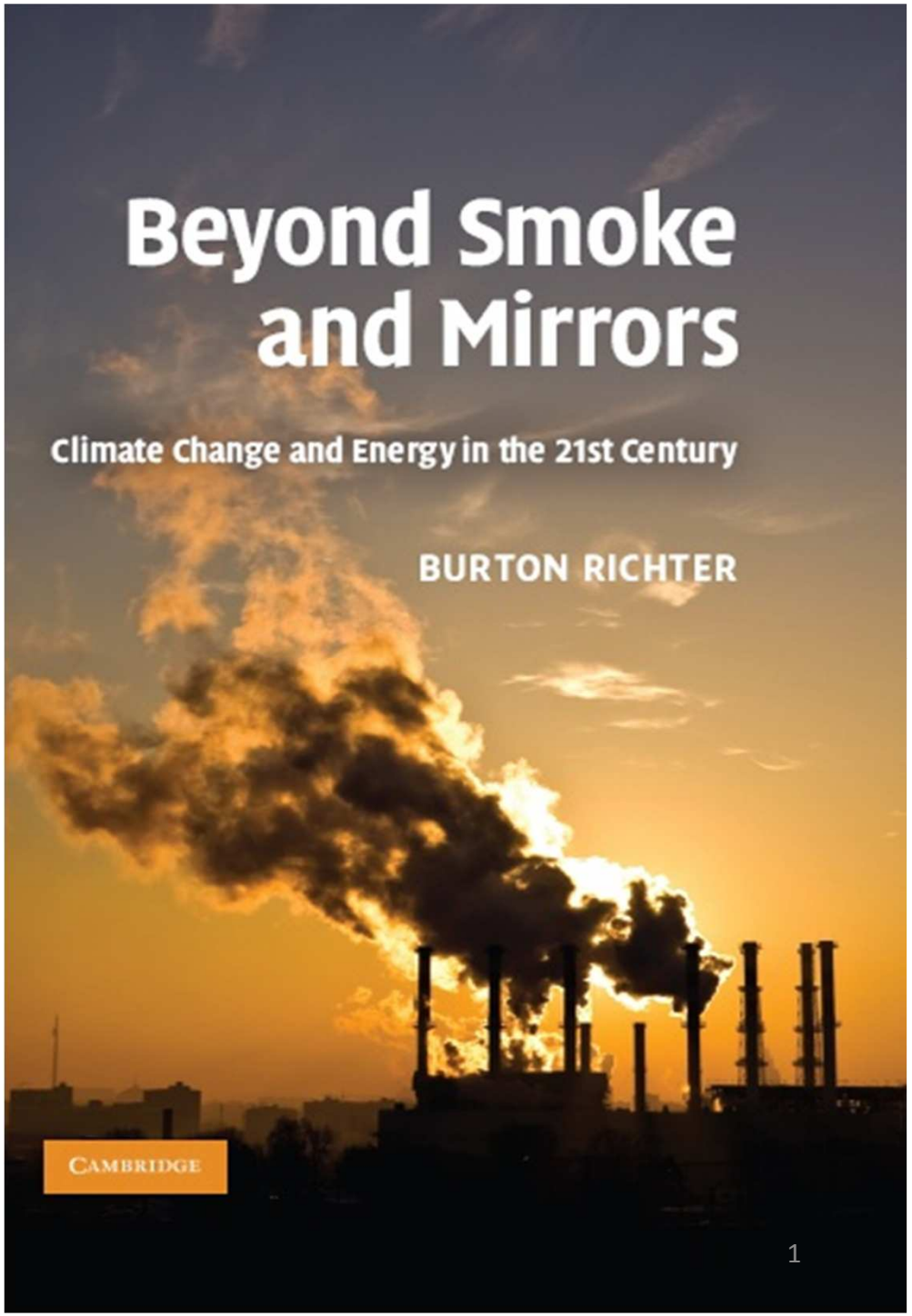
Hoxton Lecture
University of Virginia

Burton Richter
Paul Pigott Professor Emeritus, Stanford University
April 7,, 2011



Energy in the 21st Century:

The Economy, Security, and the Environment

Energy, Economy, and Emissions

- Energy = (Pop)x(GDP/Pop)x(En/GDP)
- GrnGas = (Pop)x(GDP/Pop)x(GG/GDP)
- Population is increasing to 9 billion by 2050
- Per Capita Income is going up
- Energy and GG Intensities relate to state of development and to efficiency of energy generation and sources of energy.
- This is what all the arguments at Kyoto, Copenhagen, and Cancun are all about
- **Options – reduce energy intensity (efficiency) and/or reduce emission intensity (efficiency and/or fuel switching)**

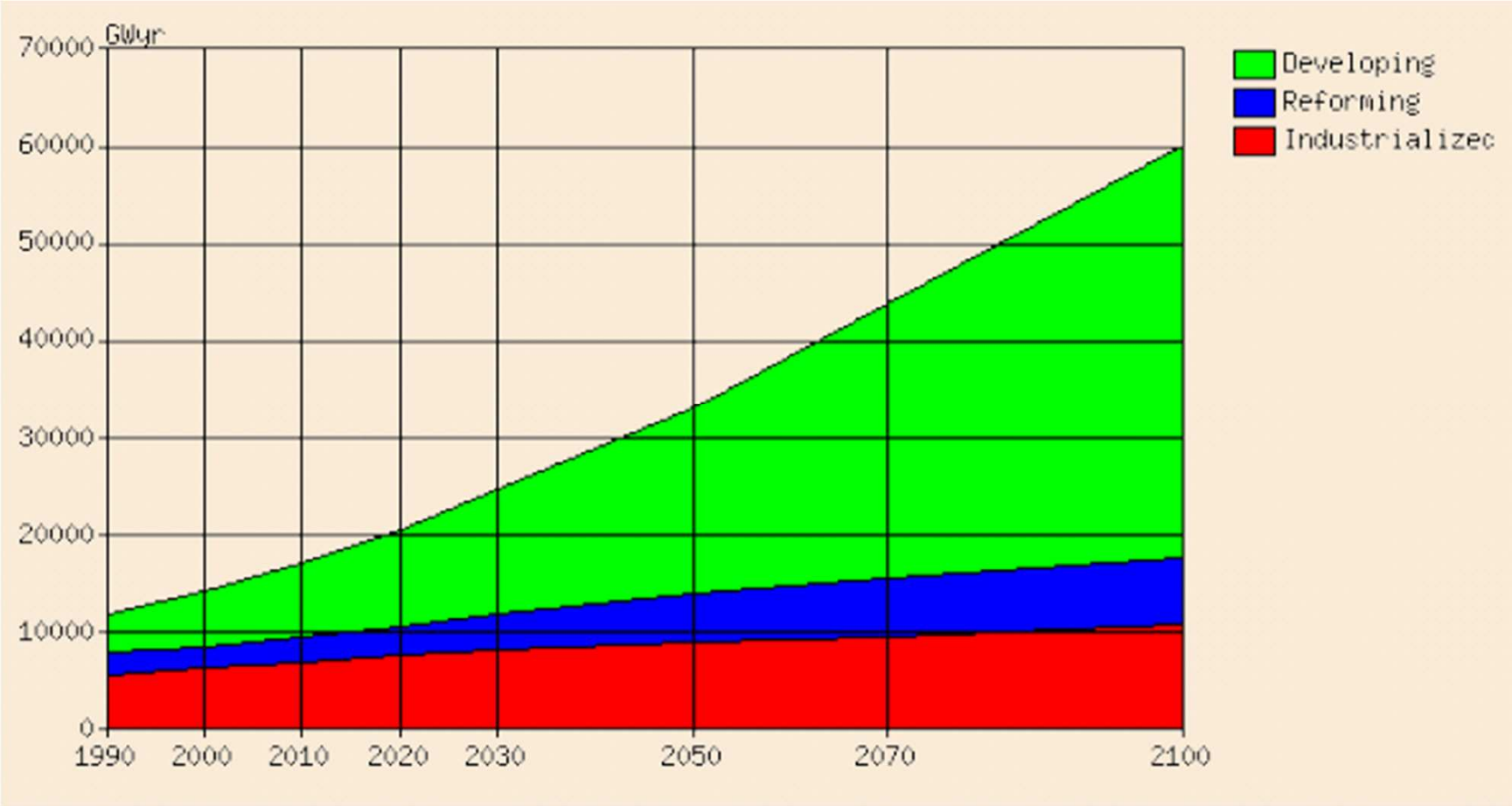

Energy use per unit of GDP
Tonnes of oil equivalent per $'000*
1.2
1.0
0.8
0.6
0.4
0.2
0
FORECAST
China
United States
Russia
World
India
1820 30 40 50 60 70 80 90 1900 10 20 30 40 50 60 70 80 90 2000 10 20 30
Source: BP
*At 2009 purchasing-power-parity exchange rates

CO_2 Intensity

(IEA, Key World Energy Statistics 2003)

Area	GDP (ppp) (Billions of U.S. Dollars)	CO_2/GDP Kg/$(ppp)
World	42,400	0.56
France	1,390	0.28

IIASA Projection of Future Energy Demand Scenario A1 (High Growth)



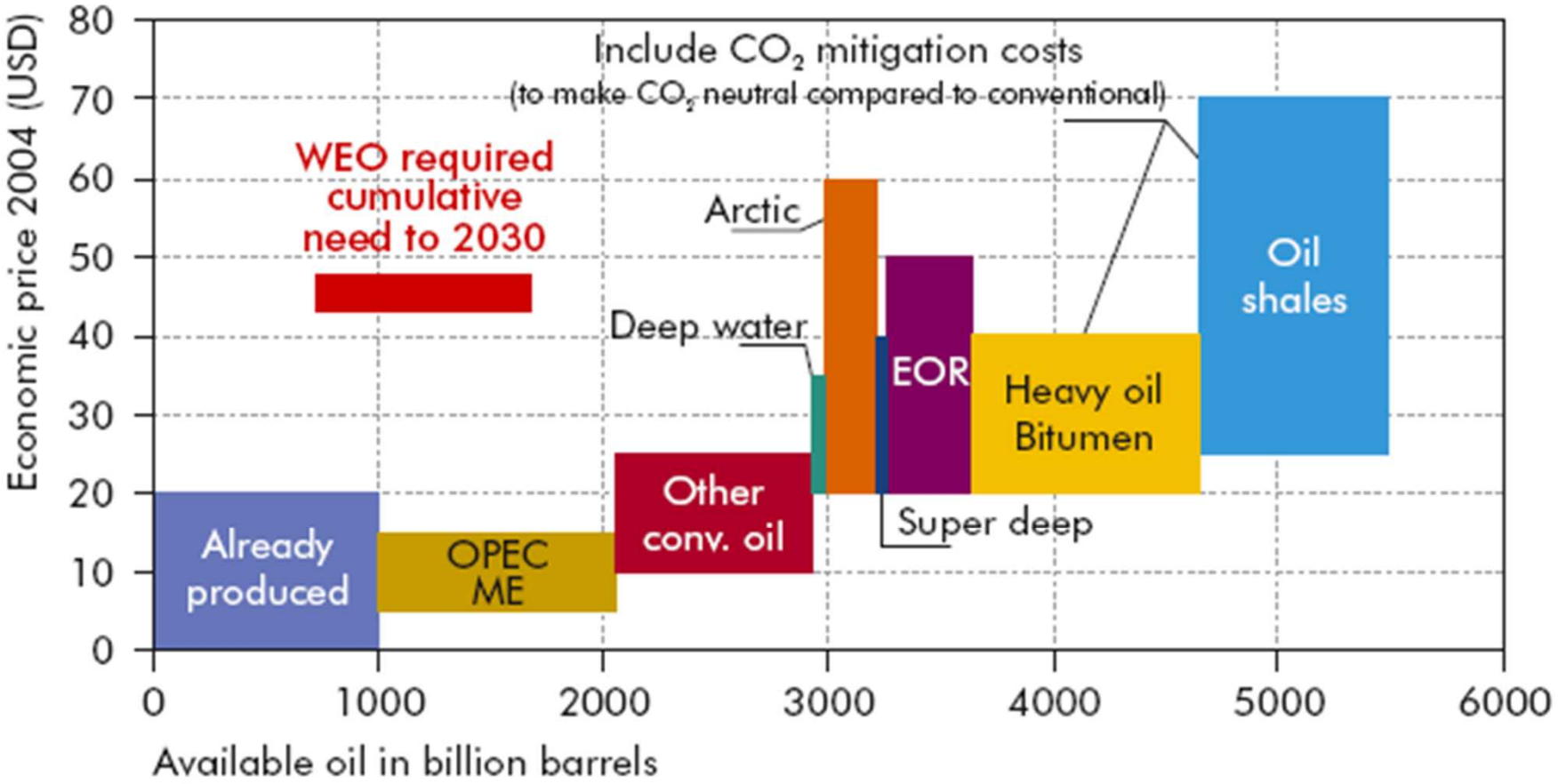
Percentage of Total Primary Energy Supply (TPES) and World CO_2 Emissions by Fuel

Energy Source	Percentage of TPES	Percent of World CO_2 Emissions
Oil	34	40
Coal	26	40
Natural Gas	21	20
Nuclear Power	6	0
Hydroelectric	2	0
Combustibles	10	0
Other	1	0

Source - IEA 2007

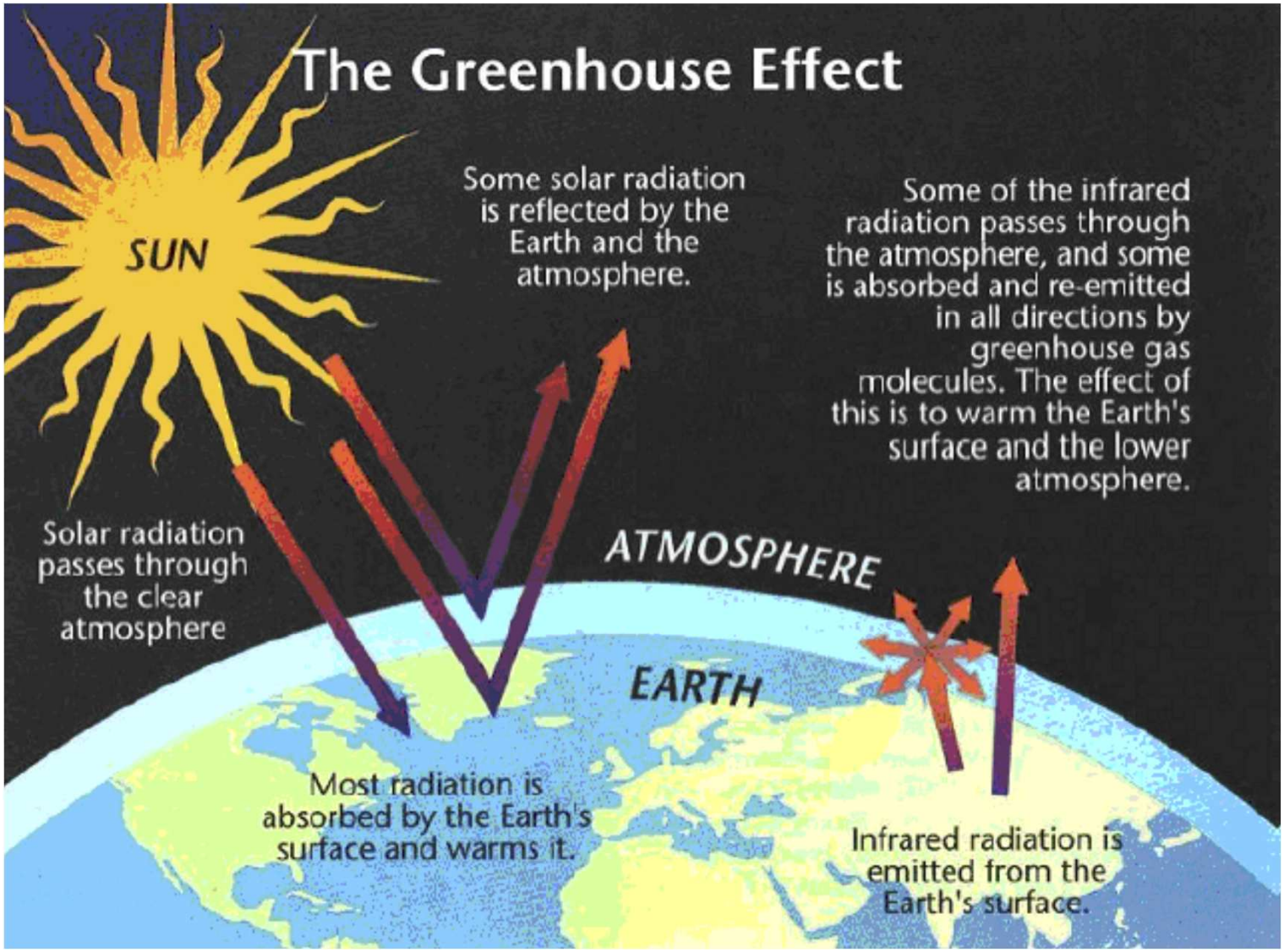
Oil Supply and Cost

Availability of oil resources as a function of economic price

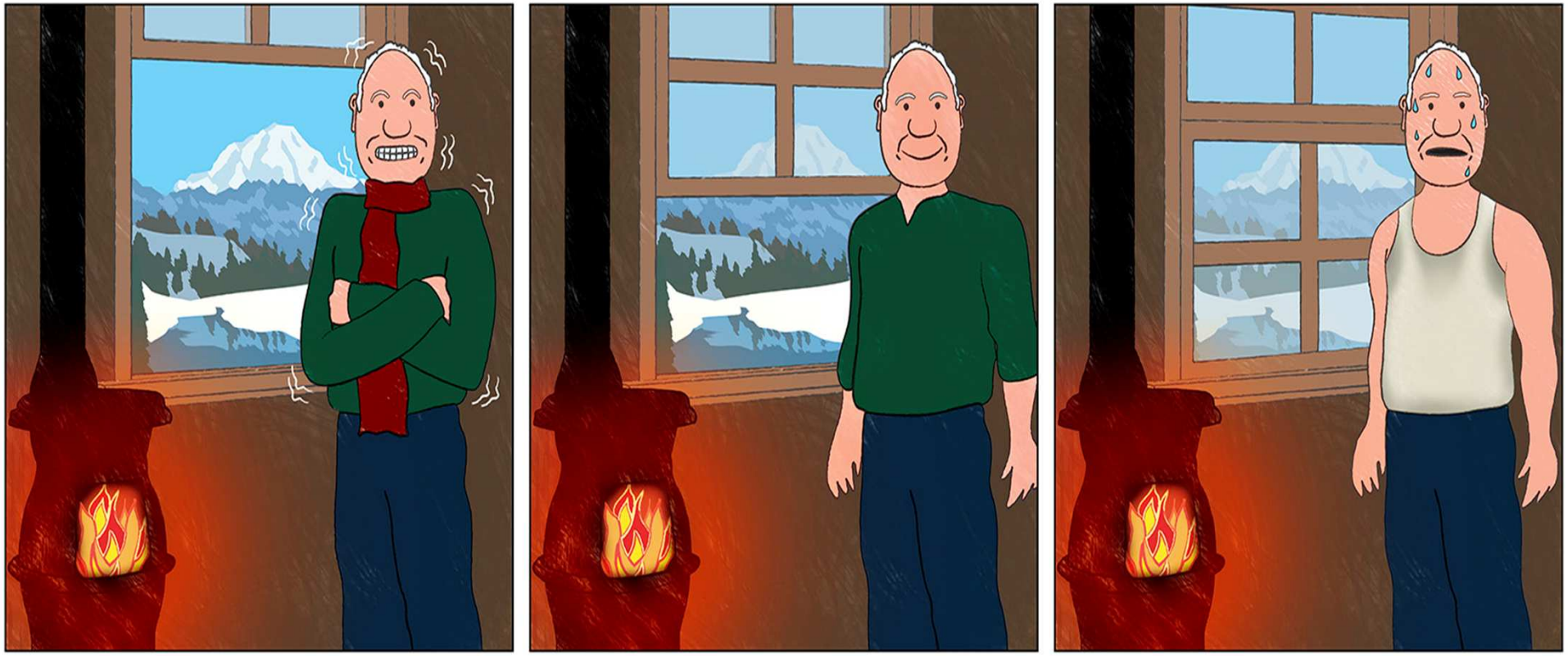


Source: IEA (2005)

