EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Renewable Energy Outlook and Future R&D Needs

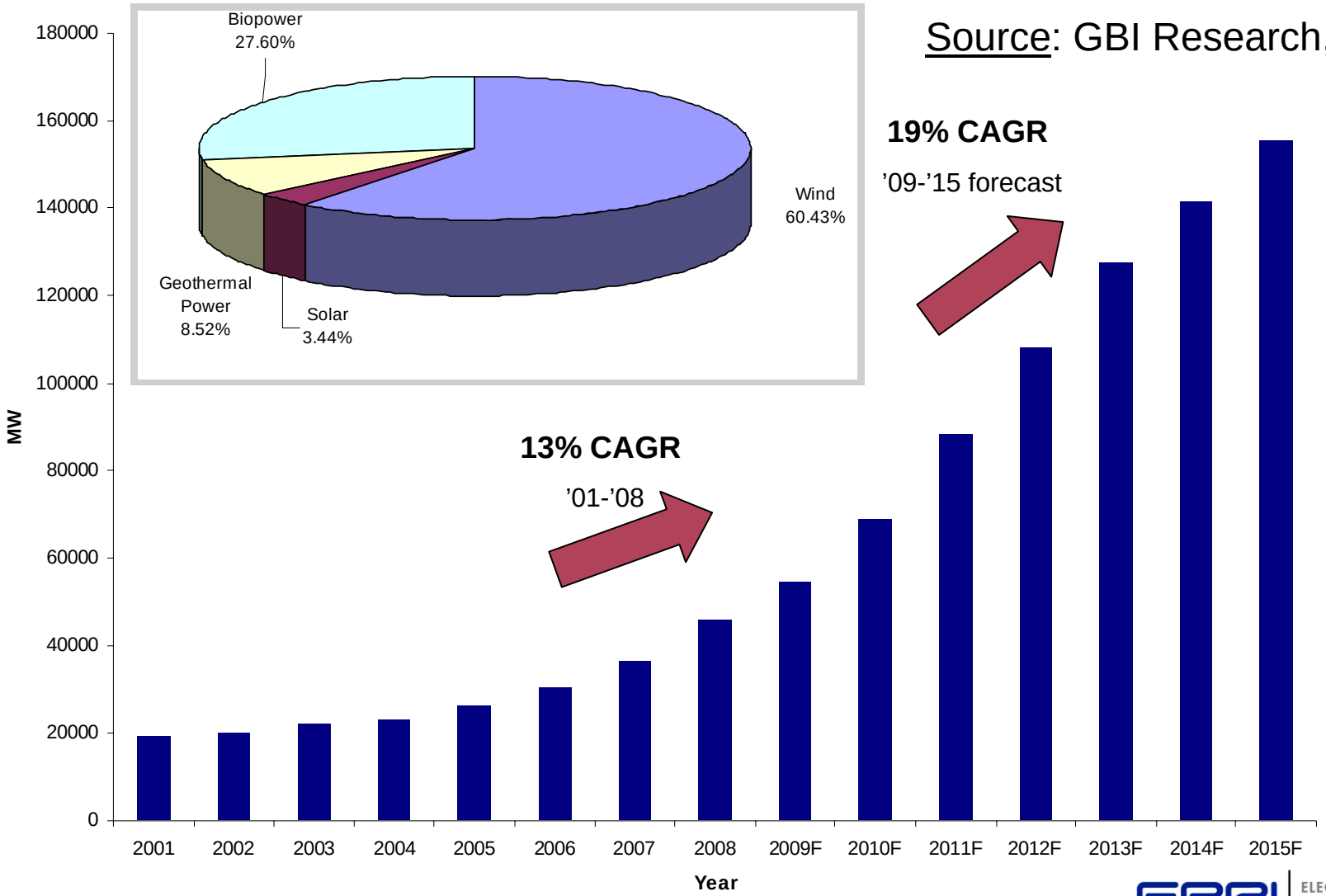
Bryan Hannegan, Ph.D.
Vice President, Environment & Renewables

EPRI Climate Research Seminar

May 18, 2010

Renewables: Why Now?

