

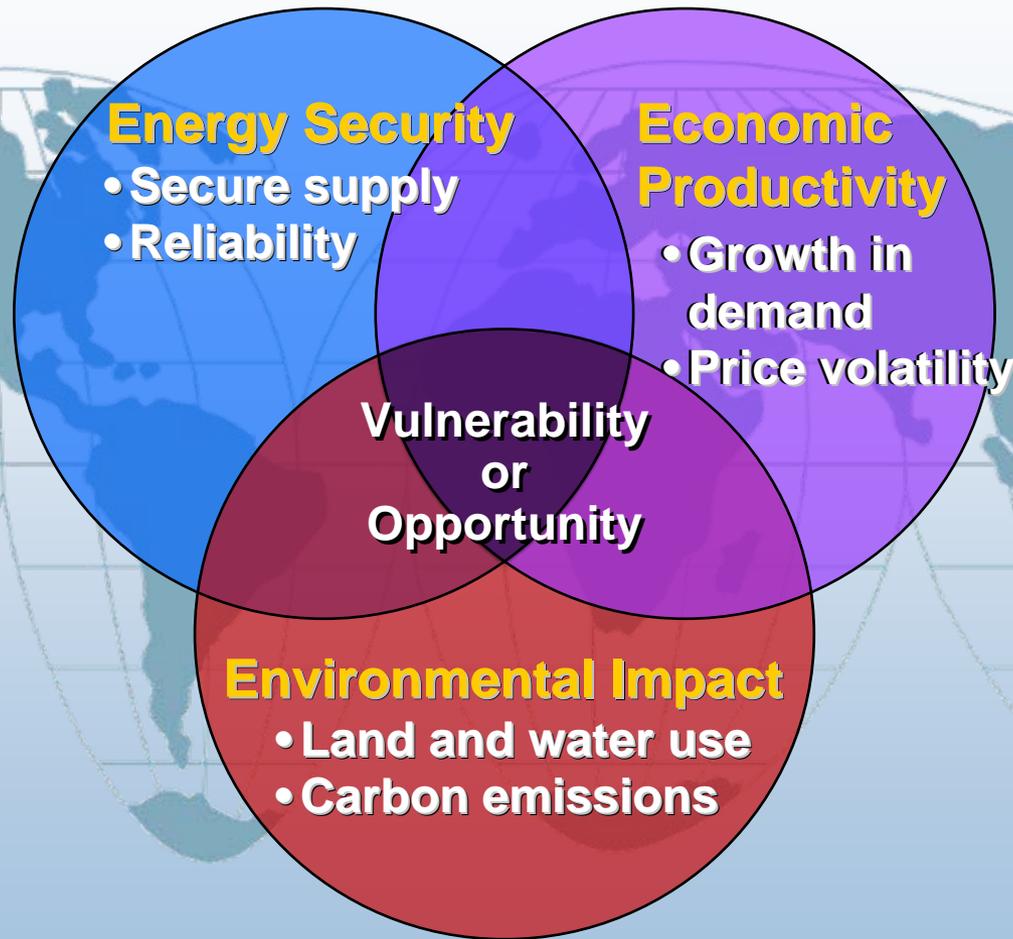
Thinking Differently: A New Energy Future

Thomas Weisel Partners
Alternative Energy Conference

June 13, 2007

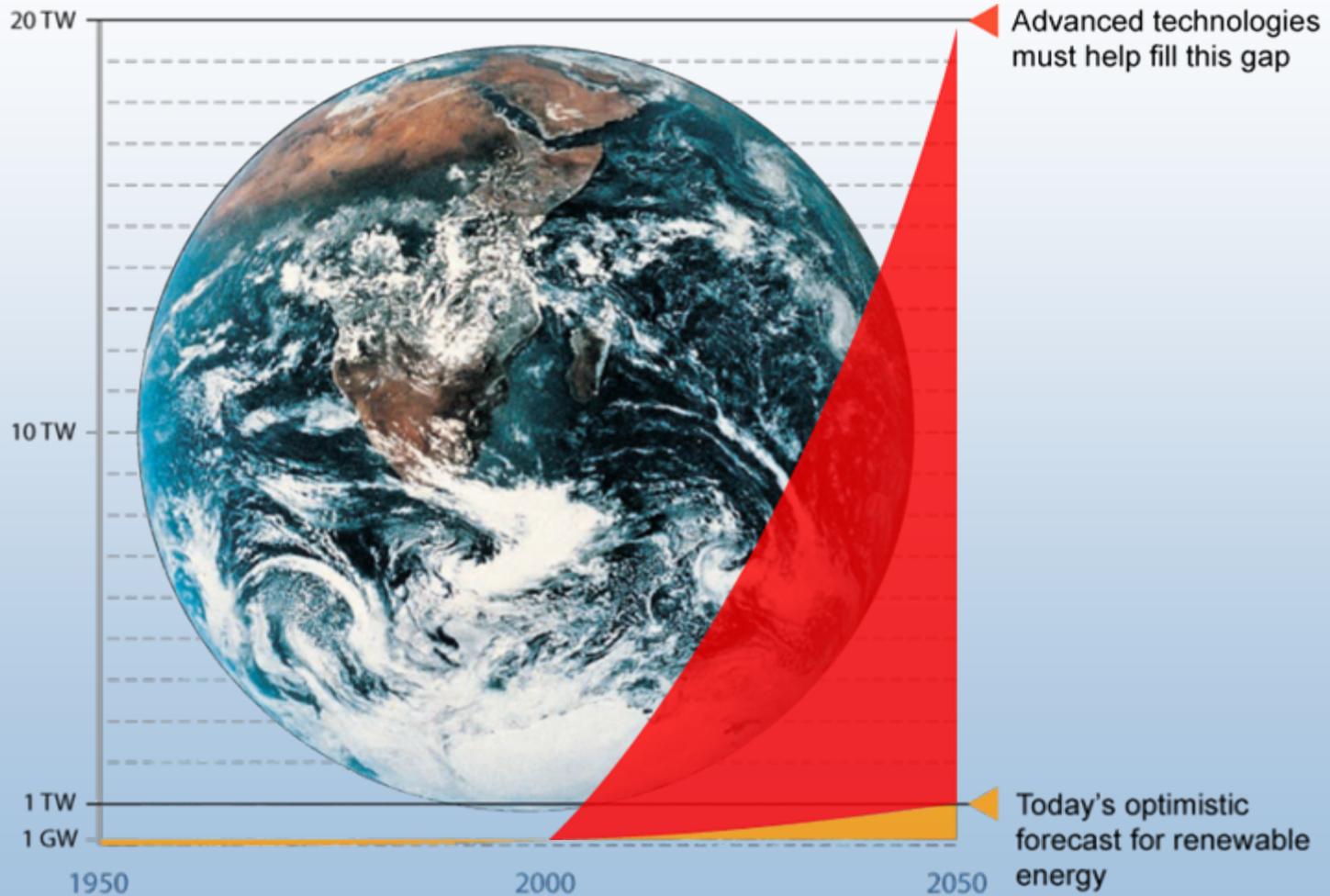
Dan E. Arvizu
Director, National Renewable Energy Laboratory

Energy Solutions Are Enormously Challenging



Must address all three imperatives

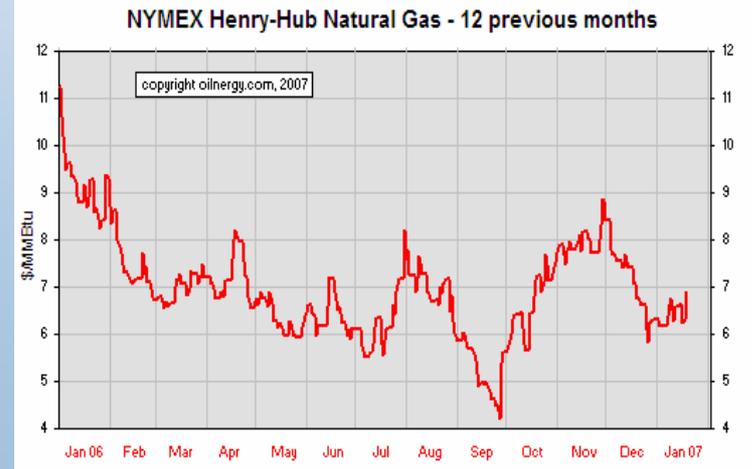
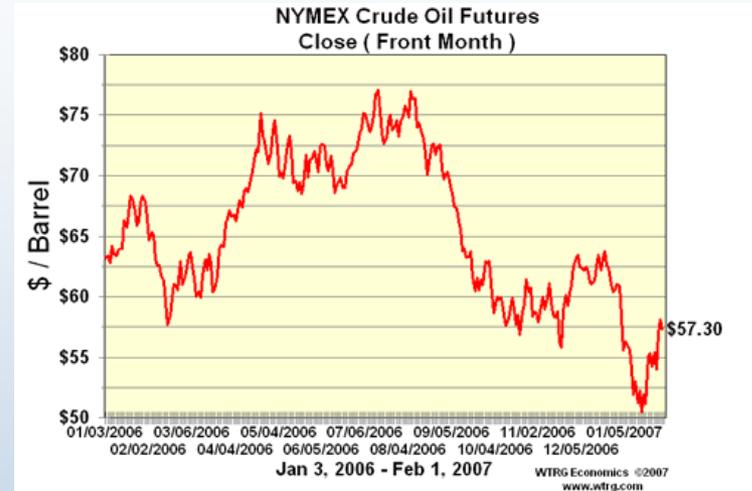
How Big is the Challenge?



