

Biomass and Renewables Opportunities



The Promise of Energy Independence

Examining national policy and regional action

Secretary Cohen's Papers

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National Bioenergy Center

October 5, 2005

Major DOE National Laboratories

Operated for the U.S. Department of Energy by
Midwest Research Institute • Battelle



Nuclear Security

Science

**Energy Efficiency and
Renewable Energy**

Nuclear Energy

Fossil Energy

National Renewable Energy Laboratory

- Only national laboratory ***dedicated*** to renewable energy and energy efficiency R&D
- Research spans fundamental ***science*** to ***technology*** solutions
- ***Collaboration*** with industry and university partners is a hallmark
- Research programs ***linked*** to market opportunities



River Valley Biorefinery Consortium



MOU Signing Maine Organizations/NREL

Witnessed by the Maine Delegation Visitors to NREL

March 22, 2004



Outline

- Brief Biomass and Bioenergy History
1973-2000
- 2000 - 2005
- The Future of Renewable Energy

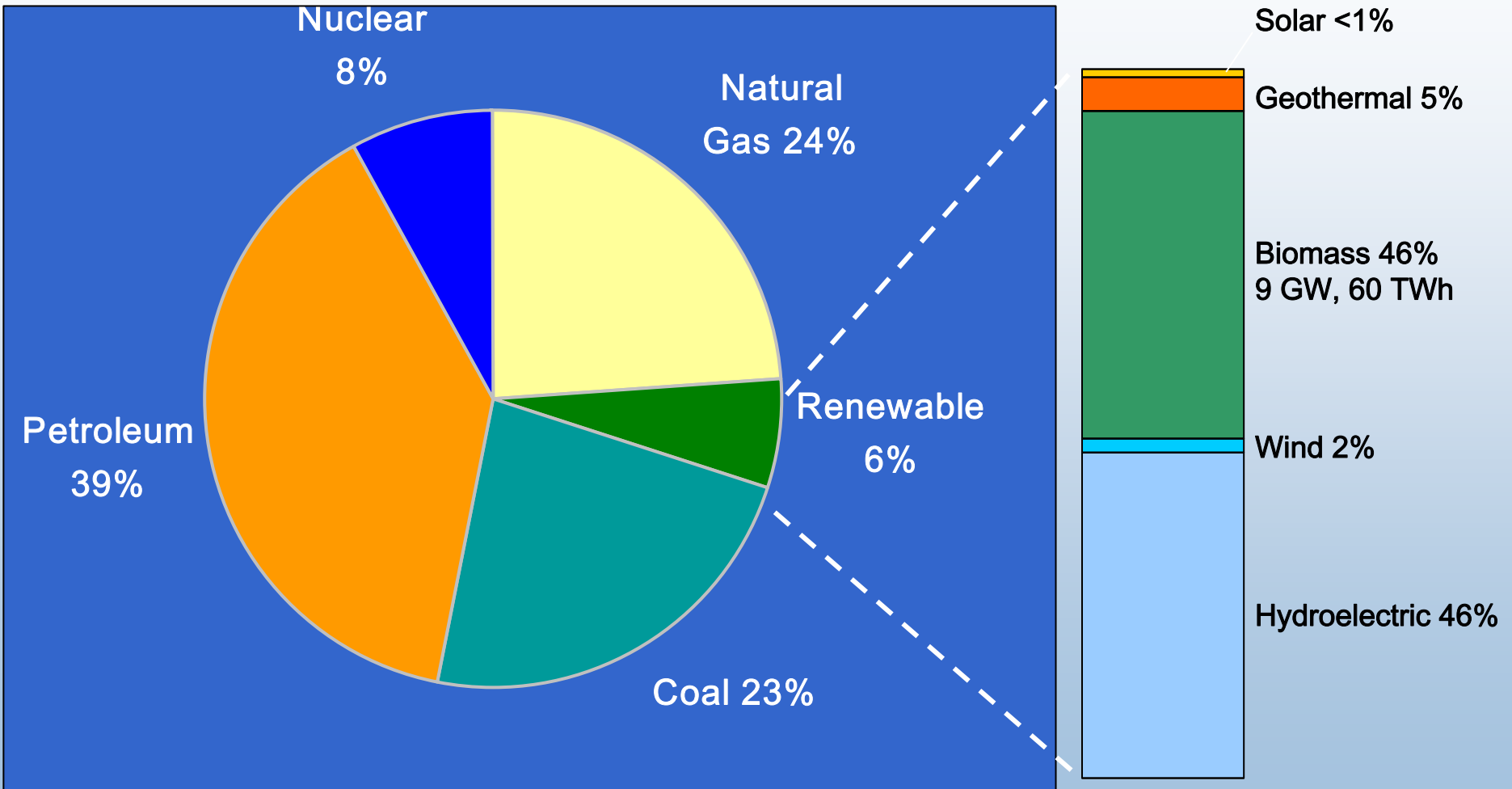
Secretary Cohen's statements 1973-1975

- “The era of cheap, abundant oil is over, and the sooner we accept this fact, the sooner we can get on with the task of developing *alternative energy sources*” – 1973
- “...the crux of the energy challenge confronting us revolves around not only recognizing, but *reconciling multiple concerns* of environmental quality, economic development, and national security” - 1975

Equally valid in 2005 - but technology, markets, and policies made progress

Renewable Share of U.S. Energy Supply

(data for 2003)

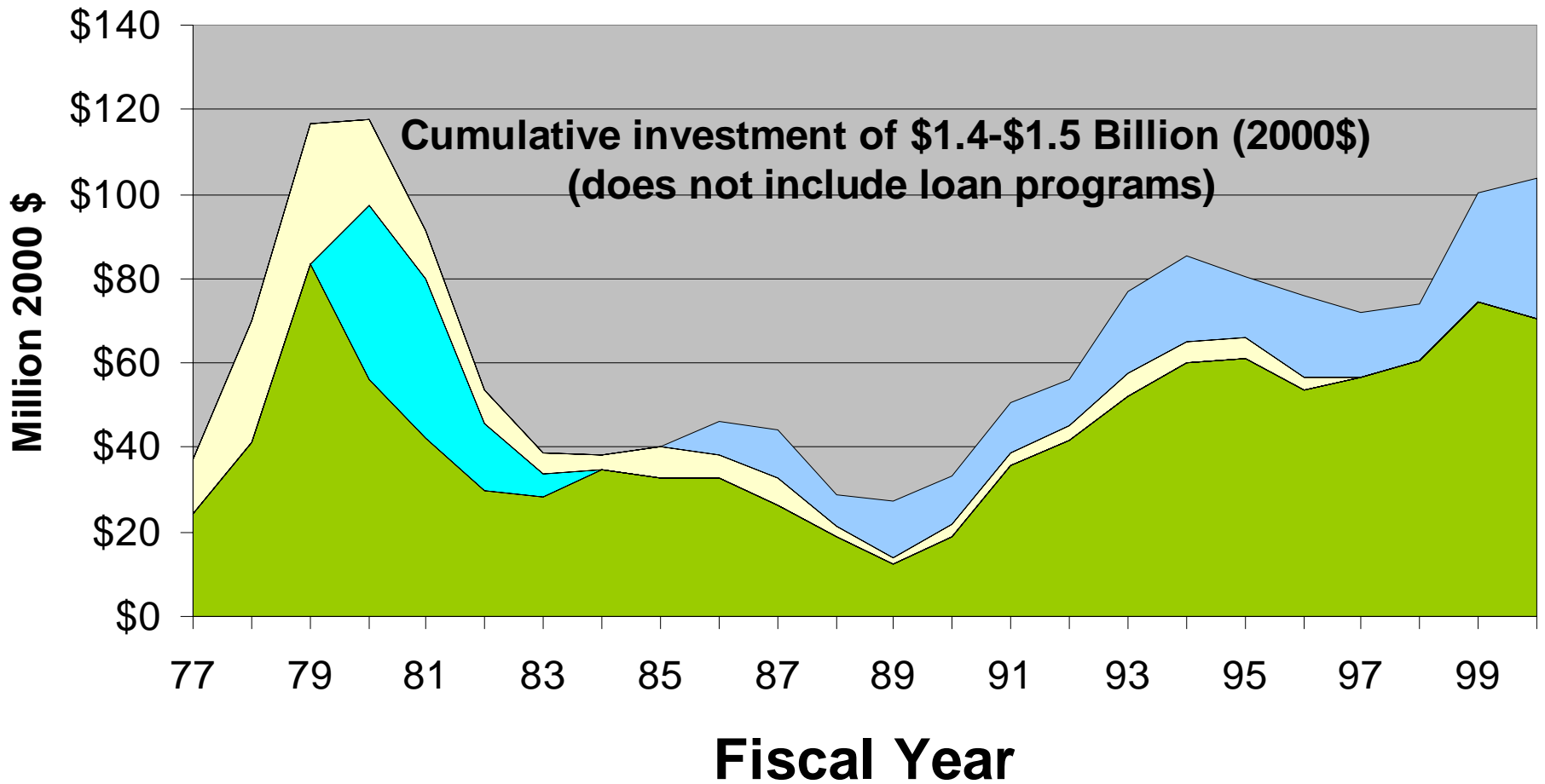


Source: AEO 2004 tables (released in December 2003) based on US energy consumption. Overall breakdown Table A1 (Total Energy Supply and Disposition), and Renewable breakdown Table A18 (Renewable Energy, Consumption by Section and Source).

Reference

- Chum, H. L.; Overend, R. P. (2003).
- Chapter 3: Biomass and Bioenergy in the United States.
- Goswami, D. Y., ed.
- Advances in Solar Energy: An Annual Review of Research and Development, Volume 15.
- Boulder, CO: American Solar Energy Society, Inc. (ASES); pp. 83-148

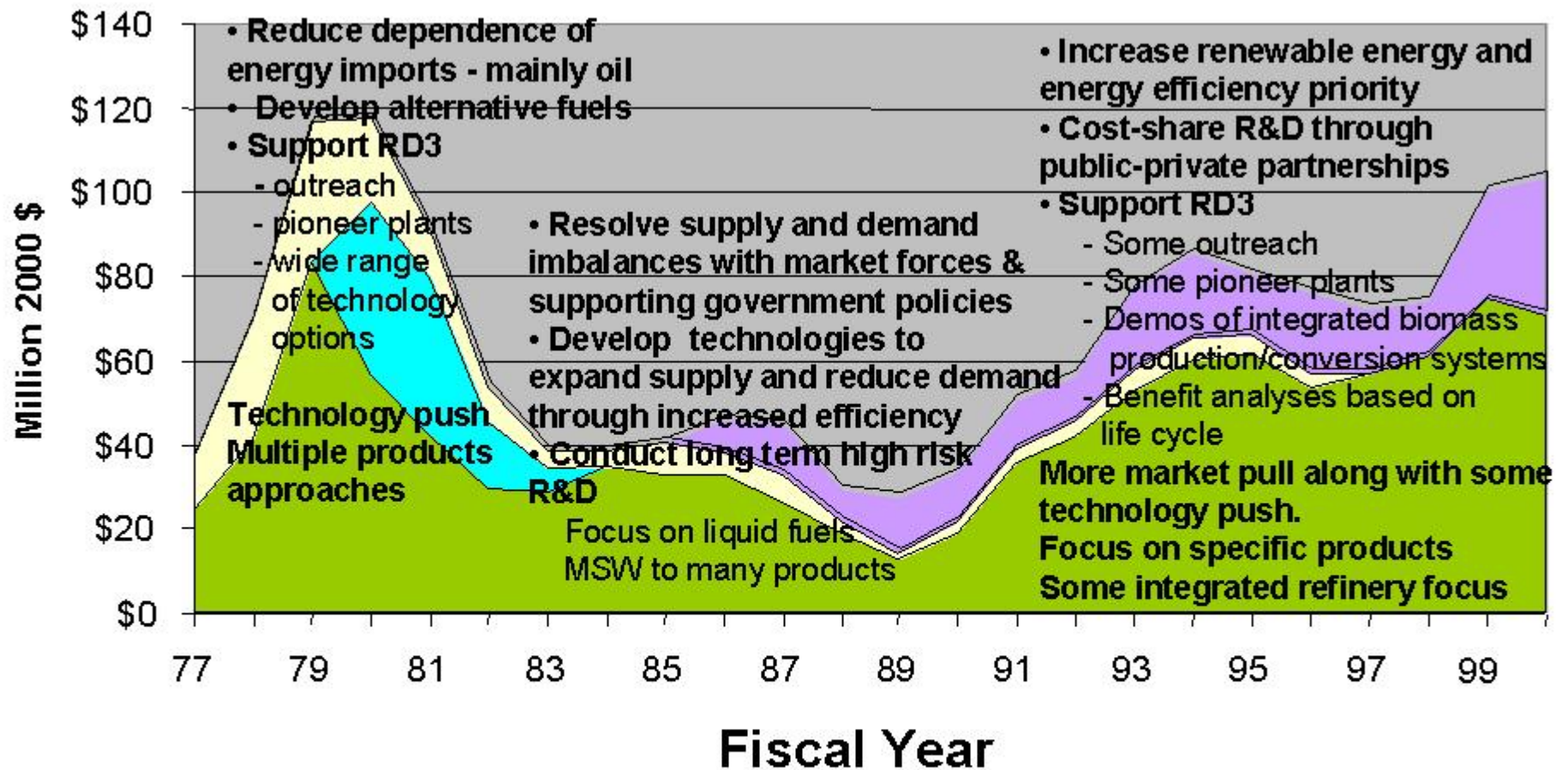
DOE Bioenergy and Biobased Products



- Biobased Products - includes Forest Products and Agriculture (Interior)
- Energy from Municipal Waste-EMW (Interior and E&W)
- Alcohol Fuels R&D & Market Development
- Biomass, Biofuels, Biopower, Bioenergy (E&W)

