# Renewable Energy: Poised to Realize Long-Term Potential

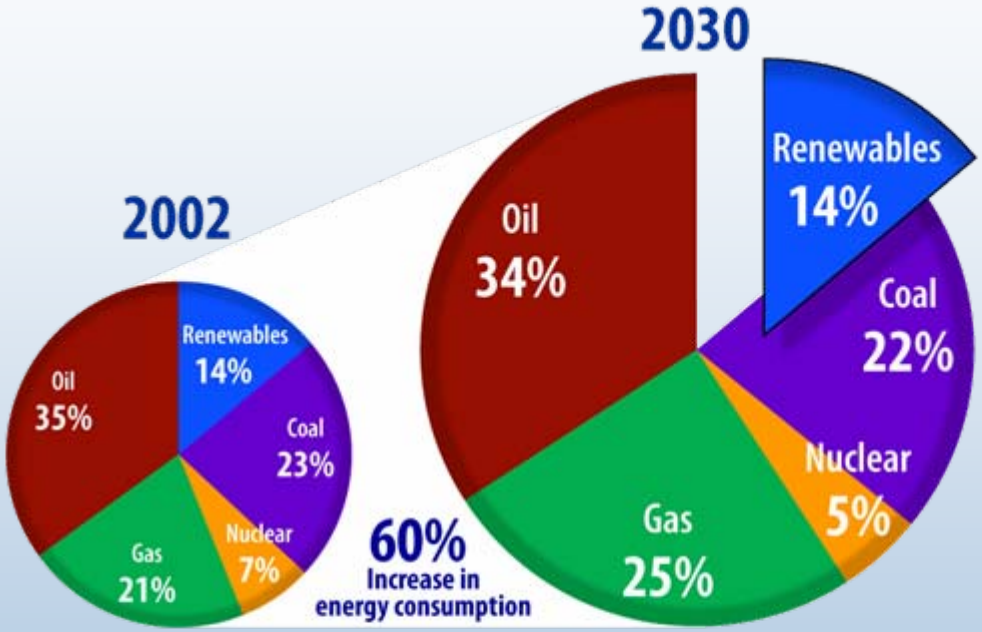
**Presented at the**
**International Association for Energy Economics Conference**
**Potsdam, Germany**

**June 10, 2006**

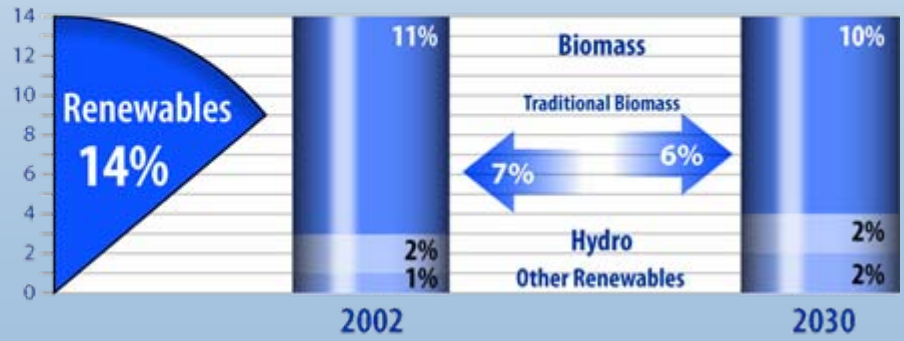
Dr. Dan E. Arvizu
Director, National Renewable Energy Laboratory

