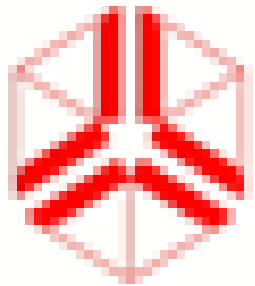
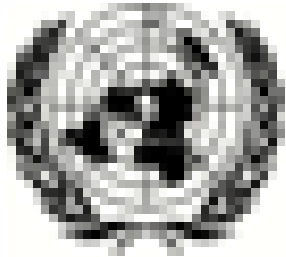


# Energy Futures 2020



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*The Millennium Project*

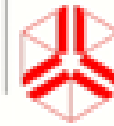
**José Luis Cordeiro**

**Director, Venezuela Node**

**[www.StateOfTheFuture.org](http://www.StateOfTheFuture.org)**

***The Millennium Project***

# Millennium Project...



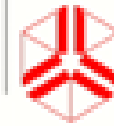
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Helsinki  
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Madurai  
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Buenos Aires Sidney

# Millennium Project...



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... is a ***TransInstitution*** ([www.acunu.org](http://www.acunu.org))

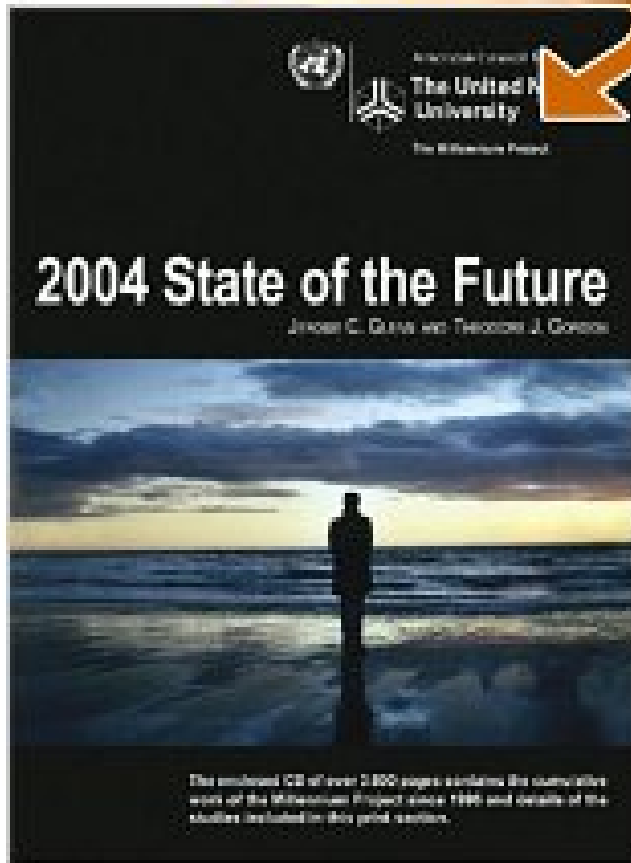
# Millennium Project...



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**SEARCH INSIDE!™**



**SEARCH INSIDE!™**

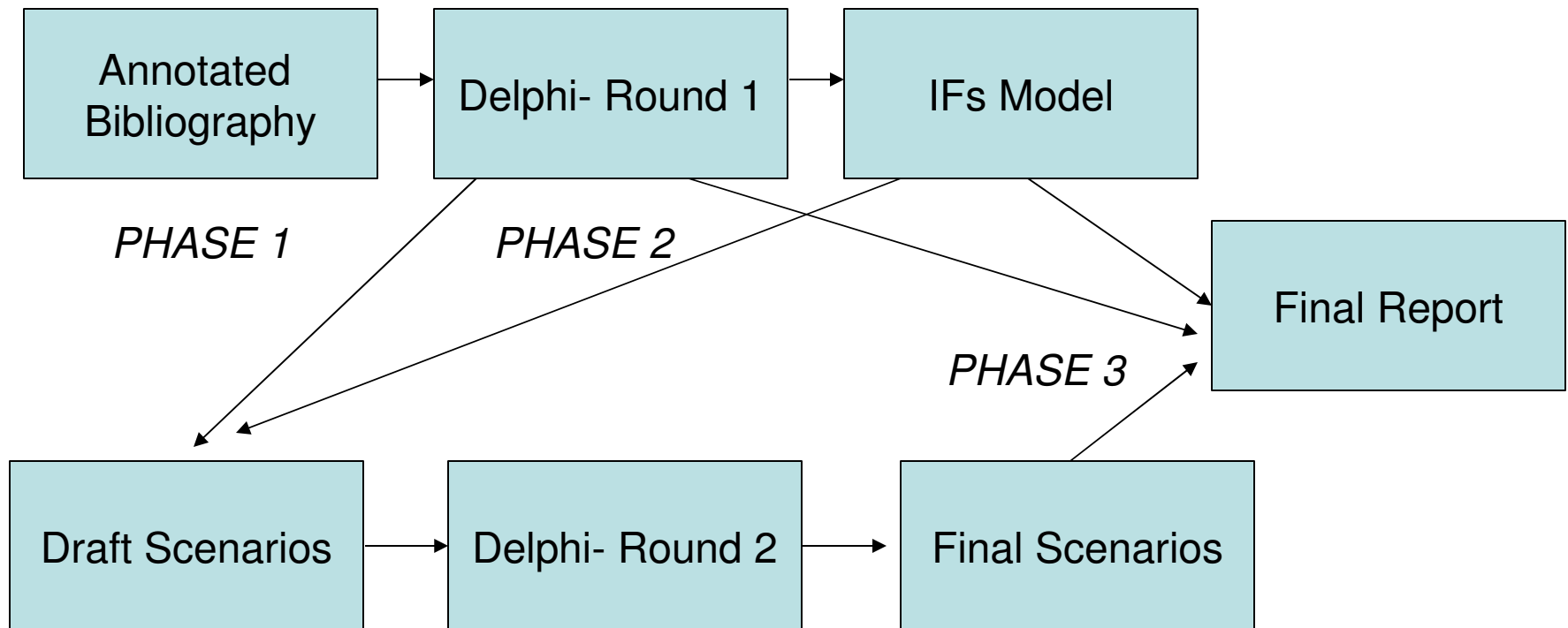


# Millennium Project...



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## Energy Scenarios 2020: Study Flow



# Four Assumed Scenarios

1. ***Business as usual.*** Global changes continue without great surprises or much change in energy patterns, other than those resulting from dynamics and trends already in place
2. ***Environmental backlash.*** The international environmental movement becomes more organized and violent, attacking fossil energy industries
3. ***High tech economy.*** Technological innovations accelerate beyond current expectations, and have large scale impacts in the energy supply mix and consumption patterns
4. ***Political turmoil.*** Increasing political instability and conflicts, relating to or resulting from energy needs and capacities

# **Comments on Comments**

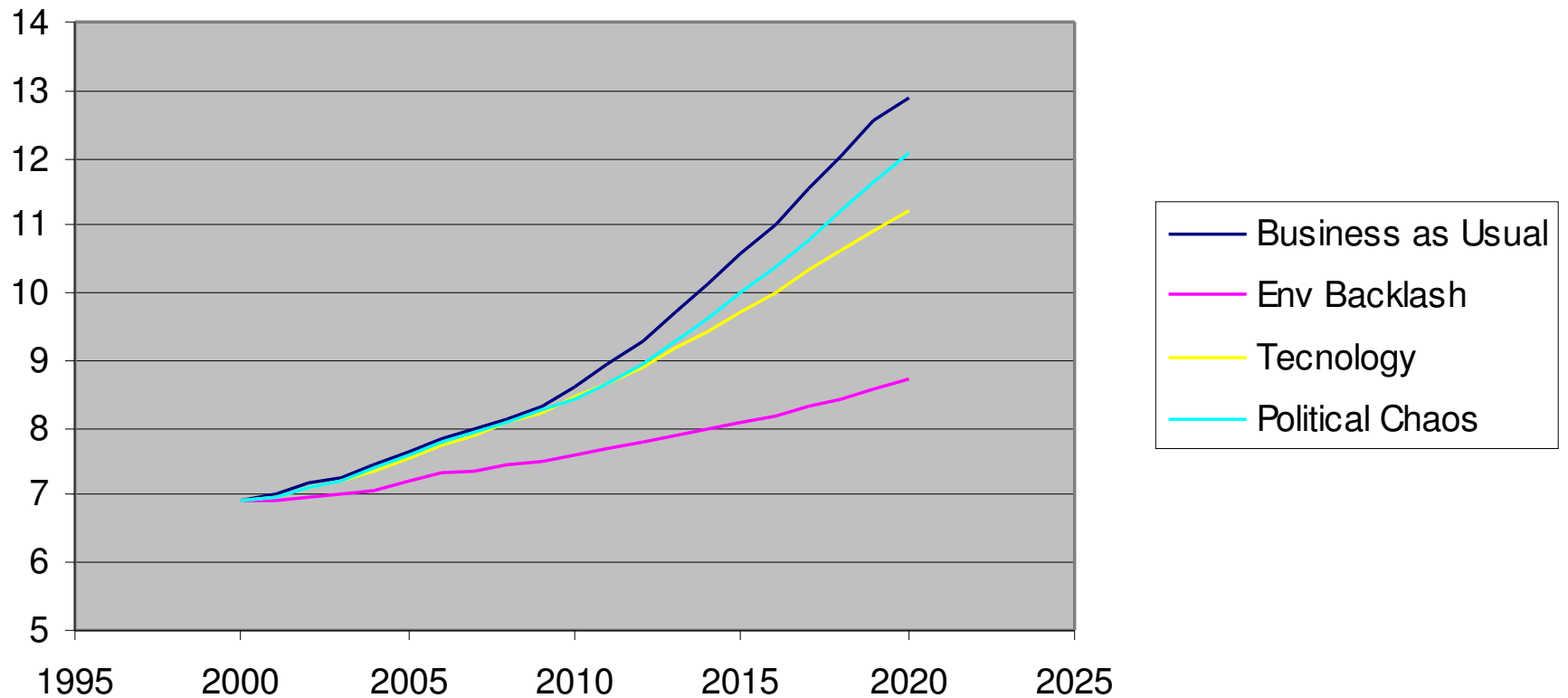
- **Some 3,000 comments were received**
- **From 200 energy experts around the world**
- **Led to more complete formation of the 4 final scenarios**

