

Fulfilling the Promise of Renewable Energy: A Look at the Future

Energy 2050: The Future of Renewable Energy

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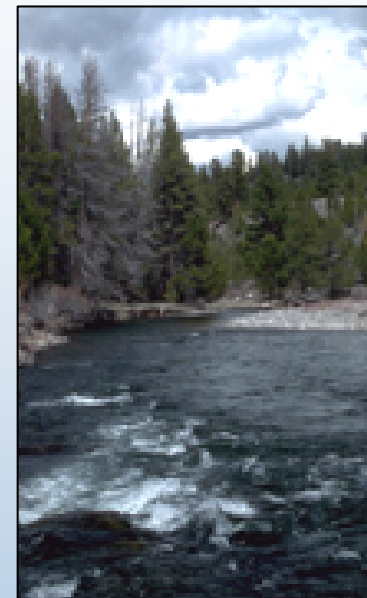
Energy Challenges are Enormous



Energy Security
and Reliability



Economic Growth



Environmental
Impact

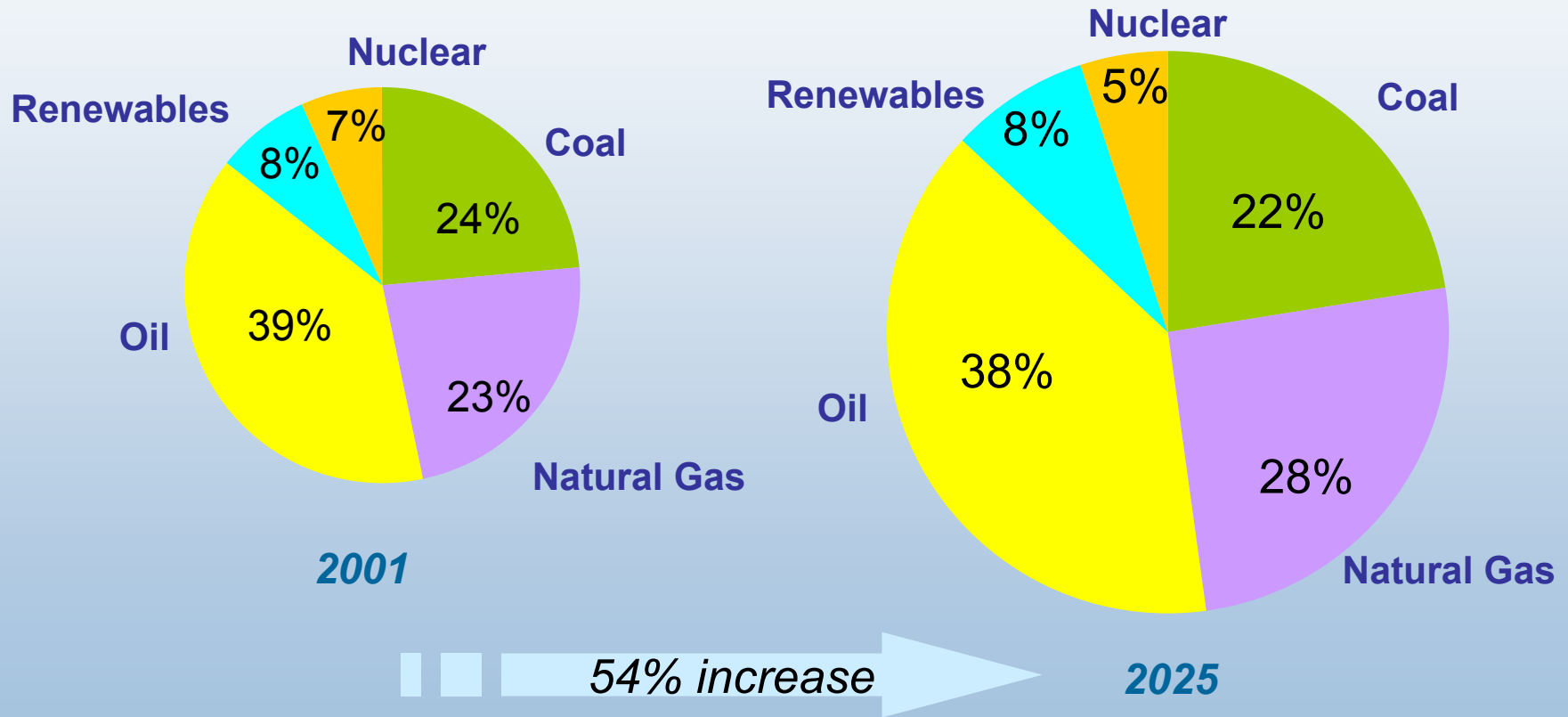


Market Restructuring

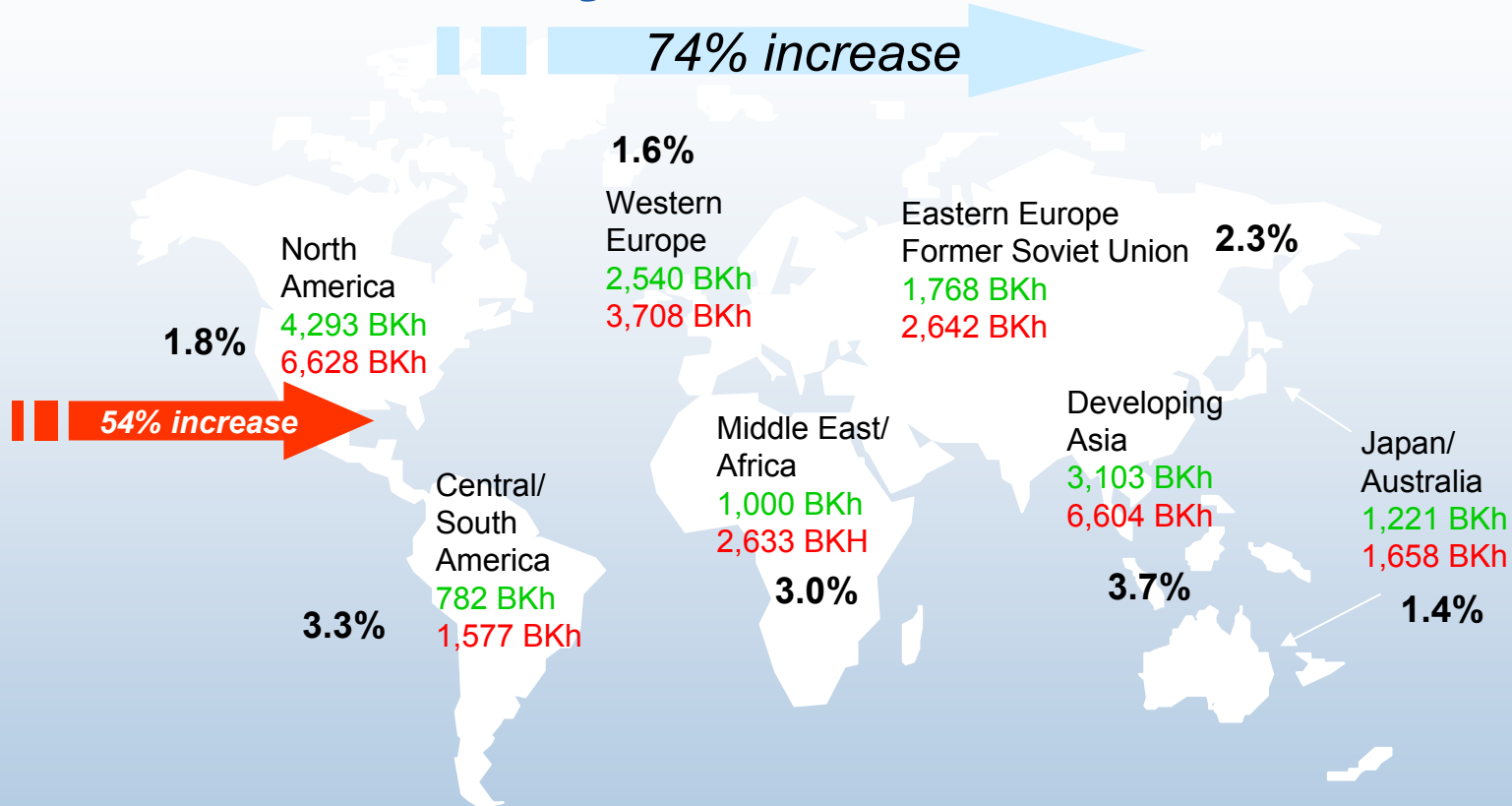


National Renewable Energy Laboratory

