OUR ENERGY FUTURE: A SLATE REPORT

SC 210

December 12, 2006

The Slate Panel

Carolyn Kimme Smith	George Hume
Dennis Silverman	Max Lechtman
Paul Engelder	Vern Roohk
Stephen Jeckovich	Ron Williams
Dorothea Blaine	John Bush

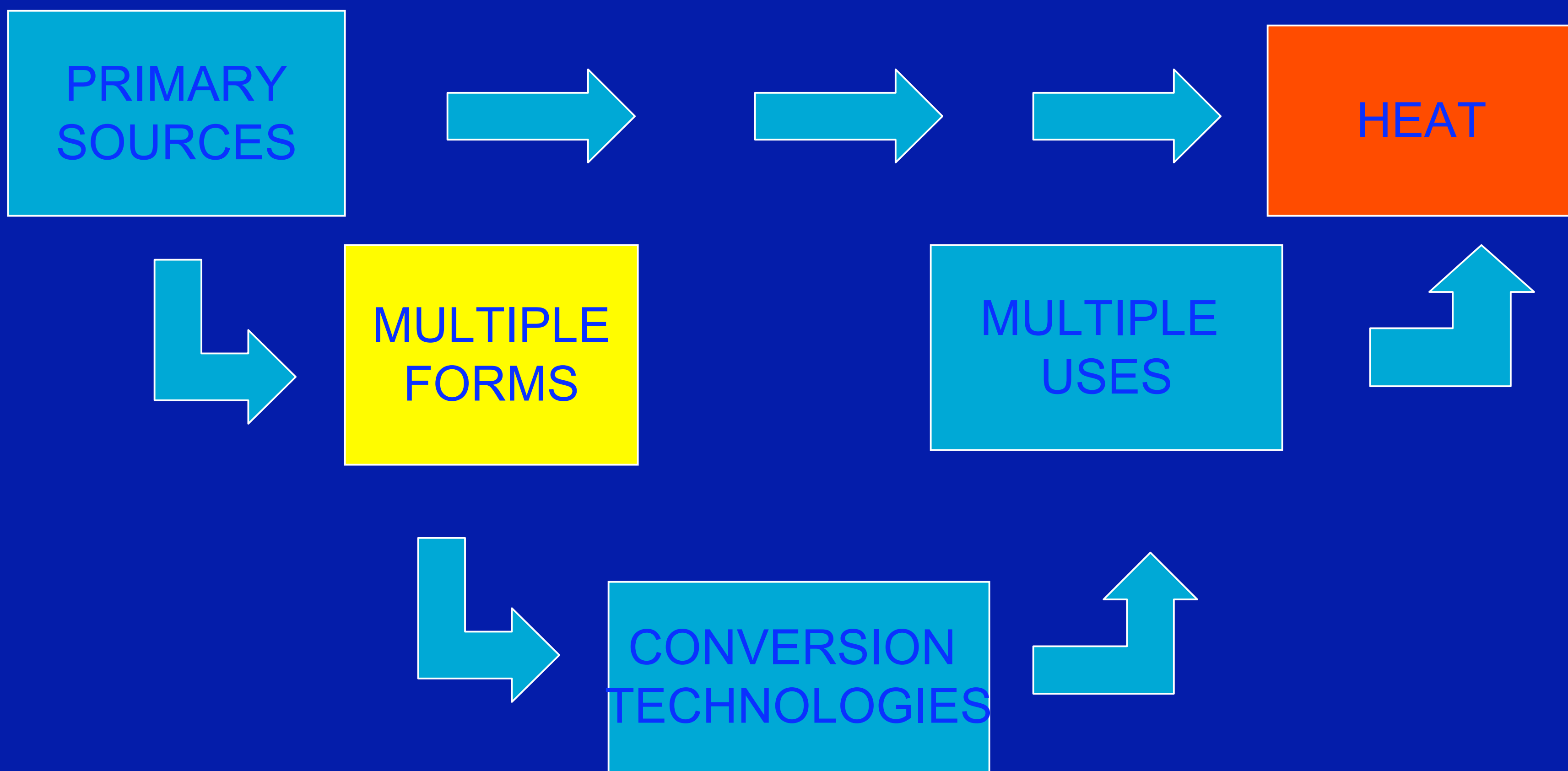
ENERGY SLATE
A History

- Planned: Spring 2005
- Initiated: Fall 2005
  - Global Warming --Peak Oil
  - Energy Policy --Nuclear Energy
- Concluded : Spring 2006
- Subsequent Events:
  - $ 78 per barrel oil/ $3.50 per gal gasoline
  - Increasing evidence for Global Warming
  - Intensifying Shiite/Sunni hostilities
  - California policy on Global Warming
  - Proposition 87

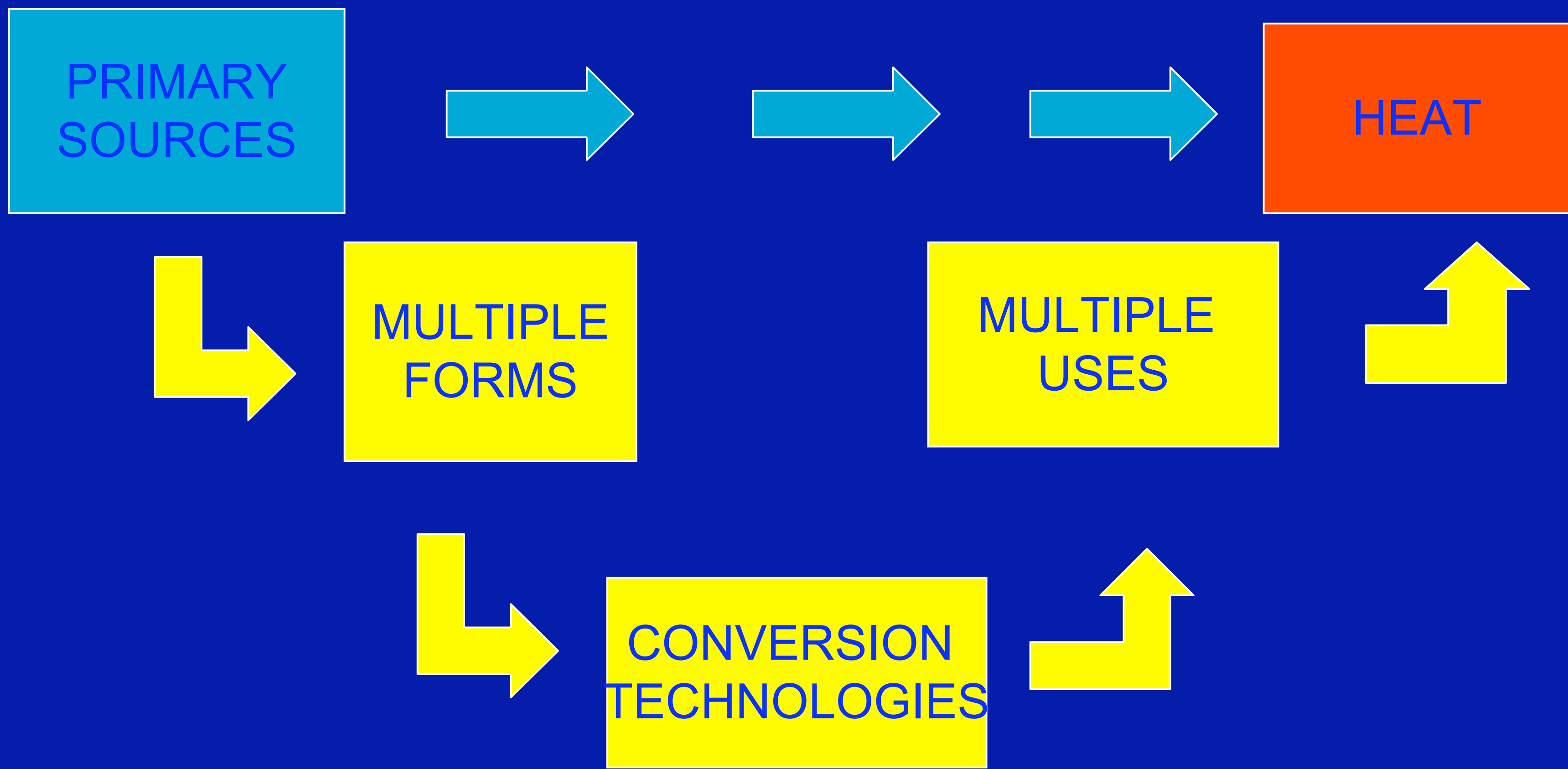
FRAMING THE SLATE DISCUSSIONS

- Points of view
  - 1) Residents of California
  - 2) Citizens of the United States
  - 3) Inhabitants of the Earth
- Time frames
  - 2010
  - 2015
  - 2025
  - "Forever"—2050 and beyond

FLOW OF ENERGY



ROLES OF TECHNOLOGIES



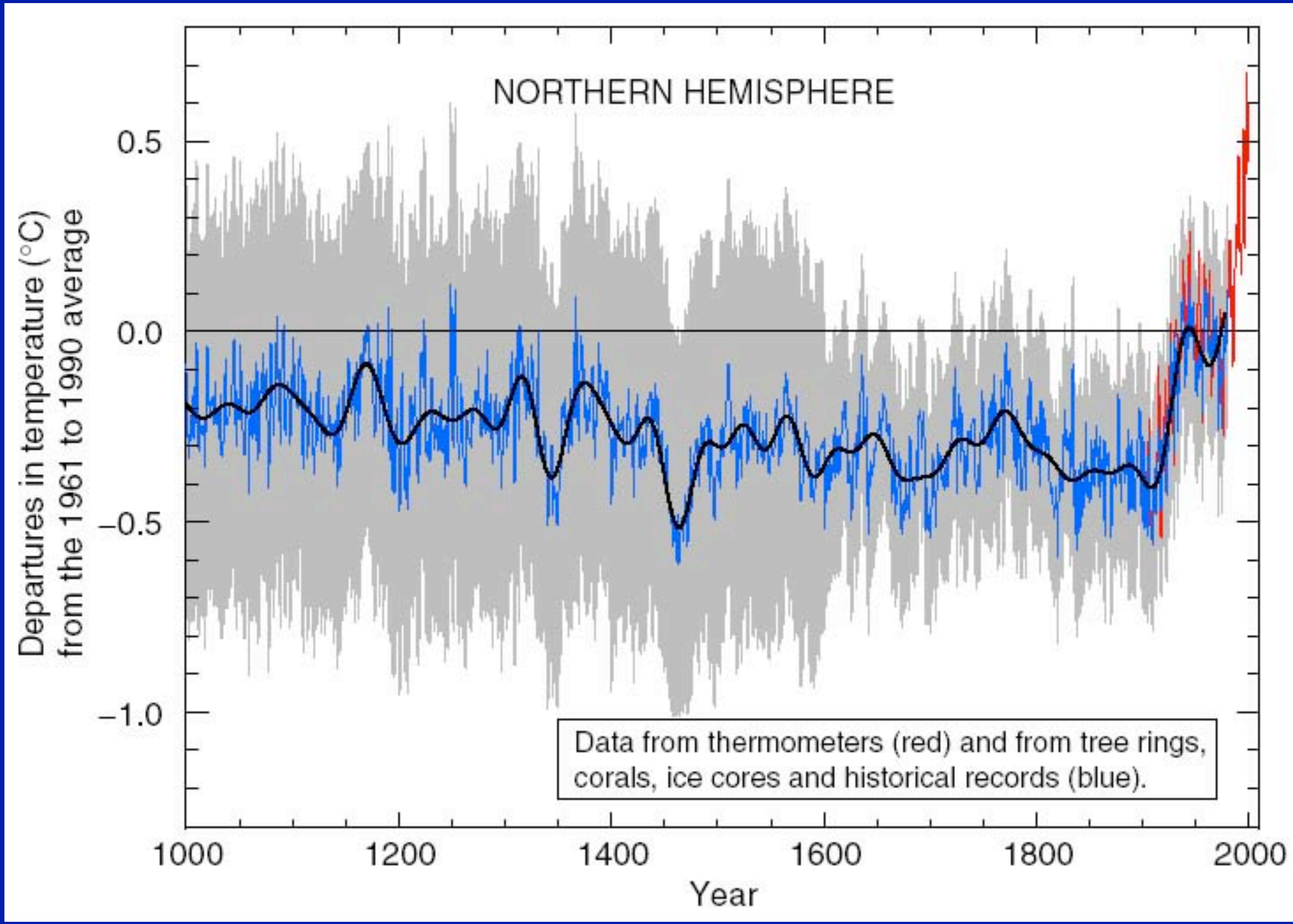
SUMMARY OF ISSUES

- By using so much fossil fuel are we making the Earth an unfit place for life?
- Is the world running out of oil?
- Is our nation endangered by our dependence on imported oil?
- How will global demographic and economic trends affect our energy future?
- How will energy supply choices affect the availability of supplies of water and food?
- How might our “American Lifestyle” be affected?

Global Warming

Dennis Silverman
Physics and Astronomy
U C Irvine

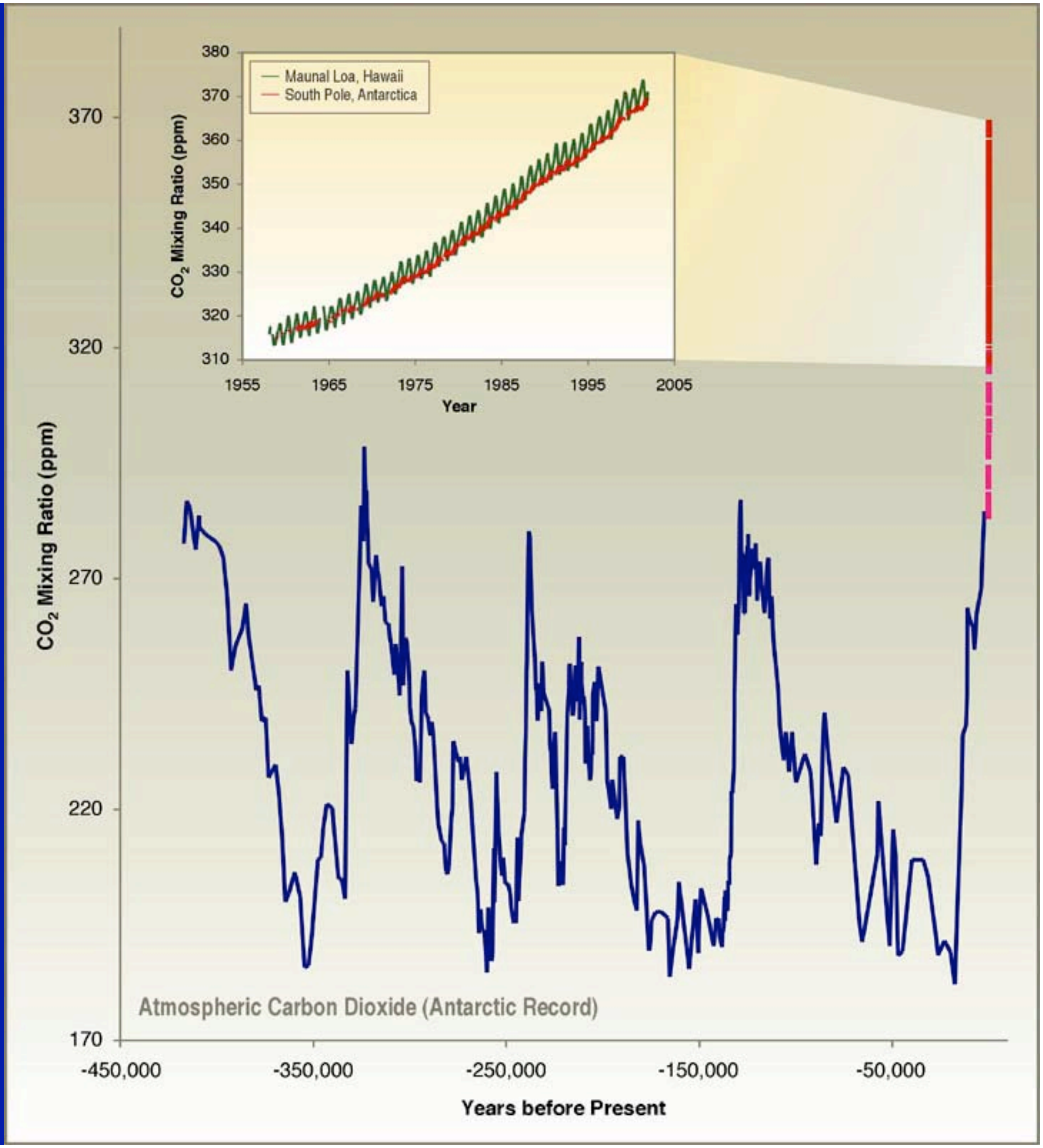
Definitive Evidence of Rapid 1.2° F Temperature Rise over the Last Century



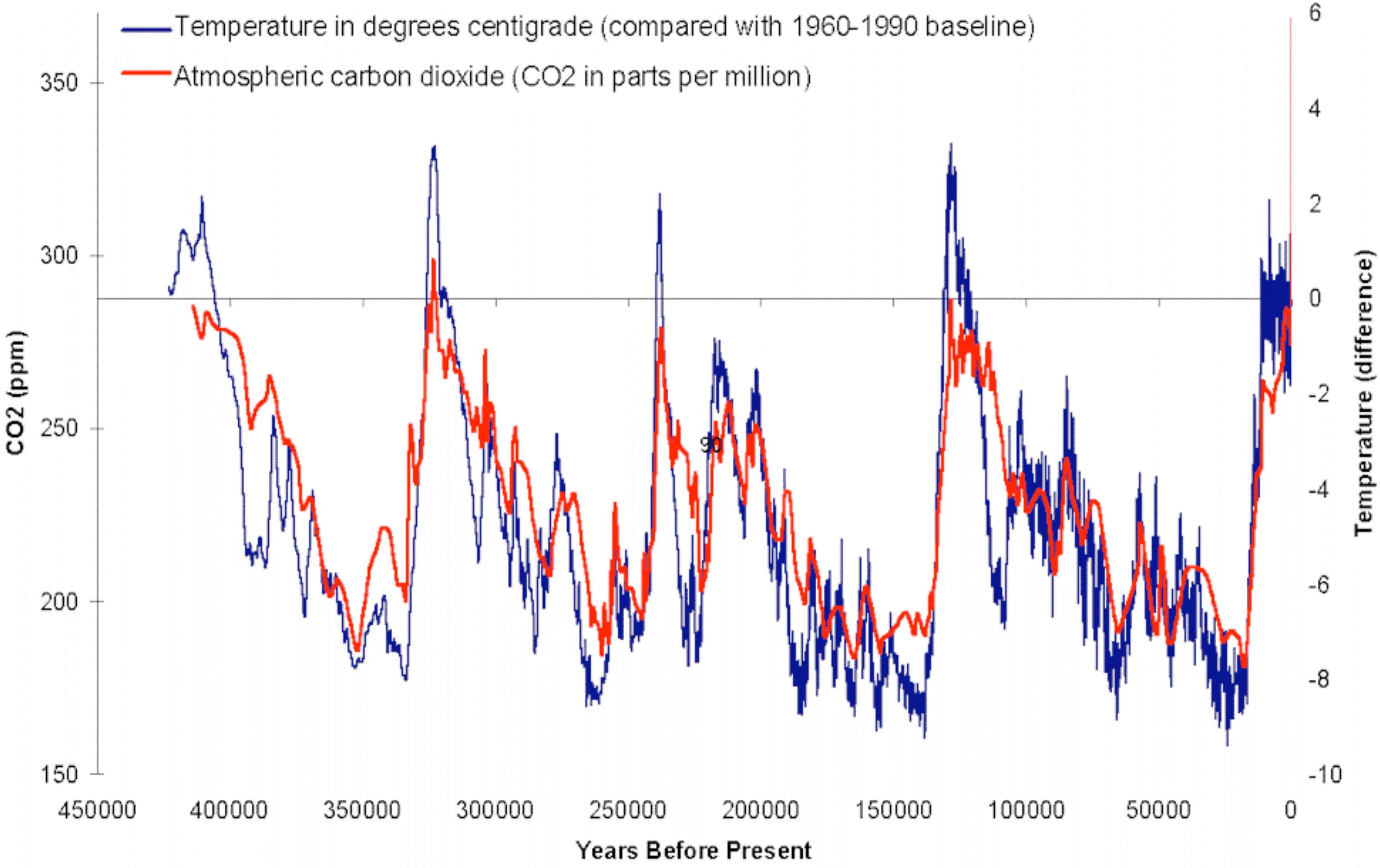
Carbon Dioxide concentrations are low in glacial periods and higher in warmer interglacial periods

However, concentrations now are higher than at any time in the last 450,000 years.

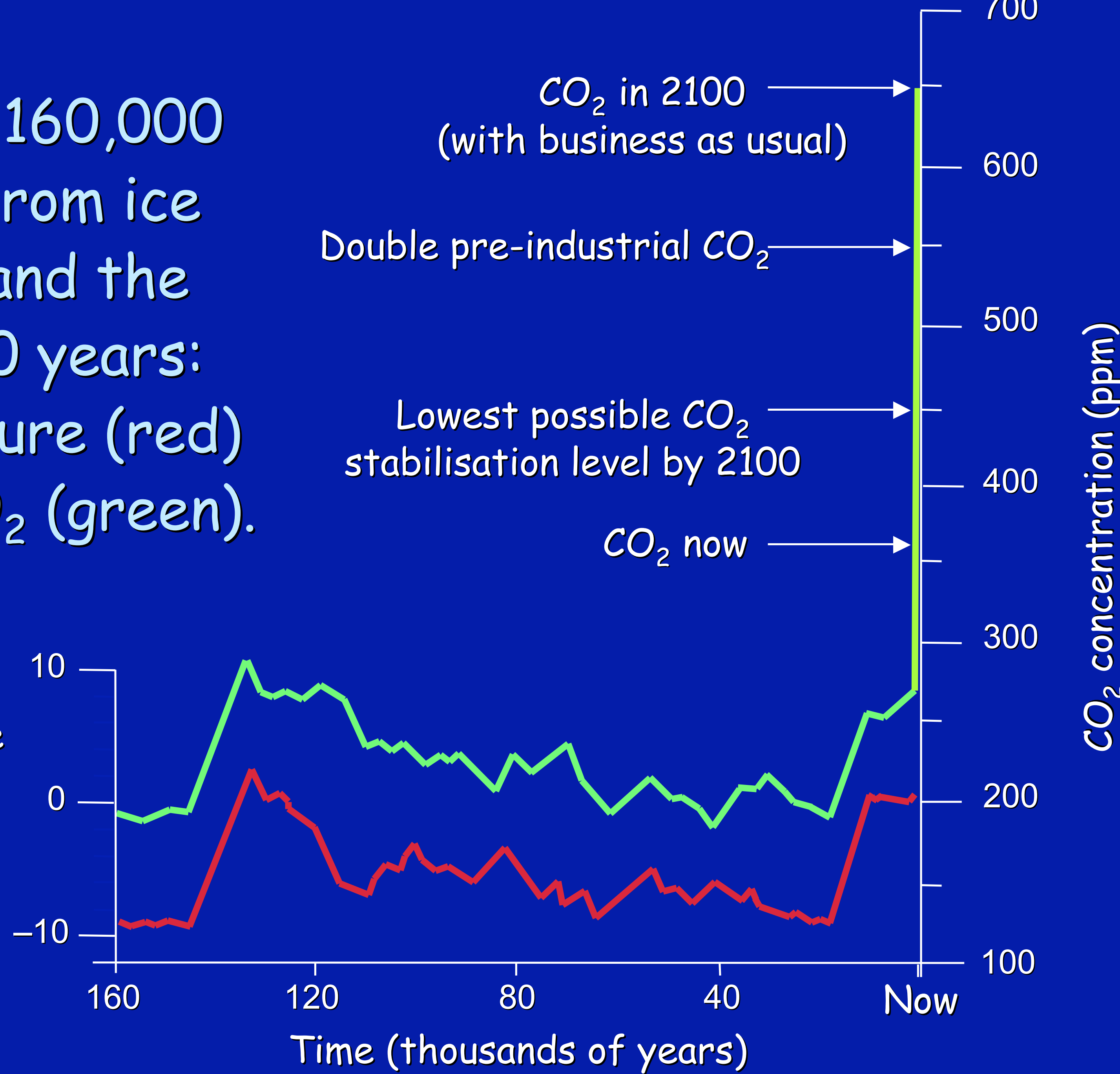
In the insert is the dramatic growth over the last 50 years.



