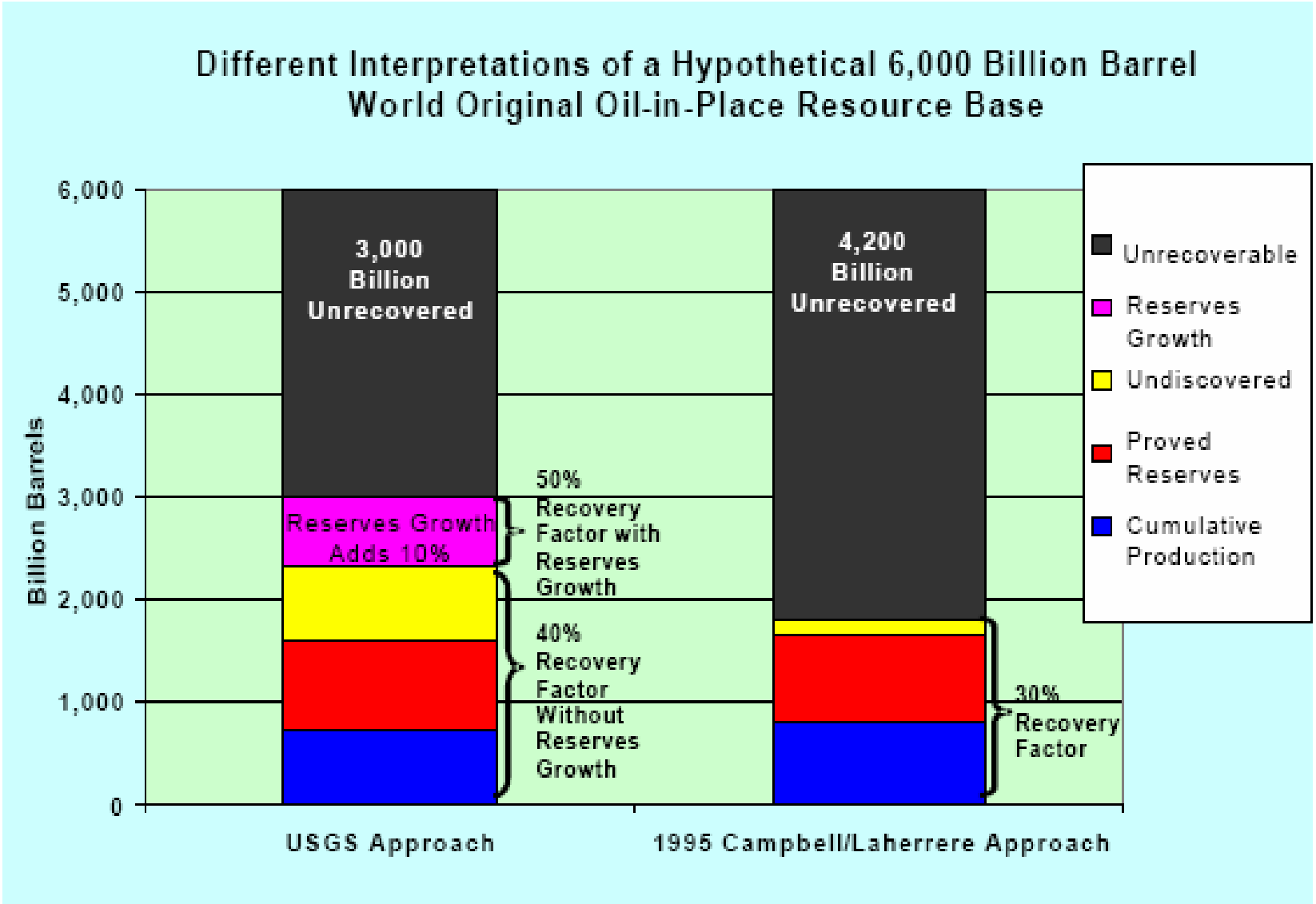
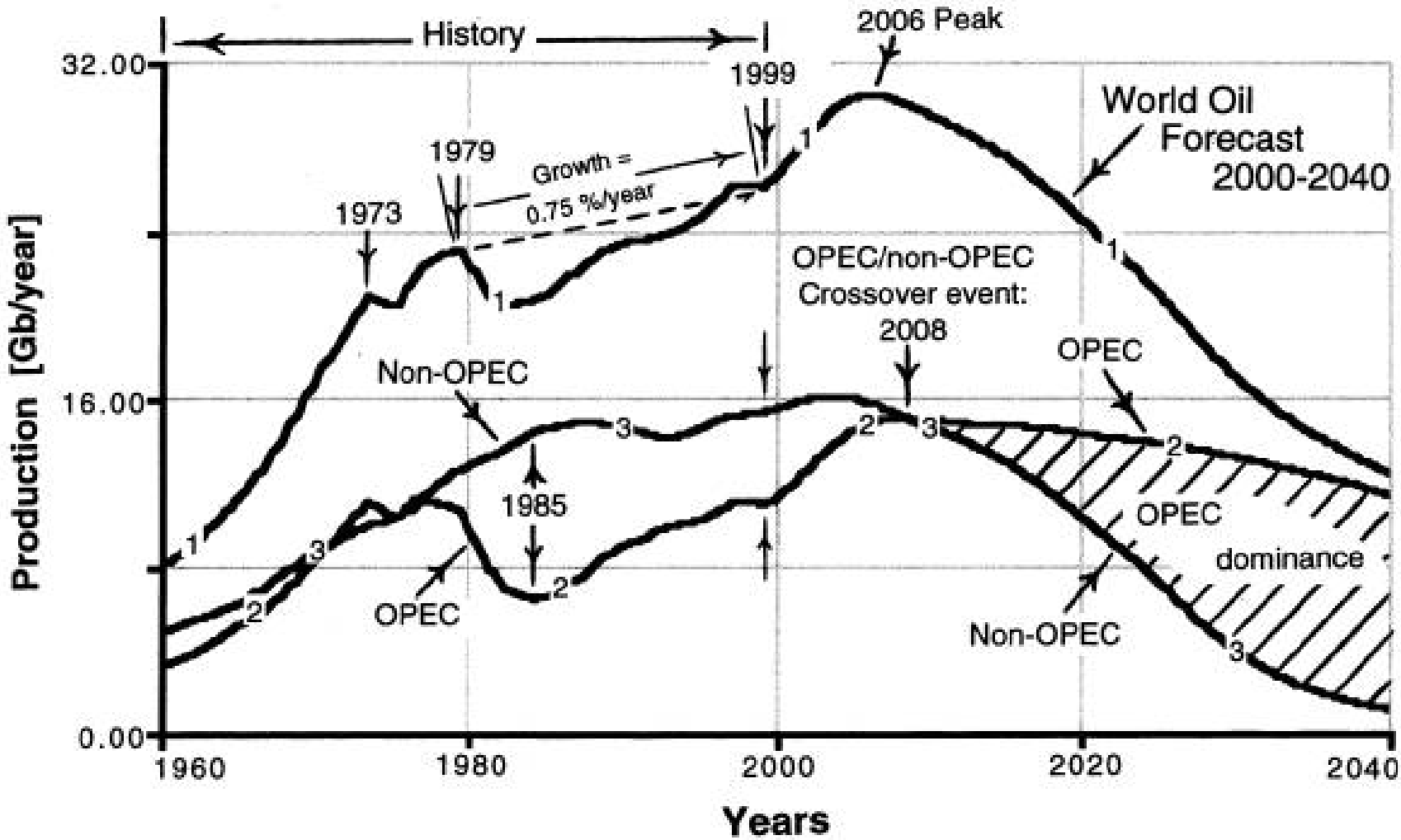


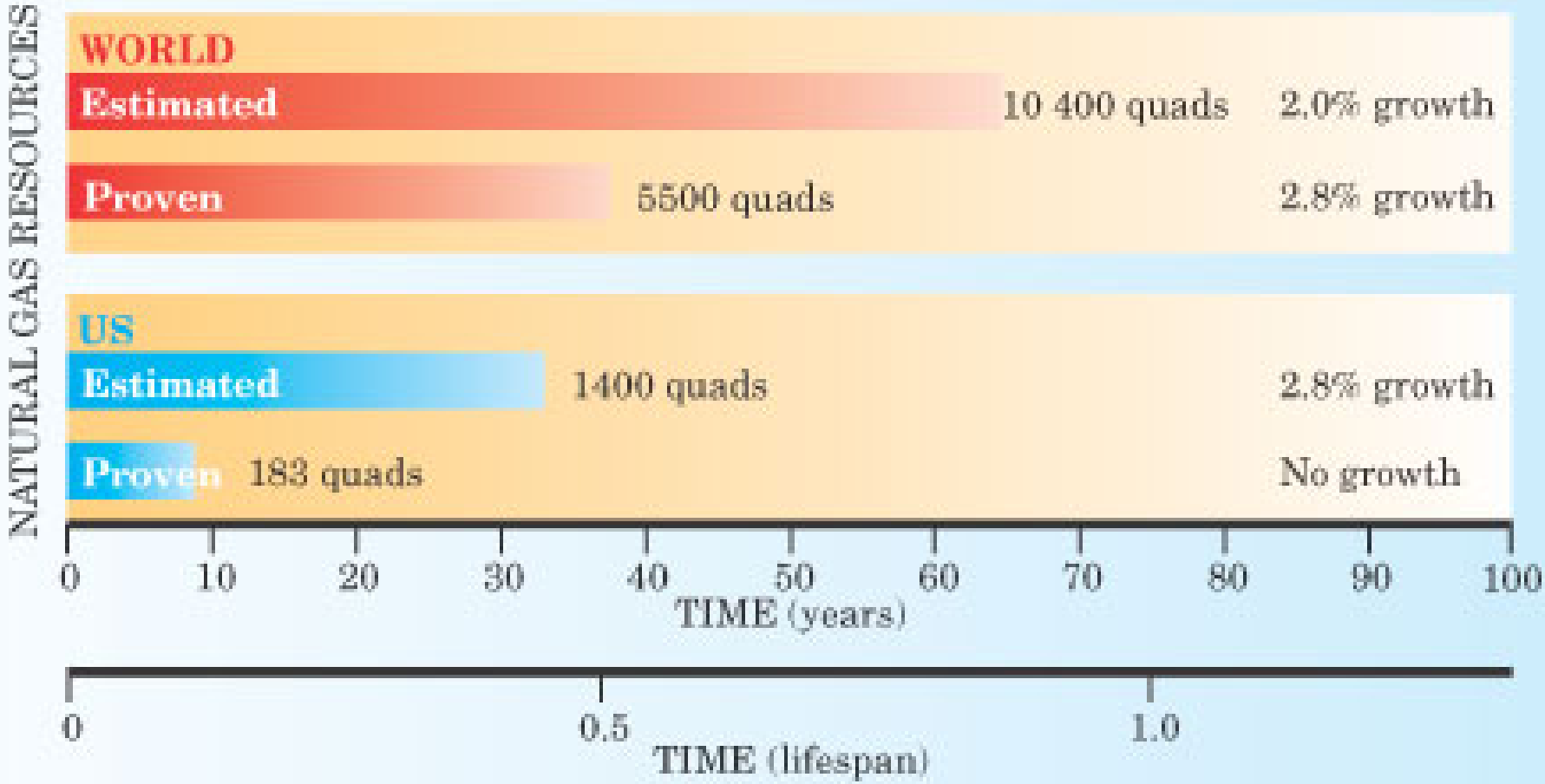
Figure: "Different Interpretations of a Hypothetical 6,000 Billion World Original Oil-in-Place Resource Base" [33]

Oil Growth and Decline (1,000 Bbl reserves)



US and World Natural Gas

- US demand growth is 3% per year.
- A shortage now exists in the US and plans for Liquid Natural Gas (LNG) terminals for imports exist around the country (Ventura, Long Beach, Baja California)
- The graphs are for the time the supply will last.
- The units are in Quads (Quadrillion BTUs)
- The whole US energy consumption in all forms is 100 Quads per year.


