

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

Energy 2050: The Future of Renewable Energy

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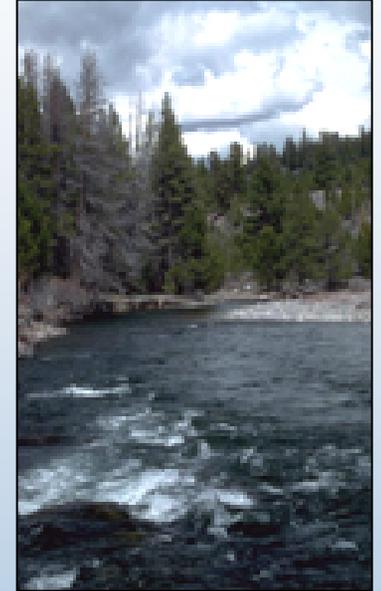
# Energy Challenges are Enormous



Energy Security  
and Reliability



Economic Growth

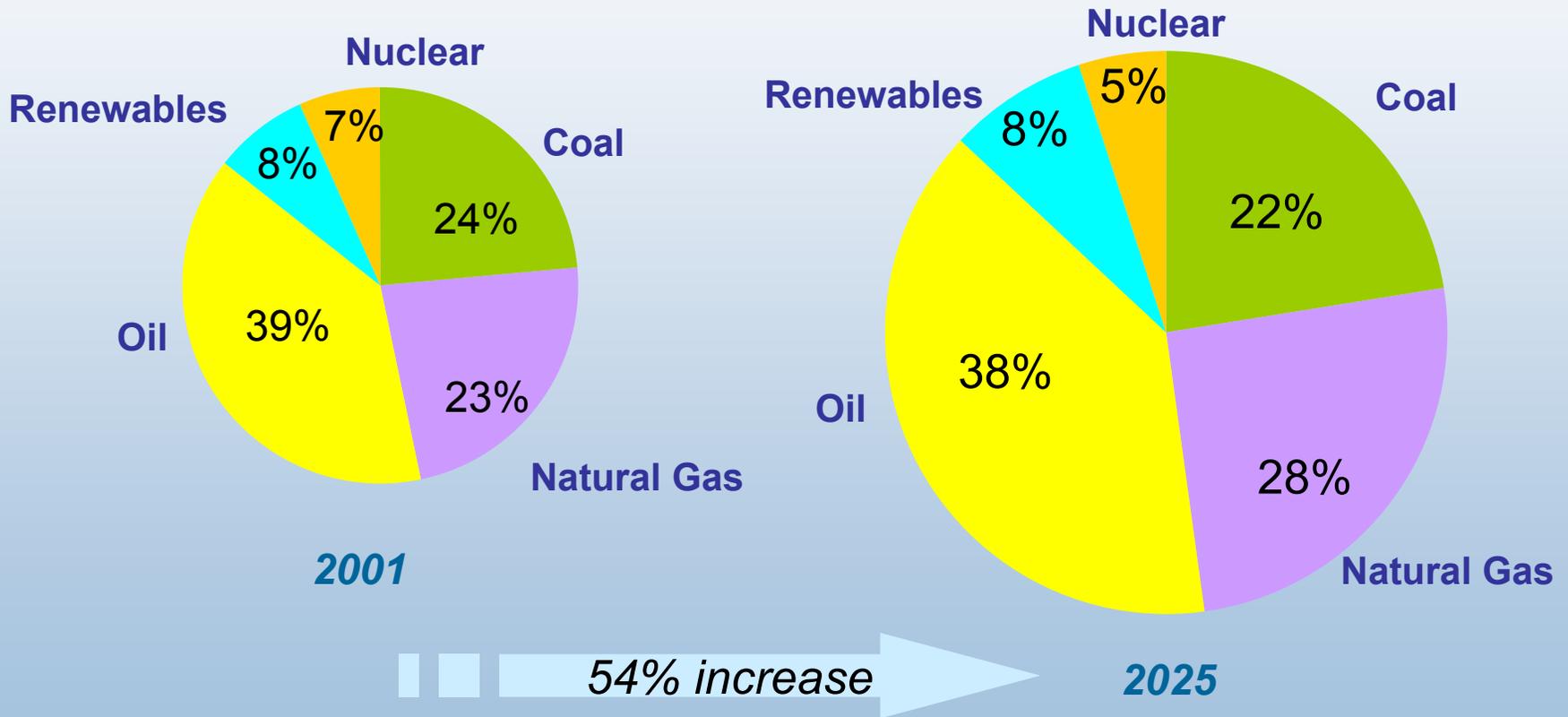


Environmental  
Impact

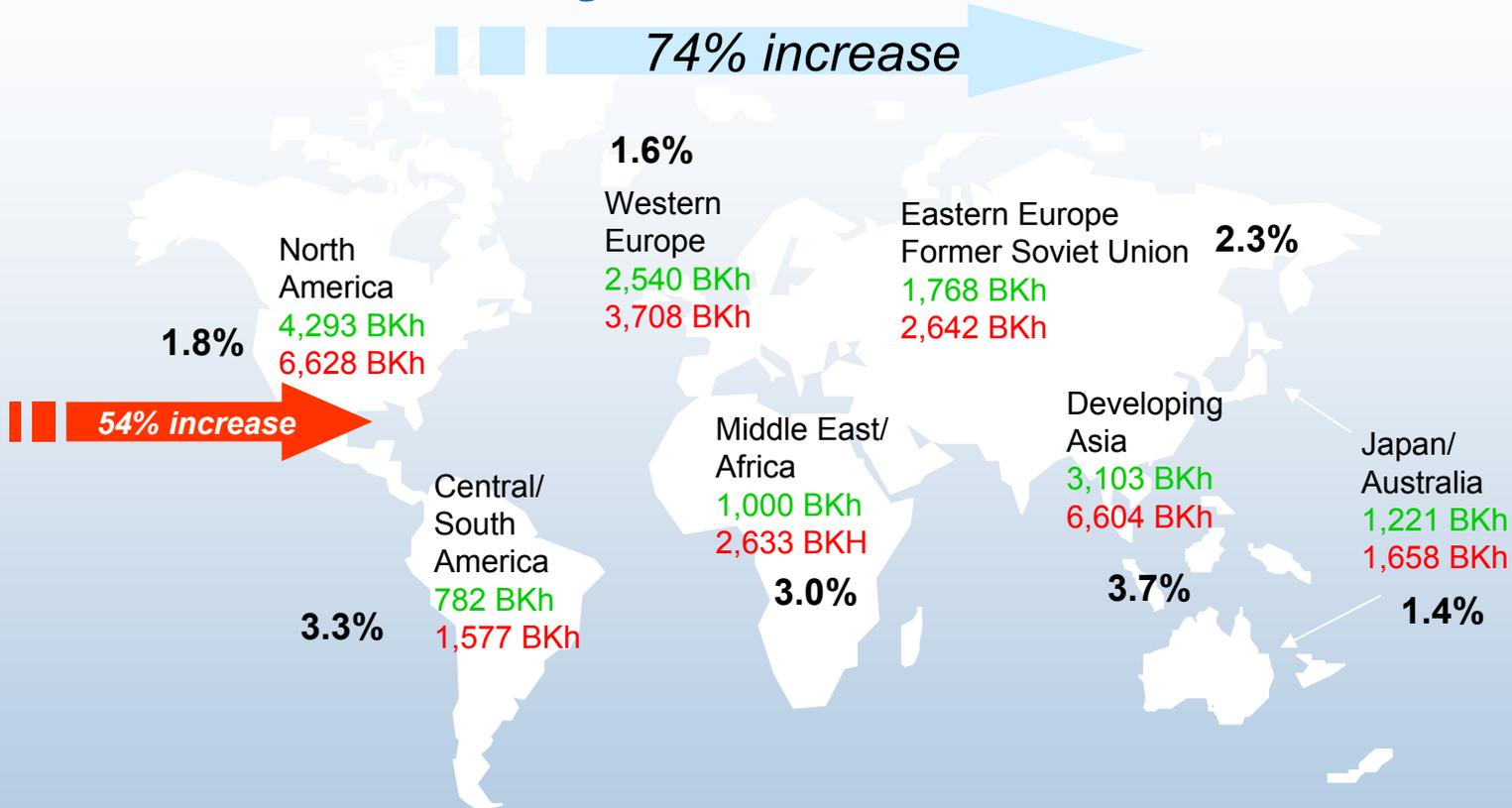


Market Restructuring