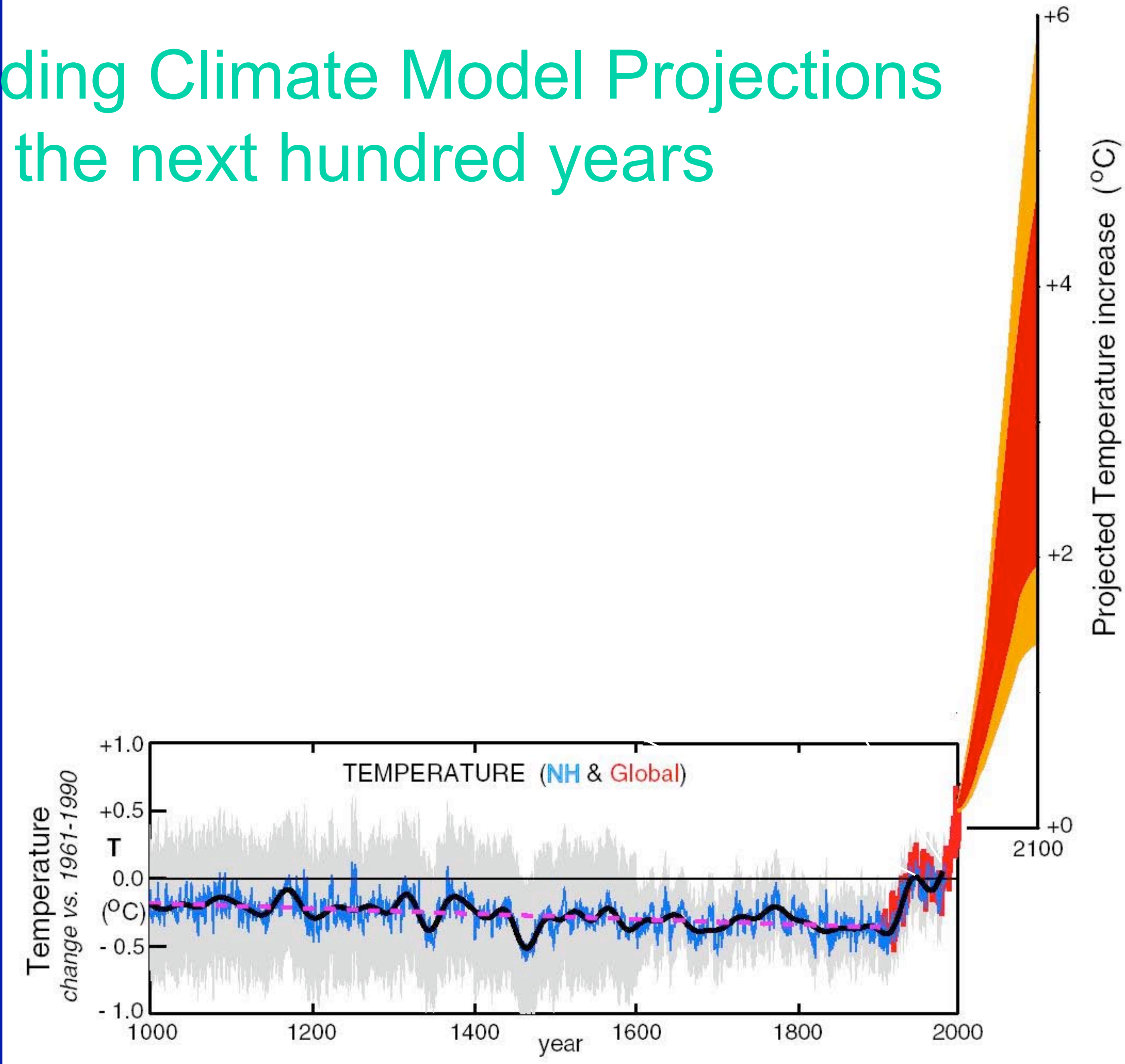
Temperature and CO2 Correlation



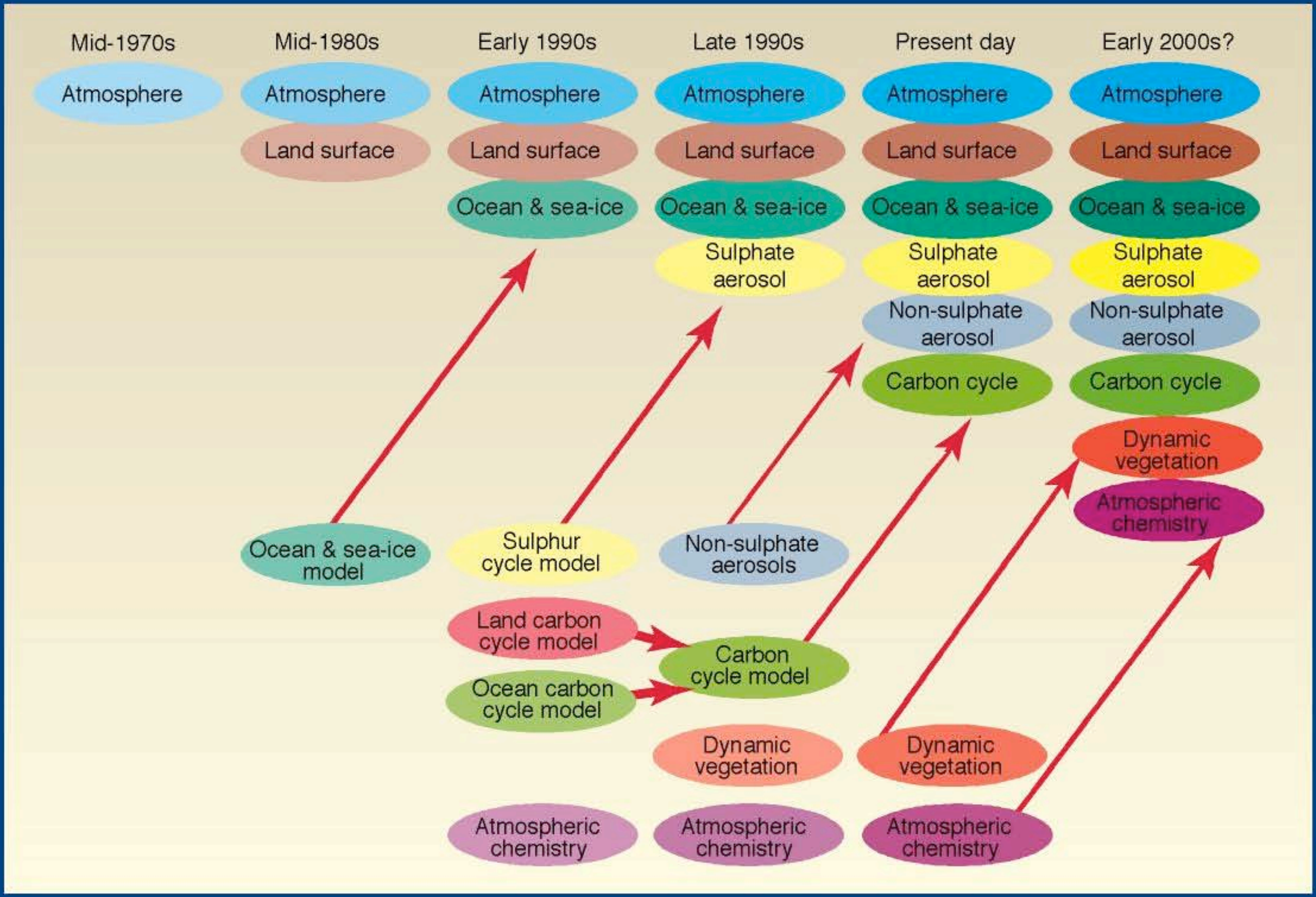
The last 160,000 years (from ice cores) and the next 100 years: temperature (red) tracks CO_2 (green).



Adding Climate Model Projections for the next hundred years



The development of climate models, past, present and future



WG1 - TS BOX 3
FIGURE 1

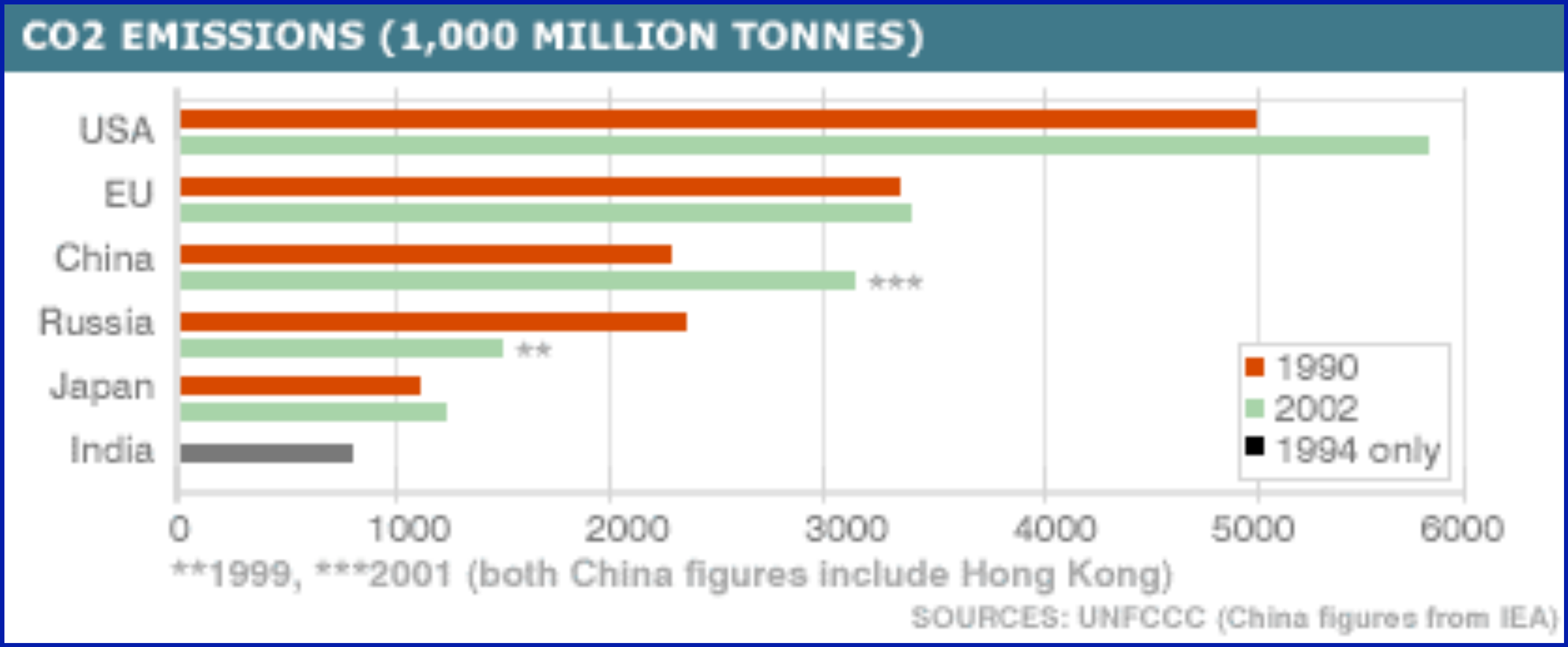
Global Warming Effects

- 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 farming, year round water supplies, household and business heating and cooling energy. These may require large and costly modifications.
- Some cold areas may benefit, and some hot areas will become unfarmable and costly to inhabit.
- Recent projection: US agriculture up 4%, CA down 15%.
- It is very misleading to portray the problem as a purely environmentalist issue which affects only polar bears, a few Pacific islanders, and butterflies.

Greenhouse Gases and the Kyoto Treaty

- The treaty 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 ¼ the emissions of the US per capita, some of which is used to make products for export, it has significantly lowered its birth rate, it is planning a massive nuclear reactor program, and only has one private car per hundred inhabitants.)

Comparative World CO2 Emissions



Global Warming Scenario

- Greenhouse gases: CO_2 , 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.
- Stabilizing the amount of CO_2 would require a reduction to only 5% to 10% of present fossil fuel emissions

Effects of the Doubling of CO_2

- Doubling of CO2 projected by end of century, causing ~ approximately a 5° F increase in average temperature (most rapid change in over 10,000 years)
  - ~1.5 foot maximum sea level rise
  - More storms and fiercer ones as illustrated by Atlantic hurricanes last year with 10° hotter Caribbean sea temperatures
  - Loss of coral reefs
  - Increase in tropical diseases since no winter coolness to kill insects
  - 25% decline in species that cannot shift range
  - Warming expected to be greater over land
  - Hot areas expect greater evaporation from hotter winds causing drought
  - In the past, half of produced carbon has gone into storage as in the oceans.
  - Heating of the surface ocean layer could stop ocean mixing and absorption into lower layers, thus shutting off carbon absorption.

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
- Rainfall is hard to predict. It could be increased or decreased.
- Drought can partly be caused by increased evaporation at the higher temperature.

Global Warming effects in 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.

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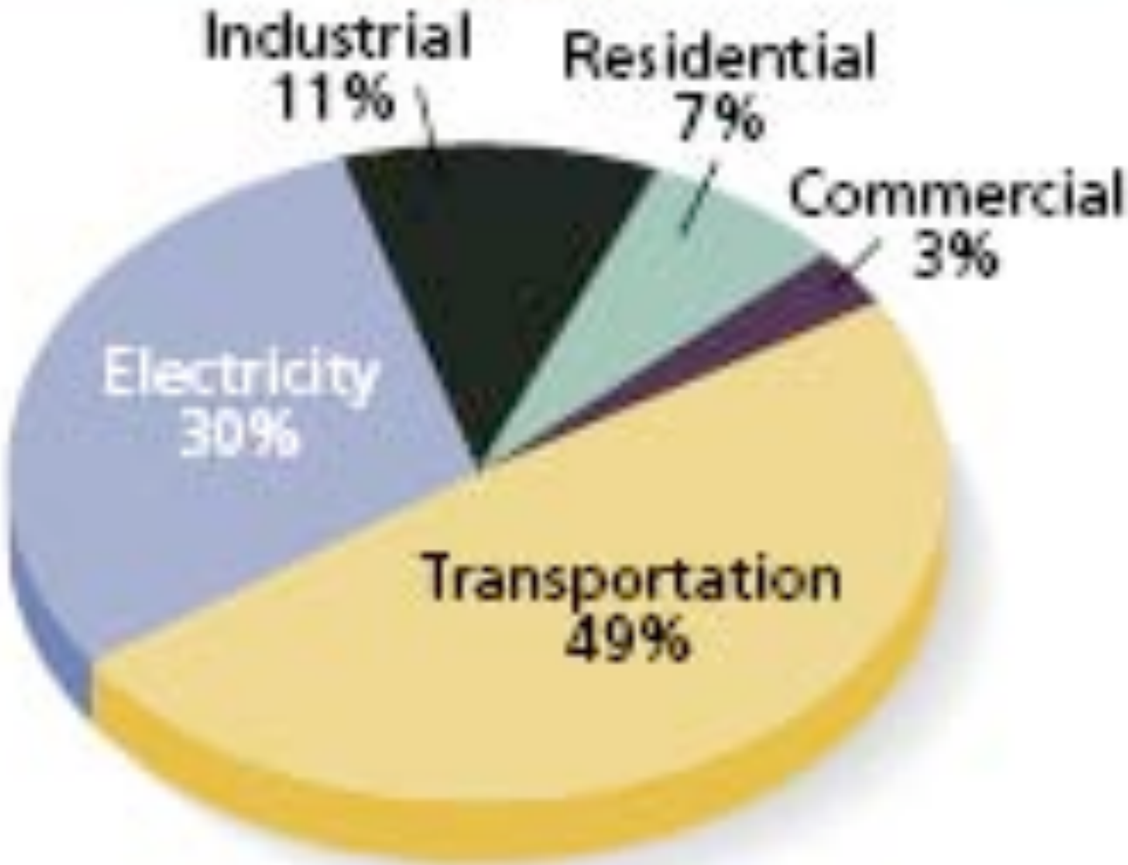
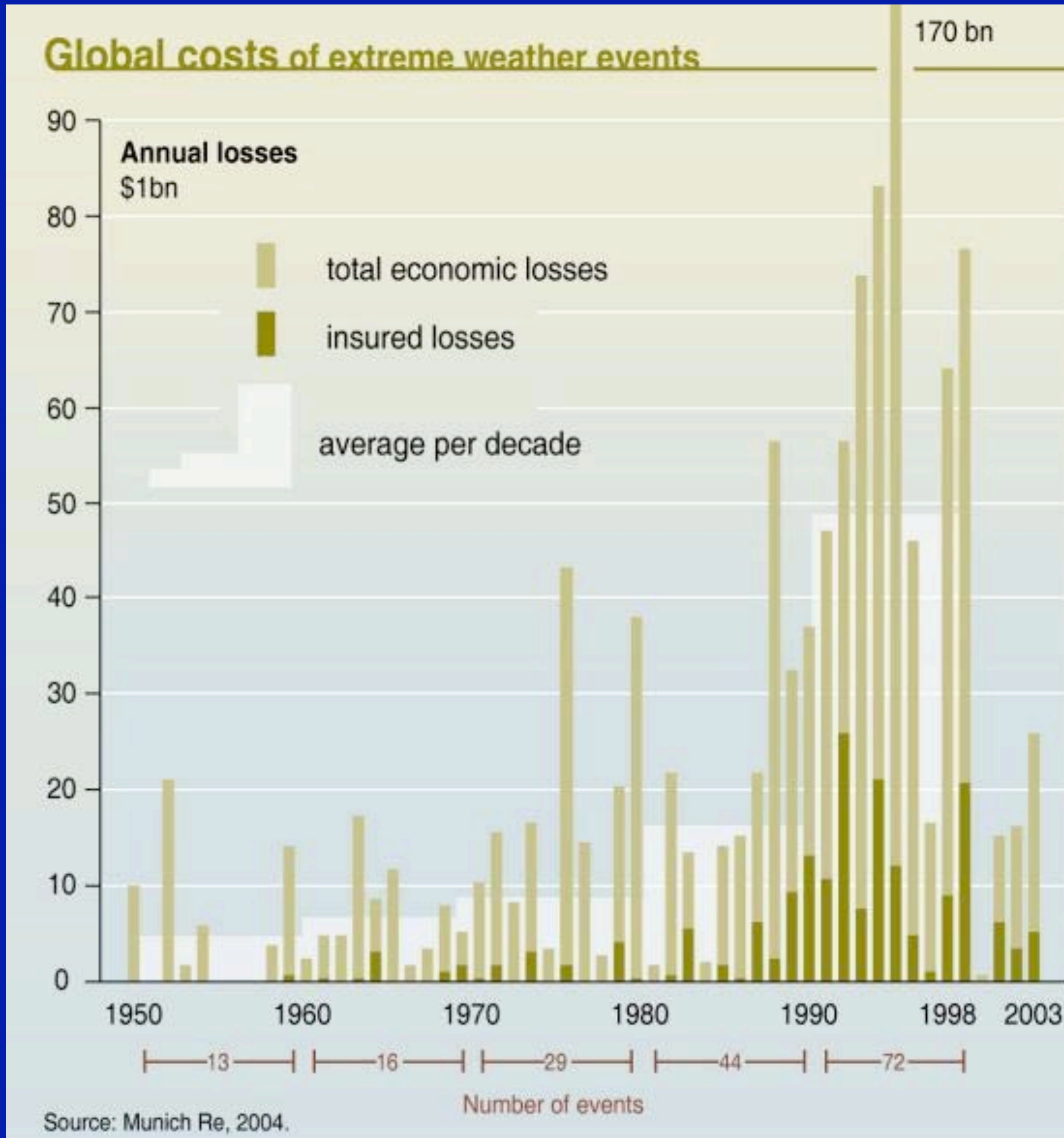
Figure 1: California CO_2 Emissions (1999)



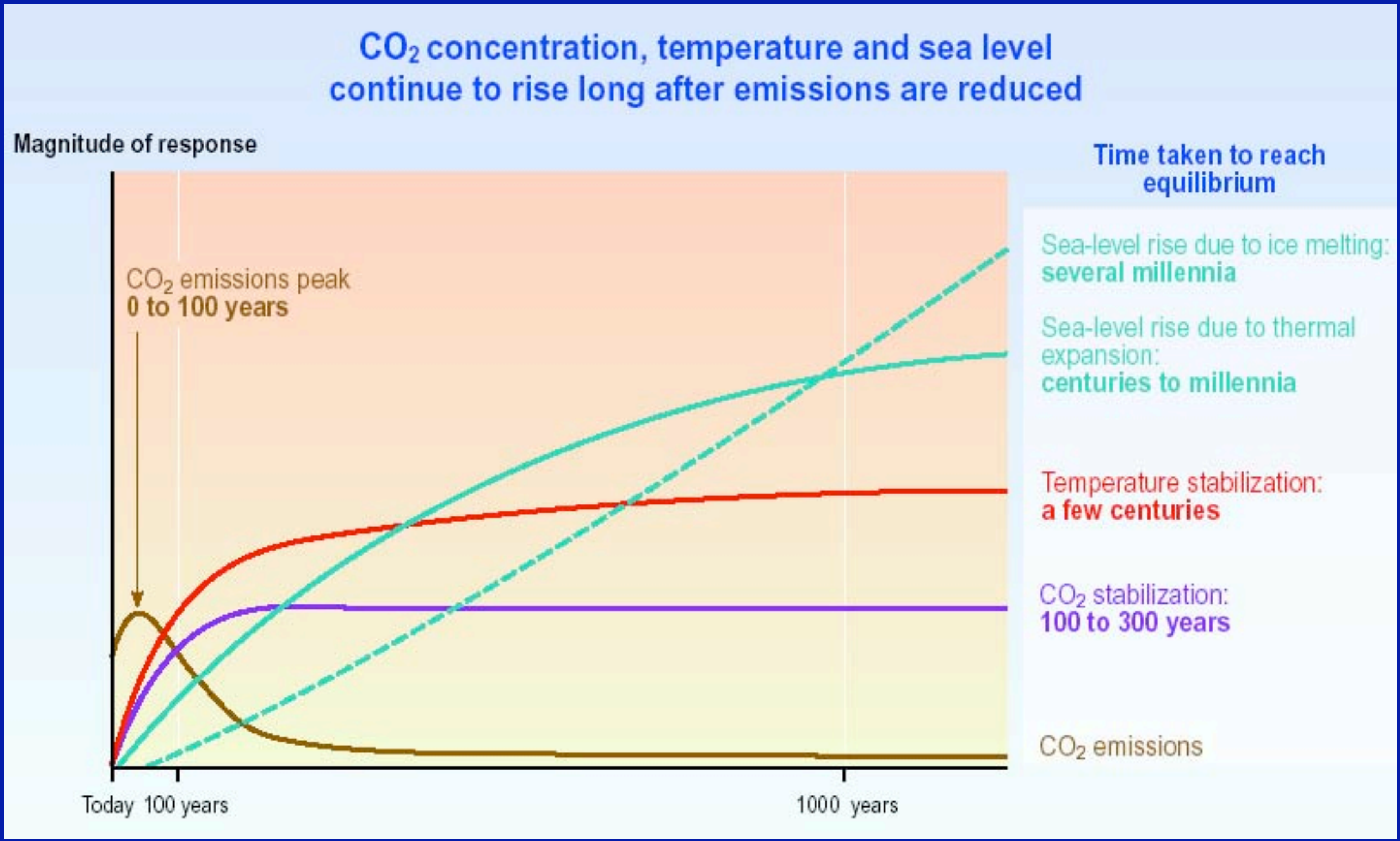
Note: Includes emissions from imported electric power.

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



Global costs of extreme weather events
170 bn
Annual losses
$1bn
90
80
70
60
50
40
30
20
10
0
total economic losses
insured losses
average per decade
1950
1960
1970
1980
1990
1998
2003
13
16
29
44
72
Number of events
Source: Munich Re, 2004.

CO2 Effects to Increase Over Centuries



GLOBAL WARMING

- Yes, the use of fossil fuels is profoundly changing the temperature of our living spaces.
- What is likely to happen as a result?
  – Some change now appears to be inevitable: adjust lifestyle to accommodate to then
  – Some change now appears to be preventable: adjust lifestyle & use more benign energy technologies---the sooner the better!

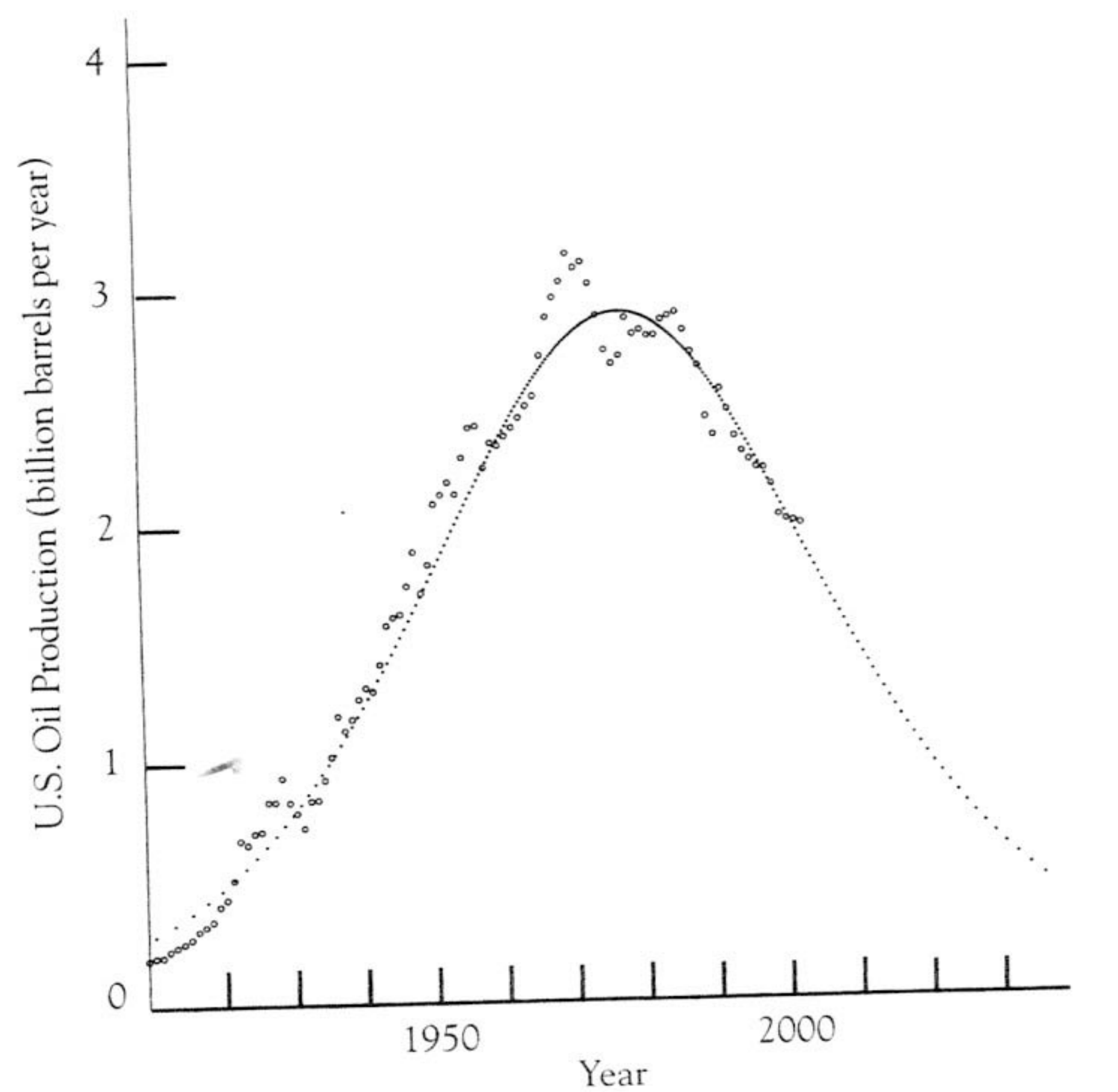
PEAK OIL

John Bush

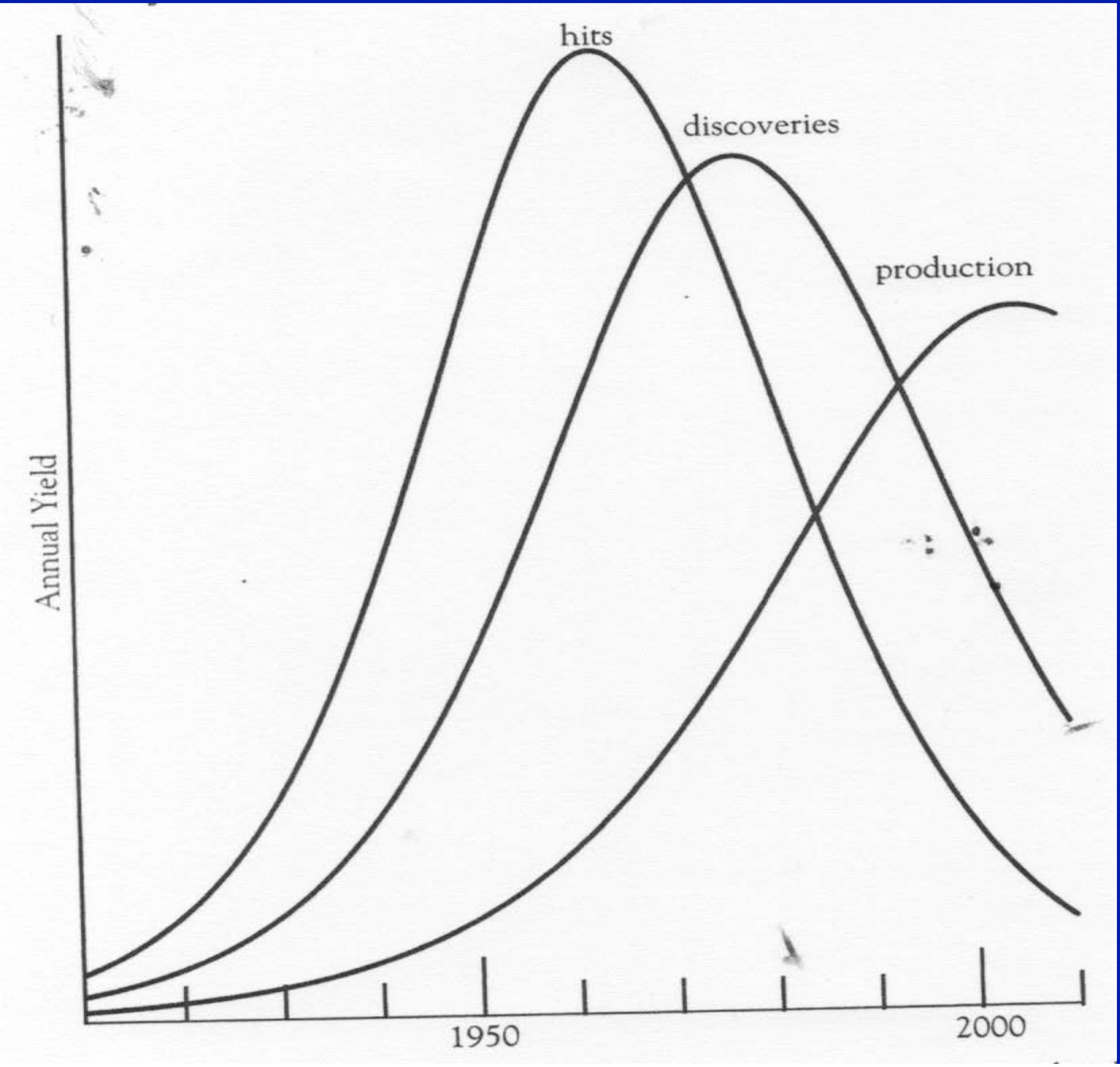
PEAK OIL

- Is the world running out of oil?-- Yes
- How near is the peak in global oil production?—Controversial
- What happens after the peak?—Without replacement technologies, society as we know i will collapse.
- What can we do to delay/avert social collapse?
  - Alter lifestyles to conserve oil
  - Develop replacement technologies
- Do we have enough time?—Yes, probably

HUBBERT'S PEAK



WORLD'S PEAK?