Worldwide Energy Consumption by Source

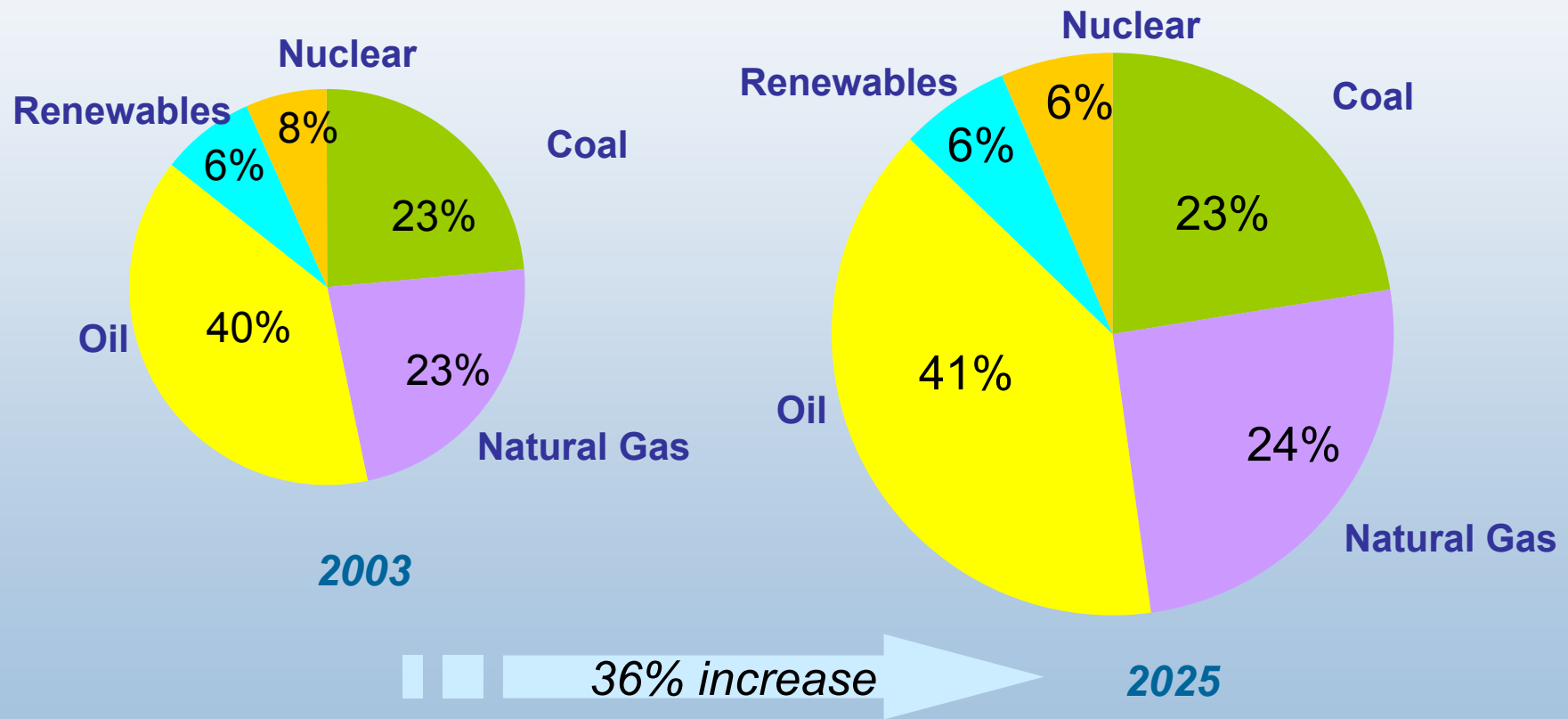


Electricity Outlook: 2001-2025

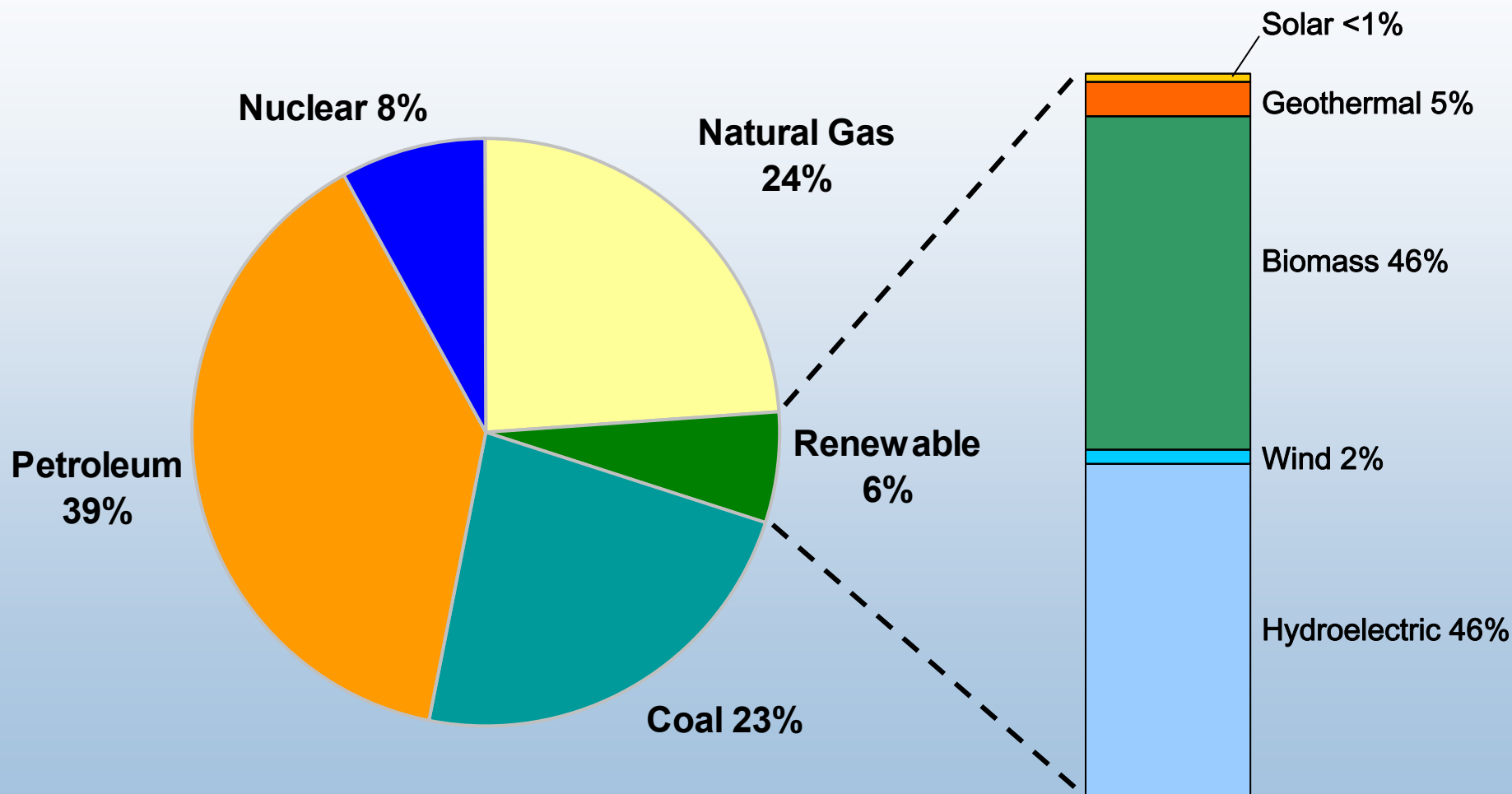


- Total annual average world electricity growth - 2.4% from 2001 to 2025
- Growth rates in transitioning economies higher than developed economies
- Natural gas and coal will be near-term fuels of choice for generation
- Distributed generation and renewable may offer attractive options

