

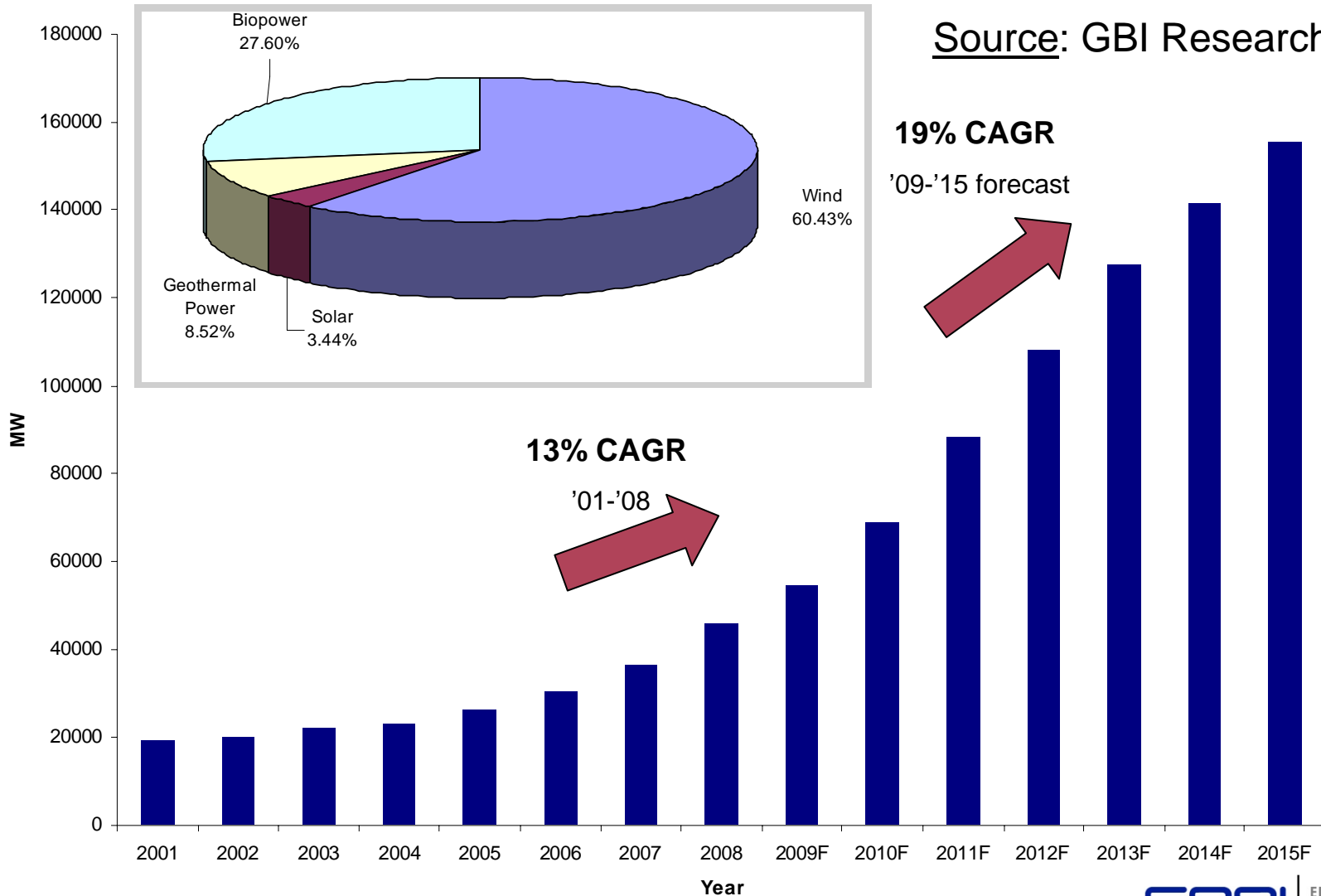
## Renewable Energy Outlook and Future R&D Needs

**Bryan Hannegan, Ph.D.**  
Vice President, Environment & Renewables

**EPRI Climate Research Seminar**  
May 18, 2010

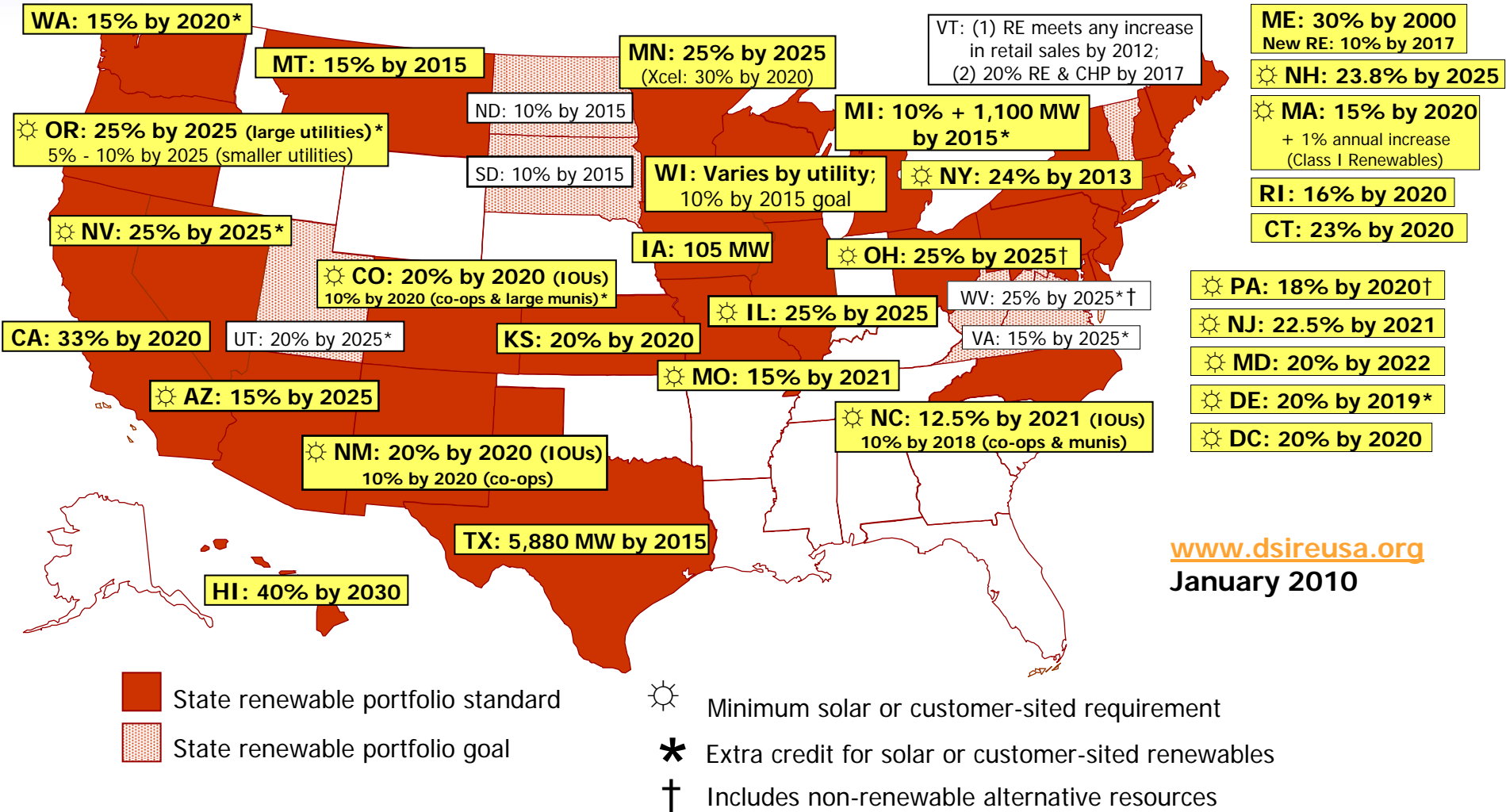
# Renewables: Why Now?

