

Global Warming and Our Energy Future

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[www.physics.uci.edu/~silverma/
gwenergy.ppt](http://www.physics.uci.edu/~silverma/gwenergy.ppt)

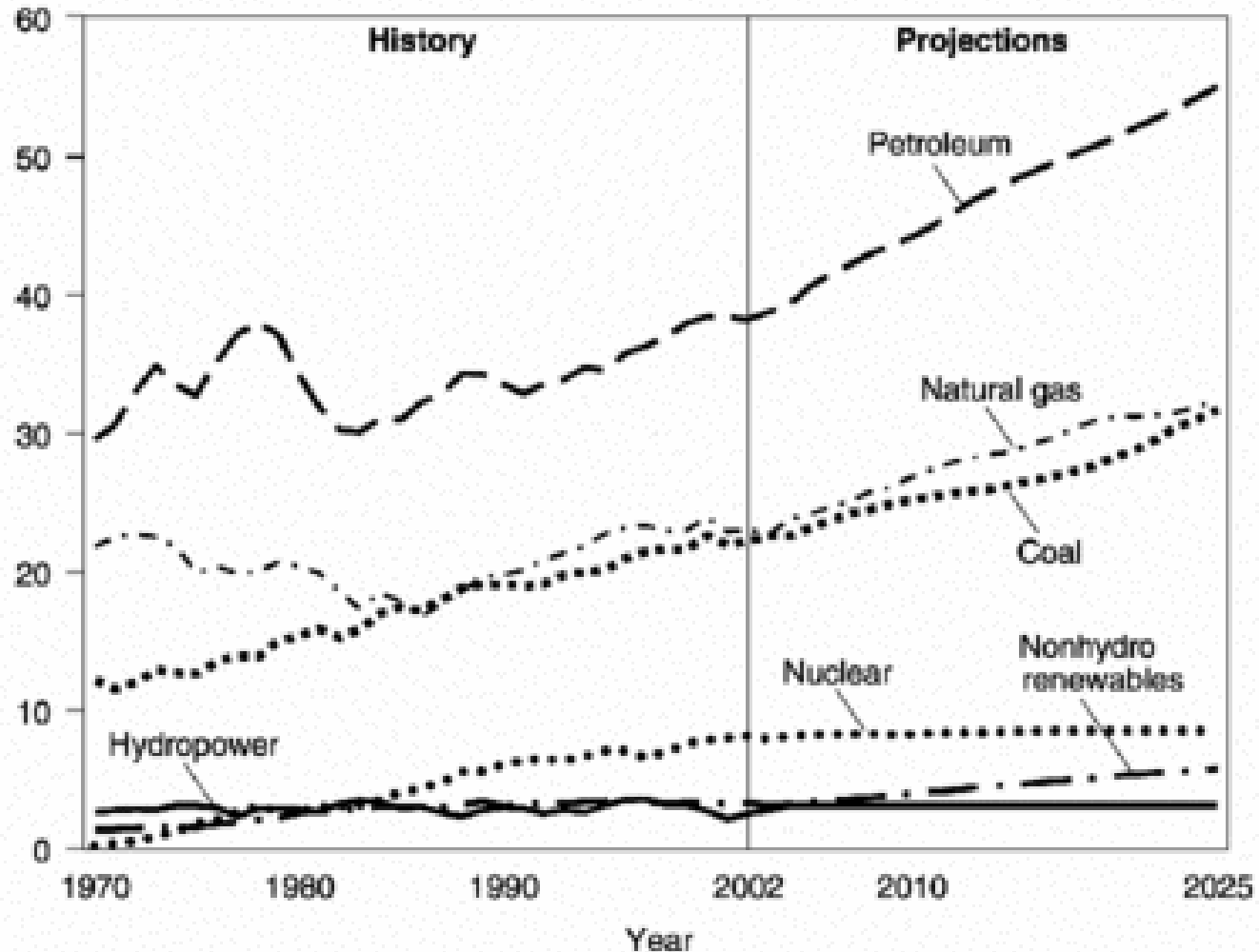
Our Energy Future

- I. Future of Fossil Fuels
- II. Alternate Energy Sources
- III. Worldwide Nuclear Power
- IV. Global Warming

I. Future of Fossil Fuels

- Petroleum
- Natural Gas
- Coal
- Oil Shale and Tar Sands
- CO₂ Emissions

U.S. 20 Year Projections of Energy Use in Quads (US Uses 100 Quads/year)



Petroleum Fuel Future

- US oil production peaked around 1970.
- US energy consumption is increasing at 1.5% a year.
- The US currently imports 60% of its oil.
- Proven world oil resources are about 2,000 billion barrels - about half of this has already been used.
- Unproven resources may boost this to 3,000-4,000 billion barrels total.
- At the **peak** the price rises steeply and consumption must fall, perhaps leading to recession.
- However, we may see a very flat, long peak where prices rise, bringing in new oil resources to keep production flat, and efficiency and conservation setting in to hold demand flat to a fixed supply.



Different Interpretations of a Hypothetical 6,000 Billion Barrel World Original Oil-in-Place Resource Base

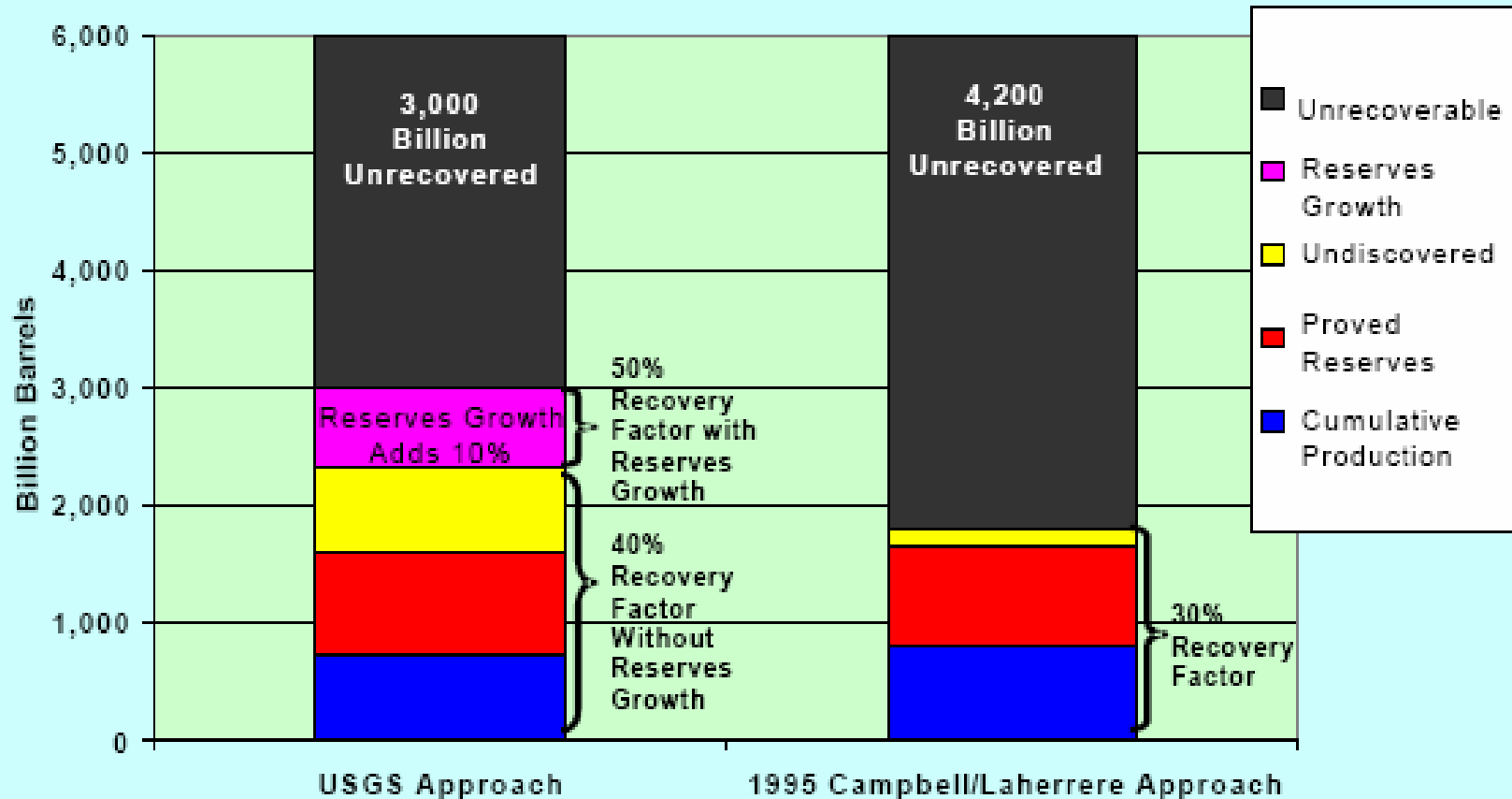


Figure: "Different Interpretations of a Hypothetical 6,000 Billion World Original Oil-in-Place Resource Base" [33]

