

The End of Oil? The Future of What?

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Energy and Resources Group & Goldman School of Public Policy
University of California, Berkeley

Papers all online at: <http://socrates.berkeley.edu/~rael>

Cornell Alumni Association of Northern California, September 29, 2005

MIT Club, October 4, 2005



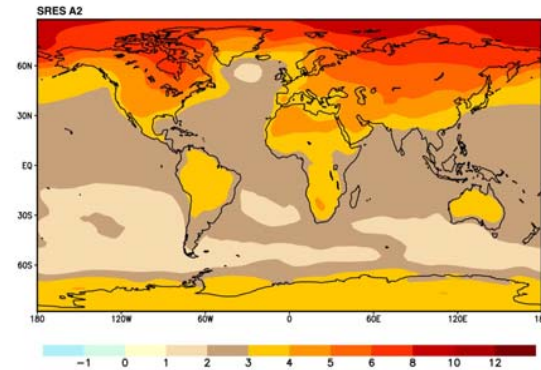
The UC Berkeley Institute of the Environment

A new campus initiative with over 200 faculty engaged in research, teaching efforts around cutting-edge environmental research and teaching.

- Co-Directors: Dan Kammen & Inez Fung

Initial focal areas:

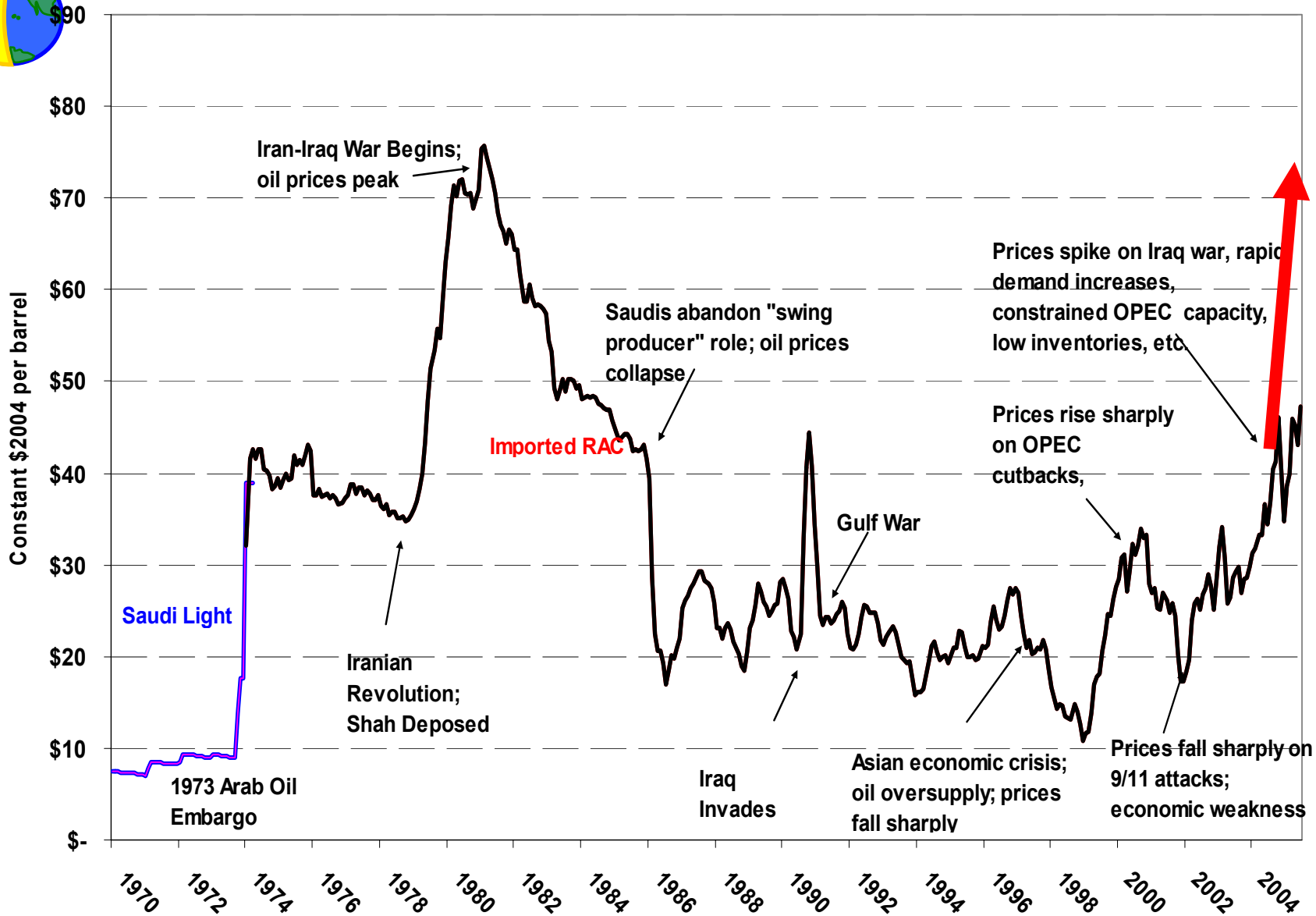
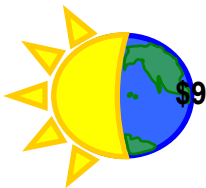
- Urban sustainability in the 21st Century (in partnership with the National Academies)
- Water Science and Technology
- Carbon Management



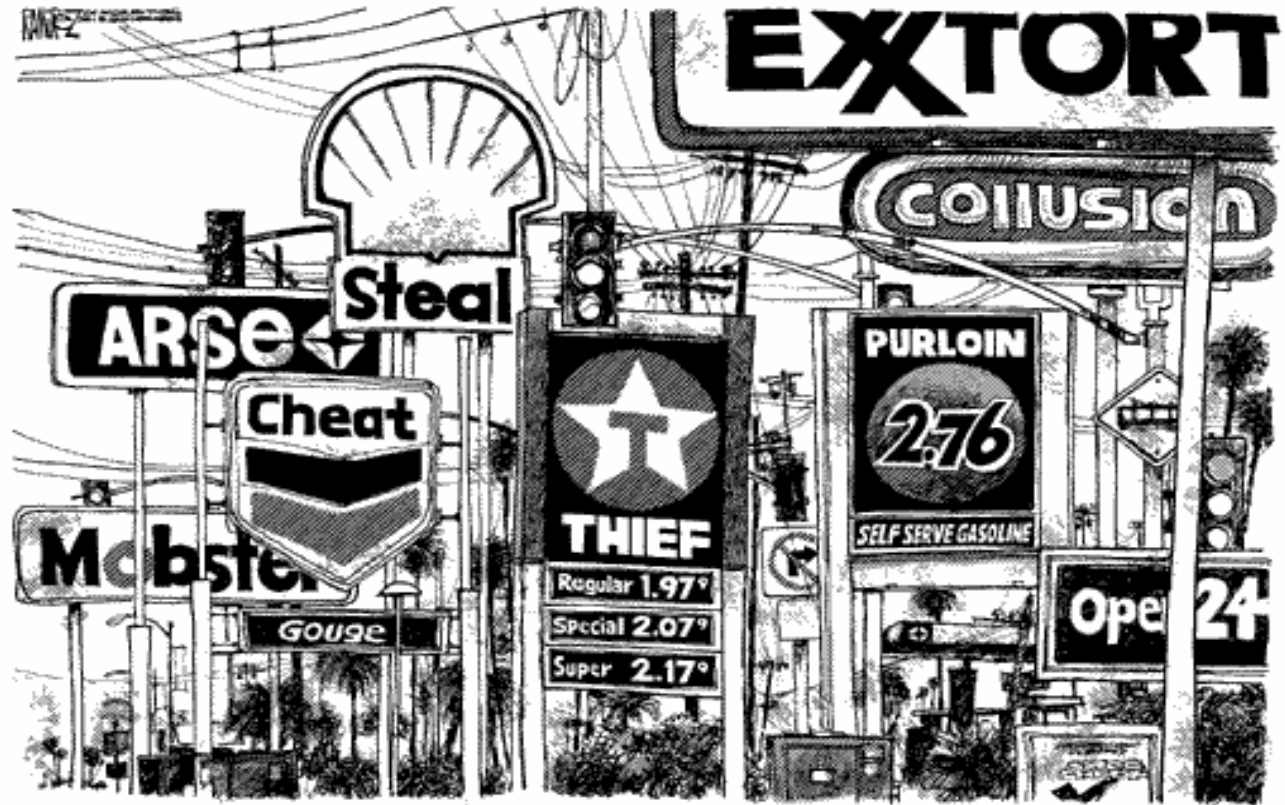
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Major Events and Real World Oil Prices, 1970-2005

(Prices Adjusted by Quarterly GDP deflator, 2Q 2005 Dollars)

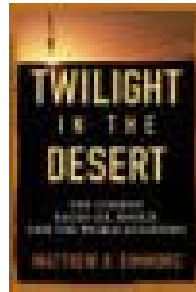
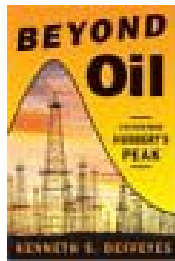
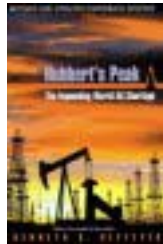


Cartoons Can't Even Keep Up...

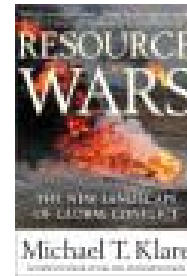




The end of oil?



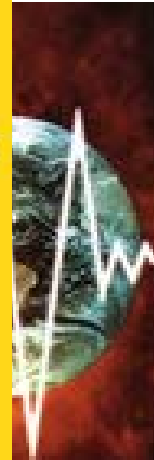
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Creating Oil Oligo-	00 00 00
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by	00 00 00
C. J. Campbell	00 00 00
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The LONG EMERGENCY

SURVIVING the CONVERGING CATASTROPHES
of the TWENTY-FIRST CENTURY

JAMES HOWARD KUNSTLER
AUTHOR OF *THE GEOGRAPHY OF NOWHERE*



KENNETH B. DEFFRELL

THE 2030 SPIKE

COUNTDOWN TO GLOBAL CATASTROPHE

COLIN MASON

The END of SUBURBIA

Oil Depletion and The Collapse
of The American Dream



*"We're literally stuck up a cul-de-sac
in a cement SUV without a fill-up"*

- James Howard Kunstler

KLARE
AUTHOR OF *RESOURCE WARS*

OD DIL

THE DANGERS AND
CONSEQUENCES OF
AMERICA'S GROWING
OLEUM DEPENDENCY



THE AMERICAN EMPIRE PROJECT

Hubbert's most famous prediction

(Hubbert, Shell Development Company document #95, June 1956)

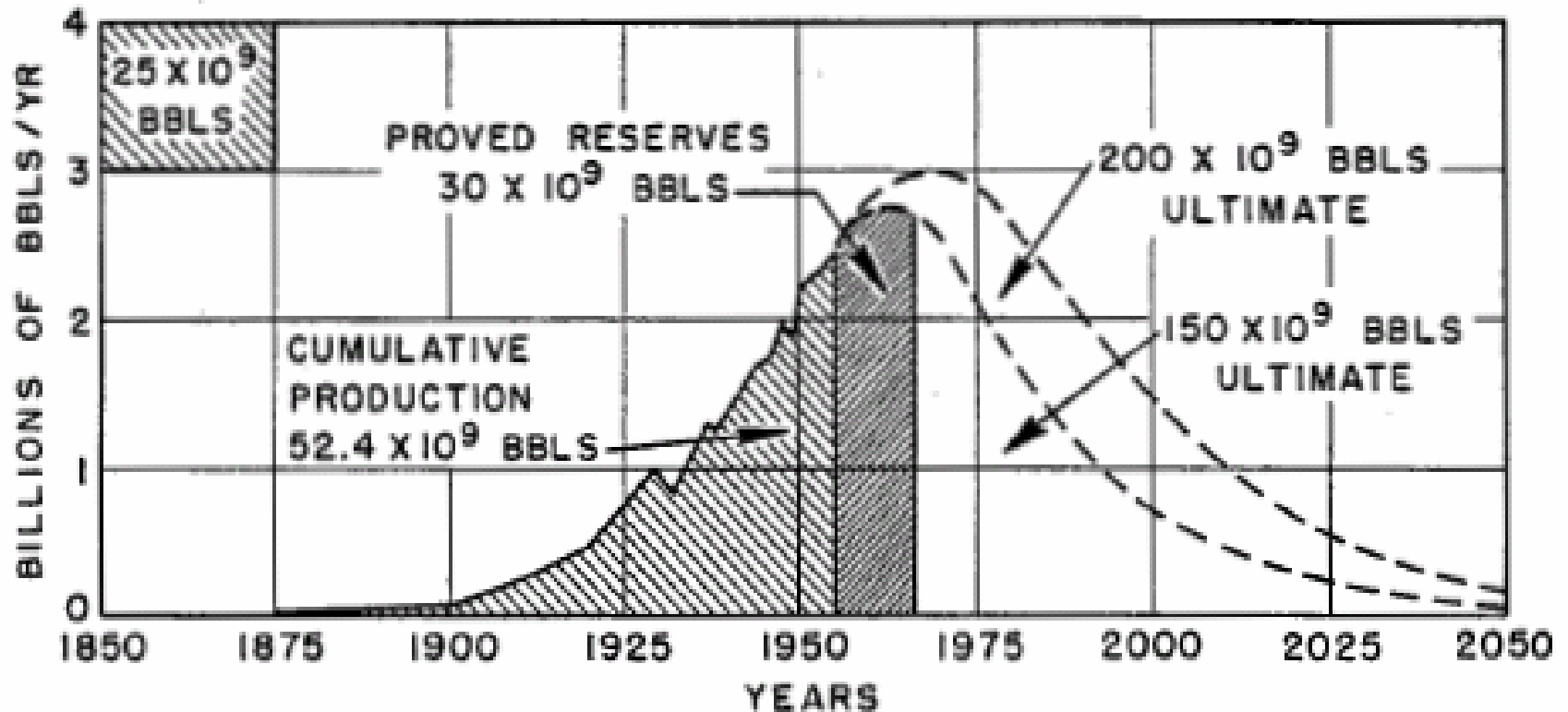
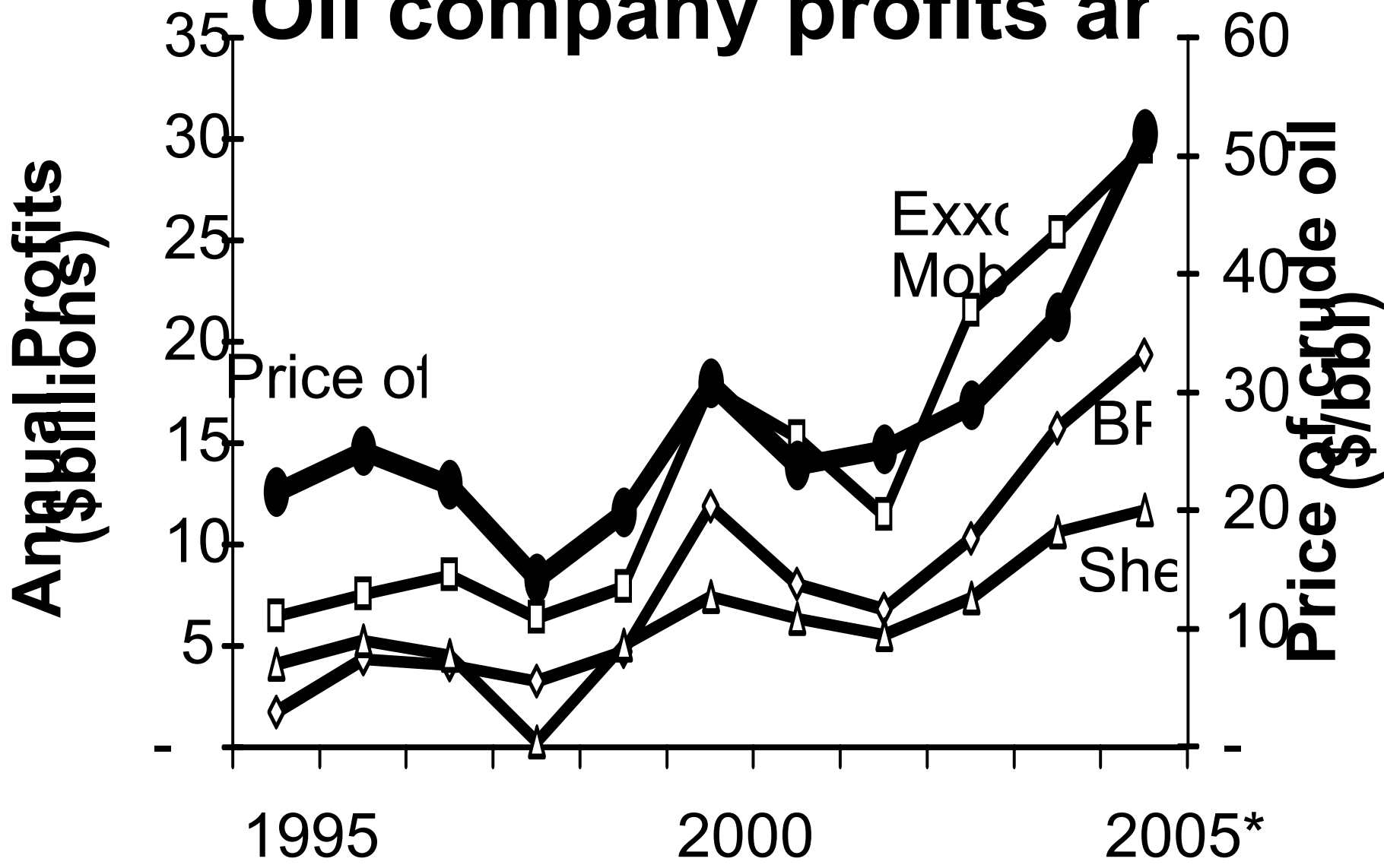


Figure 21 - Ultimate United States crude-oil production based on assumed initial reserves of 150 and 200 billion barrels.

