


Our Energy Future: Opportunities, Risks, Trade-offs

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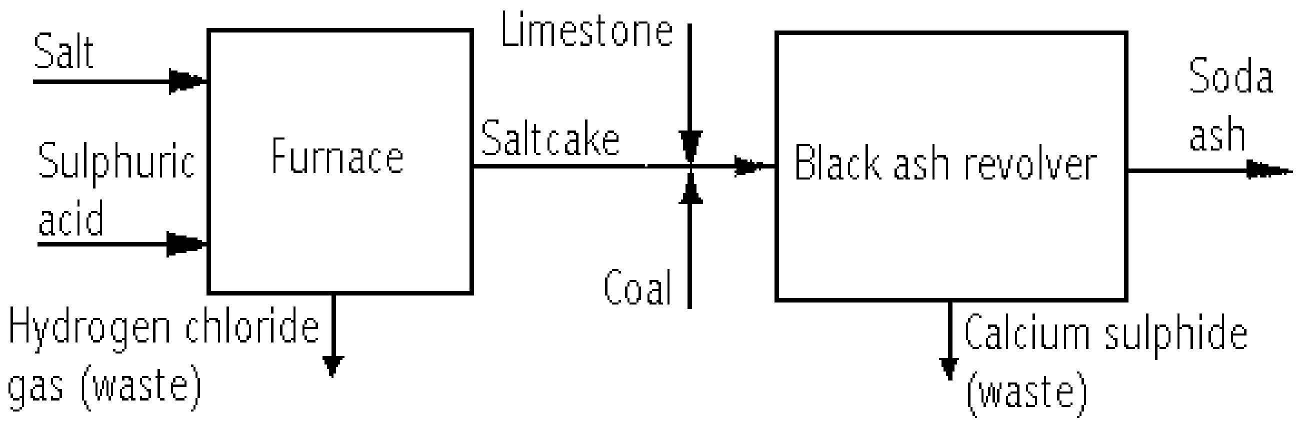
SAIC
From Science to Solutions

French Academy of Sciences
1783 Challenge

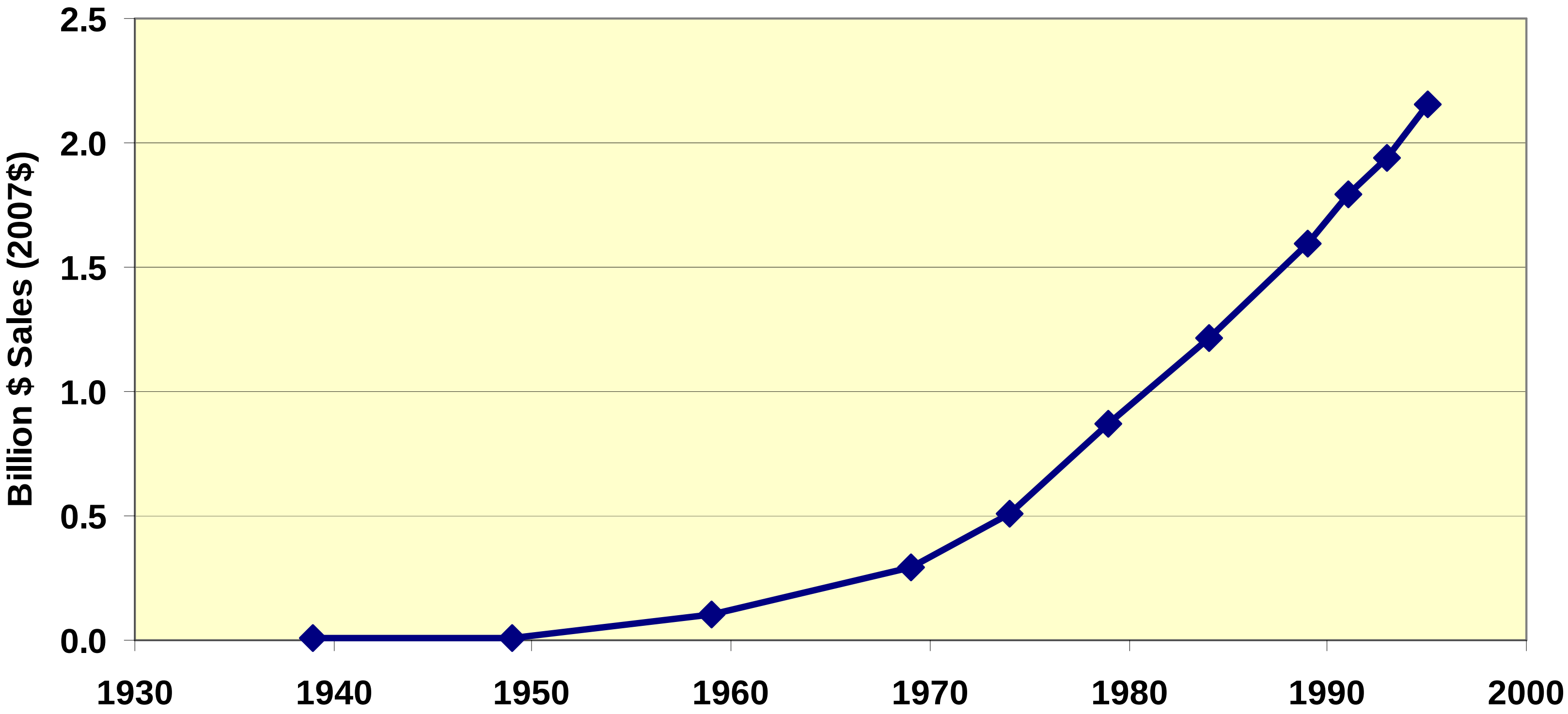
- **Alkali important to glass, textile and soap industries**
- **Potash from wood ashes had been source**
- **Deforestation - led to uneconomic source**
- **Alkali had to be imported - potash and soda ash**
- **Source: plant materials, wood ashes, trona**
- **France at odds with Great Britain and Europe**
- **Louis XVI ordered Academy to offer prize -**
  produce alkali from sea salt

Nicolas Leblanc – French Physician

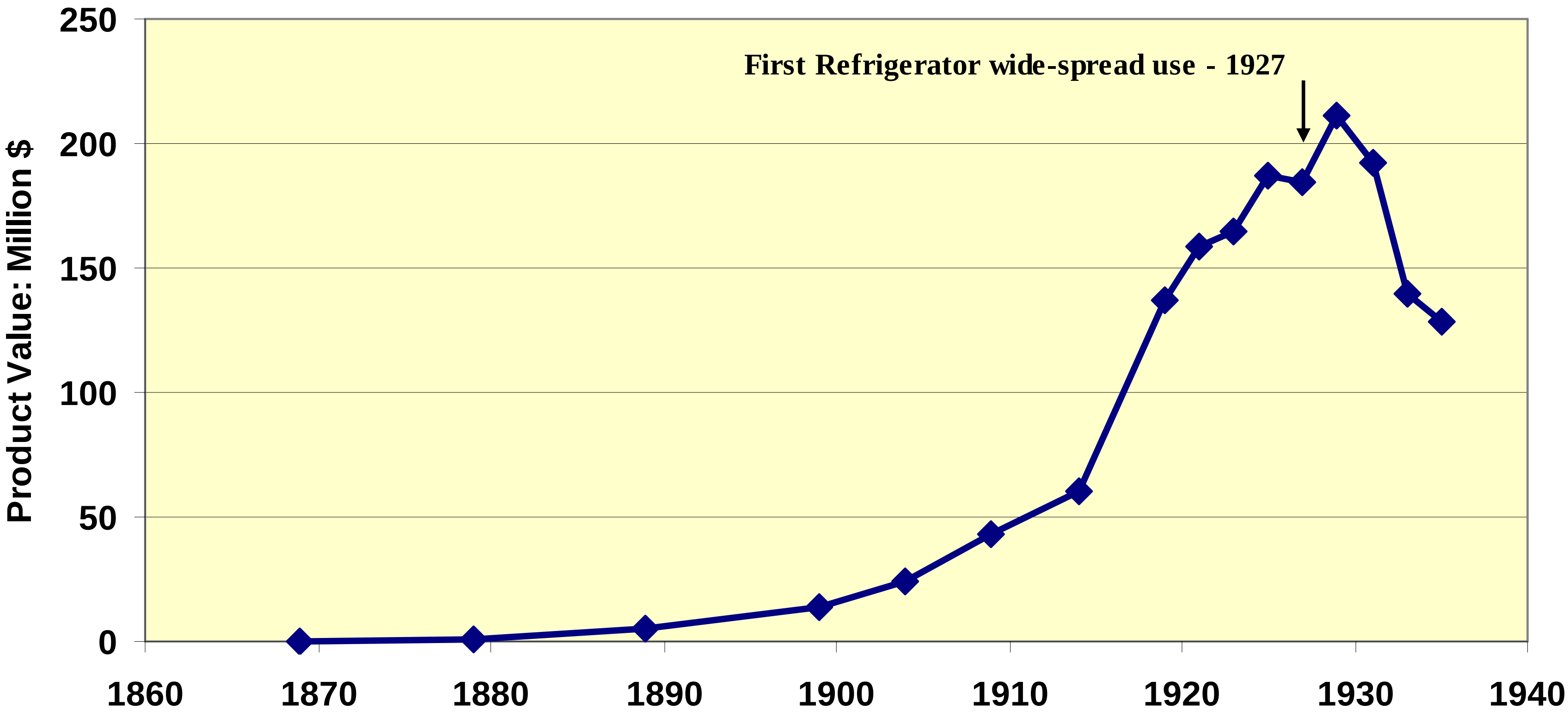
- **Leblanc devised only process that proved practical – 1791**
- **Basis for development of industrial chemical industry**