U.S. Energy Consumption by Source

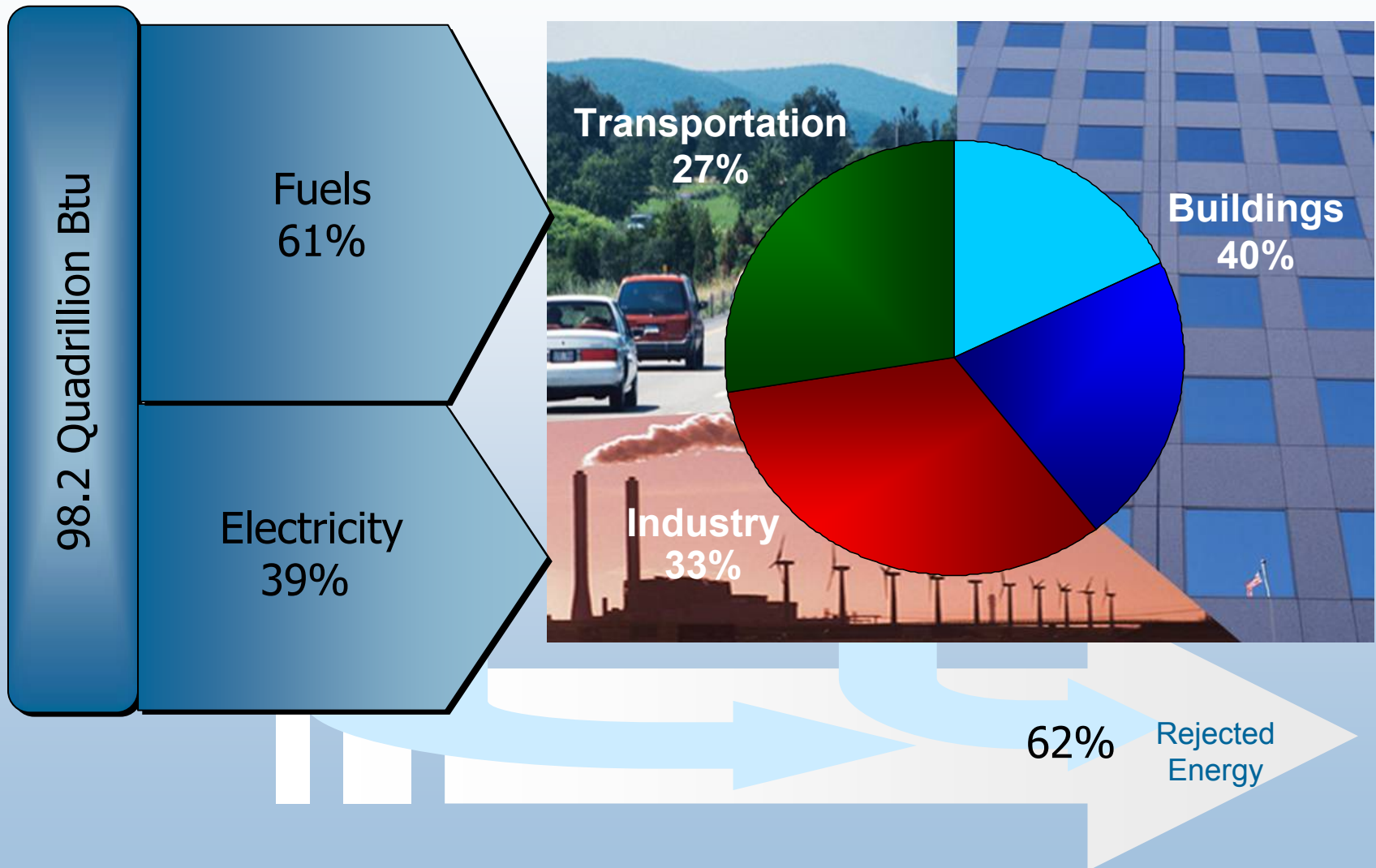


The Role of Renewables in the U.S. Energy Supply - 2003



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).

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

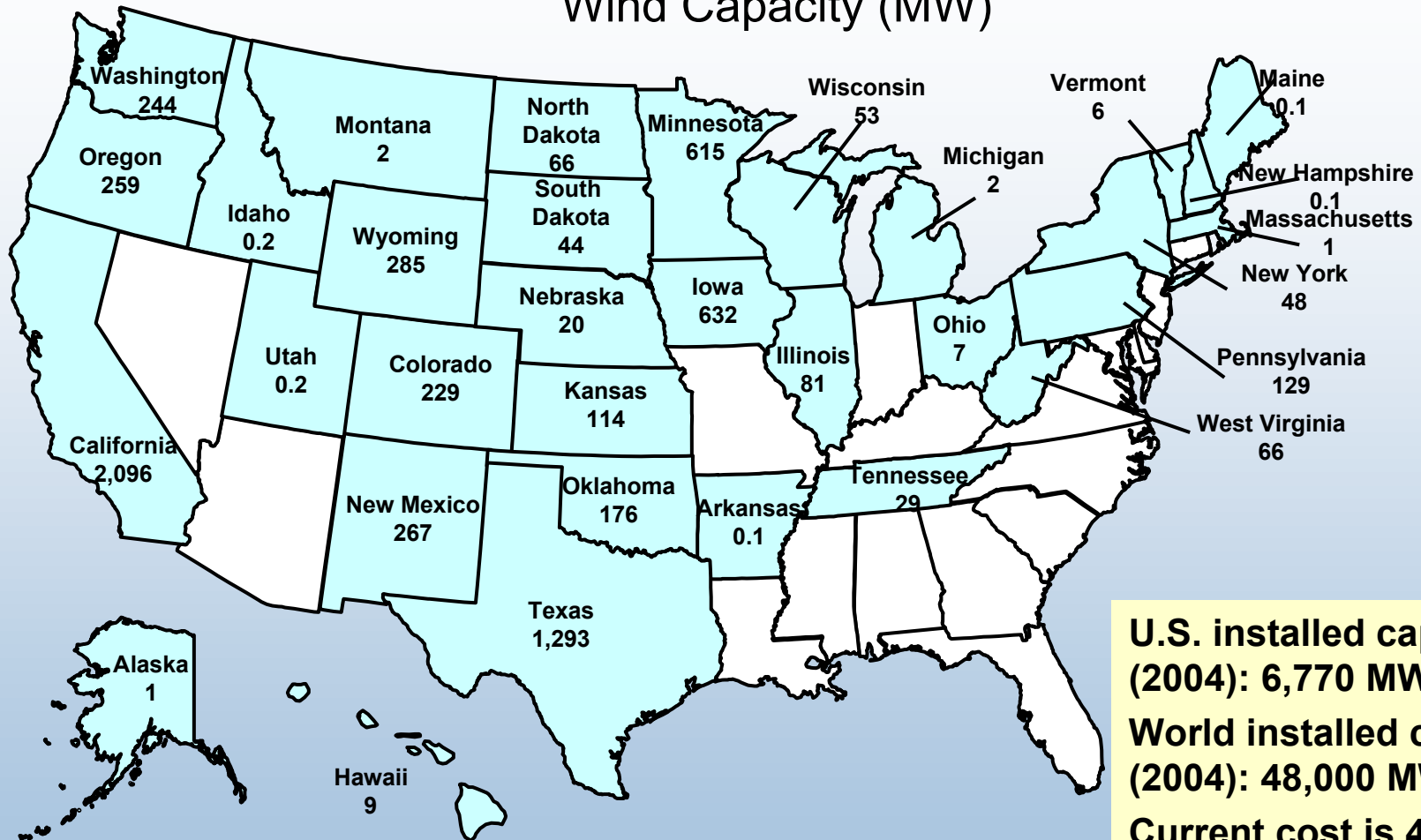


Renewable Energy Must Play a Key Role in a More Diverse and Secure Energy Supply



Wind Energy Status

Wind Capacity (MW)



**U.S. installed capacity
(2004): 6,770 MW**

**World installed capacity
(2004): 48,000 MW**

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

Source: Worldwatch Institute

Solar Energy Status

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



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

U.S. installed capacity (2004) - PV and solar thermal: 0.5 GW

World capacity (2004):

- **Solar PV, grid-connected: 1.8 GW**
- **Solar PV, not grid-connected: 2.2 GW**

Source: Worldwatch Institute

Biomass/Biofuels 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.