Greenhouse Effect and Climate Change for Skeptics


The Greenhouse Effect
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere, and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation passes through the clear atmosphere
ATMOSPHERE
EARTH
Most radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

Greenhouse Effect

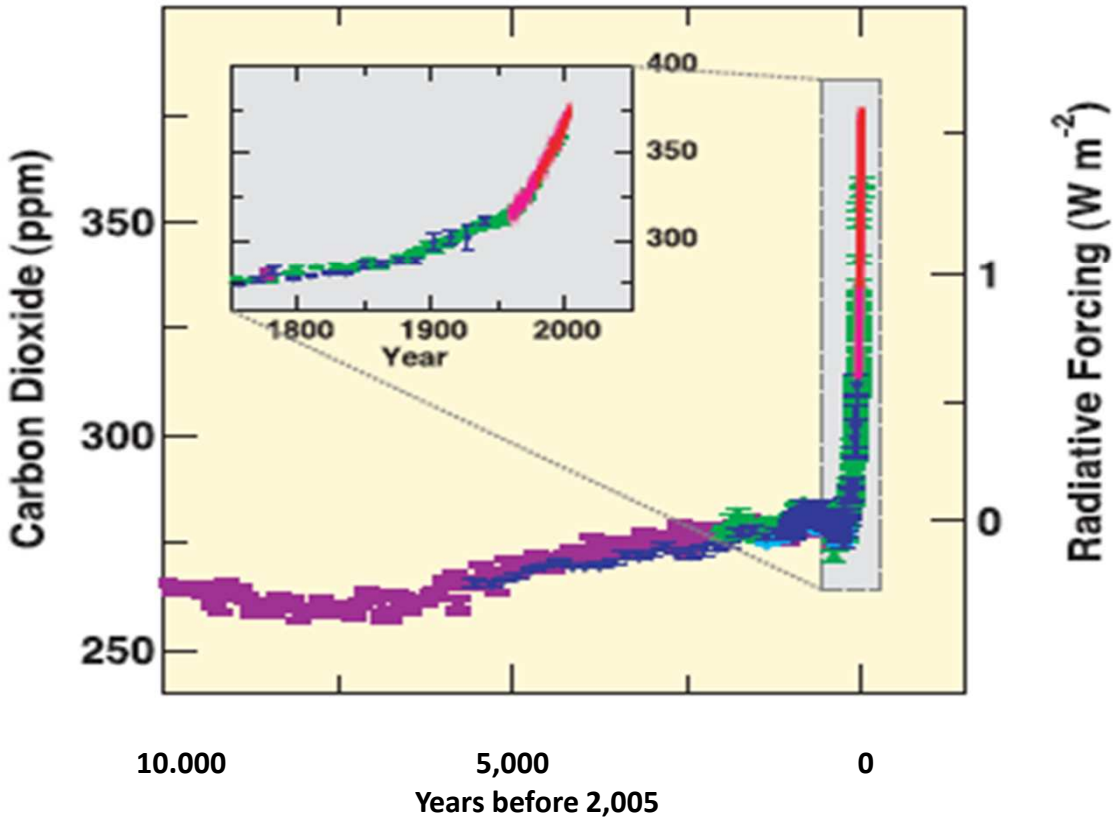


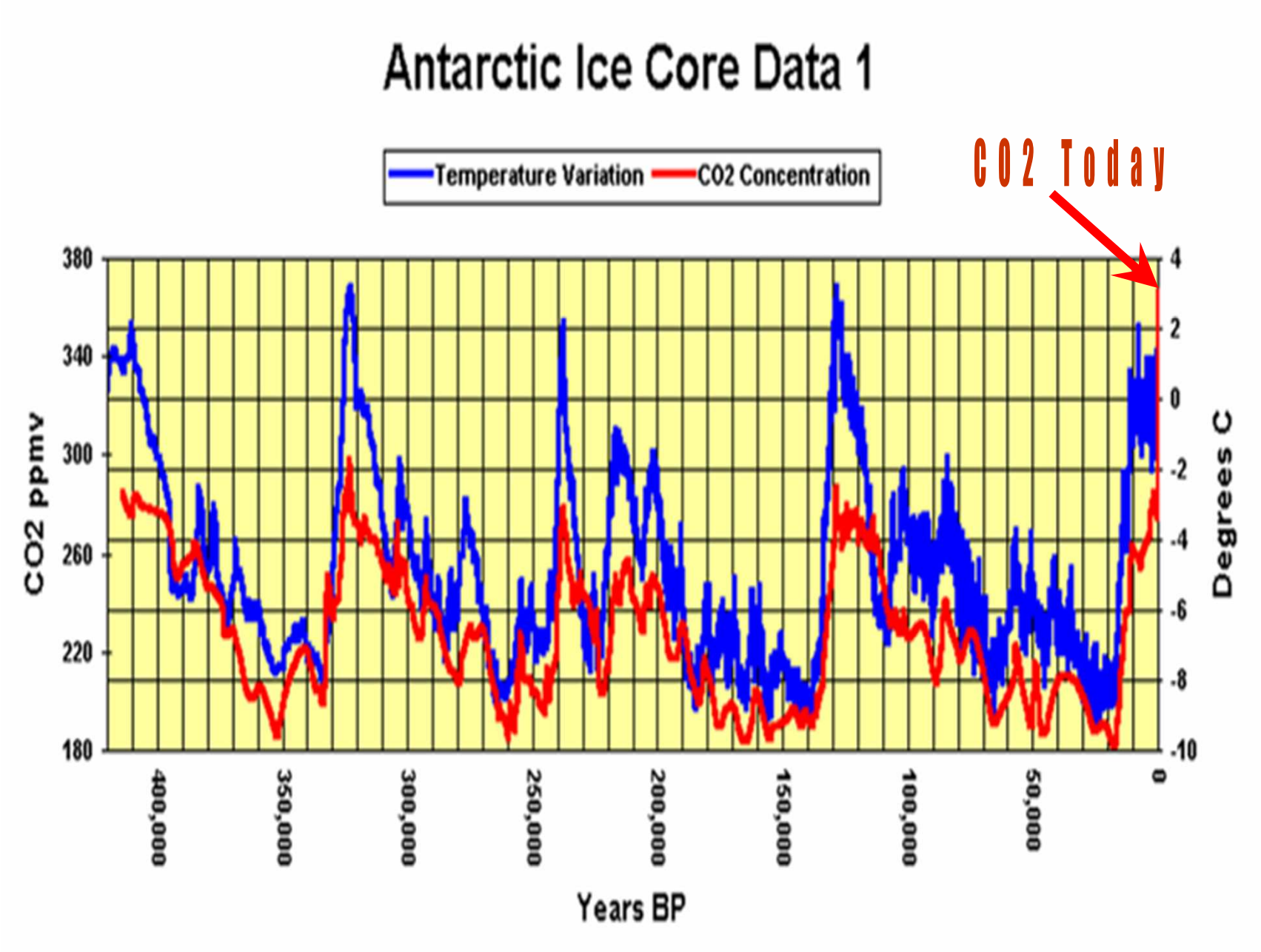
Too Little

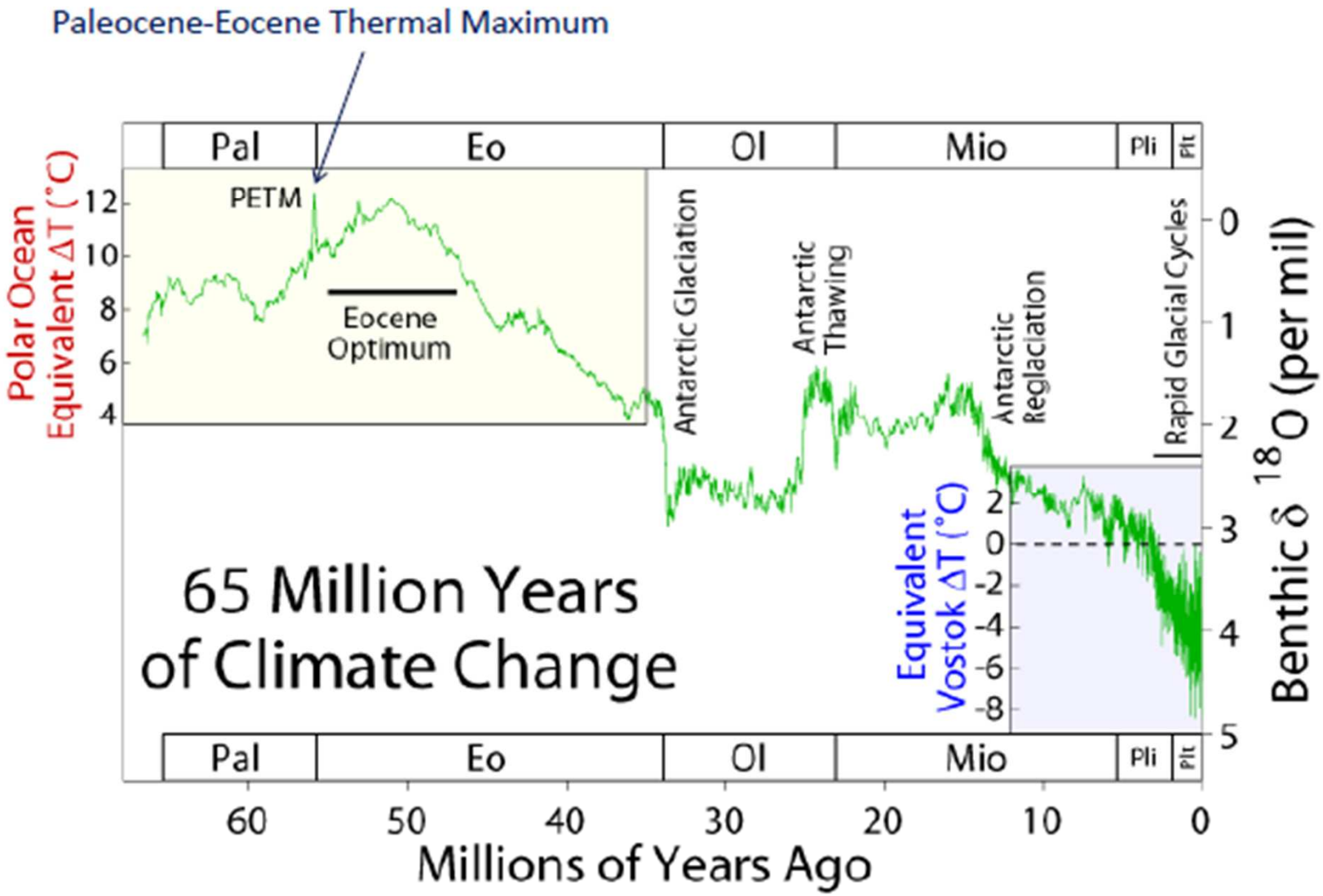
Just Right

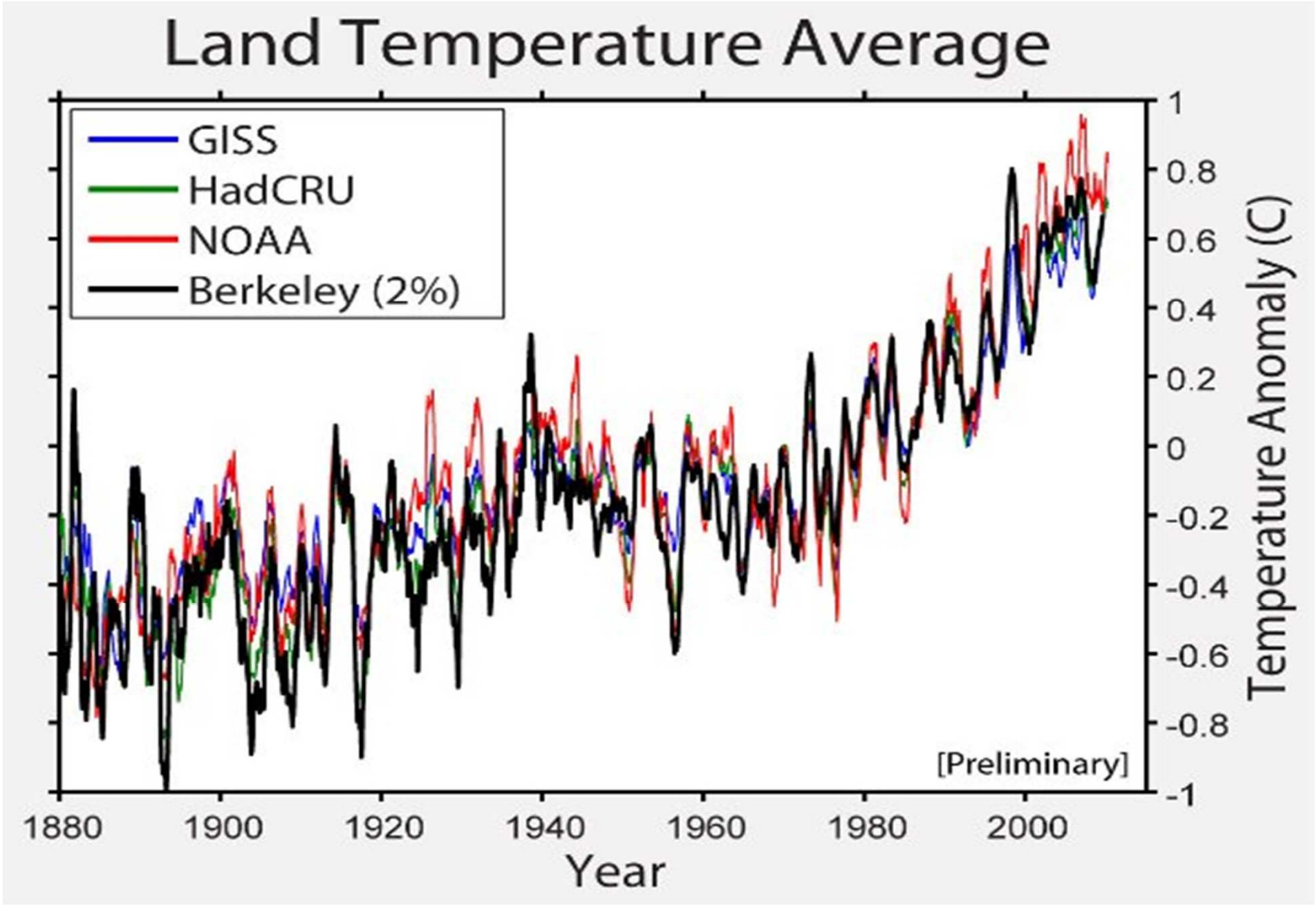
Too Much

Changes in Greenhouse Gases from Ice Core and Modern Data




Antarctic Ice Core Data 1
Temperature Variation
CO2 Concentration
CO2 Today
CO2 ppmv
380
340
300
260
220
180
Degrees C
4
2
0
-2
-4
-6
-8
-10
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Years BP

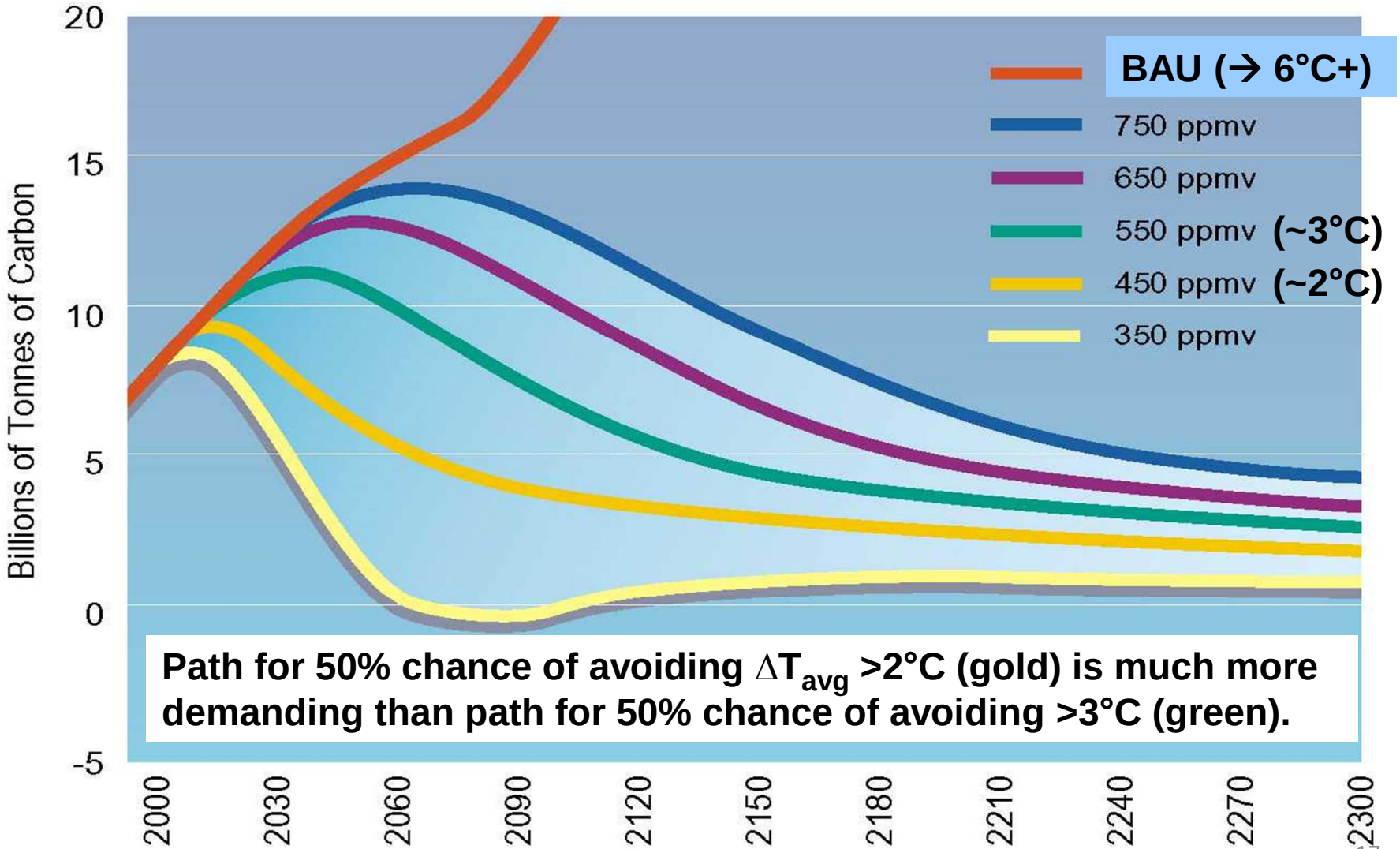

Paleocene-Eocene Thermal Maximum
Pal
Eo
Ol
Mio
Pli
Plt
PETM
Eocene Optimum
Antarctic Glaciation
Antarctic Thawing
Antarctic Reglaciation
Rapid Glacial Cycles
Polar Ocean Equivalent ΔT (°C)
12
10
8
6
4
Equivalent Vostok ΔT (°C)
2
0
-2
-4
-6
-8
Benthic δ 18O (per mil)
0
1
2
3
4
5
65 Million Years of Climate Change
60
50
40
30
20
10
0
Millions of Years Ago