DOE Bioenergy and Biobased Products

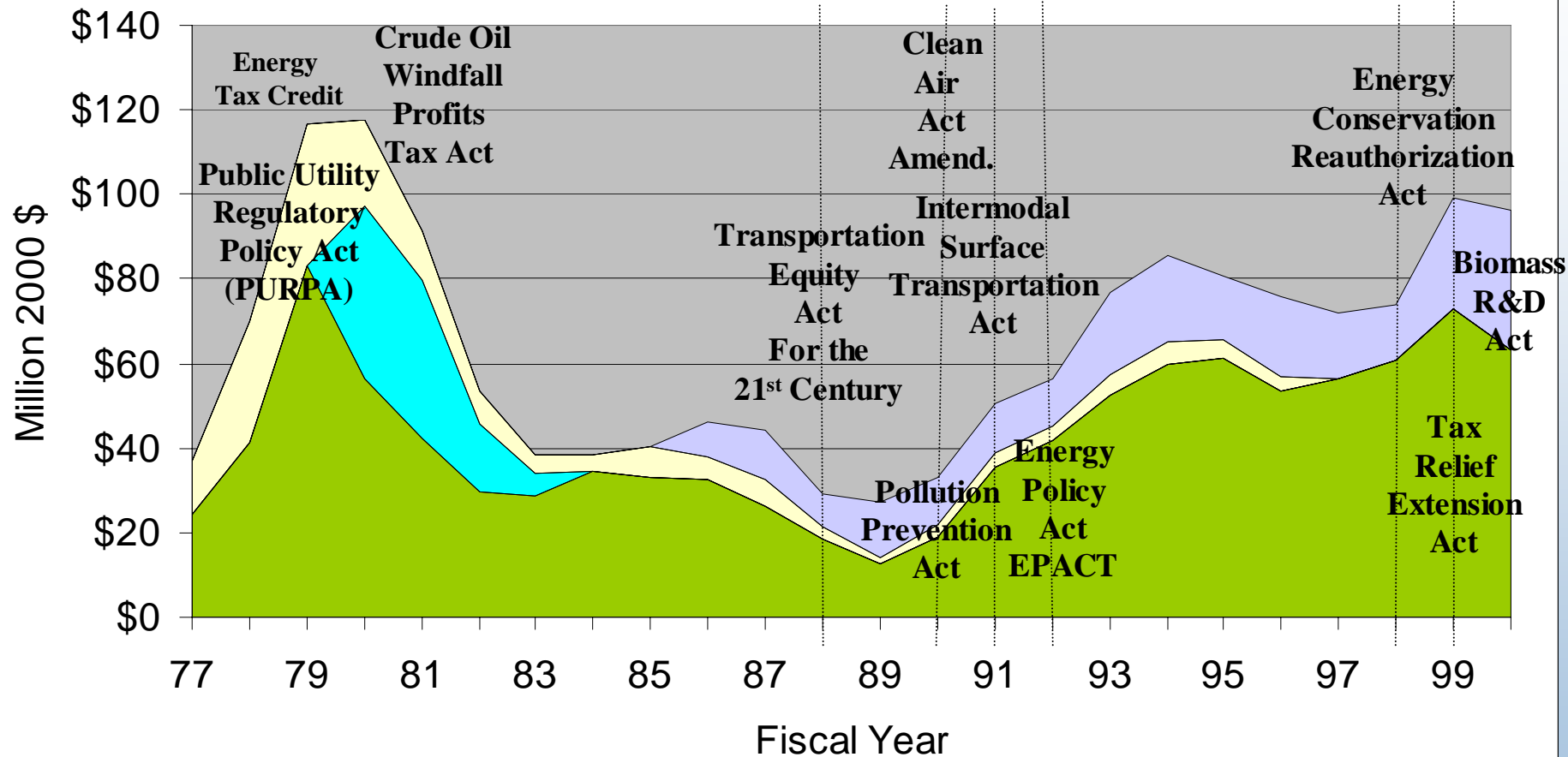
The context: key policies shifted periodically



- Biobased Products - includes Forest Products and Agriculture (Interior)
- Energy from Municipal Waste-EMW (Interior and E&W)
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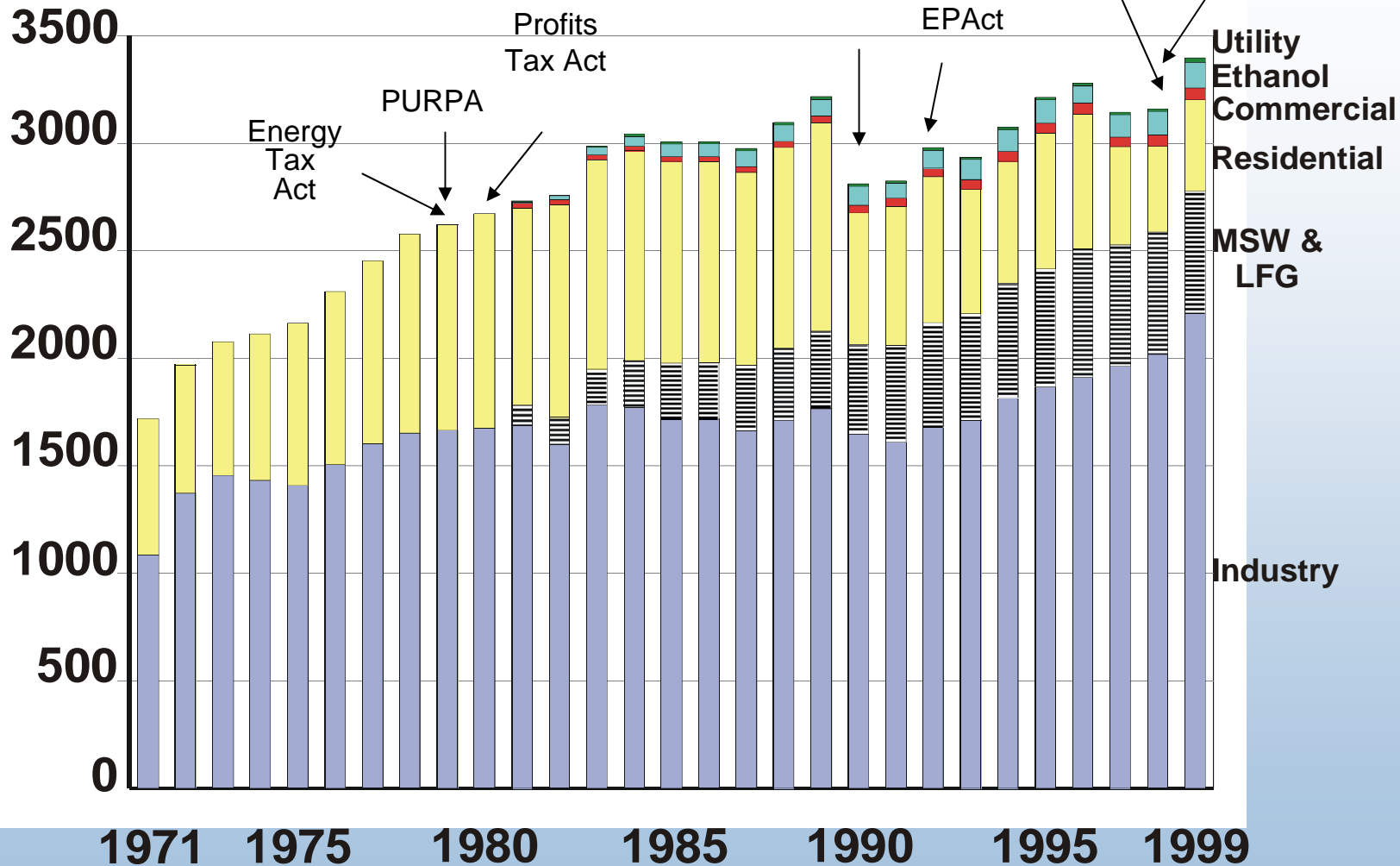
Bioenergy and Biobased Products and Key Government Regulatory and Financial Incentives (1987-2000)

President: Carter Reagan Bush Clinton



- Biobased Products - includes Forest Products and Agriculture (Interior)
- Energy from Municipal Waste-EMW (Interior and E&W)
- Alcohol Fuels R&D & Market Development
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Biomass Primary Energy
Peta 10¹⁵ Joule



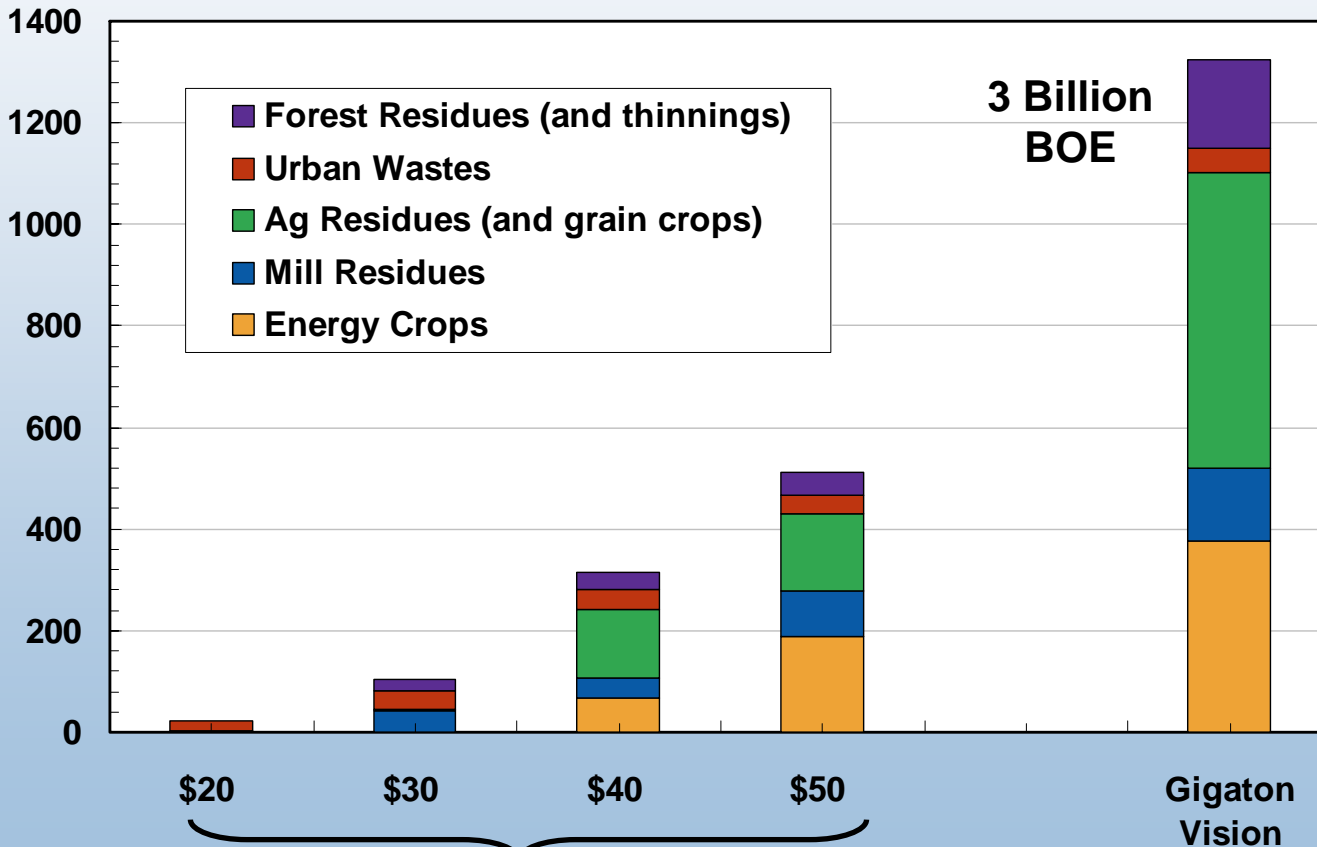
OTA (1981). Energy from Biological Processes.
Washington, D.C., Congress of the United States,
Office of Technology Assessment: p 113.
EIA (2000). Renewable Energy Annual 1999.
DOE/EIA 0603(99) Washington D.C., USA, 117.

