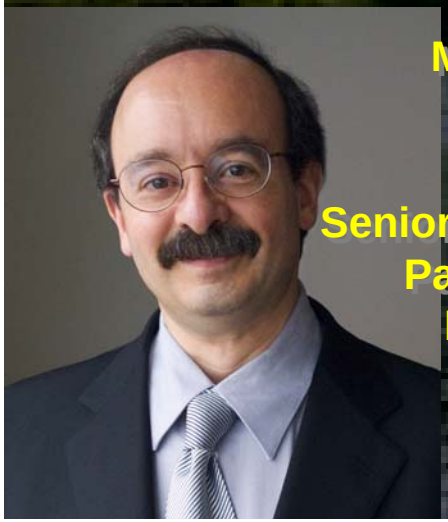
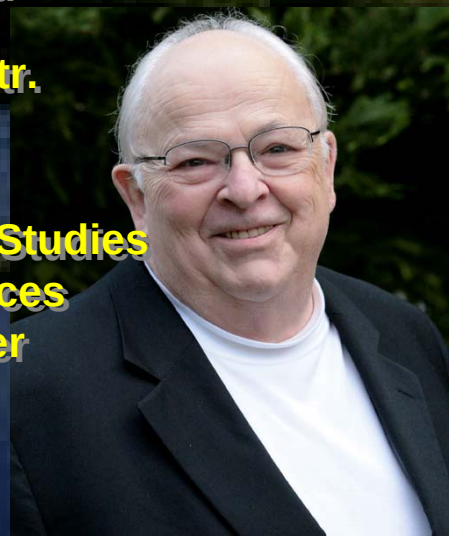
The Energy Seminar

The Discussion: Nuclear Energy



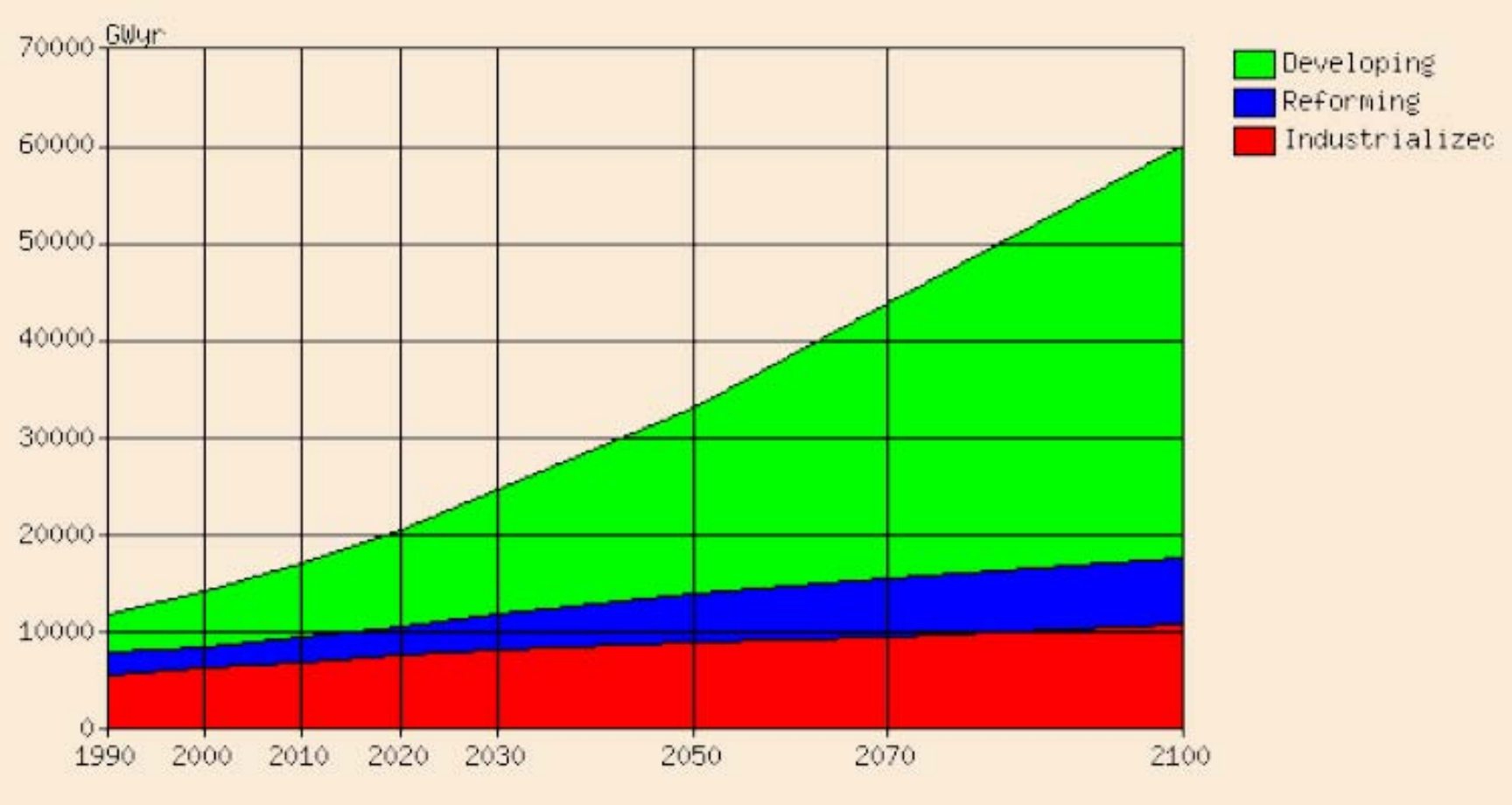
Amory B. Lovins
Chief Executive Officer and Chairman of the Board
Rocky Mountain Institute
MAP/Ming Professor, Stanford University, Spring Qtr.