NREL/PR-100-40768

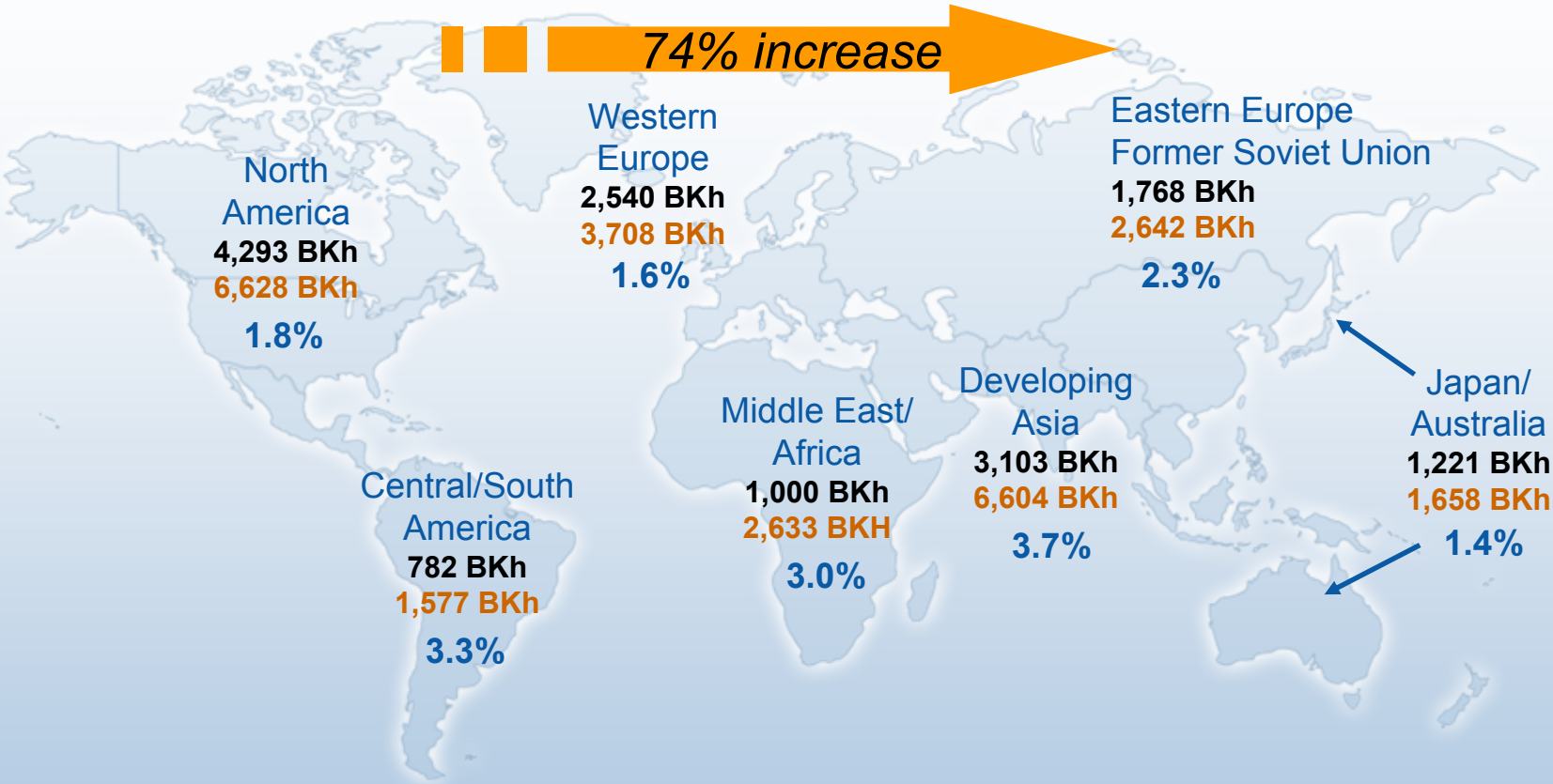
# World Energy Supply and the Role of Renewable Energy