# The IFs Model

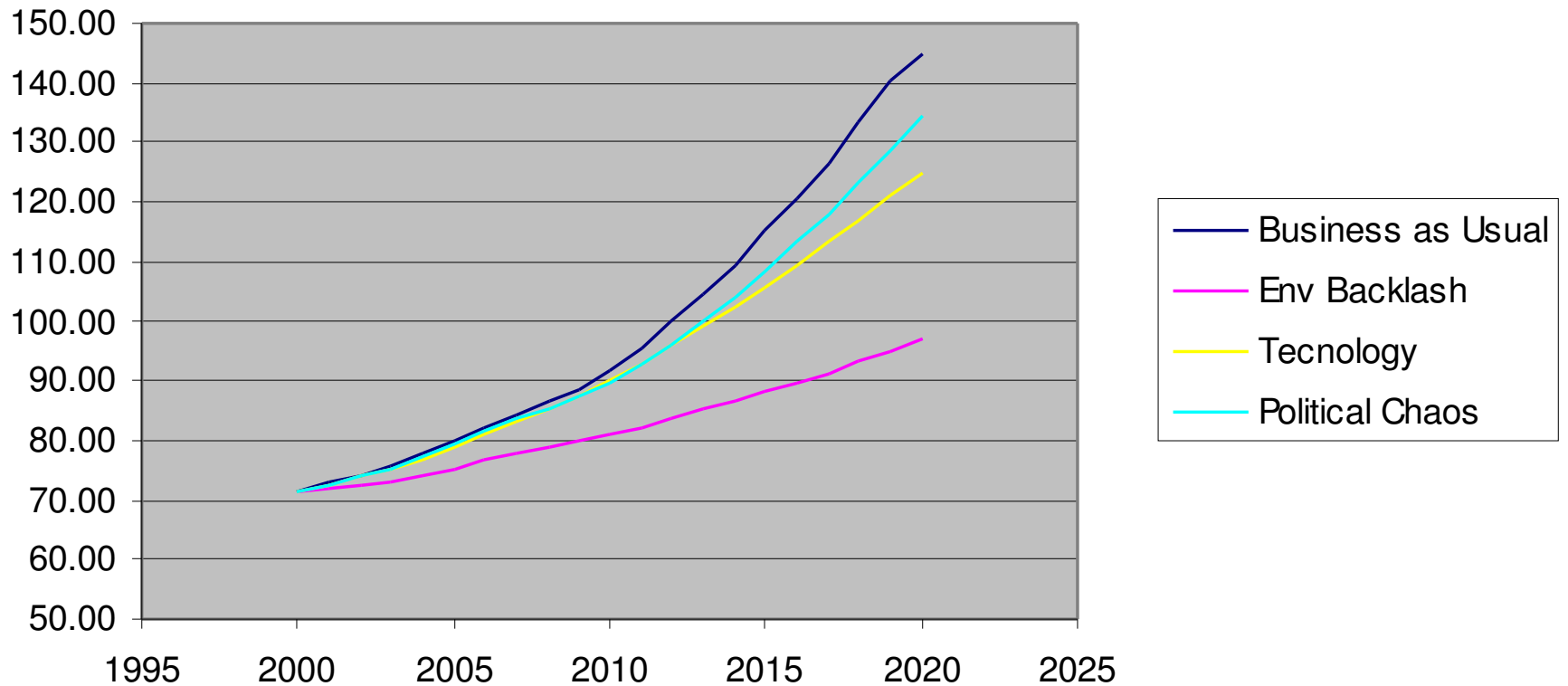
- The International Futures (IFs), University of Denver, was for additional quantitative scenario data.
- The models were produced for UNEP GEO Project and for the National Intelligence Council, 2020 Project
- Characteristics of the MP scenarios were used to estimate exogenous energy efficiency.
- Existing IFs scenarios were used where possible
- Five output variables computed
  - Annual emissions from fossil fuels- billion tons
  - Energy demand- bil barrels OE
  - Energy price: index, base 100 in 2000
  - GDP per capita in PPP 95 dollars- thousand dollars
  - Annual water usage- cubic km



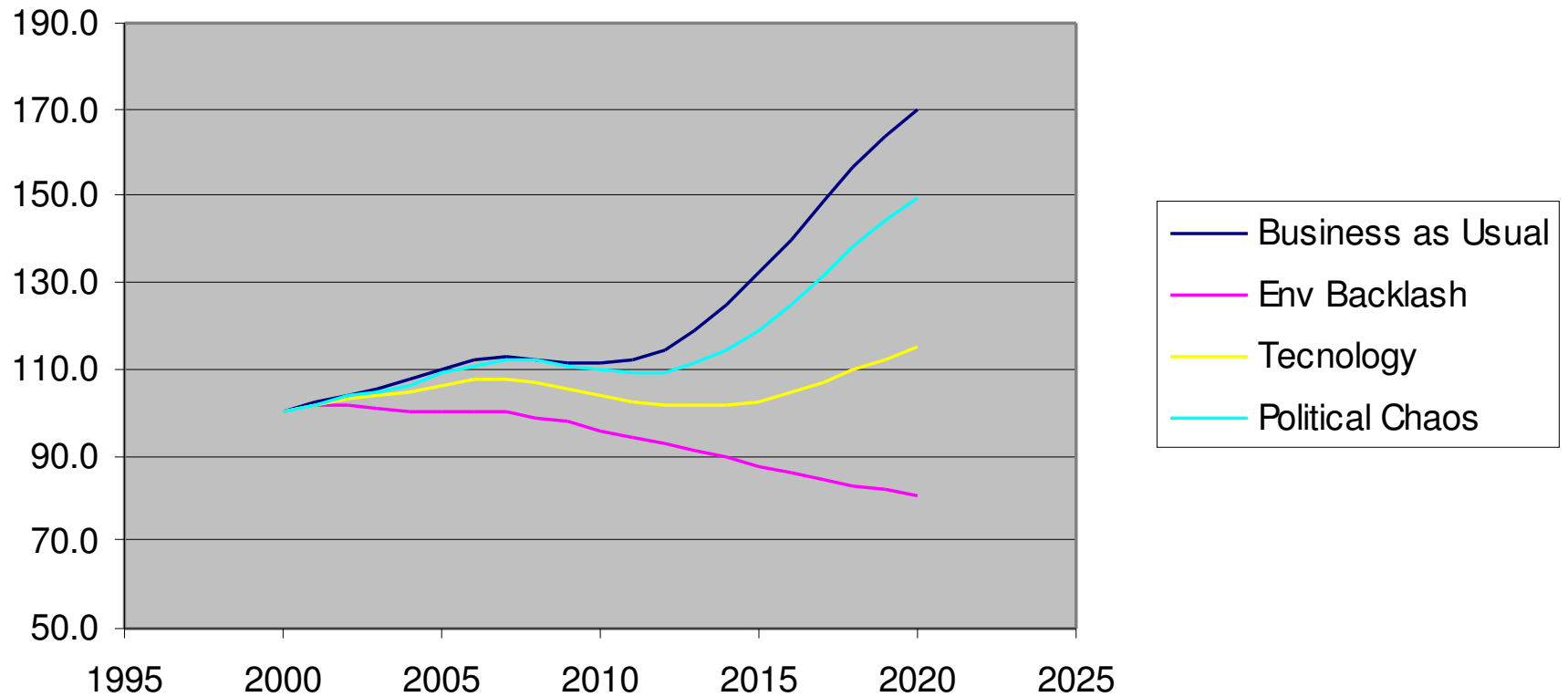
## Annual Emissions from Fossil Fuels (bil tons)



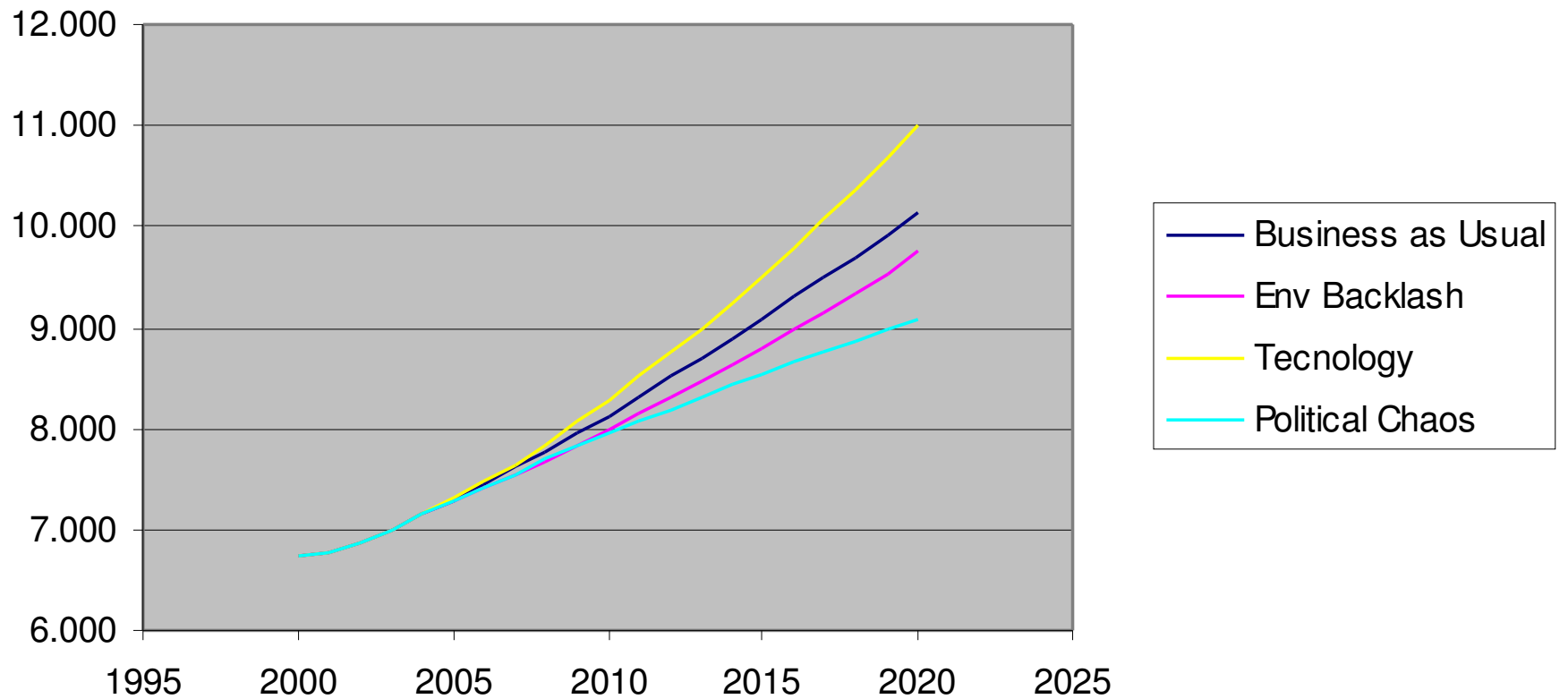
## Energy Demand (bil barrels OE)