# Worldwide Energy Consumption by Source

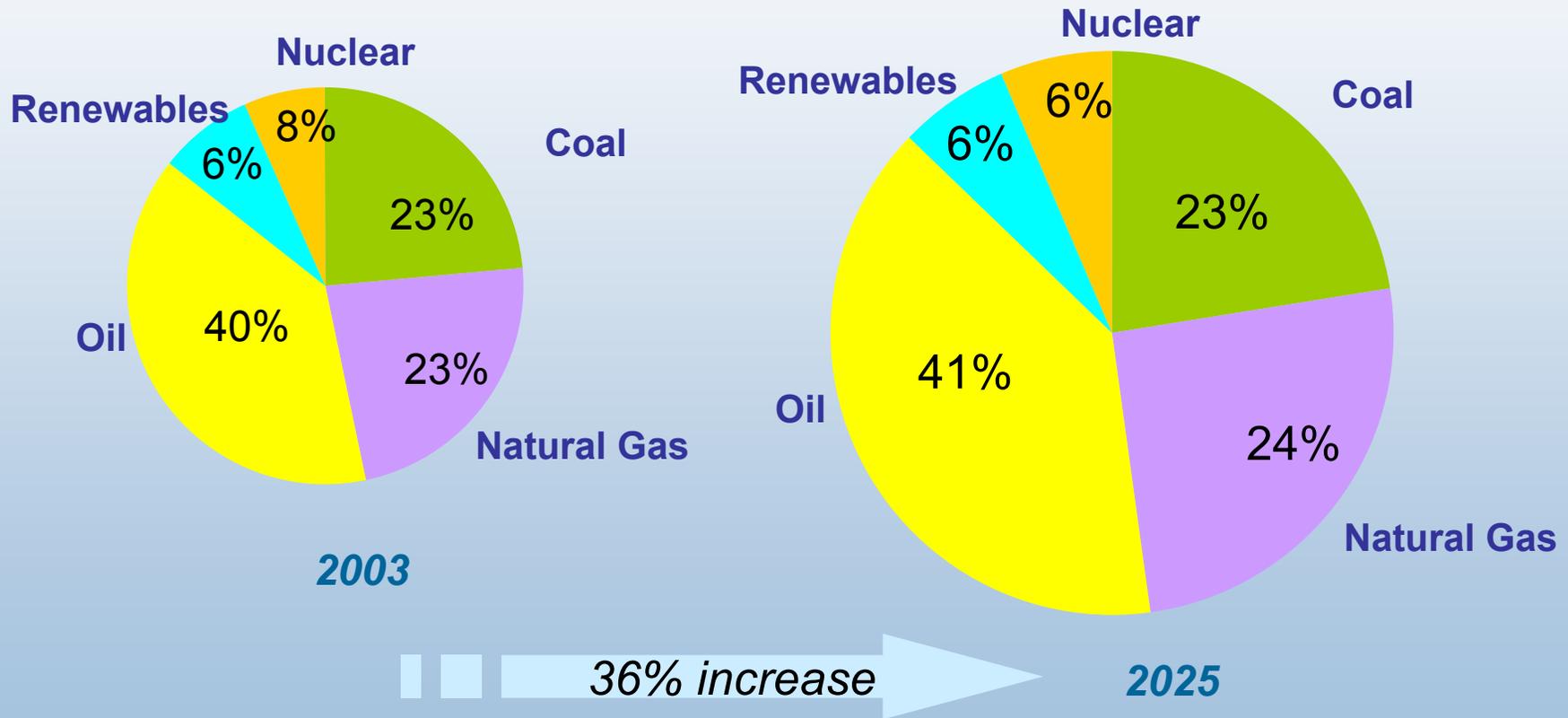


# Electricity Outlook: 2001-2025

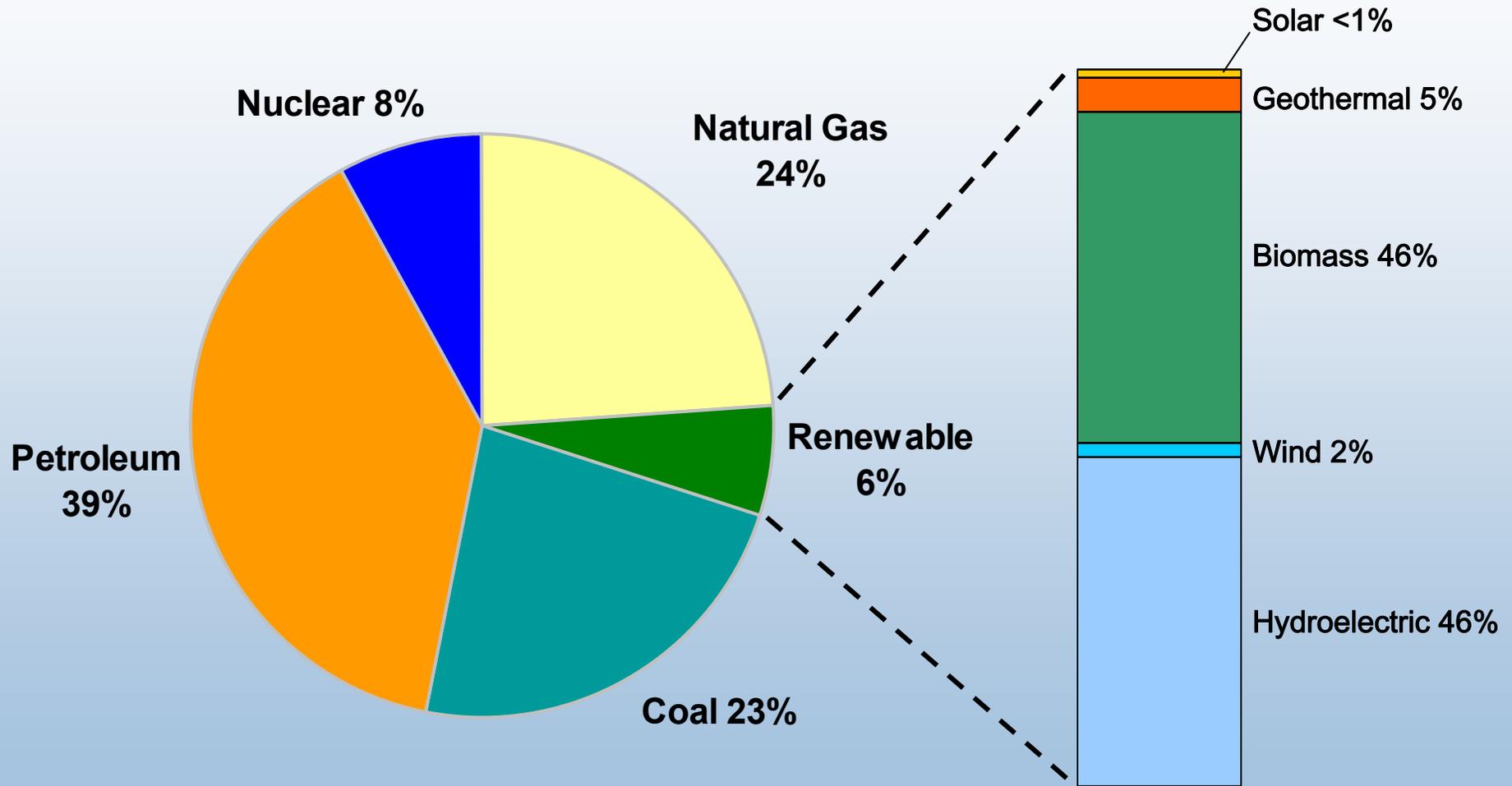


- Total annual average world electricity growth - 2.4% from 2001 to 2025
- Growth rates in transitioning economies higher than developed economies
- Natural gas and coal will be near-term fuels of choice for generation
- Distributed generation and renewable may offer attractive options

