Why Nuclear Energy
Energy Panel

Presentation at

Council of State Governments

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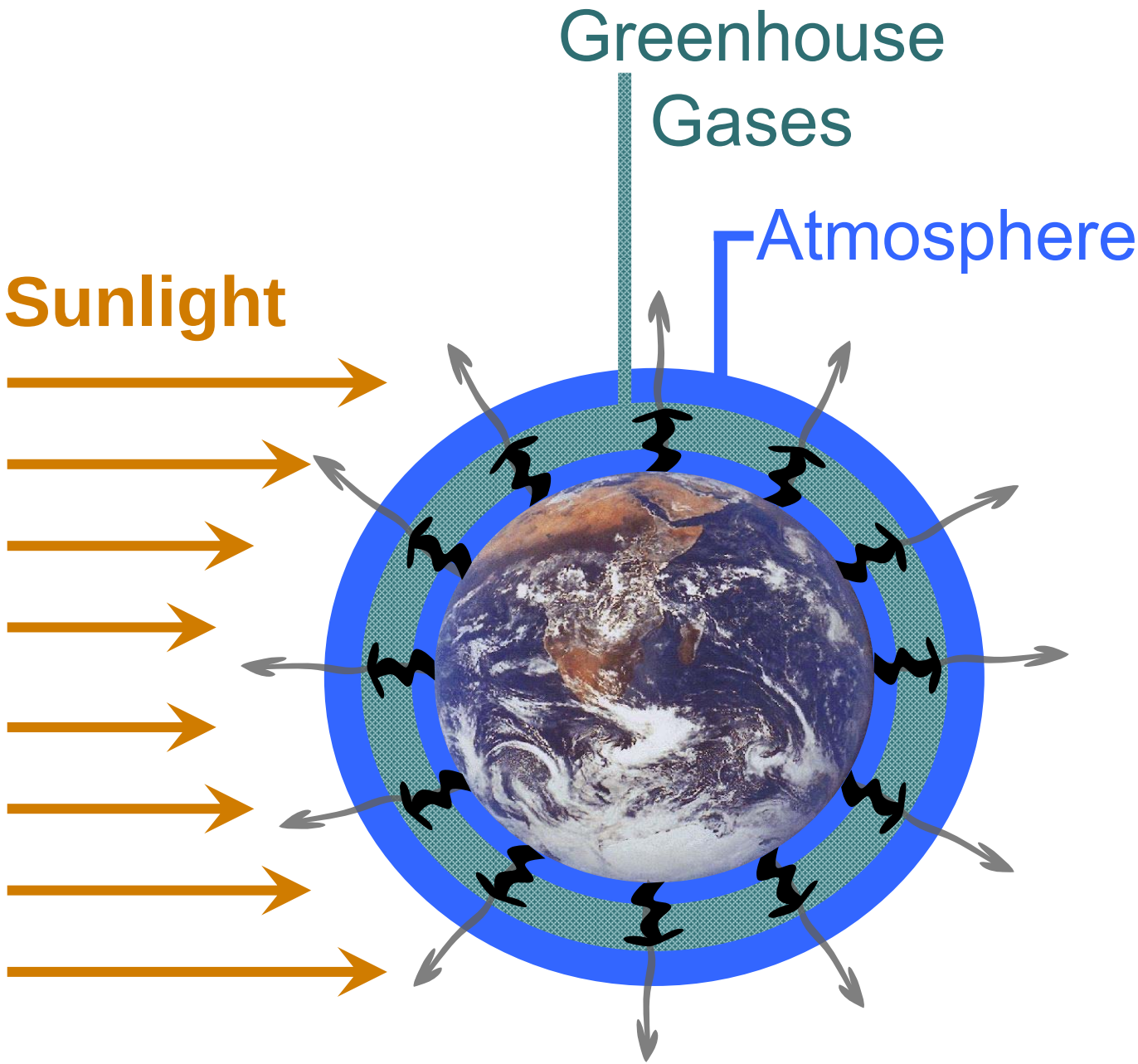
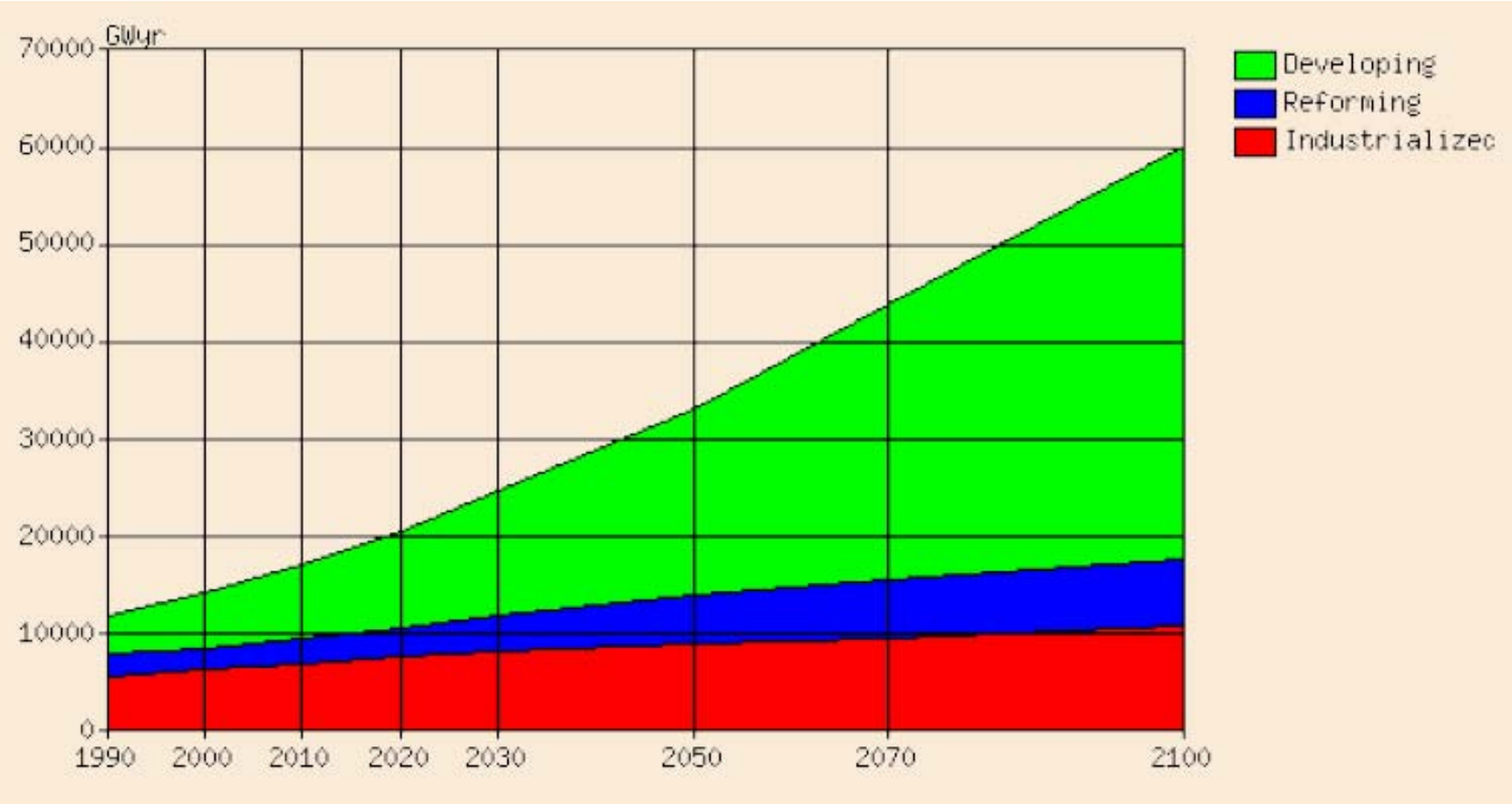
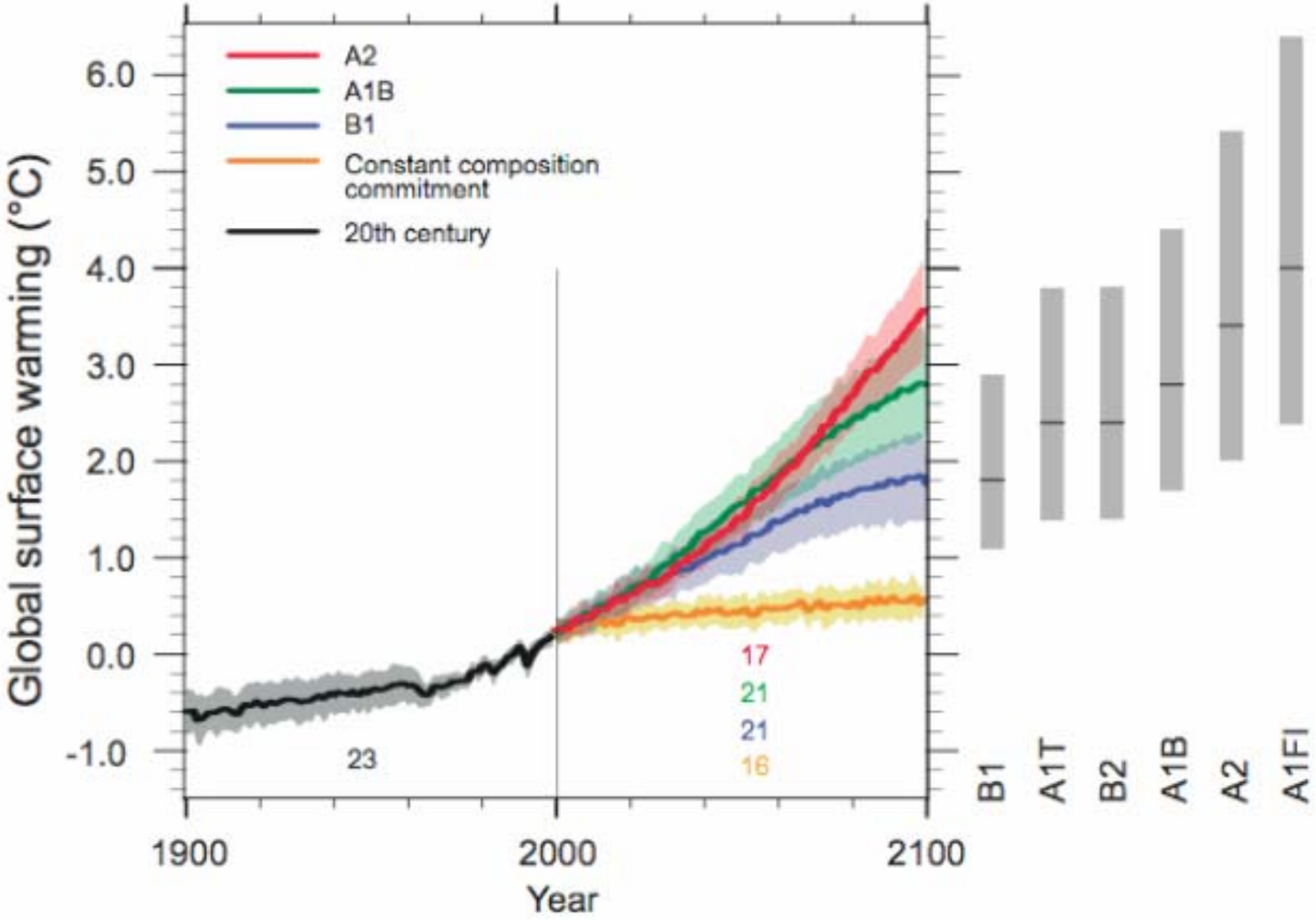
Burton Richter

