Harnessing Innovation for a Renewable Energy Future

Presented at the Texas Tech College of Engineering Summit on Energy Sustainability

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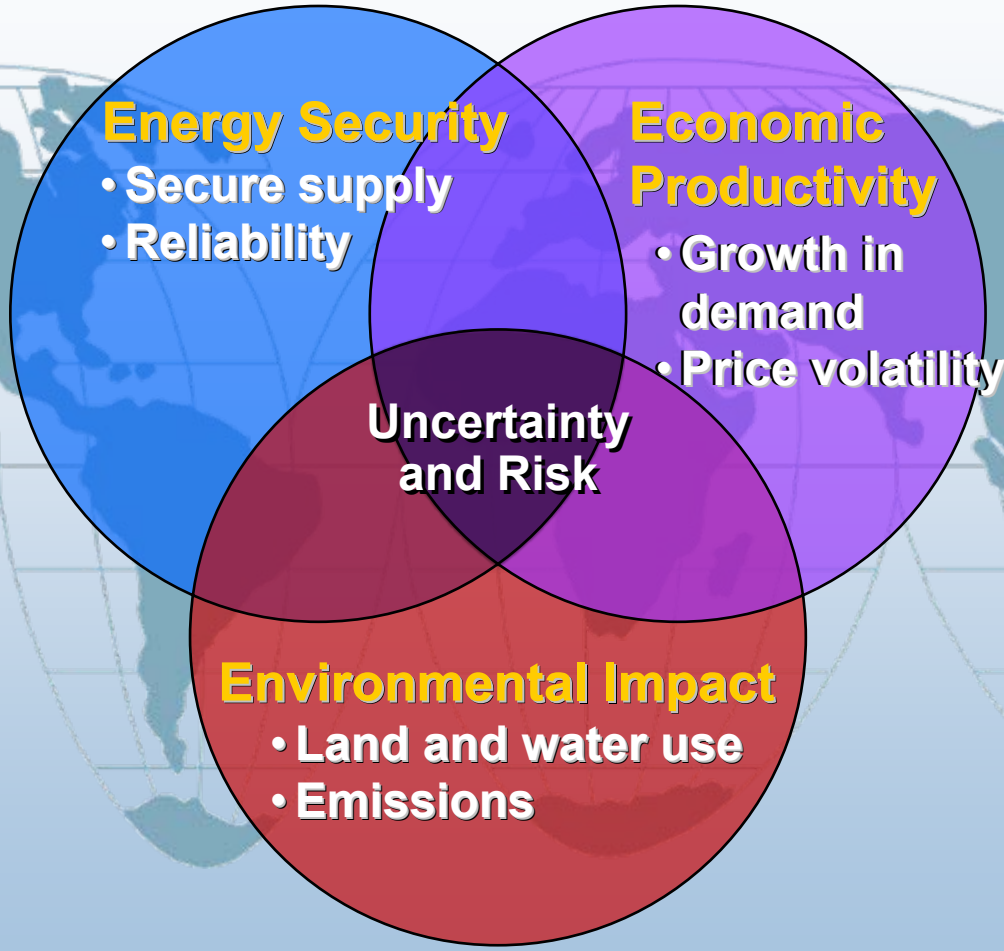
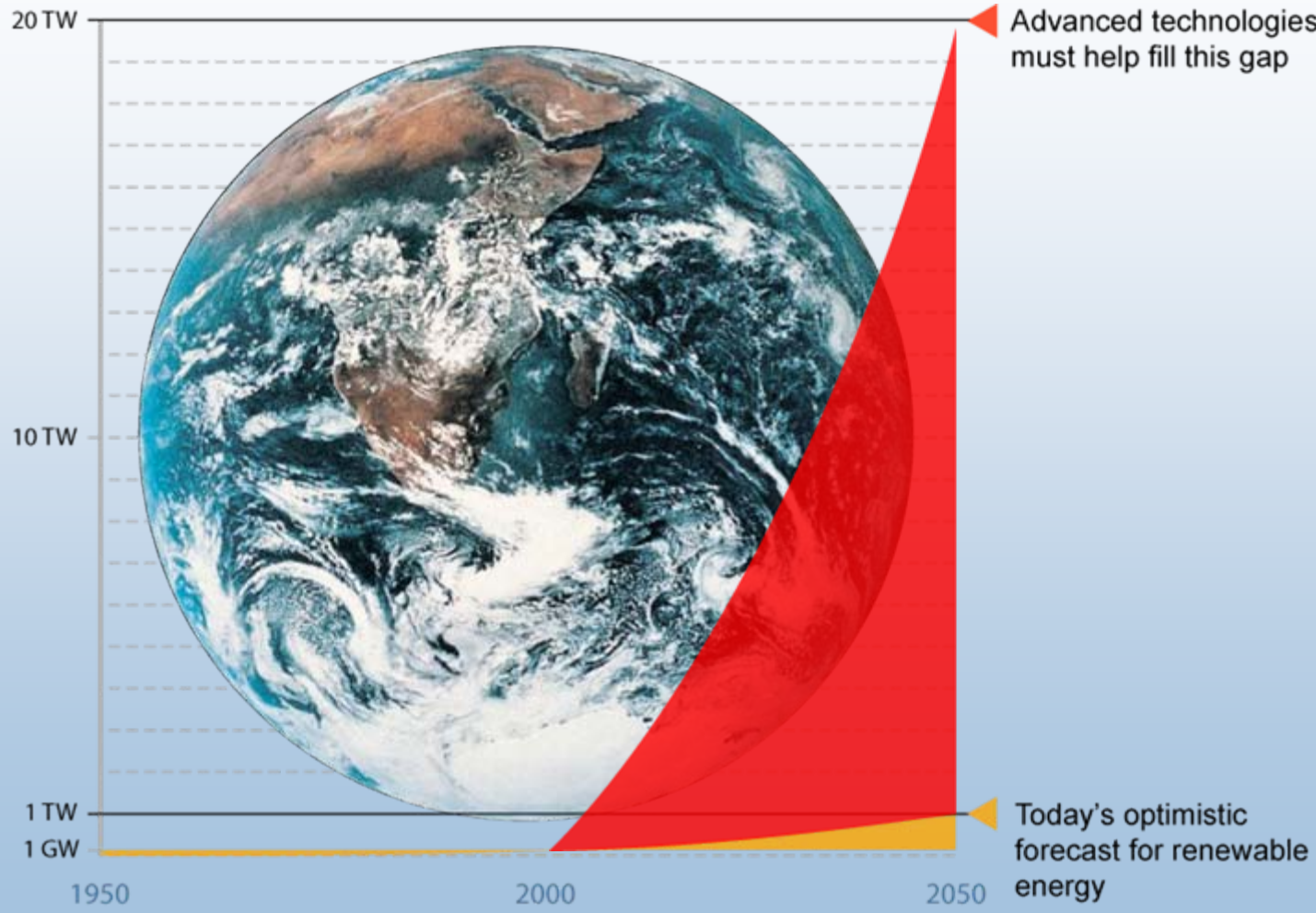
Presented at the Texas Tech University College of Engineering's Energy Sustainability Forum held in Lubbock, Texas on September 13, 2006.