# U.S. Energy Consumption by Source

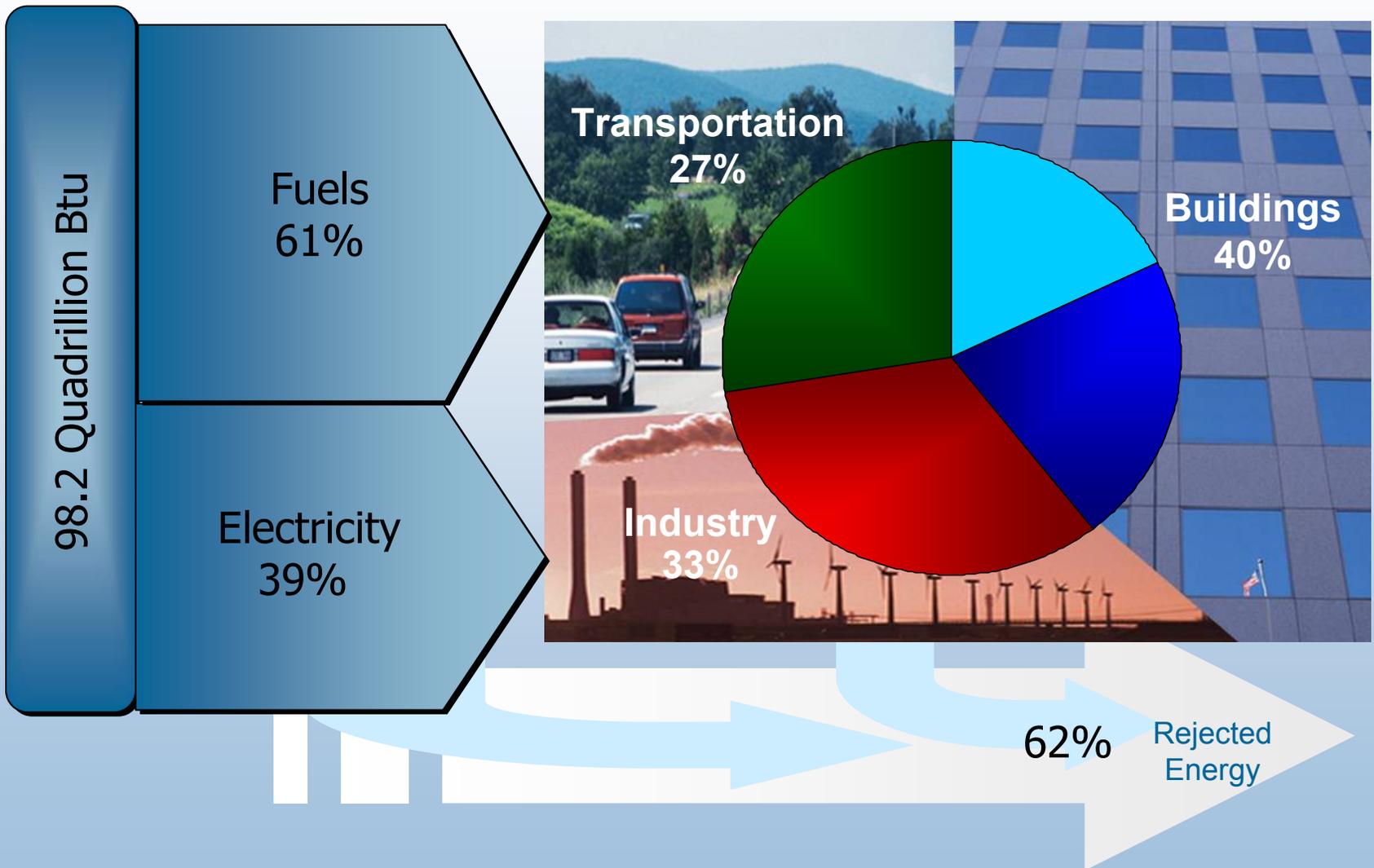


# The Role of Renewables in the U.S. Energy Supply - 2003



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 CO<sub>2</sub> 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