Year
1000 Peta Joules = 1 Exa Joule = 0.95 Quads

Biomassprimary

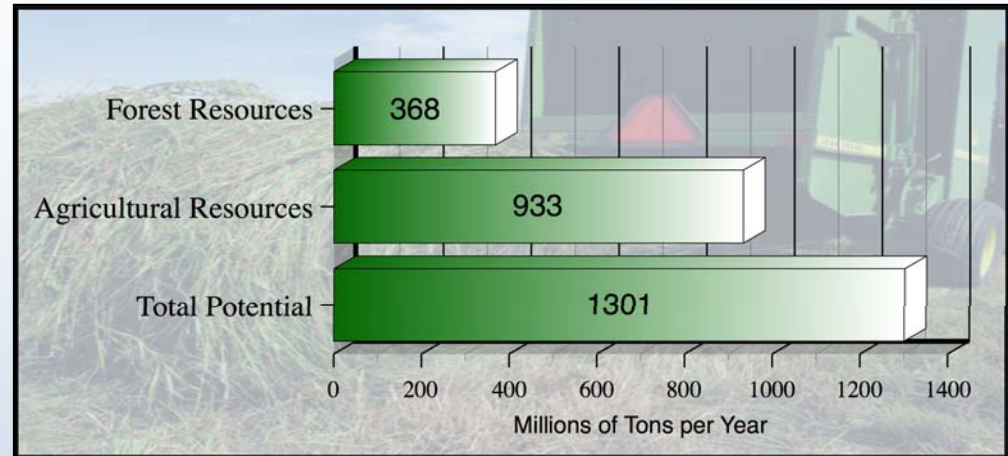
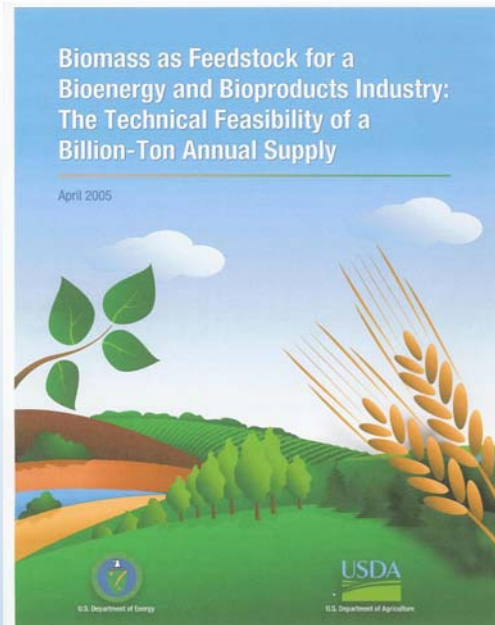
U.S. Biomass Resource Potential

•Millions dry tons per year



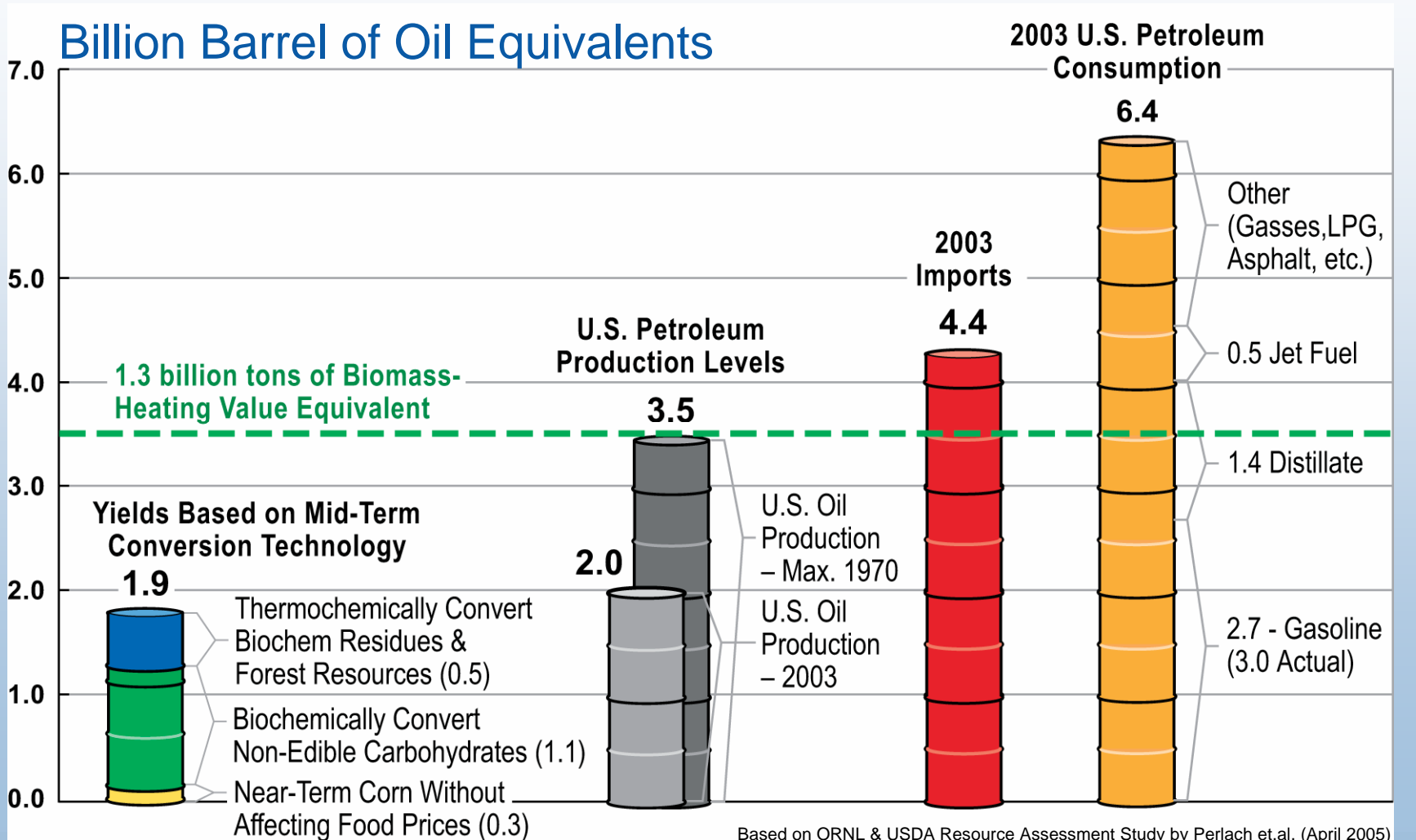
From 2000 Supply Curve by ORNL

Biomass Availability and Type



- “Billion Ton” study indicates that enough biomass is potentially available to displace > 30% of current U.S. petroleum consumption
- But it requires variety of biomass types
 - Agricultural lands
 - Corn stover, wheat straw, soybean residue, manure, switchgrass, poplar/willow energy crops, etc.
 - Forest lands
 - Forest thinnings, fuelwoods, logging residues, wood processing and paper mill residues, urban wood wastes, etc.

The 1.3 Billion Ton Biomass Scenario



Today's Options

- **Ethanol**

- Primarily produced from corn (U.S.) and sugar cane
- Most use as 10% blends in U.S.
- All vehicles compatible

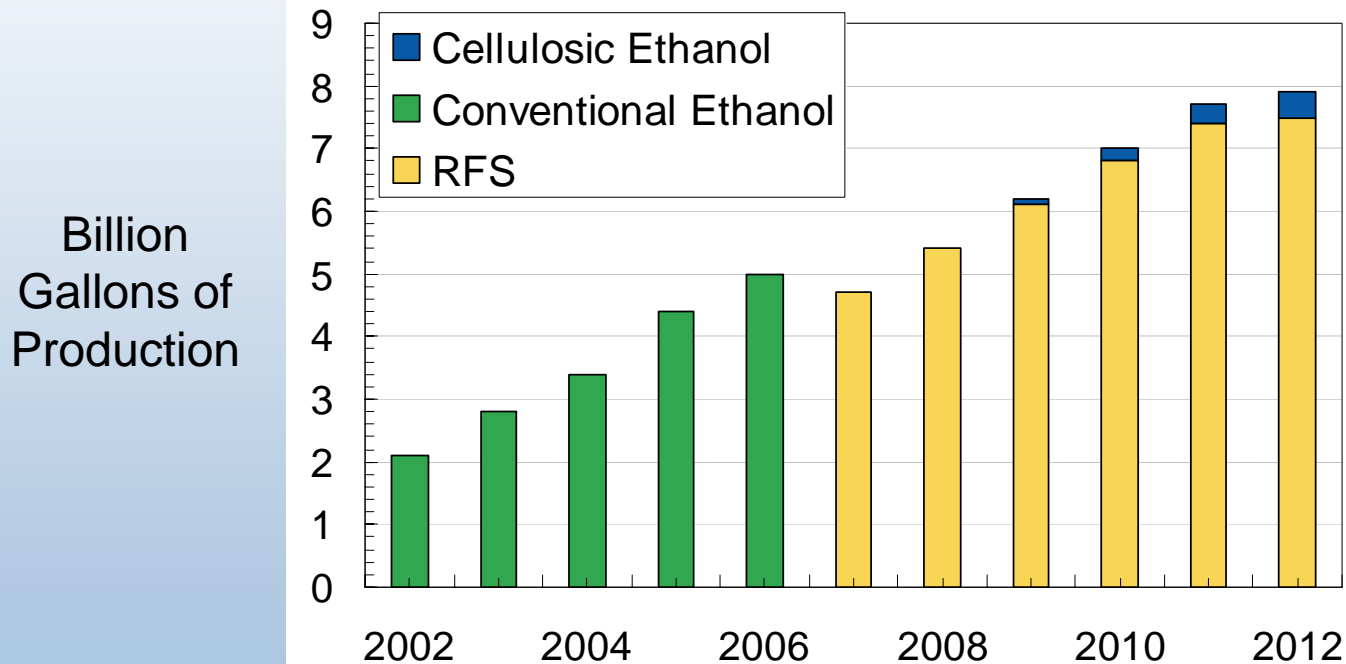
- **Biodiesel**

- Primarily produced from soy (U.S.) and rapeseed
- Most use as 20% blends in U.S.
- Research to insure compatibility ongoing
 - But all vehicles are compatible with 5% blends

Energy Policy Act of 2005

Ethanol Production

Actual and Projected U.S. Ethanol Production
2002 - 2012

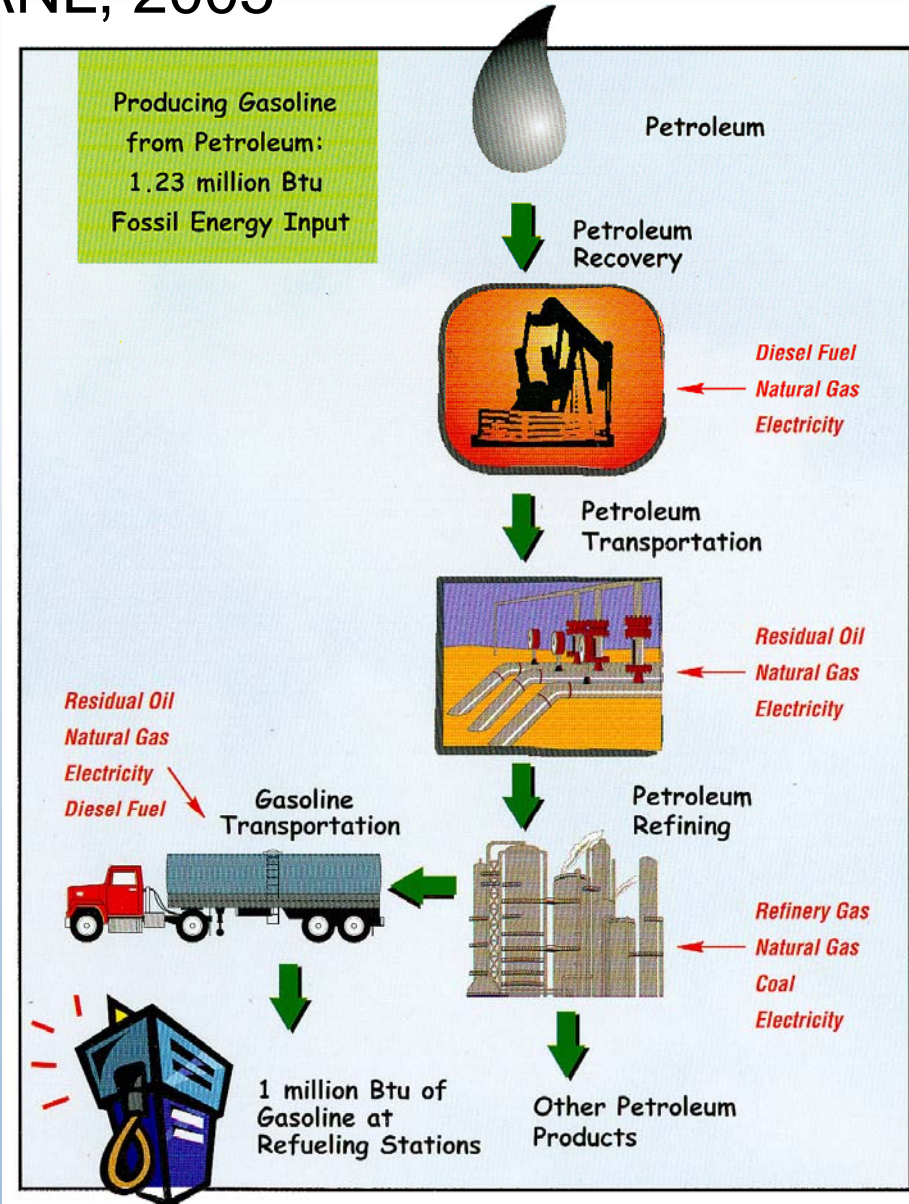
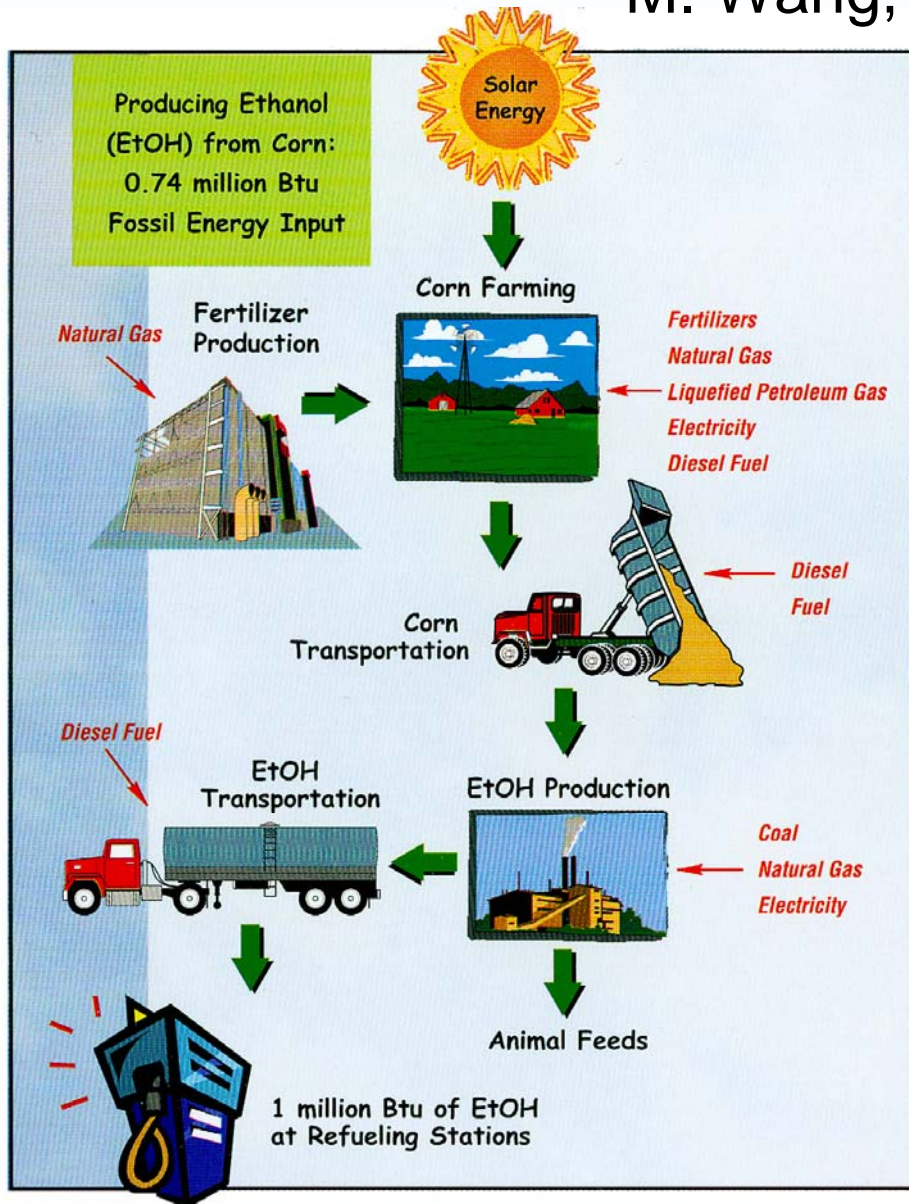