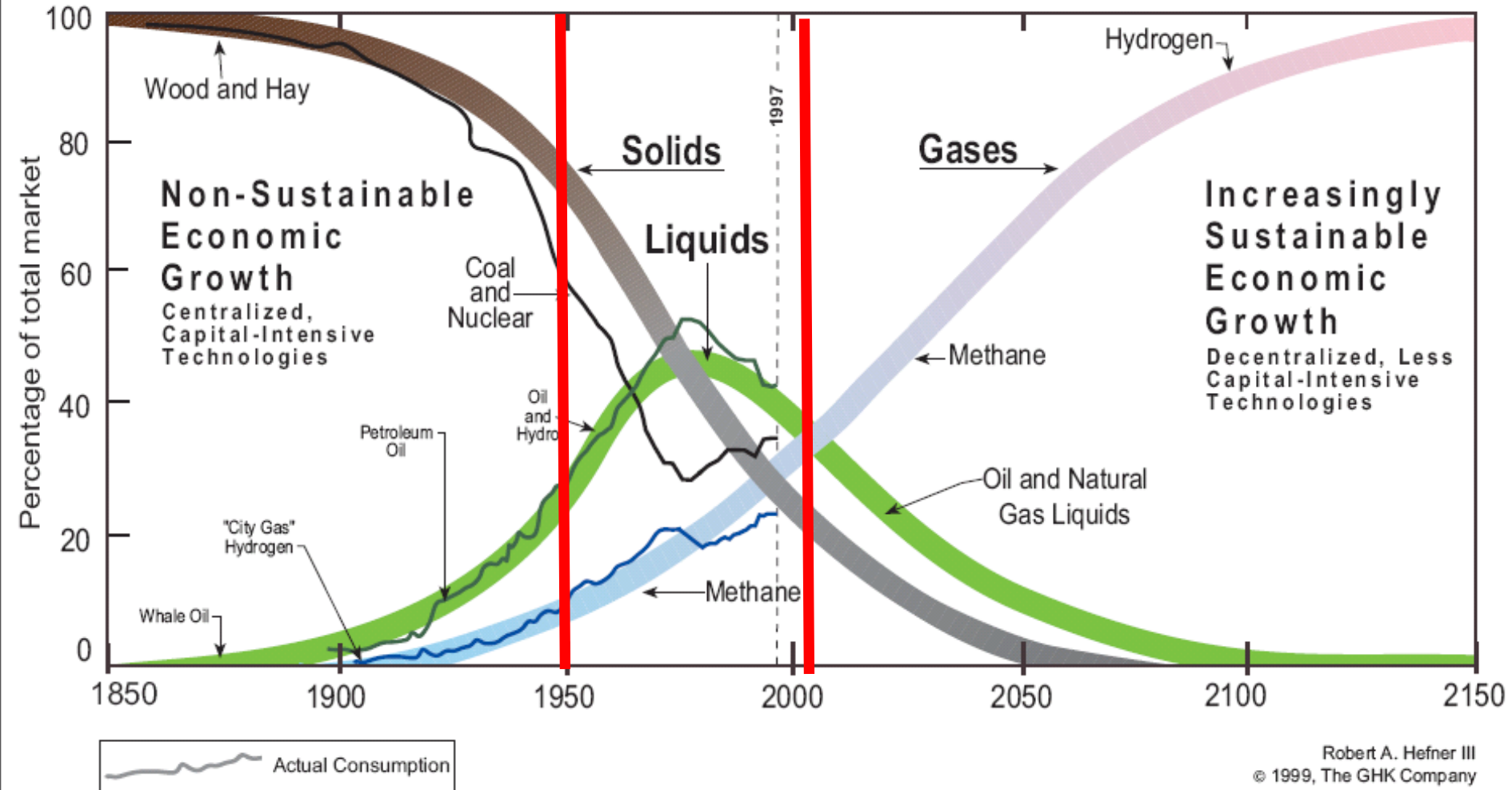
Oil company profits ar



Source: Nemet & Kammen (2005)

Oil and society

Global Energy Systems Transition





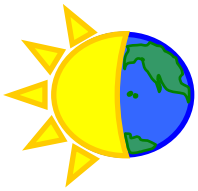




PLT 36 SULFUR BLOCK & TANK AREA

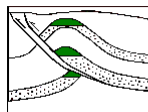
RESTRICTED ACCESS

PERMITS CALL SECONDARY U/G 15474
EMERGENCY CALL 1911
FLAME RESISTANT COVERALLS REQUIRED
NO SMOKING, NO BEARDS



Western Hemisphere – Alberta Oil Sands

- The Canadian Association of Petroleum Producers estimates that production from oil sands in Alberta will be 2.8 million BOPD in 2015, up from 1.2 million BOPD in 2004.
- In the Athabaska area, mining operations are used to recover solid hydrocarbons from near-surface sands.
- At Cold Lake, Wabasca and Peace River, cyclic steam injection and SAGD are used to recover very heavy crudes.



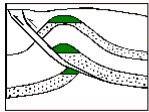
Greg
Croft Inc.





Western Hemisphere: Venezuela Heavy Oil Belt

- The Heavy Oil Belt is divided into four parts; Machete, Zuata, Hamaca and Cerro Negro.
- Original oil in place is estimated to be 1,250 billion barrels.
- Producing depths range from 1,200 to more than 3,000 feet.
- The oil is much less viscous than in the Alberta oil sands.
- Cyclic steam stimulation produces good flow rates.

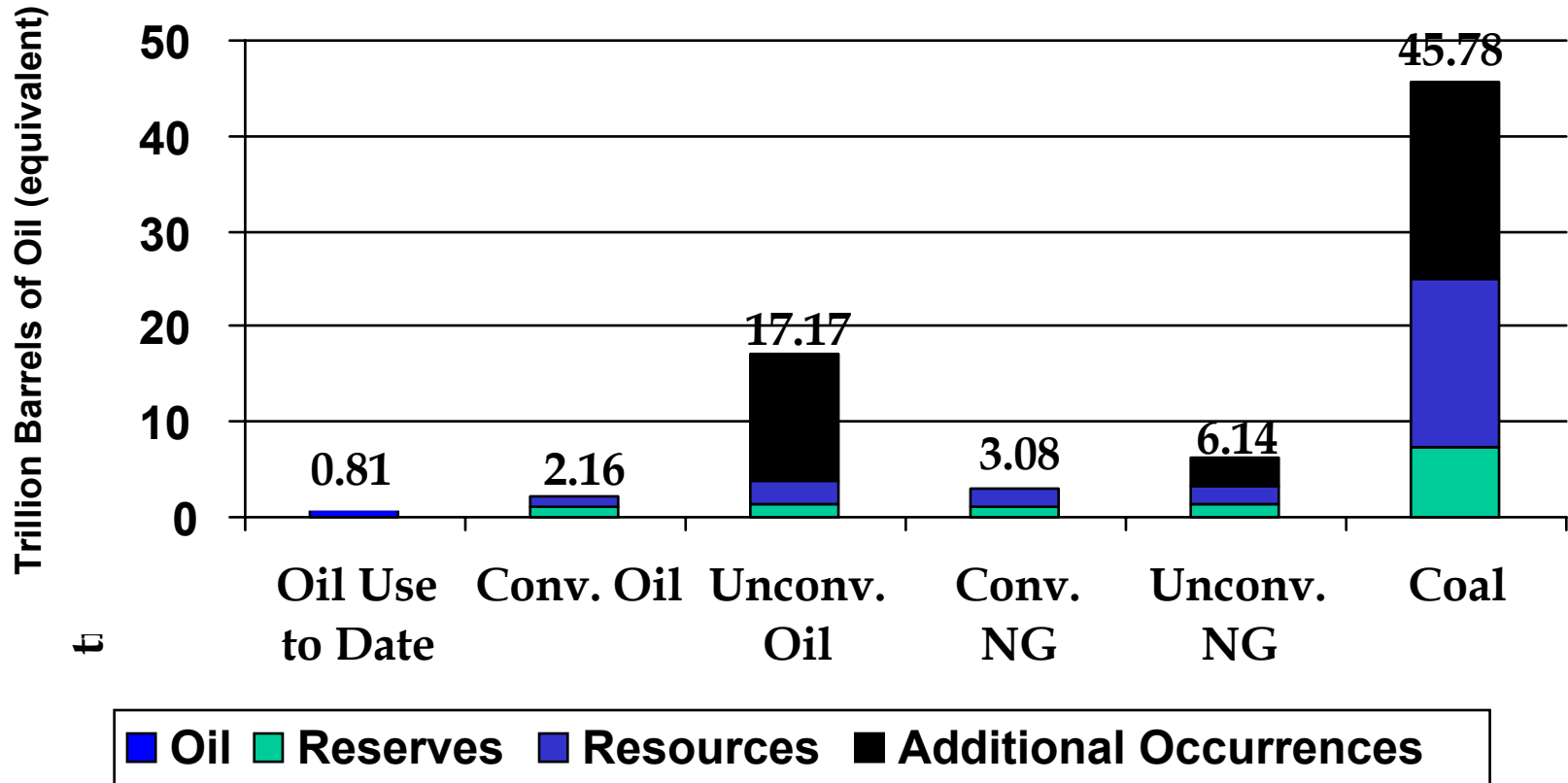


Greg
Croft Inc.

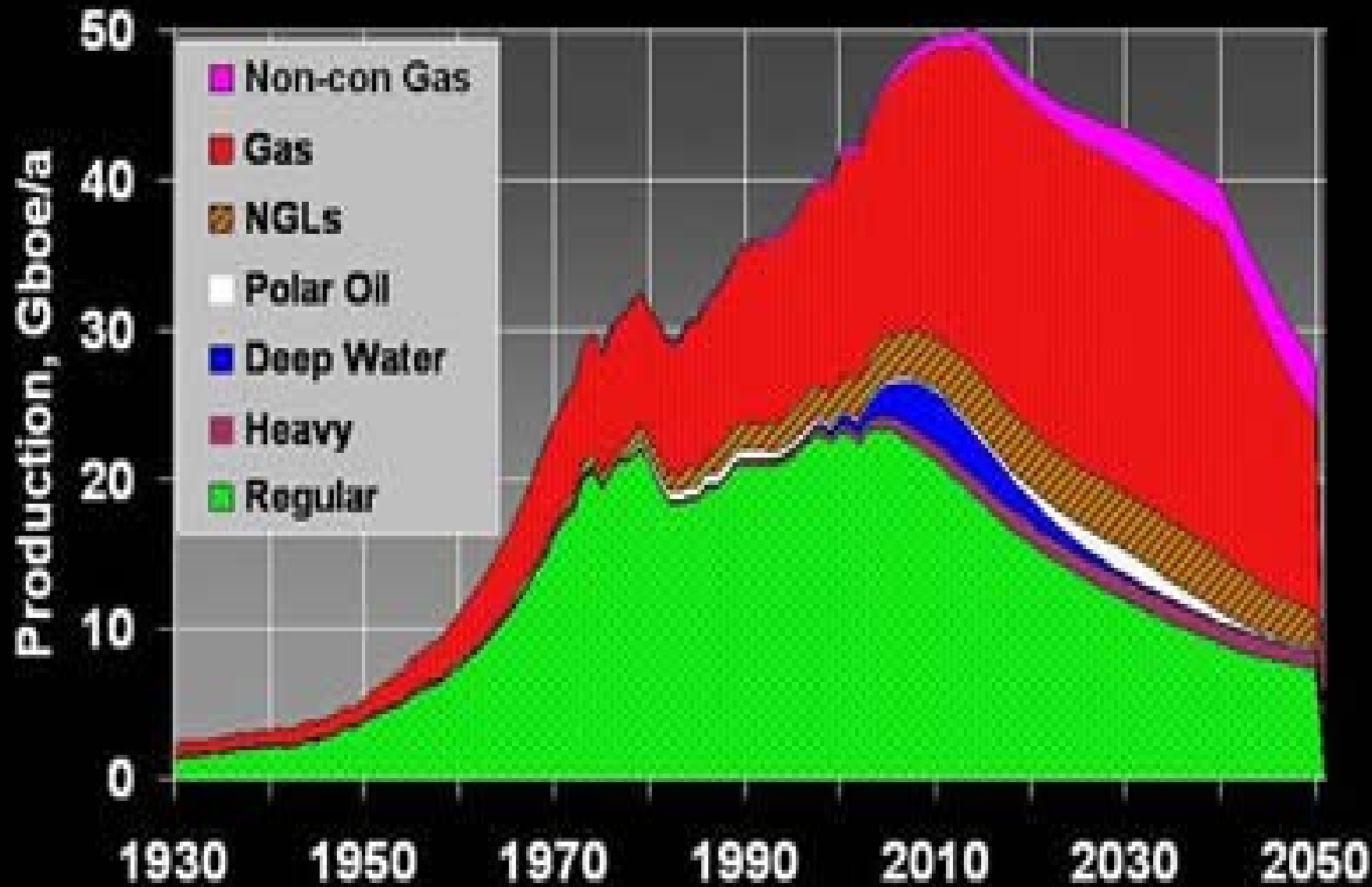





The Fossil Fuel Potential is *very* Big



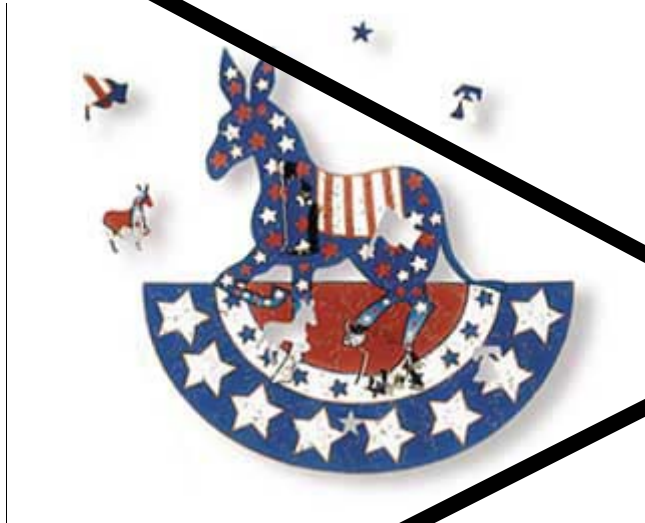
Source: KAMMEN, D. M. & PACCA, S., *ANNUAL REVIEW OF ENVIRONMENT AND RESOURCES*, 2004.