Muller et al, preliminary

Energy

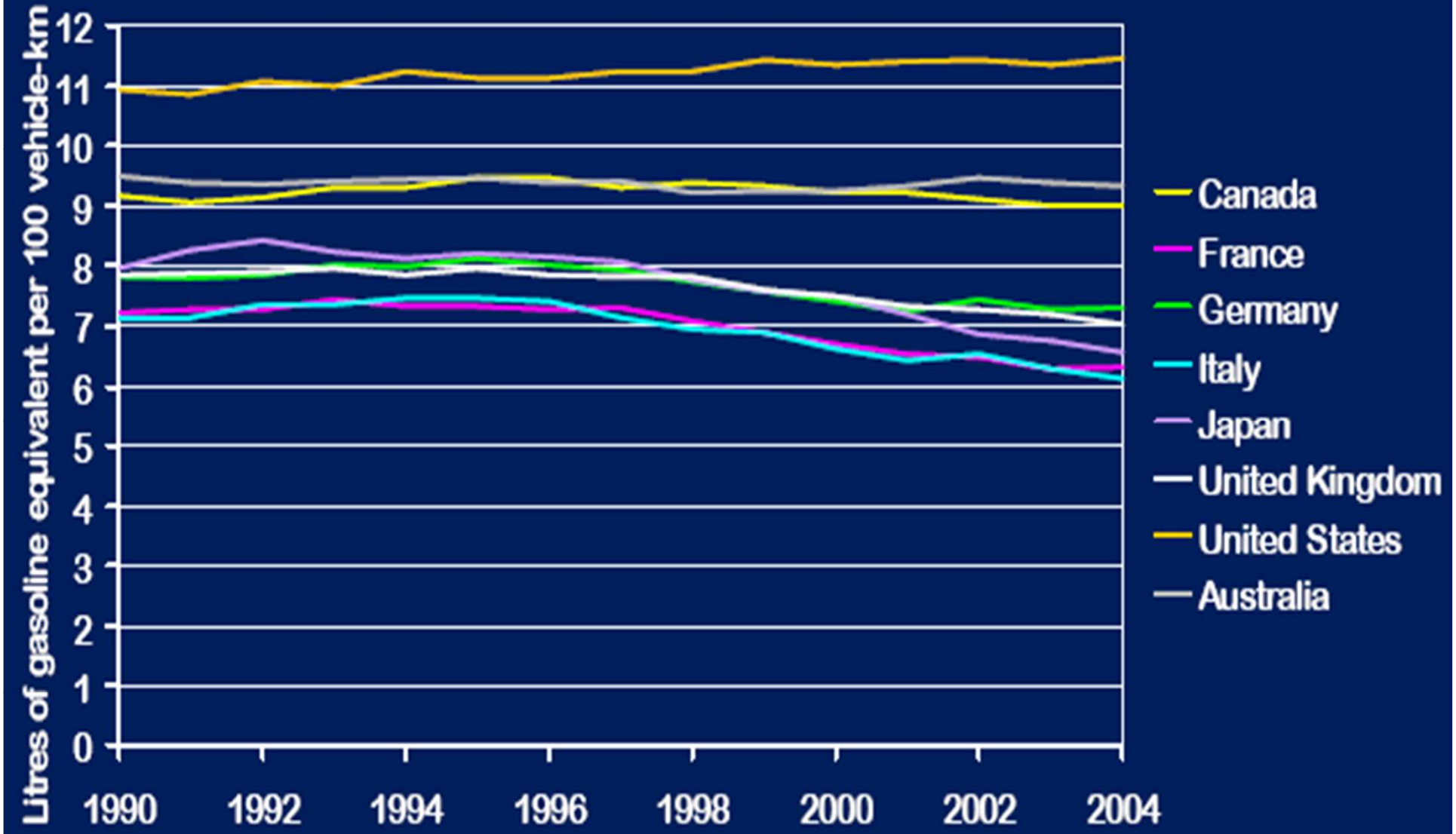
CO_2 emissions paths: BAU versus stabilizing CO_2 concentration to limit ΔT_{avg}



Decarbonization

- Transportation – Efficiency + Electrification (50 mpg for gasoline; decarbonized electricity, reduced imports)
- Electricity – Efficiency + Fuel Switching (one GWe coal gives 8 million tonnes of CO_2 per year; gas gives 1/3 of coal; nuclear – hydro – wind – solar – geothermal give zero)
- Buildings – Efficiency + fuel switching (electricity plus gas)
- Industry – Efficiency + fuel switching (electricity, coal, oil, gas)
- Agriculture – ????
- More on efficiency see http://www.aps.org/energyefficiencyreport/

Energy efficiency of passenger cars



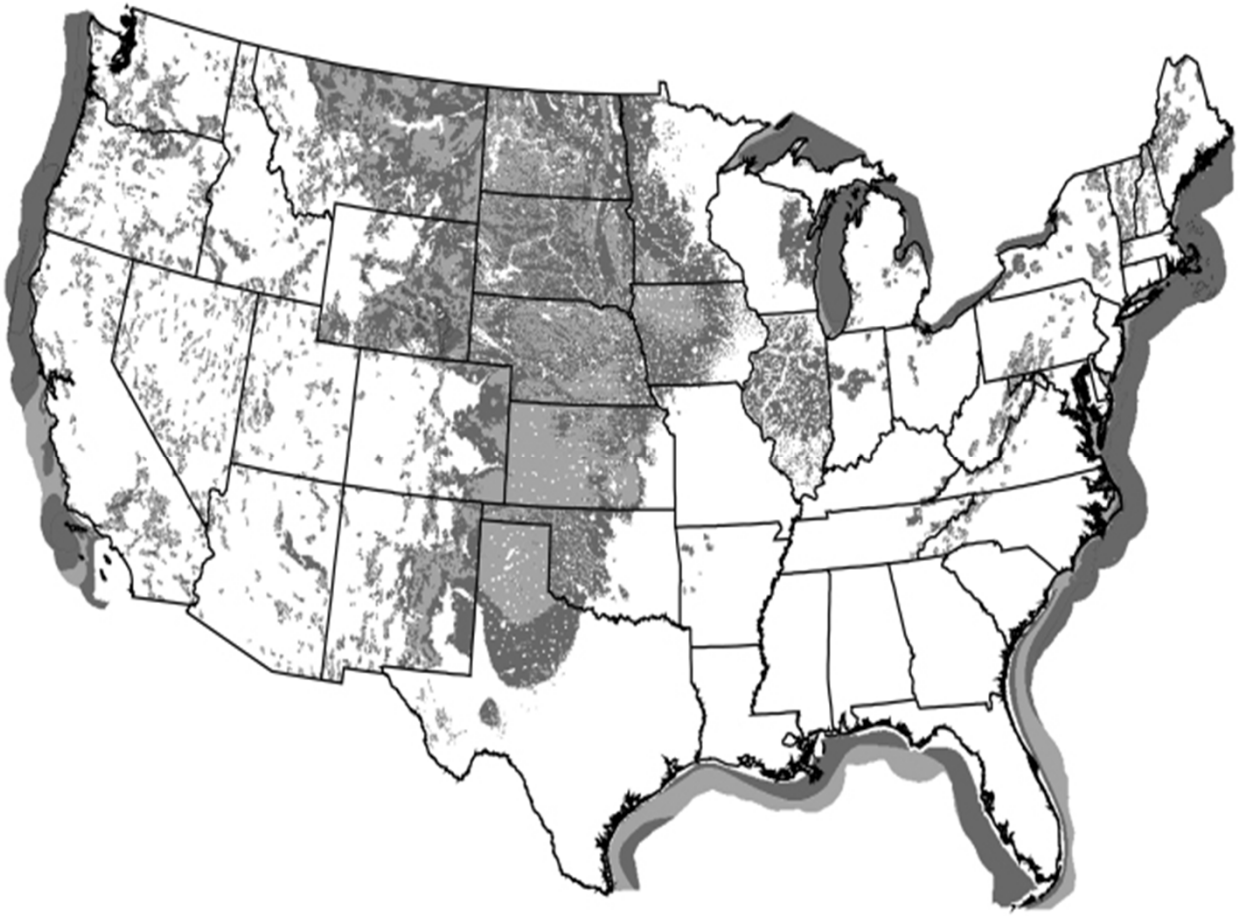
IEA, 2007, Energy Use in the New Millennium

Fraction of Electricity Generation by Fuel 2007

Fuel	U.S.	World
Coal	50%	40%
Natural Gas	22%	20%
Oil	0%	6%
Nuclear	20%	16%
Hydroelectric	6%	16%
Biomass	1%	1.3%
Wind	0.6%	0.5%
Geothermal	0.3%	0.3%
Solar	0.1%	0.02%

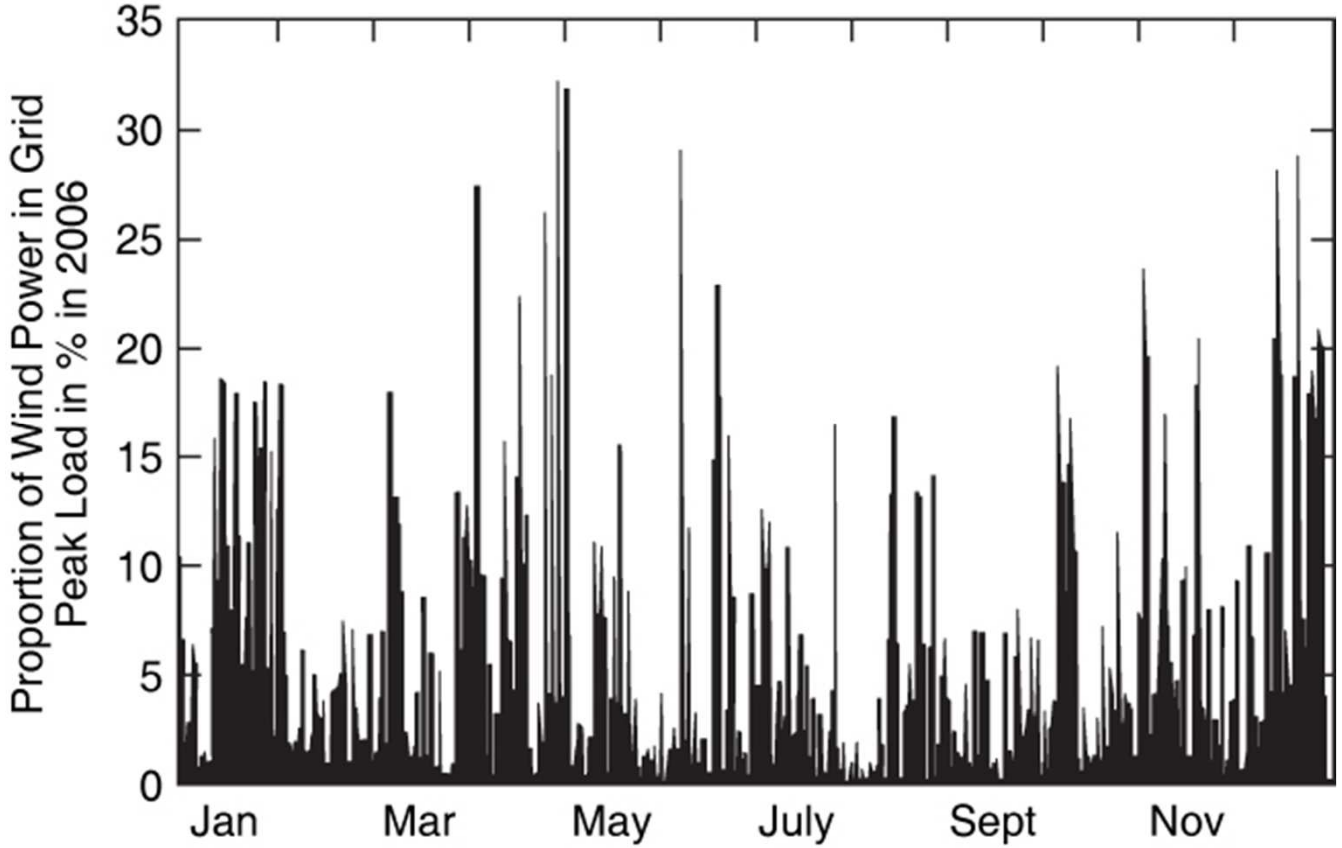
Source: EIA 2007; IEA World Energy Outlook 2008

United States
Wind Resource Map



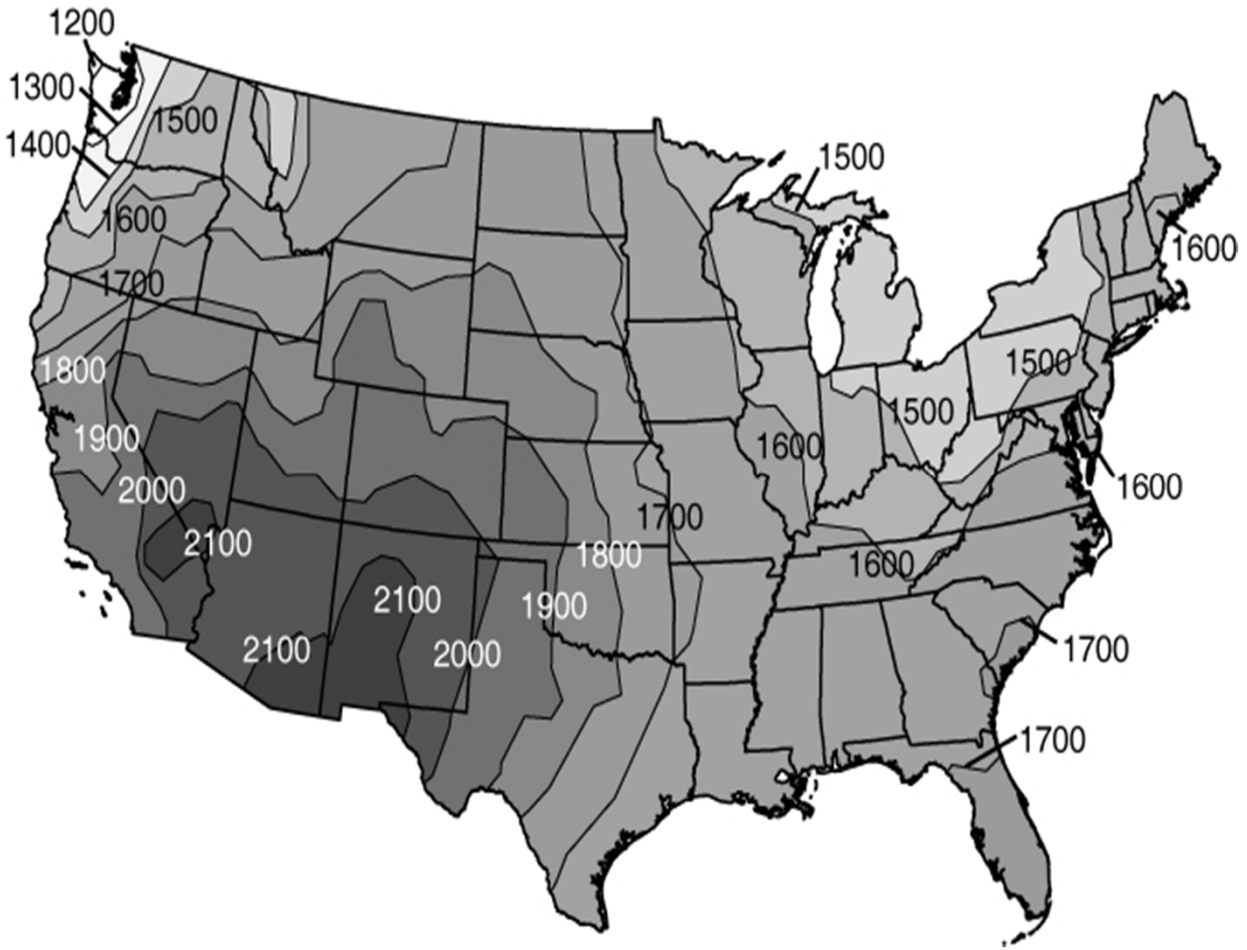
Wind quality for electricity generation. Darker is better. Source: U.S. Department of Energy, Energy Efficiency and Renewable Energy Division.

Wind Variability in Germany



Percentage of Electrical Demand Delivered by all the Wind Turbines of E.ON Energie during the year 2007. Averaged over the year, wind power delivered 18% of installed capacity. Figure courtesy of E.ON Energie.

Solar Efficiency Map

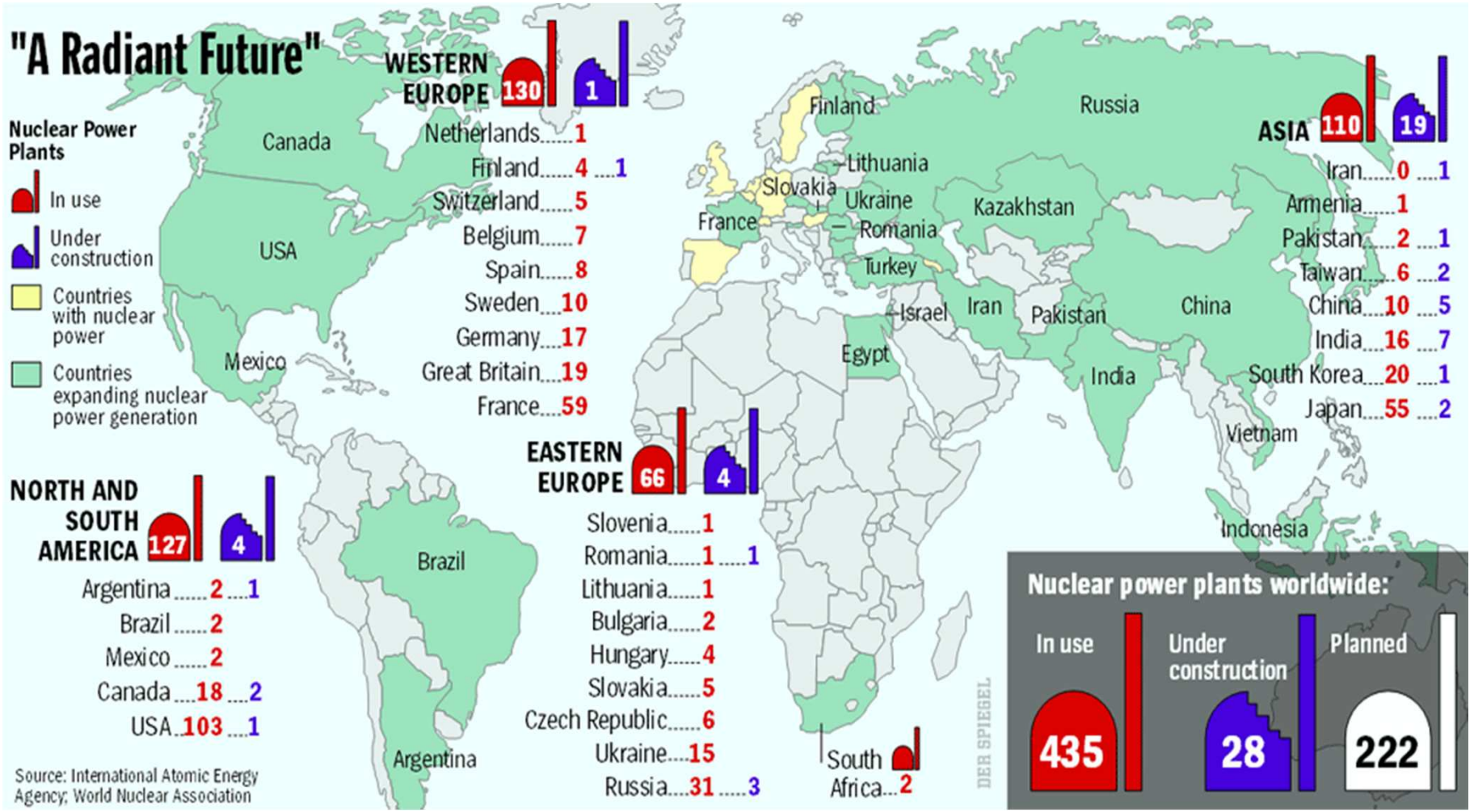


Effective hours of sunlight per year on a flat plate collector including weather effects. Source: DOE's Energy Efficiency and Renewable Energy Division.