## North American Installed Capacity 2001-2015



# Renewables: Why Now?

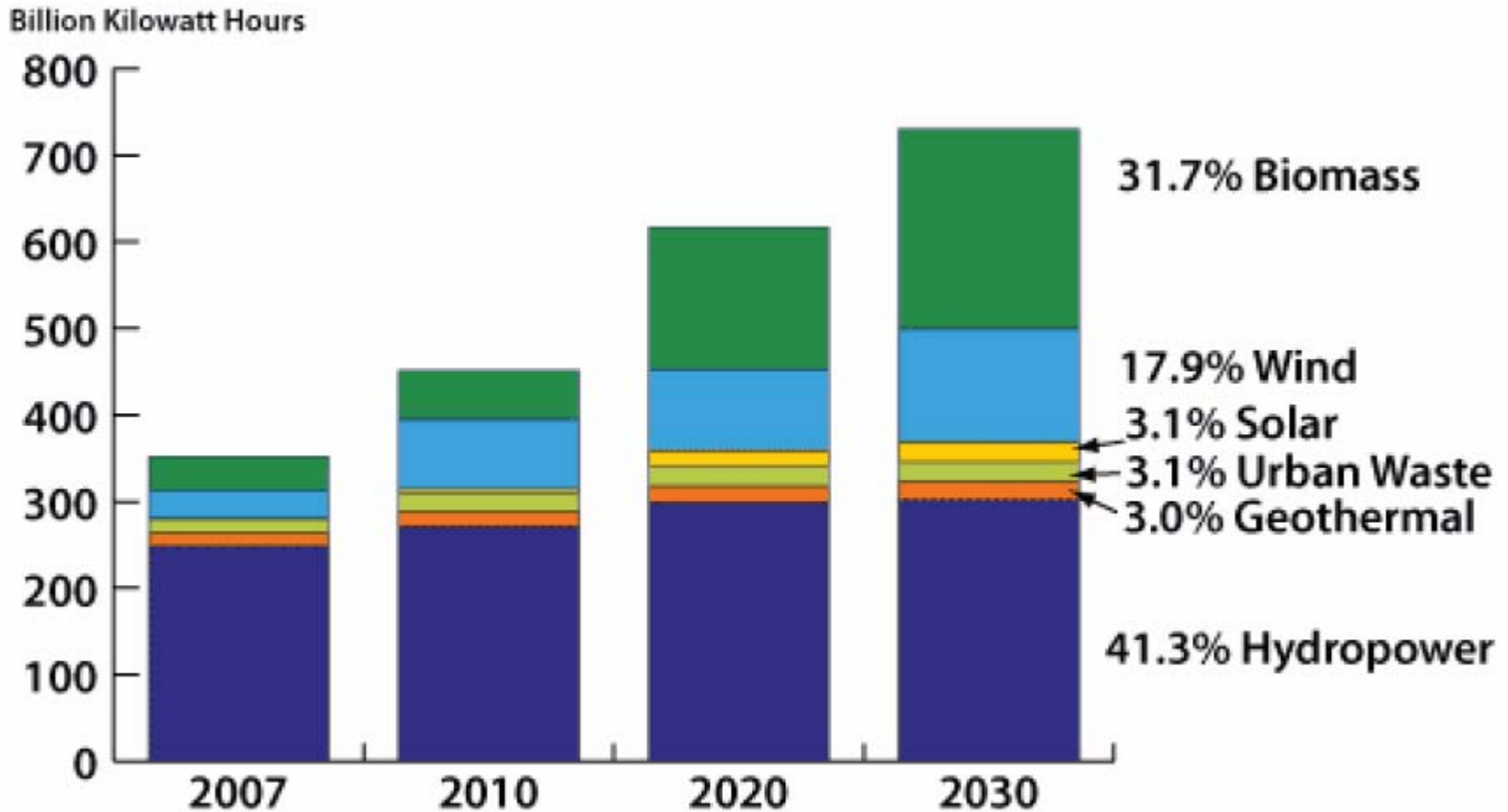
## 29 States + DC Have Renewable Portfolio Standards



