



EPRI

ELECTRIC POWER
RESEARCH INSTITUTE

Generation Options and Renewables

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Nicaraguan Delegation Visit

18 September, 2009

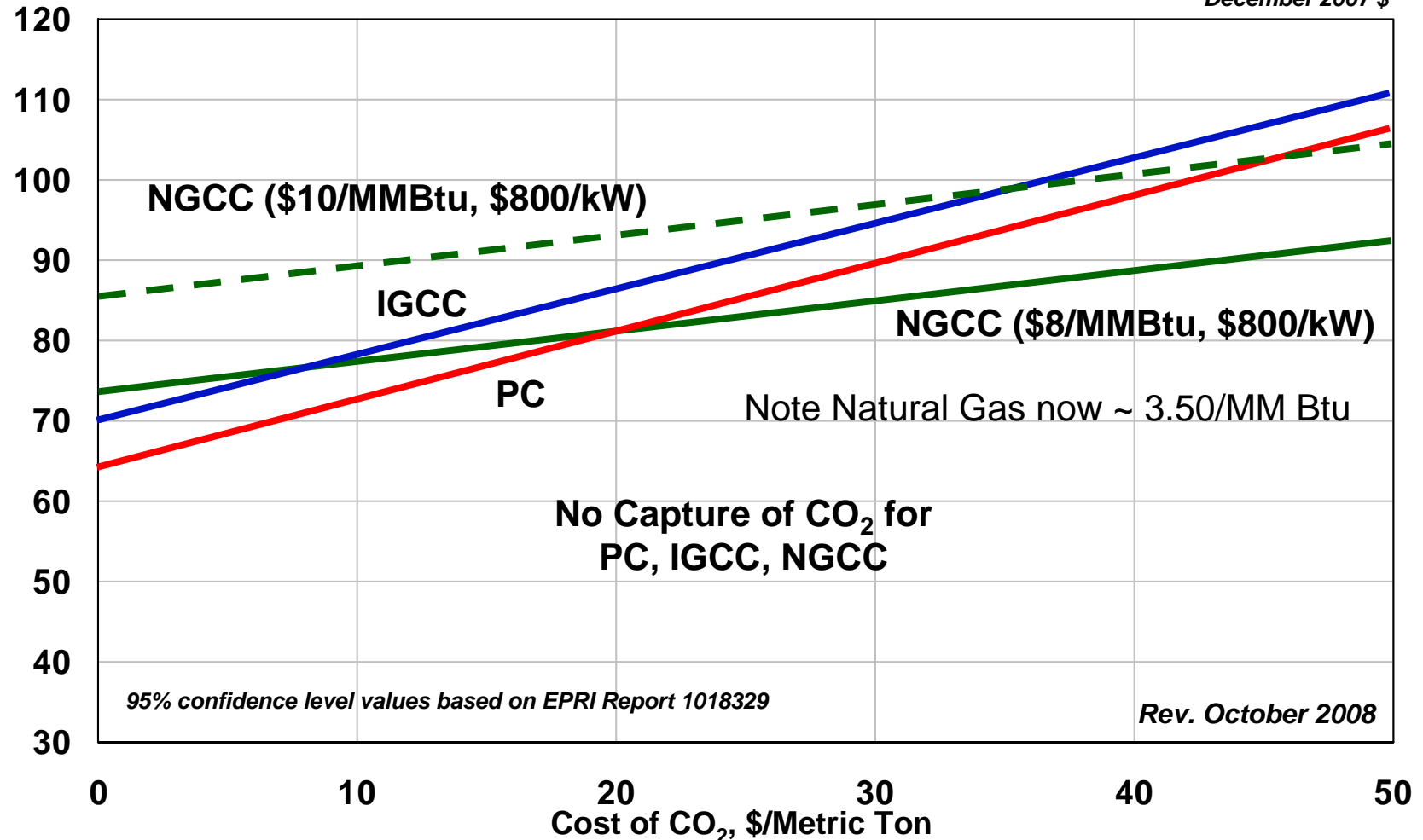
Cost of Electricity (Generic, Wholesale) Near-Term: 2015