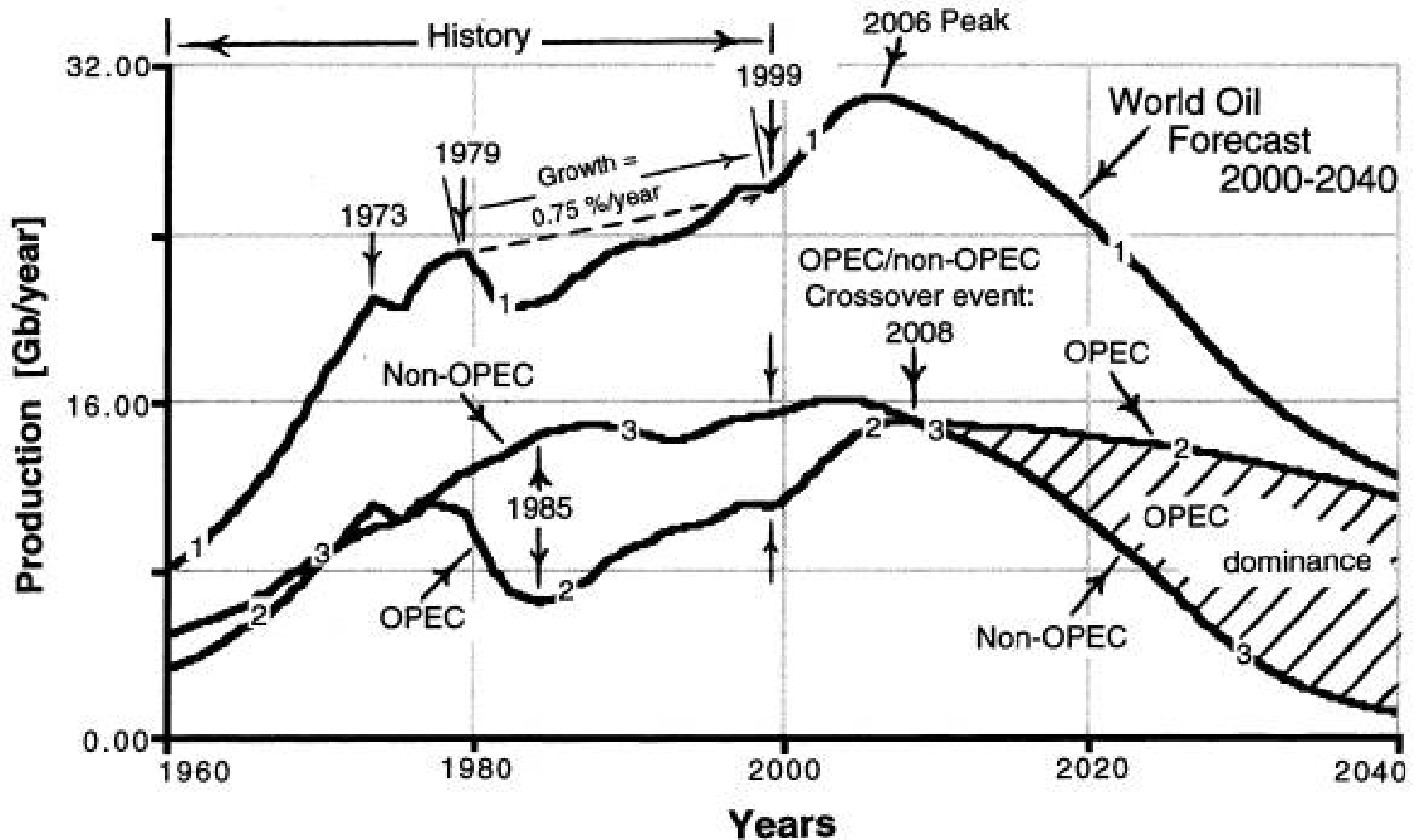
Peaking of World Oil Production

Hirsch Report: Feb. 2005

Table I-1. Predictions of World Oil Production Peaking

<u>Projected Date</u>	<u>Source of Projection</u>
2006-2007	Bakhitari
2007-2009	Simmons
After 2007	Skrebowski
Before 2009	Deffeyes
Before 2010	Goodstein
Around 2010	Campbell
After 2010	World Energy Council
2010-2020	Laherrere
2016	EIA (Nominal)
After 2020	CERA
2025 or later	Shell
No visible Peak	Lynch

World Oil Growth and Decline - Pessimistic 2,000 Bbl resources (1,000 Bbl reserve)



Optimistic 3,000 Bbl of oil total resources. US Geological Service

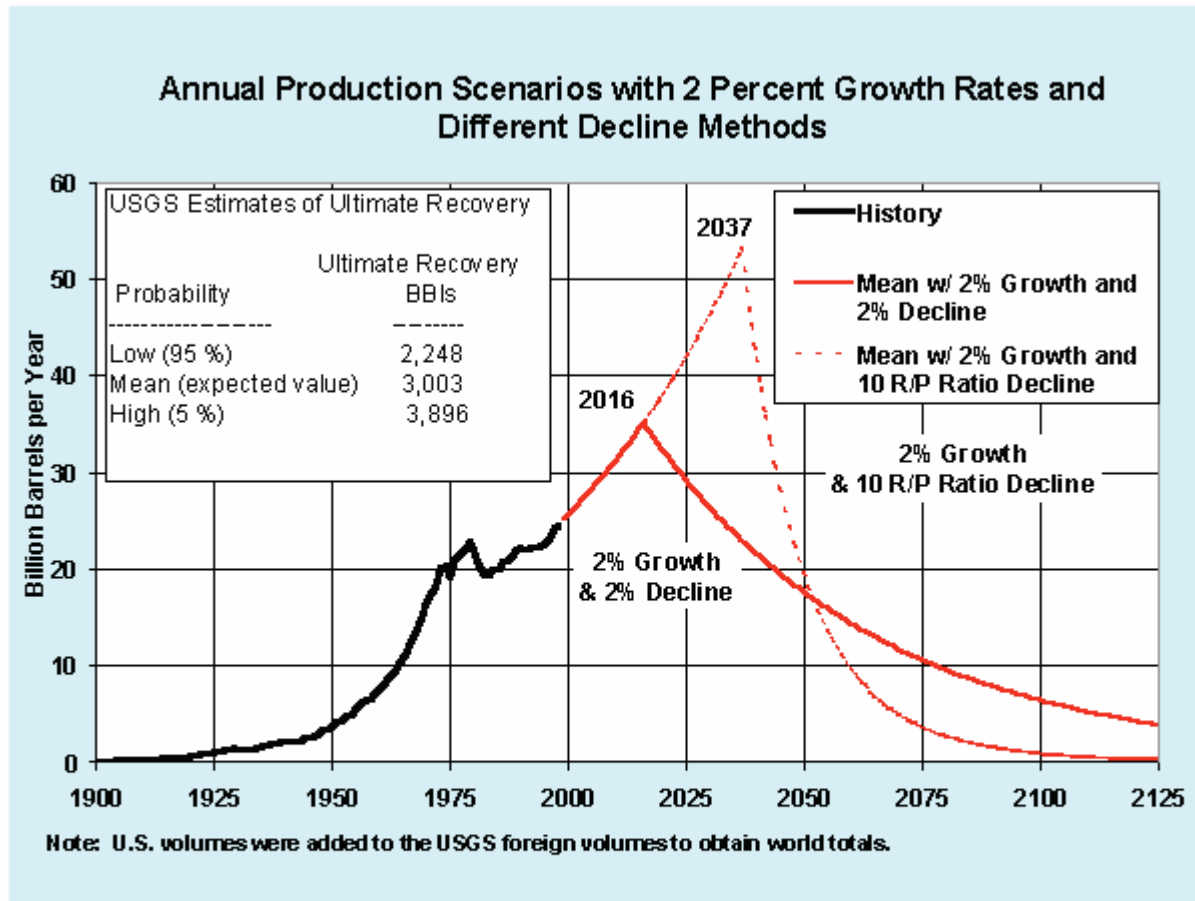
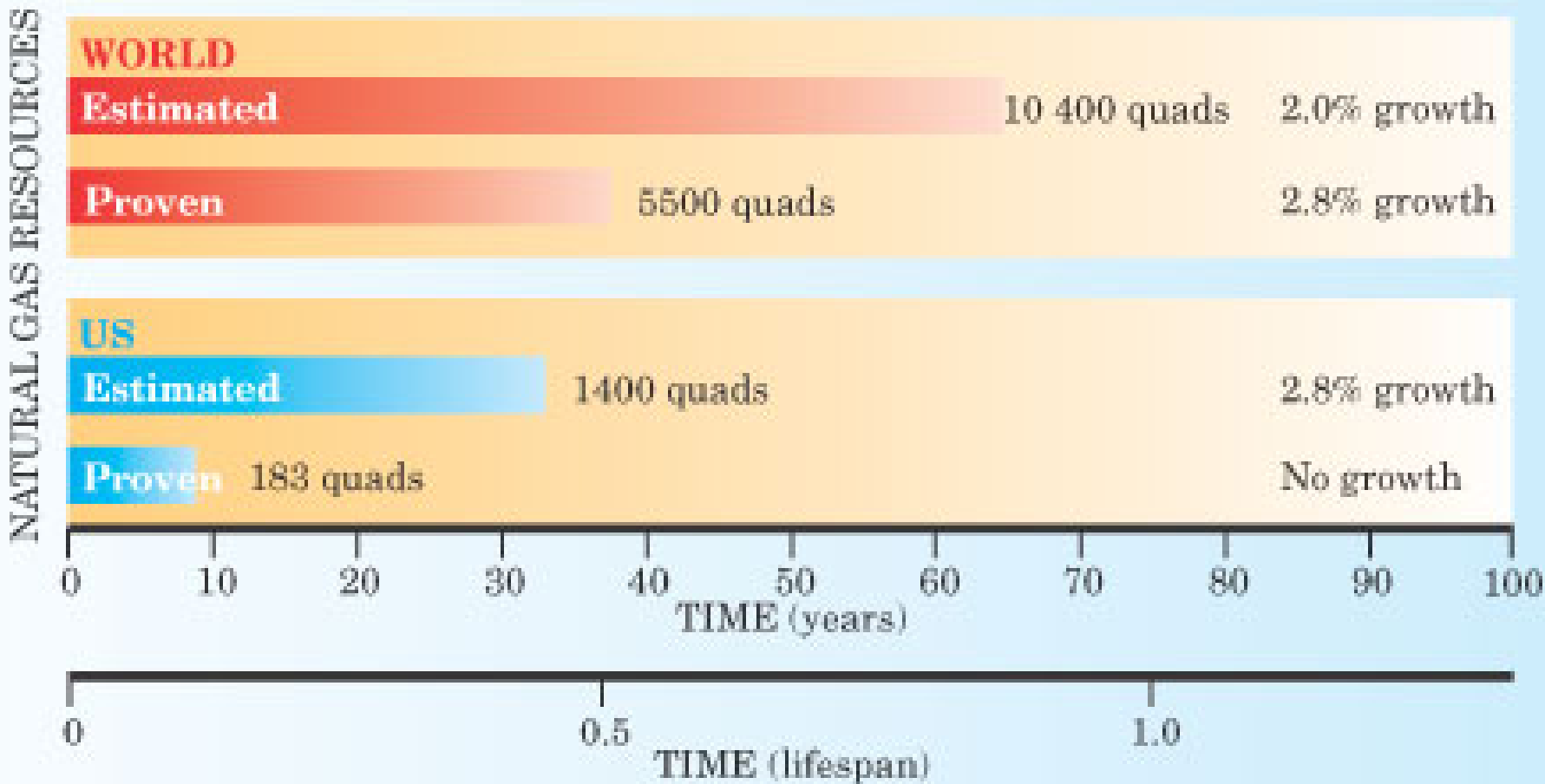


Figure A-1. Two EIA oil production scenarios based on expected ultimate world-recoverable oil of 3,003 billion barrels and a 2 percent annual world oil demand escalation

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, up to 40 sites).
- The Federal Government wants the final say on allowing siting of these terminals.
- LNG could grow from 1% now to 20% by 2020.
- The graphs are for the time the supply will **last**.
- The lighter color is less likely than the darker part.

