National Renewable Energy Laboratory
Innovation for Our Energy Future

The Role of Renewables in a Sustainable Energy Economy

Dr. Dan E. Arvizu

Laboratory Director

Clean-tech

Investor's Summit

Palm Springs, CA

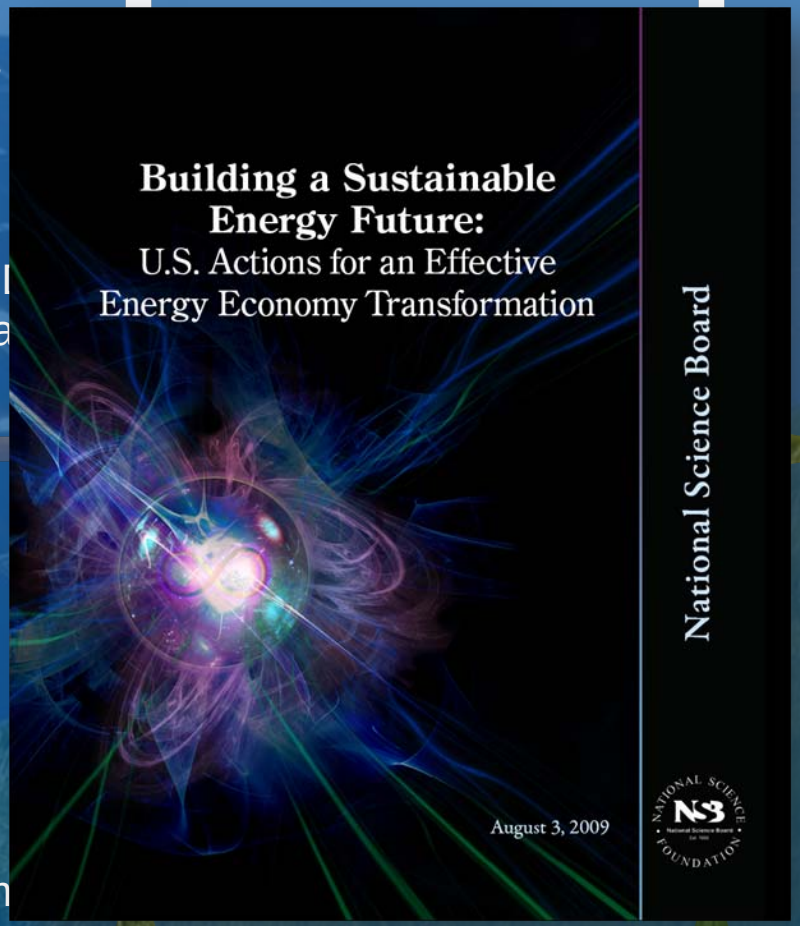
January 20, 2010

Energy Challenges

Achieving a Sustainable Energy Economy

*Requires a National Energy Grand Challenge**

Lead Coordinated RI
Strategy in Sustaina
Energy



Construct Essential Policies & Market Conditions

Support Education Workforce Developm

Promote Public Awareness & Action

* Recommendations of the National Science Board Task Force on Sustainable Energy

The New National Priorities

- Invest $150B in alternative energy over 10 years
- Create green jobs with clean, efficient American energy
- Double production of alternative energy in three years – enough to power 6 million homes
- Upgrade the efficiency of more than 75% of federal buildings and two million private homes
- Put one million PHEVs on U.S. roads by 2015
- Reduce CO_2 emissions by 80% below 1990 levels by 2050
- Transform our economy with science and technology

G8Website/ANSA Photo: Alessandro Di Meo

Our Energy System

Supply & Conversion

Transmission & Distribution

Utilization

100 Quads

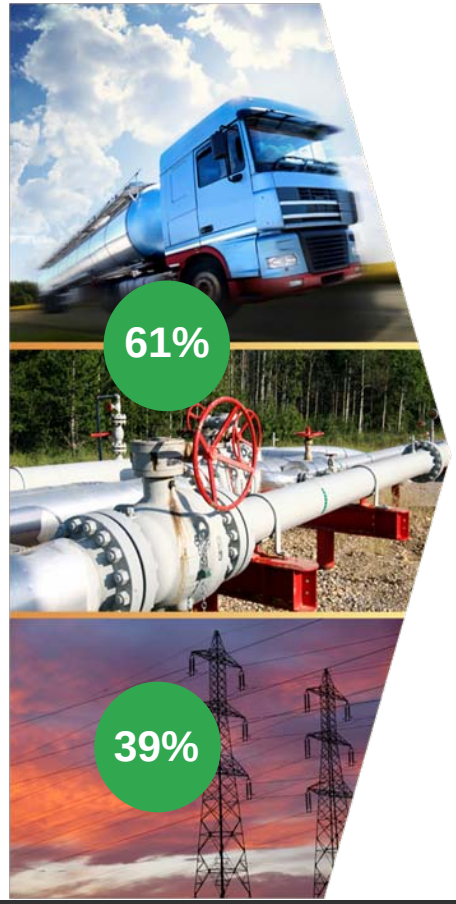
Oil 40%

Coal 23%

Natural Gas 23%

Nuclear 8%

Hydro
Wind
Solar
Biomass
Geothermal
6%



27%

40%

33%

Lost energy as inefficiencies – 62%

Energy is a means to an end, not an end in itself

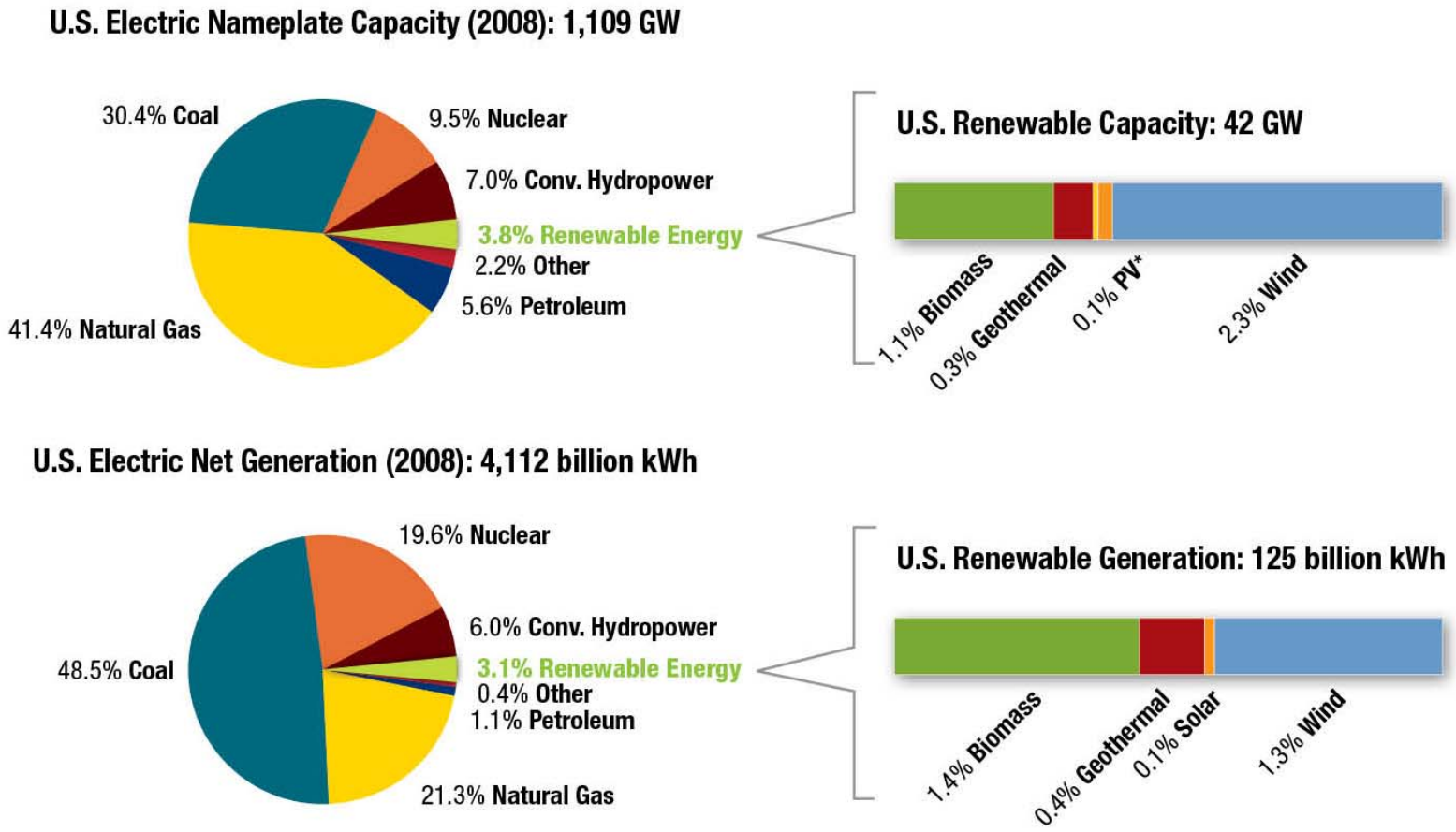
Heat and power for where we live and work

Sustainable Electricity System

Fuel and power for mobility and access

Sustainable Transportation System

U.S. Nameplate Capacity and Generation



Source: EIA

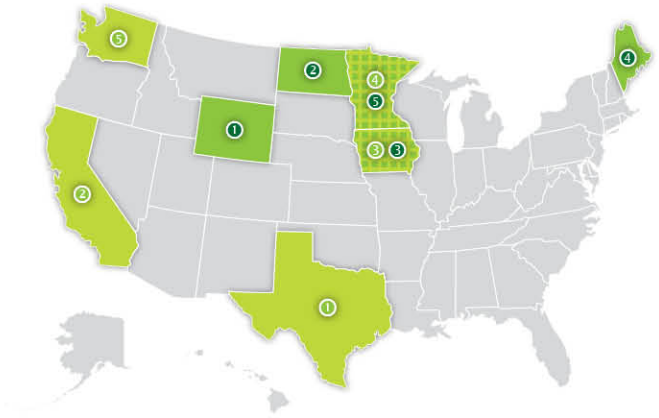
Other includes: pumped storage, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, tire-derived fuels, and miscellaneous technologies.

* Includes on- and off-grid capacity.

EERE 2008 Renewable Energy Data Book

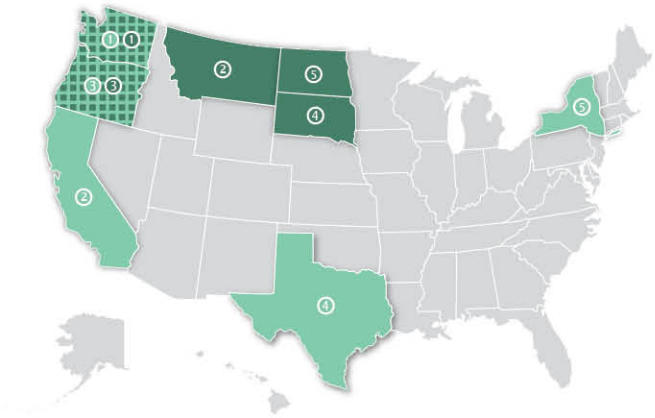
U.S. Energy Background Information | July 2009

Top States for Renewable Electricity Installed Nameplate Capacity



Total Renewables *(excluding hydropower)*
1 Texas
2 California
3 Iowa
4 Minnesota
5 Washington

Per Capita Renewables *(excluding hydropower)*
1 Wyoming
2 North Dakota
3 Iowa
4 Maine
5 Minnesota



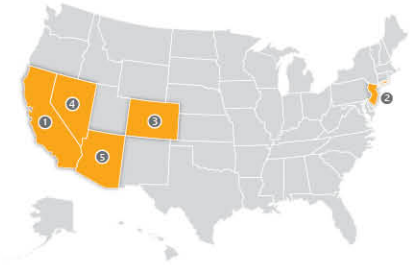
Total Renewables *(including hydropower)*
1 Washington
2 California
3 Oregon
4 Texas
5 New York

Per Capita Renewables *(including hydropower)*
1 Washington
2 Montana
3 Oregon
4 South Dakota
5 North Dakota

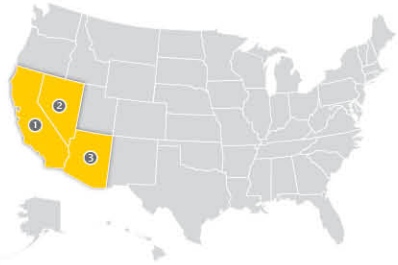
Sources: EIA, Navigant, AWEA, GEA, NREL, EERE, Larry Sherwood/IREC, SEIA, USDA