- Renewable Fuels Standard mandates 7.5 billion gallons by 2012
- Total US gasoline market ~140 billion annual gallons

Ultimate Potential of Ethanol

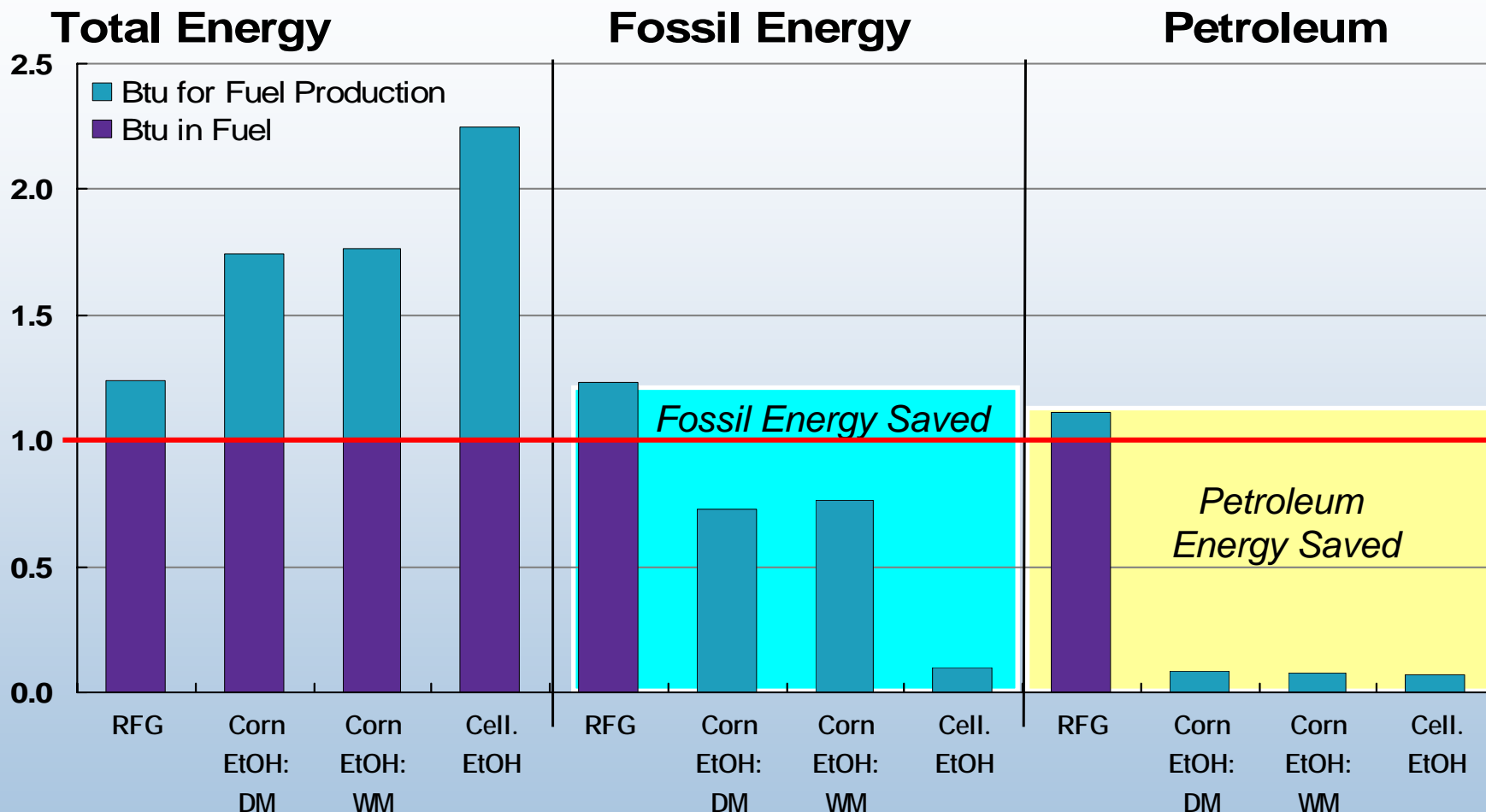
- On track to use 10% ethanol in all US gasoline
- Main barriers are ethanol transport and distribution
- Higher volumes might be produced from lignocellulosic biomass
- Technical barriers remain in manufacturing process
 - Utilization of larger volumes will require expanded use of E85 and flex-fuel vehicles

Ethanol: the complete energy lifecycle picture, M. Wang, ANL, 2005



Energy Required to Produce Fuels

- Total Btu spent for 1 Btu available at fuel pumps

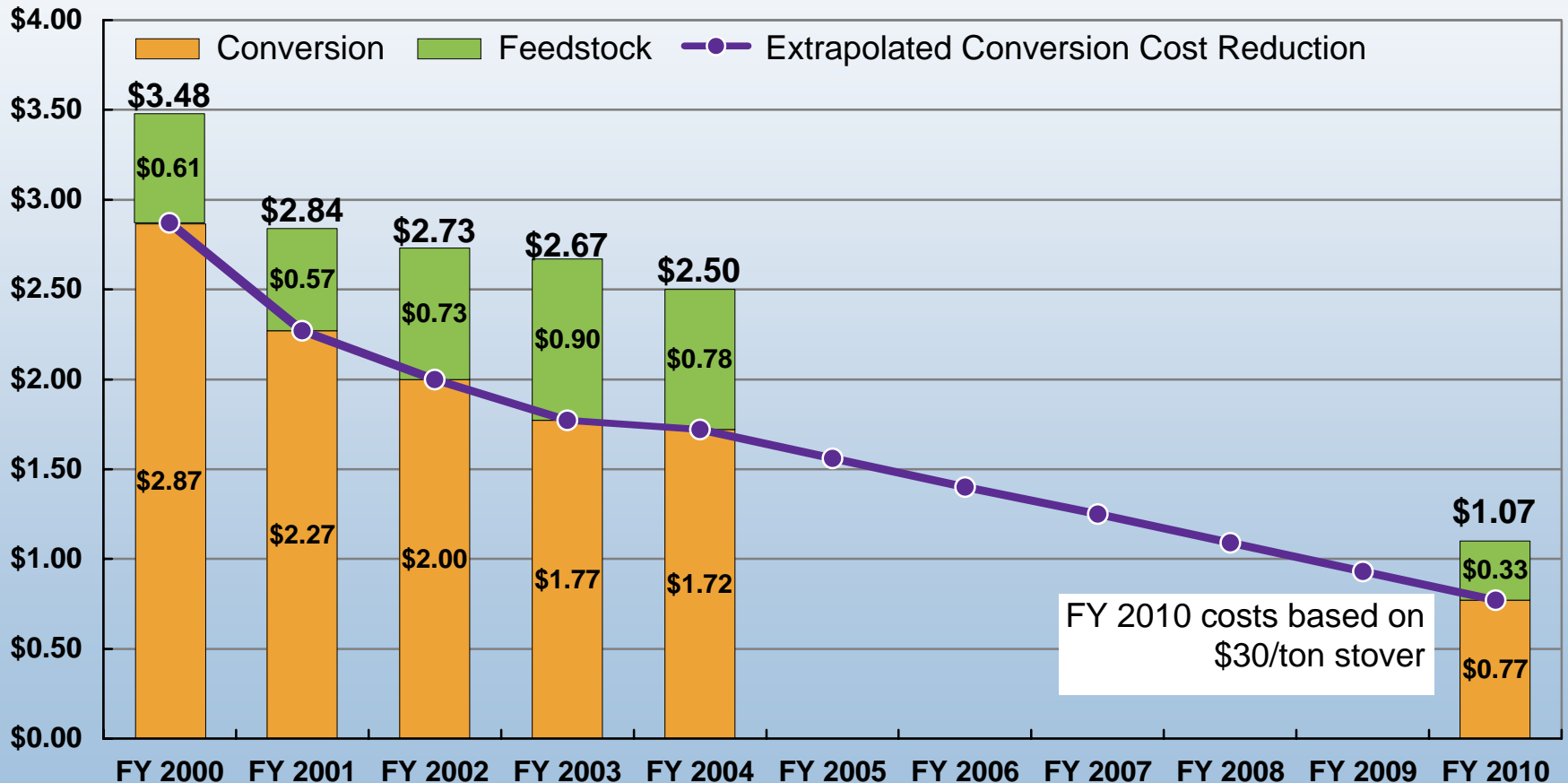


Source: Argonne National Laboratory's results from GREET simulations

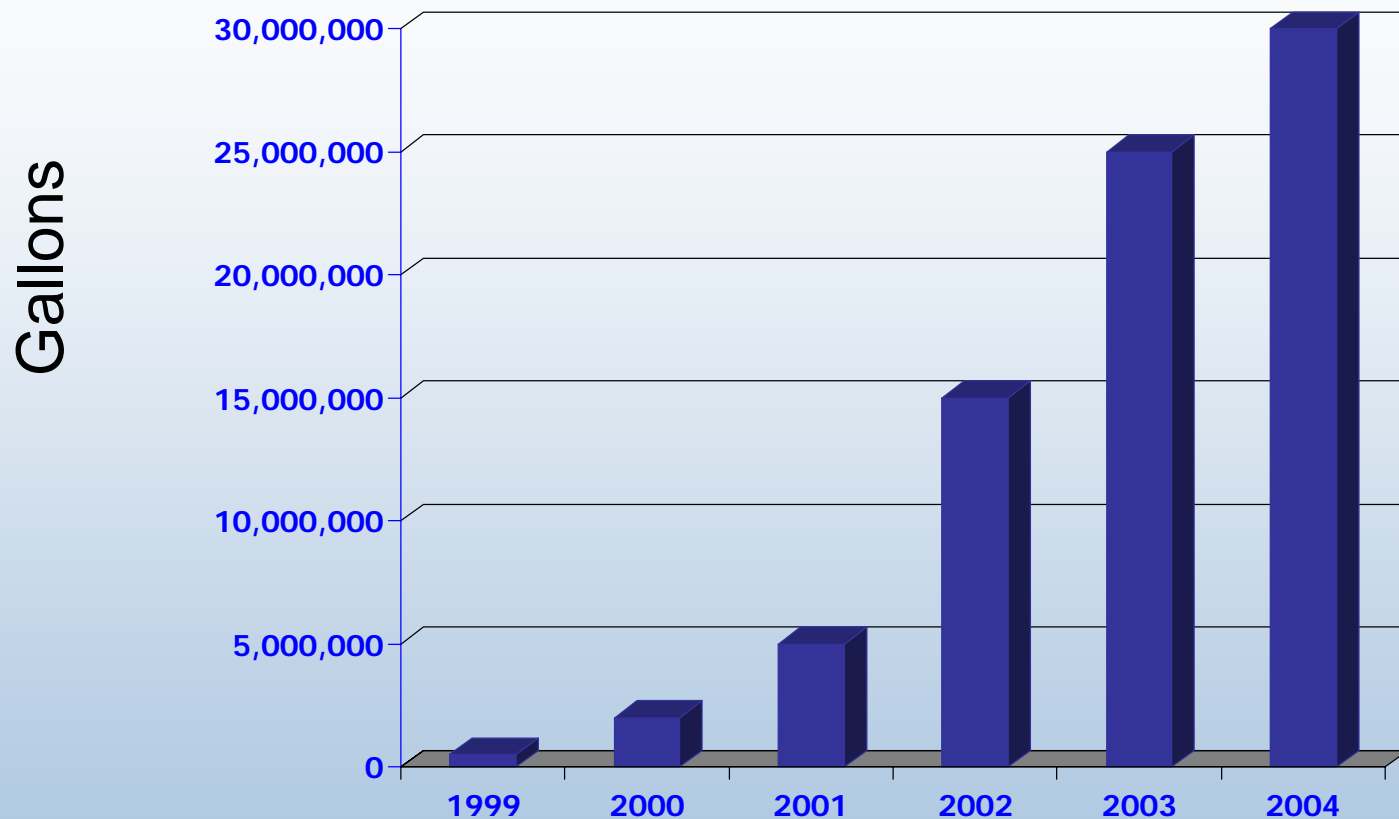
Tracking Progress in Reducing Costs

- The NBC uses Process Engineering and Economic Models

Cellulosic Ethanol Cost (\$/gallon)