Growth Business Illustration



Ice Manufacture

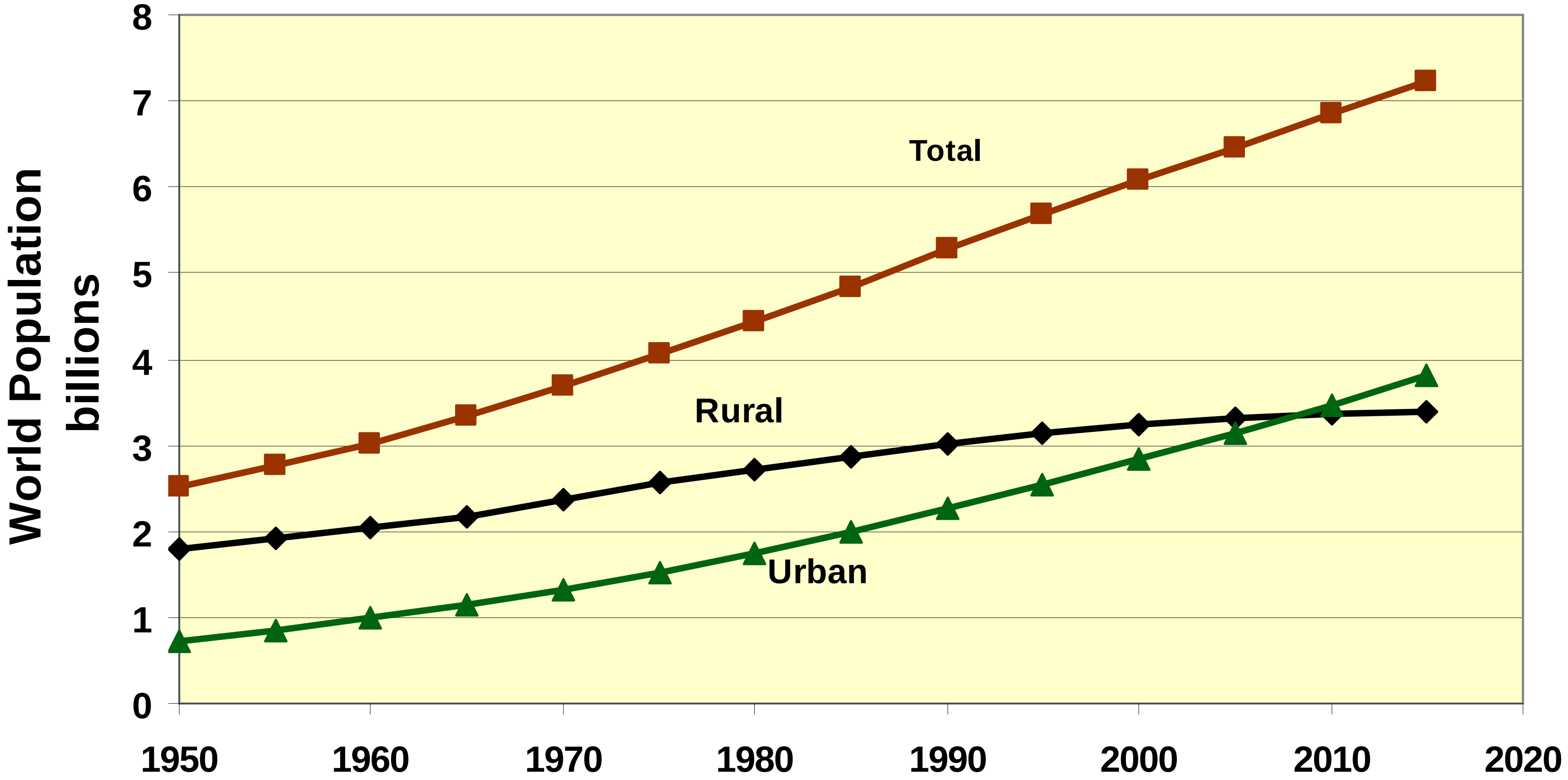


Situation Assessment

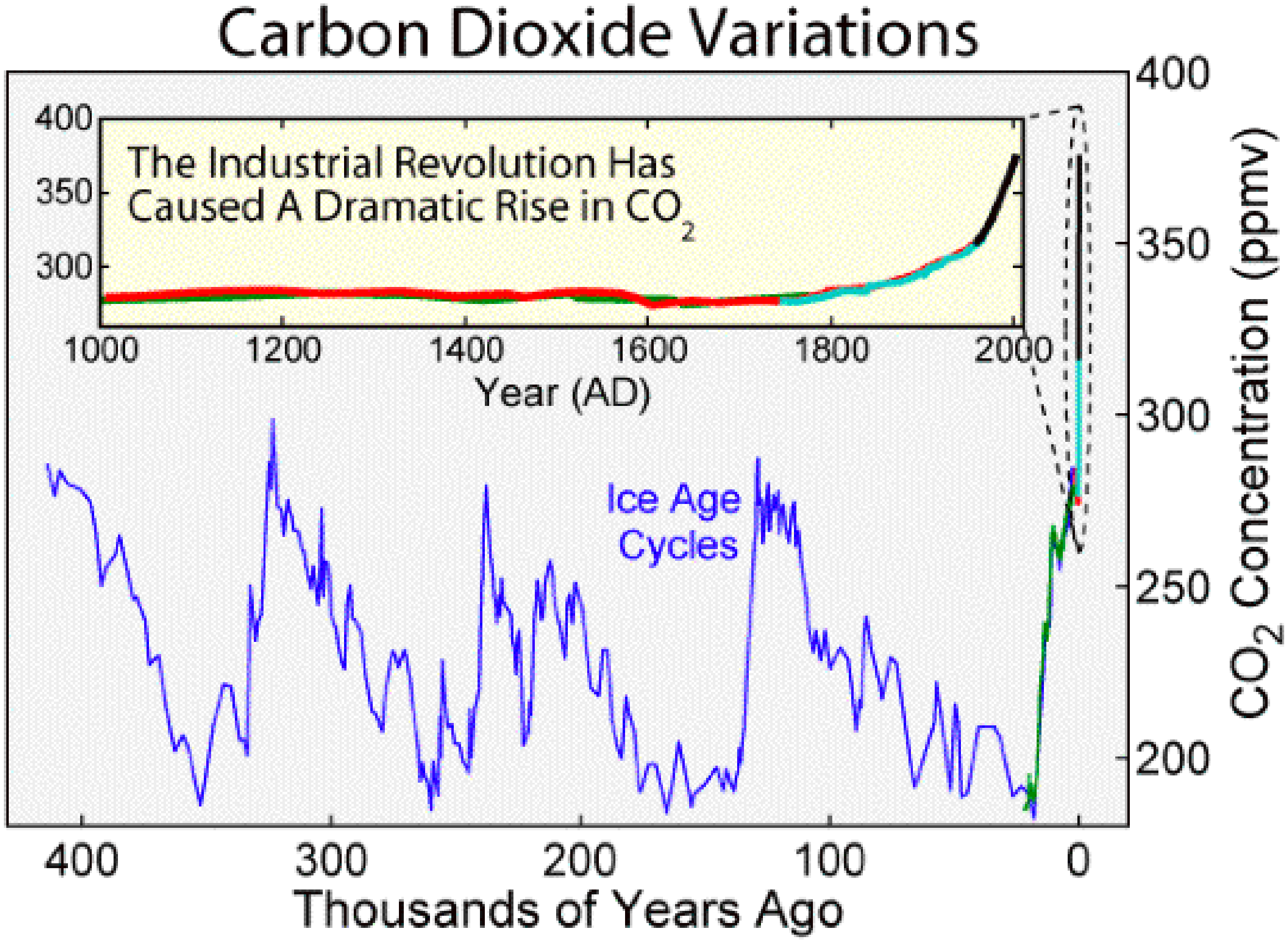
- 2.7 billion people live on less than $4/day and cannot access electricity, clean water or sanitation
- Growing demand for energy/
  the ways energy is used will change
- Rapid technology diffusion
- Extensive environmental threats/climate change
- Inequalities of income and power
  (both within and between countries)