## Energy Price (2000= 100)



## GDP per capita; PPP 95\$





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# **Scenario 1**

## **The Skeptic**

### **Business As Usual (BAU)**



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# **Scenario 2**

## **Environmental Backlash**



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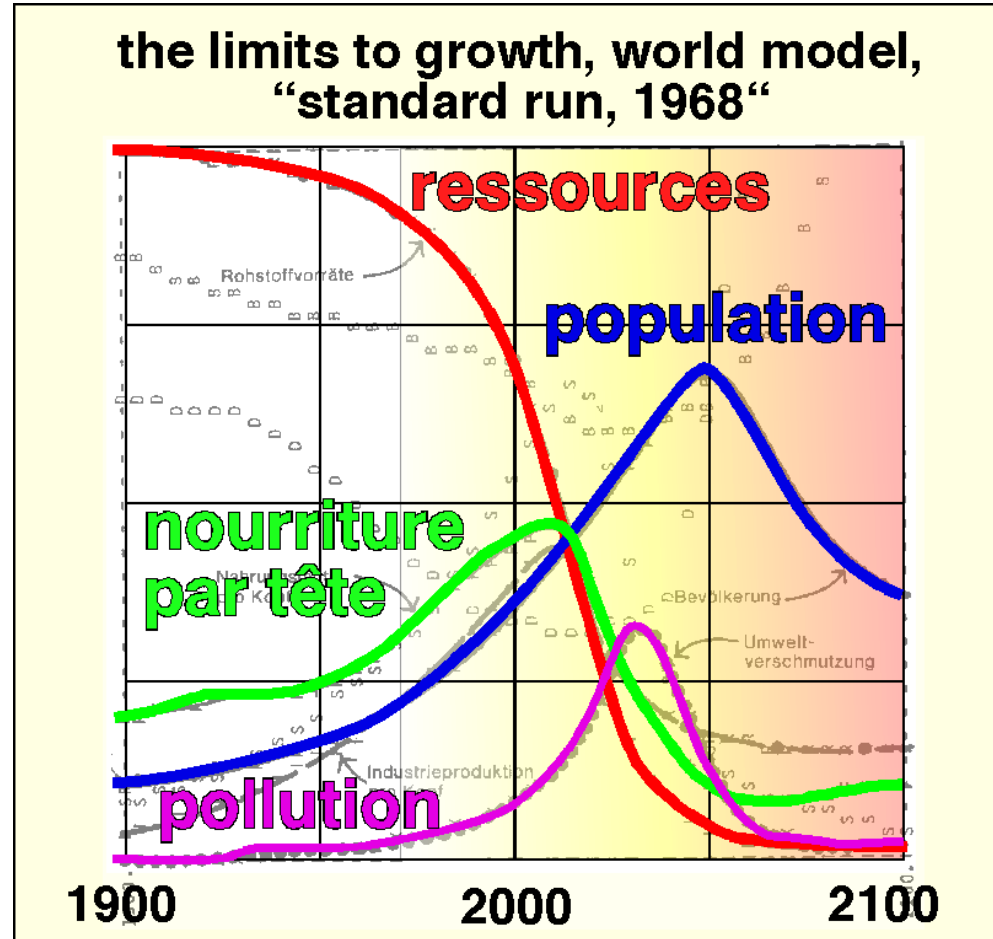
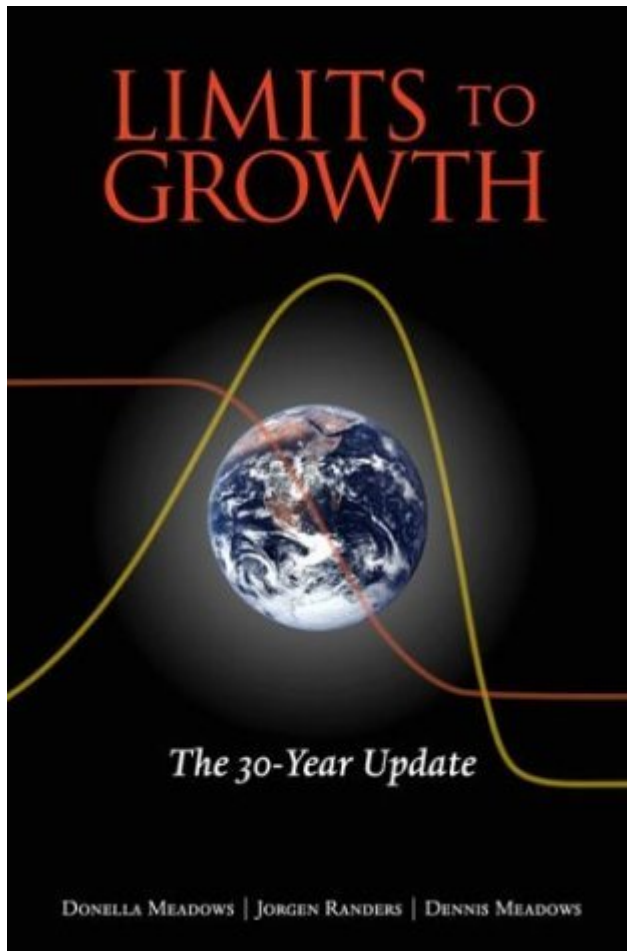
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# **Scenario 3**

## **High Tech**

**Technology Pushes Off the  
Limits to Growth**

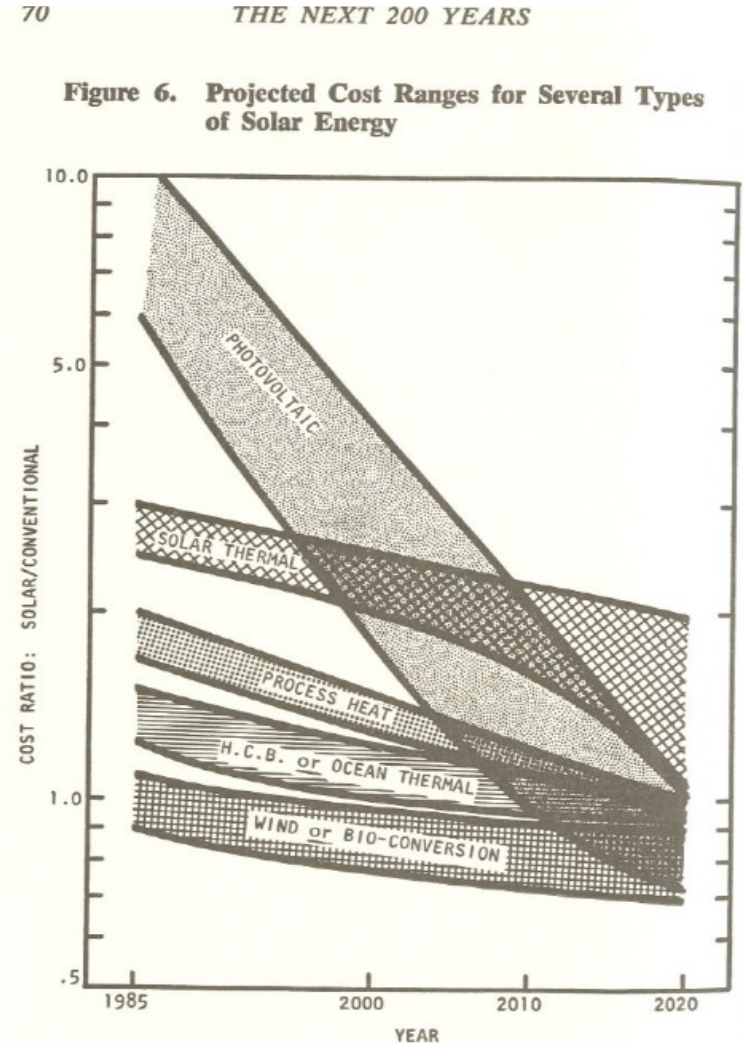
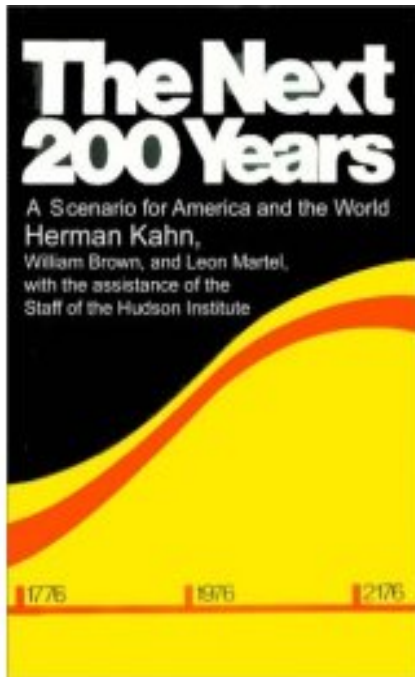
# Limits to growth?