Freeman Spogli Institute of International Studies Senior Fellow
Paul Pigott Professor in the Physical Sciences Emeritus
Stanford University
Director Emeritus
Stanford Linear Accelerator Center


Greenhouse
Gases
Atmosphere
Sunlight

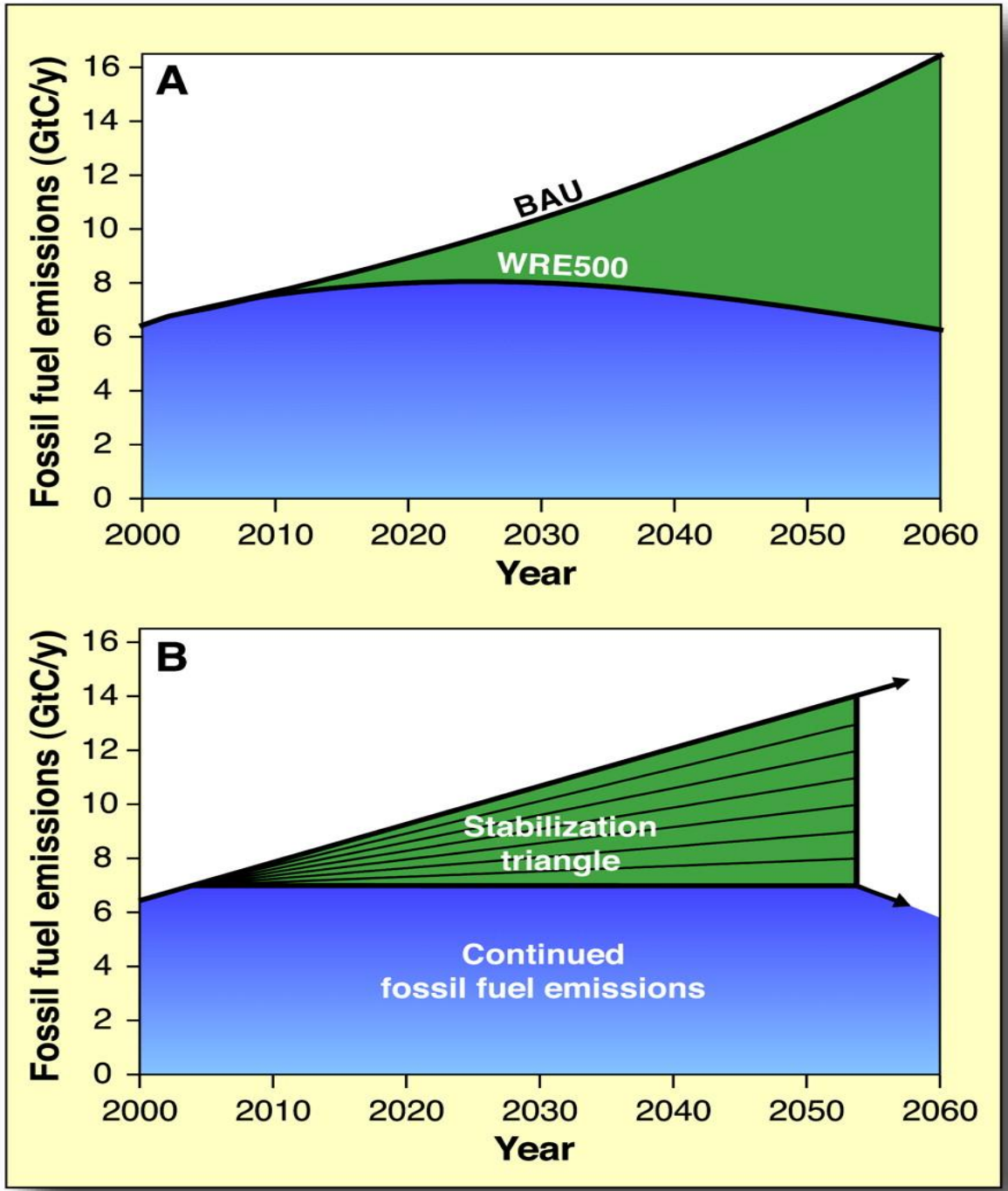
IIASA Projection of Future Energy Demand Scenario A1 (High Growth)




A2
A1B
B1
Constant composition commitment
20th century
Global surface warming (°C)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
1900
2000
2100
Year
23
17
21
21
16
B1
A1T
B2
A1B
A2
A1FI

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%



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

Ready for Large-Scale Deployment Now

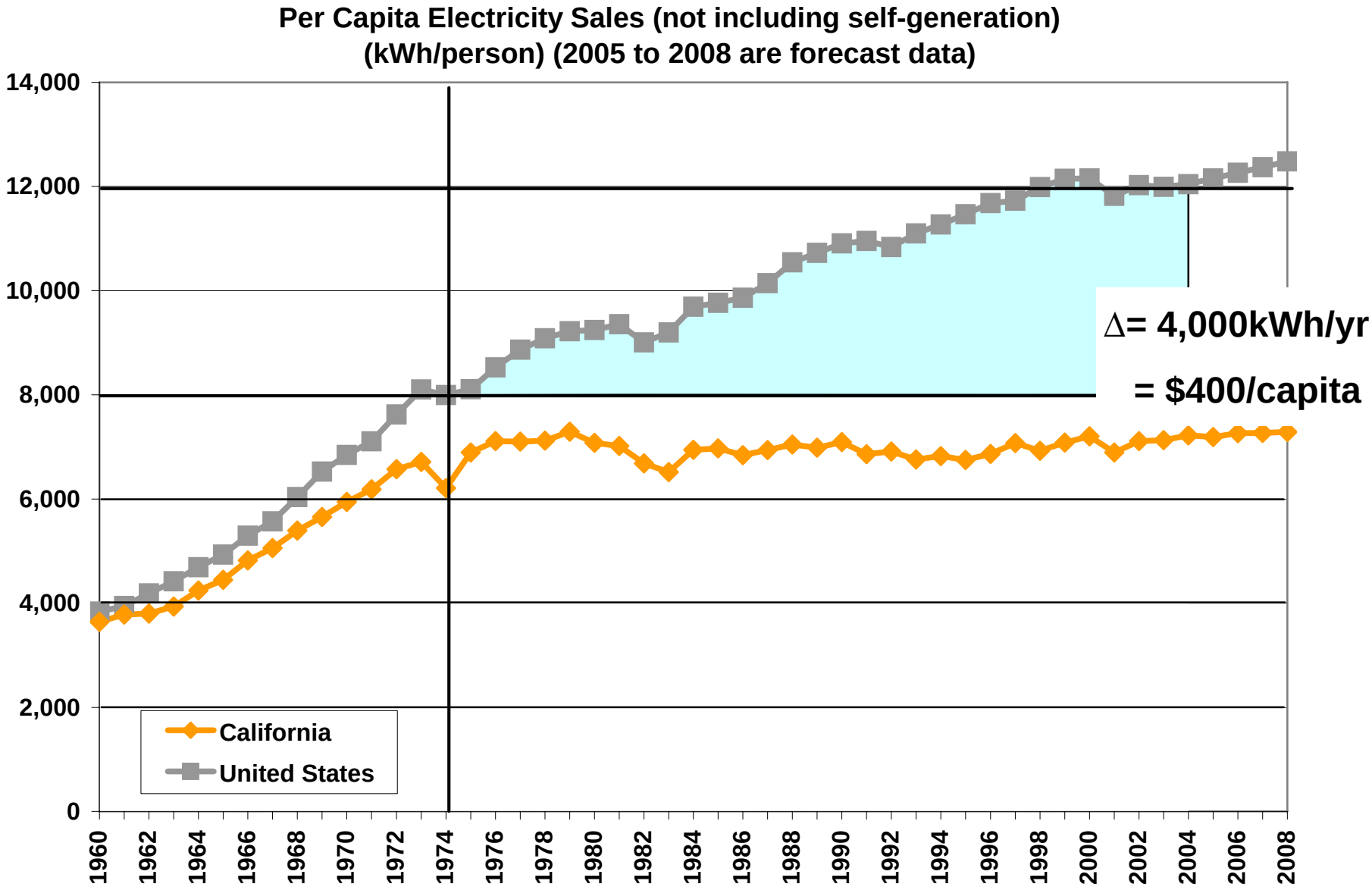
Conservation and Efficiency.