EERE 2008 Renewable Energy Data Book

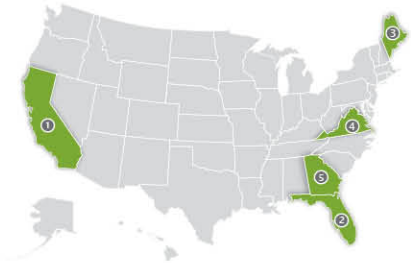
Top States for Renewable Electricity Installed Nameplate Capacity



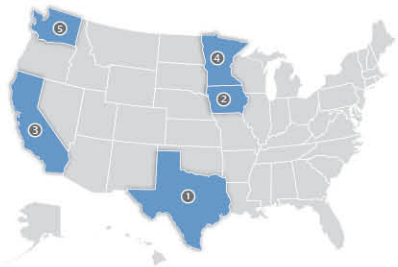
Solar PV
1 California
2 New Jersey
3 Colorado
4 Nevada
5 Arizona



CSP
1 California
2 Nevada
3 Arizona

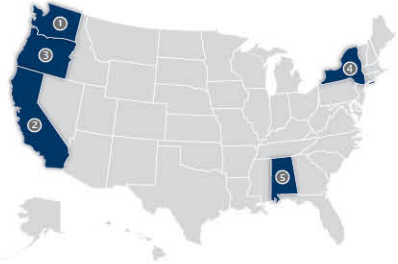


Biomass
1 California
2 Florida
3 Maine
4 Virginia
5 Georgia



Wind
1 Texas
2 Iowa
3 California
4 Minnesota
5 Washington

Geothermal
1 California
2 Nevada
3 Utah
4 Hawaii
5 Idaho



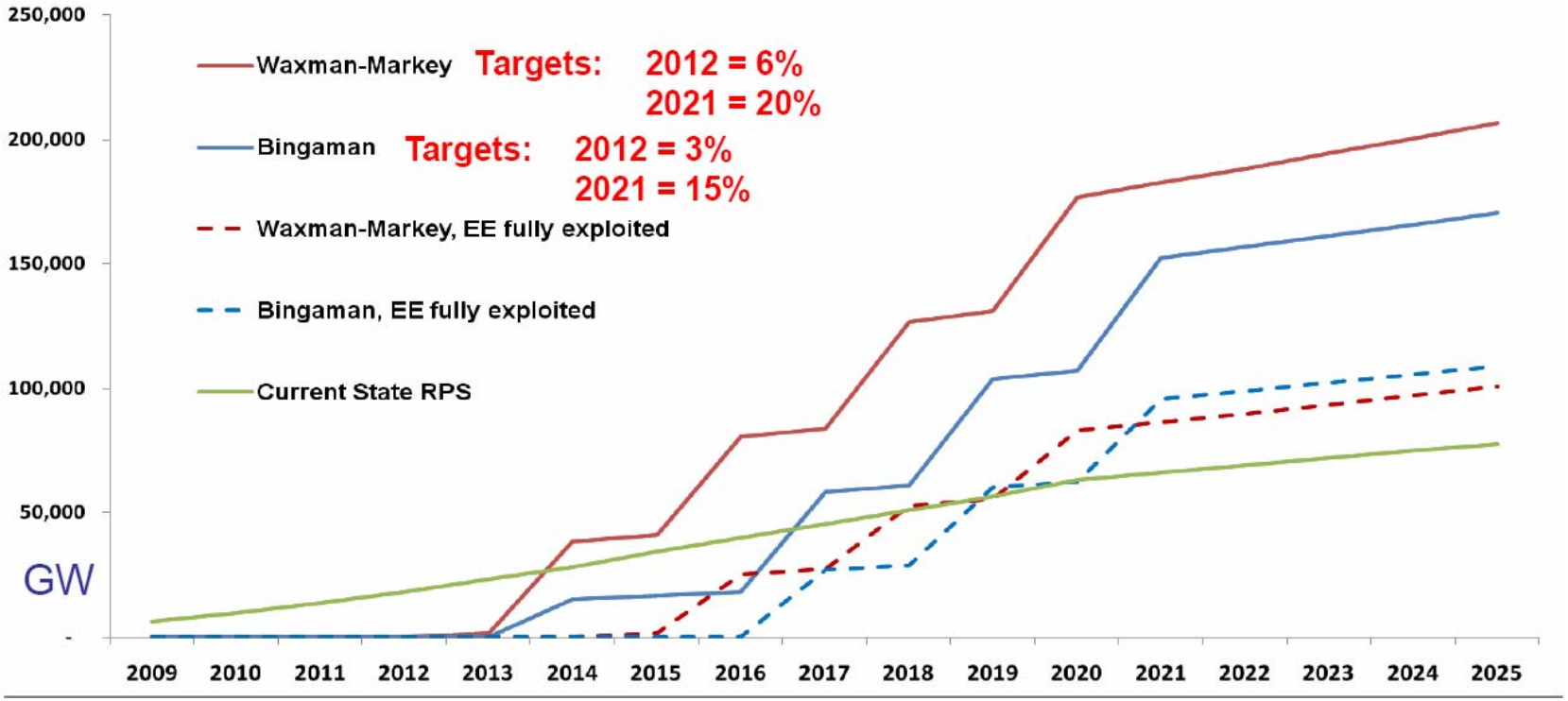
Hydropower
1 Washington
2 California
3 Oregon
4 New York
5 Alabama

Sources: EIA, Navigant, AWEA, GEA, NREL, EERE, Larry Sherwood/IREC

EERE 2008 Renewable Energy Data Book

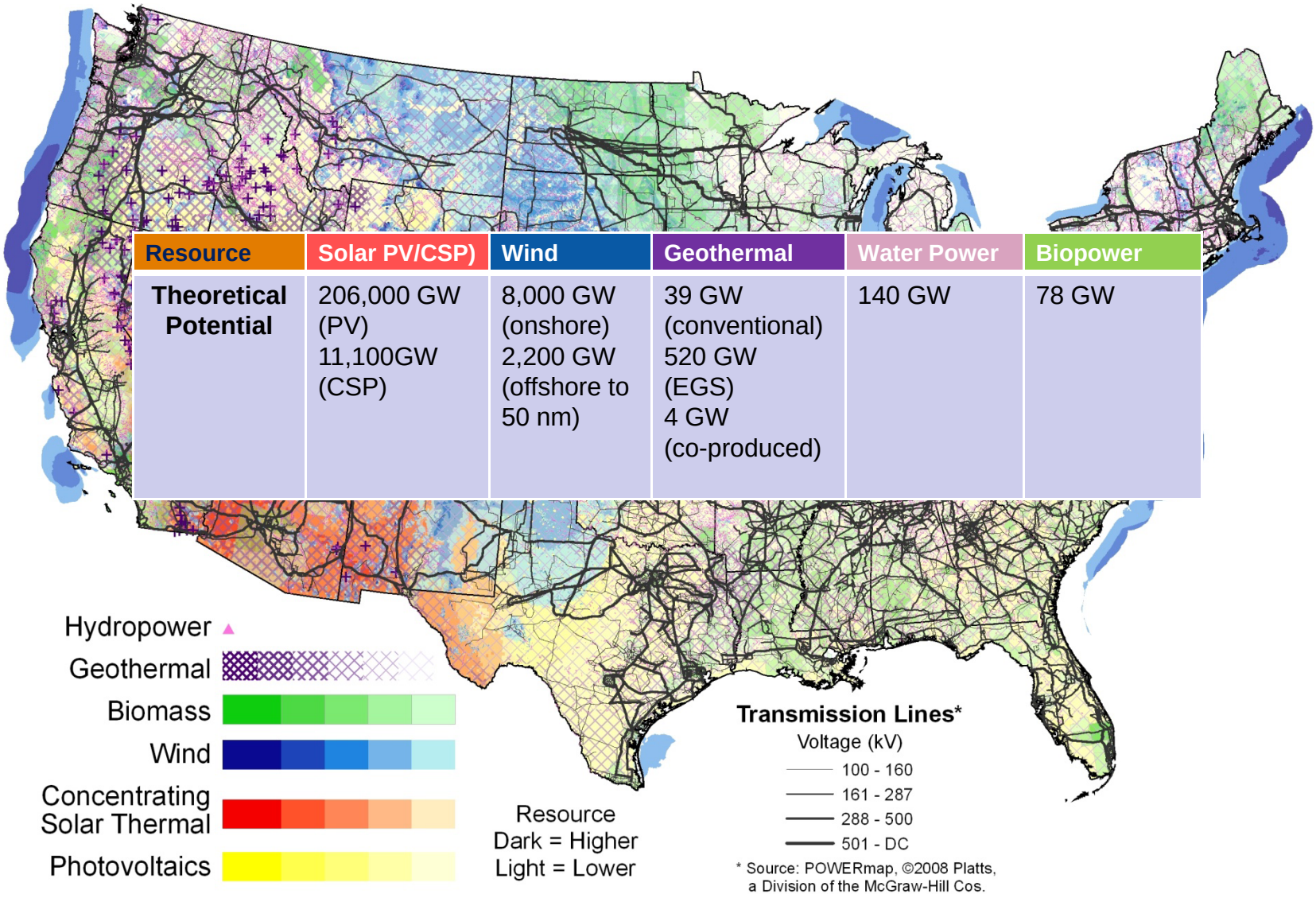
Renewable Electricity in the U.S. | July 2009 p.33

Federal RES vs. State Requirements: Mandated New MW Capacity



Source: Global Environment Fund

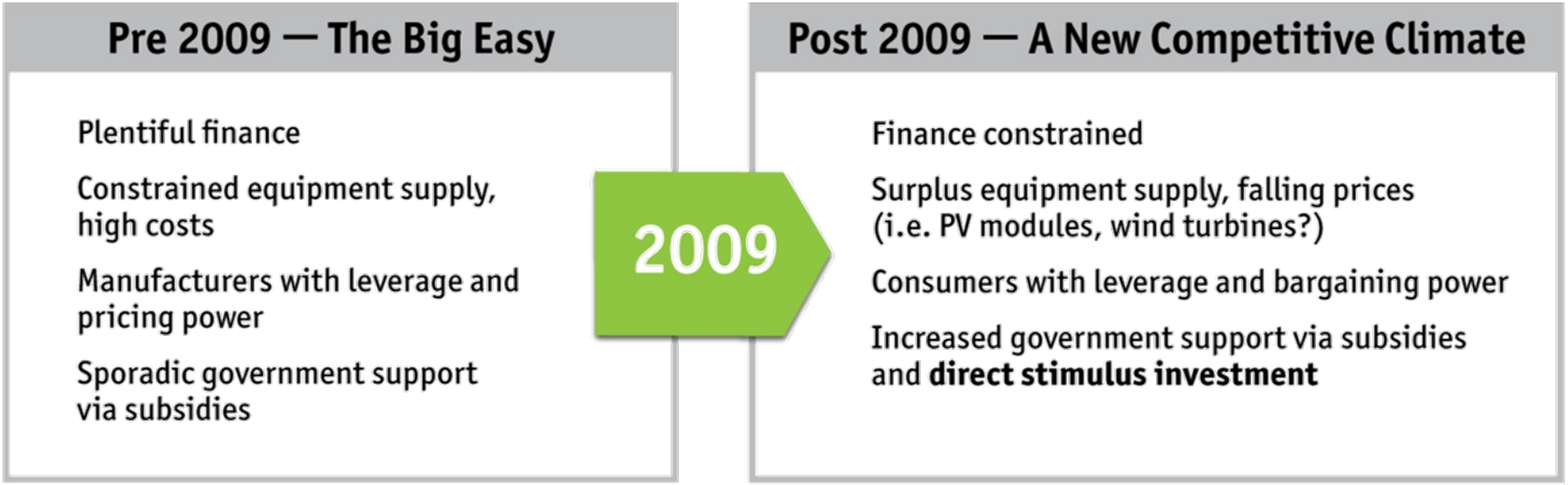
U.S. Renewable Resources



Resource	Solar PV/CSP)	Wind	Geothermal	Water Power	Biopower
Theoretical Potential	206,000 GW (PV) 11,100GW (CSP)	8,000 GW (onshore) 2,200 GW (offshore to 50 nm)	39 GW (conventional) 520 GW (EGS) 4 GW (co-produced)	140 GW	78 GW

Evolution of U.S. Renewable Energy Sector:

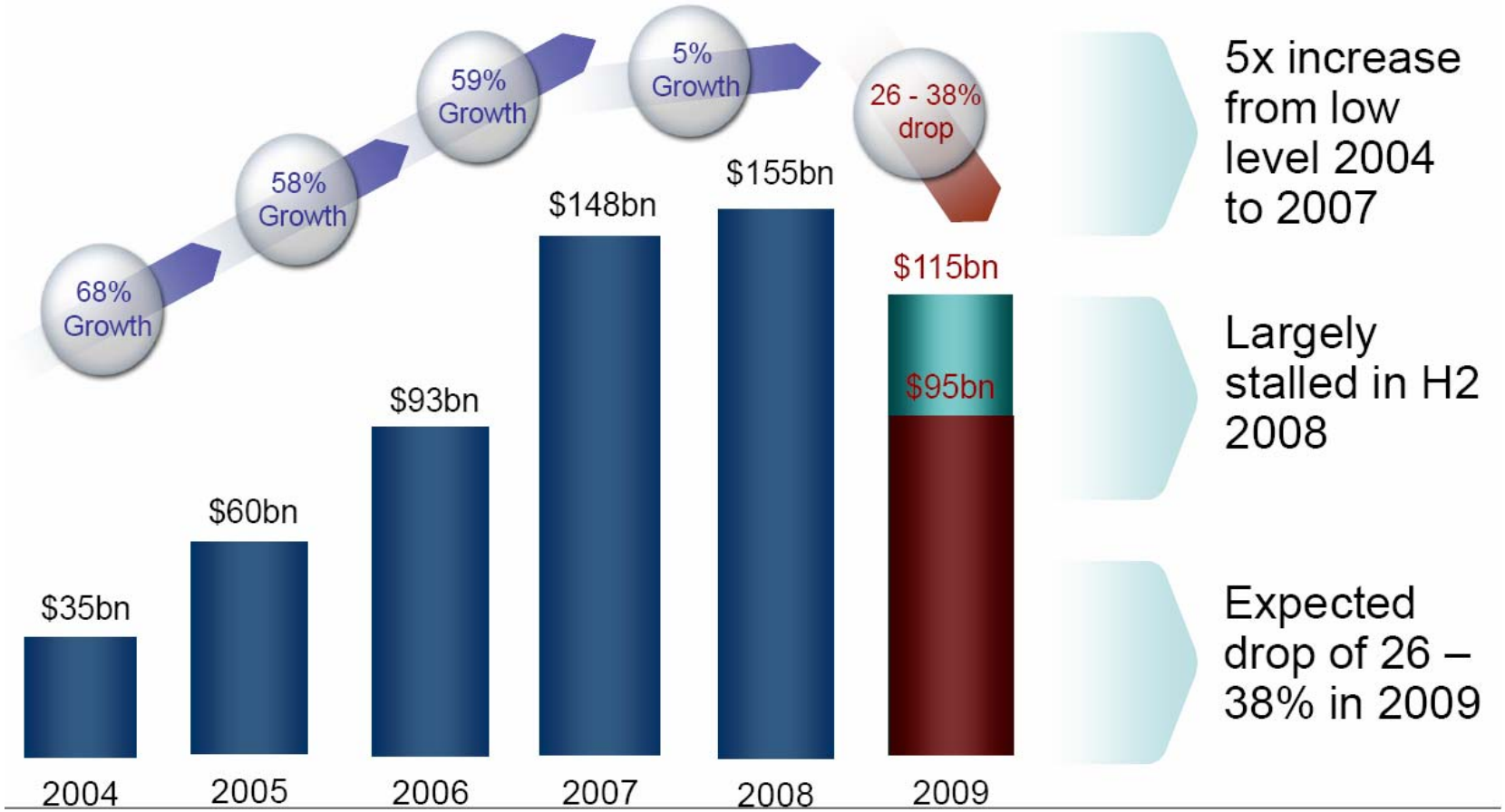
the 2009 transition…



GLOBAL ENVIRONMENT FUND

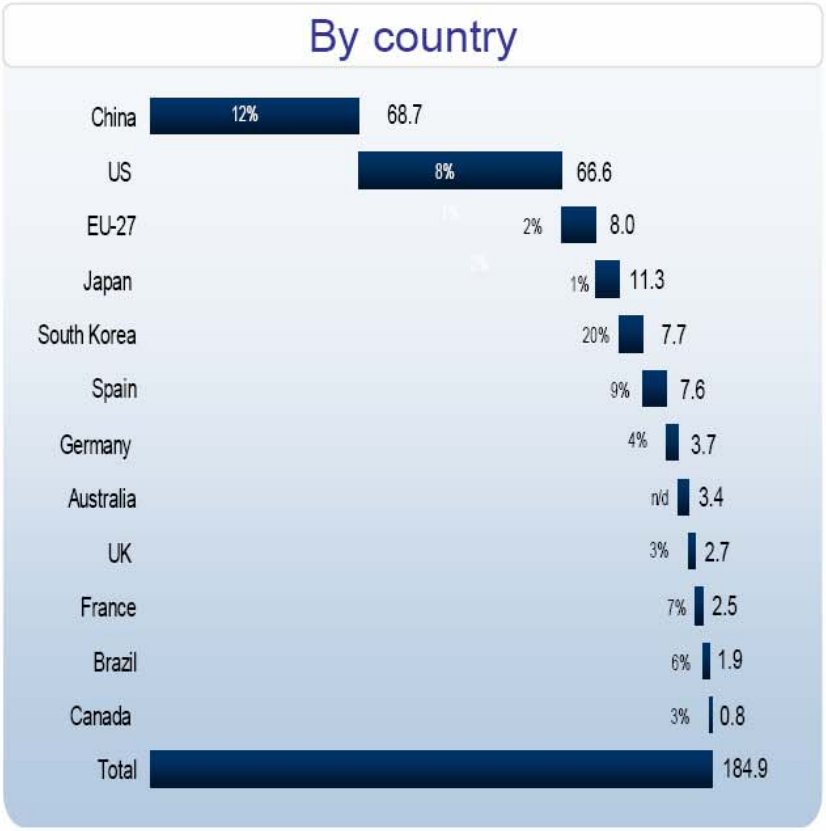
Source: Global Environment Fund

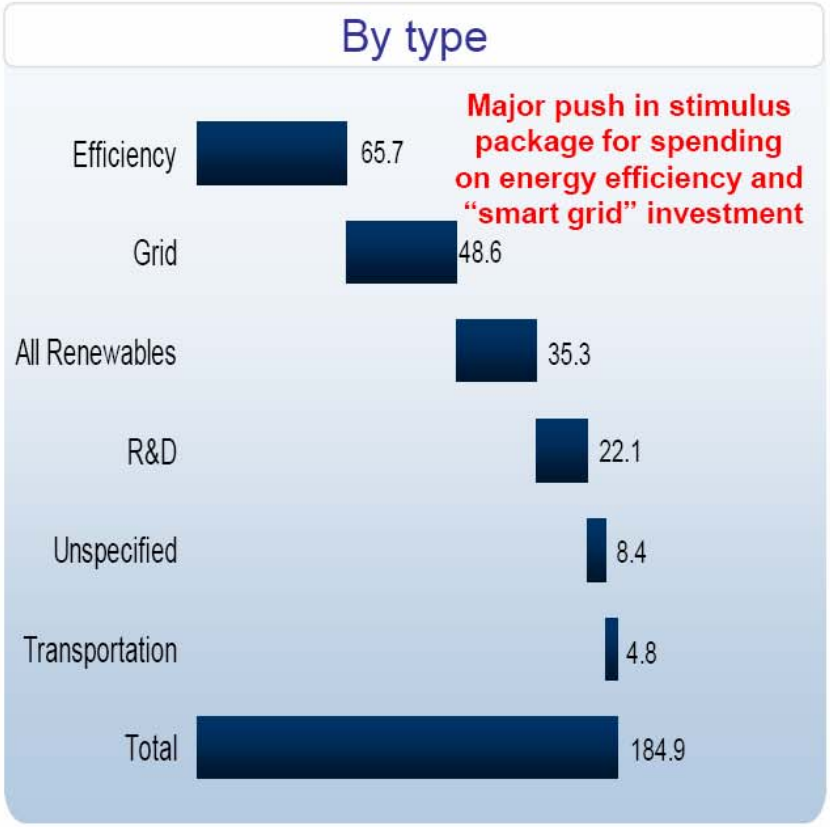
Global New Investment in Clean Energy 2004-2009



Source: New Energy Finance

Stimulus Components Targeted at Clean Energy ($ billions)





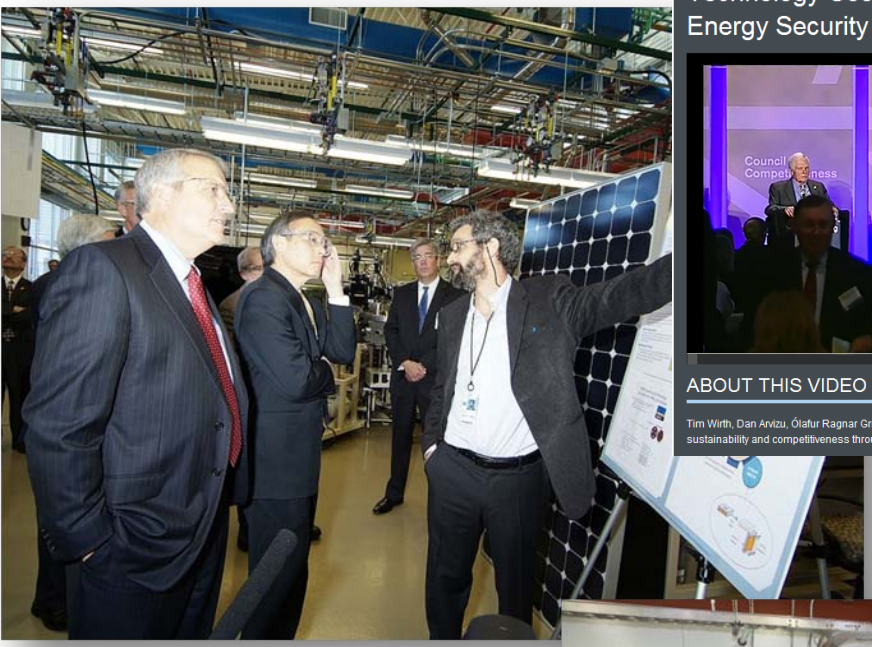
Source: New Energy Finance

DOE Strategic Technologies-for-Energy Plan (STEP)

Kristina Johnson – 9/2/09

- Previous roadmap re-scoped
- Objectives: set strategic priorities, align S-3 R&D budget with priorities
- Big question: what is the impact on important national goals of “research/science” investment

Driving a New National Strategy
NREL at the Forefront

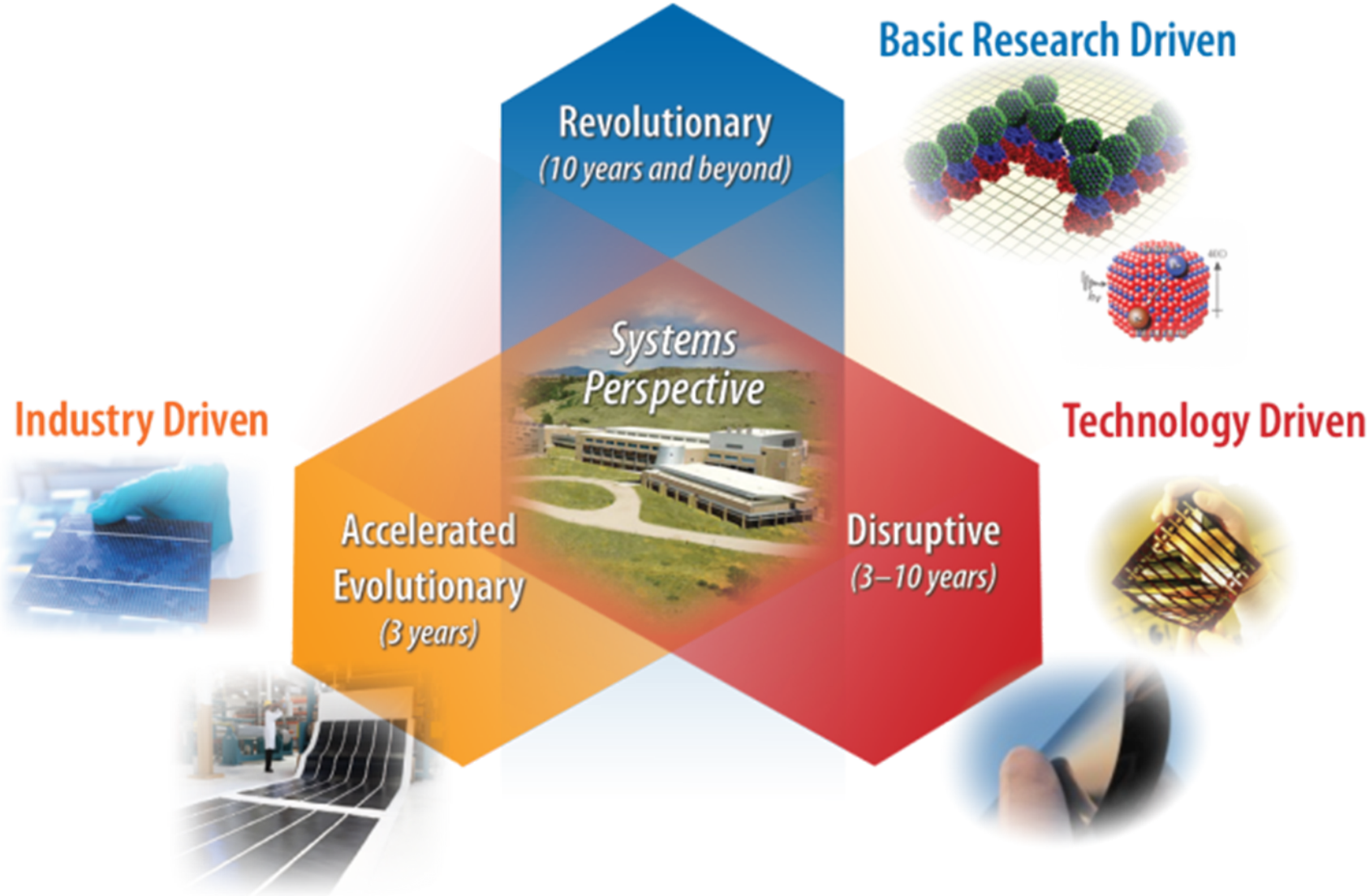


Technology Cooperation & Deployment for Energy Security & Sustainability

ABOUT THIS VIDEO

Tim Wirth, Dan Arvizu, Ólafur Ragnar Grímsson and Ted Turner discuss the role technology can play in achieving sustainability and competitiveness through alternative energy sources.

