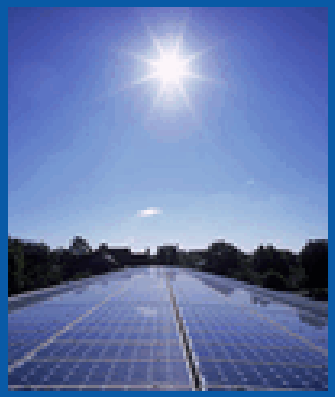
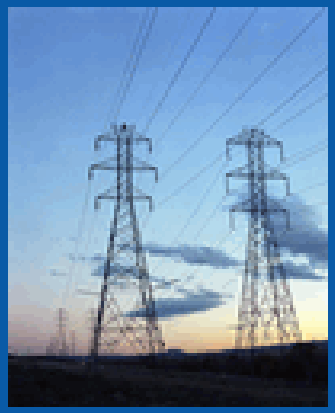
National Renewable Energy Laboratory
Innovation for Our Energy Future

Renewable Electricity Overview

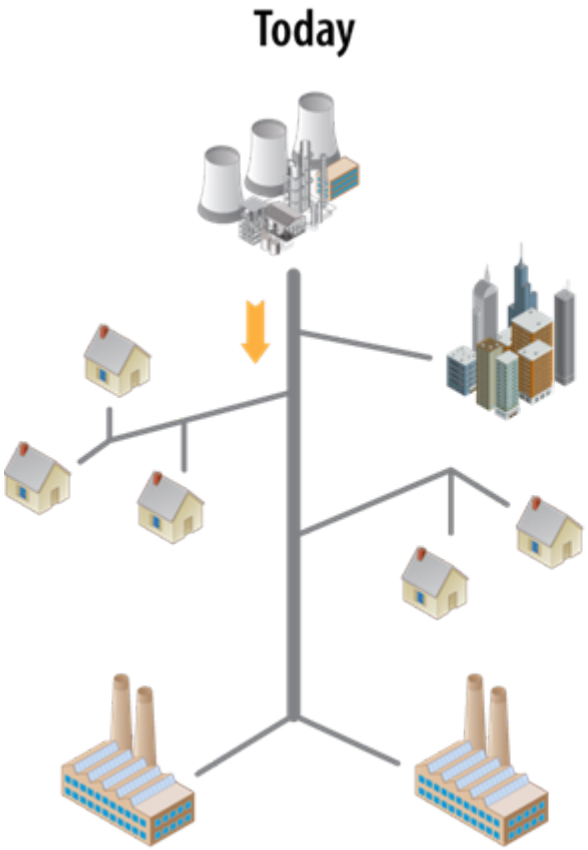

State Energy Advisory Board

STEAB

Bobi Garrett
Associate Director, Renewable Electricity Science & Technology

12 August 2008

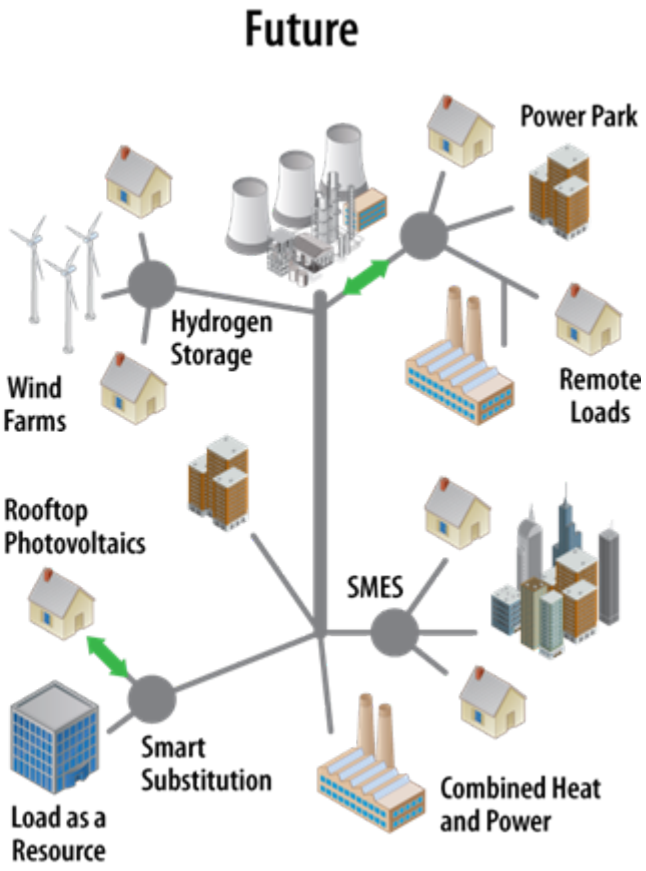
Transforming Our Electricity System



Transform Demand
Smart Growth
High Energy Productivity
Digital Economy
Controllable Loads

Change Supply Mix
Carbon-Neutral Systems
Domestic Resources
Renewable Resources

Create Smart Grid
Two-Way Power Flow
Higher Capacity
High Reliability/Self Healing



Business-as-usual will not adequately address growing demand, environmental issues, and security