Thinking Differently: Account for Externalities

Today's energy marketplace does not appropriately "value" certain public objectives or social goods, instead we have:

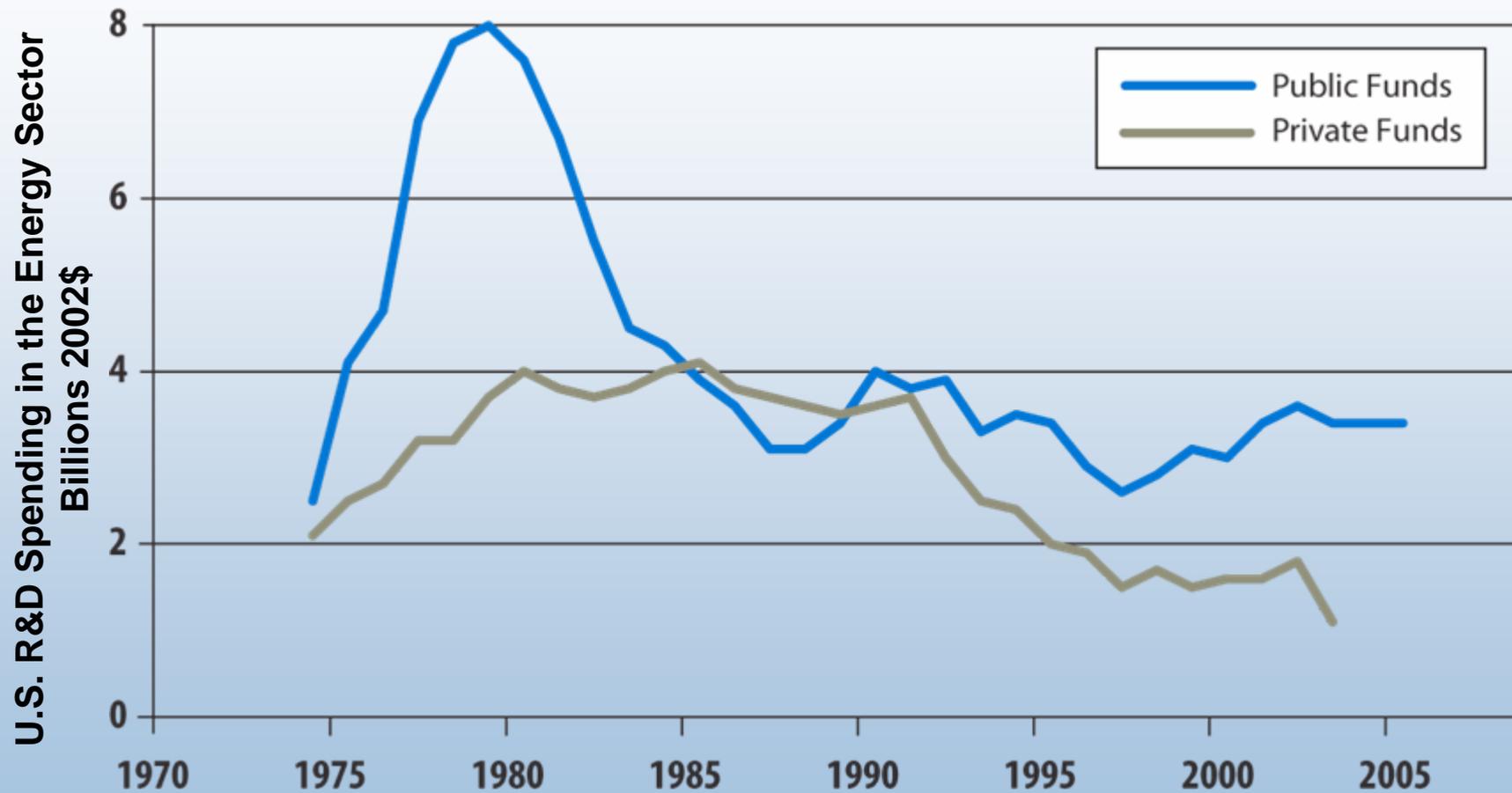
- Price volatility
- Serious environmental impacts
- Underinvestment in energy innovation



Mounting Evidence

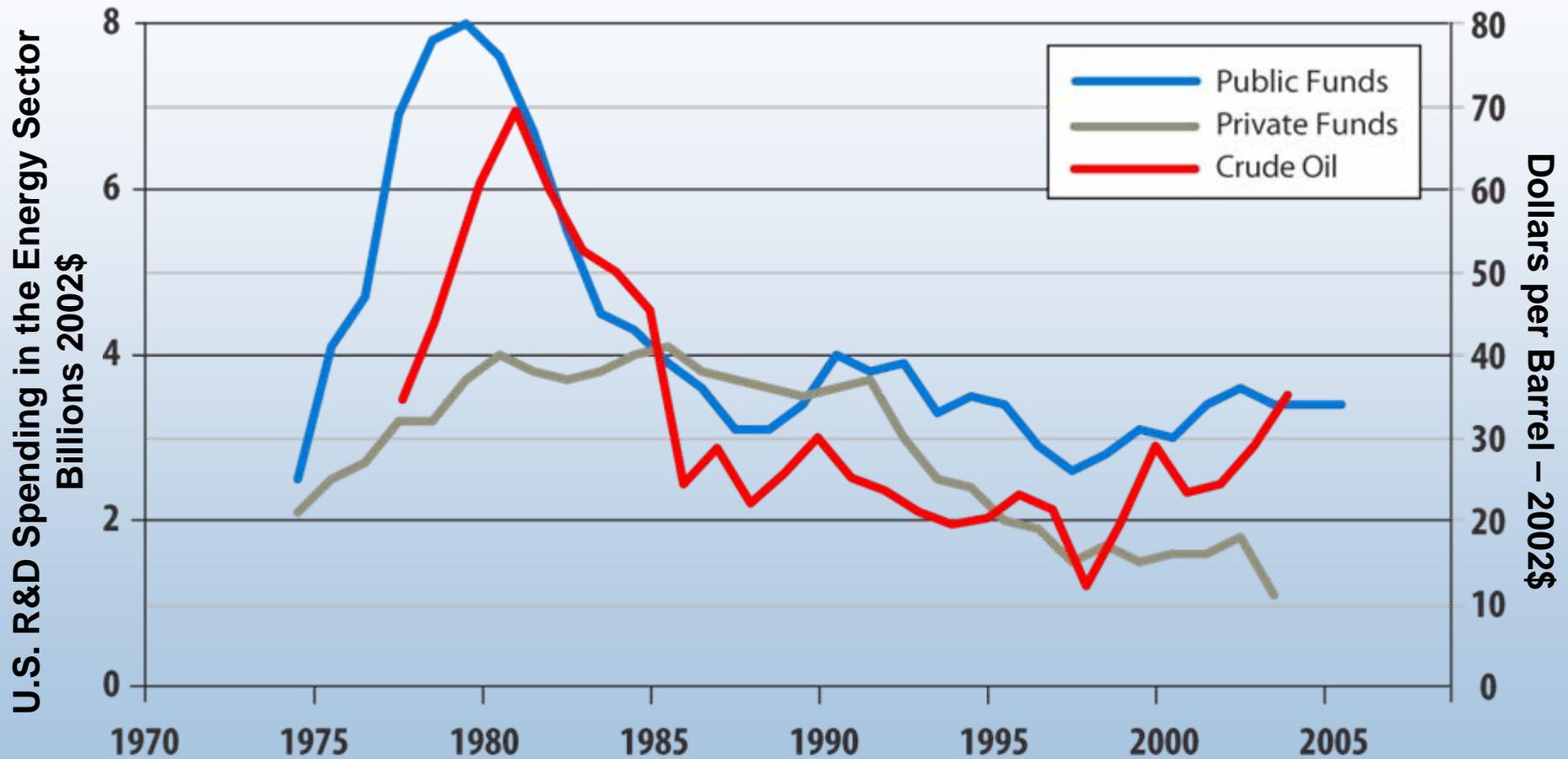


Declining Energy R&D Investments...



Source: Daniel Kammen, Gregory Nemet *Reversing the Incredible, Shrinking Energy R&D Budget* <http://rael.berkeley.edu/files/2005/Kammen-Nemet-ShrinkingRD-2005.pdf>
Table 10.3, Edition 25, *Transportation Energy Data Book* <http://cta.ornl.gov/data/chapter10.shtml>

Declining Energy R&D Investments... Reflect World Oil Price Movement



Source: Daniel Kammen, Gregory Nemet *Reversing the Incredible, Shrinking Energy R&D Budget* <http://rael.berkeley.edu/files/2005/Kammen-Nemet-ShrinkingRD-2005.pdf>
 Table 10.3, Edition 25, *Transportation Energy Data Book* <http://cta.ornl.gov/data/chapter10.shtml>

Setting the Bar Higher

- **U.S. National goals**
 - Biofuels: reduce gasoline usage by 20% in ten years
 - Wind: 20% of total provided energy by 2030
 - Solar: Be market competitive by 2015 for PV and 2020 for CSP
- **Challenge goals**
 - 25% of nation's energy supply from renewable sources by 2025
 - Others...

Getting to “Significance” Involves...

