

# Climate Change and Renewable Energy: The Technology Challenges and Opportunities

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NREL is operated by Midwest Research Institute - Battelle 

## National Renewable Energy Laboratory What Makes Us Unique?

- 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 is market relevant because of a systems focus



# Energy Efficiency and Renewable Energy Technology Development Programs

NREL R&D Portfolio



## Efficient Energy Use

- Vehicle Technologies
- Building Technologies
- Industrial Technologies



## Renewable Resources

- Wind
- Solar
- Biomass
- Geothermal

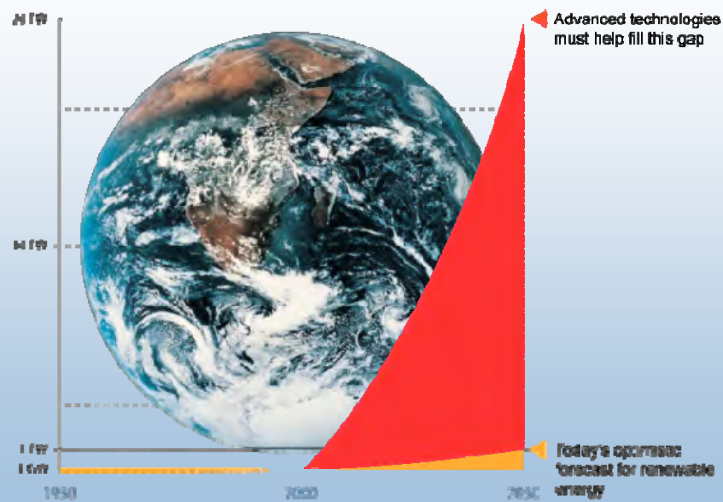


## Energy Delivery and Storage

- Electricity Transmission and Distribution
- Alternative Fuels
- Hydrogen Delivery and Storage

**Foundational Science and Strategic Analysis**

## How Big is the Challenge?

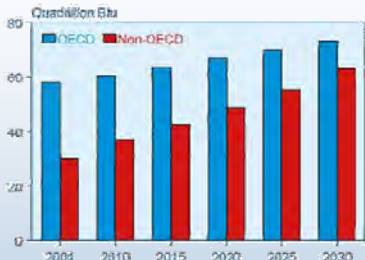


Source: Arvizu, NREL

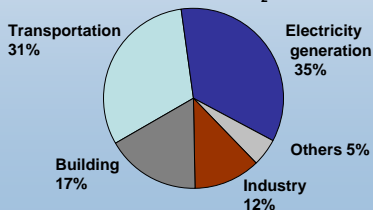
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# Setting the Context

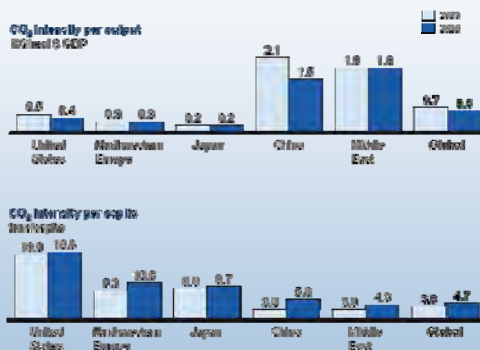
1) Transportation Sector Energy Consumption 2004-2030



2) 2003 North America CO<sub>2</sub> Inventory Total 6805 Mt CO<sub>2</sub>



3) CO<sub>2</sub> Intensity per Output and per Capita



Sources: 1) 2004: Derived from EIA, International Energy Annual 2004 (May-July 2006). Projections: EIA, System for the Analysis of Global Energy Markets (2007) 2) Honda Motor Company, *GHG Emissions Reduction From Mobile Sources* (Sept 19, 2007) 3) McKinsey Global Institute, *Curbing Global Energy Demand Growth: The Energy Productivity Opportunity* (May 2007)