**The USA uses
25% of all energy
human use on the
planet.**

The Two Energy Philosophies

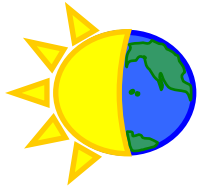


Consume Less!



Generate More!

Now: Subsidize All!



We are living as energy *hunter-gatherers* We could be energy *farmers*

What we have:

- Energy is the largest industry on the planet, *by far*
- The energy industry, already a monopolistic, is consolidating
- The U. S. spends \$1 billion *per day* on fuel, 60% imported
- We have entered an era of high and volatile oil prices.
- We are *running out of atmosphere faster than we are out of oil*

What we know:

- Energy diversity is our best defense against shortages & crises
- Large changes are needed, but *tool exist to make this happen*
- Despite its central importance, we continue to completely neglect energy policy (the current federal debate is, sadly, an example)

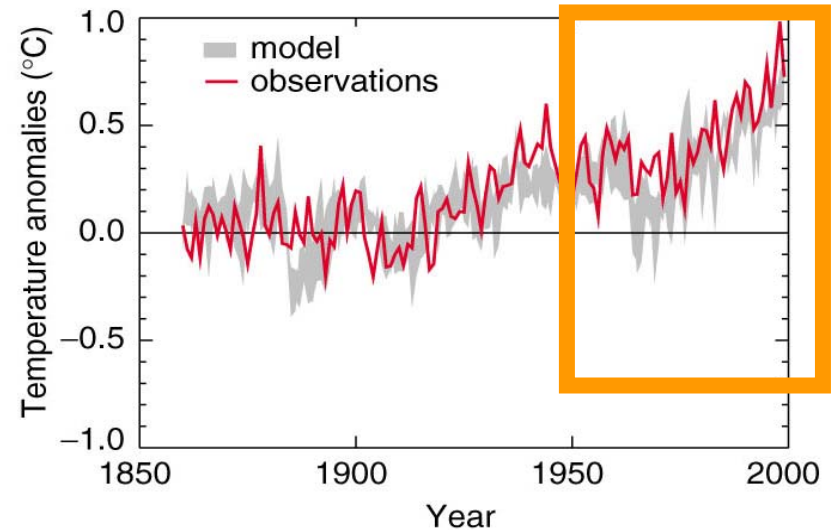
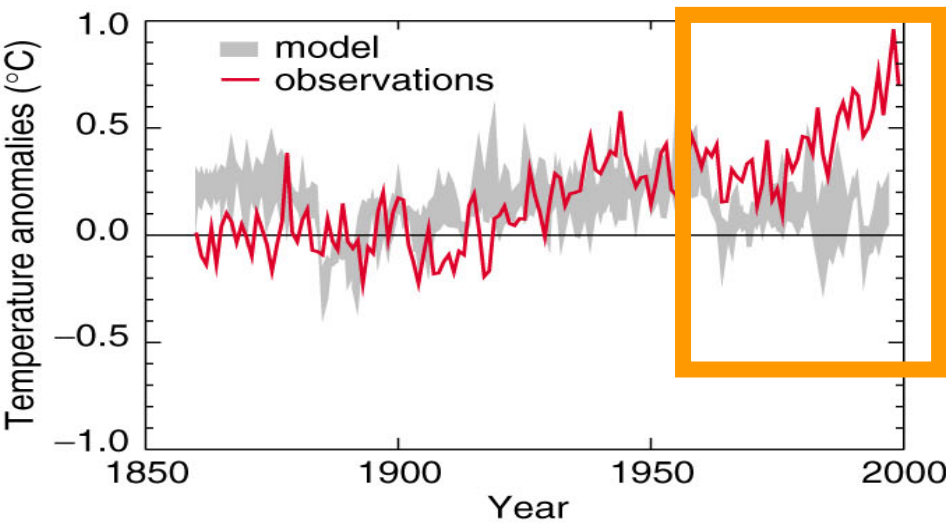
At A gas Station Near You

QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

Modeled Response to Natural & Anthropogenic Climate Forcings

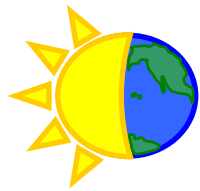
GCM: Natural forcings only

GCM: human + natural forcings

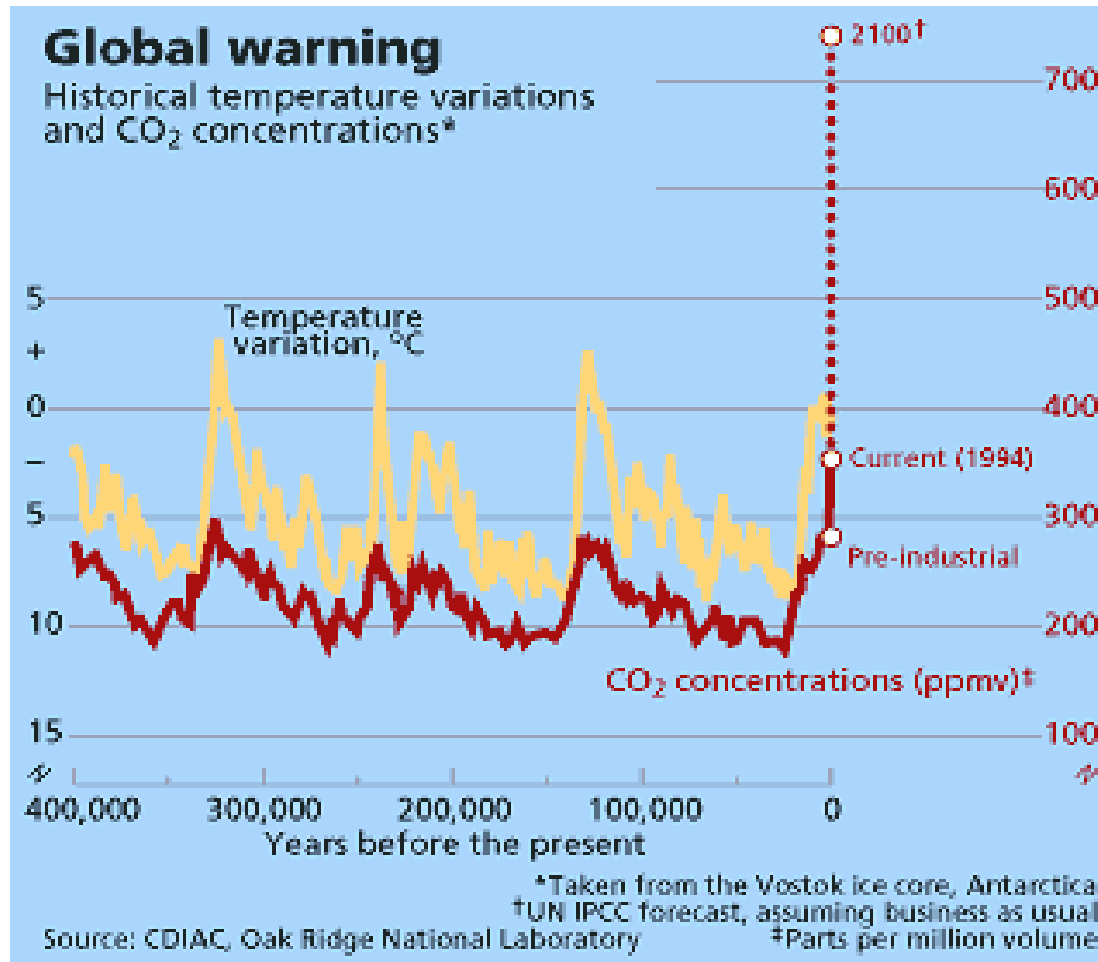


Global Circulation Model (GCM) results; summarized in IPCC 2001

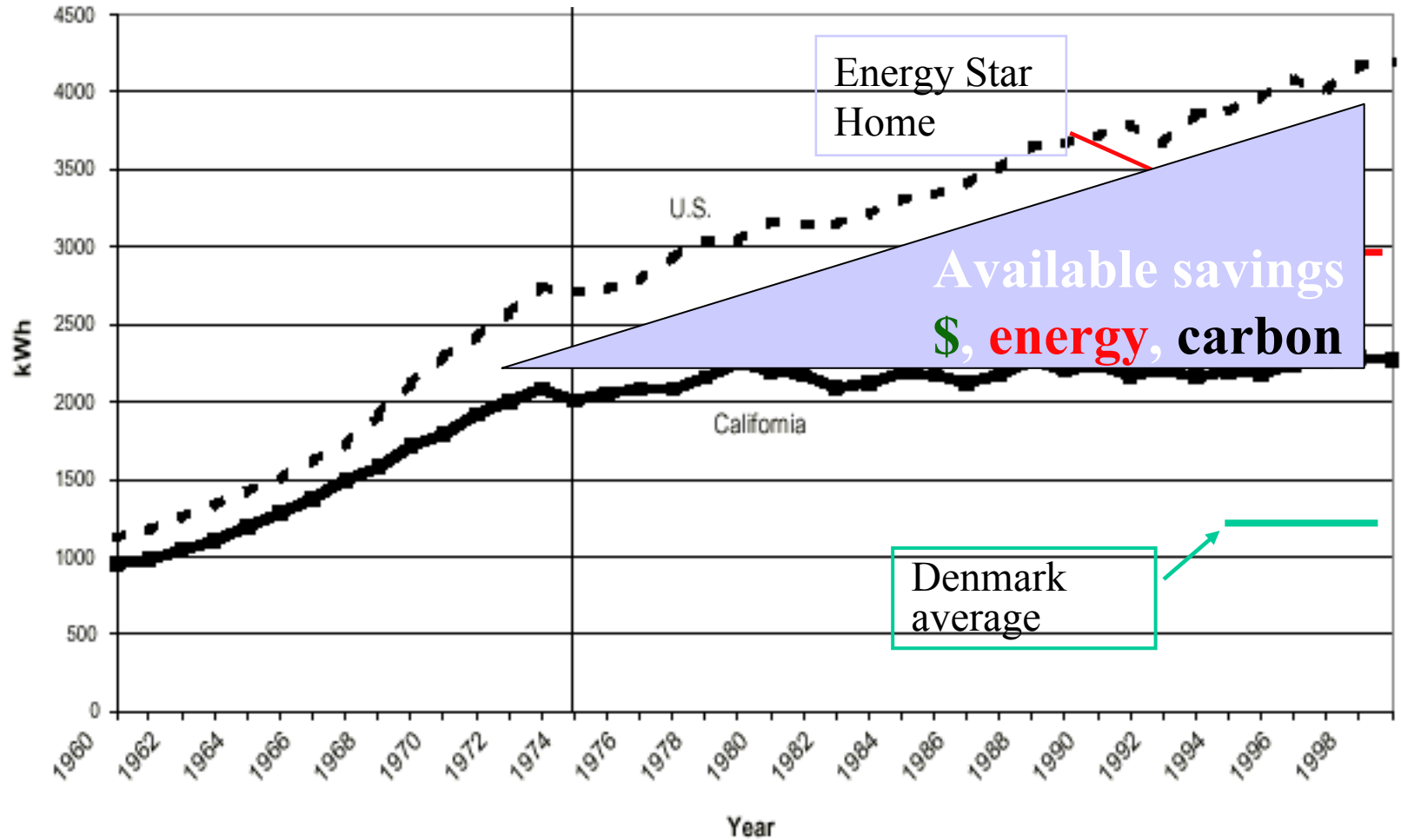
**Observational and model data agree:
We now have the 'smoking gun'**

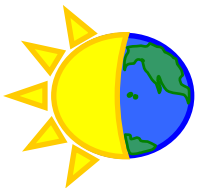


The Current Climate Experiment

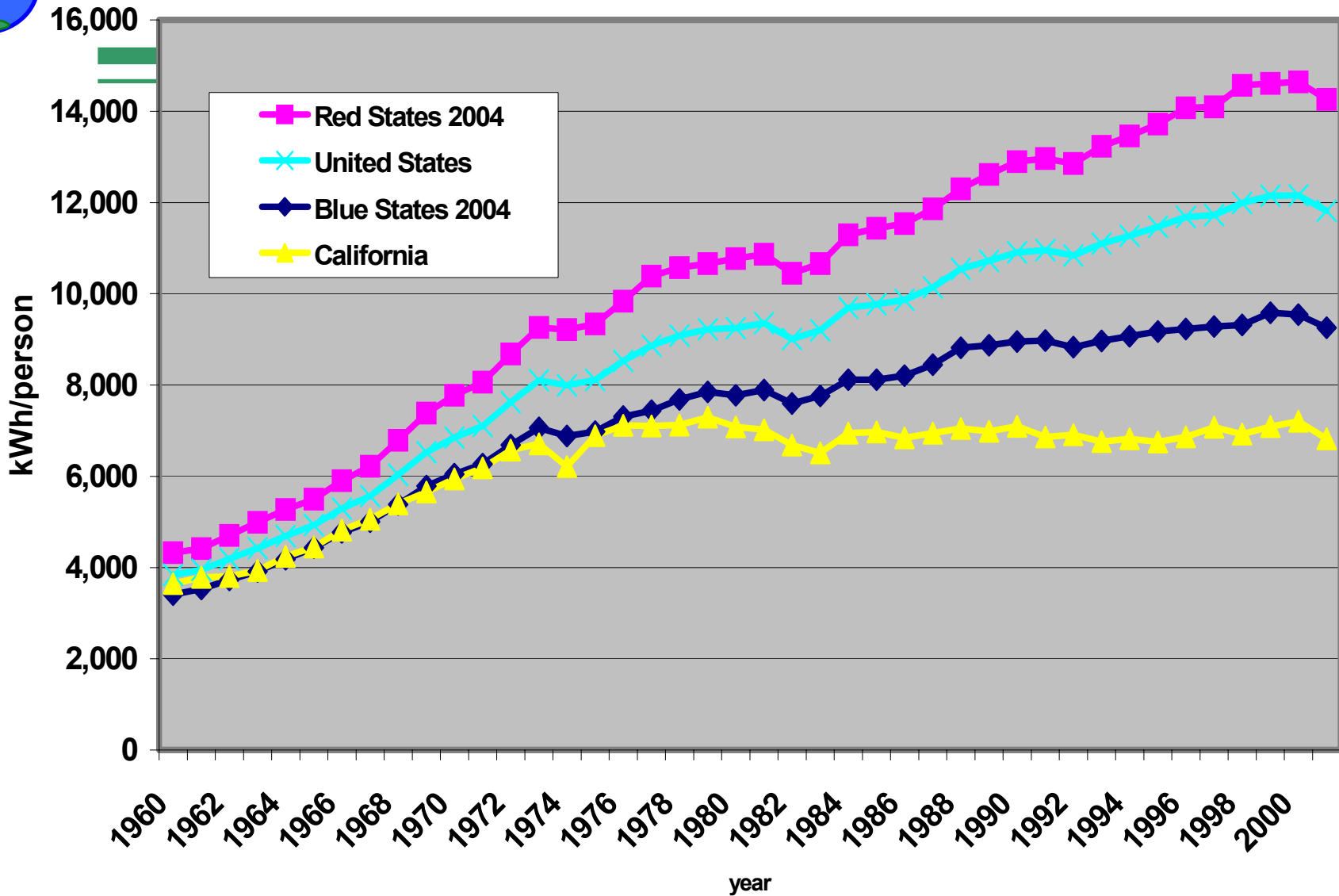


U. S. Residential Electricity Use (kWh/capita, 1960 - 2000)





Per Capita Electricity Consumption





So What Do the Skeptics Say?