Other Renewables

- Big Hydro – not in favor by environmentalists
- Small Hydro – not a large source
- Hydrogen for Transportation – back to the lab
- Geothermal – good where there are sites
- Enhanced Geothermal – a failure so far
- Ocean systems – a good way to lose money
- Biofuels – corn ethanol is a farm subsidy; 2nd generation biofuels not ready for the big time yet

An increasing nuclear electricity demand



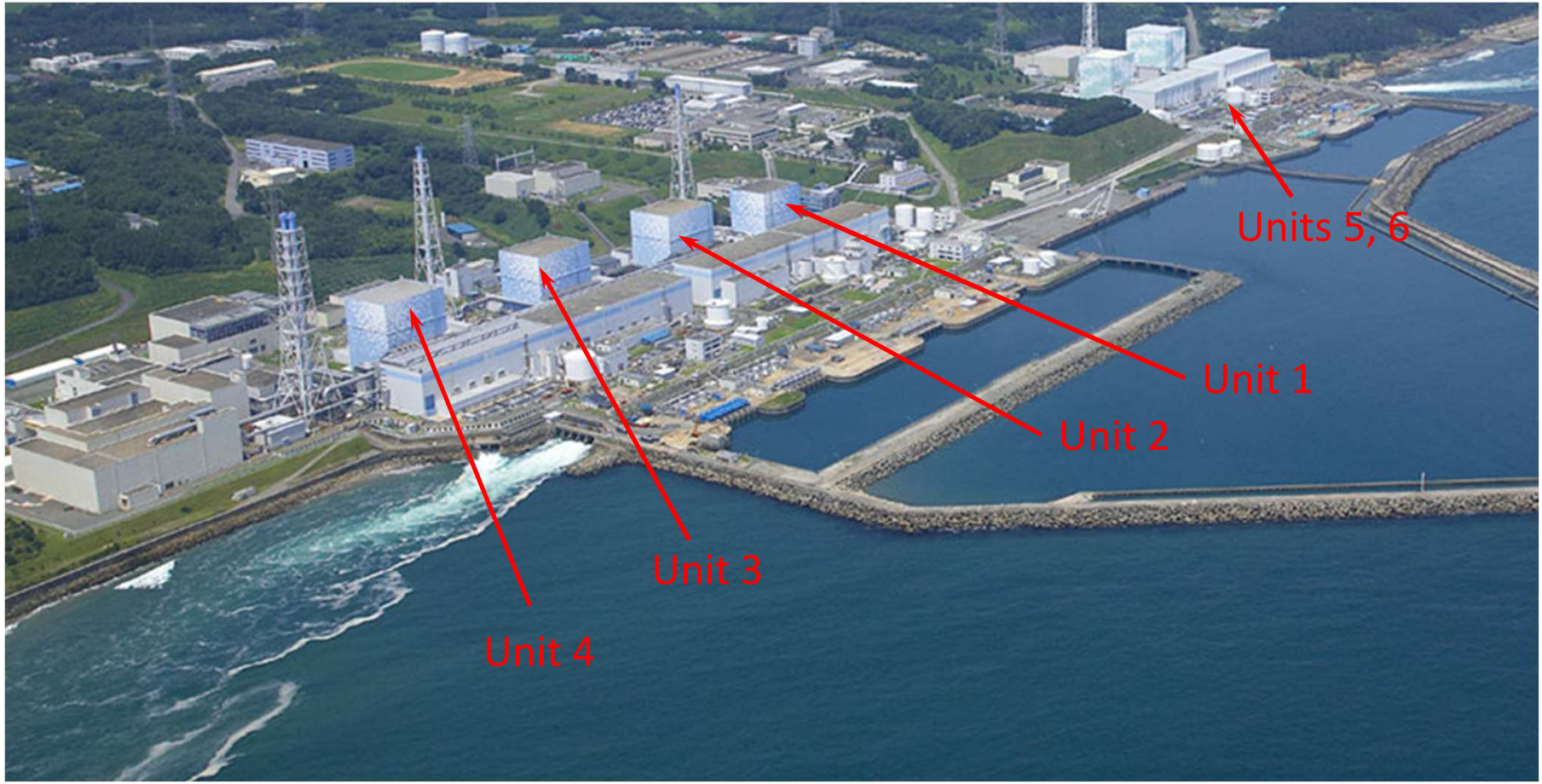
Numbers are from Jan 2009. In October 2010 441 are operating and 58 are under construction

Japanese Nuclear Accident
And the Future of Nuclear Power

Nuclear Energy in Japan

- 54 operating nuclear reactors (49 gigawatts)
- Two nuclear plants under construction
- Tokyo Electric Power Co. produces 27% of Japan's electricity
- 12,000 MW of nuclear energy capacity shut down

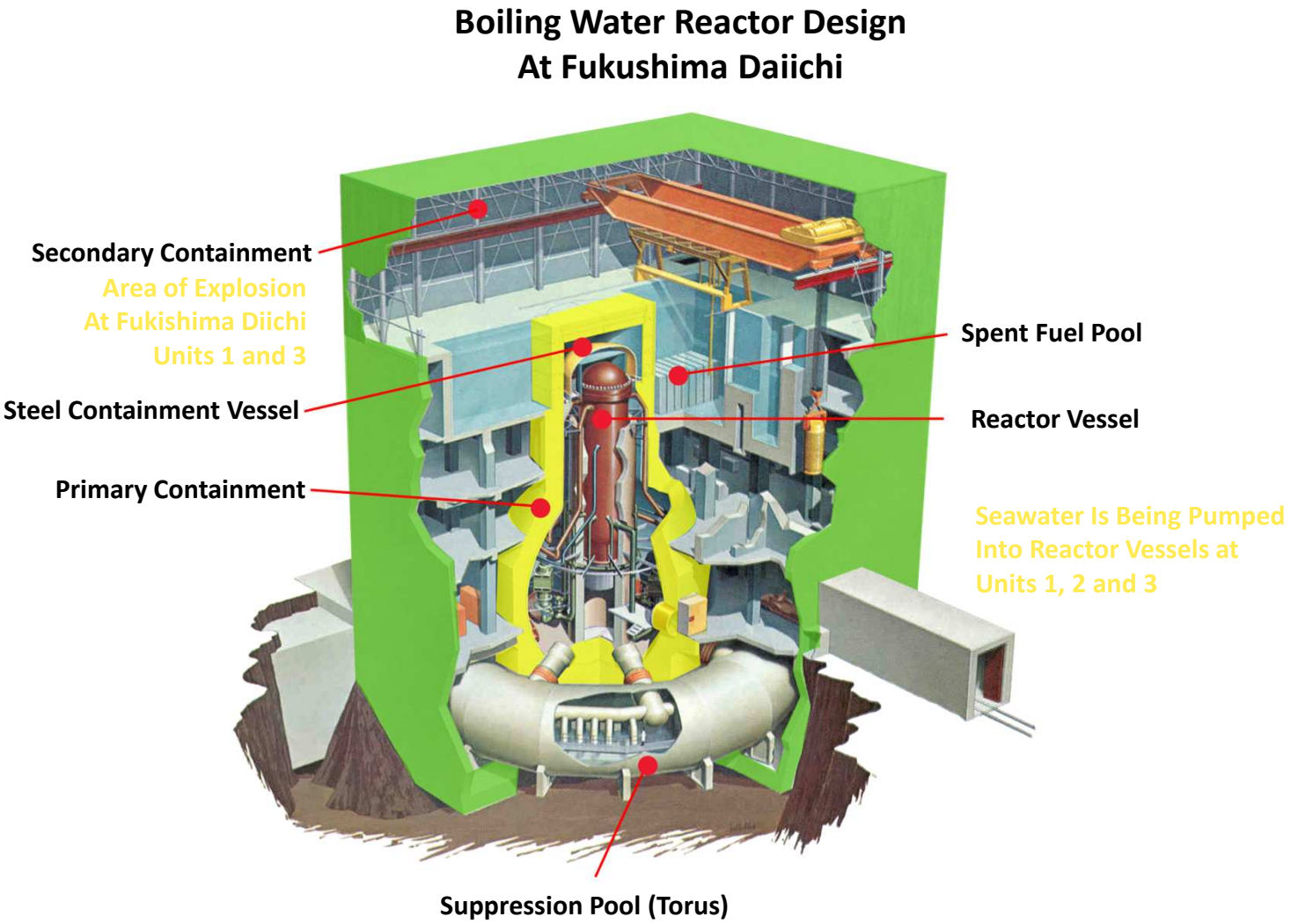
Fukushima Daiichi Nuclear Power Plant Before the Accident




テレトラック
MIYAKO

Photo Kyodo-Reuters

Boiling Water Reactor Design




Reactor No. 4
Reactor No. 3
Reactor No. 2
Reactor No. 1
Reactor No. 4
Reactor No. 3
Reactor No. 2
Reactor No. 1


Emergency Planning: Protecting the Public and Environment
Food Safety Sampling
Milk and Livestock
50-mile food sampling area
Fish and Water
2-mile radius
5 miles downwind
10-mile radius
Crops and Soil

Radiation Exposures

Source	Radiation Dose Millirem/year
Natural Radioactivity	240
Natural in Body (75kg)*	40
Medical (average)	60
Nuclear Plant (1GW electric)	0.004
Coal Plant (1GW electric)	0.003
*Included in the Natural Total	

U.S. Nuclear Power Plants Prepared for Extreme Events

- Maximum credible earthquakes and floods
- Loss of off-site power and on-site power
- Hydrogen generation as a result of fuel damage during loss-of-coolant accidents
- Post 9/11: aircraft impact, loss of large areas of the plant

Information Sources

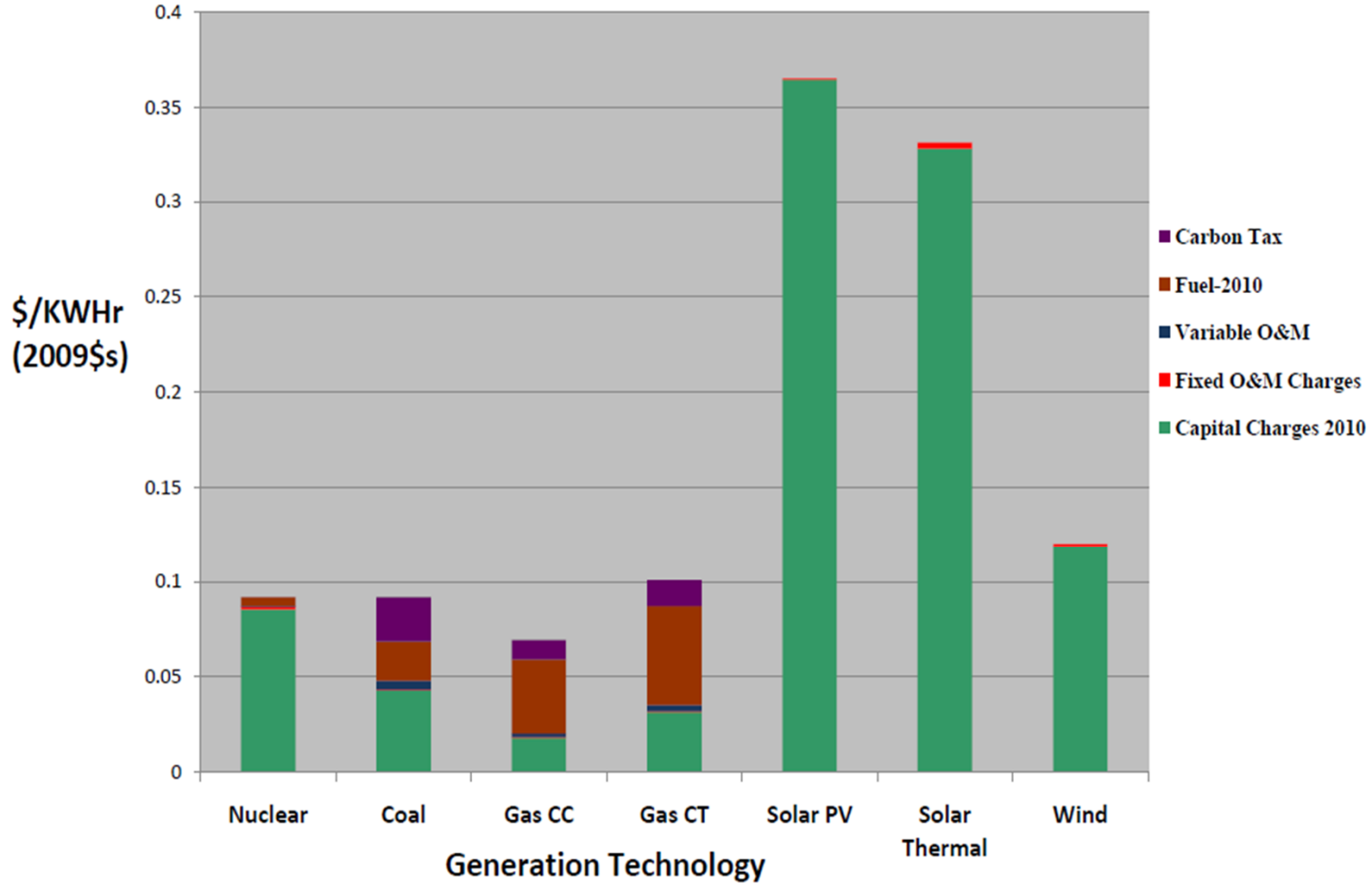
- Nuclear Energy Institute (www.nei.org)
- U.S. Nuclear Regulatory Commission (www.nrc.gov)
- U.S. Department of Energy (www.energy.gov)
- International Atomic Energy Agency (www.iaea.org)
- Health Physics Society (www.hps.org)
- Japanese Nuclear and Industrial Safety Agency (http://www.nisa.meti.go.jp/english/)
- Japan Atomic Industrial Forum (www.jaif.or.jp/english/)
- Tokyo Electric Power Company (http://www.tepco.co.jp/en/index-e.html)
- New York Times – Global Edition (http://global.nytimes.com/)

Public Health Impacts per TWh*

	Coal	Lignite	Oil	Gas	Nuclear	PV	Wind
Years of life lost:							
Nonradiological effects	138	167	359	42	9.1	58	2.7
Radiological effects:							
Normal operation					16		
Accidents					0.015		
Respiratory hospital admissions	0.69	0.72	1.8	0.21	0.05	0.29	0.01
Cerebrovascular hospital admissions	1.7	1.8	4.4	0.51	0.11	0.70	0.03
Congestive heart failure	0.80	0.84	2.1	0.24	0.05	0.33	0.02
Restricted activity days	4751	4976	12248	1446	314	1977	90
Days with bronchodilator usage	1303	1365	3361	397	86	543	25
Cough days in asthmatics	1492	1562	3846	454	98	621	28
Respiratory symptoms in asthmatics	693	726	1786	211	45	288	13
Chronic bronchitis in children	115	135	333	39	11	54	2.4
Chronic cough in children	148	174	428	51	14	69	3.2
Nonfatal cancer					2.4		

*Krewitt et al., “Risk Analysis” Vol. 18, No. 4 (1998).

Levelized Cost Comparison for Electric Power Generation With $100 per Ton Tax on Carbon (2010 Fuel Prices)



Energy Winners and Losers in the Next 20 Years

Winners	Losers	Maybes
Efficiency in all sectors	**Coal** without capture and storage	**Enhanced geothermal**
Natural Gas as replacement for coal	**Oil** to be replaced with electric or PHEV drive	**Solar thermal electric** needs cost reduction
Hydroelectric	**Corn ethanol**	**Solar photovoltaic** with subsidies (only for rich countries until costs decline)
Nuclear	**Hydrogen** for transportation	**Phase-2 and-3 biofuels**
Wind, but limited "till intermittency addressed		**Ocean systems**
Solar Photovoltaic for off grid applications only		**Coal** with capture and storage
Geothermal at natural hotspots		
Solar heat and hot water		
Biofuels, only Sugarcane ethanol now		

Action Agenda

- **Efficiency –** 30% improvement target overall
- **Transportation** – 50 MPG by 2025, biofuels?
- **Electricity –**
  - Gas and Nuclear to Replace coal in the short term
  - Wind and Solar can get to 10% to 15% in next 15 years and more when transmission and intermittency problems are addressed
  - Buildings efficiency can go up by 30% for retrofits and much more in new construction
- **R&D** on Energy Storage, CCS, and other innovations

POLICY

Richter's Laws of Government Inaction

- 1st Law: The future is hard to predict because it hasn't happened yet.

- 2nd Law: No matter how good a solution is, some will demand we wait for a better one.

- 3rd Law: Short-term pain is a deterrent to action no matter how much good that action will do in the long-term.

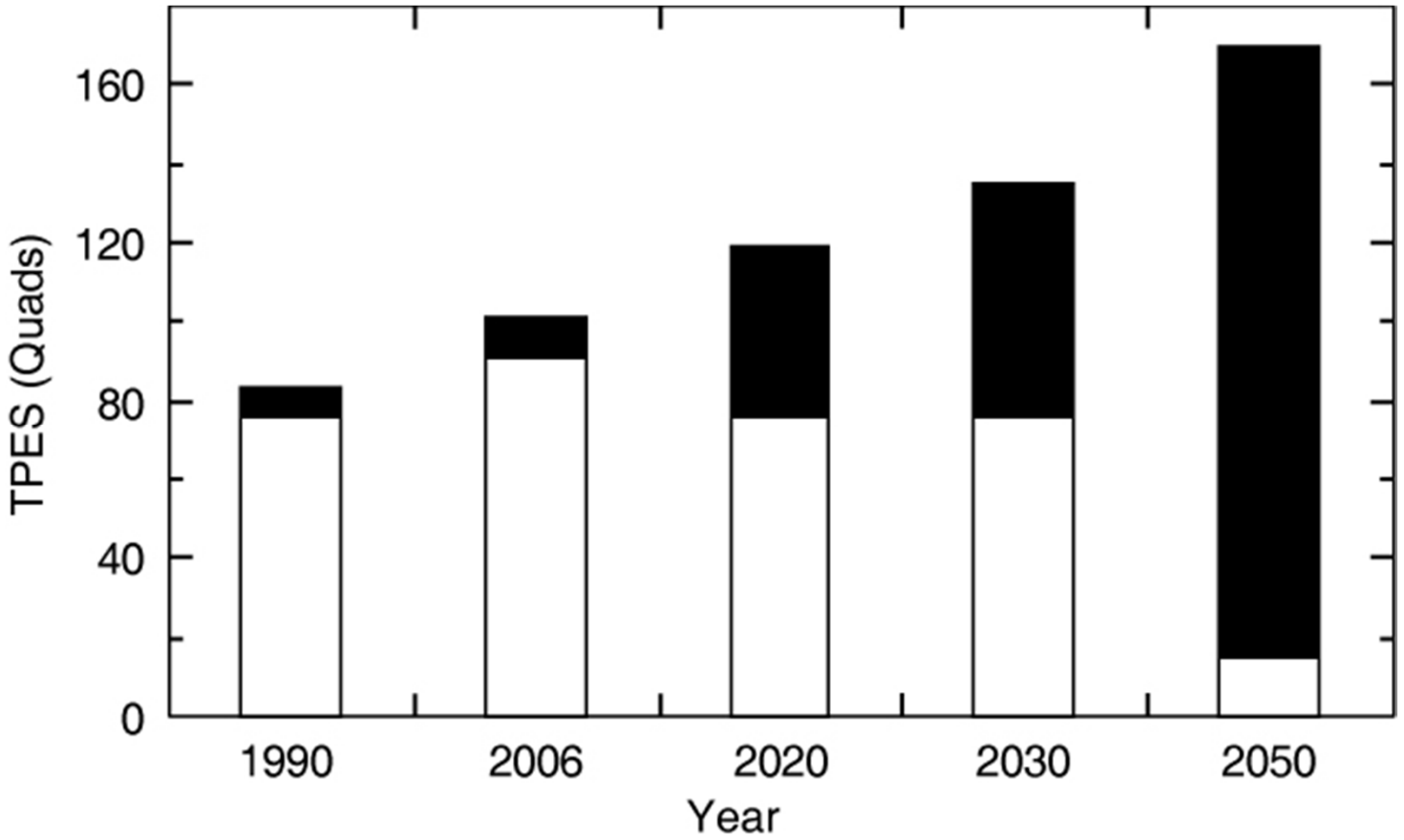
- 4th Law: The largest subsidies go to the least effective technologies.