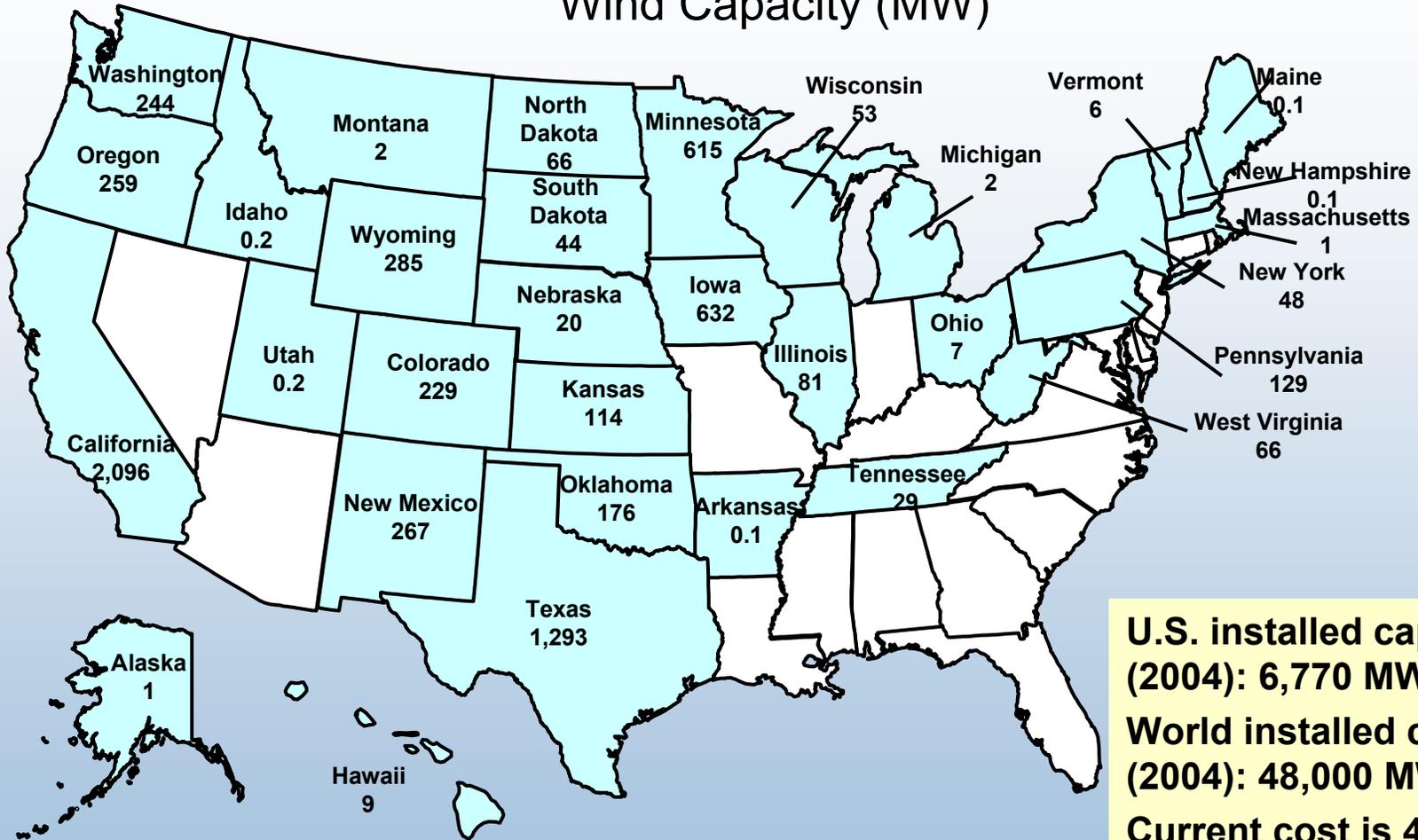


# Renewable Energy Must Play a Key Role in a More Diverse and Secure Energy Supply



# 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

**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.**

# 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

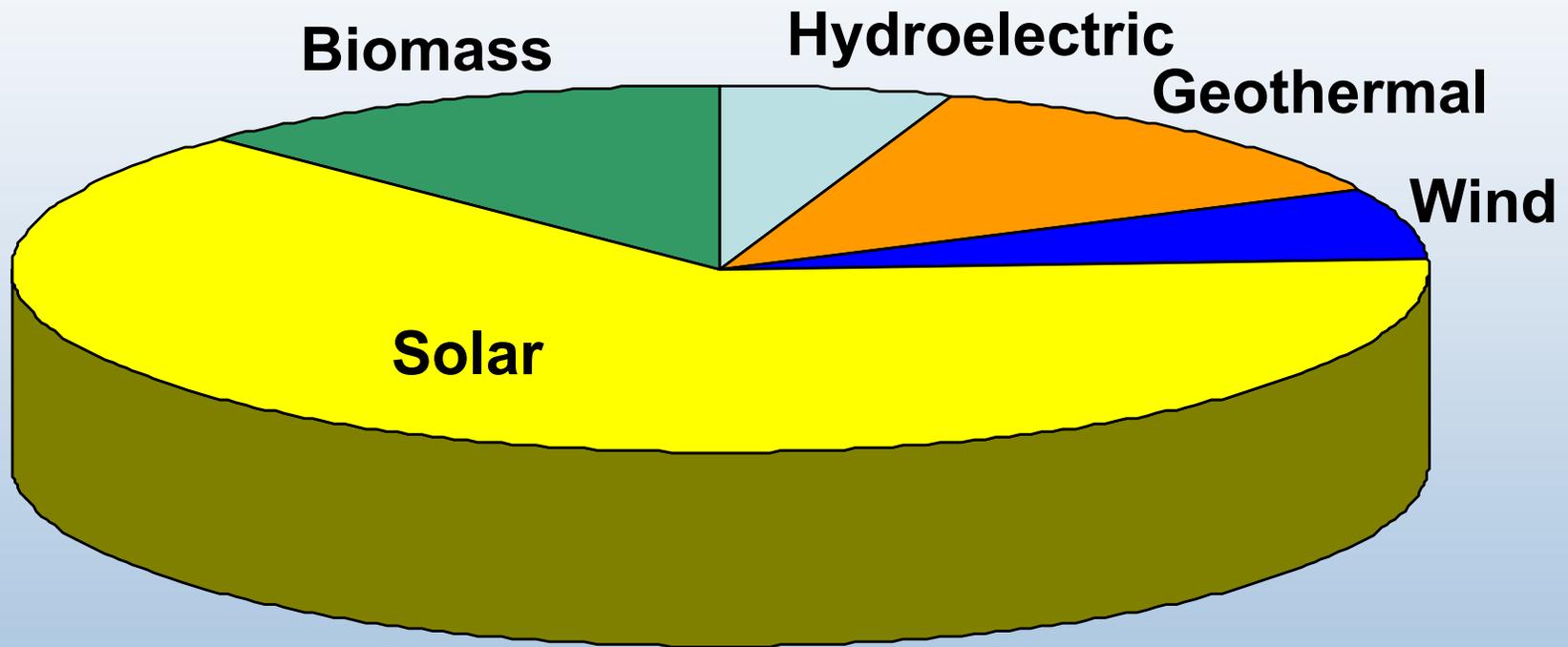


***Can renewables have sufficient  
impact to change the energy  
future?***



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

Meeting the RE Challenge Depends Heavily on Solar



*Far exceeds today's world energy consumption*

# The Future for Renewable Energy: A Technology Outlook

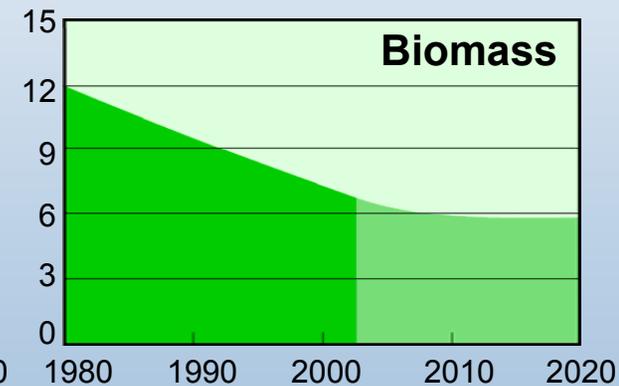
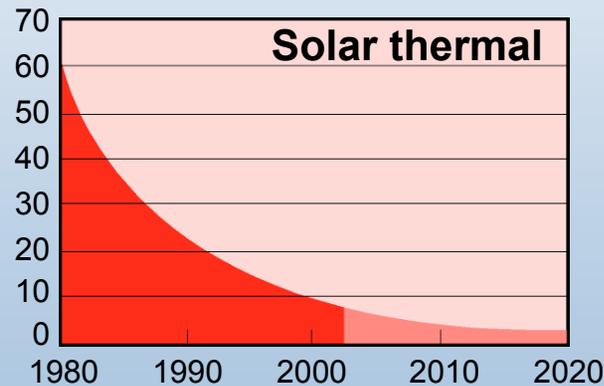
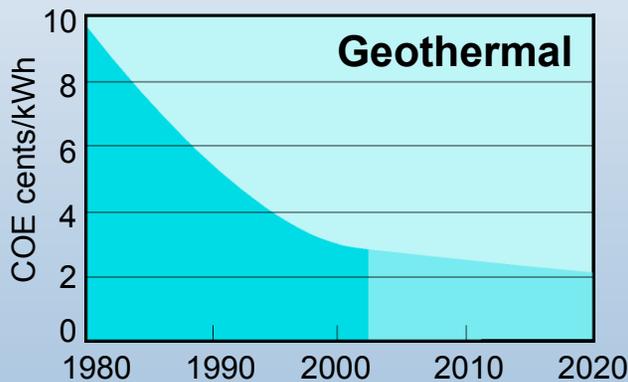
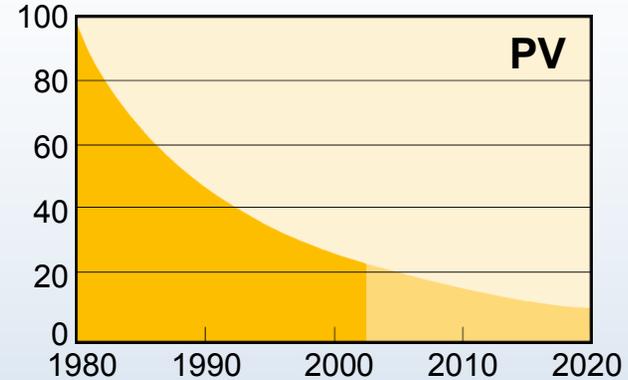
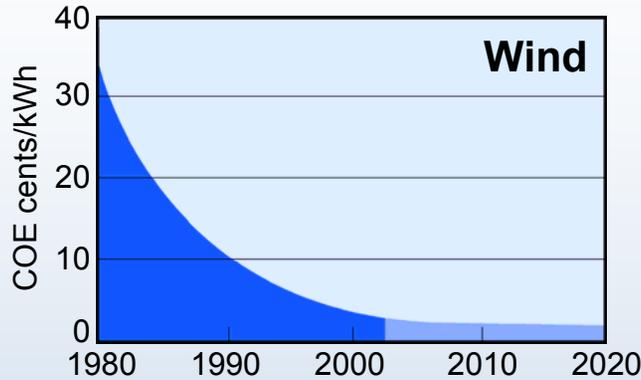


**Wind**  
**Solar**  
**Biomass**



# Renewable Energy Costs are Decreasing

Levelized cents/kWh in constant \$2000<sup>1</sup>



Source: NREL Energy Analysis Office ([www.nrel.gov/analysis/docs/cost\\_curves\\_2002.ppt](http://www.nrel.gov/analysis/docs/cost_curves_2002.ppt))

<sup>1</sup>These graphs are reflections of historical cost trends NOT precise annual historical data.