Energy Efficiency?

Too unimportant

Solar?

Too expensive

Wind?

Too intermittent

Biomass?

Too bulky

Geothermal?

Too isolated

Fission?

Oh, we love this one.

Fusion?

Too far off

Newest guide for home buyers — the



You'll get more value for
 help from *The Medallion*, electrically
 inspected homes. TV stations:
 Washington, Daily Post-Times
 (beginning 3:45, 6 P.M.); CBS Network—
 Monday—10 P.M.; N.Y.C.,
 General Electric Theater
 (7:15 Network—
 Sunday—9 P.M.; N.Y.C.,
 Wednesday—Derry, Conn., Bob Crowley,
 The Edgewater and Today, 15 Out—
 NBC Network.

Betty Furness
WESTINGHOUSE

Ronald Reagan
GENERAL ELECTRIC

YOU GET WONDERFUL FEATURES



ELECTRIC APPLIANCES. Mrs. Stanley Johnson, Arlington Heights, Ill.: "I just love our Medallion home — especially the kitchen. All these electric appliances that came with it — like this wall oven — sure make my job much easier. And my husband says they're easier to buy this way, because we pay for them on the mortgage."



LIGHT FOR LIVING. Mr. and Mrs. Charles R. McCarty, Greensboro, N. C.: "We never knew you could do so many beautiful things with lighting until we bought a Medallion home. Valance lighting, for example, makes our furniture and drapes look wonderful — and at the same time gives our son a well-lighted place to practice the piano."

BETTER HOMES & GARDENS, OCTOBER, 1958

Live Better Electrically MEDALLION

This new Medallion assures you a home has been inspected by the local electric utility... meets modern standards for wiring, appliances and lighting. Look for the Medallion. It means a wonderful new way of life for you and your family!



Fran Allison
WHIRLPOOL

What Sterling is to silver... that's what this Medallion is to a new home! It's the new national symbol of the finest in electrical living. Let these three top TV stars, speaking here for the electrical industry, tell how you save trouble, time, and money by choosing a home that wears the Live Better Electrically Medallion.

BETTY: In a Medallion home, you start right off with a mod-

ern electric range, plus at least 3 additional major appliances, maybe more. They're installed, ready to go to work the day you move in! Appliances are easier to pay for this way.

RONNIE: The lighting in every Medallion home is specially planned, too. It provides better light for better sight, plus new beauty for your home. You also get full Housepower. This means enough power, wiring, circuits, switches, and outlets to handle all the appliances you want to use.

FRAN: You'll be glad all your life you bought a Medallion home. Read below what a few

of the thousands of new Medallion home owners think of them. They go over the Medallion homes in your neighborhood. Your electric utility will tell you where they are.

New Ideas for Better Living

The new Medallion is made up by home builders, electric utilities, and electrical manufacturers (Exelairs, General Electric, Hotpoint, Kelvinator, Thermador, Westinghouse, Whirlpool, and others). This year, utilities will award Medallions to 100,000 new homes — in every styled area — nationwide across the country. You'll see lots of new ideas in the Medallion homes on display now!

LIKE THESE IN MEDALLION HOMES!



FULL HOUSEPOWER. Mrs. Nick Piscopiello, Meriden, Conn.: "One of the things I like most in my Medallion home is all the handy outlets. I can plug in my portable cooking appliances wherever I want and use them — even with the washer going — without ever blowing a fuse. And I can cook a meal anywhere in the house — and outdoors, too."

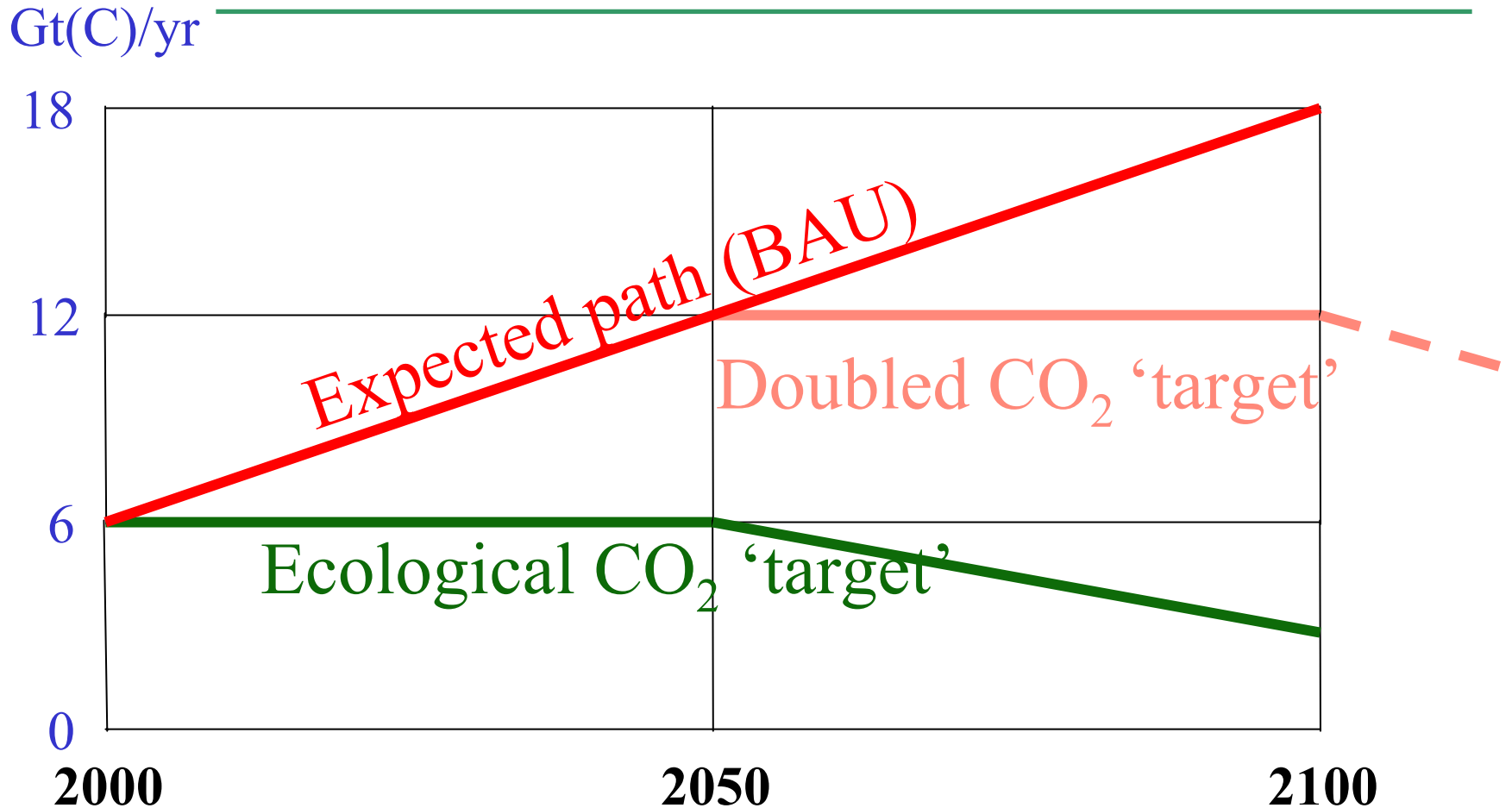


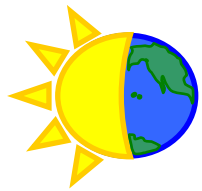
ELECTRIC HEATING. Many Medallion homes feature electric heating, too. These are awarded a special Gold Medallion. The all electric heat pump, shown here in the home of Mr. and Mrs. William Jones, Beverly Hills, California, provides year-round comfort from a central unit which automatically heats or cools as the weather requires.

BETTER HOMES & GARDENS, OCTOBER, 1958

Figure 14. Advertisement for the All-Electric Home, with Betty Furness, Ronald Reagan, and Fran Allison. Reproduced from *Better Homes and Gardens*, October 1958, with permission from the Edison Electric Institute.

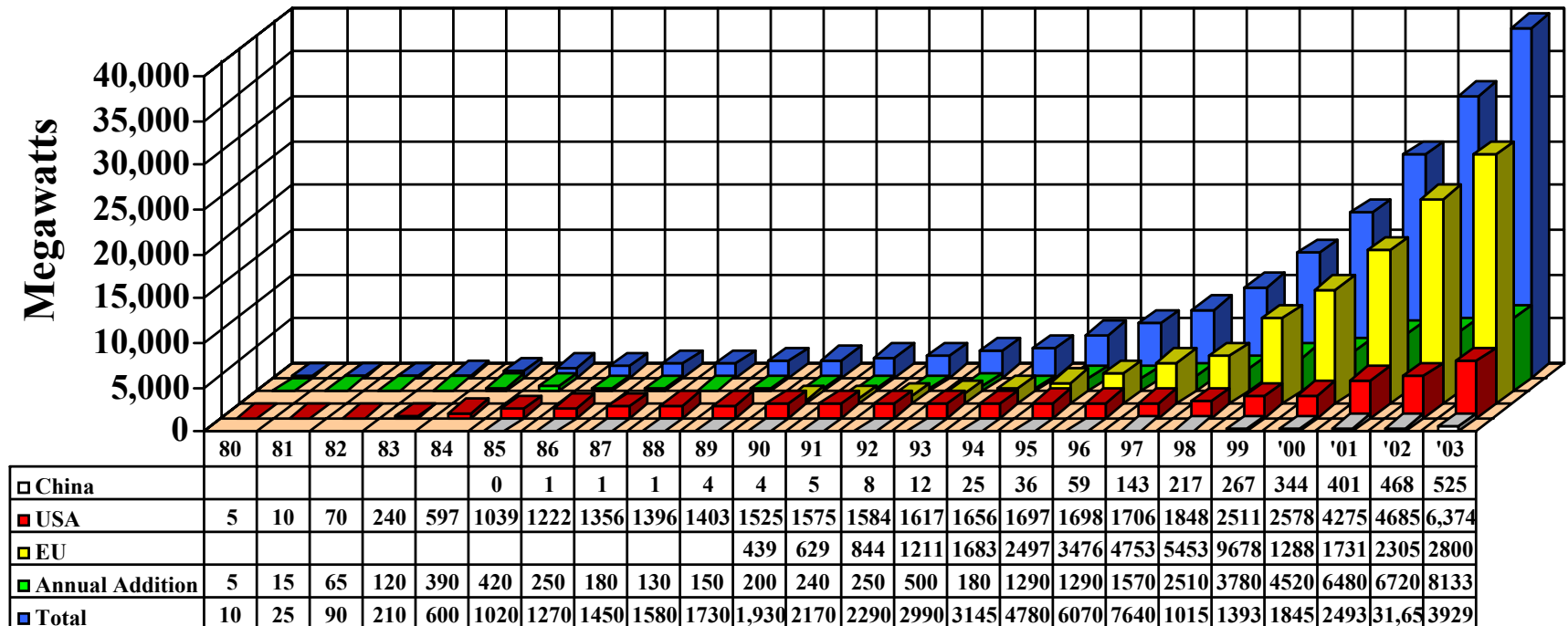
A Simple Carbon Heuristic





World Wind Electricity Capacity (Megawatts)

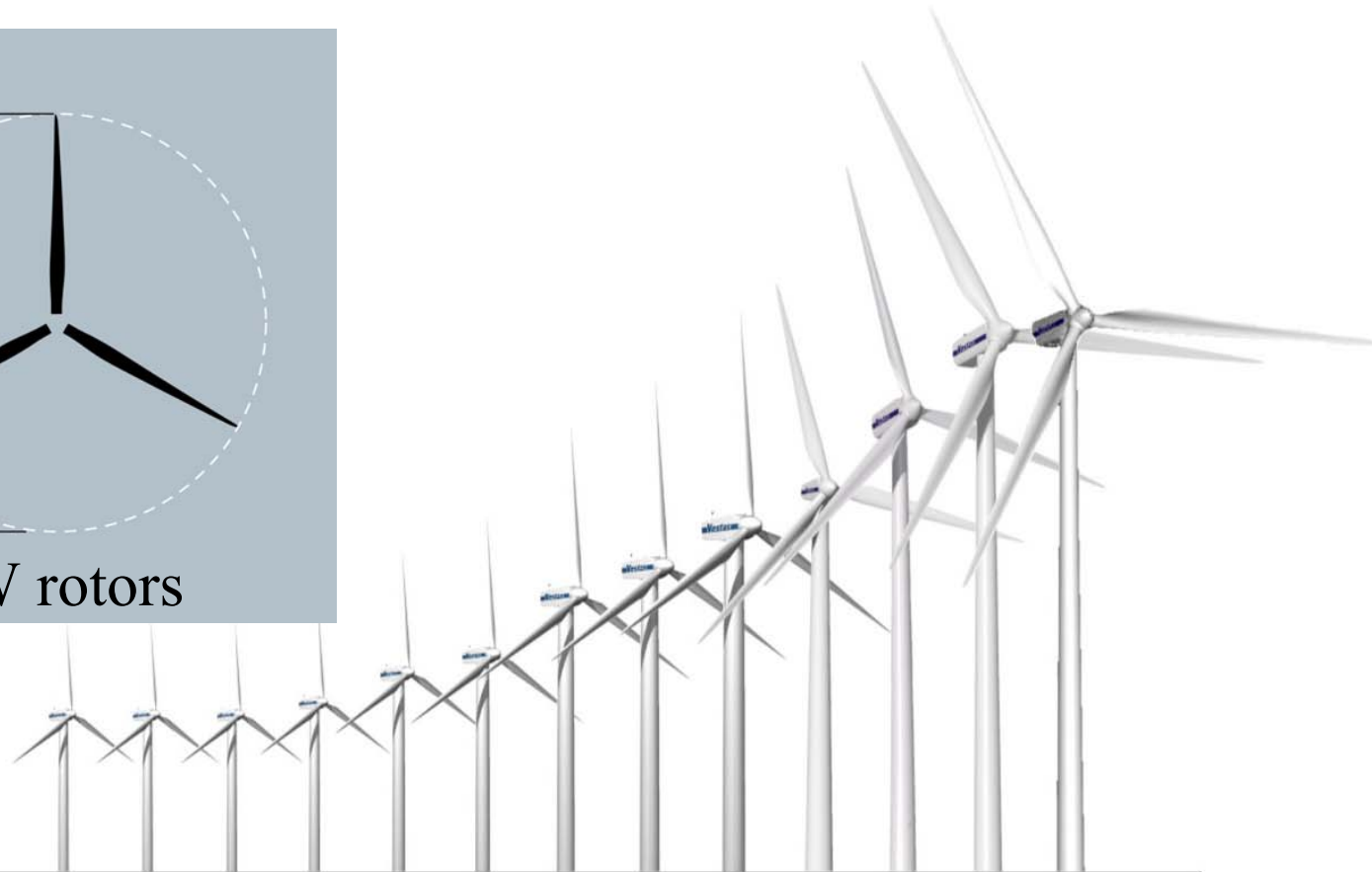
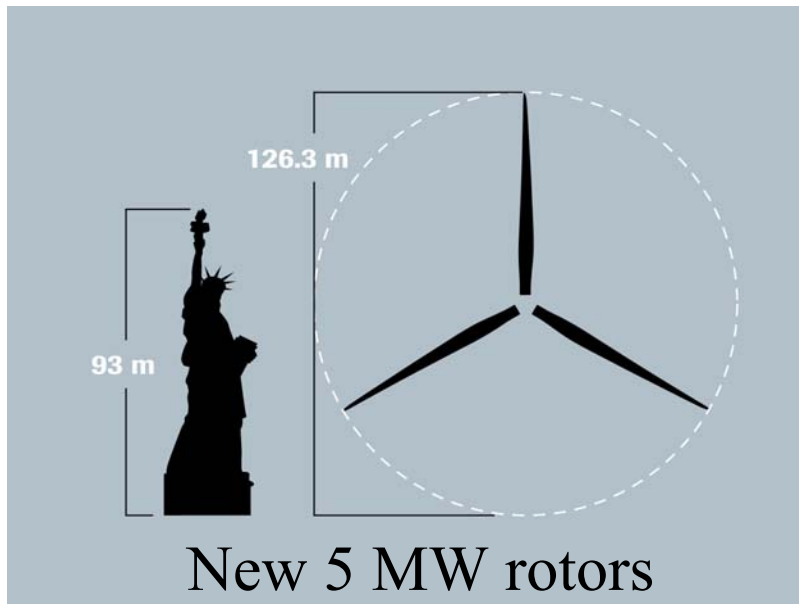
(20%+ annual growth for over a decade!)