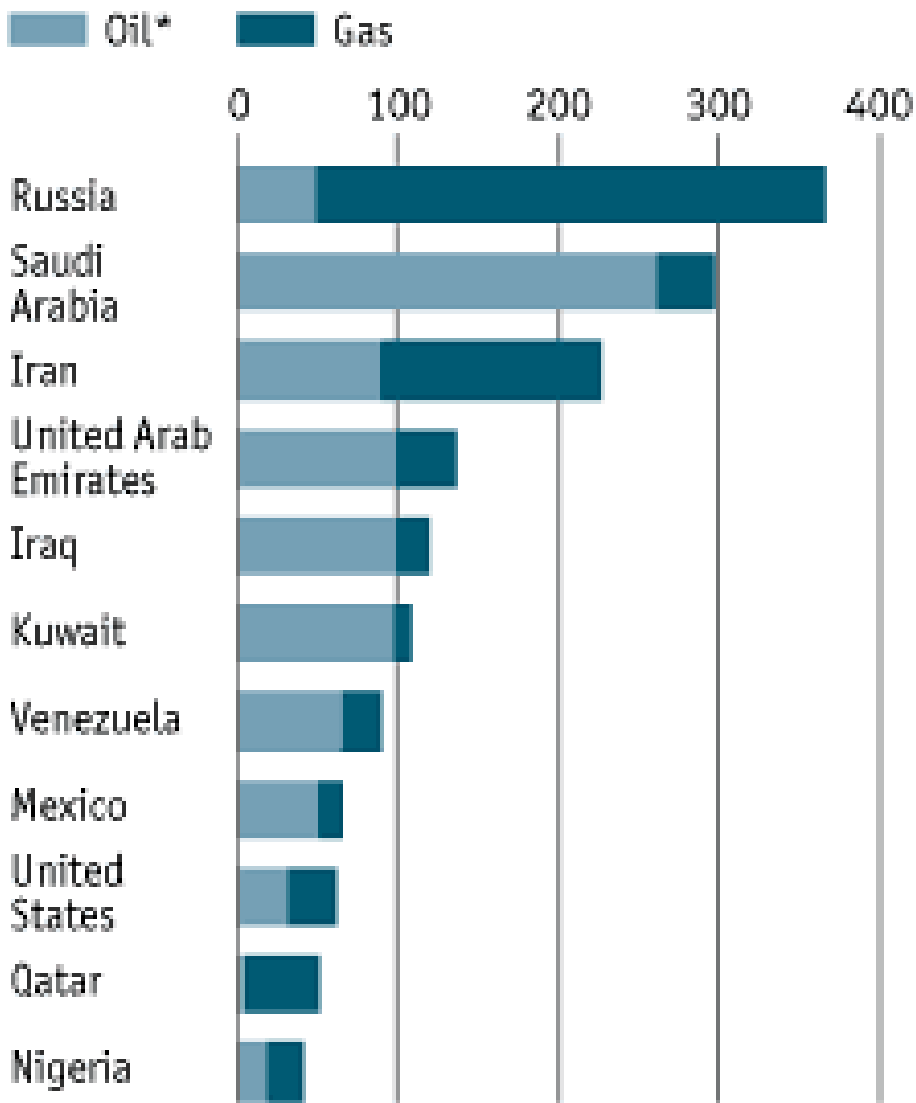
Natural Gas
Physics Today, July
by Paul B. We



World
Natural
Resources

Resourceful

Largest proved oil and gas reserves
Barrels of oil equivalent, bn



- 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.