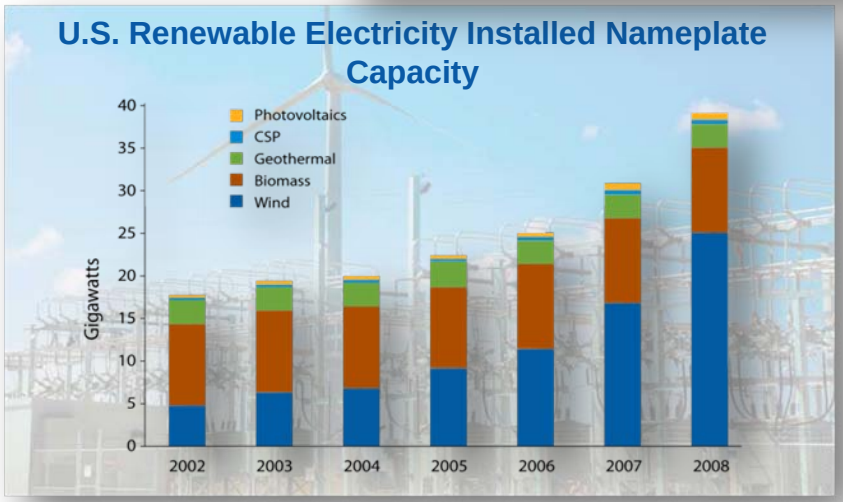
Achieving the Potential Requires A Balanced Portfolio



Near-Term Impact: Harvest Past R&D Energy Investments

Remove Barriers to Broad Deployment

- Fuels Economic Recovery
- Creates Jobs



Source: EIA Annual Energy Outlook 2009 Early Release

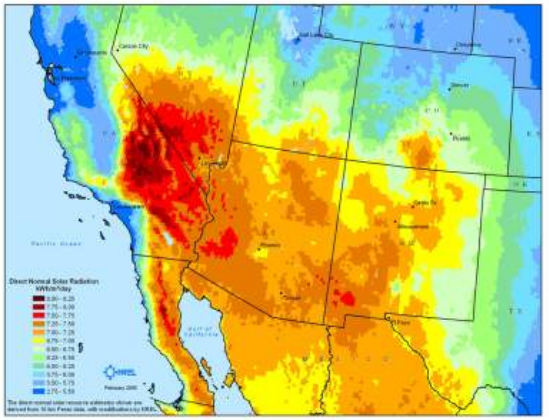
NREL Provides Data, Tools and Technical Assistance to:

Educate and inform

Develop codes and standards

Inform policy options, program design, and investment choices

- Resource Assessment
- Technology Analysis
- Policy Analysis



Mid-Term Impact: Accelerate Next-Generation Technology to Market

NREL Focus on Technology and Systems Development

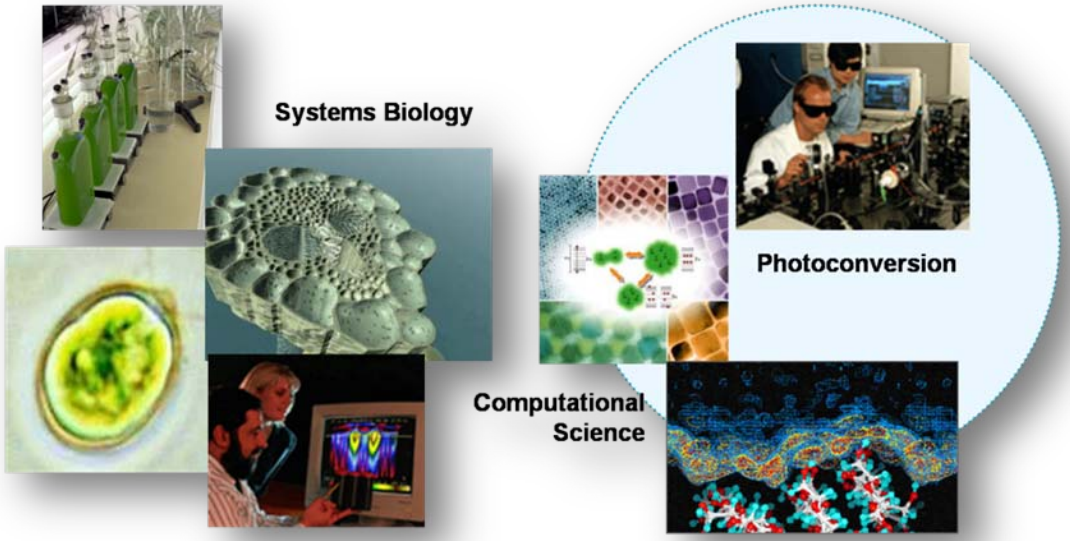
Unique Partnering Facilities

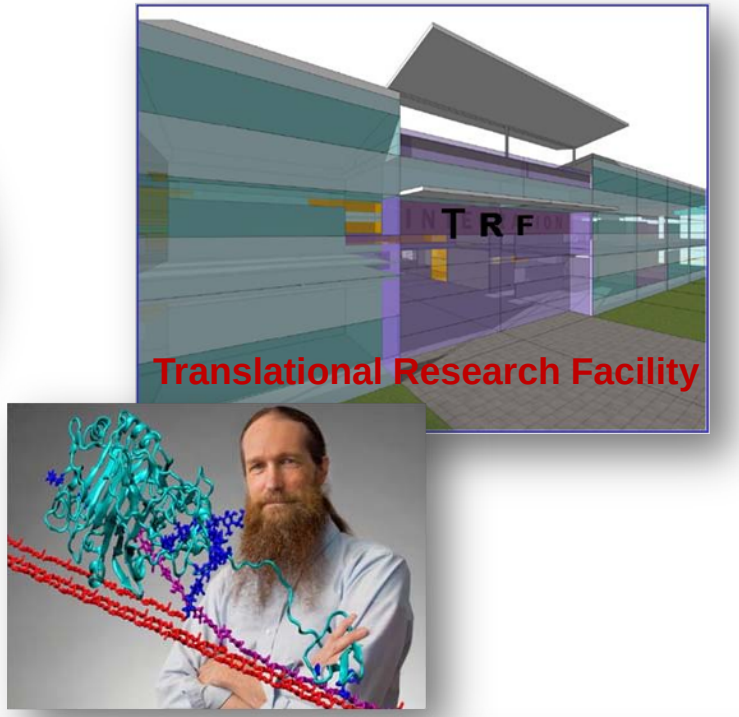
Testing and Validation Capabilities

Integrated Biorefinery Research Facility

Energy Systems Integration Facility

Long-Term Impact: Requires Breakthrough/Translational Science





Managing the science-to-technology interface

The Latest Renewables Integrations Studies Will Drive RD&D

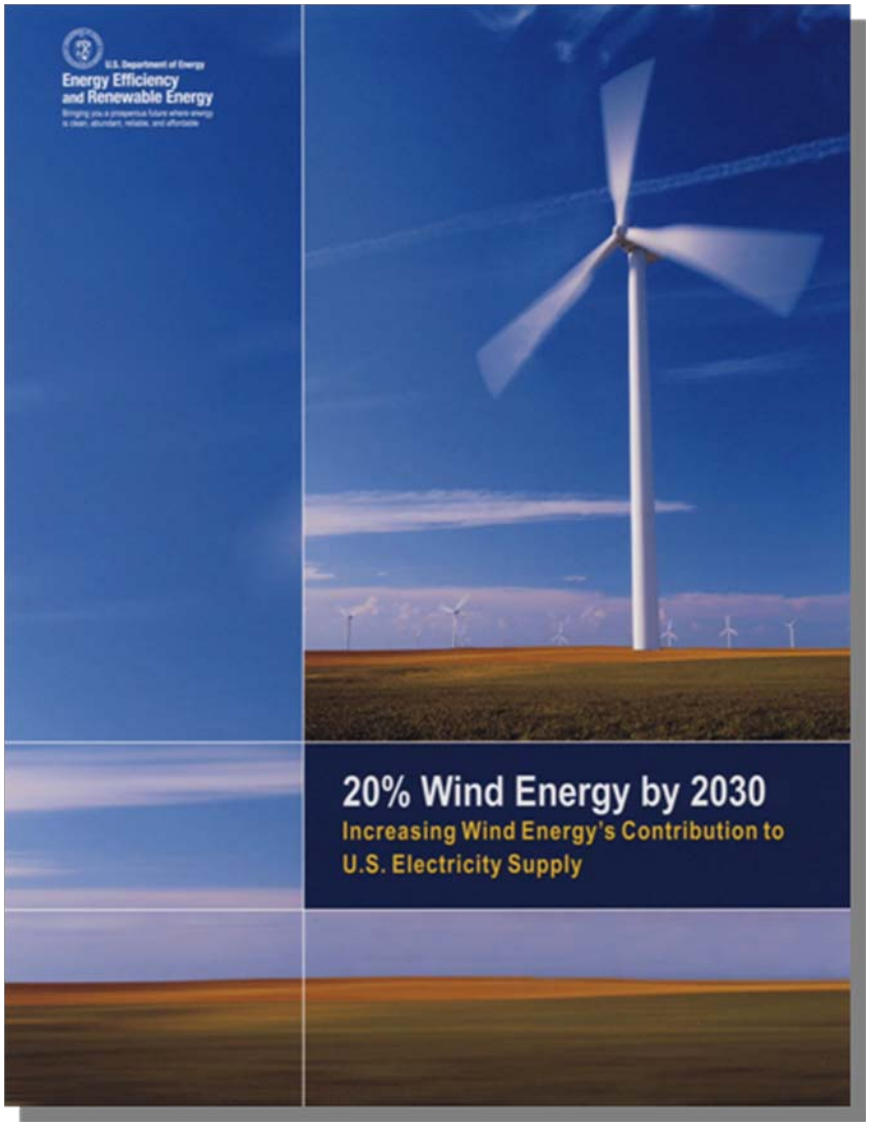
The 20% Wind Energy by 2030 Scenario

Primary Assumptions:

- U.S. electricity consumption grows 39% from 2005 to 2030—to 5.8 billion MWh (Source: EIA)
- Wind turbine energy production (capacity factor) increases about 15% by 2030
- Wind turbine costs decrease about 10% by 2030
- No major breakthroughs in wind technology

Primary Findings:

- 20% wind electricity would require about 300 GW (300,000 MW) of wind generation
- Affordable, accessible wind resources available across the nation
- Cost to integrate wind modest
- Emissions reductions and water savings
- Transmission a challenge



www.eere.energy.gov/windandhydro

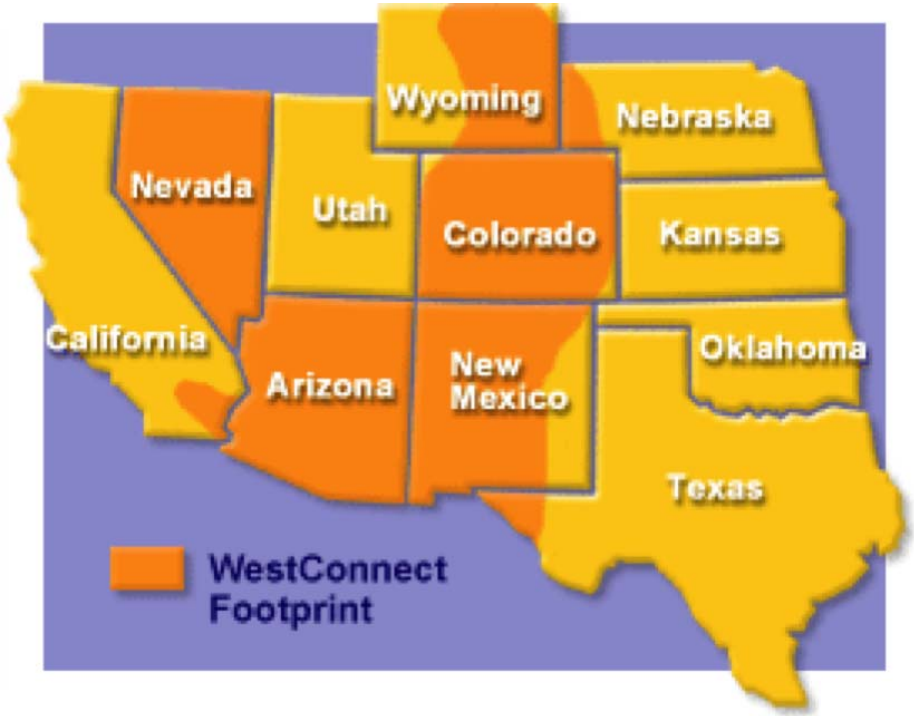
Western Wind and Solar Integration Study

Goal

- To understand the costs and operating impacts due to the variability and uncertainty of wind, PV and concentrating solar power (CSP) on the WestConnect grid

Utilities

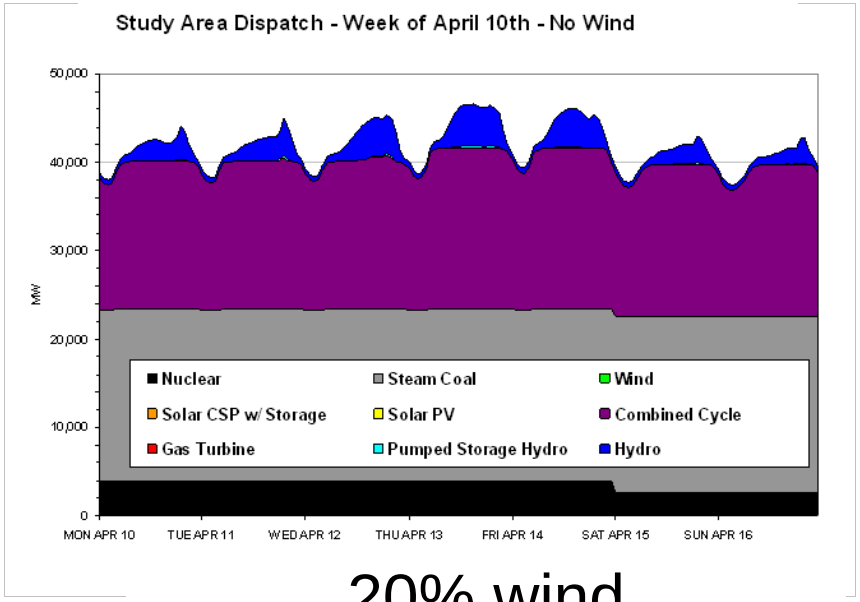
- Arizona Public Service
- El Paso Electric
- NV Energy
- Public Service of New Mexico
- Salt River Project
- Tri-State G&T
- Tucson Electric Power
- Xcel Energy
- WAPA



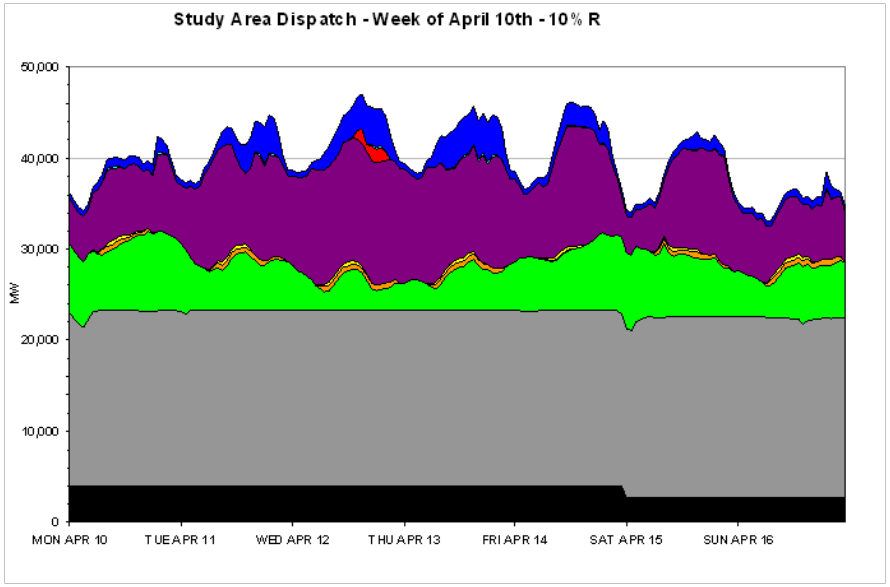
Can we integrate 35% renewables in the West?

Dispatch during the worst week (April)

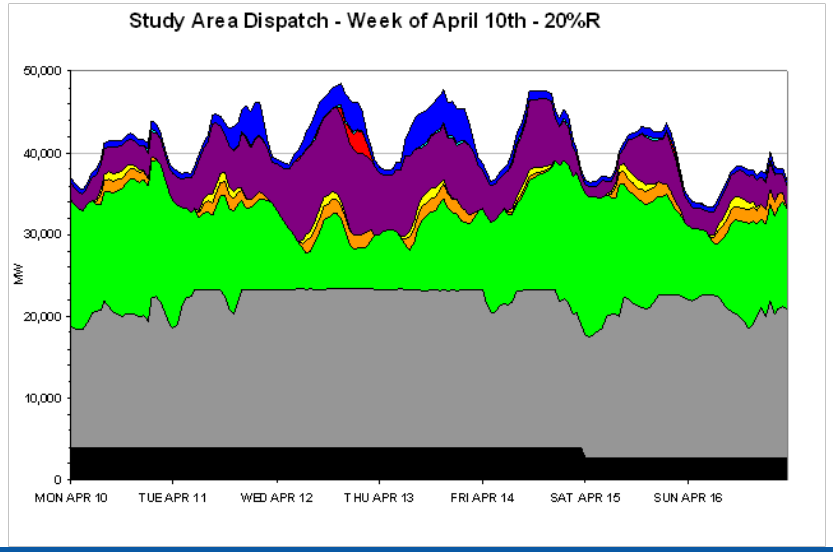
No wind



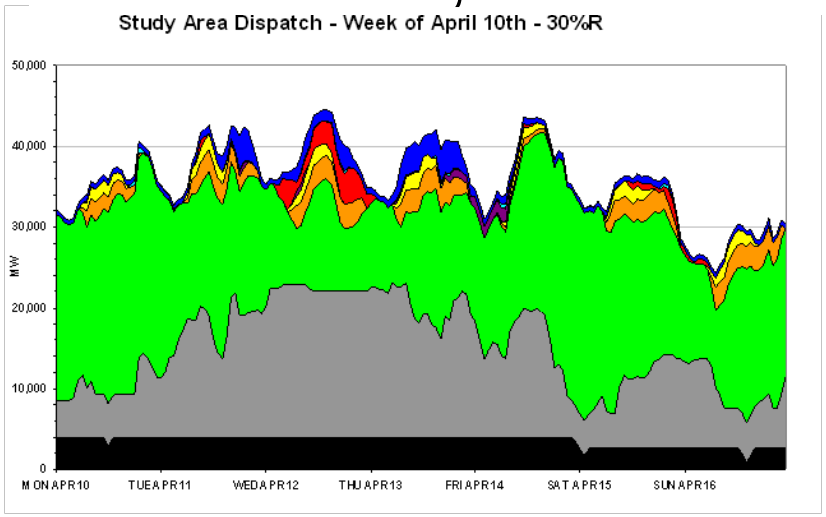
10% wind



20% wind



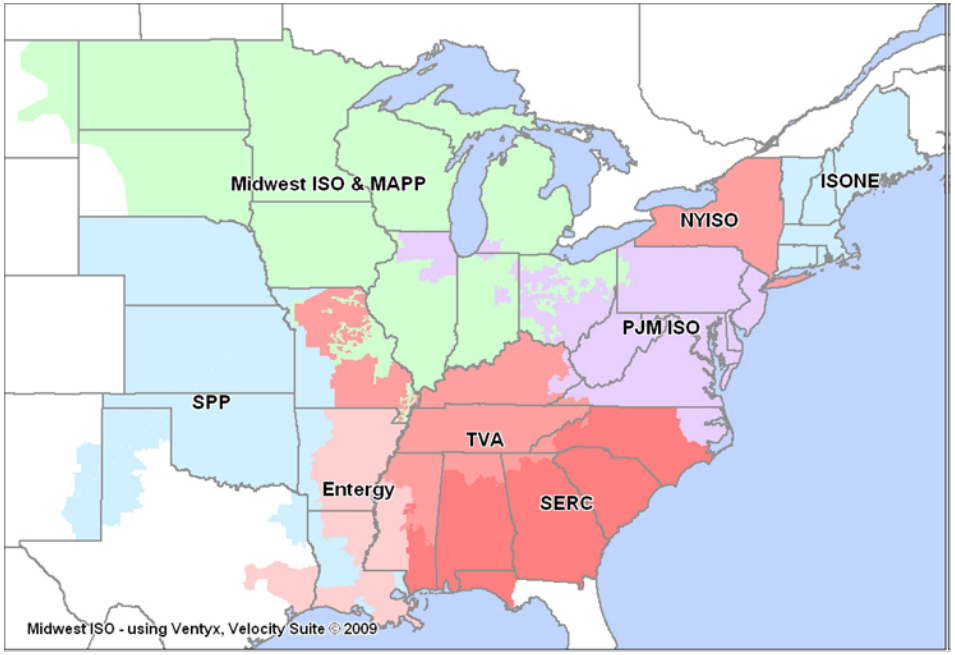
30% wind, 5% solar



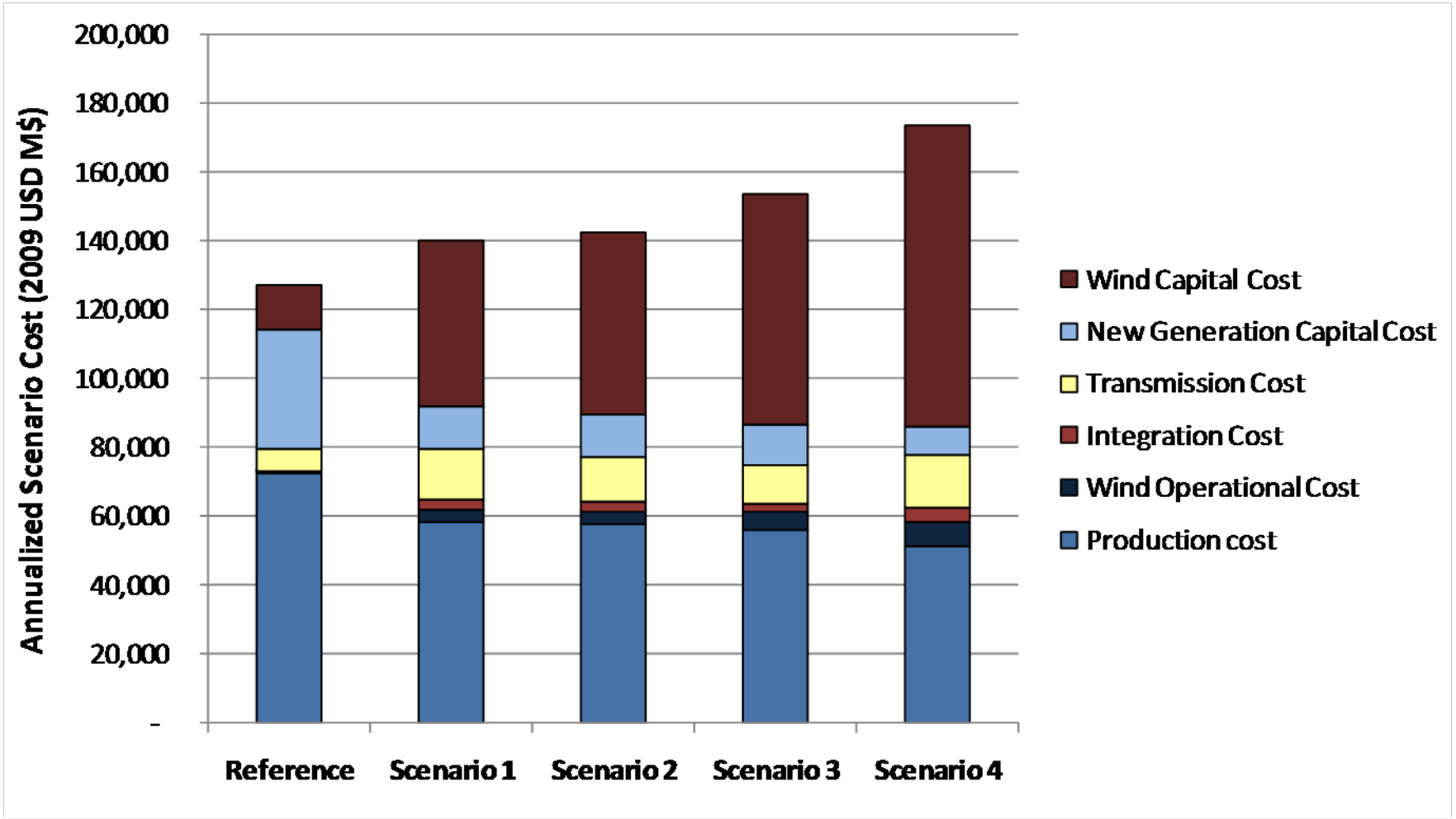
Eastern Wind Integration and Transmission Study

What is Needed to Integrate 20% Wind in the Eastern Interconnect?