Global leaders: Germany, Denmark, Spain, US, UK, China, India (> 85 of global market)
US was a global leader, today we are a player, but not the leader.

The Wind Turbine Revolution

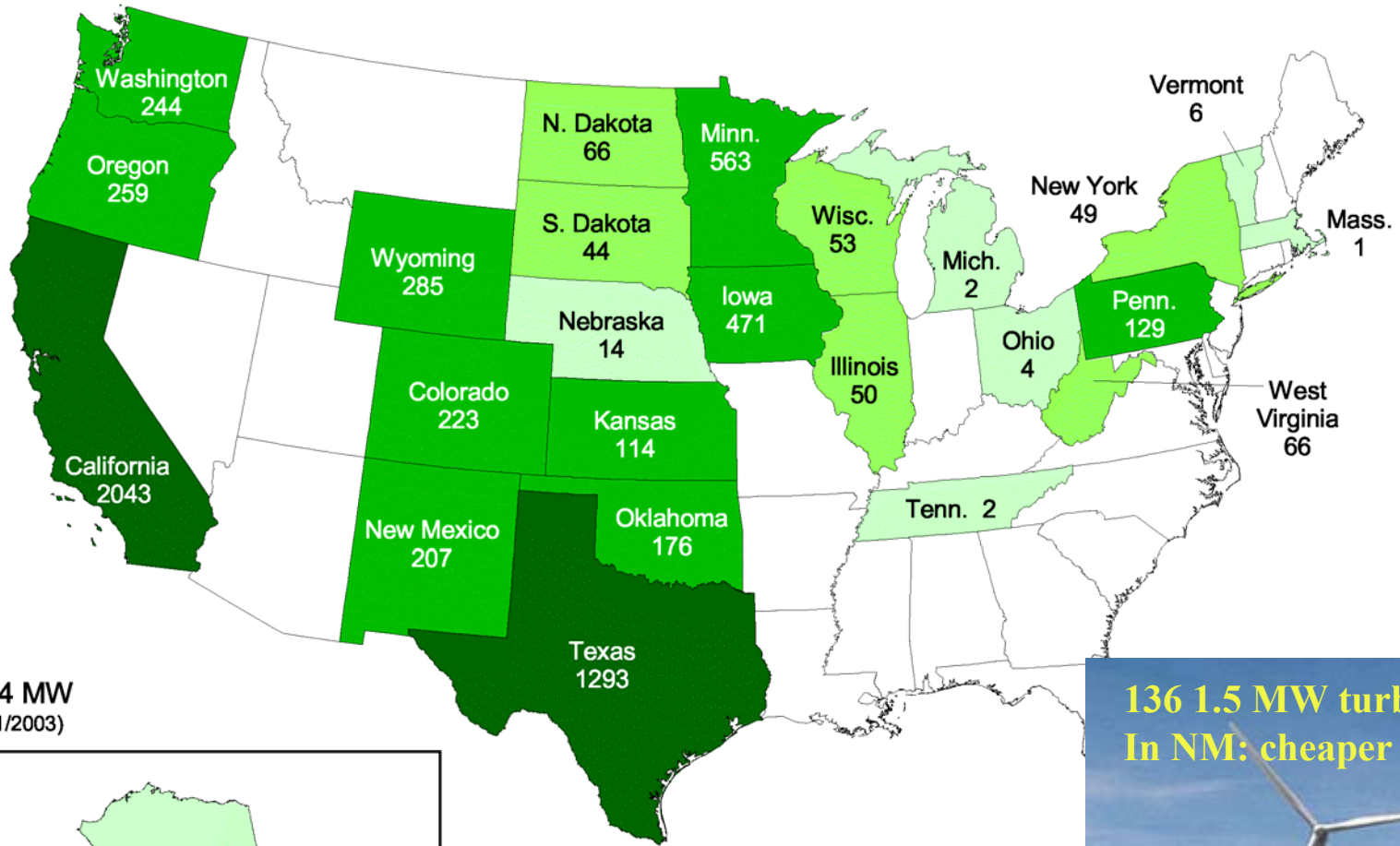
(at 4 - 7 ¢/kWh)



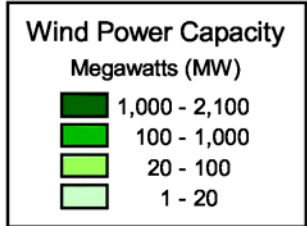
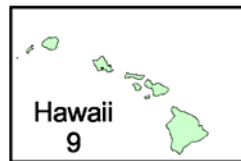
Product/Rotor diameter (m)	V15	V17	V19	V20	V25	V27	V39	V44	V47	V52	V66	V80	V90
Year of installation	1981	1984	1986	1987	1988	1989	1991	1995	1997	2000	1999	2000	2002
Capacity (kW)	55	75	90	100	200	225	500	600	660	850	1750	2000	3000
MWh/year	217	265	301	346	481	647	1304	1581	1947	2530	4705	6768	9152

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

United States - 2003 Year End Wind Power Capacity (MW)



Total: 6,374 MW
(Updated 12/31/2003)



**136 1.5 MW turbines
In NM: cheaper than coal!**

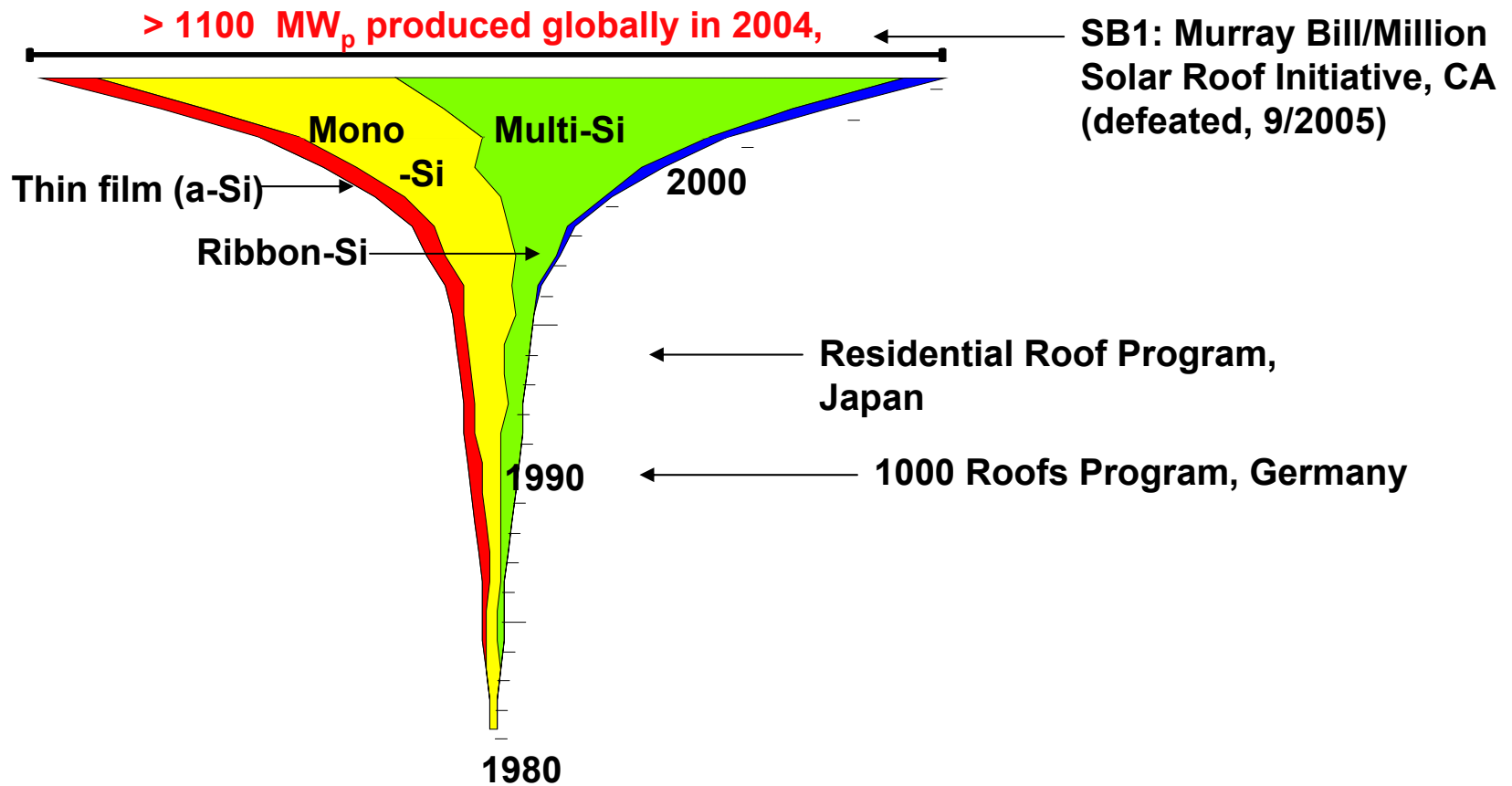
Wind Power is the Fastest Growing Source of Electricity



Major research & policy questions remain:

- Grid integration & wind farm planning
- Turbine materials
- Energy storage
- Siting

Expansion of Global Solar Industry: 20% Growth Per Year for 10 years



Solar Energy for Many Applications

Moscone Center: 675,000 W



Kammen home: 2400 W



Key finding: Investment in solar energy research and deployment pays dividends for *many* applications and for businesses *across scales*.

Kenyan PV market:
Average system: 18W



Inside the San Francisco Moscone Center



New T-5 Lights

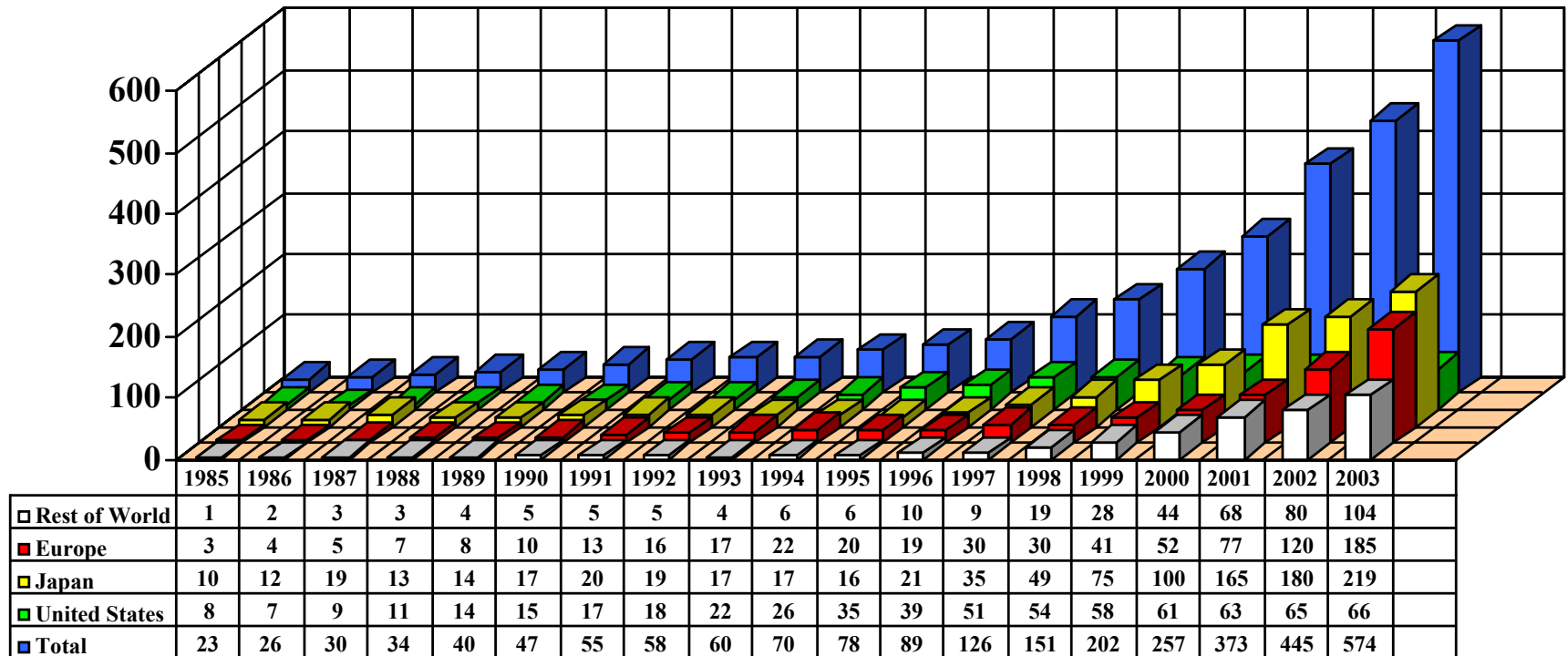
Old
Incandescent
Lights

The Many Values of Efficiency:

Financial: solar funded efficiency; efficiency paid for solar.