Technologies

**Reducing
Risk**

**Mobilizing
Capital**

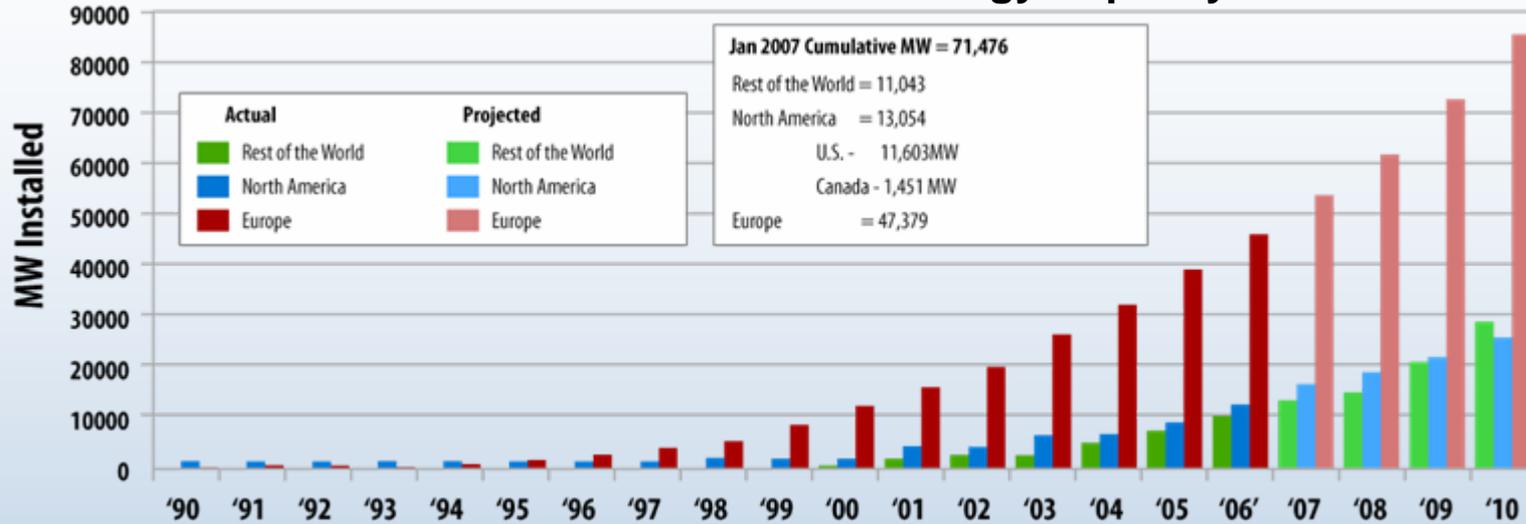
Policies

Markets

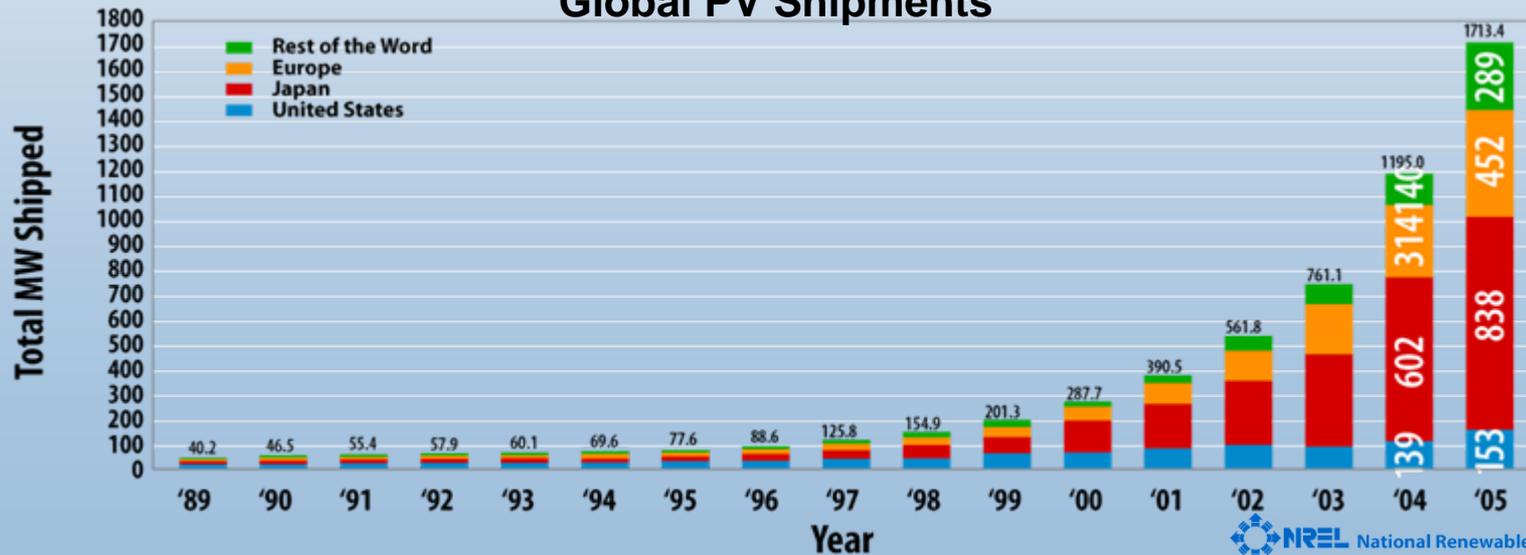


Global Markets are Growing Rapidly

Global Growth of Wind Energy Capacity

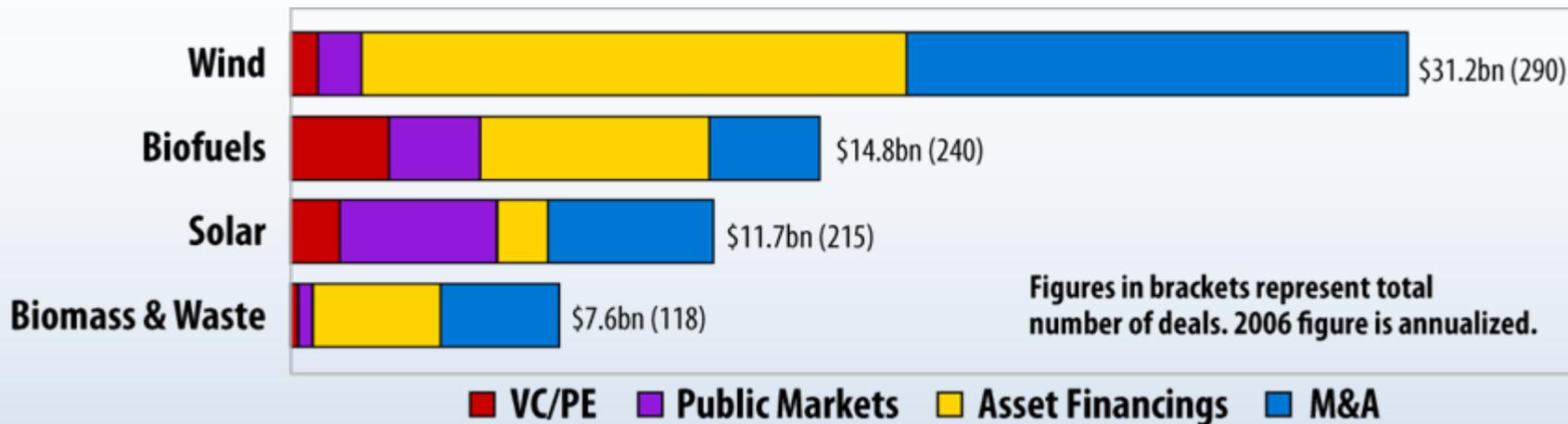


Global PV Shipments



Money Is Flowing Into the Sector

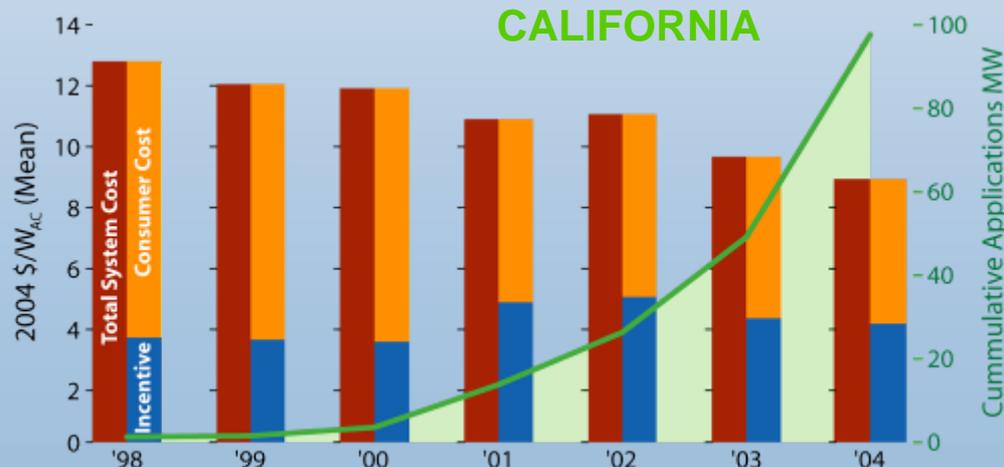
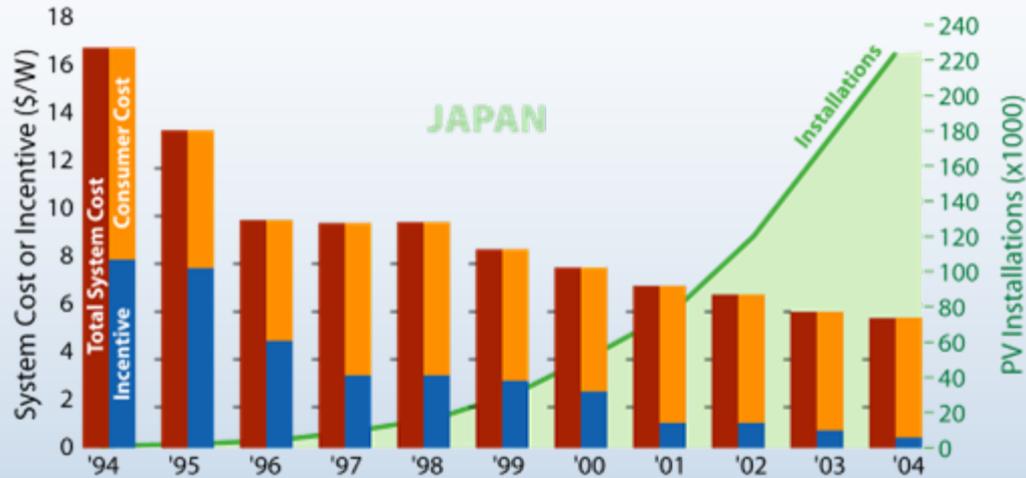
2006 Investment and M&A – By Sector and Asset Class