Energy Solutions Are Enormously Challenging



We need a balanced portfolio of options

Magnitude of Challenge Requires Global Action and a Change in Trajectory



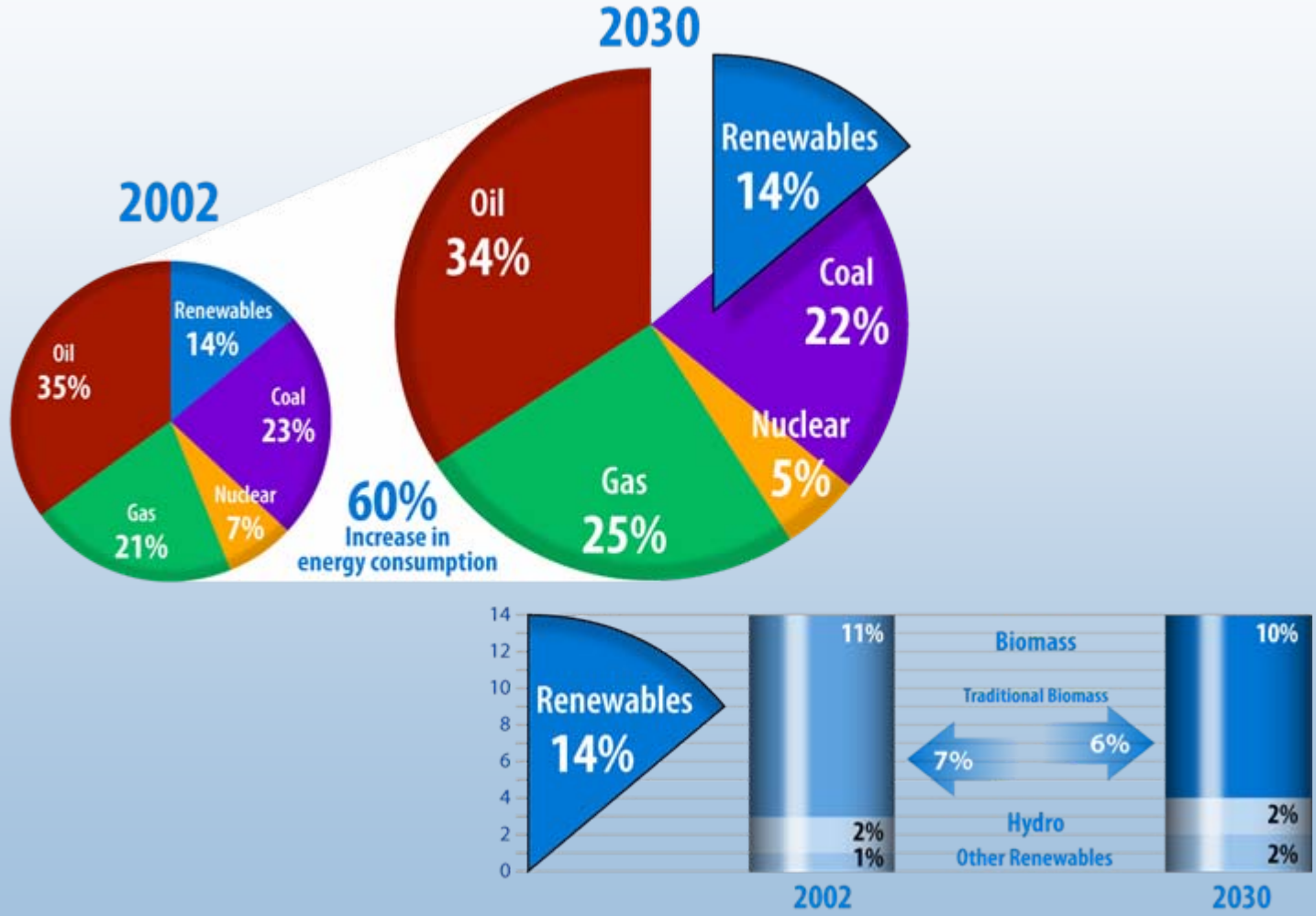
Source: Arvizu, NREL

Technology-Based Solutions:

There is no single or simple answer

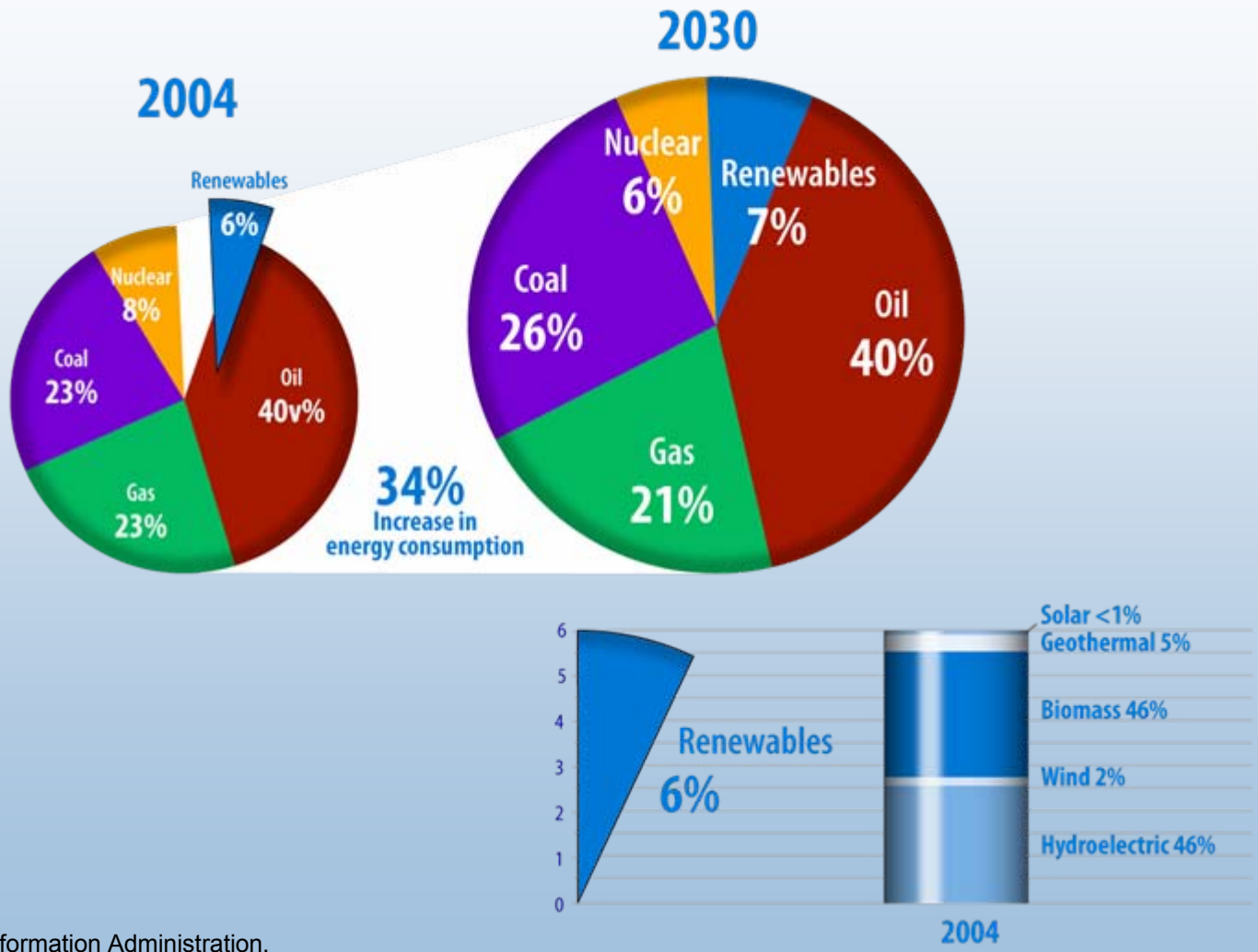
- Energy efficiency
- Renewable energy
- Nonpolluting transportation fuels
- Separation and capture of CO_2 from fossil fuels
- Next generation of nuclear fission and fusion technology
- Transition to smart, resilient, distributed energy systems coupled with pollution-free energy carriers such as hydrogen and electricity