World PV Module Shipments (Megawatts)

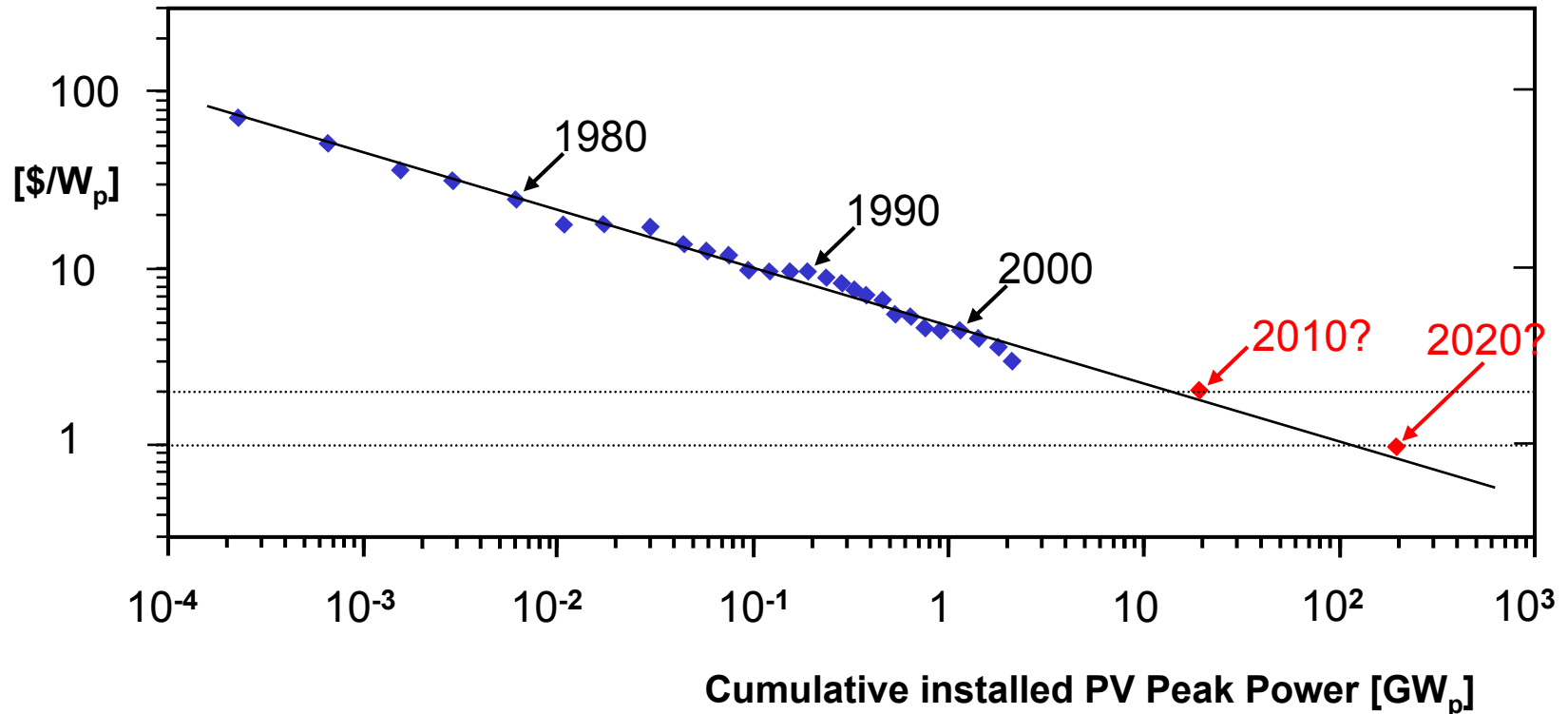
(25% annual growth for 10+ years)



2003 Annual growth: 34%; 50% in 2004 (to 1200 MW)

Today: global PV production is equivalent (MW) to one large fossil-fuel power plant/year

Learning Curve for PV Modules (*crystalline silicon*)



Today PV electricity costs about **\$0.20 - 0.25/kWh**,
Which can be compared with **\$0.32/kWh** PG&E charges for TOU
customers during peak time (noon-6pm)

**UNIVERSITY OF CALIFORNIA
BERKELEY**



**REPORT OF THE
RENEWABLE AND APPROPRIATE ENERGY
LABORATORY**

**Putting Renewables to Work:
How Many Jobs Can the
Clean Energy Industry
Generate?**

by

**Daniel M. Kammen
Kamal Kapadia
Matthias Fripp**

**of the
Energy and Resources Group &
the Goldman School of Public Policy**

APRIL 13, 2004



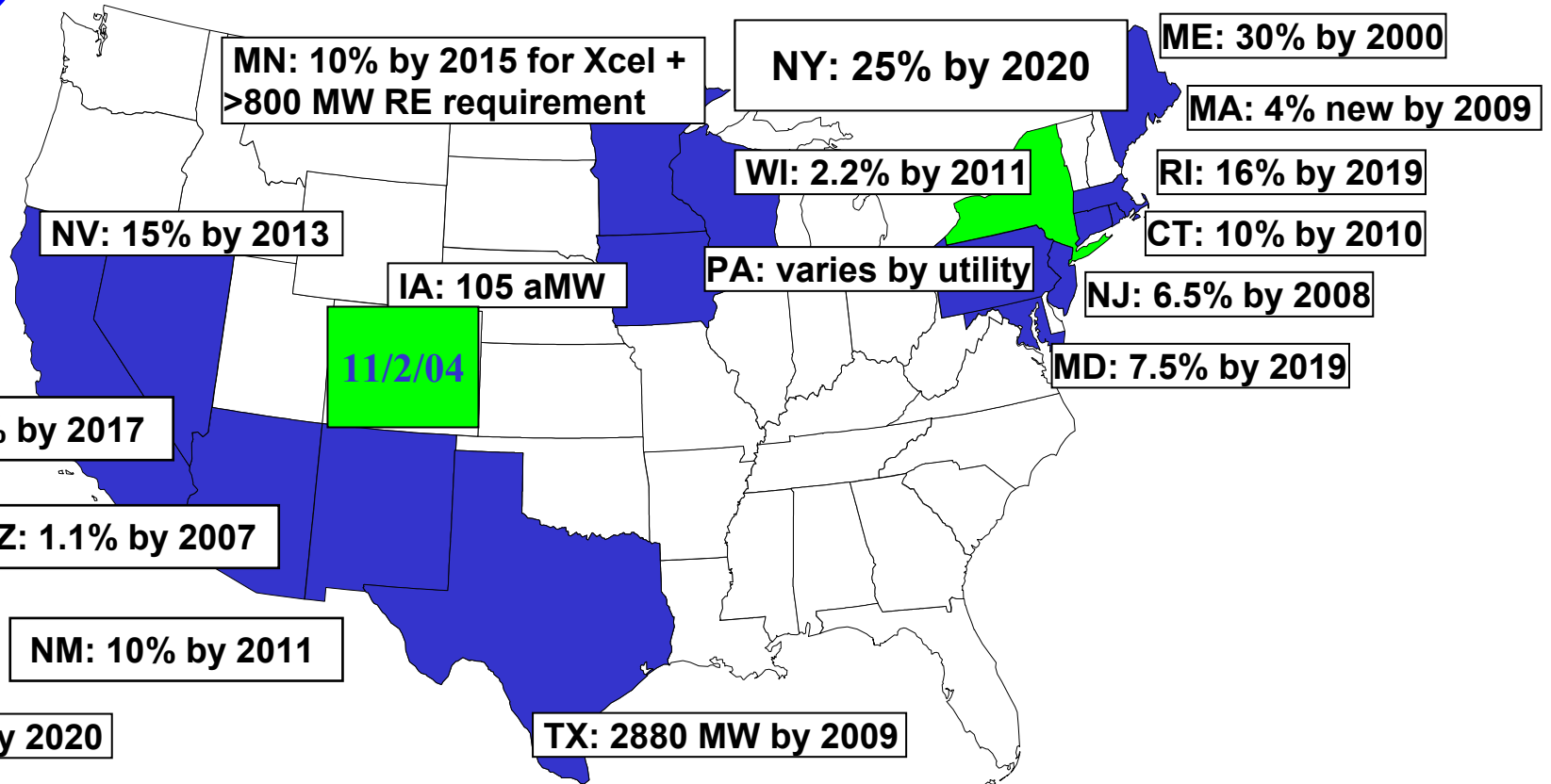
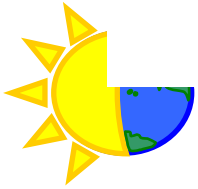
Study reviews:

- 13 studies of job creation
- 3 - 5 *times* More jobs per dollar invested in the renewables sector than in fossil fuels

**Report
available
at:**

<http://socrates.berkeley.edu/~rael/papers.html>

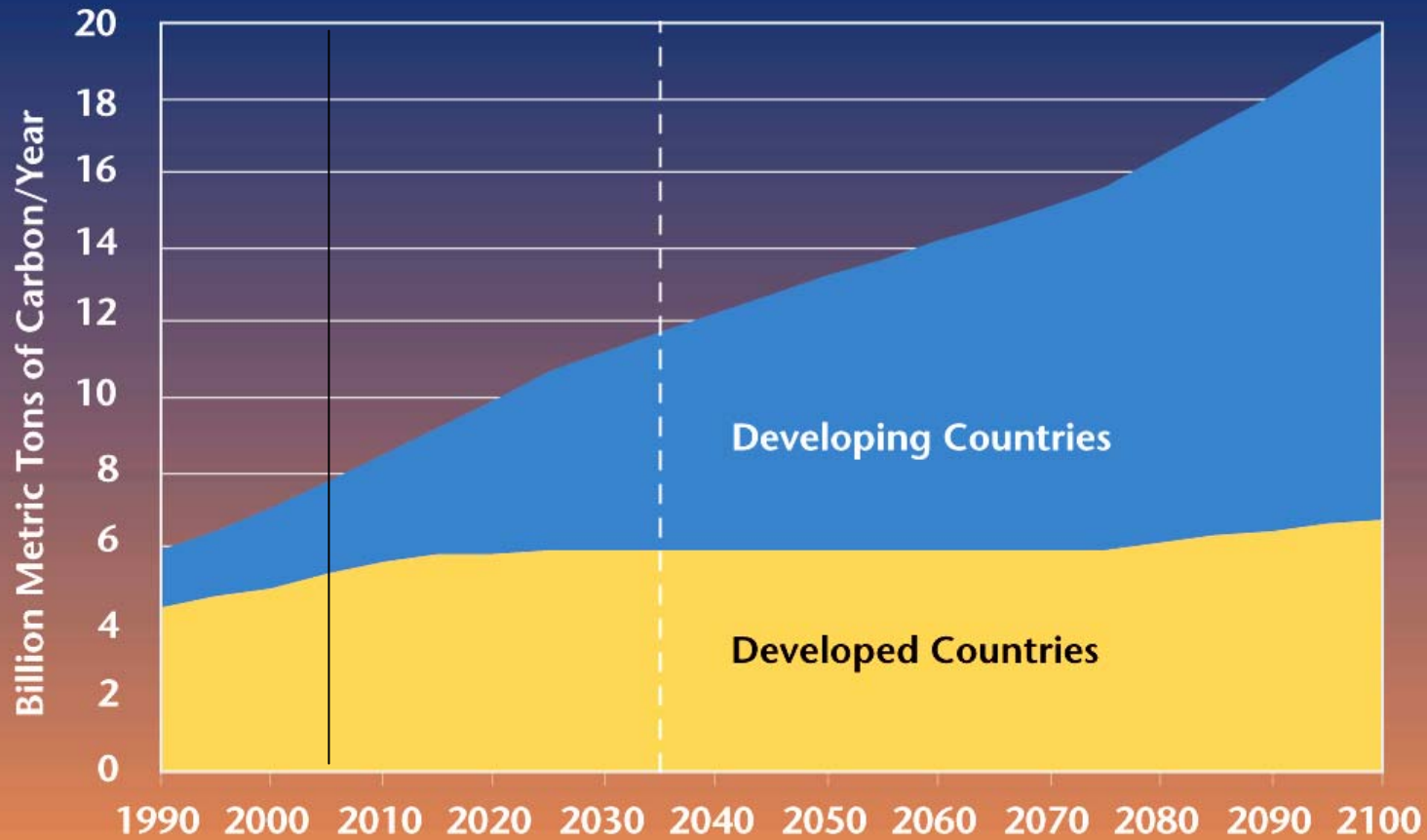
State Renewables Portfolio Standards and Mandates in 21 States + DC



- Renewable energy “goals” established in Illinois and Minnesota
- RPS being considered in many other states (e.g., VT, WA); potentially revised in others (ME, PA, WI); and national RPS is being discussed (by some)

Developed and Developing World CO₂ Emissions, 1990-2100

Developed Countries Emissions = Developing Countries Emissions by 2035





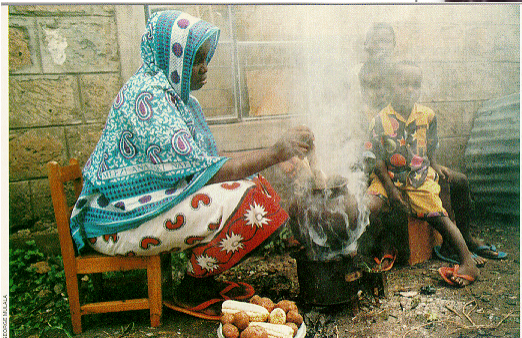
Biofuel mix: 2002

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Average: 0.72 tons/capita

Bailis, Ezzati and Kammen (2005)

Biomass – in Sub Saharan Africa (500 million tons/yr)



COOKSTOVE SMOKE is ubiquitous in Kenya, where wood, charcoal and other biomass fuels are used for cooking and heating. Particulates in smoke are a major contributor to respiratory disease, the leading cause of illness in developing nations.

Biomass accounts for :

- 70% of total energy use
- 90% of household use
- *Compared with 3% for OECD countries*

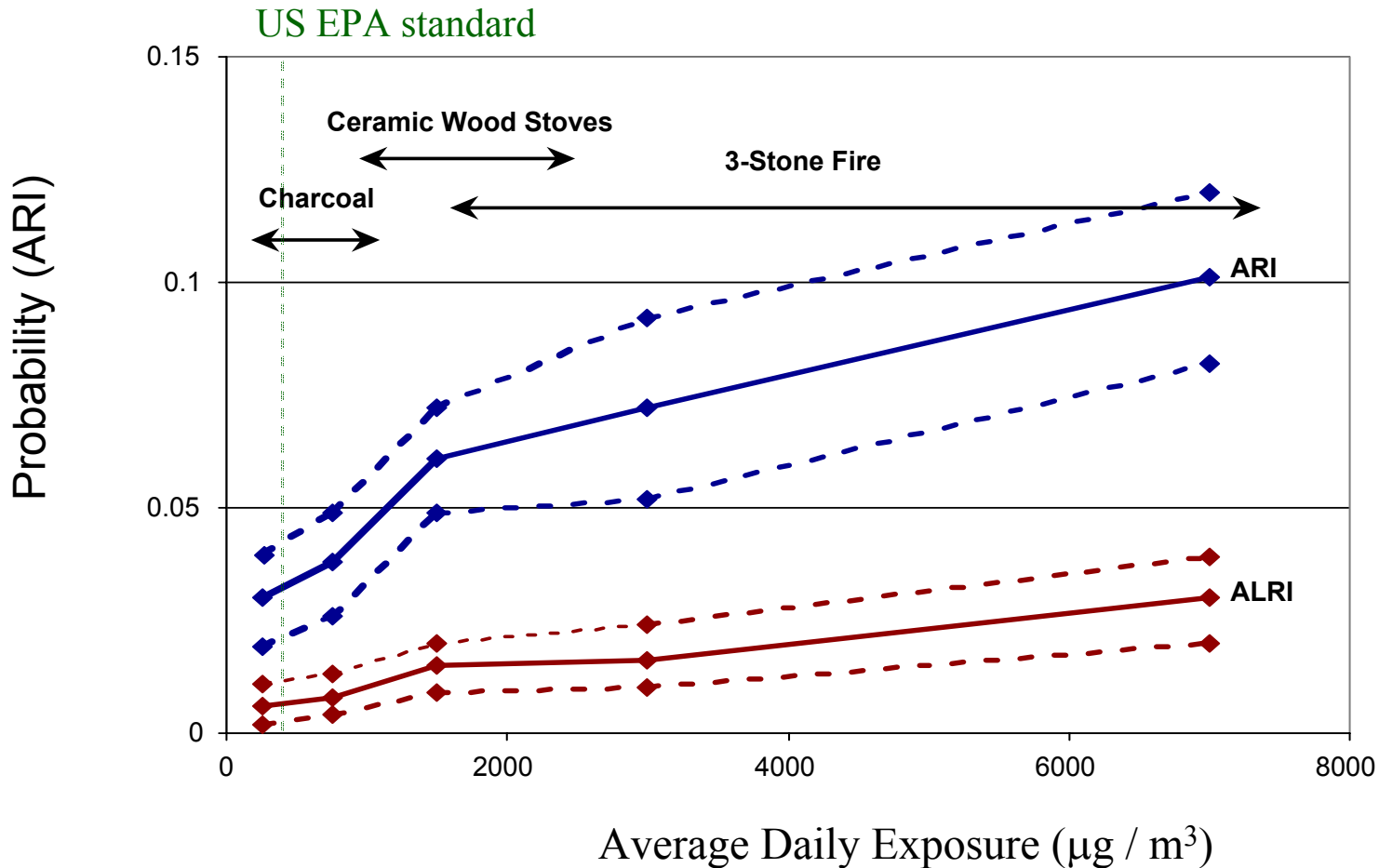
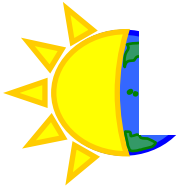
Of harvested wood :