- **World biomass electricity capacity (2004): 36 GW**
- **World biofuels production capacity (2004): ethanol 32 billion l/yr; biodiesel 2.2 billion l/yr**

Source: Worldwatch Institute

Factors Inhibiting Pace and Volume of Renewable Energy Market Entrance

RISK REDUCTION

- Consistent & predictable policies
- Continued advanced technology development
- Enabling market viability



CAPITAL MOBILIZATION

Current Federal Energy Legislative Proposals*

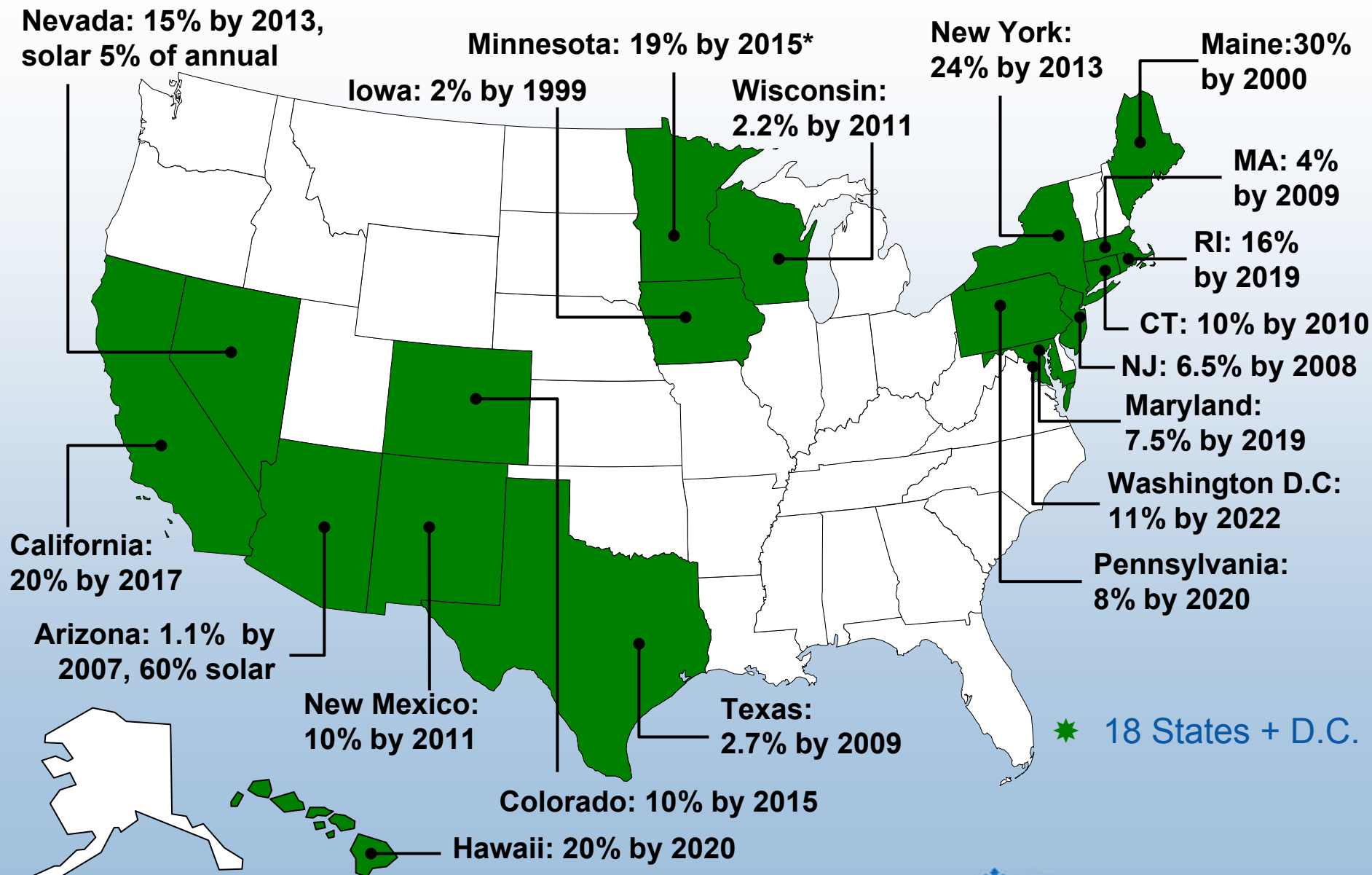
- Production tax credit extension
- Solar investment tax credits for residential and commercial property
- Tax credits for fuel cell, hybrid, biodiesel and alternative fuel vehicles
- Renewable energy portfolio standards

* Pending in Congress

State Policies are Opening Markets for Renewable Energy



Renewable Electricity Standards



*Includes requirements adopted in 1994 and 2003 for one utility, Xcel Energy.  NREL National Renewable Energy Laboratory

There is Regional Interest in Promoting Clean Energy

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 energy efficiency by 20% by 2020.
- Meet the West's generation and transmission needs over the next 25 years.

What Are Some of the Issues?

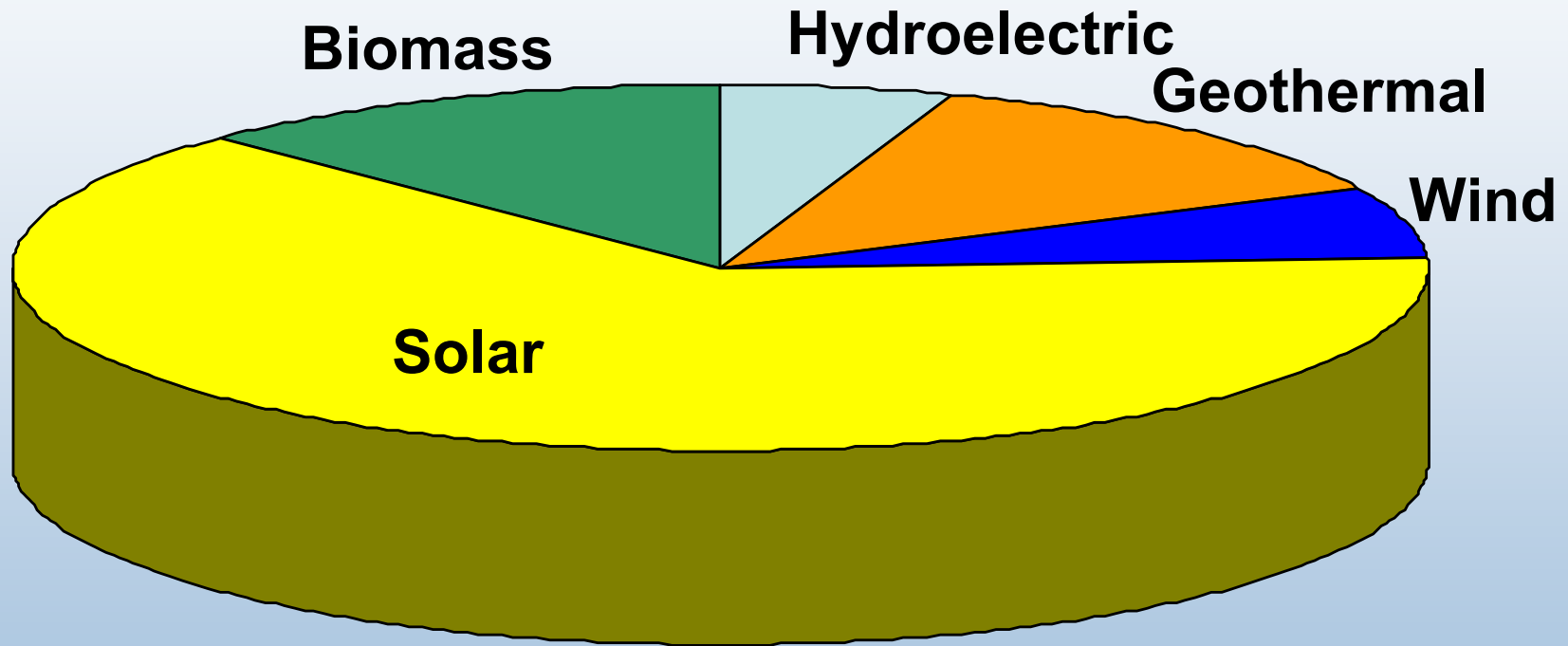
- Valuing externalities
- Connectivity to the grid
- Challenges in current regulatory environment
- Transmission capacity



***Can renewables have sufficient
impact to change the energy
future?***



Worldwide Renewable Resources Potential: Meeting the RE Challenge Depends Heavily on Solar