Biodiesel Production



- Total US distillate fuels market ~60 billion annual gallons
- Current U.S. average rack price \$2.76/gal (versus \$2.25 for No. 2 diesel)



Fischer Tropsch Fuels
Wax
Alpha-olefins

Mixed Alcohols

Hydrogen

Syngas
 $CO + H_2$

Acetic Acid

Refineries

Ammonia

Urea

Formaldehyde

MTBE

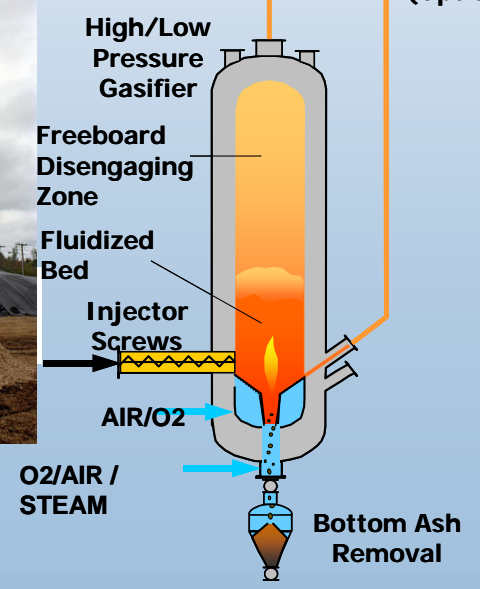
Diesel Additives

SYNGAS

Cyclone
(Optional)

Methanol

Ethanol



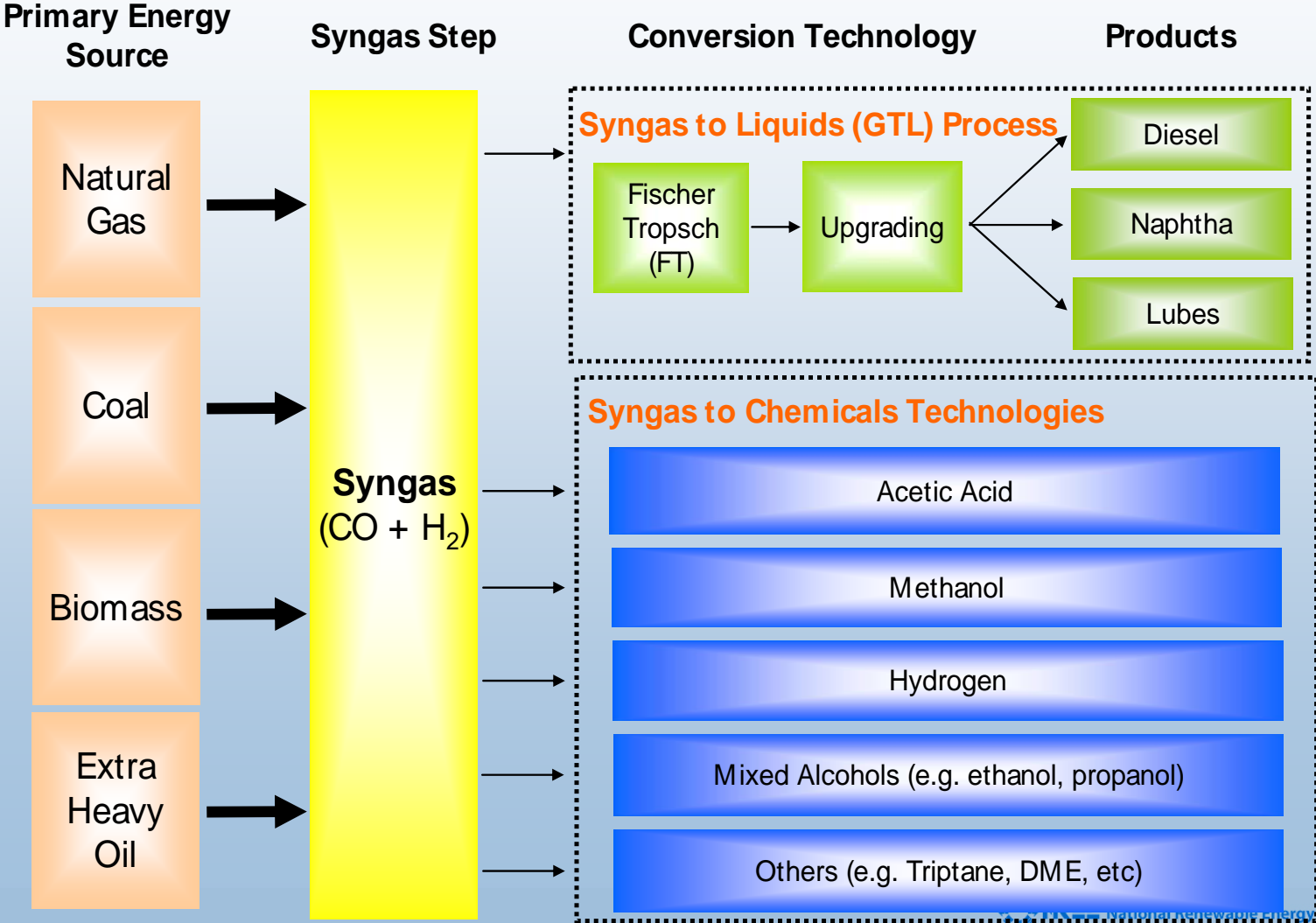
DME

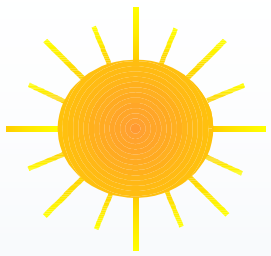
Olefins

Polyethylene
Ethylene Glycol
Alpha-olefins

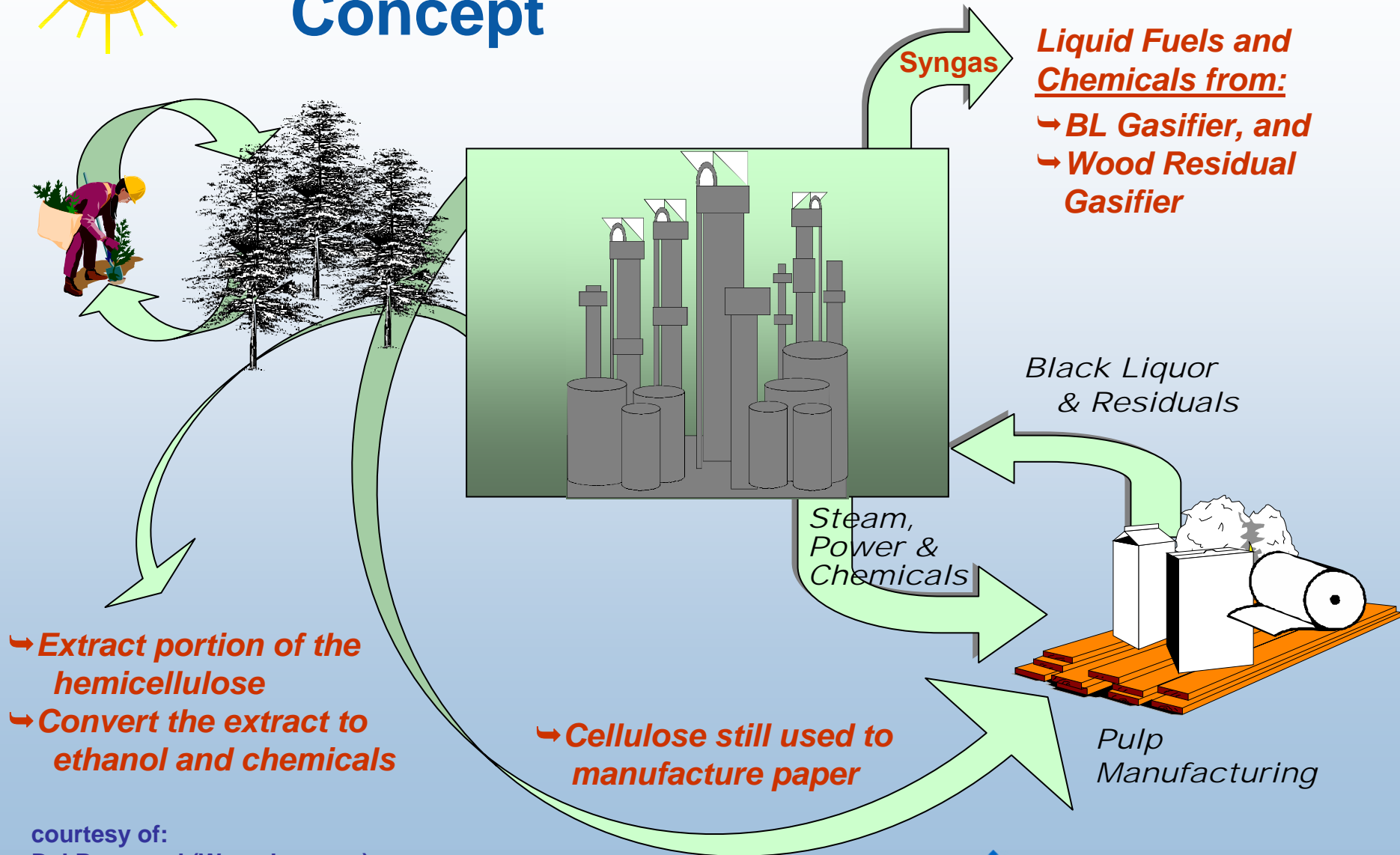
Polypropylene
Acrylonitrile

Hydrocarbon fungibility will be a key characteristic of winning technology



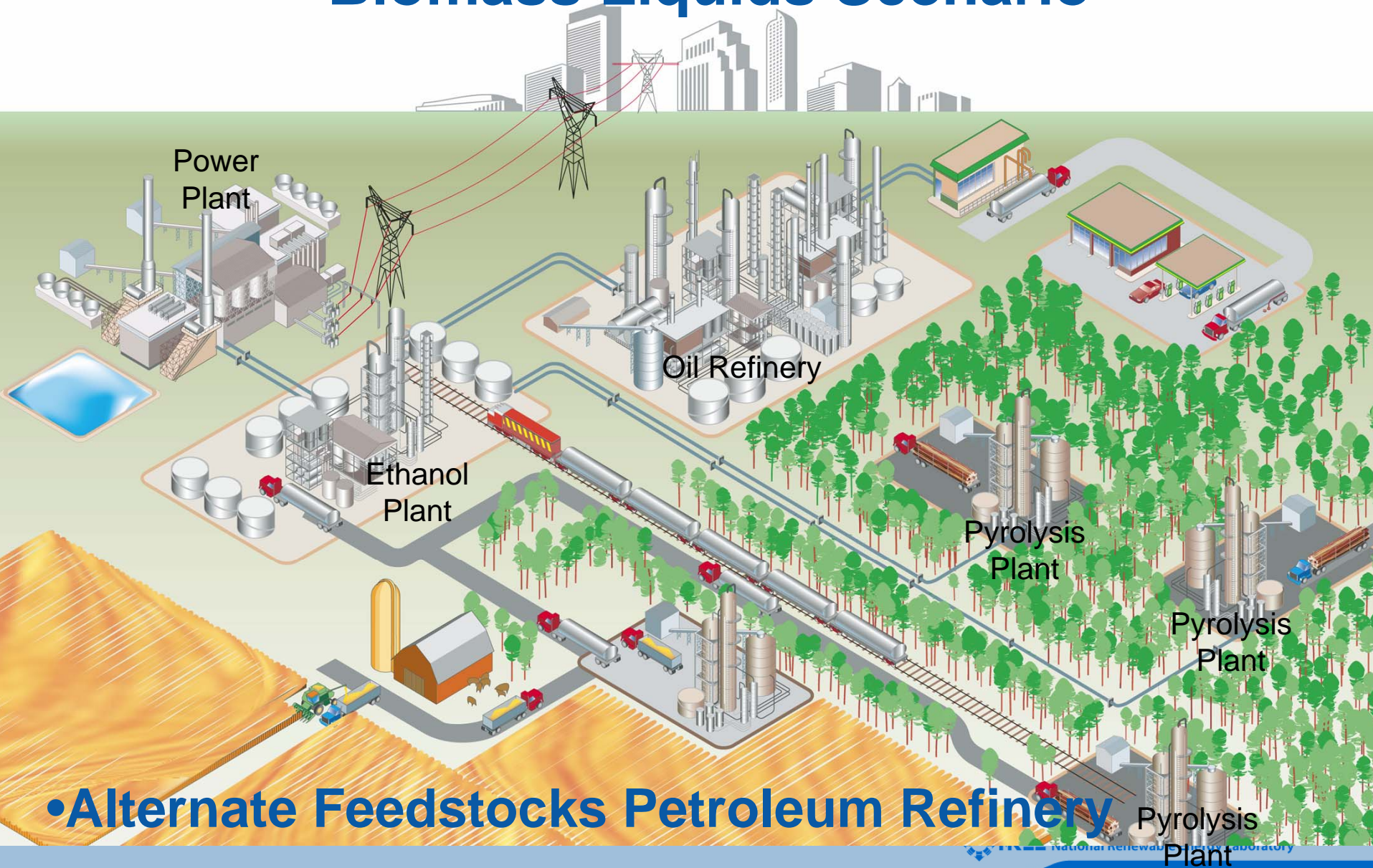


Evolving Forest Biorefinery Concept



courtesy of:
Del Raymond (Weyerhaeuser)

Evolving Decentralized Biomass Liquids Scenario



Range of Biorefinery Concepts



- Trees
- Grasses
- Agricultural Crops
- Crop Residues
- Animal Wastes
- Municipal Solid Waste



- Enzymatic Fermentation
- Gas/liquid Fermentation
- Acid Hydrolysis/ Fermentation
- Gasification
- Combustion
- Co-firing

Uses

§Fuels

- Ethanol
- Renewable Diesel
- Others

§Power

- Electricity
- Heat
- Heat and Electricity

§Chemicals

- Plastics
- Solvents
- Chemical Intermediates
- Phenolics
- Adhesives
- Furfural
- Fatty Acids
- Acetic Acid
- Carbon Black
- Paints
- Dyes, Pigments, and Ink
- Detergents
- Etc.