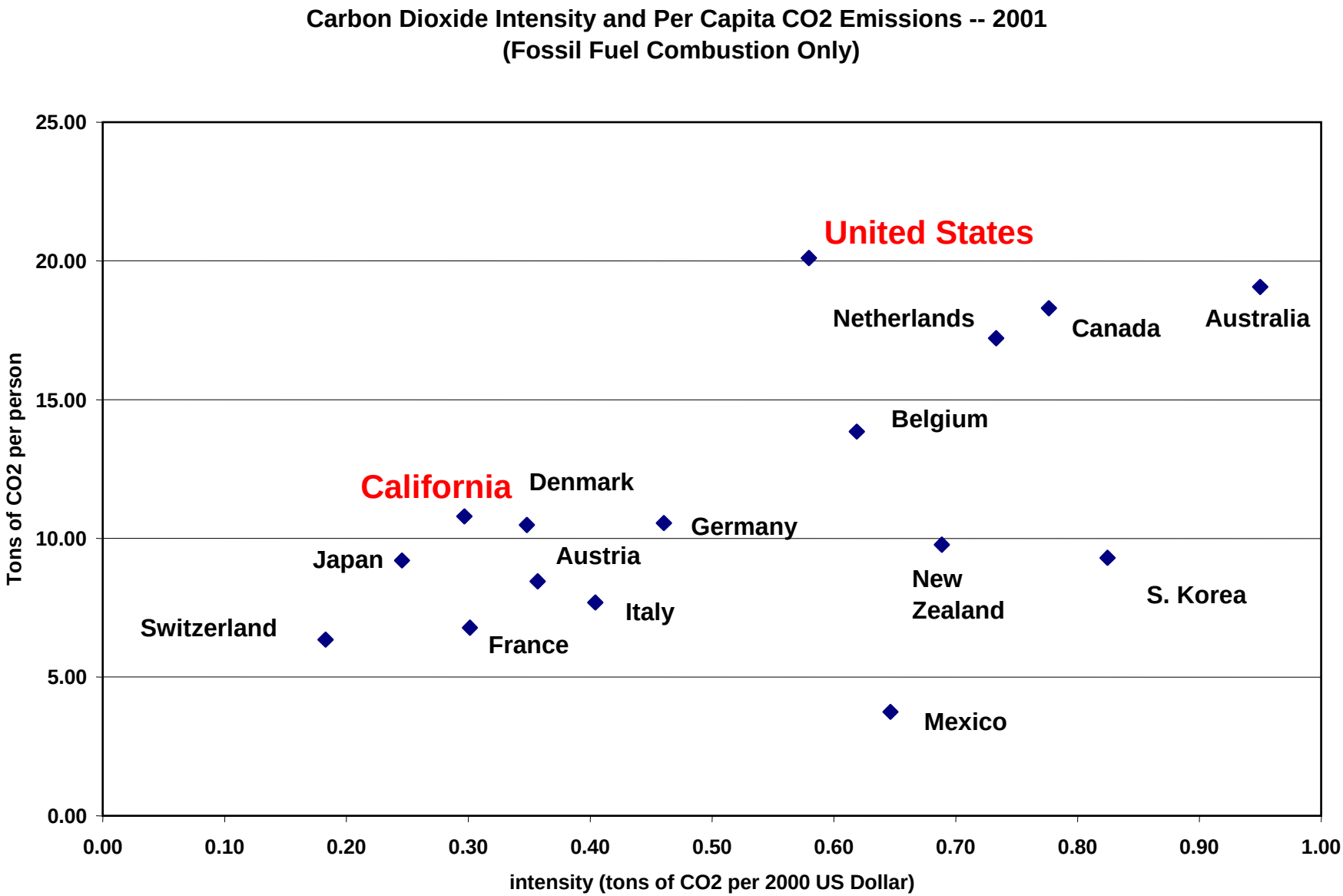
Nuclear for Baseload Application.

Ready for Limited Deployment Now

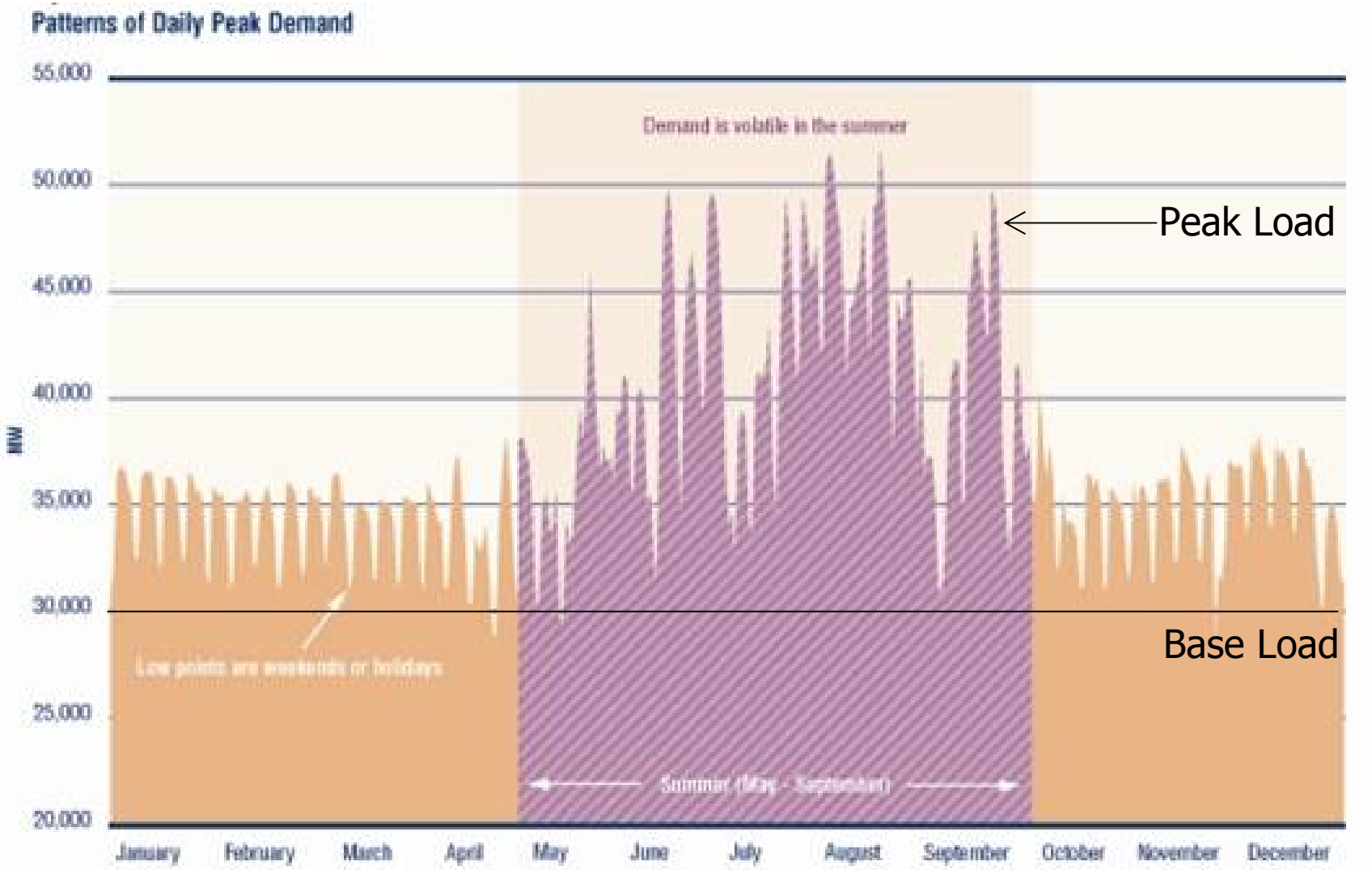
Solar for Daytime Use.