Annual VC Investment Volume – 2001-2004 Compared With 2005-2006

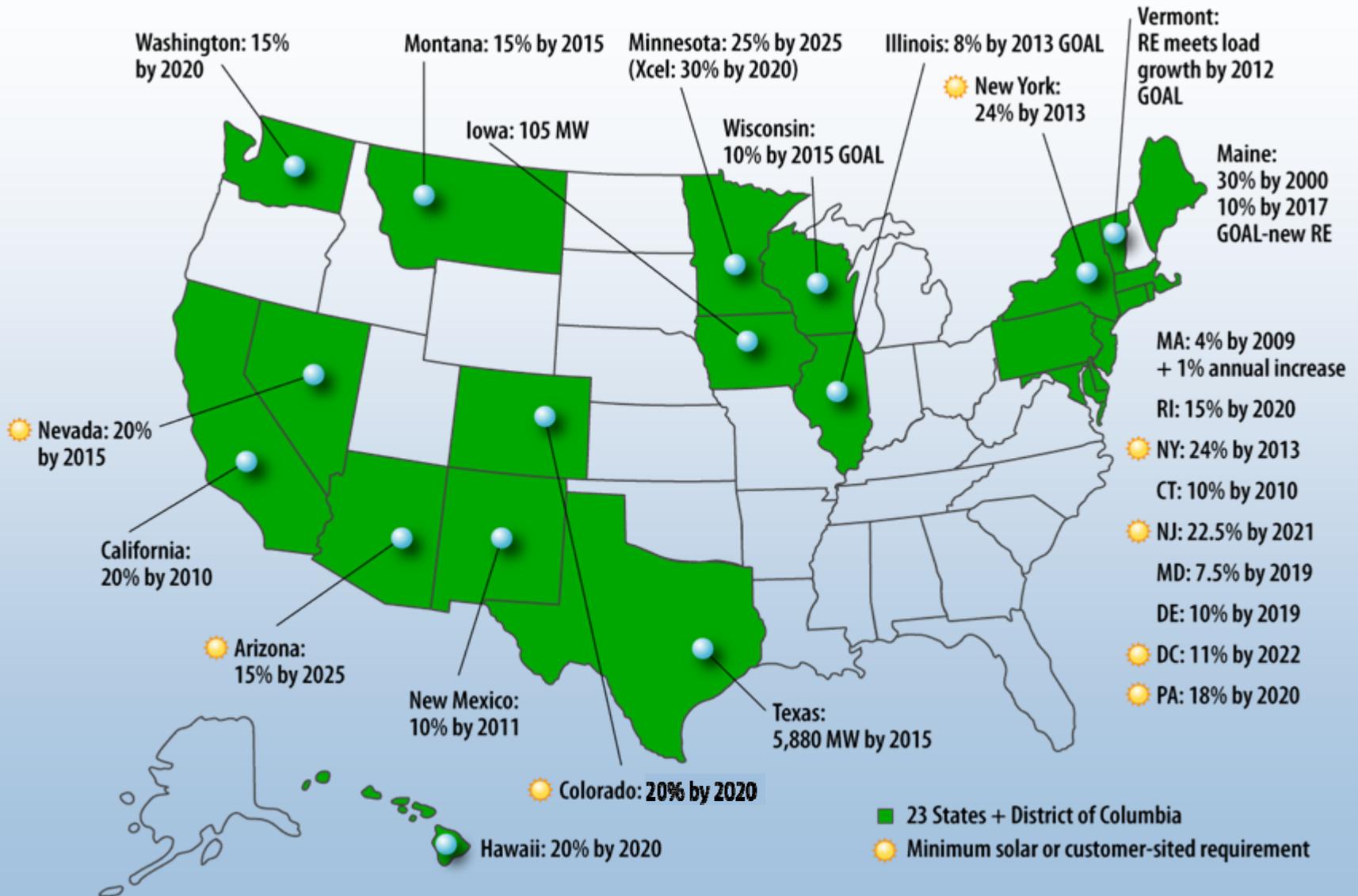


Worldwide Markets Have Driven Cost Reductions – Solar PV Example

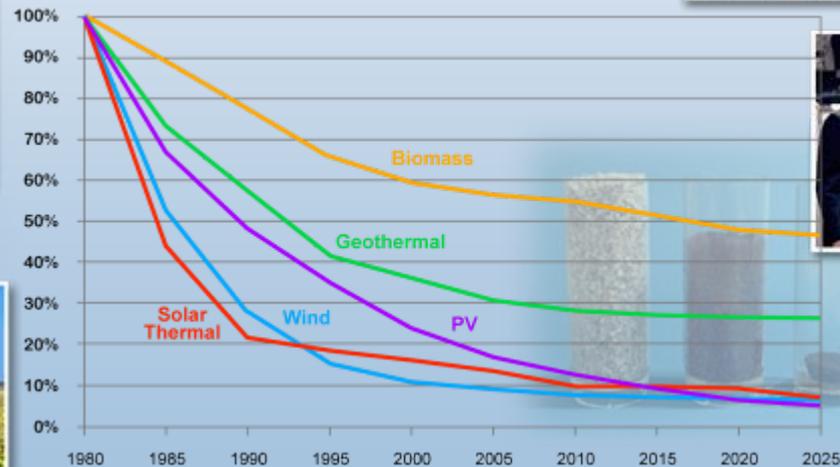
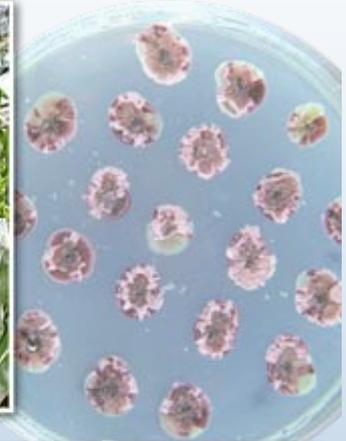


State Policy Framework

Renewable Electricity Standards



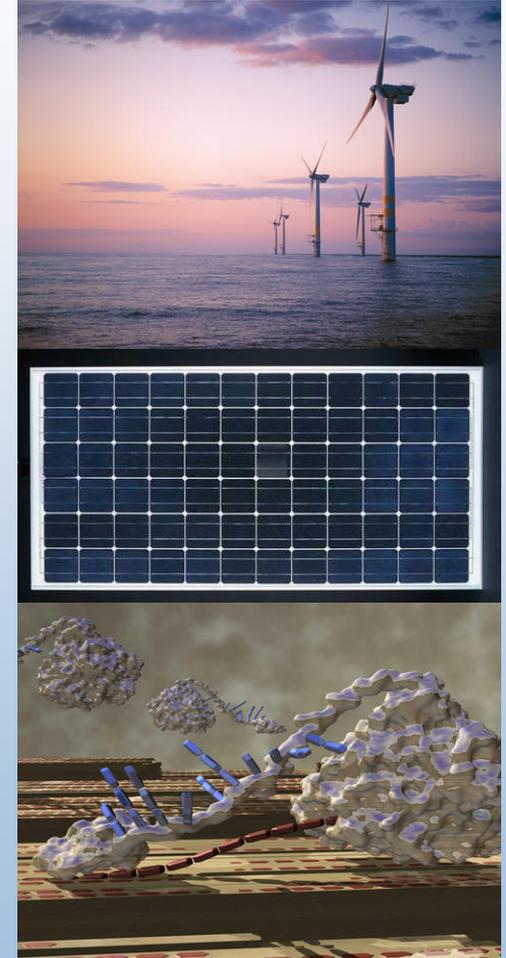
Past Investments Have Yielded Impressive Cost Reductions