- ~ 75% used for cooking
- ~ 15% used to make charcoal

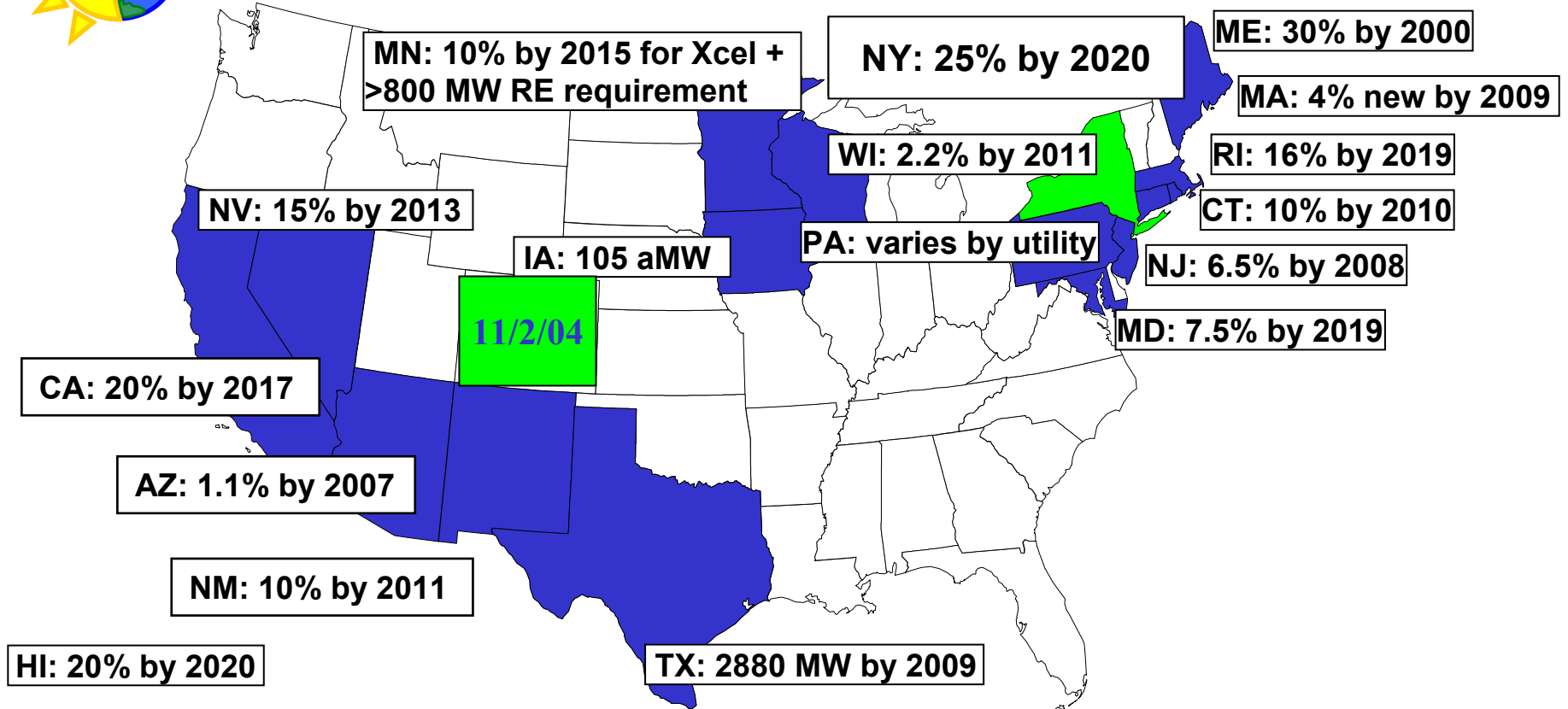
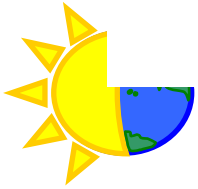
Charcoal use is:

- Growing faster than woodfuel
- Mainly commercial urban fuel
- Attributed main blame for unsustainable forest use

The Result: The Dose-Response Relationship for Acute Respiratory Illness (ARI, ALRI) (Ezzati & Kammen, *The Lancet*, 2001)



State Renewables Portfolio Standards and Mandates – 16 States



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Study reviews:

- 13 studies of job creation
- Message: energy efficiency and renewables create large numbers of high quality jobs

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1942...

When you ride **ALONE**
you ride with Hitler!



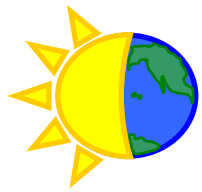
Join a
Car-Sharing Club
TODAY!

When you ride **ALONE**
you ride with bin Laden



What the Government **SHOULD** Be Telling
Us to Help Fight the War on Terrorism

BILL MAHER



New SUV Models Coming Soon



The Kenworth Grand Dominator

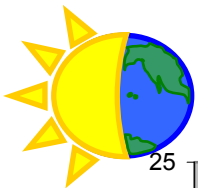
- Extra high roof/cathedral ceilings
- Power expandable sides
- Full lavatory



The Peterbilt Crusader All Sport Denali

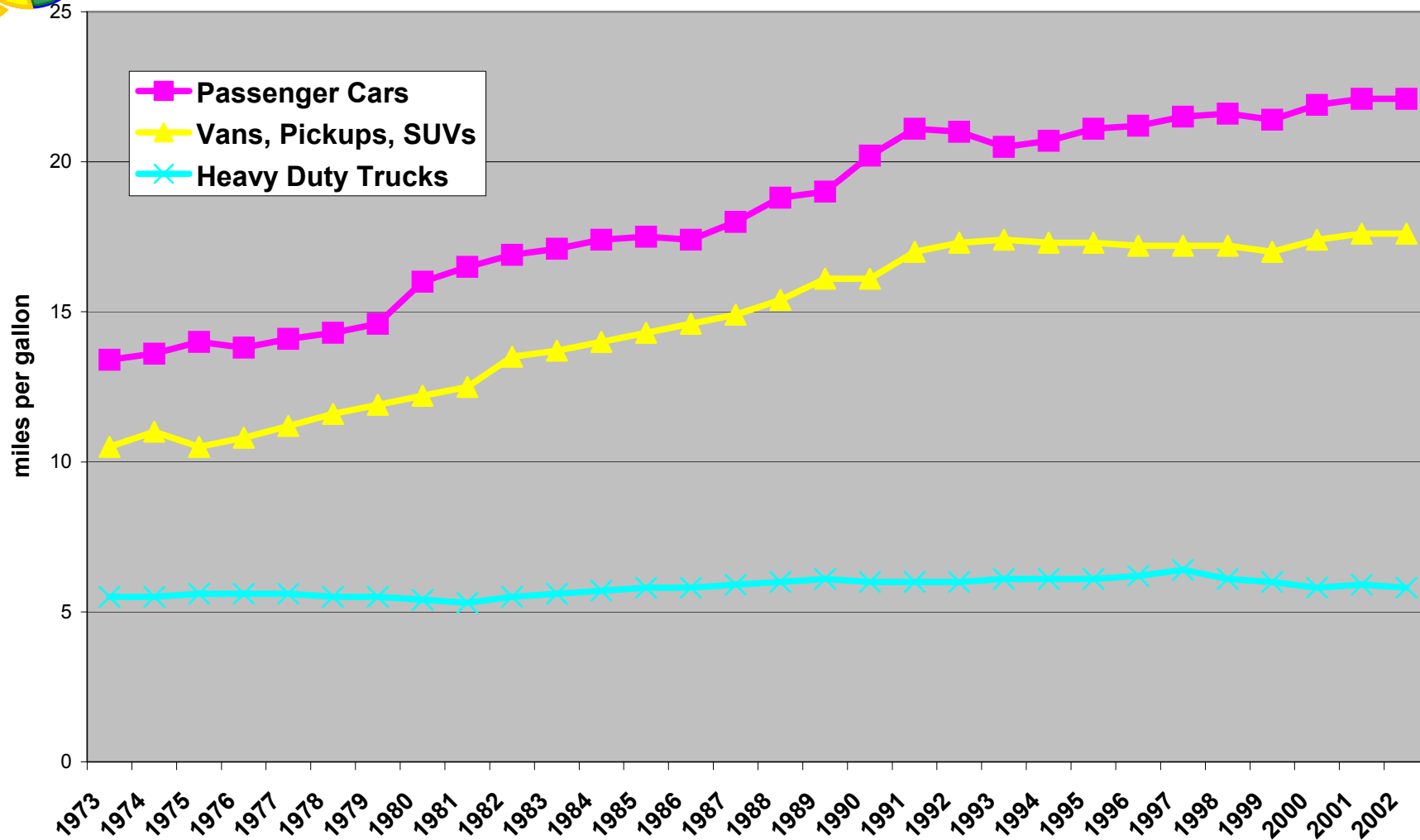
**The worlds first two story high
performance sport brute
Crusader-E Edition: includes elevator**

Source: <http://poseur.4x4.org/futuresuv.html>

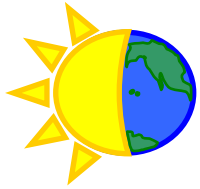


Motor Vehicle Efficiency -- United States Totals

Source: EIA, Monthly Energy Review, Table 1.9



A QUICK COMPARISON OF SEVERAL NEW AND EMERGING "GREEN" VEHICLES AS YOUR PRIMARY, URBAN CAR



CONVENTIONAL VEHICLE (CV): Ford Focus



HYBRID ELECTRIC VEHICLE (HEV): Toyota Prius

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV): "Prius Plus"

PROTOTYPE ALL-ELECTRIC VEHICLE (EV):

FUEL-CELL, HYBRID ELECTRIC VEHICLE (FCHEV): Honda FCX



ENERGY AND POLLUTION ANALYSIS FOR FIVE VEHICLES:

DRIVE CYCLE (15,600 miles/yr):

Weekdays: 50 miles/day, 13,000 mi/yr, half HiWay, half City

Weekends: 25 miles/day, local streets (2600 mi/yr)



QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

FUEL PRICES:

Gasoline: \$2.50/gal

Electricity: 12¢/kWh (Std) or 6¢/kWh (Off-Peak rate)

Hydrogen: \$3/kg H₂

FUEL EFFICIENCY:

Ford Focus: 24 mpg; Toyota Prius: 49 mpg

Prius + : 45 mpg on gasoline (HiWay), 200 Wh/mi (City)

All-Electric: 250 Wh/mi

Honda FCX: 57 miles/kg H₂



CARBON EMISSIONS:

Avg Grid: 52% coal, 3% oil, 16% natural gas: 700 gCO₂/kWh

Natural Gas, Combined Cycle 50% efficiency: 425 gCO₂/kWh

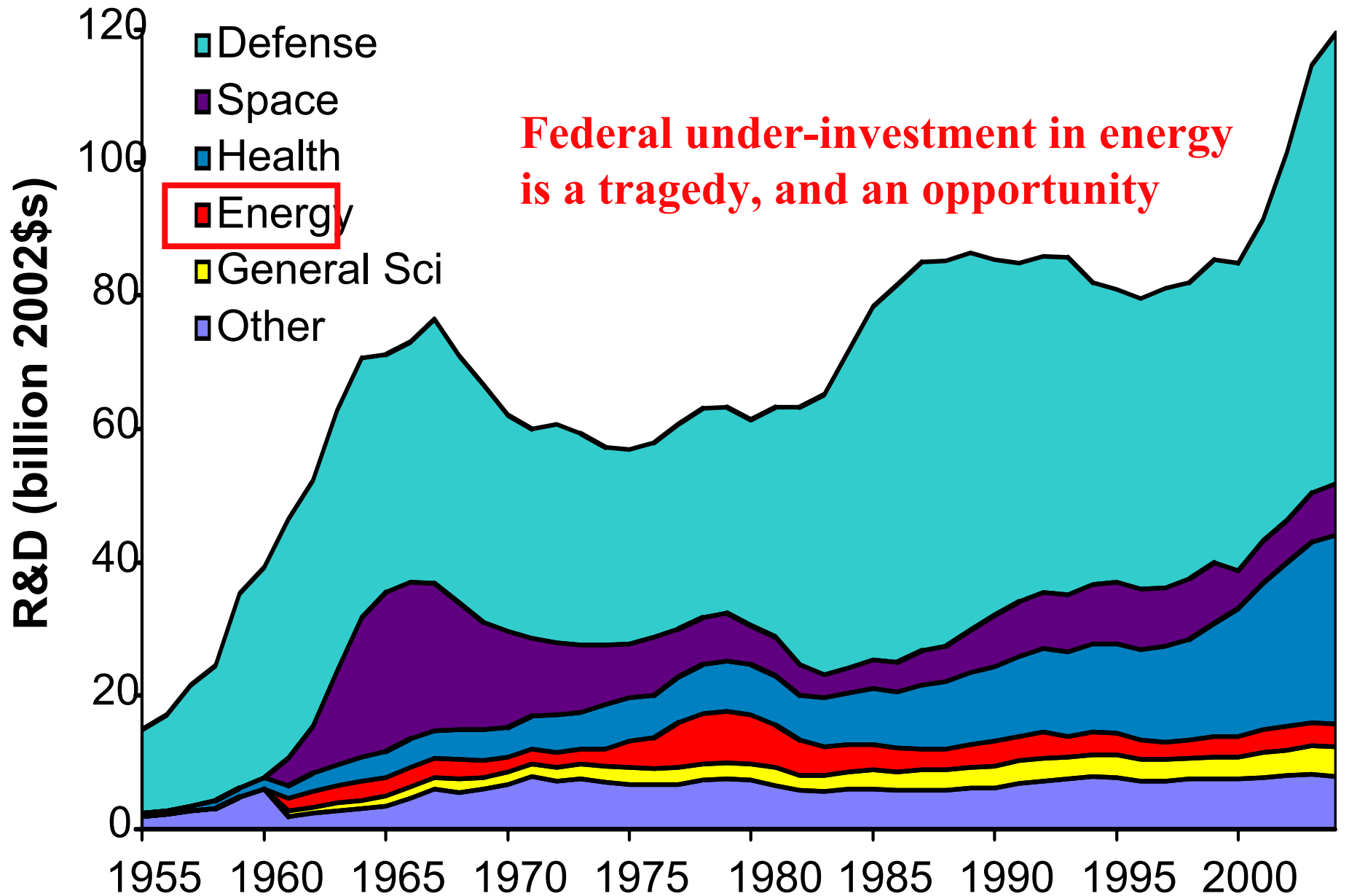
Gasoline: 80% WTP, 11.2 kg CO₂/gal

Hydrogen: 60% WTT, 57 mi/kg = 200 gCO₂/mi

FC/Electrolysis: 663 gCO₂/mi (avg grid); 402 gCO₂/mi (NGCC)