NATURAL GAS RESOURCES
WORLD
Estimated
10 400 quads
2.0% growth
Proven
5500 quads
2.8% growth
US
Estimated
1400 quads
2.8% growth
Proven
183 quads
No growth
0
10
20
30
40
50
60
70
80
90
100
TIME (years)
0
0.5
1.0
TIME (lifespan)


L N G

Wo
Na
R

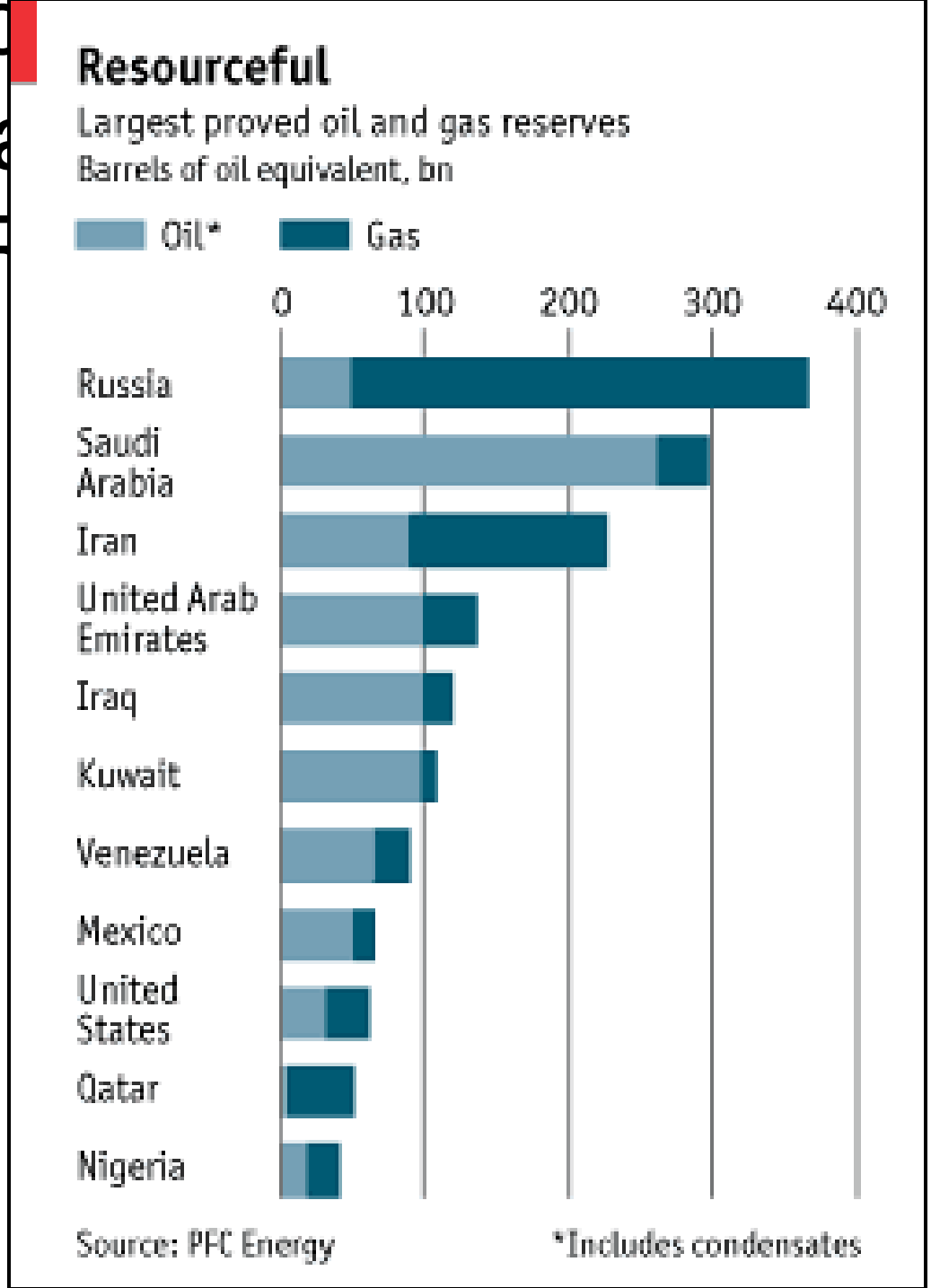
- Total reserves,

with natural gas reserves in equivalent

billion barrels of

Oil (bbl).

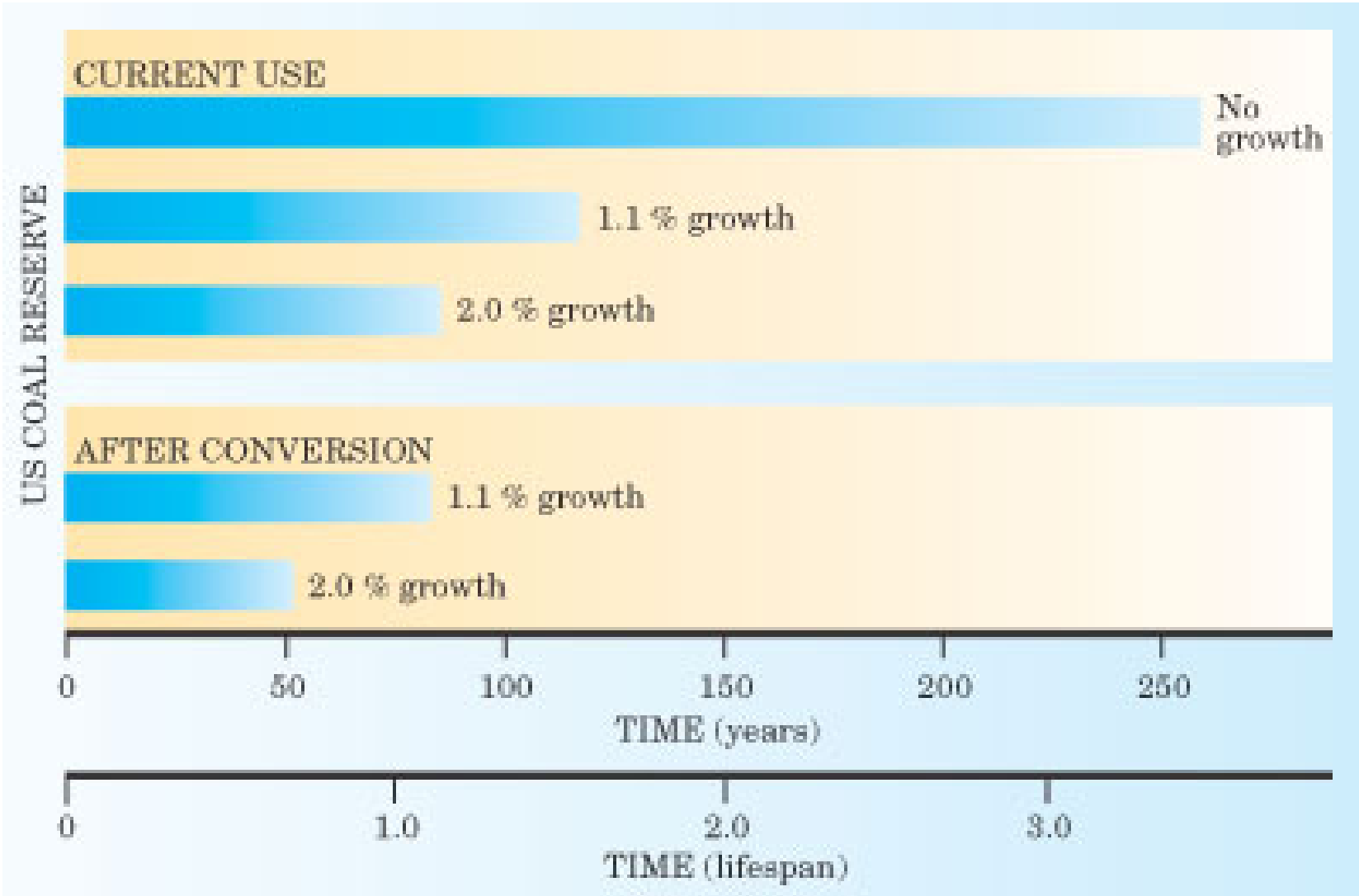
- World oil consumption is 30 bbl/year.
- Left out Canadian tar sands at 179 bbl oil.
- US has 22 bbl oil, and produces 2.0 bbl/year and would last only 11 years.