Far exceeds today's world energy consumption

The Future for Renewable Energy: A Technology Outlook

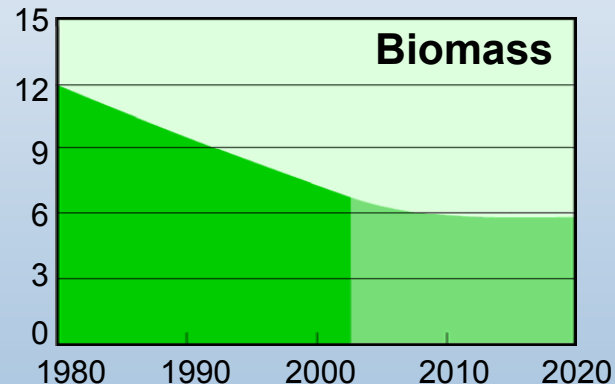
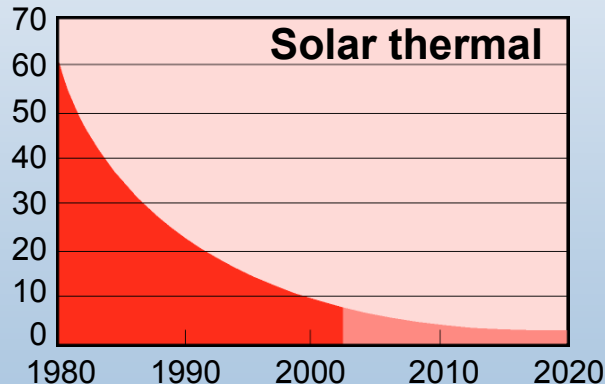
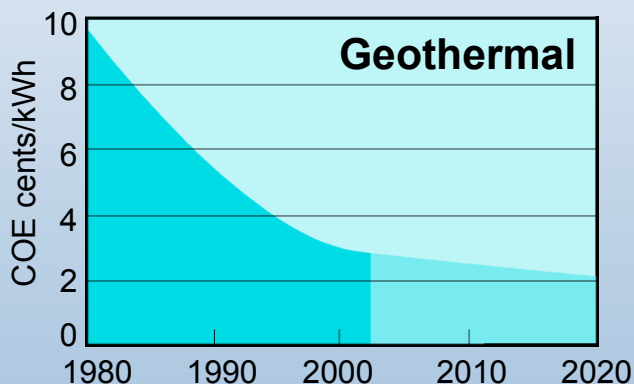
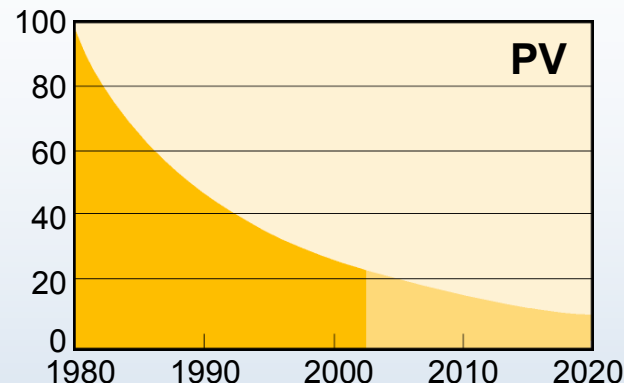
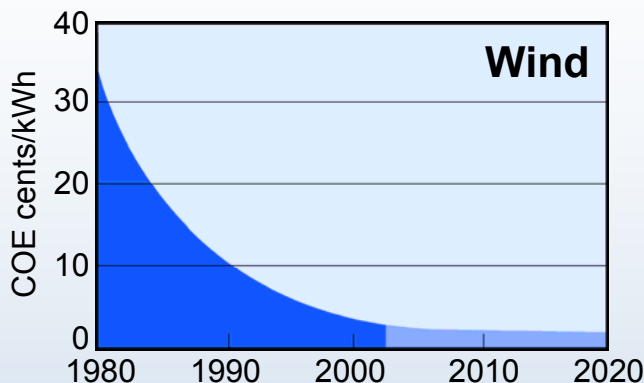


Wind
Solar
Biomass



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)

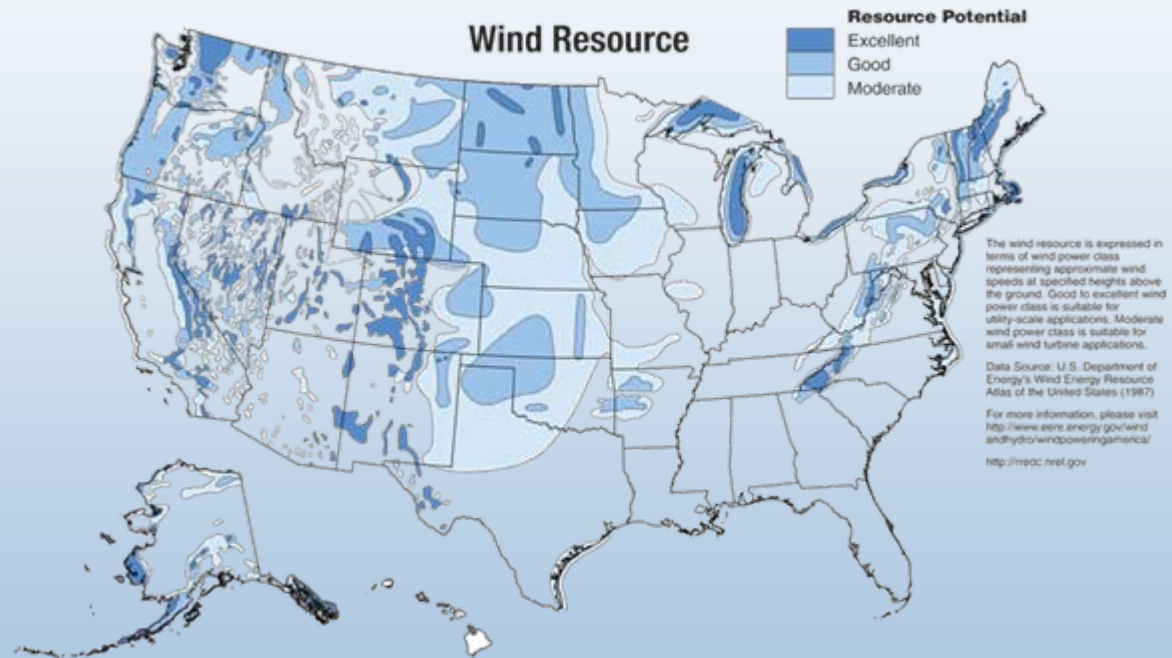
¹These graphs are reflections of historical cost trends NOT precise annual historical data.

Updated: October 2002

Wind Outlook

DOE Wind Program R&D goals:

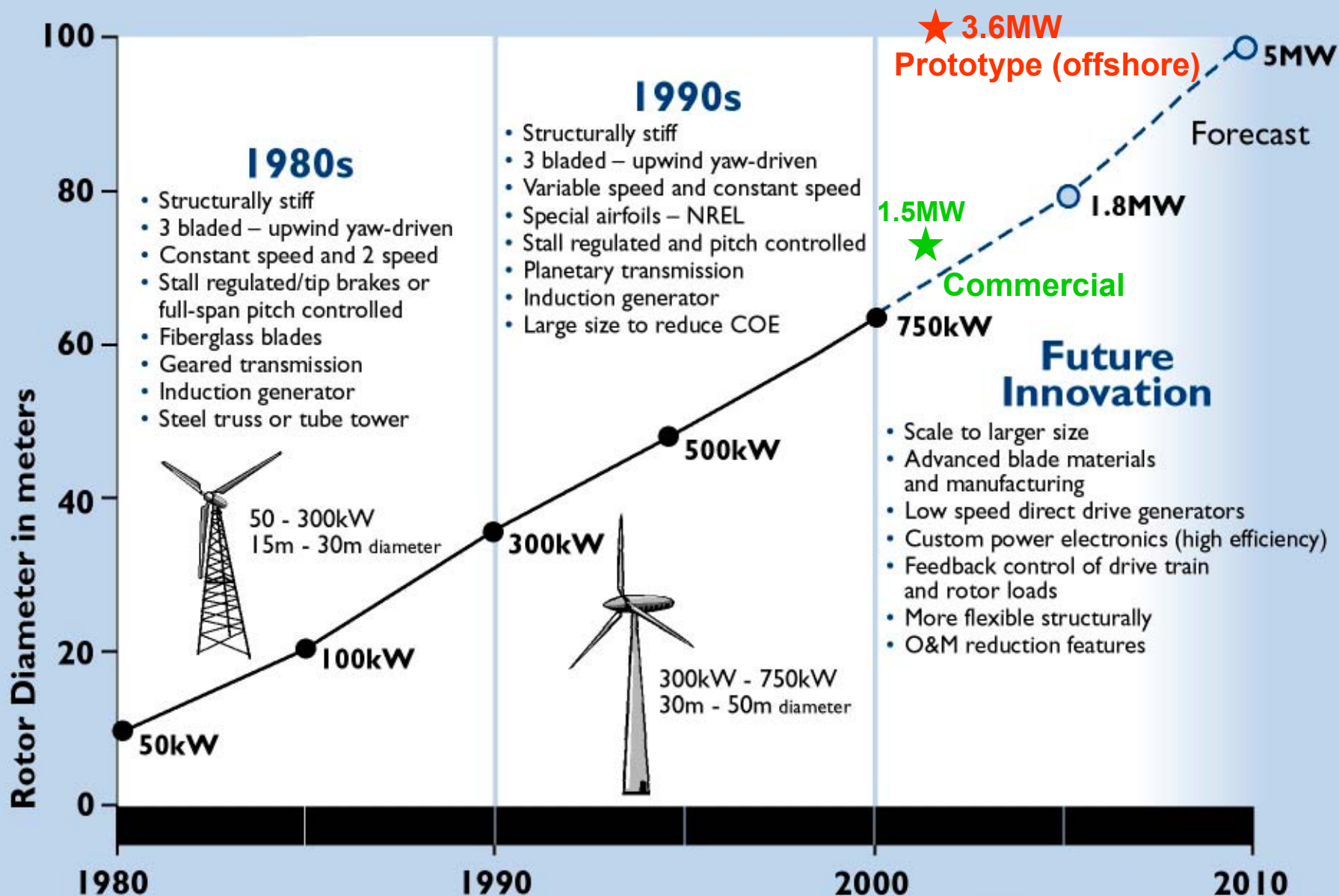
- 3¢/kWh* in class 4+ wind areas onshore
- 5¢/kWh* for offshore systems



* unsubsidized



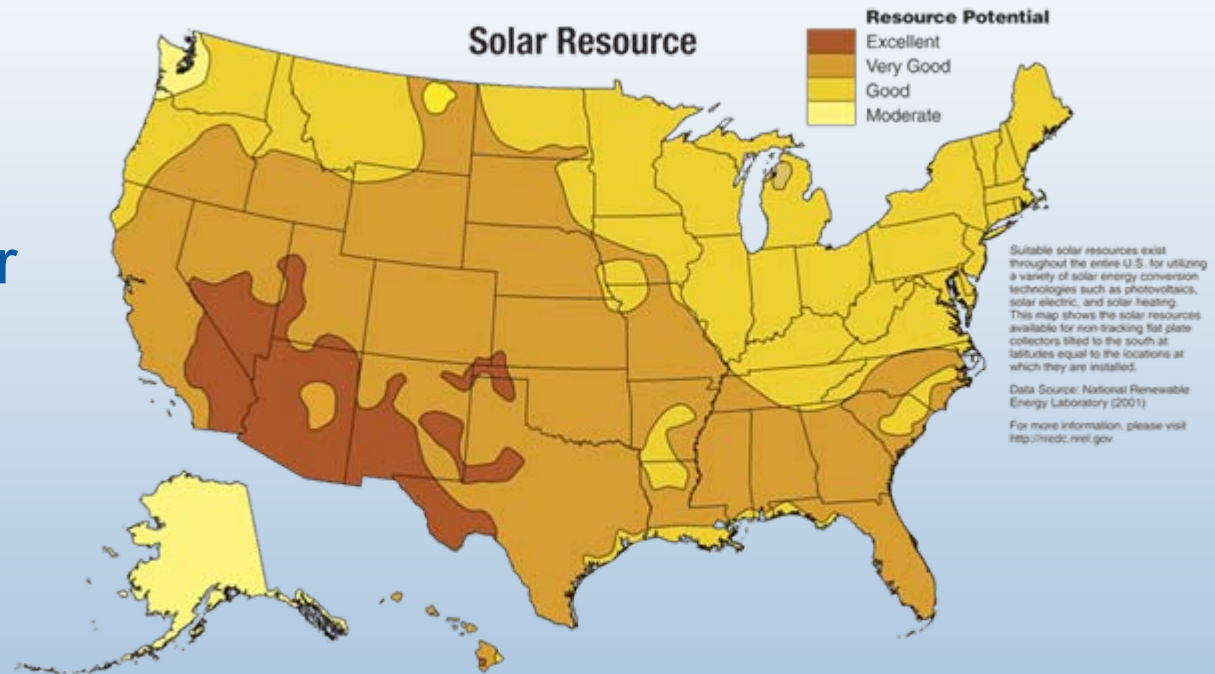
THE EVOLUTION OF COMMERCIAL U.S. WIND TECHNOLOGY



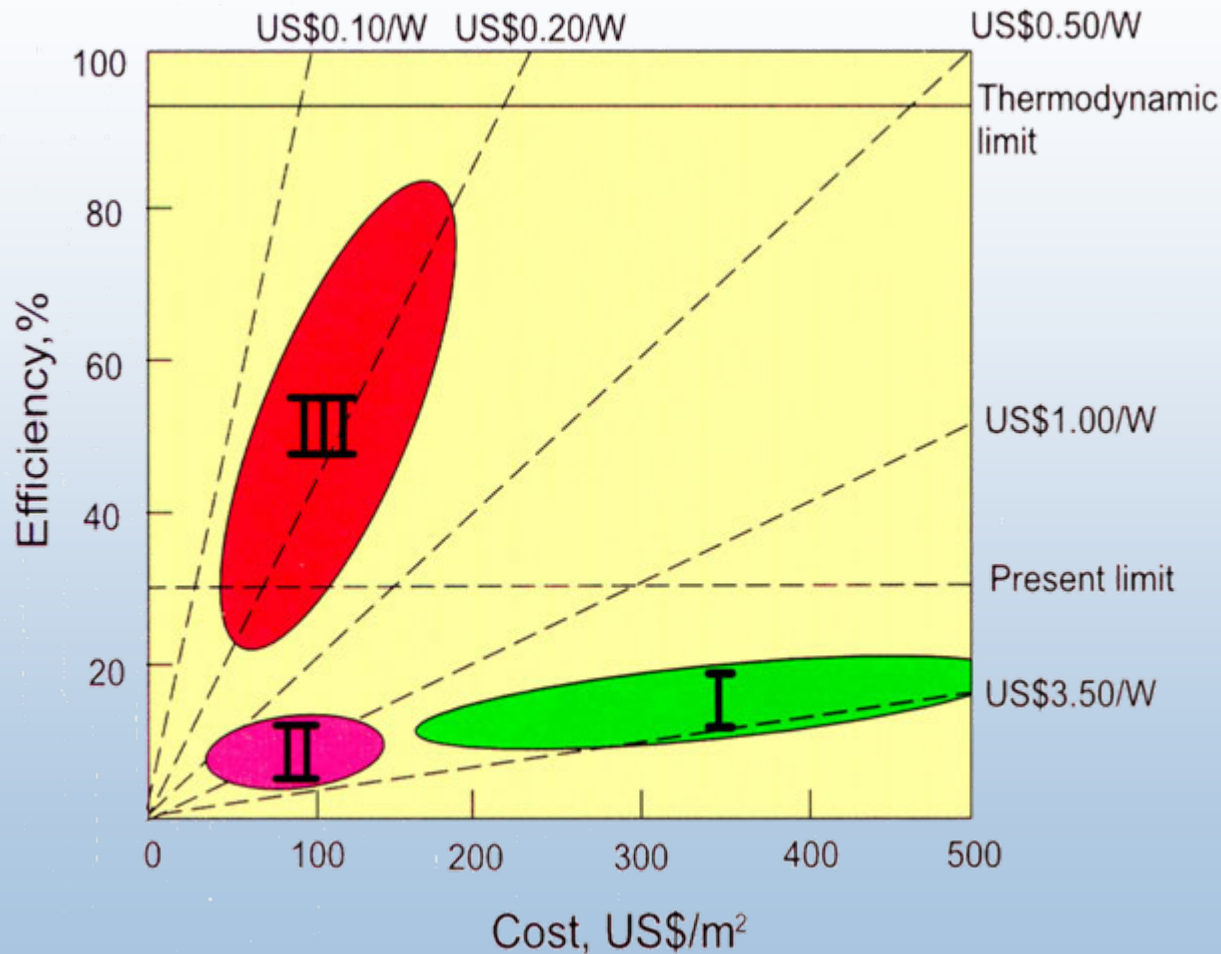
Solar Outlook

DOE Solar Program goals

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



Cost/Efficiency of Photovoltaic Technology



Future Technology Directions

- Research on crystalline silicon, thin films, and balance-of-systems components
- Higher-risk, longer-term R&D for all system components that can leapfrog beyond today's technology