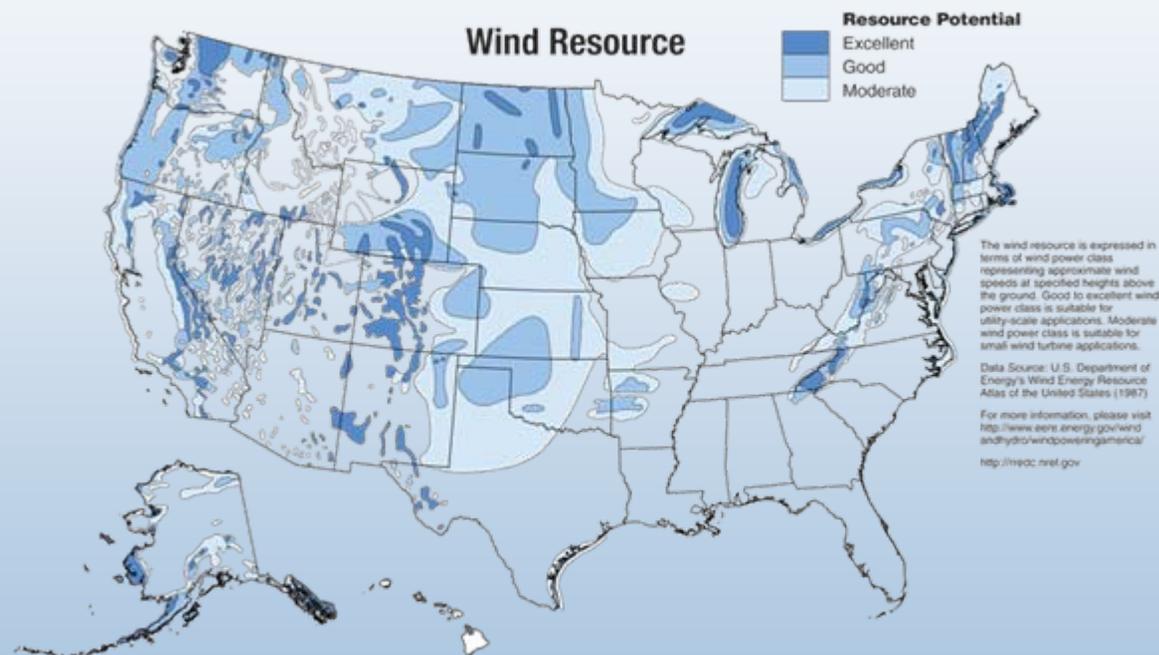
Updated: October 2002

# Wind Outlook

## DOE Wind Program R&D

goals:

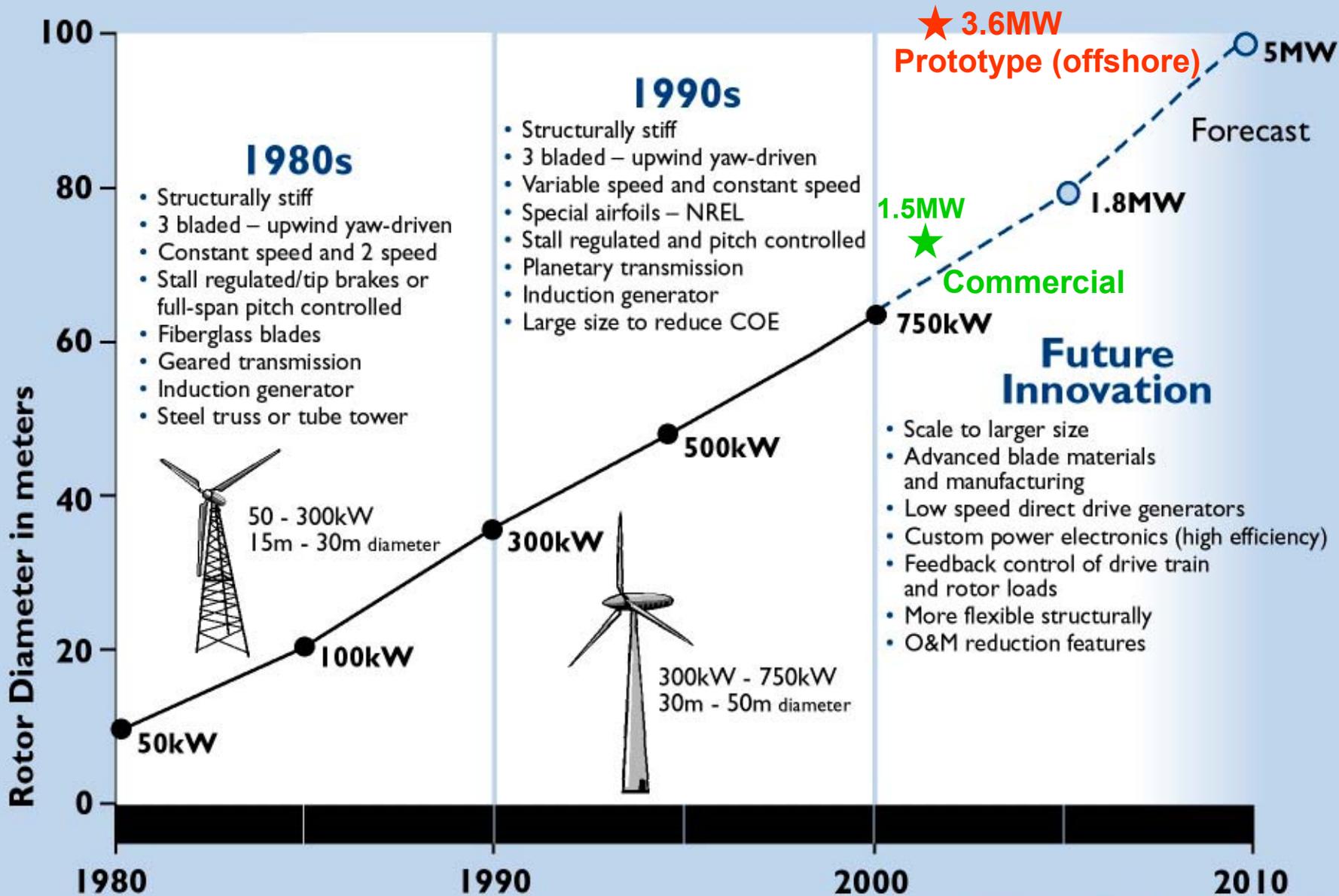
- 3¢/kWh\* in class 4+ wind areas onshore
- 5¢/kWh\* for offshore systems