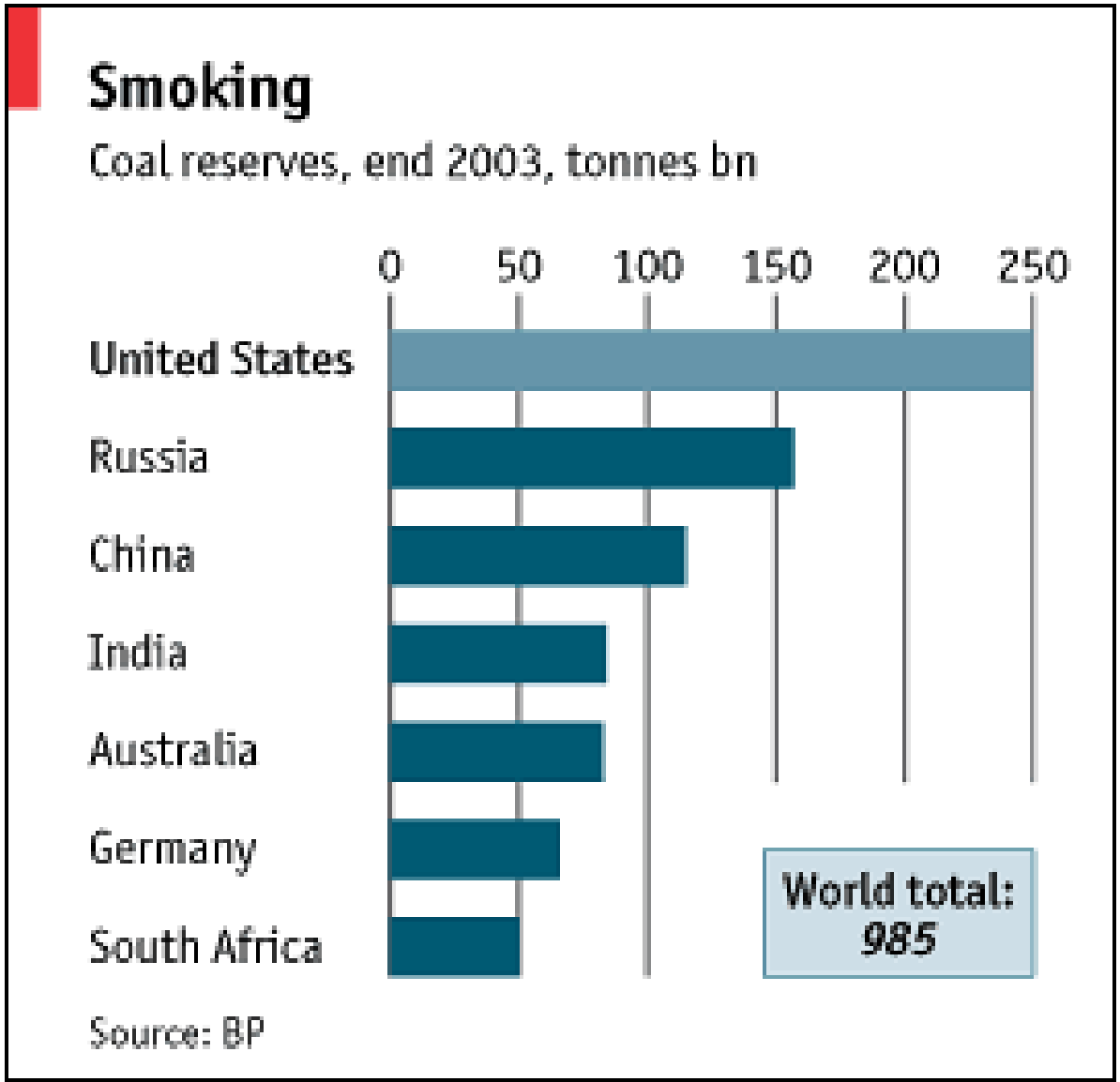
US Coal Supply

- The total US coal reserve is 5700 Quads.
- The current rate of use is about 20 Quads per year.
- Population growth will reduce its longevity from 250 years at no growth
- Conversion to motor fuel uses 2Quads of coal to generate 1Quad of fuel plus the additional CO2 emission.
- Conversion to hydrogen fuel uses even more.
- The graph assumes 54% of underground coal is recoverable.
- Estimates are for various growth rates of use.

US Coal Lifetime



World Coal Reserves



Dilute Fossil Residues

- Oil shale or tar sands has dilute amounts of heavy oil or near-solid carbonaceous residues.
  - Surface is mined at 2 tons per barrel of oil.
  - Deeper deposits are steam diluted and further processed to yield fuel, using energy, and costing CO2 production.
  - Cost is about $9/barrel before shipping.
- It also contains nitrogen and heavy metal compounds.
- The US has little. Worldwide estimates are large but speculative. 180 billion barrels worth in Canada.
- Source for several of the previous graphs is on the web in Physics Today, July 2004, by Paul B. Weisz.

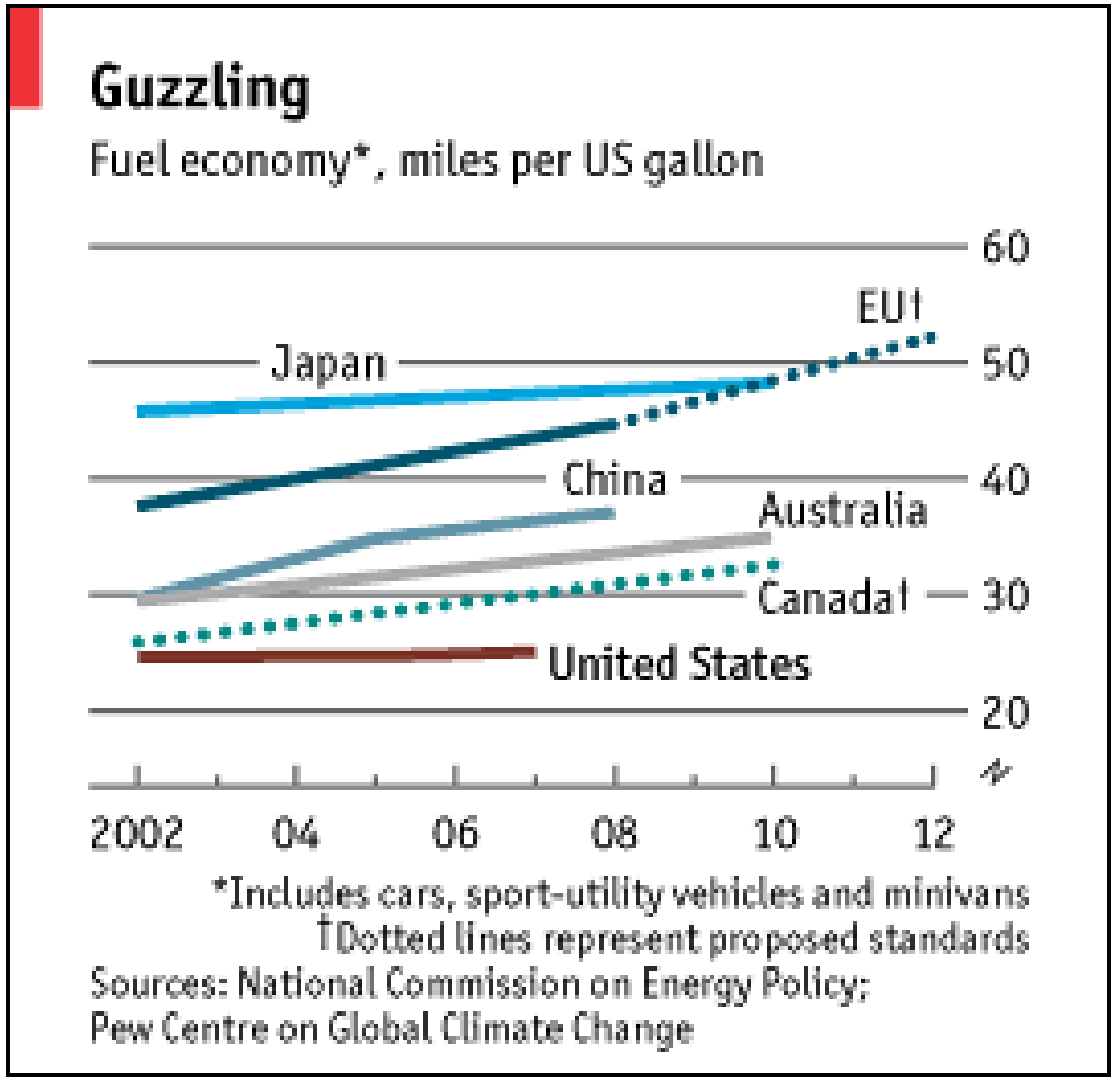
Fossil Fuel Future Summary

- Oil, Natural Gas, Shale Oil, and Coal produce CO_2.
  - Carbon sequestration requires an extra 30% of power and needs research. FutureGen $1 billion research plant.
- Oil is needed for transportation fuel
  - Too expensive for electricity generation
  - Reserves: About 50 years with growth in use
  - 2/3 is in the Middle East
- Coal may be converted to liquid fuel for transportation
  - 250 years at current rate, 100 years with conversion
- Total world reserve of oil is a large question, uses politically motivated estimates of individual countries
- Current rate of use of fossil fuels will increase world wide
- U S proposed climate technology program

Short Term Optimum

- The best way to hold down CO2 increases is to remove fossil fuels from electricity generation, but use it just for vehicles.
- Since ½ of US electricity comes from coal which generates twice as much CO2 per energy unit as does natural gas, we should switch to natural gas. This, however, involves massive and possibly costly imports.
- We need increases in alternate energy sources such as hydro, nuclear, wind and solar.
- We also need increases in energy efficiency and conservation.
- This especially includes high mileage vehicles.

Comparative Projected Vehicle Fuel Economies



Cost of Gasoline and Taxes

- Elsewhere in the world the cost of gas is around $1/liter, or $4/gallon.
- Gas taxes per gallon in various countries:
  - Great Britain $3.40
  - Italy $2.53
  - Germany $2.56
  - Japan $2.04
- US Federal Excise Tax per gallon is $0.18
  - California Excise Tax is $0.18
    - Wisconsin is $0.31, Alaska is $0.08
  - California State and Local Taxes are $0.14
- Total tax in California is $0.50/gallon

