

# Making the Transition: Solar Energy's Role in a Sustainable Energy Future

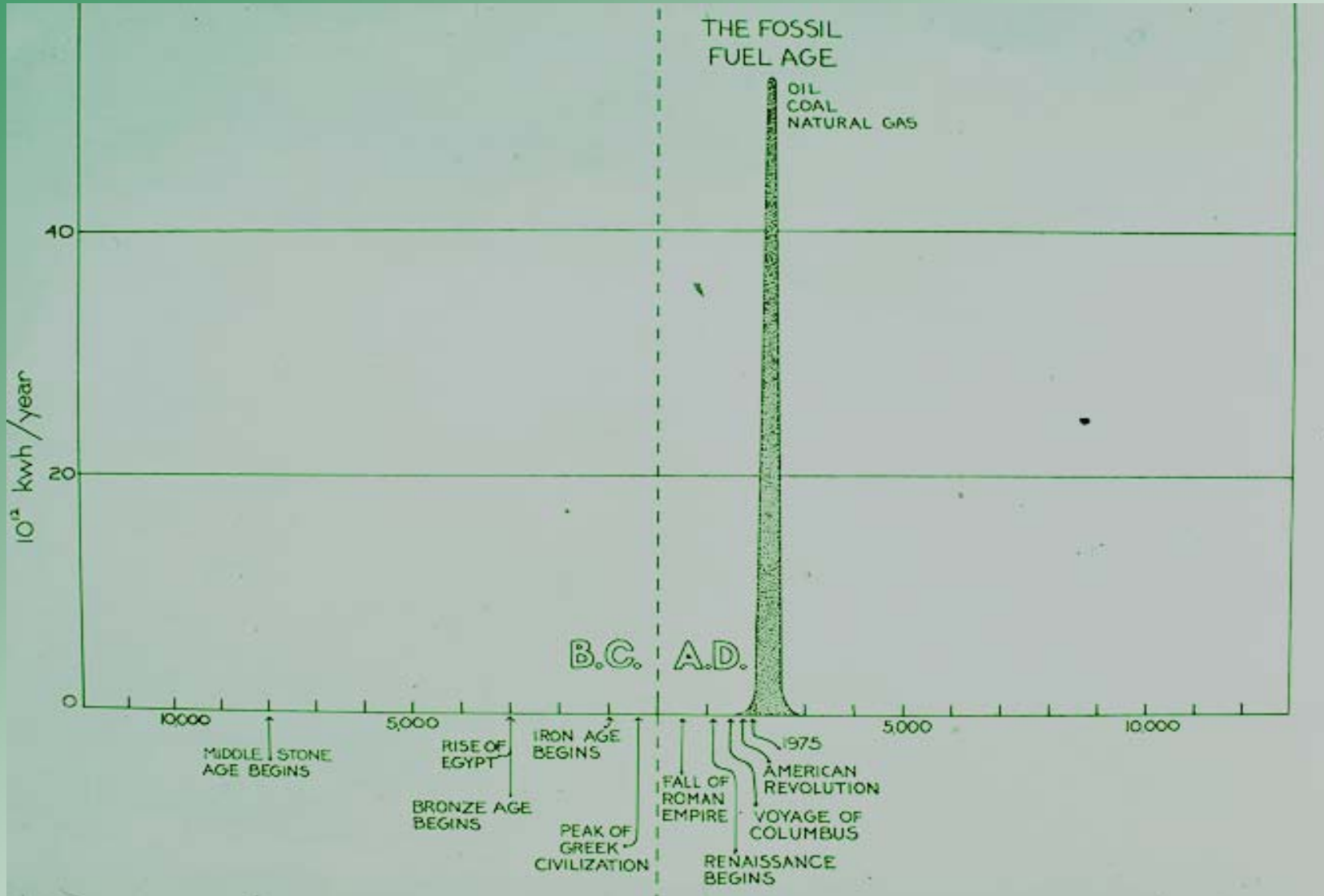


*Presented at:  
Solar Energy Conference  
San Diego Solar Energy Week  
San Diego, CA  
September 29, 2005*

*Presented by:  
Tom Starrs  
Vice President & Chief Operating Officer  
The Bonneville Environmental Foundation*

Four Million Years  
of  
Energy History  
in  
Five Minutes

# The "Blip"

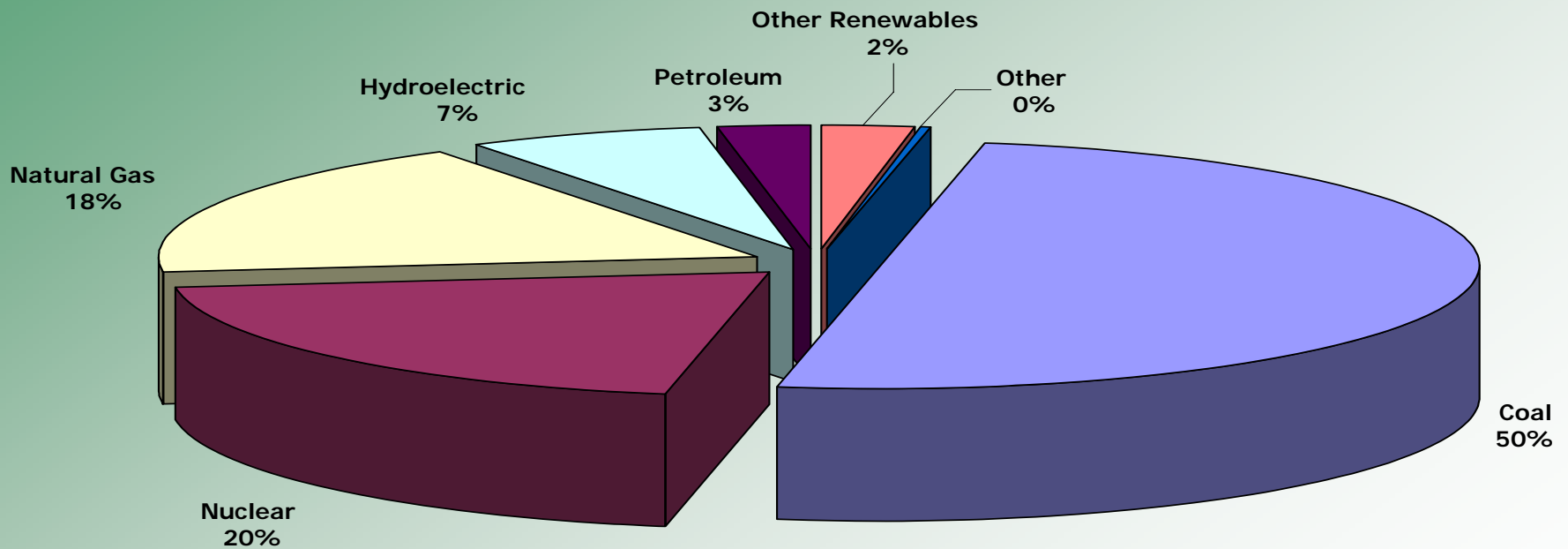


# Our Energy Now

*“This is Too Precious to Burn.”*

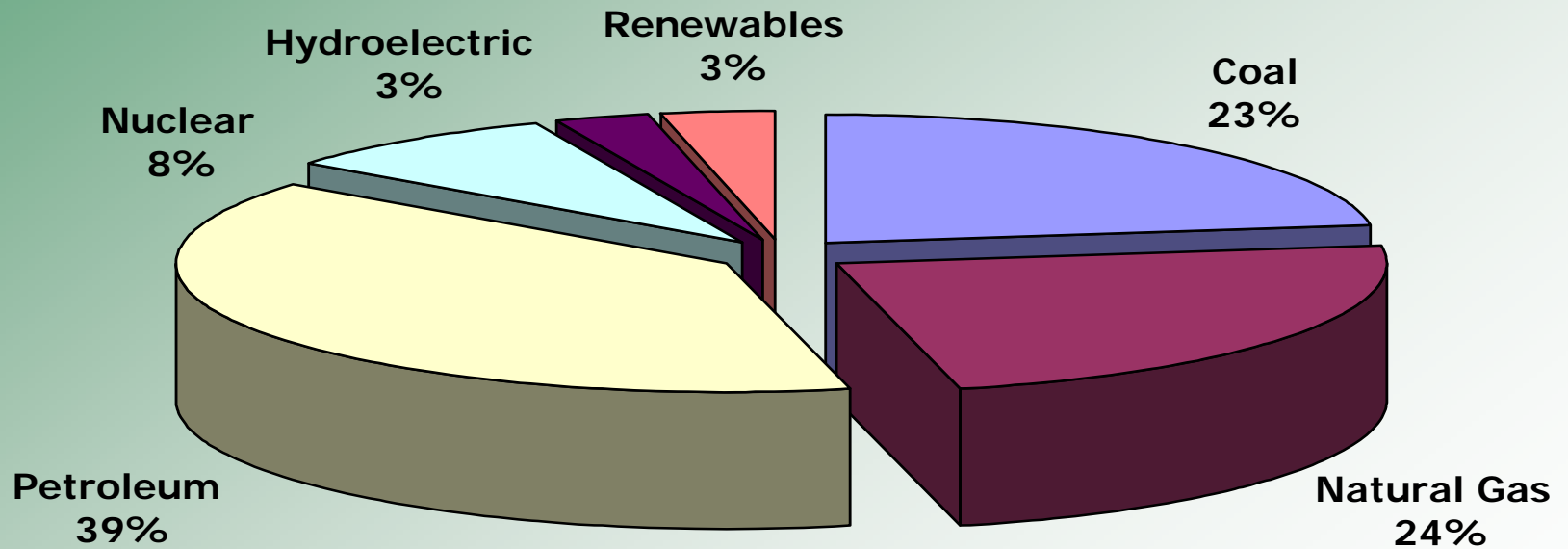
*-- Russian Chemist D.I. Mendelyeev, Co-Discoverer of Oil*