[www.dsireusa.org](http://www.dsireusa.org)  
January 2010

# Renewables: Why Now?

## *U.S. Projected Generation 2007-2030*

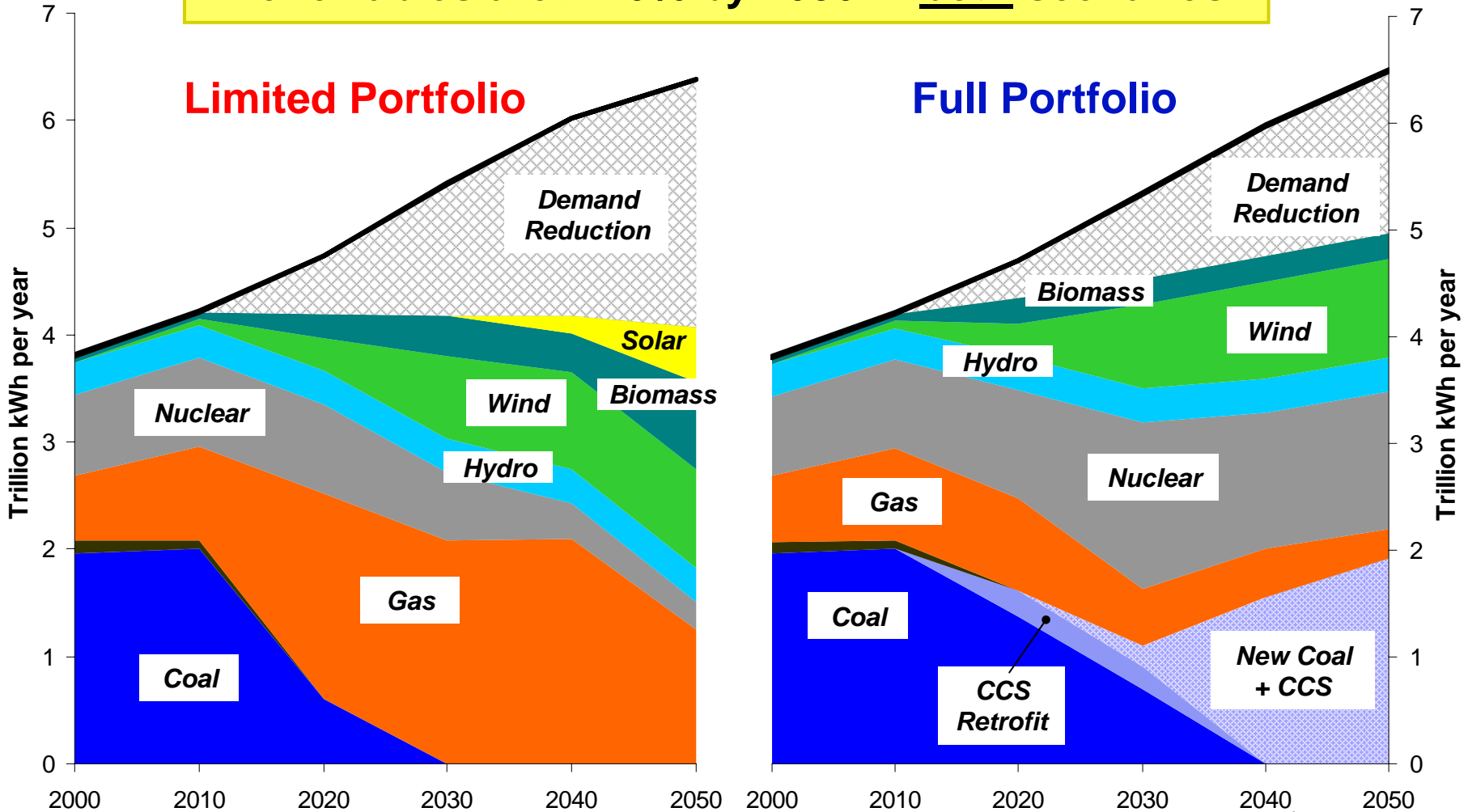


Source: EIA AEO 2009

# Renewables: Why Now?

## EPRI MERGE – Two Possible Future Mixes

Renewables are > 20% by 2030 in both scenarios

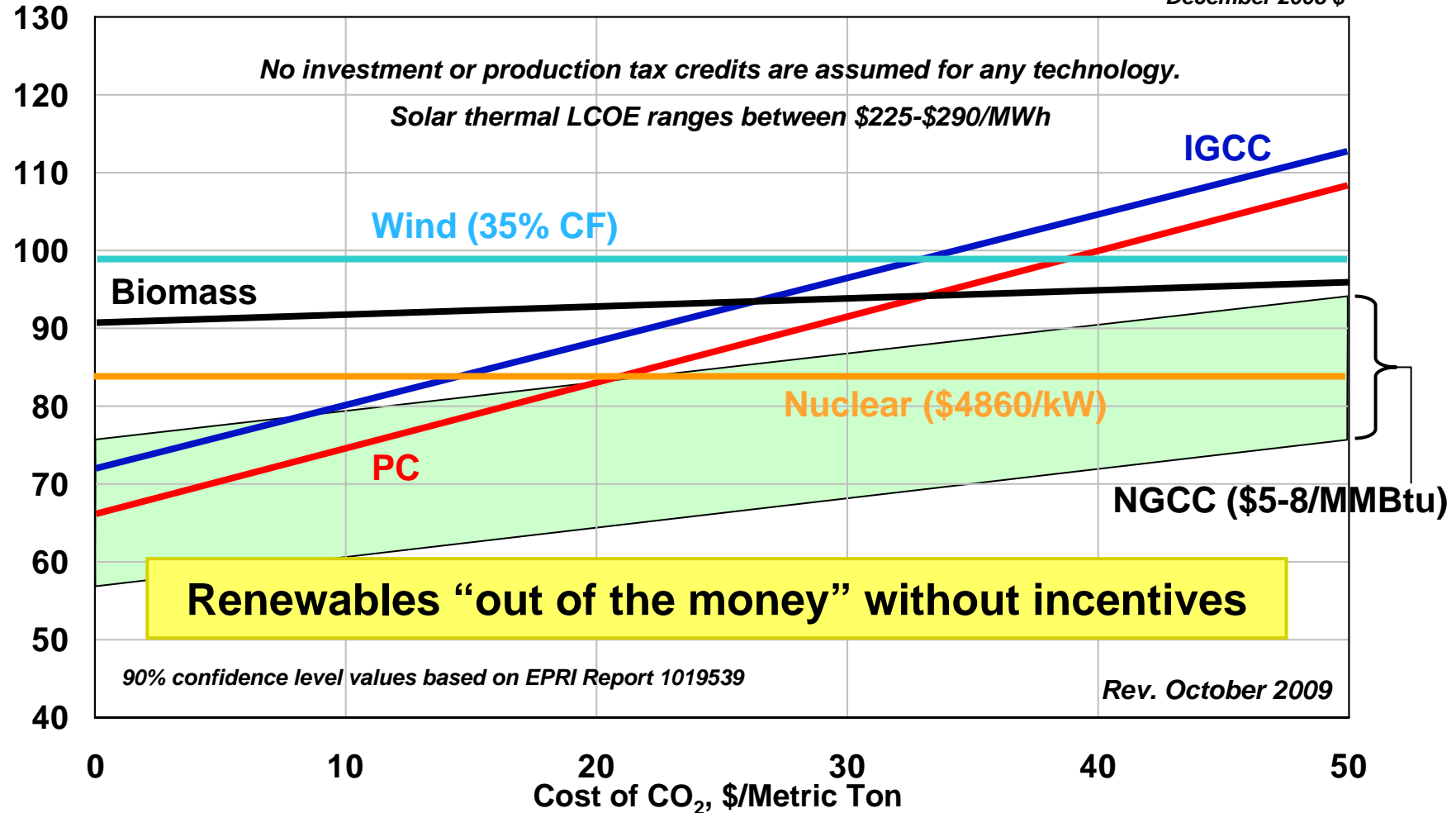


# What are the **challenges** posed by increasing amounts of renewable energy?

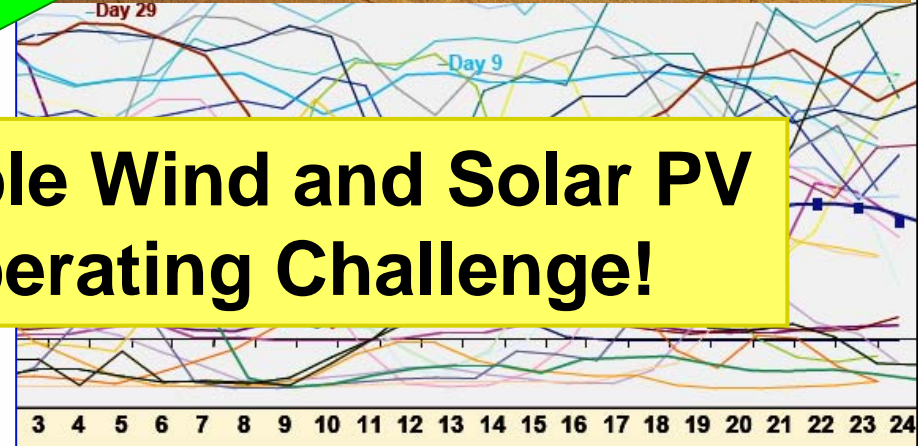
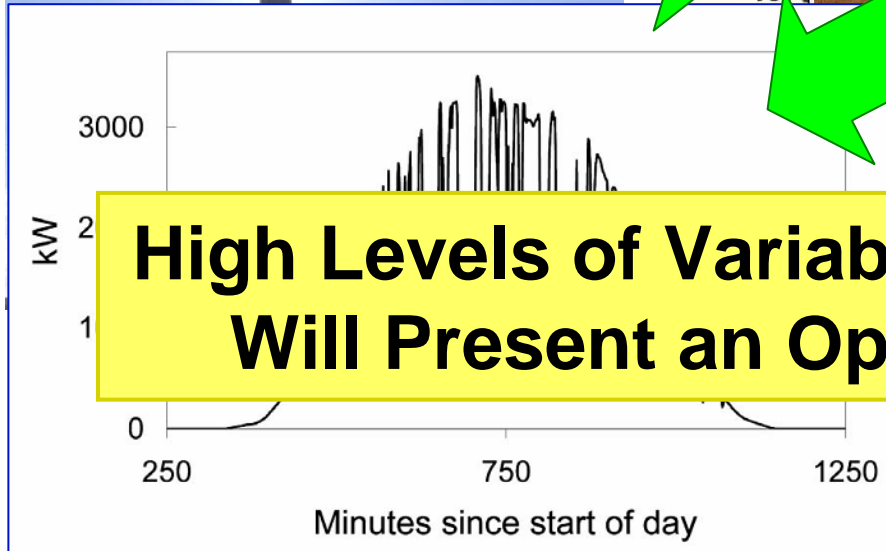
# The Cost Challenge

Levelized Cost of Electricity, \$/MWh

All costs are in December 2008 \$



# The Integration Challenge



**High Levels of Variable Wind and Solar PV Will Present an Operating Challenge!**

# The Environmental Challenge

- **Understanding the interactions**
  - Characterizing the renewable resource
  - Interactions with species and habitat
  - Life cycle assessment
  - Human health and safety
- **Advancing improved approaches**
  - Siting methodologies
  - Technology and operational improvements
  - Mitigation strategies
- **Large scale impacts and limitations**
  - Assess the impacts of “harvesting” renewables at large scales



What are the **opportunities** to enable increasing amounts of **wind** energy?