World Energy Supply and the Role of Renewable Energy



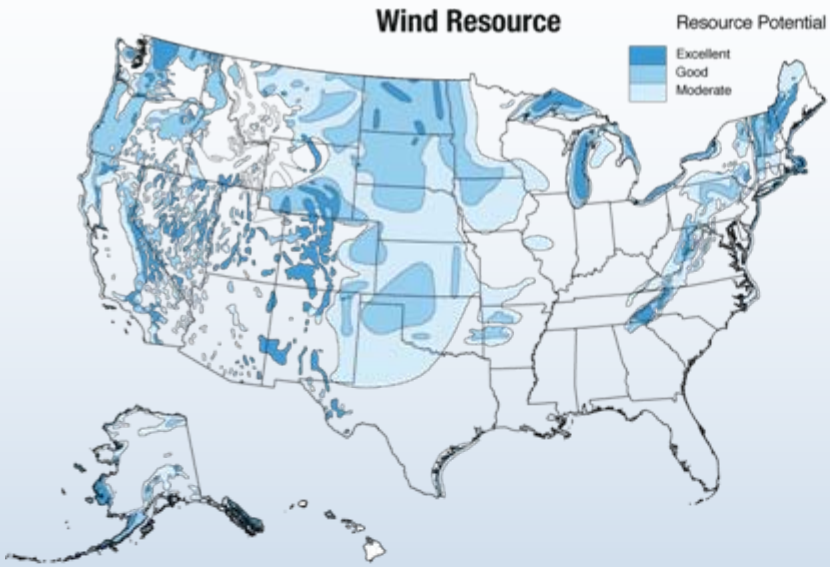
Source: OECD/IEA, 2004

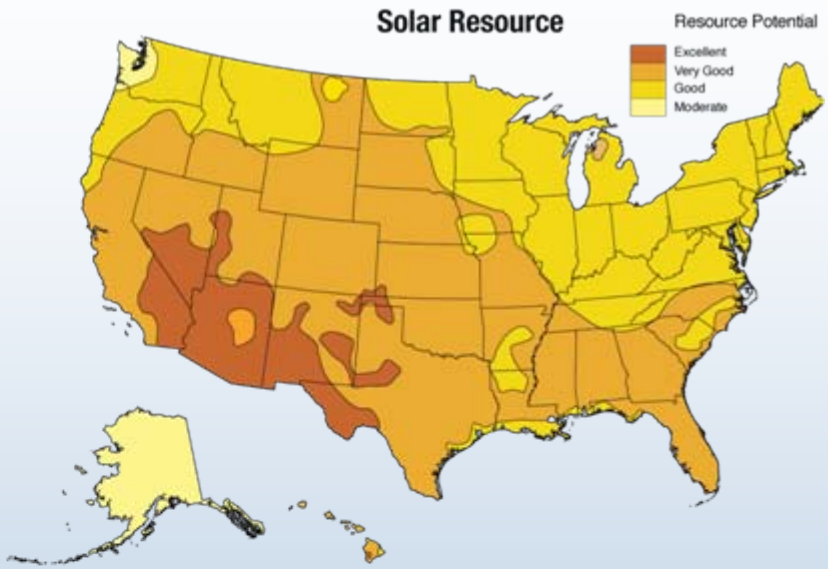
U.S. Energy Consumption and the Role of Renewable Energy

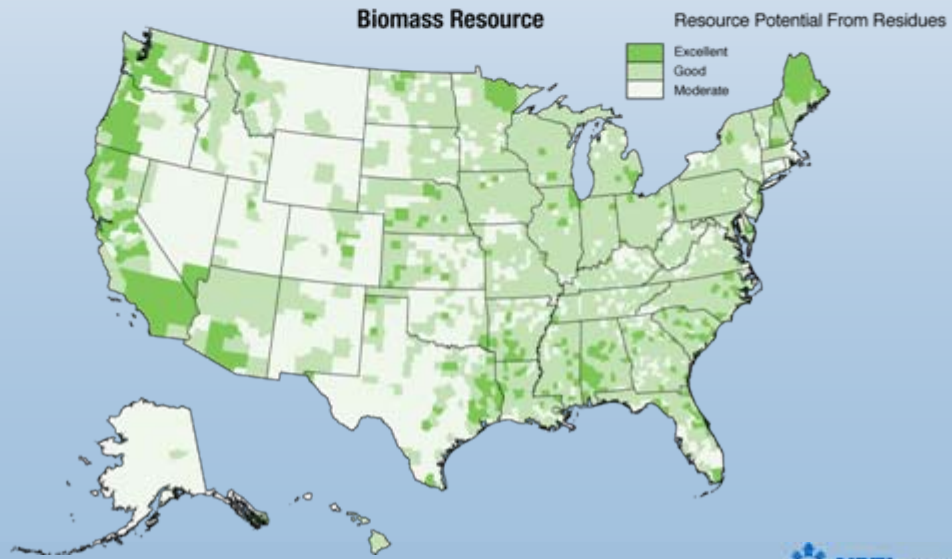


Source: Energy Information Administration, *Annual Energy Outlook 2006,* Table D4