# U.S. Electric Power Generation (2002)



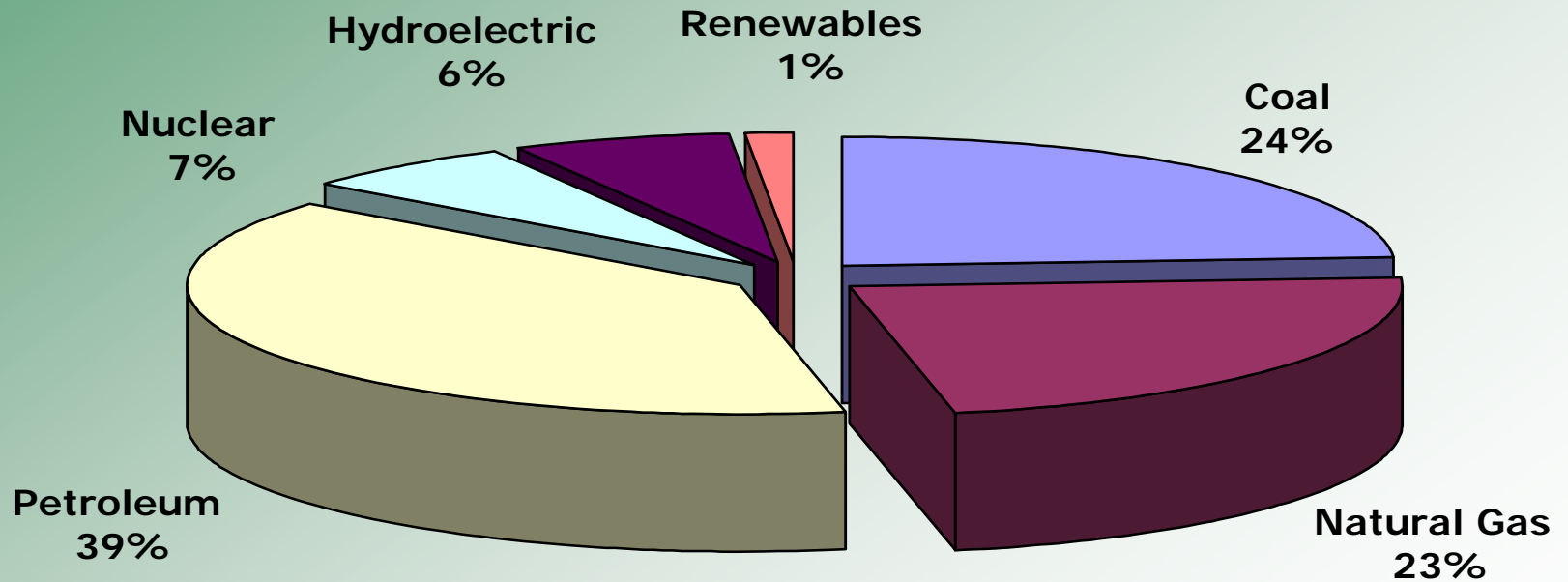
Source: U.S. Energy Information Administration

# U.S. Energy Consumption (2002)



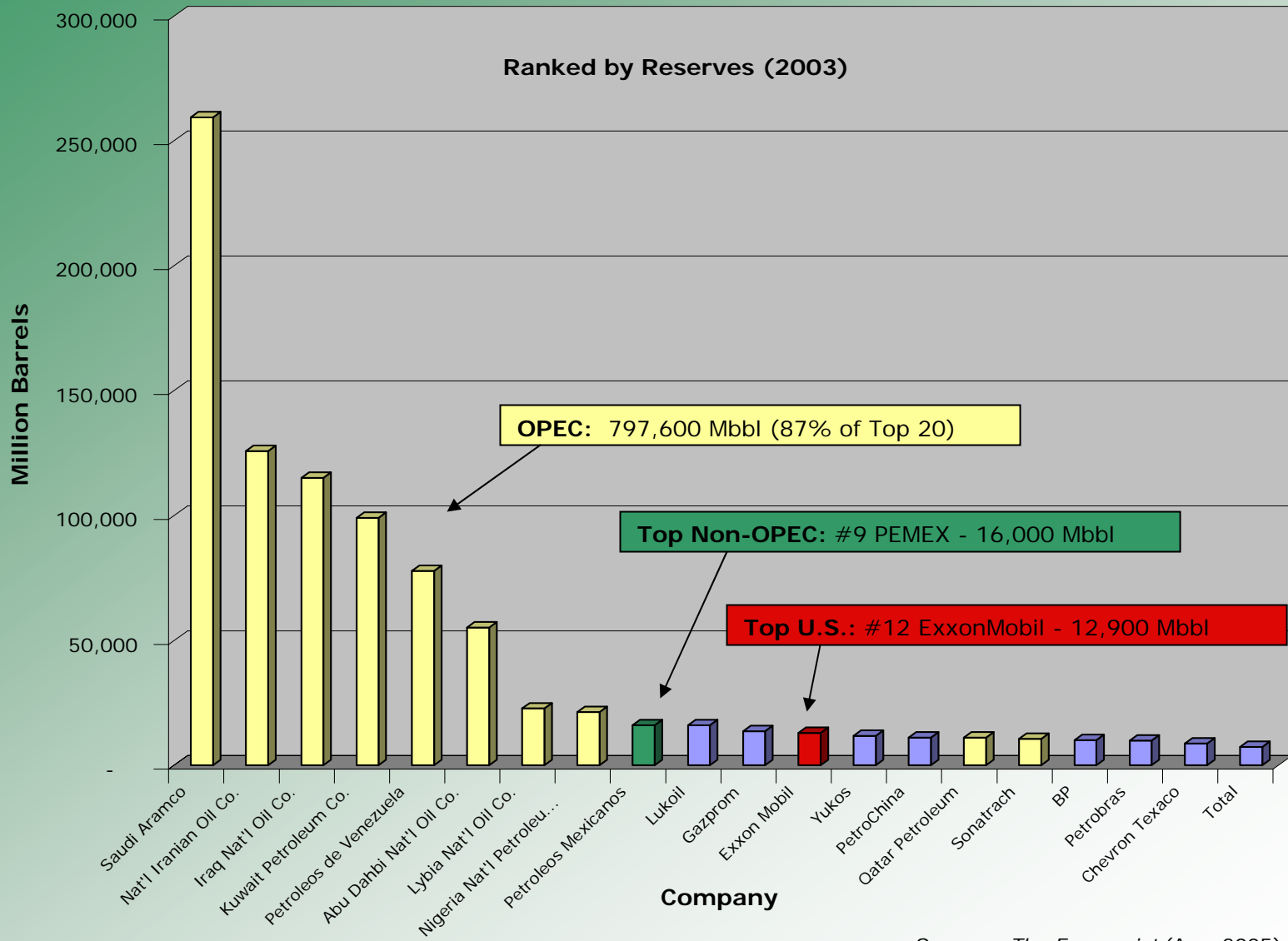
Source: U.S. Energy Information Administration