Comparative World CO2 Emissions

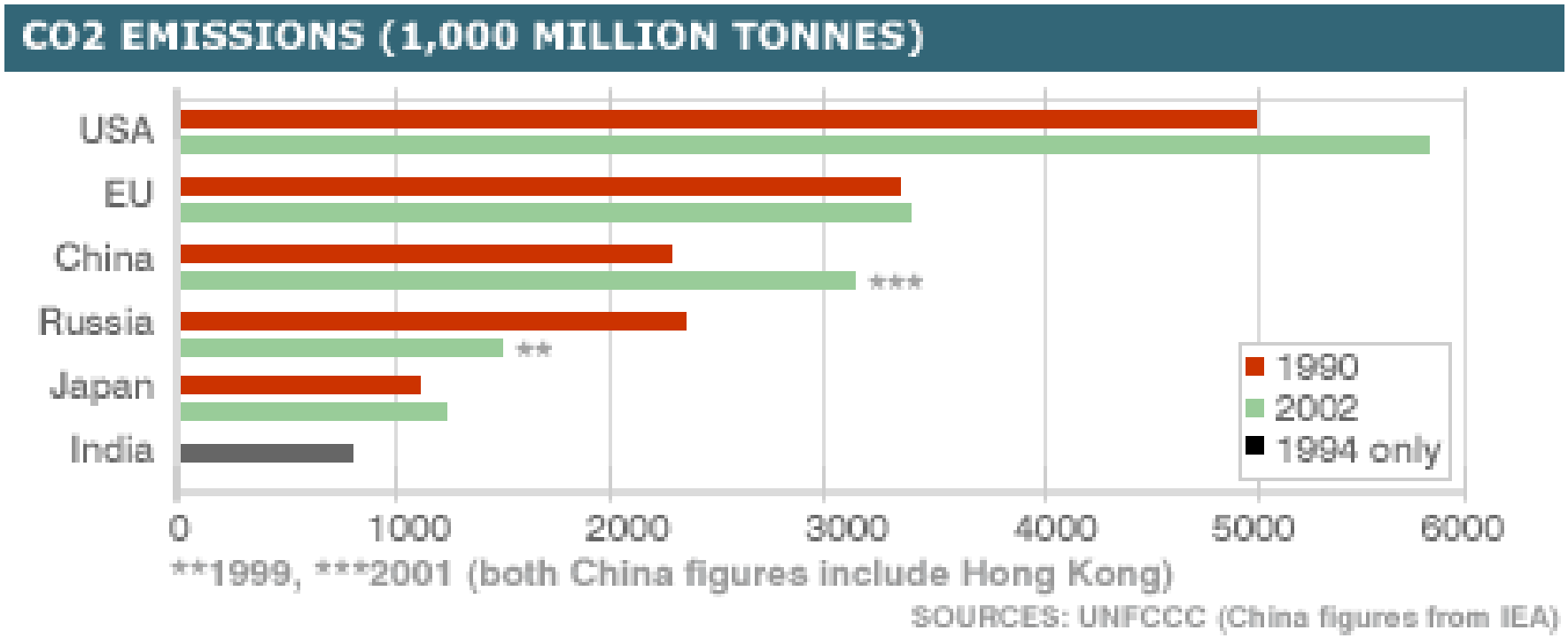
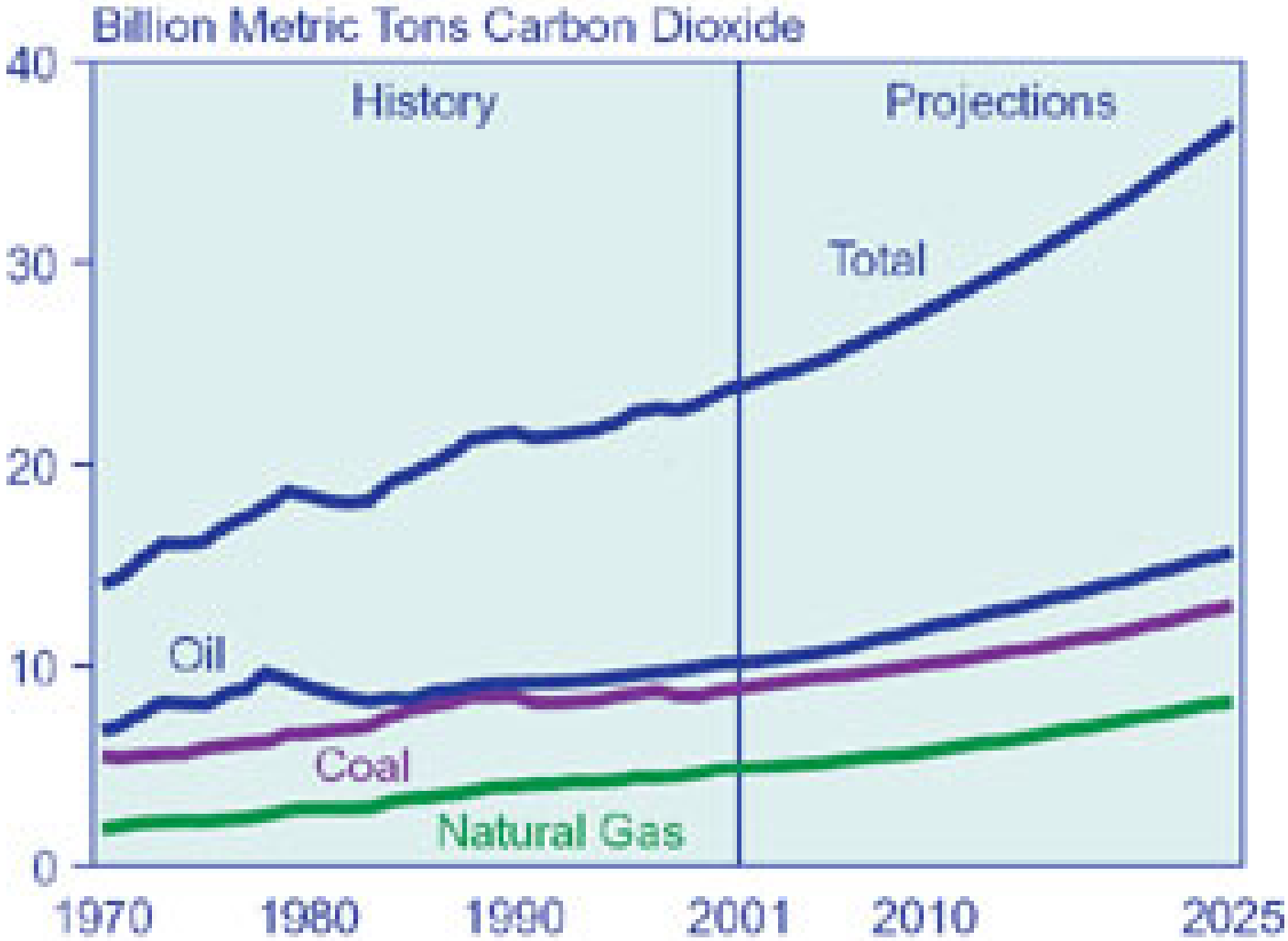


Figure 17. World Energy-Related Carbon Dioxide Emissions by Fuel Type, 1970-2025



II. Alternate Energy Sources

- Hydrogen Transmission
- Fusion Reactors
- Renewables:
  - Hydroelectric
  - Wind Power
  - Solar Power
  - Biomass, Ethanol
  - Geothermal

The Hydrogen Dream

- Hydrogen is a transmitter of energy, not a source:
  - Must use fossil fuel (creating CO_2) or high temperature reactors or solar or electrical power to create H_2 -- needs research
  - Need fuel cell technology improvement (current $3000/kw vs $30/kw for a gas engine).
  - Fuel cells combine $2H_2$ with O_2 to make $2H_2O$.
  - Yet fuel cells are 60% efficient compared to 22% for gas and 45% for a diesel engine.
  - Catalysts in fuel cells are expensive and can be poisoned by impurities.

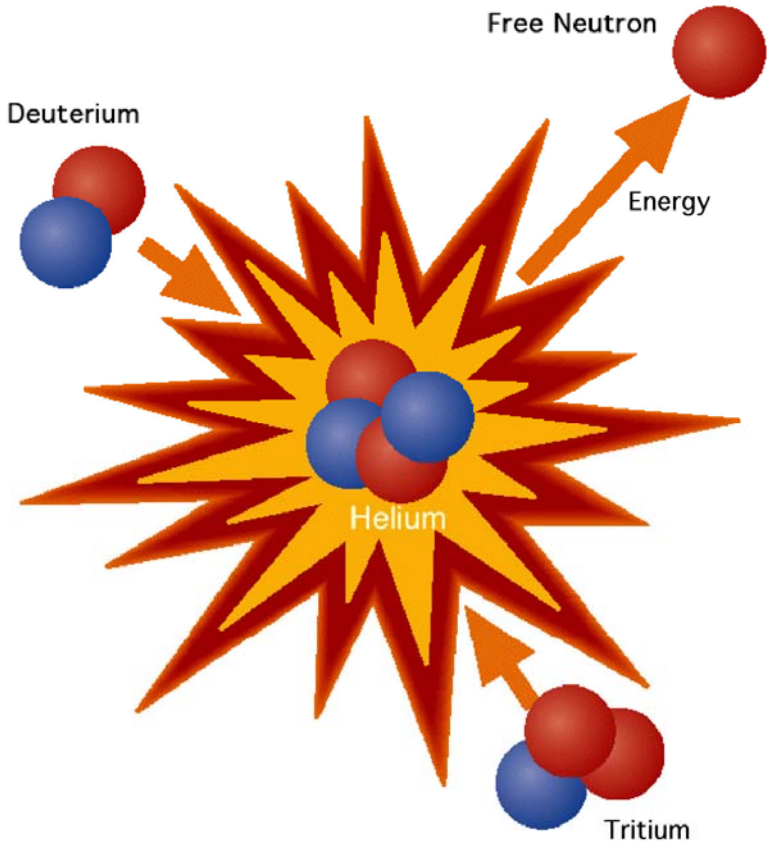
California Hydrogen Dreaming

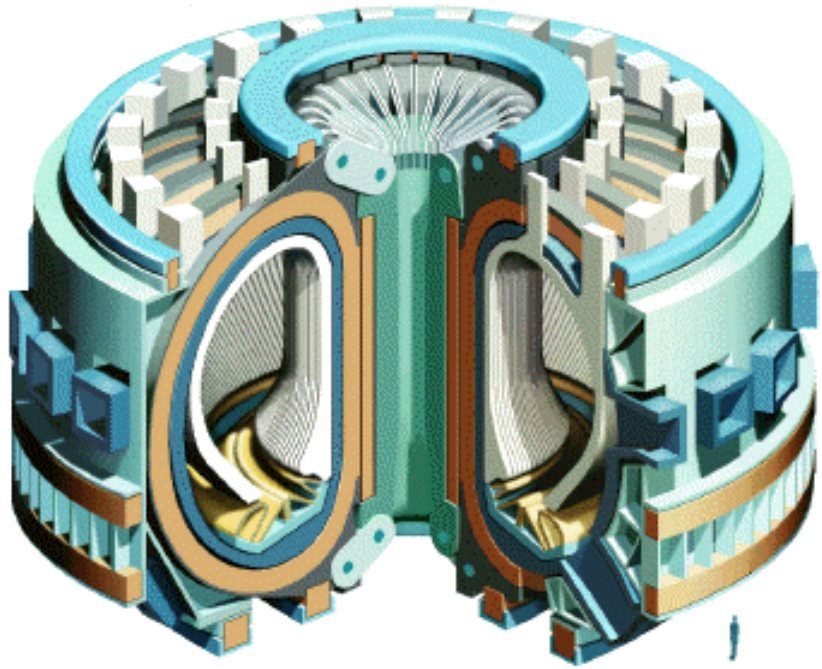
- Need to establish a distribution system on as large a scale as for gasoline
- California is establishing a Hydrogen highway of 200 stations for about $100 million
- Current cost of hydrogen is 4 times that of gasoline
- Compressed hydrogen tank has a range of only 200 miles (50 for Arnold's Hummer demo)
- H_2 will probably be stored in a smaller volume molecule like $NaBH_4$
- Won't be practical for 30 years
- Physics Today "The Hydrogen Economy"

Fusion Reactors

- Fusion easiest for Deuteron (D) + Tritium(T):
  $D(p,n) + T(p,nn) \rightarrow {}^{4}He(pp,nn) + n$
  in a high temperature plasma.
- Replacement T created from Li blanket around reactor
  $n + {}^{6}Li \rightarrow {}^{4}He + T$
- Fusion reactors
  - International ITER in 2012 for research for a decade, costing $5 billion
  - Current stalemate over siting in France or Japan
  - Followed by DEMO for a functioning plant, taking another 10 years. So not ready for building units until at least 2030.
- US Lithium supply would last a few hundred years.
- Still would be a radioactive waste disposal problem.

International Thermonuclear Experimental Reactor (ITER)





Renewable energy sources

- Hydroelectric: very useful
  - At 30% – 50% of maximum use
  - Effects of dams
  - Variable with season and climate
- Wind power: Need high wind areas on cheap land
  - 600 large turbines the equivalent of a nuclear reactor
  - Would need 30 linear miles
  - Already scenic protests
  - Many areas far from the power grid
  - Claimed as cheap as natural gas
  - Waiting for Tax Credit law renewal
- Solar power: Good for direct heating
  - Solar cell electricity more costly by a factor of 10
  - 40 square miles equivalent to one nuclear reactor