Source: OECD/IEA, 2004



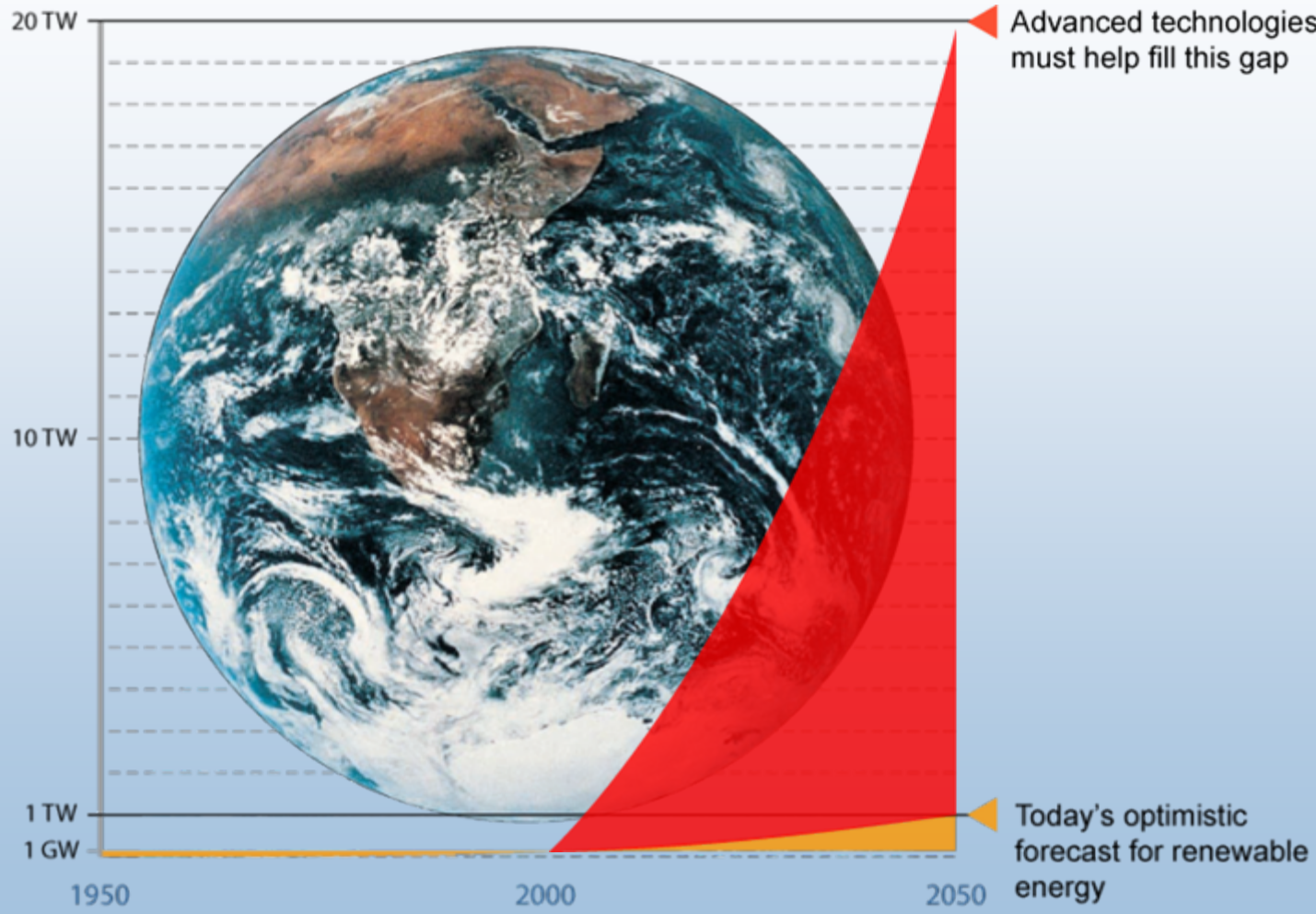
# Electricity Outlook: 2001-2025




- 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 energy will offer attractive options

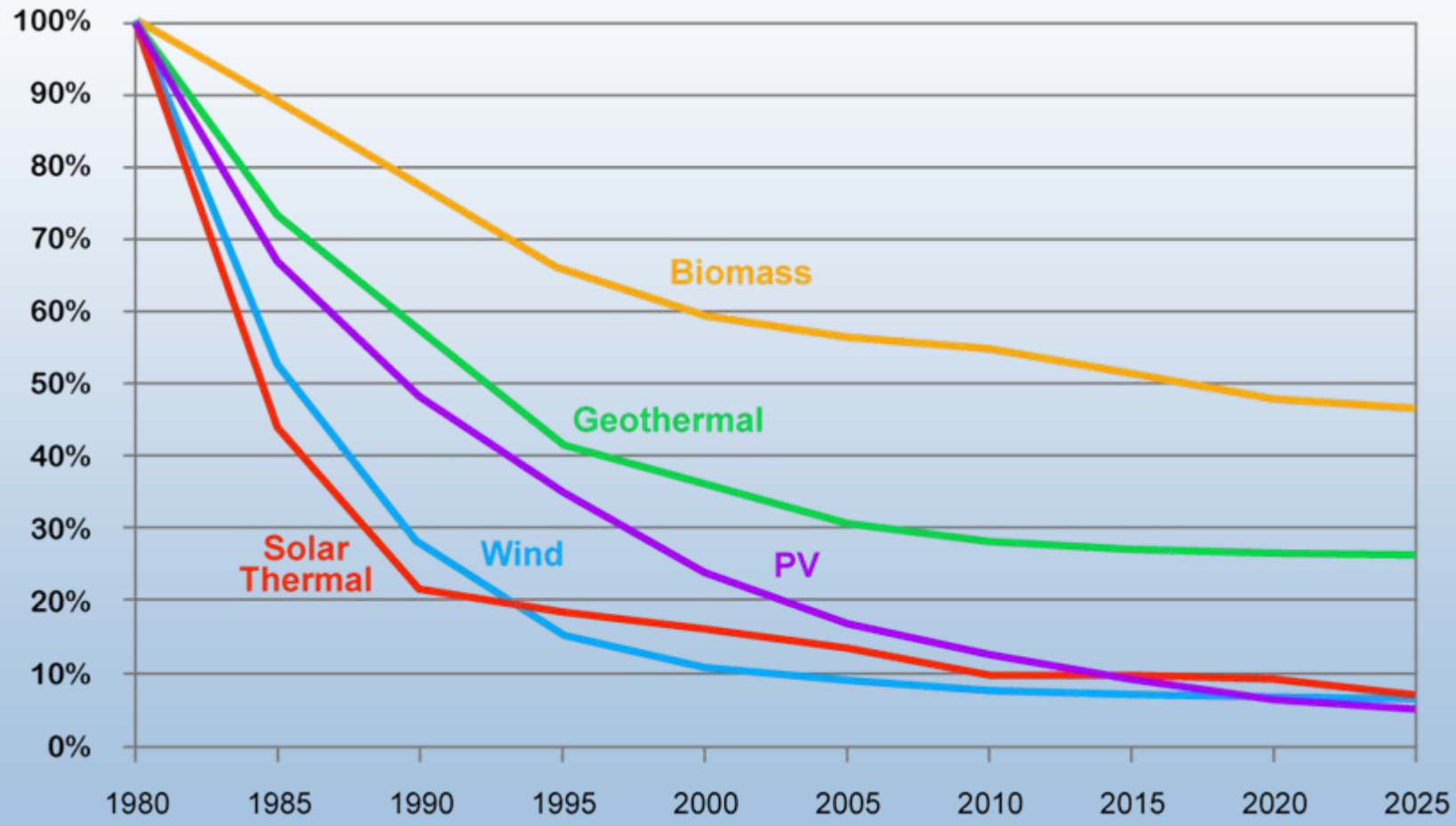
Source: International Energy Outlook 2003, Table A9