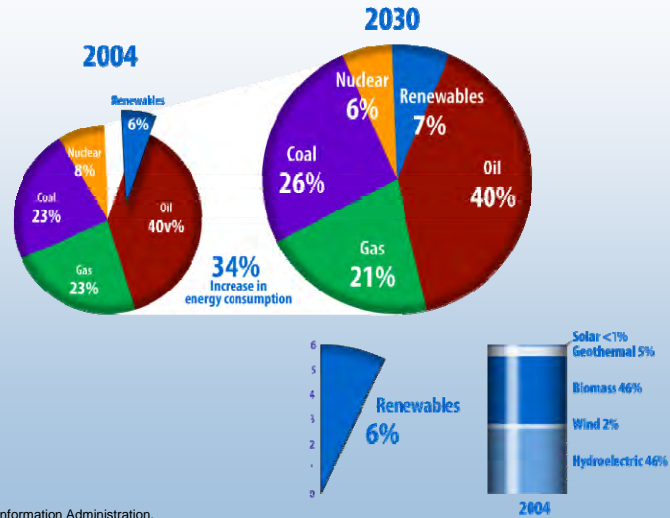


## Technology-Based Solutions: There is no single or simple answer

- Energy efficiency
- Renewable energy
- Nonpolluting transportation fuels
- Separation and sequestration of CO<sub>2</sub>
- Next generation nuclear energy technologies
- Transition to distributed energy systems with pollution-free energy carriers



## U.S. Energy Consumption and the Role of Renewable Energy



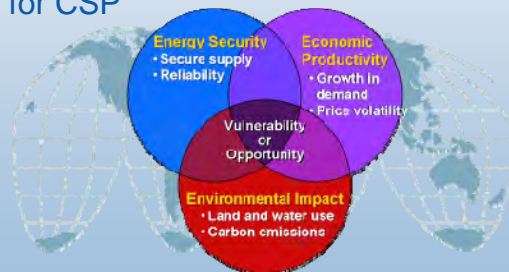
Source: Energy Information Administration, Annual Energy Outlook 2006, Table D4

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## We Are Now Setting Aspirational Goals – Setting the Bar Higher

### U.S. national goals

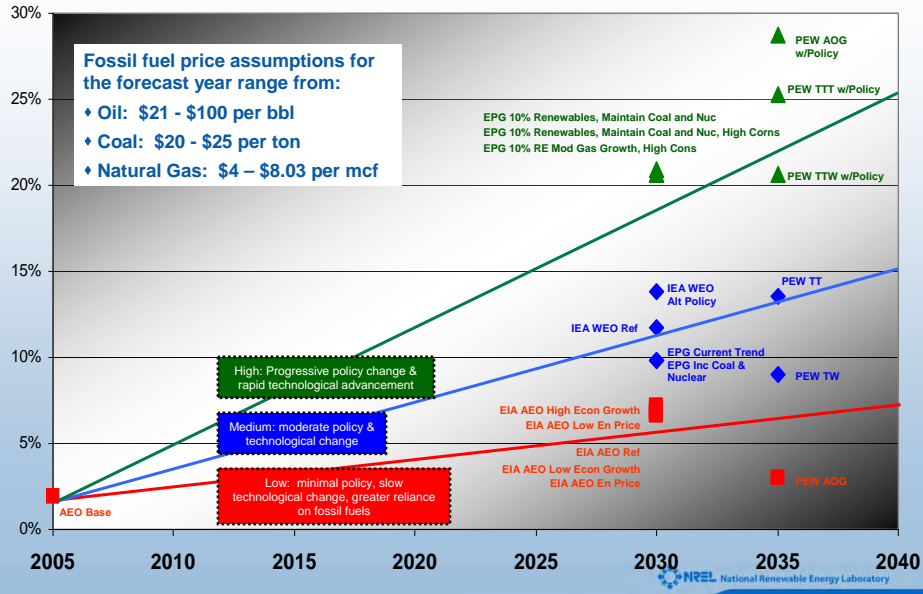
- Biofuels: reduce gasoline usage by 20% in ten years
- Wind: 20% of total provided energy by 2030
- Solar: Be market competitive by 2015 for PV and 2020 for CSP