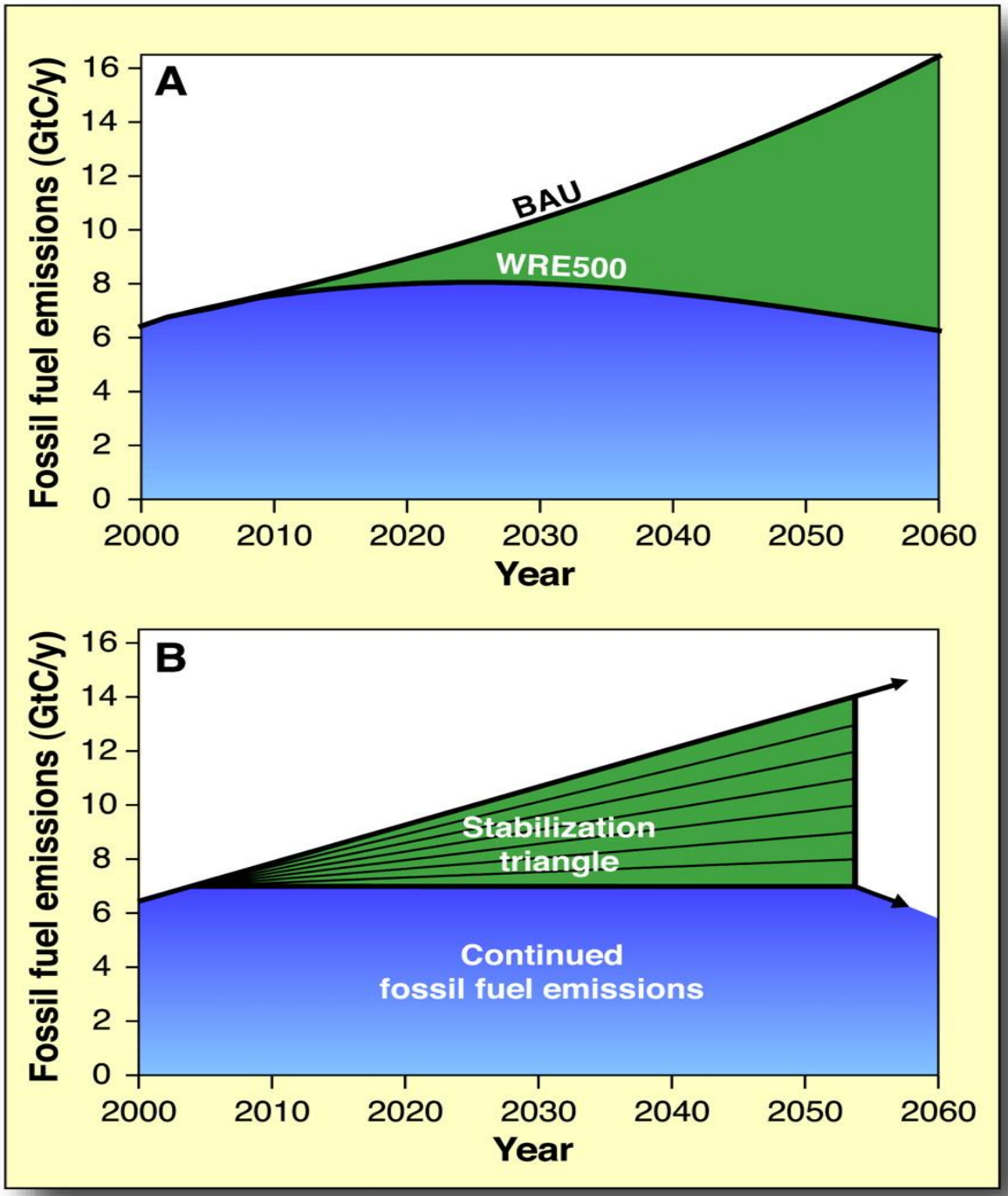
Burton Richter
Senior Fellow, Freeman Spogli Institute for International Studies
Paul Pigott Professor Emeritus in the Physical Sciences
Former Director, Stanford Linear Accelerator Center
Nobel Laureate (Physics, 1976)