Excesses of Environmental Zeal - Two Examples

Renewable Portfolio Standards compared to Emission Reduction Standards

Low Carbon Fuel Standards compared to Tailpipe Emission Standards

TPES for the US projected to 2050 under a business-as-usual scenario. Shaded areas are efficiency and emission free energy to meet emission goal.



The TPES number for 1990 and 2006 are DOE EIA actuals. The shaded areas for 1990 and 2006 are actual emission-free energy including nuclear, big hydro and renewables. The totals for 2020, 2030 and 2050 are EIA projections. The shaded areas show the emission-free contribution required to match 1990 in 2020 or 2030 or to be at 20% of 1990 in 2050.

Advice to Washington & the Environmental Movement

- Slow down – don't try to do everything at once. Focus first on cars, electricity and efficiency
- Tell the private sector what to do, not how to do it.
- No one knows what technologies will be winners 50 years from now – include today's big winners in your menu like gas for coal, and nuclear.

Two International Climate Treaties

- Montreal Protocol – Ozone Hole (1987)

  -Signed by Reagan, Thatcher and many others

  -Origin in Vienna convention of 1985

  -Worked, economic impact small, everyone agreed

- Kyoto – Climate change (1997)

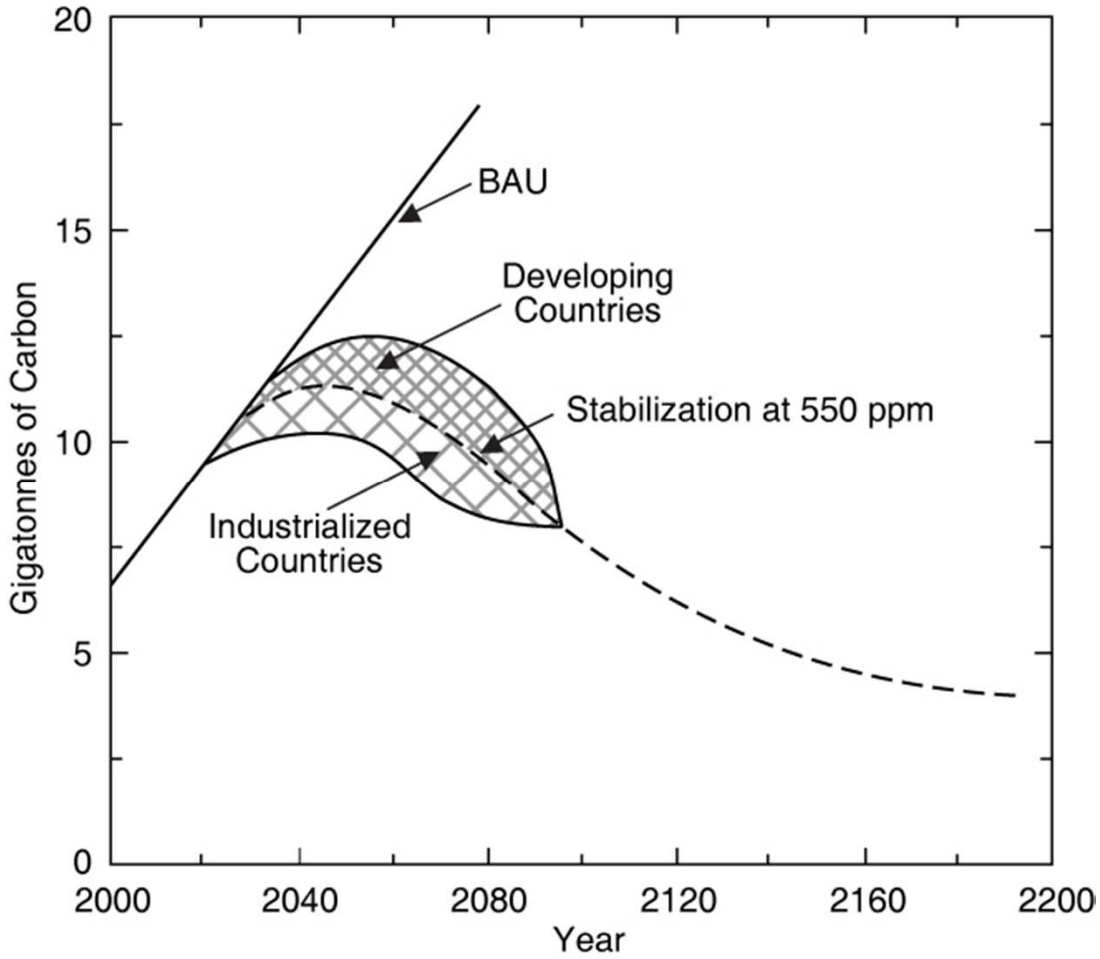
  -Divided world into two classes those who did nothing (developing);, and those who did something Annex B (industrialized)

  -All missed targets EU Canada, Japan, Russia etc plus US (nonsigner)

Top 15 Emitters Represent 82% of World Emission						
	Country	**Population** (millions)	**C0₂ Emissions** (millions of tonne)	**C0₂ Emmision per Capita** (kg per person)	**CO₂ Emission per Dollar of GDP** (2000 Dollars, market rates)	**CO₂ Emission per Dollar** (2000 Dollars, PPP)
1	People's Rep. of China	1,325.64	6,508.24	4.91	2.50	0.60
2	United States	304.56	5,595.92	18.38	0.48	0.48
3	European Union	498.92	3,849.53	7.72	0.32	0.31
4	Russian Federation	141.79	1,593.83	11.24	3.71	0.97
5	India	1,139.97	1,427.64	1.25	1.73	0.33
6	Japan	127.69	1,151.14	9.02	0.22	0.32
7	Canada	33.33	550.91	16.53	0.63	0.52
8	Islamic Rep. of Iran	71.96	505.01	7.02	3.15	0.86
9	Korea	48.61	501.27	10.31	0.67	0.44
10	Mexico	106.57	408.30	3.83	0.53	0.34
11	Australia	21.51	397.54	18.48	0.77	0.59
12	Saudi Arabia	24.65	389.16	15.79	1.54	1.04
13	Indonesia	228.25	385.38	1.69	1.56	0.43
14	Brazil	191.97	364.61	1.90	0.43	0.22
15	South Africa	48.69	337.42	6.93	1.84	0.63
	World	**6,688.00**	**29,381.00**	**4.39**	**0.73**	**0.46**

International Energy Agency Key World Energy Statistics 2010

A Global Model for Stabilization



The dashed line is the allowed emissions to stabilize the atmosphere. A world agreement might allow, for example, the developing nations to run above the dashed line while the industrialized countries run below. Where a given region or country lies should depend on both its emissions, and its state of development. Eventually all will have to agree to a common measure.

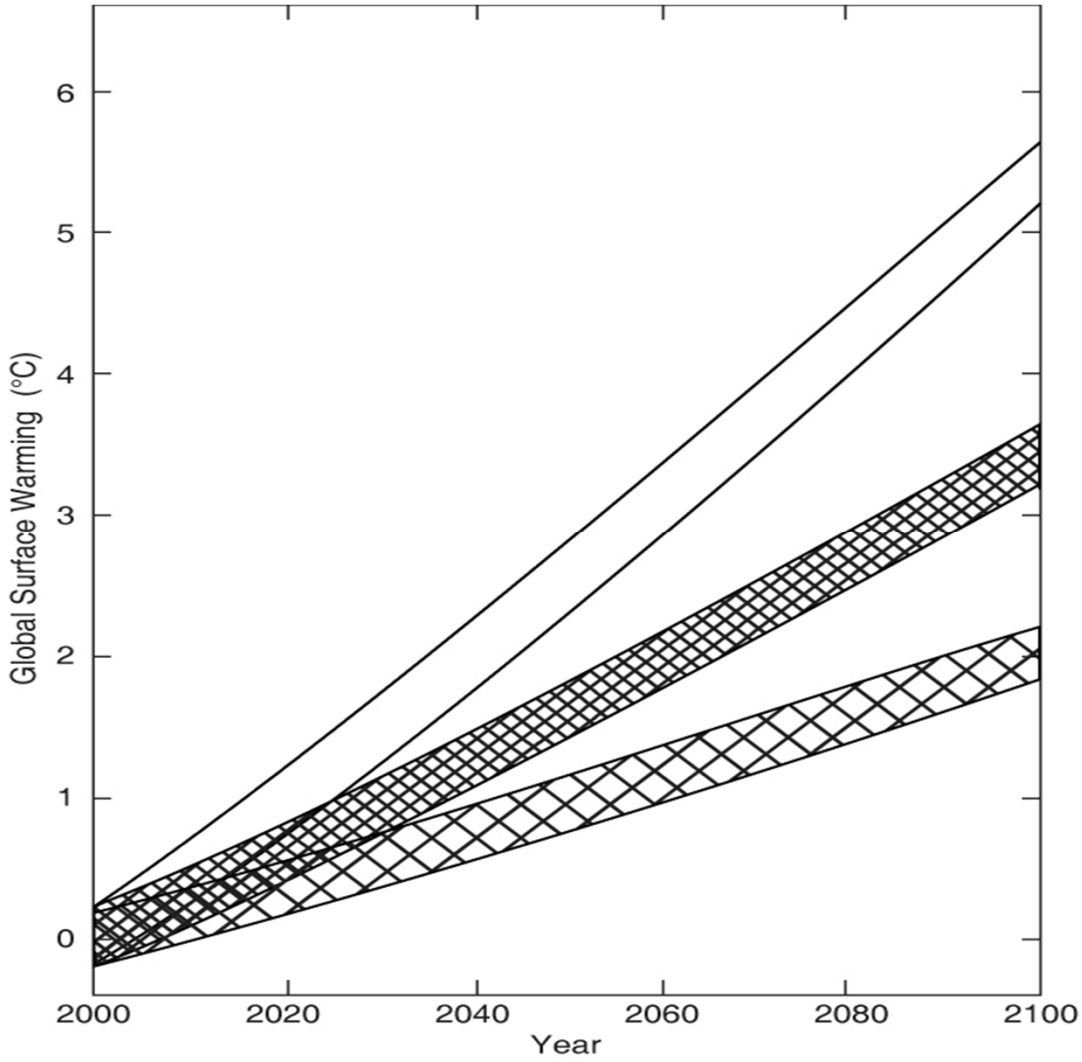
Summary

- Is the Greenhouse Effect Real? Yes
- Is the world getting warmer? Yes
- Are we doing it? Yes
- How hot will it become if we do nothing? Not sure yet
- Can we do anything? Yes
- When should we start? Now
- Will it cost a lot? Not if we do it right
- Will we do anything? Up to you

Earth from Apollo 17 (NASA)

Back Up

Scenario A2 with noise



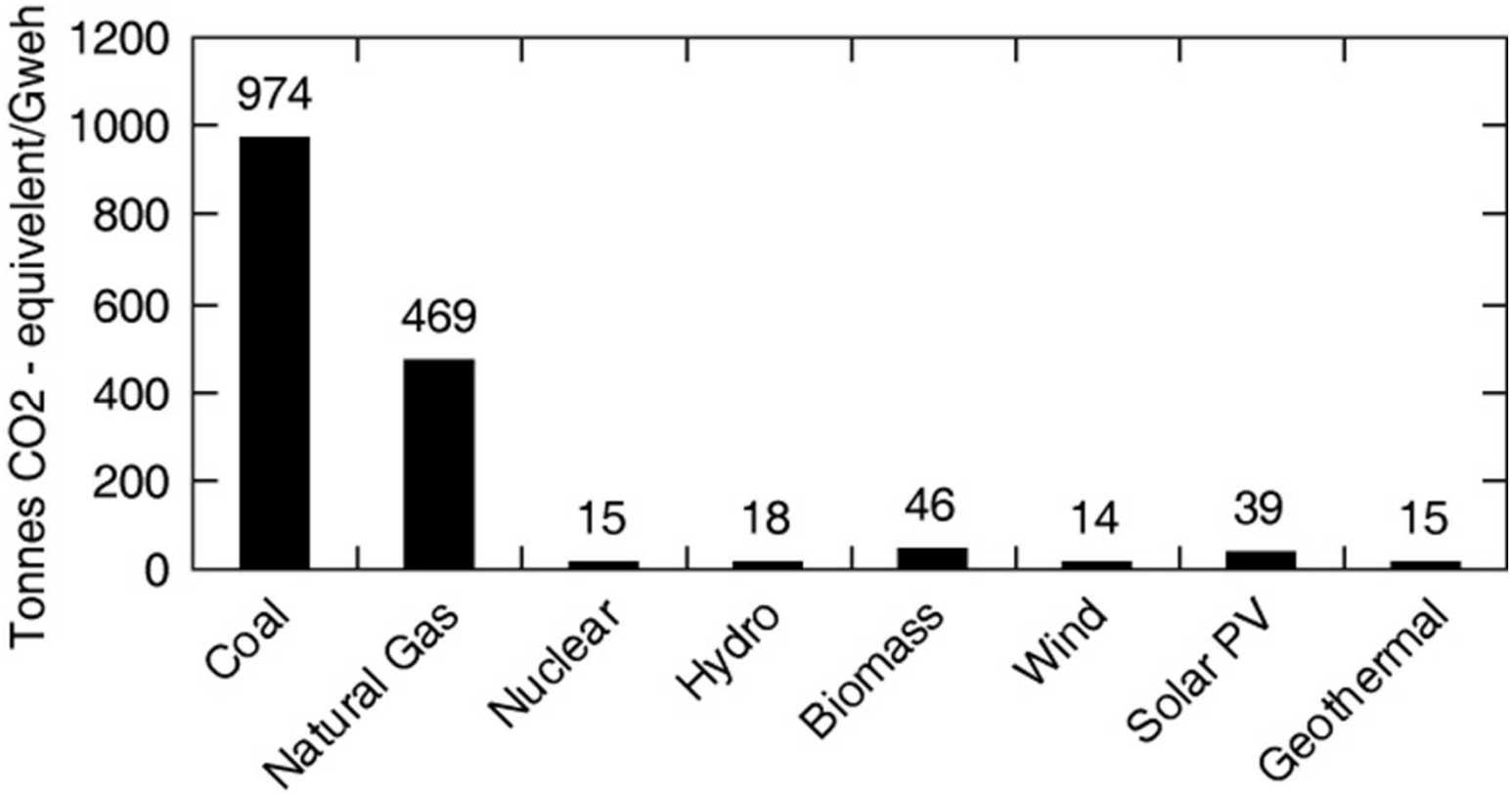
Projected Global Average Surface Warming at the End of the 21st Century

Case	Global Average Temperature changes relative to 1980-1999			
	Best Estimate		**Range**	
	°F	°C	°F	°C
B1	3.2	1.8	2.0 – 5.2	1.1 – 2.9
A1T	4.3	2.4	2.5 – 6.8	1.4 – 3.8
B2	4.3	2.4	2.5 – 6.8	1.4 – 3.8
A1B	5.0	2.8	3.1 – 7.9	1.7 – 4.4
A2	6.1	3.4	3.6 – 9.7	2.0 – 5.4
A1FI	**7.2**	**4.0**	**4.3 – 11.5**	**2.4 – 6.4**

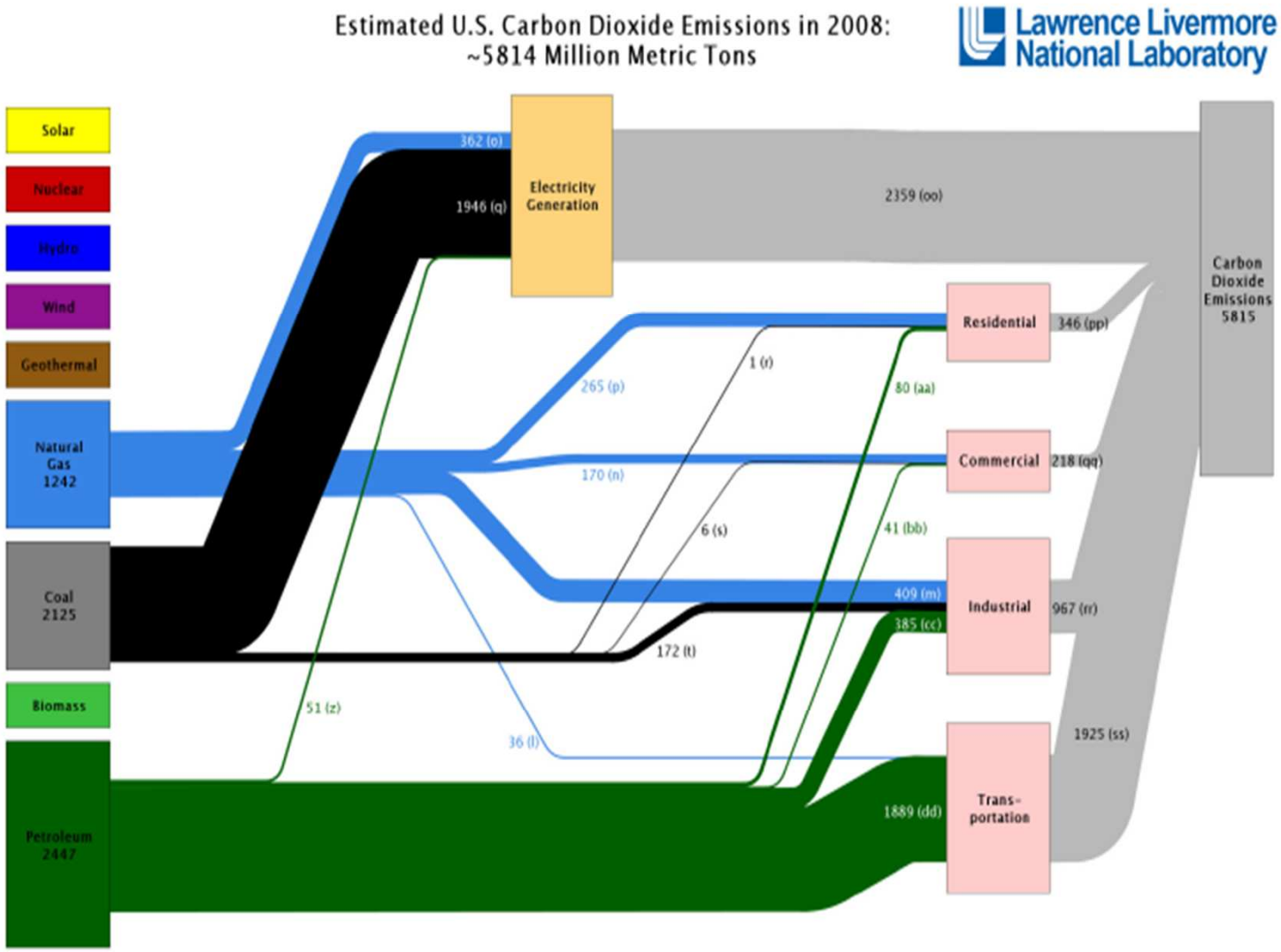
Removal Time and Percent Contribution to Climate Forcing