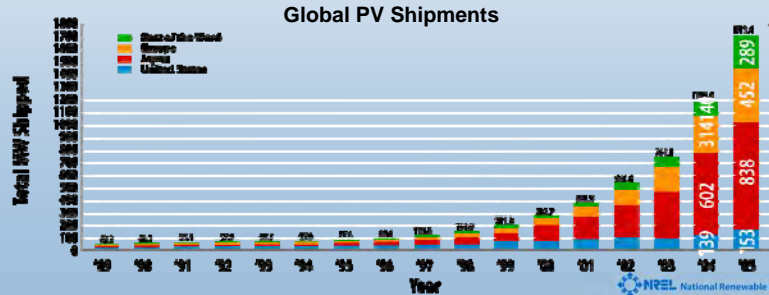
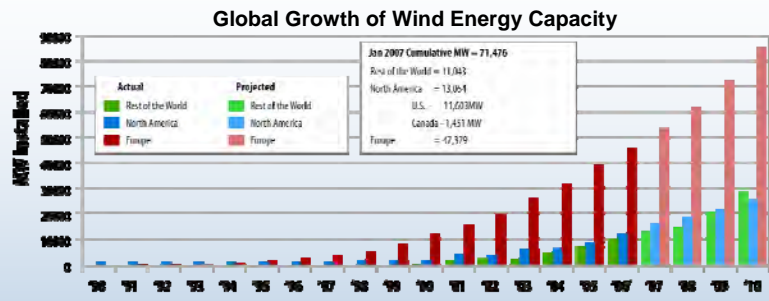
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# U.S. Renewable Energy Contributions

## Percent of Total Electric Generating Capacity

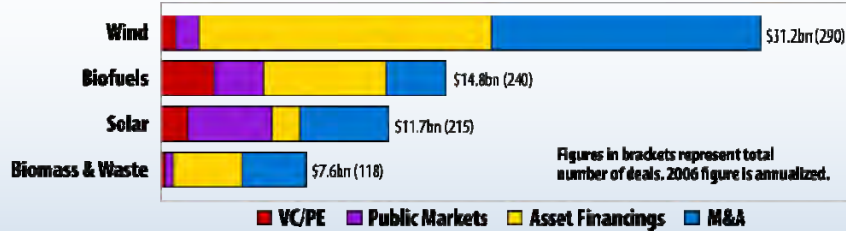


# Global Markets are Growing Rapidly

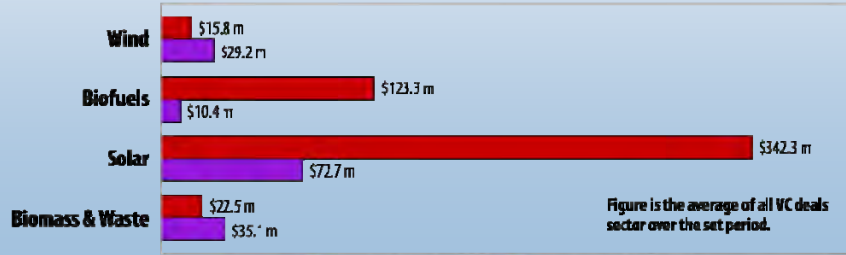


# Money Is Flowing Into the Sector

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



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



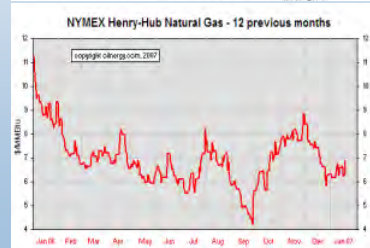
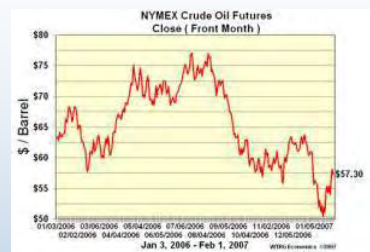
Source: New Energy Finance 2007

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## Thinking Differently: Account for Externalities