6 June 2007

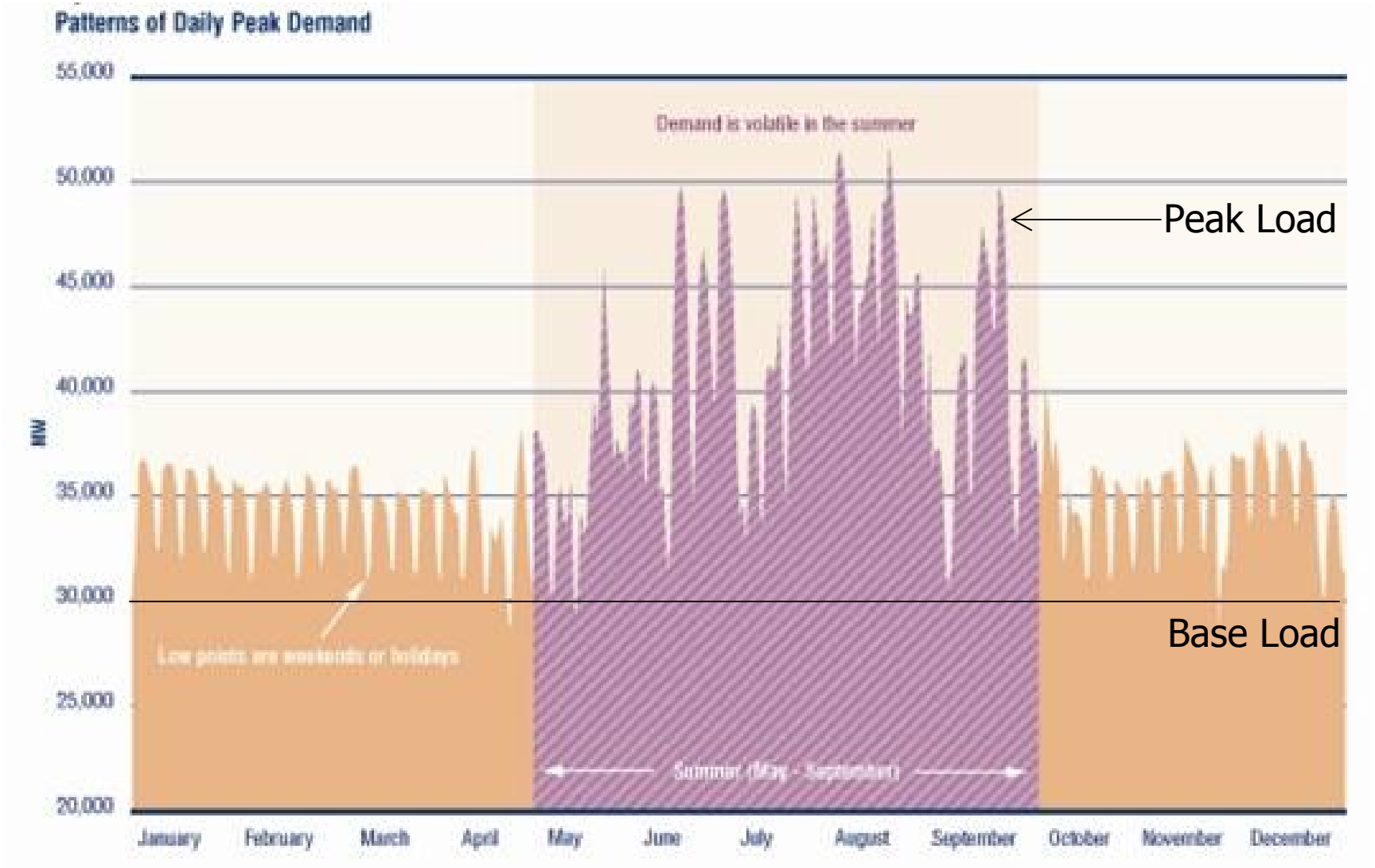
IIASA Projection of Future Energy Demand Scenario A1 (High Growth)





"Science," **305,** 968 (August 13, 2004)

Peak Load vs. Base Load



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

The Nuclear Critics

- It can't compete in the market place.
- It is too dangerous.
- We don't know what to do with spent fuel.

Costs

Nuclear	1800 €≈$2500/KW	(Areva)
Coal	$1500 – 2000/KW	(EIA)
Wind	$1600/KW (peak)	(NYT 5/1/07)
	$8000/KW (avg.)	(20% duty factor)
Solar	$5000/KW (peak)	(CA Energy Commision)
	$25,000/KW (avg.)	