Wind with Back up from Others.


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
Δ= 4,000kWh/yr
= $400/capita

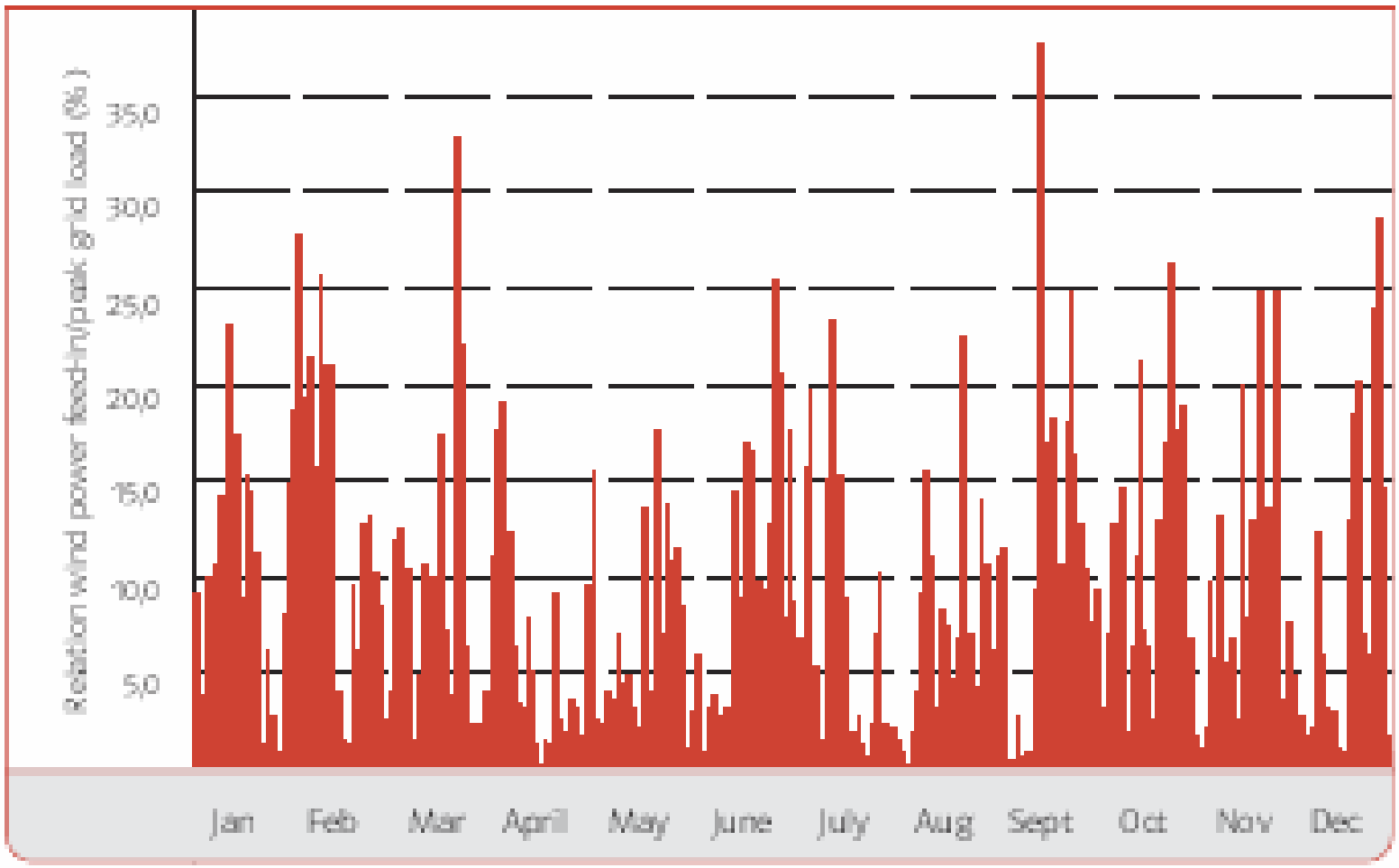

Carbon Dioxide Intensity and Per Capita CO2 Emissions -- 2001
(Fossil Fuel Combustion Only)
Tons of CO2 per person
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
intensity (tons of CO2 per 2000 US Dollar)
United States
Netherlands
Canada
Australia
Belgium
California
Denmark
Germany
Japan
Austria
New Zealand
S. Korea
Switzerland
Italy
France
Mexico

Peak Load vs. Base Load



Wind

- Commercially viable now (with 1.9¢/kw-hr subsidy).
- Nationally about 5000 Megawatts of installed capacity (2500 in CA).
- But, the wind does not blow all the time and average energy delivered is about 20% of capacity.
- Wind cannot be “base load” power until an energy storage mechanism is found.



EON-NETZ (GERMANY) WIND POWER VARIABILITY

AVERAGE IS 20% OF INSTALLED WIND CAPACITY

Solar Photovoltaic

- Expensive but costs are coming down.
- Also has a storage problem (day-night, clouds, etc.)
- Some places solar can be important.
- In U.S. solar is negligible now (less than 10% of wind, mostly in CA), but growing.

World Nuclear Expansion
(as of January 2007)

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

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.