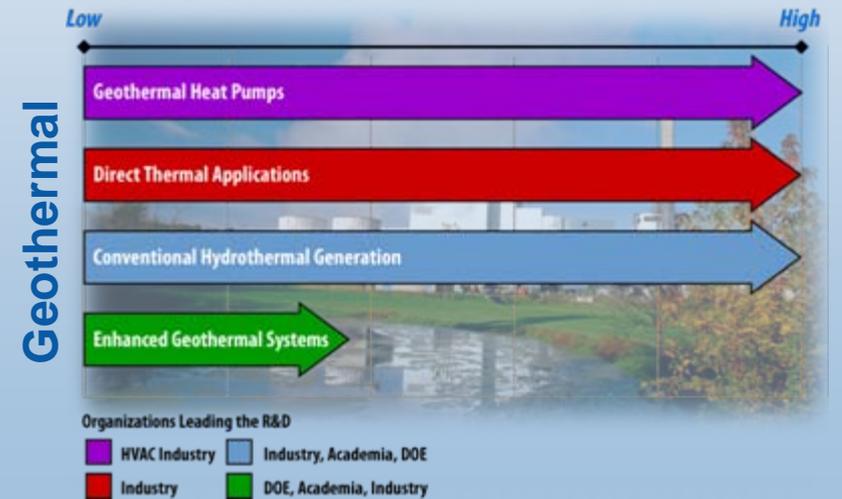
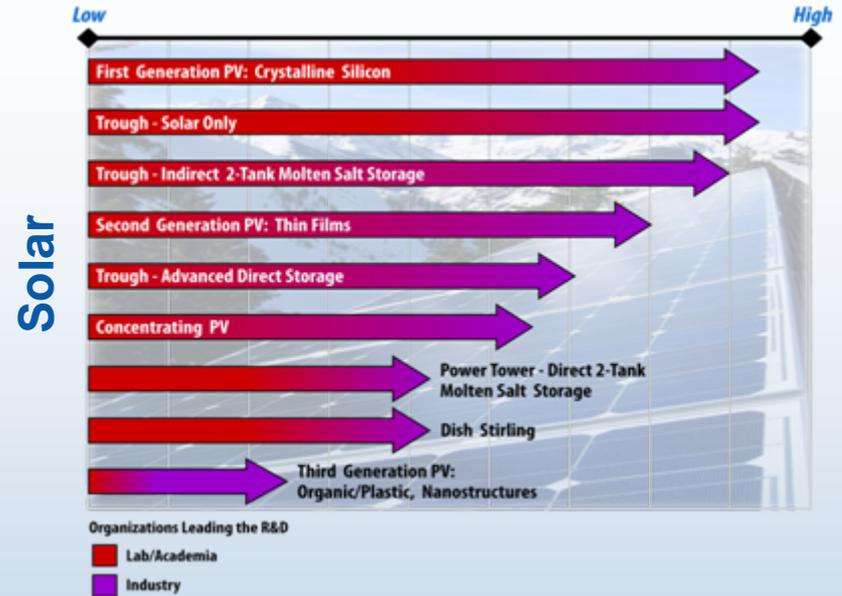
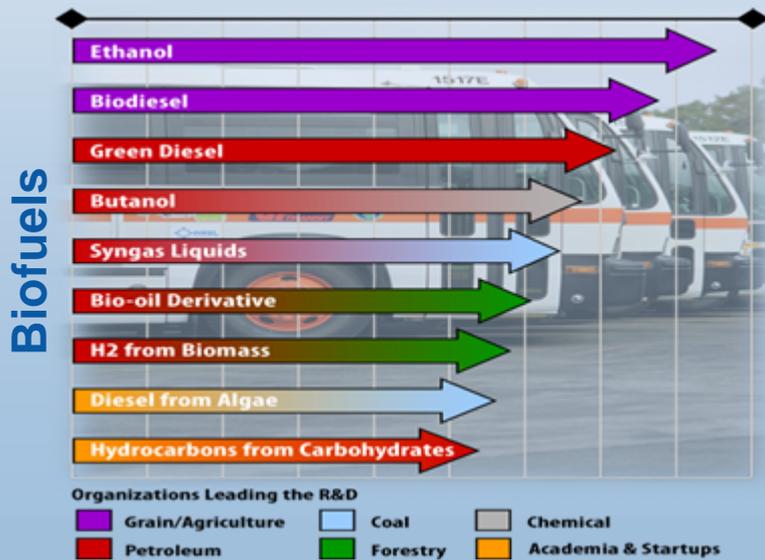
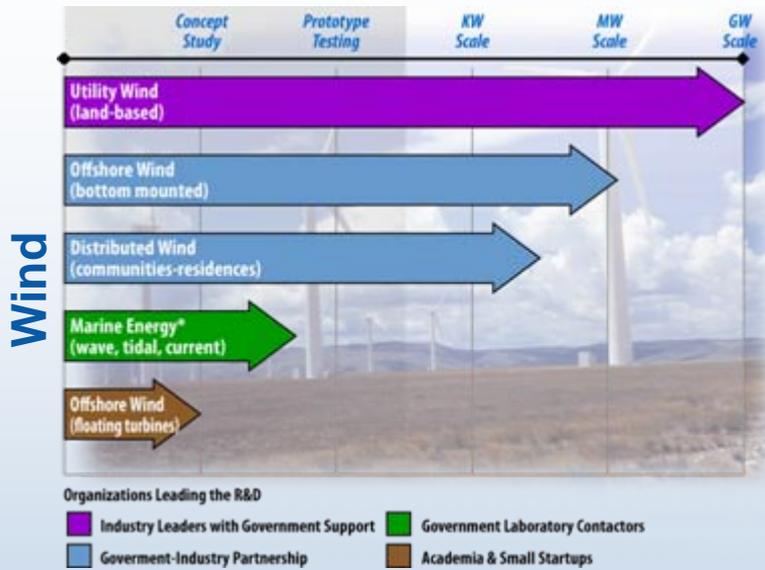
Technology Innovation Challenges

The Next Generation

- Wind Turbines
 - Improve energy capture by 30%
 - Decrease costs by 25%
- Solar Systems
 - Improved performance through, new materials, lower cost manufacturing processes, concentration
 - Nanostructures
- Biofuels
 - New feedstocks
 - Integrated biorefineries



Technology Maturity Pathways



Energy Efficiency and Renewable Energy Technology Development Programs



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

Solar

Photovoltaics and Concentrating Solar Power

Status in U.S.

PV

- 526 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:

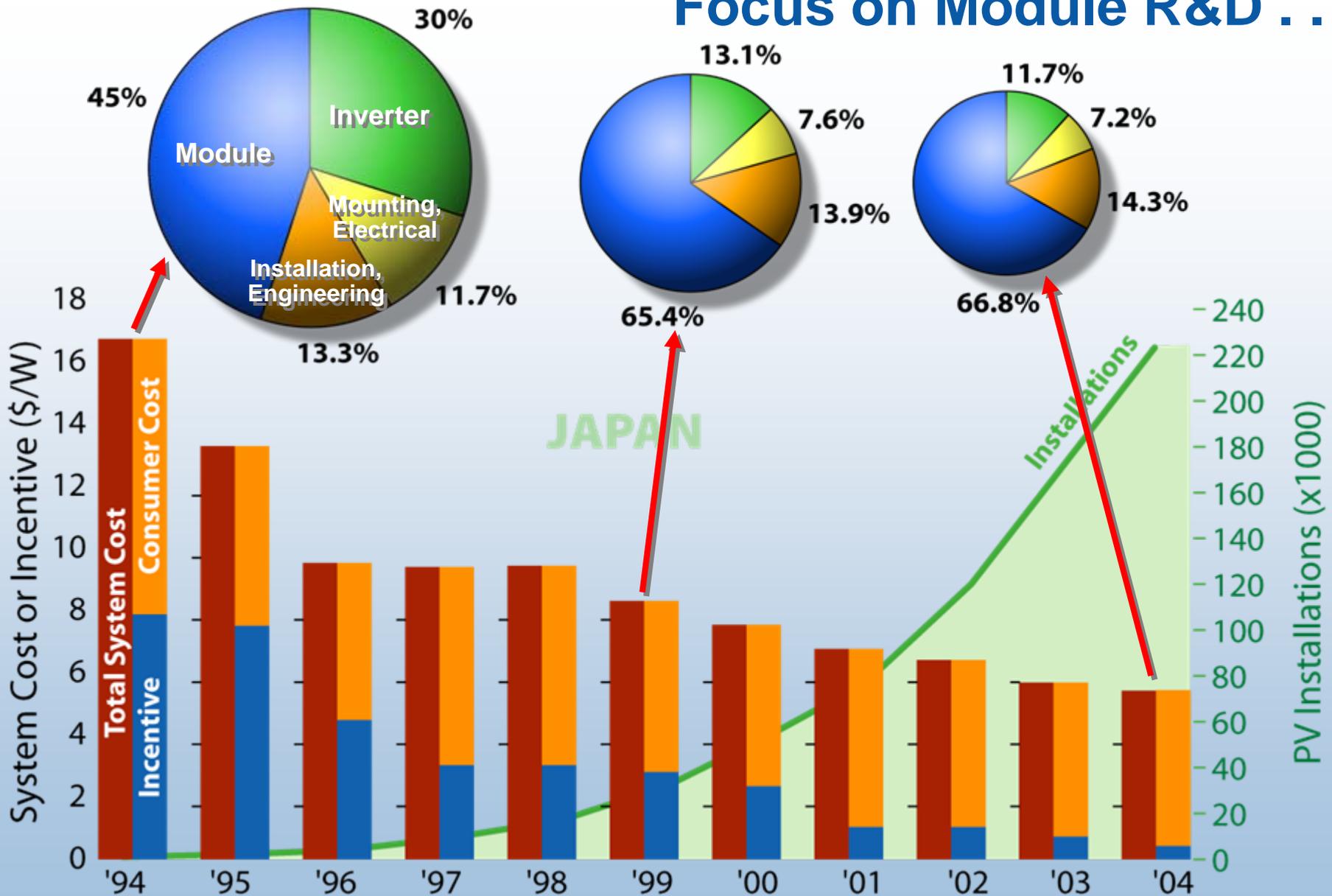
PV

- Partnering with industry
- Higher efficiency devices
- New nanomaterials applications
- Advanced manufacturing techniques

CSP

- Next generation solar collectors
- High performance storage

Focus on Module R&D . . .