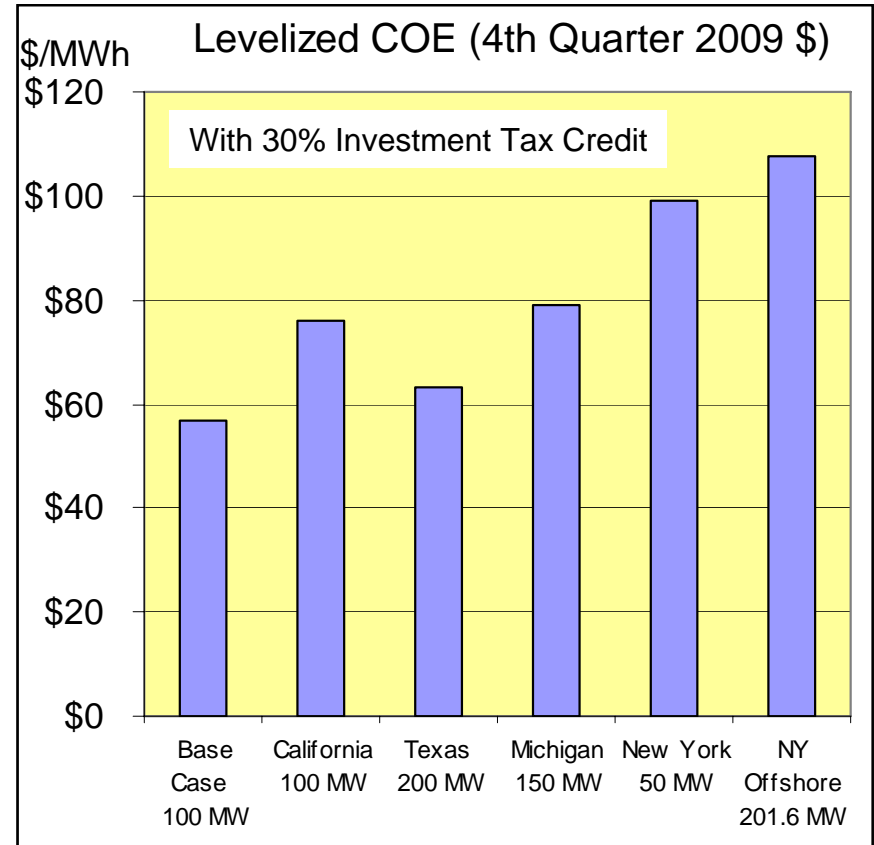
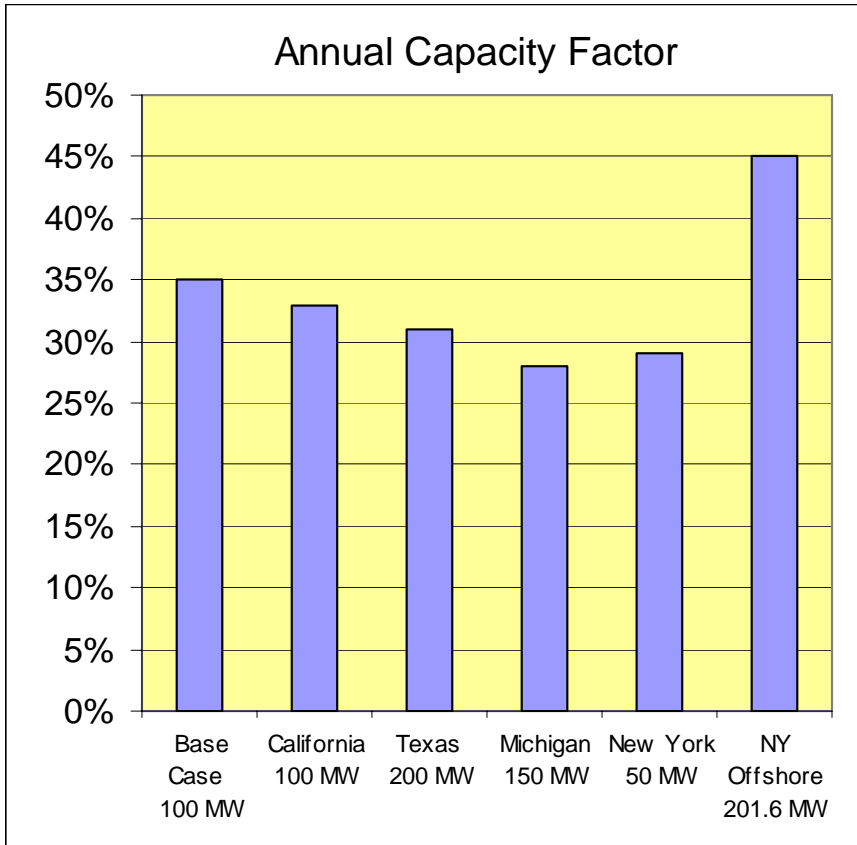
# Current Wind Project Cost and Performance

## Utility-Scale Wind Evaluation

- Locations:
  - Base Case
  - California
  - Texas
  - Michigan
  - New York
  - Offshore NY
- Conceptual design, performance, capital and O&M cost, levelized COE
- Source: EPRI Renewable Energy Technology Guide (1017598, 2/28/10)



# Current Wind Project Cost and Performance



# Wind Generation R&D Needs

- Wind Power Technology Assessment
  - Drive train, generators, blades, towers, sensors and controls
- Wind Power Asset Management
  - Status of O&M and asset management technologies
    - Condition Monitoring and NDE
    - O&M procedures
  - Wind turbine asset management guidebook



# Wind Integration R&D Needs

## NERC IVGTF Special Report



Defines Reliability Needs

## Transmission Development

- New Transmission Planning Tools and Methods to Integrate High Variable Resources

## Resource Adequacy

- New Methods to Determine Supply Capacity and Reserve Requirements

## Advance Operator Tools

- New Methods to Determine Supply Capacity and Reserve Requirements
- New Operator Decision-Making Tools and Improved Frequency Control Methods