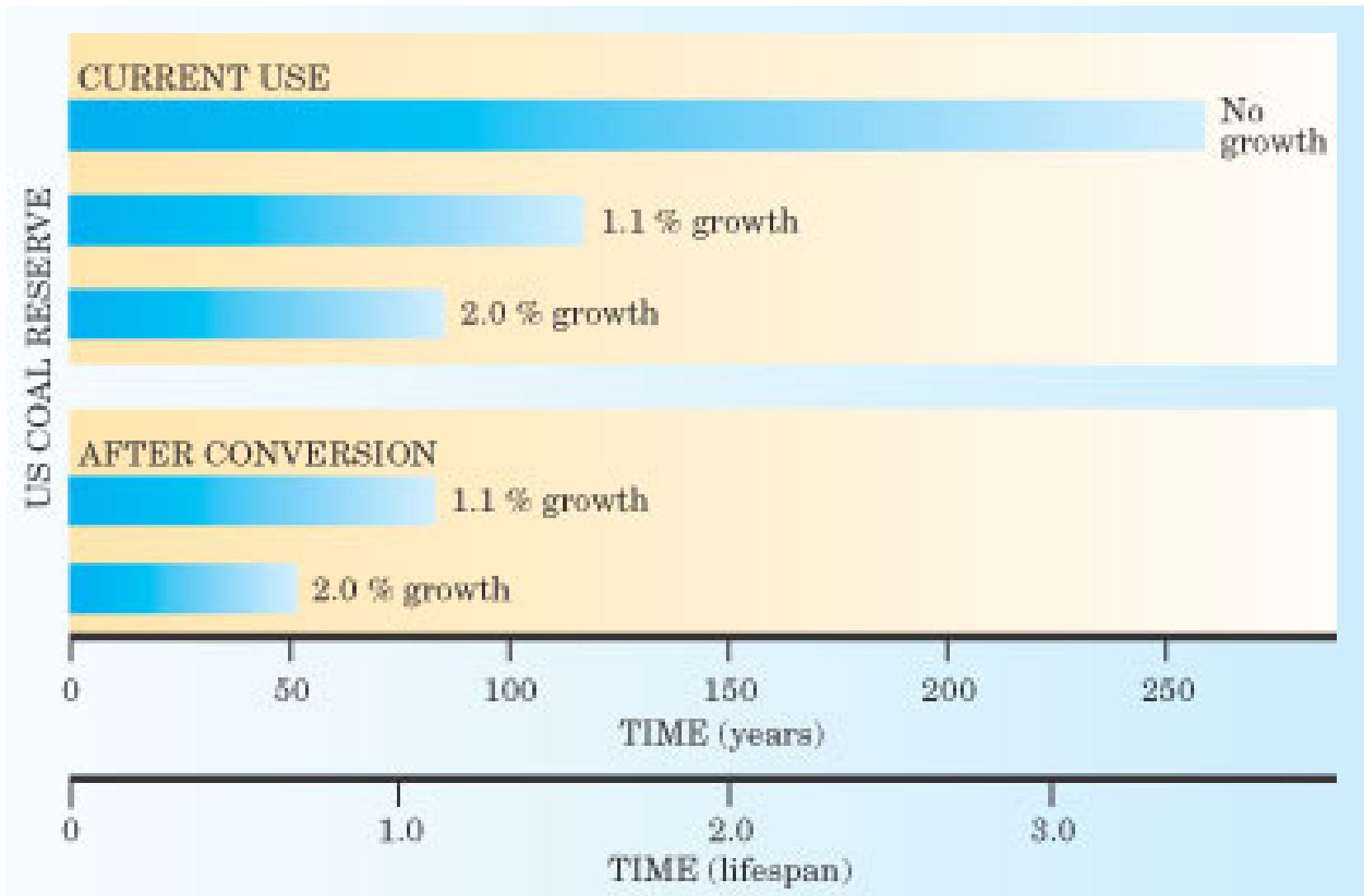
Source: PFC Energy

*Includes condensates

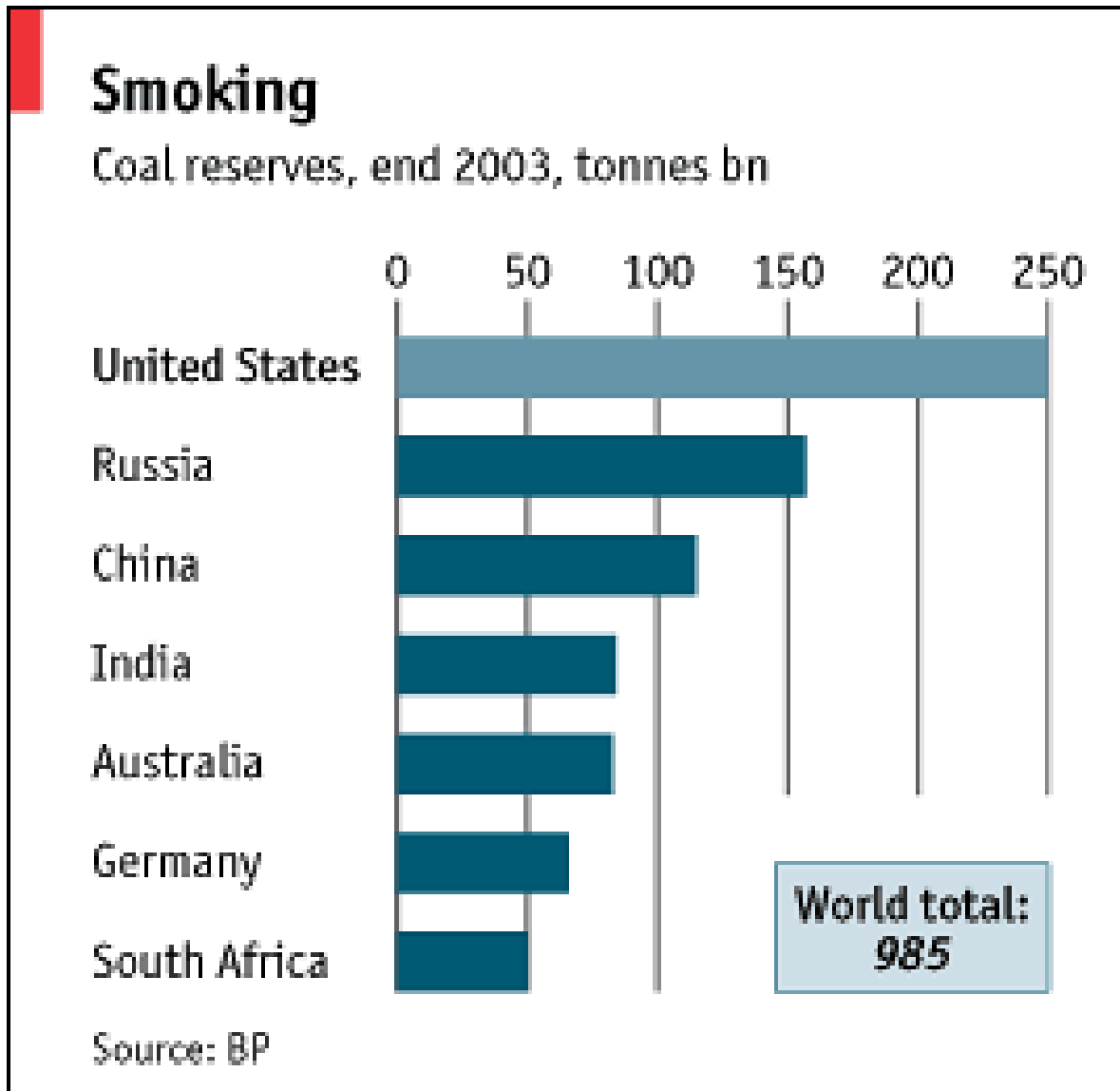
US Coal Supply

- 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 of 250 years with no growth
- Conversion to motor fuel uses 2 Quads of coal to generate 1 Quad 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



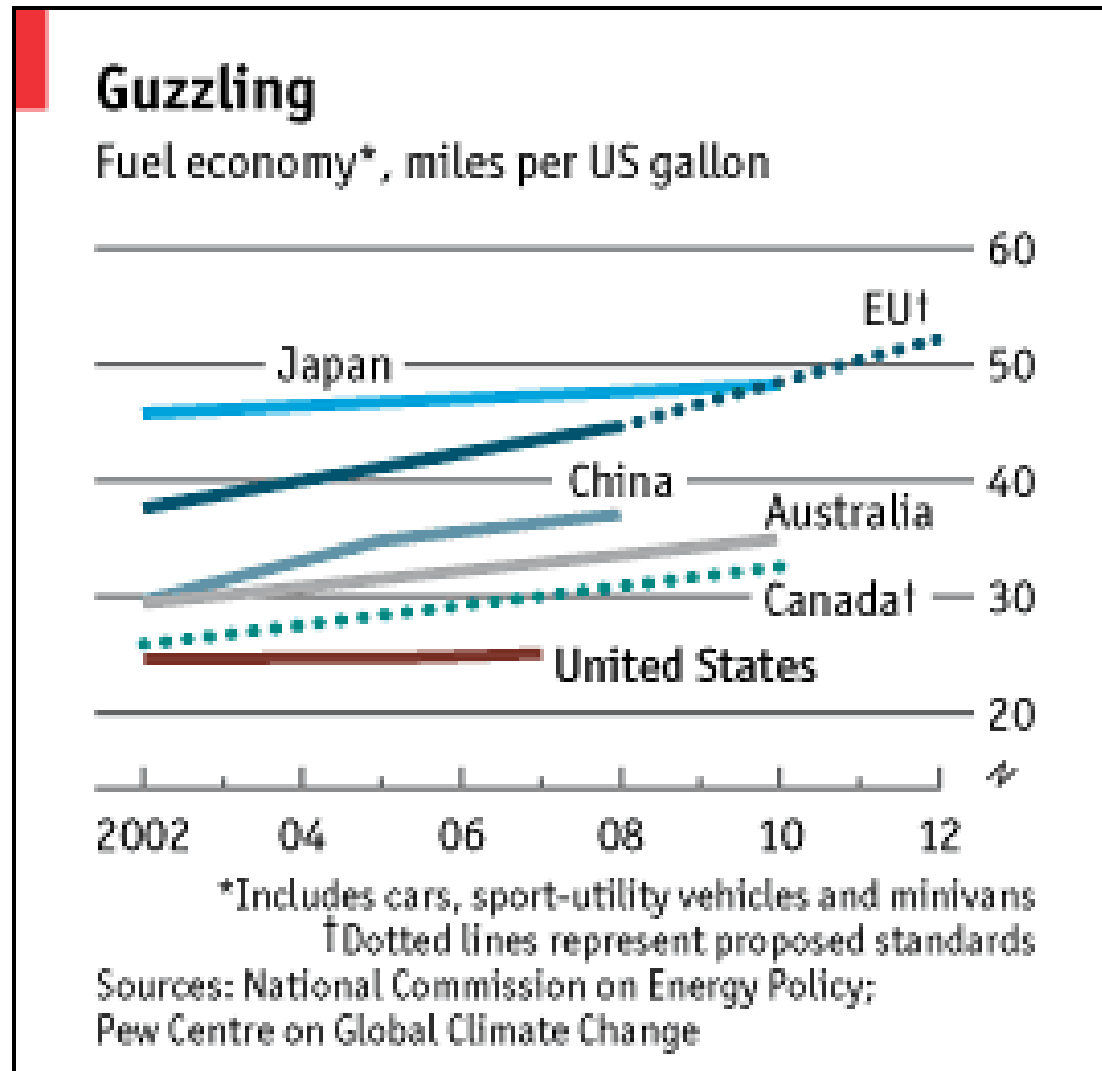
Fossil Fuel Future Summary

- Oil, Natural Gas, Shale Oil, and Coal produce CO₂.
 - 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
 - Total world reserve of oil is a large question, uses politically motivated estimates of individual countries and industry secrets
 - Reserves: About 50 years with growth in use
 - 2/3 is in the Middle East
- Coal may last 100 years with growth in usage, but only 70 years if partly converted to replace oil
- Current rate of use of fossil fuels will increase worldwide
- [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 just use gasoline for transportation and natural gas for heating.
- Since $\frac{1}{2}$ 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 imports.
- We need increases in alternate energy sources such as hydro, nuclear, wind and solar.
- However, coal and LNG will be cheaper than nuclear, so a sacrifice is required here.
- Solar cells are very expensive. Direct solar water heating is much more efficient.
- We also need increases in energy efficiency and conservation.
- This especially includes high mileage vehicles.

Comparative Projected Vehicle Fuel Economies



Paris: Energy efficient small car and convenient parking



II. Alternative 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 $2\text{H}_2\text{O}$.
 - 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.
 - Electric cars can do similar things with cheap motors and already established electricity distribution. Range of 50 miles can be accommodated by work or shopping charging stations, or higher tech batteries.

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)
- H₂ will probably be stored in a smaller volume molecule like NaBH₄
- Won't be practical for 30 years
- [Physics Today "The Hydrogen Economy"](#)

Fusion Reactors

- Fusion easiest for Deuterium on Tritium in a high temperature plasma.
- Replacement Tritium created from a Lithium blanket around the reactor absorbing a produced neutron.
- Fusion reactors
 - [International ITER](#) in 2012 for research for a decade, costing \$5 billion
 - Current stalemate over siting in France or Japan
 - To be followed by DEMO for a functioning plant, taking another 10 years. So not ready for building units until at least 2030.
 - DEMO will cost \$50 billion for a similar capacity as a nuclear reactor.
- US Lithium supply would last a few hundred years.
- Still would be a radioactive waste disposal problem.

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 of turbines
 - Already scenic protests
 - Many areas far from the power grid
 - Claimed to be as cheap as natural gas
 - Waiting for Tax Credit law renewal
- **Solar power:** 80% efficient for water heating on roofs
 - Only 10% efficient for rooftop electricity
 - Solar cell electricity more costly by a factor of 10
 - 40 square miles equivalent to one nuclear reactor
 - Need more research to improve efficiency and lower manufacturing costs

Solar Reflections

- Rooftop water heating elements are 80% effective.
- But solar cells are only 10% effective.
- Therefore during a hot summer it would be better to reflect sunlight off the roof at near 100% efficiency.
- During the winter it would be better to absorb all of the sunlight, rather than just using 10% of it as electricity for inside heating or power.
- Similarly in cities, which heat up because of asphalt and tarred or rocky roofs, it would be better to reflect energy during the summer by painting roads and roofs white or light colored.
- Also, tree planting cools cities, as well as patio or walkway covers, and covered parking garages or stalls.
- Water can also be evaporated for transpiration cooling.
- California is about to waste \$23 billion on a million rooftop program of solar cells, which will generate electricity equivalent to only one-half of a nuclear reactor (SB1).