Today's U.S. Energy Economy

Supply & Conversion	Transmission & Distribution	Utilization

100 Quads

Oil 40%

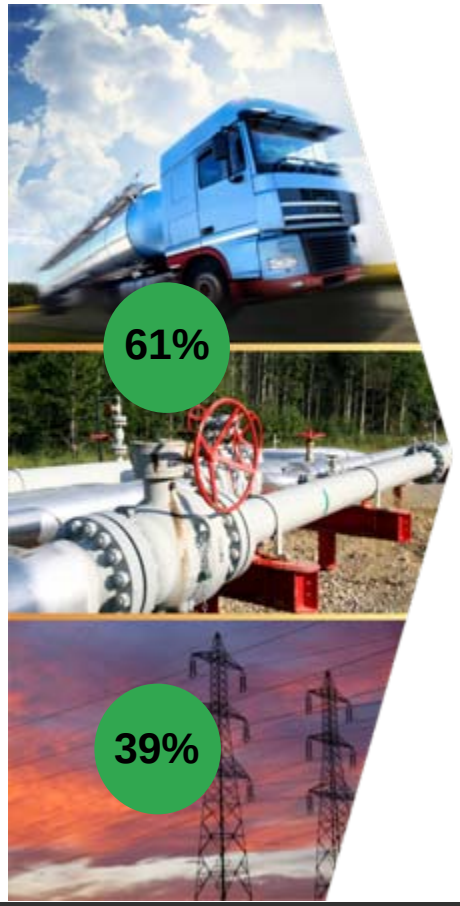
Coal 23%

Natural Gas 23%

Nuclear 8%

Hydro
Wind
Solar
Biomass
Geothermal

6%



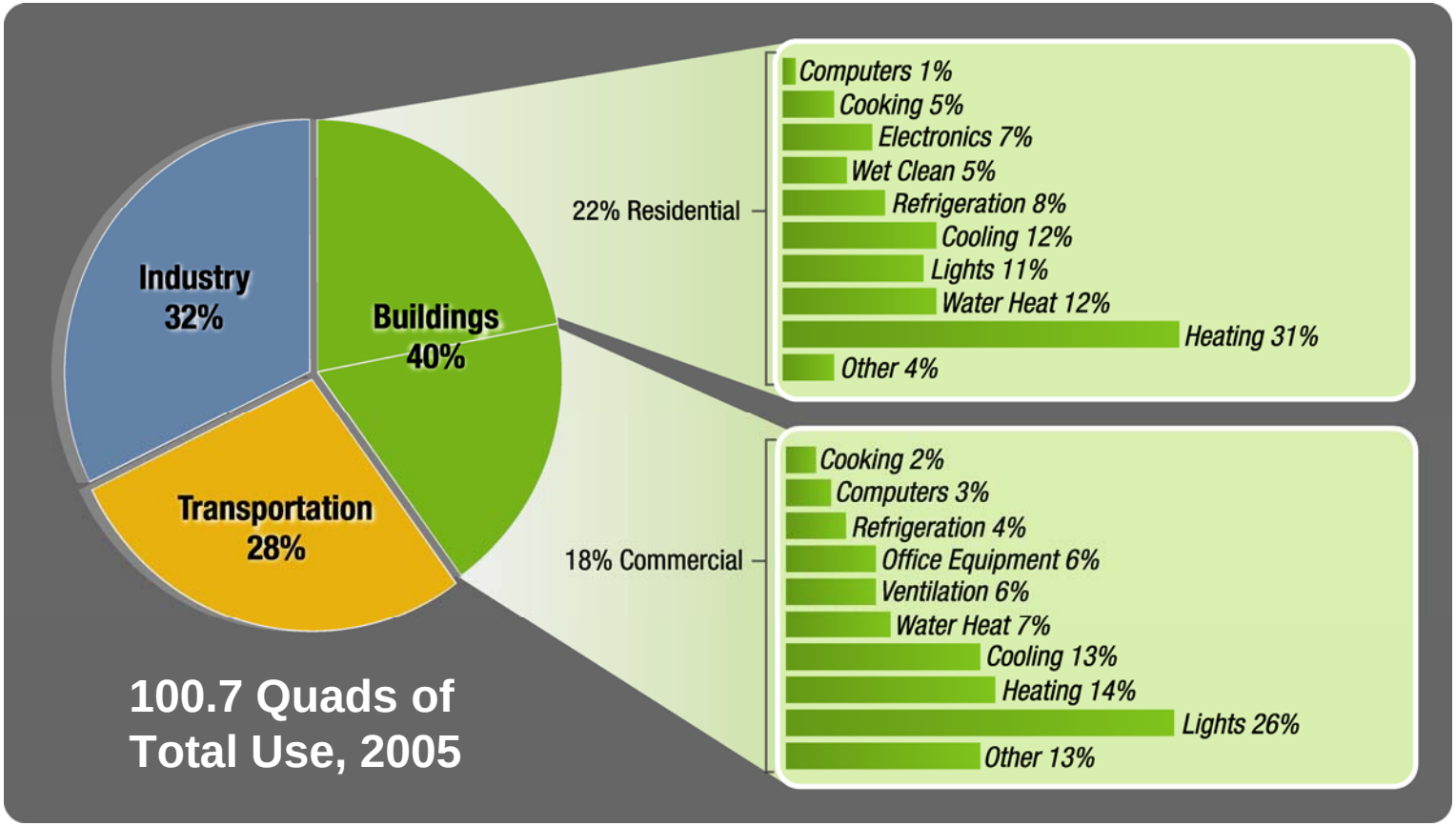
27%

40%

33%

Lost energy as inefficiencies – 62%