## Flexible System Resources

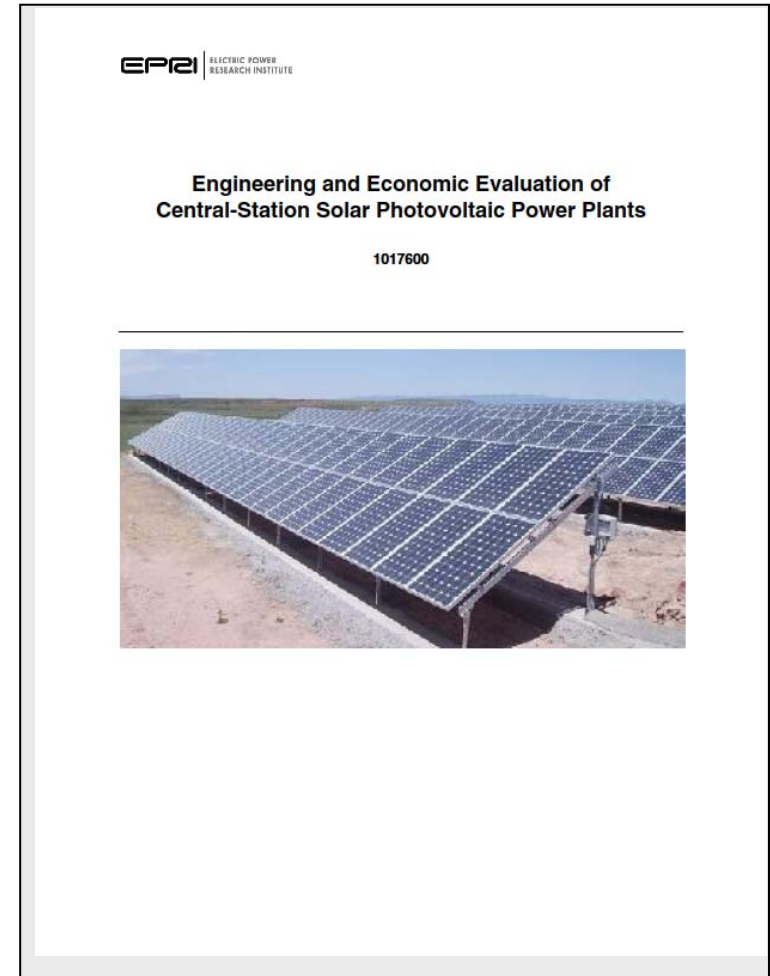
- Technical Performance Specs for VG/DR/PHEV
- Other EPRI Programs – ElectriNet, Storage

What are the **opportunities** to enable increasing amounts of **solar** energy?

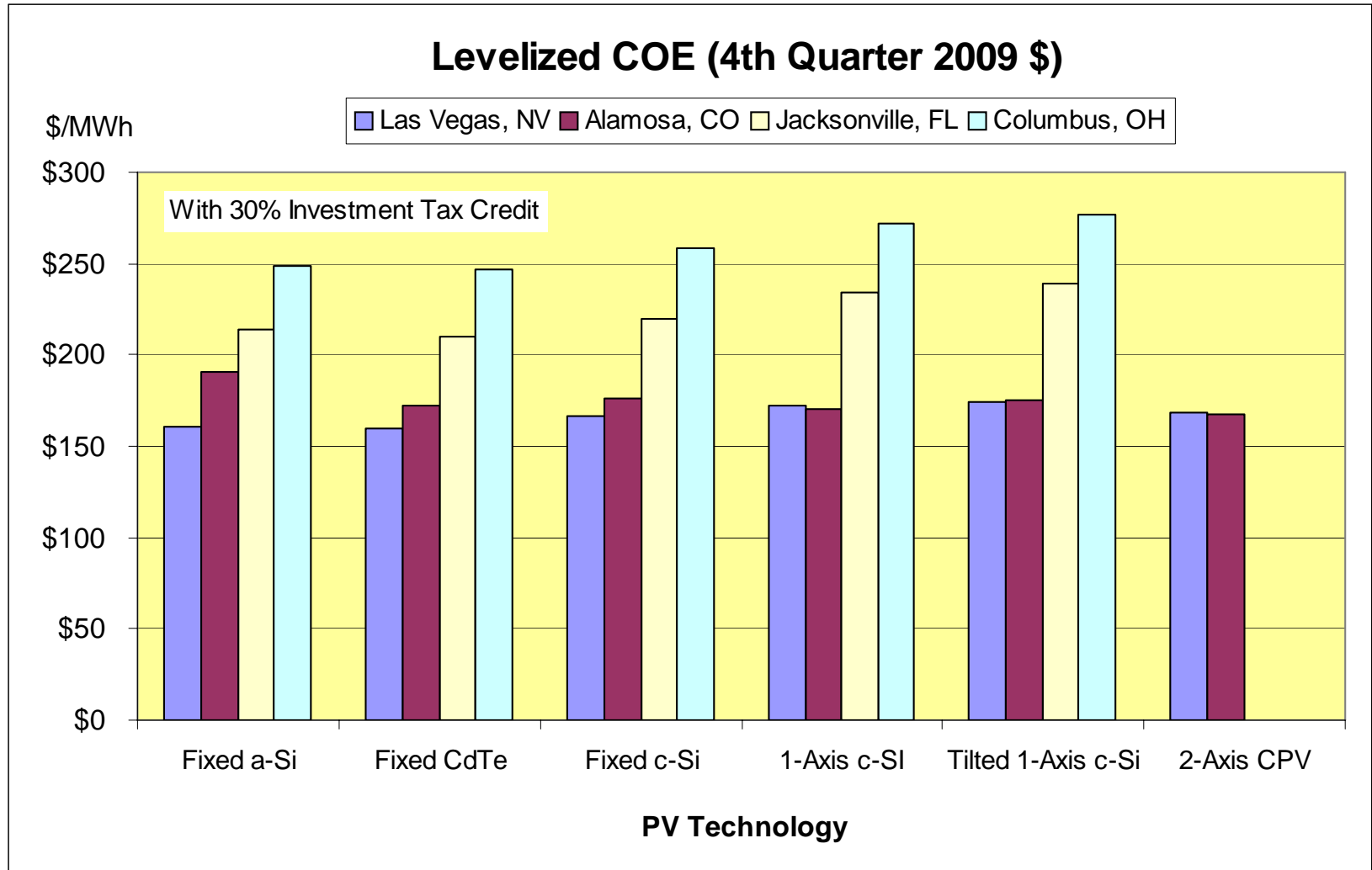
# Current Solar PV Cost and Performance

## Central Station PV Evaluation

- 6 PV Technologies:
  - Fixed Flat Plate a-Si
  - Fixed Flat Plate CdTe
  - Fixed Flat Plate c-Si
  - 1-Axis Tracking c-Si
  - Tilted 1-Axis Tracking c-Si
  - 2-Axis Tracking CPV
- Four Locations:
  - Las Vegas, NV
  - Alamosa, CO
  - Jacksonville, FL
  - Columbus, OH



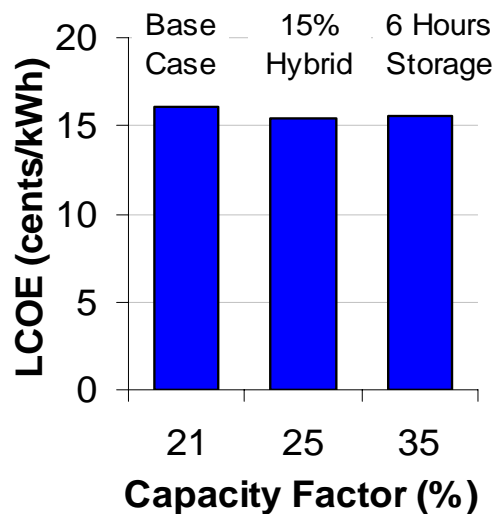
# Current Solar PV Cost and Performance



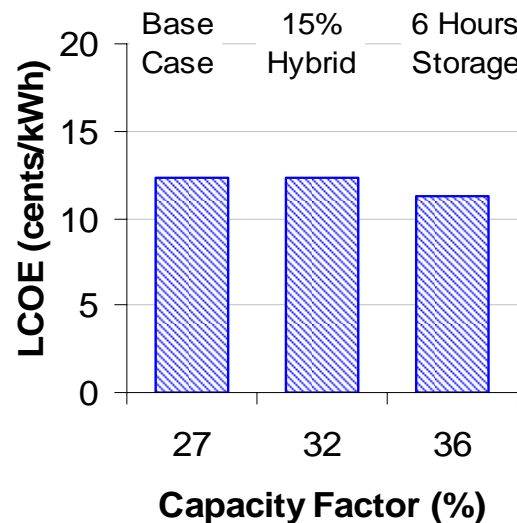
# CSP Feasibility Study in New Mexico

- Participants: PNM, Tri-State, Xcel, SCE, SDG&E, EPE
- Conclusions:
  - Molten salt central receiver has potential for 20% cost reduction
  - Storage and hybridization lower LCOE by up to 8%
  - Capacity factors approach 40% with 6 hours storage