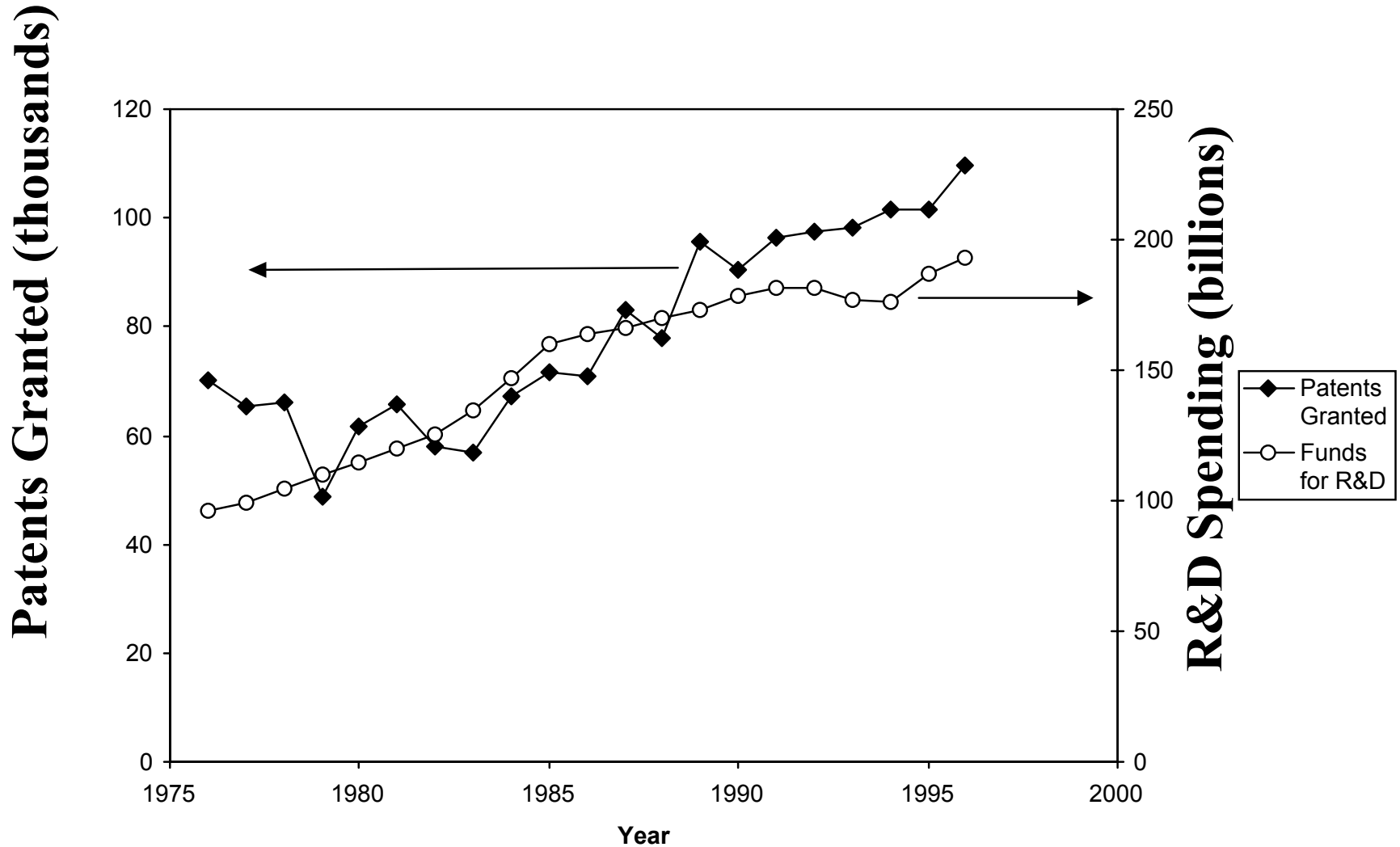


Federal R&D Investments, 1955 - 2004

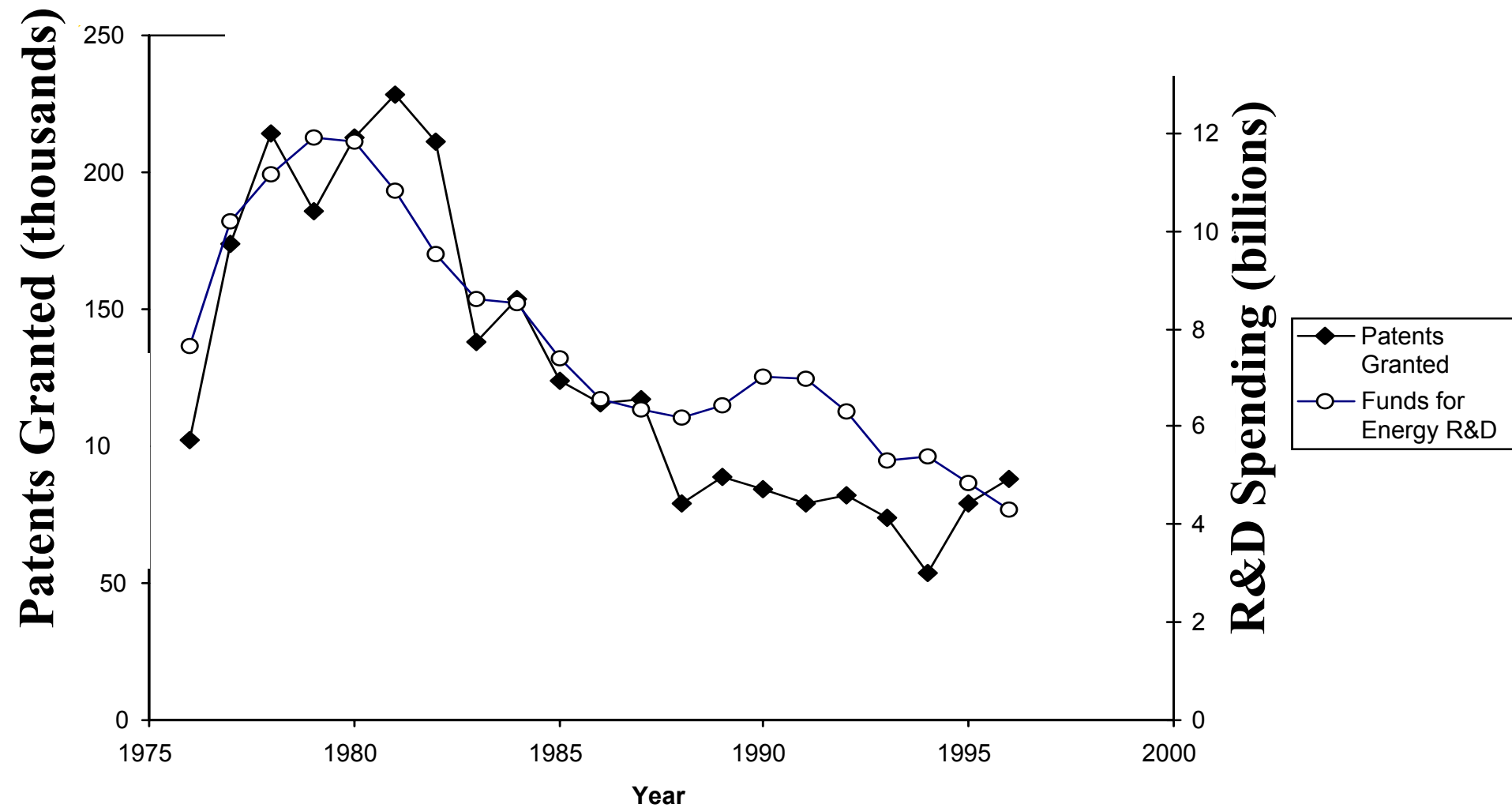


Federal under-investment in energy is a tragedy, and an opportunity

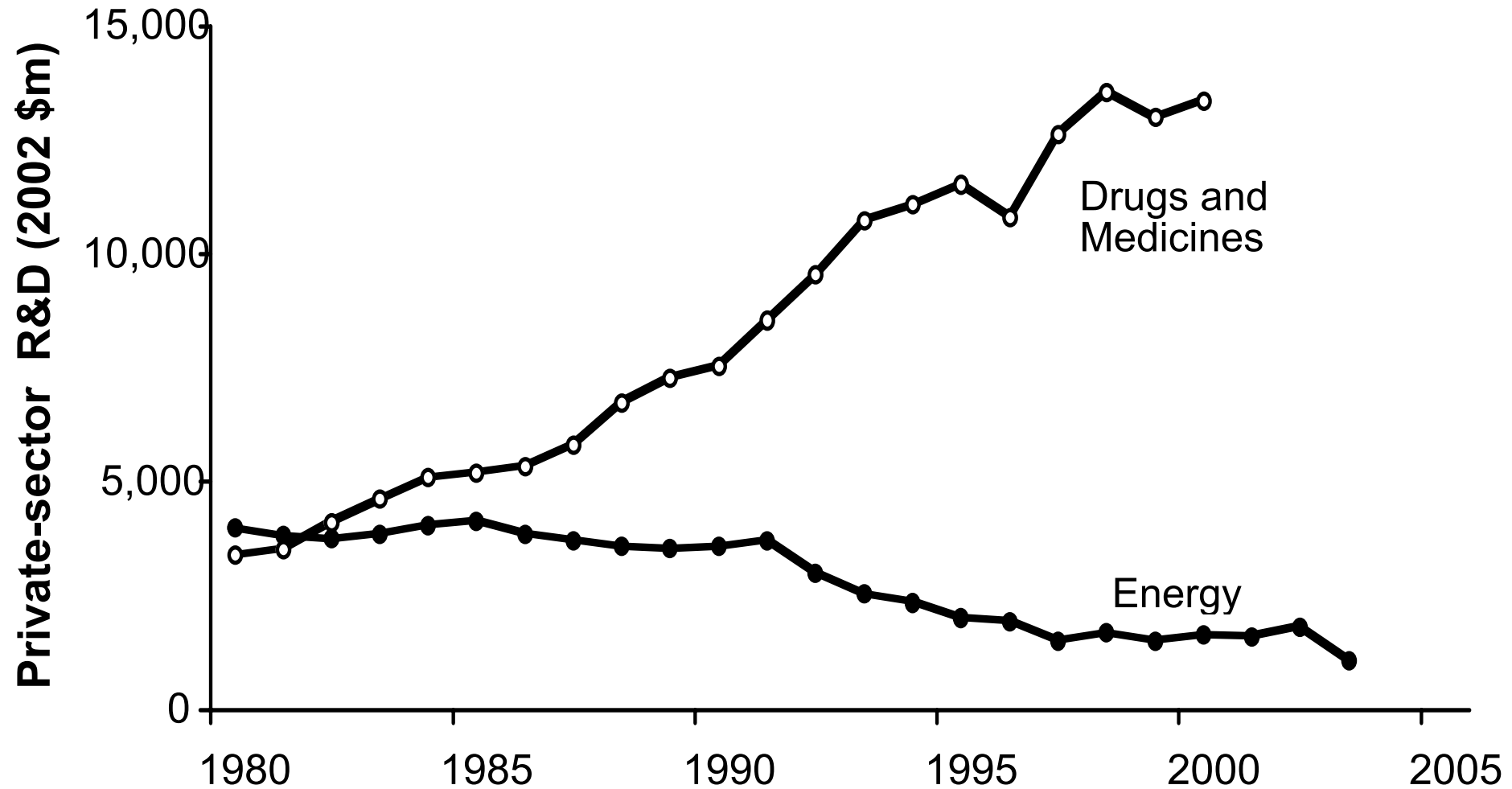
Federal R&D Policy Can be Very Effective (All sectors of the U. S. Economy)



The Same Funding-Patent Correlation ... But Now for Energy Only

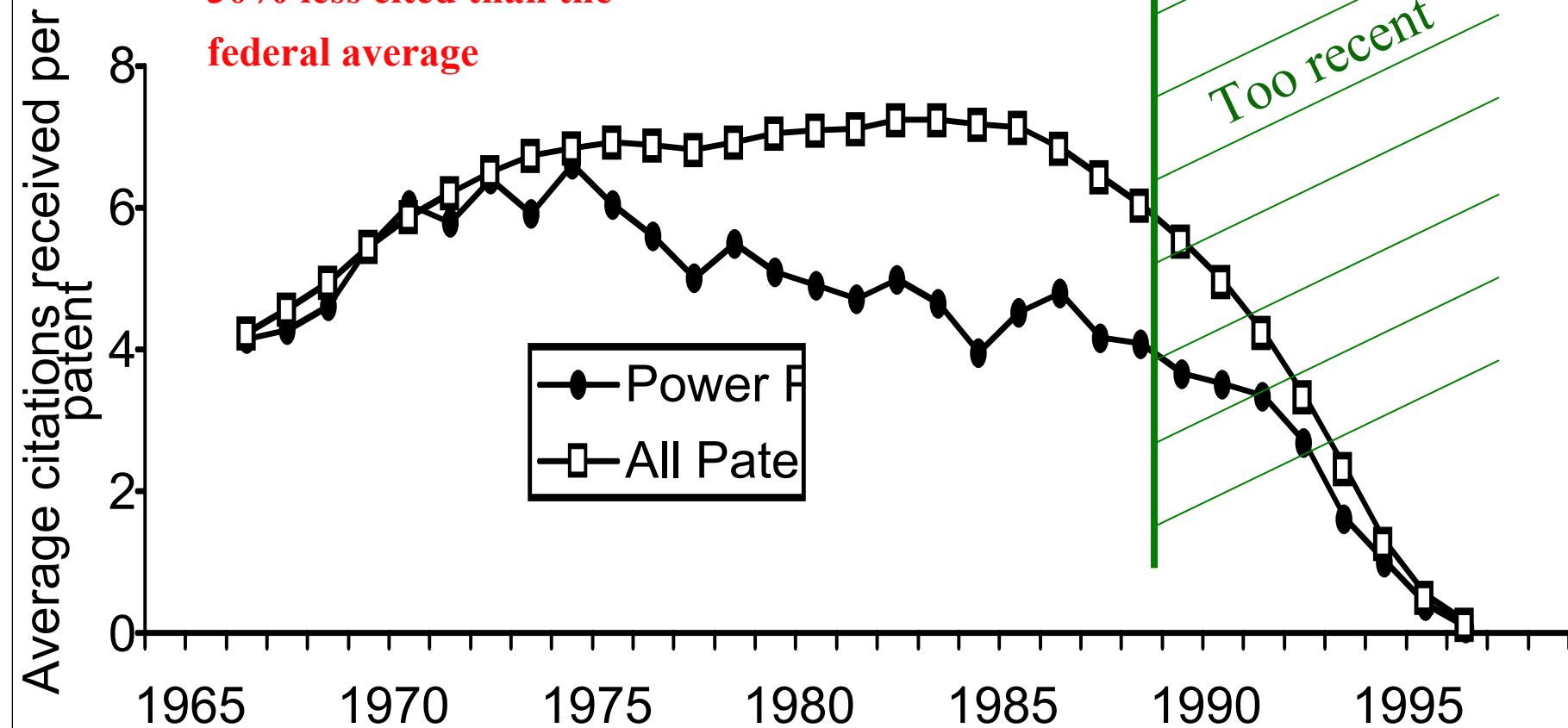


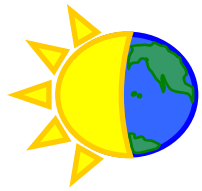
Private Sector R&D Investment in Health and Energy



Citations Receive "Energy Sector" v

Energy patents: Over
30% less cited than the
federal average





Opportunities for Policy Action

- **Expand state renewable energy portfolio standards**
- **Support Solar Home bills (build clean energy markets) & renewable energy/energy efficient mortgages**
- **Support state initiatives like the CA Climate Plan (Executive Order 3-05)**
- **Enact carbon cap & trade: work with western states, northeast US (RGGI), UK**
- **Enact a *carbon tax*** (2003: oil = \$28 a barrel. 2005: \$60/barrel; this is the equivalent to \$271/ton carbon; \$74/ ton CO₂)
- **Get serious about global energy leadership**

<i>Class</i>	<i>Type</i>	<i>Est. Available (EJ)</i>	<i>Used in 2004 EJ/yr (Total use = 490 EJ)</i>
FOSSIL	Oil (conventional)	10,000	150
	Oil (unconventional)	35,000	3
	Gas (conv.)	18,000	160
	Gas (unconv.)	68,000	small
	Coal (conv.)	100,000	100
	Coal (unconv.)	32,000	0
	NUCLEAR	U²³⁵ (\$130/kg)	5,800
U²³⁸ and Th		>400,000	very small
Fusion		?	0
RENEWABLE	Hydro	60/yr	25
	Wind	600/yr	~0.5
	Solar (PV and Thermal)	1,600/yr	~0.2
	Geothermal*	5,000/yr	~2
	Biomass	250/yr	~50 (6)
	Ocean	~10/yr	.002



Some Critical Needs for Research

- **Low cost photovoltaics (< \$1/Watt)**
 - **Drivers: funding; technology diversity; markets**
- **Biomass gassification across scales of application**
- **Power electronics for mini-grids, distributed systems**
- **Carbon sequestration**
- **Nano energy and wireless systems to initiate a second 'wave' of energy efficiency increases**
- **Understanding and action on the economics of carbon (and pollutants generally)**