# Magnitude of Challenge Requires Global Action and a Change in Trajectory



# Renewable Energy Electricity Generation Costs as Percentage of 1980 Levels:

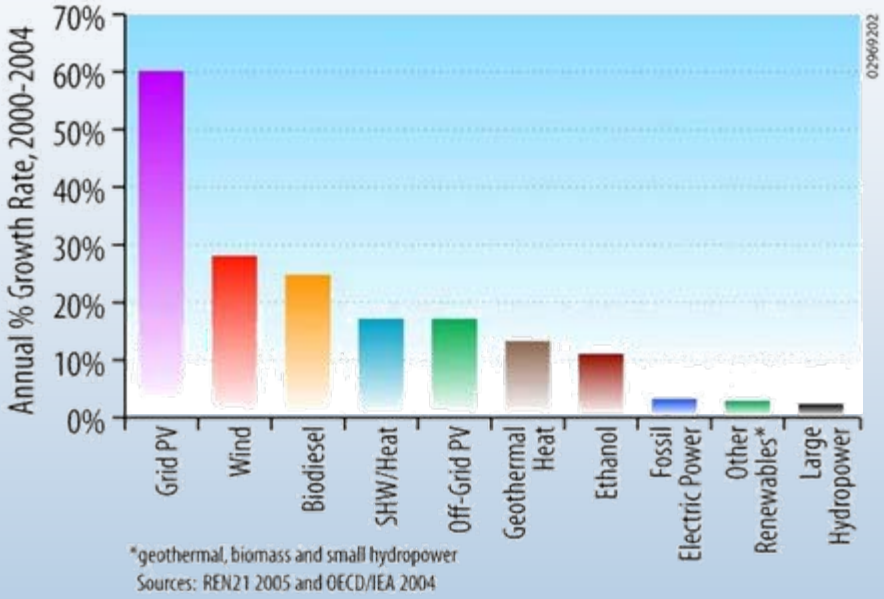
## Historical and Projected



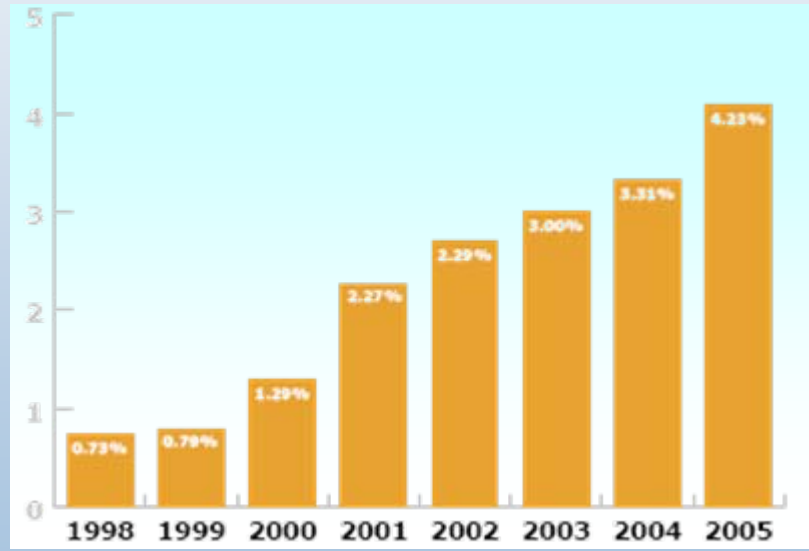

Source: NREL 2005, 2002

# Renewable Energy is Growing

**Renewable Energy Annual Growth Rates**




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




**Source: Nth Power LLC**

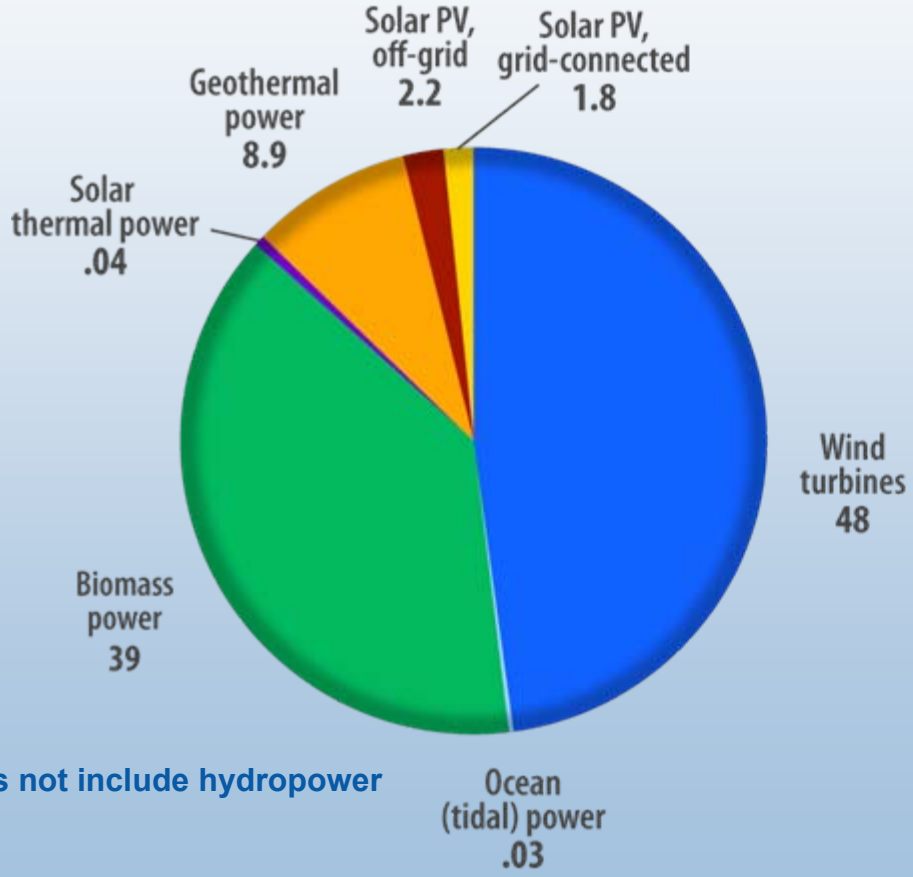
**Wind & Solar are each $10B+ industries and there is over a $1B clean energy venture capital market**

# Renewable Energy Indicators

## As of Year End 2004

### Power Generation

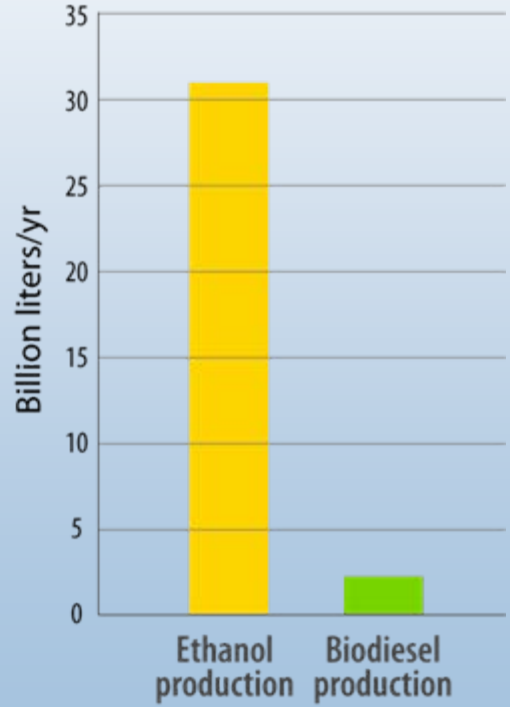
#### Existing Capacity* – GW




*Does not include hydropower

### Transport Fuels

#### Billion liters/year




Source: REN21 Renewables 2005 Status Report,

# Wind

**Today's Status in U.S.:**

- 9,200 MW installed as of Dec 2005
- Cost 6-9¢/kWh at good wind sites with no PTC

**U.S. 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
- Major benefits to rural economy

**NREL Research Thrusts:**

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

Source: U.S. Department of Energy, Wind Power Monthly January 2006

# Where is Wind Energy Going?

## Today 2005

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