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**	

Nuclear Accidents

Chernobyl (1986) – World's Worst

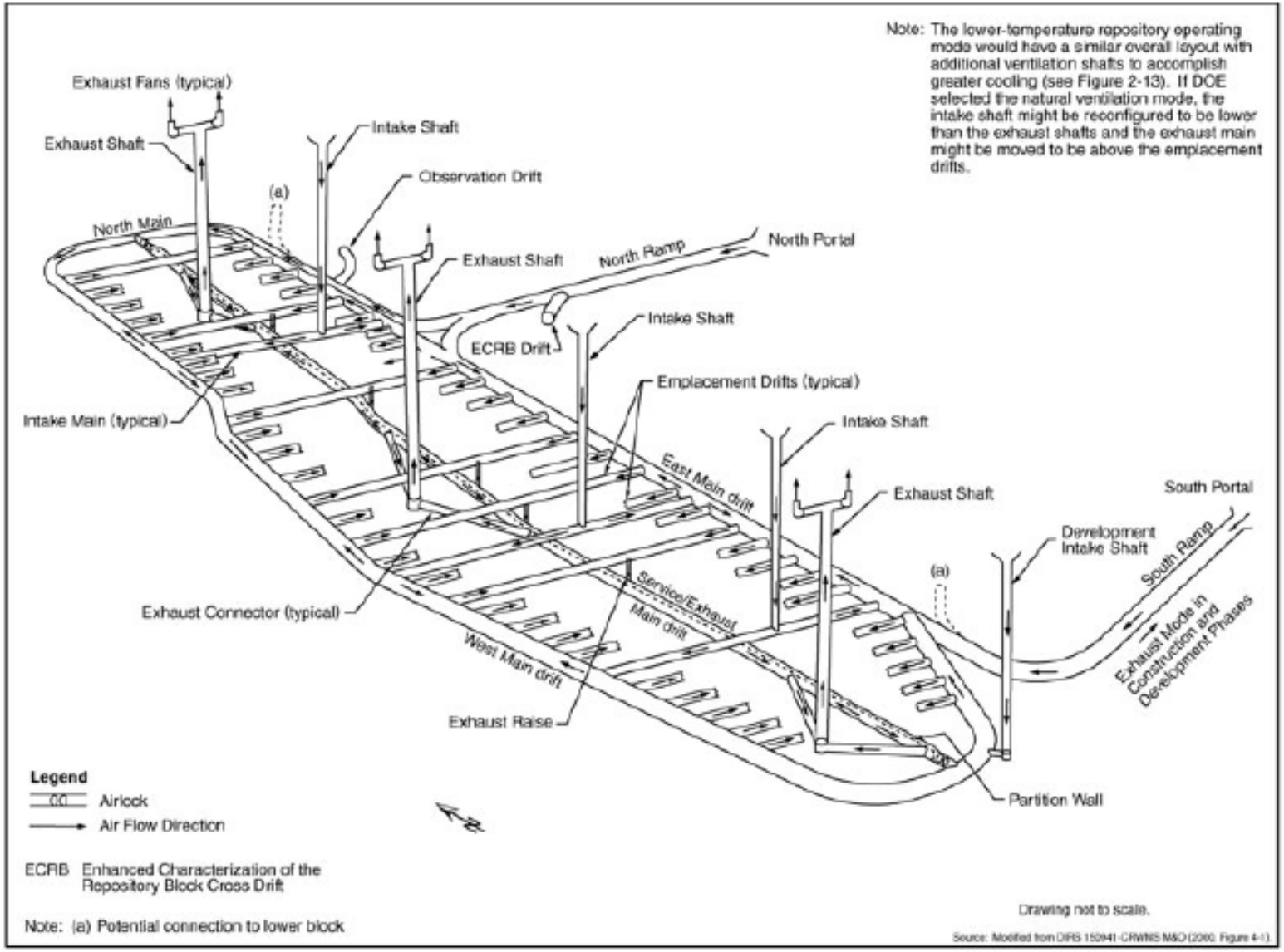
- Reactor type not used outside of old Soviet bloc (can become unstable)
- Operators moved into unstable region and disabled all safety systems.

Three Mile Island (1979) – A Partial Core Meltdown

- LWRs are not vulnerable to instabilities
- All LWRs have containment building
- Radiation in region near TMI about 10 mr.

New LWRs have even more safety systems.