SOME OIL MEN'S VIEWS

- Hubbert's Model could be applied to the United States but not to the World
- New technology will lead to major discoveries
- Globally there is the potential to supply oil at the present rate for 140 years

RECENT DEVELOPMENTS

- US reserves increased 1.8% last year
- There have been major finds in the deep waters of the Gulf
- Mexico’s reserves have declined 15% since 2000

DO WE HAVE TIME TO ACT?

- Oil production will peak between now and 2070
- From small scale demonstration to widespread commercialization of energy technologies may ordinarily take 20 to 50 years
- Fossil energy conversion facilities have an average productive life of about 30 years
- **Conclude we will need to demonstrate the economic feasibility of technologies in the next 10 to 20 years to have them widely available by the time oil production peaks**

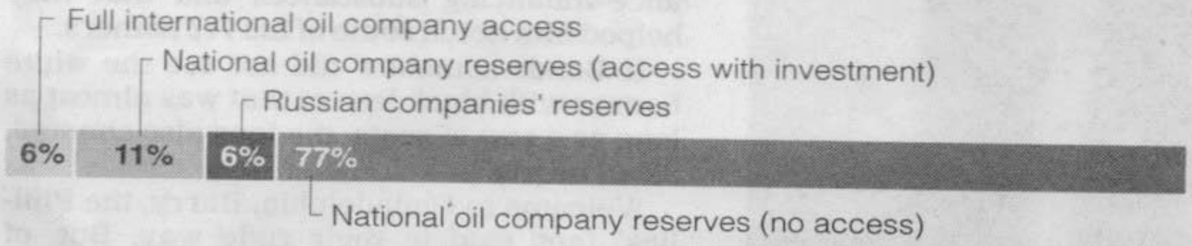
NATIONAL SECURITY

George Hume

NATIONAL SECURITY

- Is our military security endangered?—No
- Is our economic security endangered?—Yes
  - Major increase in competition for energy resources
  - Energy supplies sensitive to regional instability
- Are our foreign policy choices constrained?—Yes
- Can we become independent of imports?
  - Theoretically yes but at an unacceptable cost
  - Practically not until we deploy economically acceptable alternatives to oil.
- Energy independence is a myth at least in the next 10 to 20 years.

WORLDWIDE PROVEN OIL RESERVES ACCESSIBILITY



	COMPANY	HOME COUNTRY	COMBINED OIL AND NATURAL GAS RESERVES* (BILLIONS OF BARRELS)
1	**Gazprom**	Russia	254.0
2	**Saudi Aramco**	Saudi Arabia	250.0
3	**PDVSA**	Venezuela	247.9
4	**Qatar Petroleum**	Qatar	199.4
5	**Iraqi Oil Ministry**	Iraq	136.9
6	**Exxon Mobil**	United States	71.3
7	**KPC**	Kuwait	61.3
8	**BP**	Britain	56.5
9	**ADNOC**	U.A.E.	55.8
10	**Royal Dutch Shell**	Britain/Netherlands	52.7
11	**NIOC**	Iran	49.3
12	**Total**	France	39.5
13	**Chevron**	United States	38.8
14	**Rosneft**	Russia	38.1
15	**Pemex**	Mexico	32.5
16	**NNPC**	Nigeria	31.3
17	**Lukoil**	Russia	27.7
18	**Sonatrach**	Algeria	26.8
19	**ConocoPhillips**	United States	24.1
20	**PetroChina**	China	22.1

Sources: PFC Energy; Wood Mackenzie

*Estimates for proven, probable and undeveloped reserves

GLOBAL POPULATION/ECONOMIC GROWTH

Stephen Jeckovich

GLOBAL POPULATION/ECONOMIC GROWTH

- Can an economic model based on US practice be applied globally?—No
- Is the US model being adopted by relatively poor countries with large populations?--Yes
- How are the economic aspiration of three quarters of the worlds people going to be met?—With only the technical alternatives now available they won't be.
- What if suitable alternatives are not deployed?-A grim future

WATER & FOOD SCARCITY

Carolyn Kimme Smith

WATER & FOOD SCARCITY

- Can intensive agriculture as practiced in the US provide adequate food for the growing global population?—Not without some new form of energy technology
- Can agriculture meet both the food and energy requirements of the growing world population?—Probably not
- Will there be enough clean, fresh water for the growing world population?—Not without some new form of energy technology

CURRENT WATER NEEDS AND USES

- Southern California water usage: 66% for homes, 34% for agriculture.
- In single homes, 35% is for outdoor irrigation.
- On average, 400 gallons used per household. Seasonal difference: 519-268 gallons
- Central Valley uses 70% for agriculture.
- LADWP has 670,000 hookups for 3.8 million people.
- Hydoelectric power is 20% of state's total.

EFFECTS OF GLOBAL WARMING

- Expected population gains in CA of 50% by 2020, even with no global warming.
- This will result in a 36% increase in urban water use, similar to severe drought. (5.1 maf vrs 6.2maf)
- By 2098, water storage decreased by 7%, due to smaller snow pack, will decrease energy generated by 12%.

EFFECTS OF GLOBAL WARMING

- The snow pack accounts for one third of CA water storage.
- By 2089, 10 to 30% of the snow pack will be left.
- We can expect the same amount of precipitation, just as rain, not snow.
- We will need to replace hydroelectric power in order to use water for homes, agriculture.

NATIONAL AND WORLD WATER

- Rainfall patterns are expected to be disrupted. Reservoirs and hydroelectric plants may no longer be located where needed.
- Less arable land, less agriculture water, less food, less power from hydroelectric plants.
- During the last 50 years, competition for oil.
- During the next 50 years, will there be competition for water and arable land?

AMERICAN LIFESTYLE

Carolyn Kimme Smith

THE AMERICAN LIFESTYLE

- Can a lifestyle based on intensive use of inexpensive fossil fuels be sustained?—No
- What may have to change?
  - Primacy of individual transport
  - Dispersed housing, work, and services
  - Low cost distribution of goods
  - Adequate, reliable utilities
  - Environmental qualities
  - Energy usage habits

TECHNOLOGIES

- Fossil Fuels……………………………….John Bush
- Biofuels……………….Max Lechtman/Vern Roohk
- Nuclear Fission/Fusion……..........George Hume
- Solar Thermal/Photovoltaic.…Dennis Silverman
- Hydroelectric/Geothermal……………John Bush
- Wind/Waves/Tides…………………George Hume
- Electric System…………………………John Bush
- Hydrogen……………………Carolyn Kimme Smith
- Transportation…………………Stephen Jeckovich
- Conservation……………….......Dennis Silverman

FOSSIL FUELS

- Oil
- Natural Gas (Methane)
- Coal
- Synfuels

RELATIVE CARBON DIOXIDE PRODUCED BY COMBUSTION

Pounds of

Carbon Dioxide/MBTU

Coal…………………210

Gasoline…………157

Natural Gas……..112

OIL: APPLICATIONS

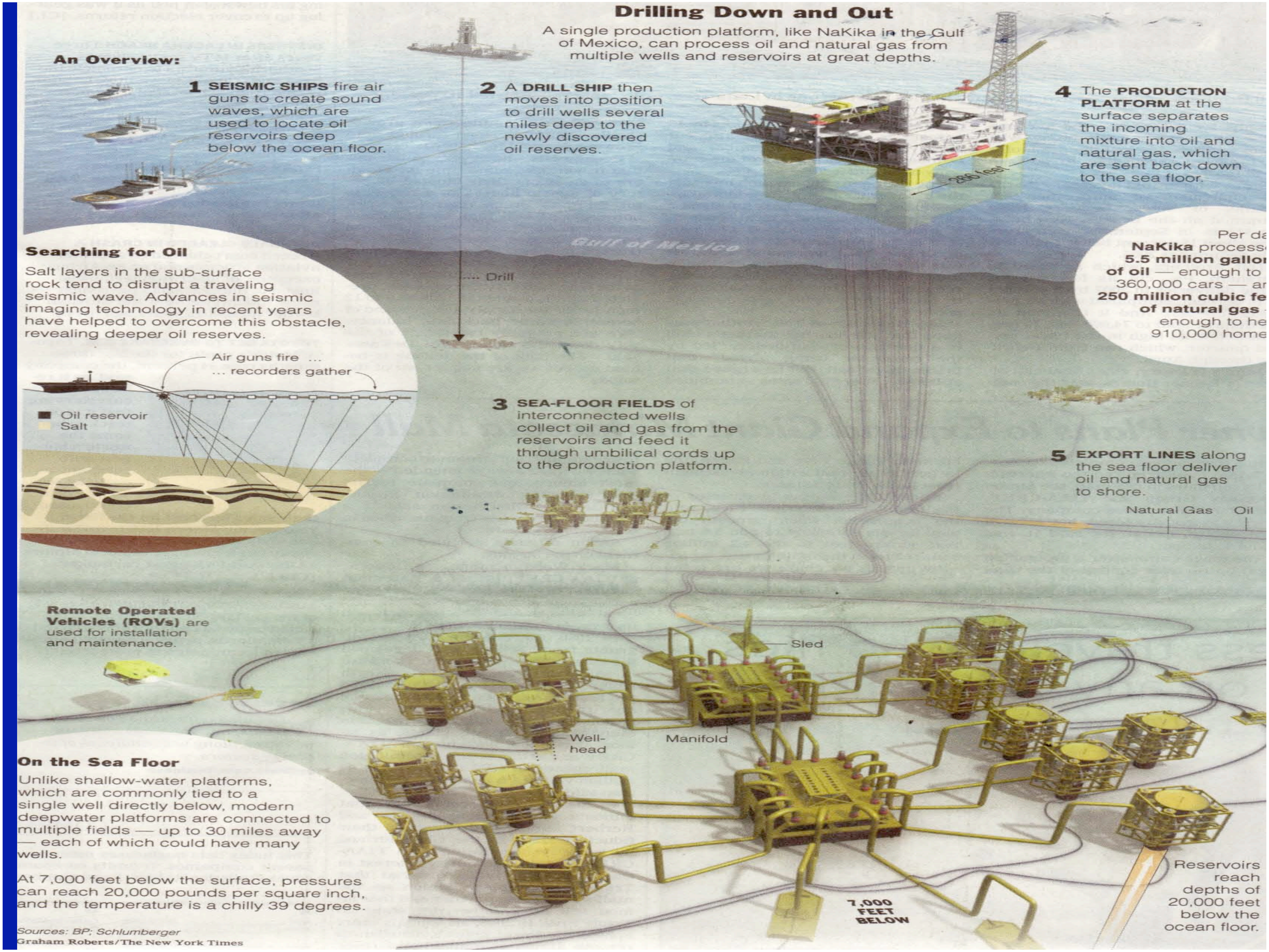
- How is it used?—combustion to produce carbon dioxide, water, and heat
- Where is it used?--primarily transportation
- A secondary use is in industry

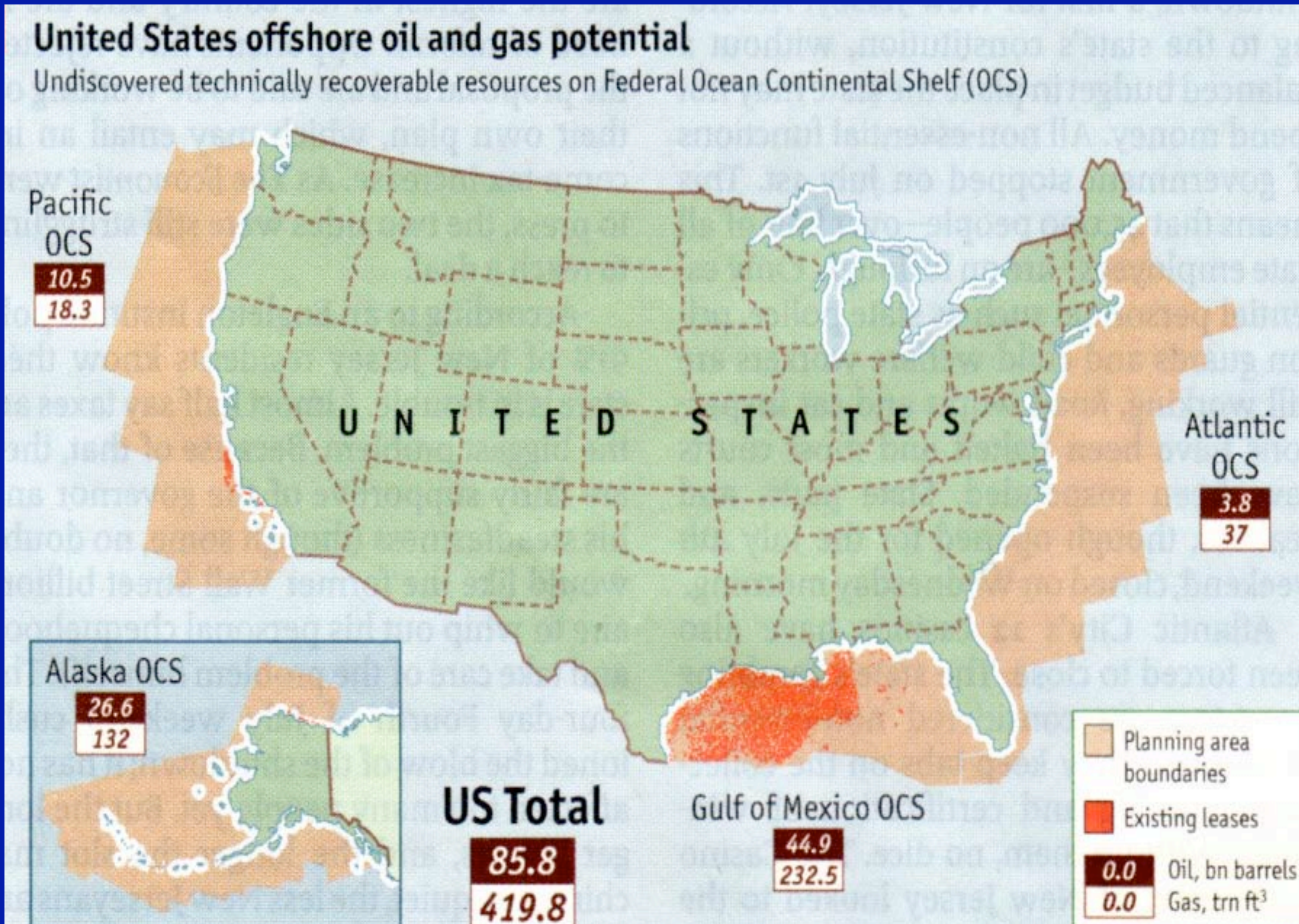
US PETROLEUM FLOW
Million Barrels/Day

- Supply 20.6
  - Petroleum Imports……………….13.5
  - Petroleum Exports……………… (1.2)
  - Petroleum Production……………. .6.8
  - Other /Ethanol………….. ………..1.6
- Refined Products
  - Motor Gasoline………………….... 9.1
  - Fuel Oil…………………………....4.1
  - Jet Fuel……………………………1.6
  - LPG………………………………. 2.0
  - Other……………………………. ..3.8
- Consumption
  - Transportation…………………… 13.8
  - Industry…………………………. 5.0
  - Commercial……………………….. 0.4
  - Residential……………………….. 0.9
  - Electric Power…………………….. 0.5

TECHNOLOGIES

- Exploration–Seismography
- Drilling—Deep water
- Production—Recovery
- Efficient Use—Transportation applications


Drilling Down and Out
A single production platform, like NaKika in the Gulf of Mexico, can process oil and natural gas from multiple wells and reservoirs at great depths.
An Overview:
1 SEISMIC SHIPS fire air guns to create sound waves, which are used to locate oil reservoirs deep below the ocean floor.
2 A DRILL SHIP then moves into position to drill wells several miles deep to the newly discovered oil reserves.
4 The PRODUCTION PLATFORM at the surface separates the incoming mixture into oil and natural gas, which are sent back down to the sea floor.
286 feet
Gulf of Mexico
Drill
Searching for Oil
Salt layers in the sub-surface rock tend to disrupt a traveling seismic wave. Advances in seismic imaging technology in recent years have helped to overcome this obstacle, revealing deeper oil reserves.
Air guns fire ...
... recorders gather
Oil reservoir
Salt
Per da
NaKika process
5.5 million gallo
of oil — enough to
360,000 cars — a
250 million cubic fe
of natural gas
enough to he
910,000 home
3 SEA-FLOOR FIELDS of interconnected wells collect oil and gas from the reservoirs and feed it through umbilical cords up to the production platform.
5 EXPORT LINES along the sea floor deliver oil and natural gas to shore.
Natural Gas
Oil
Remote Operated Vehicles (ROVs) are used for installation and maintenance.
Sled
Well-head
Manifold
On the Sea Floor
Unlike shallow-water platforms, which are commonly tied to a single well directly below, modern deepwater platforms are connected to multiple fields — up to 30 miles away — each of which could have many wells.
At 7,000 feet below the surface, pressures can reach 20,000 pounds per square inch, and the temperature is a chilly 39 degrees.
7,000 FEET BELOW
Reservoirs reach depths of 20,000 feet below the ocean floor.
Sources: BP; Schlumberger
Graham Roberts/The New York Times

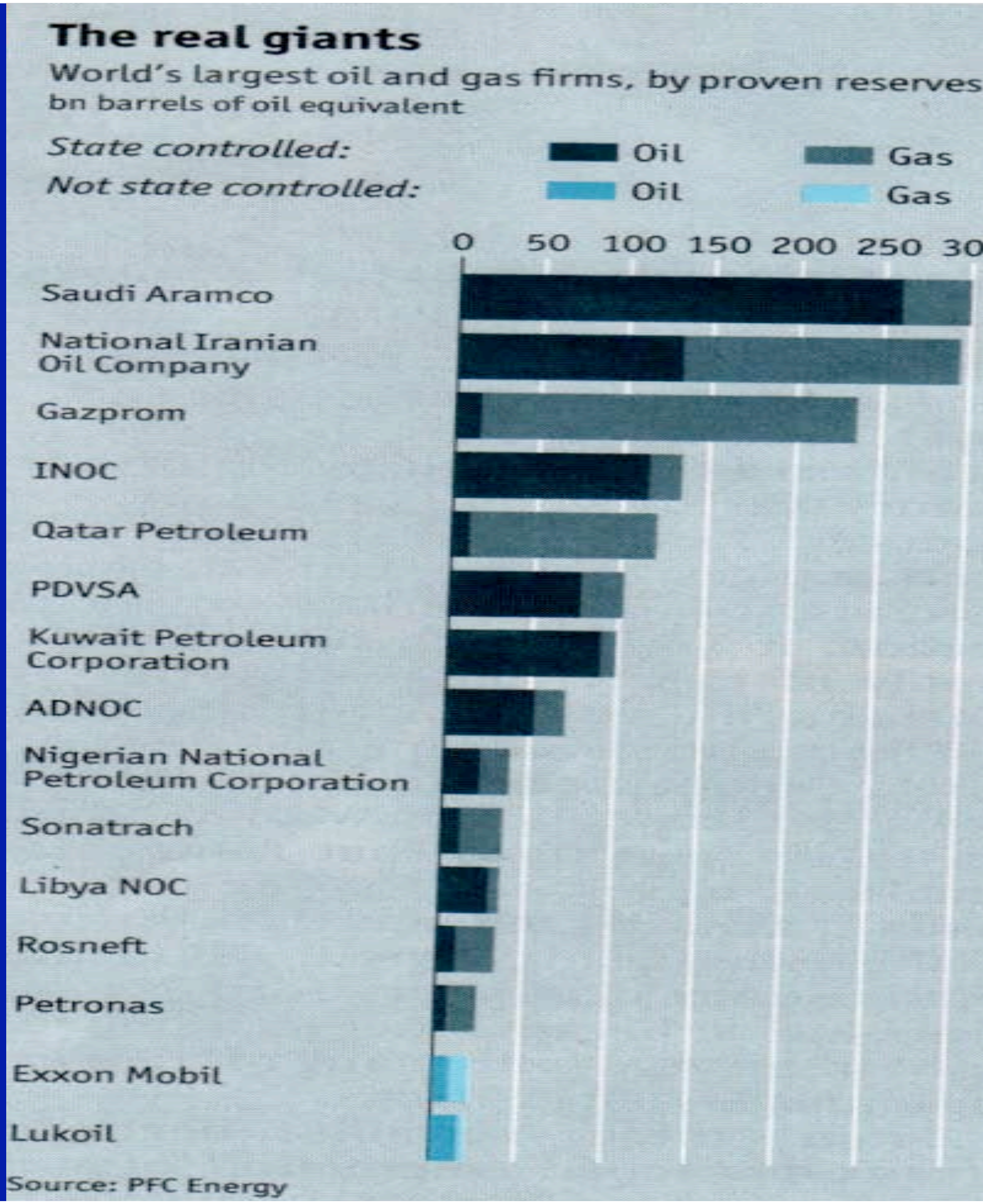


United States offshore oil and gas potential
Undiscovered technically recoverable resources on Federal Ocean Continental Shelf (OCS)
Pacific OCS
10.5
18.3
UNITED STATES
Atlantic OCS
3.8
37
Alaska OCS
26.6
132
US Total
85.8
419.8
Gulf of Mexico OCS
44.9
232.5
Planning area boundaries
Existing leases
0.0 Oil, bn barrels
0.0 Gas, trn ft³


DOES THIS RIDE EVER END?
OIL PRICES
BARLING
THE CHRISTIAN SCIENCE MONITOR

OIL CRISES

- There have been four major oil supply crises in the last fifty years
- Each time the industry has “drilled” and produced its way out of the crisis
  - Majors could draw on shut in production capacity—Saudi Arabia could “turn on the tap”
  - New fields were found and developed fairly rapidly
- But circumstances for the US have changed



The real giants
World's largest oil and gas firms, by proven reserves
bn barrels of oil equivalent
State controlled:
Oil
Gas
Not state controlled:
Oil
Gas
0
50
100
150
200
250
30
Saudi Aramco
National Iranian Oil Company
Gazprom
INOC
Qatar Petroleum
PDVSA
Kuwait Petroleum Corporation
ADNOC
Nigerian National Petroleum Corporation
Sonatrach
Libya NOC
Rosneft
Petronas
Exxon Mobil
Lukoil
Source: PFC Energy

FOSSIL-DERIVEDLIQUID SYNTHETIC FUELS

- All generate extra carbon dioxide in their production processes
- Syncrude
  – Tar Sands: requires hydrogen
  – Oil Shale: not technically feasible
- Syndiesel: from natural gas
- Syngasoline: from coal
- Methanol: from coal

METHANE

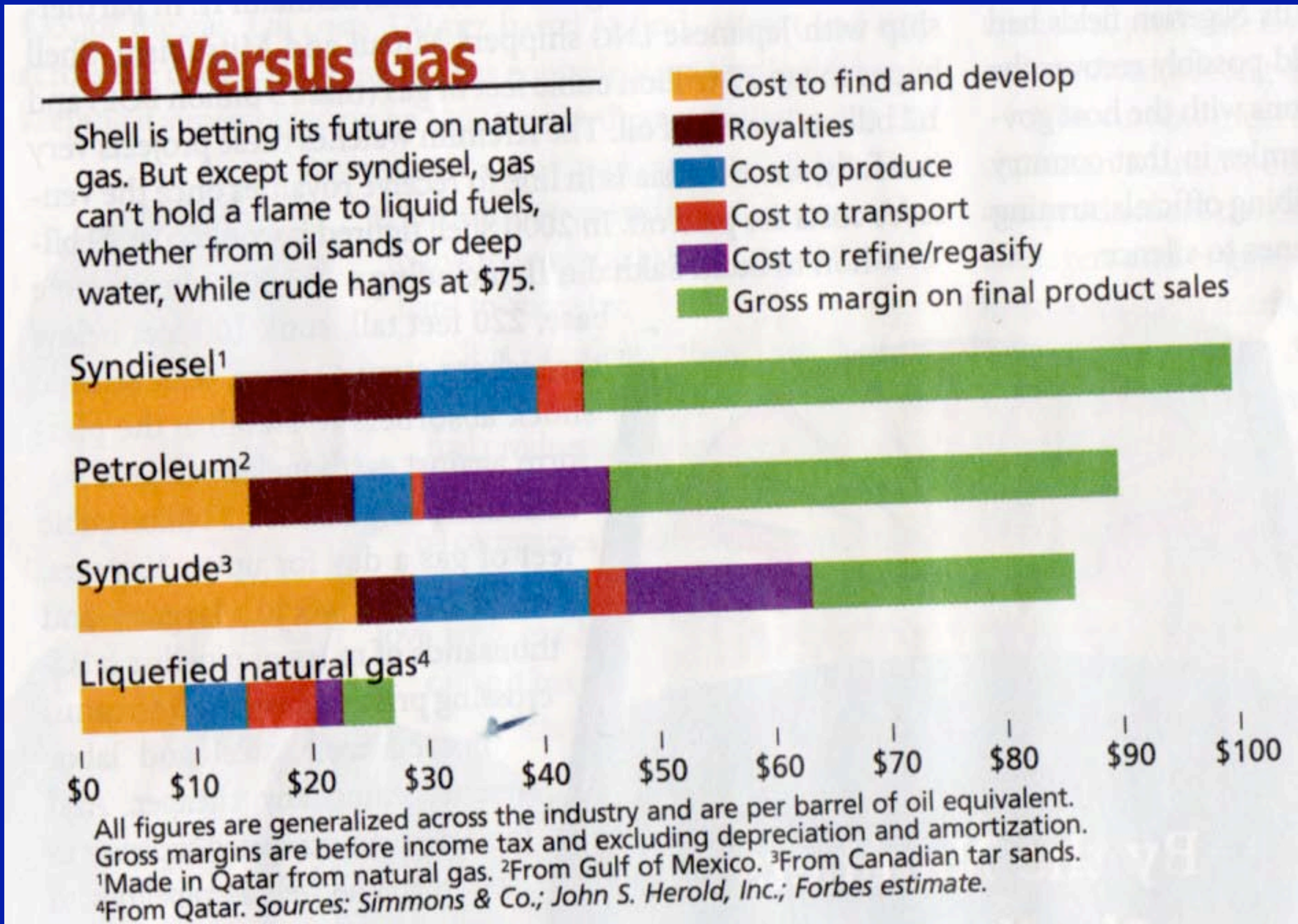
- How is it used?—combustion to produce carbon dioxide, water, and heat
- Where is it found?
  - In underground reservoirs
  - In coal beds
  - In solid hydrates
  - As product of fermentation e.g. landfills, biogas
- Where is it used?
  - Electricity generation
  - Domestic heat
  - Chemical raw material
  - Transportation

HOW MUCH IS THERE?