- Land Based
- Bulk Electricity
- Wind Farms

**Potential 20% of Electricity Market**

## Tomorrow

**Land Based Electricity Path**

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

**Transmission Barriers**

**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**

# Biopower

**Today's U.S. status:**

- 2004 Capacity – 10 GWe
  - 5 GW Pulp and Paper
  - 2 GW Dedicated Biomass
  - 3 GW MSW and Landfill Gas
- 2004 Generation – 60 TWh
- Cost 8¢-10¢/kWh

**Long-term potential:**

- Cost 4-6¢/kWh for integrated gasification combined cycle
- 160 TWh of net electricity exported to grid from integrated 60 billion gal/yr biorefinery industry by 2030

Source: Aden,et. al, NREL/TP-510-32438

# Biofuels

## U.S. 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

# Geothermal

**Today's U.S. Status:**

- 2,800 MWe installed, 500 MWe new contracts
- Cost 5-8¢/kWh with no PTC
- Capacity factor typically > 90%, base load power

**U.S. DOE Cost Goals:**

- <5¢/kWh, for typical hydrothermal sites by 2010
- <5¢/kWh, for enhanced geothermal systems by 2040

**Long Term Potential:**

- 40,000 MWe installed by 2040
- Ultimate potential to supply a significant portion of domestic electricity

**NREL Research Thrusts:**

- Low temperature conversion cycles
- Better performing, lower cost components
- Innovative materials