Public Health Impacts per TWh*

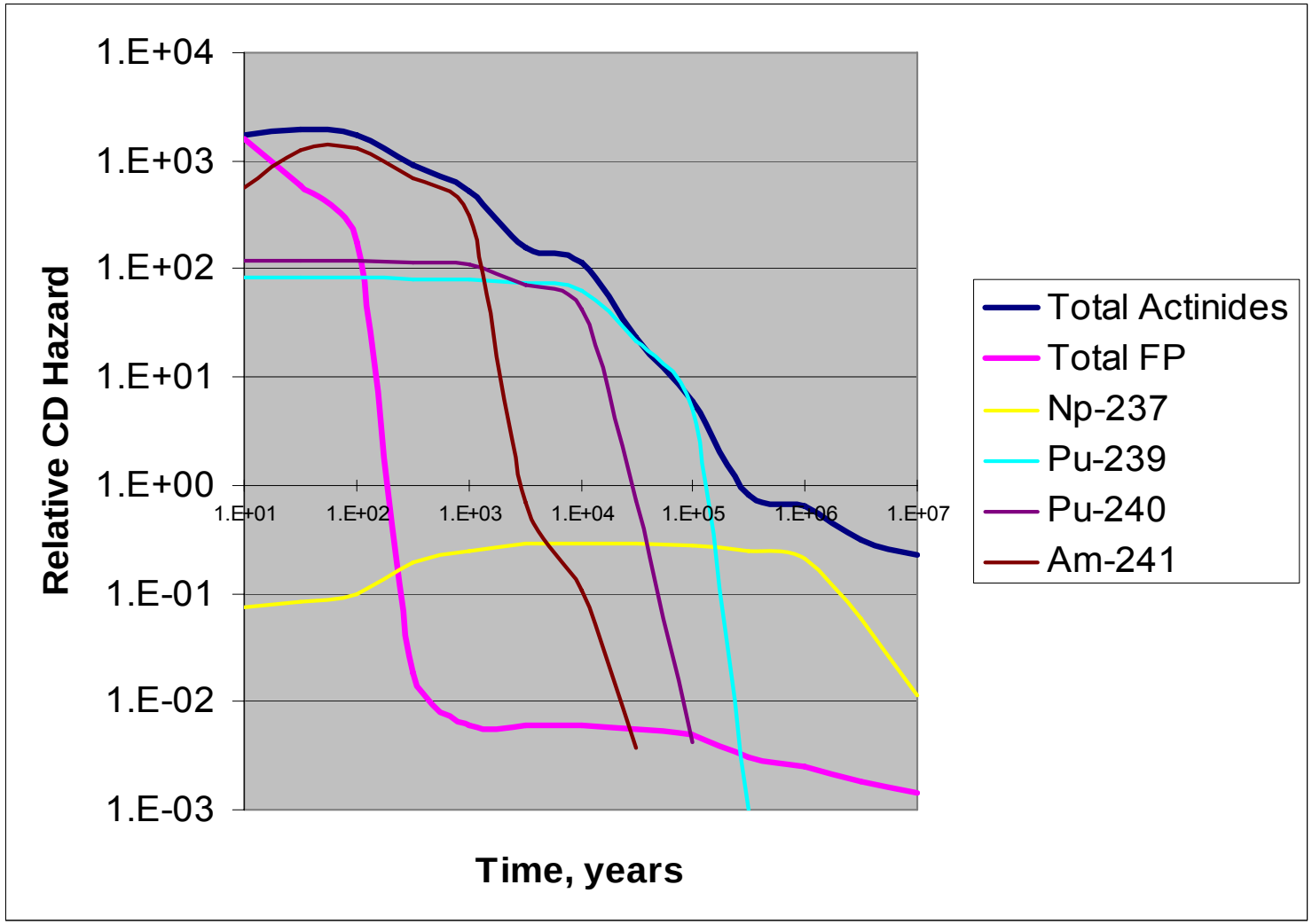
	Coal	Lignite	Oil	Gas	Nuclear	PV	Wind
Years of life lost:							
Nonradiological effects	138	167	359	42	9.1	58	2.7
Radiological effects:							
Normal operation					16		
Accidents					0.015		
Respiratory hospital admissions	0.69	0.72	1.8	0.21	0.05	0.29	0.01
Cerebrovascular hospital admissions	1.7	1.8	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).

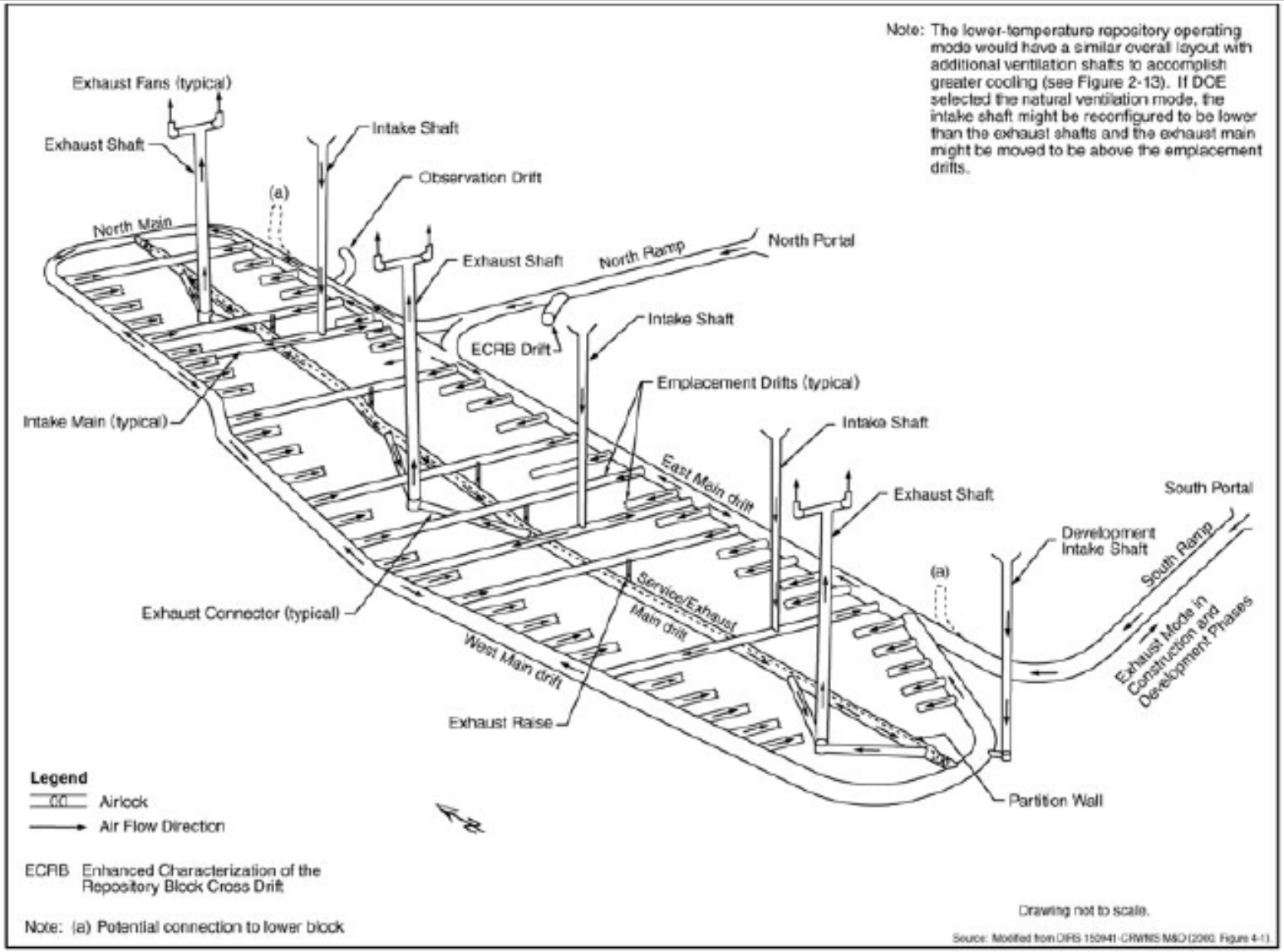
Components of Spent Reactor Fuel

Component	Uranium	Fission Fragments	Long-Lived Component
Percent Of Total	95	4	1
Radioactivity	Negligible	Intense	Medium
Untreated required isolation time (years)	0	200	300,000

Radiotoxicity of LWR Spent Fuel



Yucca Mountain Repository Layout



A Solution?