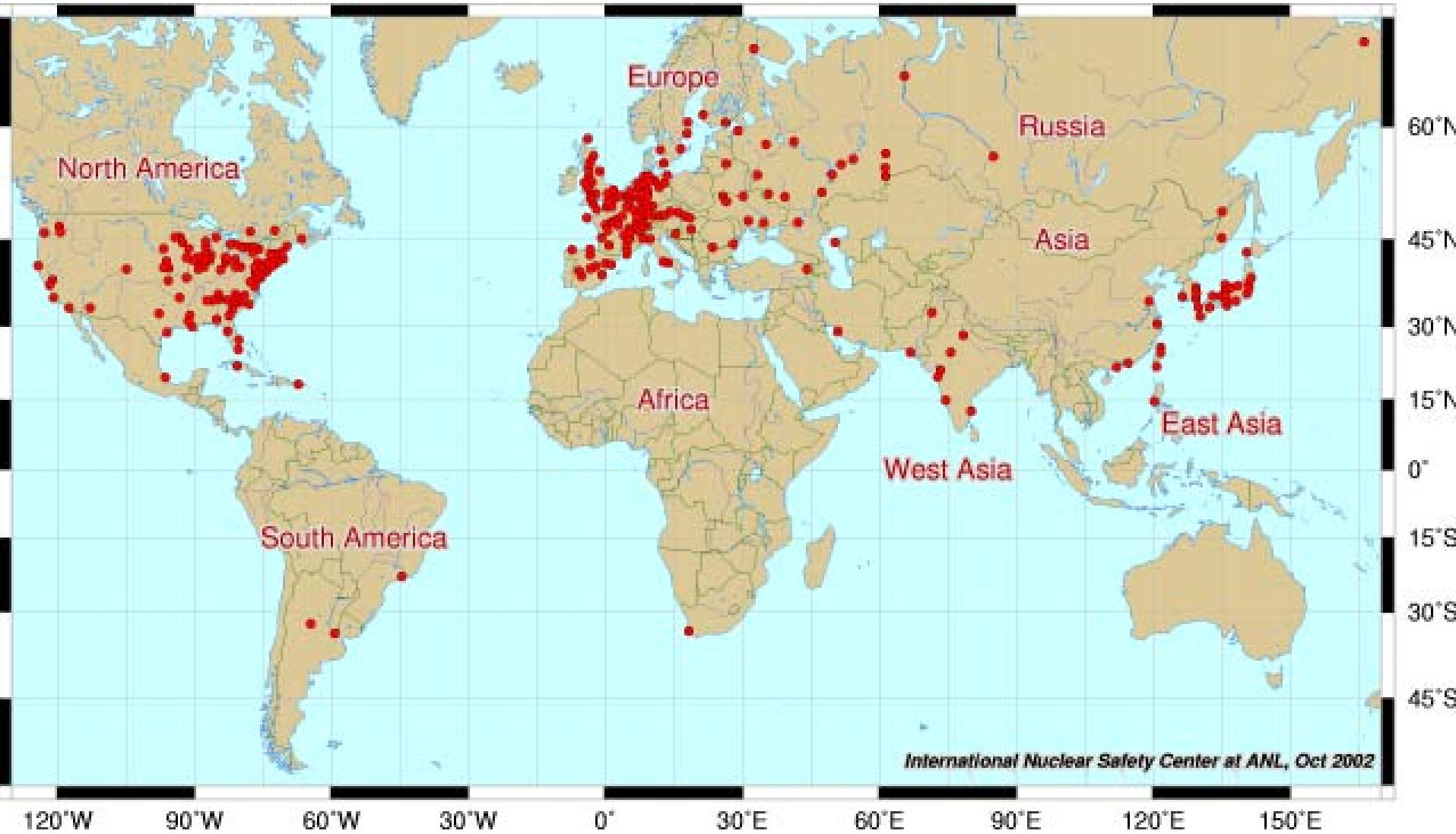
Biomass, Ethanol, and Geothermal

- Biomass: Competes with farm use for food
  - Insufficient for total power by a factor of 40
  - Gas is 30¢/pound: know of any food that cheap?
  - 2,000 square miles equivalent of one nuclear reactor
  - Burns to methane and nitrous oxide, both greenhouse gases
  - Sea growing possibilities being researched
- Ethanol: Political Issue for Rural (Red) States and areas
  - May be forced to include in gasoline as antiknock preventer, but no pipelines or ships, so truck transportation costly, and not needed by the Blue States or cities
- Geothermal: Few sites, mostly in the west
  - Produces Sulfur and heavy element pollution

III. Worldwide Nuclear Power

- Provides 20% of world's electricity
- Provides 7% of world's energy usage which also includes heat and transportation
- Cost is currently similar to fossil fuels
- Nuclear reactors have zero emissions of smog or CO_2
- There are 440 nuclear power reactors in 31 countries.
- 30 more are under construction.
- They produce a total of 351 gigawatts (billion watts) of electricity

World Nuclear Power Plants

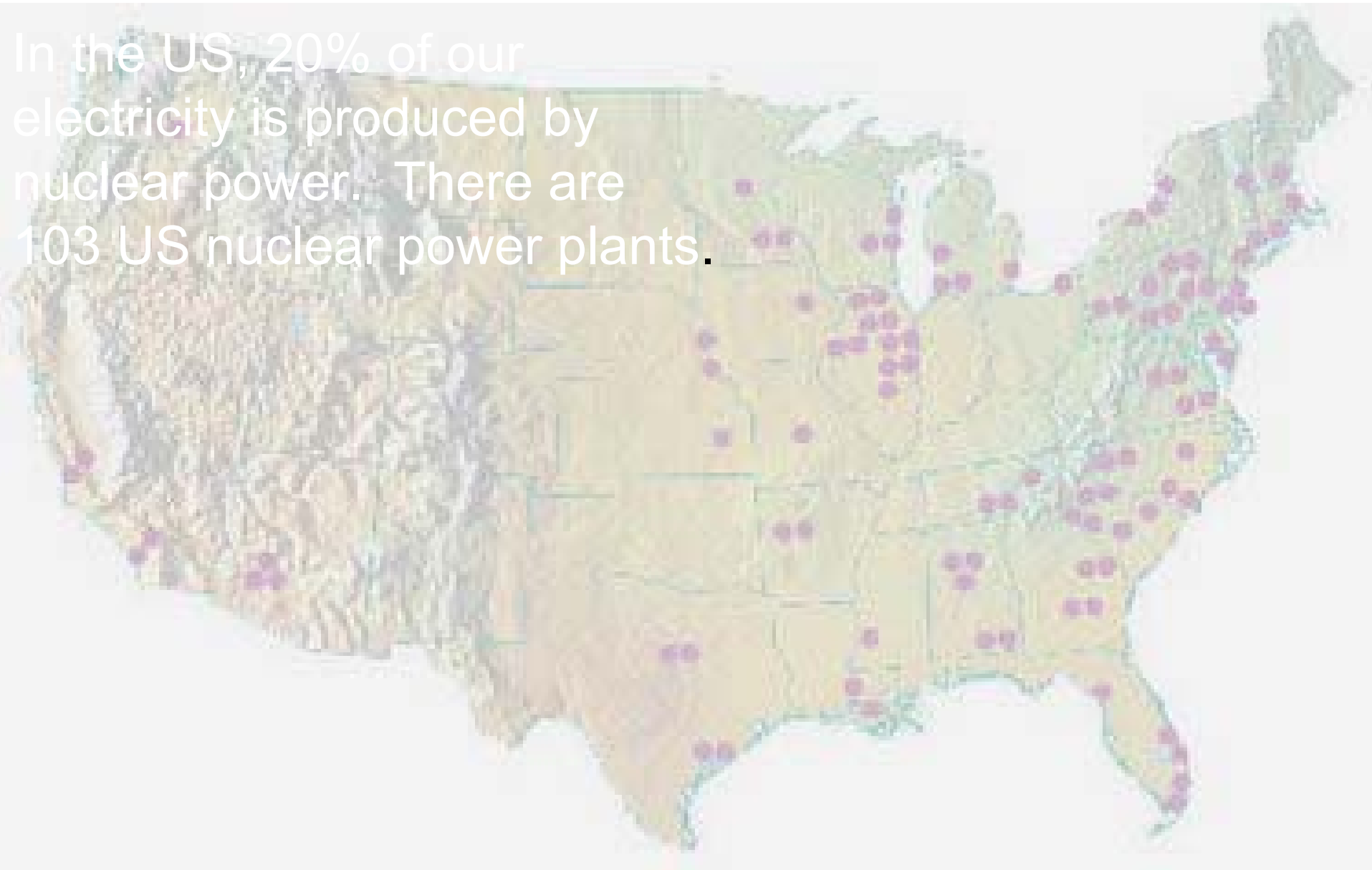


Nuclear Electricity Production by Countries and Regions in Gigawatts (World Total 350 Gigawatts)

US	97	Trend: declining
North America Region	109	
France	63	Increasing
Germany	21	Being phased out
U. K.	12	
Western Europe Region	126	
Japan	44	Increasing
Asia Region	66	Increasing
Eastern Europe Region	11	
Former Soviet U. Region	34	

US Nuclear Power

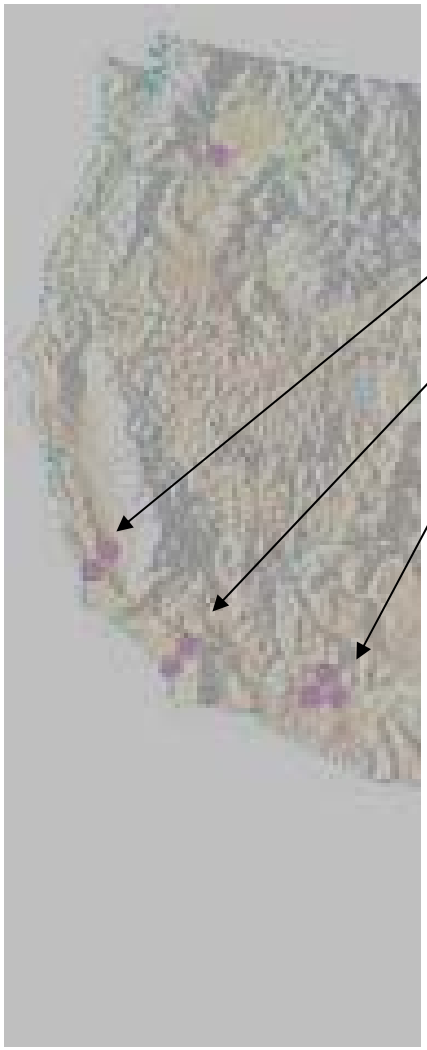
In the US, 20% of our electricity is produced by nuclear power. There are 103 US nuclear power plants.



Soviet Nuclear Weapons to US Reactor Fuel

- We are buying highly enriched uranium (20% ^{235}U) from the former Soviet Union's nuclear weapons. The delivery is over 20 years from 1993—2013.
- We are converting it to low enriched uranium (3% ^{235}U) for reactor fuel.
- It will satisfy 9 years of US reactor fuel demand.
- It comes from 6,855 Soviet nuclear warheads.

California related reactors



Diablo Canyon, two reactors

San Onofre, two reactors

⅓ of Palo Verde 1, 2, & 3 in Arizona

California Nuclear Energy

- Each 1,100 megawatt reactor can power one million homes.
- Each reactor's production is equivalent to 15 million barrels of oil or 3.5 million tons of coal a year.
- The total 5,500 megawatts of nuclear power is out of a peak state electrical power of 30,000 – 40,000 megawatts.
- The PUC is now faced with a decision to approve $1.4 billion to replace steam generators in San Onofre and Diablo canyon and pass costs onto consumers.
- While the plants are approved to run to 2022 and 2025, they might have to shut down by 2009 and 2013, respectively.
- The replacements would save consumers up to $3 billion they would have to pay for electricity elsewhere.

Nuclear Power Proposed Solution?

- If 50 years from now the world uses twice as much energy, and half comes from nuclear power
- Need 4,000 Gigawatt nuclear reactors, using about a million tons of U a year (Gigawatt is 1,000 megawatts)
- With higher cost terrestrial ore, would last for 300 years
- Breeder reactors creating Pu could extend supply to 200,000 years, but nuclear proliferation problem
- Nonpolluting, non-CO_2 producing source
- Reference: Richard Garwin , also MIT and industry
- Problems: Need more trained nuclear engineers and radiation specialists
- Study fuel reprocessing, waste disposal, safety

Conservation

- Limiting world population
- Limiting population of largest CO_2 producing countries
- Mass transit
- Transit Villages built around transportation lines
- Fuel economy improvements
- Hybrid and Electric cars, cylinder shut down engines
- Transportation decreases
  - internet and communications
  - urban structuring
- Smart offices, houses and buildings
- Energy cost increases will drive conservation: however, this sends the increased profits to OPEC.
- CO_2 production taxes and increased fuel taxes keeps the added price and payments to slow demand at home for use in conversion.