PC, IGCC, NGCC Comparison – 2015

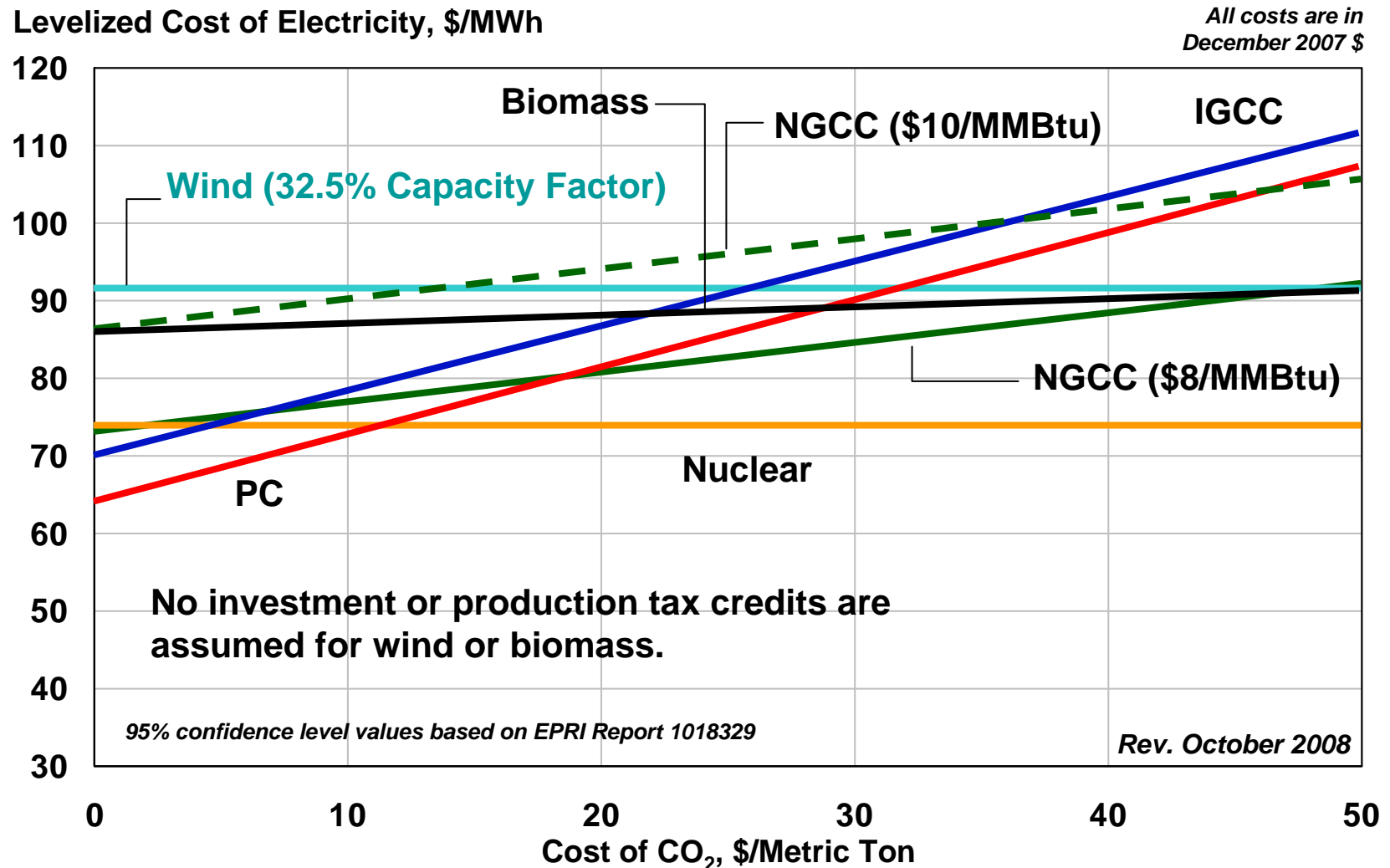


Levelized Cost of Electricity, \$/MWh

All costs are in
December 2007 \$



Comparative Levelized Costs of Electricity – 2015

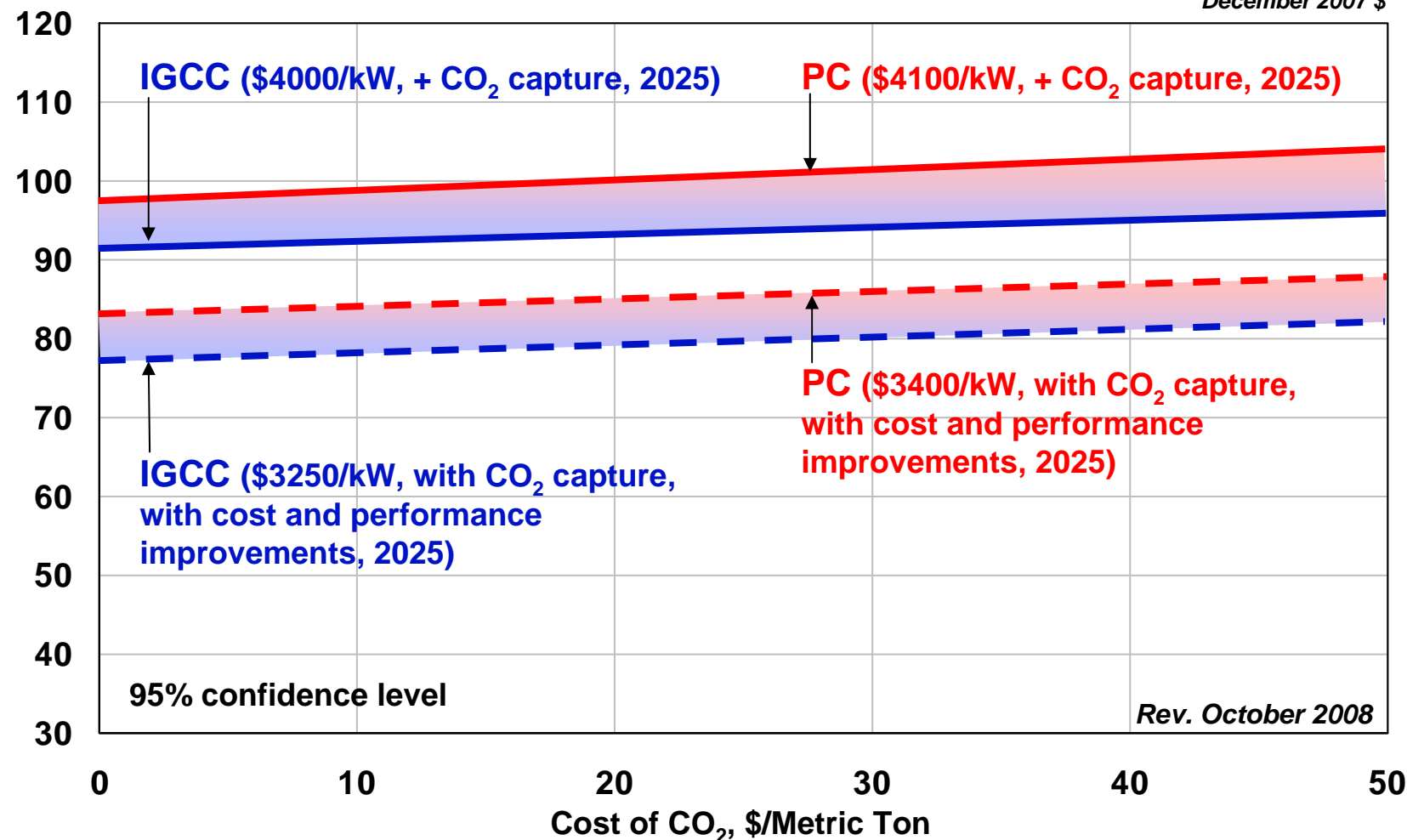


Longer-Term: 2025

Impact of CO₂ Removal and Cost and Performance Improvements on Levelized Cost of Electricity