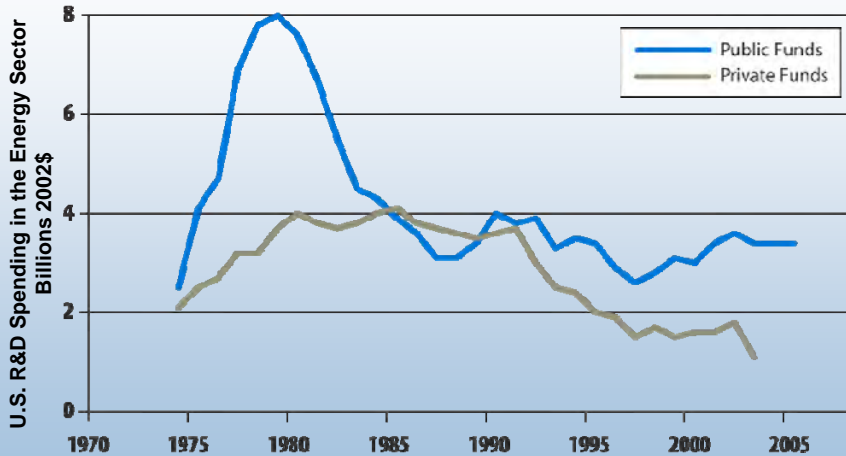
Today's energy marketplace does not appropriately "value" certain public objectives or social goods, instead we have:

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



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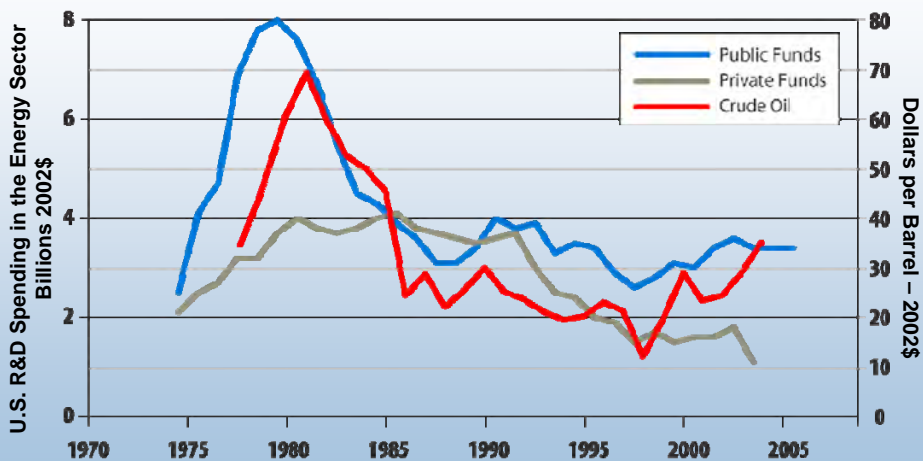
## Declining Energy R&D Investments...



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>

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## 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>

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# 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 turbine performance and reliability
- Distributed wind technology
- Drivetrain reliability
- Utility grid integration



\* With no Production Tax Credit  
Updated 1/07, validated 7/07  
Source: U.S. Department of Energy, American Wind Energy Association

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# Solar

## Photovoltaics and Concentrating Solar Power

### Status in U.S.

#### PV

- 565 MW
- Cost 18-23¢/kWh

#### CSP

- 420 MW
- Cost 12¢/kWh

### Potential:

#### PV

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

#### CSP

- 8.5¢/kWh by 2010
- 5-7¢/kWh by 2020

Source: U.S. Department of Energy, IEA, Solar Energy Technologies Program Multi-Year Plan 2007

Updated July 2007

### NREL Research Thrusts:

#### PV

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

#### CSP

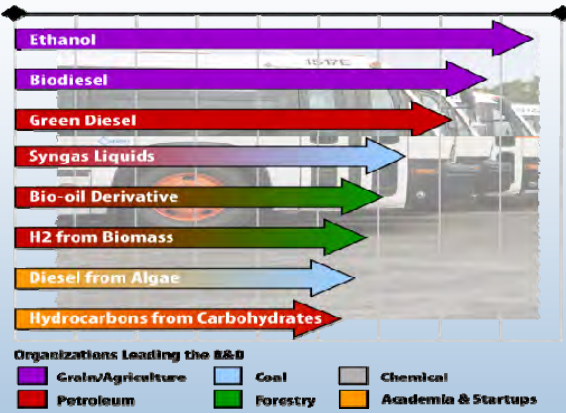
- Next generation solar collectors
- High performance storage