- North America
- Australia
- Middle East
- Russia
- Probably a lot more to be found
- Problem: how to get the gas to the user?

TECHNOLOGIES

- Liquefaction in tanker ships: LNG
- Convert to liquid fuel
  - Tulsa Okla. DOE Demo 70 bbl/day
  - Qatar Exxon/Chevron/Shell 750,000 bbl/day
  - Possibility for Alaska?
- Convert to hydrogen
- Convert to electricity: hydrocarbon fuel cell


Oil Versus Gas
Shell is betting its future on natural gas. But except for syndiesel, gas can't hold a flame to liquid fuels, whether from oil sands or deep water, while crude hangs at $75.
Cost to find and develop
Royalties
Cost to produce
Cost to transport
Cost to refine/regasify
Gross margin on final product sales
Syndiesel1
Petroleum2
Syncrude3
Liquefied natural gas4
$0
$10
$20
$30
$40
$50
$60
$70
$80
$90
$100
All figures are generalized across the industry and are per barrel of oil equivalent. Gross margins are before income tax and excluding depreciation and amortization. 1Made in Qatar from natural gas. 2From Gulf of Mexico. 3From Canadian tar sands. 4From Qatar. Sources: Simmons & Co.; John S. Herold, Inc.; Forbes estimate.

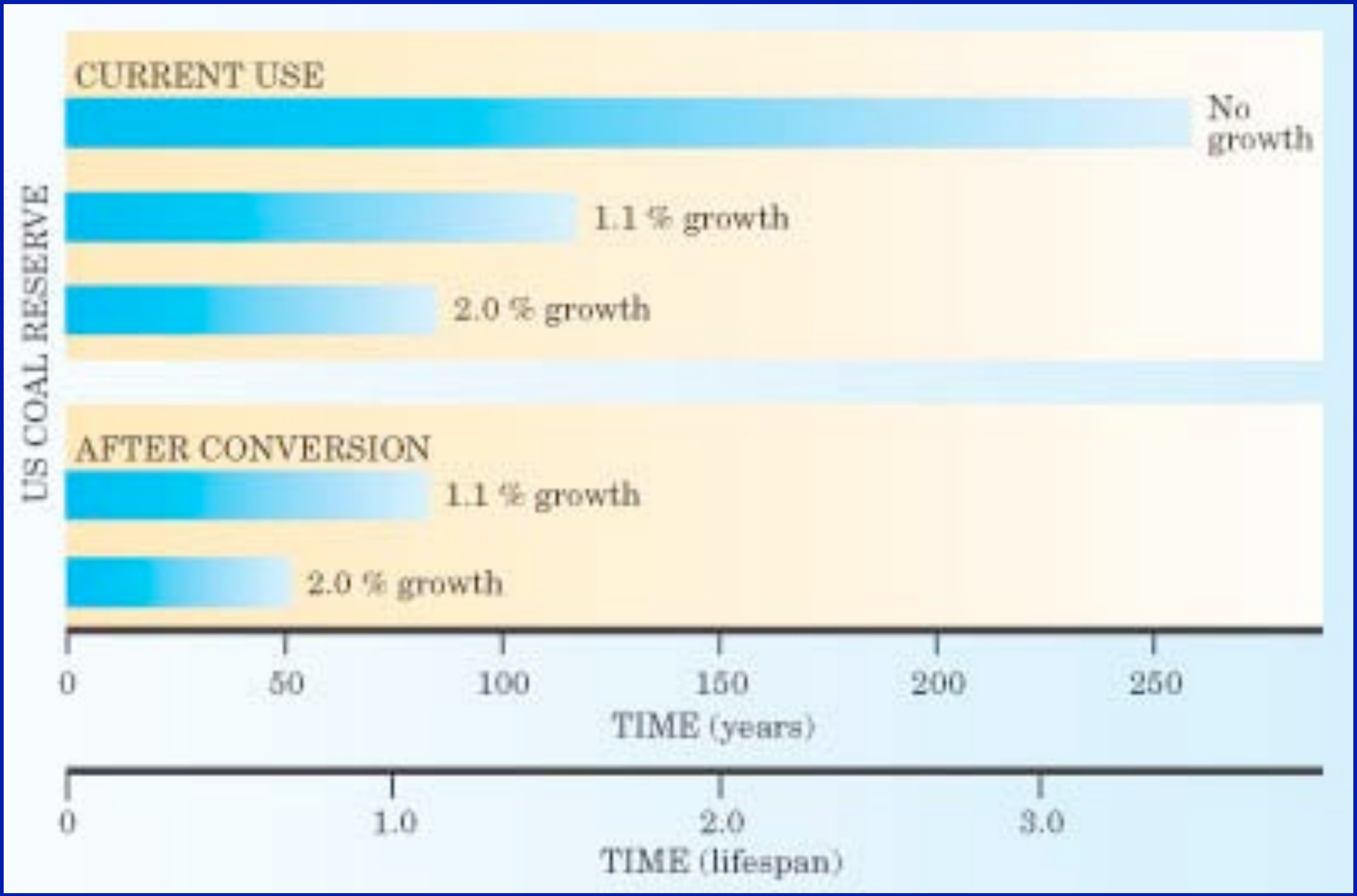
COAL

- How is it used?—Combustion to produce carbon dioxide, water, **ash**, and heat
- Where is it found?—As a rock formation
- Where is it used?—Primarily to generate electricity

GENERATION OF ELECTRICITY FROM COAL

- About half of US electricity comes from coal
- Currently 115 coal-fired plants are under construction
- Negatives of coal to electricity
  - Coal generates twice as much carbon dioxide per unit of energy as does natural gas
  - Air & water pollutants
  - Aesthetics
  - Mortality of miners and users

US COAL LIFETIME



TECHNOLOGIES

- Underground gasification
- Increased efficiency of electricity generation
  - Supercritical pulverized coal combustion
  - Integrated Gasification Combined Cycle
  - High temperature fuel cell
- Conversion to gas or liquid fuels
- Carbon dioxide sequestration

CONVERSION OF COAL TO SYNFUELS

- Gasoline: technology well established
- Methane: technology well established
- Methanol: a new proposal
- All produce large amounts of extra carbon dioxide

CARBON DIOXIDE CAPTURE/STORAGE "SEQUESTRATION"

- Capture/Transport/Store: each element of technology has been technically demonstrated but they have not integrated
- Demonstration projects are underway
  - FutureGen $1B over 10 yrs.
  - Statoil in North Sea bed
- Adds to cost of electricity
  - Capture adds 2.5 to 4 cents/kwh
  - Underground storage adds 1 to 5 cents/kwh

CARBON DIOXIDE STORAGE

- There seems to be storage capacity for 80 years worth of current carbon dioxide emissions
- Will the carbon dioxide stay in place?
- Some wilder ideas for storage
  - Ocean storage
  - Genetic manipulation of plant life
  - Increase soil carbon

SUMMARY: FOSSIL FUELS

Conventional Petroleum

Terrestrial Natural Gas

Coal

Bitumen (“Tar Sands”)

Oil Shale ????????
Seabed Methane ??????????????????????

BioRenewable Resources

Transportation Fuels

Max D. Lechtman

Vern Roohk

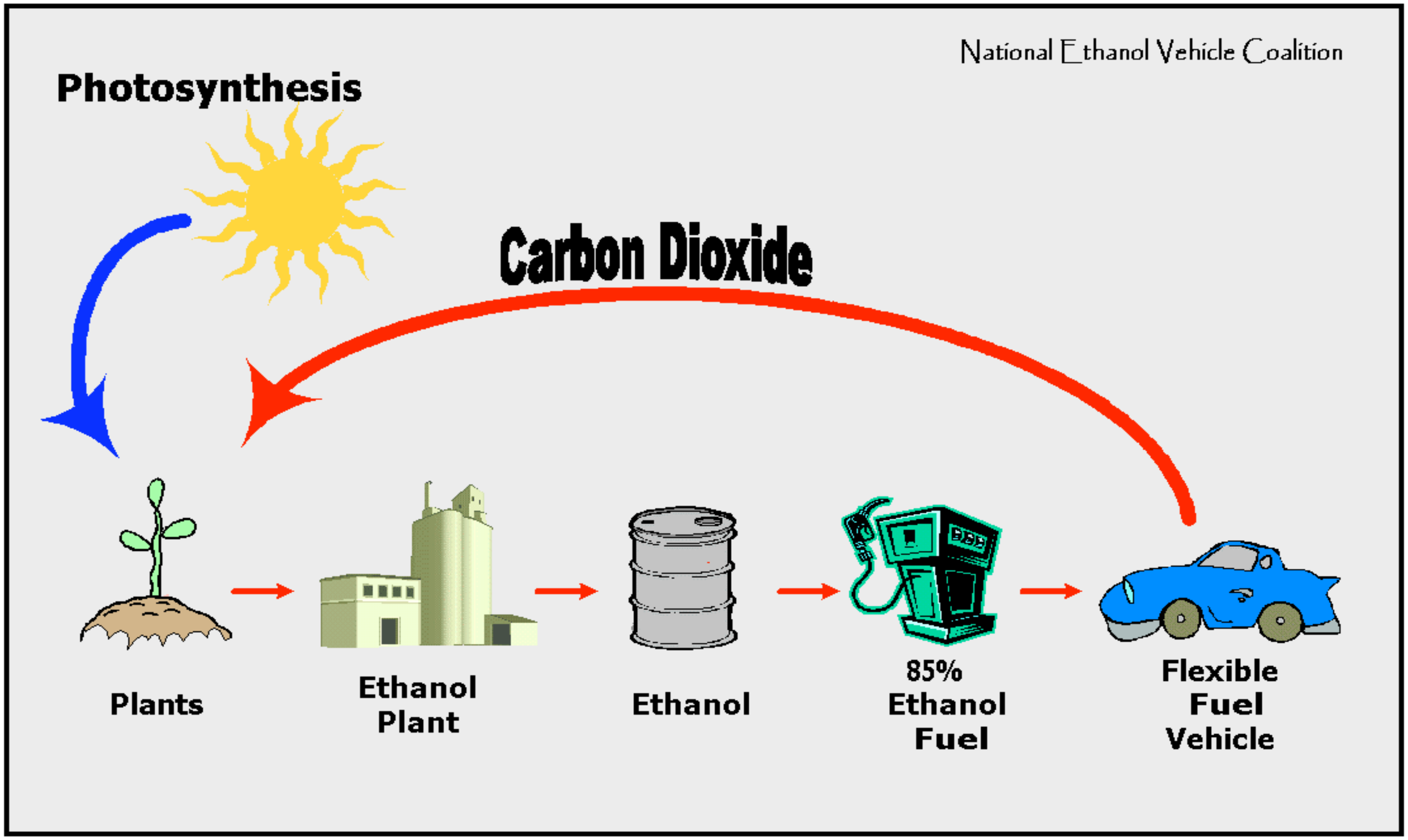
OBJECTIVES

- Reduce atmospheric carbon dioxide soon
- Decrease reliance on petroleum
- Minimize impact on vehicles/drivers
- Help the farming economy

The Usual Suspects

- Ethanol
- BioDiesel
- Natural Gas

Ethanol


National Ethanol Vehicle Coalition
Photosynthesis
Carbon Dioxide
Plants
Ethanol Plant
Ethanol
85% Ethanol Fuel
Flexible Fuel Vehicle

Biodiesel vs Diesel

Cetane Index	+
Lubricity	+
Cold Weather Performance	- -
Energy Content	-
Combustion	+
Emissions: HCs, PMs, CO	+
Emissions: NOs	-

Transportation Fuel Needs

- Gasoline/day-US is ~360 million gallons
- Gasoline/day-CA is ~47 million gallons

- #2 Diesel/day-US is ~164 million gallons
- #2 Diesel/day-CA is ~13 million gallons

Ethanol
Production (million gallons/day)

- Ethanol-US is ~13.2 from corn
  - E100 has ~71% the efficiency of gasoline
- Est. 2008 to be ~22 from corn
- Est. long term to max at ~41 from corn
- Est. long term to max at ~123 from cellulose

==

Max fuel from Ethanol(cellulose)/Gasoline mixtures:

E10 = ~1230 – Probably okay

E85 = ~ 145 – Inadequate

Ethanol Economics

- E85 in Midwest is (?)$2.90/gallon
- Using corn feedstock- ~$4/gallon for energy equivalency
- Using cellulose feedstock- ~$6/gallon for energy equivalency

BioDiesel

Production Data US-(million gallons/day) :

- BioDiesel is ~ 0.22
  - – Waste Cooking Oil is ~0.8

Biodiesel vs Diesel
Projected Production Costs/Gallon

Year	Oil	Grease	Petrol.
2005	$2.54	$1.41	$0.67
2007	2.47	1.38	0.77
2010	2.57	1.42	0.75
2013	2.80	1.55	0.75

Biodiesel costs assume output of 0.22 MGD

Biodiesel Processes
Waste Vegetable Oil

Commercial

1. Heat oil
2. Additives
3. Separate
4. Remove glycerine
5. Wash product
6. Separate
7. Remove water

Home

1. Filter debris
2. Additives
3. Stir
4. Prime pumps
5. Filter water

Prospects for Biofuels-3rd world

World Bank Report, October 2005

Near Term:

- Ethanol from sugarcane has best chance of commercial viability
- Biofuel trade liberalization beneficial to all consumers
- Biodiesel remains expensive relative to world oil prices

Prospects for Biofuels-3rd world

World Bank Report, October 2005

Medium Term:

- Fall in production costs
- New feedstocks
- Growing Trade

Prospects for Biofuels-3rd world

World Bank Report, October 2005

Long Term:

- Commercialization of cellulosic ethanol-widespread availability, abundance, and significant lifestyle greenhouse gases emission reduction potential
- Higher oil prices favoring biofuel economics

OBJECTIVES

- Reduce atmospheric carbon dioxide soon
- Decrease reliance on petroleum
- Minimize impact on vehicles/drivers
- Help the farming economy

NUCLEAR FISSION/FUSION

George Hume

CONTEXT OF OUR STUDY

- Nuclear power (fission) is an economically viable energy source
- PROBLEM: Many U.S. citizens have a negative attitude toward nuclear power
- QUESTION: What must be done to address the problem so that we can employ nuclear power to:
  - Meet our increasing demand for electric power?
  - Reduce our greenhouse gas emissions?

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 Generation

(in 2000)

Country	No. Reactors	Generation, kWh	% Total
United States	103	754	20
France	59	395	76
Japan	53	305	34
United Kingdom	35	78	22
Germany	19	160	31
Russia	29	120	15
So. Korea	16	103	41
Canada	14	69	12
India	14	14	3
Sweden	11	55	39
21 Others			
Totals:	437	2,447	16

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.

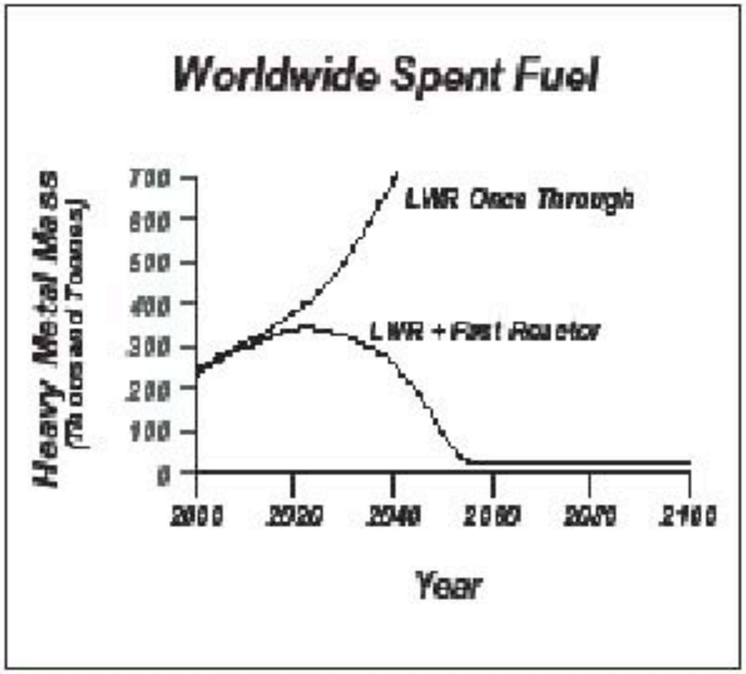
The total 5,500 megawatts of nuclear power is out of a peak state electrical power of 30,000 – 40,000 megawatts.

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.

Naval Reactors

- U.S. Navy
  - Has about 104 reactors used as primary propulsion and electric power generation in submarines, aircraft carriers, a cruiser and a destroyer.
  - Has safely accumulated over 5400 reactor-years of operation
  - Since USS Natilus got underway on nuclear power in 1955, our Navy has safely steamed 130 million miles on nuc. Power
  - Uses more enriched fuel than commercial reactors
  - Source of trained personnel in reactor operation.
- Foreign Navies
  - Russia, France, United Kingdom and China. Approx. quantities are: Russia ~100; France ~20; UK ~20; and China ~ 6.


Worldwide Spent Fuel
Heavy Metal Mass
(Thousand Tonnes)
700
600
500
400
300
200
100
0
2000
2020
2040
2060
2080
2100
Year
LWR Once Through
LWR + Fast Reactor


Worldwide Uranium Resource Utilization
Cumulative Natural U
(Million Tonnes)
50
40
30
20
10
0
2000
2020
2040
2060
2080
2100
Year
LWR Once Through
Fast Reactors
Introduced 2050
Speculative Resources
Fast Reactors
Introduced 2030
Known
Resources

Selected policy recommendations: waste management

- Long-term storage of spent fuel for several decades should become an integral part of the waste management system architecture
  - a network of centralized storage facilities should be established in the U.S. and internationally.
- The scope of waste management R&D should be significantly broadened
  - Should include an extensive program on deep borehole disposal

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, and
Study of fuel reprocessing, waste disposal, and safety

FUSION POWER
"a promising technology"

- Research has been underway for 50 years
- ITER Project: European Union, United States Canada, Japan, Russian Federation
- Purpose: To demonstrate that electrical power from fusion is technically feasible
  - Design took 10 years
  - Cost to build and operate is more than $4.5 billion over 10 years
- Expect results in 10-20 years
- Demonstration of economical feasibility probably 50 years away

Conclusions and Recommendations

- Proven Technology is Available in Generation III and III+ Reactor Designs (such as ABWR, AP1000,PBMR) for Deployment by 2010 if Political/Attitude Problems can be Altered.
- Attitude Adjustment and some further R&D are Needed to Progress from "Once Through" No Reprocessing Fuel Cycles to the More Advanced Multiple Pass Cycles Used and Advocated by other Countries in Gen. IV Designs to Achieve:
  - Efficient Use of Uranium Fuel Resources
  - Reduce "Spent Fuel" Impact on Long Term Storage Facilities
- Governmental (Political/Attitude) progress is Needed to Activate and Use Long Term Nuclear Waste Storage
- Selected Gen. IV Reactor Designs Should be Funded for Further Definition and Developed for Deployment by 2020 and Beyond.
- Keep Fusion Power Efforts at the R&D Stage with Carefully Controlled Funding Pending Positive Results from ITER.

Power from the Sun

Dennis Silverman

Solar Power

- Most of all energy we use comes or has come from the sun.
- Fossil fuels arise from fossil plants and animals converted to carbon (coal), or hydrocarbons (methane and petroleum).
- We are 1/3 to 1/2 through the process of burning hundreds of millions of years of fossil fuel accumulations in two centuries.

Free Solar

- The sun would heat the planet to 0° Fahrenheit without the atmosphere.
- It runs the greenhouse that keeps the earth warmed up to an average of 58° F with the greenhouse gas atmosphere.
- It evaporates the oceans to provide the rain and fresh water for crops and drinking water and hydropower.
- It grows our crops and forests through photosynthesis
- Solar energy provides our vast amount of daylight and moonlight.
- It heats our homes in the daytime, and the sea and land hold heat for the night.

Solar Manipulation

- The next best way to use solar is to modify its effects.
  - Reflective roofs to keep buildings cool
  - Reflective windows to keep out direct sunlight during the summer, and keeping heat in in the winter
  - Windows and skylights for indoor daytime lighting

Direct Solar Energy

- Mediterranean climates now using rooftop or nearby solar water heating – Greece, Israel, Japan. It is 80% efficient.
- Solar clothes drying

Solar Photovoltaic Electricity

- Silicon wafers doped to form photovoltaic cells
  - Power is free, but
  - Large wafers still thick and crystal grown as chips, so still expensive
  - Cost still 3 to 10 times as expensive as fossil fuel power
  - Efficiency only 10 to 15%, so large areas needed
  - Daily and yearly average only 1/5 of maximum power capacity installed
  - Storage could be in charging car batteries or in hydrogen fuel, or
  - Concentrate on using more energy during the daytime
  - Silicon valley investigating thin film disk technology to make cheaper

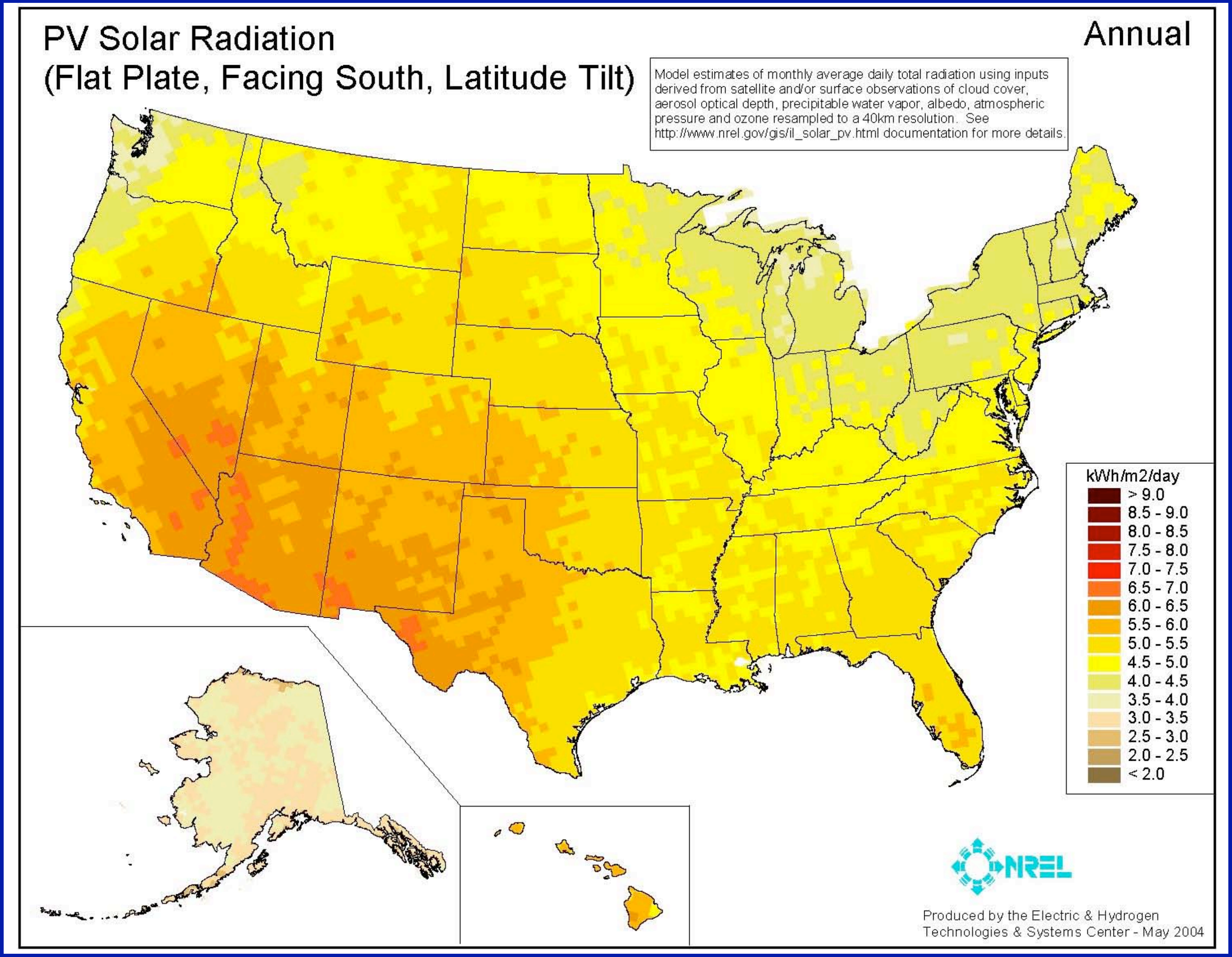
Unelectrified Areas

- Two billion people do not have electricity
- To save on kerosene lanterns, solar cells with batteries and lcd lights have been developed for nighttime lighting
- Also used to charge freeway phones