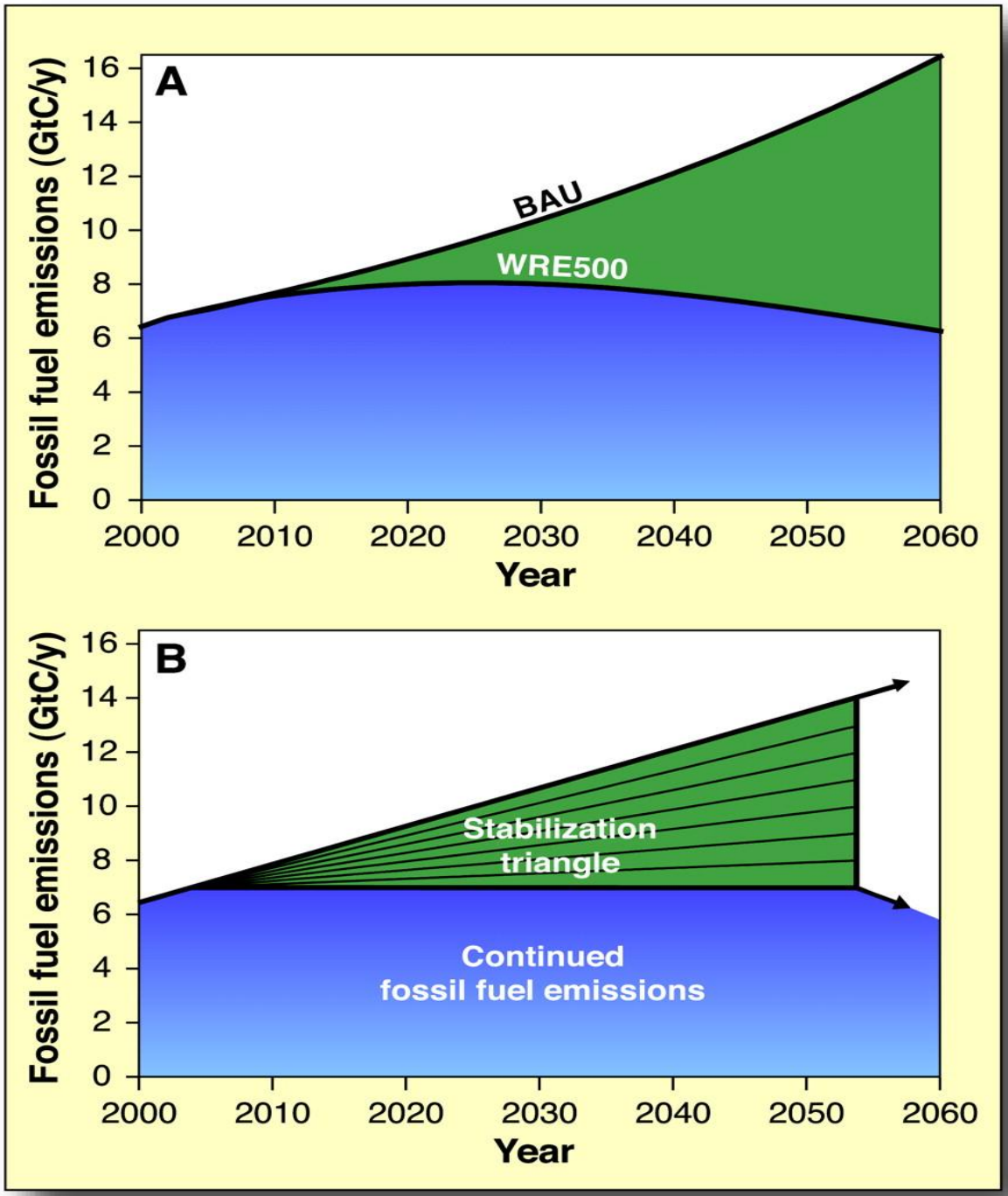
Yucca Mountain Repository Layout



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

	2000	2050	
Source		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)