Source: NREL 2006

# Solar

## Photovoltaics and Concentrating Solar Power

### U.S. Solar Status:

**PV**
- 450 MW
- Cost 18-23¢/kWh

**CSP**
- 355 MW
- Cost 12¢/kWh

### Potential:

**PV**
- 11-18¢/kWh by 2010
- 5-10 ¢/kWh by 2015

**CSP**
- 8.5¢/kWh by 2010
- 6¢/kWh by 2015

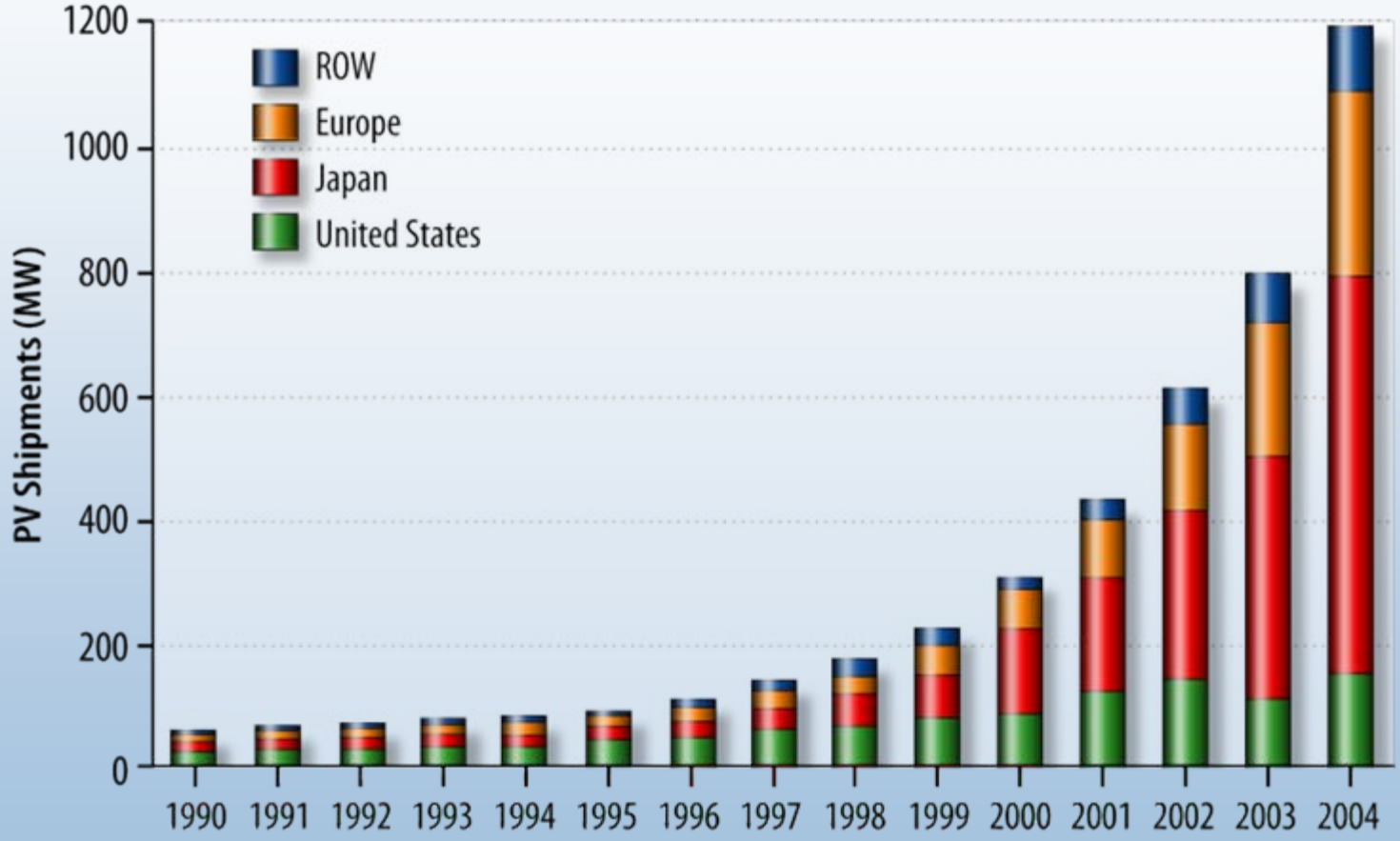
### NREL Research Thrusts:

**PV**
- Advanced manufacturing techniques
- Higher efficiency devices
- New nanomaterials applications

**CSP**
- Next generation solar collectors
- High performance, high efficiency storage

Source: U.S. Department of Energy, NREL
Updated 5/15/06

# Worldwide PV Shipments

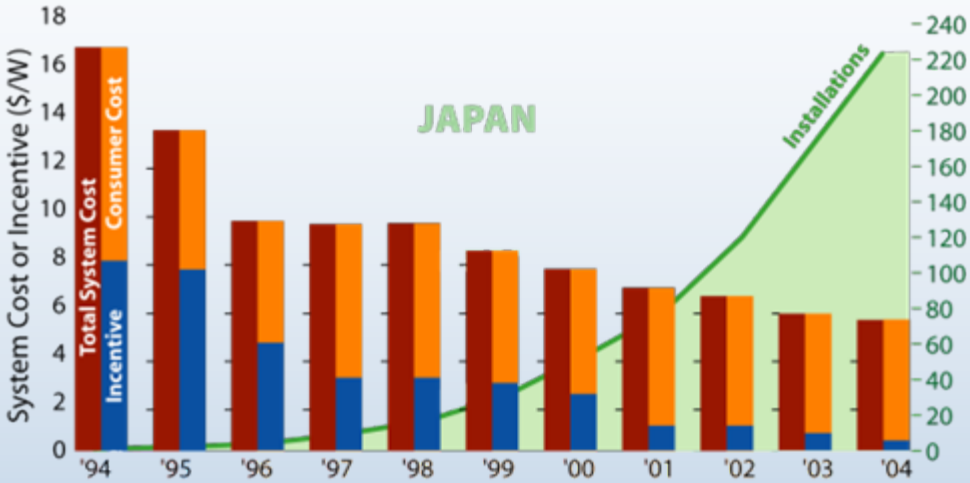


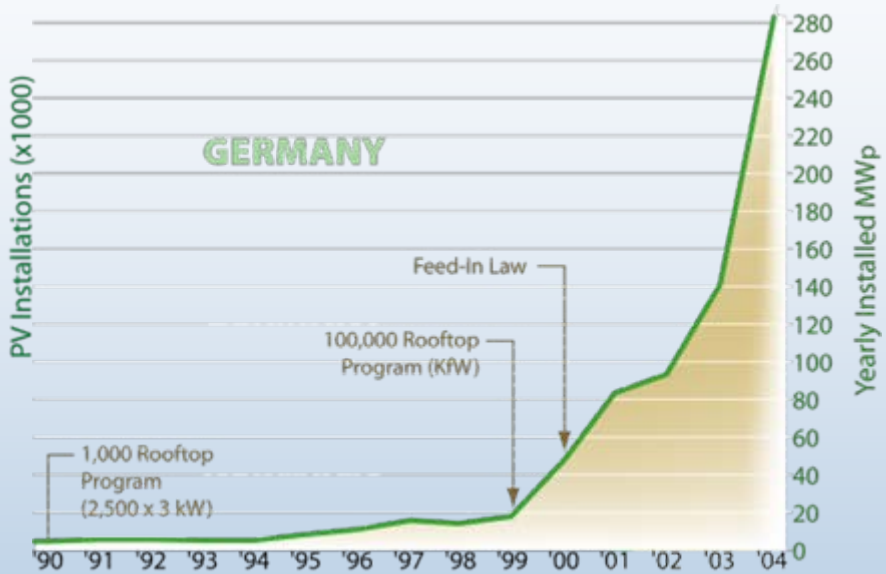

Source: Paul Maycock, PV News, February/March 2005.