Costs are modules per peak W; installed is \$5-10/W; \$0.35-\$1.5/kW-hr

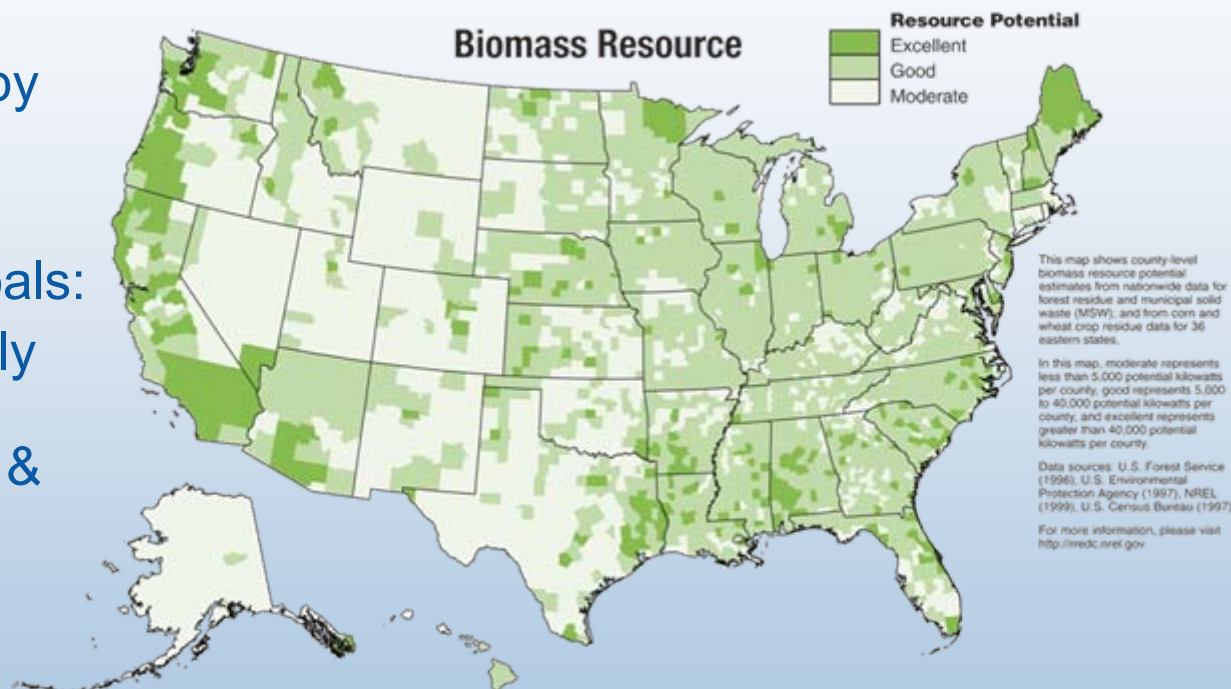
Biomass/Biofuels Outlook

DOE Biomass Program goals:

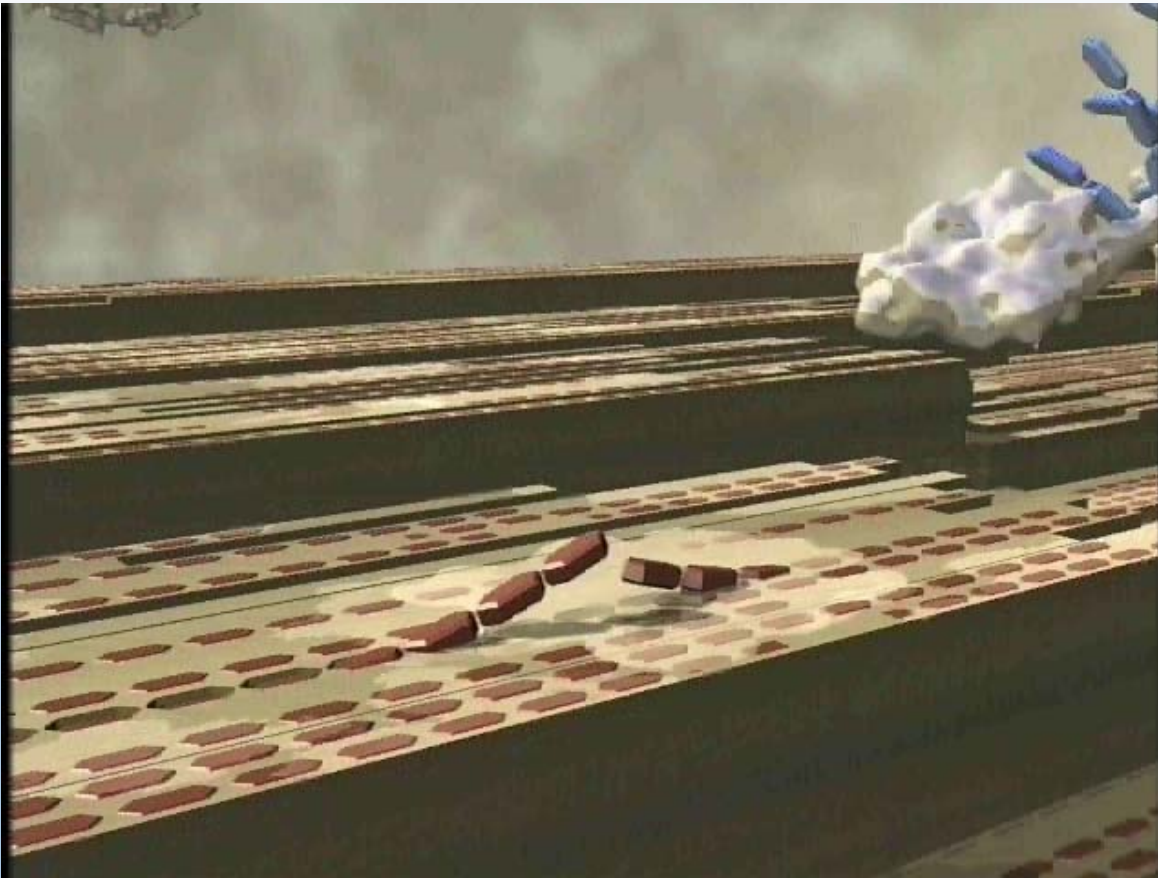
- Competitive electricity by 2020

DOE Biofuels Program goals:

- Produce ethanol cheaply from lignocellulose resources – agriculture & forestry
- Use of biology together with thermo-chemistry
- Target: \$1.07/gal by 2020



Biomass Technology Advances



Future Technology Directions

- Plant cell wall deconstruction
- Robust ethanologens
- Better options for thermochemical fuels
- Process intensification

U.S. Industry Market Viability

Technology Roadmaps and Vision for the Future



A Future Vision for Wind Energy Markets

**Today
2005**



**Bulk Power
Generator
4-6¢ at 15mph**

- Land Based
- Bulk Electricity
- Wind Farms

**Future Potential=
20% of
Electricity Market**

Land Based Electricity Path

**Land Based LWST
Large-Scale
2-5 MW**

**Transmission
Barriers**

Tomorrow

LWST Turbines:

- 3¢/kWh at 13mph
- Electricity Market
2012

Offshore Electricity Path

**Offshore Turbines
5 MW and Larger**

**Cost & Regulatory
Barriers**

Offshore LWST Turbine:

- 5 cents/kWh
- Shallow/**Deep** water
- Electricity Market
- Higher wind Sites
2012 and Beyond