# International Energy Consumption (2002)



Source: U.S. Energy Information Administration

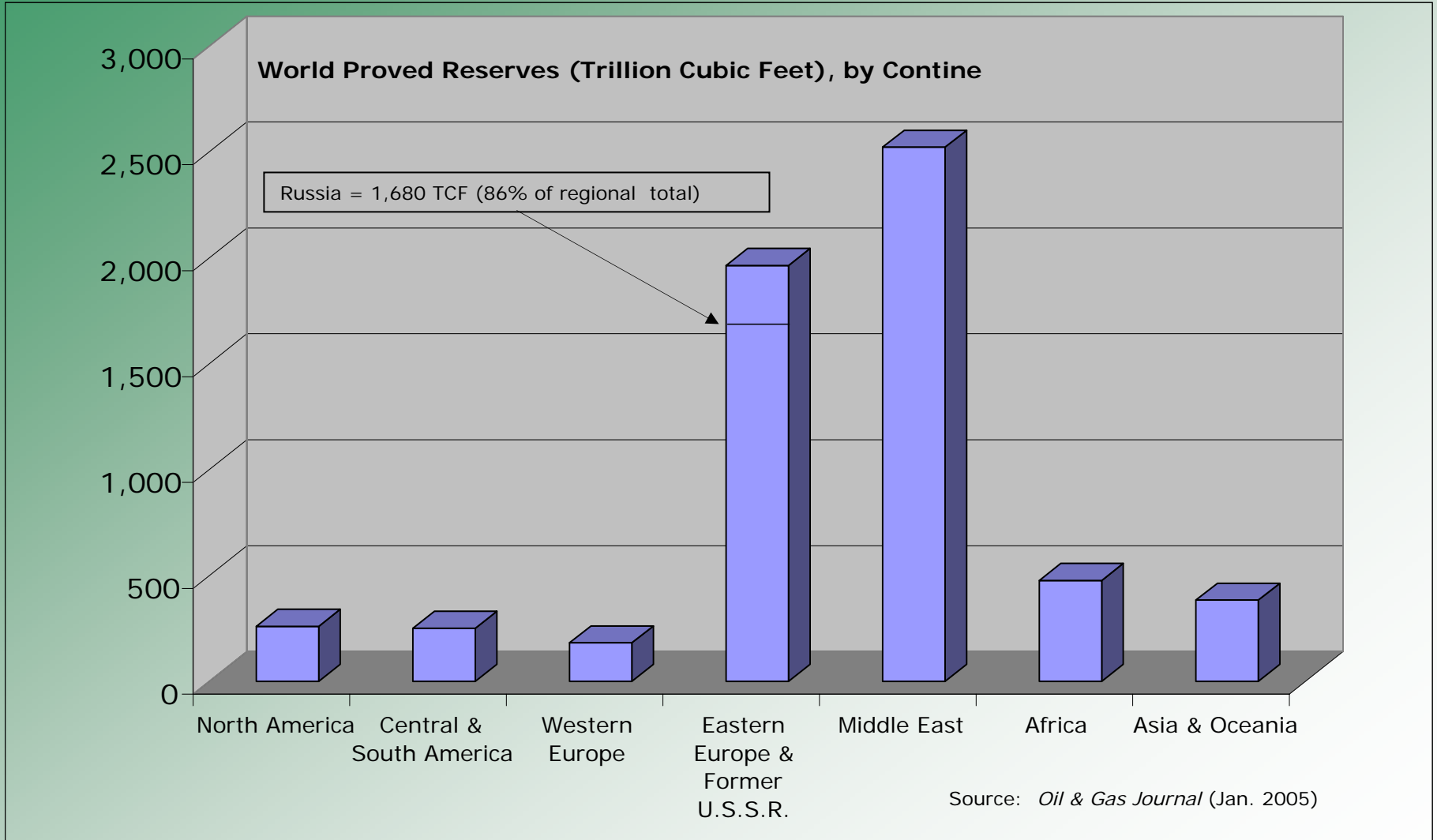
# Top Twenty Oil Companies Worldwide



Source: *The Economist* (Apr. 2005)



# World Natural Gas Reserves



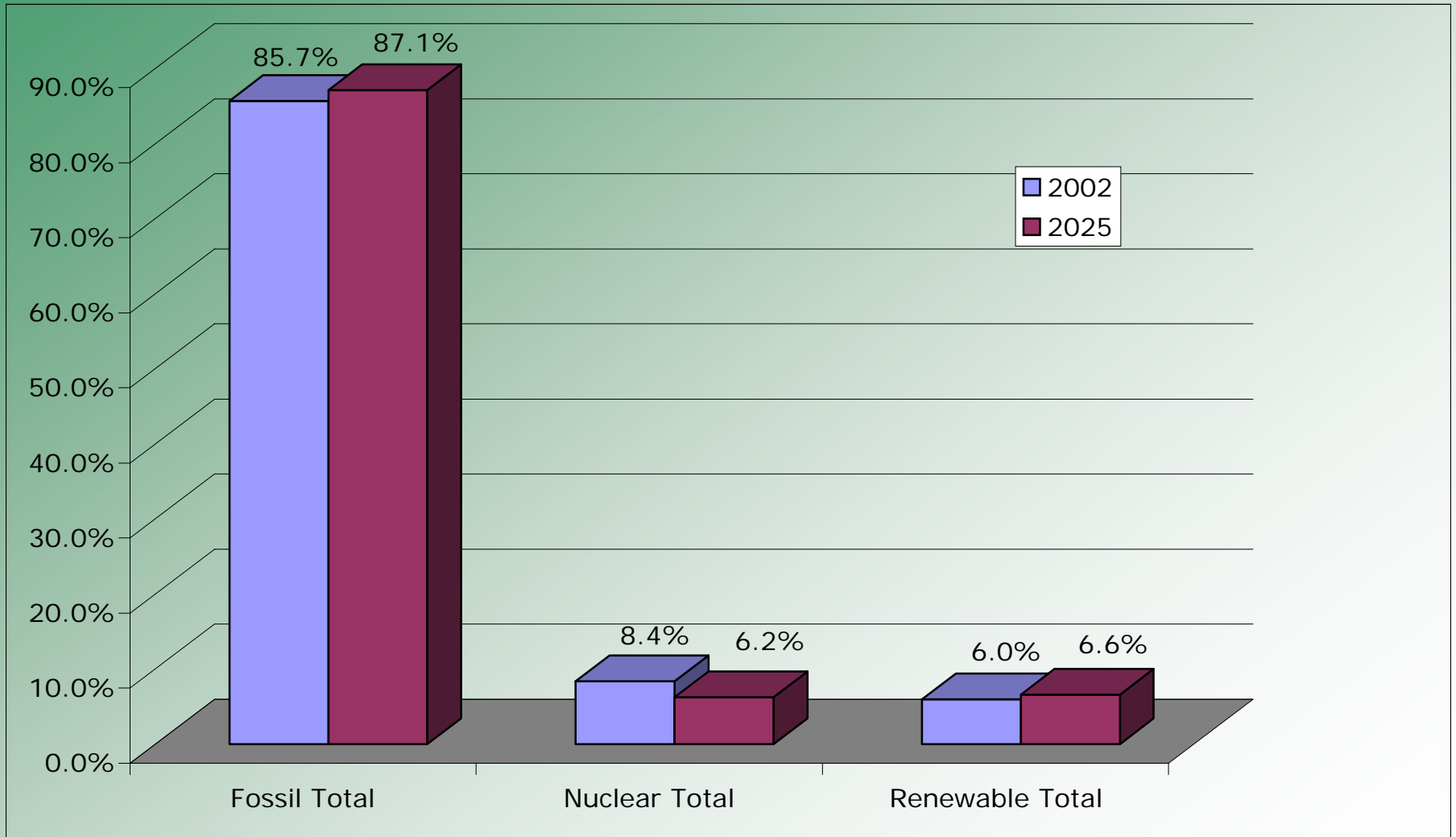
Energy Axiom #1:

Forecast Is Not Destiny

*. . . And It's a Damn Good Thing, Too!*

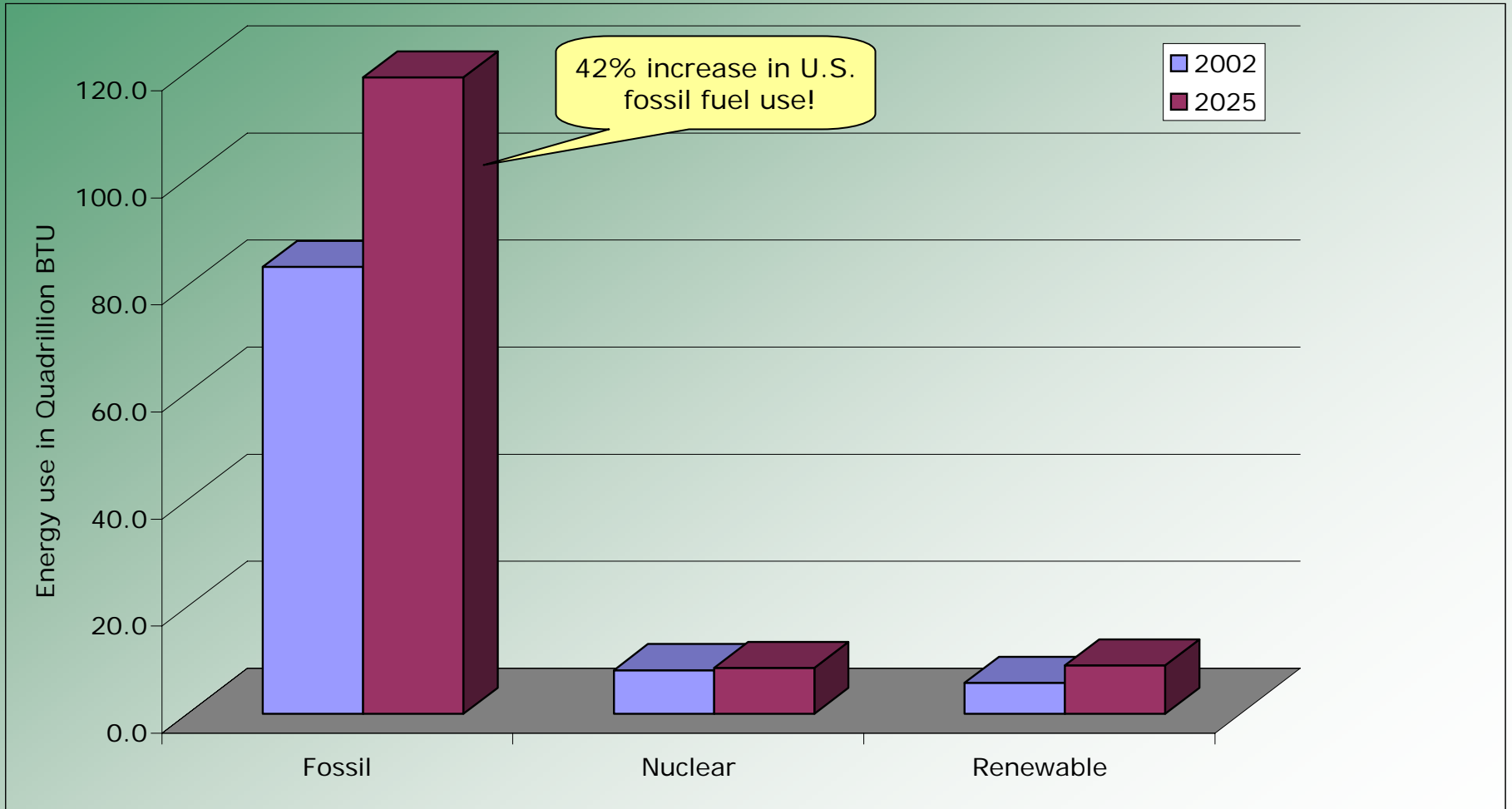
# U.S. Energy Consumption

## 2002 (Actual) vs. 2025 (EIA Projection)



# U.S. Energy Consumption

## 2002 (Actual) vs. 2025 (EIA Projection)



Energy Axiom #2:

Be Worried.