Status quo is not sustainable –
politically, economically, environmentally

Significant Life-Style Changes



Atmospheric CO_2 Concentration



Climate Change
Temperature - Precipitation - Sea Level

~ 126,000 years ago

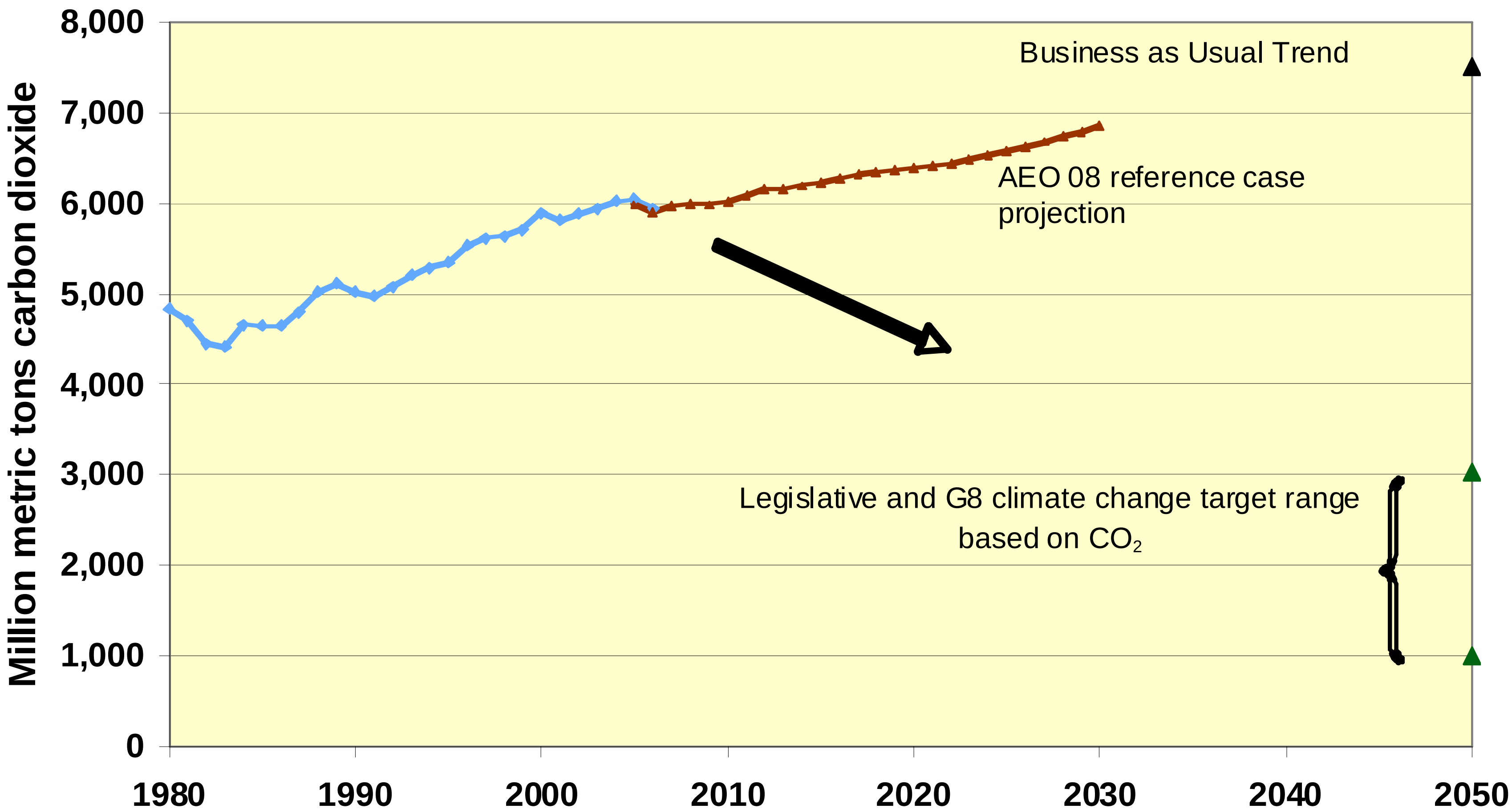
Today

Human intervention: influences the rate of change

Affects Health, Agriculture, Forest, Water Resources, Ecosystems

Graphics - Ron Blakey, Uni. Northern Arizona

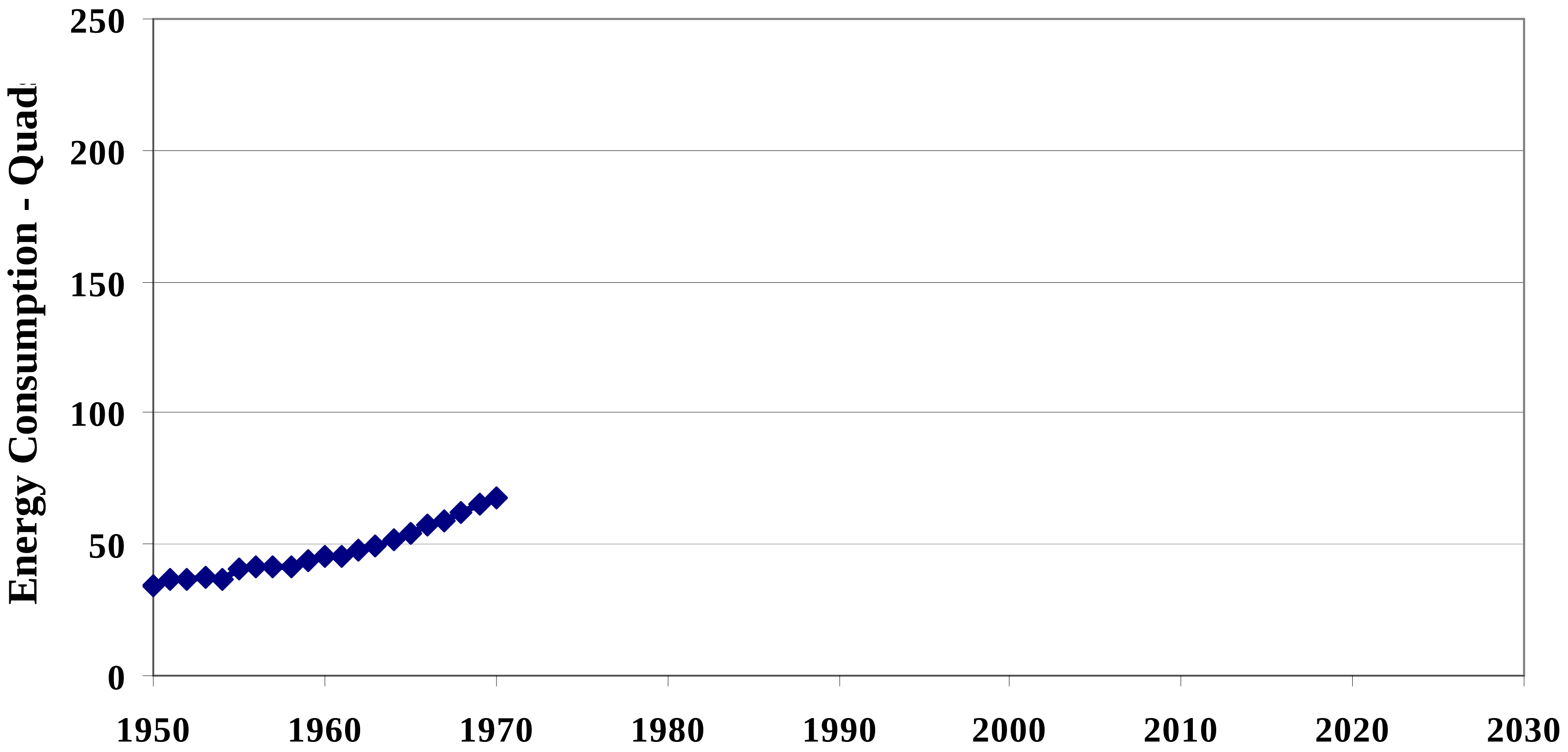
Targets for CO_2 Management



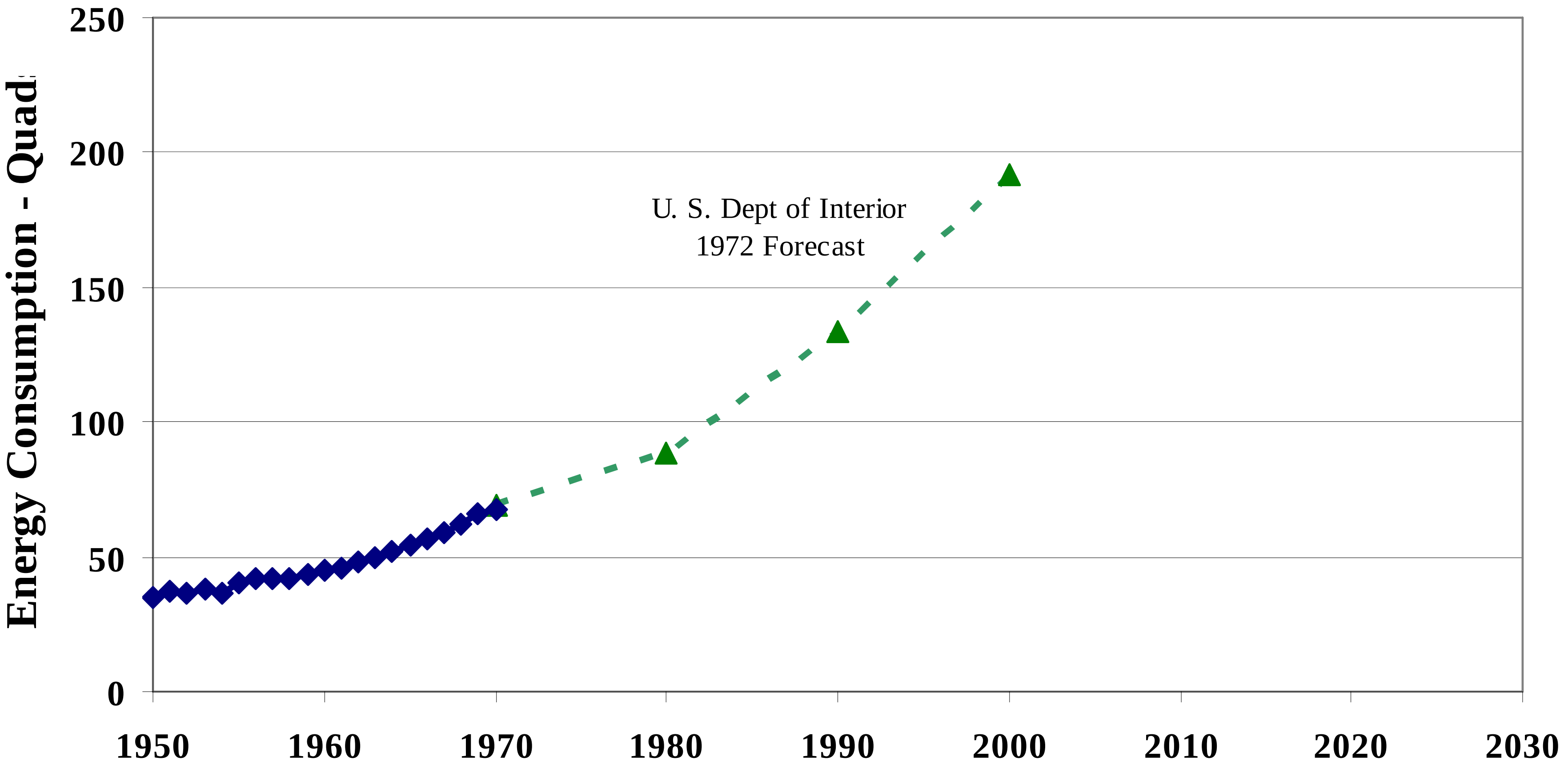
Energy Forecasting

- **Many approaches**
  - ✓ Models: economic development, technology change
  - ✓ Extension of trends
  - ✓ Scenarios
- **Limitations**
  - ✓ Failure to capture disruptive events
  - ✓ How we view data
  - ✓ Predictions tell us more about group psychology than reality