North American Installed Capacity 2001-2015

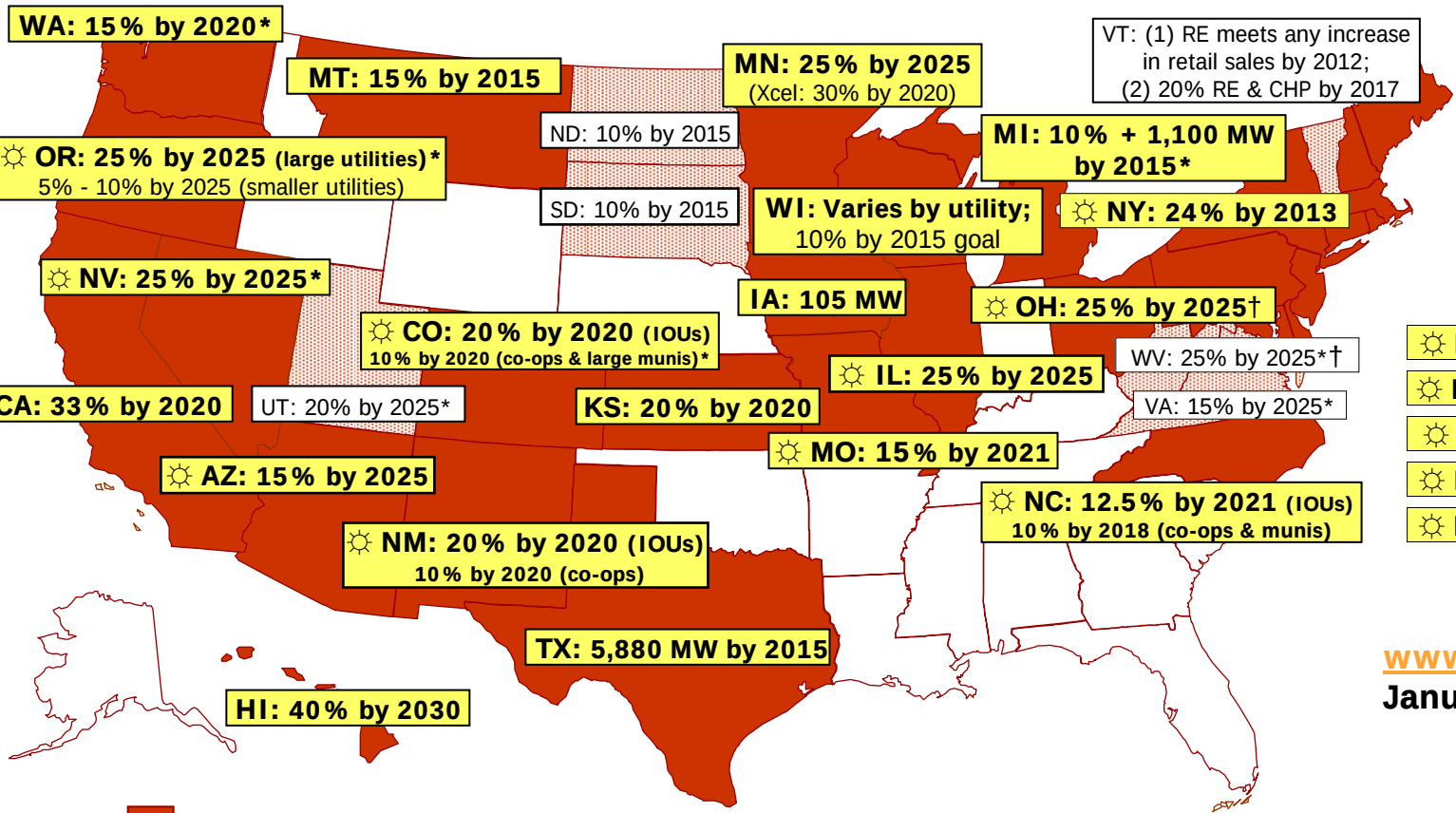


Source: GBI Research, 2010

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Renewables: Why Now?

29 States + DC Have Renewable Portfolio Standards



www.dsireusa.org
January 2010

State renewable portfolio standard

State renewable portfolio goal

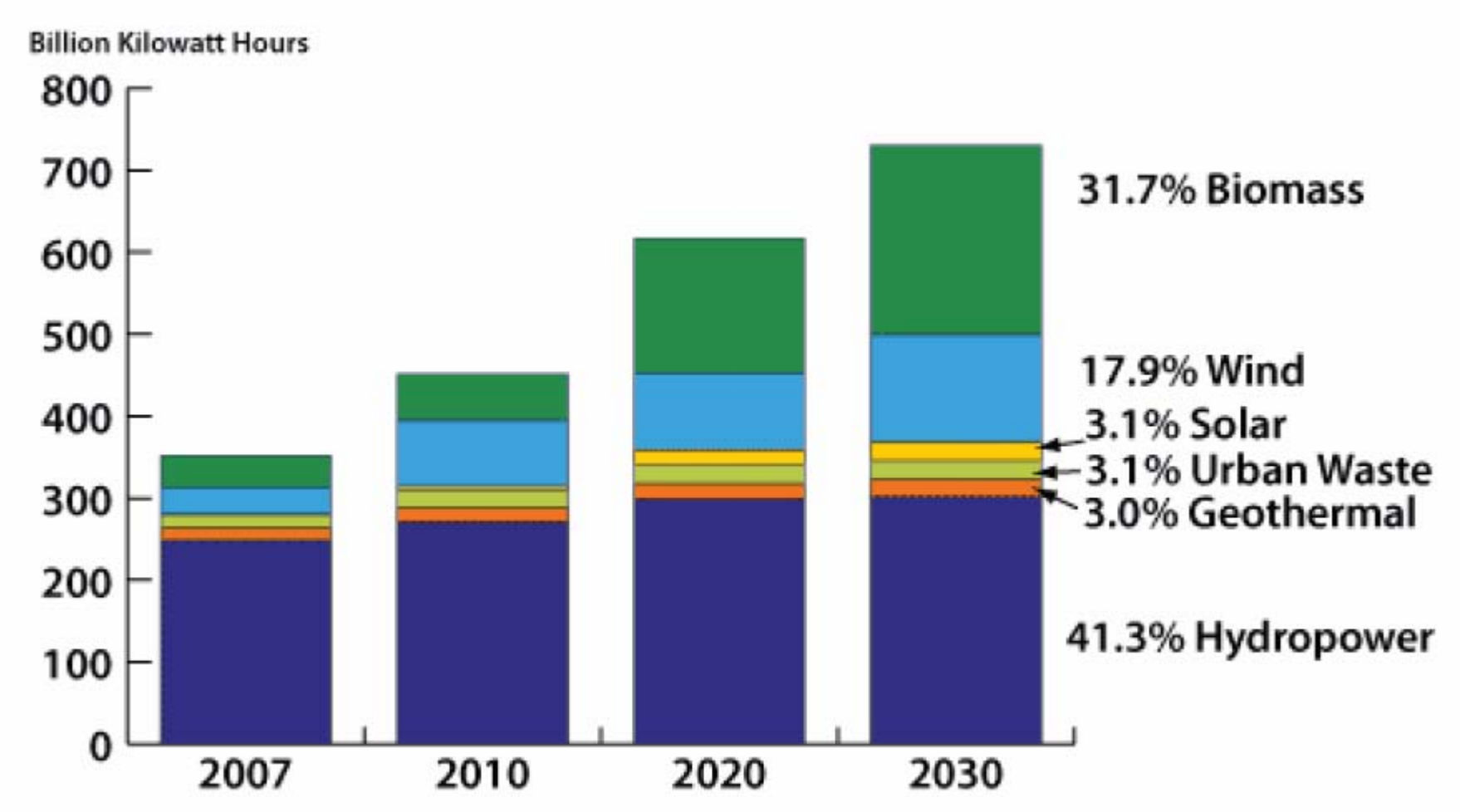
☼ Minimum solar or customer-sited requirement

* Extra credit for solar or customer-sited renewables

† Includes non-renewable alternative resources

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Renewables: Why Now?
U.S. Projected Generation 2007-2030