- Evaluate the power system operating impacts and transmission associated with increasing wind energy to 20% and 30%
  - Impacts include operating due to variability and uncertainty of wind; reliability
- Build upon prior wind integration studies and related technical work;
- Coordinate with current regional power system study work;
- Produce meaningful, broadly supported results
  - Technical Review Committee



Total Scenario Costs



The results of this study pose some interesting policy and technology development questions

- Could the levels of transmission, including the Reference Case, ever be permitted and built, and if so, what is a realistic time frame?
- Could the level of offshore wind energy infrastructure be ramped up fast enough to meet the aggressive offshore wind assumption in the EWITS scenarios?
- Would a different renewable profile or transmission overlay arise from a bottom-up planning process?
- How can states and the federal government best work together on regional transmission expansion and the massive development of onshore and offshore wind infrastructure?
- What is the best way for regional entities to collaborate to make sure wind is integrated into the bulk electrical grid optimally and reliably ?
- What is the difference between applying a carbon price versus mandating and giving incentives for additional wind?

EWITS Conclusions

- High penetrations of wind generation—providing 20% to 30% of the electric energy requirements of Eastern Interconnection—are technically feasible with significant expansion of the transmission infrastructure.
- New transmission will be required for all the future wind scenarios in the Eastern Interconnection, including the reference case. Planning for this transmission, then, is imperative because it takes longer to build new transmission capacity than it does to build new wind plants.
- Without transmission enhancements, substantial curtailment of wind generation would be required for all of the 20% scenarios.
- Interconnection-wide costs for integrating large amounts of wind generation are manageable with large regional operating pools, where benefits of load and wind diversity can be exploited and large numbers of supply resources are efficiently committed and dispatched.

An Integrated Approach is Required

Making Transformational Change


NREL
National Renewable Energy Laboratory
Innovation for Our Energy Future

Renewable Electricity Supply

Wind

Today's Status in U.S.

- 25,300 MW installed capacity
- Cost 6-9¢/kWh at good wind sites*

DOE Cost Goals

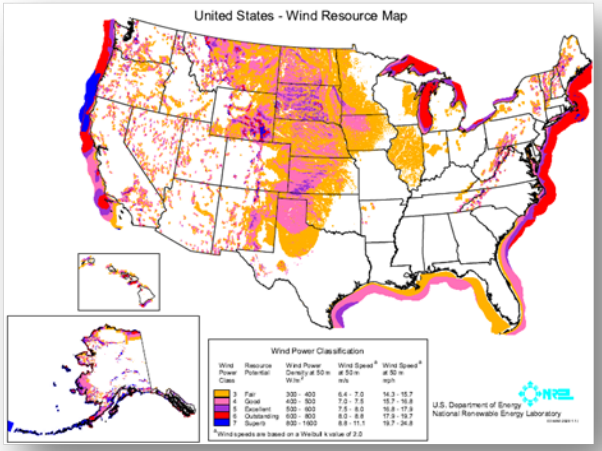
- 3.6¢/kWh, onshore at low wind sites by 2012
- 7¢/kWh, offshore in shallow water by 2014

Long Term Potential

20% of the nation's electricity supply

* With no Production Tax Credit
Updated May 8, 2009
Source: U.S. Department of Energy, American Wind Energy Association

Wind Energy Technology



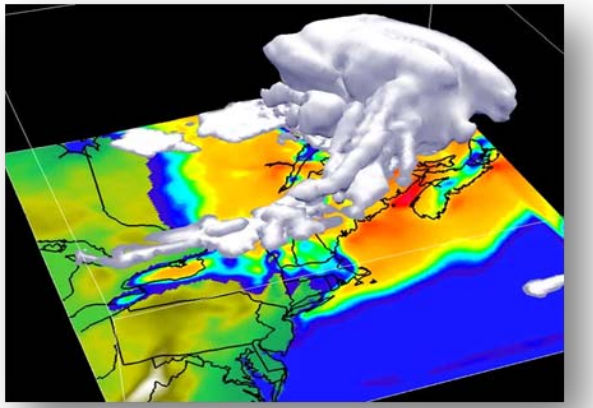
US Wind Resource Exceeds Total Electrical Demand

Offshore Wind

Advanced Blades

Innovative Tall Towers

Giant Multi-megawatt Turbines

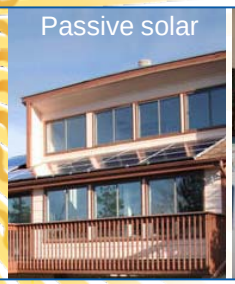


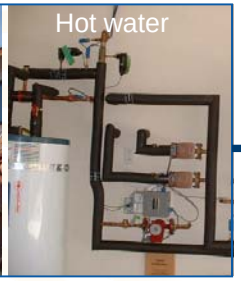
Courtesy:WindLogics, Inc. St. Paul, MN

Wind Forecasting

Applications of Solar Heat and Electricity

Solar Thermal





Photovoltaics (PV)

Concentrating Solar Power (CSP)

Distributed Generation, on-site or near point of use

Centralized Generation, large users or utilities

Transportation

Residential & Commercial Buildings

Industrial

Solar – Photovoltaics and CSP

Status in U.S.

PV
- 1,000 MW installed capacity
- Cost 18-23¢/kWh

CSP
- 419 MW installed capacity
- 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

Source: U.S. Department of Energy, IEA
Updated January 1, 2009

Solar Research Thrusts

Photovoltaics

Higher performance cells/modules

New nanomaterials applications

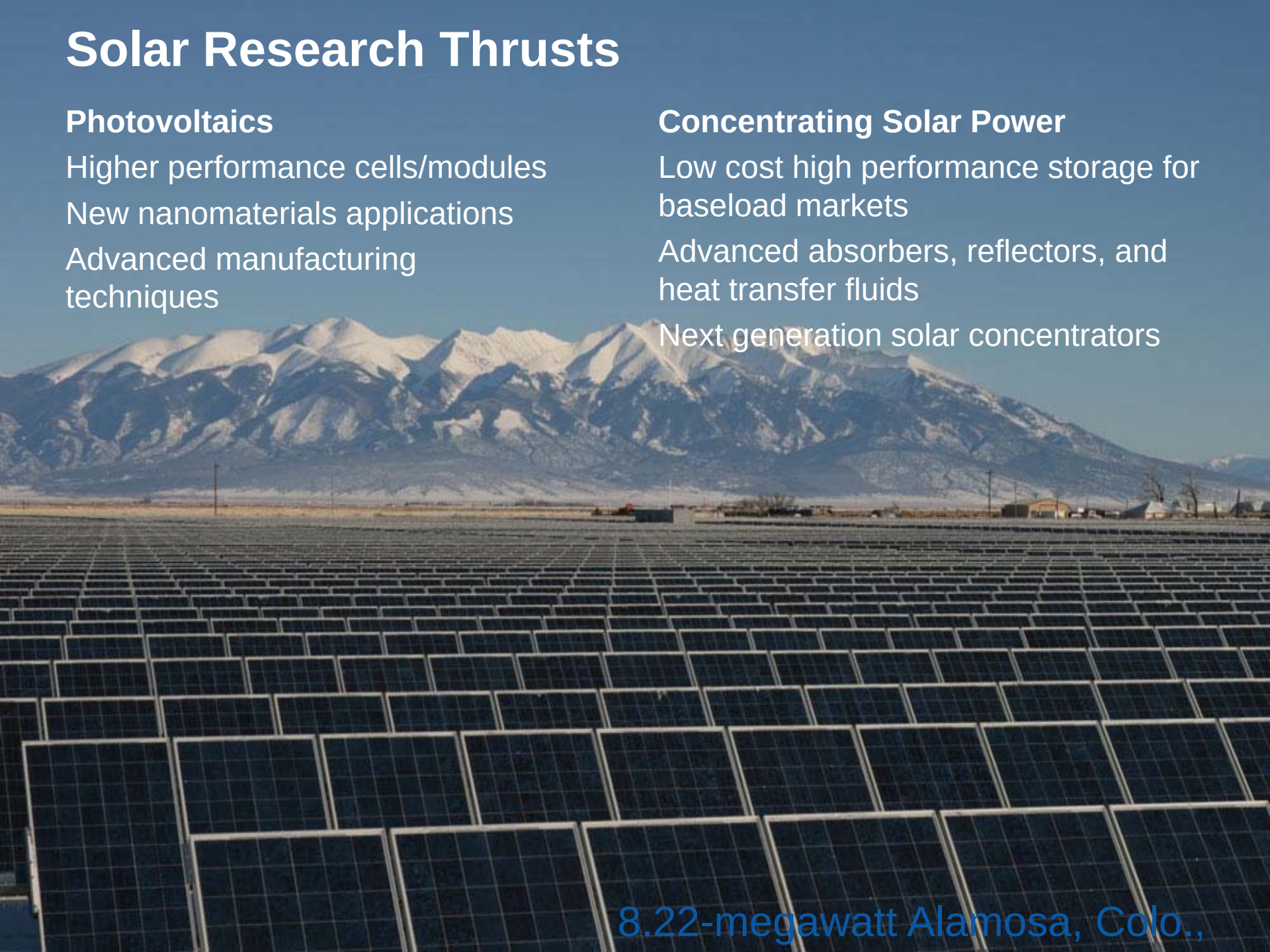
Advanced manufacturing techniques

Concentrating Solar Power

Low cost high performance storage for baseload markets

Advanced absorbers, reflectors, and heat transfer fluids

Next generation solar concentrators



8.22-megawatt Alamosa, Colo.,

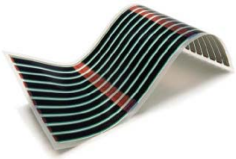
PV Conversion Technology Portfolio

Market-Competitive Targets

Market Sector	Current U.S. Market Price Range (¢/kWh)	Cost (¢/kWh) Benchmark 2005	Cost (¢/kWh) Target 2010	Cost (¢/kWh) Target 2015
Residential	5.8-16.7	23-32	13-18	8-10
Commercial	5.4-15.0	16-22	9-12	6-8
Utility	4.0-7.6	13-22	10-15	5-7

Thin Films (aSi)

Advancing amorphous and wafer replacement crystal silicon film solar cells on low-cost substrates



Organic PV

Customizing molecules, substrates, and deposition techniques to yield ultra low-cost modules

Next Generation

Investigating advanced concepts aimed at delivering revolutionary performance improvements

Crystalline Silicon

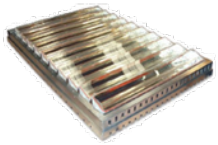
Developing higher efficiency devices and lower cost processing methods for traditional silicon cells

Crosscut

Synergistic technologies, evaluation approaches, and process engineering approaches applicable across multiple absorber materials and processes

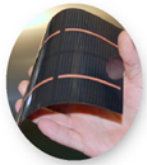
Concentrating PV

Combining new, lower cost multijunction cells and innovative optical packages



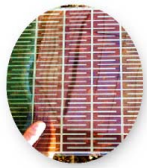
Thin Films (CIGS)

Supporting the manufacture of non-vacuum processes and transferring record efficiency device performance into large area commercial modules



Dye-Sensitized Cells

Advancing the efficiency and stability of inexpensive dye-based solar cells with novel nanostructures



Building Integrated PV

Creating module form factors aimed at dramatically reducing or eliminating solar installation costs

Geothermal

Today's Status in U.S.