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# Transportation Fuels

- Advanced fossil fuels
  - Carbon neutral
- Biofuels
  - Next gen biofuels
  - Sustainability
- Hydrogen
  - Production
  - Storage
  - Use
- Electricity
  - Fossil (CCS)
  - Nuclear
  - Renewables



Source: International Energy Agency, World Energy Outlook 2006, p.492

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# Biofuels

## Current Biofuels status

- Biodiesel – 1.3 billion gallons/yr capacity<sup>1</sup>
- Corn ethanol
  - 121 commercial plants<sup>2</sup>
  - 6.3 billion gal/yr. capacity<sup>2</sup>
  - Additional 6.2 billion gal/yr planned or under construction
- Cellulosic ethanol (current technology)
  - Projected commercial cost ~\$3.50/gge



## Key DOE Goals

- 2012 goal: cellulosic ethanol ~\$1.62/gge
- 2017 goal : 35 billion gal alternative fuel – President
- 2022 goal: 36 billion gal renewable fuel – Congress/draft
- 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 July 2007  
Sources: 1- National Biodiesel Board, 2- Renewable Fuels Association, all other information based on DOE and USDA sources

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# Hydrogen

## Status

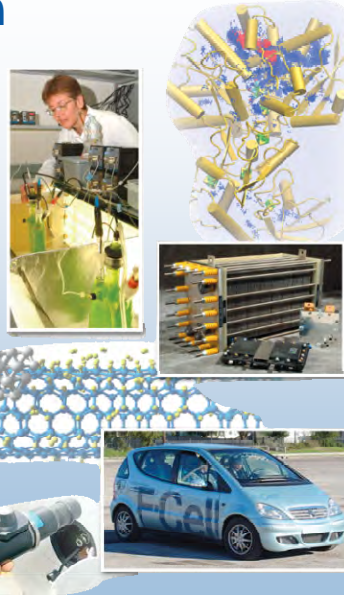
- Working with industry to develop technologies in quantities large enough, and at costs low enough, to compete with traditional energy sources.

## 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
- H<sub>2</sub>-to-Wind – NREL/Xcel Project
  - Maximize wind energy by reducing uncertainty and variability
  - Hydrogen produced through electrolysis



Source: DOE, NREL, 9/07

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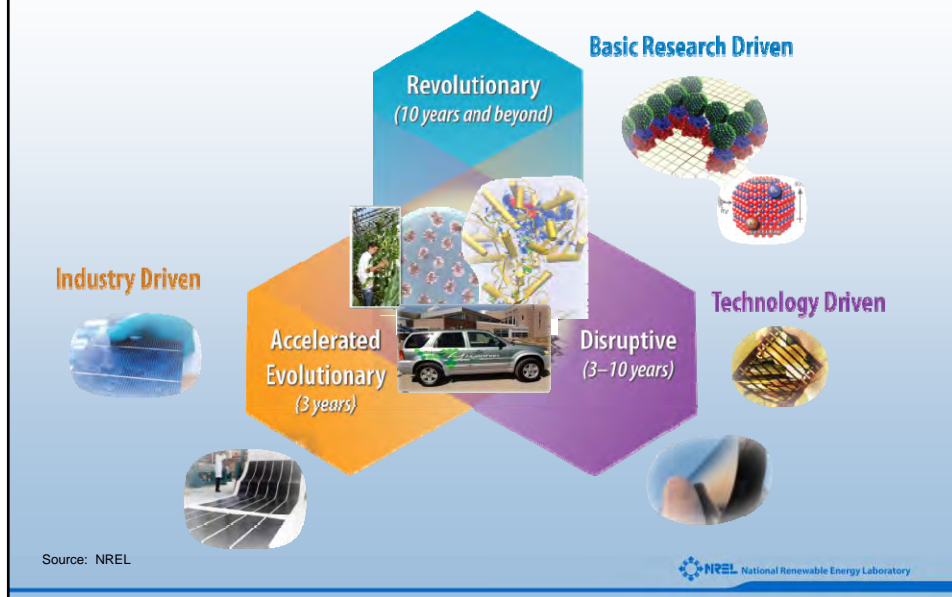
# Getting to “Significance” Involves...



Source: NREL

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## Technology Investment Pathways



## 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*



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Golden, Colorado