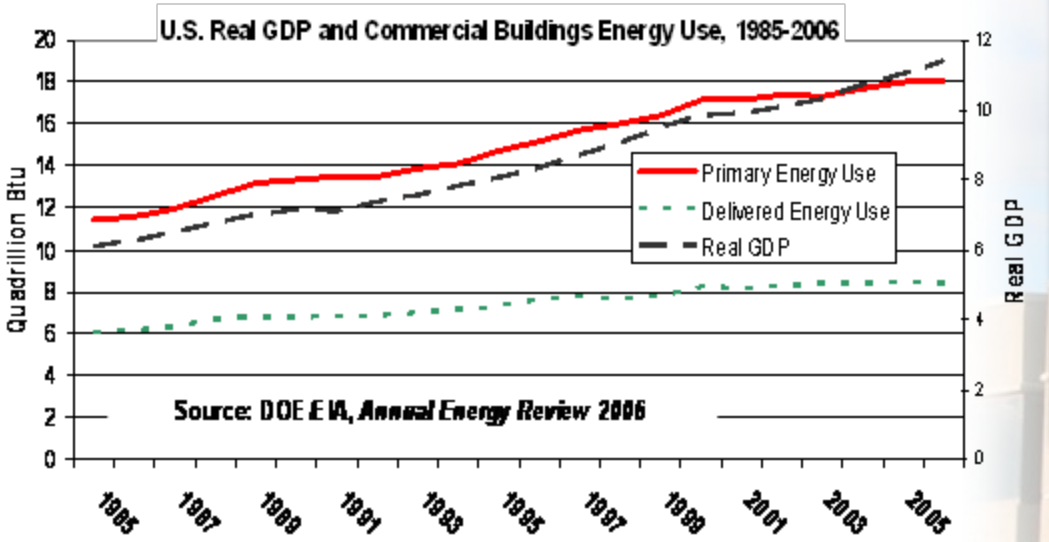
Energy Used in Buildings



Buildings use 72% of nation's electricity and 55% of its natural gas

Source: *Buildings Energy Data Book 2007*

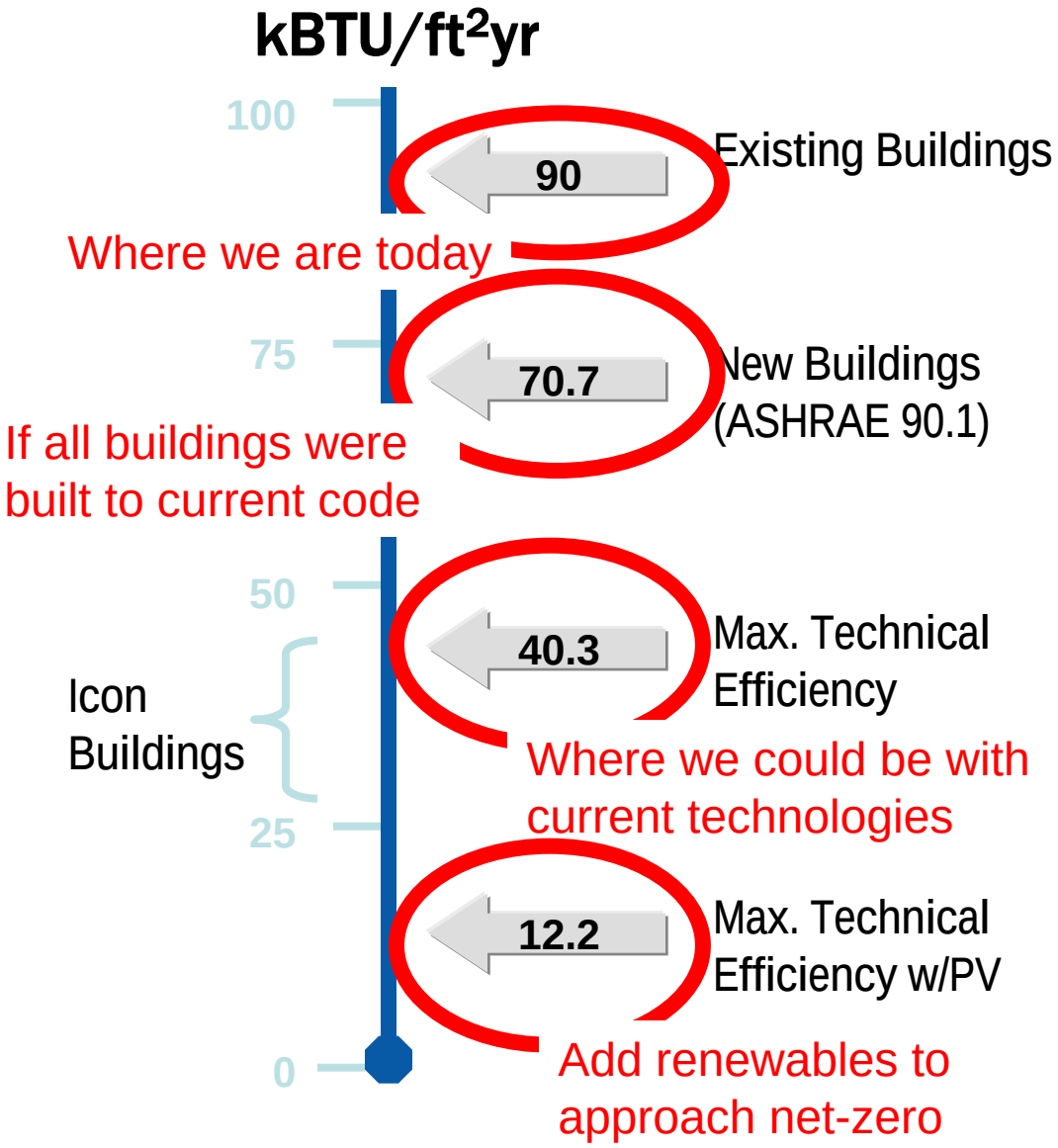
Commercial Buildings Energy Use



Commercial energy use rising at faster rate than GDP