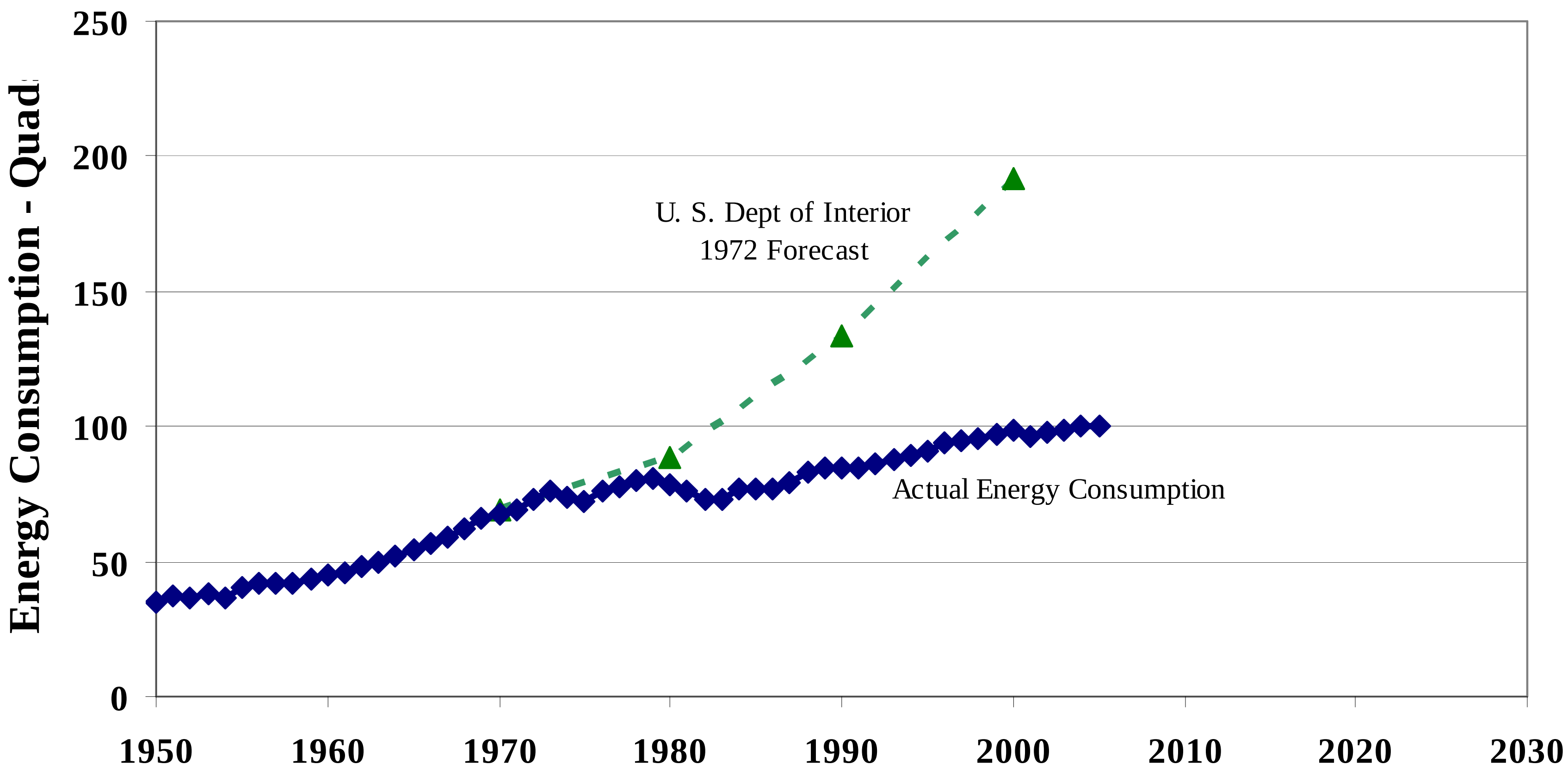
U. S. Energy Use: 1950 - 1970



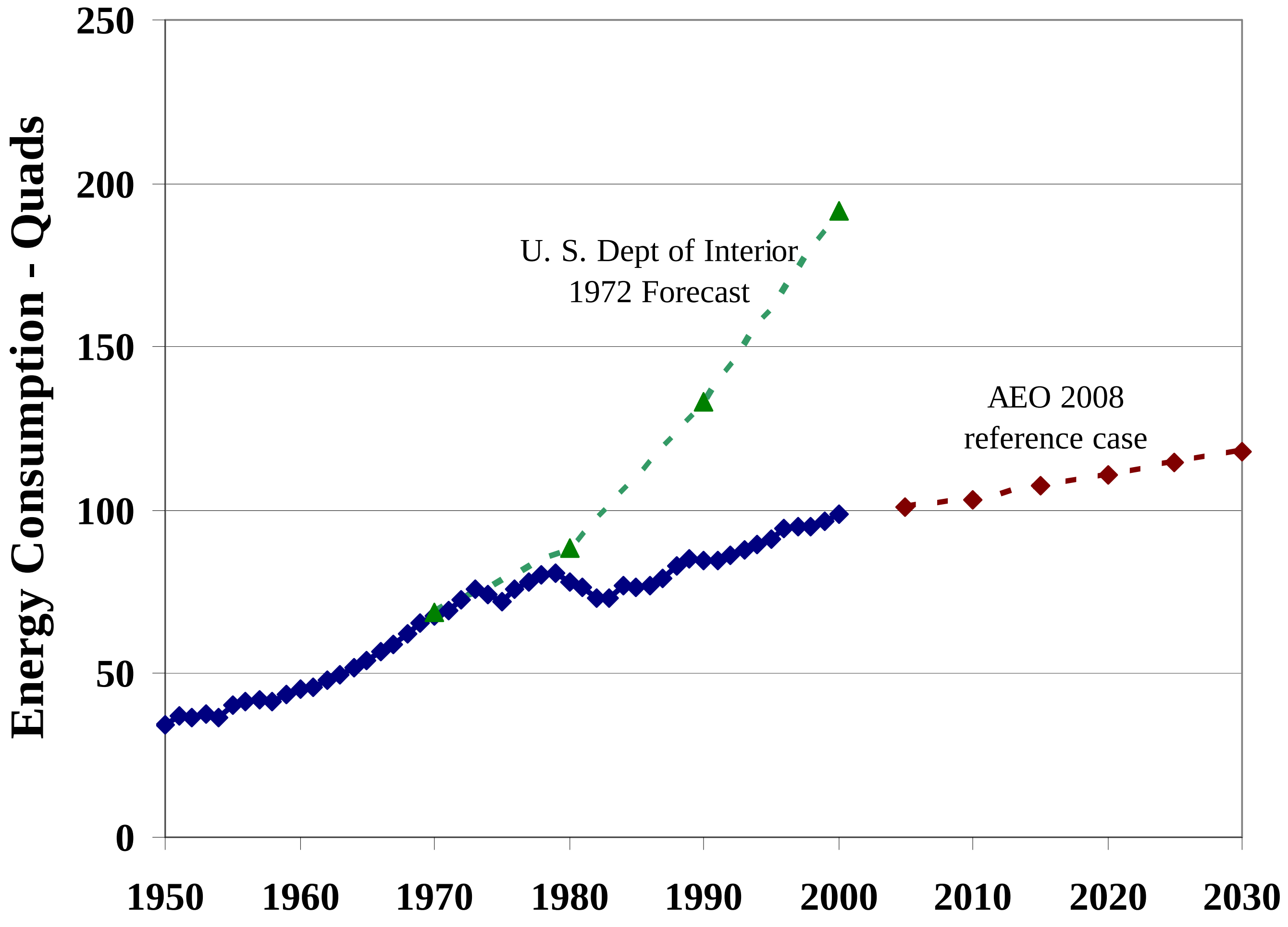
U. S. Energy Use Forecast in 1972



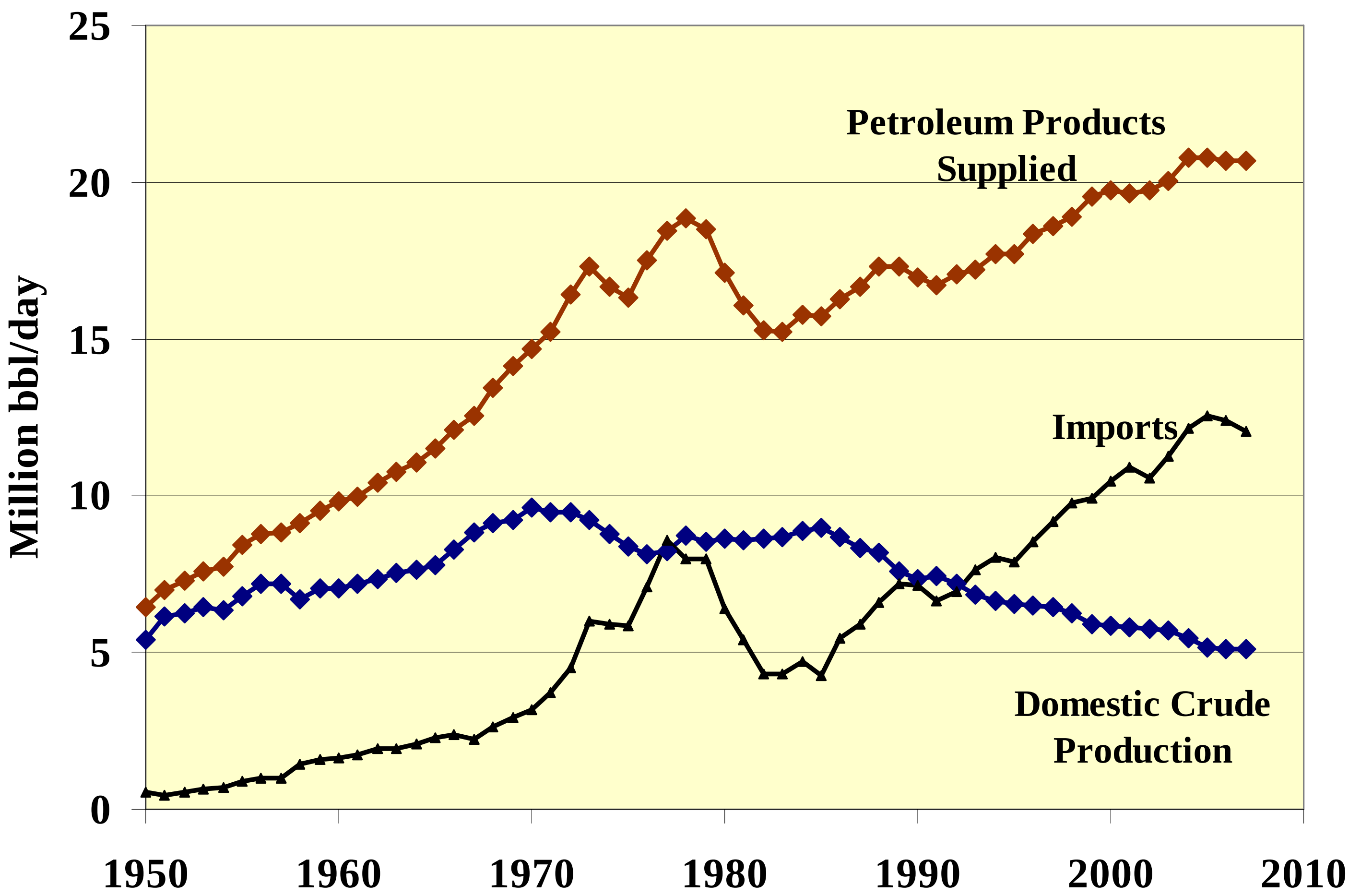
U. S. Actual Energy Use



U. S. Energy Use Forecast

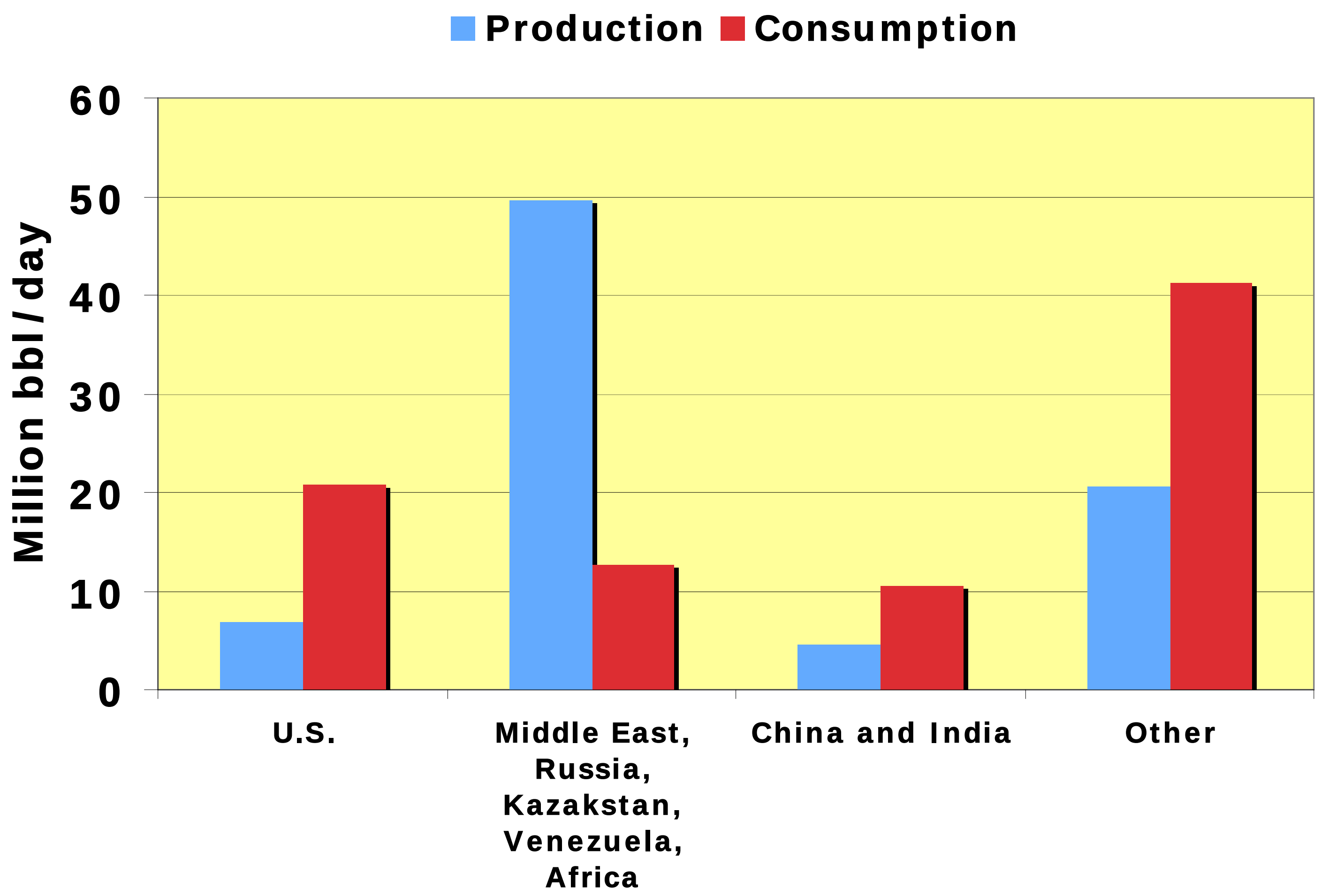


Petroleum Perspective



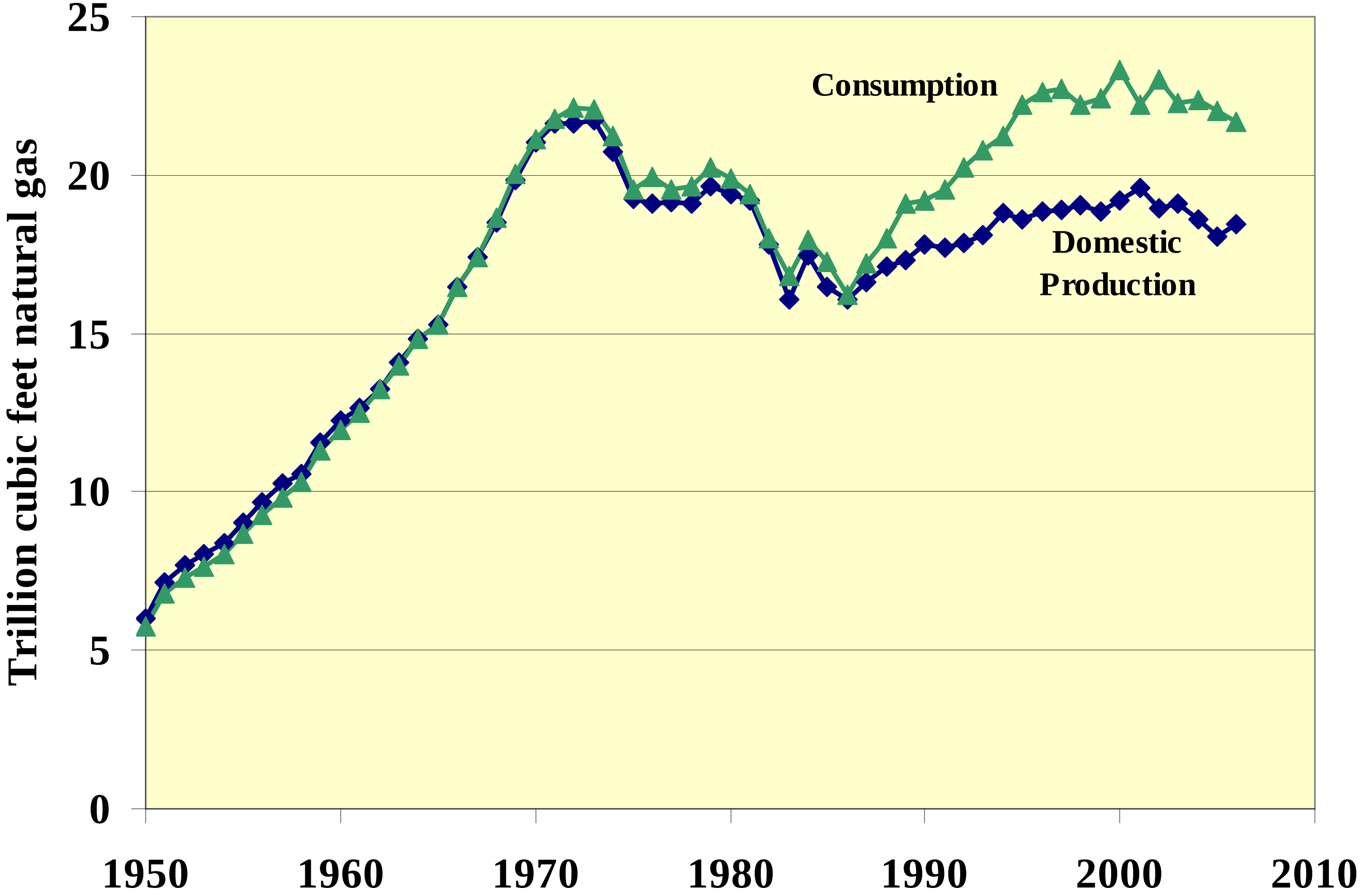