Levelized Cost of Electricity, \$/MWh

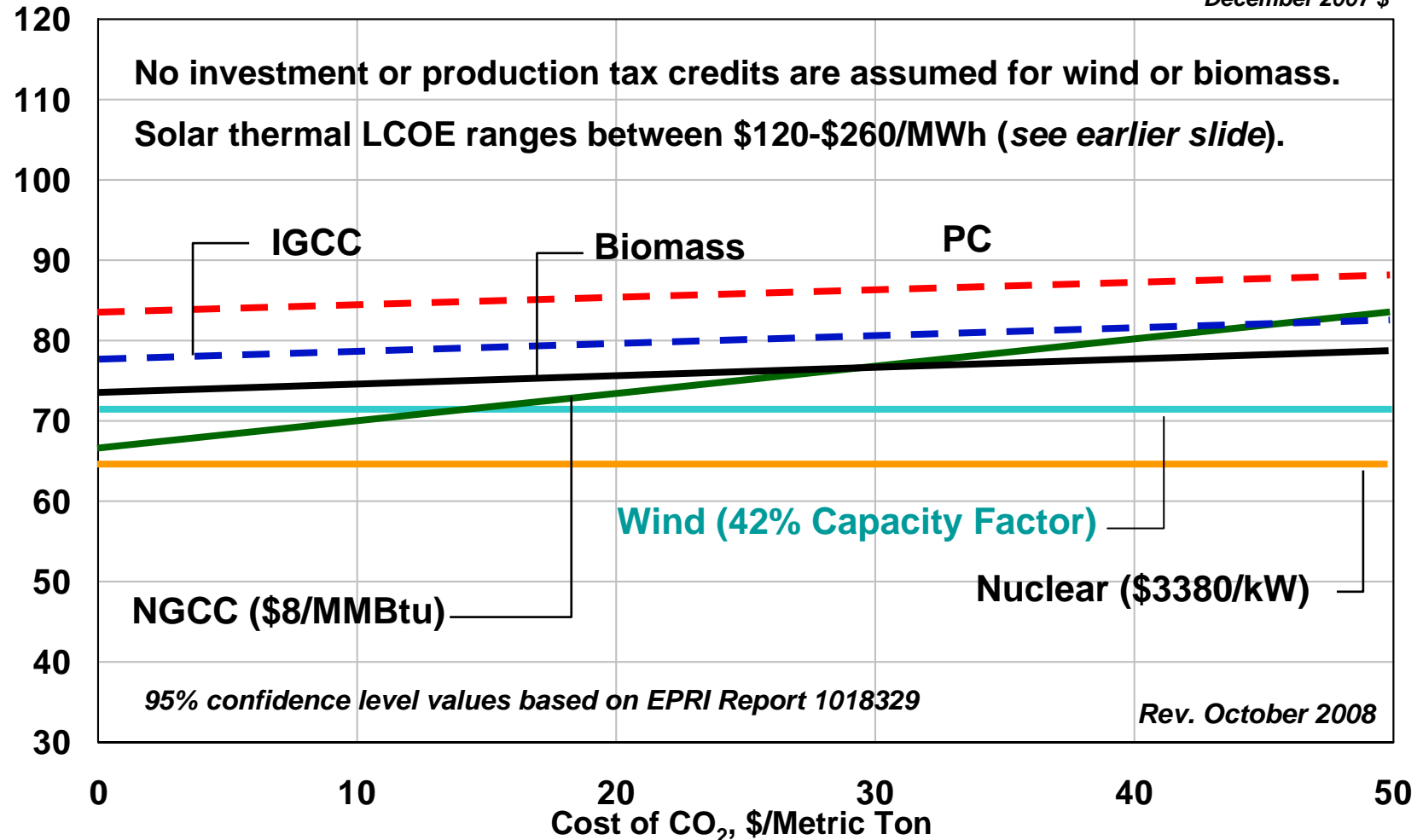
All costs are in
December 2007 \$



Comparative Levelized Costs of Electricity – 2025 (Capital plus O&M)

Levelized Cost of Electricity, \$/MWh

All costs are in
December 2007 \$



Renewables - Significant Growth

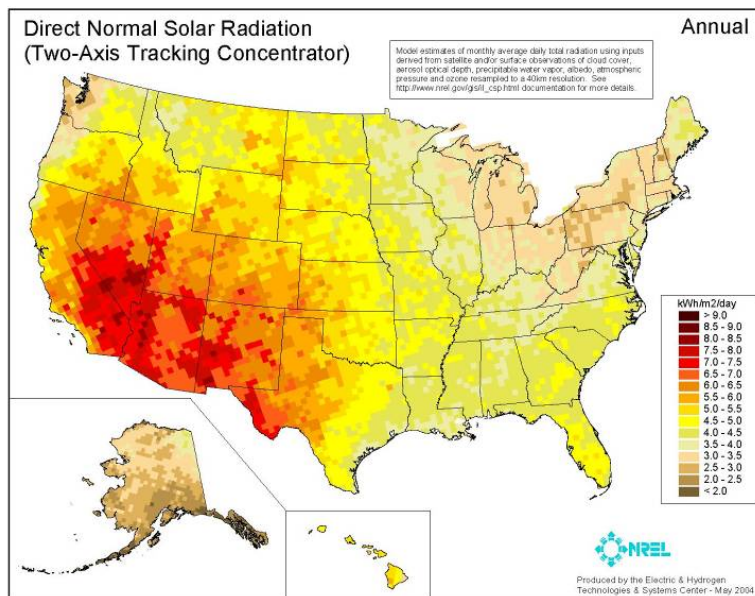
Technology	Growth Rate	2008 World Installed GW
Wind	29%	121
Biomass Combustion	4%	52
Geothermal	4%	10
Solar PV	71%	13
Solar Thermal	14%	0.5
Ocean Energy	N/A	0.3

Source: 2009 Global Status Report



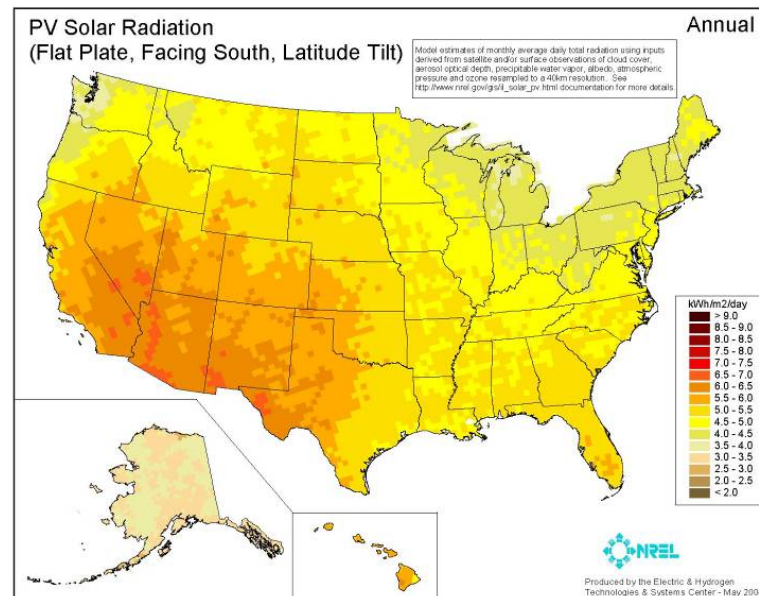
Solar Resource

Concentrating Solar Thermal (CST): Direct Normal Solar Radiation



- 530 MW installed worldwide
- > 8,000 MW planned by 2013

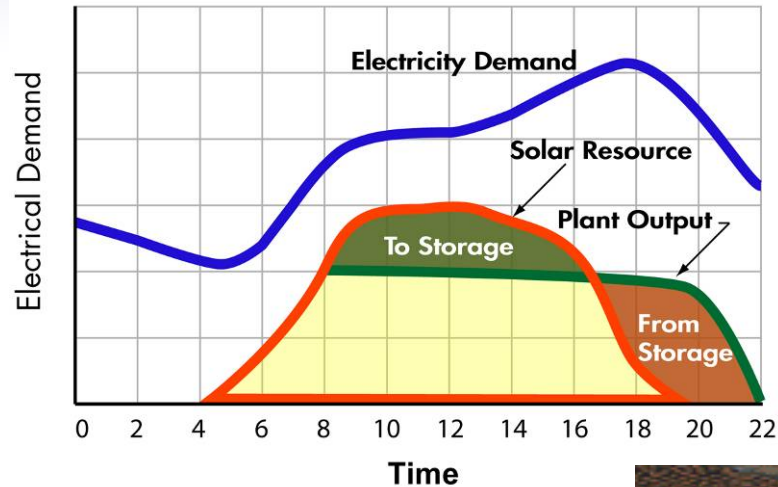
Photovoltaic (PV): Diffuse Solar Radiation