National Resources

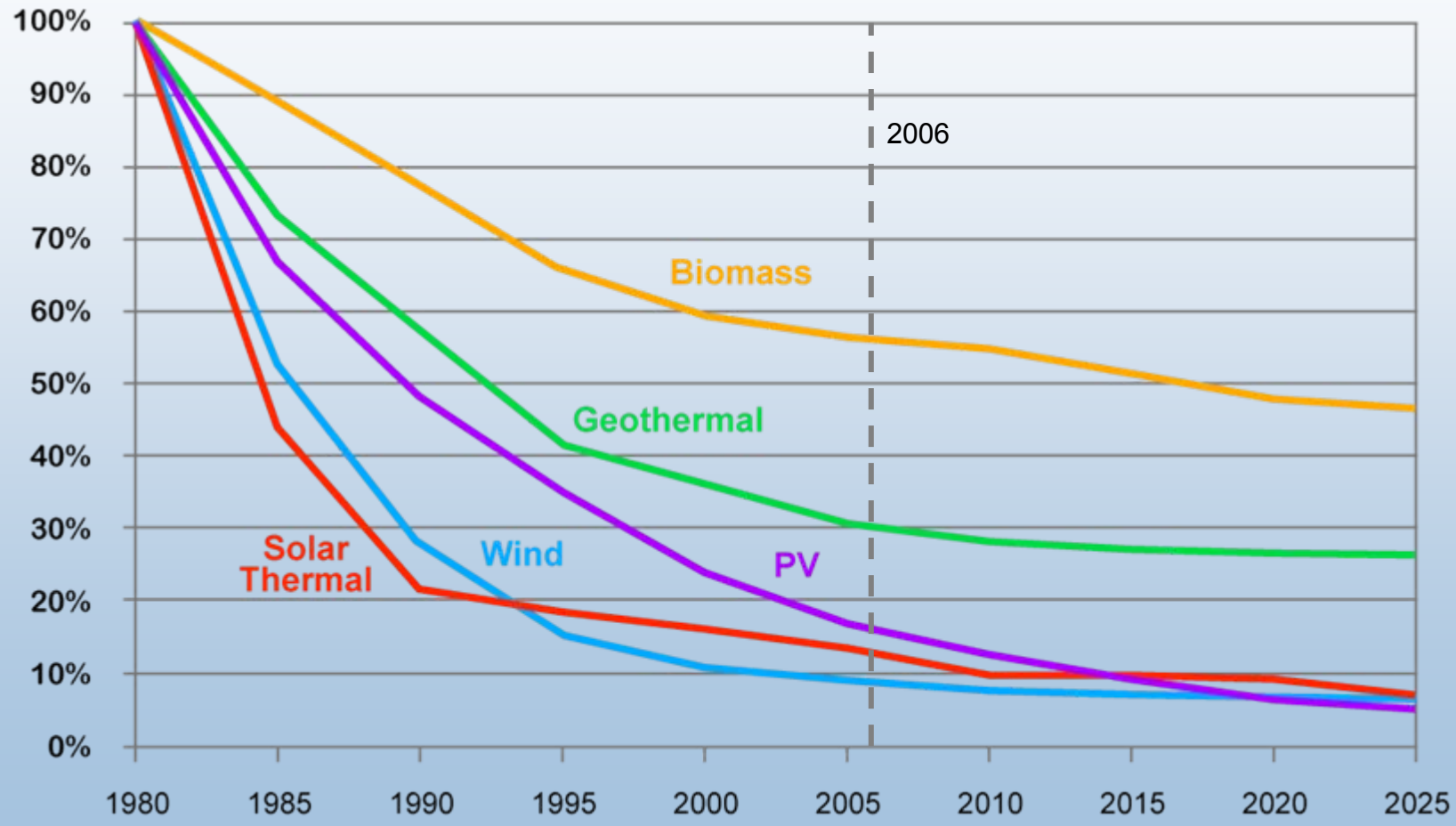






Renewable Energy Costs Have Decreased

Historical and Projected

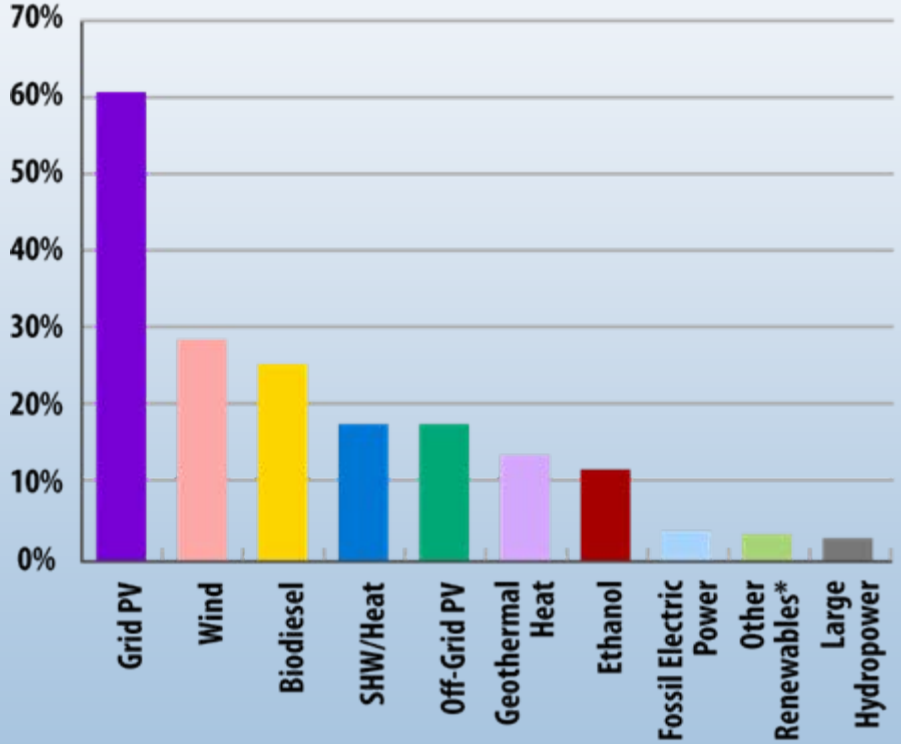


Costs as percentage of 1980 levels

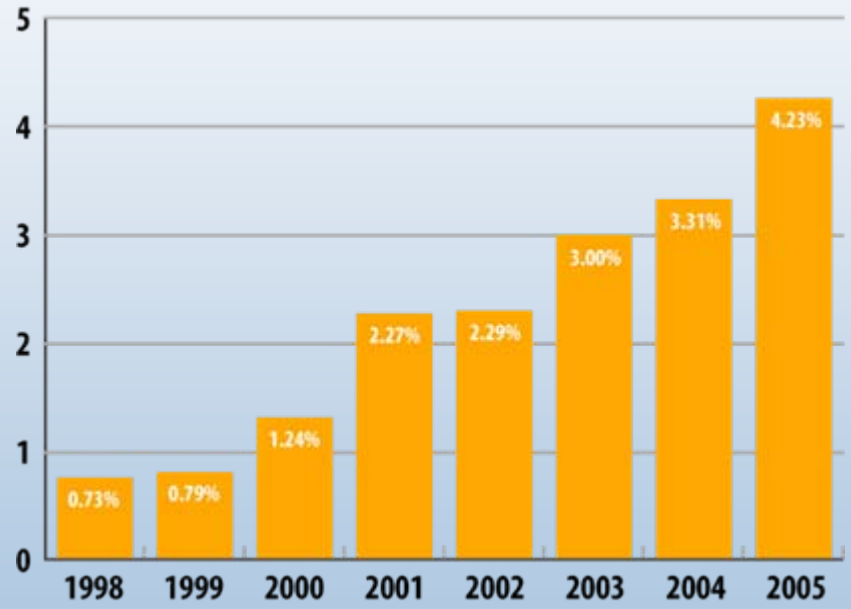
Source: NREL 2005, 2002

Renewable Energy Is Growing

Renewable Energy Annual Growth Rates 2000-2004



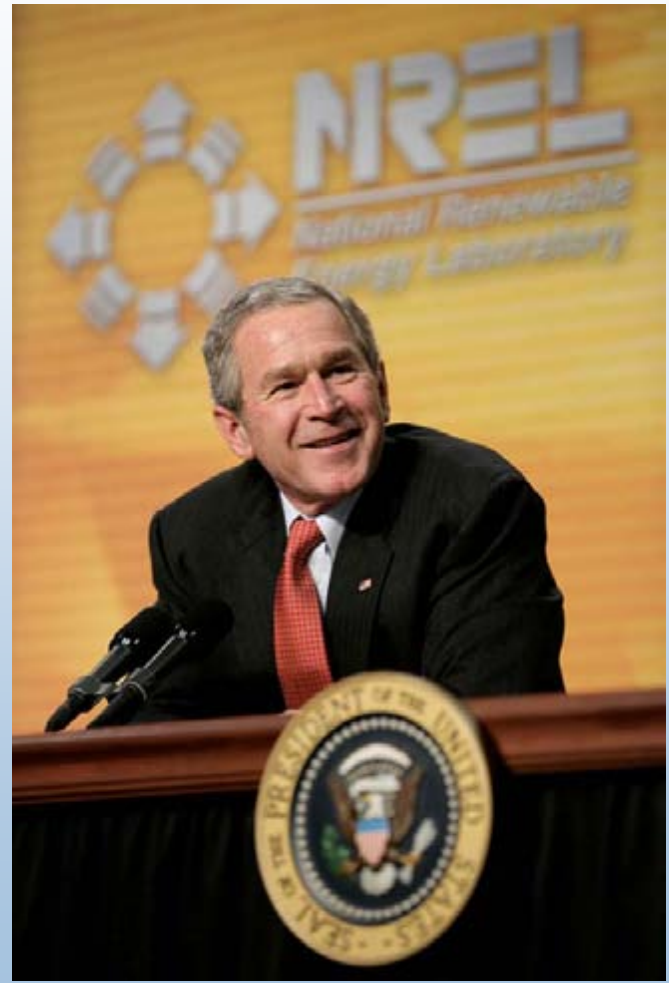
Energy-Tech Investments Percent of Total U.S. Venture Capital



Sources:
Renewables 2005 Global Status Report, REN21
Clean Energy Trends 2006, Nth Power LLC

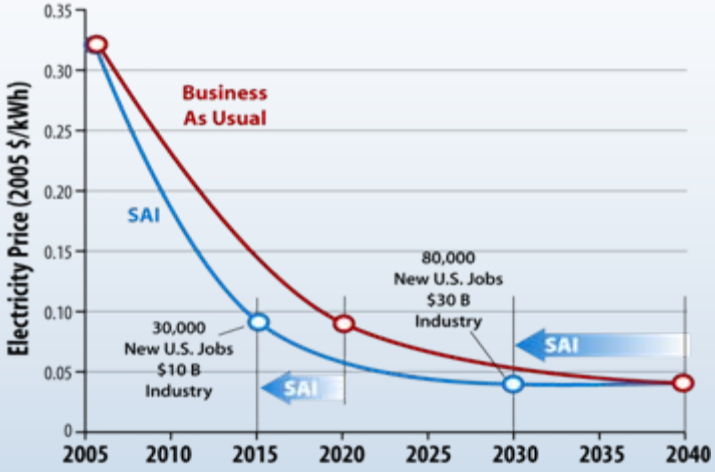
President's Advanced Energy Initiative 2007 Budget

- National goals to address American "addiction to oil"
- 22% increase in DOE "clean energy" funding
- Major new R&D investments in solar, wind, biorefinery and hydrogen fuel cells

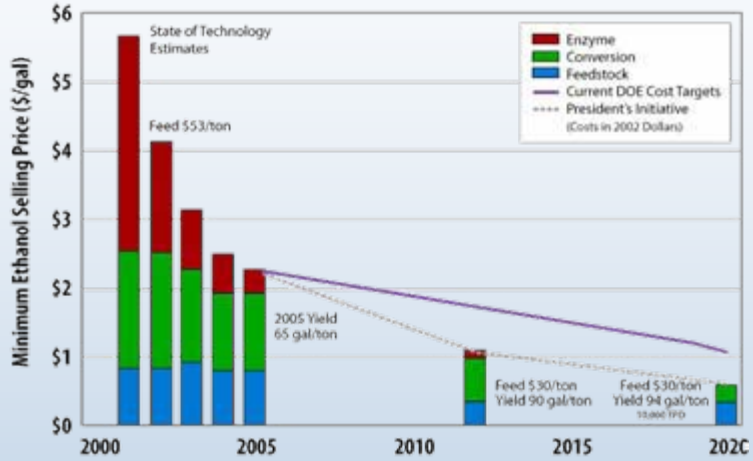


Value to the Nation
Initiatives Will Accelerate Progress

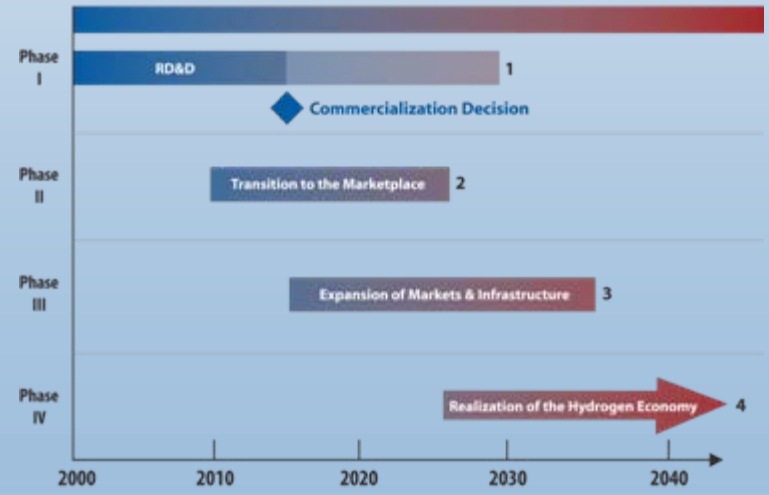
Solar America Initiative



Biorefinery Initiative



Hydrogen Fuel Initiative



Without a different approach, meeting these aggressive goals is a high-risk proposition

Energy Efficiency and Renewable Energy Technology Development Programs

NREL R&D Portfolio

Efficient Energy Use

- Vehicle Technologies