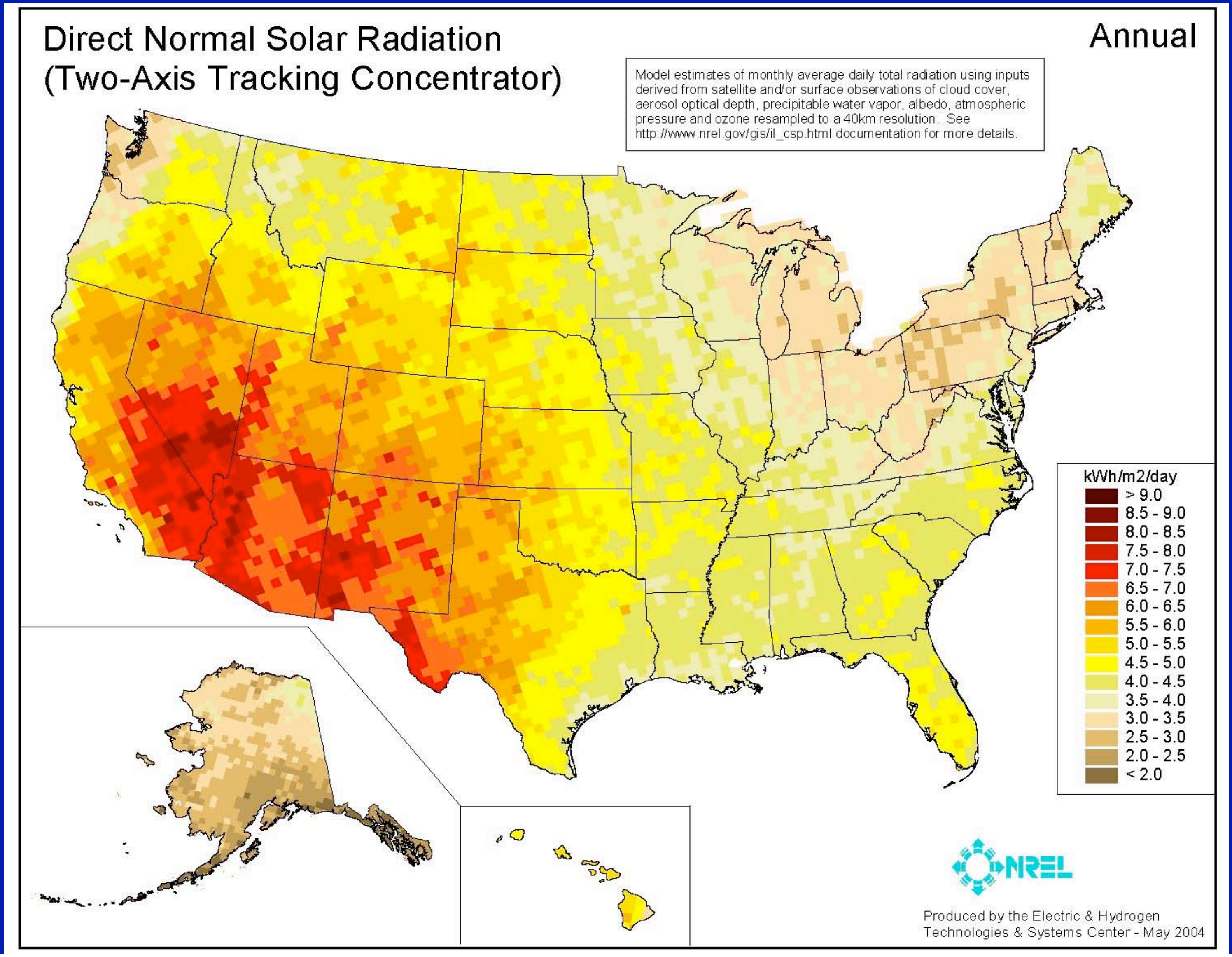
California’s Million Solar Roofs

- California SB1 (Senate Bill 1) to provide rebates to equip solar power installations
- Companies rebated per kwh generated
- New homes must offer solar option by 2011
- 500,000 more homes can be added to generating electricity into the power network
- 3.3 billion dollar cost, but for less electricity than a comparable nuclear plant
- Could only nearly pay if it brings down costs through economies of scale
- Or if it leads to technological breakthrough through research and competition
- Only 100 million dollars for solar water heating

U. S. Solar Resources



U. S. Tracking Mirror Solar



Solar Troughs
(Max Lechtman)

- Suitable For Large Systems
- Grid-connected Power
- 30-200 MW size
- Proven Technology
- Available Today

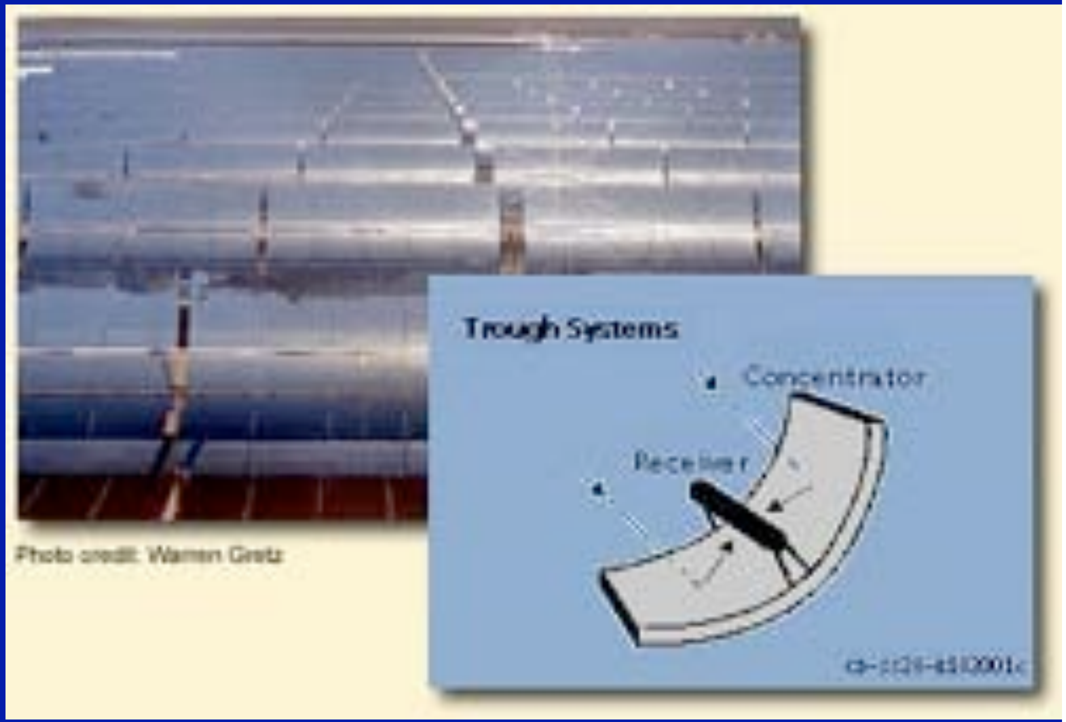


Photo credit: Warren Gretz

Dish with Sterling Engine (Max Lechtman)

- Modular
- Remote Applications
- Demonstration Installations
- High Efficiency
- Conventional Construction
- Commercial Engines Under Development

Solar Tower
(Max Lechtman)

- Suitable For Large Systems
- Grid-connected Power
- 30-200 MW size
- Potentially Lower Cost
- Potentially Efficient Thermal Storage
- Need To Prove Molten Sa Technology

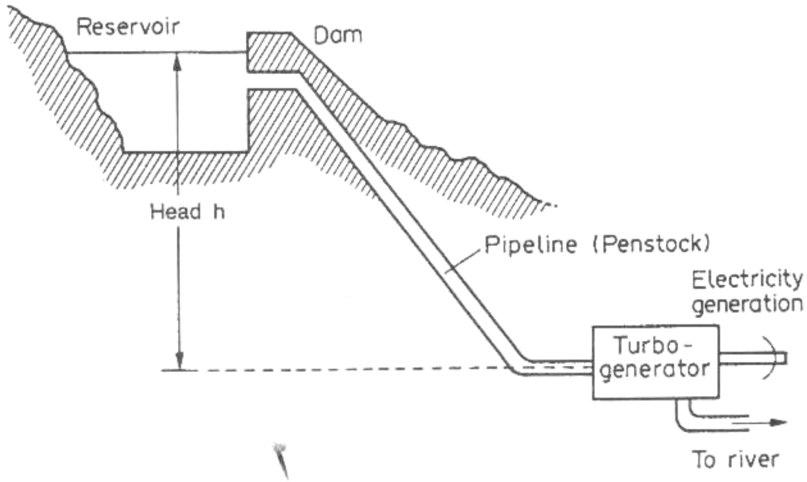
Cost Of Energy*
(Max Lechtman)

	Trough	Dish/Engine	Tower
2000	11.8	17.9	13.6
2010	7.6	6.1	5.2
2020	7.2	5.5	4.2
2030	6.8	5.2	4.2

*Cents/kWh in 1997 $

HYDROELECTRIC/GEOTHERMAL

John Bush


Reservoir
Dam
Head h
Pipeline (Penstock)
Electricity
generation
Turbo-
generator
To river

(a)

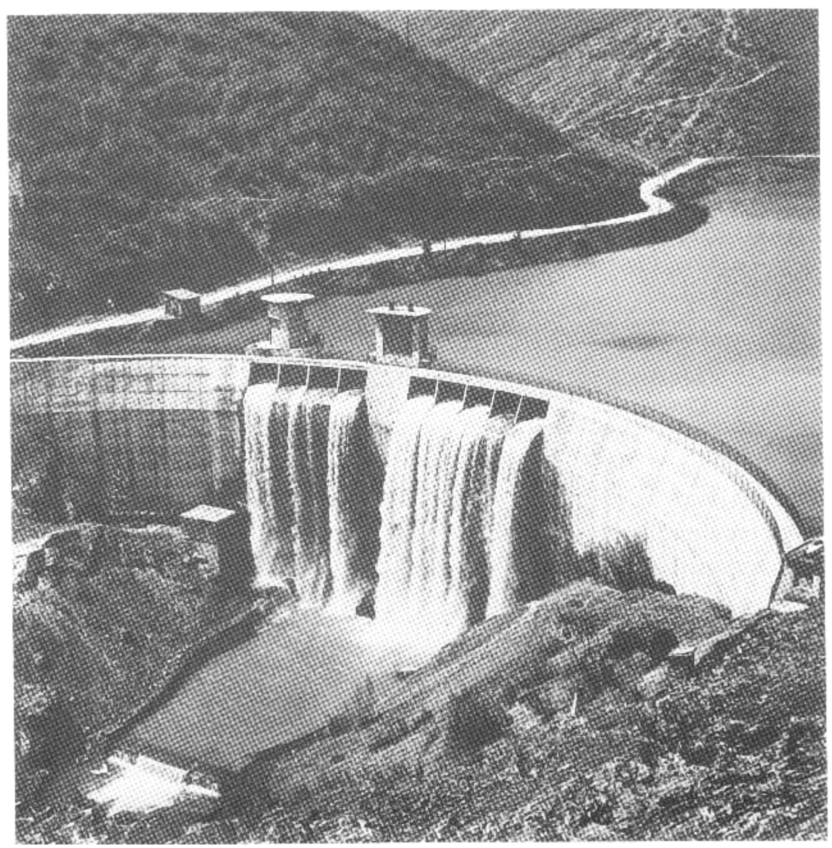
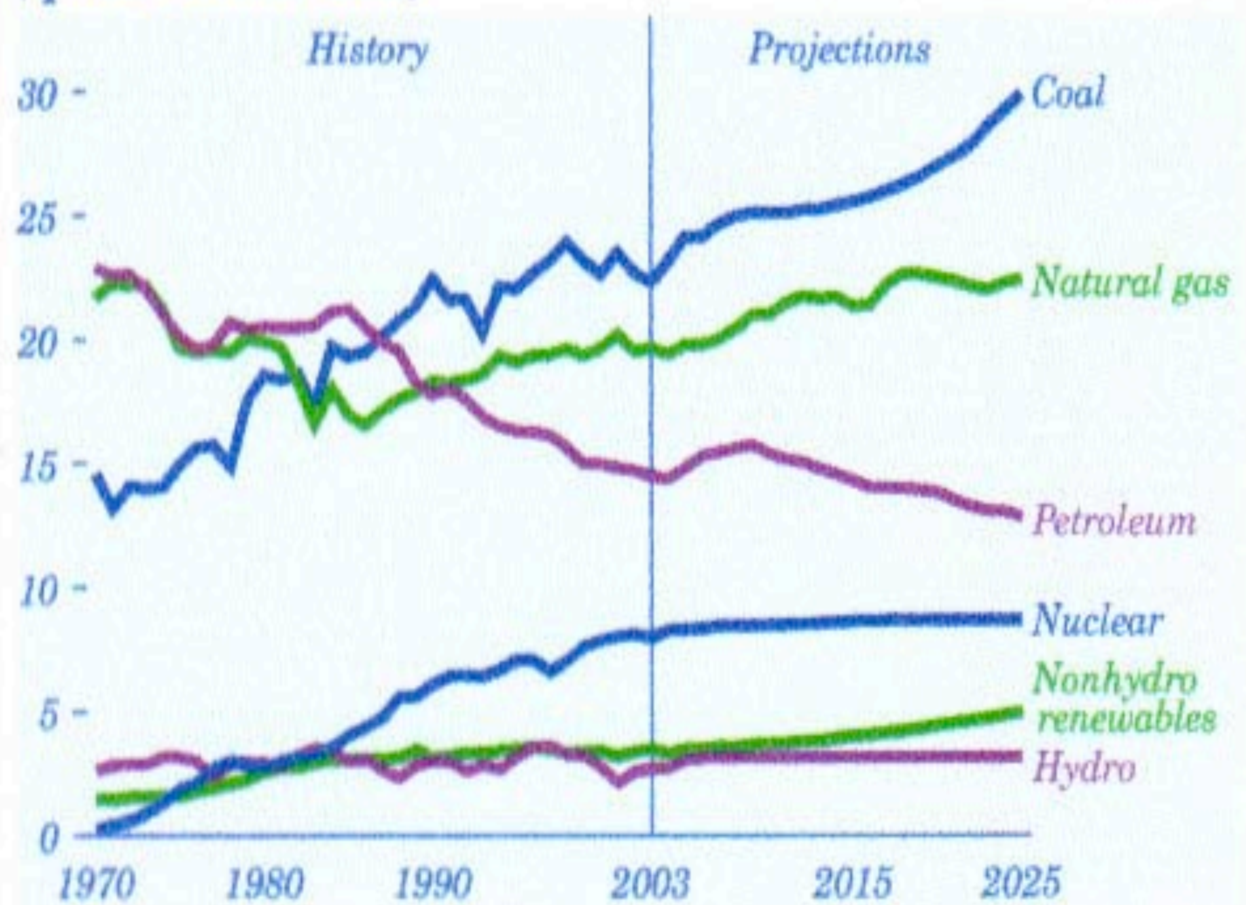


Figure 7. Energy production by fuel, 1970-2025 (quadrillion Btu)



HYDROELECTRICITY IN CALIFORNIA

- Significant to State's Electricity supply
  – About 15% of California's in-state generation
  – Substantial imports from the Pacific Northwest
- Future large installations in California are unlikely
- Some current facilities may be removed

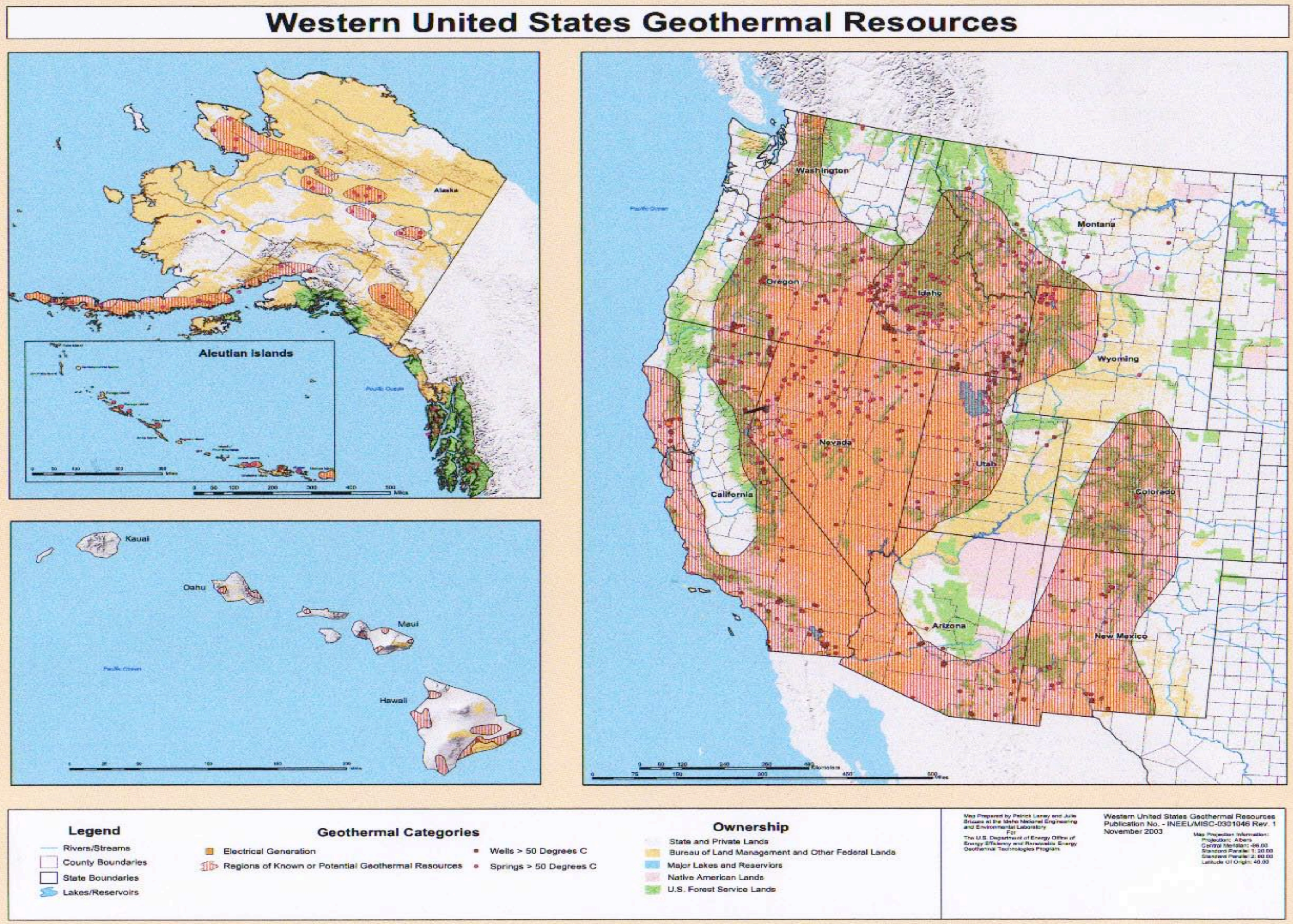
HYDROELECTRIC TECHNOLOGIES

- An established technology
- No DOE sponsored programs
- Small hydro installations
  - 30,000 MWe is feasible (Idaho National Lab)
  - Over 5000 sites
  - No new technology

GEOTHERMAL POWER

- Direct use of underground heat
  - Warm water for buildings, greenhouses, etc.
  - Water source heat pumps
- Electricity generation
  - Proven technology requires source hotter than 300º F (150º C)--steam
  - Feasibility depends on site characteristics
- Potential: 5% of electric supply in western United States with current technology

Western United States Geothermal Resources
Publication No. - INEEL/MISC-03-01046 Rev. 1
November 2003



GEOTHERMAL TECHNOLOGIES

- Binary Cycles
- Magma Reservoirs
- No DOE sponsored programs

SUMMARY

- Conventional hydroelectric generation has little future growth potential in the US
- Small sites are available
- Sites suitable for current geothermal electricity generation are limited but will likely be developed
- New technology may extend suitability of geothermal sites

WINDS/WAVES/TIDES

George Hume

POWER FROM TIDES AND CURRENTS

- Technical Approaches
  - Tidal dams (barrages)
  - Tidal fences
  - Turbine fields
- Common features
  - Generate electricity using water driven fans or turbines
  - Low operating costs if avoid storm damage/biofouling
  - High construction costs
  - Various negative impacts on marine environment

TIDAL BARRAGES

- Dams across estuaries with gates to control water flow and hydroturbine generators to produce electricity
- Depend on minimum tidal difference of 16 feet—perhaps 40 sites in the world
- The LaRance facility has operated reliably for many years
- Possible sites in Pacific Northwest and Atlantic Northeast
- Cause silting, destroy wetlands and interfere with fish migrations
- Probably of limited potential for the U.S.

AXIAL FLOW HYDRO TURBINES

- Technology is in very early stage
- Installations look like underwater wind farms
- Ideally in rivers or near shore at depths of 60-100ft
- High capital cost: $4300/KWe
- U.S. potential is speculative: equivalent to 12 to 170 coal-fired (1000MWe) plants?
- Demonstration project in Manhattan's East River—6 turbines, 200KWe in 2006

WAVE ENERGY

- Several technical approaches
  - Floats or pitching devices
  - Oscillating water columns
  - Wave surge focusing devices
- Demonstration installations in Great Britain (oscillating water column) and off Portuguese coast (floats)
- Issues
  - Storm damage
  - Biofouling
  - Grid connection and power conditioning
  - Wave damping (surfers)
- Potential: 7% of current U.S. electricity demand (EPRI)

WIND POWER

- The most promising near-term renewable resource
- Issue: What will happen when the subsidies vanish?
- U.S. installed capacity growing about 25% per year
- Intermittent, irregular supply
  - Value depends on installed capacity, site specific capacity factor, and timing of generation (summer is more valuable than winter)
  - At greater than 20% of a grid's supply, managing the grid becomes difficult and expensive.

SOME GENERAL ATTRIBUTES

- Best where there is reliable strong wind: U.S. midwest and southwest
- Adaptable to either centralized (wind farm) or decentralized siting
- Siting issues: Martha's Vineyard & Nantucket
  - Aesthetics, visibility– NIMBY
  - Noise
  - Electromagnetic interference
  - Banned within 1.5 miles of shipping/ferry lanes
- Wild life fatalities: California, West Virginia
  - Low flying, migratory song birds (Altamount Pass)
  - Bats

TECHNOLOGIES

- Horizontal axis fans are the best proven technologies
- Windmills have been in use since the Middle Ages
- New designs are proliferating
- Issues
  - Mechanisms are complex and expensive to maintain
  - Large blades for efficient units are expensive to make and transport
  - Grid connection issues seem to be solved

WINDPOWER POTENTIAL FOR THE UNITED STATES

- Battelle estimate: 20% of U.S. electricity demand with siting constraints
- DOE goal to meet 6% of U.S. demand by 2020
- Unconstrained potential equivalent to operating ~1500 1000MWe nuclear or coal plants
- States potential: North Dakota, Texas, Kansas, South Dakota, Montana—California is 17th
- North Dakota could supply 25% of current U.S. electricity demand –need a major growth of electric (or hydrogen?) transmission capacity

WINDPOWER PROSPECTS

- Big potential market: world capacity growing at 30% per year
- Annual equipment sales ~ $2 billion in 2005
- Project financing for renewables in 2005
  - Wind Power $ 3.5 billion
  - Solar Photovoltaic $ 2.2 billion
  - All other $ 1.25 billion
- Major companies are involved
  - General Electric
  - British Petroleum
  - Goldman Sachs
  - J P Morgan chase
  - Siemens AG

OUR ENERGY FUTURE: A SLATE REPORT

SC 210

December 19, 2006

<u>The Slate Panel</u>

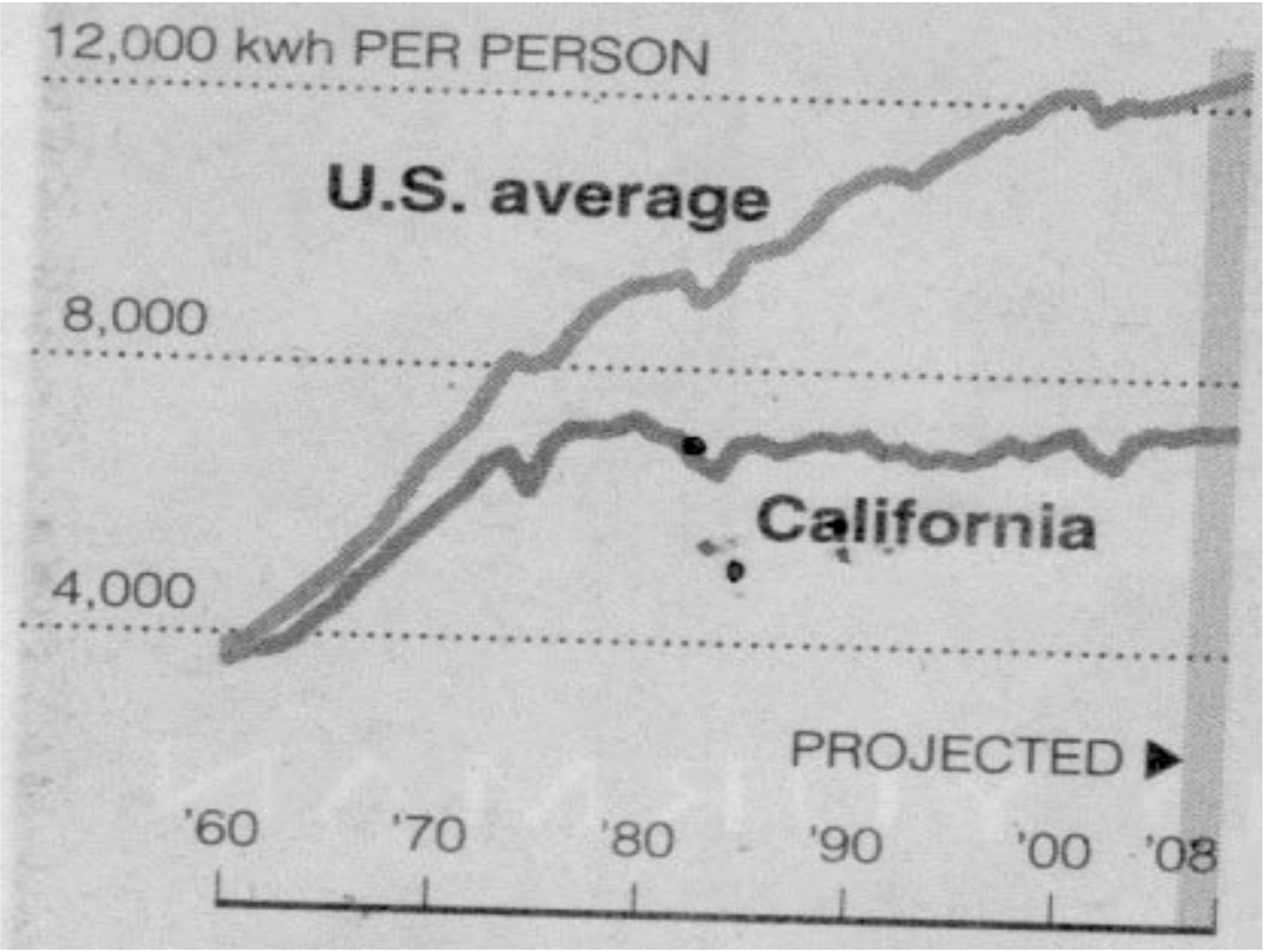
Carolyn Kimme Smith	George Hume
Dennis Silverman	Max Lechtman
Paul Engelder	Vern Roohk
Stephen Jeckovich	Ron Williams
Dorothea Blaine	John Bush