Possibility of New Unforseen Energy Solutions

- 100 years of technology discoveries is unpredictable.
- In the last century we created:
  - Autos, petroleum industry
  - Aircraft
  - Nuclear Age
  - Electronics age: TV, computers, cell phones
  - Biological Age Starting: DNA, Genomics
  - Medical diagnosis and care
  - Etc.

Signs of Progress

- Globally: The Kyoto Treaty will go into effect in Jan. 2005, with signers reducing emissions to 5% below 1990 levels, except for developing countries which includes China.
- Nationally: Western governors committing to 20% renewable energy sources by 2020.
- The Hummer H3 will be their new model and will resemble other SUVs in gas mileage like 20 mpg on highway.
- GM Gen IV V-8 with cylinder shutdown technology to 4 cylinders to give 6-20% better fuel economy. Honda will apply this to V-6 also including hybrids.

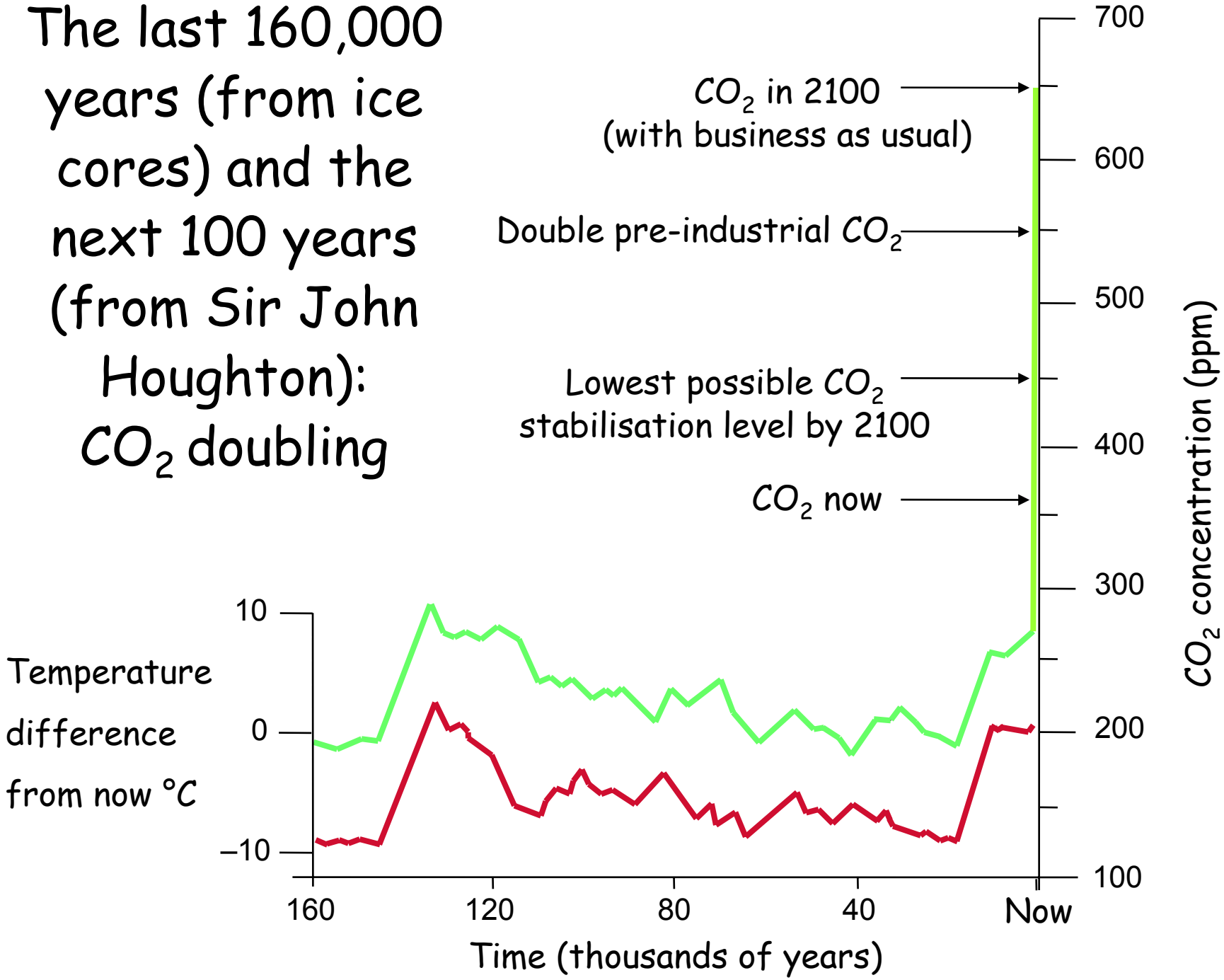
CO_2 and the Kyoto Treaty

- The treaty will go into affect in Feb. 2005 to reduce greenhouse gas emissions of developed countries to 5% below their 1990 level.
- The U.S., as the largest CO_2 emitter in 1990 (36%), will not participate because it would hurt the economy, harm domestic coal production, and cost jobs.
- China has signed the protocol, but as a developing country, it does not have to reduce emissions.

IV. Global Warming Effects – or Nature's Experiments in Telling Us What Effects GW Will Have

- Arctic Warming
- Antarctic Warming
- Florida Hurricanes
- European Heat Wave
- California Questions

The last 160,000 years (from ice cores) and the next 100 years (from Sir John Houghton): CO_2 doubling



Global Warming Scenario

- Greenhouse gases: CO_2 ,methane, and nitrous oxide
- Already heat world to average 60° F, rather than 0° F without an atmosphere
  - Absorbs all outgoing infrared in some bands
- Doubling of CO_2 projected by end of century, causing ~5° F increase in average temperature
  - ~2 foot sea level rise
  - More storms and fiercer ones
  - Loss of coral reefs
  - Increase in tropical diseases
  - 25% decline in species that cannot shift range
  - Possible removal of Gulf Stream, causing ice age in Northern Europe
- Stabilizing the amount of CO_2 would require a reduction to only 5% to 10% of present fossil fuel emissions

Global Warming Effects

- Global Warming is an average measure
- Local warming or climate fluctuations can be very significant
  - Arctic is 5° warmer and ice is melting
- Antarctic is 5° warmer
  - Ice shelves over the sea are melting and breaking off
  - The breaking shelves may allow the 10,000 foot thick ice sheet over Antarctica to slide off the continent faster
  - This would cause a sea level rise
- An analogous local effect is that while ozone is affected everywhere, there is a seasonal ozone hole over Antarctica

Example of slippery slope of environmental catastrophe – 2004 Hurricanes

- In a costly $42 billion experiment on what effects warming will have. The water temperature in the Caribbean was 9° F hotter this summer than normal.
- This heat is transported north in hurricanes with high wind and water content.
- The hurricanes that hit are larger, more damaging, and more frequent than normal.
- The frequency does not allow cleanup and restoration between storms, causing more damage.
- Flooding is increased with frequent storms.
- Losses to tourism industry, crops, property values, and employment.
- The state raises deductibles to $2,500 to keep insurance companies in the state.
- Houses in extreme peril may be cut off from policies.
- Developments have destroyed buffering wetlands.

GW effects on California

- Summer temperatures rise by 4-8° F by 2100 for low emission scenario: 8-15° F for higher emissions.
- Heat waves will be more common, more intense, and last longer.
- Spring snowpacks in the Sierra could decline by 70-90%, as winters will be warmer.
- Agriculture affected by water shortages and higher temperatures, including wine and dairy.
- More forest fires.
- Tree rings show that in eras of global warming, megadroughts of decades hit the southwest US.

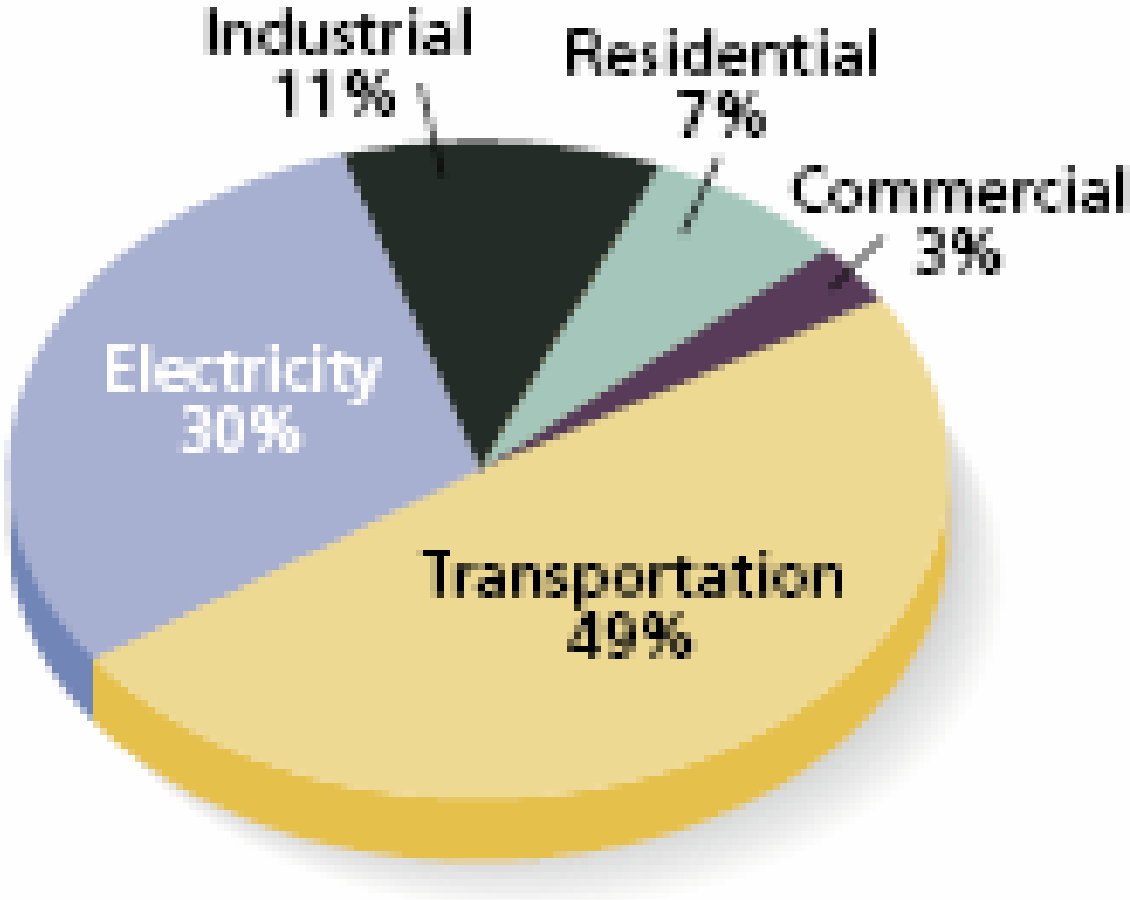
Lake Powell, Glen Canyon Dam, Navaho Coal Fired Generating Plant, Phoenix and Tucson Water

- For the last four years, flow has been half of normal.
- The lake reservoir is half full.
- Water level is 130 feet below maximum
- If it drops another 100 feet by 2006-9, won't have water to cool Navajo generating plant.
- Planning to dig tunnels 80 feet deeper.
- Plant powers pumps to deliver water to Phoenix and Tucson. (Also to California)
- Glen Canyon dam would shut down if level drops another 80 feet. Reduced power now.