# No limits to growth?

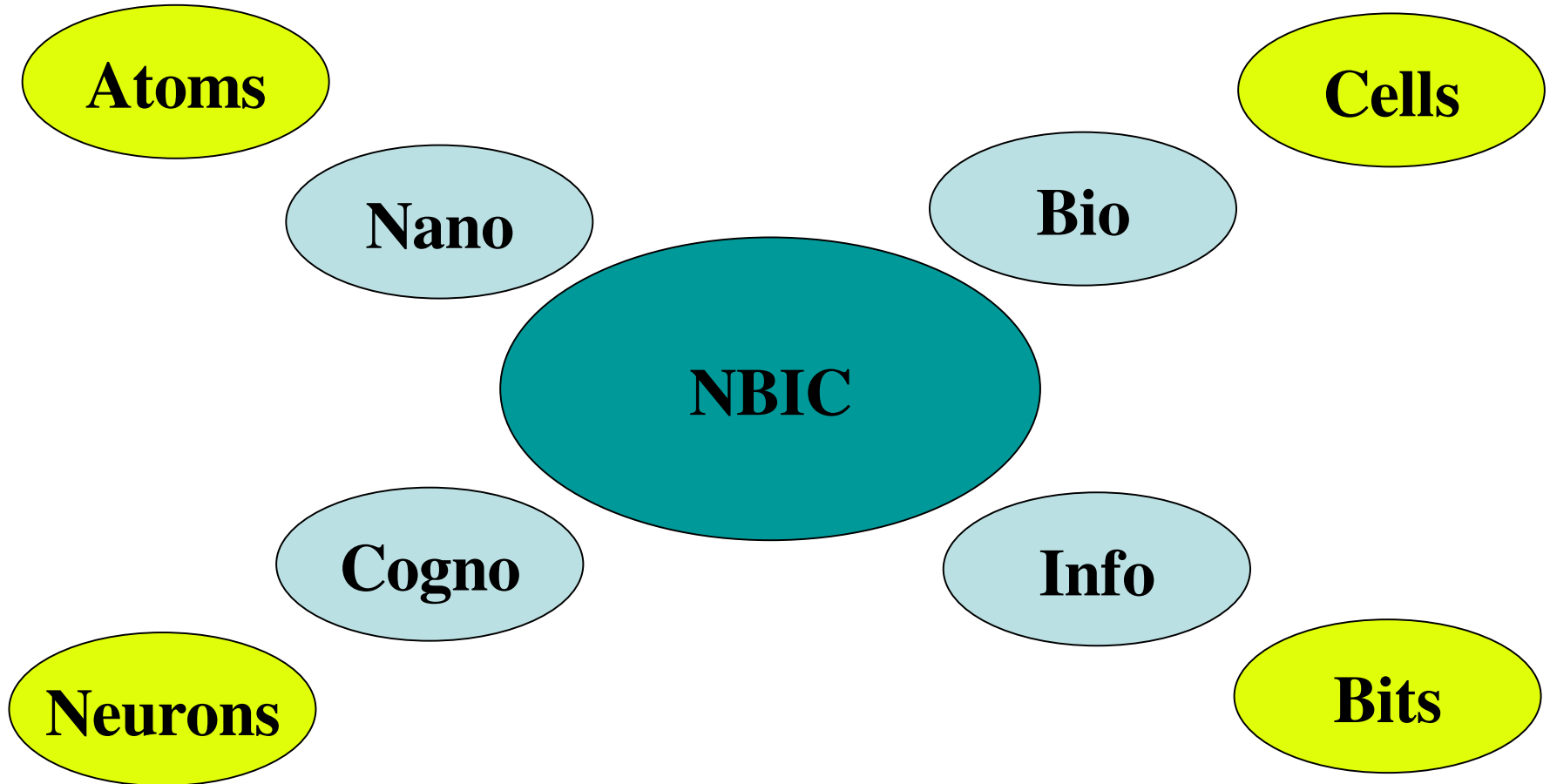
## Herman Kahn: The Next 200 Years



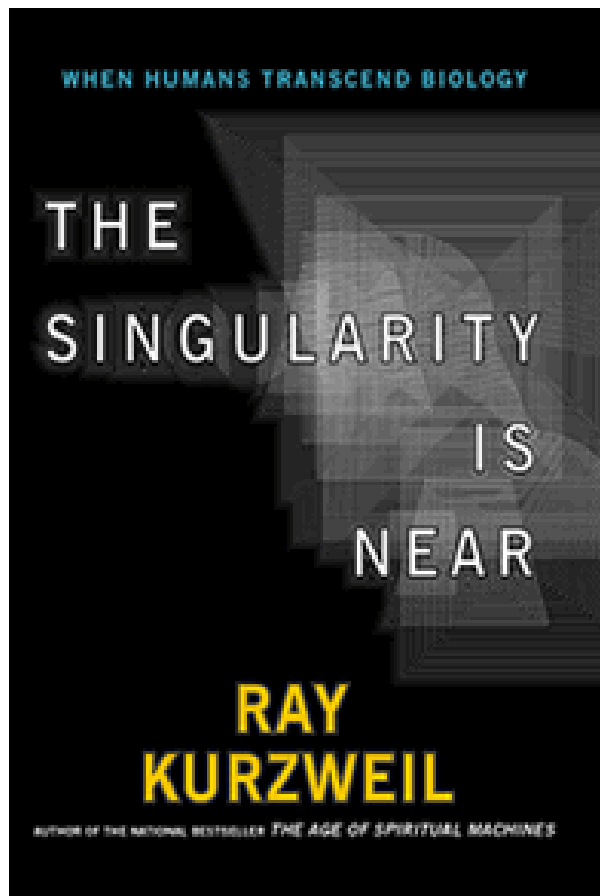
# Technology pushes off the limits

- World economy reaches US\$ 80 trillion
- Internet 4.0 connects over half of humanity, which is growing stable at 7,5 billion people
- Technological convergence accelerates
- NBIC: Nano-Bio-Info-Cogno bloom
- Moore's Law survives and thrives due to quantum computing, 3D circuits and sub-atomic particles
- Artificial intelligence reaches human intelligence levels, and a technological "singularity" is expected any time soon
- Biological evolution, slow and erratic, is overtaken by technological evolution, fast and designed
- Cyborgs and clones are becoming normal and accepted in societies, and their numbers increase faster than those of the "naturals"
- Humans will never be the same, in fact, the first transhumans and posthumans have already arrived
- Advanced robotics and space exploration are ready to take-off