Net-Zero Energy Commercial Buildings Initiative

Commercial Building Opportunities



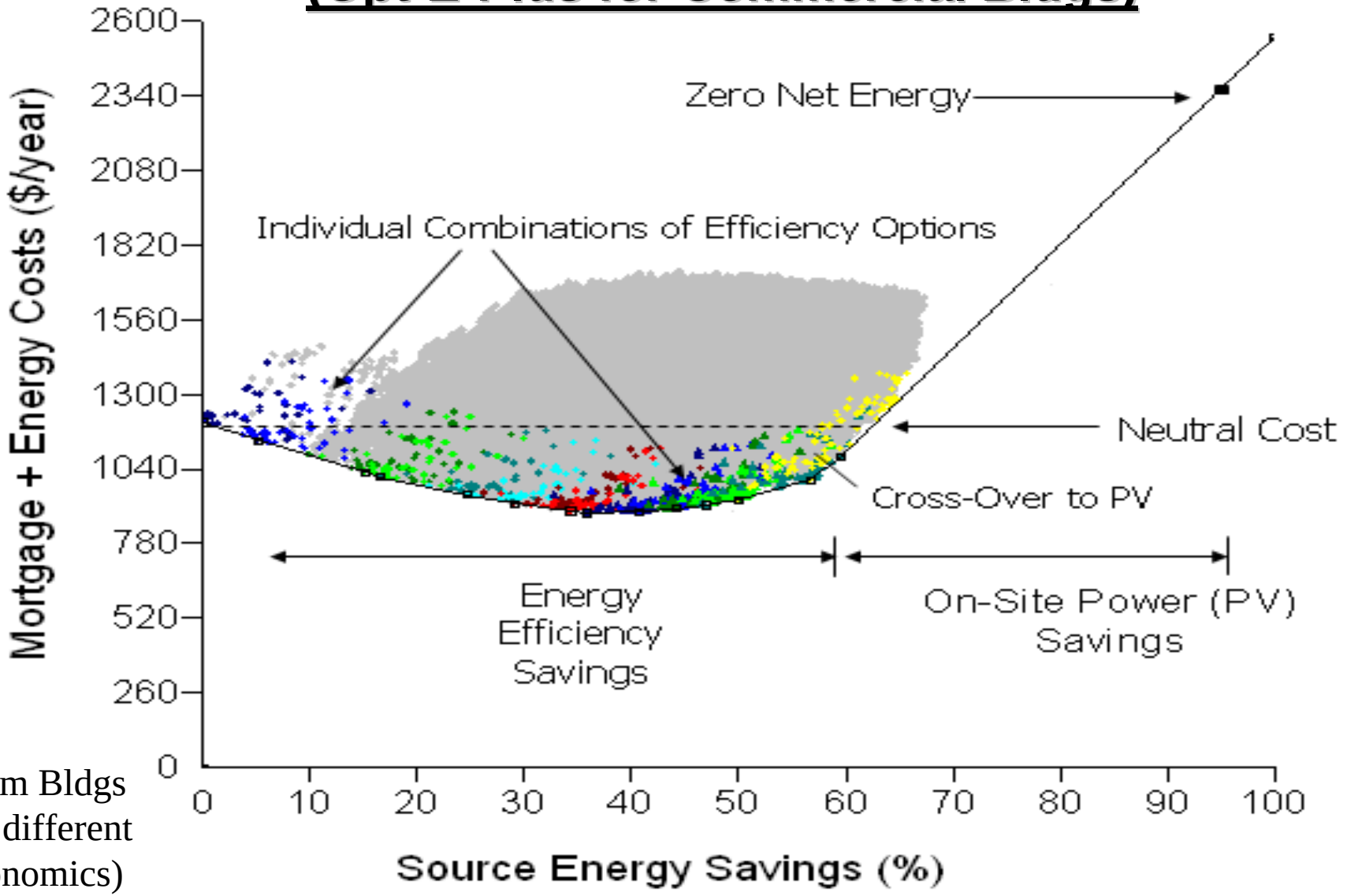
Technology Directions

- Standards
- Net-Zero Energy Buildings
- Solid-State Lighting
- Smart-Control Systems
- Combined Heating and Cooling
  - ➢ Thermally-activated systems
  - ➢ Waste heat use