My Warming questions for California

- More rainfall rather than snow is expected in the winter, causing a summer water shortage. More dams will have to be built.
- Will more storms forming in the tropics head north in the summer, and wipe out our beaches?
- Rainfall is difficult to project. Before, modeling predicted more rain, now rainfall is reduced by 15-30%
- What will be the effects on the marine layer that covers us part of the day?
- Will drought ensue?
- Will more lightning storms and drought cause more fires in our mountains?
- Will we have more heat waves or more Santa Ana conditions?
- Will this require more power plants for air conditioning?

Figure 1: California CO_2 Emissions (1999)



Note: Includes emissions from imported electric power.

Source: California Energy Commission. 2002. Inventory of California Greenhouse Gas Emissions and Sinks: 1990–1999. November.

What can California Do?

- California is the world's fifth largest economy, and has led the way on reducing vehicle pollution before.
- State law for utilities to increase renewable electricity to 20% by 2017. Can increase and extend to city power.
- Use combined heat and electricity systems in large plants.
- Clean up older, high polluting plants.
- Mass transit and growth planning.
- Removing firewood in forests and increasing them as a carbon storage component.
- See Union of Concerned Scientists: www.climatechange.org
- Unfortunately, they leave out a nuclear plant option.

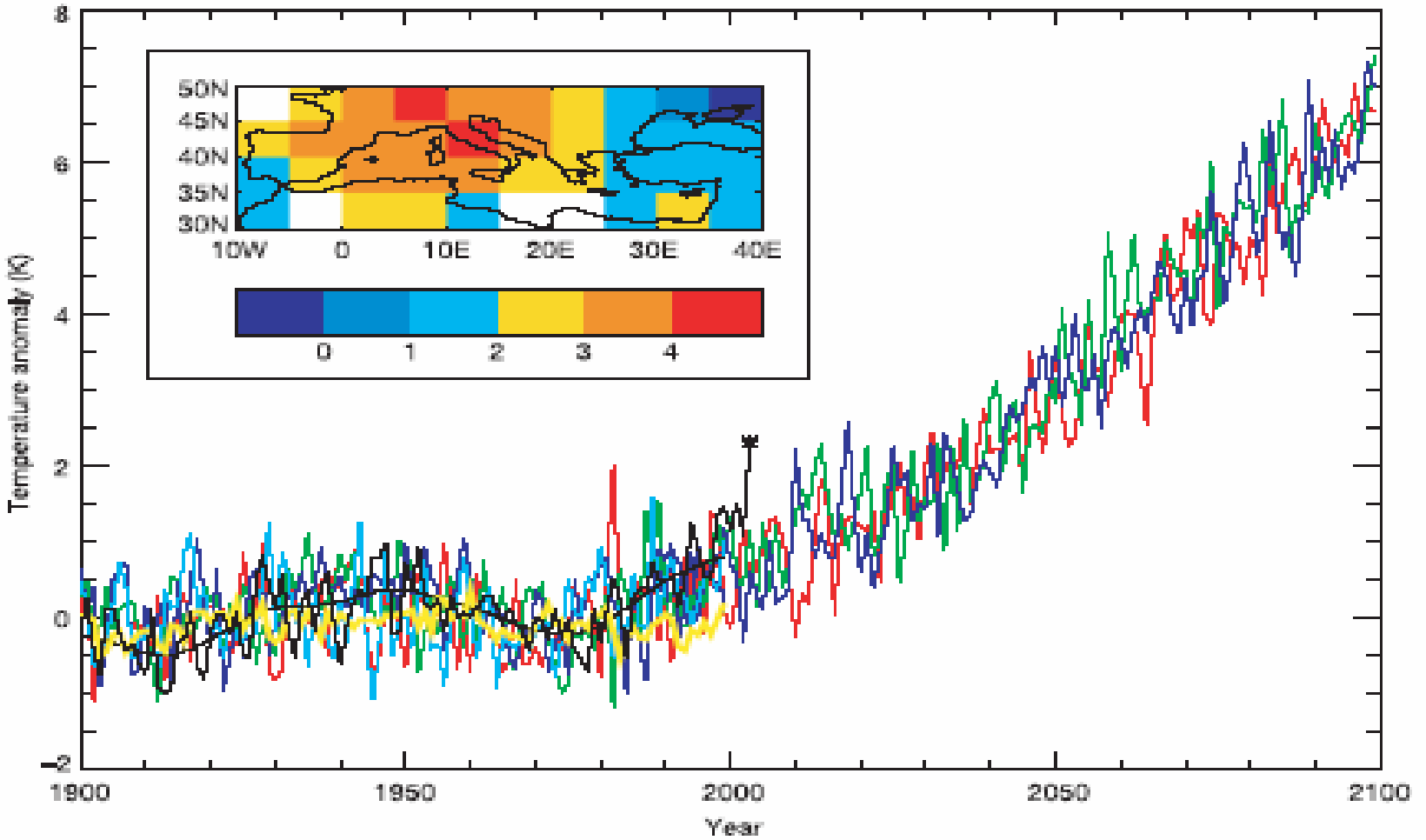
Signs of Progress

- Nationally: US reducing off-road vehicle diesel emission 90% by 2010.
- California: Committing to lower greenhouse emission fuel in new autos by 30% by 2016.
- Seven northeastern states likely to follow this (NY, NJ).
- Canada demanding 25% reduction in new cars by end of this decade.
- CA estimates cost of $1,000 per vehicle with continuously variable transmission, alternative AC coolant, and engines that shut off cylinders.
- A 20% reduction in GW gasses with existing technology would pay off in fuel cost savings in three years of driving.
- Zero Emission Vehicle regulation will generate 200,000 hybrids per year by 2015.

Signs of Regression

- Nationally: Bush still to ignore Kyoto treaty for next four years to protect coal industry.
- Administration ruled that CO2 is not a pollutant under the Clean Air Act.
- Federal government to press Artic Natl. Wildlife Refuge, Rocky Mountain, and offshore drilling sites.
- Half of new vehicles sold are SUVs or light trucks.
- California: Considering removing fuel tax, which punishes gas guzzlers, for a mileage tax. Heavier vehicles also do more road wear and damage.
- Car makers suing over the 30% GW gases reduction, claiming costs will be $3,000 per vehicle.
- No new state refineries being built. California is an “island” for refined gas, yet keeps adding new vehicles including more low mileage SUVs and light trucks.

European Temperatures and 2003 Heatwave (black x is 4° F average increase). Red boxes are 8° F hotter.



European Heat Waves

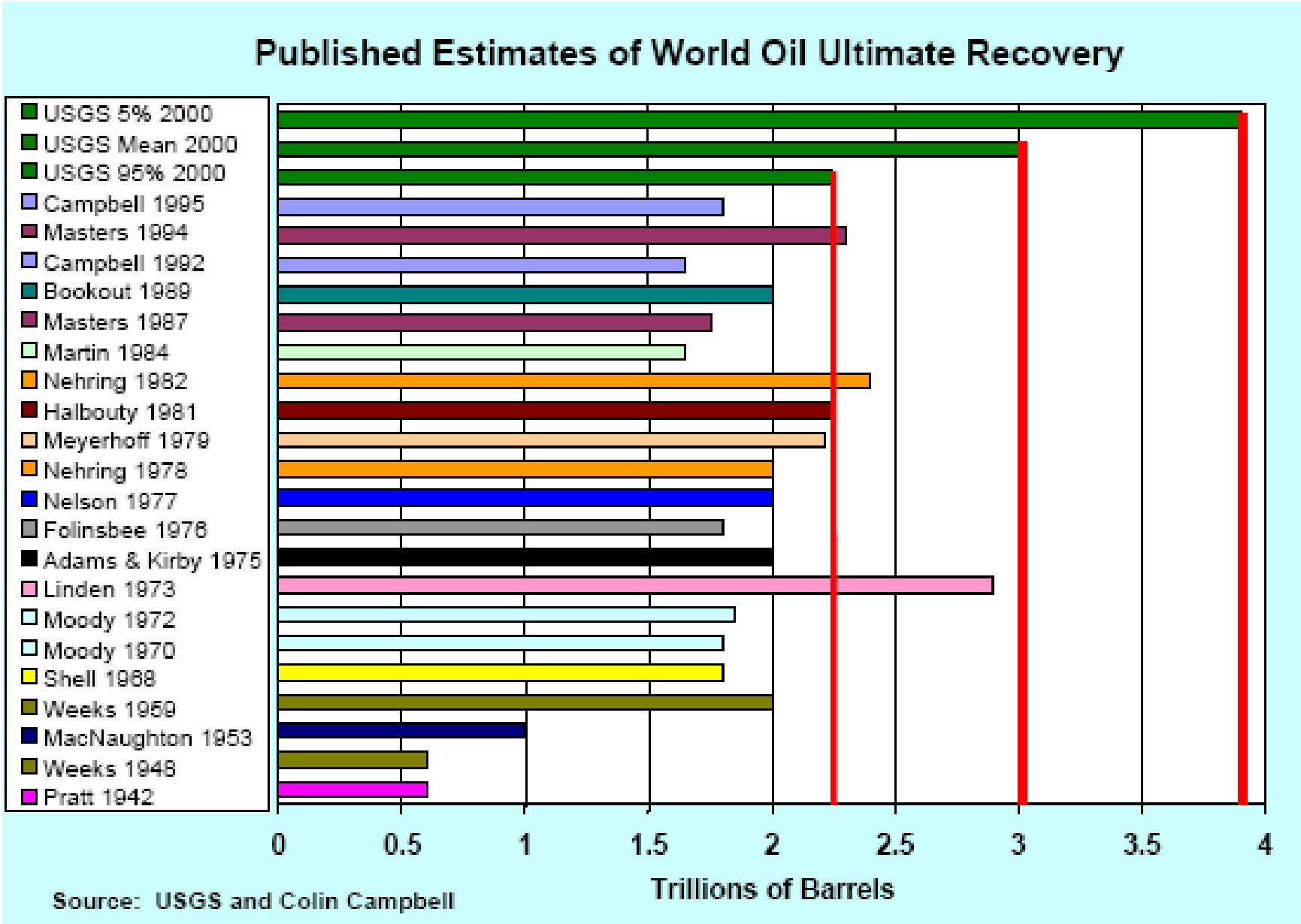
- August 2003 heat wave caused at least 35,000 excess deaths.
- Models show with 90% probability that global warming doubled or quadrupled the chances of that large an excess over the average.
- By 2040, half of Europe's summers will be as hot as that of 2003.
- Possible legal liabilities of plants producing excess carbon being discussed.
- Models still do not have high resolution and are being questioned.
- In a non-linear effect, some power plants could not produce electricity for home cooling due to low river water for plant cooling.
- Better emergency response being set up for future heat waves.

Conclusions on Energy and GW

- At current or increased rates of production, cheap oil and natural gas will be gone in 50 years or so.
- Conversion from coal and tar sands may be expensive enough to make the cost of energy the primary consideration in everything.
- Global warming will continue until we drop fossil fuel use to a small fraction of its present rate.
- The costs of relocation, substitution, extreme weather, increased deaths, and diminishing fuel will soon exceed the costs of developing alternate energy sources.
- The sooner we act in research and development, and conservation and conversion, the easier and less costly the transition will be.