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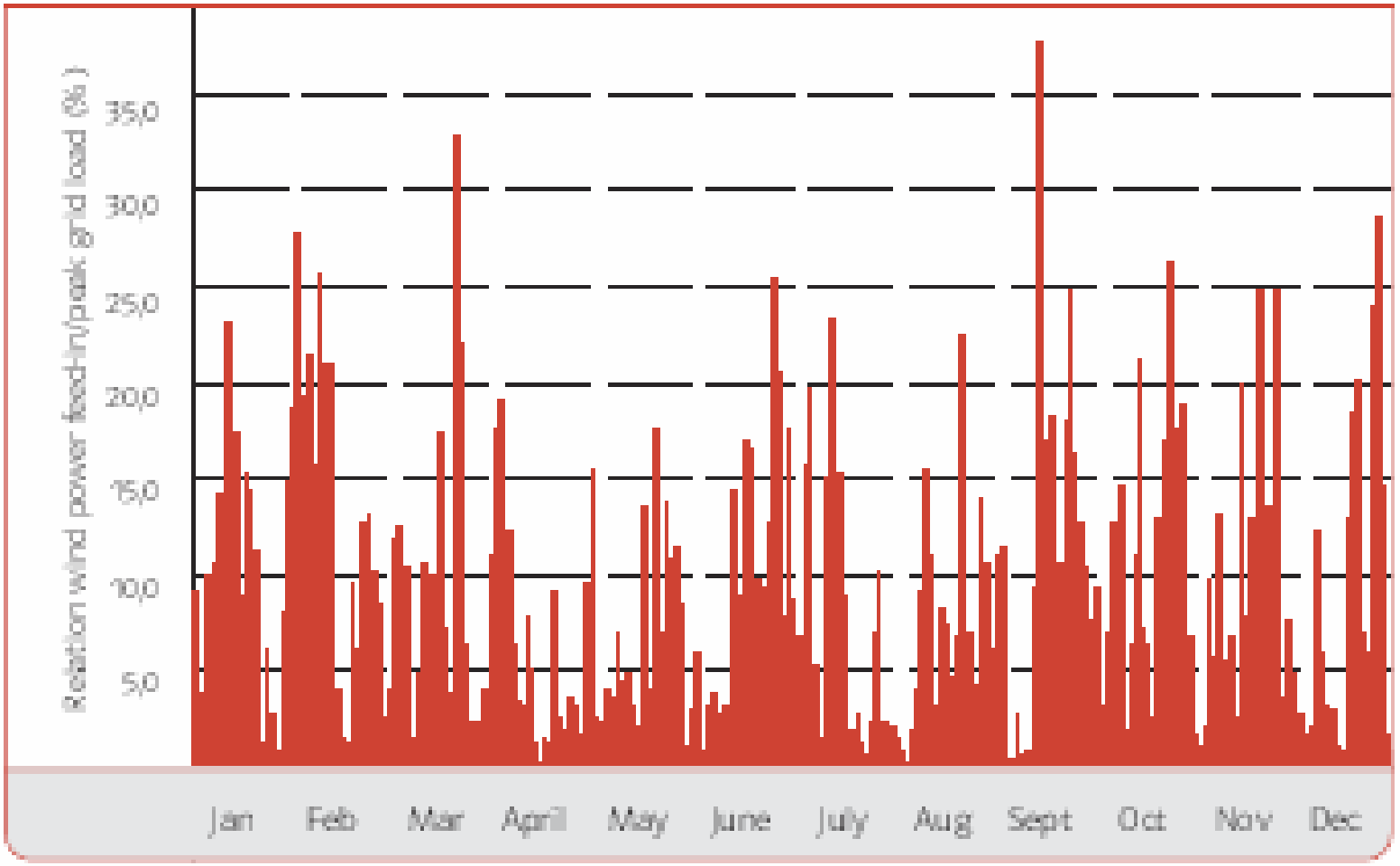
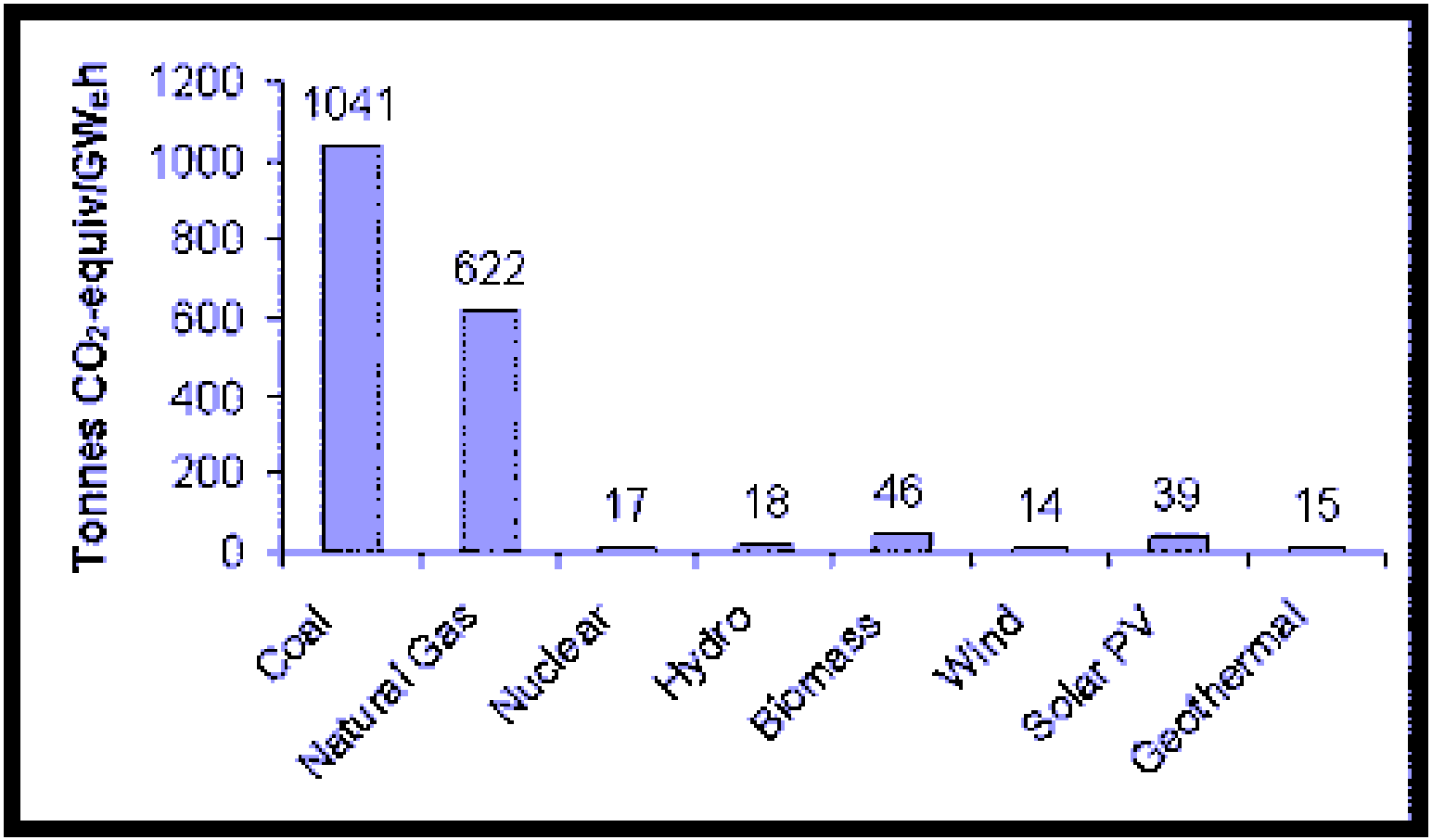
Back Up



EON-NETZ (GERMANY) WIND POWER VARIABILITY

AVERAGE IS 20% OF INSTALLED WIND CAPACITY

Comparison of Life-Cycle Emissions



Source: "Life-Cycle Assessment of Electricity Generation Systems and Applications for Climate Change Policy Analysis," Paul J. Meier, University of Wisconsin-Madison, August, 2002.