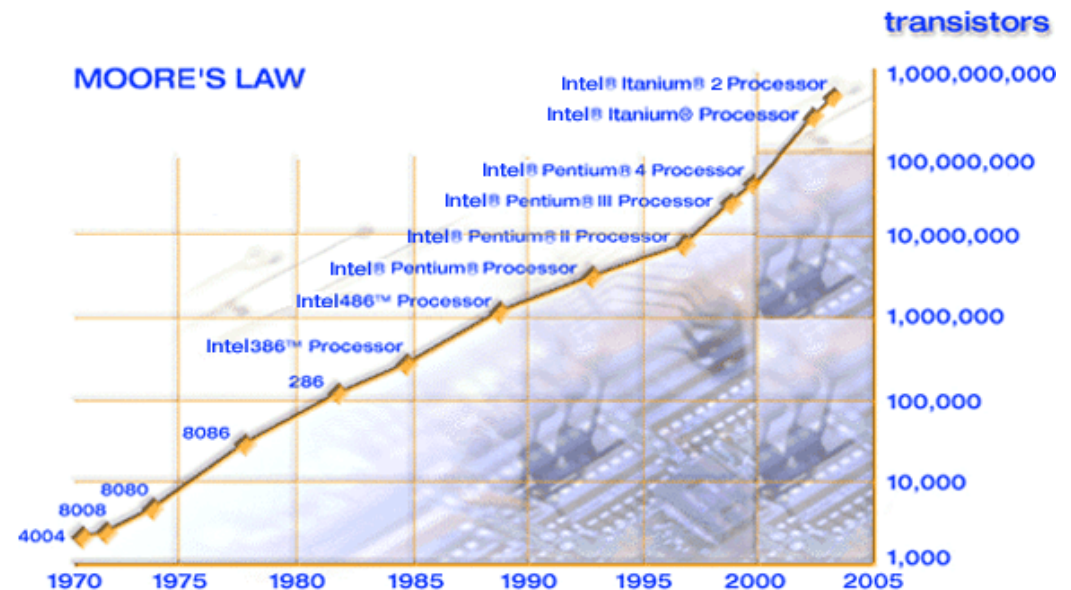
# Technological Convergence: NBIC



# Ray Kurzweil (MIT): The Singularity is Near

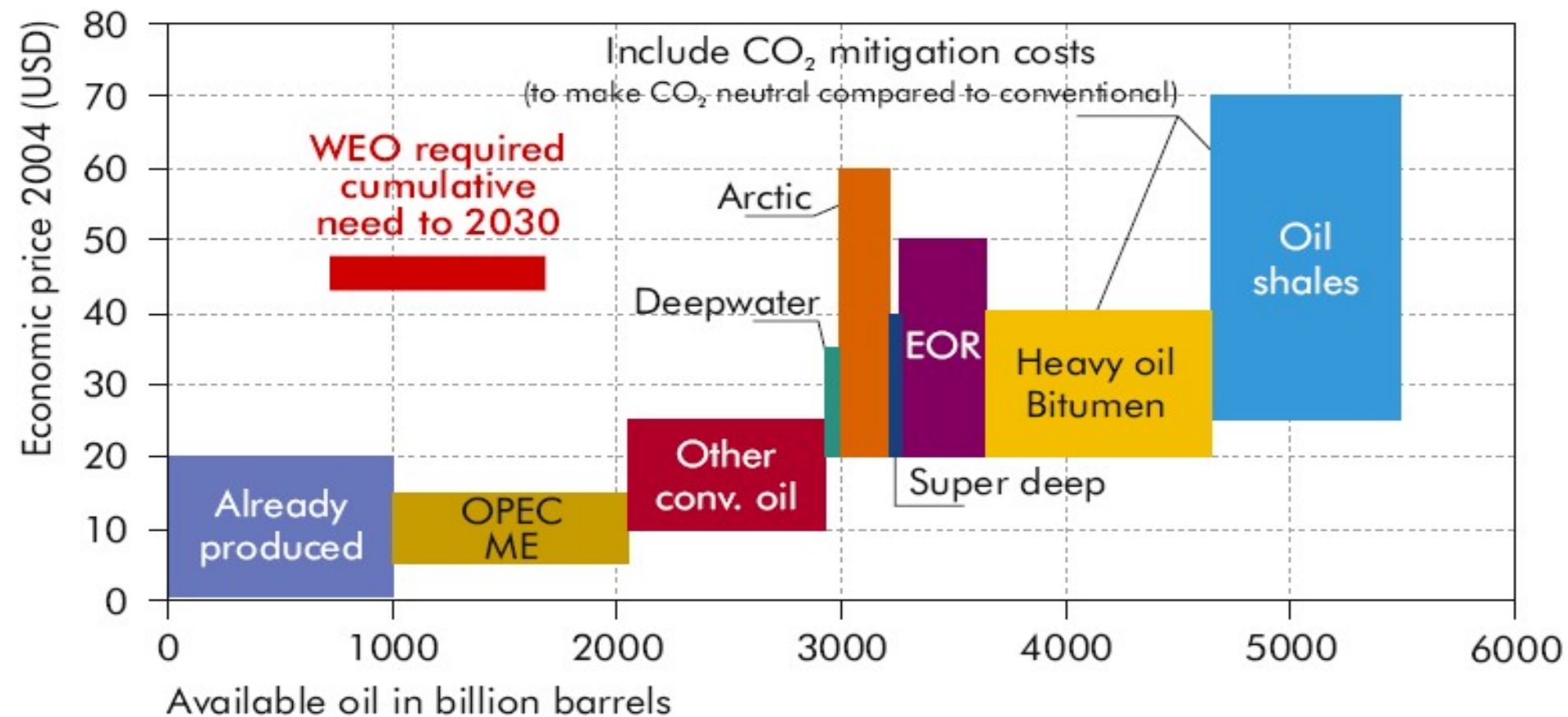


- [www.singularity.com](http://www.singularity.com)
- Bill Gates



# Oil costs and reserves

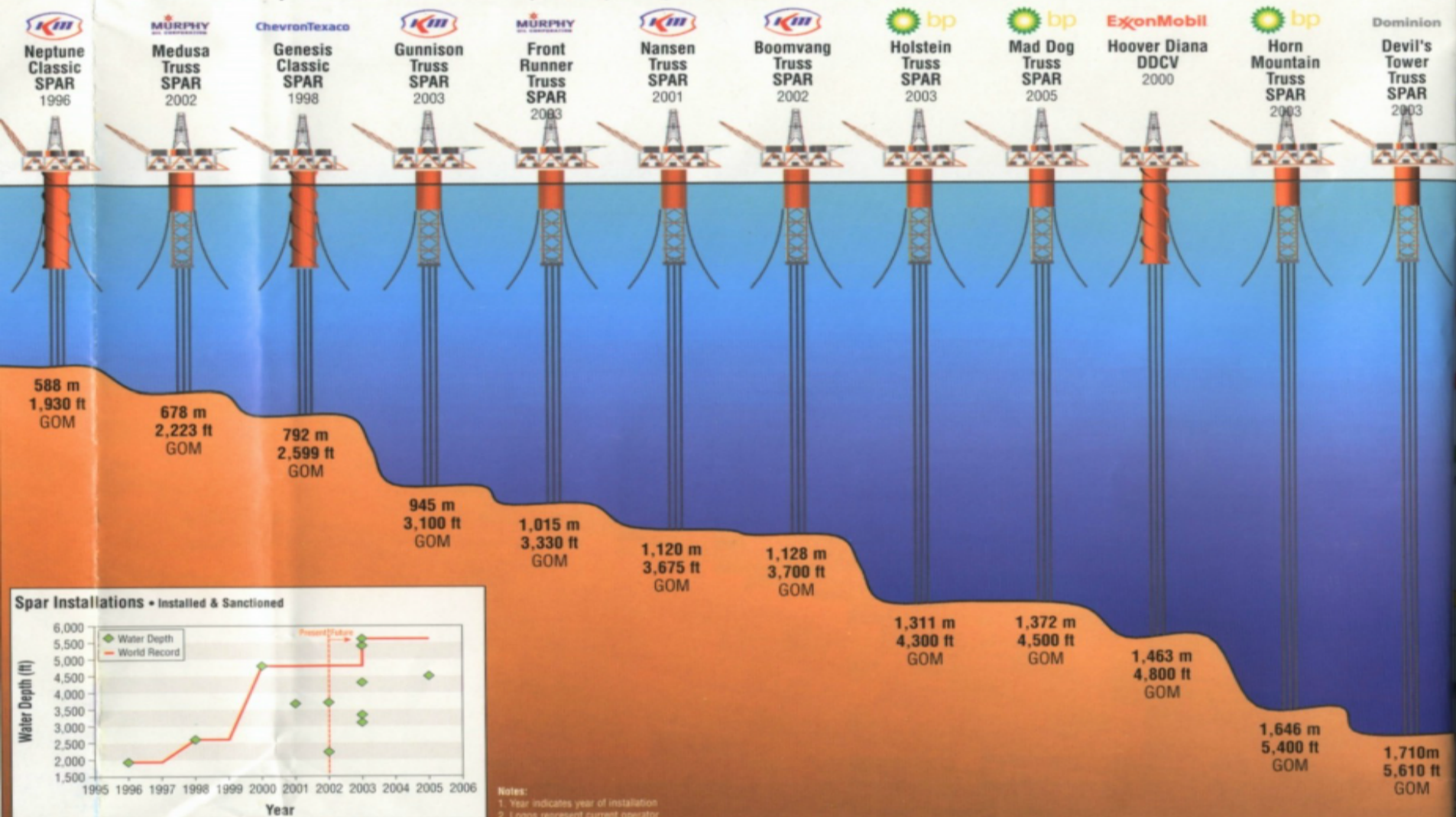
**Figure 7.1 •** Oil cost curve, including technological progress:  
availability of oil resources as a function of economic price



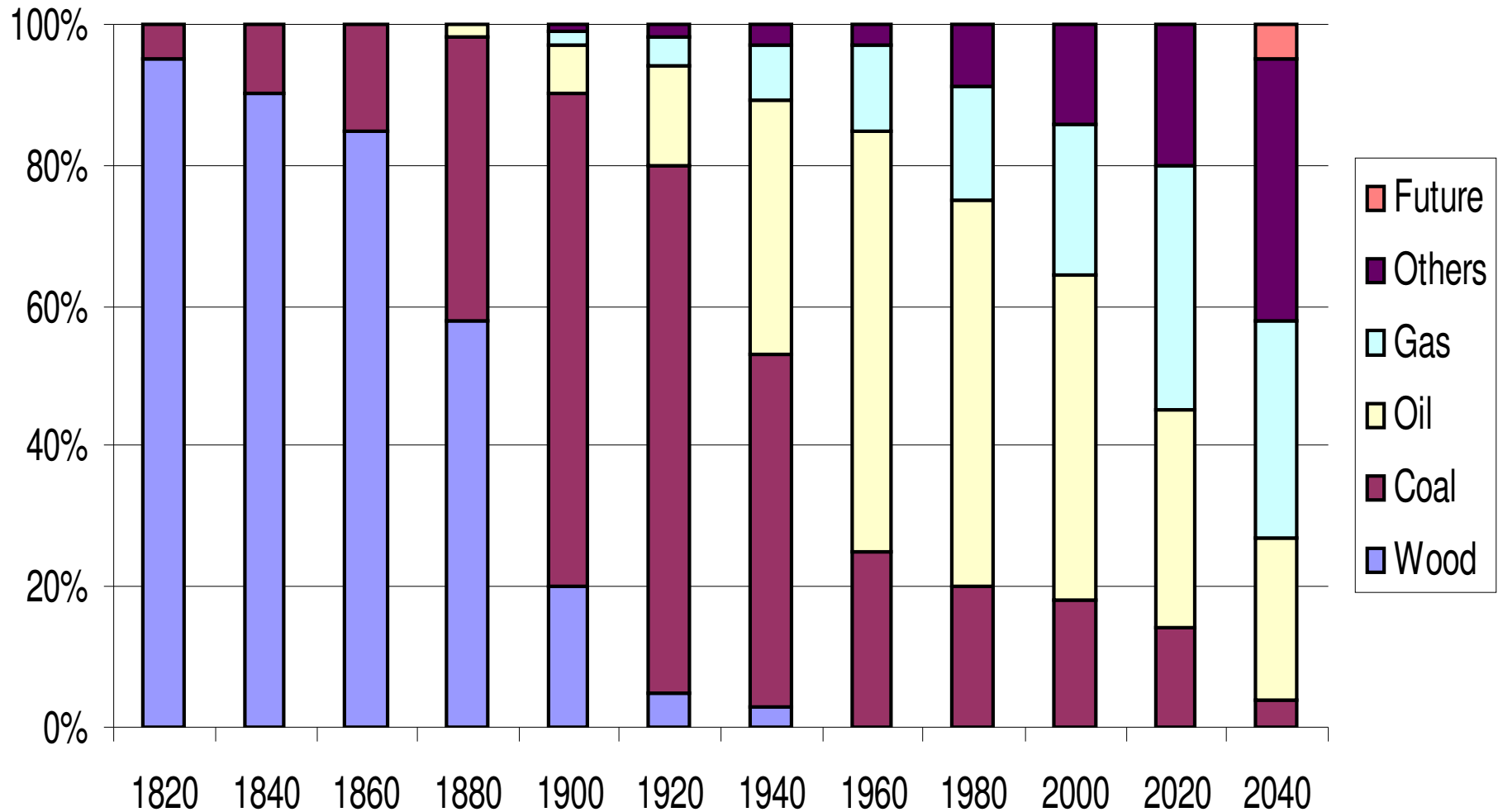


# Deeper and deeper

Spars, Deep Draft Floaters (DDFs), Caisson Production Units (CPUs),  
Deep Draft Caisson Vessels (DDCVs), Single Column Floaters (SCFs) – Installed or Sanctioned



# Energy “waves”: “decarbonization”



# Technology pushes off the limits

- 21st century energy drivers
  - Technological change
  - New discoveries
  - Resource substitution
- The proper energy mix
  - Old oil and new oil
  - Gas and more gas
  - Coal and less coal
  - Renewables
  - New energy sources