Ref. DOE EIA data

Resource Control Implications
Transfer of Wealth



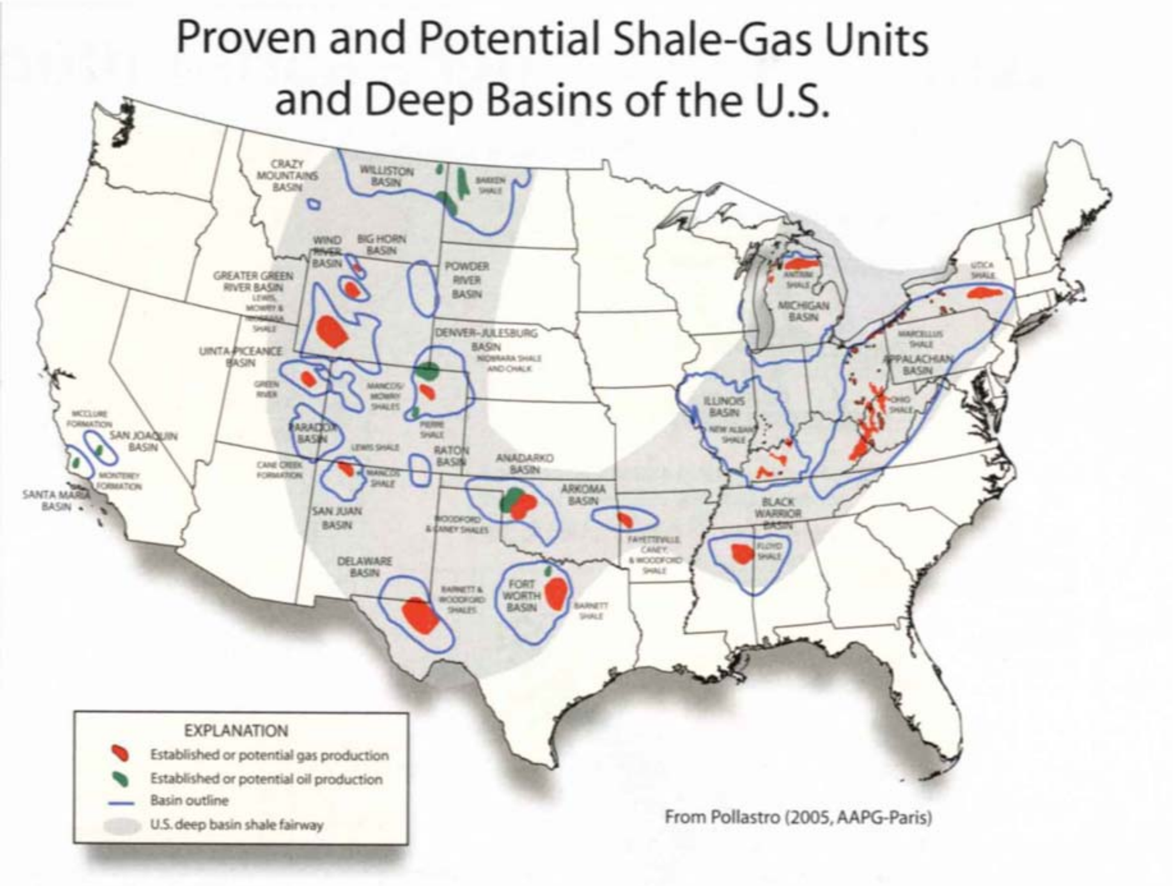
Ref. BP 2008 data

Natural Gas Perspective

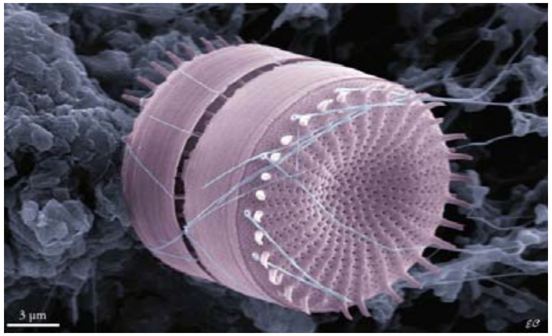


Ref. DOE EIA data

Illustrating Unconventional Resources

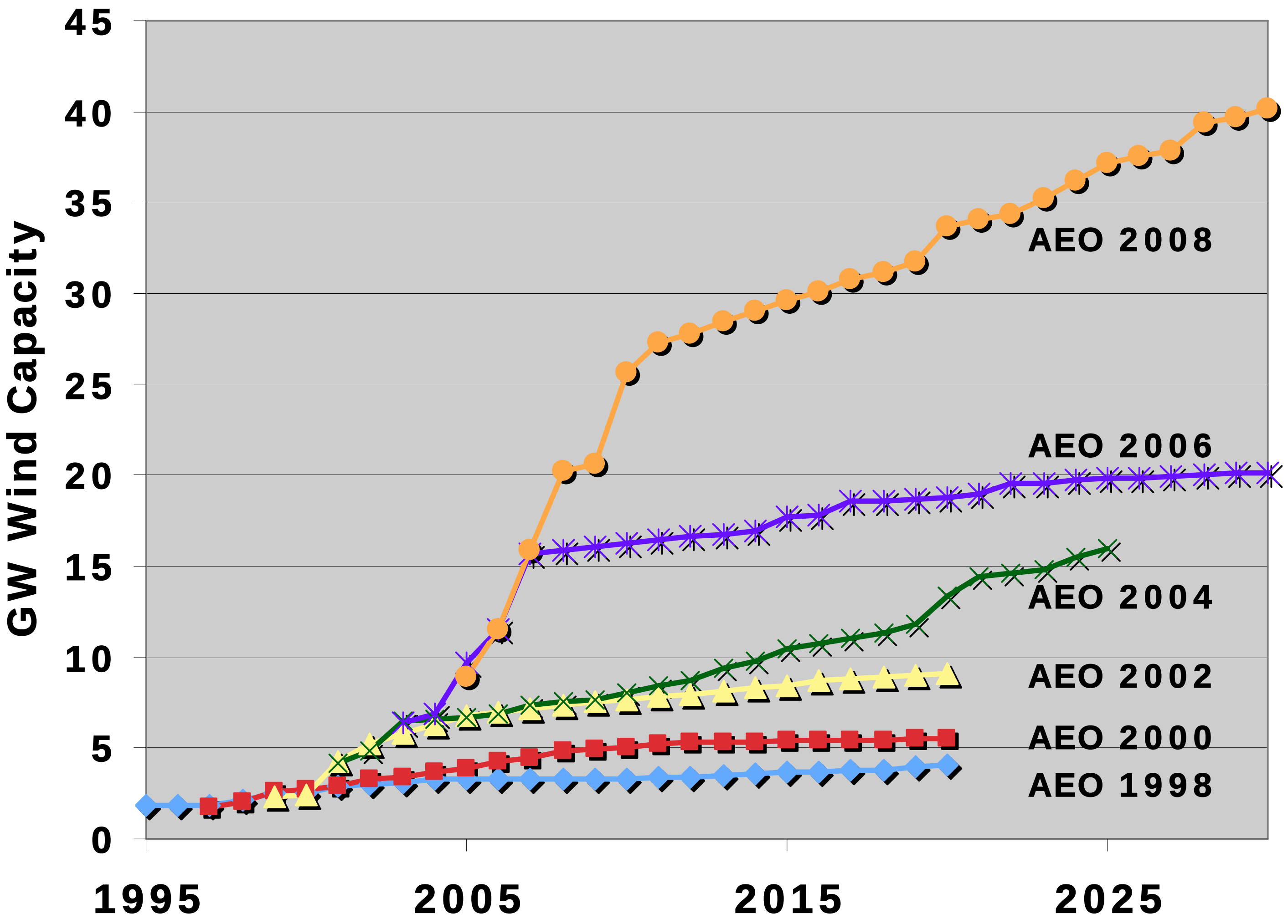


The Barnett Shale and other potential shale gas plays in the US.