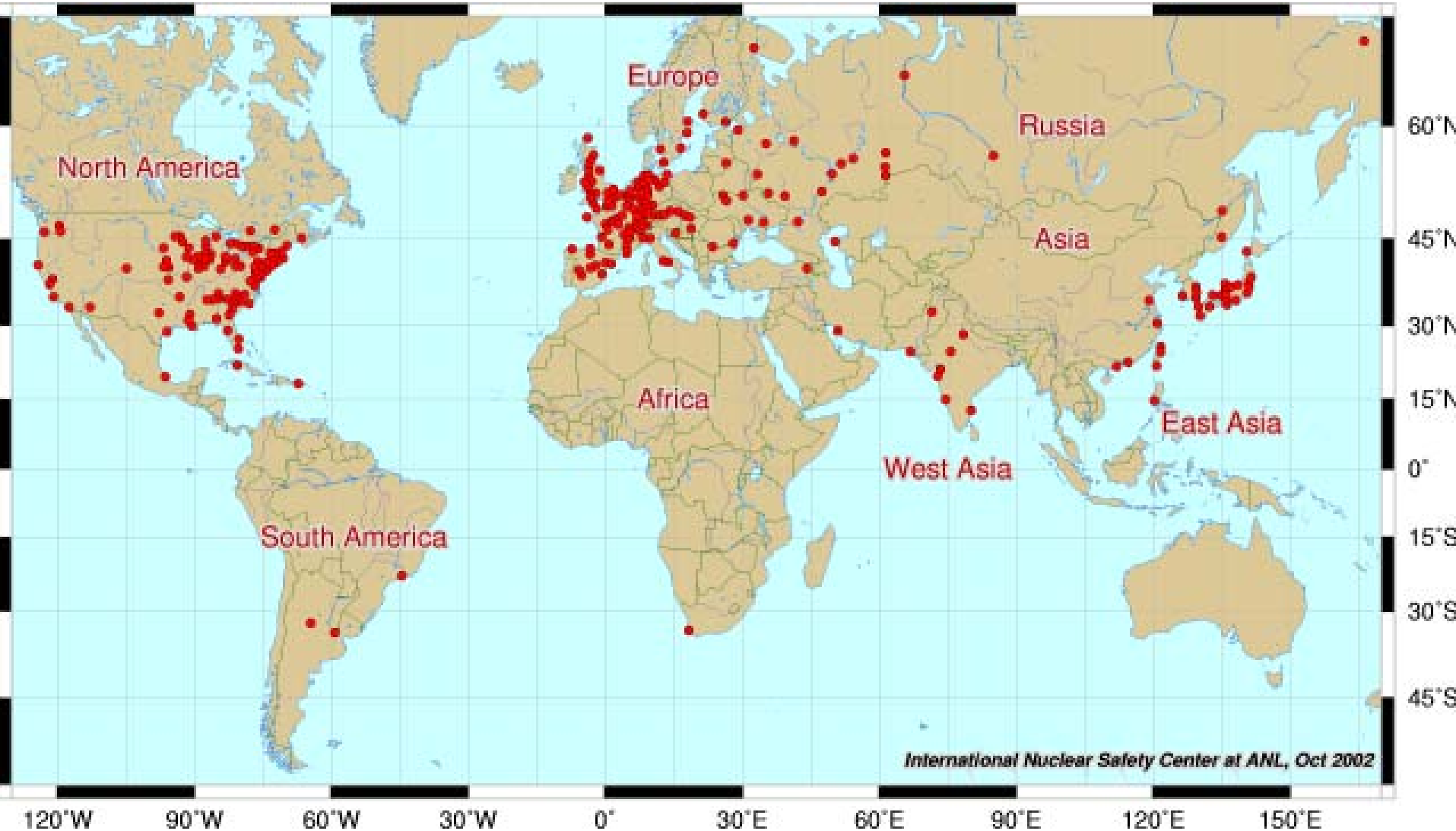
Biomass, Ethanol, and Geothermal

- **Biomass:** Competes with farm use for food
 - Insufficient for total power by a factor of 40
 - 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. Again, generates CO₂.
- **Geothermal:** Few sites, mostly in the west
 - Produces Sulfur and heavy element pollution
 - Drilled holes cooled after sufficient water is heated

III. Worldwide Nuclear Power

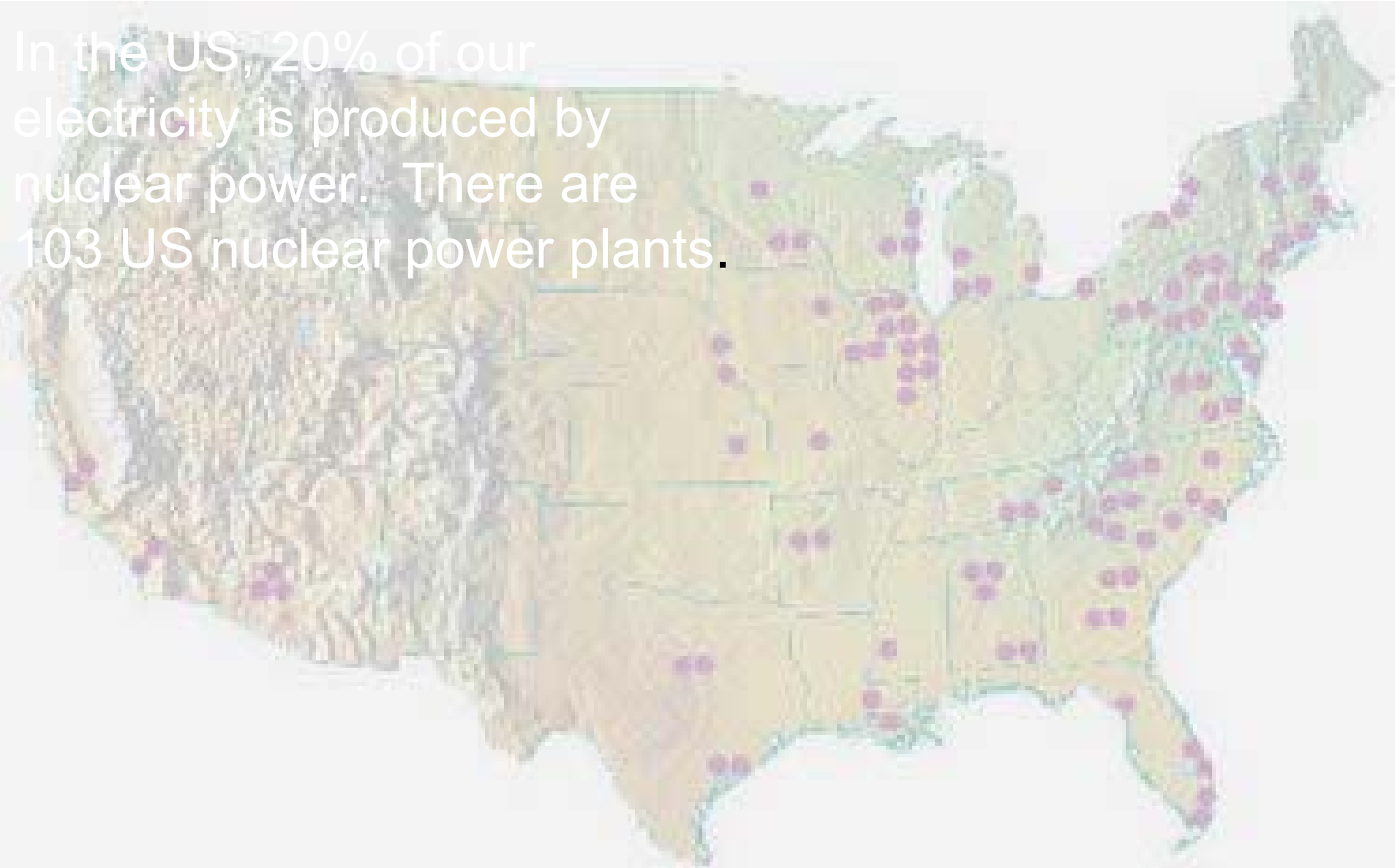
- Provides 20% of the world's electricity
- Provides 7% of world's total energy usage
- Cost is currently similar to fossil fuels
- Nuclear reactors have zero emissions of smog or CO₂
- There are 440 nuclear power reactors in 31 countries
- 30 more are under construction
- They produce a total of 351 billion watts of electricity

World Nuclear Power Plants



US Nuclear Power

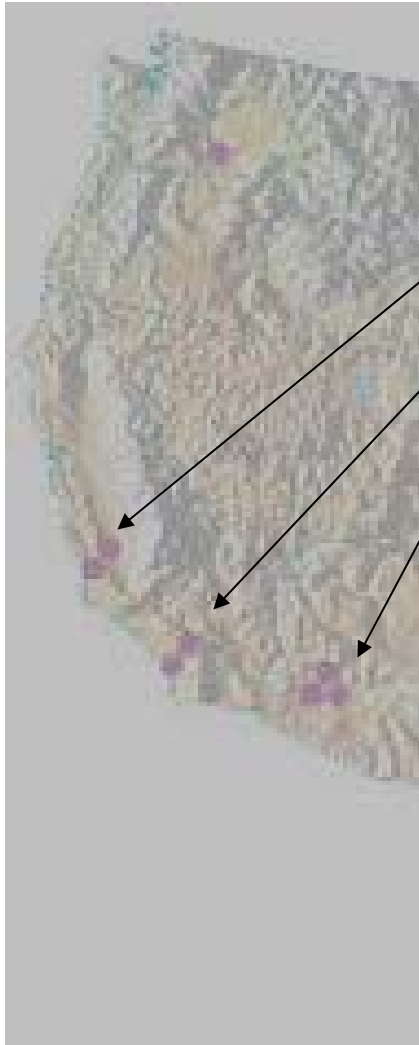
In the US, 20% of our electricity is produced by nuclear power. There are 103 US nuclear power plants.



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

$\frac{1}{3}$ of Palo Verde 1, 2, & 3 in
Arizona

California Nuclear Energy

- Each 1,100 megawatt reactor can power one million homes.
- Each reactor's output 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.
- The replacements would save consumers up to \$3 billion they would have to pay for electricity elsewhere.

Nuclear Power Proposed Solution?