Be Very, Very Worried.

*“What, Me Worry?”*

*-- Alfred E. Neuman, Mad Magazine*

# Three Reasons The *Status Quo* Won't Do

- Economic Risks
- Security Risks
- Environmental Risks

# The Economic Risks

- Fossil Fuel Supply Disruptions
- Fossil Fuel Price Volatility
- Associated Economic Fallout

# The Security Risks

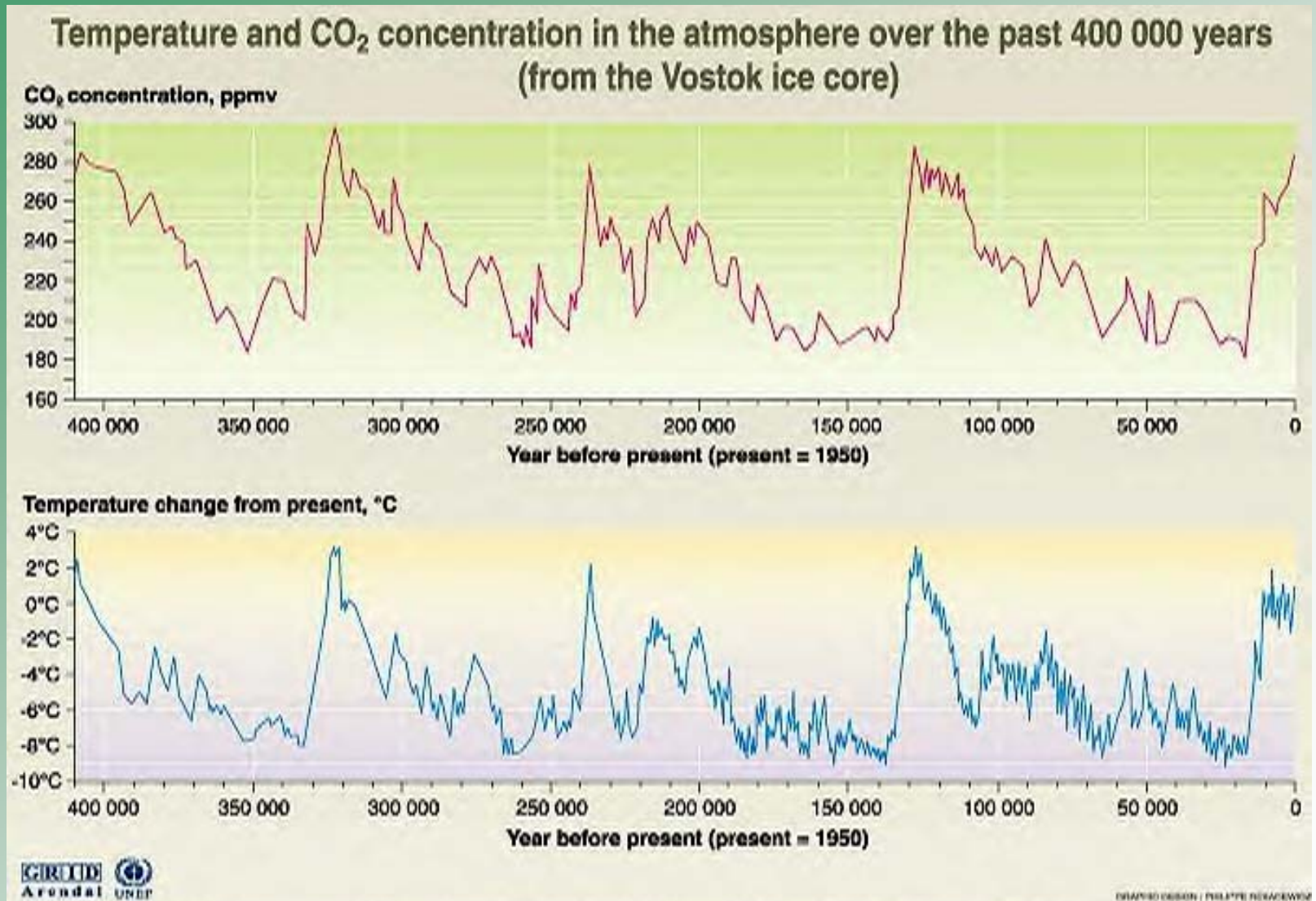
- Oil Supplies Are Concentrated in Unstable Areas
- Reserve Oil Production Capacity is Too Low
- Increased Natural Gas Use Means Increased LNG



# The Environmental Risks

- Climate Change!
- Climate Change!!
- Climate Change!!!

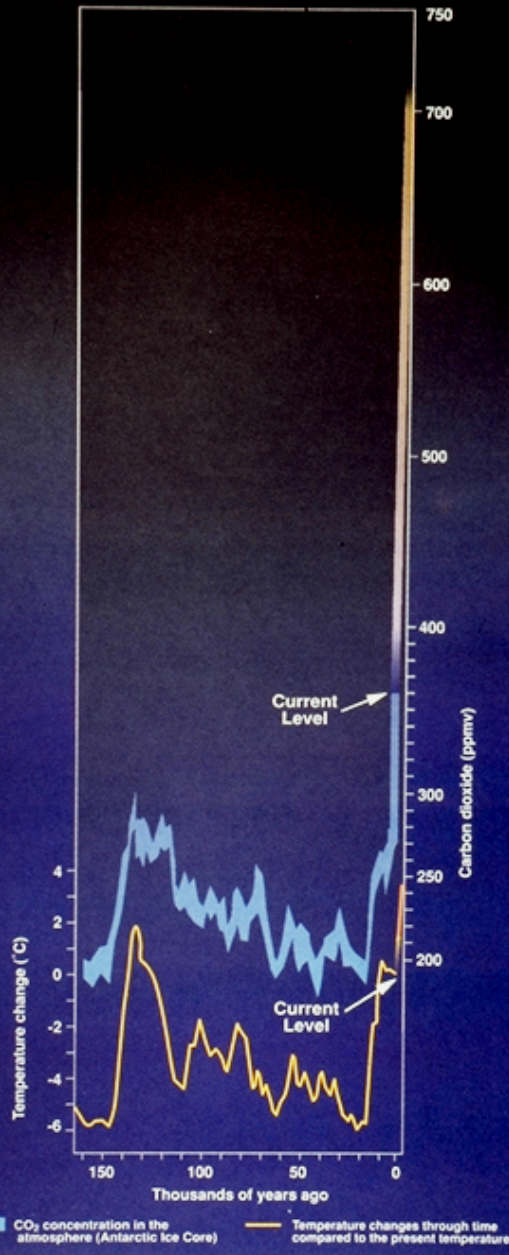
# You Don't Have to Be a Statistician . . .



Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, *Nature* 399 (3June), pp 429-436, 1996.

Source: U.S. Global Climate Research Program

## Atmospheric Carbon Dioxide Concentration and Temperature Change



- Concentration of CO<sub>2</sub> is at levels unseen for at least 150,000 years, and probably 400,000 years
- Further increases are virtually certain
- National Academy of Sciences: “In essence, we are conducting an uncontrolled experiment with the planet.”\*