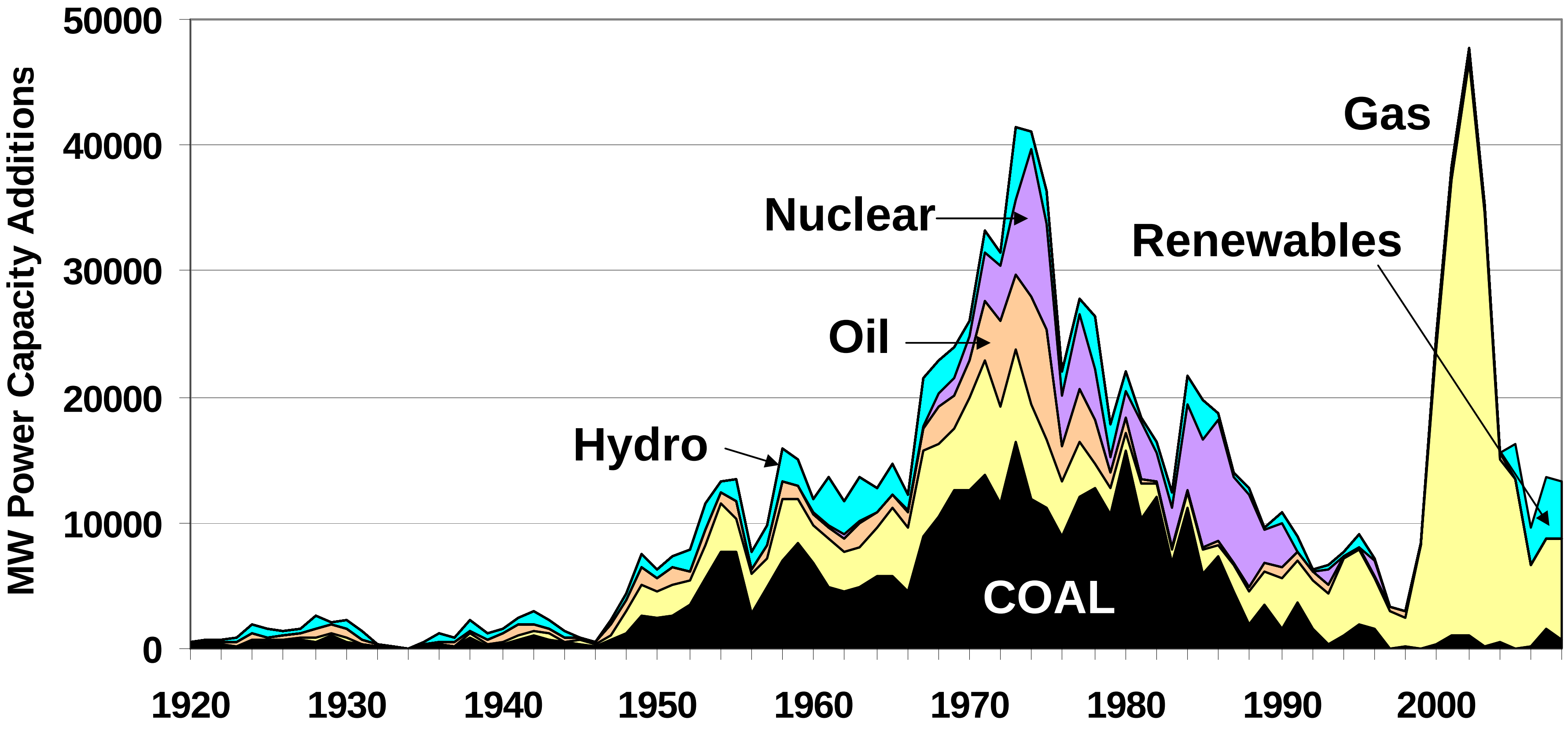


Source of Shale Gas: Diatoms and other microscopic marine organisms

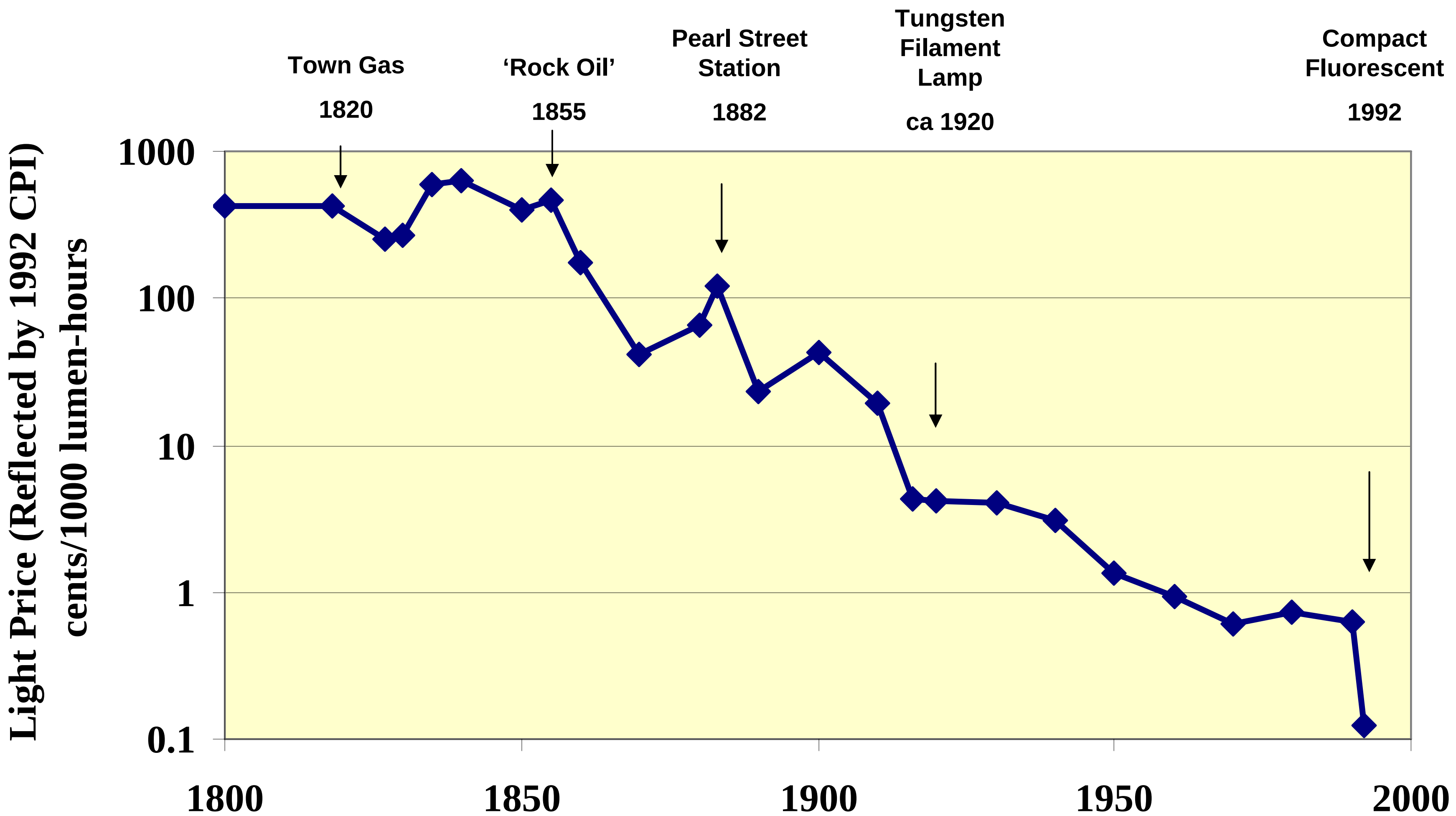
Projecting Wind Electric Power Capacity



U.S. Electric Power Capacity Perspective

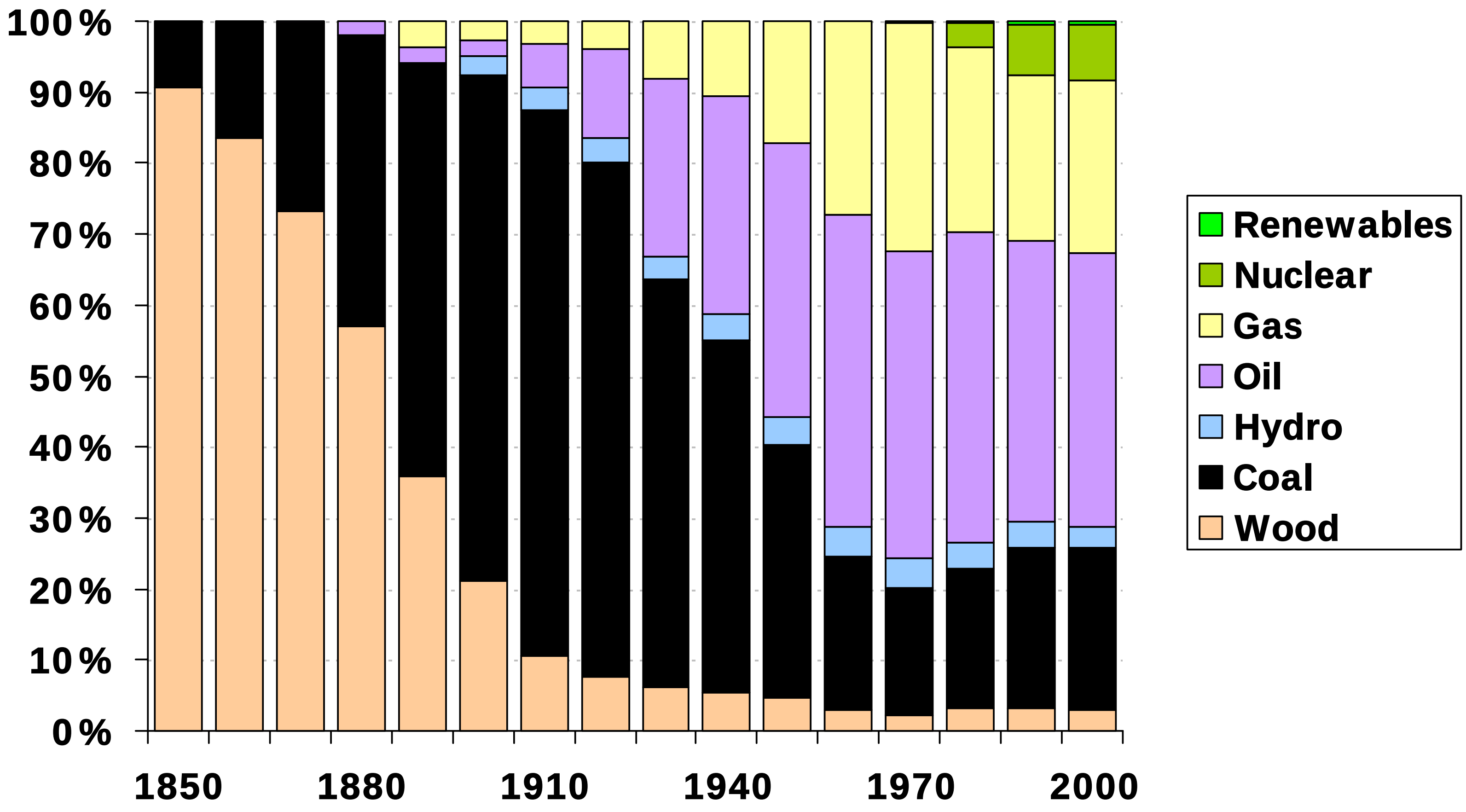


Technology / Price of Light



Data from William D. Nordhaus 'Do Real-Output and real-Wage Measures Capture Reality? The History of Lighting Suggests Not', published in The Economics of New Goods, edited by Bresnahan and Gordon, 1997

U.S. Energy Supply Since 1850



Data Source: EIA

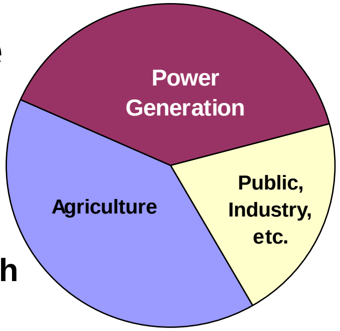
Today’s Grand Challenges

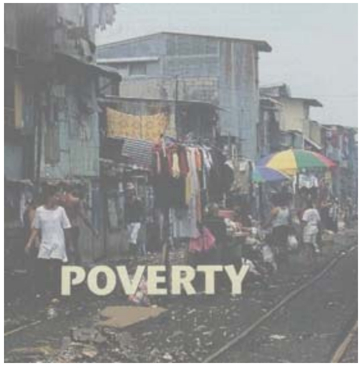
Disaster Resilience

Energy

Water

350 billion gal fresh water/day: U. S.





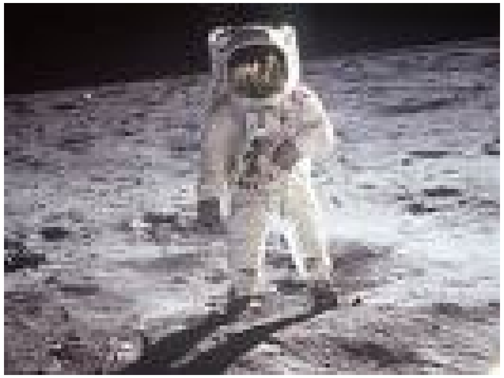
Climate Change

Terrorism

Illustrated Past R&D Grand Challenges

Manhattan Project
(1940s)

~ $25 billion



Apollo Project
(1960s)

~ $91 billion

Characteristics

Complex, Large scale, Multi-disciplinary, Captures the imagination

Characteristics of Grand Challenges: Boundaries Have Changed

	Historic Grand Challenges	Today's Grand Challenges
Activities	Isolated 'just had to get there'	Interdependent; Conflicting Goals
Implementation	Technical Community 'linear thought process'	Diverse Stakeholders: Requires collaborative strategy
Funding	Government 'limited constraint'	Multiple Sources; Competition

Borderless Profession

Disappearance of borders between disciplines

Need for new team, organization, communication concepts

What Metrics Guide Decisions?
Corn-Ethanol Biofuel

Emissions: Air, Water, Solids

By-Products
(e.g. animal feed, starch sweeteners, corn oil)