- > 10,000 MW installed worldwide
- > 33,000 MW expected by 2011

Source: NREL

CSP: Parabolic Trough & Molten Salt Storage



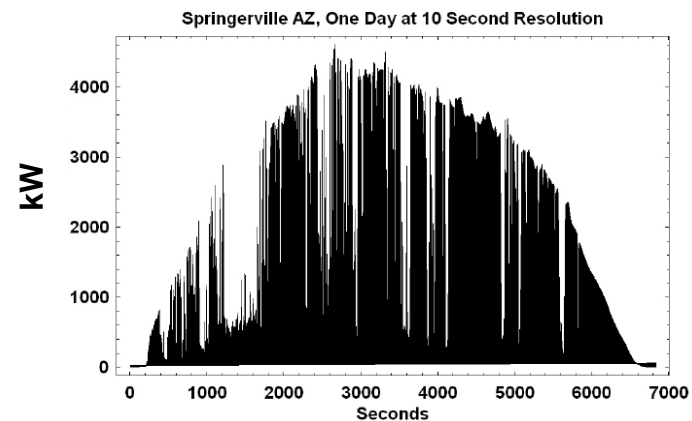
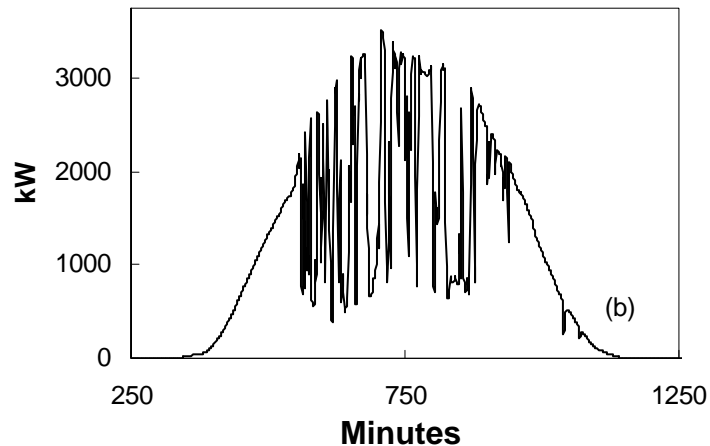
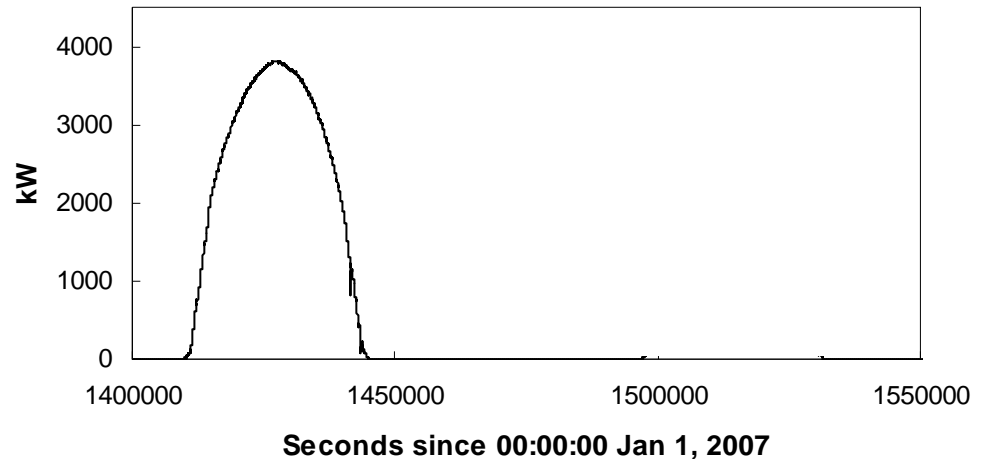
Thermal
Energy
Storage
Andasol (Spain)



What About Large Scale Solar PV Plant?



TEP Springerville



Source: Jay Apt CMU, 4.6 MW TEP Solar Array (Arizona)

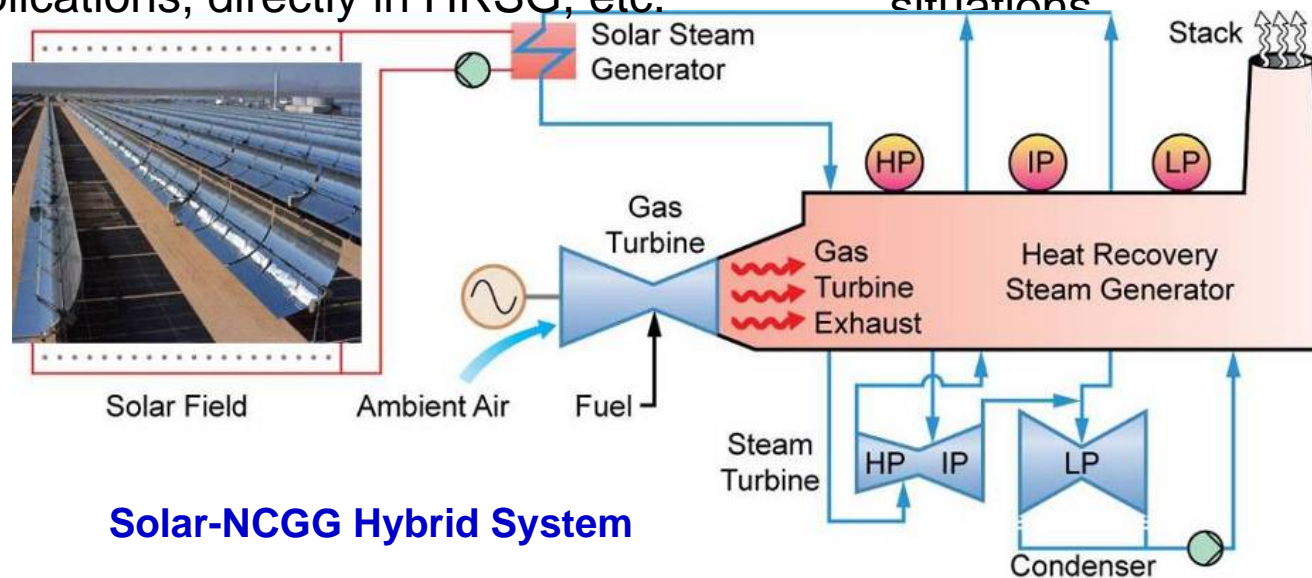
Solar-Fossil Hybrid Systems

Approach:

- Utilize heat from a solar field in a fossil-based plant
- Applicable to NGCC or coal-fired systems where conditions permit
- Heat can be used for feedwater heating, inlet-air chilling, cogen applications, directly in HRSG, etc.