THE ELECTRIC SYSTEM

John Bush

SOME CHARACTERISTICS OF ELECTRICITY

- Electricity is an energy “carrier” (as is hydrogen)
  - A good conductor is required for efficient transmission—currently copper or aluminum wires
  - Conductors must be insulated for economy and safety
  - Generation characteristics must be matched to transmisson and application characteristics
- Electricity cannot be stored in large quantities
  - Demand and supply must be kept constantly matched
  - Storage requires conversion to some other form of energy
- At point of use electricity is clean, convenient, and versatile since its characteristics can be tailored to the application on site



12,000 kwh PER PERSON
U.S. average
8,000
California
4,000
PROJECTED
'60
'70
'80
'90
'00
'08

MORE CHARACTERISTICS OF ELECTRICITY

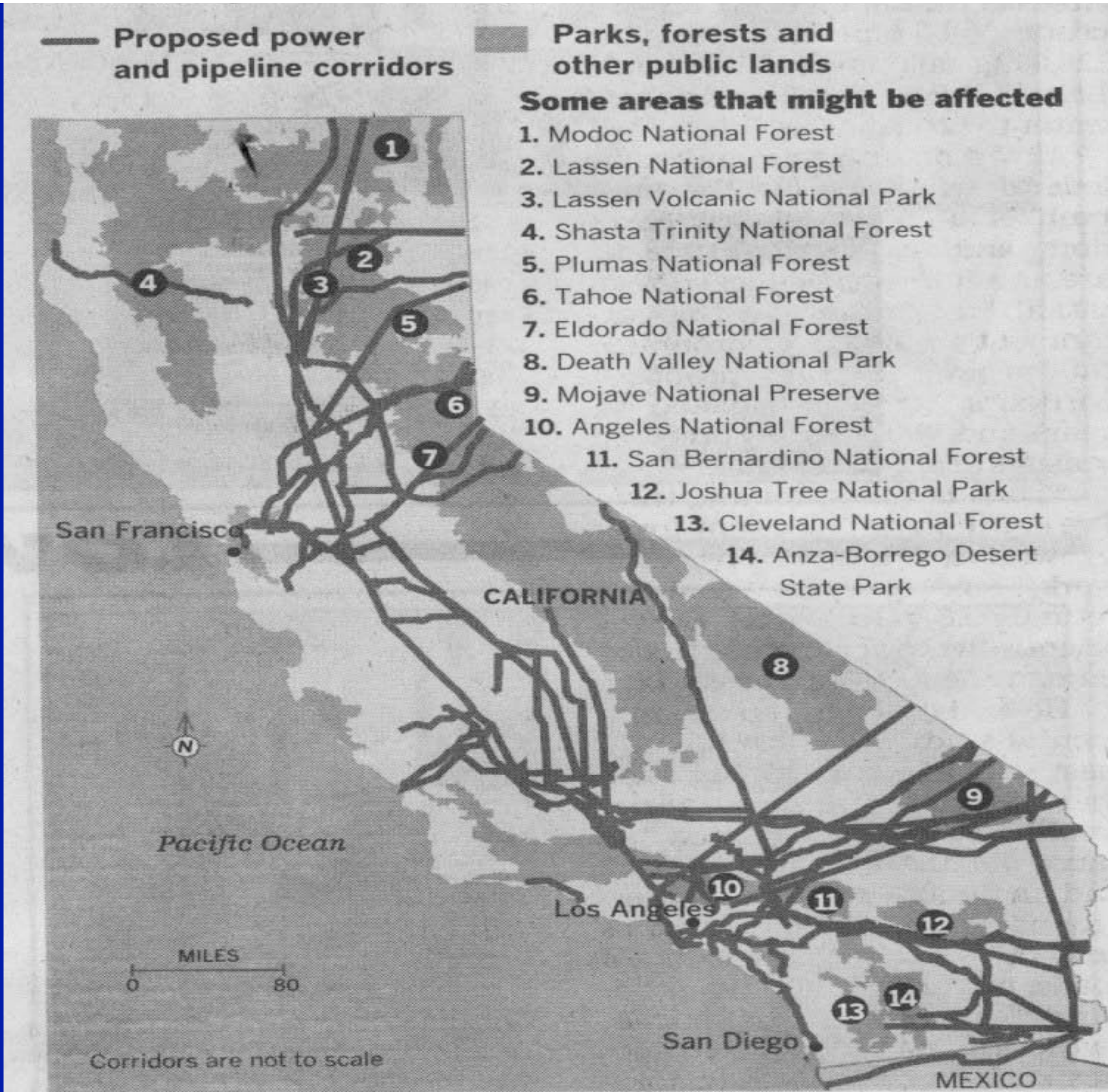
- Cost Elements
  – Energy costs: $/kwh
  – Power costs: $/kw
- Efficiency
  – Conversion: fuel efficiency, photoelectric efficiency, mechanical efficiency
  – Transmission
  – Application

MEASURES TO REDUCE GREENHOUSE GAS EMISSIONS

- Generation from coal or methane
  - Increase generation efficiency
  - Decrease use of carbon dioxide generating technologies
- Transmission
  - Increase transmission efficiency
  - Distribute generating sites nearer to application sites
  - Control sulfur hexafluoride emissions
- Application
  - Increase application efficiency
  - Practice conservation

ELECTRIC SYSTEM RELIABILITY

- Matching demand to supply: “load following”
  - Intermittent, variable supply
  - Inflexibility of large scale generation technologies
  - Intermittent, variable usage
- Maintaining system stability
  - Yoking different generation and application technologies together
  - Keeping chaos from taking over the system
- Providing adequate capacity in time
  - Installing generating capacity : regulatory approval
  - Installing transmission capacity: siting



Sources: California Wilderness Coalition; California Energy Commission

TECHNOLOGIES

- Generation Efficiency
  - Combined cycle generation
  - Fuel cell generation
  - Thermoelectric generation
- Transmission Efficiency
  - Solid state AC/DC Converters
  - Superconducting cables
  - Distributed generation technologies
- Energy Storage
  - Batteries
  - Superconducting magnets
  - Other?
- Real-time monitoring and control
- Application Efficiency
  - LED Lamps
  - Heat Recovery Systems
  - Supervisory HVAC Controls
  - High Efficiency Washer/Driers
  - Super-efficient Refrigerators

HYDROGEN

Carolyn Kimme Smith

MOLECULAR HYDROGEN FACTS

- Three times energy content of gasoline (120 Mj/kg vs. 44Mj/kg)
- Cost of liquefying it is 30 to 40% of its energy content
- Pipelines are 50% greater diameter than for gas (for equivalent energy transmission rate), so more $.
- Distribution doubles cost of production ($1.03/kg).
- Flammable concentration has a wide spread from 4% to 75%.

MOLECULAR HYDROGEN GENERATION

- Three different scales of generation: Central Station, Midsize, and Distributed.
- Central Station: 1,080,000 kg/day would support 2M cars. Distributed by pipeline. Generated by fossil fuel or nuclear energy.
- Midsize: 21,600 kg/day would support 40k cars. Distributed by cryogenic truck. Generated by natural gas or biomass
- Distributed: 480 kg/day would support 800 cars. No distribution system needed. Renewable fuels used.

HYDROGEN PRODUCTION

- Electrolysis: from fossil fuels or renewable energy sources
- Fossil Fuels requires carbon storage
- Hydroelectric, Nuclear Energy, Photovoltaic, grid based energy, wind power, have either periodic generation, which may not match usage, or have constant generation, which does not match usage.
- Energy storage at peak times is a problem for these energy sources that hydrogen generation could solve.
- Cost for all distributed (renewable) sources is two to five times cost of gasoline (2004)

HYDROGEN PRODUCTION—RENEWABLE FUELS

- From wind energy. Electrolyze water. Wind is the most cost effective renewable energy source: \$0.04 to \$0.07/kWh costs about \$6.64/kg per H2 if grid back up used.
- From Biomass. Only 0.2 to 0.4% of solar energy converted to H2. Costs \$7.05/kg by gasification, not including fertilizers and land degradation.
- From Solar energy. Either by electrolysis (Photo voltaic) or using photoelectrochemical cell (in a early stage of development). Cost now is \$28.19/kg and solar energy is only available 20% of the time.

HYDROGEN SAFETY

- Small leak more flammable than for gasoline, but more likely to disperse, so ignition less likely.
- Static spark can ignite, so ground the car during transfer.
- Detonation more likely than with gasoline because of wider flammable concentration and higher flame speed.
- Need high pressure to transfer efficiently: 5-10k psi.
- Odorless, burns with a blue flame. Small molecule precludes adding scent molecule.

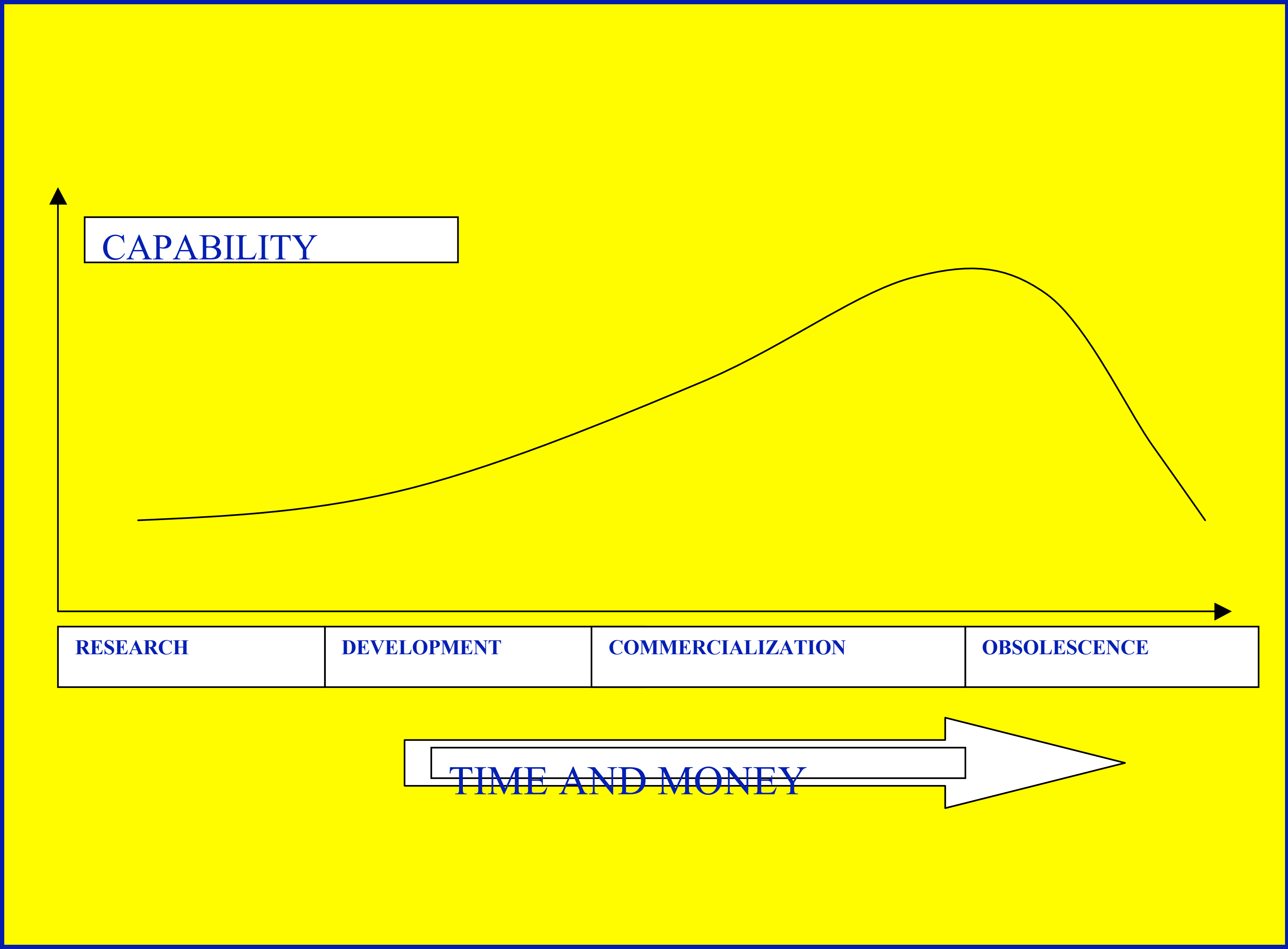
HYDROGEN CAR PROBLEMS

- Cost high because of fuel cell costs. Fuel cell provides only 1 V=$36,000. Car =$1 million?
- H under pressure of 5000 PSI. Heat generated during filling, so less H occupies more space.
- Takes 10 min to fill to 80%,(100 miles)
- Deterioration of tanks, fittings, due to metal hydrides. Unknown MTBF (Mean time between failure)
- Unknown H distribution---twenty years away?

TRANSPORTATION

Stephen Jeckovich PhD

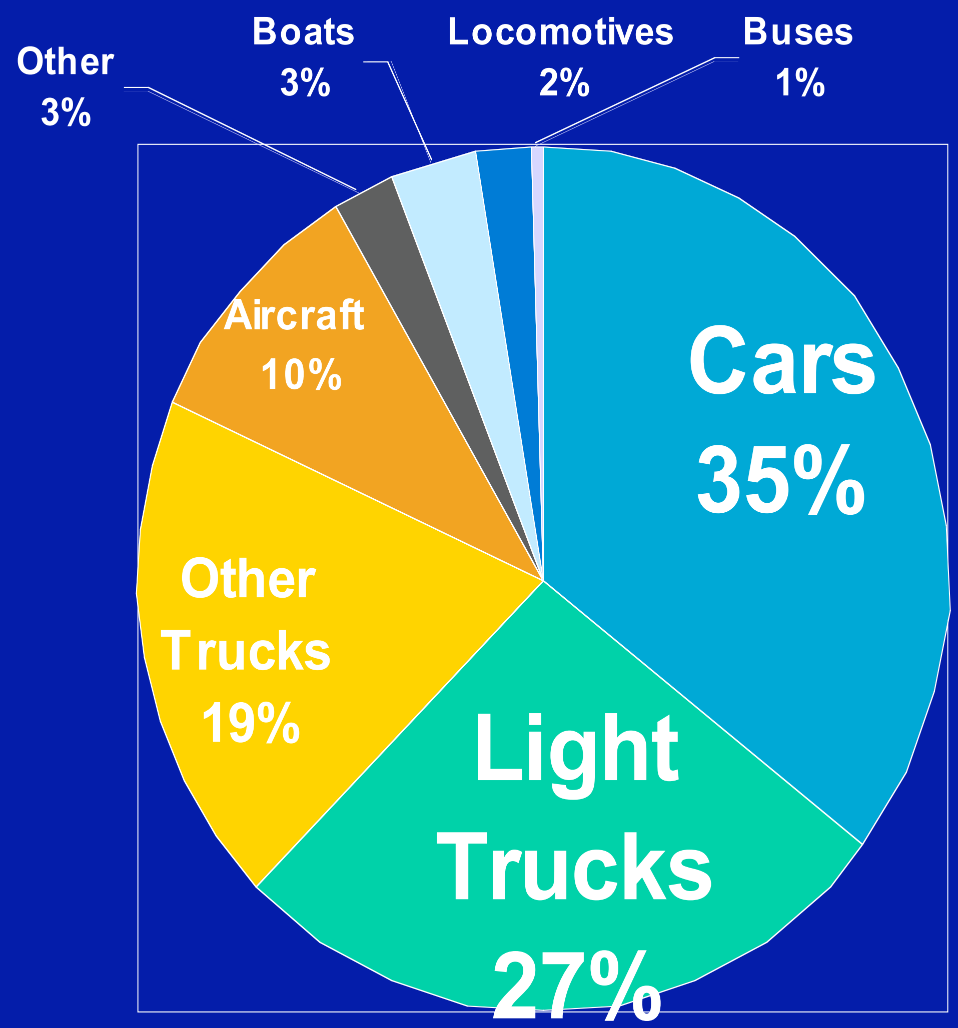
TECHNOLOGY DEVELOPMENT



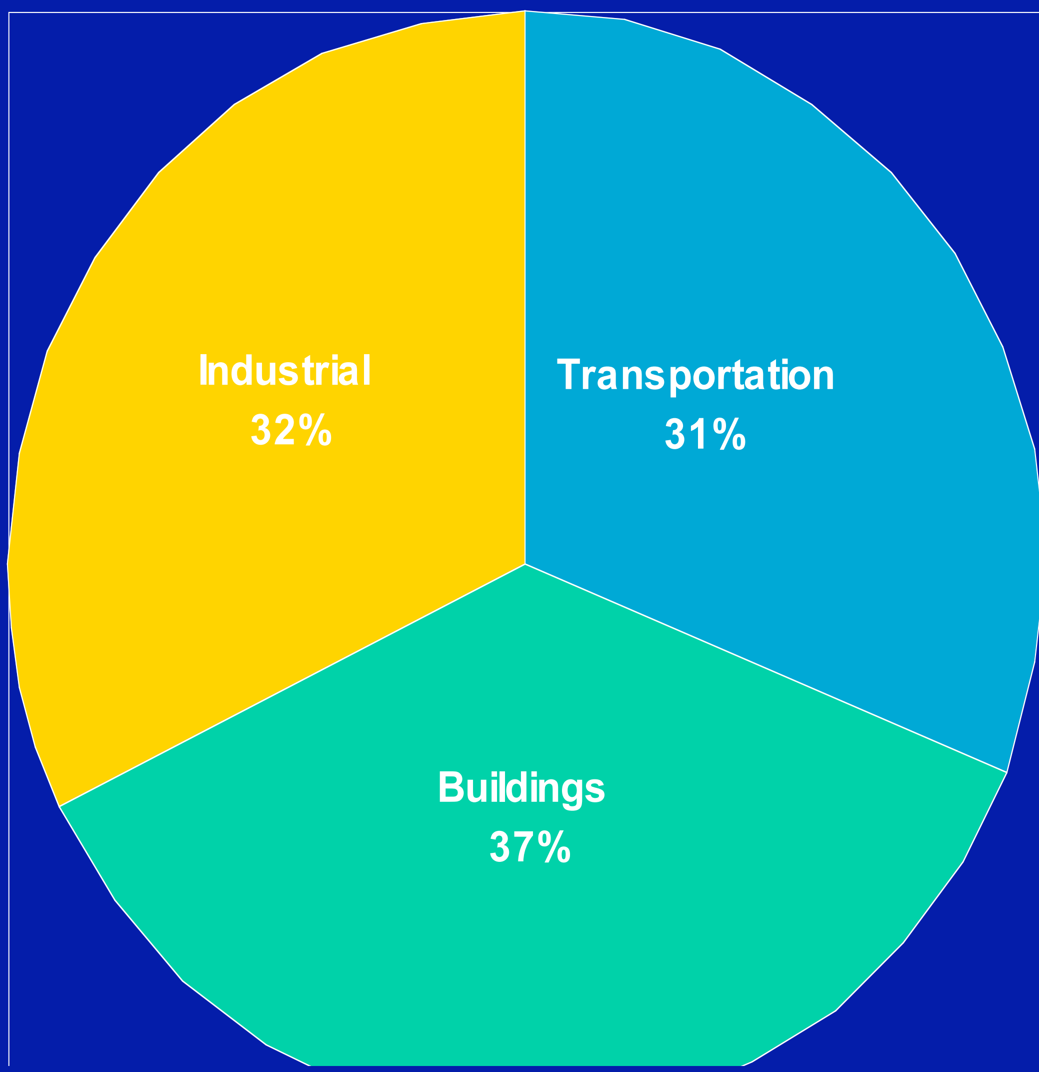
Transportation

Dennis Silverman
U. C. Irvine
Physics and Astronomy

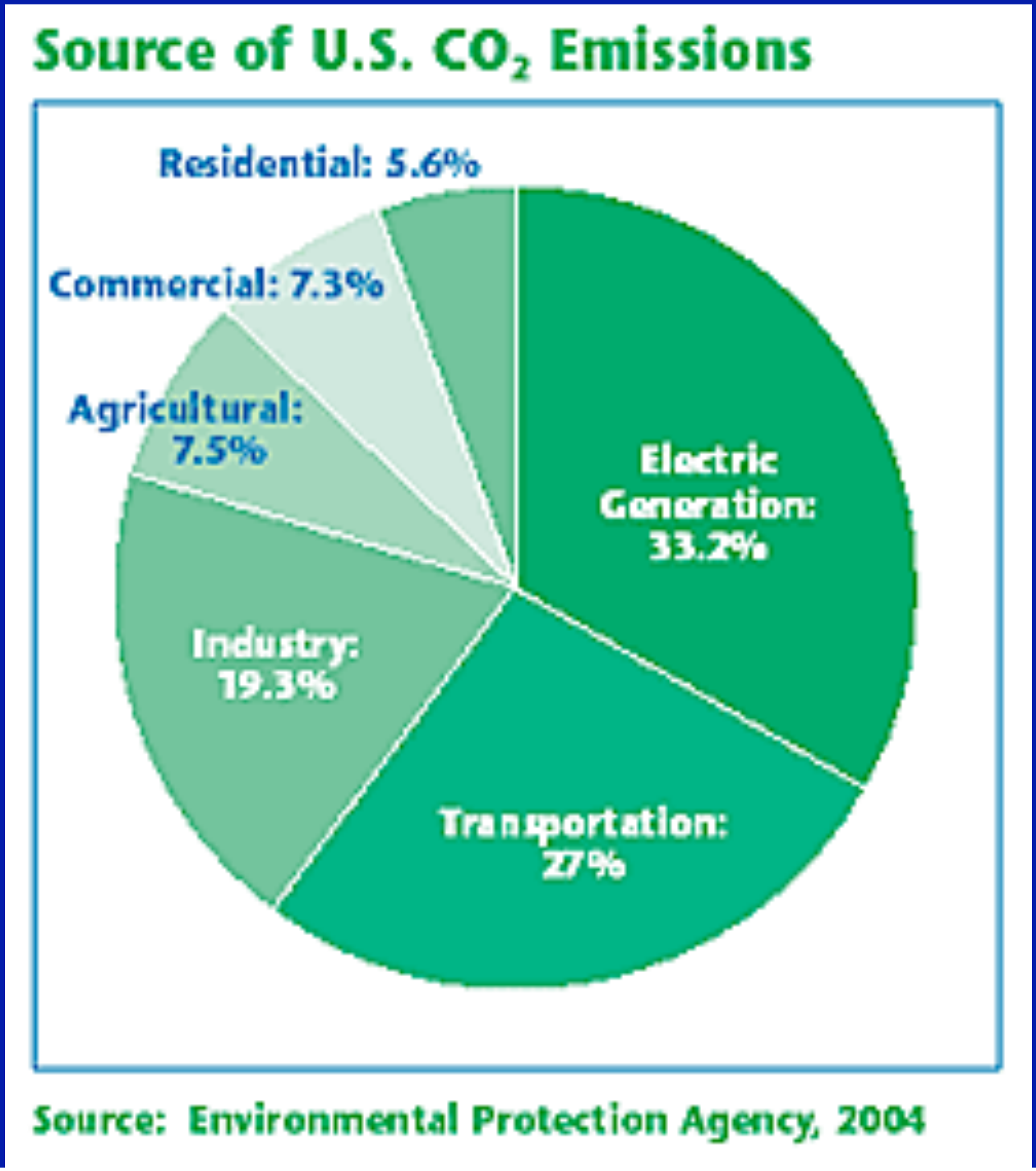
US CO2 Emissions from Transportation



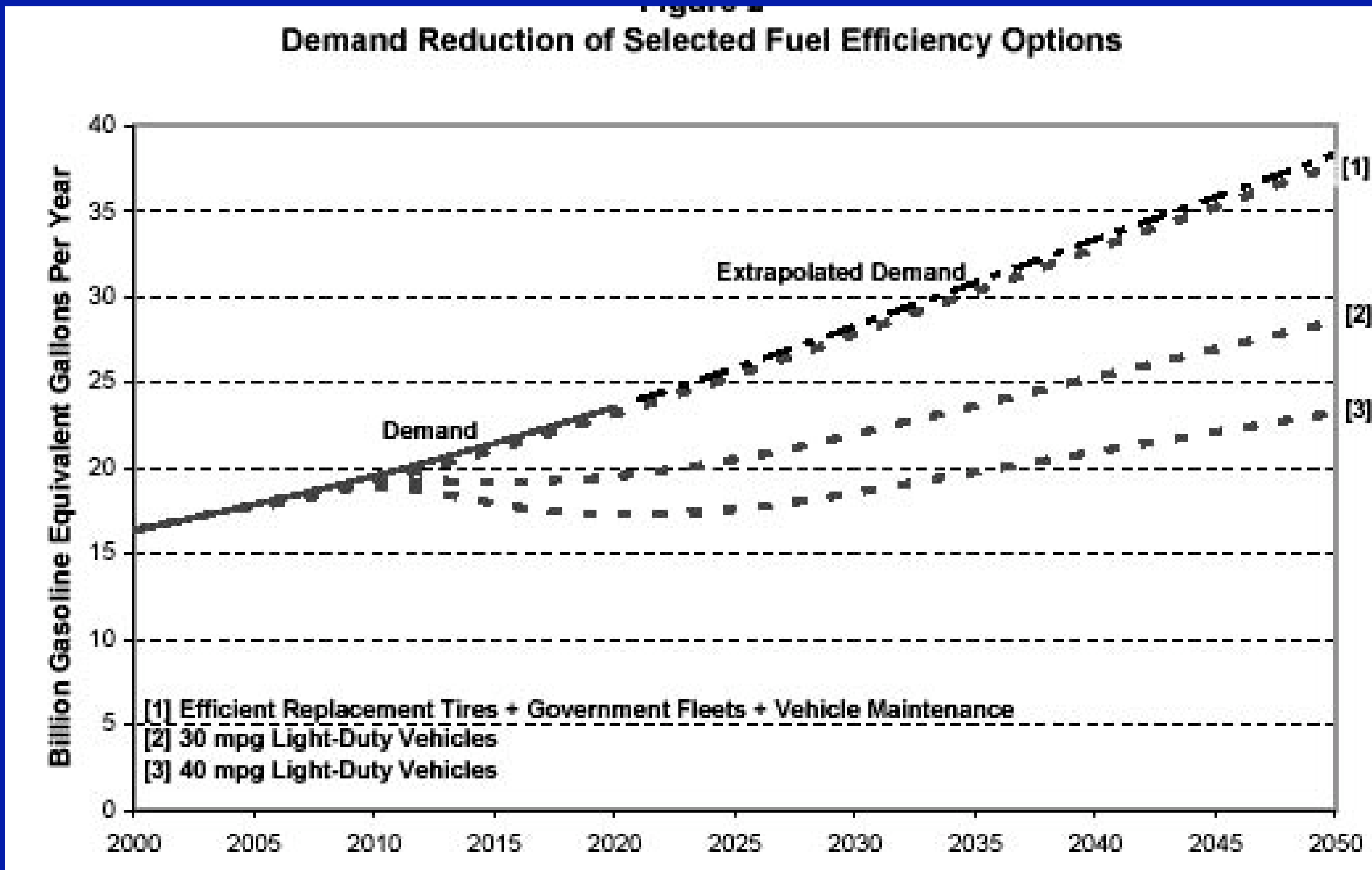
CO2 Emissions in the US by End-Use Sector



CO2 Emissions in the US



DEMAND REDUCTION DUE TO USE OF FUEL EFFICIENCY OPTIONS



FEDERAL FUEL ECONOMY STANDARDS PROGRAM

- Known as the Corporate Average Fuel Economy (CAFE) standards
- Each model year (MY) manufacturers are required to:
- - Achieve average of **27.5 mpg** for fleet of new passenger cars
- - Achieve average of **20.7 mpg** for fleet of new light duty trucks (includes minivans and SUVs). Increased to 21.6 for MY 2006 and 22.2 for MY2007
- Despite its flaws, as a result of CAFE, gasoline consumption is down roughly 2.8 million barrels/day from what it would be without CAFE and greenhouse gas emissions translate to a 7% reduction in CO_2.
- In Europe, per capita gas usage is 286 liters/year compared to 1,624 liters/year in the U. S.