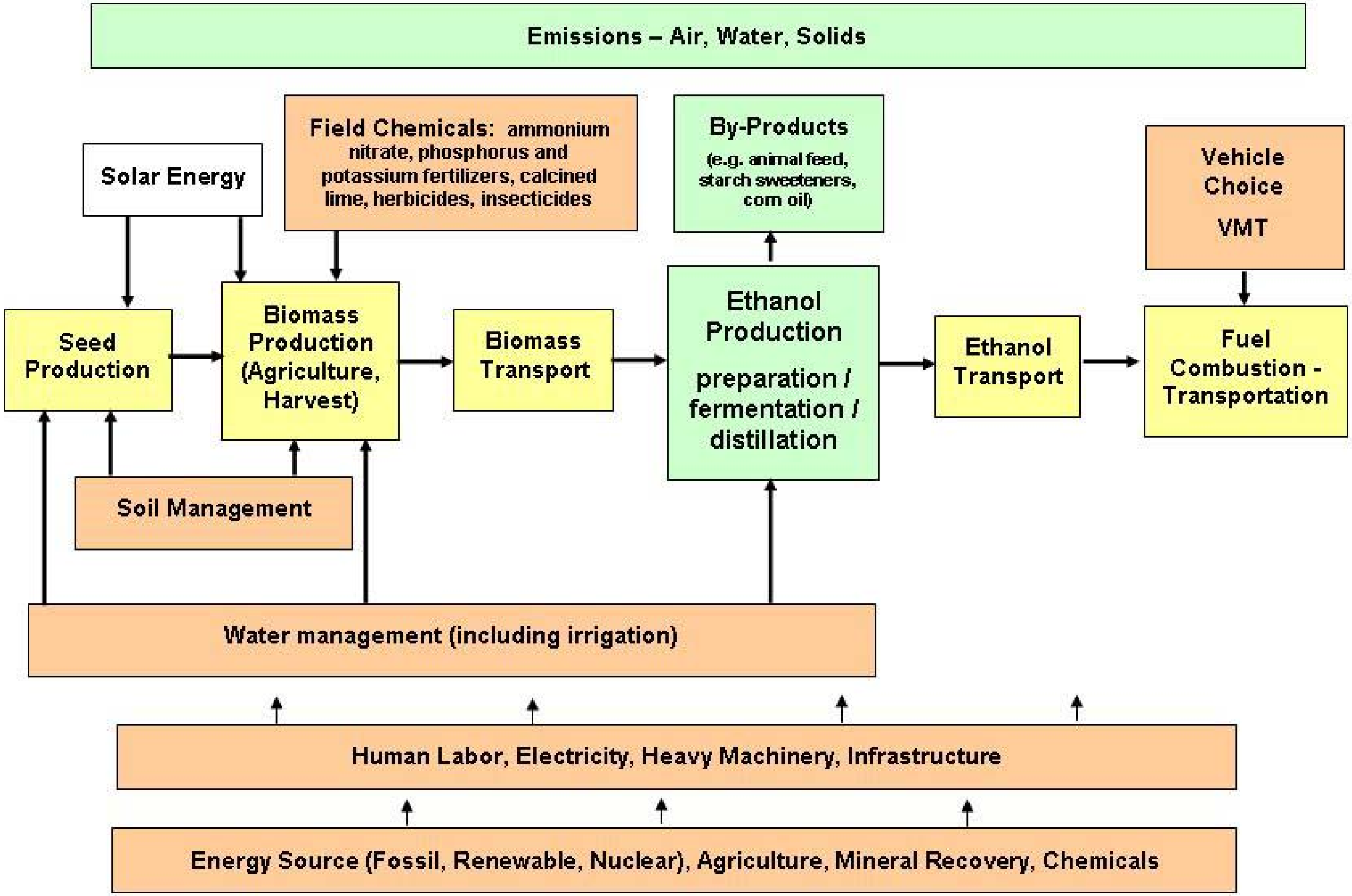
Biomass → **Ethanol Production**

Preparation, Fermentation, Distillation → **Ethanol**

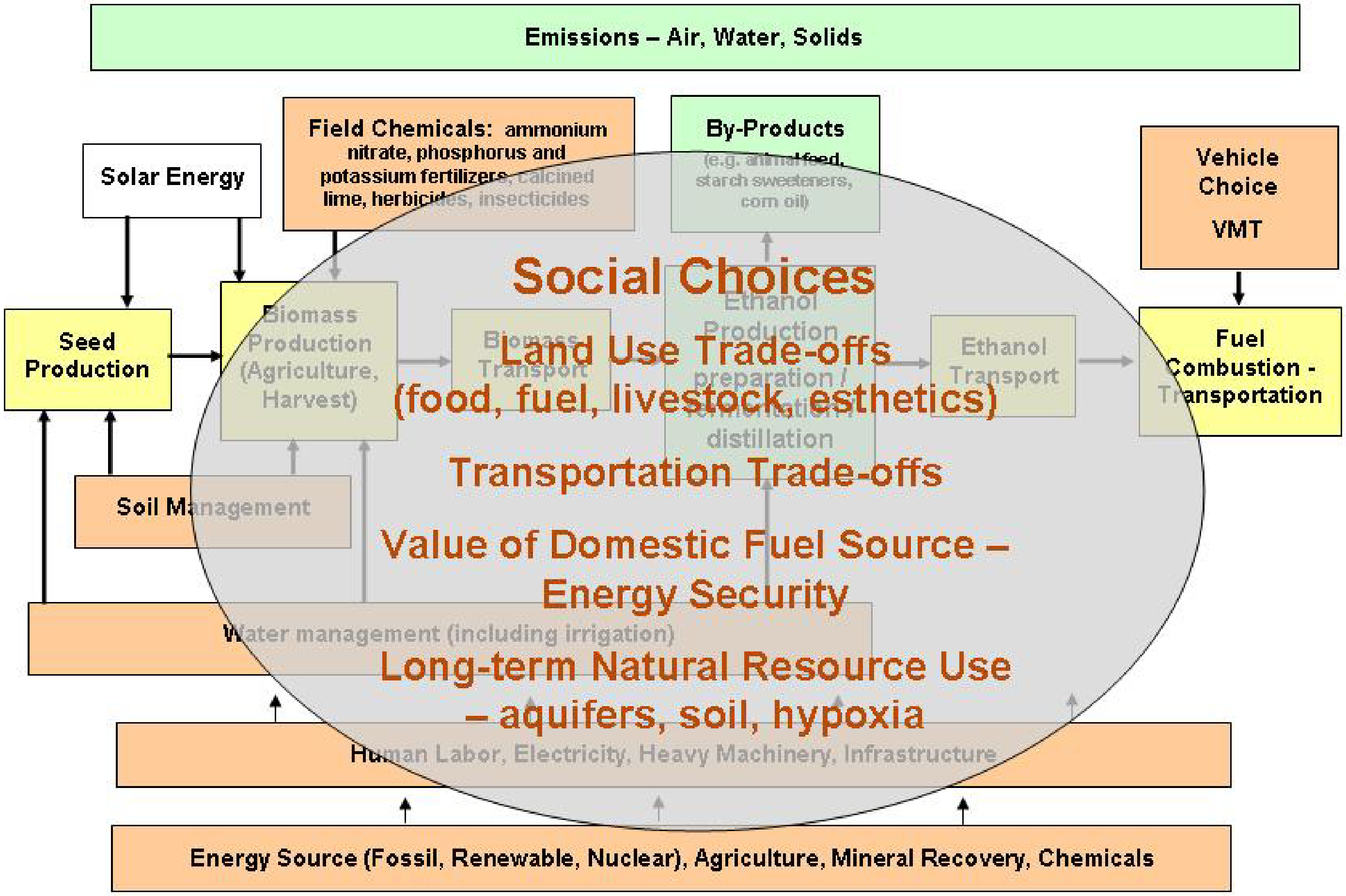
Utilities

- **Energy security**
- **Renewable**
- **Farmer benefit**

Where Do We Draw the Boundary?
Corn-Ethanol Biofuel



What Are the Options? Trade-Offs?



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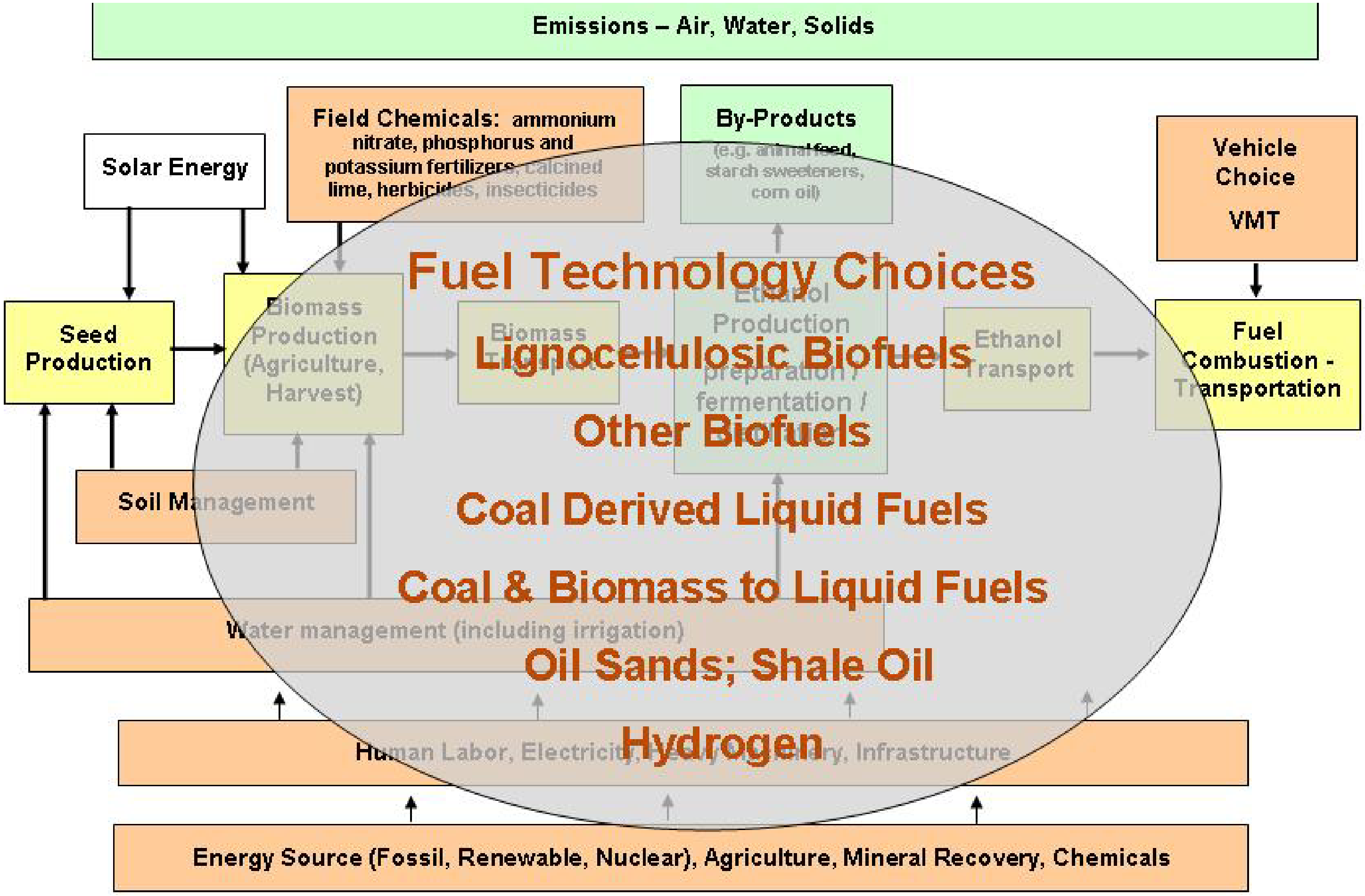
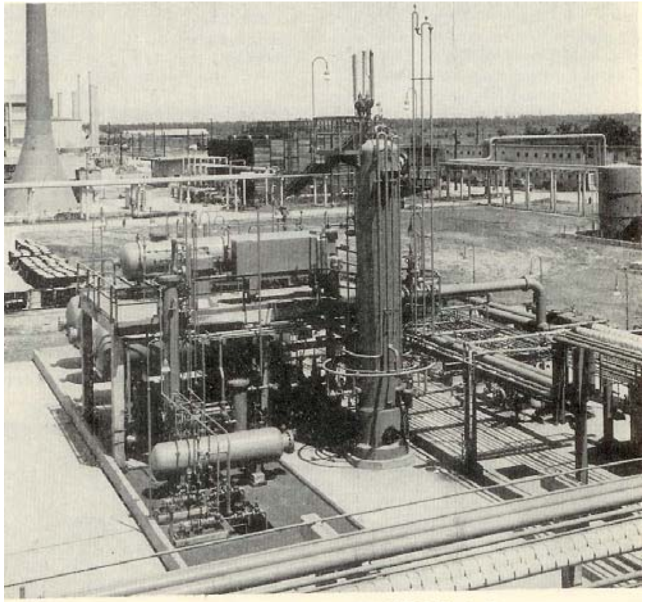


What Metrics Will We Use?

Plant Design and Economics for Chemical Engineers

Max Peters

1958



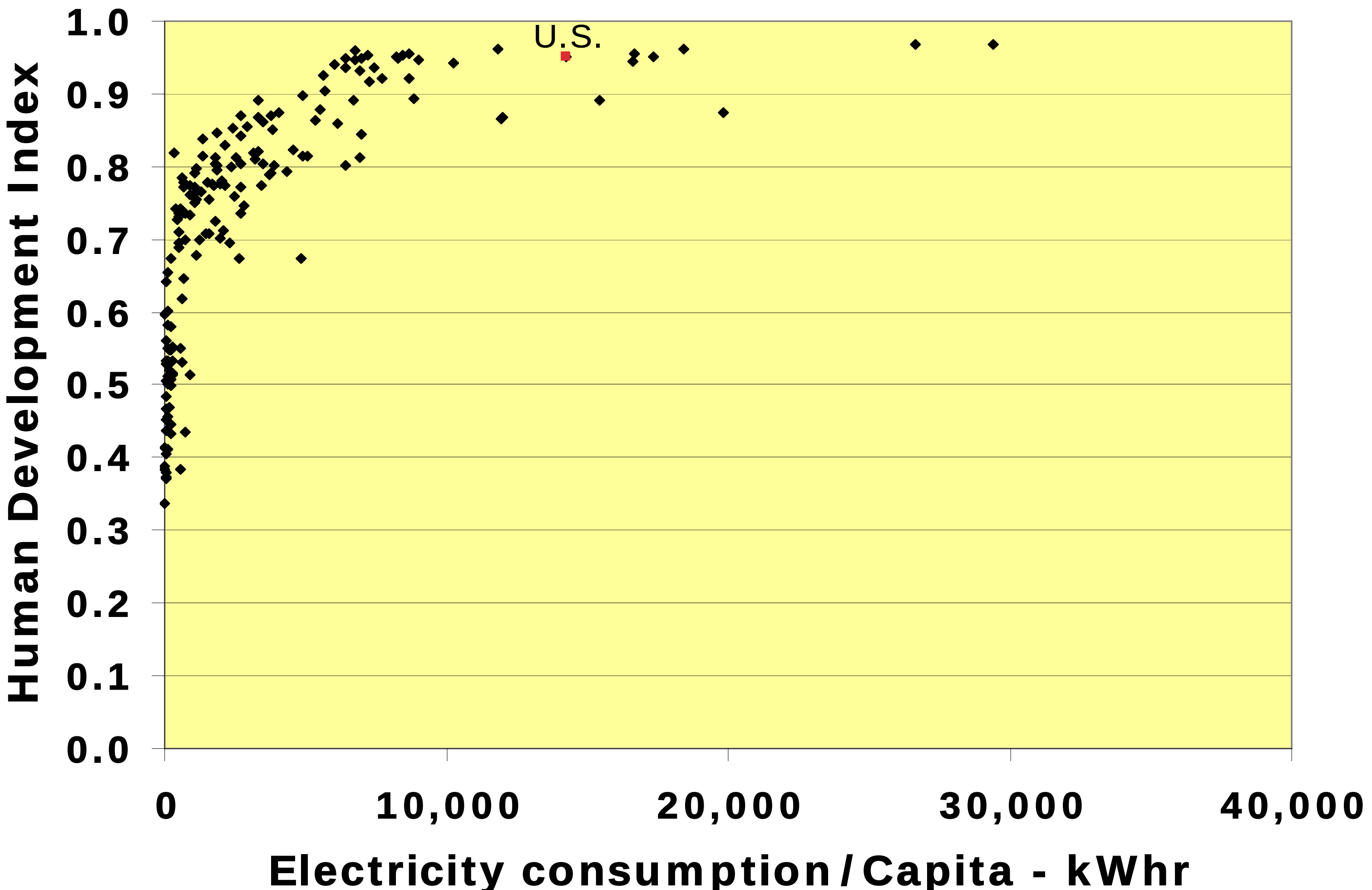
$\$ + CH_2{=}CH_2 + Cl_2 \rightarrow CH_2ClCH_2Cl + \$$