Benefits:

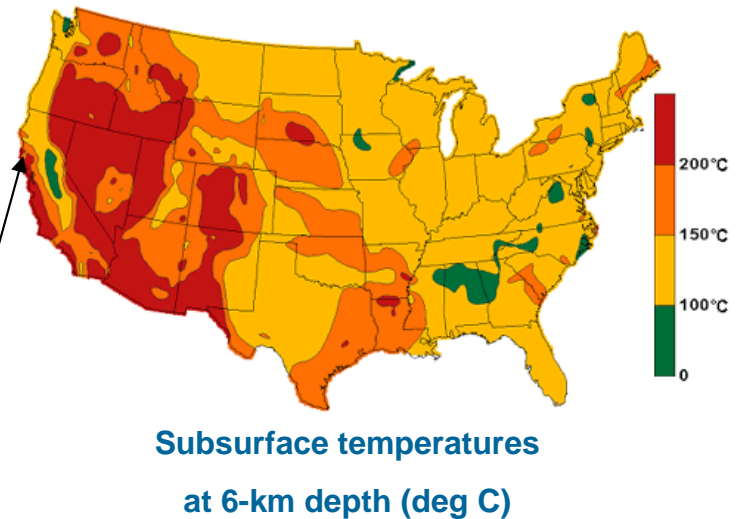
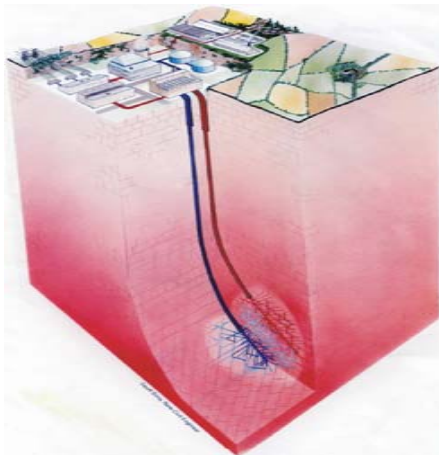
- Avoid fuel costs
- Reduce emissions
- Address regulatory pressures
- Increase utilization of existing plant assets
- Promising economics in right situations



Solar-NGCC Hybrid System

Geothermal Energy Status

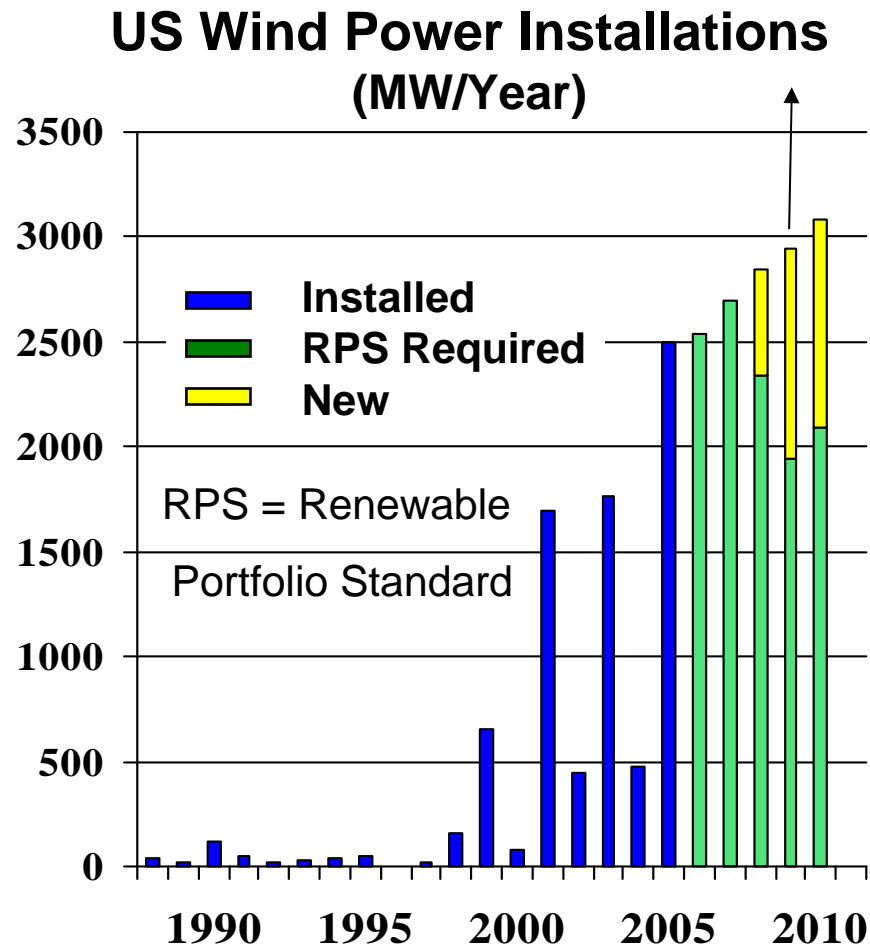
- **Geothermal energy**
- 2500 MW in the U.S., mostly in California and Hawaii. Issues include high cost of geothermal wells, decrease output over time.
- Current interest is in both “conventional” (dry steam), and “enhanced” deep geothermal (drill, fracture, inject and extract energy)



“dry steam”
The Geysers (Calpine)

Enhanced -Geoff Sims New Civil Engineer

Wind Power in the U.S.