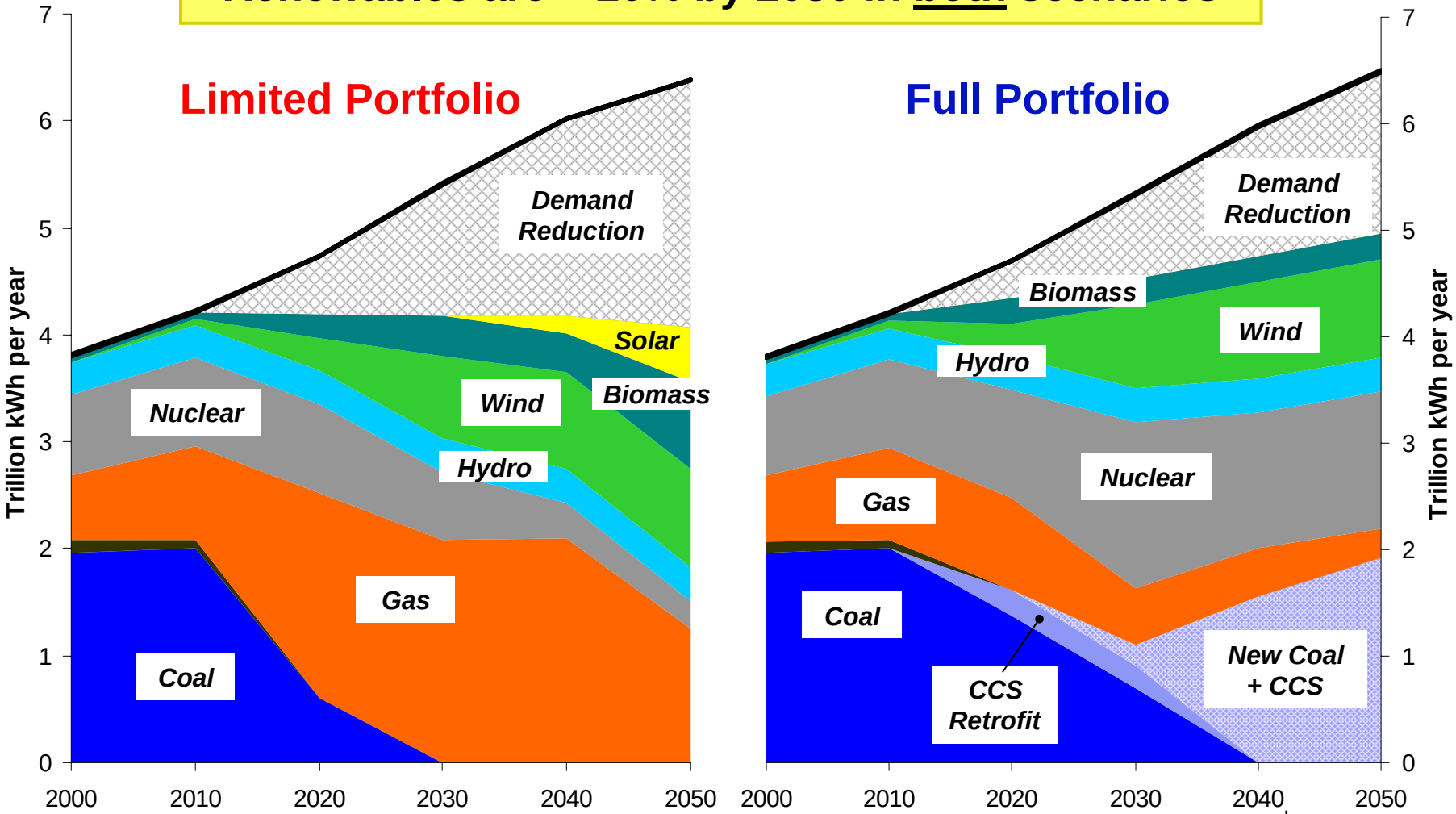


Source: EIA AEO 2009

Renewables: Why Now?

EPRI MERGE – Two Possible Future Mixes

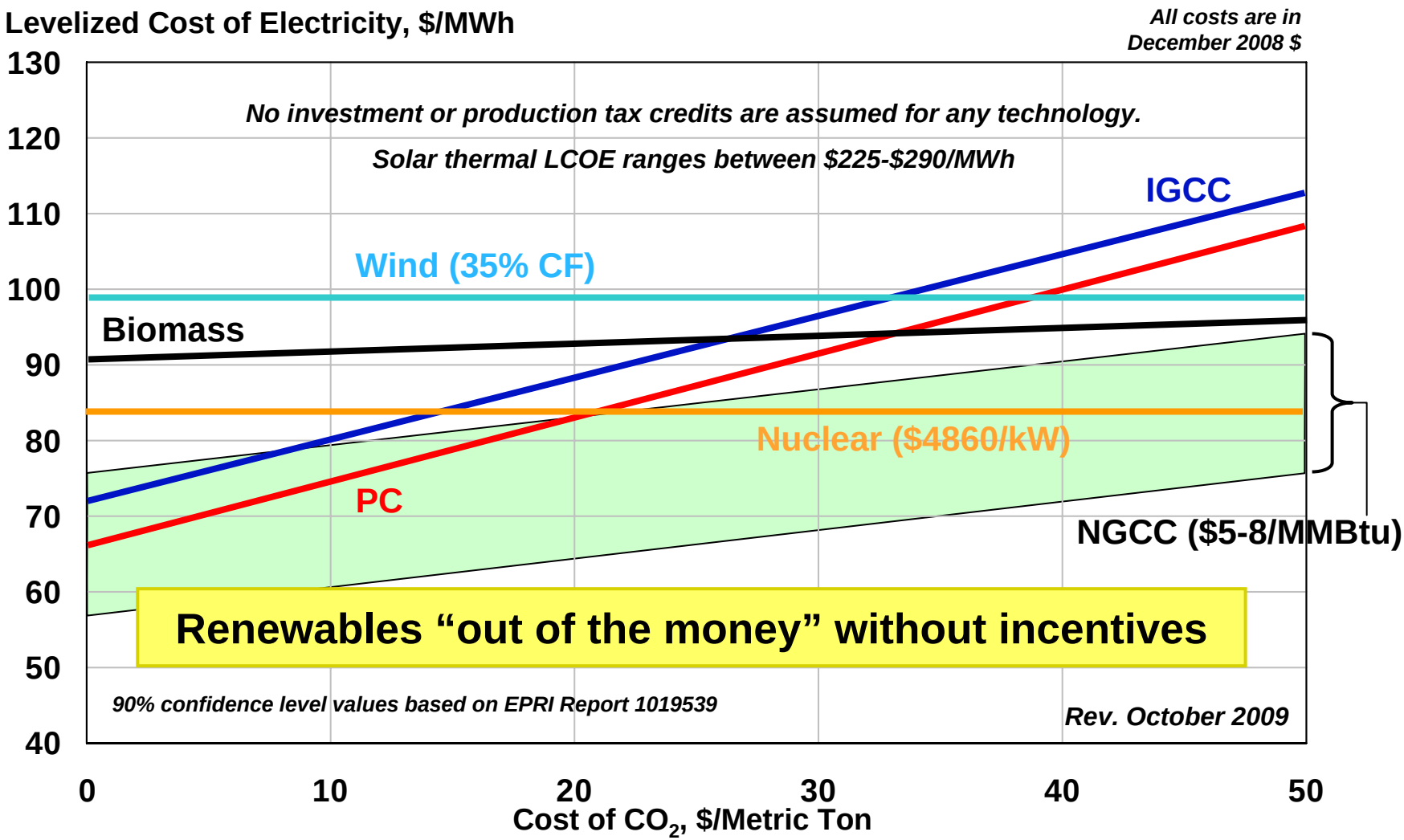
Renewables are > 20% by 2030 in <u>both</u> scenarios