- Building Technologies
- Industrial Technologies

Renewable Resources

- Wind
- Solar
- Biomass
- Geothermal

Energy Delivery and Storage

- Electricity Transmission and Distribution
- Alternative Fuels
- Hydrogen Delivery and Storage

Foundational Science

Solar

Status:
- 450 MW
- Cost 18-23¢/kWh

Potential:
- 11-18¢/kWh by 2010
- 5-10 ¢/kWh by 2015

NREL Research Thrusts:
- Higher efficiency devices
- New nanomaterials applications
- Advanced manufacturing techniques

Source: U.S. Department of Energy, updated March 16, 2006

Wind

Today's Status

- 10,000 MW installed as of August 2006
- Cost 6-9¢/kWh at good wind sites

DOE Cost Goals

- 3.6¢/kWh, onshore at low wind sites by 2012
- 5¢/kWh, offshore in shallow water by 2014

Long Term Potential

- 20% of the nation's electricity supply

NREL Research Thrusts

- Low wind speed technology
- Distributed wind technology
- Advanced rotor development
- Utility grid integration

Updated September 7, 2006
Source: U.S. Department of Energy, American Wind Energy Association

Biofuels

Biofuels status

- Biodiesel – 75 million gallons (2005)
- Corn ethanol
  - 81 commercial plants
  - 3.9 billion gallons (2005)
  - Today's cost ~$1.35/gallon of gasoline equivalent (gge)
- Cellulosic ethanol
  - Projected commercial cost ~$3.00/gge