- 2,800 MWe installed, 500 MWe new contracts, 3000 MWe under development
- Cost 5-8¢/kWh with no PTC
- Capacity factor typically > 90%, base load power

DOE Cost Goals:

- <5¢/kWh, for typical hydrothermal sites
- 5¢/kWh, for enhanced geothermal systems with mature technology

Long Term Potential:

- Recent MIT Analysis shows potential for 100,000 MW installed Enhanced Geothermal Power systems by 2050, cost-competitive with coal-powered generation

NREL Research Thrusts:

- Analysis to define pathways to commercialization of enhanced geothermal systems (EGS)
  Systems engineering/integration to enable fast track development of EGS and other Program goals
  Geothermal energy conversion RD&D
  Low temperature geothermal, direct use, and ground source heat pump RD&D

Biomass Power

Biopower status in U.S.

- 2007 capacity – 10.5 GWe
  - 5 GW Pulp and Paper
  - 2 GW Dedicated Biomass
  - 3 GW MSW and Landfill Gas
  - 0.5 GW Cofiring
- 2004 Generation – 68.5 TWh
- Cost – 8-10¢/kWh

Potential

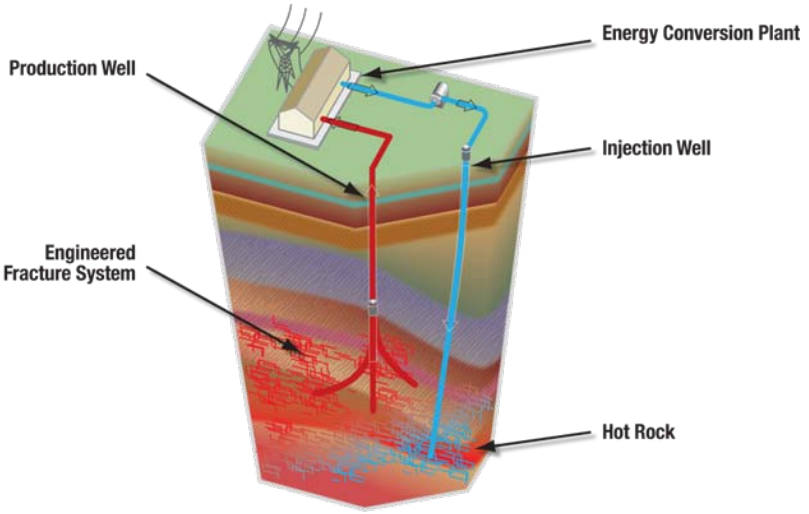
- Cost – 4-6¢/kWh (integrated gasification combined cycle)
- 2030 – 160 TWh (net electricity exported to grid from integrated 60 billion gal/yr biorefinery industry)

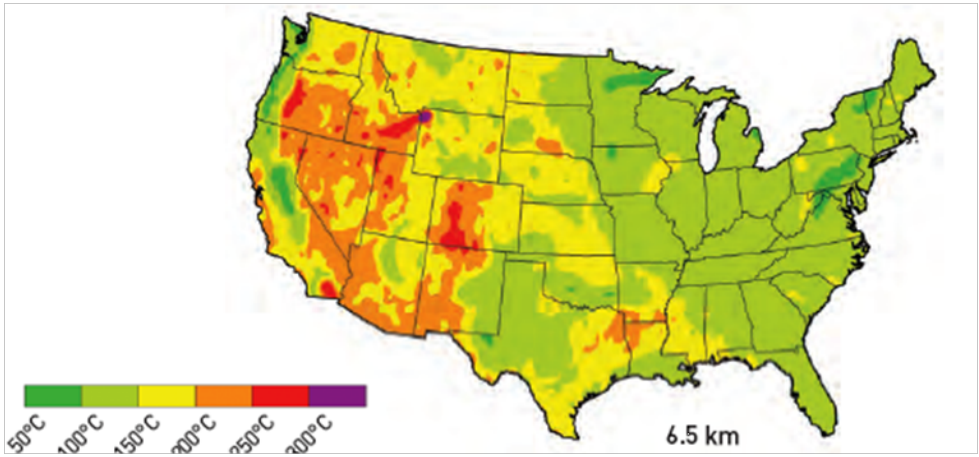
July 16, 2009

New Directions

Geothermal: Beyond 2015

- Enhanced Geothermal Systems
  - Enable a massive increase of the US geothermal “footprint” through critical R&D to reduce risk and improve economics
    - Reservoir creation, characterization, and modeling
    - Drilling, tools and sensors
    - Advanced energy conversion technologies
    - Techno-economic and policy analysis
    - Next-generation resource assessment: beyond hydrothermal regions

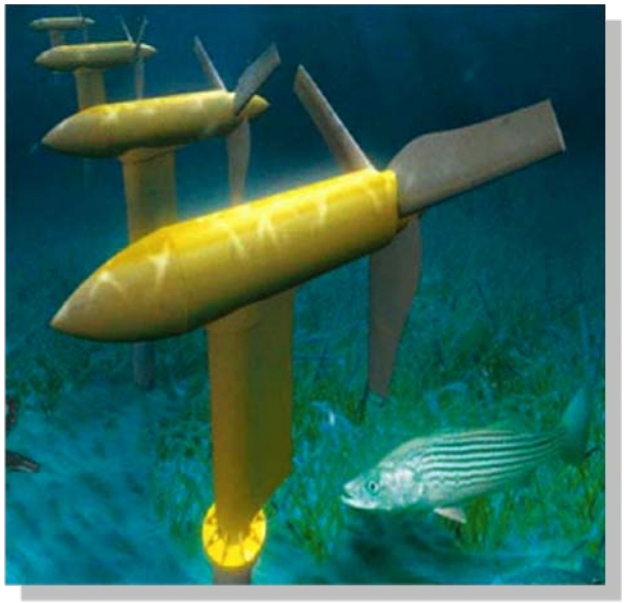




FY09 NREL Water Program

Market Development and Transformation

- International Collaborations and Standards
- Technical Support
- Industry Technology Support



Industry Status

- New industry extracting power from natural Ocean and River Currents, Tidal, Wave, and Thermal energy

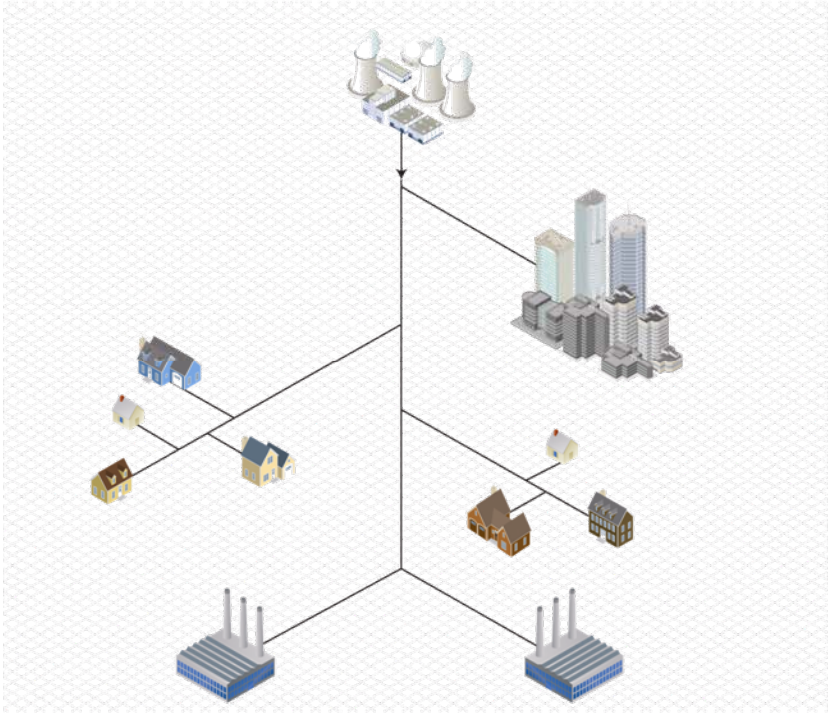
Water Power Mission

Assess the potential of extractable energy from water resources and facilitate the development and deployment of renewable, environmentally-friendly, and cost-effective energy systems from domestic rivers, estuaries and coastal waters

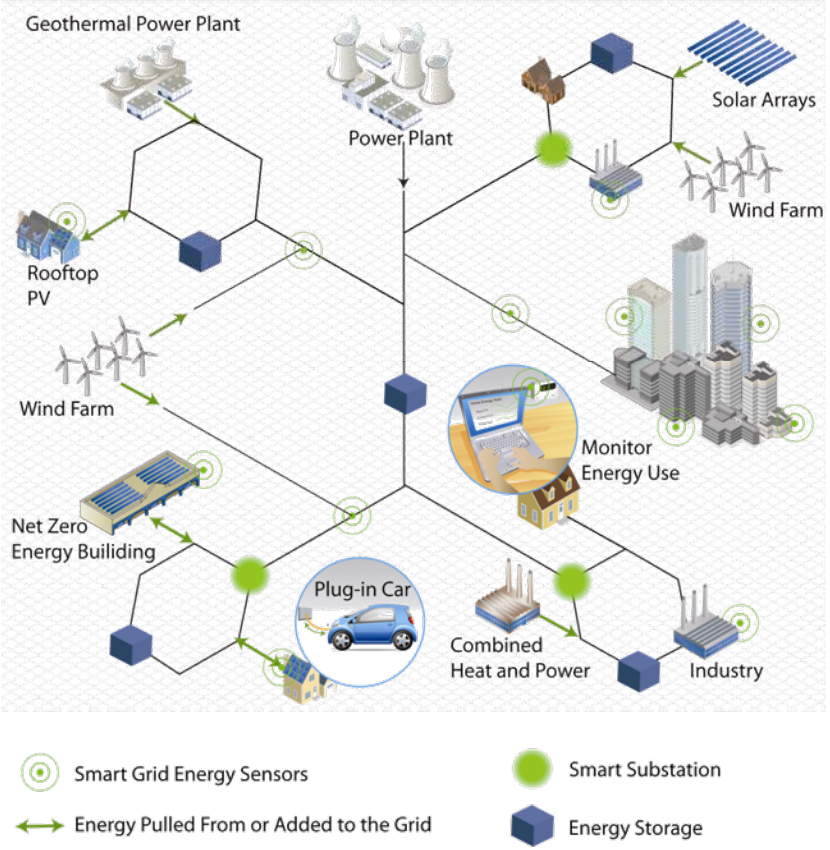
Include R&D for economic and environmental improvements to existing hydroelectric facilities and dams

Smart Grid – Renewable Energy Integration in Systems at All Scales

Today



Future



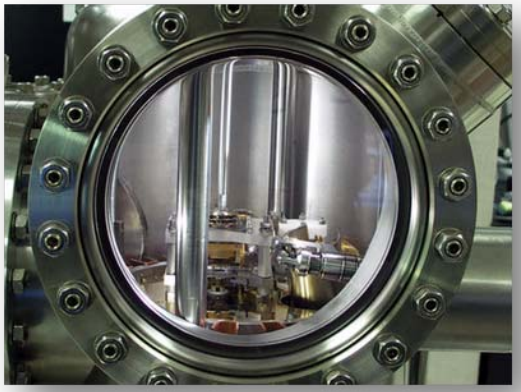
Energy Solutions Require a New Approach

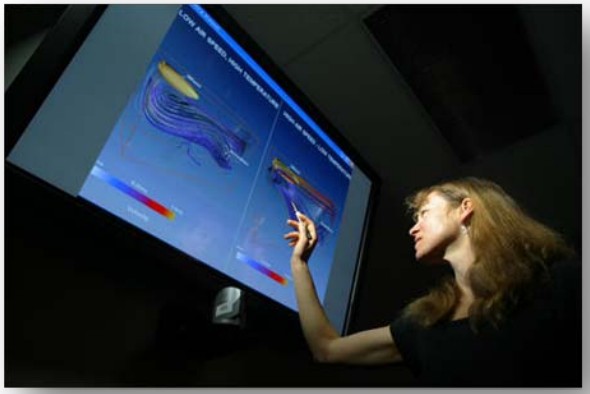
Multi-disciplinary/multi-institutional collaboration