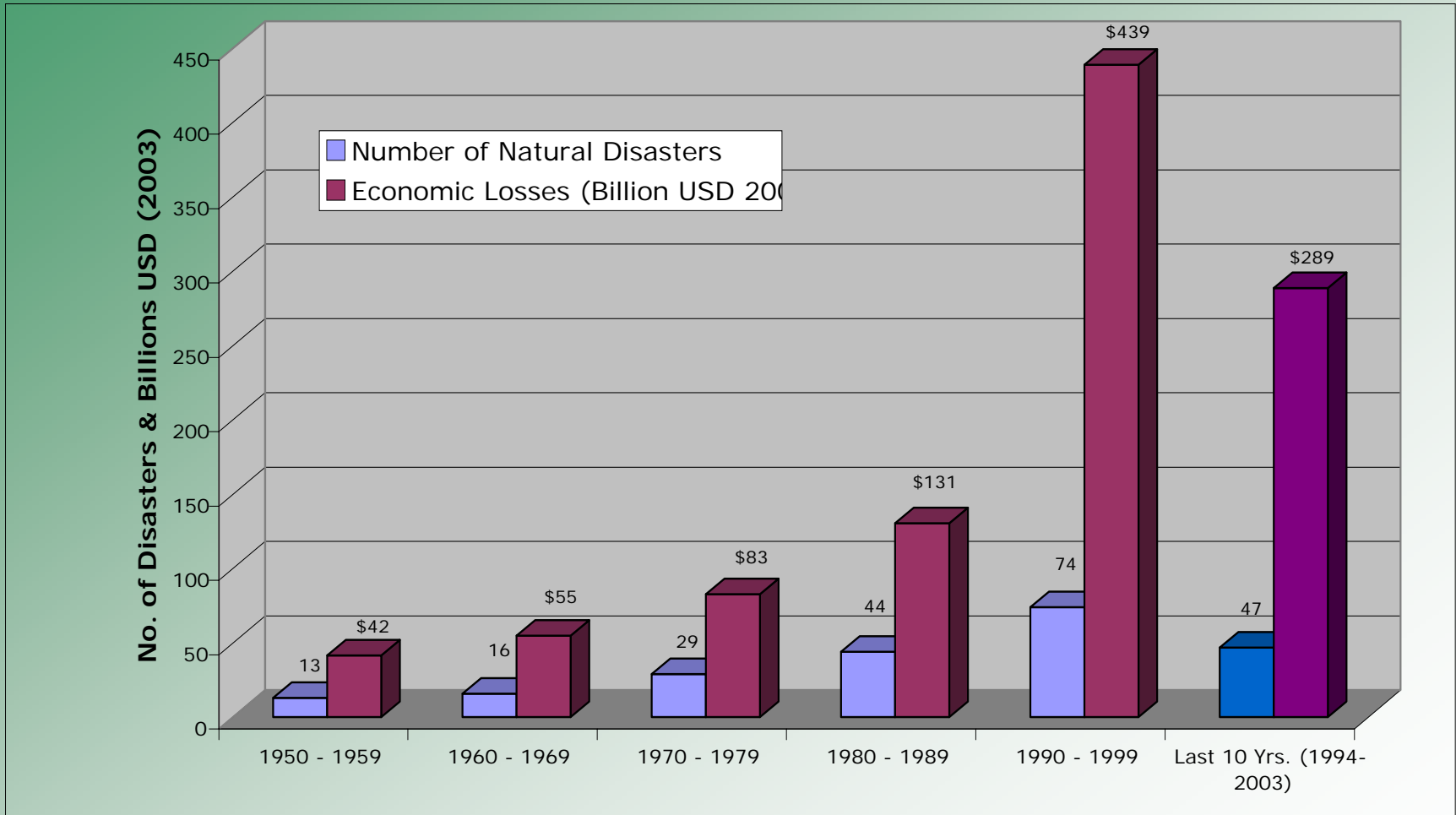
\* Silver & DeFries, *One Earth, One Future: Our Changing Global Climate* (National Academy Press, 1990)

“The increased intensity of all convective processes in the atmosphere will force up the frequency and severity of tropical cyclones, tornadoes, hailstorms, floods and storm surges in many parts of the world, with serious consequences for all types of property insurance.”

-- Gerhard Berz  
Director, Geo Risks Research  
Munich Reinsurance

*(Munich Re is the world's largest insurer of insurance companies)*

# The Economic Costs of Natural Disasters



Source: P. Hopee & G. Berz, "The Risks of Climate Change" (Munich Reinsurance, 2005)

Energy Axiom #3:

It's The Policy, Stupid!

*Or, Why We're Not Going to Engineer Our Way Out of This*

# U.S. Energy Independence?

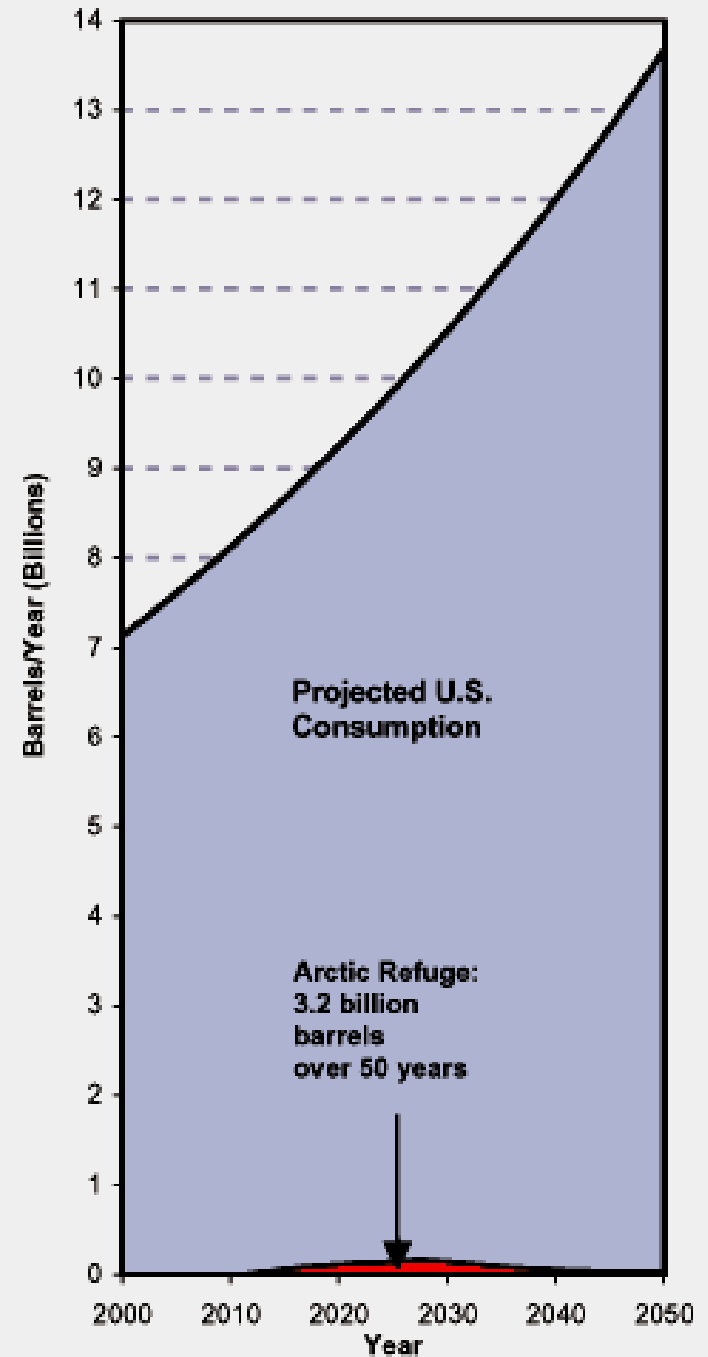
“Join me to make our air significantly cleaner, and our country much less dependent on foreign sources of energy.”

-- President George W. Bush  
State of the Union Address  
January 28, 2003

*But according to the U.S. Energy Information Administration:*

\* Increase in U.S. oil imports by 2025 under “business as usual”: **84.9%**

\* Increase in U.S. oil imports by 2025 under the Energy Policy Act: **82.9%**



# The Animal Farm Energy Policy

*“All Energy Technologies Are Equal,  
But Some Are More Equal Than Others”*



# Promoting Solar: Pick a Policy, Any Policy

- *Renewable Portfolio Standards (RPS)*: Most successful in stimulating renewable energy investment in the U.S.; do little for solar technologies without a set-aside.
- *Direct Financial Incentives*: Rebates (\$/Watt) and performance-based incentives (\$/kWh) -- the debate continues.
- *Tax Incentives*: Tax credits and accelerated depreciation benefits (federal and state) -- key to stimulating commercial-scale investment.
- *Interconnection Policies*: The 'sleeper' issue, key for distributed applications.
- *Utility Rates and Tariffs (including Net Metering)*: Boring -- and crucially important.

“The stone age didn’t end  
because we ran out of stones.”

-- Former Saudi OPEC Minister Sheikh Zaki Yamani

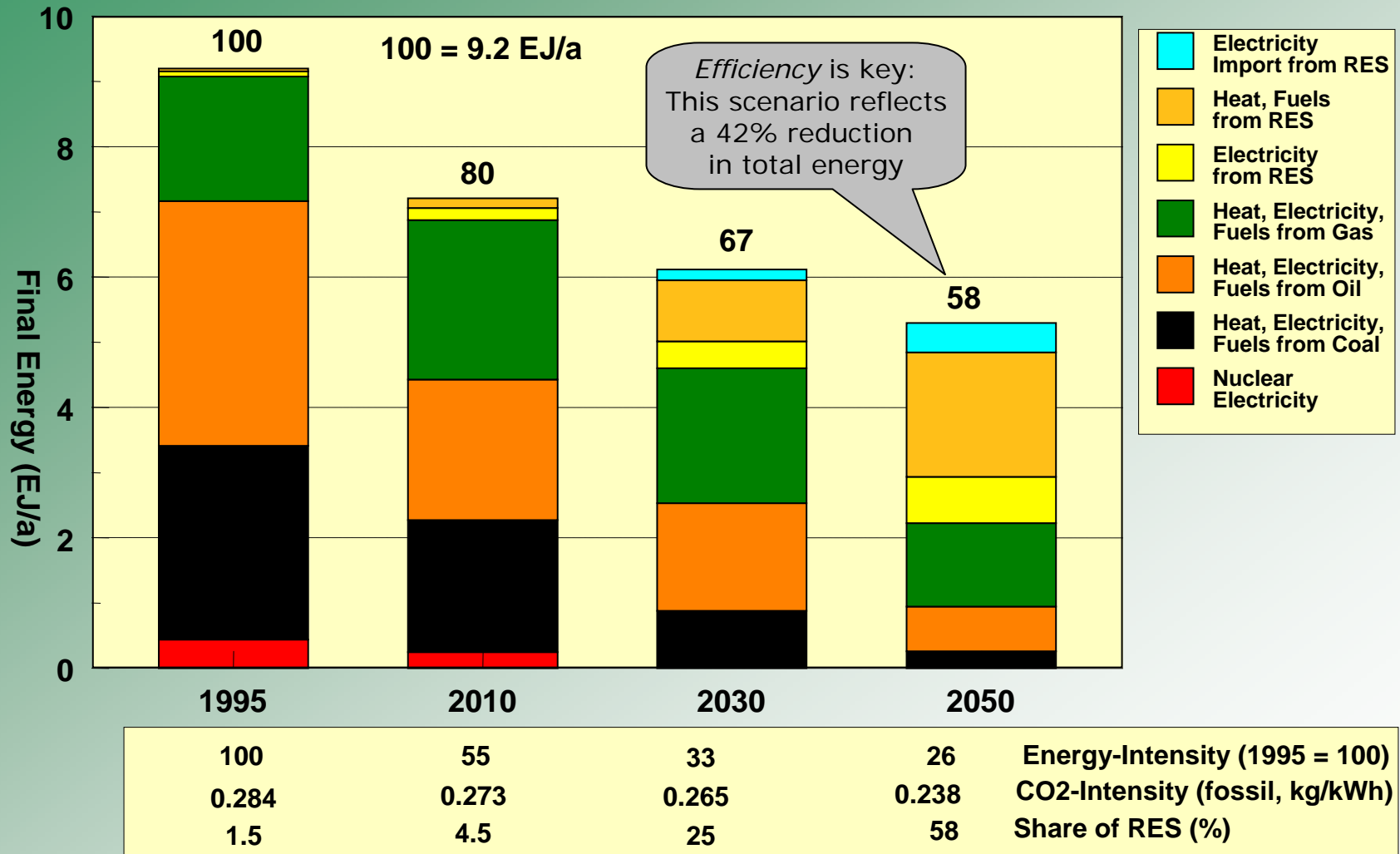
. . . and the oil age won’t end because we run out of oil.