RECOMMENDED PLAN TO REDUCE CALIFORNIA'S PETROLEUM DEPENDENCE

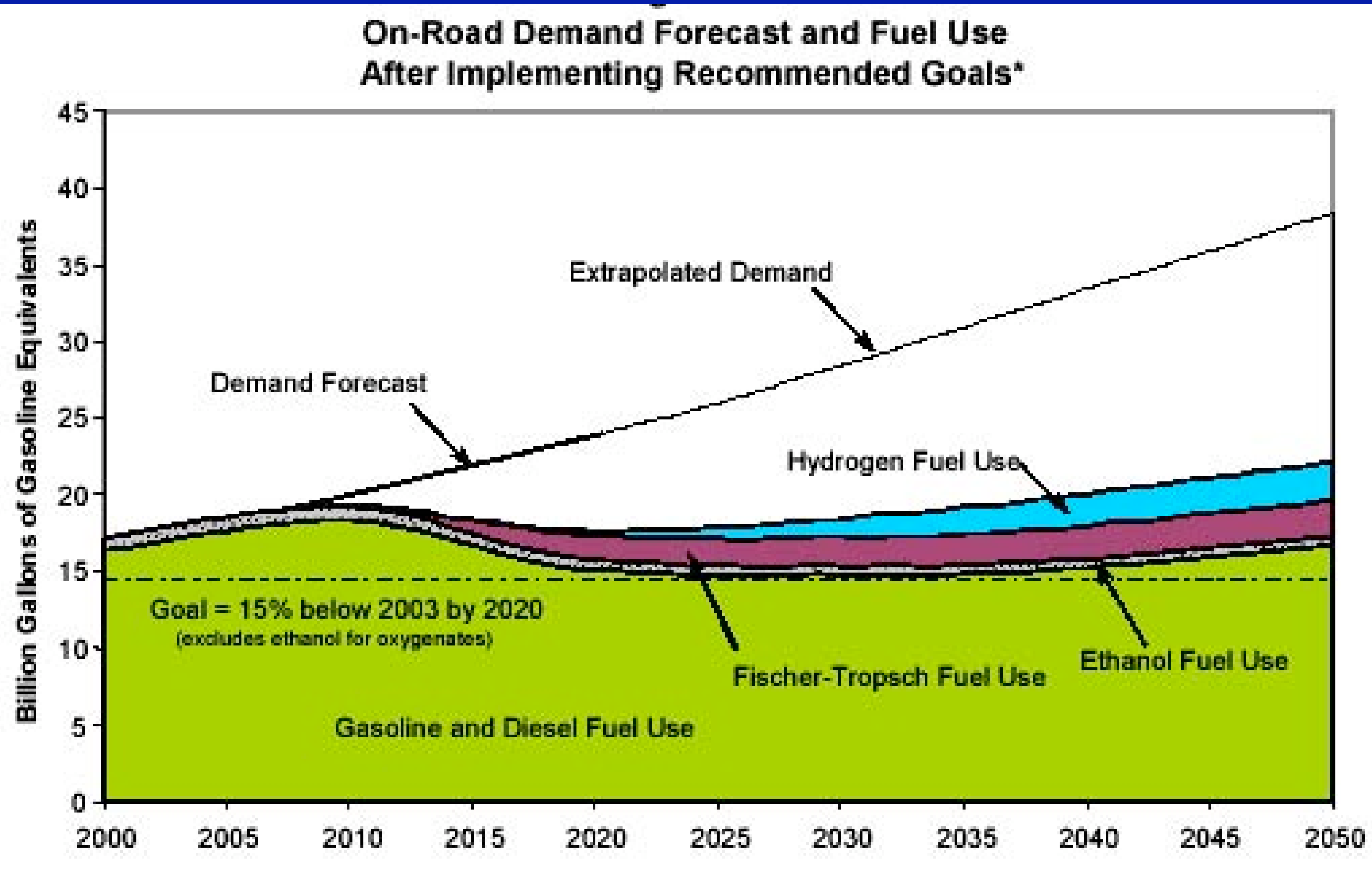
(as proposed by CA Energy Commission & Air Resources Board)

- I. Adopt a statewide goal of reducing demand for on-road gasoline and diesel to **15%** below the 2003 demand level by 2020 and maintain that level for foreseeable future.

- II. Work in the national political arena to gain establishment of federal fuel economy standards that **double** the fuel efficiency of new cars, light trucks and SUVs.

- III. Establish a goal to increase use of non-petroleum fuels to **20%** of on-road fuel consumption by 2020 and to **30%** by 2030.

OVERALL SUMMARY OF EFFECTS OF OPTIONS IN ON-ROAD DEMAND FORECAST



* Note that the white area below the Demand line represents the amount of petroleum reduced due to increased vehicle efficiency, specifically: 40 mpg vehicles, near-term options, and the increase in efficiency of hydrogen vehicles relative to gasoline vehicles.

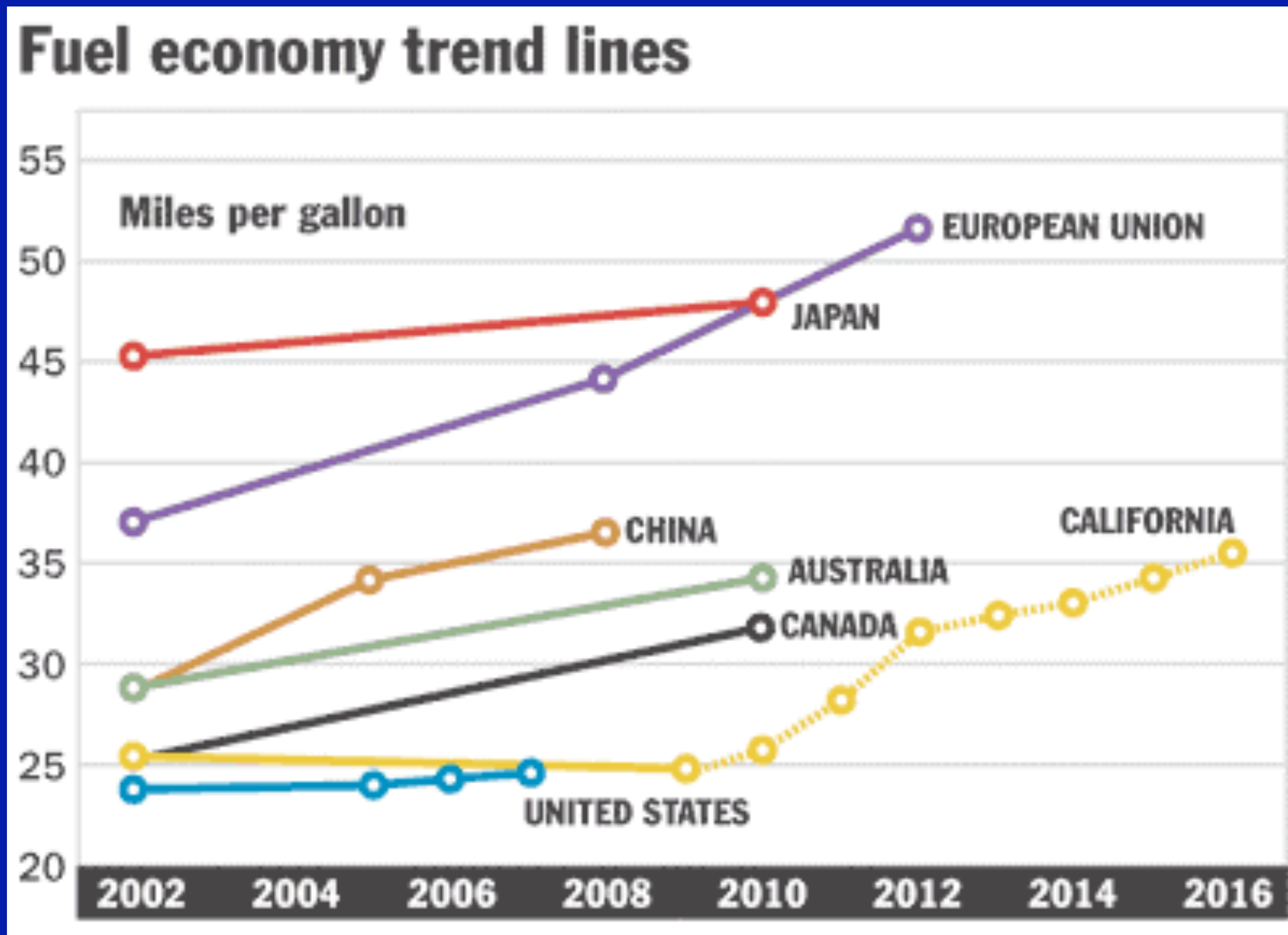
Vehicles as Part of the Solution?

- 8 cylinder vehicles are 25% of the market.
- 6 cylinder are 41%.
- 4 cylinder are only 30%.
- Hybrids are 1.5%, expected to grow to 4% in 6 years.
- Moving motorists down one step in engine size would clearly increase the fleet mileage, without inventing or buying new technology.
- Plug-in hybrids which can do 40 mile trips on electricity alone, but have to say where extra electricity will come from.
  - They cost $2,000 more than a regular hybrid.
  - But their usage is equivalent to paying $1.00 to $1.50 per gallon of gas.
- Cylinder-shutdown engines that change 8 to 4 cylinders when cruising, can save 10-20% on gas mileage.

Automotive conservation solutions

- People could :
  - Drive less aggressively on the gas pedal
  - Drive at the speed limit
  - Plan trips for less total driving
  - Use their higher gas mileage vehicle more
- People could use car pooling
- People could take public transportation
- These actions would actually have an *immediate* effect on lowering consumption and bringing down the price of gas.

Comparative National Fuel Economies



Energy Conservation

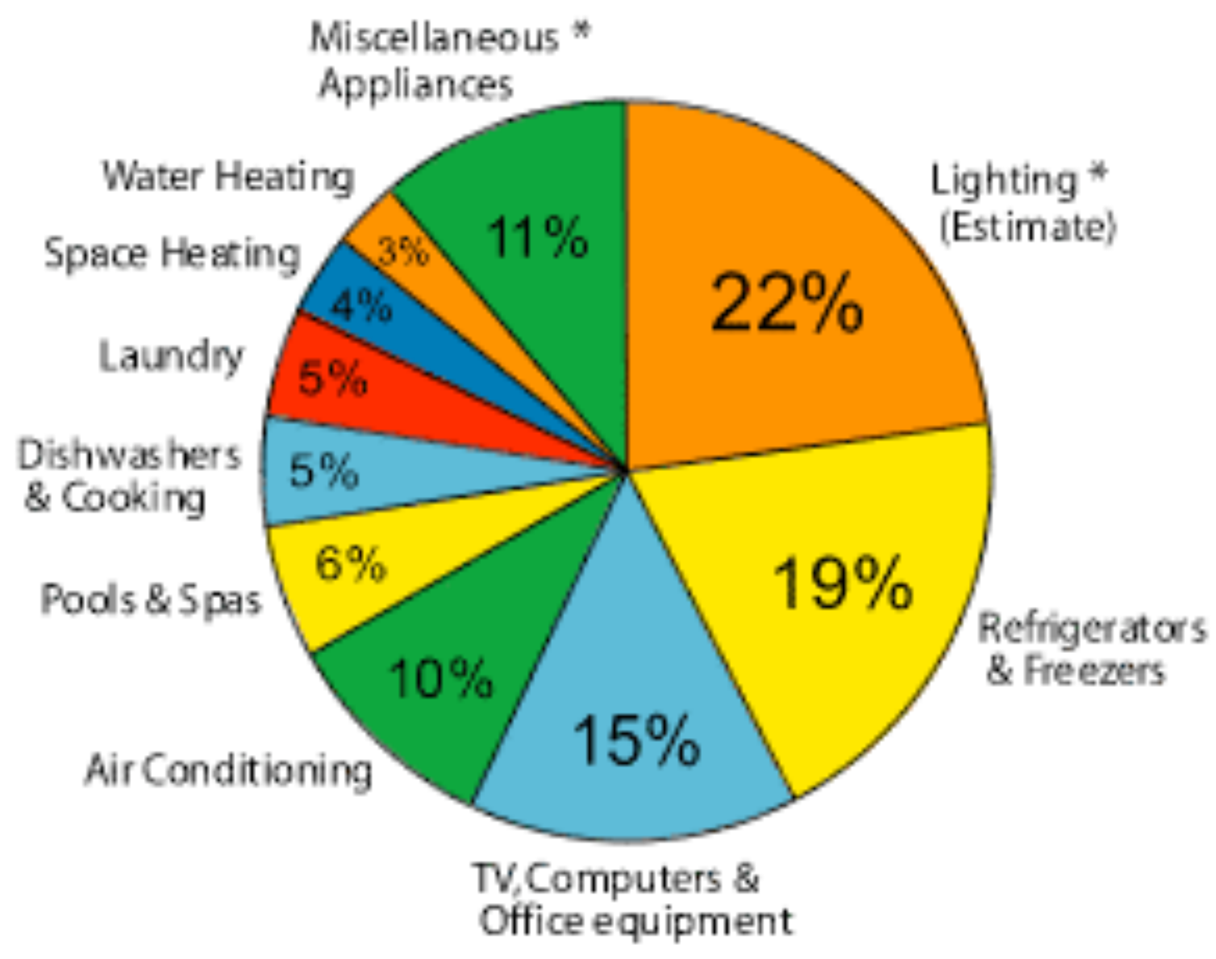
A Major Part of the Solution to Energy Generation and Global Warming

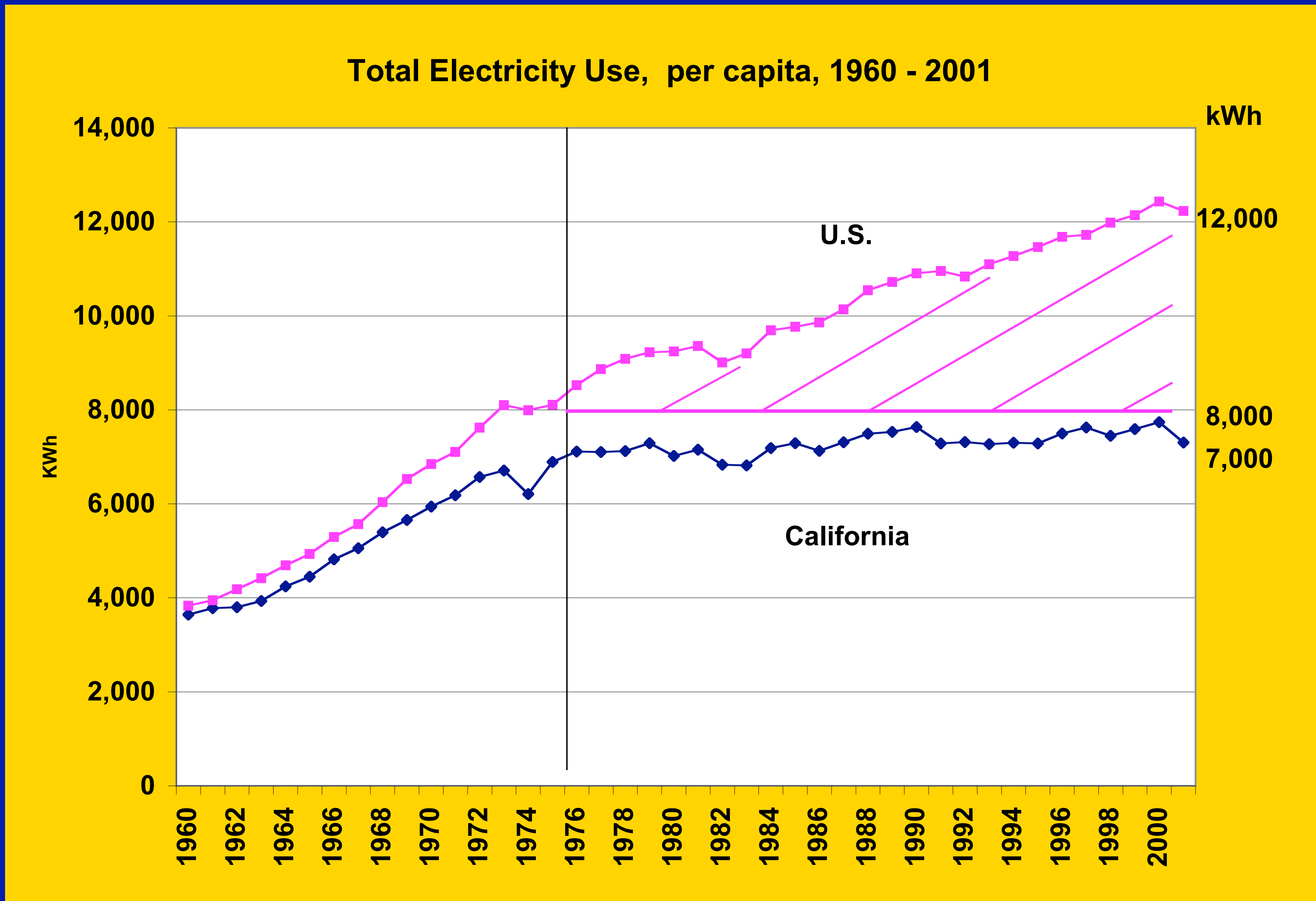
Dennis Silverman
U. C. Irvine Physics and Astronomy

Why Us (U.S.)?

- With 5% of the world's population, the U.S. uses 26% of the world's energy.
- A U.S. resident consumes 12,000 kWh of electricity a year, nine times the world's avg.
- The average American household emits 23,000 pounds of CO2 annually.
- Two billion people in the world do not have electricity.
- Using just using off the shelf technology we could cut the cost of heating, cooling, and lighting our homes and workplaces by up to 80%.

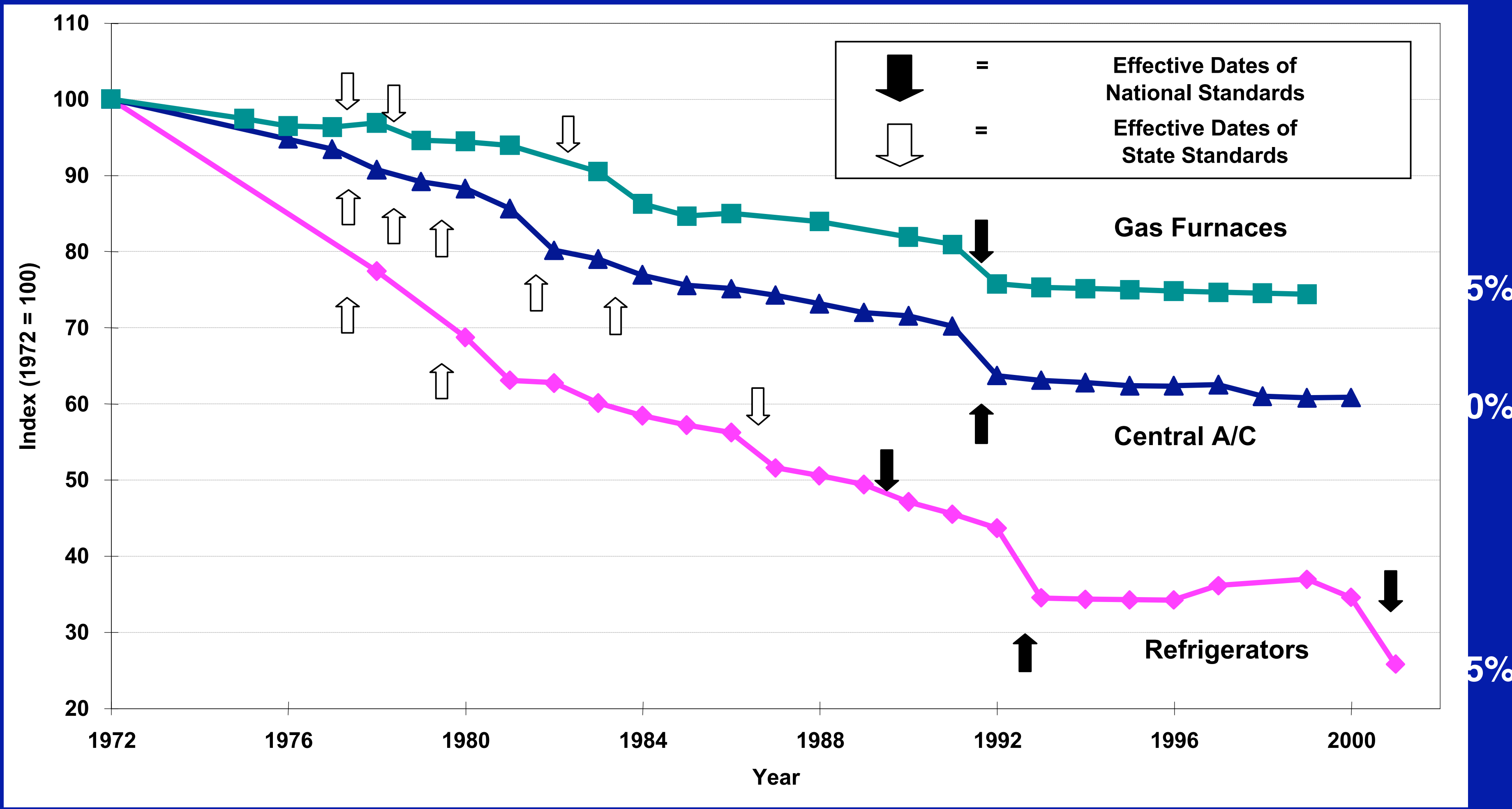
Annual Electricity Use Per California Household (5,914 kWh per household)





Total Electricity Use, per capita, 1960 - 2001
kWh
KWh
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
12,000
8,000
7,000
U.S.
California
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000

Impact of Standards on Efficiency of 3 Appliances



Source: S. Nadel, ACEEE, in ECEEE 2003 Summer Study, www.eceee.org

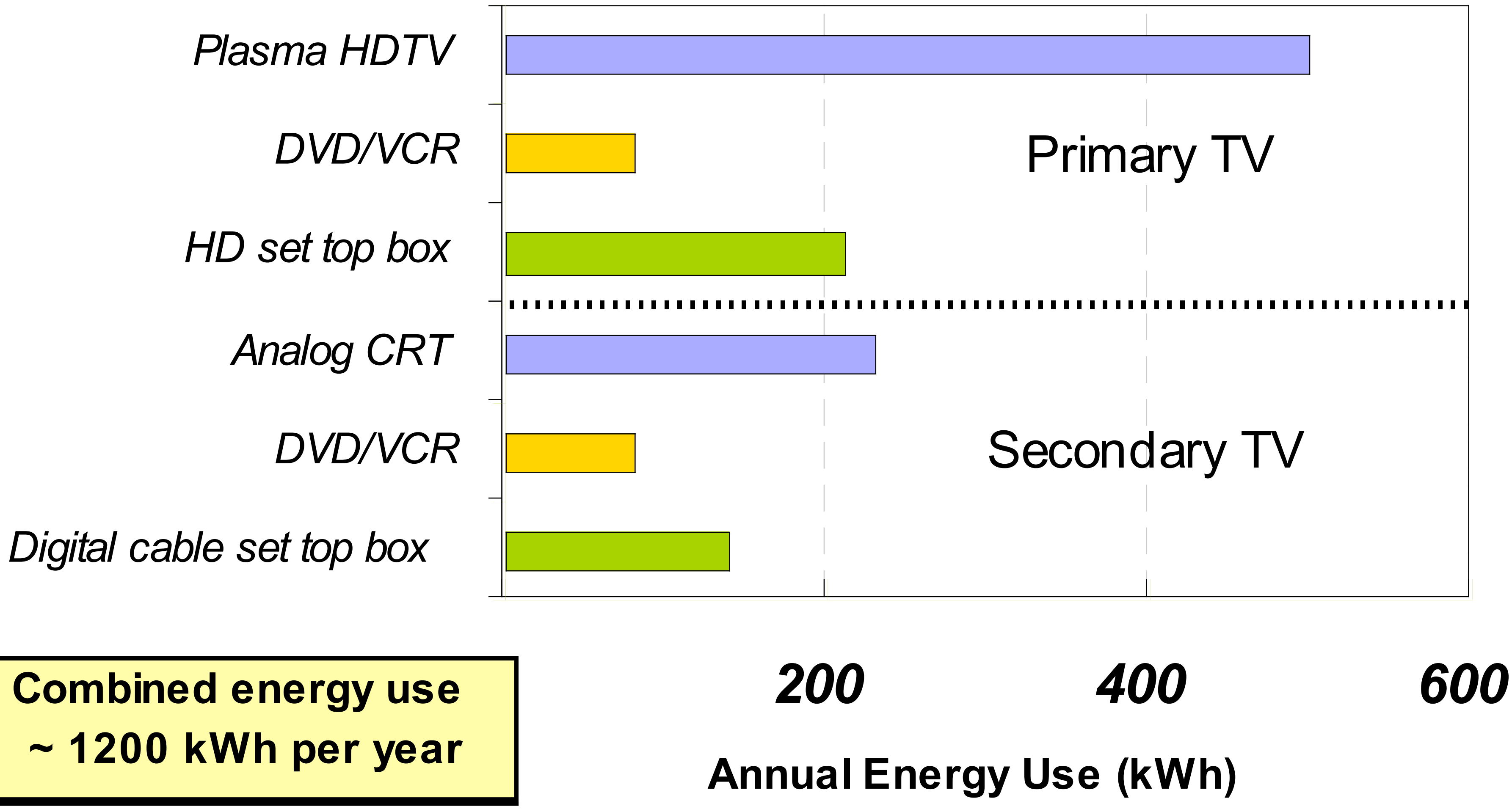
Conservation Economic Savings

- If California electricity use had kept growing at the US rate, kWh/person would have been 50% higher
- California electric bill in 2004 ~$32 Billion…
- so we've avoided ~$16 B/yr of electricity bills.
- Net saving (accounting for cost of conservation measures and programs) is ~$12 B/year, or about $1,000/family/yr.
- Avoids 18 million tons per year of Carbon
- **Appliance standards save ~$3B/year (1/4)**

Lighting

- Compact Fluorescents or Long Fluorescents using plasma discharges use only 1/3 of the energy and heat of incandescent lights, which derive their light from heating filaments hot enough to emit visible light.
- If every home changed their five most used lights, they would save $60 per year in costs.
- This would also be equal to 21 power plants.
- The fluorescents also last up to 10 times as long.
- Replacing one bulb means 1,000 pounds less CO2 emitted over the compact fluorescent’s lifetime.
- Traffic signal LEDs use 90% less energy and last 10 years rather than 2 years.