Potential

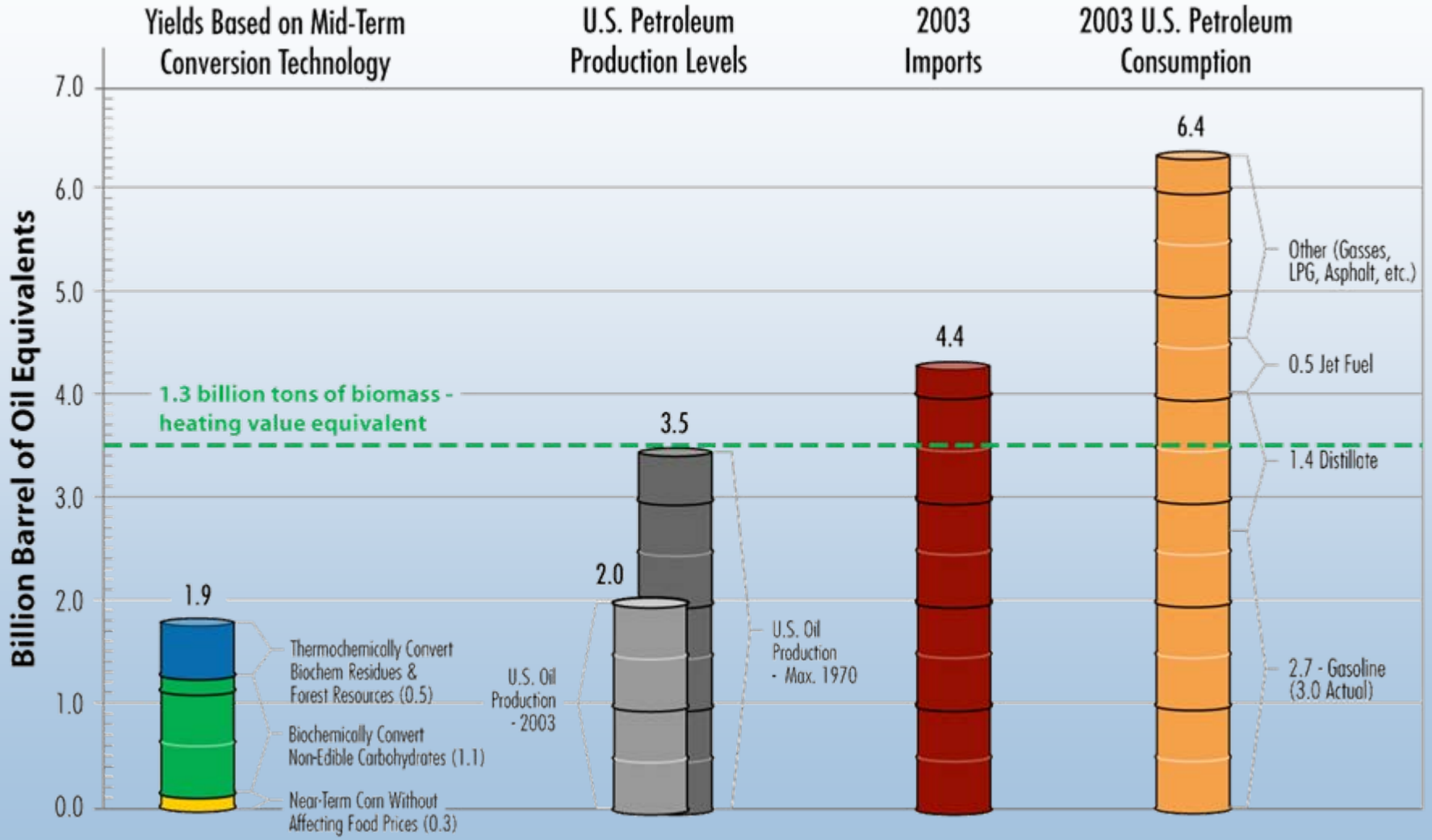
- 2012 goal – cellulosic ethanol ~$1.42/gge
- 2030 goal – all ethanol = 30% of transportation fuels

NREL Research Thrusts

- The Biorefinery
- Solutions to under-utilized waste residues
- Energy crops

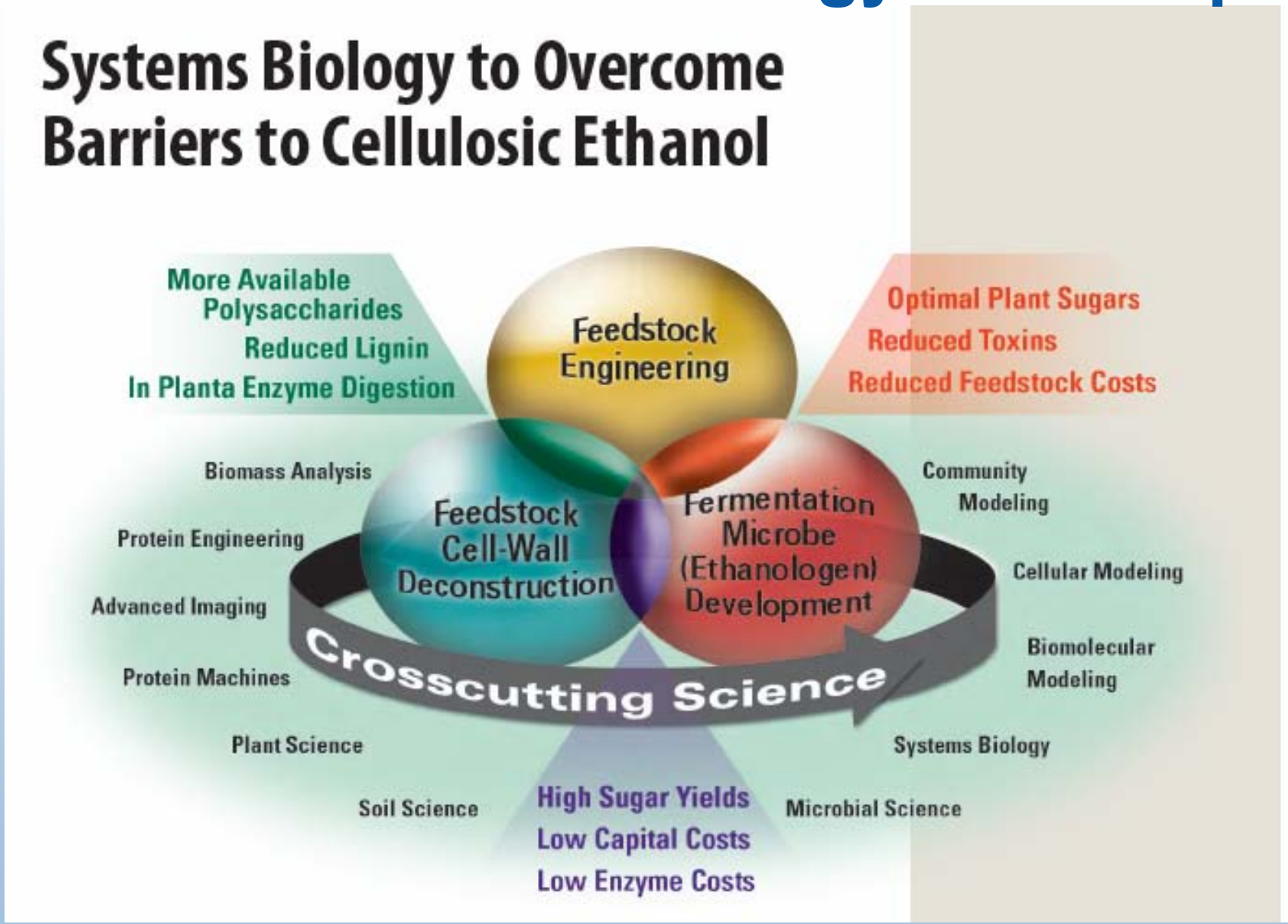
Source: U.S. Department of Energy, National Biodiesel Board, Renewable Fuels Association