National Renewable Energy Laboratory
Innovation for Our Energy Future

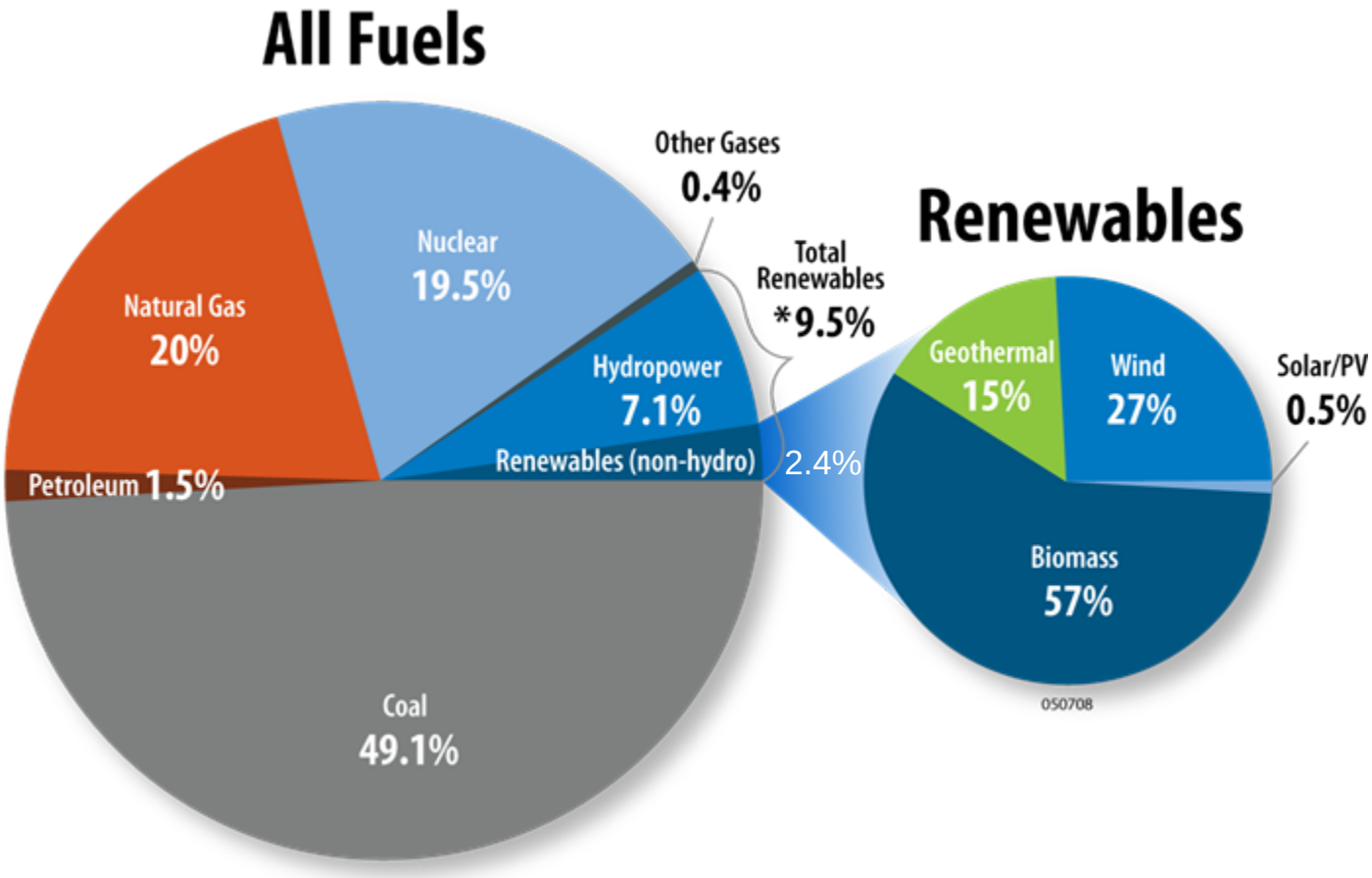
Example Results: Costs and Energy Savings of All Possible Combinations of Options (BEopt)

(Opt-E-Plus for Commercial Bldgs)



(Com Bldgs use different Economics)

U.S. Electricity Net Generation



Net generation for 2006 = 3814 TWhr UCb

Source: EIA Annual Energy Review 2007, AEO 2008

Wind

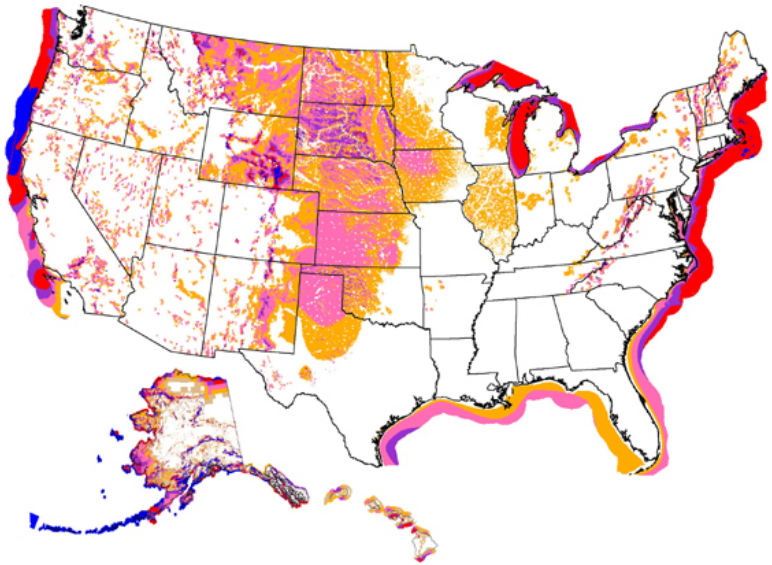
Current Status in U.S.