- [Richard Garwin](#) , [MIT](#) and industry propose:
- If 50 years from now the world uses twice as much energy, and half comes from nuclear power
- Need 4,000 nuclear reactors, using about a million tons of Uranium a year
- With higher cost terrestrial ore, would last for 300 years
- Breeder reactors creating Plutonium could extend the supply to 200,000 years
- Nonpolluting, non-CO2 producing source
- Need more trained nuclear engineers and sites
- Study fuel reprocessing, waste disposal, and safety

Conservation

- Populations of largest CO₂ producing countries are stabilizing
- Mass transit, car pooling, cash for not parking
- Transit Villages built around transportation lines
- Fuel economy improvements
- Hybrid and Electric cars, cylinder shut down engines
- Transportation replaced by communications
- Smart offices, houses and buildings
- Energy cost increases will drive conservation
- CO₂ production taxes and increased fuel taxes

Possibility of New Energy Solutions and Improved Technology

- 100 years of scientific discoveries and technological innovations is unpredictable.
- In the last century we created:
 - Autos, petroleum industry
 - Aircraft
 - Household appliances
 - Mechanized industrial efficiency
 - Nuclear Age
 - Electronics age: TV, computers, cell phones
 - Biological Age Starting: DNA, Genomics
 - Medical diagnosis and care
- What lies ahead?

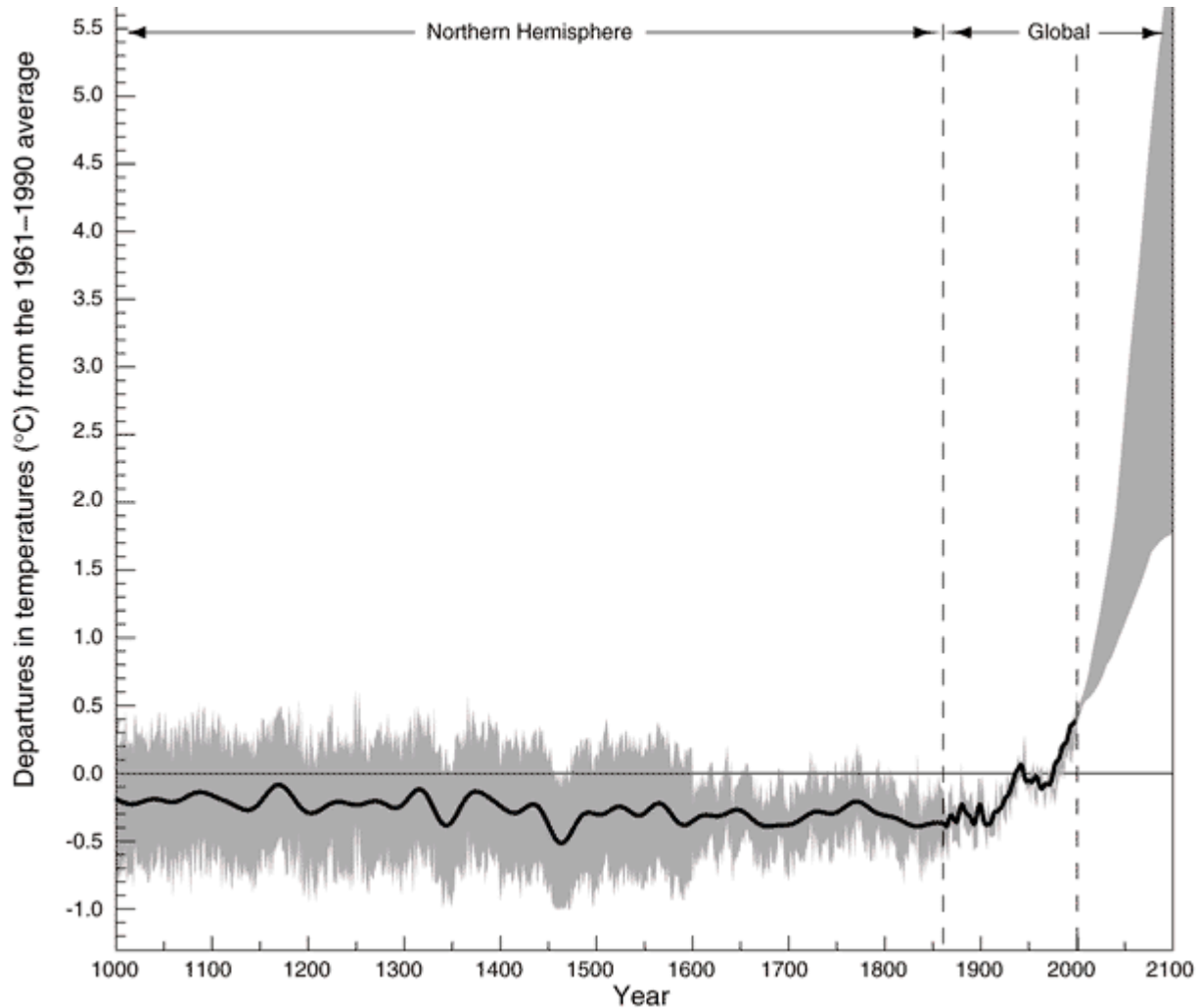
Signs of Progress

- **Globally:** The Kyoto Treaty went into effect in Feb. 2005, with signers reducing emissions to 5% below 1990 levels, except for developing countries which includes China. China, however, with many smoggy cities, is planning 30 nuclear reactors by 2020, and considering 200-300 by 2050, including breeder and pebble bed reactors.
- **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.

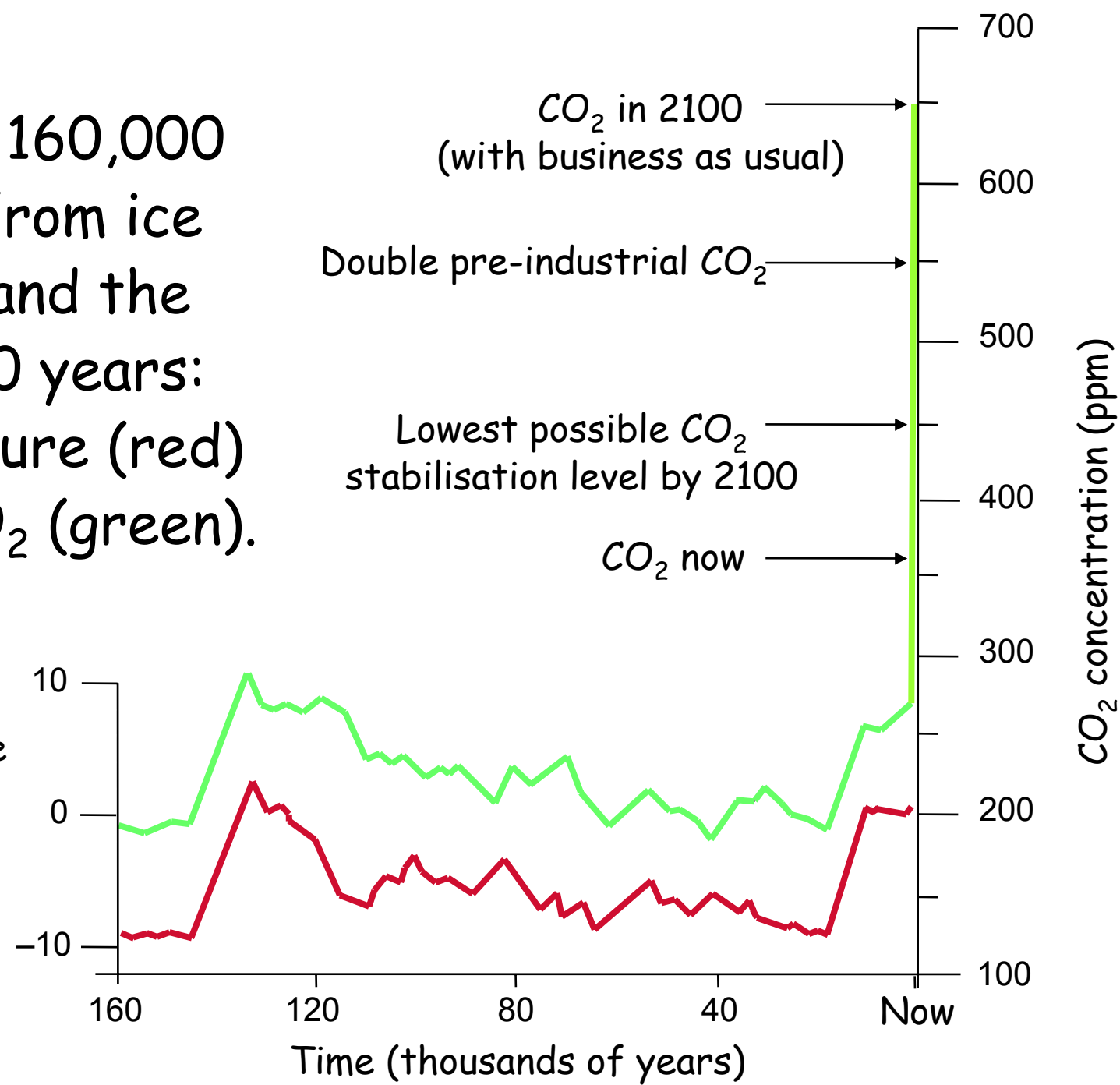
IV Global Warming Effects

- Predicted Global Warming of 5°F will affect everyone in most structural aspects of society and in their costs.
- We don't realize how our present housing, business, and supply nets are closely adapted to our current climates.
- The major increase in temperature and climate effects such as rainfall, drought, floods, storms, and water supply, will affect household and business insulation, heating and cooling energy, and farming. These may require large and costly modifications.
- Some cold areas may benefit, and some hot areas will become unfarmable and costly to inhabit.
- It is very misleading to portray the problem as a purely environmentalist issue which affects only polar bears, a few Pacific islanders, and butterflies.

Global Temperature Record: Unusual 1° F Rise in the Last Century



The last 160,000 years (from ice cores) and the next 100 years: temperature (red) tracks CO₂ (green).