Household Energy Use for Entertainment Electronics



Combined energy use ~ 1200 kWh per year

NRDC, "Tuning in to Energy Efficiency: Prospects for Saving Energy in Televisions," January 2005.

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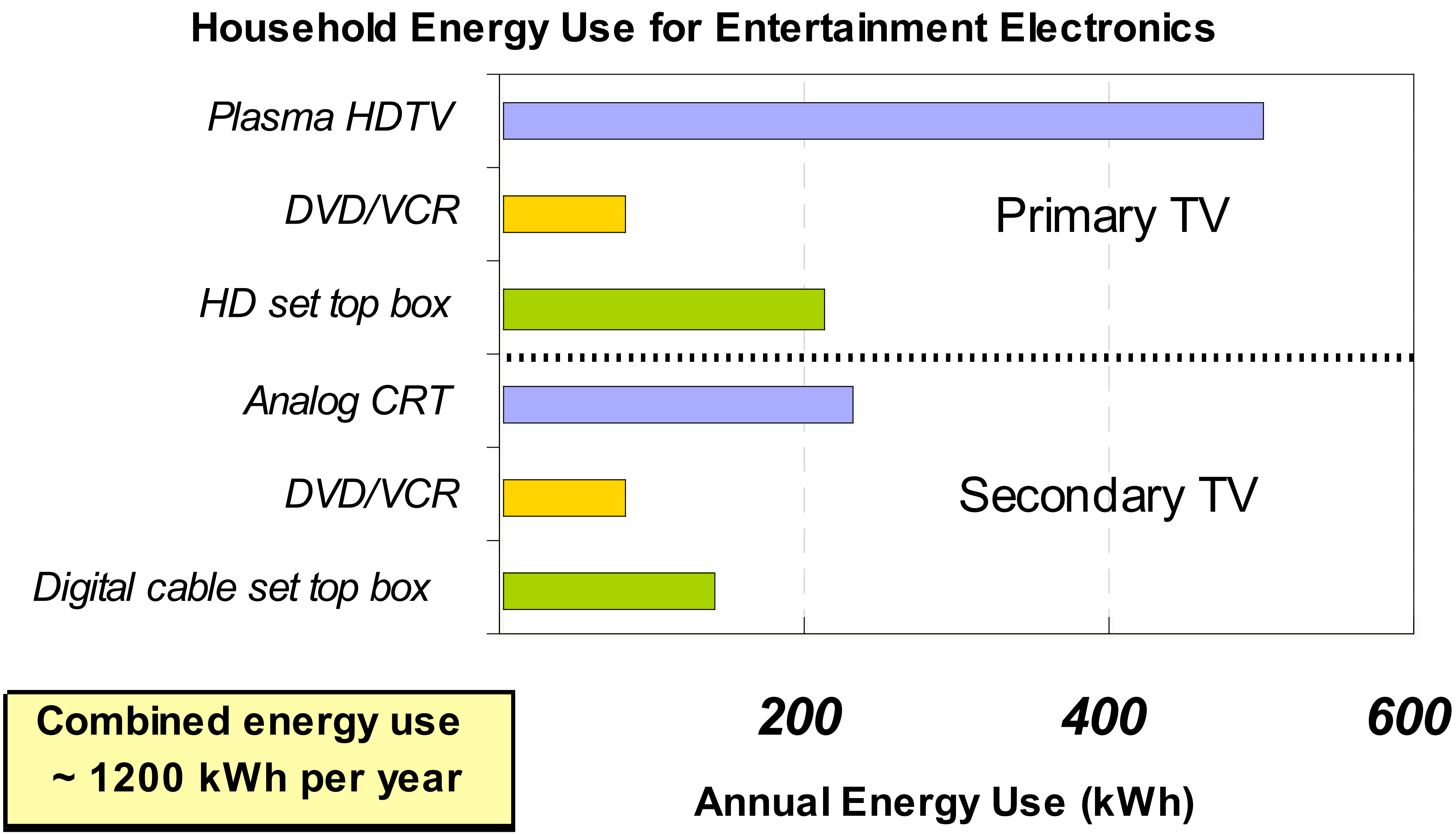


NRDC, "Tuning in to Energy Efficiency: Prospects for Saving Energy in Televisions," January 2005.

“Zero energy” new homes

- Goals:
  - 70% less electricity => down to ~2,000 kWh/yr
  - 1 kW on peak
- Electronics are a problem!
  - 1,200 kWh/ yr for TVs, etc.
  - 100-200 W for standby
- TV Power
  - Plasma TV (50”) 400 W
  - Rear Projection TV (60”) 200 W
  - Large CRT (34”) 200 W
  - LCD (32”) 100 W

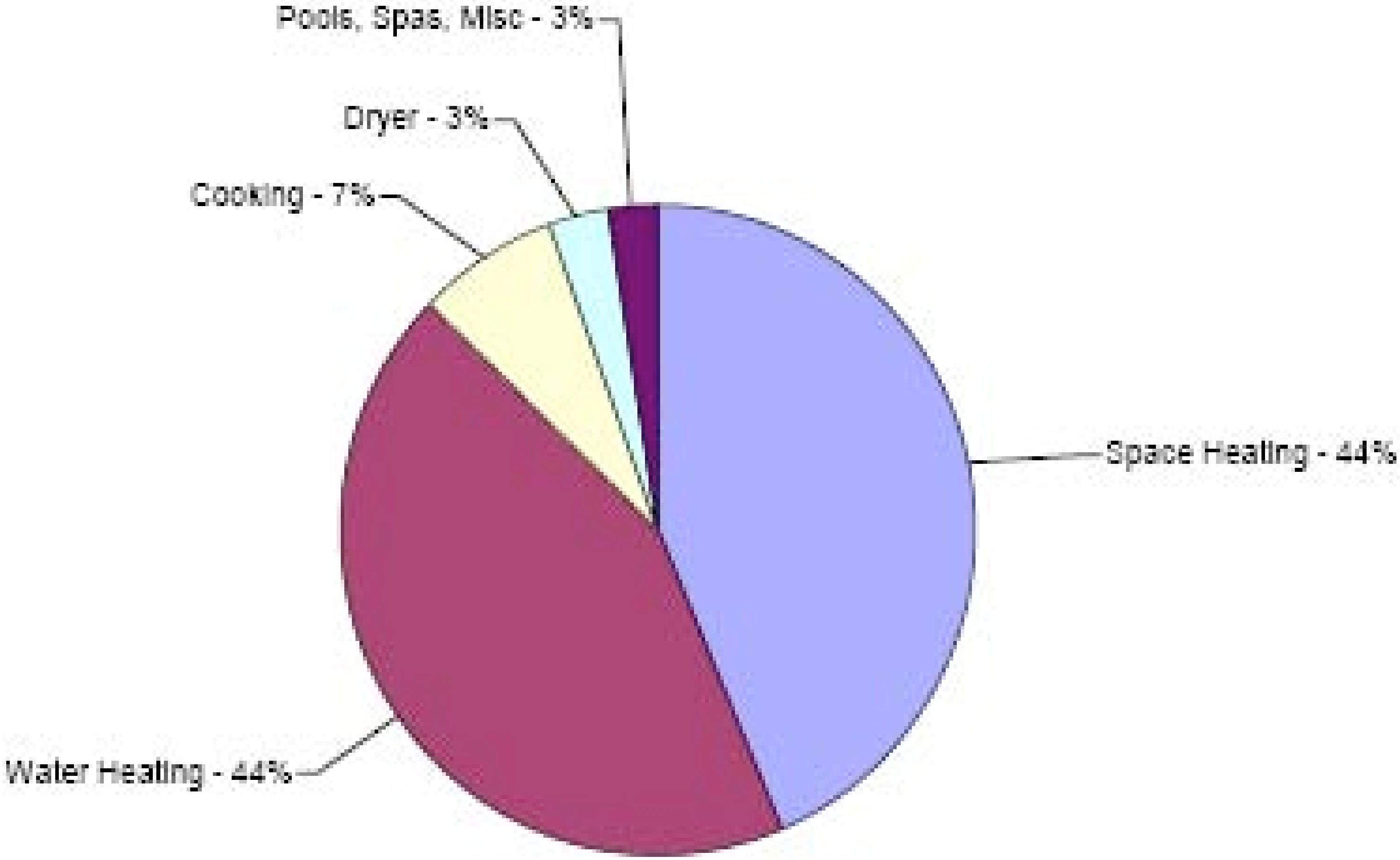
Home Energy Conservation

- Department of Energy: Energy Efficiency and Renewable Energy
- Central resource for the following slides on home energy technology
- We only select some topics of interest
- Other sources
  - California Consumer Energy Center
  - California "Flex Your Power"

Heating and Cooling in the Home

- Accounts for 45% of energy bill or $1,000 per year
- Efficiency standards have been increasing.
- Cool Roofs: white reflective roofs on a summer’s day lower roof temperature from 150-190° F to 100-120° F. Saves 20% on air conditioning costs.

Statewide Gas Energy Use



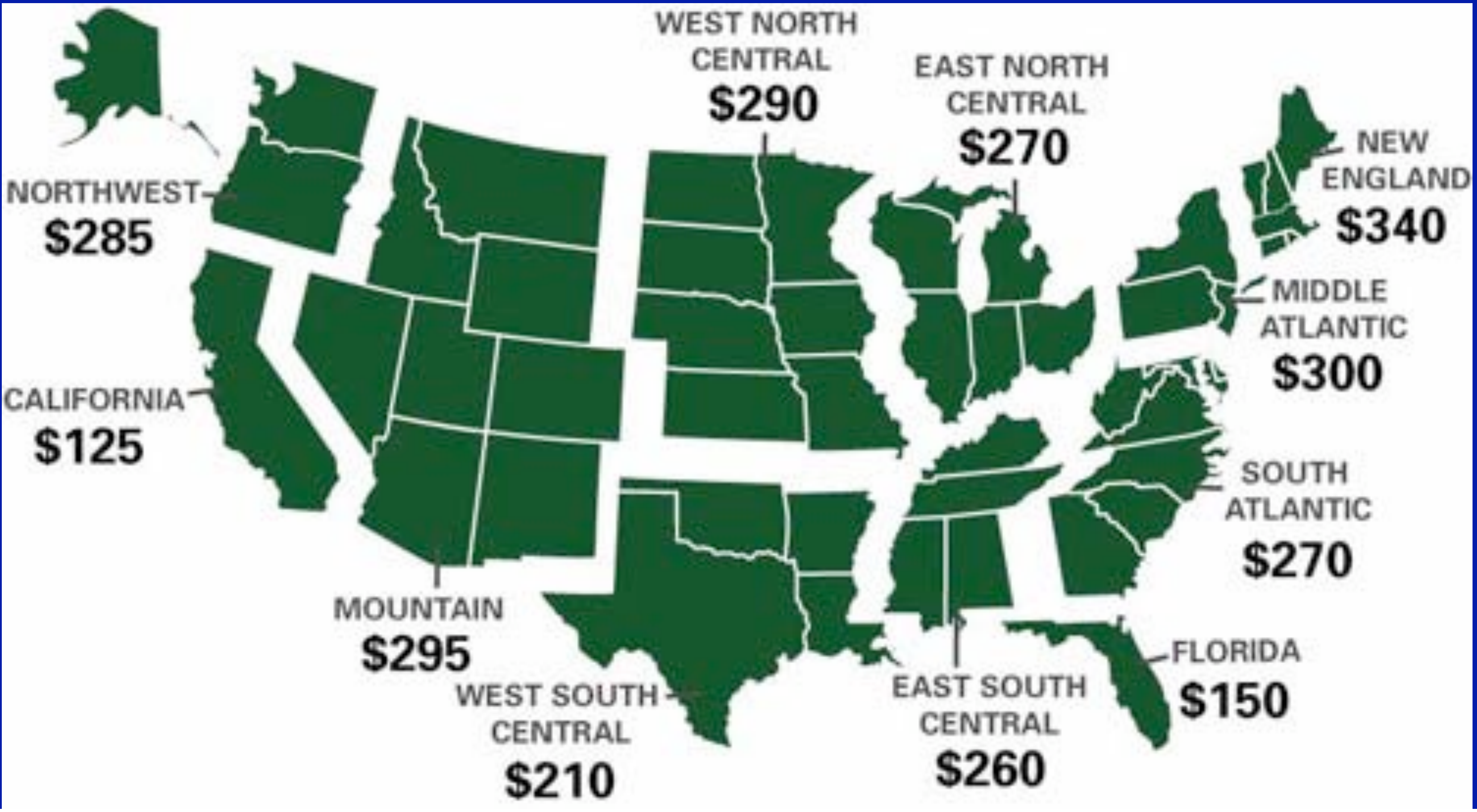
Setback Thermostats

- Program to lower temperature setting at night and if gone on weekdays.
- Required in California
- Winter suggested: 55° at night, 68° when at home
- Summer suggested: 85° when gone, 78° when at home
- 20 to 75% energy savings

Solar Water Heating

- Water heating uses 14-25% of energy use
- Solar water heating replaces the need for 2/3 of conventional water heating.
- Virtually all homes in Greece and Israel (700,000) use solar water heating. Japan has over 4 million units.
- The US has over a million systems, with most systems in Florida and California, and Hawaii has 80,000.
- Each saves 1.5 to 2.5 tons of CO2 a year.
- Typical cost is $3,000 for 50 square feet.
- DOE is trying to lower this to $1,000 to $1500.
- Energy saved would be about 3,000 kWh per year per household
- DOE would like to have 3 million new units by 2030.
- Current payback is 10-13 years (solar lobby says 4-8 years), whereas for 50% market penetration, 5-6 years is needed.

Estimated savings for a typical home from replacing single pane with ENERGY STAR qualified windows are significant in all regions of the country, ranging from $125 to $340 a year.



Conclusions on Energy Conservation

- Energy conservation has saved the need for many power plants and fuel imports.
- It has also avoided CO_2 and environmental pollution.
- Energy conservation research is only funded at $306 million this year at DOE, which is low considering the massive amounts of energy production that are being saved by conservation.
- Regulations on efficiency work, but voluntary efforts lag far behind.
- Much has been done, but much more can be done
- In this new era of global warming and high energy costs and energy shortages, the public must be informed and politicians sought who are sensitive to these issues.

CONSIDERATIONS IN SELECTING A TECHNOLOGY

Does the technology?

- Perform the desired function in a satisfactory way? (Technically Feasible)
- Cost the same or less than technically feasible alternatives? (Economically Feasible)
- Have no nasty consequences nor the potential to create unpleasant surprises? (Environmentally Acceptable)

STAGES OF TECHNOLOGY DEVELOPMENT

- Concept idea
- Concept demonstration
- Technical feasibility demonstration
- Economic feasibility demonstration*
- Established technology
- Widely applied technology

*Circumstantial

GEOTHERMAL TECHNOLOGIES MILESTONES

Years: 5 10 20 Beyond

- **Concept**
  Idea
- **Concept** ……Magma Source
  Demo
- **Technical**
  Feasibility
- **Economic**……….Binary Cycles
  Feasibility
- **Established**….Steam Electric
  Technologies…Heat Pump

METHANE TECHNOLOGIES MILESTONES

Years: 5 10 20 Beyond

- **Concept Idea** ……………………………………………*Methane Hydrates*
- **Concept Demo**…………………………..*Coal Bed Methane*
- **Technical Feasibility**…………….HT Fuel Cell
- **Economic Feasibility**…………*Biogas*
- **Established Technologies**…..LNG
  ..Syndiesel
  ...Hydrogen

HYDROGEN TECHNOLOGIES MILESTONES

Years: 5 10 20 Beyond

- **Concept** ……………………………………………………Biohydrogen
  Idea……………………………………………………..Photoelectrolysis
- **Concept**………………………Solid Storage
  Demo……………Distribution
- **Technical**............................. HTNuclear
  Feasibility
- **Economic** ………………………..Electrolysis
  Feasibility……………..H2Fuel Cell
- **Established**…Methane
  Technology

PRINCIPAL DRIVERS OF OUR ENERGY FUTURE

- Global warming
- Peak oil
- National security
- Global increase in energy demand
- Global scarcity of arable land and fresh water
- Constraints
  - Economics
  - Self-interests

AN ULTIMATE GOAL

- Long term—2050?: Replace petroleum and natural gas with alternative energy sources
- But which energy sources—coal, renewables, nuclear?
- Given only established technologies the answer depends on the driver you emphasize
  - Peak oil: coal/nuclear/renewables
  - National security: coal/renewables
  - Global warming: renewables/nuclear
- With new key technologies America can make use of its full resource endowment to replace oil and gas

KEY TECHNOLOGY GOALS

- Coal:
  - Carbon dioxide capture and storage
  - Liquid fuels production
  - Improved environmental/safety impacts
- Renewables:
  - Biofuels– agricultural compatibility, sustainablity
  - Wind/solar– compatible electric grid
- Nuclear:
  - Fuel reprocessing
  - Waste minimization and disposal
- Then economic choice will determine the final mix

GOALS OF TECHNOLOGY POLICY

TO ESTABLISH AS ECONOMICALLY FEASIBLE

- Highest priority
  - Nuclear fuel reprocessing and waste storage
  - Carbon capture and storage
  - Electric system management
  - Hybrid/electric vehicles
  - Energy storage
  - Cellulosic ethanol production
  - Conservation technologies
- Important
  - Coal to liquid fuels
  - High efficiency coal to electricity
  - Biofuels beside ethanol
- Supporting
  - Hydrogen production & distribution
  - Hydrogen fuel cells
  - Superconducting transmission

Potential for fossil fuel replacement and CO_2 reduction

Fossil fuel use	Fossil fuel replaced (%)	CO_2 emissions reduction (%)
Replaced by electricity from alternative sources		
All coal for electricity	25	33
All natural gas and petroleum for electricity	7	6
All fossil fuels for residential and commercial	13	11
65% of petroleum for transportation	20	21
70% of natural gas used in industry	7	5
Replaced by syngas processes from biomass		
All petroleum + 30% of natural gas used in industry	14	9
35% of petroleum for transportation	12	12
Total	98	97

[Source (*4*)]

- NOW WE SWITCH FROM TECHNOLOGY TO BEHAVIOR

WHOSE ACTIONS AFFECT CALIFORNIA'S ENERGY FUTURE?

- Individual California residents—Us
- Businesses
- Other institutions
- State and national governments
- Other nations

APPROPRIATE ACTIONS FOR ALL

- Change practices to reduce energy usage
- Invest in purchasing and using appropriate new technologies
- Invest in increasing the efficiency of current technologies

ACTIONS FOR INDIVIDUALS

- **Change practices to reduce energy usage**
- **Invest in purchasing and using appropriate new technologies**
- **Invest in increasing the efficiency of current technologies**
- Make appropriate political and economic choices
- Show leadership by influencing others
- Constraints on actions
  - Economics—what you can afford
  - Self-interest—what you value

Dennis Top and Easy Energy Conserving Tips

Air Conditioning

- Set thermostat somewhat warm in the summer
- Use outside shades or inside blinds to keep sunlight from coming in windows in the summer
- Use a fan to bring in outside air in the evenings instead of air conditioning
- Isolate rooms not needed for air conditioning

Fossil Fuels Count

- Isolate rooms not needed for heating
- Use a warm comforter and turn down the heat at night
- Never floor your car accelerator
- Drive near the speed limit
- Recycle - it saves ½ the energy cost of initially making the objects
- Carpool to work

Electrons Cost

- Switch to compact fluorescent bulbs (market penetration only 2%, 5% in CA)

  Uses as little as 1/3 of incandescent bulb.
- Turn off lights and electronics if you have left the room, and teach this to your kids
- Use local lighting for reading
- If your fridge is really old, replace it (those bought before 1991 burn twice the power of new ones)
- Don’t buy a 400 watt plasma screen HDTV

Use the Econ Modes

- Use Econ for air in your car
- Use Light Wash and turn off heated drying in your dishwasher
- Use cold water wash and rinse in the washing machine

Carolyn's Lifestyle Survey Results

ACTIONS FOR BUSINESSES

- **Change practices to reduce energy usage**
- Invest in demonstrations of the feasibility of new technologies
- **Invest in purchasing and using appropriate new technologies**
- Invest in research to enhance efficiency and economics of present technologies
- **Invest to upgrade efficiency of present technologies**
- Support appropriate political actions
- Show leadership to influence individuals behavior
- Constraints on actions
  - Economics—what is most profitable
  - Self-interest—what enhances competitive power and sustainability

ACTIONS FOR OTHER INSTITUTIONS

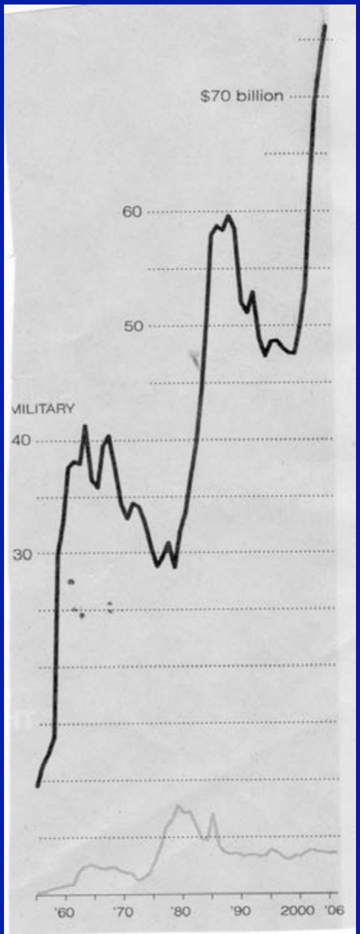
- Religious/fraternal:
  - Influence members to act
  - Respond to members requests for action
- Public interest/educational: provide fact-based education on energy alternatives
- Universities
  - Educate the people who will create new technologies
  - Perform research and feasibility demonstrations to establish new energy technologies
- Financial: mobilize capital to finance investments in new or upgraded technologies

ACTIONS FOR STATE & NATIONAL GOVERNMENTS

- **Change practices to reduce energy usage**
- **Invest in purchasing and using appropriate new technologies**
- **Invest in upgrading current technologies**
- Show political leadership to influence the perception of interests by individuals and institutions
- Invest in research to enable new technologies
- Co-sponsor feasibility demonstrations
- Invest to implement new technologies?
- Invest in demonstrations of the feasibility of new technologies
- Promote desired outcomes with incentives and penalties
- Constraints on actions
  - Economics—what electorate will tolerate
  - Self-interest—what enhances political power

ASPECTS OF ENERGY POLICY

- Technology policy: RD&D funding pattern
- Public awareness/information policy
- Regulation/enforcement policy
- Tax/incentive policy
- Acquisition policy



SOME EXAMPLES

- Electricity rate structure
- Gasoline/diesel taxes/subsidies
- Railroad land grants
- Highway construction funding
- Solar energy subsidies
- Wind energy subsidies
- Electric vehicle subsidies
- Car pool lane exemptions

A BREAKDOWN OF EDISON RATES

Southern California Edison has deferred until January introduction of an additional rate tier for customers who use more than 200 percent of their "baseline" allocation (baseline is a subsistence amount of energy that varies by climate zone). The table shows a comparison of Edison's rates before two increases kicked in earlier this year, what they are now, and what they would have been if Edison hadn't deferred the additional tier and a third rate increase.

	December 2005	Now	Authorized but deferred
Tier 1 (baseline allotment of kWh)	11.8 cents per kilowatt-hour	11.8 cents	11.8 cents
Tier 2 (1%-30% more than baseline)	13.7	13.7	13.7
Tier 3 (31%-100%)	16.6	22.3	22.8
Tier 4 (101%-200%)	19.8	31.2	35.2
Tier 5 (More than 200%)	19.8	31.2	47.5

Source: Southern California Edison

SOME OTHER OPTIONS

- Mass transit funding/subsidies
- Carbon tax
- Substantial fuel tax
- Biofuels subsidy
- Vehicle age penalty
- Residential space surcharge

SUGGESTED NATIONAL ENERGY POLICY ULTIMATE GOALS

- Provide alternative energy systems that will replace petroleum use by 2050 or sooner
- Establish an economically optimal mix of energy sources based on America's fullresource endowment
- Reduce carbon emissions to a world-agreed level
- Through a mix of conservation and efficiency improvements reduce domestic energy use per capita by 25%

NATIONAL ENERGY POLICY INTERIM GOALS

- Maintain net fuel costs to industry at or below world petroleum prices to maintain economic competitiveness
- Provide established technologies in time to match hydrocarbon price increases with economic alternatives
- Establish a coherent system of incentives, penalties and regulations to promote national energy conservation
- Reduce greenhouse emissions ahead of global reductions to establish leadership in limiting global warming
- Export established technologies to promote reduction of global greenhouse gas emissions
- Provide nuclear fuel reprocessing/reactor technology to other nations to limit opportunities for nuclear weapons proliferation
- Sustain technology development as world petroleum prices rise and fall

WHAT DO YOU THINK?

- Are these the right goals?
- Are they realistic in view of the technology options we have?
- Do we have the political will to carry them out?
- Will the rest of the world follow our leadership?

ECONOMIC CHOICE

- Maximize the excess of the value of the output produced over its cost to produce — "maximize efficiency"
- Issues that must be decided
  - How will the value measured?
  - How will the production cost be measured?
  - How will the excess value be allocated between producer, distributor and consumer?

DETAILS OF ECONOMIC CHOICE
An Investor's Perspective

- Value: determined by what the market will bear, subject to politically motivated market regulation
- Cost components
  - Cost of energy input
  - Money required to build and operate a facility
  - Cost to meet purchasers' requirements
  - Taxes/Incentives
  - Costs of meeting regulatory requirements
  - Cost of money (Interest)
- Payback period—risk of not getting money back
- Externalities
  - Environment
  - Health
  - Impacts of system failures