- 16,850 MW installed at end of 2007
- Cost 6-9¢/kWh at good wind sites*

Globally

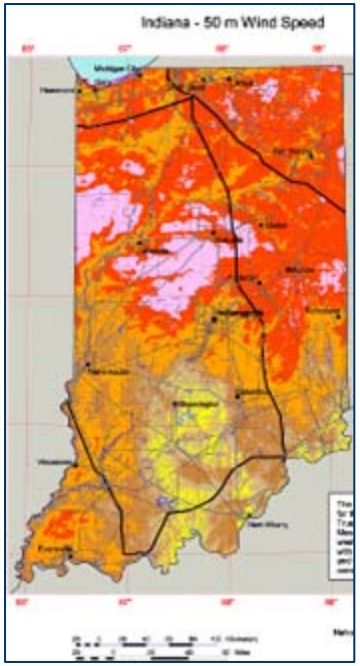
- $50B industry
- 68% annual growth

Wind Resources

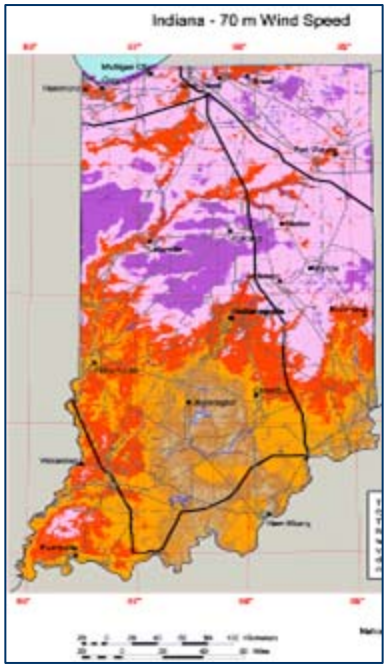


* With no Production Tax Credit
Updated March 12, 2008
Source: U.S. Department of Energy, American Wind Energy Association

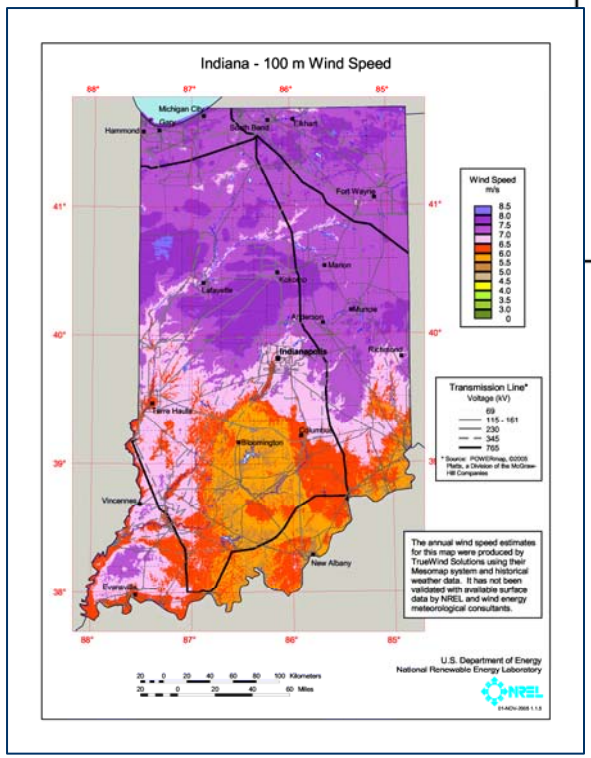
Wind Resources Vary with Hub Height



Best areas 6.5-7 m/s
Capacity factors 30-35%



Best areas 7-7.5 m/s
Capacity factors 35-40%



Best areas 7.5-8.2 m/s
Capacity factors 40-45%

National Renewable Energy Laboratory
Innovation for Our Energy Future

Technology Directions

- Larger turbines
- Offshore technology
- Component performance and reliability
  - Wind Forecasting
  - In situ ‘health’ monitoring
  - Gearbox reliability
- Utility grid integration/storage
- Manufacturing
- Siting and wildlife issues

Source: Megavind Report *Denmark’s future as leading centre of competence* within the field of wind power

Solar Energy

Photovoltaics (PV) - Current U.S. Status

- 824 MW installed capacity
- Cost 18-23¢/kWh

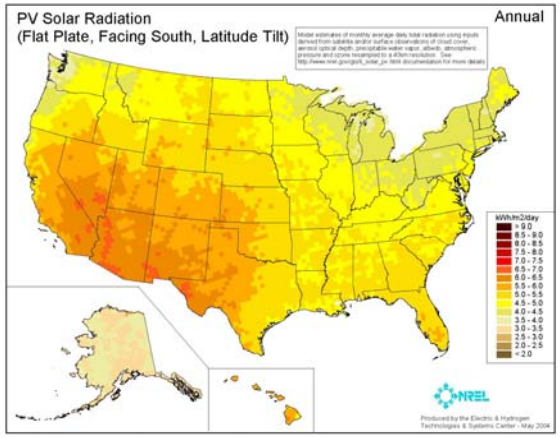
Concentrating Solar Power (CSP)