CO2 and the Kyoto Treaty

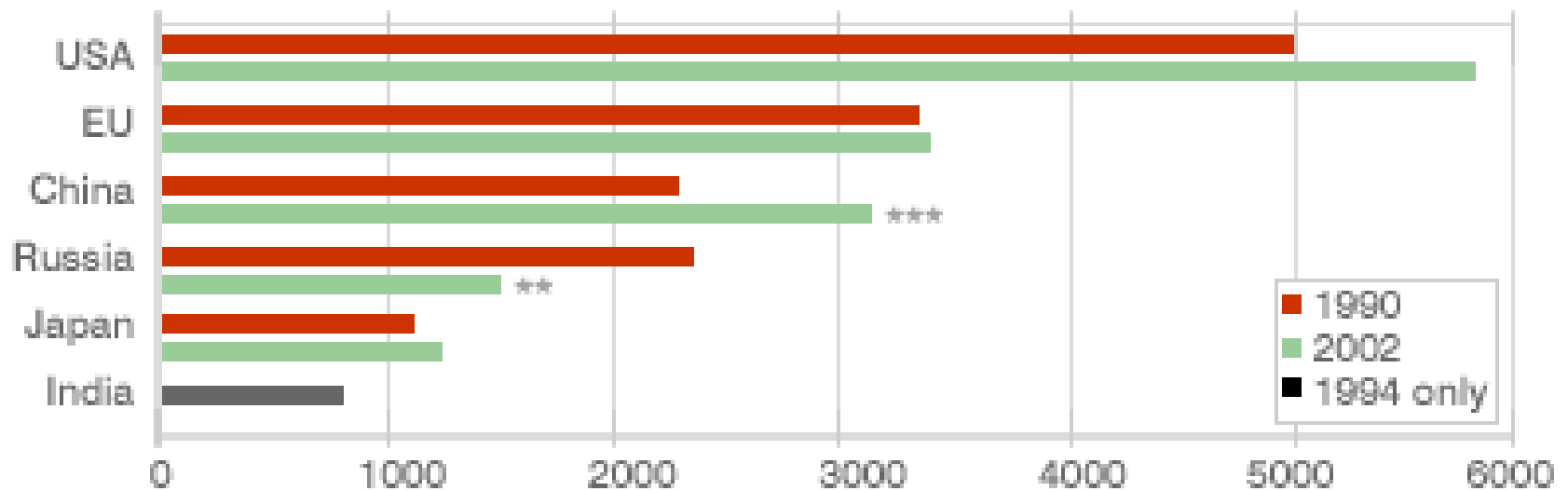
- The treaty just went into effect in Feb. 2005 to reduce greenhouse gas emissions of developed countries to 5% below their 1990 level.
- The U.S., as the largest CO2 emitter in 1990 (36%), will not participate because it would hurt the economy, harm domestic coal production, and cost jobs.
- China has signed the protocol, but as a developing country, it does not have to reduce emissions.
- (In China's defense, it only has $\frac{1}{4}$ the emissions of the US per capita, it has significantly lowered its birth rate, and it is planning a massive nuclear reactor program.)

CO2 Production Rate

- Preindustrial 275 ppm CO₂ will be doubled at 550 ppm by adding 200 ppm to the present 350 ppm. This will happen in 65 years at the current rate.
- Present burning of 240 Quads of fossil fuel per year can increase CO₂ by 3.0 ppm per year.
- Thus 200 ppm will be added by 67 years, or sooner if fuel use increases.
- Climate models have a mean prediction of an increased temperature of 5° F for this doubling of CO₂.

Comparative World CO2 Emissions

CO2 EMISSIONS (1,000 MILLION TONNES)



1999, *2001 (both China figures include Hong Kong)

SOURCES: UNFCCC (China figures from IEA)

Global Warming Scenario

- Greenhouse gases: CO₂, methane, and nitrous oxide
- Already heat world to average 60° F, rather than 0° F without an atmosphere
- The present radiation imbalance will cause another 1° F heating by 2050, even without more greenhouse gas emissions.
- Recent cleaning of air is causing the earth's surface to be hotter and brighter.
- Doubling of CO₂ projected by end of century, causing ~5° F increase in average temperature (most rapid change in over 10,000 years)
 - ~2-3 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
 - Warming over land expected to be greater
 - Hot areas expect greater evaporation from hotter winds
- Stabilizing the amount of CO₂ would require a reduction to only 5% to 10% of present fossil fuel emissions

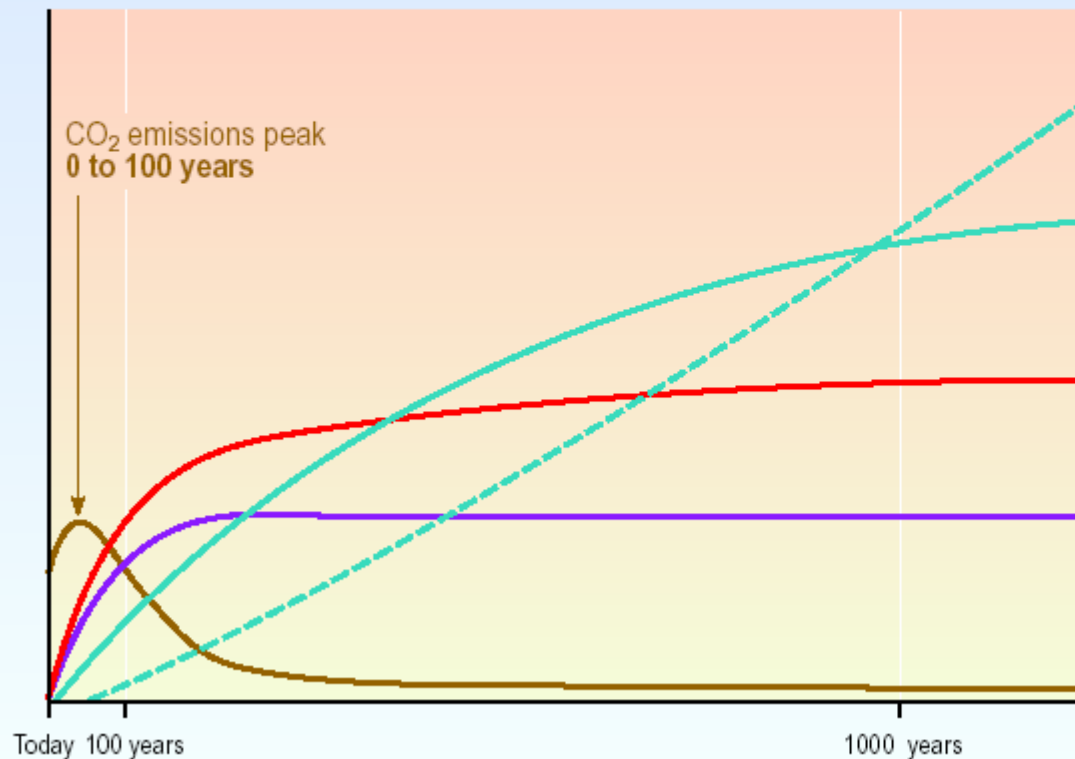
Global Warming Effects

- Global Warming is an average measure
- Local warming or climate fluctuations can be very significant
- Arctic is 5° warmer
 - Ice cap is ½ the thickness of 30 years ago
- Antarctic is 5° warmer
 - Ice shelves over the sea are melting and breaking off and 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
- Rainfall is hard to predict. It could be increased or decreased.
- Drought can partly be caused by increased evaporation at the higher temperature.

CO₂ Effects to Increase Over Centuries

CO₂ concentration, temperature and sea level continue to rise long after emissions are reduced

Magnitude of response



Time taken to reach equilibrium

Sea-level rise due to ice melting: several millennia

Sea-level rise due to thermal expansion: centuries to millennia

Temperature stabilization: a few centuries

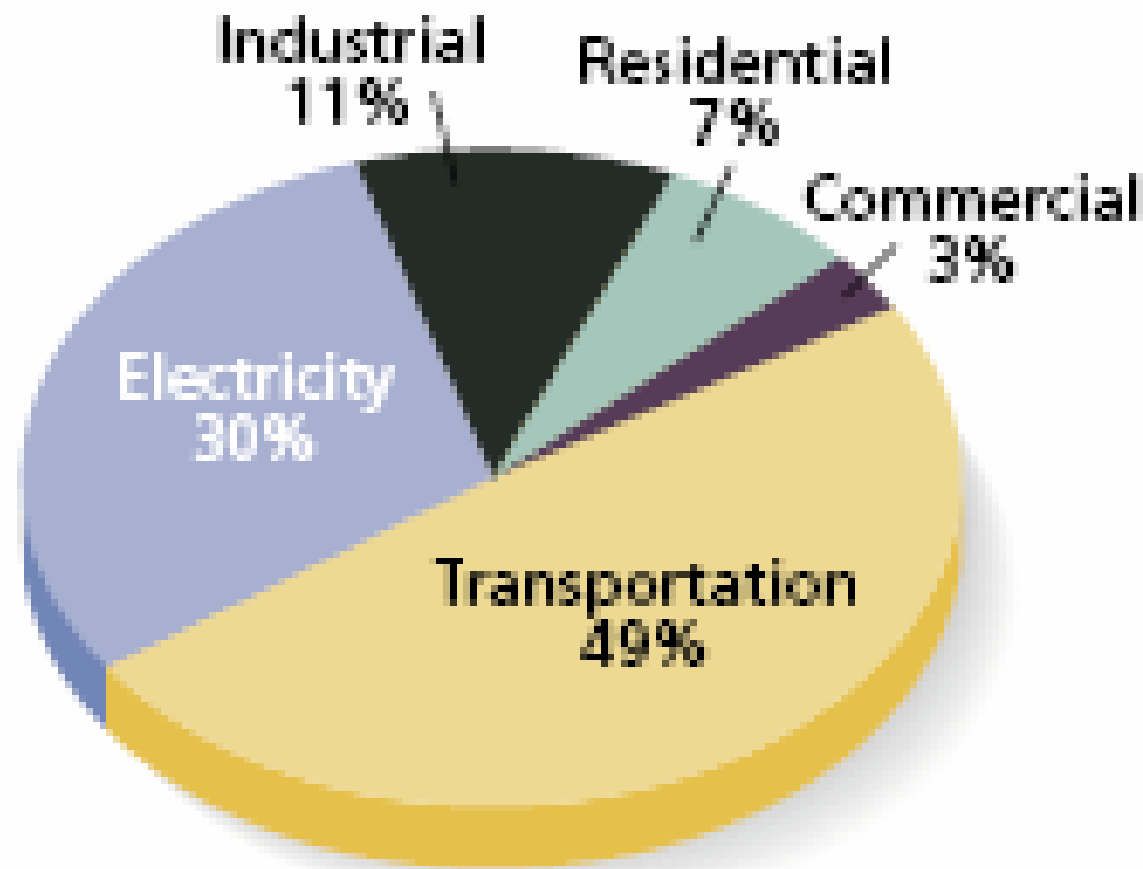
CO₂ stabilization: 100 to 300 years

CO₂ emissions

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, including wine and dairy, could be affected by water shortages and higher temperatures.
- More forest fires.
- Tree rings show that in eras of global warming, megadroughts of decades hit the southwest US.