from The Economist, “The End of the Oil Age,” October 23, 2003

# Long Term Scenario for a "Solar Energy Economy" in Germany

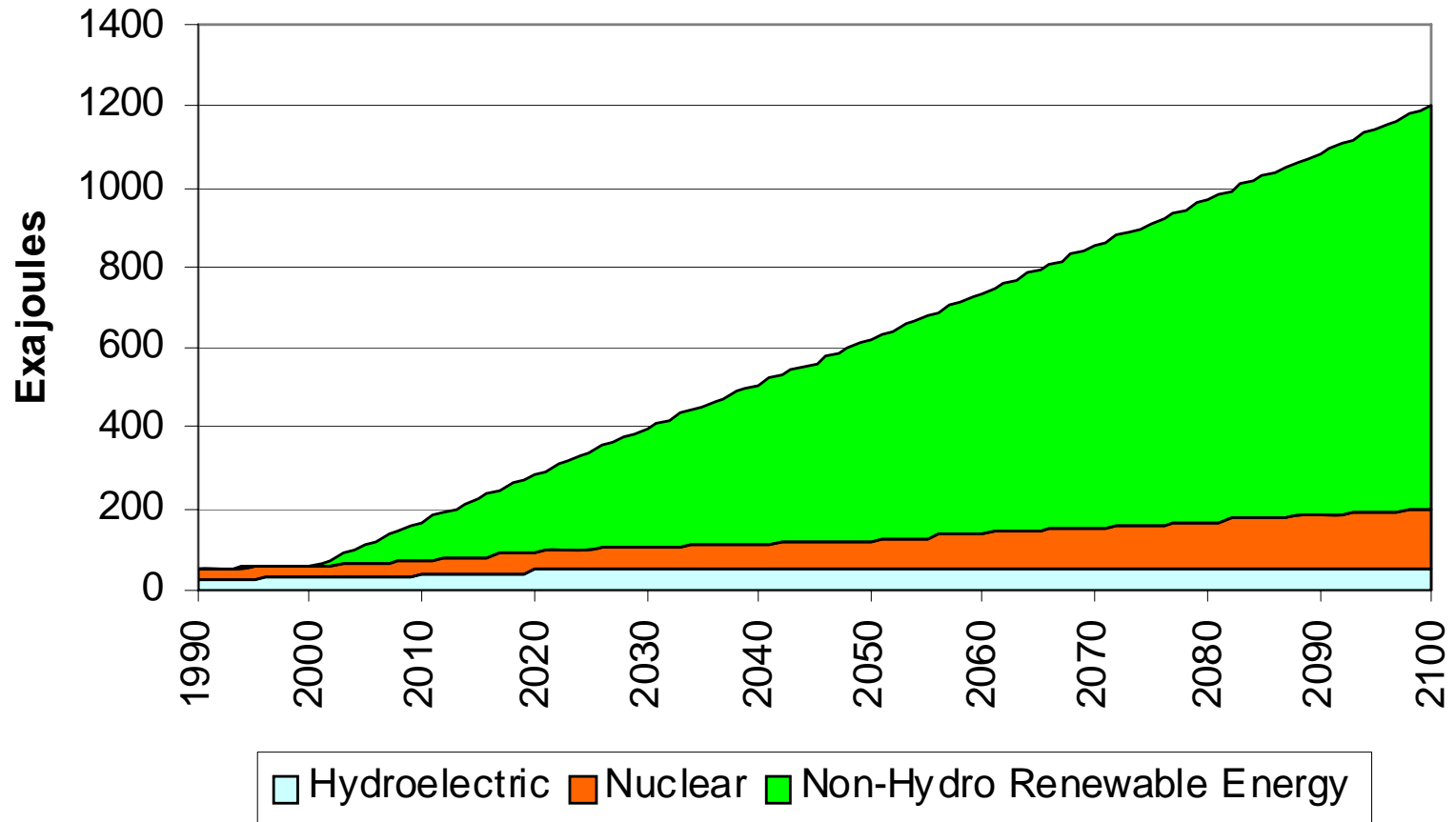
- Final Energy by Sources -



from the German Federal Environment Ministry

Courtesy Donald Aitken Associates

# Filling the 550 ppm Carbon-Neutral Gap: Hydro - resource constrained Nuclear - modest growth Renewables - balance of the gap



# Compound Annual Growth Rates Needed to Stabilize at 550 ppm CO<sub>2</sub> (the “10/20/50” Scenario)

|            | 2000-2010 | 2010-2020 | 2020-2030 |
|------------|-----------|-----------|-----------|
| Solar      | 30%       | 20%       | 14%       |
| Wind       | 30%       | 20%       | 14%       |
| Biomass    | 25%       | 18%       | 4%        |
| Geothermal | 10%       | 10%       | 5%        |
| Hydro      | 2%        | 2%        | 0%        |

Source: from Aitken, SOLAR TODAY (Jan/Feb 2005); Bull & Billman, NREL (2004)

# Energy Axiom #4:

## There Is No Silver Bullet

*Or, Why It Takes a Mix of Policies and Technologies  
to Get Where We Need to Go*

# BioEnergy

- 11 Percent (~40 Quads) of Primary Energy in 2000
- Current Use Is About 18 Percent of Potential Capacity

*Could Provide ~200 Quads in 2050 -- perhaps 15% of global demand? A significant contribution, but . . .*

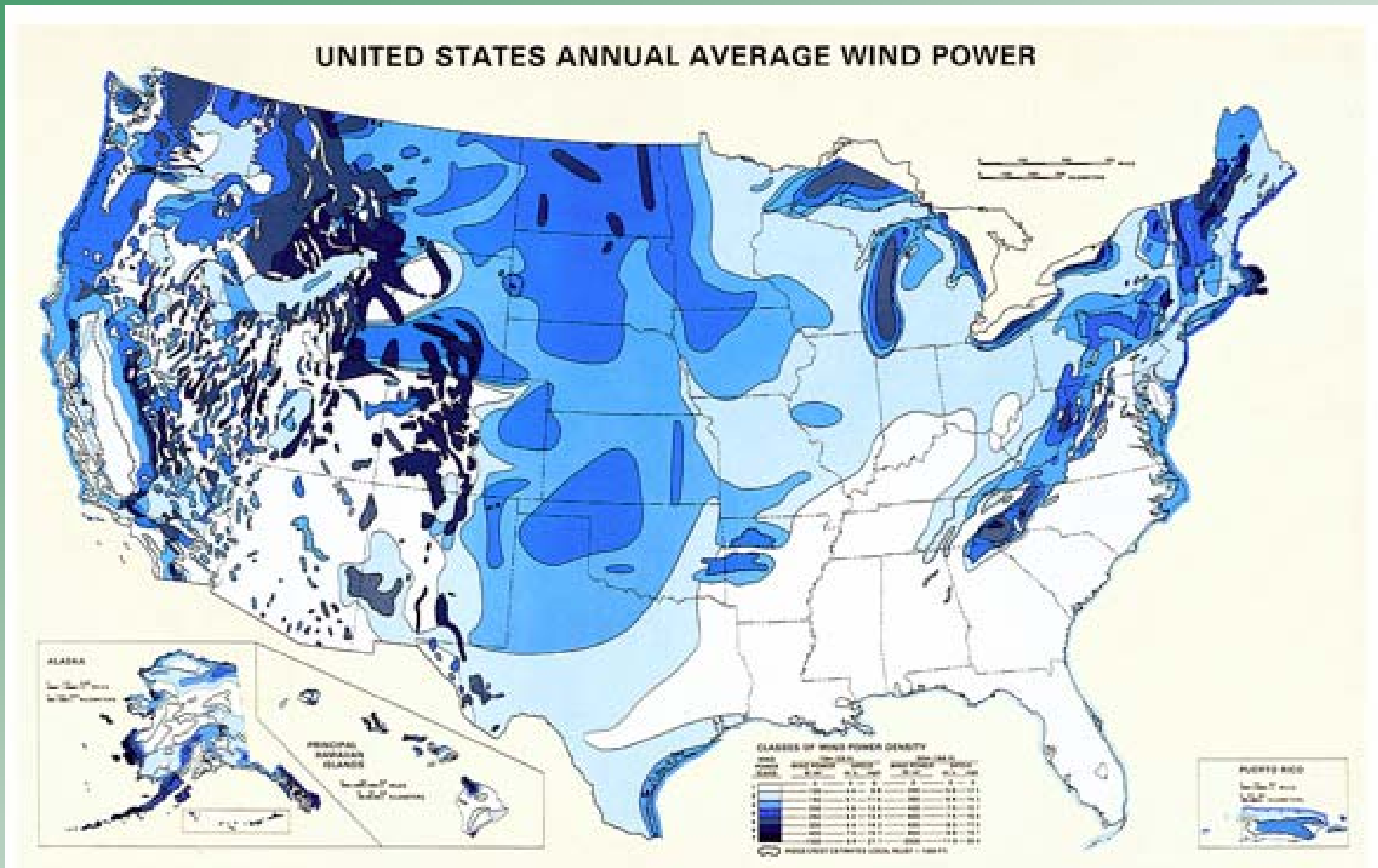
# Geothermal

- 27 Countries Use Geothermal; Another 25 Have Significant Geothermal Potential
- Could Provide 10% or More of Energy for 56 Countries