125 MW Parabolic Trough



125 MW Central Receiver



\* 2009\$

\* Includes financial incentives

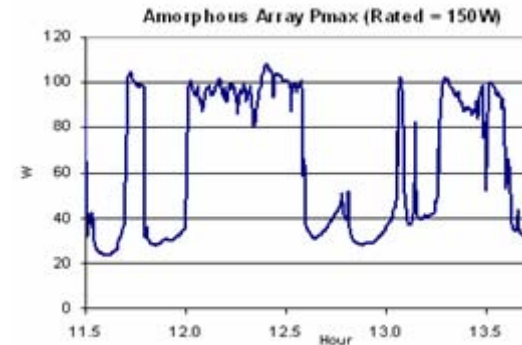
# Central Station Solar R&D Needs

- Solar Augmented Steam Cycle Applications Analysis
  - Analyze new applications
    - Greenfield
    - Integration with biomass or geothermal
- Solar Technology Acceleration Center (SolarTAC)
  - Benchmark PV/CPV technologies
  - SolarTAC demo projects
- Solar Thermal Storage Technology Assessment
  - Field data for installations
  - Identify hosts for collaborative evaluations of thermal storage performance



# Distributed PV Integration R&D Needs

- High Penetration PV Impact on Circuits
  - Model development and system impact evaluation
  - Economic Assessment
  - Demonstration on selected feeders
- Distribution PV Monitoring Project
  - Understand the performance characteristics under various environmental and climatic conditions
  - Large population of units
  - Monitoring protocol and package
- Operations and Maintenance Needs
  - Assess maintenance practice
  - Develop needs, gap analysis
  - Identify opportunities for improvement



# Distributed PV Monitoring at Alabama Power

- 4 different arrays (1.1 kW each)
- Side-by-side performance comparison
- System integration, evaluation using micro-inverters on each panel
- Increased understanding of PV operations in southeast climate

Panel Type (Silicon)	Panel Cost June '09 (\$/W)	Panel Cost May '10 (\$/W)
Polycrystalline	\$ 3.54	\$ 2.42
Monocrystalline	\$ 3.50	\$ 2.74
Thin film (flexible)	\$ 4.22	\$ 3.54
Heterojunction with intrinsic thin layer	\$ 4.60	\$ 4.46

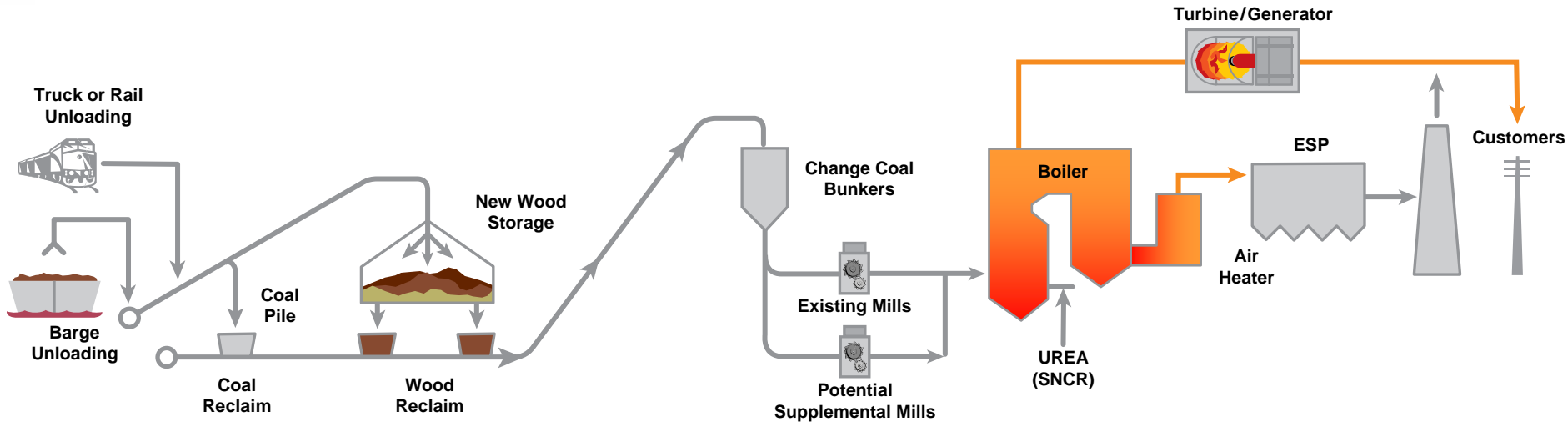
as purchased ↗

today ↗



What are the **opportunities** to enable increasing amounts of **biomass** energy?

# Biomass Repowering of Existing Units



n **Weatherproof barge unloading and conveyance**

- Keep pellets dry
- New buildings

n **New wood storage buildings**

n **Change conveyor**

- Keep pellets dry
- Address steep angles
- Dust suppression
- Fire protection

n **Bunker and mill changes for wood pellets**

- Fuel milling
- Dust suppression
- Fire protection

n **Boiler changes**

- Accommodate higher flue gas velocities and temperatures

n **New burner system**

- Reduce NOx emissions

n **Change SNCR system**

n **Change ash handling and disposal system**

Slide courtesy of FirstEnergy, 2009

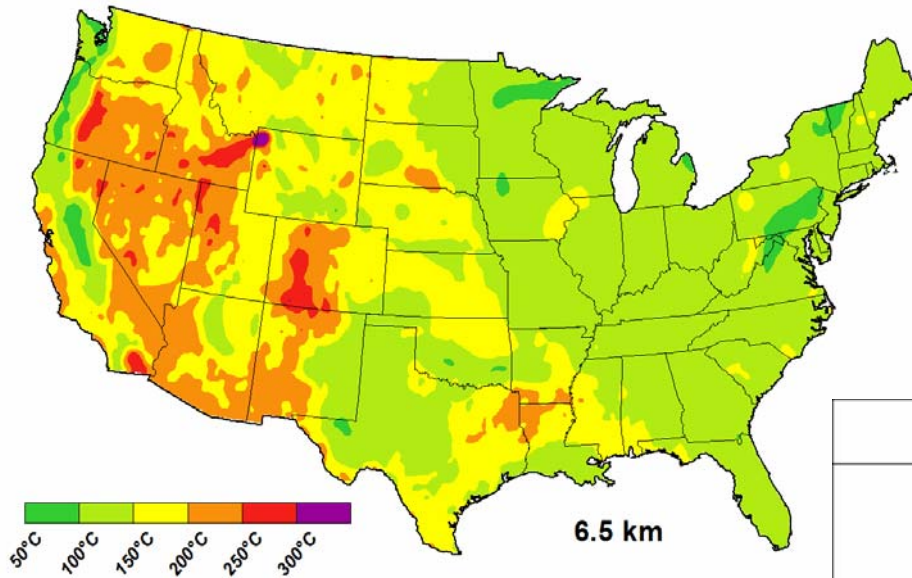
# Biomass R&D Needs

- Biomass Supply Management
  - Long-term supply security
  - Development of multiple supply chains
  - Assessment of energy plantations
- Power Generation from Biomass
  - Impact on environmental equipment
  - Biomass plant cost database
  - Ash utilization
  - Torrefied wood full-scale tests
  - Methods to increase co-firing fraction
- Life Cycle Analysis of Biomass-Based Power
  - Updated biomass-to-power carbon footprint
  - Land, water implications of biomass supply
  - Broad deployment of biomass power plants: environmental implications



What are the **opportunities** to enable increasing amounts of **geothermal** energy?