Liquid Metal Fast Breeder Reactor

- Uses the fast neutrons from ^{235}U fission on surrounding ^{238}U to produce ^{239}Pu
- In 10-20 years, enough Pu is produced to power another reactor
- No moderators are allowed
- No water, must use liquid sodium coolant
- U must be at 15%-30% enrichment to generate power with fast neutrons while breeding Pu
- This is at weapons grade enrichment, however
- Super-Phenix in France has operated for 20 years


Published Estimates of World Oil Ultimate Recovery
USGS 5% 2000
USGS Mean 2000
USGS 95% 2000
Campbell 1995
Masters 1994
Campbell 1992
Bookout 1989
Masters 1987
Martin 1984
Nehring 1982
Halbouty 1981
Meyerhoff 1979
Nehring 1978
Nelson 1977
Folinsbee 1976
Adams & Kirby 1975
Linden 1973
Moody 1972
Moody 1970
Shell 1968
Weeks 1959
MacNaughton 1953
Weeks 1948
Pratt 1942
0
0.5
1
1.5
2
2.5
3
3.5
4
Trillions of Barrels
Source: USGS and Colin Campbell

Fossil fuel near-term caveats

- We have also seen decreases in proven reserves. Some examples:
- Shell reduced its estimates by 15% in a desire to conform to corporate honesty.
- The US DOE continues to project Saudi future output at 15 million barrels a day, despite the Saudi's claim that they won't grow much beyond the new 12.5 million barrels a day.
- Estimates are that Iraq has ruined its oil fields and that its reserves, once thought to be greater than the Saudi's, will only come in at 15% of previous estimates.
- DOE claims Iraq reserves at 200-300 bbl, USGS claims only 78 bbl known and only 45 bbl undiscovered.
- The Russians seem to be finding that using water to pump more oil out of fields only seems to ruin them, and their fields will not be as productive as previously estimated.

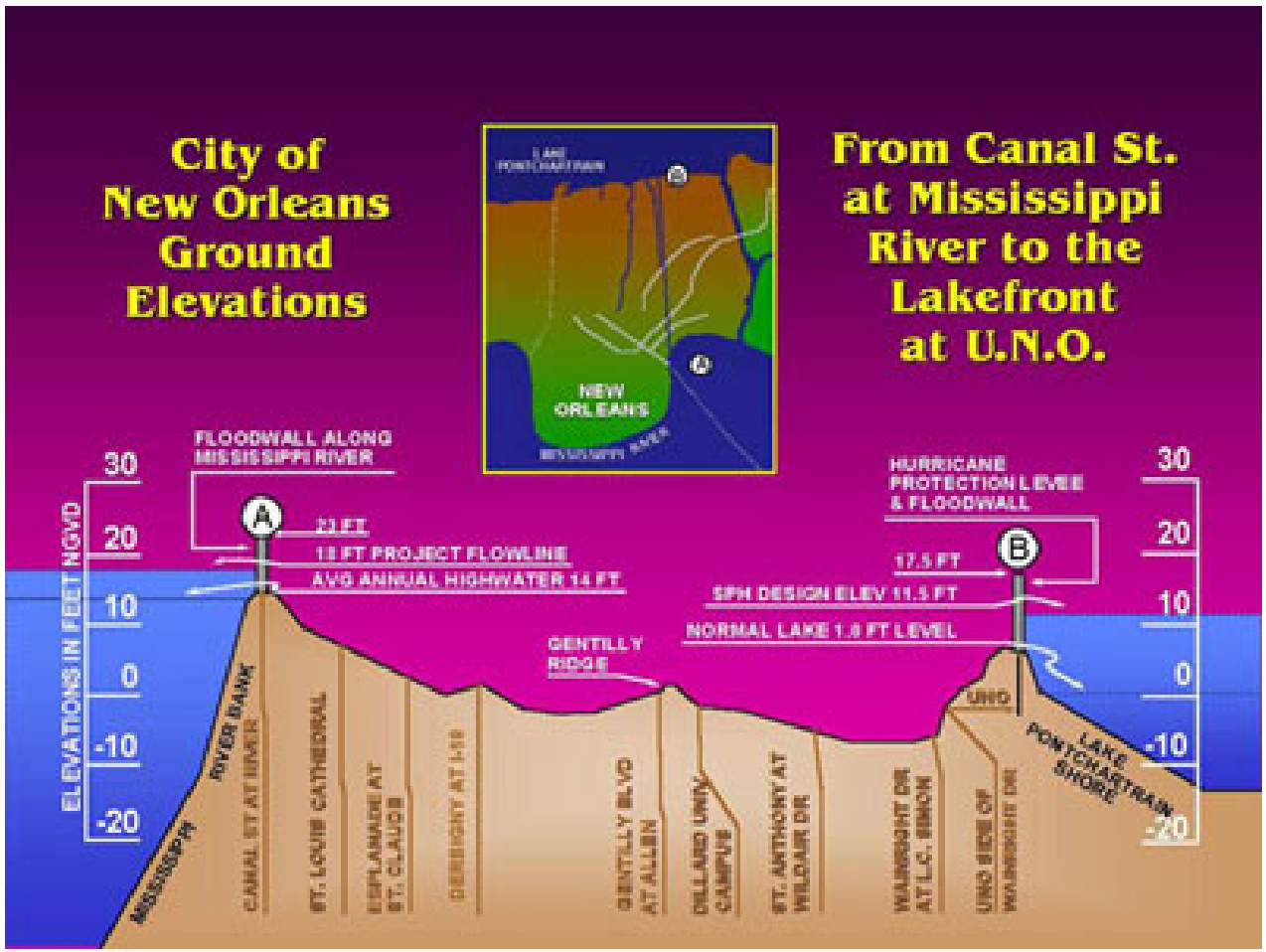
Methane (Gas) Hydrates Possibilites

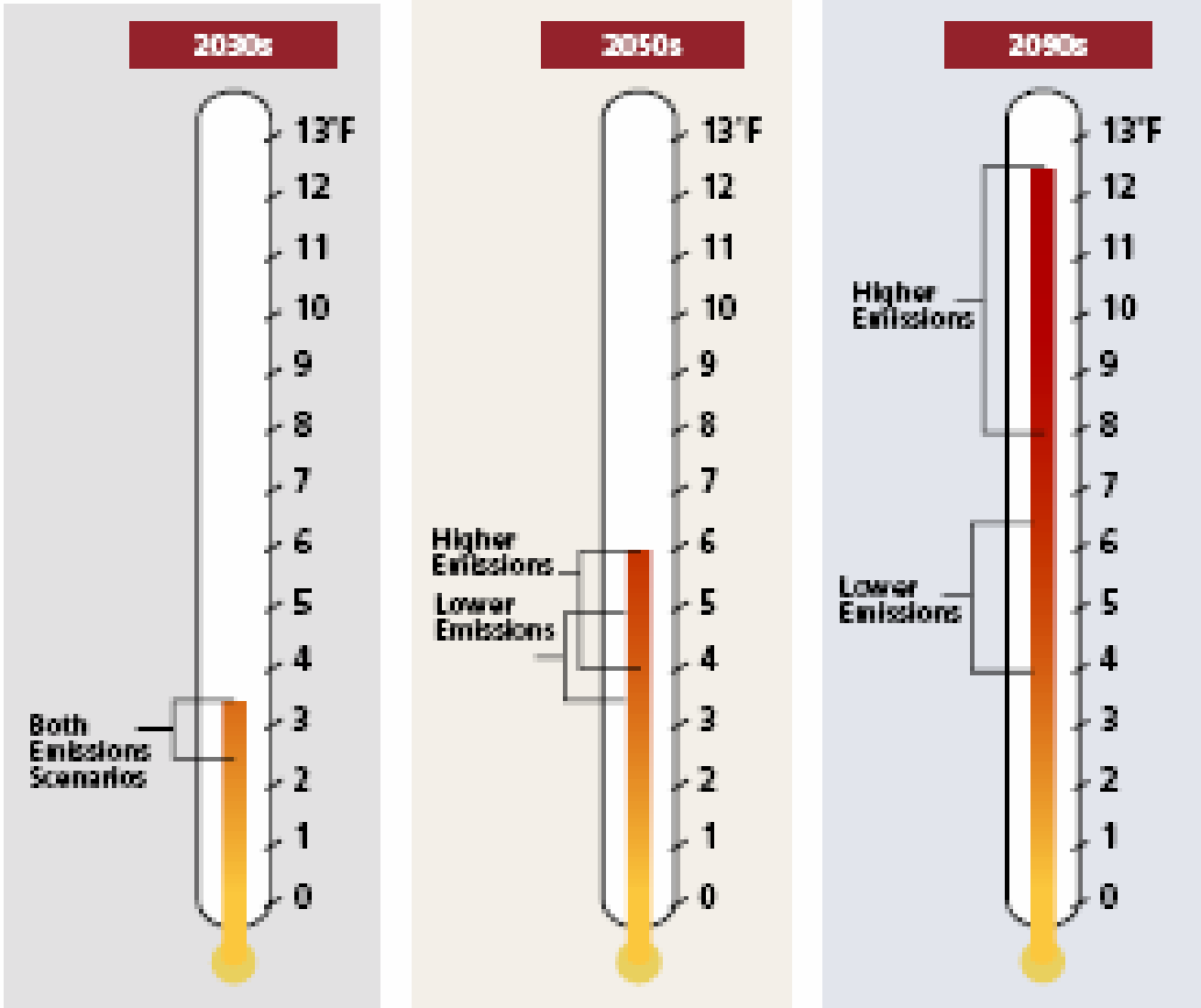
- Methane, CH4, surrounded by water molecules in an ice form is methane hydrate.
- Either 200,000 Tcf or 2,000 Tcf exists under the Arctic permafrost and continental margins in the US.
- The US consumes 24 Tcf per year of natural gas (methane). So if the former reserves exist, and if 1-10% are recoverable, this could last 40-400 years.
- Dangers: GW and increased sea levels could flood the Arctic and melt the permafrost, releasing methane as a Greenhouse gas.
- Some past rapid warming may have occurred from methane release.
- Methane accounts for ½ the warming of CO2 at only 1.7 ppm.
- William Reeburgh at UCI investigating these gases.

DOE Statement of US Policy

- In the United States, the Bush Administration has stated that it will not seek to ratify the Kyoto Protocol. Its policy on limiting greenhouse gas emissions focuses on initiatives aimed at reducing greenhouse gas intensity as an alternative to the Protocol. Under the President's Clear Skies Initiative and Global Climate Change Initiative, the United States will work to reduce greenhouse gas intensity by 18 percent from 2002 levels by 2012. Carbon dioxide intensity is defined as the amount of carbon dioxide emitted per dollar of GDP. This measurement illustrates the relationship between emissions and the expansion of economic activity. The Administration argues that reducing the amount of greenhouse gases emitted per dollar of GDP will slow the rate of increase in emissions without sacrificing needed economic growth.

New Orleans can be flooded by a slow moving Category 2 or 3 storm





California is expected to experience dramatic warming during this century, and the amount of warming depends on our emissions of heat-trapping gases. This figure shows projected increases in statewide average annual temperatures for three 10-year periods. Ranges for each emissions scenario represent results from two climate models.