- Food, Feed and Fiber

Natural Disasters

U.S. Dependence on Foreign Oil

The U.S. uses more than the next 5
oil importing nations combined.

Wars

2005



Katrina & Rita

National Predicament

- Very slow renewal of existing infrastructure geared to cheap fuel
- Need to maintain security of:
 - Fuel supply
 - Generating capacity
- We have only today's technology for 2025
- Energy needs will grow

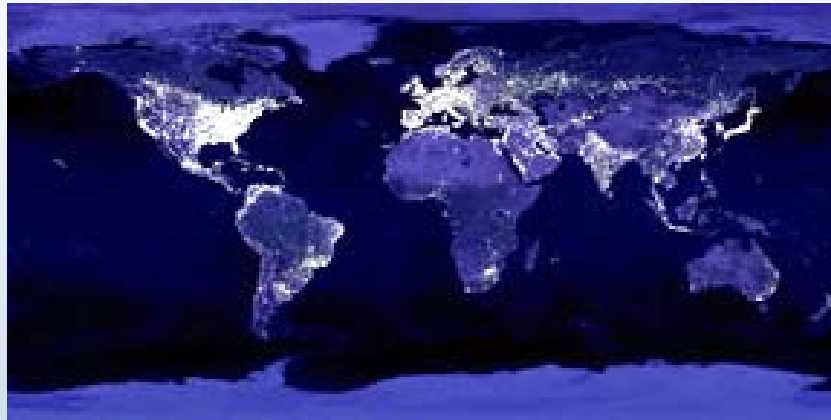
Infrastructure	Life, years
Cars	10 -15
Aircraft	20 -30
Wind turbines	25
Power plants	40+
Trains	30+
Electrical distribution	40+
Houses	70+

Source: Lord Ron Oxburgh, Royal Dutch Shell

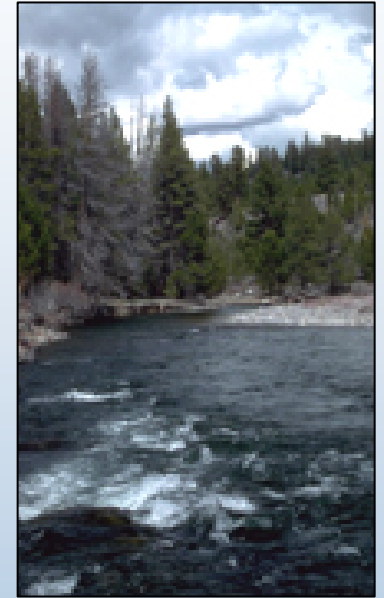
Energy Challenges are Enormous



Energy Security
and Reliability



Economic Growth

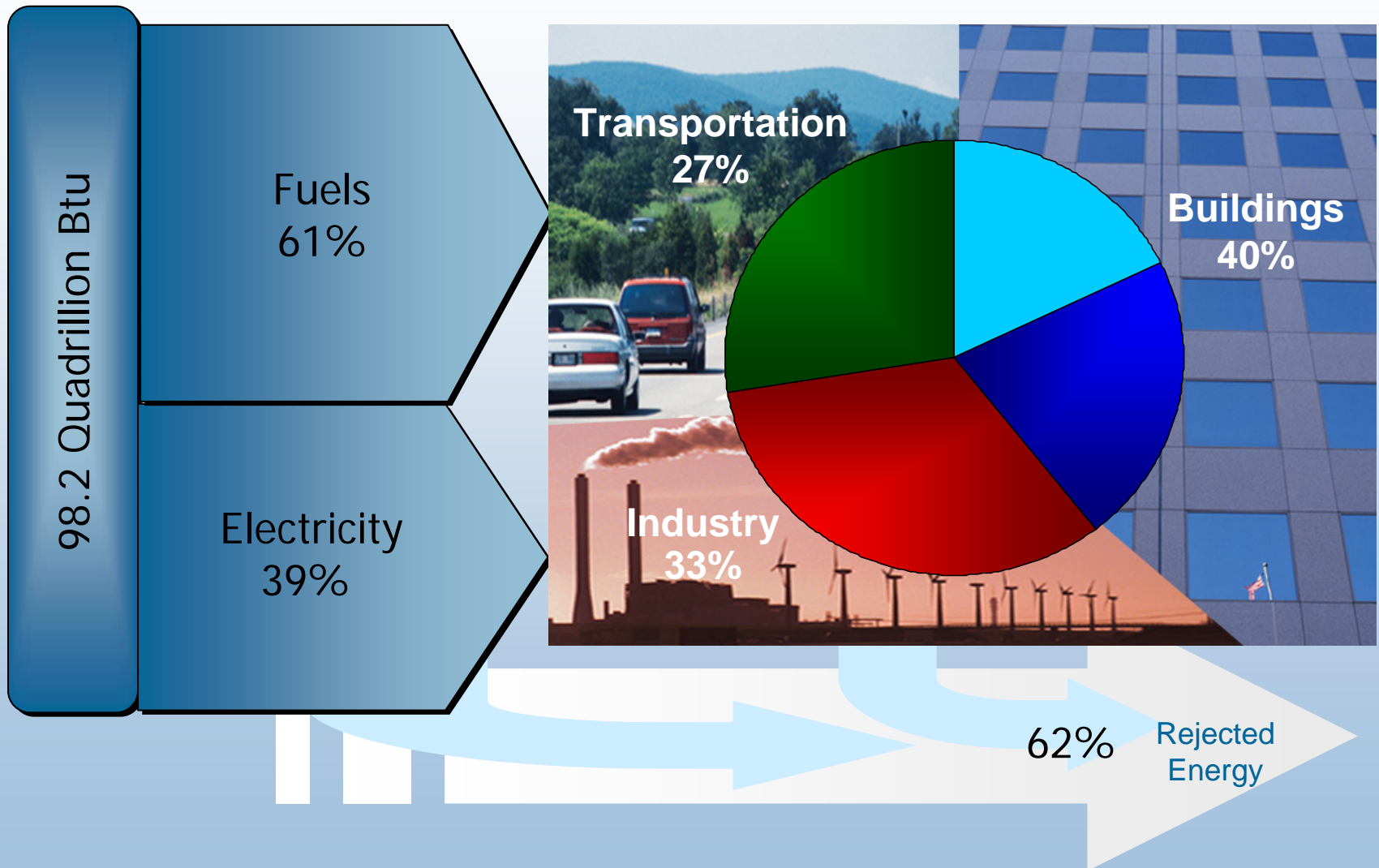


Environmental
Impact



Market Restructuring

U.S. Energy Flows



Technology-based Solutions:

There is no one silver bullet, we need many

- Energy efficiency
- Renewable energy
- Non-polluting transportation fuels
- Separation and capture of CO₂ from fossil fuels
- Next generation of nuclear fission and fusion technology
- Transition to smart, resilient, distributed energy systems coupled with pollution-free energy carriers, e.g. hydrogen and electricity



Renewable Energy Will Play a Key Role in a More Diverse and Secure Energy Supply

The Future for Renewable Energy

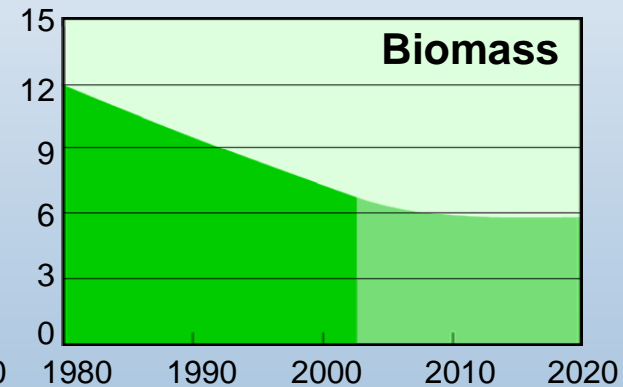
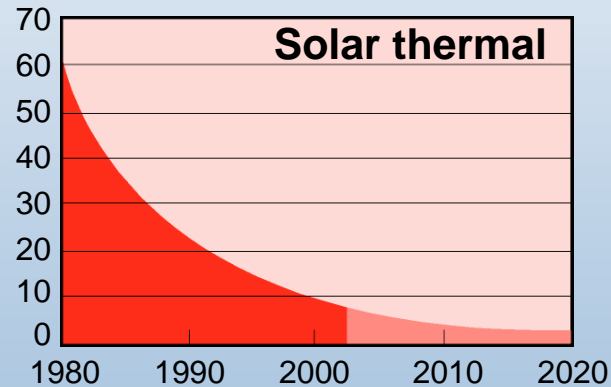
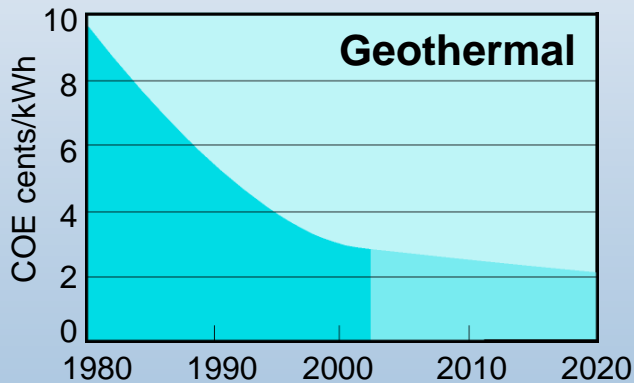
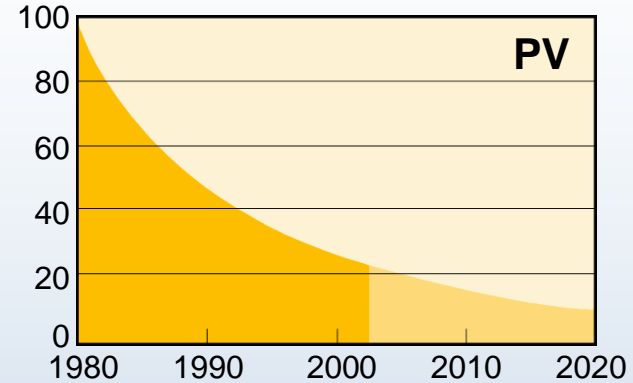
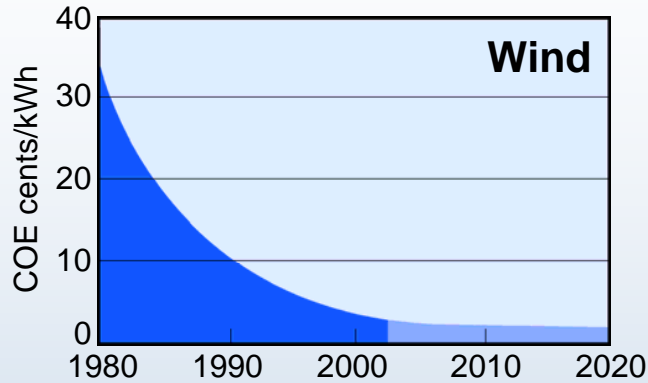
- Wind
- Solar
- Biomass