World Nuclear Expansion
(as of January 2007)

Under construction	28
Approved and to be started	64
Under discussion	158
Total	250

Some Comparative Electricity Generating Cost Projections for Year 2010 on

	Nuclear	Coal	Gas
Finland	2.76	3.64	-
France	2.54	3.33	3.92
Germany	2.86	3.52	4.90
Switzerland	2.88	-	4.36
Netherlands	3.58	-	6.04
Czech Republic	2.30	2.94	4.97
Slovakia	3.13	4.78	5.59
Romania	3.06	4.55	-
Japan	4.80	4.95	5.21
Korea	2.34	2.16	4.65
USA	3.01	2.71	4.67
Canada	2.60	3.11	4.00

US 2003 cents/kWh, Discount rate 5%, 40 year lifetime, 85% load factor.
Source: OECD/IEA NEA 2005.

In the U.S.

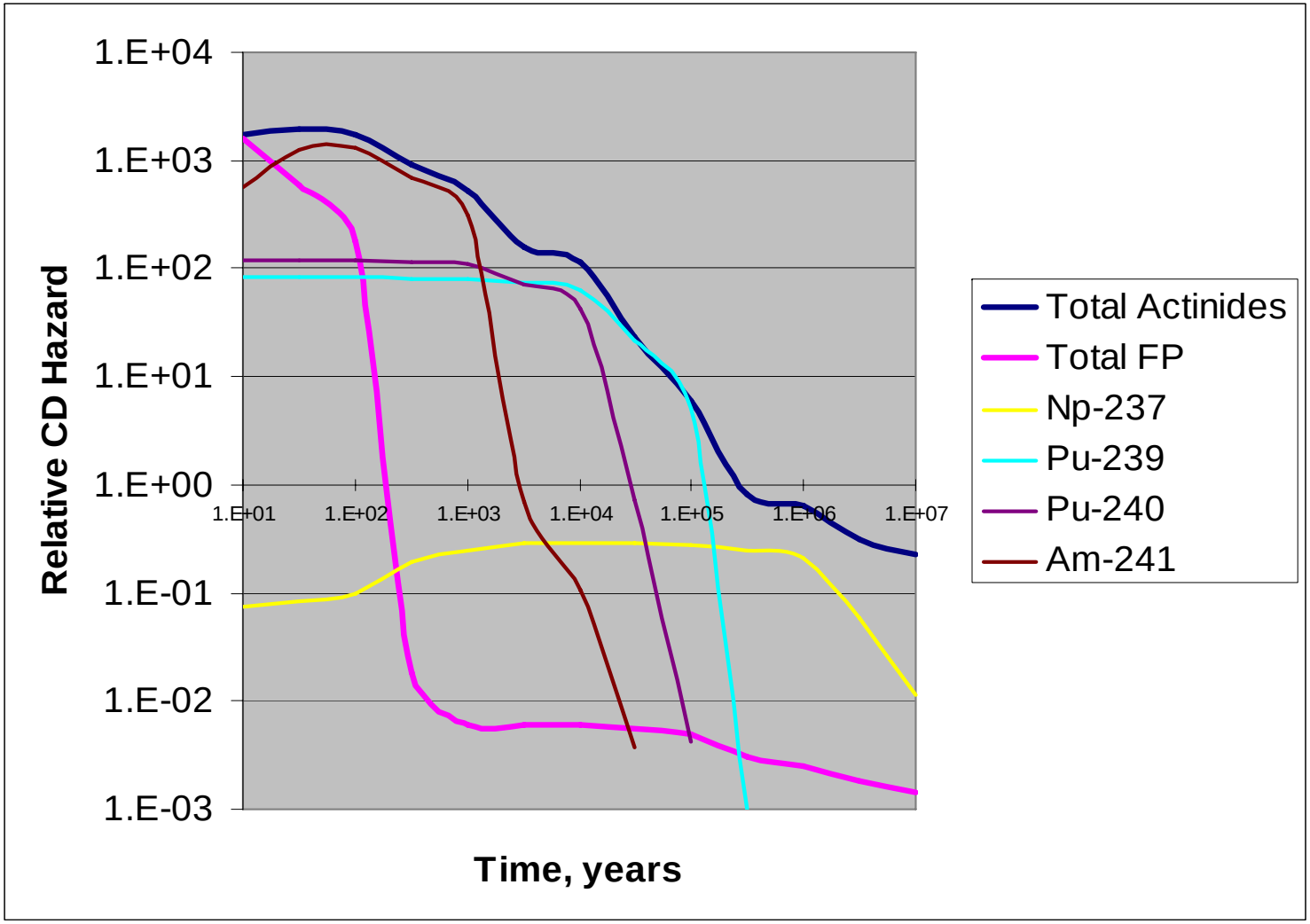
- Nuclear Incentives in 2006 Energy Bill
  - Licensing streamlined
  - “Insurance” against regulatory delays
  - Cost sharing for First-of-a-Kind costs
- GNEP
  - Waste treatment change
  - Proliferation risk reduction