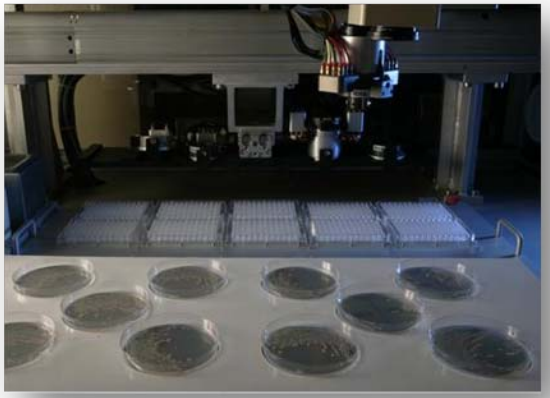
- Chemistry, materials science
- Computational modeling
- Biology

Translational science—bridge basic to applied

Revolutionary opportunities at the nano-scale

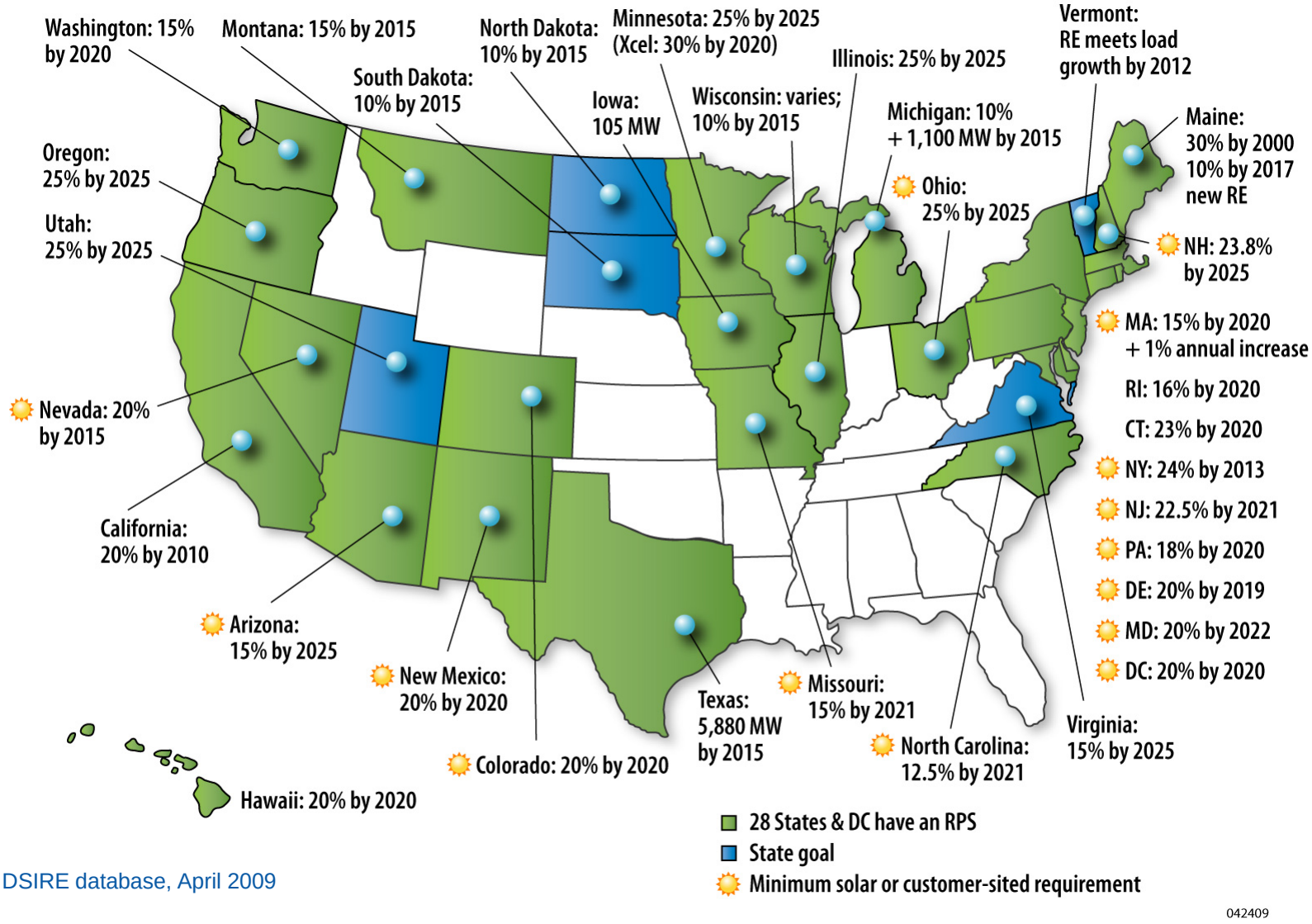






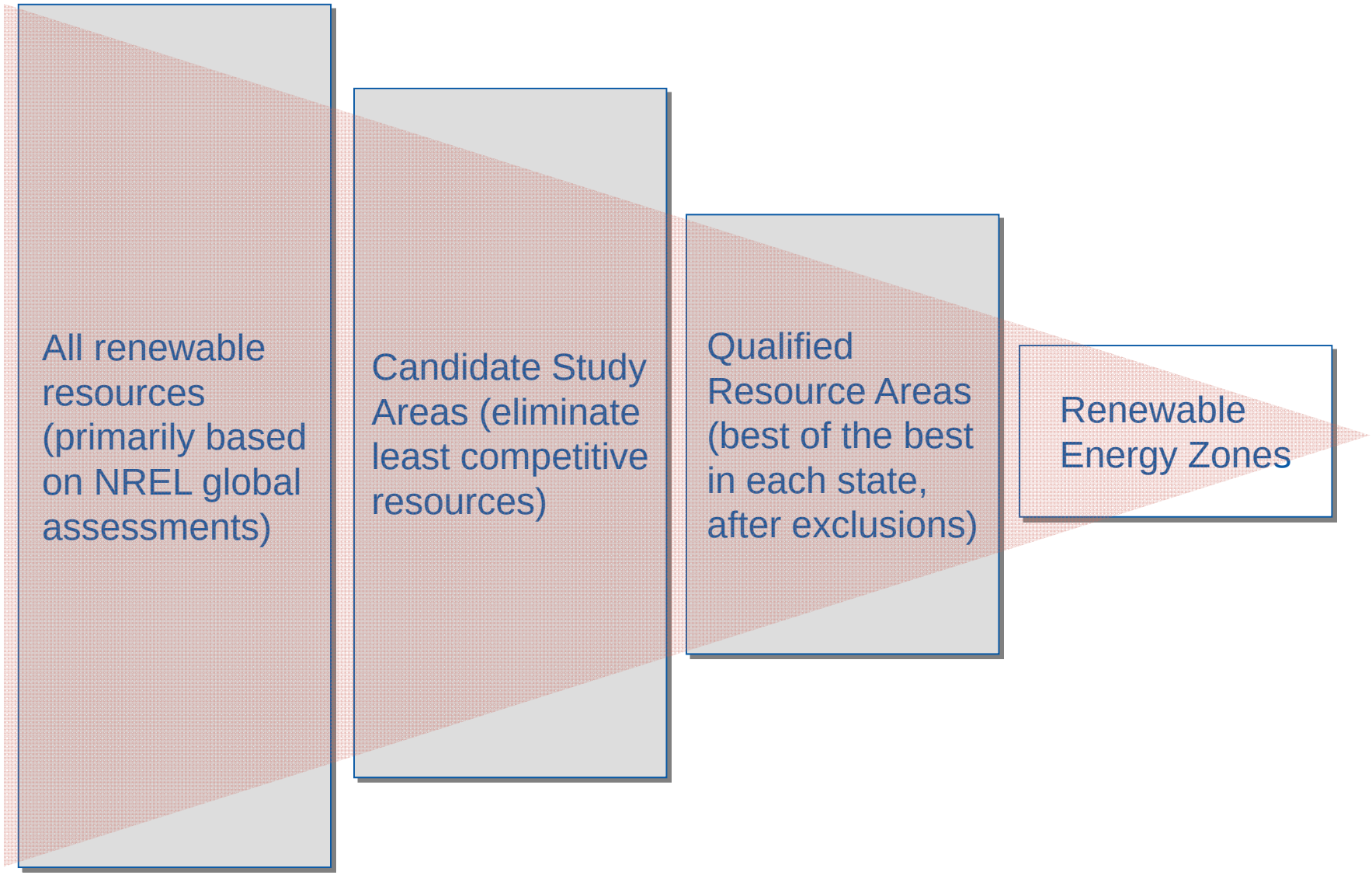
State Policy Framework

Renewable Portfolio Standards



Source: DSIRE database, April 2009

The Western Renewable Energy Zone Initiative



WREZ objectives for Phase 1

- Evaluate ***regional*** transmission options for renewable energy, on the assumption that in-state evaluations can be done by states themselves
  - Purpose is ***not*** to identify all developable renewable resources
- Identify the highest concentrations of the least-cost renewable resources, in sufficient quantity to sustain competition among potential developers
- Identify in advance the environmental and other land use issues that may limit development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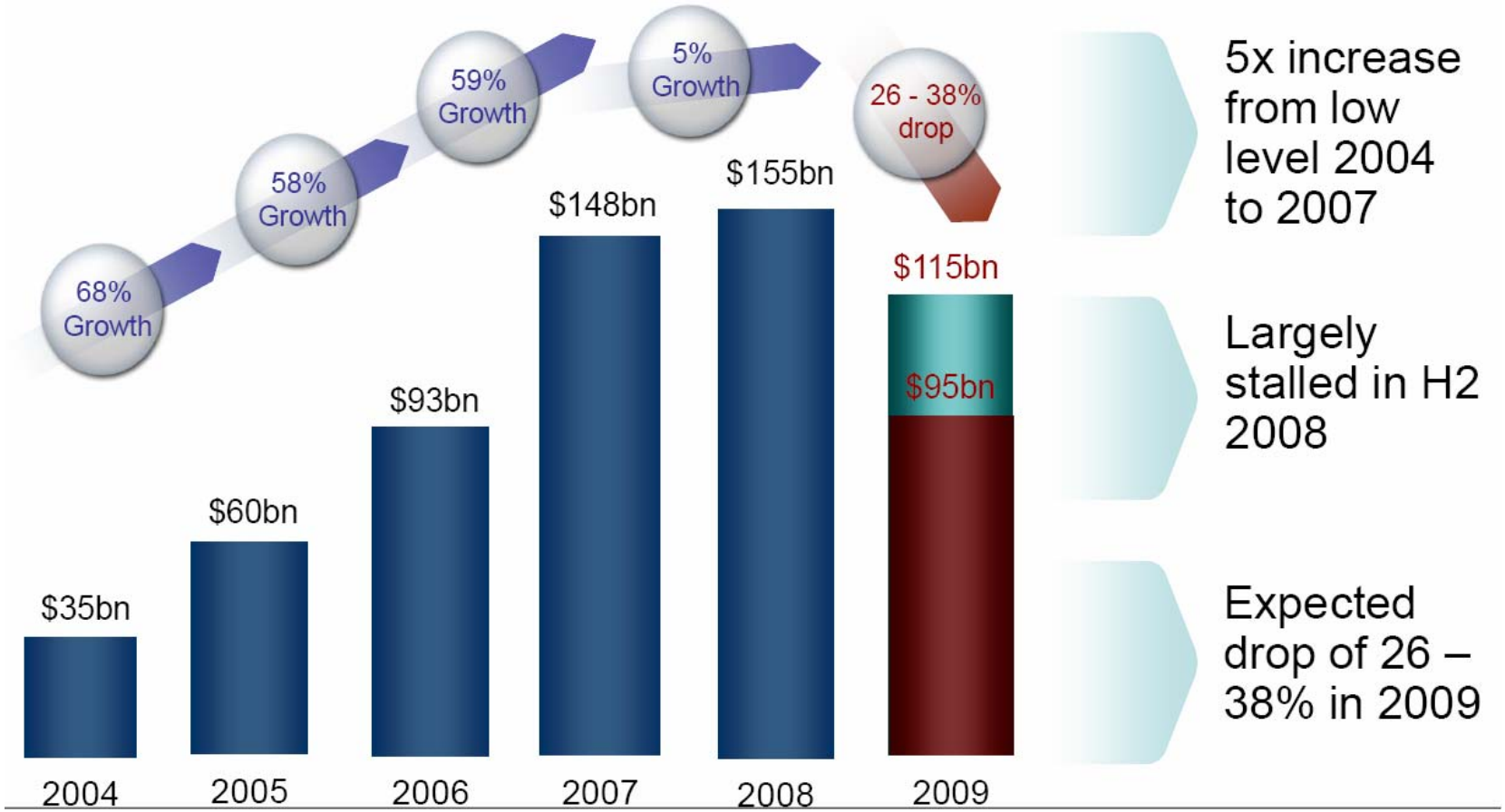
Global New Investment in Clean Energy 2004-2009



Source: New Energy Finance