## In reserve

Fuel cost

Oil price at which energy source is economically viable

\$80	Biodiesel*
\$60	US corn-based ethanol*
\$50	Shale oil
\$40	Tar sands; Brazilian cane-based ethanol; Gas-to-liquids†; Coal-to-liquids‡
\$20	Conventional oil

\*Excludes the impact of tax credits

†GTL economic at \$40 if gas feedstock price is \$2.50 or less per m BTUs

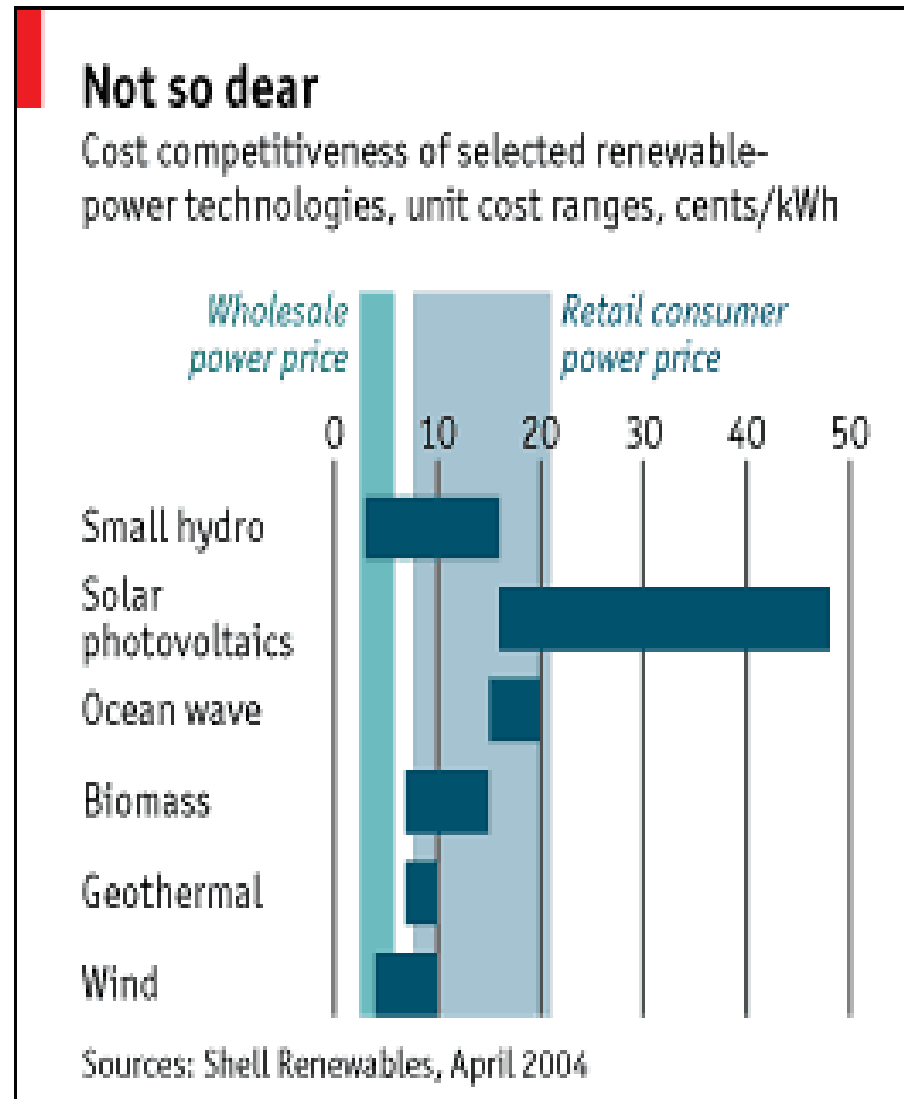
‡CTL economic at \$40 if feedstock price is \$15 per tonne or less

Sources: Cambridge Energy Research Associates;  
*The Economist*



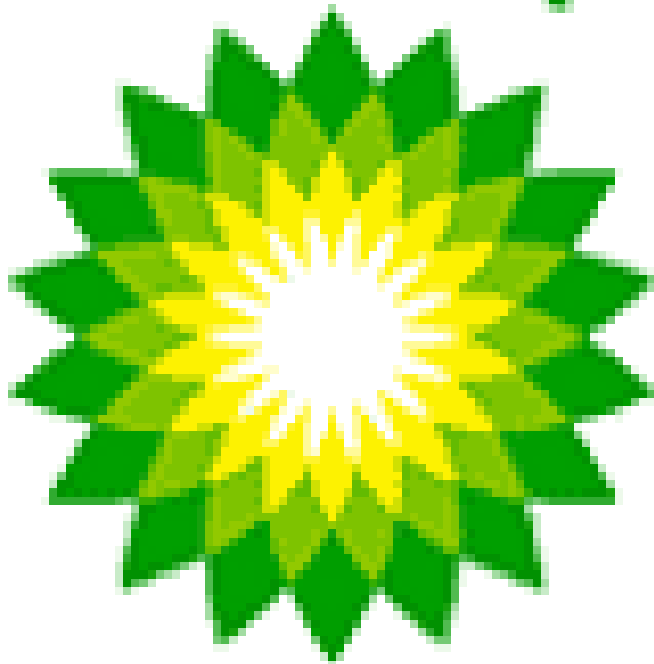
# The economic problem: EROEI

- Gasoline taxes
- Carbon taxes
- Fixed costs
- Sugar versus oil
- Market mechanisms
  - Supply and demand
  - Cost considerations
  - Energy substitutes
  - Policy incentives



# Towards a Post-Petroleum World

bp

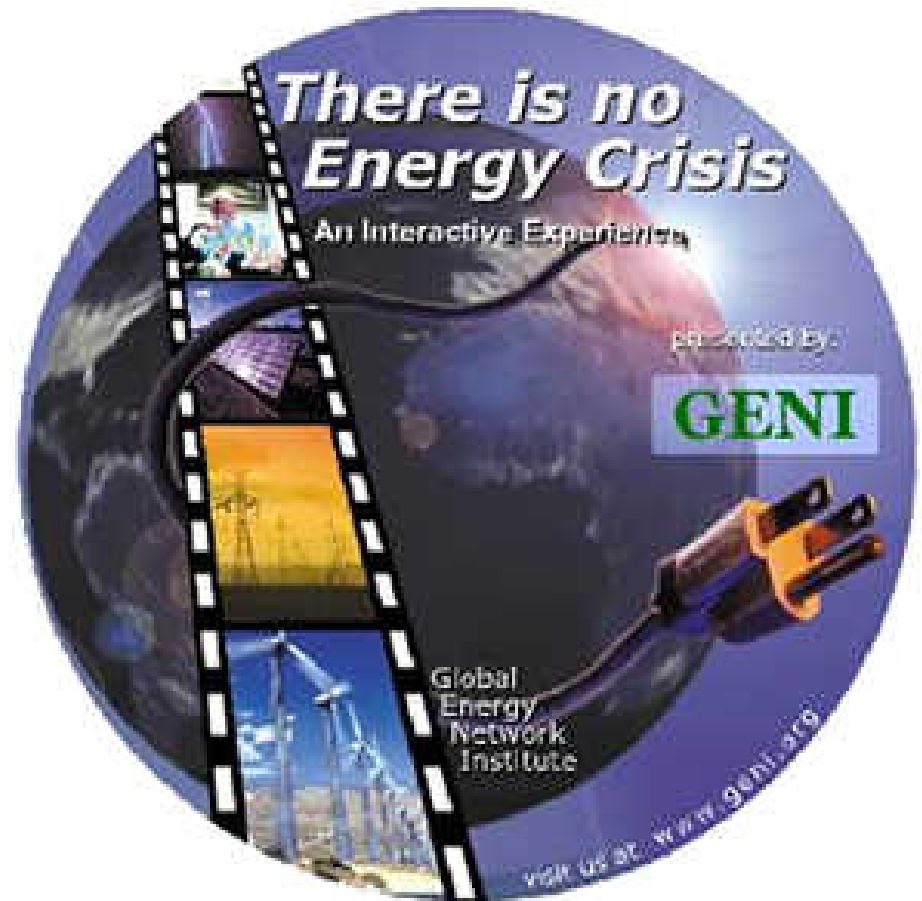
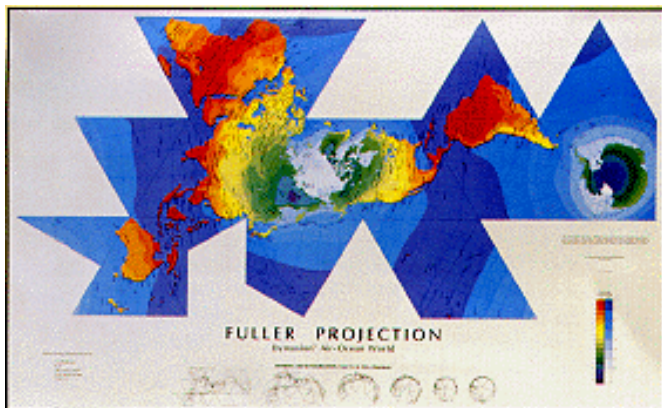