Figure 1: California CO₂ Emissions (1999)

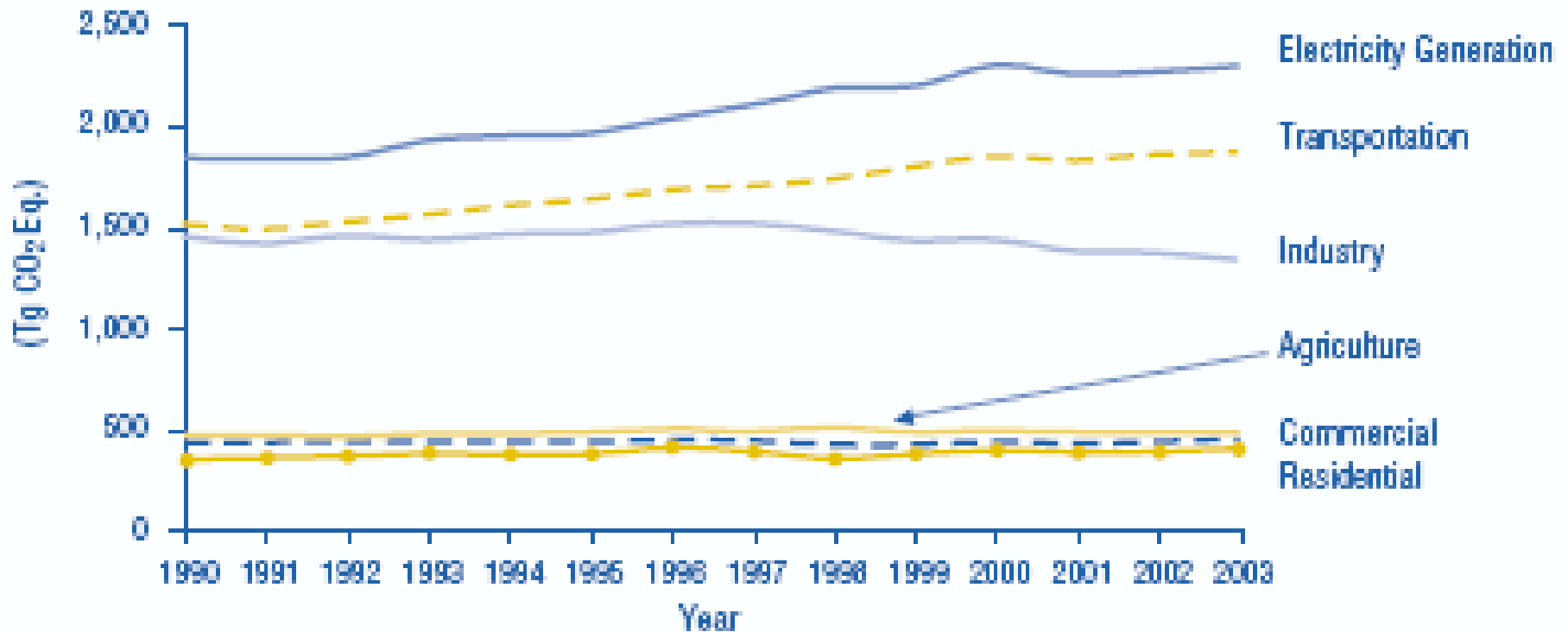


Note: Includes emissions from Imported electric power.

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

U.S. Carbon emission sources

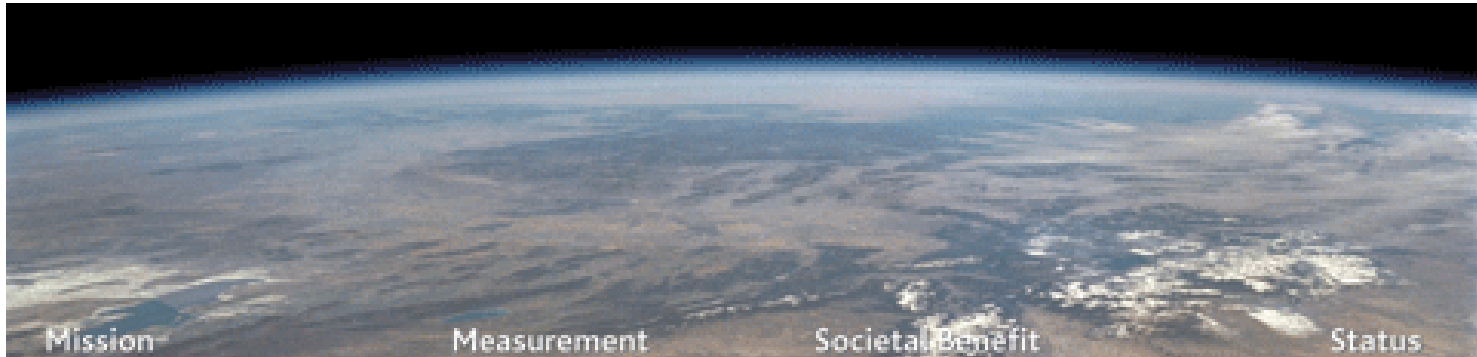
Emissions Allocated to Economic Sector



Energy Research

- For comparison, the European Union is completing a \$1 billion program on renewable energy to end in 2006, and expects double that afterwards to 2010.
- In 2005, the US will spend \$1 billion, but mostly at national labs ([DOE National Renewable Energy Laboratory in Colorado](#)), but university funding is “bleak”.
- Stanford has a [Global Climate and Energy Project \(GCEP\)](#) of \$225 million over ten years from industry.

Climate Satellite Research Setbacks



Mission	Measurement	Societal Benefit	Status
Global Precipitation Measurement	Precipitation	Reduce vulnerability to floods and droughts; improve forecasts of hurricanes	<i>delayed</i>
Atmospheric Soundings From Geostationary Orbit	Temperature and water vapor	Improved weather forecasts and severe storm warnings	<i>anceled</i>
Ocean Vector Winds	Wind speed and direction near the ocean surface	Improved warnings to ships at sea; better predictions of El Niño	<i>anceled</i>
Landsat Data Continuity	Land cover	Monitor land-use changes; find mineral resources	<i>anceled</i>
Glory Instrument	Optical properties of aerosols; solar irradiance	Improved understanding of climate change	<i>anceled</i>
Wide Swath Ocean Altimeter (on the Ocean Surface Topography Mission)	Sea level in two dimensions	Monitor changes that affect fisheries, navigation, and ocean climate	<i>instrument canceled, descope of mission</i>

Also, 4 years of data from the Earth Radiation Budget Satellite is unanalyzed for lack of funds.

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.
- BEWARE: Million solar roof initiative will spend \$23 billion to create the power of only half a nuclear reactor.
- 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.

Conclusions on Energy and GW

- At current or increased rates of production, oil and natural gas will be gone in 50 years or so, and will be expensive long before that.
- Production of oil from coal and tar sands could be somewhat expensive.
- Use of coal for electricity would highly pollute smog prone areas.
- With the high costs of fuel and of fuel conversion or substitution, the costs of global warming should be added in to promote alternate energy sources, including nuclear power.
- 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.

The Invisibility of Modern Energy and Global Warming

- In ancient times we gathered firewood and watched it burn. With steam powered transportation we saw the coal loaded and burned, and the steam go off.
- Today, we pump gas invisibly, and burn it with no visible emission.
- We don't see the oil being pumped from the ground, although we can see tankers in the harbor and refineries. We don't see it flowing through pipelines.
- We don't see the electricity powering our houses except through light, and don't monitor its usage. We usually don't see the power plants. We often don't even see power lines to our houses.
- In natural gas heating we don't see the gas burn or the heater and we don't monitor it.
- The greenhouse gases are invisible to us so we can't see their emission or buildup.
- Their effects on temperature show up globally with careful averaging, and often in subtle effects.
- Any particular warming area or period is hard to precisely attribute to global warming.
- Eventually global warming effects will be more prevalent, after much of its prevention period is gone.

Cost of Conversion to Industry (and Consumers) – Order of magnitude

- At \$50/barrel for oil, we are currently sending \$100 billion per year to foreign oil sources.
- The 1st gulf war required our presence to retake Kuwait and defend Saudi Arabia for their oil resources.
- The 2nd gulf war (Iraq) may be costing us \$100 billion per year at present, to someday make available more oil resources.
- Even if nuclear reactors cost as much as \$5 billion each, we could build 40 nuclear plants a year with this money.
- Since nuclear is 20% of our electricity with 100 plants, in 10 years of such payments we could produce 400 more plants and have 100% of our electricity nuclear.
- Then we could start building a nuclear generated hydrogen economy for transportation with no CO₂ pollution.
- The economics is similar to the question of renting versus owning.
- The costs of building and operating U.S. plants also go to American workers, not overseas.
- So we are already spending the magnitude of funds necessary to convert, but not accomplishing it.