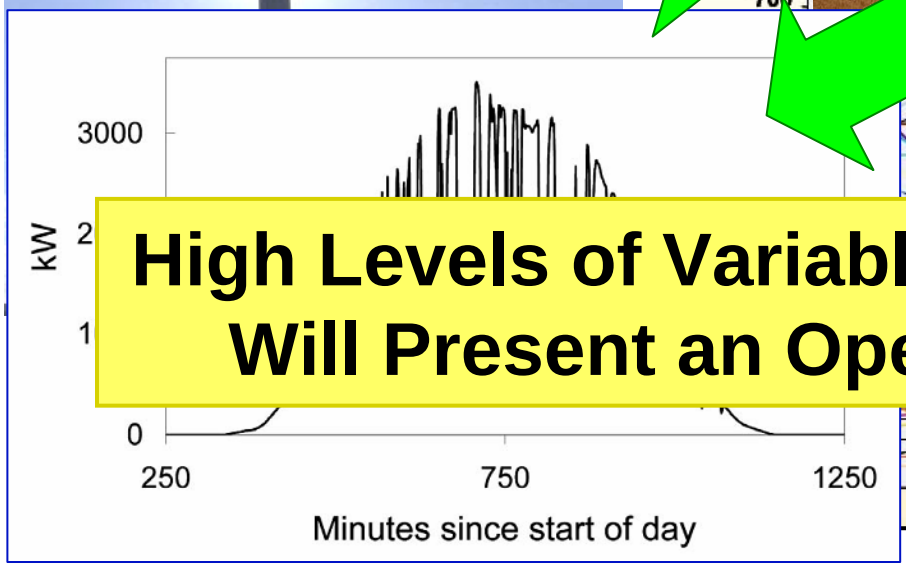
EPRI ELECTRIC POWER RESEARCH INSTITUTE

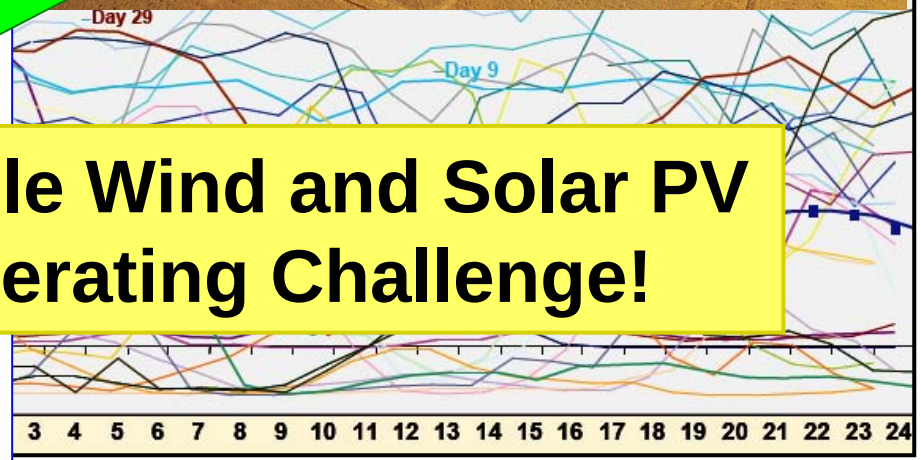
What are the challenges posed by increasing amounts of renewable energy?

The Cost Challenge



The Integration Challenge





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

EPRI ELECTRIC POWER RESEARCH INSTITUTE

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

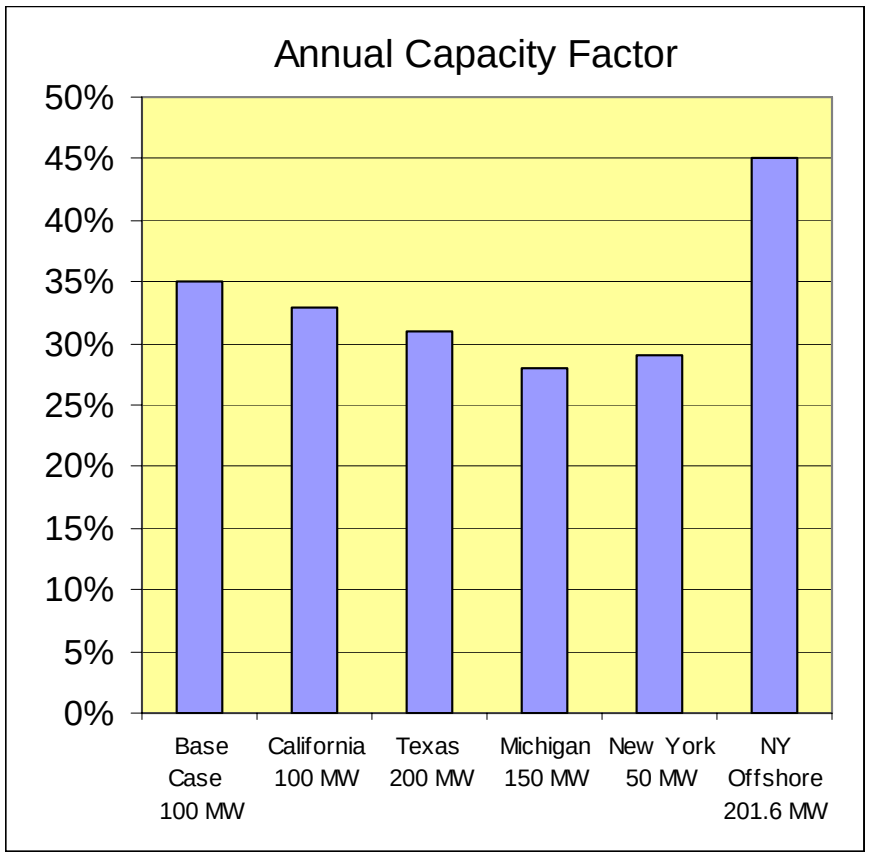
What are the opportunities to enable increasing amounts of wind energy?