**British Petroleum**

**Beyond Petroleum**

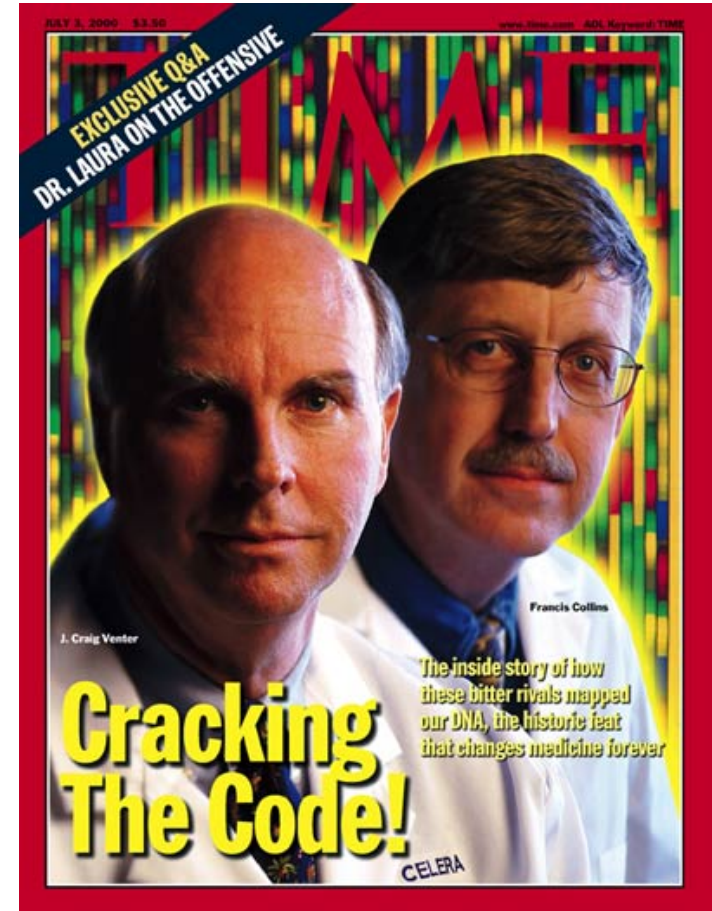
# The Energy “Internet”

- Buckminster Fuller
- Global Energy Network Institute
- GENI.org



# Bioenergy and “eternal” energy

- The cells of life
- Photosynthesis
$$\text{CO}_2 + 2 \text{H}_2\text{O} + \text{light} \rightarrow (\text{CH}_2\text{O}) + \text{O}_2 + \text{H}_2\text{O}$$
- From fossil hydrocarbons to live carbohydrates
- Craig Venter and his petroleum bacteria
- Bacteria *Clostridium acetobutylicum* produces ethanol naturally
- Bacteria *Petroleum artificiali* produces “gasoline”



- **The Stone Age did not end because of lack of stones, and the Oil Age will end soon and not because of lack of oil.**

**Sheik Ahmed Yamani, 2000**  
**Saudi Arabia**

<b>Fuel type</b>	<b>Energy content (MJ/kg)</b>
Pumped stored water at 100 m dam height	0.001
Bagasse	10
Wood	15
Sugar	17
Methanol	22
Coal (anthracite, lignite, etc.)	23 - 29
Ethanol (bioalcohol)	30
LPG (liquefied petroleum gas)	34
Butanol	36
Biodiesel	38
Oil (medium petroleum average)	42
Gasohol or E10 (90% gasoline and 10% alcohol mix)	44
Gasoline	45
Diesel	48
Methane (gaseous fuel, compression-dependent)	55
Hydrogen (gaseous fuel, compression-dependent)	120
Nuclear fission (Uranium, U 235)	90
Nuclear fusion (Hydrogen, H)	300
Binding energy of helium (He)	675
Mass-energy equivalence (Einstein's equation)	89,880,000
Antimatter as fuel (estimated according to $E = mc^2$ )	180,000,000

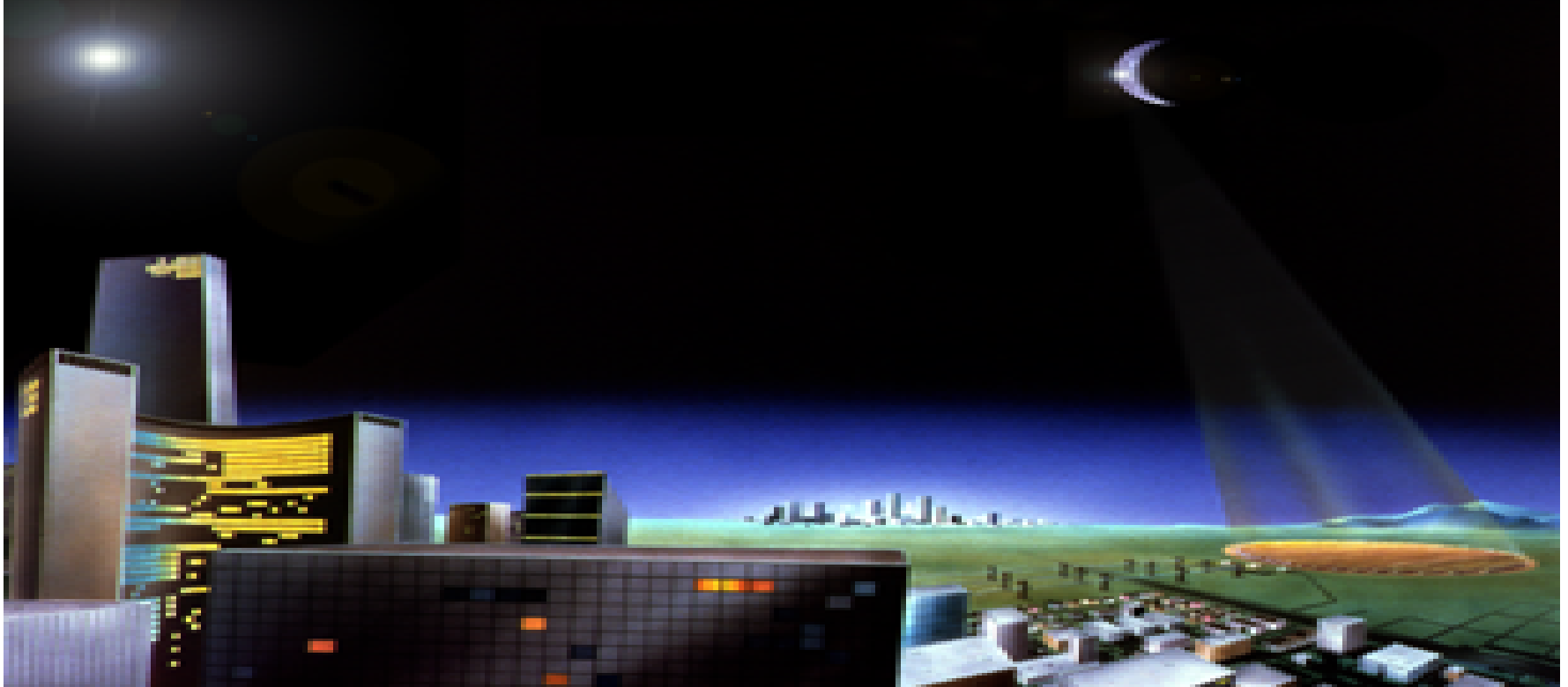
# Earth-based solar energy



**6 land blocks of 3 TW are enough for humanity today**

# Sun-Moon-Beam-Rectenna

Solar Power -> Lunar Bases -> Power Beams -> Earth Receivers



**KEY PROMOTER: DAVID CRISWELL**

**(Institute of Space Systems Operations, University of Houston)**



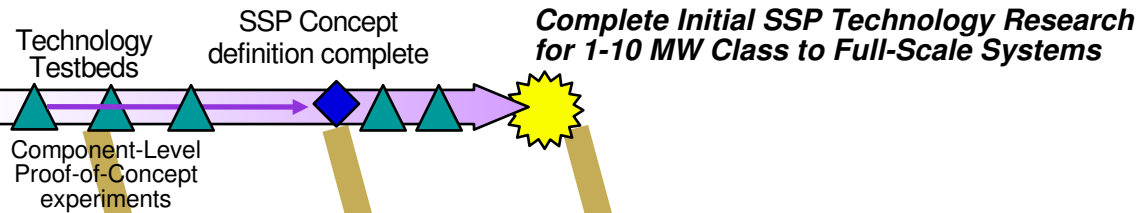
# Moon Energy $\geq 20$ TWe



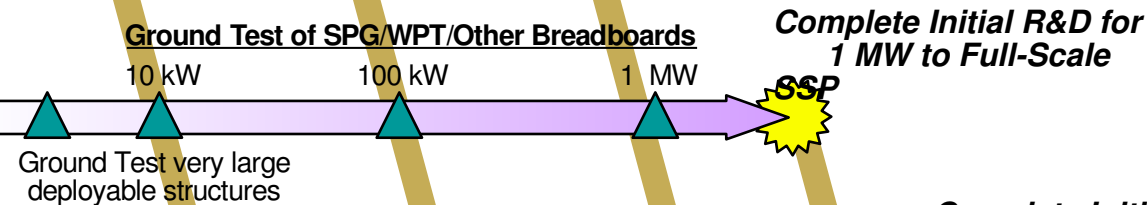
# NASA: Space Solar Power (in stand-by)

2002-2003-2005 | 2006-2010 | 2011-2015 | 2016-2020  
 FY99 FY00 FY01 FY02 FY03 FY04 FY05 FY06 FY07 FY08 FY09 FY10 FY11 FY12 FY13 FY14 FY15 FY16 FY17 FY18 FY19 FY20

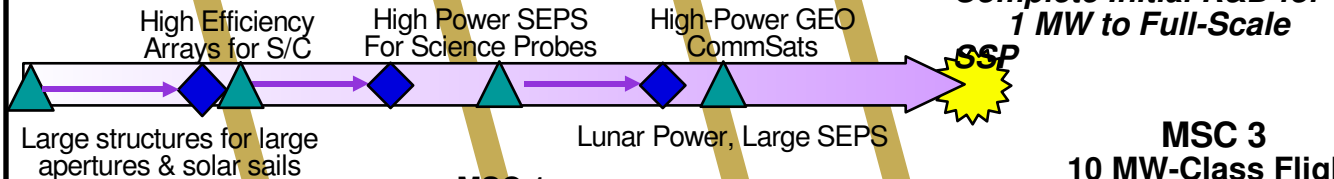
**Studies & Proof-of-Concept Technology Research (TRL 2-4)**