Agent	Rough Removal Time	Approximate Contribution in 2006
Carbon Dioxide	>100 years	60%
Methane	10 years	25%
Tropospheric Ozone	50 days	20%
Nitrous Oxide	100 years	5%
Fluorocarbons	>1000 years	<1%
Sulfate Aerosols	10 days	-25%
Black Carbon	10 days	+15%

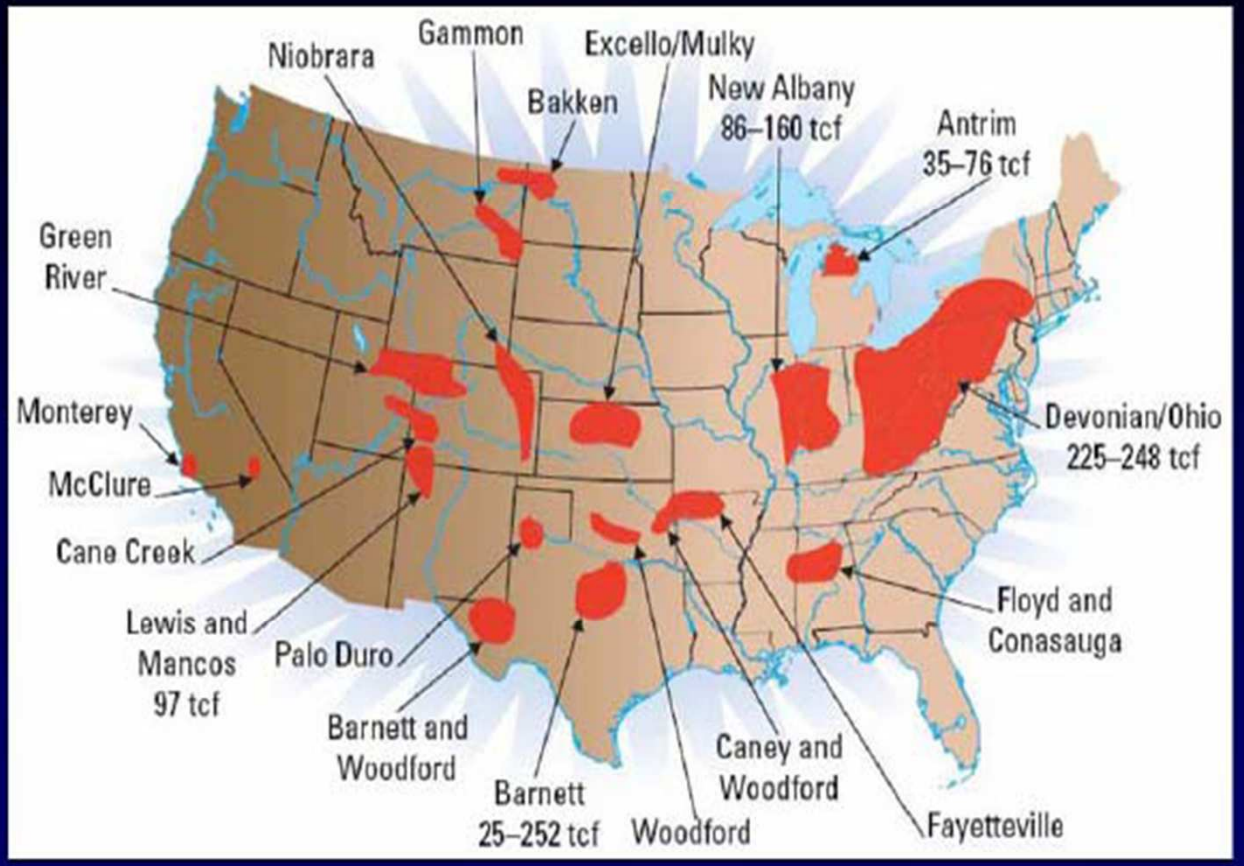
Lifecycle Emissions for Various Electricity Generation Technologies



Comparison of Life Cycle Emissions in Metric Tonnes of CO_2e per GW-hour for various modes of Electricity Production; P.J. Meier, *Life-Cycle Assessment of electricity Generation Systems with Applications for Climate Change Policy Analysis,*
Ph.D. dissertation, University of Wisconsin (2002); S. White, *Emissions form Helium-3, Fission and Wind Electrical Power plants,* Ph.D. Dissertation, University of Wisconsin (1998); M. K. Mann and P. L. Spath, *Life Cycle Assessment of a Biomass Gasification Combined-Cycle System*,
(1997), www.nrel.gov/docs/legosti/fy98/23076.pdf *(ref 33).*


Estimated U.S. Carbon Dioxide Emissions in 2008:
~5814 Million Metric Tons
Lawrence Livermore National Laboratory
Solar
Nuclear
Hydro
Wind
Geothermal
Natural Gas 1242
Coal 2125
Biomass
Petroleum 2447
362 (o)
1946 (q)
Electricity Generation
2359 (oo)
Carbon Dioxide Emissions 5815
Residential
346 (pp)
Commercial
218 (qq)
Industrial
967 (rr)
Trans-portation
1925 (ss)
265 (p)
170 (n)
409 (m)
172 (t)
1 (r)
6 (s)
80 (aa)
41 (bb)
385 (cc)
51 (z)
36 (l)
1889 (dd)
Source: LLNL 2010. Data is based on DOE/EIA-0573(2008), December 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon embodied in industrial and commercial products such as plastics is not shown. The flow of petroleum to electricity production includes both petroleum fuels and the plastics component of municipal solid waste. The combustion of biologically derived fuels is assumed to have zero net carbon emissions – lifecycle emissions associated with biofuels are accounted for in the Industrial and Commercial sectors. Emissions from U.S. Territories and international aviation and marine bunkers are not included.
Totals may not equal sum of components due to independent rounding. LLNL-MI-411167

U.S. Gas Shale Basins and Resources

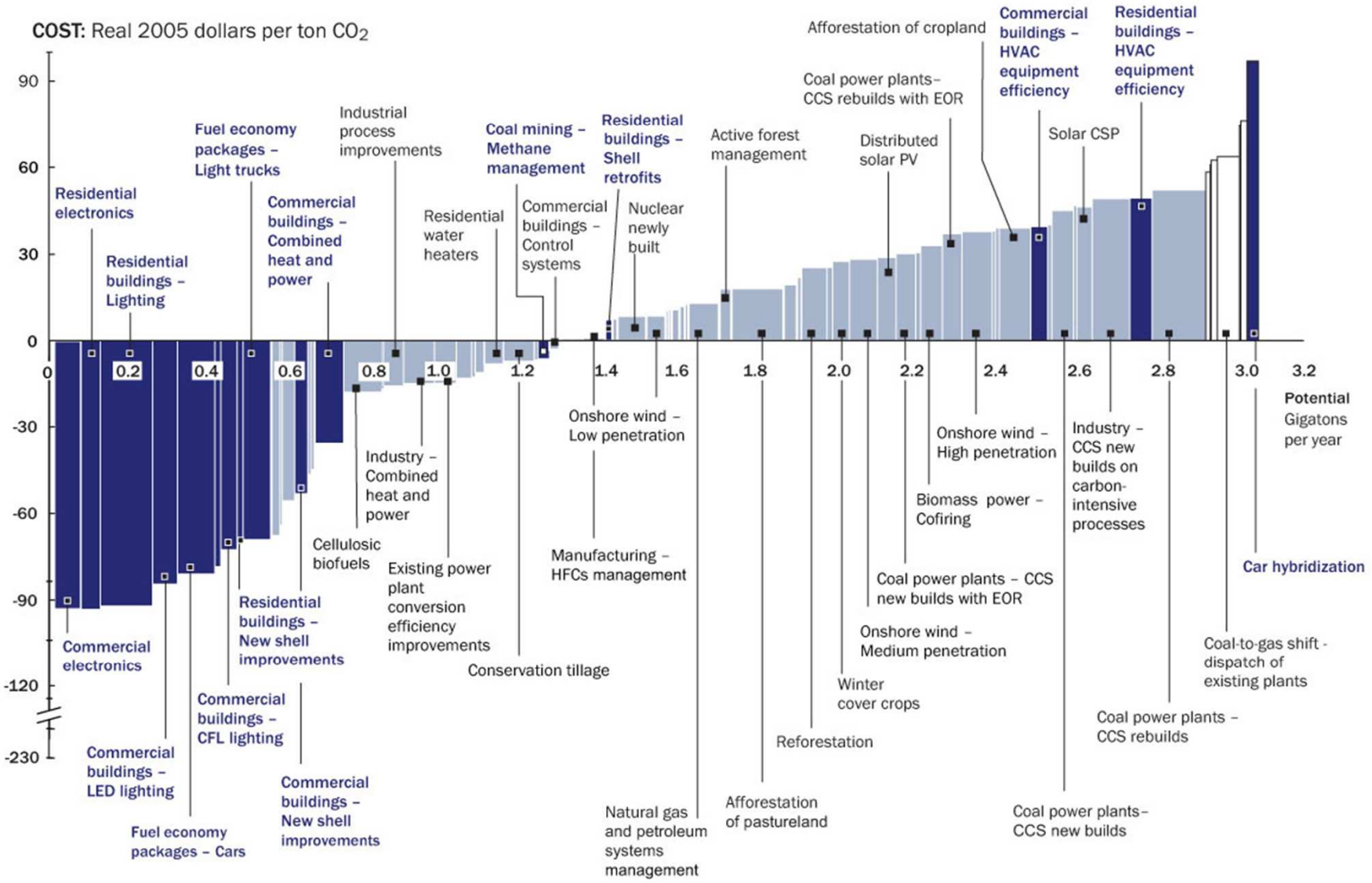


Schlumberger (2005)

Figure 2

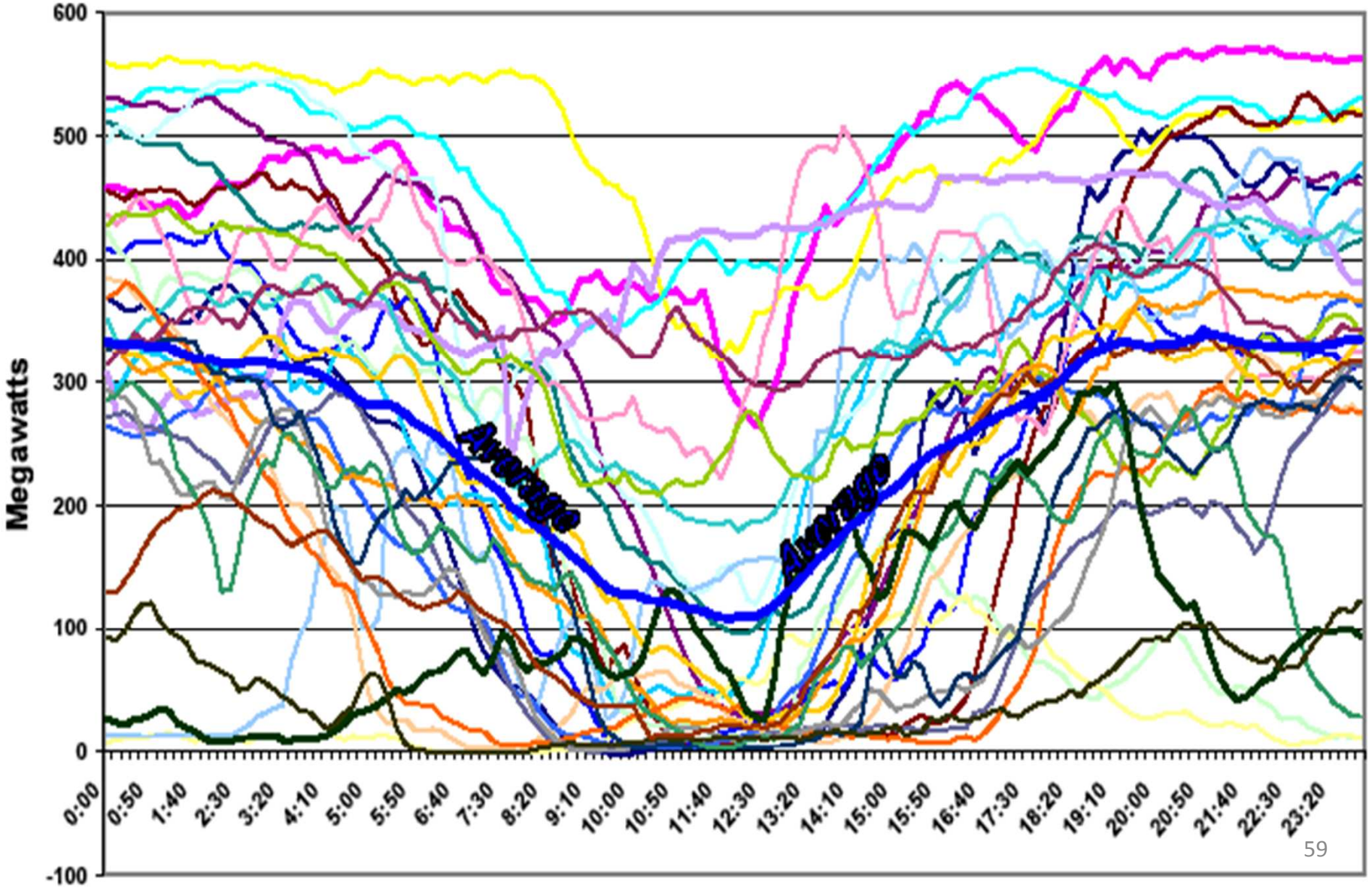
U.S. mid-range abatement curve - 2030

Carbon dioxide abatement: estimated removal cost per ton of CO_2 in 2005 dollars and removal potential in gigatons/yr for various strategies.



Source: *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?*, Executive Report, McKinsey & Company, December 2007

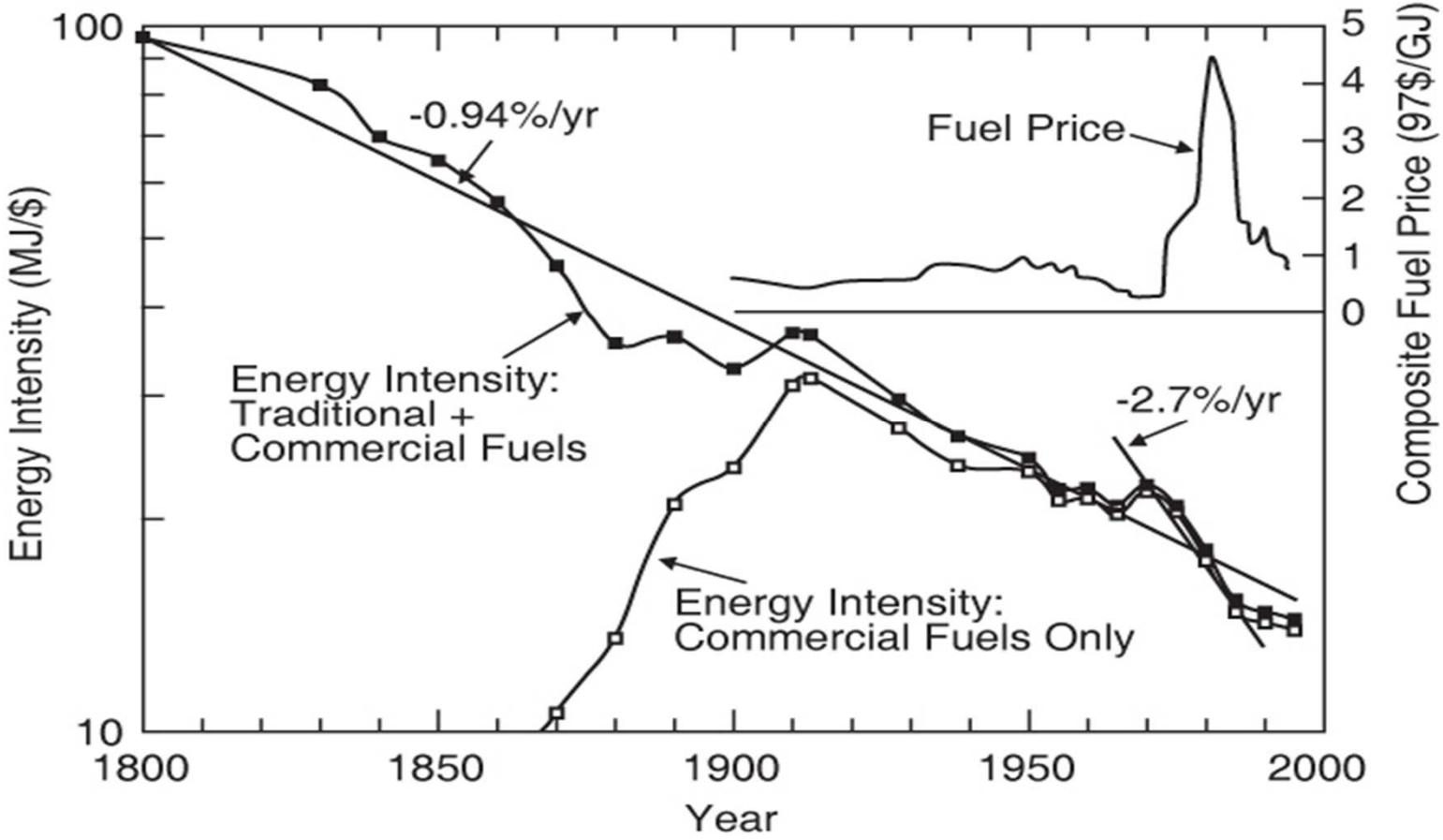
Tehachapi - June 2006
Daily Energy Production



U.S. Gasoline Requirements for Light Vehicles as Technology Changes

- 12 million barrels/day at 25 mpg (today) – equal to total oil imports, costing about $400 billion
- 8.5 Mbl/day at 35 mpg (2016 target for new vehicles)
- 6 Mbl/d 2025 at 50 mpg (2025 requirement for new vehicles?)
- 5 Mbl/d Plug-in-Hybrids with 40 mile electric range
- 2 Mbl/d P-i-H with 100 mile electric range
- 0 Mbl/d all electric which would wipe out trade deficit.