- 1000 MW installed capacity
- Cost 12-14¢/kWh

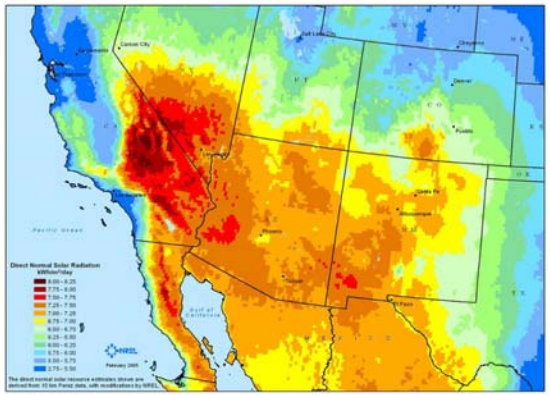
Globally Solar is:

- $28.6B
- Growing 199% annually

Solar Flat Plate Potential



Direct Normal Solar Resources

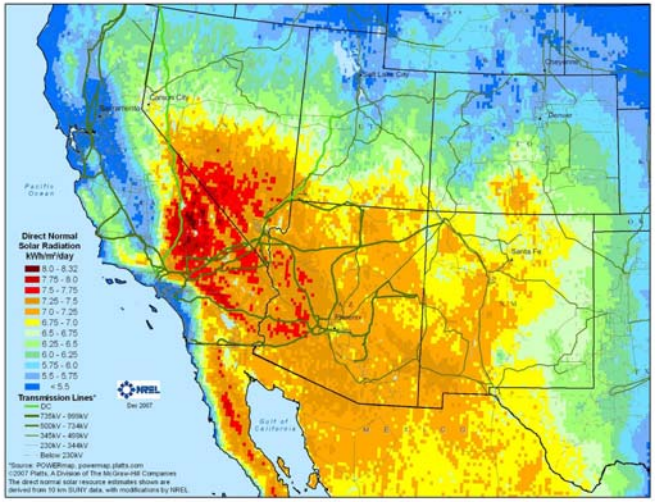


Sources: NREL 2008
New Energy Finance

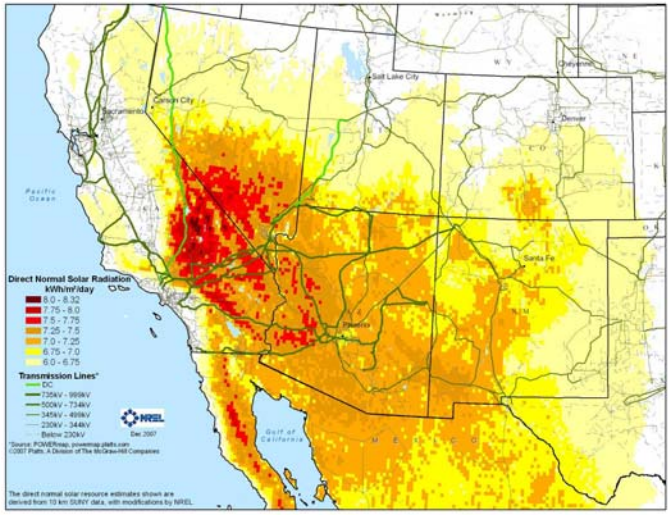
National Renewable Energy Laboratory
Innovation for Our Energy Future