\* unsubsidized



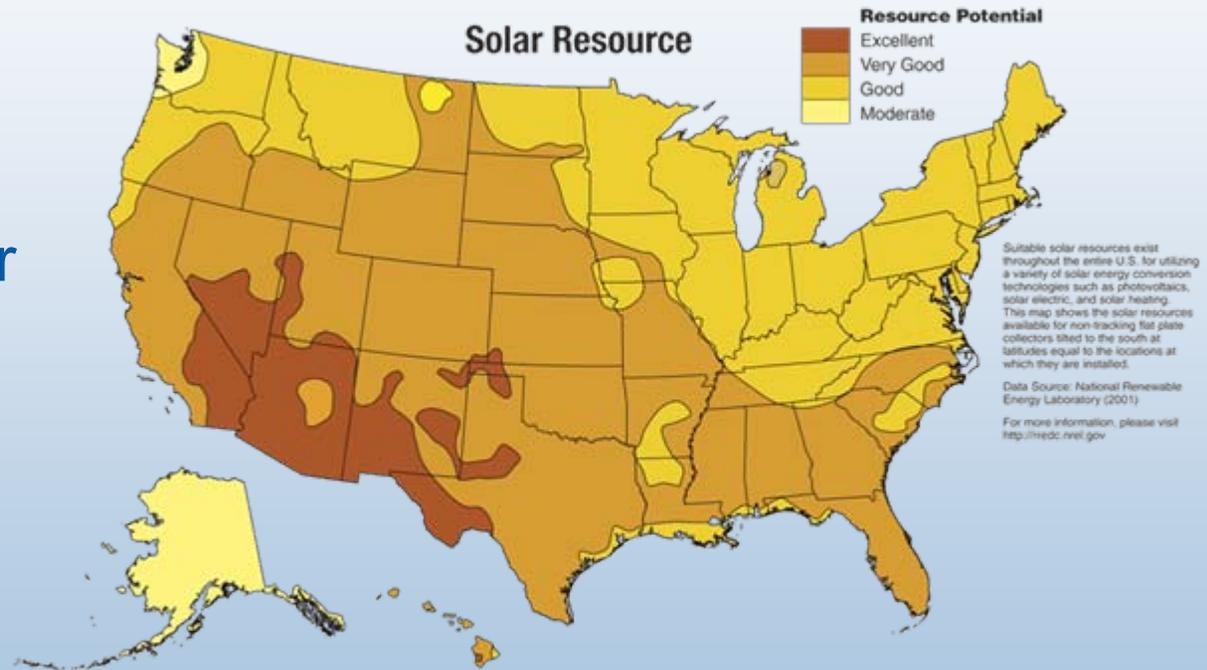
# THE EVOLUTION OF COMMERCIAL U.S. WIND TECHNOLOGY