Ridge Vineyards
PV Rooftop
65 kW, CA



WorldWater & Power, Irrigation System
267 kW, Seley Ranches, CA



Powerlight, Bavarian community
6.750 MW, single-axis tracking
Mühlhausen, Germany

Shell Solar at Semitropic Wash
980 kW, single-axis tracking



PowerLight PowerGuard
536 kW, Toyota Motor C



RWE Schott Stillwell Avenue Subway
Station, PV Canopy Roof, 250,000
kWh/yr, Brooklyn, NY



Moving Toward Our Destination

er & Geothermal Energy Co.
Wastewater Plant, 622 kW,
CA



op system,



Biofuels

Current Biofuels status

- Biodiesel – 91 million gallons¹
- Corn ethanol (Nov. 2006)
 - 106 commercial plants²
 - 5.1 billion gallon/yr. capacity²
 - 3rd Q 2006 rack price highly variable \$3.50 – 5.50/gallon of gasoline equivalent (gge)³
- Cellulosic ethanol
 - Projected commercial cost ~\$3.50/gge

Key DOE Goals

- 2012 goal: cellulosic ethanol ~\$1.62/gge
- 2030 goal: 60 billion gal ethanol (30% of 2004 gasoline)

NREL Research Thrusts

- The biorefinery and cellulosic ethanol
- Solutions to under-utilized waste residues
- Energy crops



Updated November 10, 2006

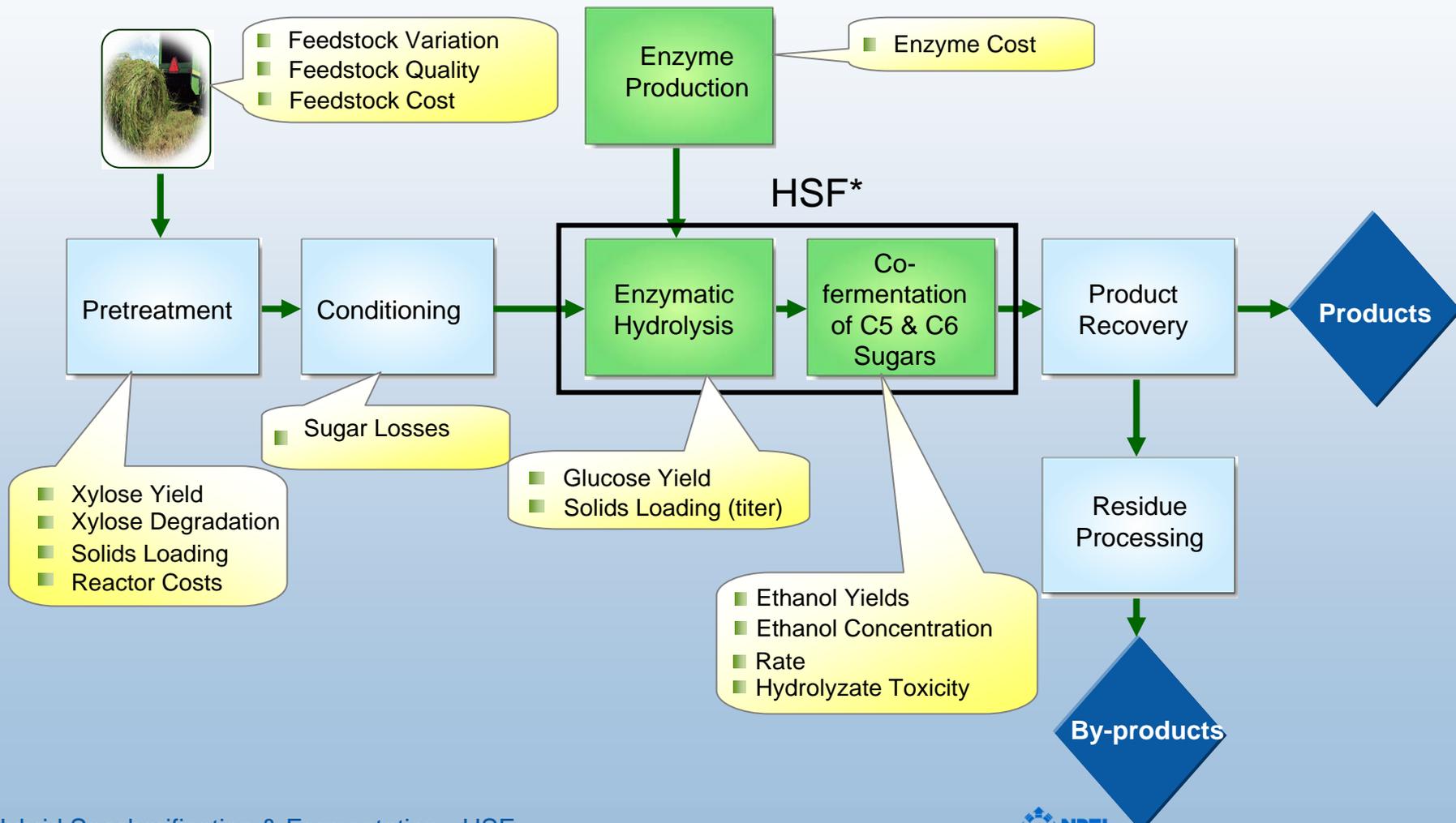
Sources: 1- National Biodiesel Board, 2 - Renewable Fuels Association, 3 – American Coalition for Ethanol, all other information based on DOE and USDA sources

NREL Expertise Covers the Range of Biomass and Biofuels R&D

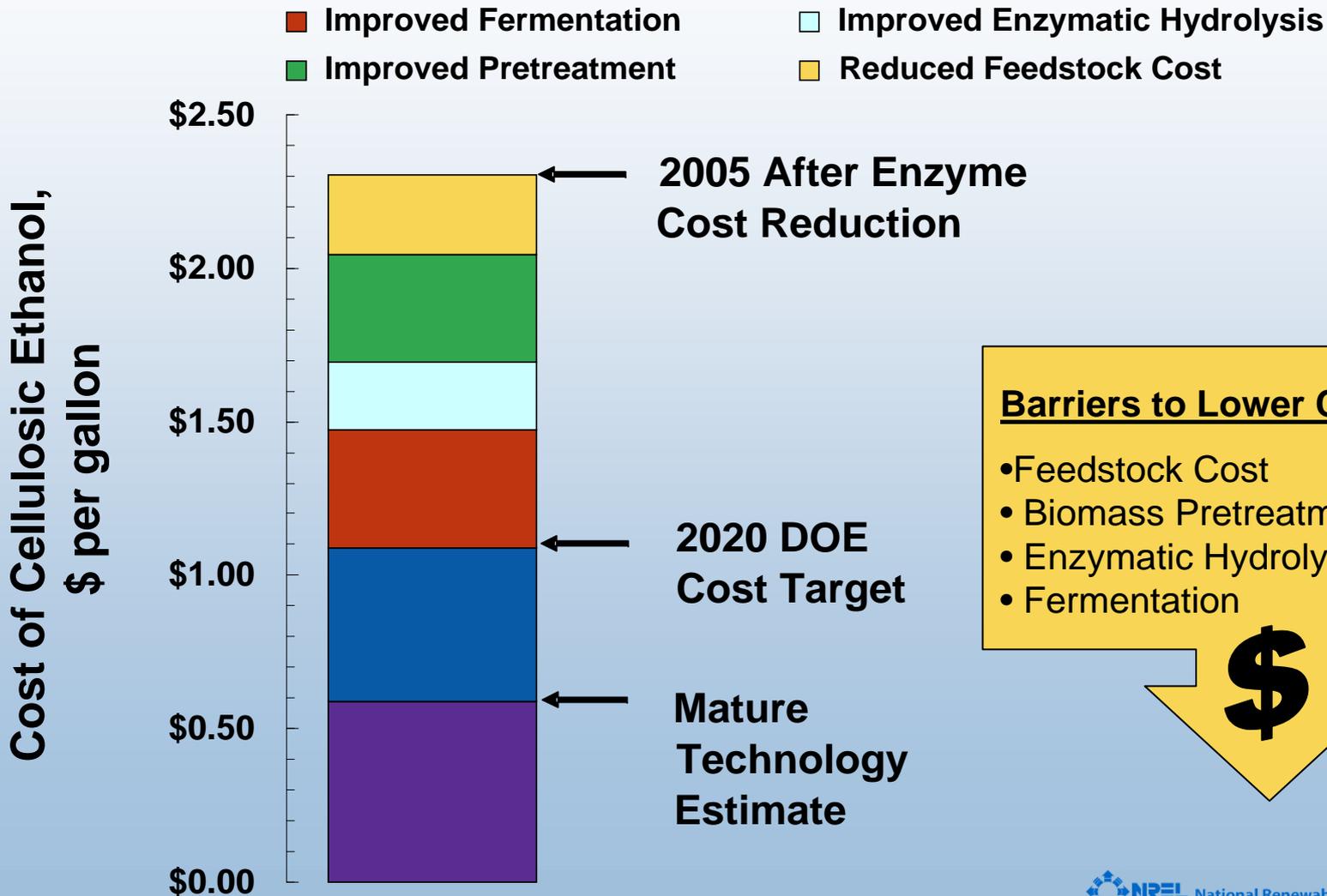
- Biochemical Pathway
 - Compositional analysis
 - Feedstock pretreatment & enzymatic hydrolysis
 - Advanced fermentation organism testing and development
 - Technoeconomic analysis
- Thermochemical Pathway
 - Compositional analysis
 - Syngas production and cleanup
 - Pyrolysis liquids
 - Catalytic upgrading of syngas & liquids to fuels & chemicals



Technical Barrier Areas for \$1.07 Biochemical Ethanol



Remaining Technology and Cost Barriers



Wind

Today's Status in U.S.