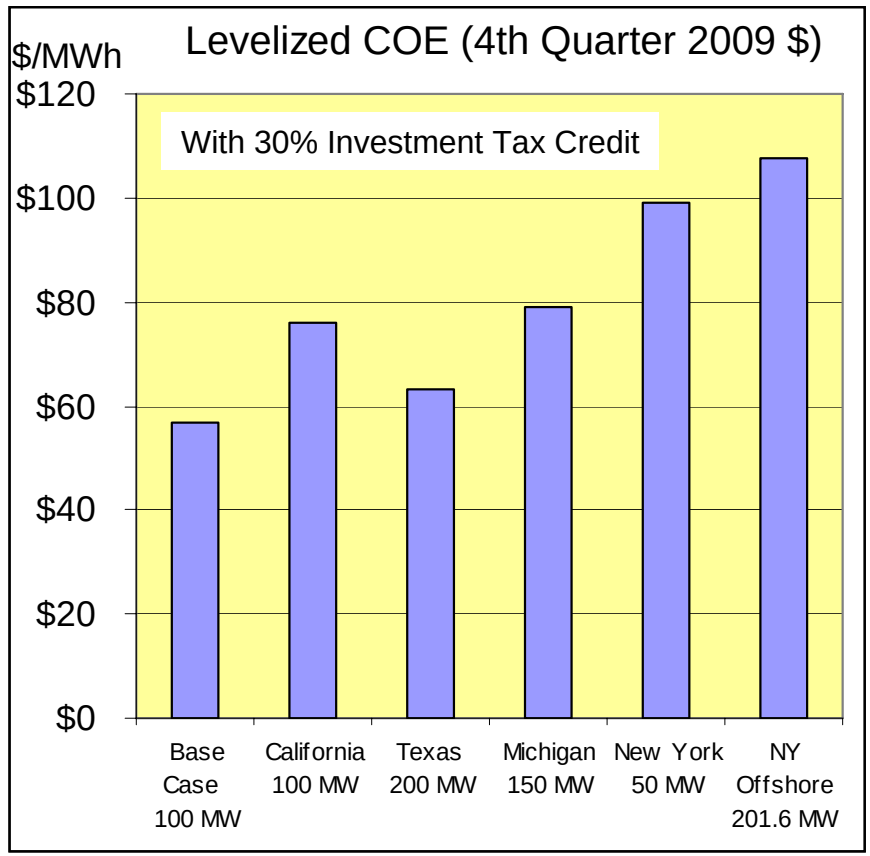
Current Wind Project Cost and Performance

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

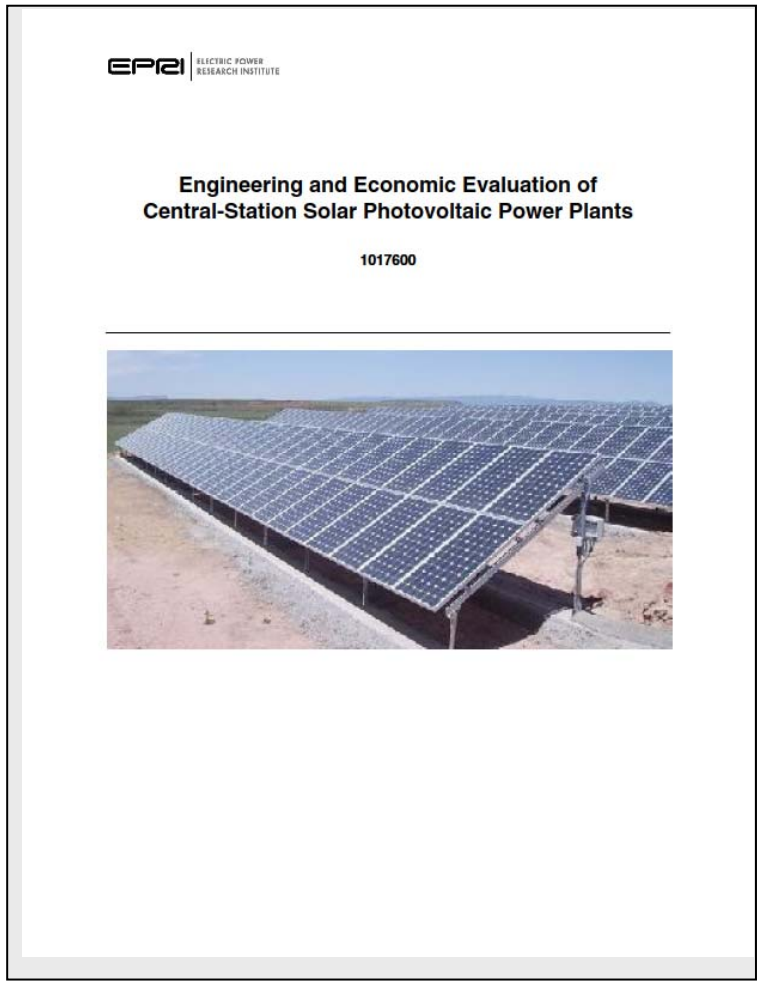
- Technical Performance Specs for VG/DR/PHEV
- Other EPRI Programs – ElectriNet, Storage