Significance of the 1.3 Billion Ton Biomass Scenario



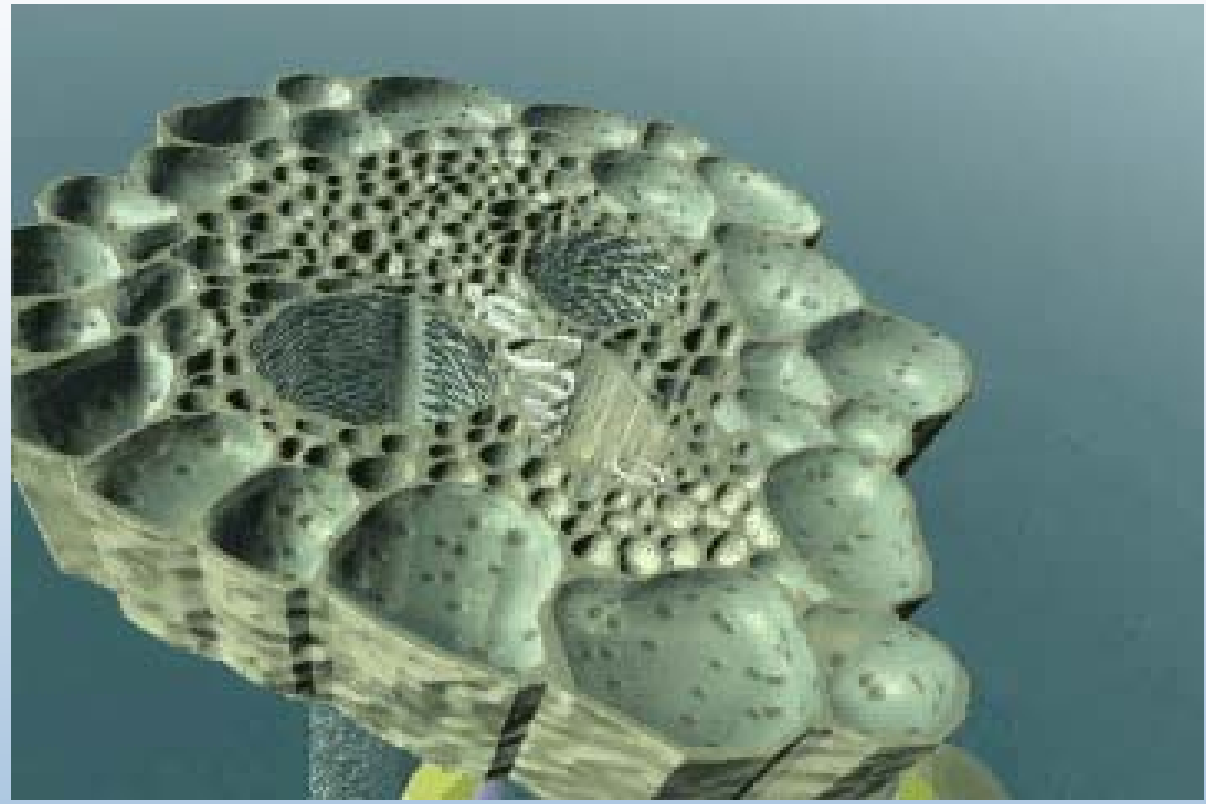
Based on ORNL & USDA Resource Assessment Study by Perlach et.al. (April 2005)
http://www.eere.energy.gov/biomass/pdfs/final_billionton_vision_report2.pdf

From DOE GTL Bioenergy Roadmap



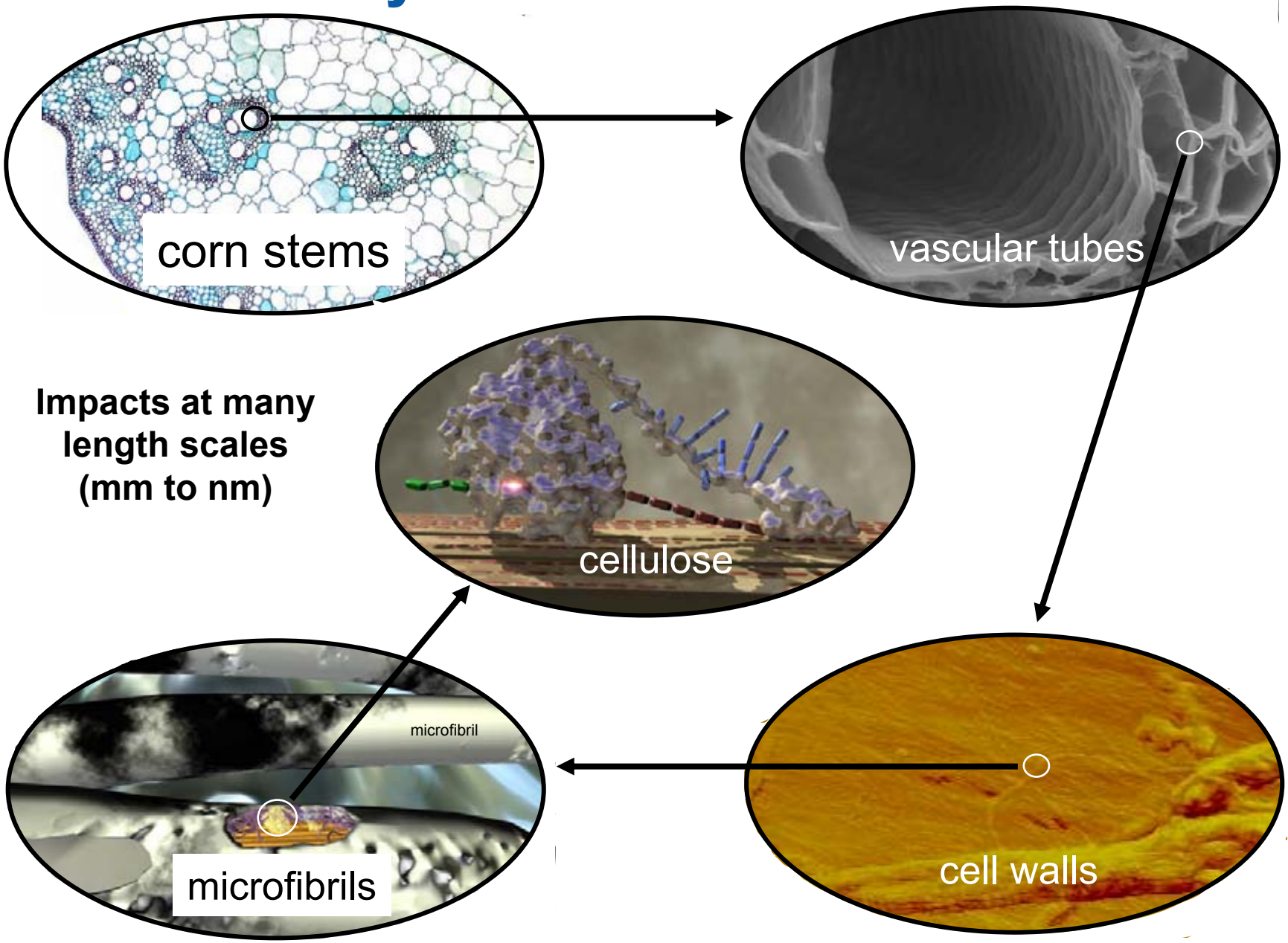
Feedstock Engineering

- Increase crop production (agronomics and plant engineering)
- Increase composition of desirable polysaccharides (cellulose)
- Decrease composition of undesirable polymers (lignins)