Energy Intensity vs Time

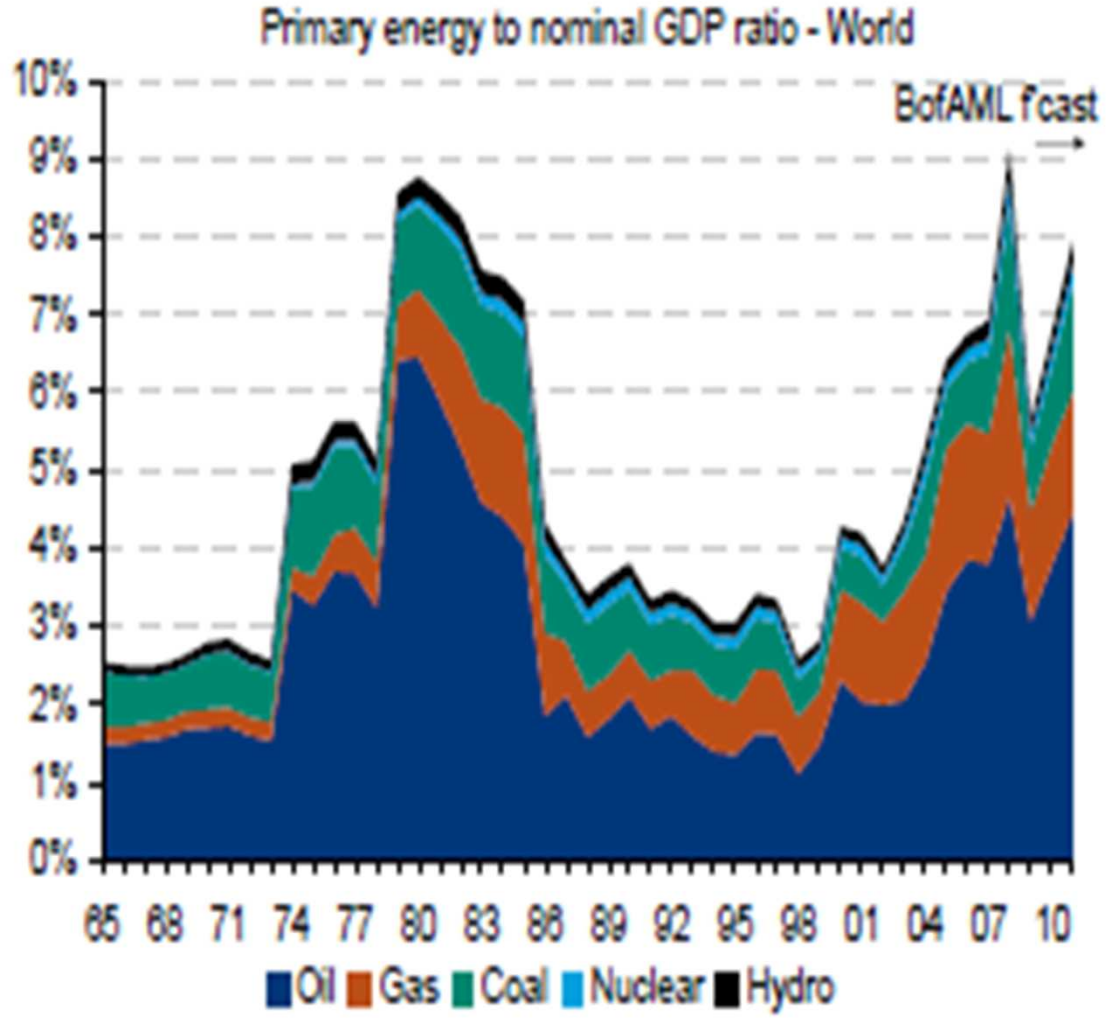


Energy intensity versus time, including what happened to fuel prices in the 1970s and 1980s . It shows the coupling between a price shock and a move toward higher efficiency and, hence, lower energy intensity. (Courtesy of Prof S. Fetter, U. of Maryland. Steve Fetter, Climate Change and the Transformation of World Energy Supply (Stanford: Center for International Security and Cooperation, 1999)).

Primary Power Requirements for 2050 for Scenarios Stabilizing CO_2 at 450 ppm and 550 ppm

Source	2000	2050	
		450 ppm	550 ppm
Carbon Based	11 TW	7 TW	12 TW
Carbon Free	3 TW	20 TW	15 TW

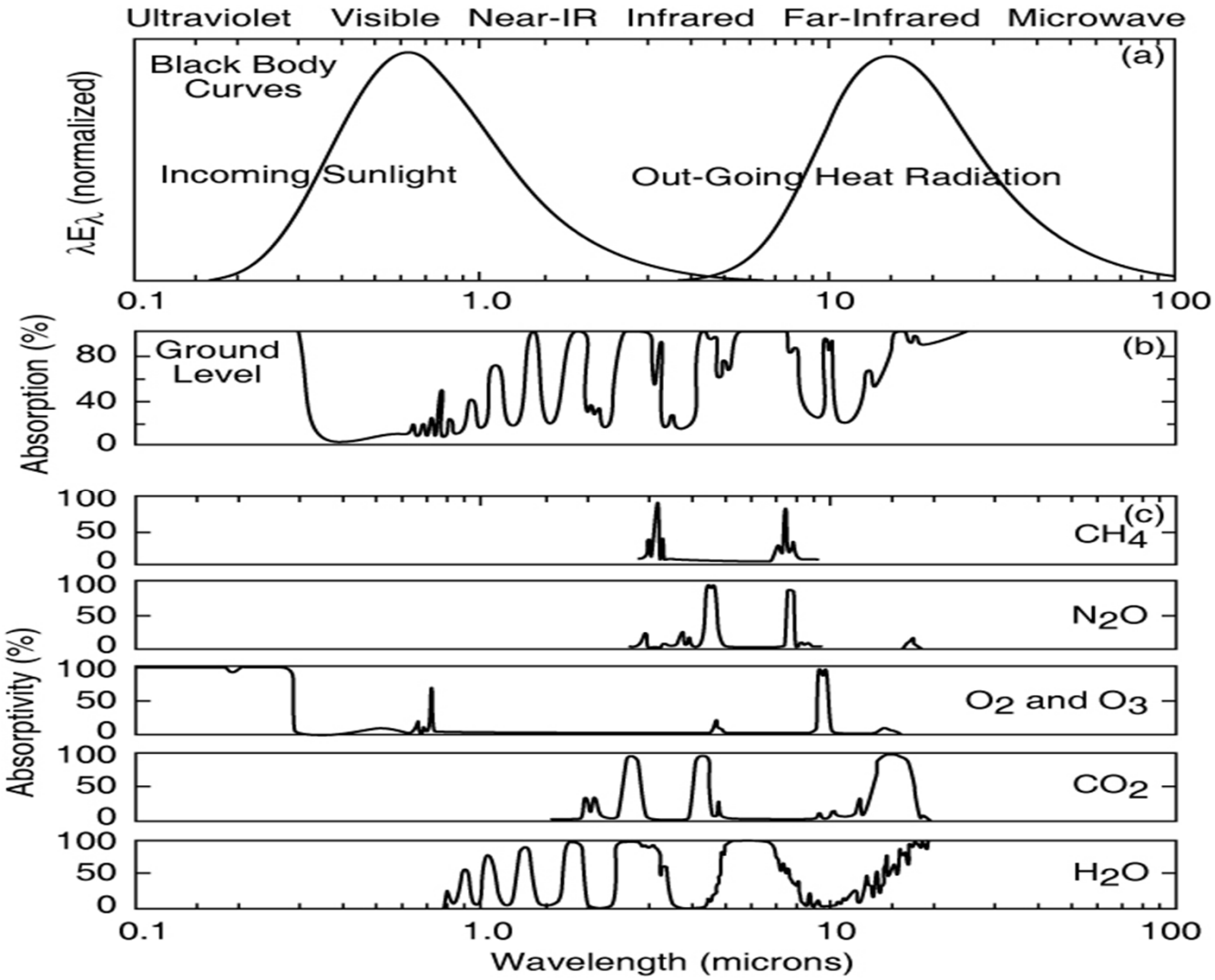
M. Hoffert, et al., Nature, 395, p881, (Oct 20, 1998)



Source: IMF, World Bank, Bloomberg, IEA, BP, BofAML Global Commodities Research


© AP

Fig. 2.1


Ultraviolet
Visible
Near-IR
Infrared
Far-Infrared
Microwave
(a)
Black Body Curves
Incoming Sunlight
Out-Going Heat Radiation
λEλ (normalized)
0.1
1.0
10
100
Absorption (%)
80
40
0
Ground Level
(b)
(c)
CH4
N2O
O2 and O3
CO2
H2O
Absorptivity (%)
100
50
0
Wavelength (microns)

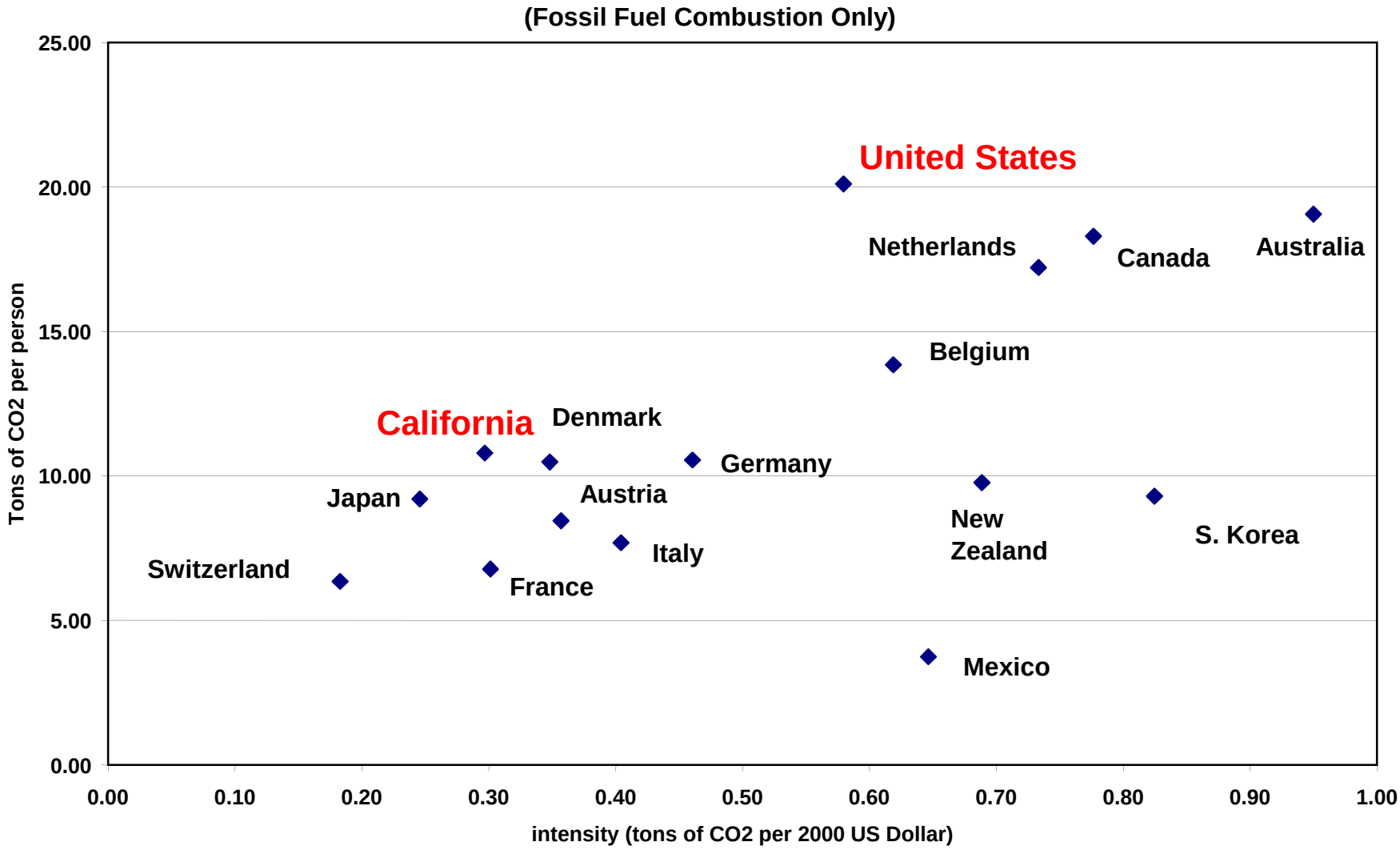
Natural Energy Sources Compared to the Total Primary Energy Supply of 2004

Item	Amount relative to TPES (2004)	Amount relative to TPES (2100 - BAU)
TPES	1	1
Solar Input	8000	2000
All the World's Winds	60	15
All the Ocean's Waves	4	1
All the Earth's Tides	0.25	0.06
All the World's Geothermal Potential	2.3	0.6
All the World's Photosynthesis	6.5	1.6
All the World's Rivers	0.5	0.13

Wind Energy Output as Percent of Capacity (2007)

Country	Wind Capacity (Gigawatts)	Wind Output (Terawatt-hours)	Average Output (% of capacity)
U.S.	17	48	32%
Denmark	3	7	20%
Germany	22	39	20%
Spain	15	27	20%
China	6	4	17%
India	8	8	12%
World	94	152	18%

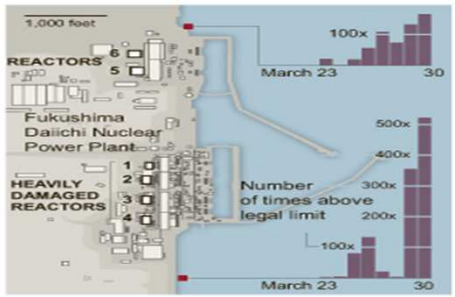
Carbon Dioxide Intensity and Per Capita CO_2 Emissions -- 2001



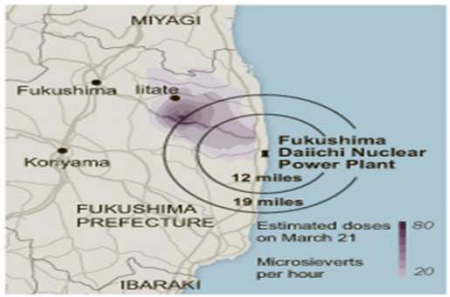
Harmful after a short period
Possibly harmful after a longer period
No current cause for concern

	At the Plant	Near the Plant	In Japan	Around the World
AIR	Readings about a quarter mile from the most heavily damaged reactors have been stable for several days. Near 1 millisievert per hour, these levels could be associated with slightly higher cancer risk after four days.	A daily dose of 0.8 millisieverts was recorded 19 miles northwest of the plant on Thursday. I.A.E.A. guidelines recommend temporary relocation if levels reach 30 millisieverts per month.	Other than in Fukushima and Ibaraki, levels are not far from normal. In Tokyo, levels were 25 percent above the normal range on Friday, well below the level of background radiation of some areas of the United States.	Trace amounts of radiation from Japan have been detected across the United States and Europe. But natural background radiation is more than 100,000 times the highest levels detected.
SOIL	Traces of plutnonium were detected in samples taken on March 21 and 22. The levels were not unsafe, but may have provided more evidence that a partial meltdown had occurred in at least one reactor.	Very high concentrations of cesium 137 were found near the village of Iitate, 25 miles northwest of the plant. The levels were about twice as high as the threshold for declaring areas uninhabitable around Chernobyl.	Cesium 137 was detected in more than 10 prefectures on Thursday, but the highest reading, in Utsunomiya, was 4,000 times lower than what was found in Iitate.	
WATER	Highly radioactive water from a damaged maintenance pit is leaking into the sea.	At stations 19 miles offshore, the highest readings were taken on March 23, and contaminants are expected to dissipate quickly. At some places in Fukushima, drinking tap water is not recommended for infants.	On March 22 and 23, iodine 131 above the recommended limit for infants was detected at a tap water treatment plant in Tokyo. But by the beginning of last week, no iodine 131 was detected.	Radiation in rainwater in British Columbia was less than one millionth the amount shown to cause thyroid diseases. A person would have to drink three million glasses at one time to reach a problematic dose in the thyroid.
FOOD	Fishing has been banned in the evacuation zone.	Radioactive cesium was detected in broccoli in Fukushima Prefecture well above the country's limit. The estimated increase in cancer risk of eating two unwashed pounds is about two chances in a million.	Radioactive cesium was detected in beef from Tenei at a level just above Japan's legal limit. The estimated increase in cancer risk of eating two pounds is about one chance in 10 million.	Radiation levels detected in milk from Washington State were 5,000 times lower than limits set by the Food and Drug Administration. A person would have to drink 1,552 gallons of this milk to reach the limit.

Levels of cesium 137 measured in seawater near the plant.

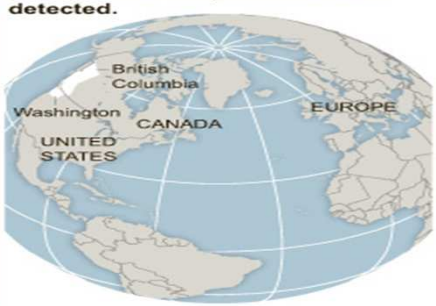


The most contaminated areas are northwest of the plant.



Prefectures with radiation in food above the legal limit.

Some places where trace levels of radiation from Japan have been detected.