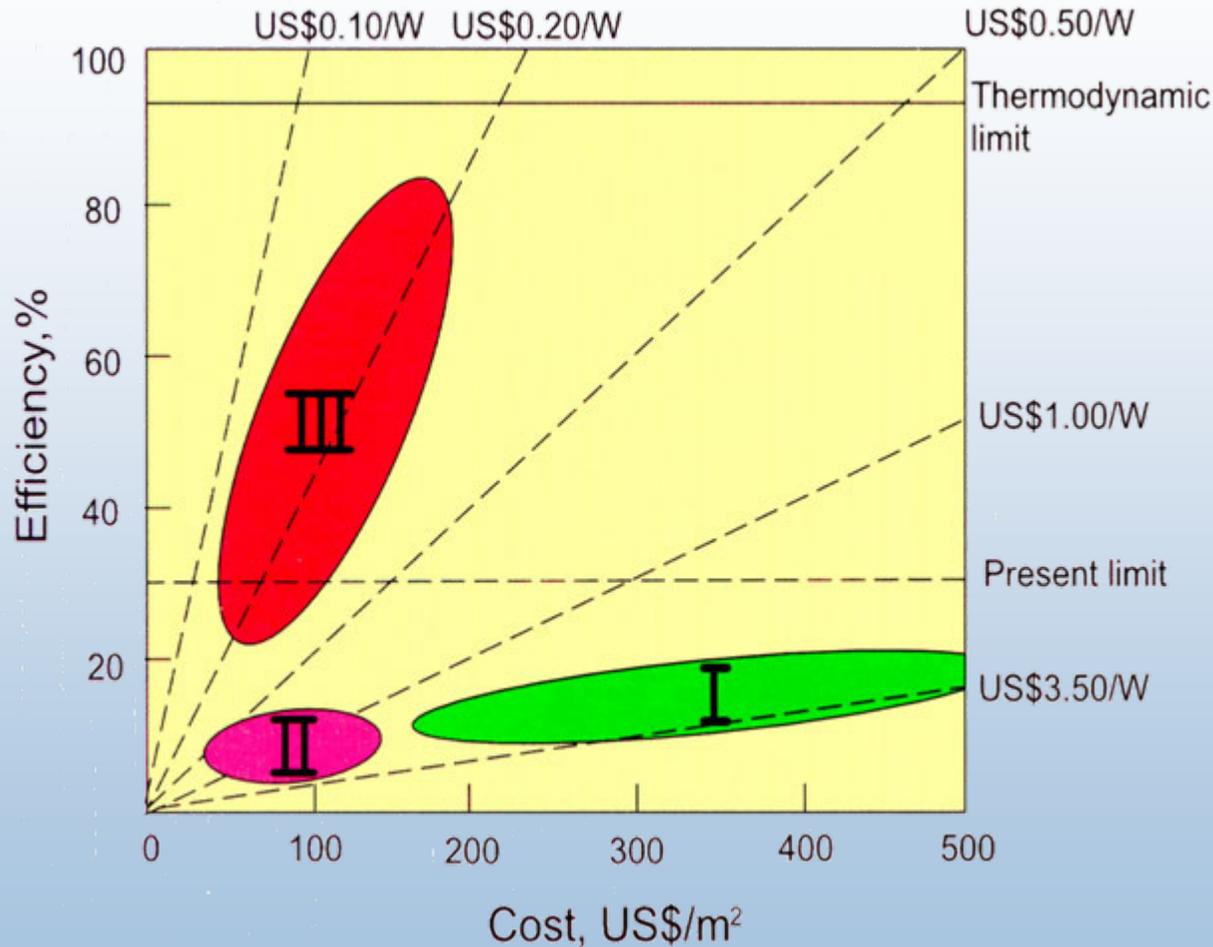
# Solar Outlook

## 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

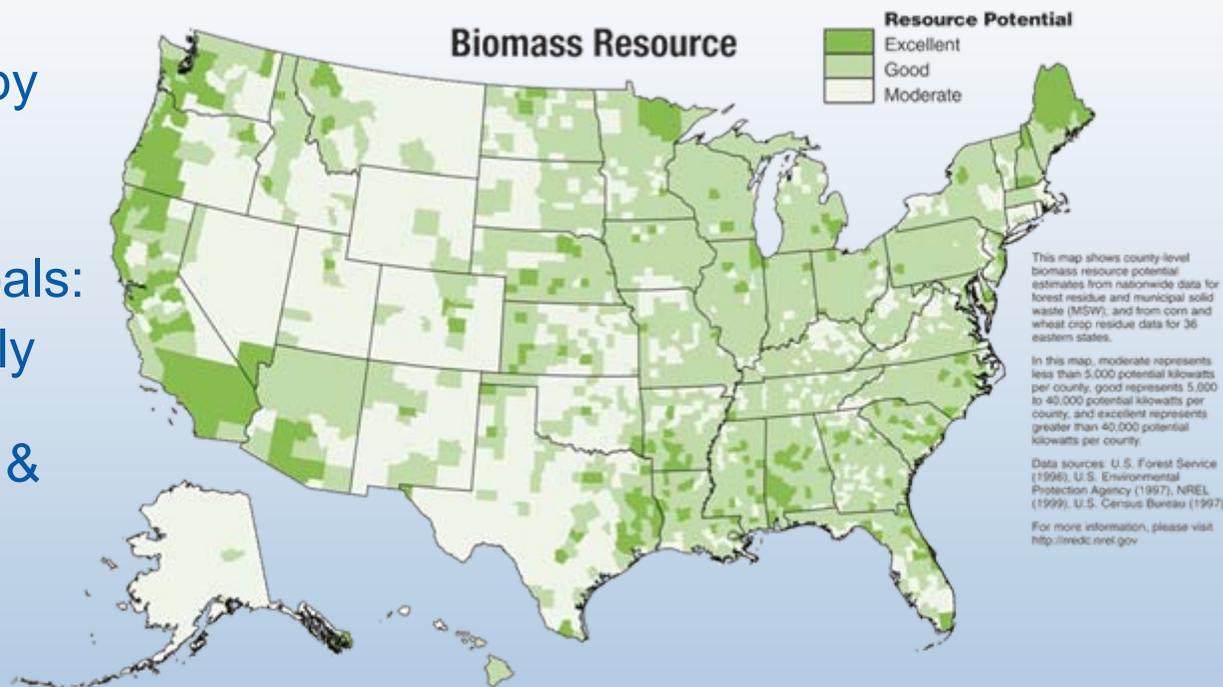
# Biomass/Biofuels Outlook

## DOE Biomass Program goals:

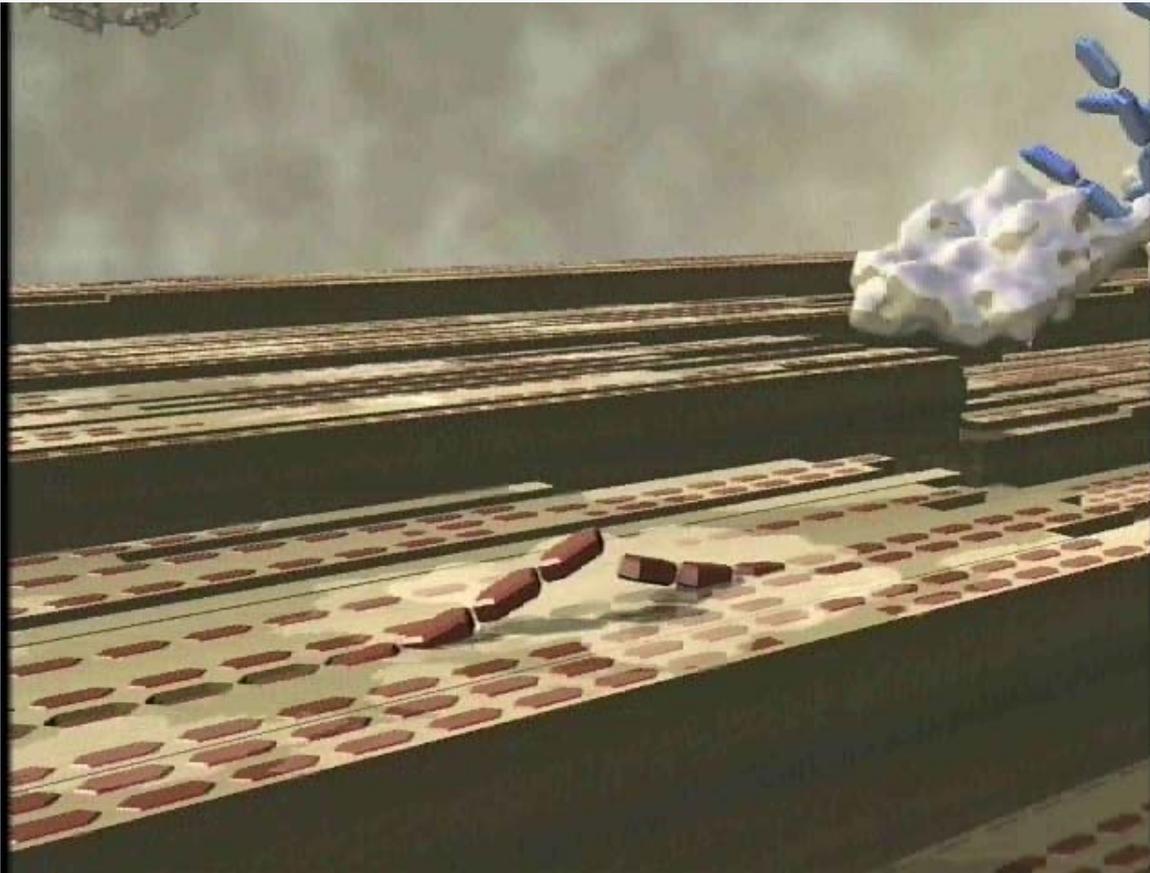
- Competitive electricity by 2020

## 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

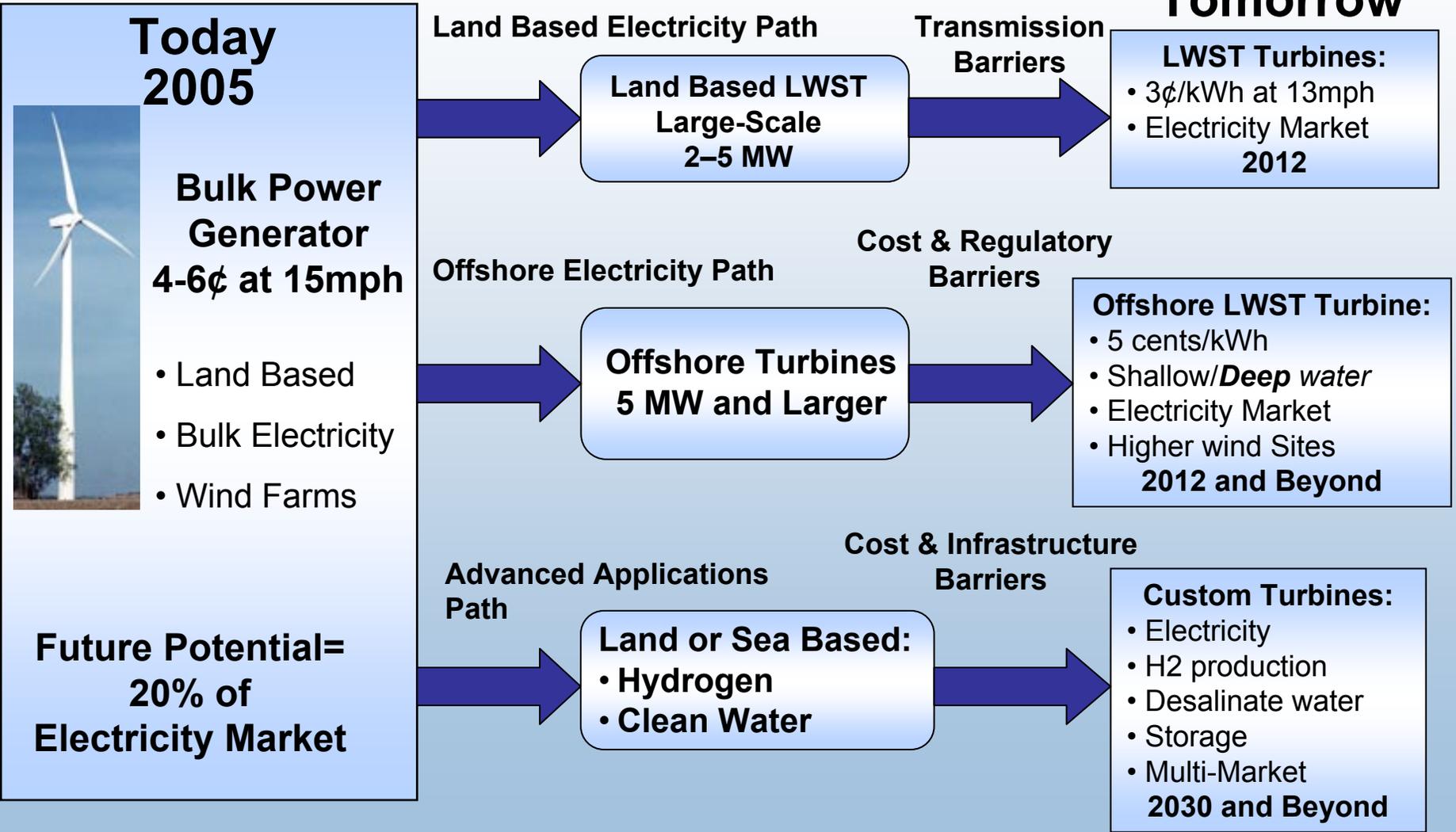
- Plant cell wall deconstruction
- Robust ethanologens
- Better options for thermochemical fuels
- Process intensification