Sources: AWEA, GE Wind, and ACORE

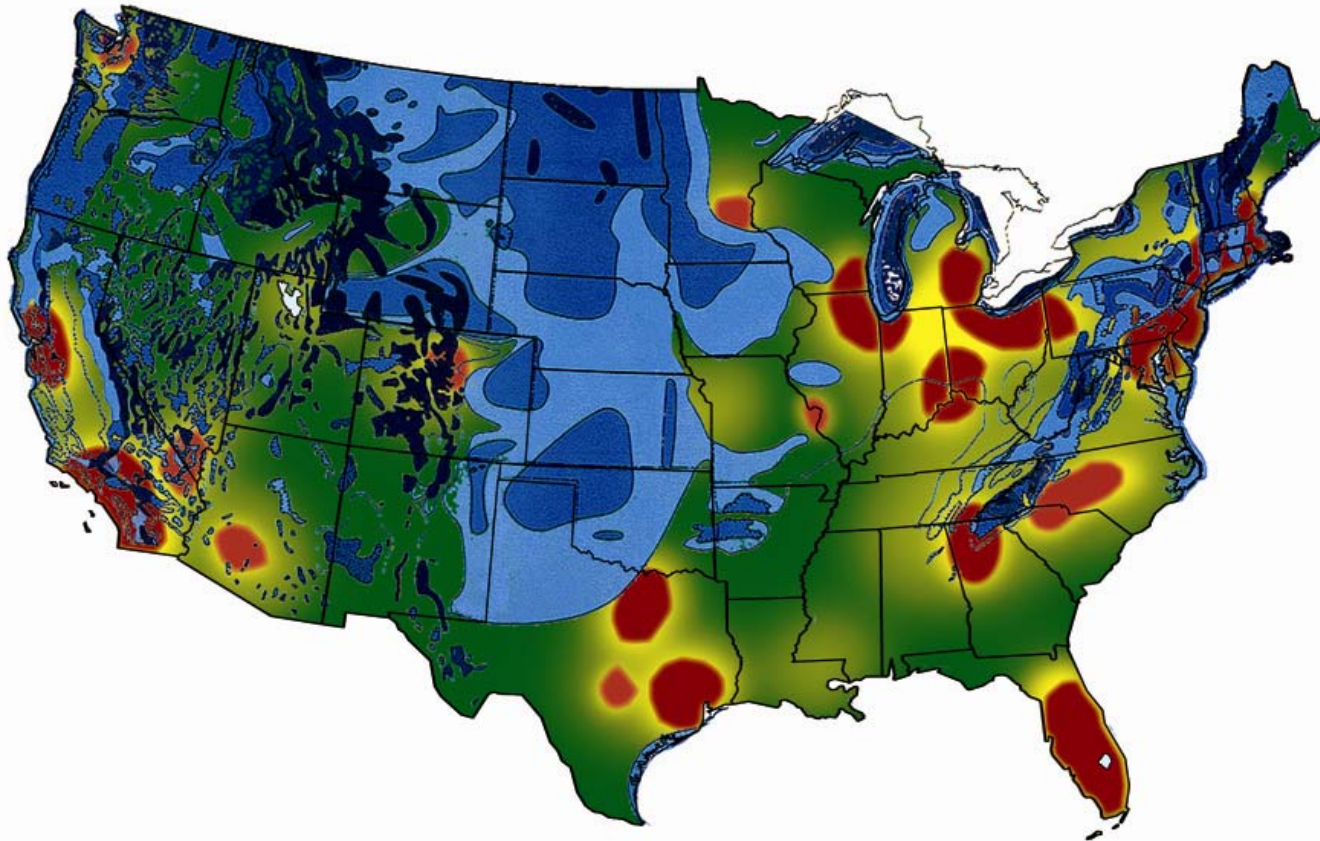


- *In 2008 wind power total 121 GW - 30% growth Globally, +8.4 GW in USA Texas, Iowa, Calif = 1-2-3*
- *US R&D investment in wind power > \$1 B.*

Wind

and

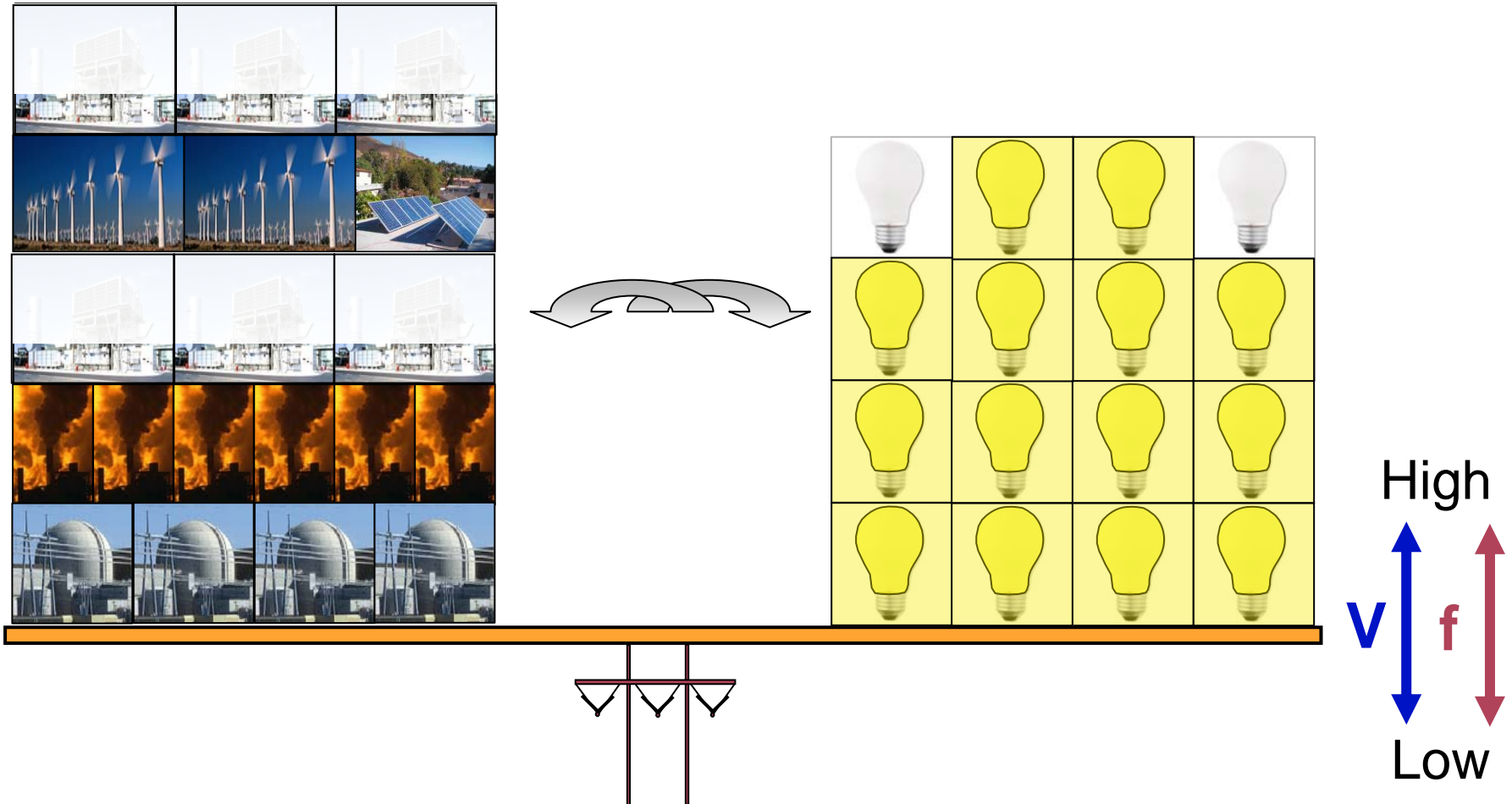
People



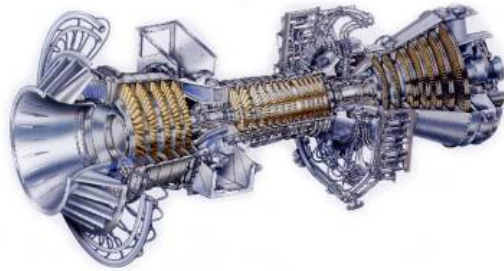
**The Median Cost of Transmission to Enable Wind is
\$300/kW and \$15/MWh**