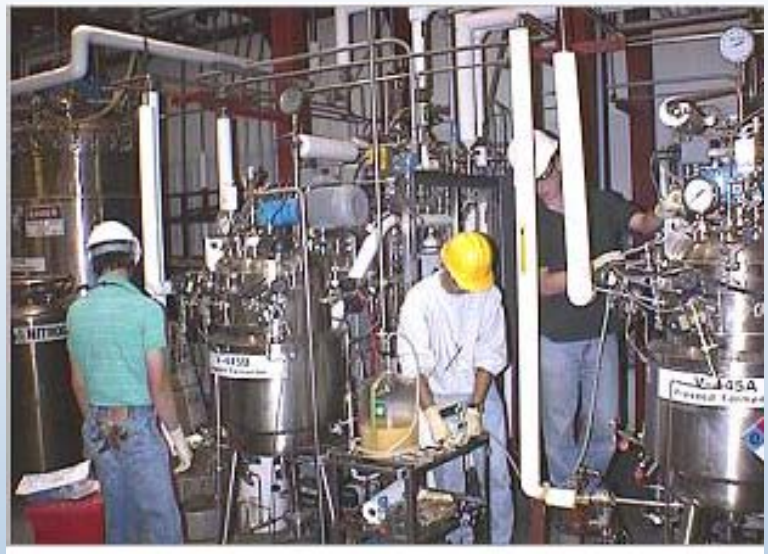
NREL “Corn Stem Tour”

Summary: Biomass Recalcitrance



Challenges in Biomass Sugar Fermentation

- Must ferment all biomass sugars at high conversion yield
  - Glucose, xylose, arabinose, mannose, galactose (most natural yeast do not ferment xylose or arabinose)
- Must be resistant to toxic compounds present after pretreatment
  - Acids (acetate), phenols, salts, sugar degradation products
- Must be robust, able to out-compete contaminant microorganisms
- High final ethanol concentration (7% or higher)



Pilot-Scale, 5-Stage Fill and Draw Fermentation with *Z. mobilis* 31821(pZB5)

Summary and Future Outlook for Bioethanol

Challenges and barriers:

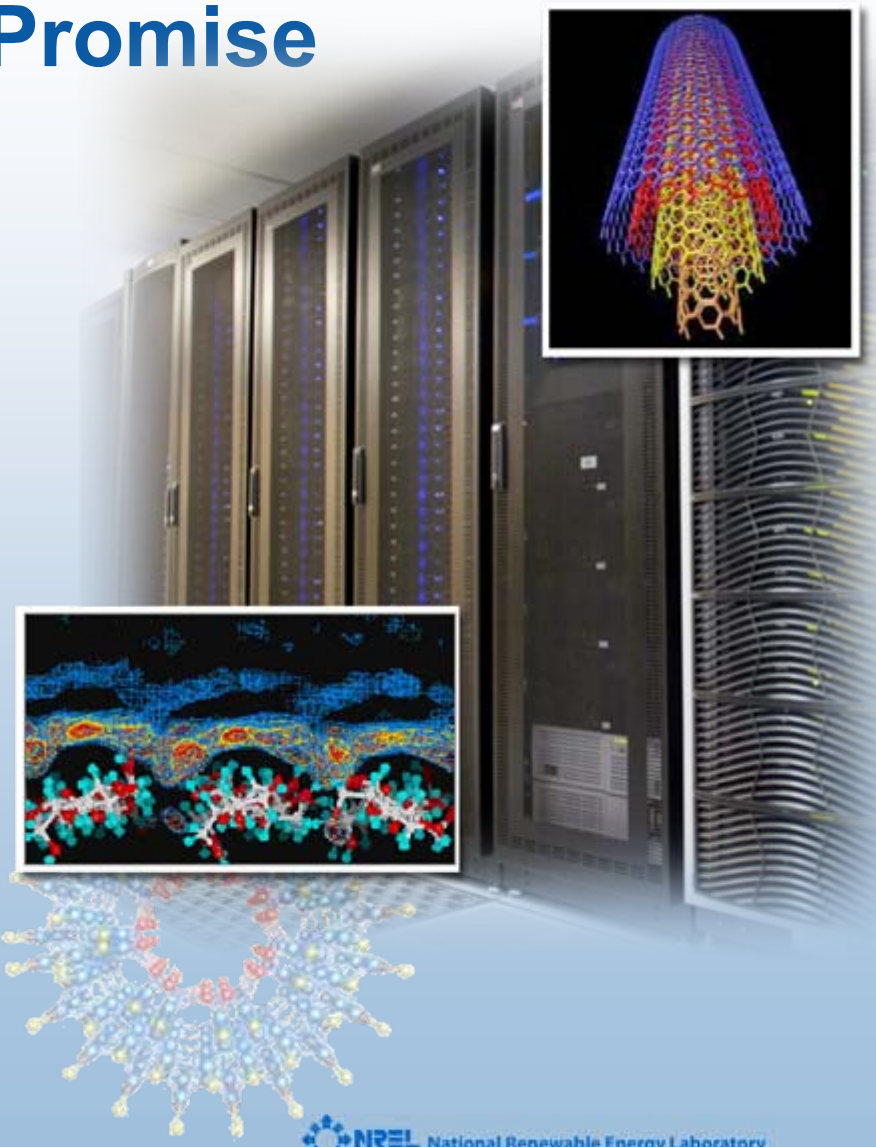
- High cost of feedstocks, biomass pretreatment, loadings of cellulase enzymes
- Inability of current fermentation strains to convert ALL biomass sugars
- Overall sugar to ethanol yields far less than theoretical
- Disagreement over “readiness” for commercialization

We need a deeper understanding of:

- Genetic controls of plant composition and ultrastructure
- Resistance of lignocellulosic biomass to deconstruction
- Structure and function of cellulases and other plant cell wall depolymerizing enzymes
- Cellular controls for multi-sugar transport and ethanol fermentation
- Cell’s mechanisms for toxicity response

Harnessing Innovation in Renewable Energy Science and Technology: The Future Promise

- Supercomputers
- Genomics
- Nanoscience
- Cellulosic and biofuels applications
- Hydrogen



Nano/Bio/Info

Renewable Energy: Getting There Involves…

Technologies
- Efficient buildings and vehicles
- New biofuels
- Clean generation
- Storage

Reducing Risk

Mobilizing Capital

Policies
- Predictable and consistent

Markets
- Infrastructure
- First plant costs
- Supplier/consumer acceptance


The U.S. Department of Energy's
National Renewable Energy Laboratory
www.nrel.gov
Golden, Colorado