# Deep EGS Potential Significant, Widespread



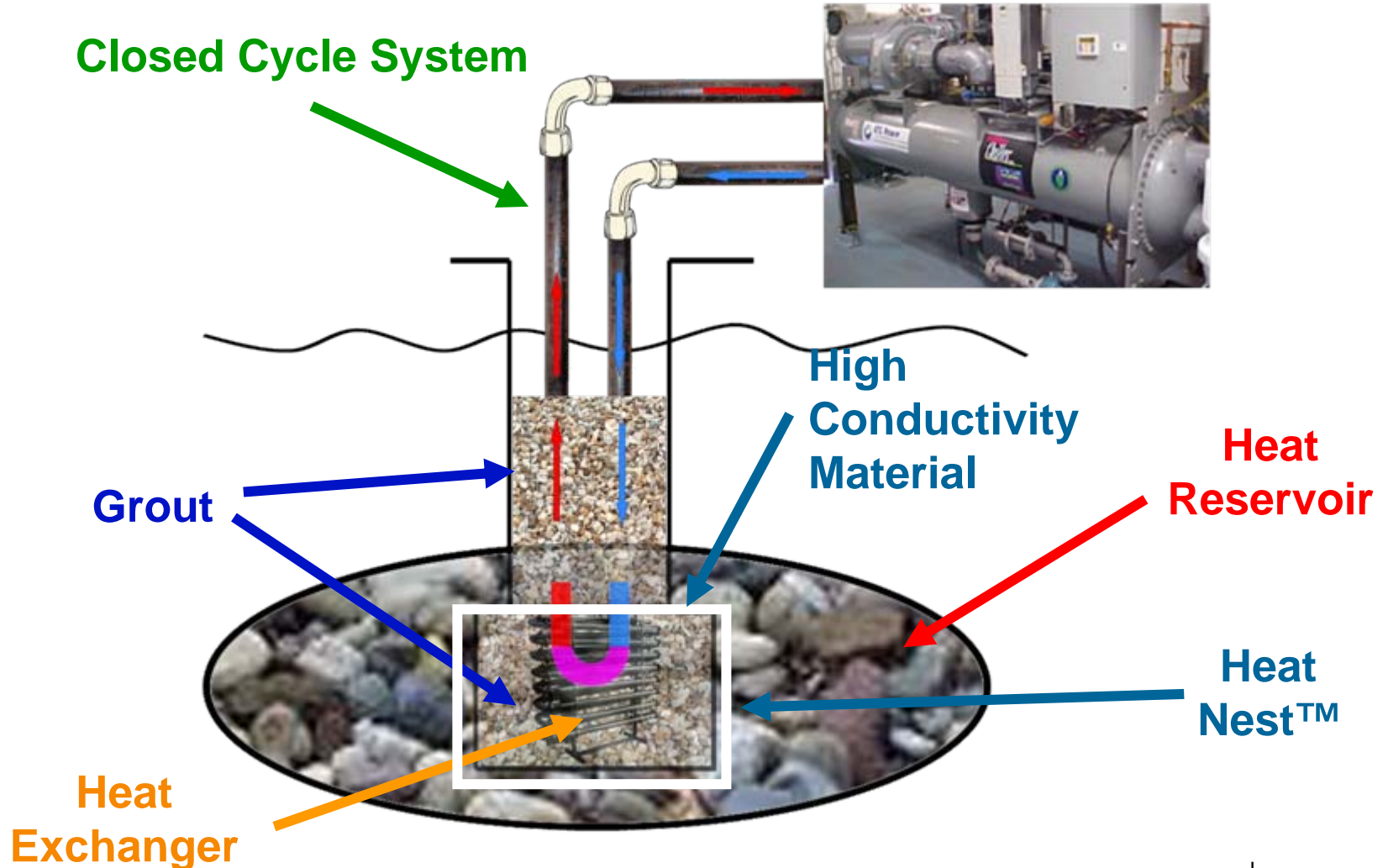
EGS – Enhanced Geothermal Systems  
Slide and data courtesy of NREL, 2010

## Challenges:

1. Resource conversion
2. Injection of fluids
3. Induced seismicity

		Potential Electric Capacity (MW <sub>e</sub> )				
		Resource Temperature (°C)				
		150-200	200-250	250-300	300-350	350+
Reservoir Depth (km)	3-4	91,516	117	0	0	
	4-5	590,763	26,526	134	0	0
	5-6	1,139,749	227,969	7,680	50	0
	6-7	1,337,049	723,692	86,057	631	0
	7-8	1,539,597	1,129,434	345,285	32,964	320
	8-9	1,881,116	1,159,750	761,653	138,204	9,922
	9-10	1,907,066	1,251,474	1,015,937	433,749	69,298

# Single-Well Technology Developed by GTherm



# Geothermal R&D Needs

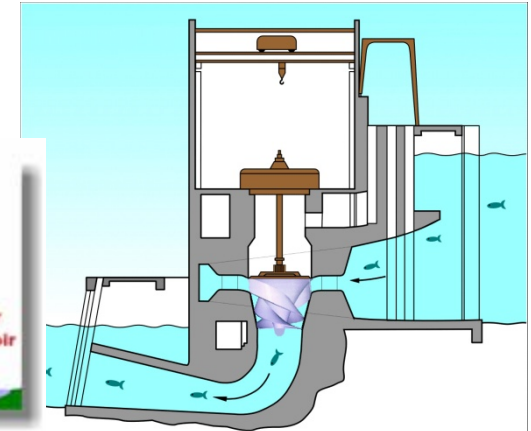
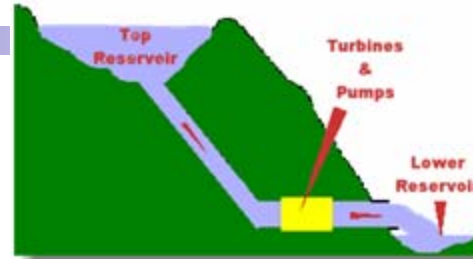
- Geothermal Operations and Maintenance
  - Plant evaluations and assessments
  - O&M handbook
  - Training and technology transfer
- Assessment of Geothermal Power Technologies
  - Engineering and economic analysis of low- and moderate-temperature geothermal resources and technologies
  - Identify demonstration projects for advanced geothermal or EGS



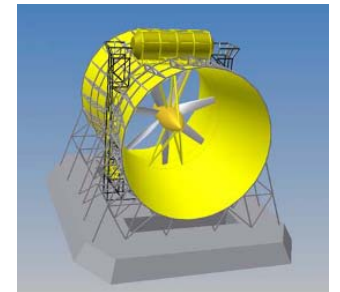
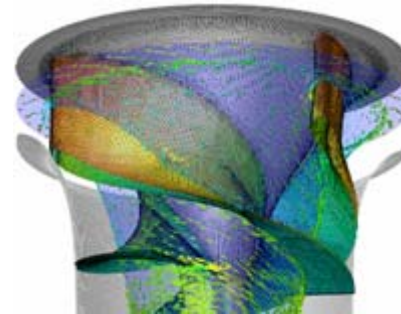
What are the **opportunities** to enable increasing amounts of **waterpower**?