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		

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

Radiotoxicity of LWR Spent Fuel



Nuclear Weapons: Proliferation & The Fuel Cycle

- There is NO proliferation-proof fuel cycle
  - Nations: Only method is binding international agreements that include sanctions for violators.
  - Terrorist Groups: It is not easy to build a Pu bomb. Risk is in buying or stealing or getting a gift of one, not so much from fuel cycle.

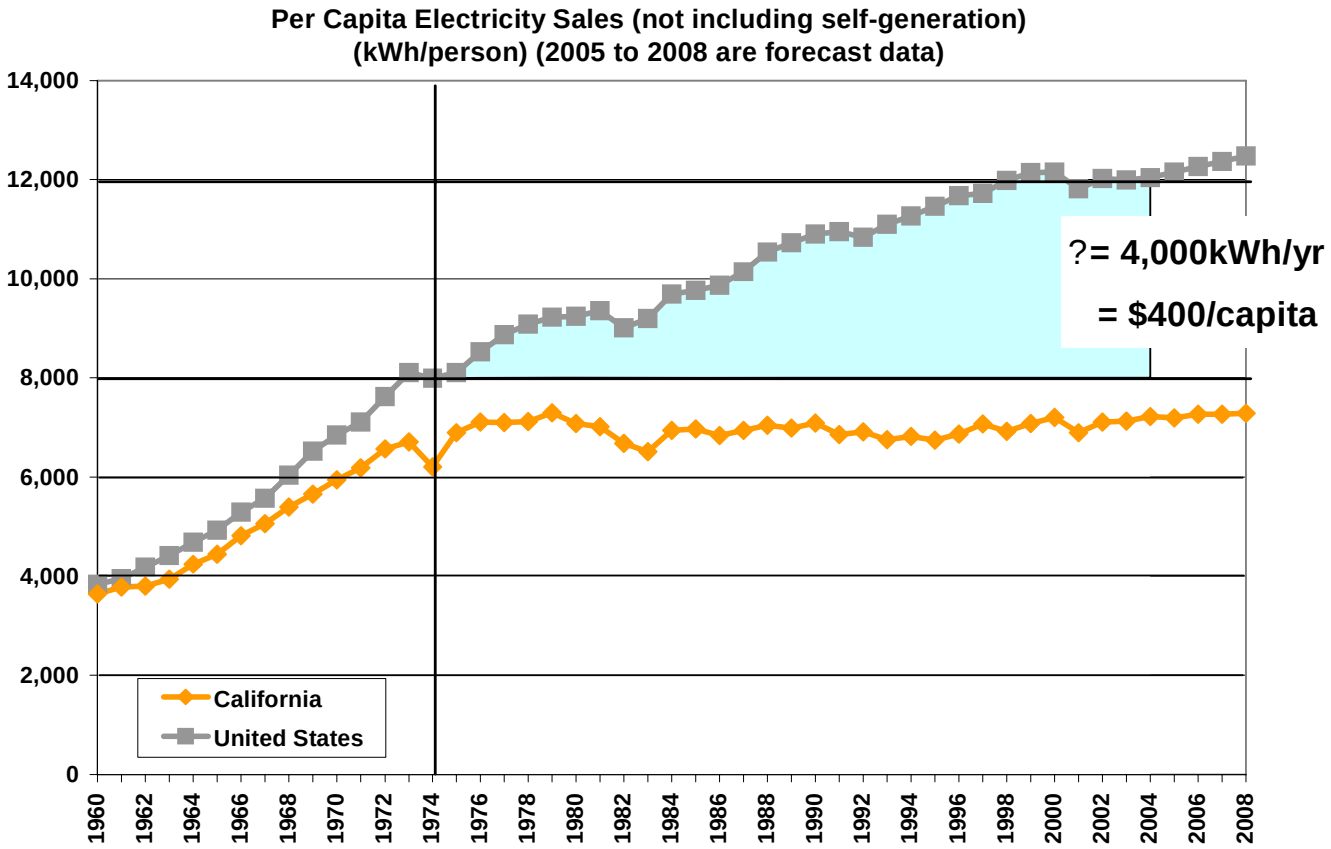
Proliferators

Enrichment Phase ("Front End") to make U(235) Weapons:

- South Africa (gave them up under IAEA supervision)
- Pakistan (centrifuge technology sold around the world)
- Libya (abandoned attempt)
- Iran ?

Reprocessing ("Back End") to make Pu Weapons:

- Israel
- India
- N. Korea


Per Capita Electricity Sales (not including self-generation)
(kWh/person) (2005 to 2008 are forecast data)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
California
United States
?= 4,000kWh/yr
= $400/capita