- 11,603 MW installed at end of 2006
- Cost 6-9¢/kWh at good wind sites*

DOE Cost Goals

- 3.6¢/kWh, onshore at low wind sites by 2012
- 7¢/kWh, offshore in shallow water by 2014

Long Term Potential

- 20% of the nation's electricity supply

NREL Research Thrusts

- Improved performance and reliability
- Distributed wind technology
- Advanced rotor development
- Utility grid integration

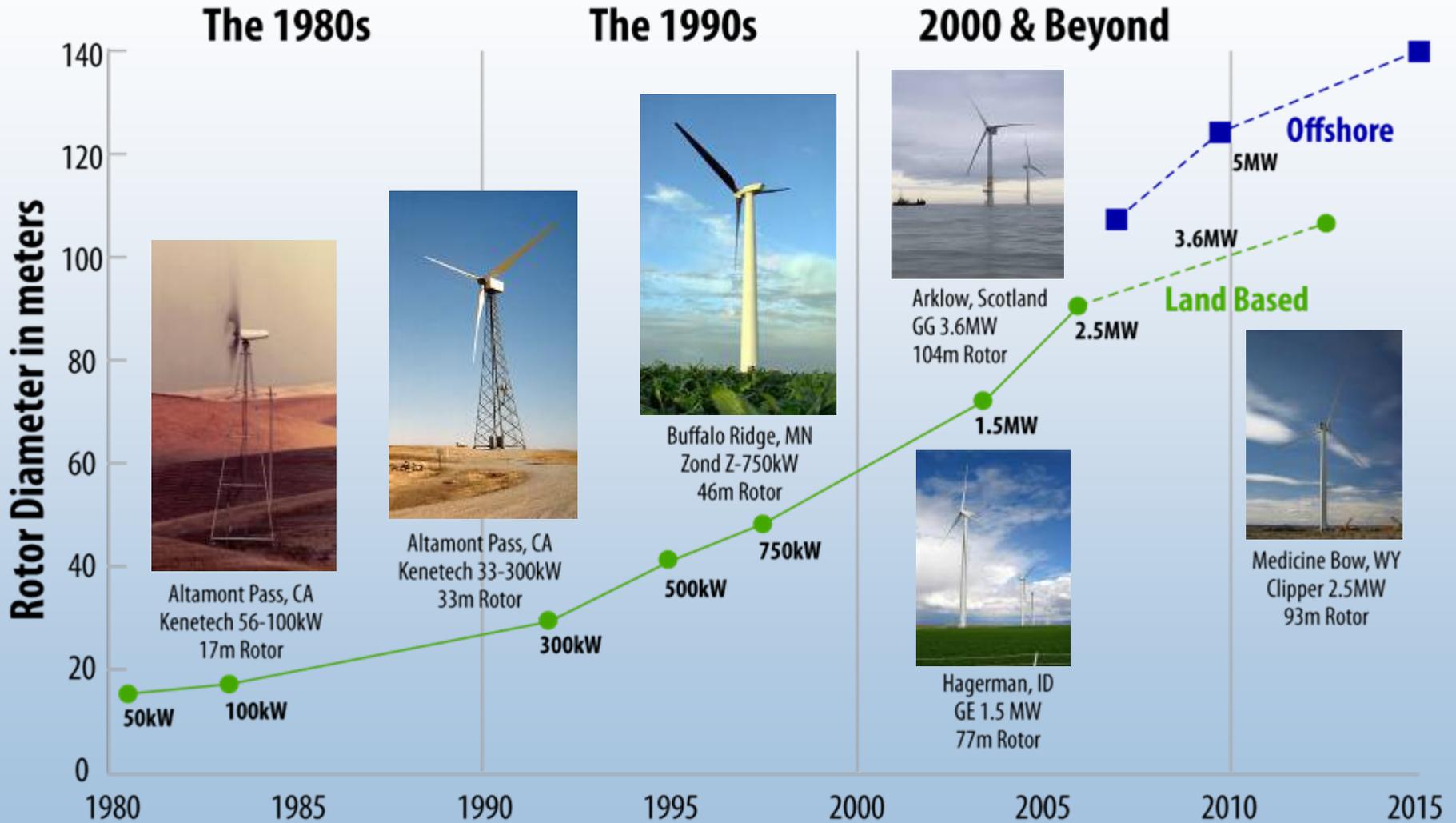


* With no Production Tax Credit

Updated January 23, 2007

Source: U.S. Department of Energy, American Wind Energy Association

Evolution of U.S. Commercial Wind Energy



Hydrogen

Status

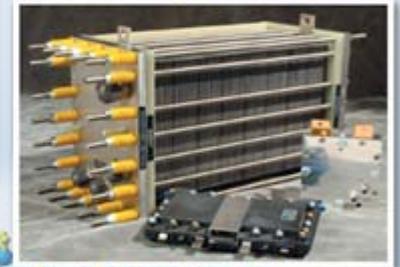
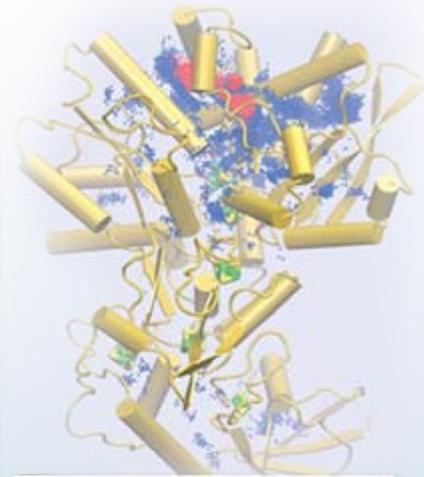
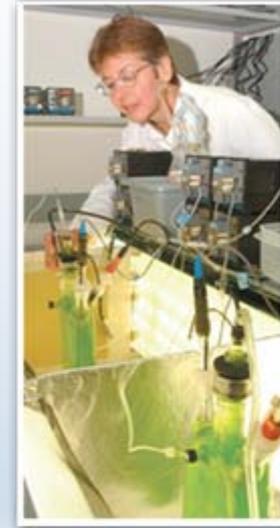
- Working with industry to develop technologies in quantities large enough, and at costs low enough, to compete with traditional energy sources.

Potential

- Commercially viable hydrogen and fuel cell systems by 2015

NREL Research Thrusts

- Hydrogen production, delivery, storage and manufacturing
- Fuel cells
- Safety, codes, and standards



Buildings

Status U.S. Buildings:

- 39% of primary energy
- 71% of electricity
- 38% of carbon emissions
- 10% of global carbon emissions

DOE Goal:

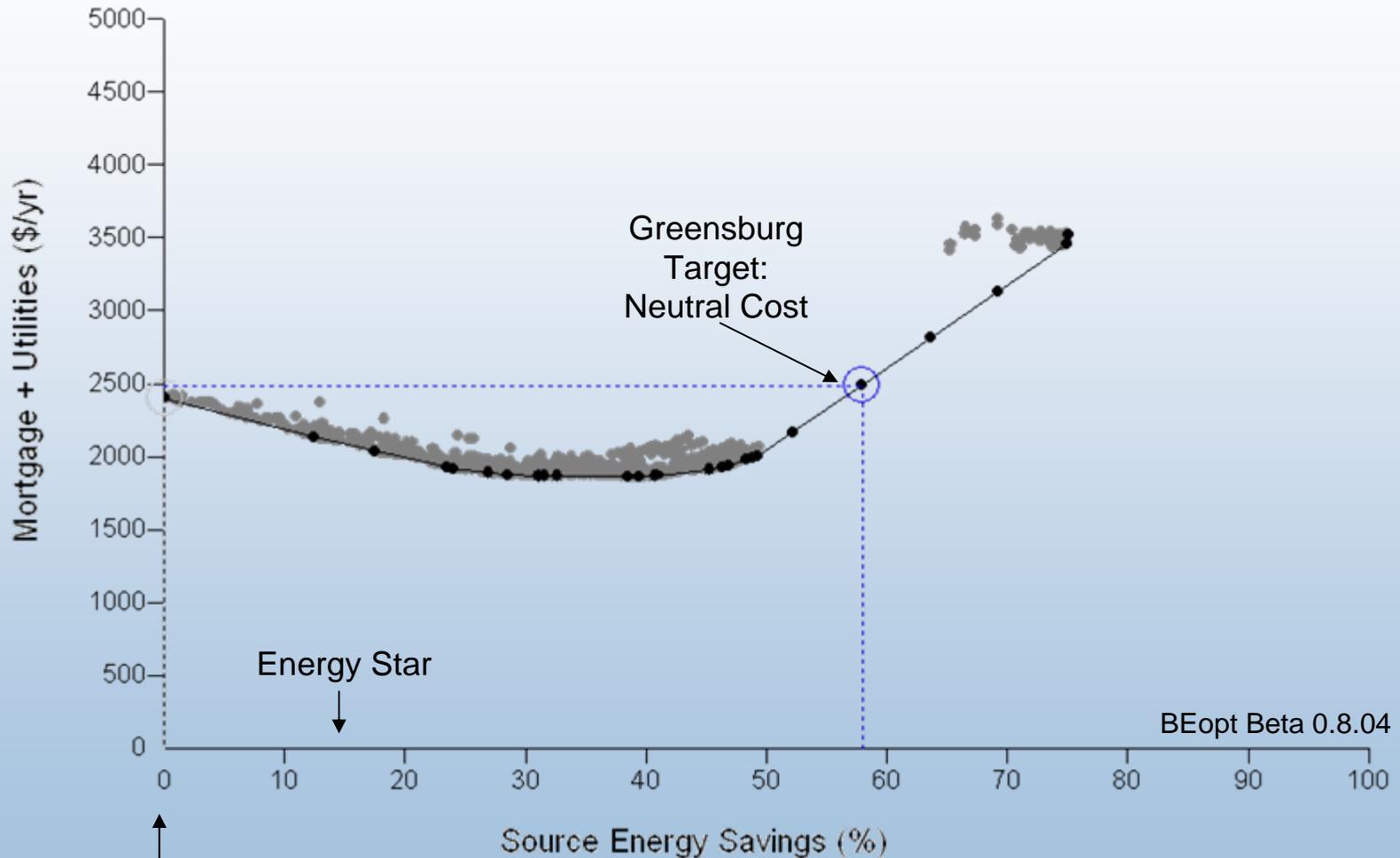
- Cost effective, marketable, zero energy buildings by 2025
- Value of energy savings exceeds cost of energy features on a cash flow basis