# What is Waterpower?

- Conventional Hydropower
- Pumped Storage
- Ocean Energy
  - Wave energy conversion
  - Thermal gradient
  - Ocean currents
- Instream Energy Conversion
  - River or inland hydrokinetics (RISEC)
  - Tidal hydrokinetics (TISEC)



**ALDEN/NREC Fish Friendly Turbine**



# EPRI Waterpower Potential Update Report

- To be published April 2010
  - 3 briefing papers to follow (potential, R&D needs, economic incentives)
- NHA used 2007 EPRI assessment to convince Congress of need for R&D funding:
  - **\$10 million FY08;**
  - **\$40 million FY09;**
  - **\$50 million FY10:**

**vs. \$0 nothing FY05-07**

(~40,000 MW by 2025)

Category	Potential	By 2025
Conv Hydro	58,000	13,750
Pumped Storage	*	10,000
HK River	12,500	500-3,000
HK Tidal	NA	500-3,000
Wave	~20,000	10,000

# Waterpower R&D Needs\*

## Conventional Priorities:

1. Advance turbine development
2. Technology deployment and testing
3. Fish passage and protection
4. Hydro GHG emissions
5. Optimization and efficiency improvement research
6. Resource assessment updates
7. Wind-hydropower integration
8. Pumped-storage development and bench-marking

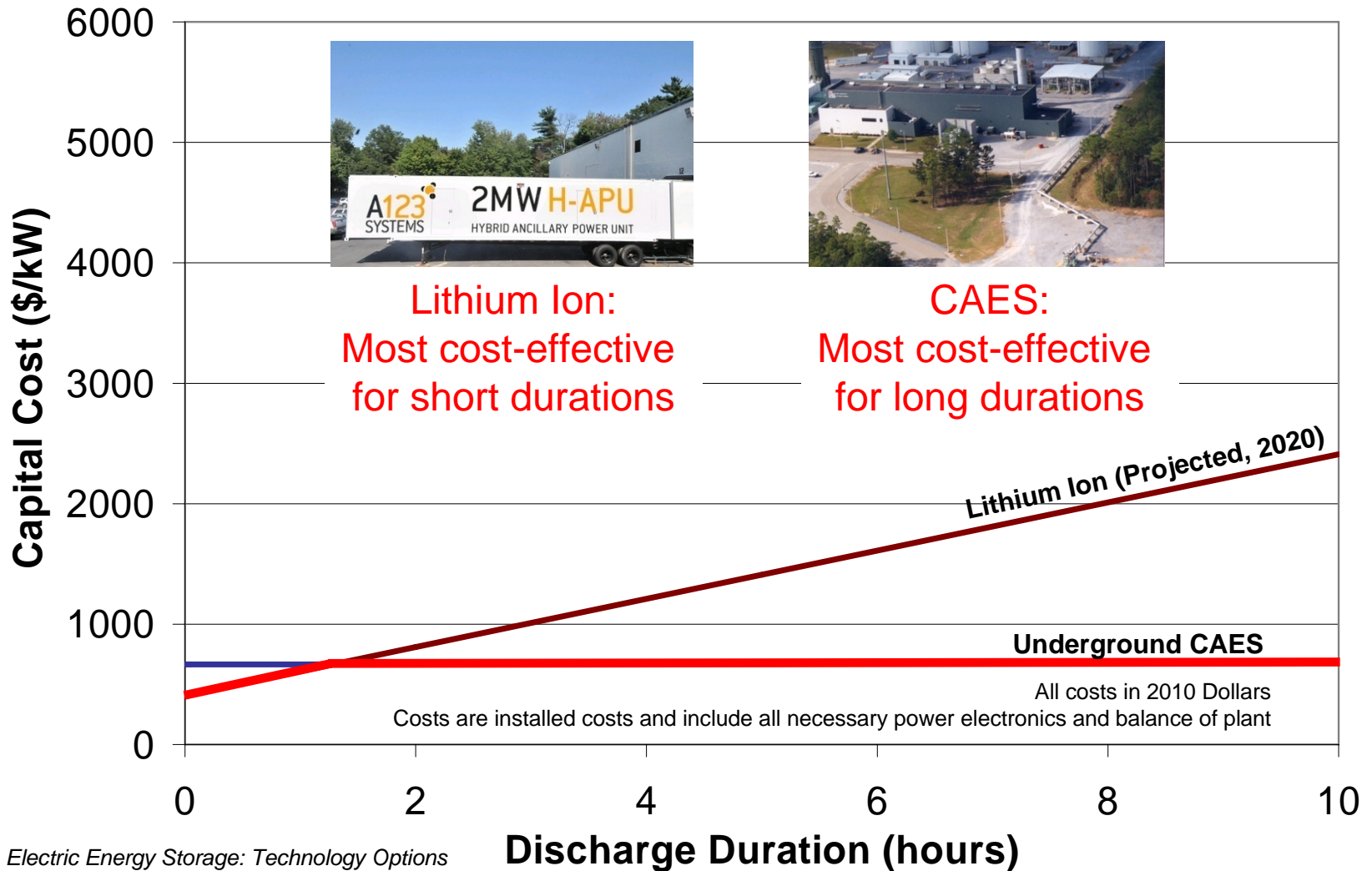
## Ocean and Hydrokinetic Priorities:

1. Technology development
2. Technology deployment and testing
3. Environmental impact research
4. Development of international standards for design, testing, and performance metrics

**\*2008 EPRI-DOE Waterpower Industry R&D Prioritization Workshop**

# How can **energy storage** and **the smart grid** enable increasing amounts of renewables?

# Energy Storage Likely to Play a Role



Data from *Electric Energy Storage: Technology Options* (EPRI White Paper to be released December 2009)

# Smart Grid Demonstrations Tie It All Together

- Deploying the Virtual Power Plant
- Demonstrate Integration and Interoperability
- Leverage information & Communication Technologies
- Integration of Multiple Types of Distributed Energy Resources (DER):

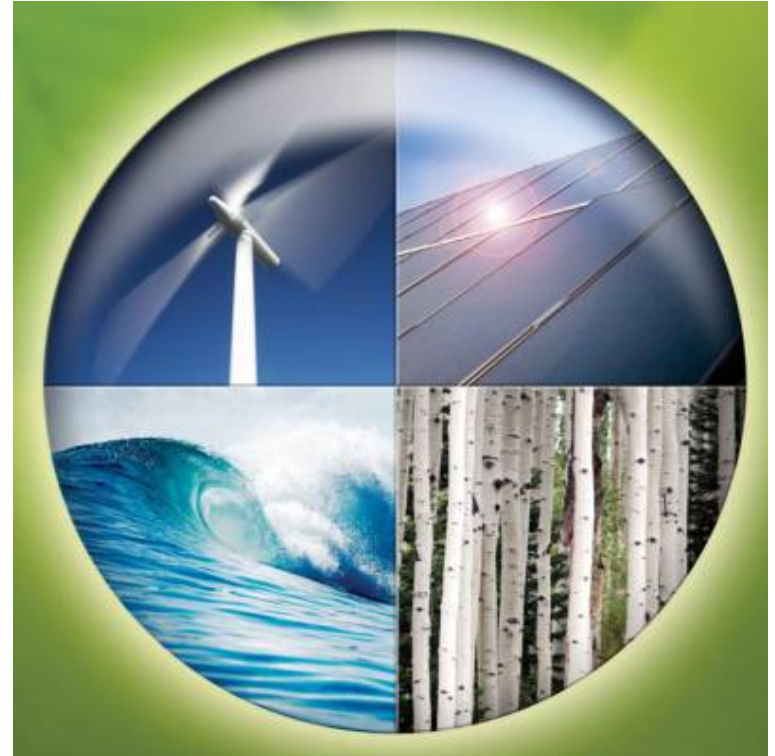
- ✱ Distributed Generation
- ✱ Renewable Generation
- ✱ Storage
- ✱ Demand Response

✱ Multiple Levels of Integration - Interoperability



# Making Renewable Energy Work

- **Reduce Cost of Generation Technology Options**
- **Integrate Variable Generation with Transmission and Distribution**
- **Optimize with Energy Storage and the Smart Grid**
- **Understand and Minimize Environmental Impacts**



***Public/Private Collaboration Needed!***

# Together...Shaping the Future of Electricity