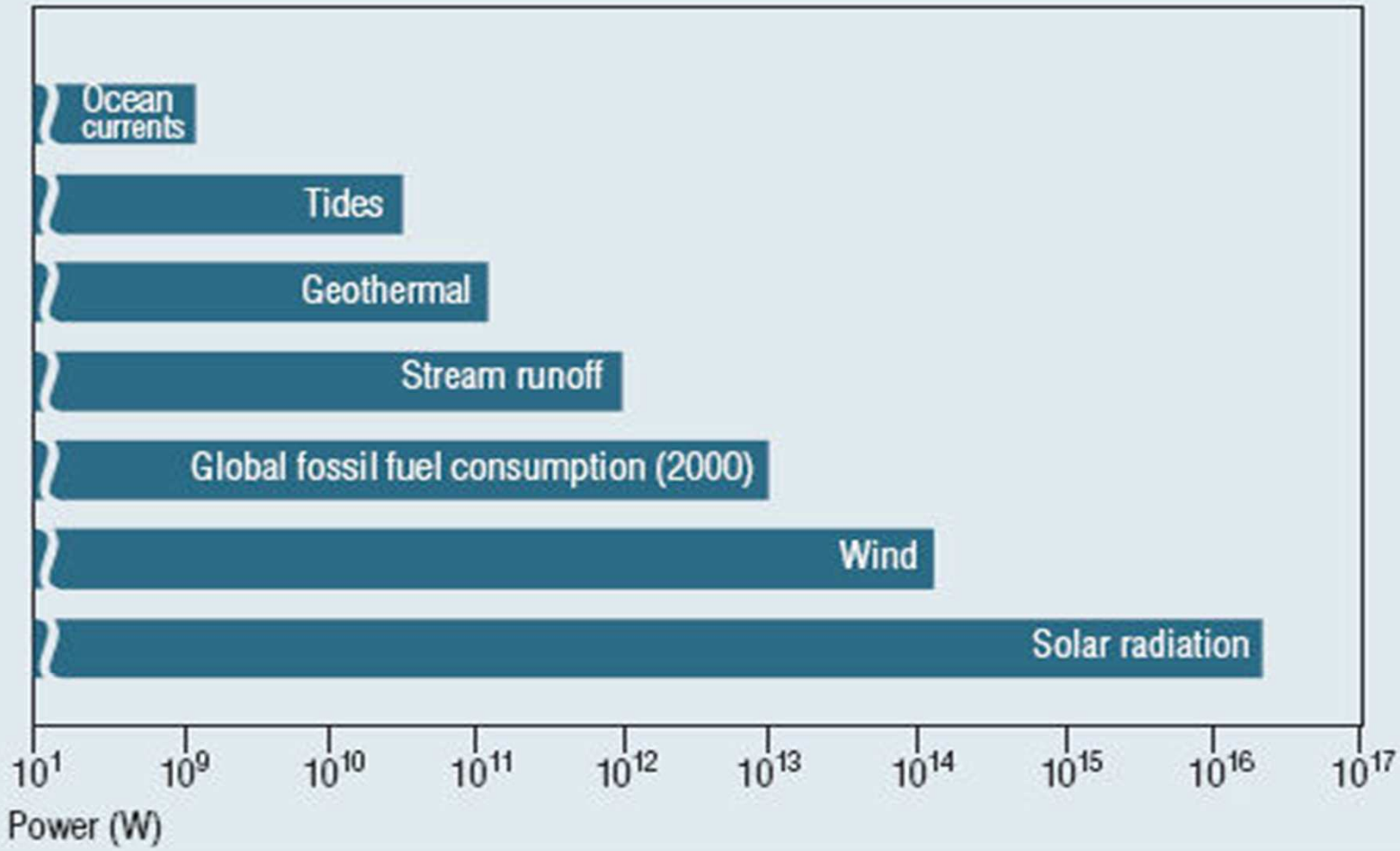


Solar comes in 3 Varieties

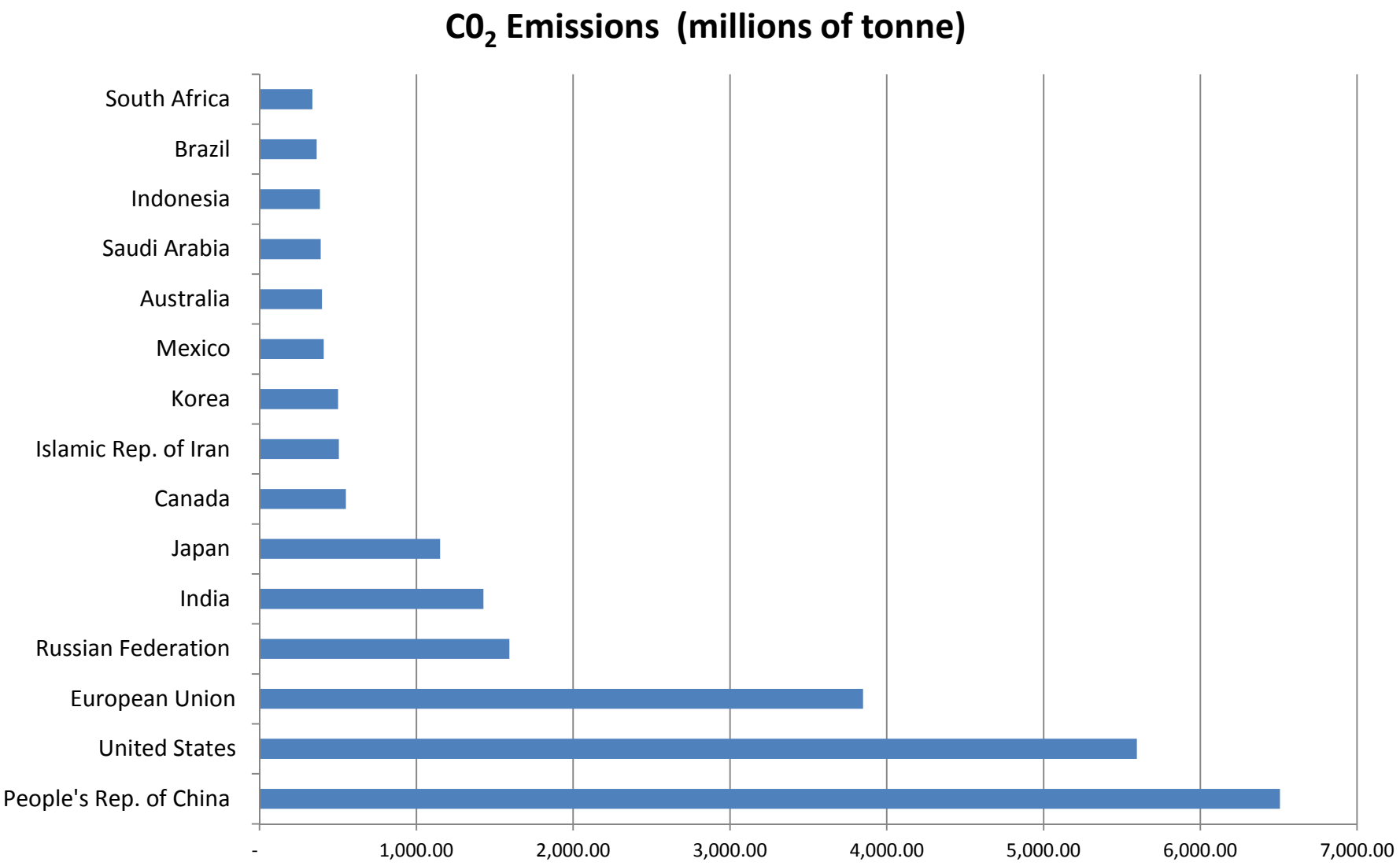
- **Solar Hot Water** – simple, cheap, old fashioned, effective
- **Solar Photovoltaic** – spreading, expensive, particularly good for small & distributed
- **Solar Thermal Electric** – large scale, beginning to be deployed more widely

1. Energy potential

Global flux of renewable energies vs. fossil fuel consumption

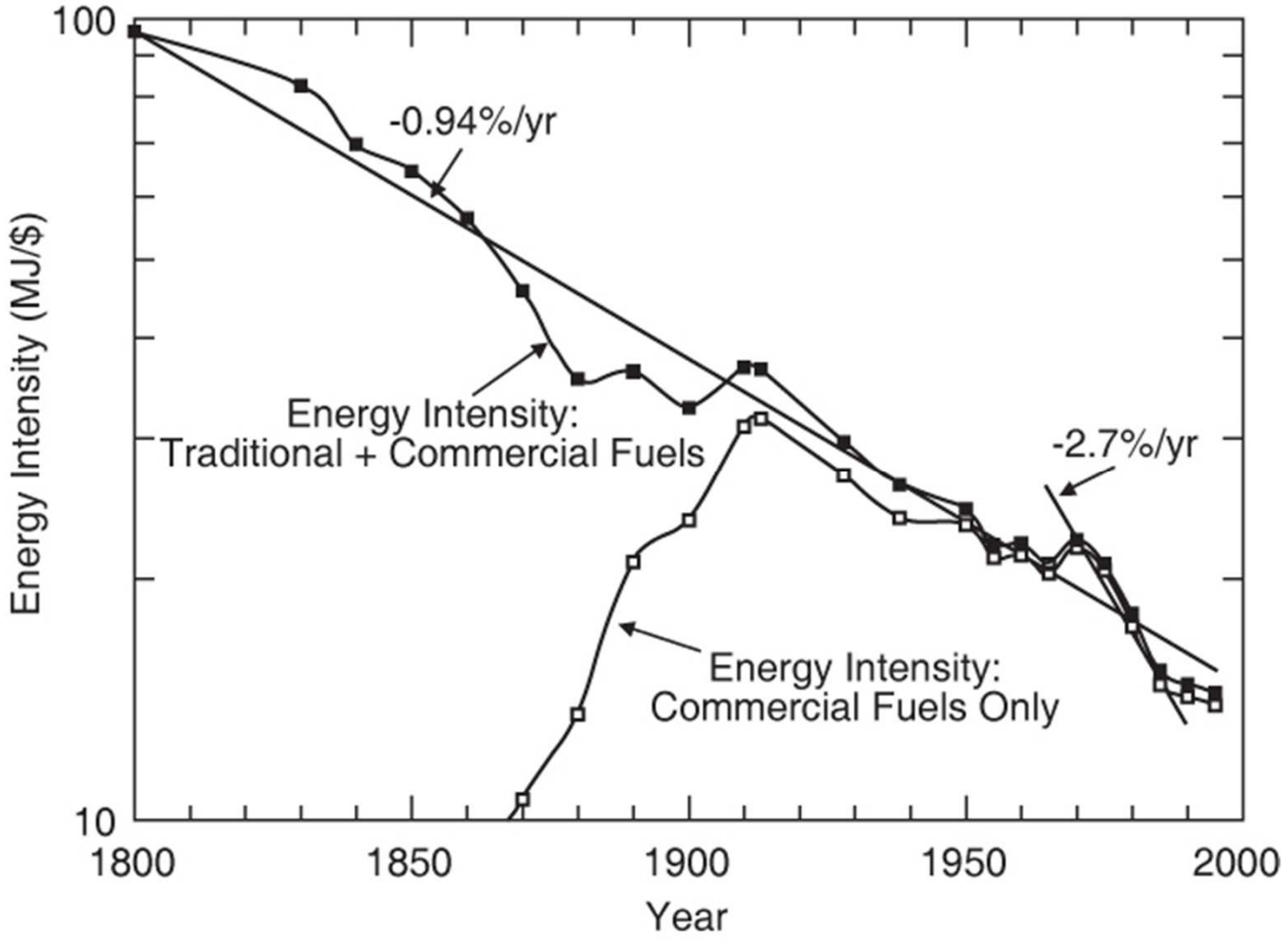


Source: V. Smil

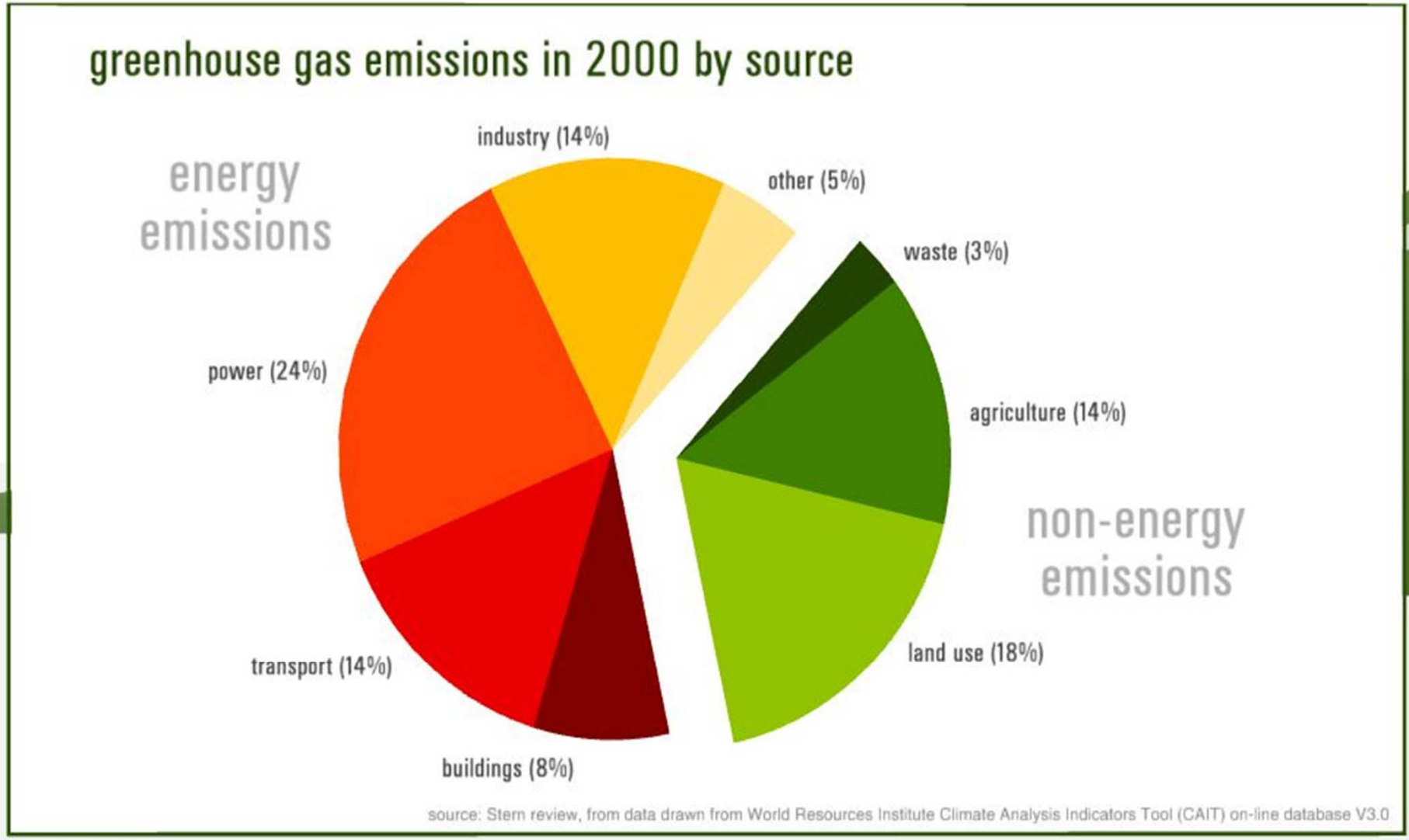


International Energy Agency Key World Energy Statistics 2010

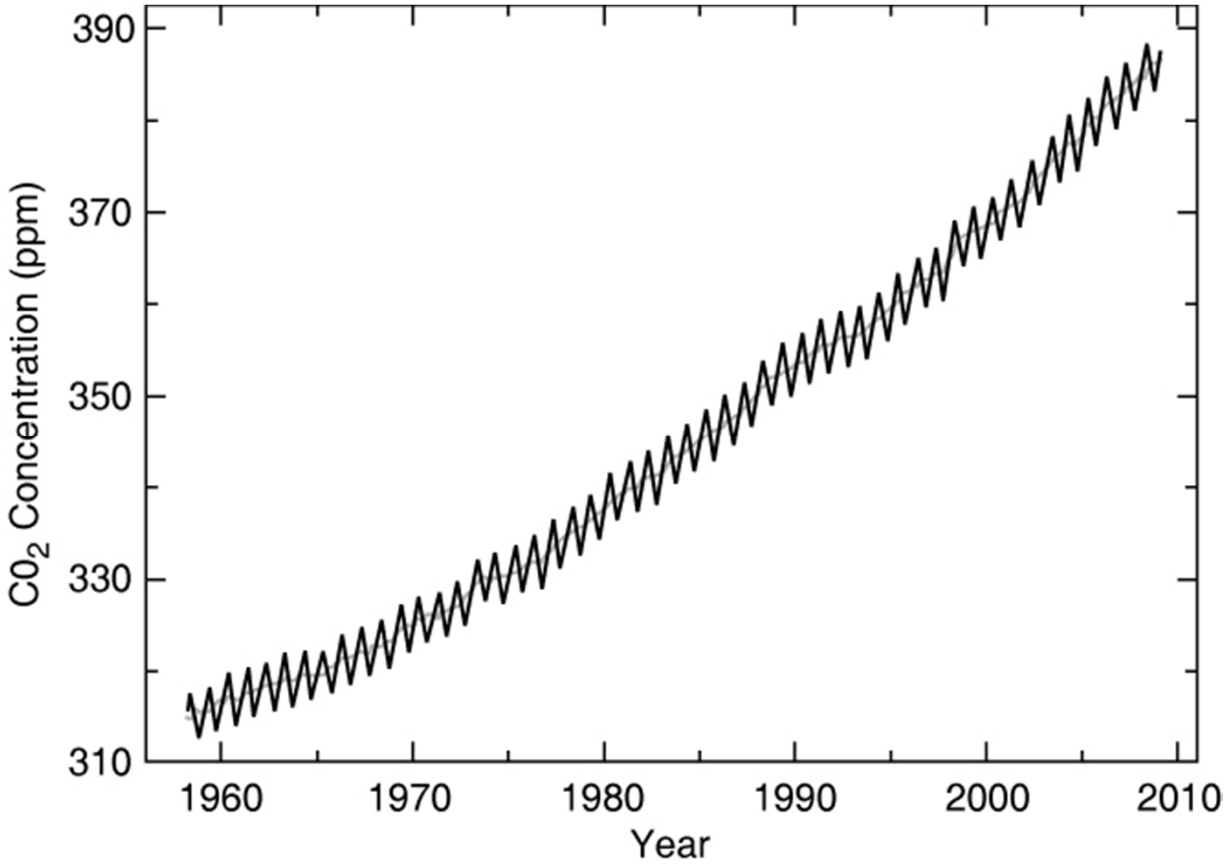
Energy intensity of the U.S. economy in megajoules per dollar from 1800 to 2000



(Courtesy of Prof S. Fetter, U. of Maryland. Steve Fetter, Climate Change and the Transformation of World Energy Supply (Stanford: Center for International Security and Cooperation, 1999)).


greenhouse gas emissions in 2000 by source
energy emissions
industry (14%)
other (5%)
waste (3%)
power (24%)
agriculture (14%)
non-energy emissions
land use (18%)
transport (14%)
buildings (8%)
source: Stern review, from data drawn from World Resources Institute Climate Analysis Indicators Tool (CAIT) on-line database V3.0

Data from the Observatory at Mauna Loa, Hawaii



Atmospheric CO_2 concentration versus year including Keeling's and more recent observations. (Source: Pieter Tans, NOAA Earth System Research Laboratory, Boulder CO., and to Ralph Keeling, Scripps Institution of Oceanography, UC San Diego, La Jolla, CA.)

1. **Is Climate Change A Real Problem?**

2. **Can We Do Something About It?**

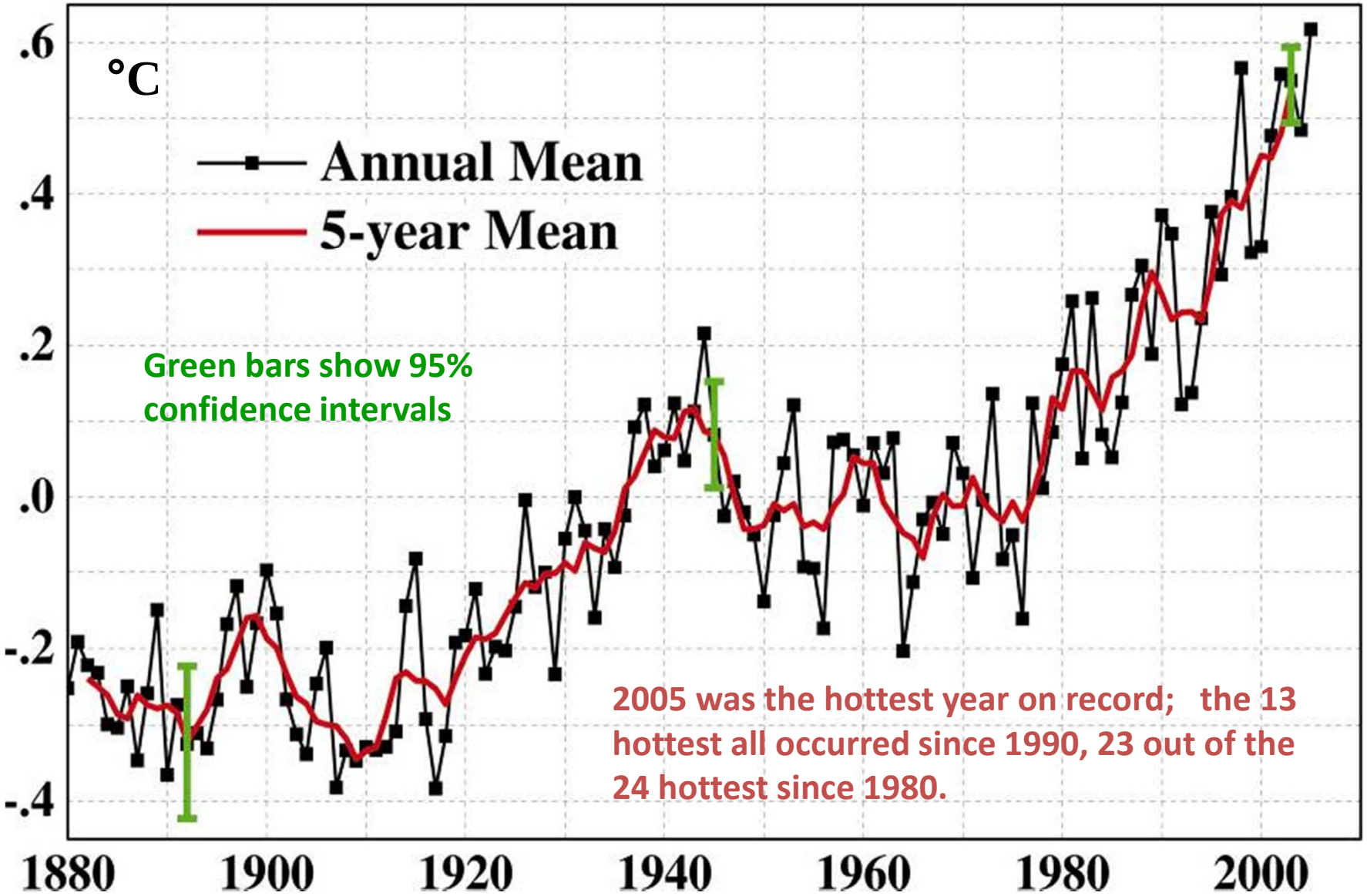
3. **Are We Doing The Right Things?**

Some of the New Nuclear Power Aspirants

A tentative list as examples
From GENIV International Forum

- UAE
- Saudi Arabia
- Yemen
- Egypt
- Jordan
- Morocco
- Tunisia
- Libya
- Algeria
- ….

- Italy
- Turkey
- Poland/Latvia/Lithuania
- Kazakhstan
- Vietnam
- Indonesia
- Philippines
- Thailand
- Ghana
- Chile



J. Hansen et al., *PNAS 103*: 14288-293 (26 Sept 2006)

Solar Thermal Electric

- Barstow Solar 2 Power Tower (photo courtesy of NREL)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百古店