NREL Research Thrusts

- Whole building systems integration of efficiency and renewable features
- Computerized building energy optimization tools
- Field experiments and monitoring
- PV/Thermal hybrid systems
- Building integrated PV
- Electrochromic windows



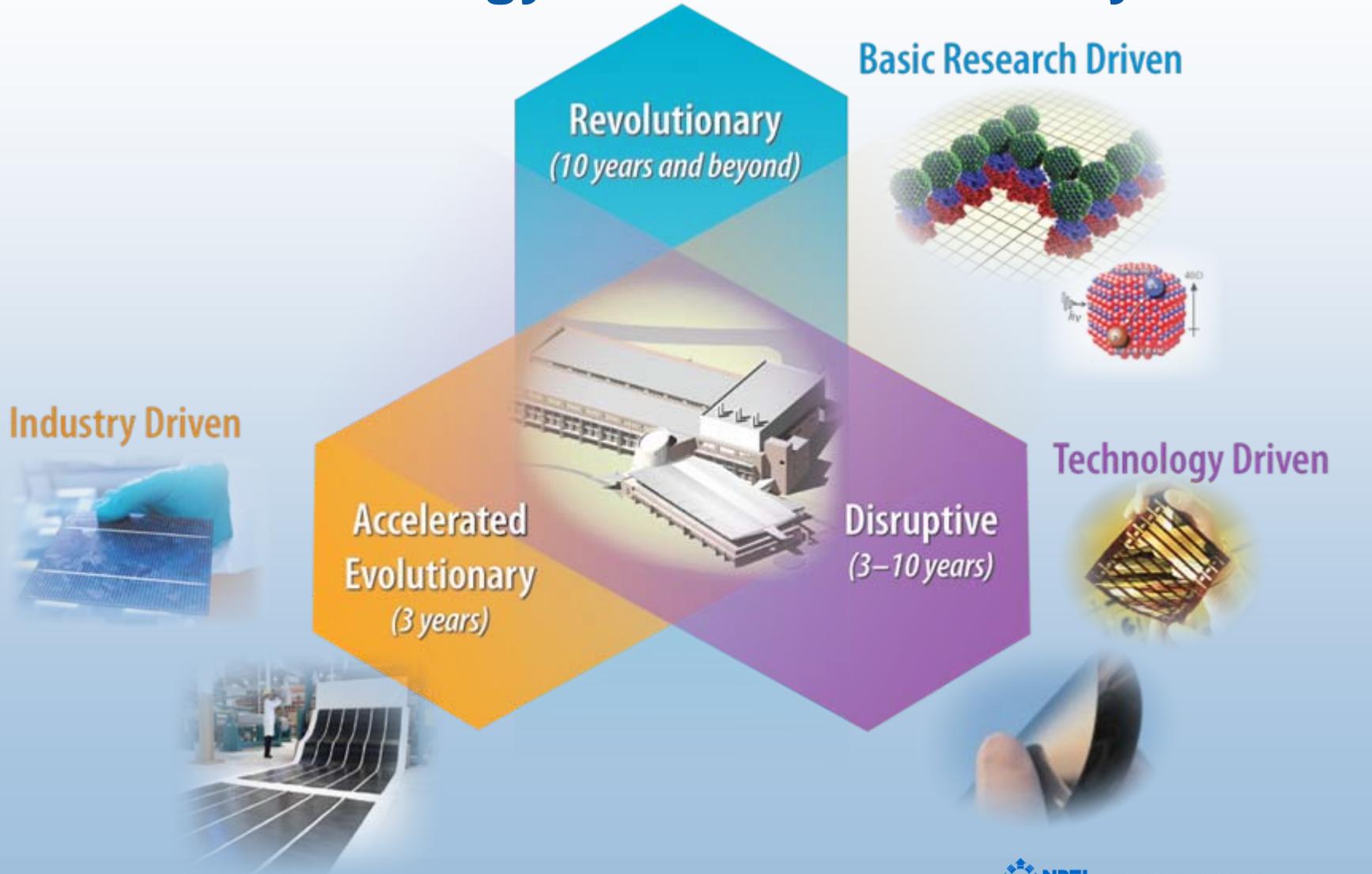
Neutral Cost Point: Greensburg



IECC 2003

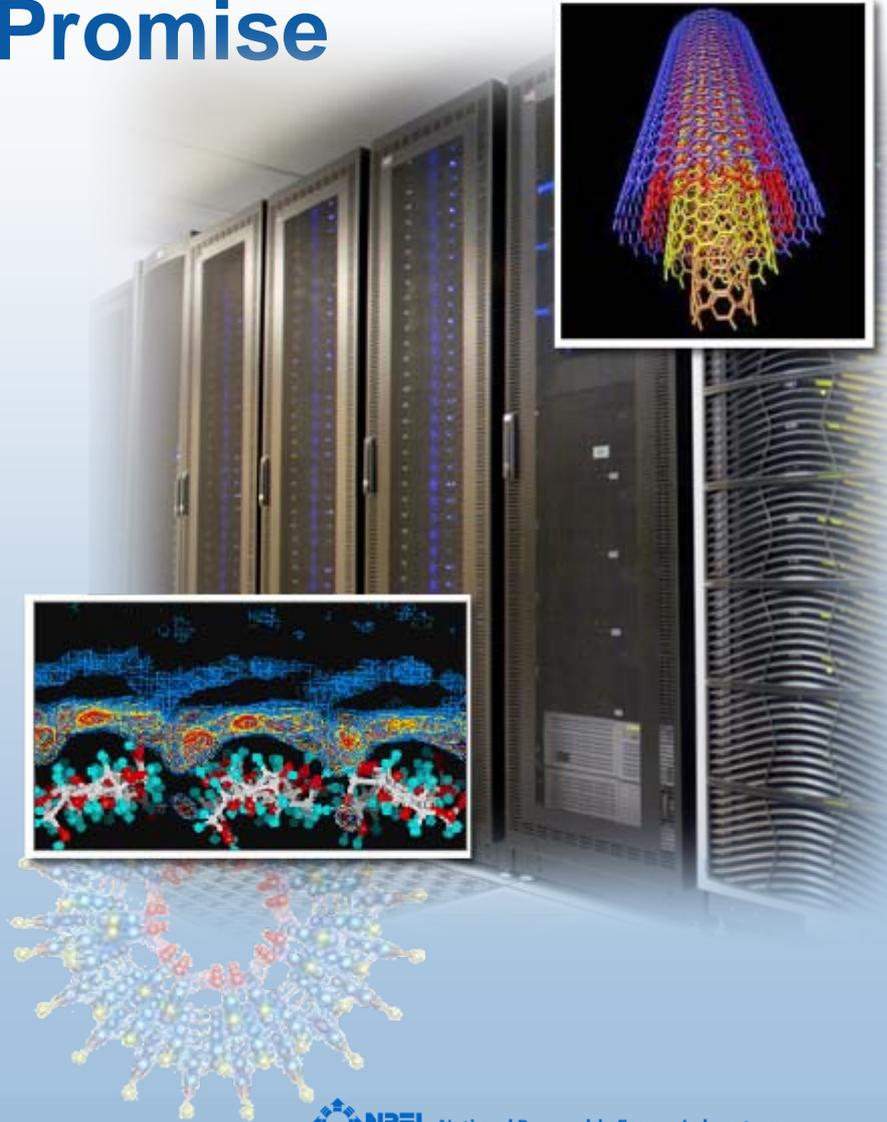
(2000 ft², 2-story, 16% window to floor area ratio, unconditioned basement)

Achieving the Right Balance: Technology Investment Pathways



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

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



Nano/Bio/Info

Promise of renewable energy is profound and can be realized if we...

- Aggressively seek a global sustainable energy economy
- Accelerate investment in technology innovation
- Acknowledge and mitigate the carbon challenge with the necessary policies

It is a matter of national will and leadership

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

www.nrel.gov



Golden, Colorado