Dollars   Ethylene   Chlorine   Ethylene dichloride   Dollars

Focus on Changing Behavior, Simple, Reproducible, Anticipate Change

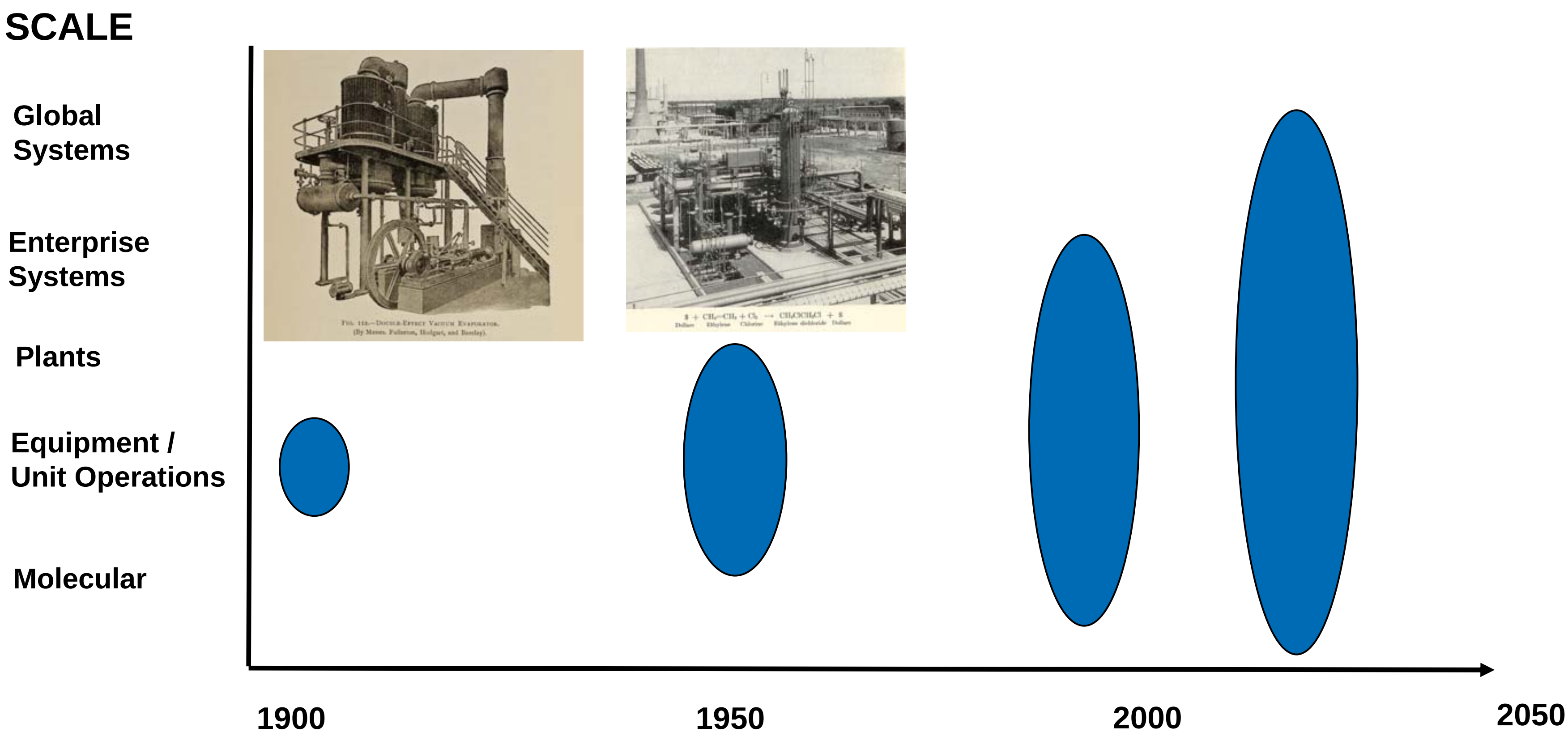
- Resource Productivity (e.g. kWhr/GDP, water productivity/hectare yield)
- Resource Use (e.g. availability/use)
- Health (e.g. safety, deaths)
- Environmental (e.g. GHG emissions/GDP)
- Economic
- Security
- Land Use / Sustainability
- Equity (e.g. share of population with electricity)
- Biodiversity

Quality of Life / Technology Relationship

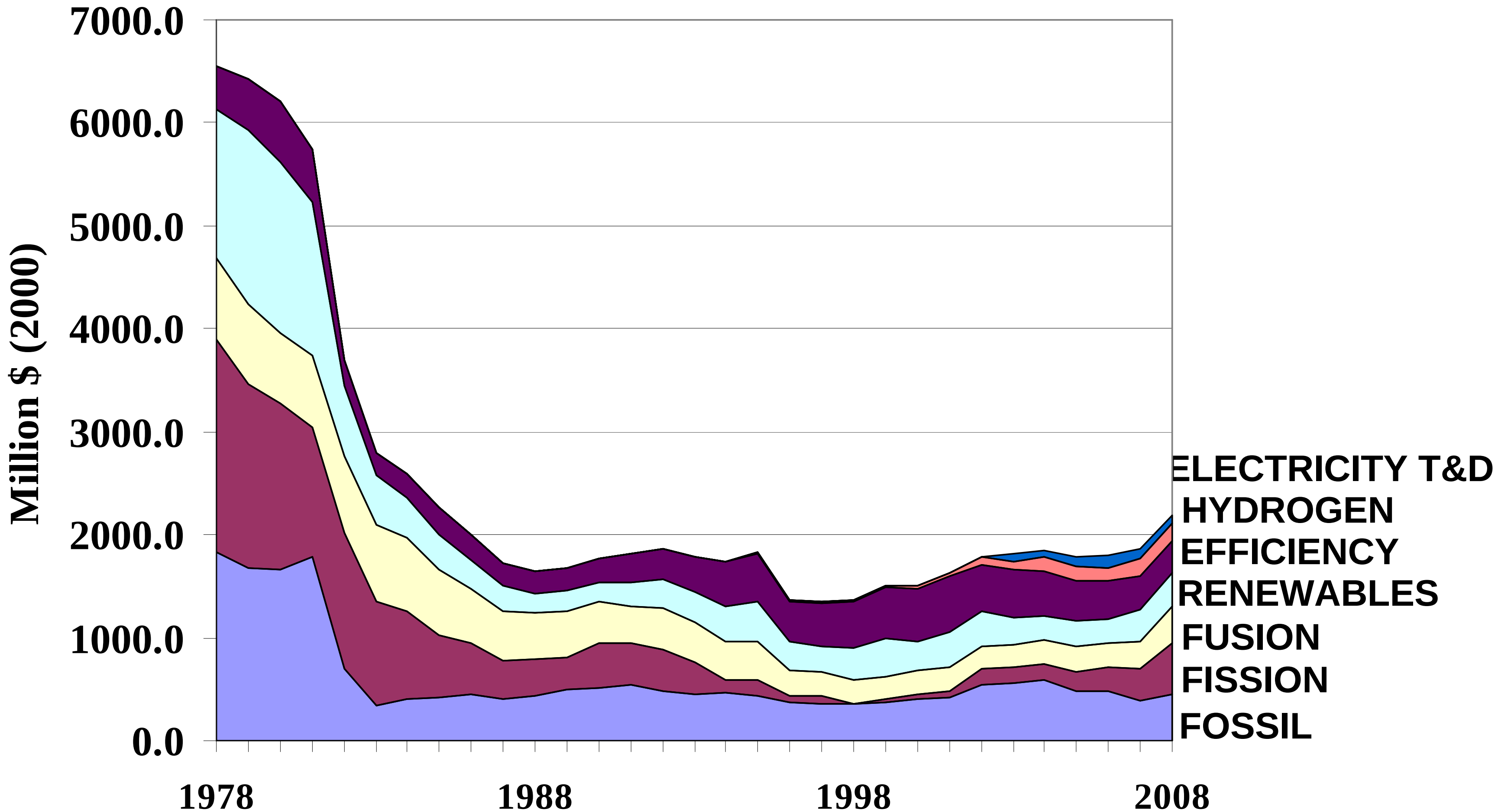


Ref. UNDP; HDI = f(life expectancy, education, GDP)

Chemical Engineering Education

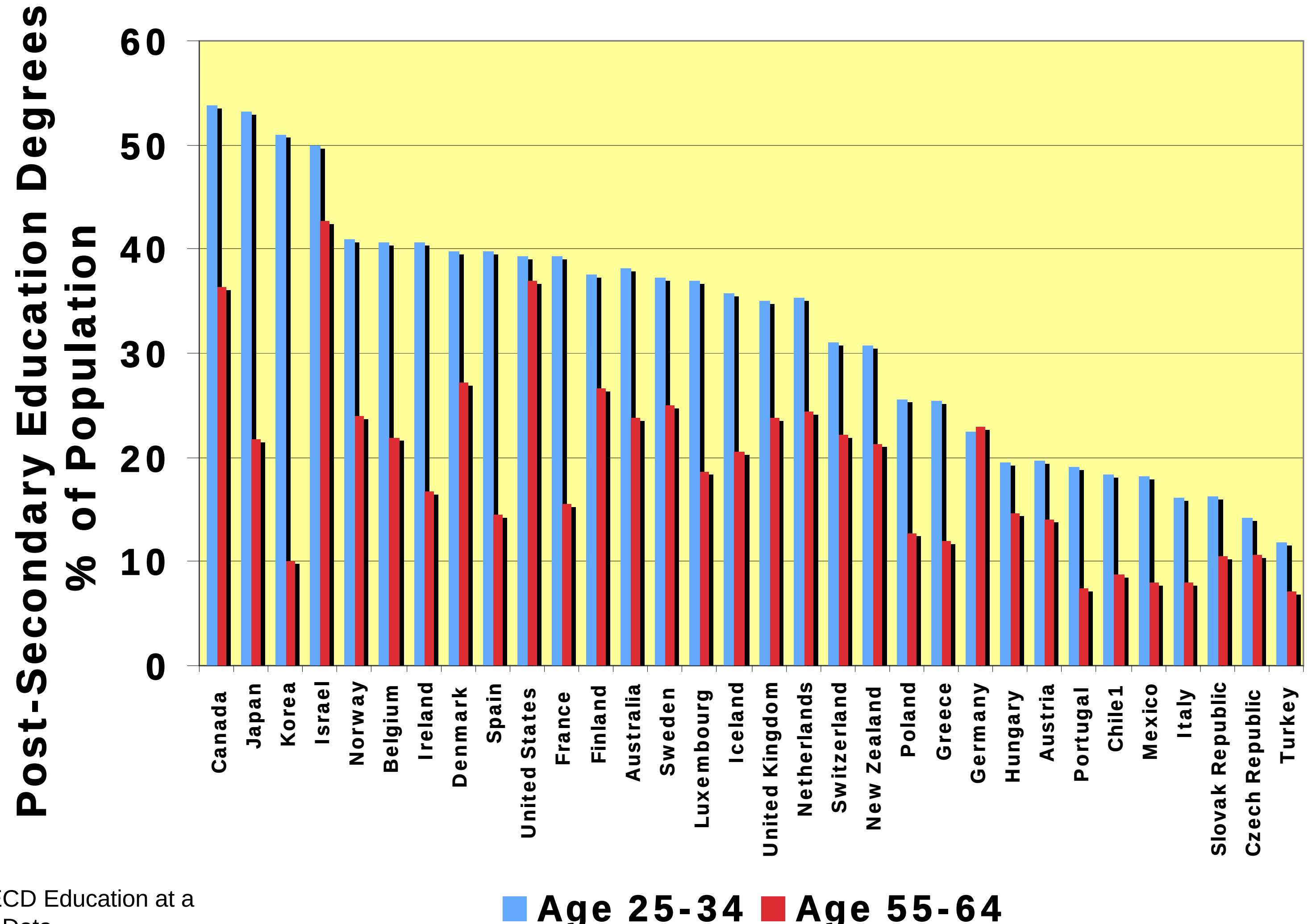


U. S. DOE Energy RD&D



Gallagher, K.S., Sagar, A, Segal, D, de Sa, P, and John P. Holdren, "DOE Budget Authority for Energy Research, Development, and Demonstration Database," 2007

Education Challenge
International Competitiveness



Based on OECD Education at a Glance 2007 Data

Reflections

- The boundaries have changed
- Complicated trade-offs – requires big-picture systems view
- Solution is not at the limits: independence, no water use, no land use, no carbon emissions
- Solutions will not come through individual technologies
- Solvable problem
- Need technology creativity and social creativity
- We have choices: engineers can inform public policy
  - Will we be an integral part of the solution?
  - Will we be leaders? What will it take?