- Above ground dry cask storage for now.
- Retrievable storage as first repository stage.
- When in a world of expanded nuclear power, partition spent fuel
  - Put away fission fragments to decay.
  - Return Uranium to the ground.
  - Save the actinides to either burn up in Fast Reactors or use a starter fuel in breeder reactors.
- Whether you love or hate nuclear power 120,000 tons of spent fuel will accumulate from **today's** reactors.

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.

Internationalize the Fuel Cycle

Supplier States: Enrich Uranium

Take back spent fuel

Reprocess to separate Actinides

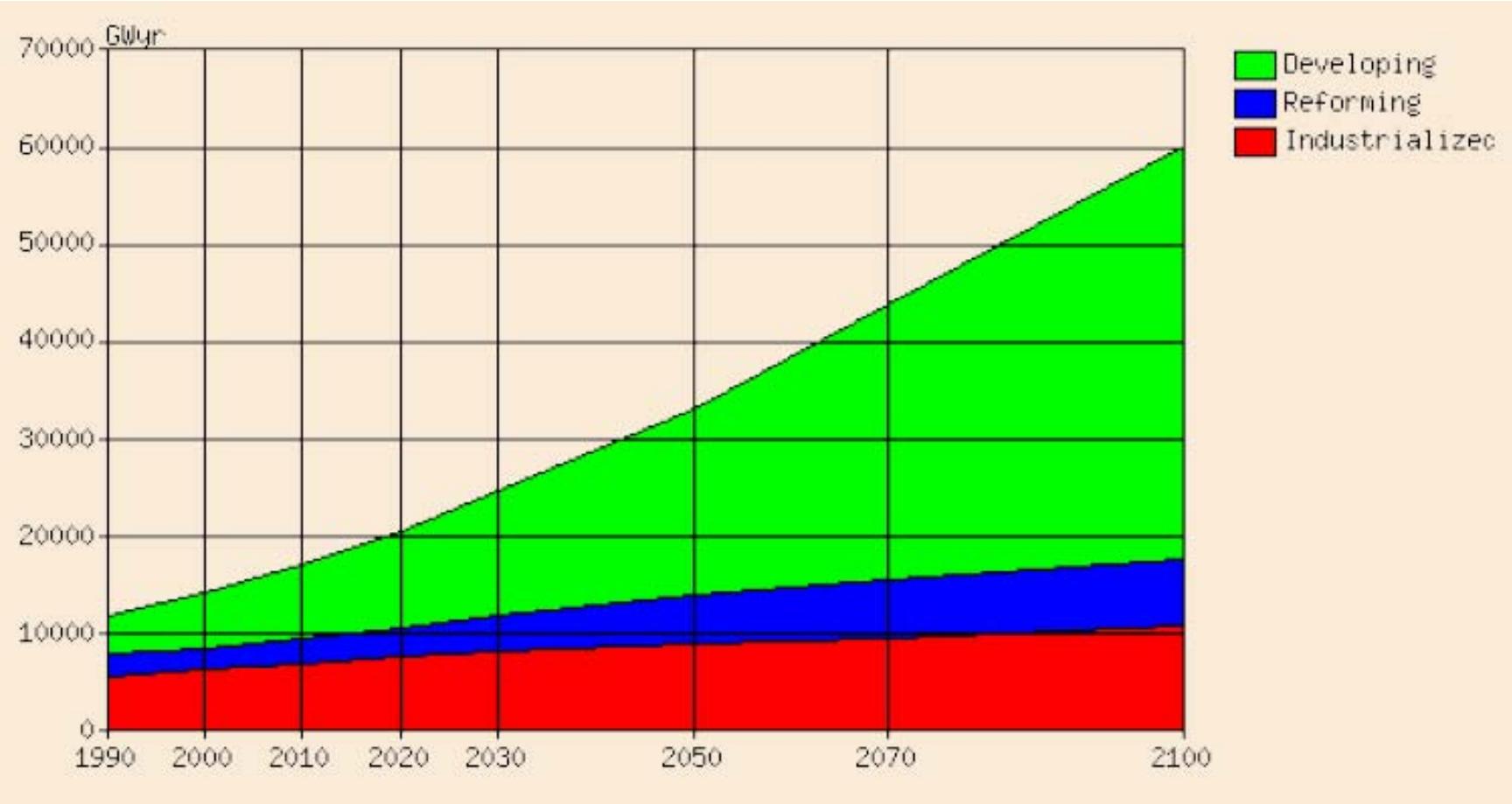
Burn Actinides in “Fast Spectrum” reactors

User States: Pay for reactors

Pay for enriched fuel

Pay for treatment of spent fuel (?)

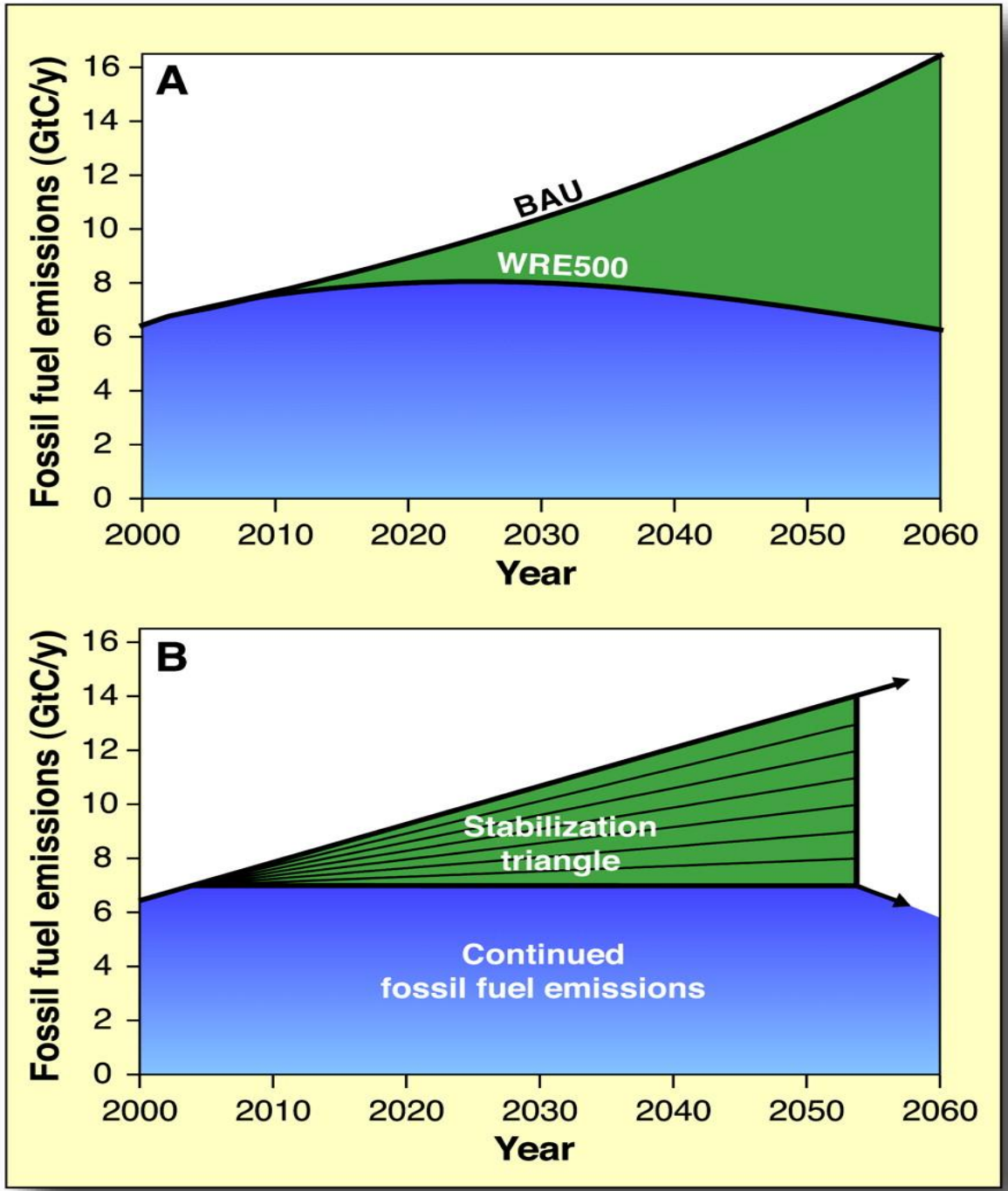
IIASA Projection of Future Energy Demand Scenario A1 (High Growth)