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

Current Solar PV Cost and Performance

Central Station PV Evaluation

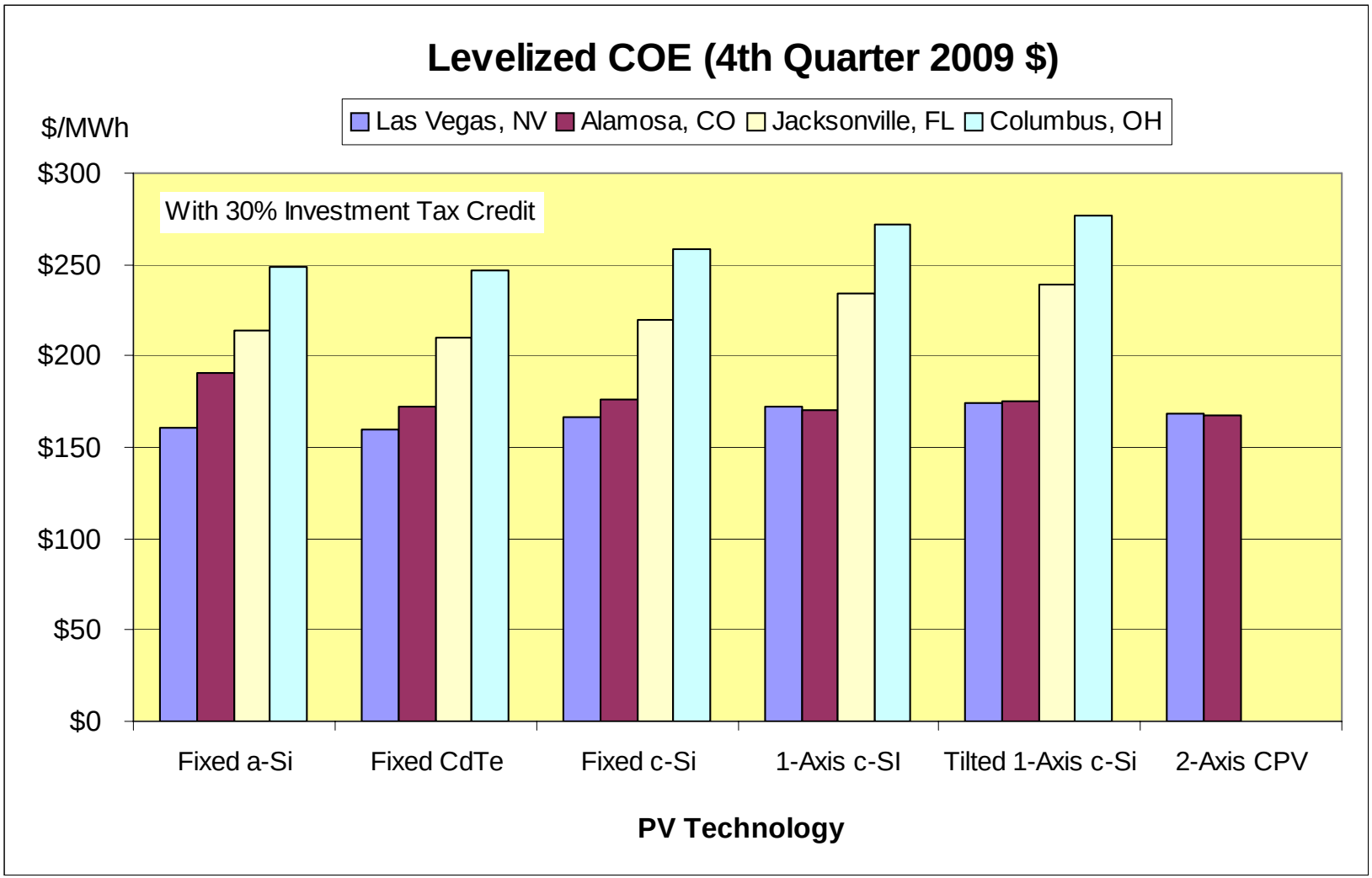
- 6 PV Technologies:
  - Fixed Flat Plate a-Si
  - Fixed Flat Plate CdTe
  - Fixed Flat Plate c-Si
  - 1-Axis Tracking c-Si
  - Tilted 1-Axis Tracking c-Si
  - 2-Axis Tracking CPV
- Four Locations:
  - Las Vegas, NV
  - Alamosa, CO
  - Jacksonville, FL
  - Columbus, OH


EPRI ELECTRIC POWER RESEARCH INSTITUTE

Engineering and Economic Evaluation of Central-Station Solar Photovoltaic Power Plants