Resource Analysis

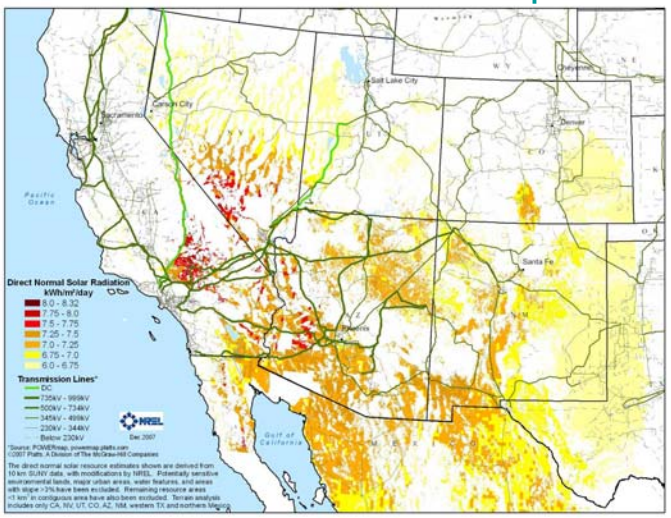
Unfiltered with Transmission



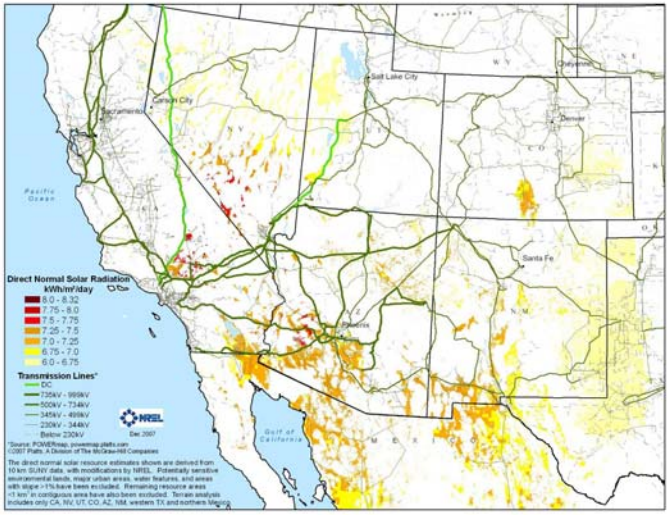
>6kWh/m^2/day



Land Exclusions and <3% slope



Land Exclusions and <1% slope



National Renewable Energy Laboratory
Innovation for Our Energy Future

CSP Technology Directions

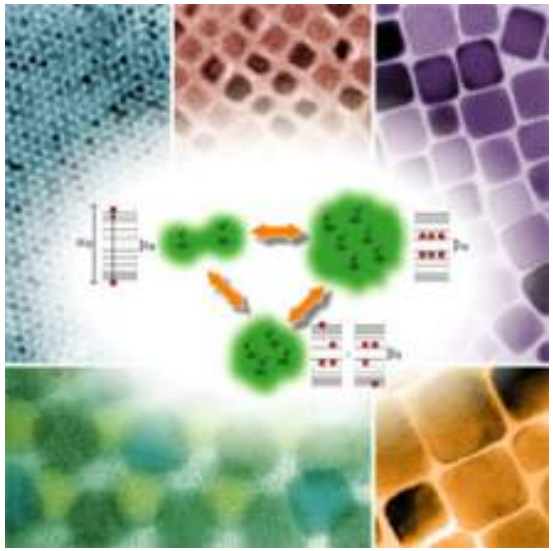
Technology Directions

- **Optimized collector and receiver designs**
- **Larger plant sizes and higher operating temperatures**
- **Storage**
  - **Advanced Heat Transfer Fluids**
  - **Lower cost options**
- **Grid Integration and Control**
- **Advanced Concepts**
  - **Tower Systems**
  - **Dish Systems**

PV RD&D Focused on Reaching Grid Parity

- Thin-film manufacturing technology
- 3rd Generation PV
- Reliability
- Grid integration
- Solar Forecasting

Process Development Integration Laboratory



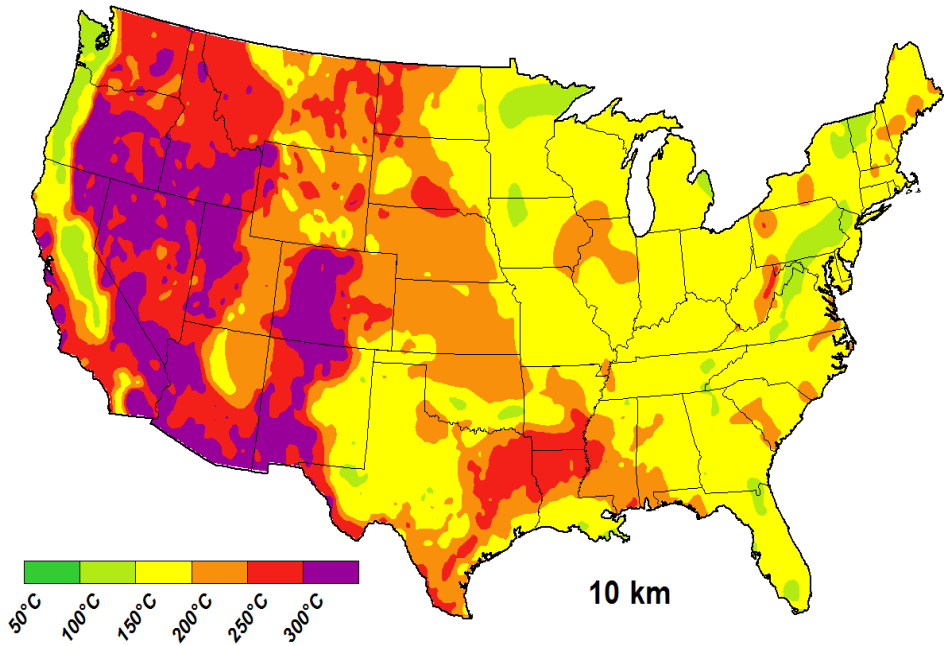
Multiple Exiton Cells

Science and Technology Facility

Geothermal

Current 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%,



Technology Directions

- Enhanced Geothermal Systems
- Resource Exploration
- Advanced Power Cycles
- Use of Low-Grade Heat

Ocean Energy

RD&D Directions

- Resource Assessment
- Standards Development
- Prototype Development & Validation

Types	Global Resource Estimate (TWh/y)	Estimated U.S. Energy Potential (TWh/y)	U.S. Electrical Demand
Wave	**8,000-80,000**	**260**	**7%**
Tidal/Current	**800+**	**88**	**2%**

NREL's Energy Systems Integration Facility (ESIF)

- 130,000 sq ft. multi-story building with high-bay and low-bay laboratories and offices
- Unique capability for testing and analysis to enable economic, reliable integration of renewable electricity, fuels, storage, and efficiency technologies with existing utility and fuels infrastructure

Full Systems Evaluation: Integrating Electricity, Fuels, Thermal, Storage, and End-use

Solar

- Interconnection
- Power electronics
- Building integration
- Thermal and PV system
- Optimization

Buildings

- Sensors & controls
- PV design and integration
- Modeling and simulation
- System integration

Hydrogen

- Hydrogen/electric interfaces
- RE electrolyzers
- Storage systems
- Standards
- Fuel cell integration
- Fueling systems

Wind

- Models, methods for wind interaction
- Mini-grid analysis

FreedomCAR

- Plug-in-hybrids and vehicle-to-grid
- Battery thermal management
- Power electronics

Biomass

- Biofueled gensets and engines


NREL
National Renewable Energy Laboratory
Innovation for Our Energy Future
Visit us online at www.nrel.gov
Operated for the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy by Midwest Research Institute • Battelle