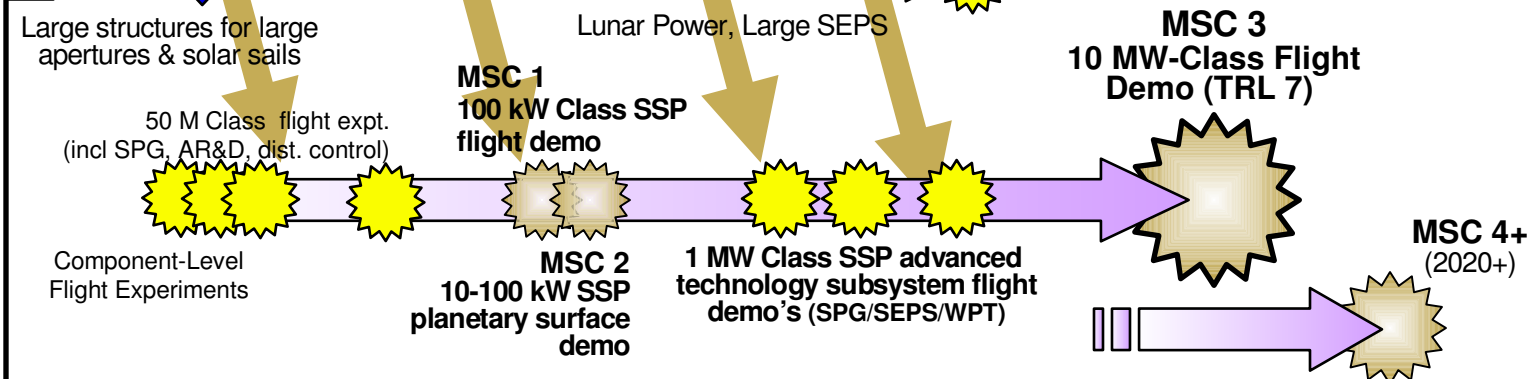
**Technology Research, Development and Test (TRL 4-5)**



**Dual-Purpose Applications R&D (TRL 4-6)**



**Technology Demos (TRL 6-7)**



## LEGEND



R&D Decision Point



Major R&D Pgm Milestone



Strategic R&T Road Map Objective



SSP Model System Concept(s)



Example	Power	Scientific notation
Power of Galileo space probe's radio signal from Jupiter	10 zW	$10 \times 10^{-21}$ watt
Minimum discernable signal at an FM antenna terminal	2.5 fW	$2.5 \times 10^{-15}$ watt
Average power consumption of a human cell	1 pW	$1 \times 10^{-12}$ watt
Approximate consumption of a quartz wristwatch	1 $\mu$ W	$1 \times 10^{-6}$ watt
Laser in a CD-ROM drive	5 mW	$5 \times 10^{-3}$ watt
Approximate power consumption of the human brain	30 W	$30 \times 10^0$ watt
Power of the typical household light bulb	60 W	$60 \times 10^0$ watt
Average power used by the human body	100 W	$100 \times 10^0$ watt
Approximately 1000 BTU/hour	290 W	$2.9 \times 10^0$ watt
Power received from the Sun at the Earth's orbit by m2	1.4 kW	$1.4 \times 10^3$ watt
Photosynthetic power output per km2 in ocean	3.3 - 6.6 kW	$3.3 - 6.6 \times 10^3$ watt
Photosynthetic power output per km2 in land	16 - 32 kW	$16 - 32 \times 10^3$ watt
Range of power output of typical automobiles	40 - 200 kW	$40 - 200 \times 10^3$ watt
Mechanical power output of a diesel locomotive	3 MW	$3 \times 10^6$ watt
Peak power output of largest class aircraft carrier	190 MW	$190 \times 10^6$ watt
Power received from the Sun at the Earth's orbit by km2	1.4 GW	$1.4 \times 10^9$ watt
Peak power generation of the largest nuclear reactor	3 GW	$3 \times 10^9$ watt
Electrical generation of the Three Gorges Dam in China	18 GW	$18 \times 10^9$ watt
Electrical power consumption of the USA in 2001	424 GW	$424 \times 10^9$ watt
Electrical power consumption of the world in 2001	1.7 TW	$1.7 \times 10^{12}$ watt
Total power consumption of the USA in 2001	3.3 TW	$3.3 \times 10^{12}$ watt
Global photosynthetic energy production	3.6 - 7.2 TW	$3.6 - 7.2 \times 10^{12}$ watt
Total power consumption of the world in 2001	13.5 TW	$13.5 \times 10^{12}$ watt
Average total heat flux from earth's interior	44 TW	$44 \times 10^{12}$ watt
Heat energy released by a hurricane	50 - 200 TW	$50 - 200 \times 10^{12}$ watt
Estimated heat flux transported by the Gulf Stream	1.4 PW	$1.4 \times 10^{15}$ watt
Total power received by the Earth from the Sun (Type I)	174 PW	$174 \times 10^{15}$ watt
Luminosity of the Sun (Type II)	386 YW	$386 \times 10^{24}$ watt
Approximate luminosity of the Milky Way galaxy (Type III)	$5 \times 10^{36}$ W	$5 \times 10^{36}$ watt
Approximate luminosity of a Gamma Ray burst	$1 \times 10^{45}$ W	$1 \times 10^{45}$ watt
Energy output of a galactic supercluster (Type IV)	$1 \times 10^{46}$ W	$1 \times 10^{46}$ watt
Energy control over the entire universe (Type V civilization)	$1 \times 10^{56}$ W	$1 \times 10^{56}$ watt



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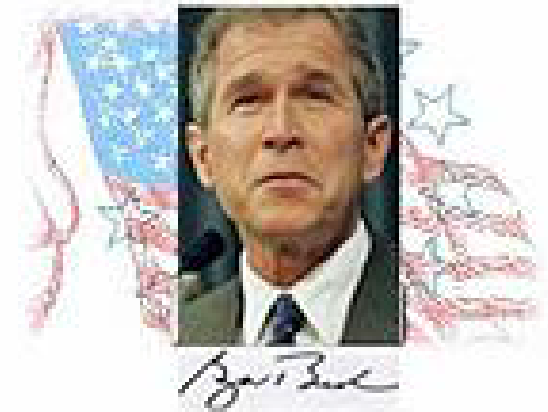
# **Scenario 4**





## **Political Turmoil**



"We  not

erate Saddam



Hussein for his actions. We will  
**Mobilize** to meet this threat to  
vital interests in the Persian   
until an ble solution is reached.  
Our best strategy is to repared.  
Failing that, we **ARCO** ming  
to kick your ass."

We have 710  
good reasons  
to be involved  
in the affairs  
of the mideast.



710



Excuse me,  
Mr. President.



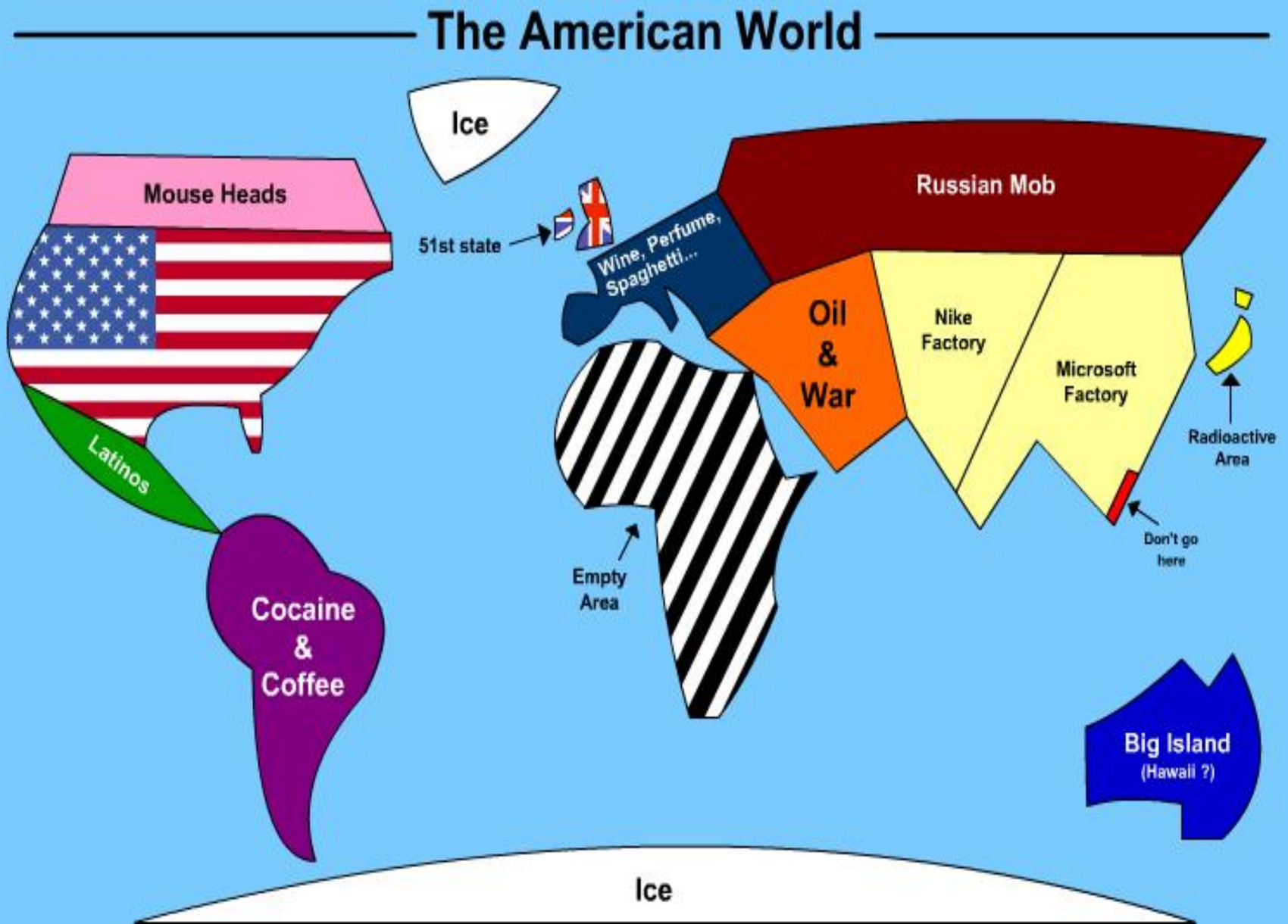
We have one  
good reason  
to be involved  
in the affairs  
of the mideast.



OIL



# The “world” according to Bush







**¡Muchas gracias!**  
**Kiitos! Thank you!**  
**[www.Cordeiro.org](http://www.Cordeiro.org)**