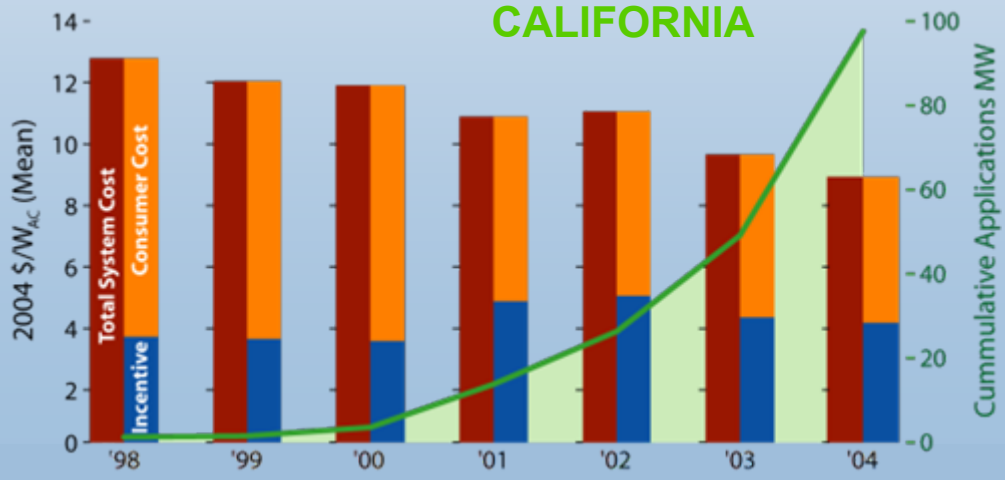
# Policy

*Stimulates markets*

Federal, state, and local governments are the STEWARDS



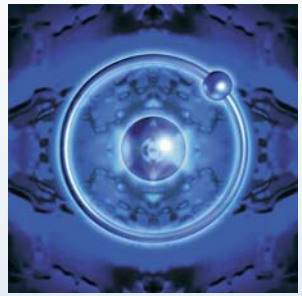



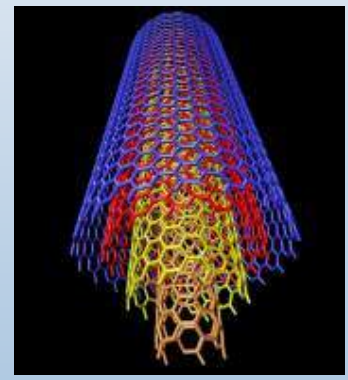

"BIG 3" Experience

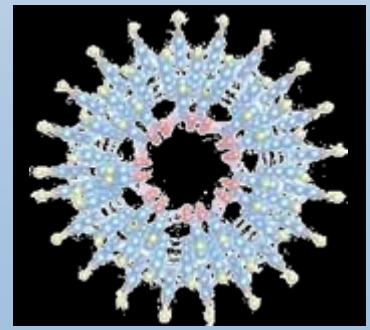
*(It works . . .!)*

# Directions in Energy Science and Technology: The Future Promise

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

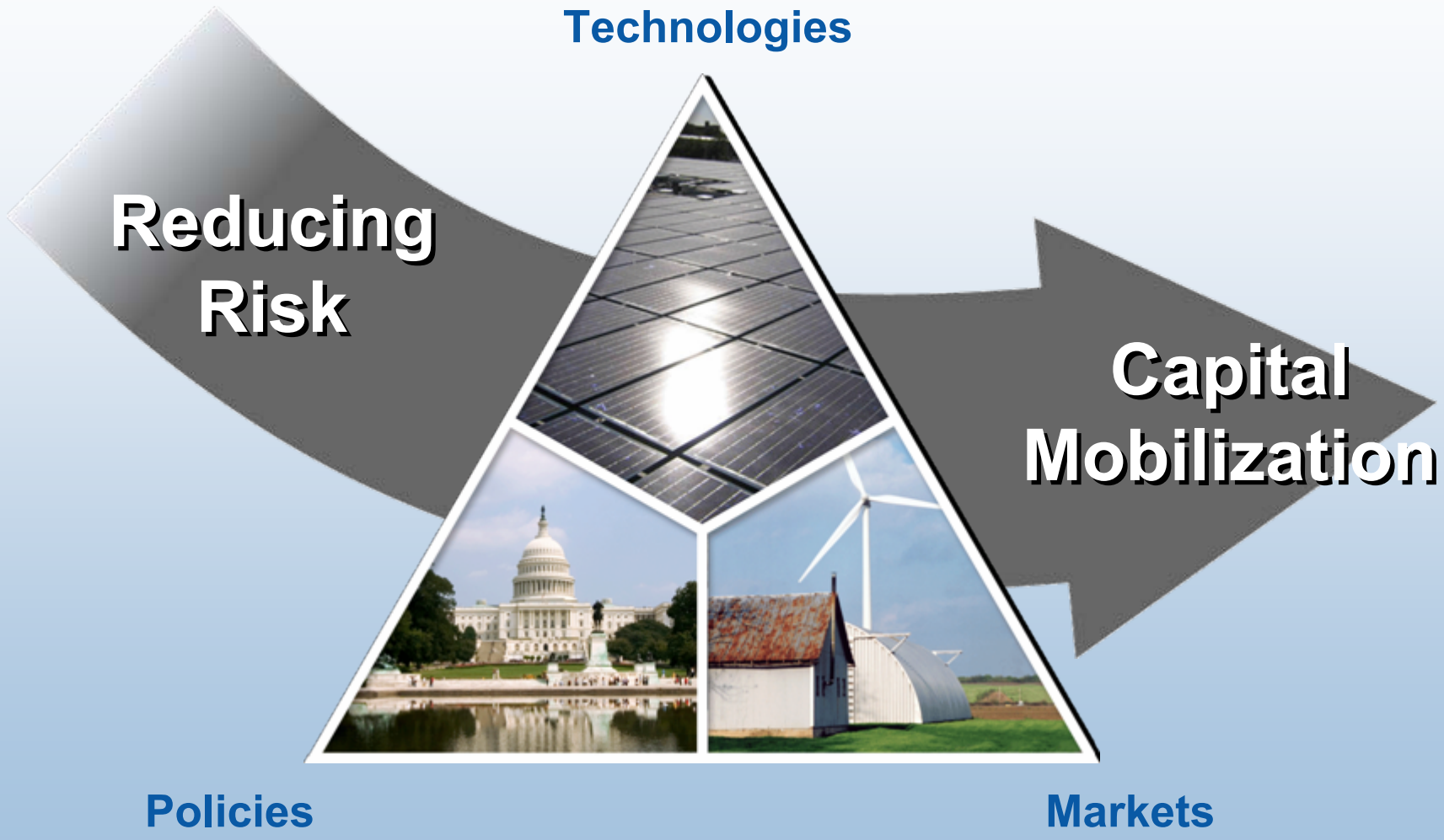






***Nano/Bio/Info***

# Getting There Involves…



The U.S. Department of Energy's

# National Renewable Energy Laboratory

www.nrel.gov

Golden, Colorado