1017600

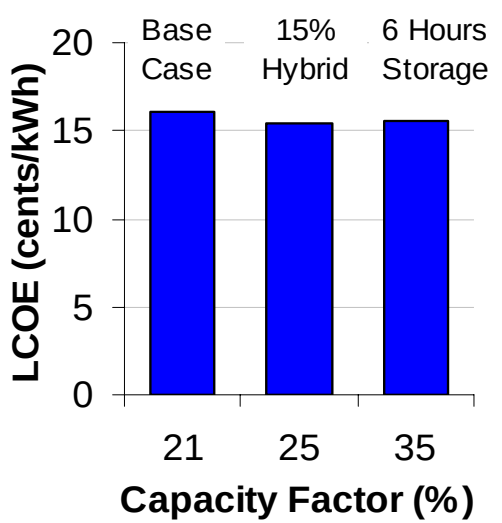
Current Solar PV Cost and Performance



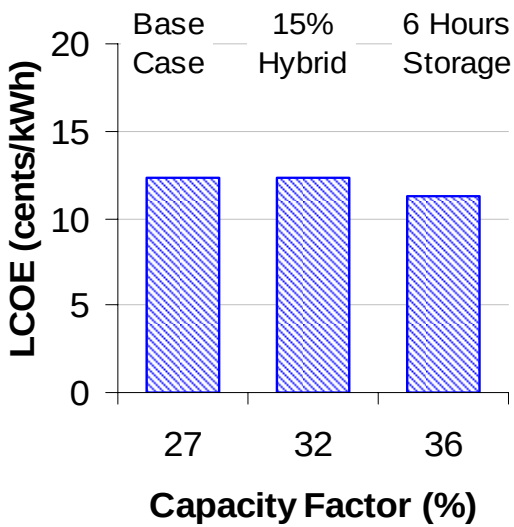
CSP Feasibility Study in New Mexico

- 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

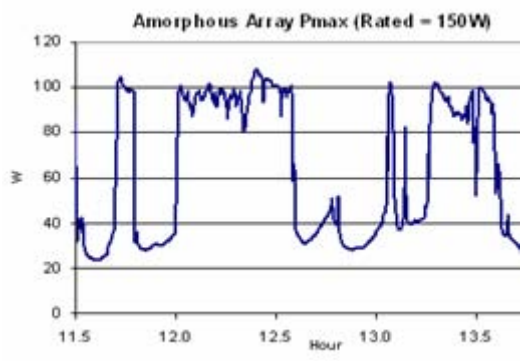
EPRI ELECTRIC POWER RESEARCH INSTITUTE

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

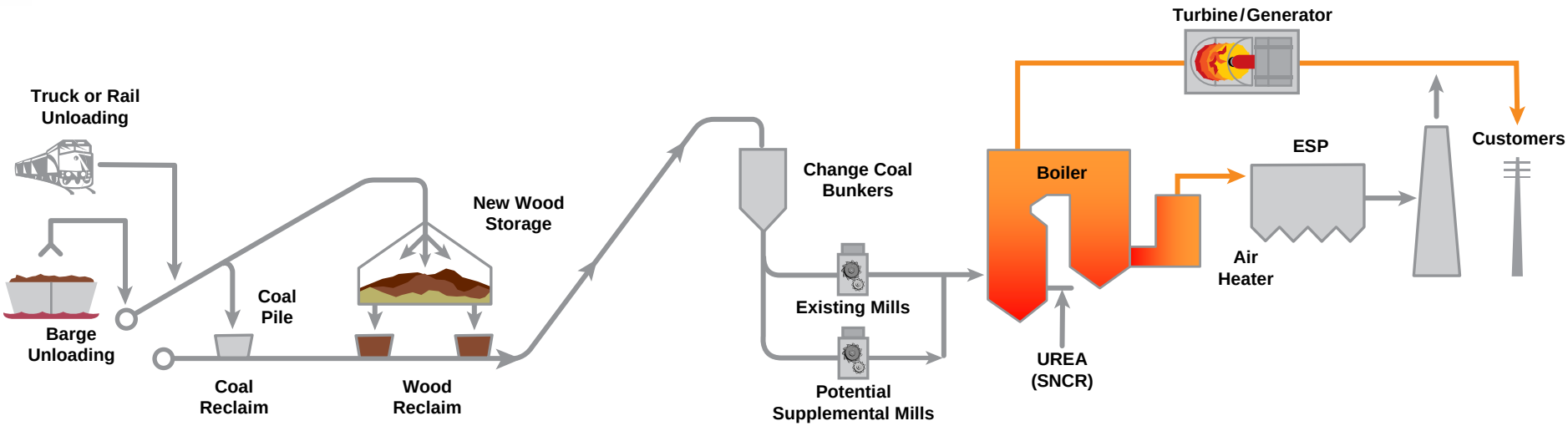
as purchased

today

EPRI ELECTRIC POWER RESEARCH INSTITUTE

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

Biomass Repowering of Existing Units



- **Weatherproof barge unloading and conveyance**
  - Keep pellets dry
  - New buildings
- **New wood storage buildings**
- **Change conveyor**
  - Keep pellets dry
  - Address steep angles
  - Dust suppression
  - Fire protection
- **Bunker and mill changes for wood pellets**
  - Fuel milling
  - Dust suppression
  - Fire protection
- **Boiler changes**
  - Accommodate higher flue gas velocities and temperatures
- **New burner system**
  - Reduce NOx emissions
- **Change SNCR system**
- **Change ash handling and disposal system**