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)



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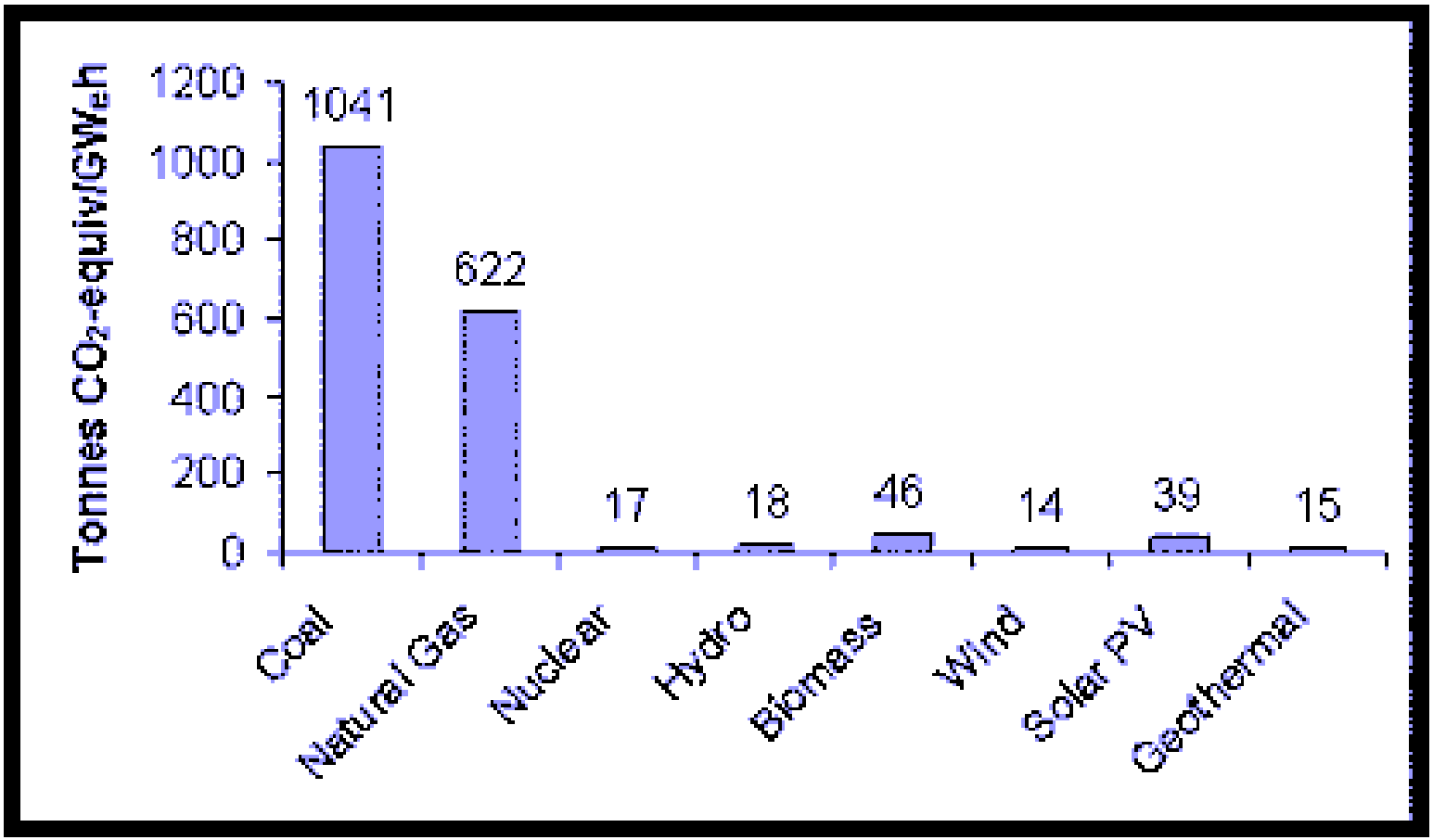
Back Up

Final Energy by Sector (IIASA Scenario B)

	2000	2050	2100
Residential and Commercial	38%	31%	26%
Industry	37%	42%	51%
Transportation	25%	27%	23%
Total (TW-yr)	9.8	19.0	27.4

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.

Table SPM-2. Projected globally averaged surface warming and sea level rise at the end of the 21st century for different model cases. The sea level projections do not include uncertainties in carbon-cycle feedbacks, because a basis in published literature is lacking. {10.5, 10.6, Table 10.7}

	Temperature Change (°C at 2090-2099 relative to 1980-1999) [a]		Sea Level Rise (m at 2090-2099 relative to 1980-1999)
Case	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations [c]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Notes:

[a] These estimates are assessed from a hierarchy of models that encompass a simple climate model, several EMICs, and a large number of AOGCMs.

[c] Year 2000 constant composition is derived from AOGCMs only

CO_2 Sequestration

- Most study has been on CO_2 injection into underground reservoirs.
- Capacity not well known.

Option	Gigaton CO_2	Fraction of Integrated Emissions to 2050
Depleted Gas Fields	690	34%
Depleted Oil Fields	120	6%
Deep Saline Aquifers	400 - 10,000	20% - 500%
Unmineable Coal	40	2%

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.

Environmental Standards

- EPA set a 10,000 year standard.
- Court held EPA violated 1992 Waste Policy Act
  - Mandated EPA follow scientific advice of NAS.
  - NAS said “Keep safe as long as dangerous”.
- EPA issued new standard that sets all sources dose limit for the dumbest person on Earth at 350mr/yr.
- Yucca goes on as before in principle.