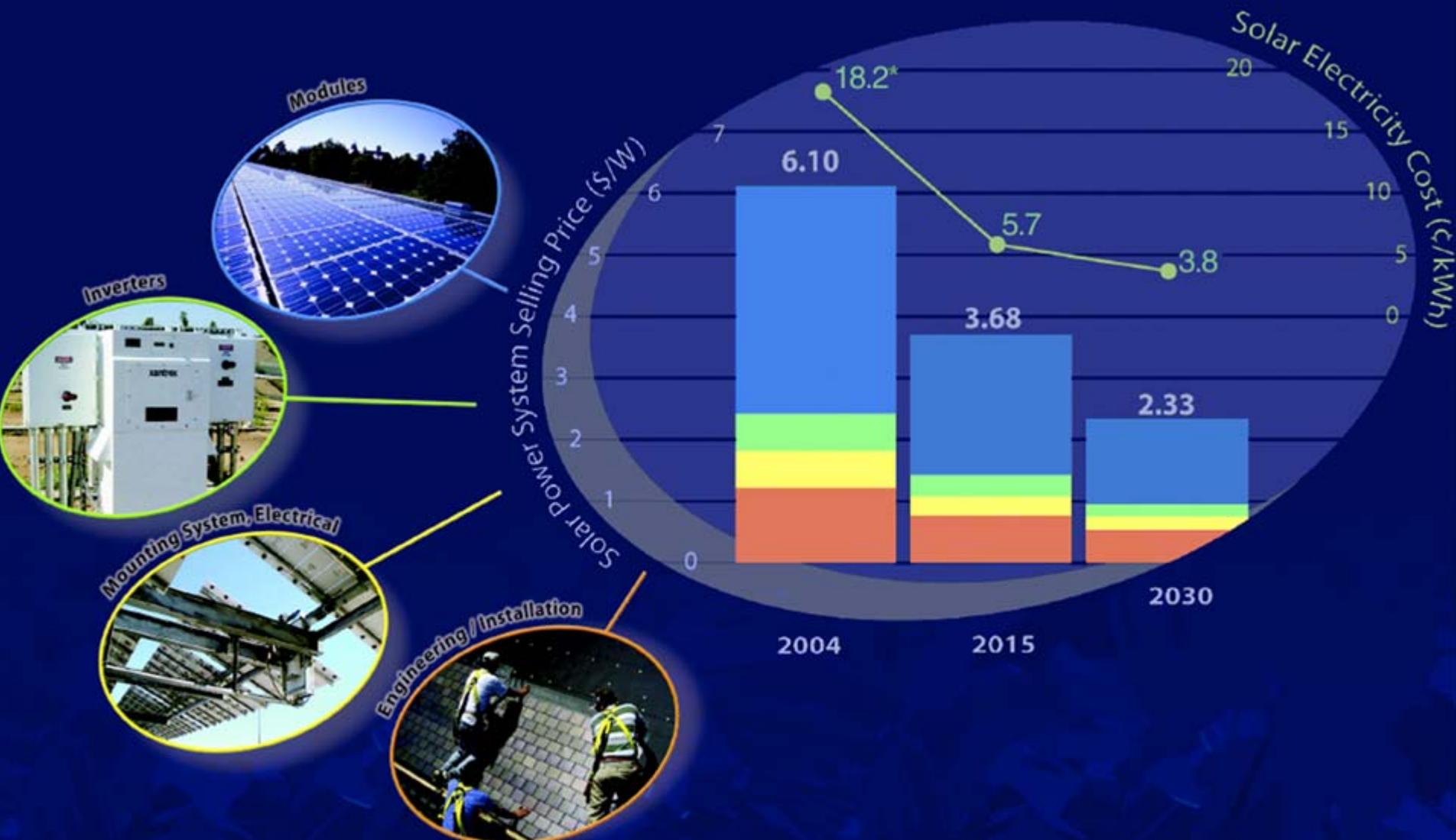
# **U.S. Industry Market Viability**

**Technology Roadmaps and Vision for the Future**



# A Future Vision for Wind Energy Markets

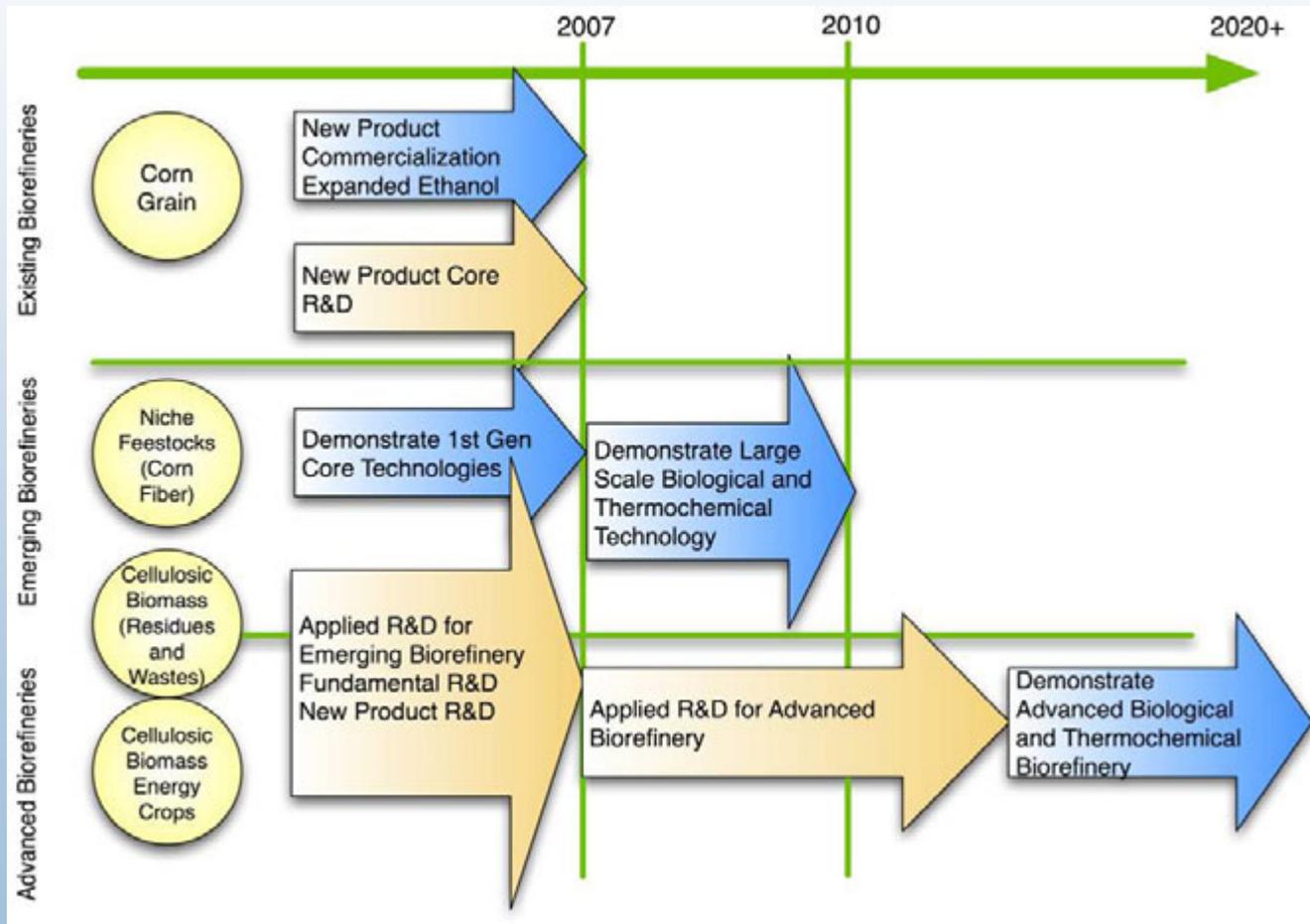




**Roadmap case for grid-connected solar system with 30-year lifetime (customer side of meter)**

*\*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](http://www.nrel.gov)



**Golden, Colorado**