*But geothermal is severely capacity-constrained, with little potential in much of the world -- a few percent of global demand in 2050?*



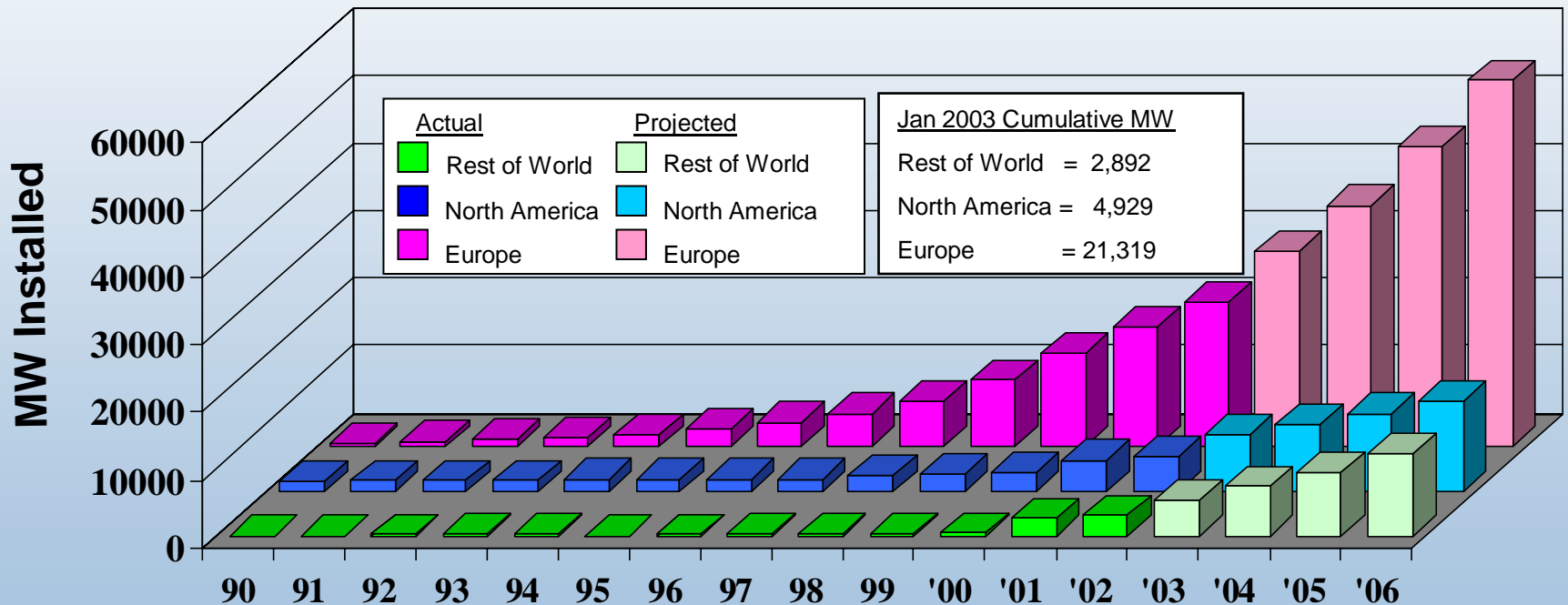
# The U.S. Wind Power Resource



Map 2-1 United States annual average wind power.

Source: NREL (2005)

# Growth of Wind Energy Capacity Worldwide



Sources: BTM Consult Aps, March 2002  
 Windpower Monthly, January 2003

06/04/04 -- 2

# Wind

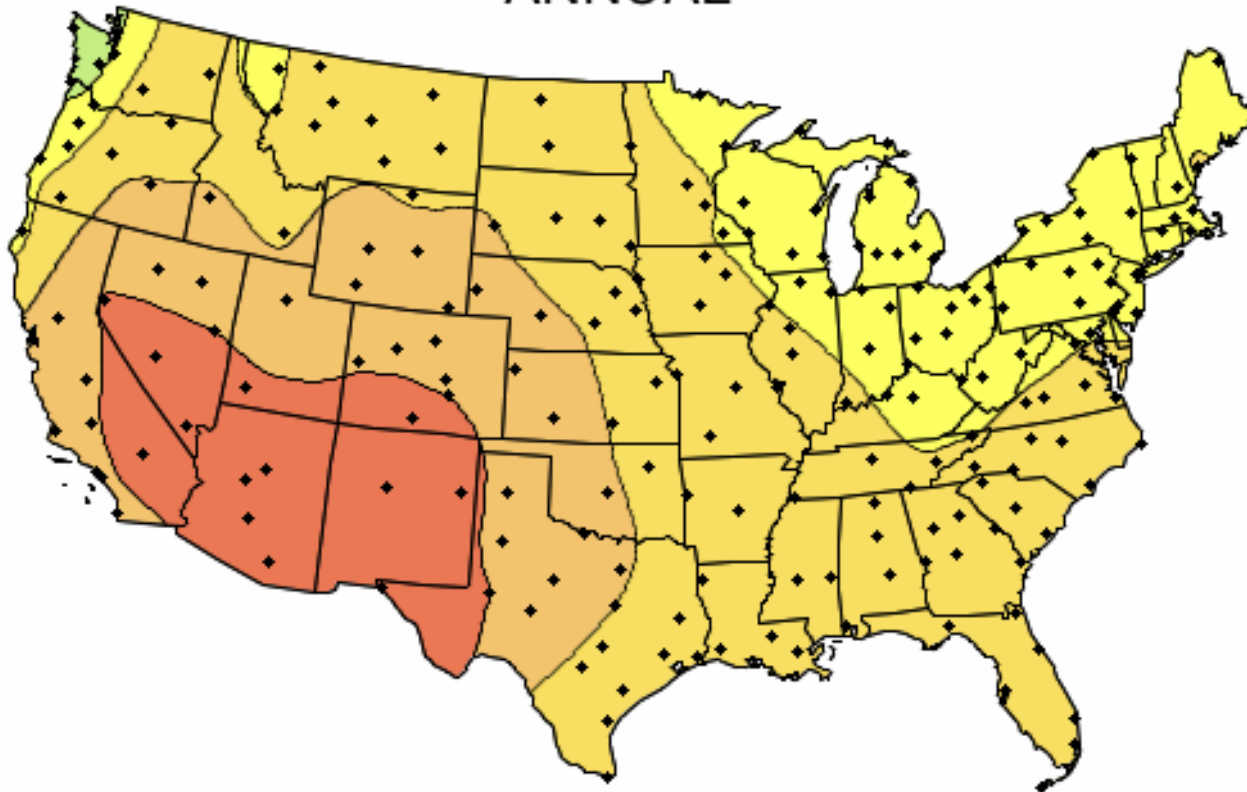
- Year-End 2003: ~40,000 MW Globally
- Annual Growth, Last Five Years: 26.3%
- U.S. Likely to Have Record Year in 2005
- Germany Produces Over 7% of Electricity from Wind
- Denmark Produces Over 20% of Electricity from Wind
- Europe is *On Target* for 10/20/50 Scenario for Wind

*But even wind is capacity-constrained in much of the world!  
Could provide perhaps 20% of global energy in 2050.*