Renewable Energy Will Play
a Key Role in a More Diverse
and Secure Energy Supply



Renewable Energy Costs are Decreasing

Levelized cents/kWh in constant \$2000¹



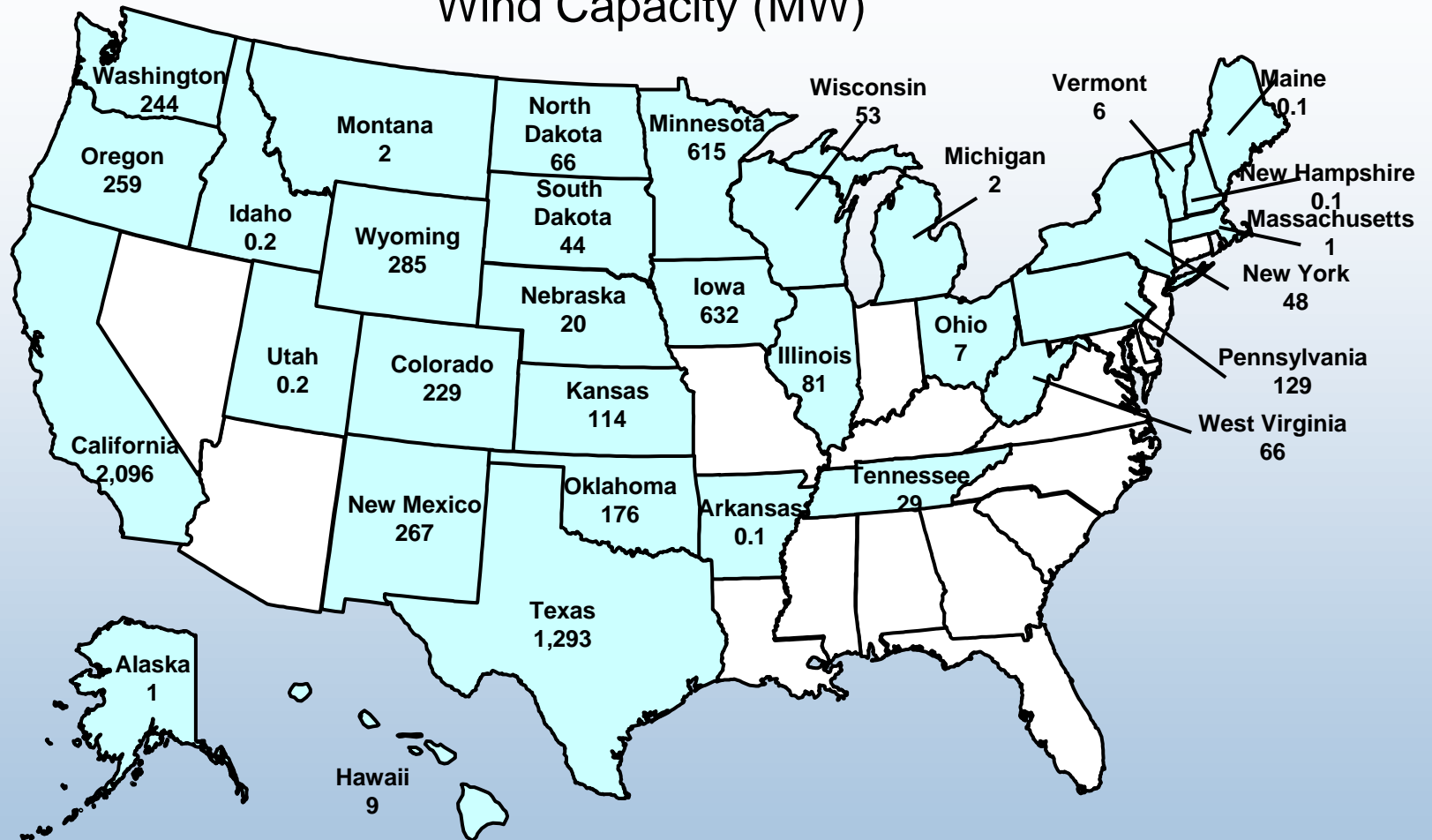
Source: NREL Energy Analysis Office (www.nrel.gov/analysis/docs/cost_curves_2002.ppt)

¹These graphs are reflections of historical cost trends NOT precise annual historical data.

Updated: October 2002

Wind Energy Status

Wind Capacity (MW)



6770 MW as of 12/31/04

Current cost is 4 to 6¢/kWh in best regimes (unsubsidized)

Solar Energy Status

- Concentrating Solar Power
 - Nine parabolic trough plants
 - 354 MW capacity
 - 12-14¢/kWh
- Photovoltaics
 - 340 MW capacity
 - Price of power from grid connected PV systems is 20 to 30¢/kWh



PV systems at the Arizona Public Service facility in Prescott, Arizona

Biomass Status

Biopower

- Grid-connected capacity
 - 9700 MW direct combustion
 - 400 MW co-firing
- Biopower electricity prices generally range from 8-12¢/kWh

Biofuels

- Biodiesel – 15 million gallons (2002)
- Corn ethanol
 - 81 commercial plants
 - 3.4 billion gallons (2004)
 - ~\$1.22/gal
- Cellulosic ethanol*
 - \$2.73/gal

* Not commercially available



Rated at 21 MW and providing the San Francisco Bay Area with baseload capacity, the Tracy Biomass Plant uses wood residues discarded from agricultural and industrial operations.

Factors Inhibiting Pace and Volume of Renewable Energy Market Entrance

- Capital mobilization
- Lack of consistent, stable policies
- Electricity pricing: valuing externalities
- Further technology advances

Mobilizing Capital: Creative Business Partnership Models

- Catalyze entrepreneurs
- Enhance strategic partnering
- Attract new corporate entrants
- Invigorate private equity/venture capital

State Policies are Opening Markets for Renewable Energy

Renewable Electricity Standards

Nevada: 15% by 2013,
solar 5% of annual

Minnesota: 19% by 2015*

New York:
24% by 2013

Maine: 30%
by 2000

Iowa: 2% by 1999

Wisconsin:
2.2% by 2011

MA: 4%
by 2009

RI: 16%
by 2019

CT: 10% by 2010

NJ: 6.5% by 2008

Maryland:
7.5% by 2019

Washington D.C.:
11% by 2022

Pennsylvania:
8% by 2020

California:
20% by 2017

Arizona: 1.1% by
2007, 60% solar

New Mexico:
10% by 2011

Texas:
2.7% by 2009

Colorado: 10% by 2015

Hawaii: 20% by 2020

★ 18 States + D.C.

Western Governors' Association Clean and Diversified Energy Initiative

- Western U.S is rich with fossil, hydro and renewable energy resources.
- Goal of 30,000 MW of clean energy by 2015, using solar, wind, geothermal, biomass, clean coal technologies and advanced natural gas technologies.
- Goal to increase the efficiency of energy use by 20% by 2020.
- Meet the West's generation and transmission needs over the next 25 years.

Create an Electricity Pricing Structure that Values Externalities

- Intangibles have value
 - Greater value if dealt with in resource planning
 - Allow a broader perspective
- Hard to quantify
 - Has been controversial
 - No accepted methodology

Wind Outlook

Technology

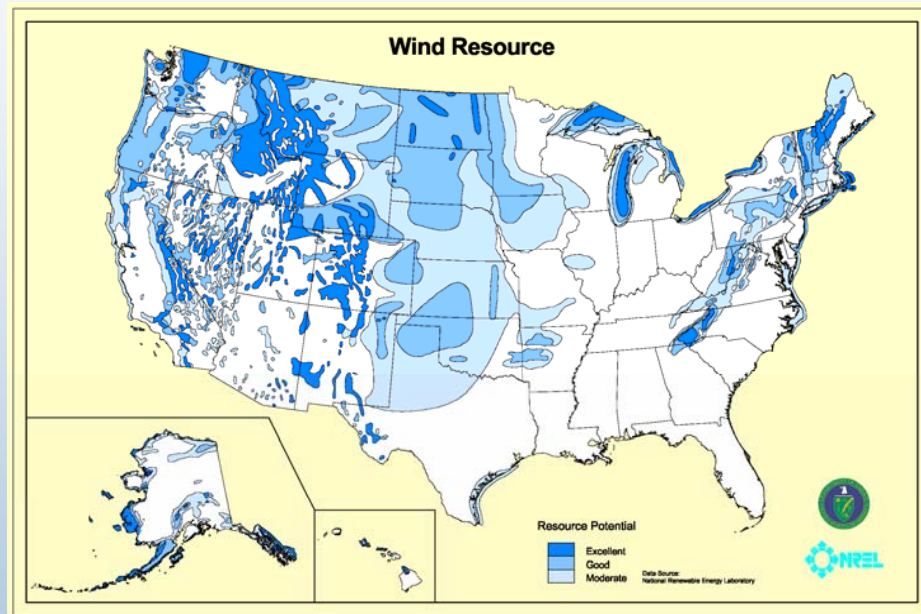
- DOE Wind Program R&D goals
 - 3¢/kWh* in class 4+ wind areas onshore
 - 5¢/kWh* for offshore systems
- New Technology will
 - Expand range of feasible sites
 - Reduce siting risk
 - Enhance system value

Policy

- State-led RPS
- Production Tax Credit

Market Drivers

- Natural gas prices
- Green purchasing



* unsubsidized

GE WindEnergy
3.6 MW Turbine

Boeing 747-200

Arklow Banks Wind Farm
The Irish Sea

Solar Outlook

Technology

DOE Solar Program goals:

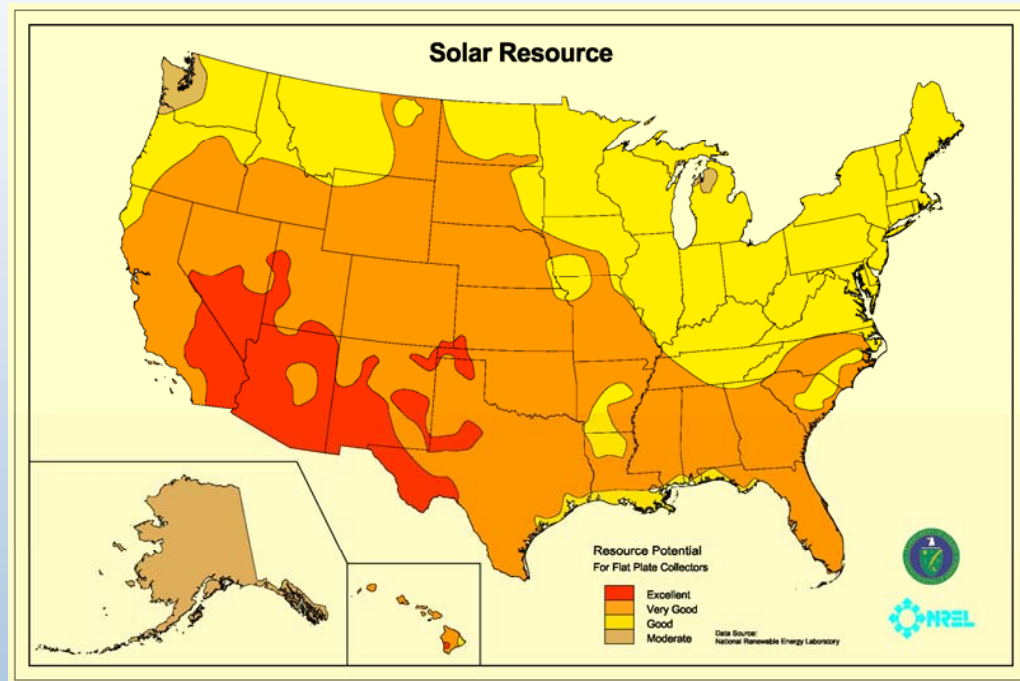
- Photovoltaics: 6¢/kWh by 2020
- Concentrating solar power/troughs: 5¢/KWh by 2012

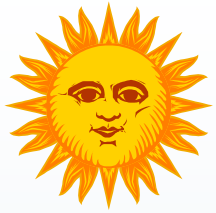
Policy

- 1000 MW initiative
- Western Governors' Association 30,000 MW by 2020 initiative
- State RPS with solar set asides