Operational Challenges

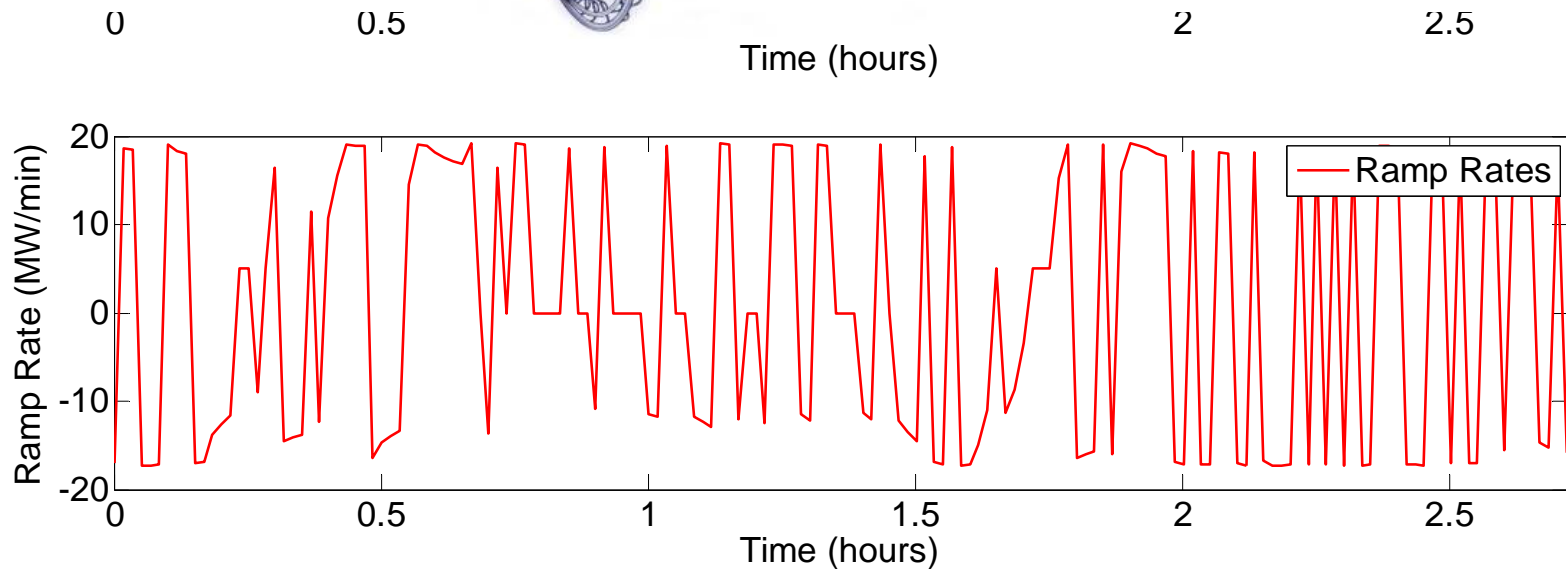
Integrating Large Wind and Solar



CT as a Balancing Resource



GE LM6000



Ramp Rate and Duty Cycle for CT Balancing Wind

Acknowledgment: Research Conducted by Warren Katzenstein and Jay Apt, CMU

Together...Shaping the Future of Electricity

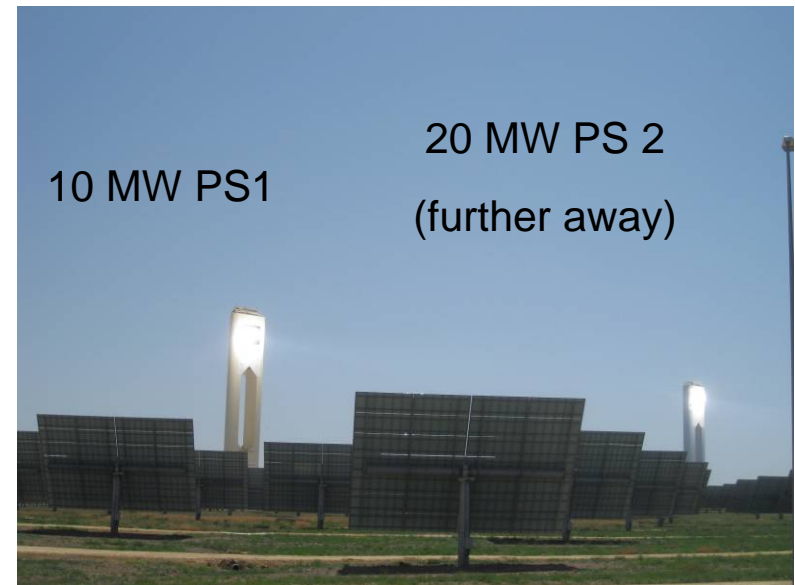
CSP: Parabolic Trough

- Status: Commercial
- Deployment (Spring 2009)
 - 420 MW operating in U.S.
 - 280 MW planned in Arizona
 - 850 MW planned in California
 - Several 50 MW plants under construction in Spain
- Key attributes
 - Proven technology
 - Low risk premium
 - Thermal storage option
- R&D opportunities
 - Direct steam
 - Advanced heat transfer fluids



CSP: Central Receiver

- Status: Demonstration to early-commercial
- Deployment
 - 10 MW operating in Spain
 - 20 MW now in operation April 2009
 - 15 MW Solar Tres (Spain) project
- Key attributes
 - High efficiency
 - Inherent thermal storage
- R&D opportunities
 - Large-scale molten salt
 - Distributed tower approach
 - Advanced receiver concepts



Photos taken by Stu Dalton - EPRI

CSP: Dish/Engine

- Status: Development to early-commercial
- Deployment
 - Small demonstrations
 - 800-1750 MW planned in CA
- Key attributes
 - Modular
 - Very high efficiency
 - No thermal storage and large ramp rates possible
- R&D opportunities
 - Capital cost reduction



Additional Renewable Slides

Solar Thermal: Linear Fresnel

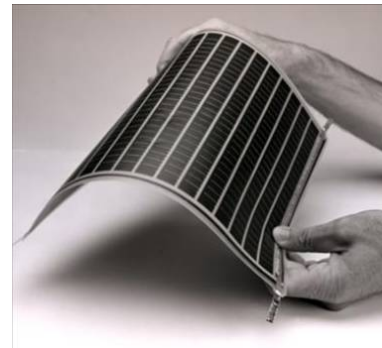
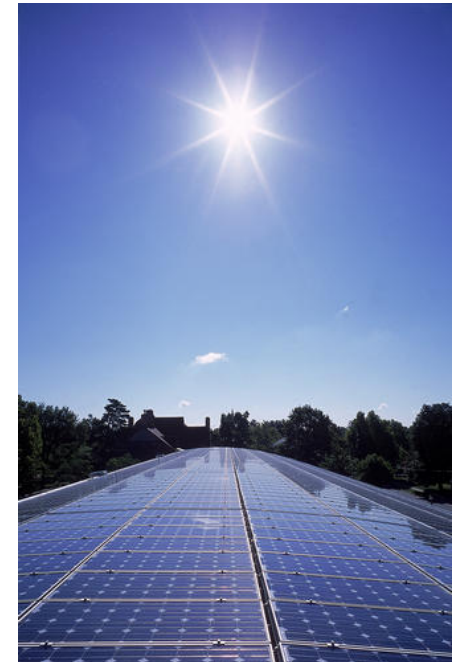
- Status: Development to early-demonstration
- Deployment
 - Steam demonstrated, but no standalone electricity
 - 500 MW planned in CA and FL
- Key attributes
 - Potentially lower capital costs
 - Efficient ground coverage
- R&D opportunities
 - Thermal storage