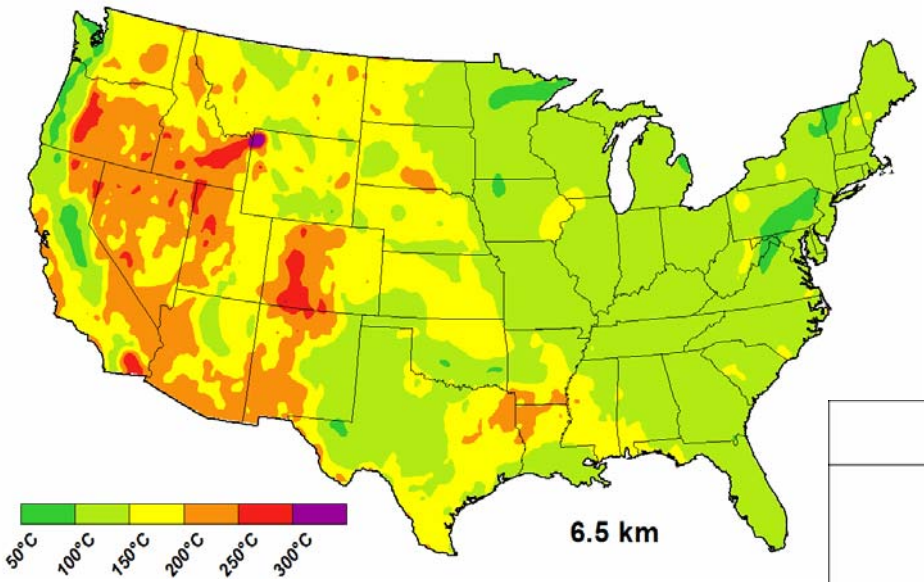
Slide courtesy of FirstEnergy, 2009

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

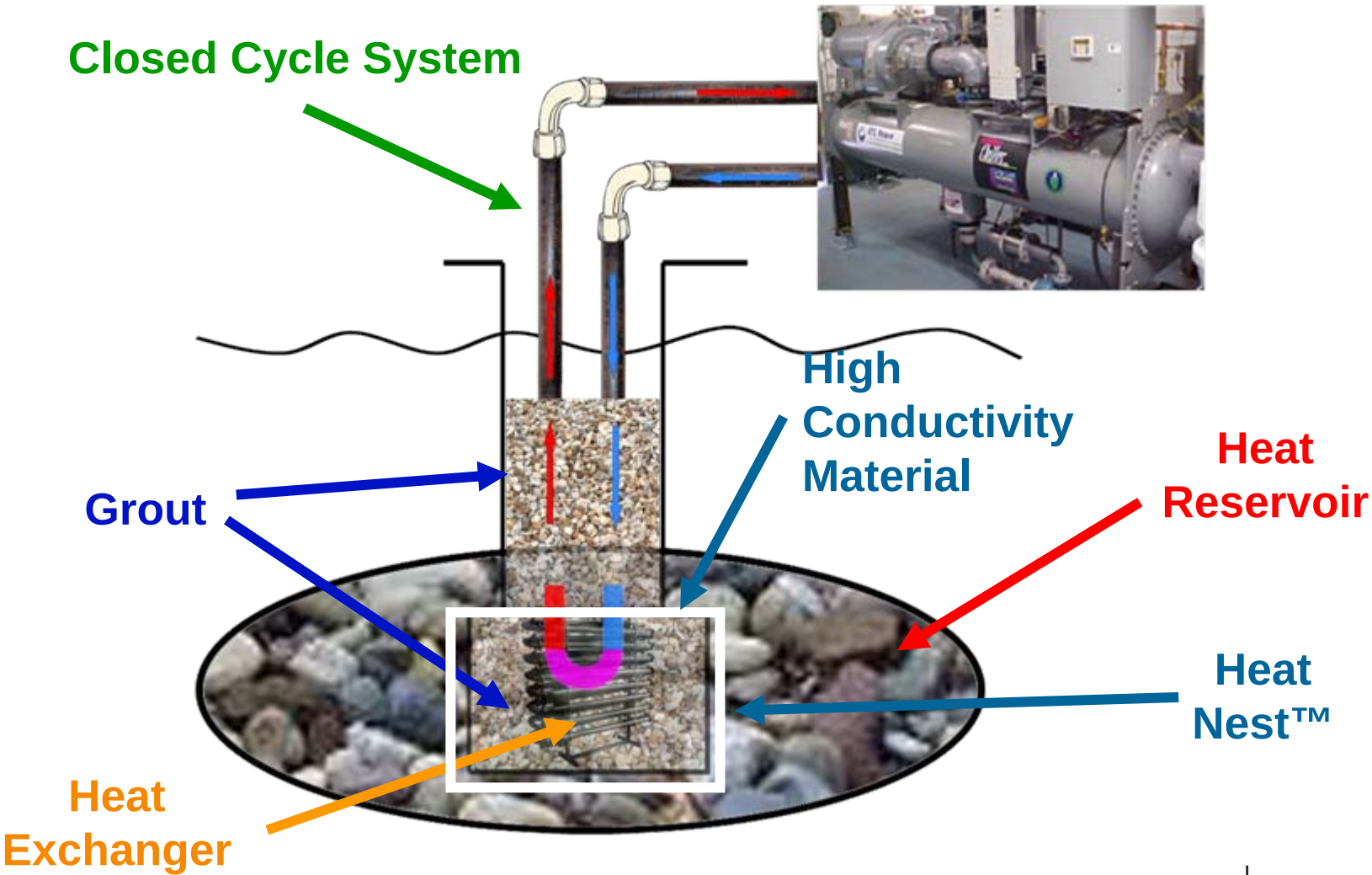
Slide and data courtesy of NREL, 2010

Potential Electric Capacity (MW_e)						
		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

Challenges:

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

Single-Well Technology Developed by GTherm



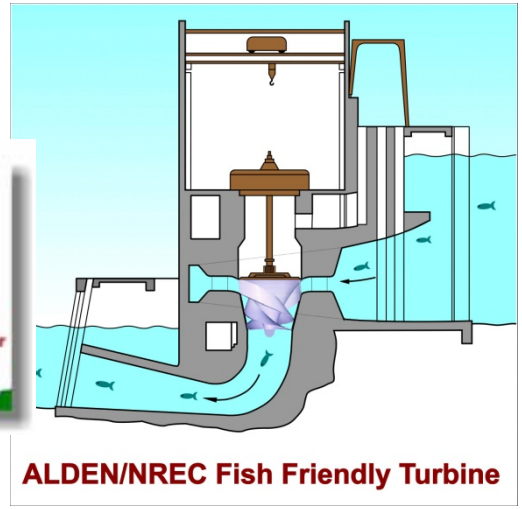
Geothermal R&D Needs

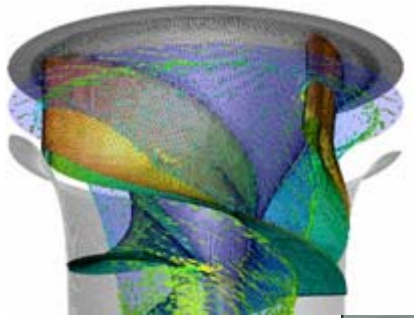
- Geothermal Operations and Maintenance
  - Plant evaluations and assessments
  - O&M handbook
  - Training and technology transfer
- Assessment of Geothermal Power Technologies
  - Engineering and economic analysis of low- and moderate-temperature geothermal resources and technologies
  - Identify demonstration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

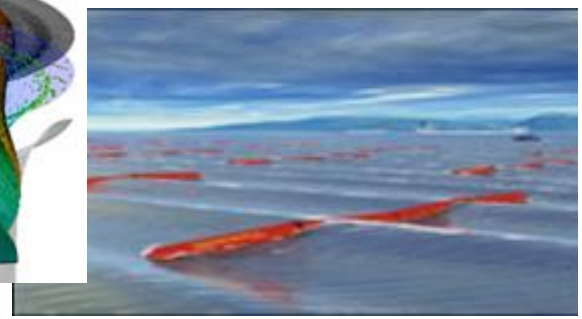
What are the opportunities to enable increasing amounts of waterpower?

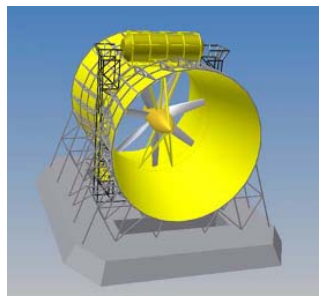
What is Waterpower?

- 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 ELECTRIC POWER RESEARCH INSTITUTE

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

Lithium Ion:
Most cost-effective
for short durations

CAES:
Most cost-effective
for long durations

Capital Cost ($/kW)

6000
5000
4000
3000
2000
1000
0

Lithium Ion (Projected, 2020)

Underground CAES

All costs in 2010 Dollars
Costs are installed costs and include all necessary power electronics and balance of plant

0 2 4 6 8 10

Discharge Duration (hours)

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

EPRI ELECTRIC POWER RESEARCH INSTITUTE

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