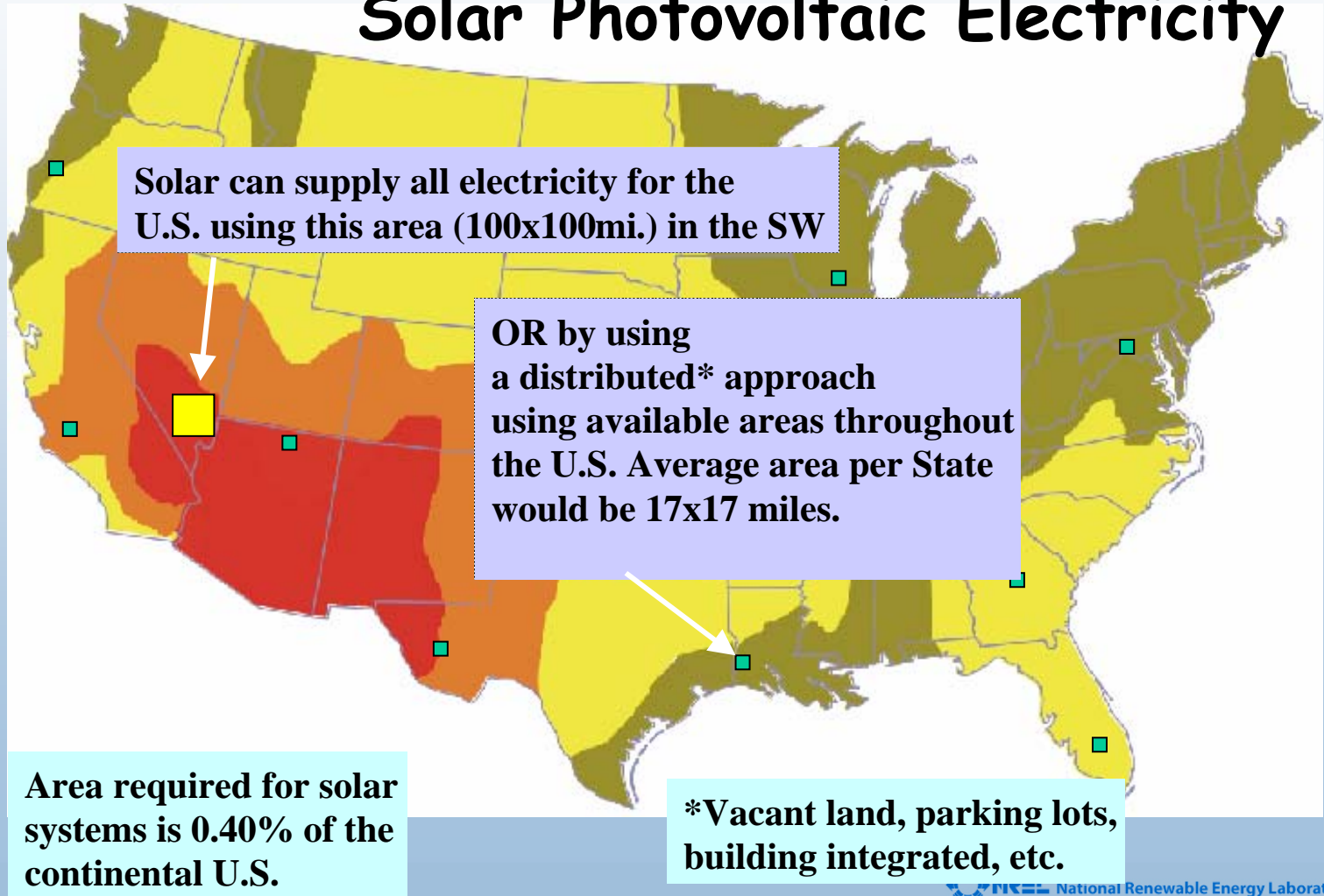
Market Drivers

- Peak power prices
- Green markets

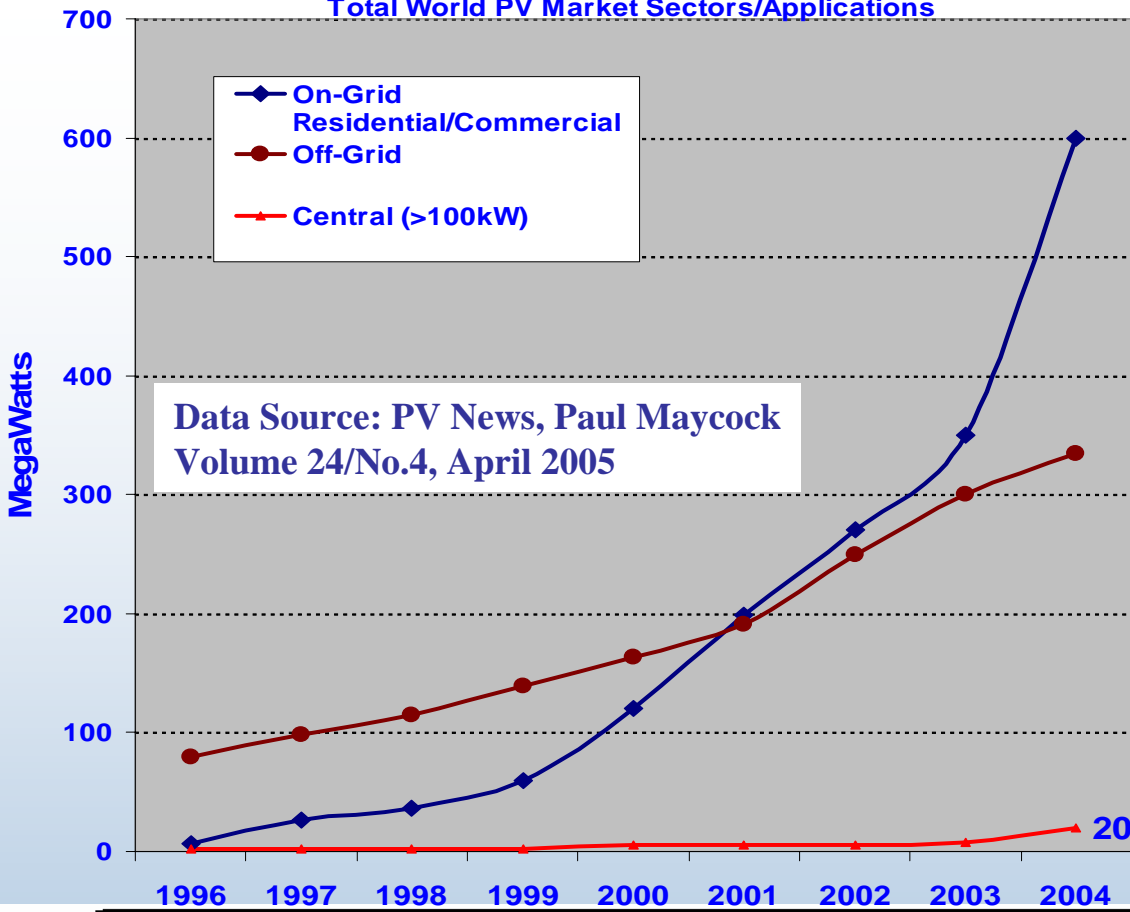




Solar Photovoltaic Electricity

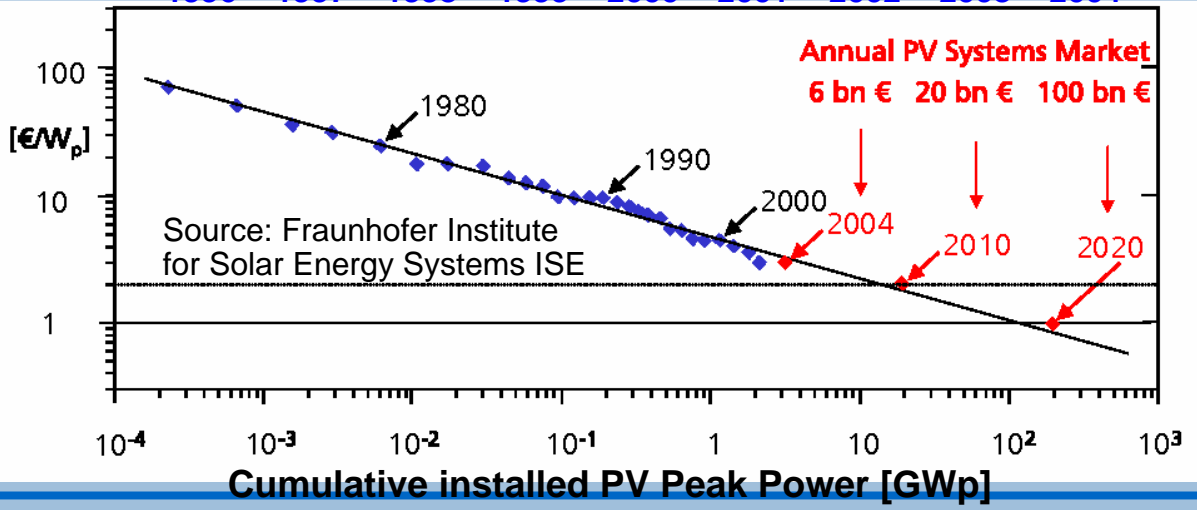


Total World PV Market Sectors/Applications



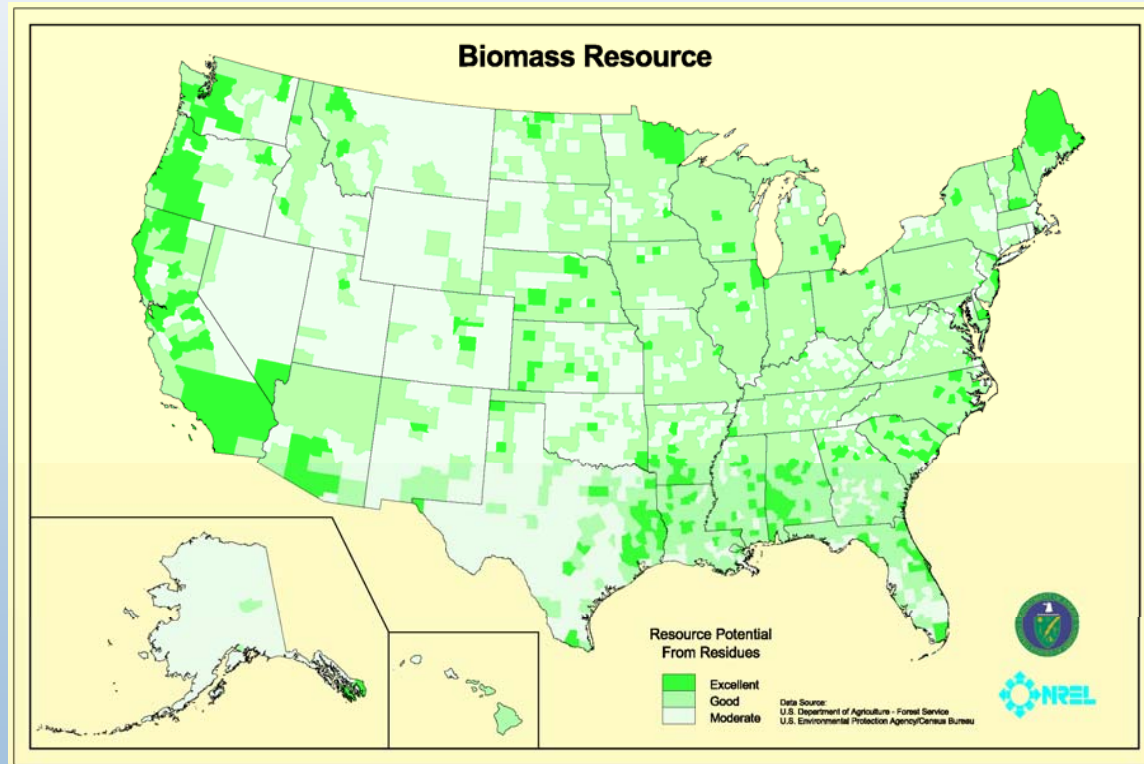
Photovoltaic Technology Penetration

and Price Experience (Learning) Curve

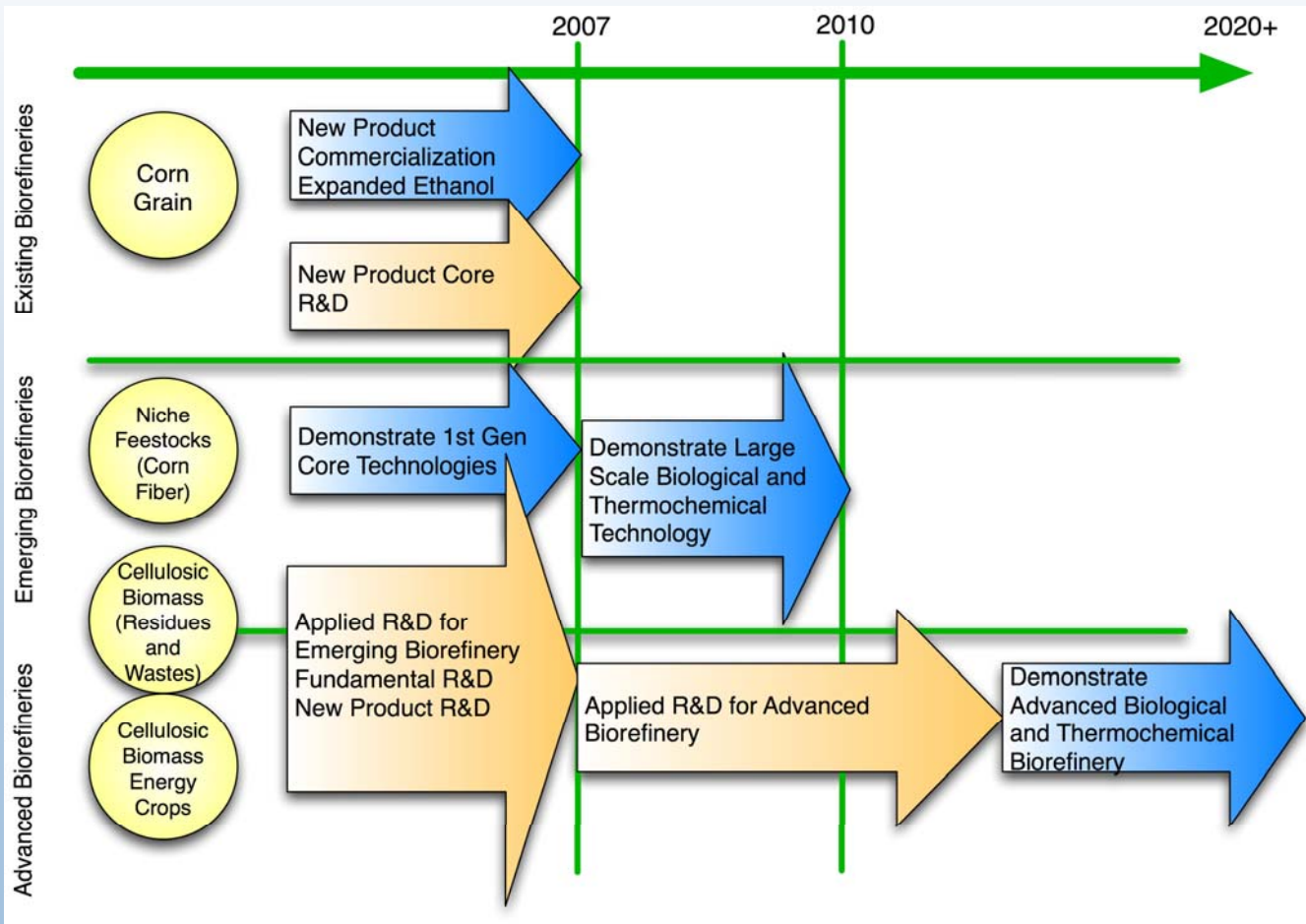


Biomass Outlook

- **Technology**
- DOE Biomass Program goals:
 - 5.5¢/kWh by 2010
 - \$1.07/gal bioethanol by 2020
- **Policy**
- 2005 Energy Policy Act created a renewable fuels standard that reaches 7.5 billion gallons/year by 2012
- **Market Drivers**
- Future outlook for crude oil prices
- Best utilization for biomass – fuels and/or electricity and/or refinery



The Biorefinery: The Path Ahead



- A diverse feedstock supply that provides 1.3 billion tons of biomass per year
- Equivalent of 2 billion barrels of crude oil per year or
- U.S. domestic petroleum production in 1970

Technologies

- High technology
- Mass production



Policies

- Incentives & mandates

Markets

- Conventional energy prices
- Green markets

The U.S. Department of Energy's National Renewable Energy Laboratory

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