Photos taken by Mike Taylor, SEPA

Photovoltaics

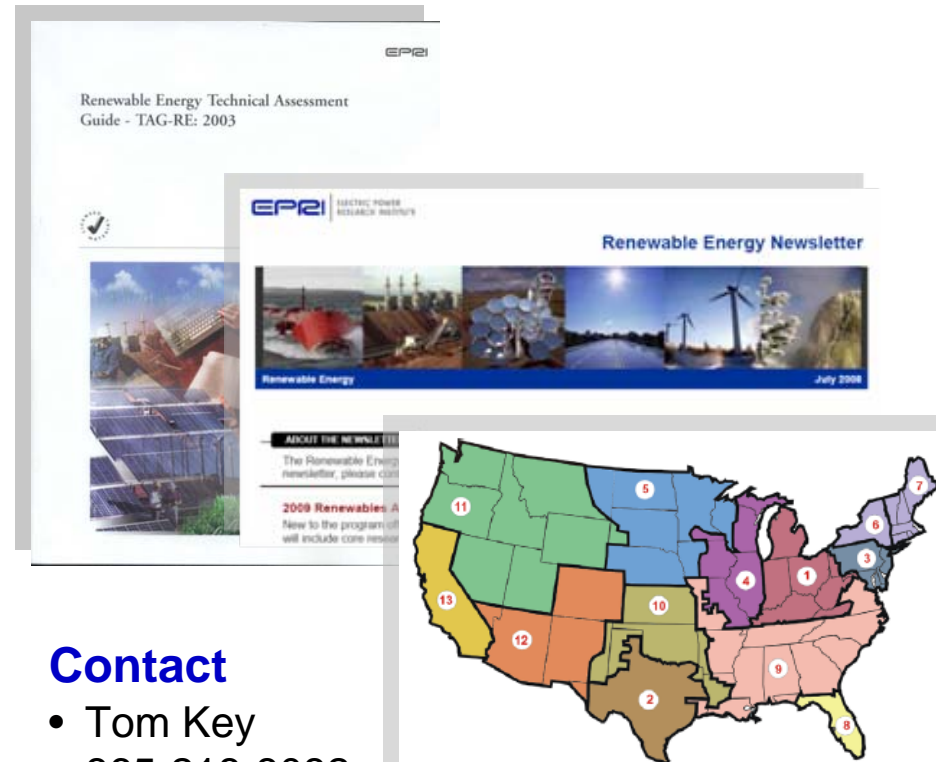
- Status
 - Crystalline silicon – commercial
 - Thin film – early commercial
 - Concentrating PV – early commercial
- Over 10 GW deployed worldwide
 - 500-600 MW in U.S.
- Key attributes
 - Potential for breakthroughs in efficiency and cost
 - Modular
 - No storage
 - Large, uncontrolled ramp rates possible



P84A – Renewable Energy Economics and Technology Status (required purchase)

Project Set Focus Areas

- 84.001 Renewable Energy Technology Guide (aka TAG-RE)
 - Status and potential of renewable technologies
 - Industry trends
 - Strategic information
 - Newsletters/perspectives
 - Conferences/workshops
 - Information Exchange
 - Tours, industry speakers
- 84.002 Engineering and Economic Evaluations
- 84.003 Analysis and Strategy
 - Role of renewables in future generation portfolios
 - Policy scenarios



Contact

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Value Proposition for P84A

- Maintains a strong collaborative
 - All funders participate
 - Strategic information
 - Information trends
 - Information exchange
- Deliverables of benefit to all members
- Pricing of 84A and single project set only incrementally higher than 2009 P84 buy
 - More robust portfolio

P84B – Biomass

Project Set Focus Areas

- 84.004 Biomass Supply Management
 - Long-term supply security
 - Development of multiple supply chains
 - Assessment of energy plantations
- 84.005 Power Generation from Biomass
 - Impact on environmental equipment
 - Biomass plant cost database
 - Ash utilization
 - Torrified wood full-scale tests
 - Methods to increase co-firing fraction
- 84.006 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



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P84C – Solar

Project Set Focus Areas

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



Contact

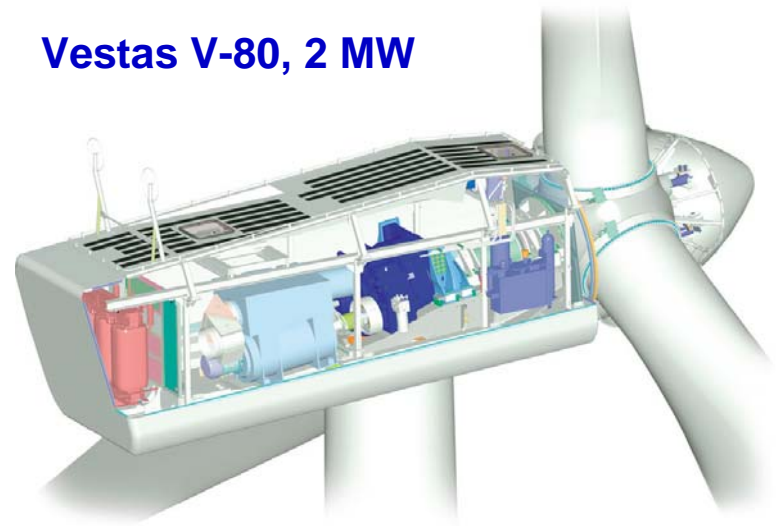
- Cara Libby
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P84D – Wind

Project Set Focus Areas

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

Vestas V-80, 2 MW



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P84E – Geothermal



Project Set Focus Areas

- 84.012 Geothermal Operations and Maintenance
 - Plant evaluations and assessments
 - O&M handbook
 - Training and technology transfer
- 84.013 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

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Geothermal Innovation in 2010

Single Well Enhanced Geothermal Systems (SWEGS)

- Polaris Initiative award and DOE Proposal (due in July)
 - Closed Loop
 - Does not contaminate aquifer
 - Dry heat (Hot Dry Rock)
 - Wide geographic potential
 - Uses limited water and space
- May use existing facilities
 - Depleted oil/gas wells
 - T&D
- 50-100 MWe fields