**Advanced Applications
Path**

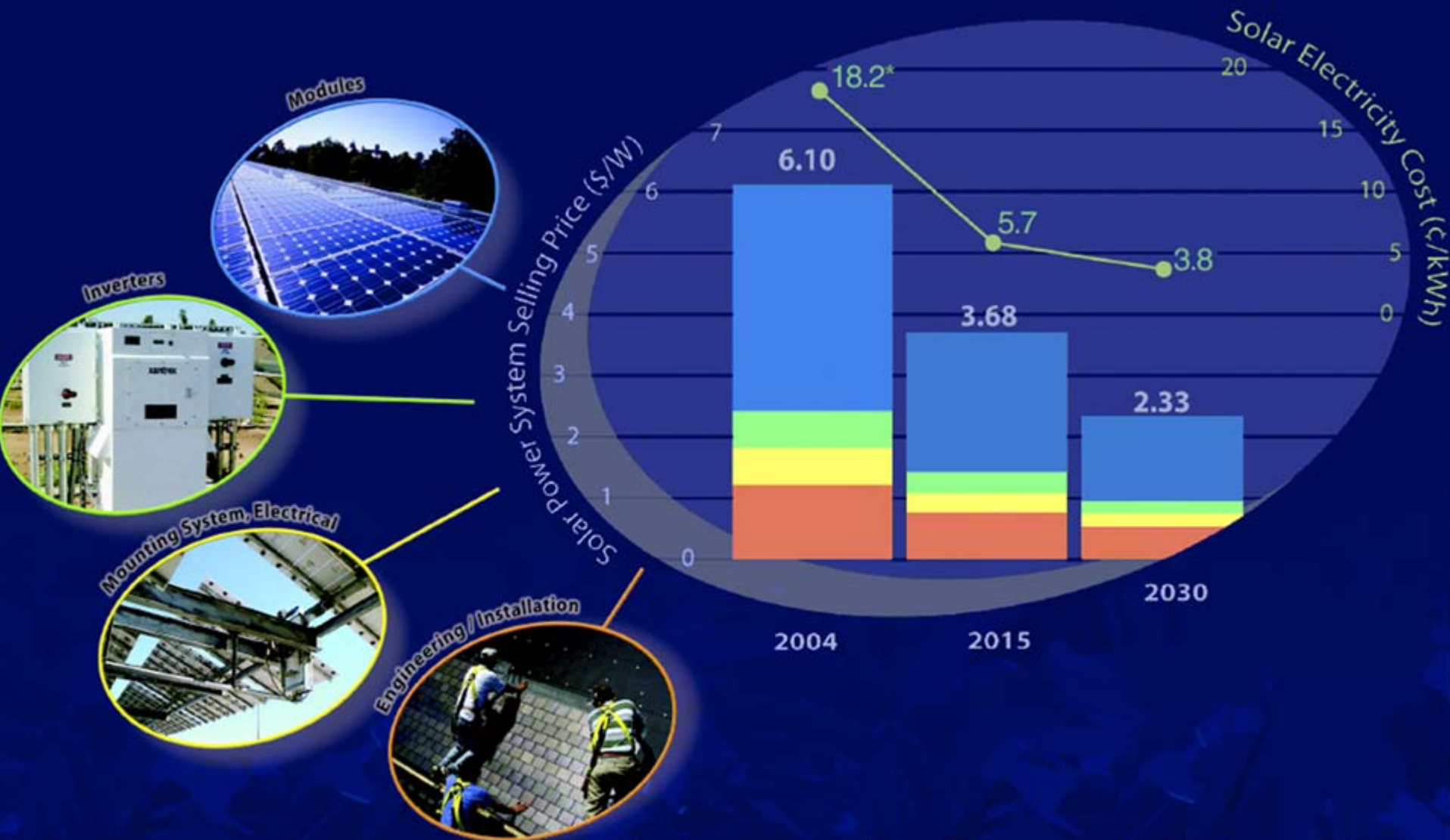
Land or Sea Based:

- Hydrogen
- Clean Water

**Cost & Infrastructure
Barriers**

Custom Turbines:

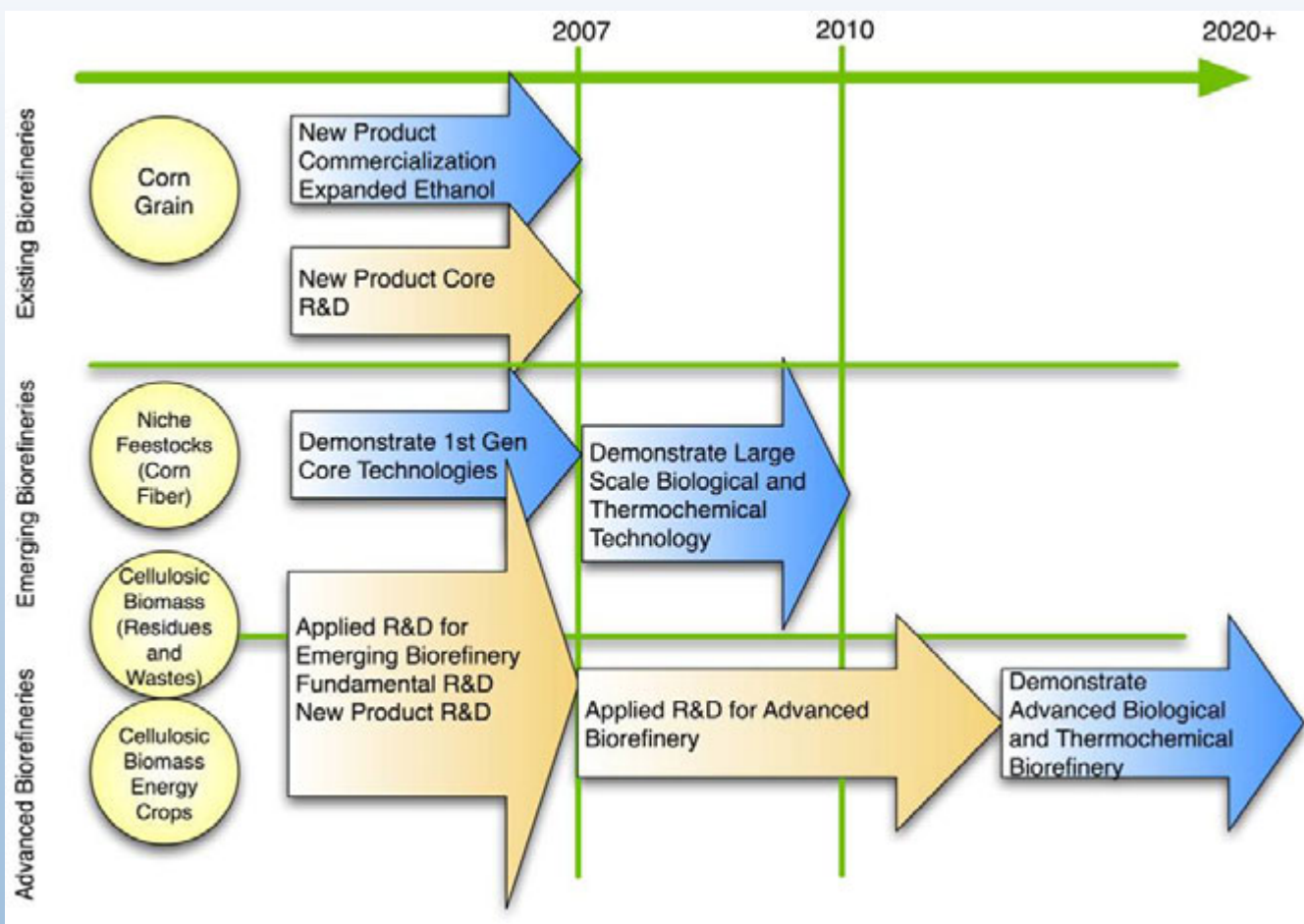
- Electricity
- H2 production
- Desalinate water
- Storage
- Multi-Market
2030 and Beyond



Roadmap case for grid-connected solar system with 30-year lifetime (customer side of meter)

**2004 electricity cost is based on present federal policies, investment tax credit, and accelerated depreciation.*

The Biorefinery: The Path Ahead



- A diverse feedstock supply that provides over 1 billion tons of biomass per year
- Equivalent of 3.5 billion barrels of crude oil per year or 55% of current U.S. petroleum demand

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**

www.nrel.gov



Golden, Colorado