# The U.S. Solar Energy Resource

Average Daily Solar Radiation Per Month

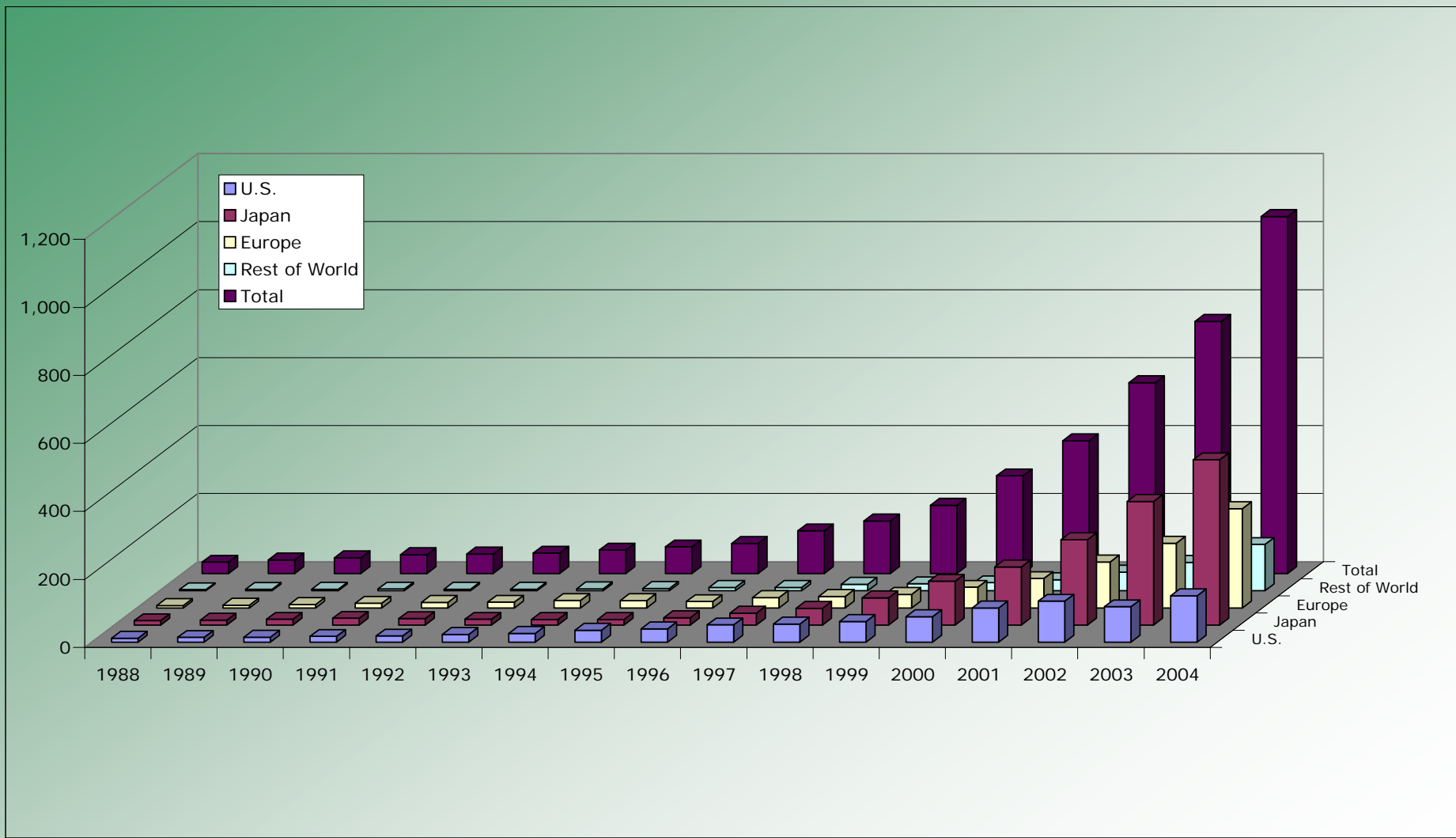
ANNUAL



Two-Axis Tracking Flat Plate

Source: NREL (2005)

# Annual Photovoltaic Production (MWp), 1988 - 2004



Source: P. Maycock, *PV News* (Various)

# Solar

- Annual Growth of PV , Last Five Years: 38.5%
- PV Crosses the 1,000 MW (1 Gigawatt) annual production threshold in 2004
- CSP: Recent announcements include --
  - Sempra: 300 - 900 MW from Stirling Energy Systems
  - SCE: 500 - 850 MW from Stirling Energy Systems
  - Nevada Power/Sierra Pacific Power: 64 MW from Solargenix
- Solar Hot Water: Huge untapped potential.

*Solar energy is the only one of the renewable resources that realistically has the potential to supply a majority of the world's future energy needs, on an ongoing basis!*

# Solar Is . . .

- The most ubiquitous and evenly-distributed renewable energy source
- The most environmentally-benign energy resource
- Extremely modular, well-suited for applications from milliwatts to megawatts
- Equally attractive for industrialized (grid-tied) and developing (grid-independent and village-power) applications

*The nearest thing we have to that “silver bullet”!*

# Energy Axiom #5:

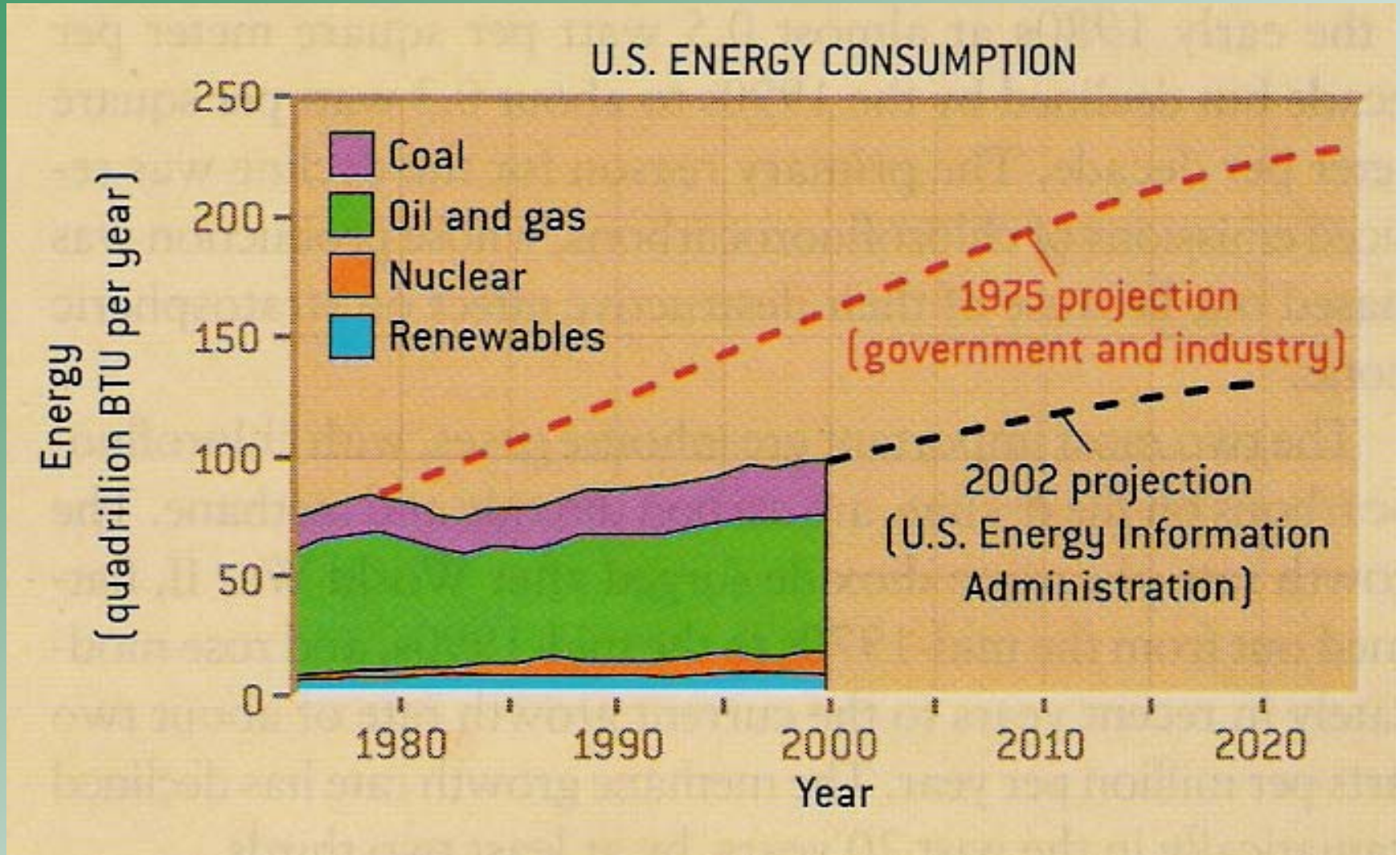
Where There's A Will,  
There's A Way

*"I think I can, I think I can . . ."*

-- Watty Piper, The Little Engine That Could



# We've Made Other Radical Transitions . . .



# Can We Get There From Here?

- It looks like it. Just barely. If we start now.
- Germany provides an illustrative and inspiring example.
- The growth rates look potentially achievable.
- On the other hand, annualizing and levelizing the capacity additions required suggests:
  - for 750 ppm: ~450 MW of Capacity Needed *Every Day* for Decades
  - for 550 ppm: ~920 MW of Capacity Needed *Every Day* for Decades

*This is an awesome challenge, that will test human civilization for the next few generations.*

*If we succeed, however, the result will be a world that is cleaner, healthier, richer, more stable and more secure.*

# Energy Axiom #6:

## Every Cloud Has A Silver Lining

*Or, Why This Is As Much an Opportunity As It Is a Threat*

# It's A Beautiful (Post-Petroleum) World

- According to the U.S. Public Interest Research Group, two modest policy initiatives\* would:
  - Create an average of more than 150,000 net jobs per year between 2005 and 2020;
  - Increase U.S. GDP an average of \$5.9 billion annually between 2005 and 2020;
  - Increase wages \$6.8 billion in 2020;
  - Save *all* consumers -- residential, commercial and industrial -- over \$27 billion on electricity and natural gas bills in 2020
  - Reduce carbon dioxide emissions in 2020 to 27 percent below 2002 levels

\* A 20% national RPS; and a shift in subsidies to renewables from fossil and nuclear technologies

*Thanks for Inviting Me To Join You!*



Courtesy *Solar Today Magazine*

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