NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Clean Alternative Energy: The New "Mainstream" Technology

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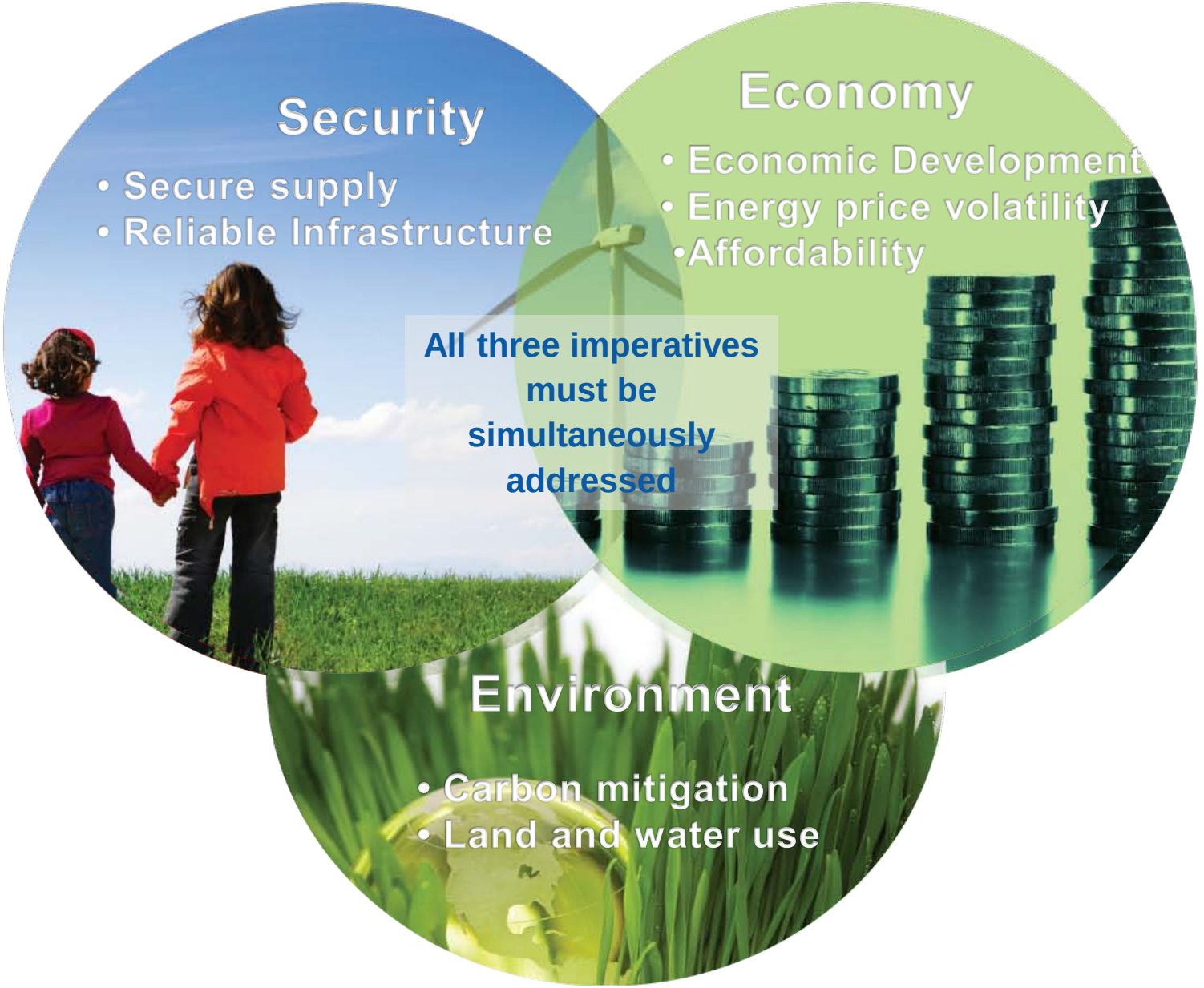
Laboratory Director

April 8, 2010

Energy Challenges



Achieving a Sustainable Energy Economy

*Requires a National Energy Grand Challenge**

Lead Coordinated RD3E Strategy in Sustainable Energy

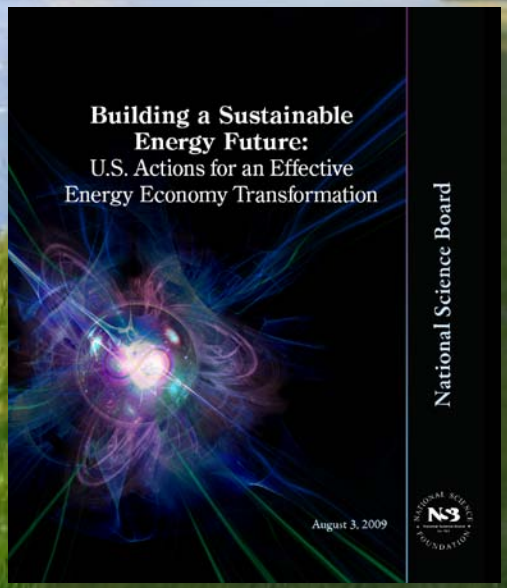
Boost R&D Investment

Construct Essential Policies & Market Conditions

Support Education & Workforce Development

Lead Globally

Promote Public Awareness & Action



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

Our Energy System

Supply & Conversion

Oil 40%

Coal 23%

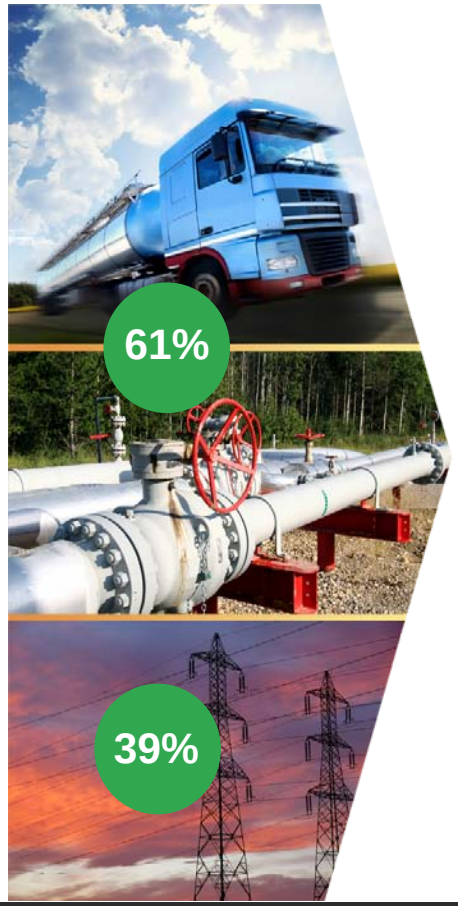
Natural Gas 23%

Nuclear 8%

Hydro
Wind
Solar
Biomass
Geothermal
6%

100 Quads

Transmission & Distribution



Utilization

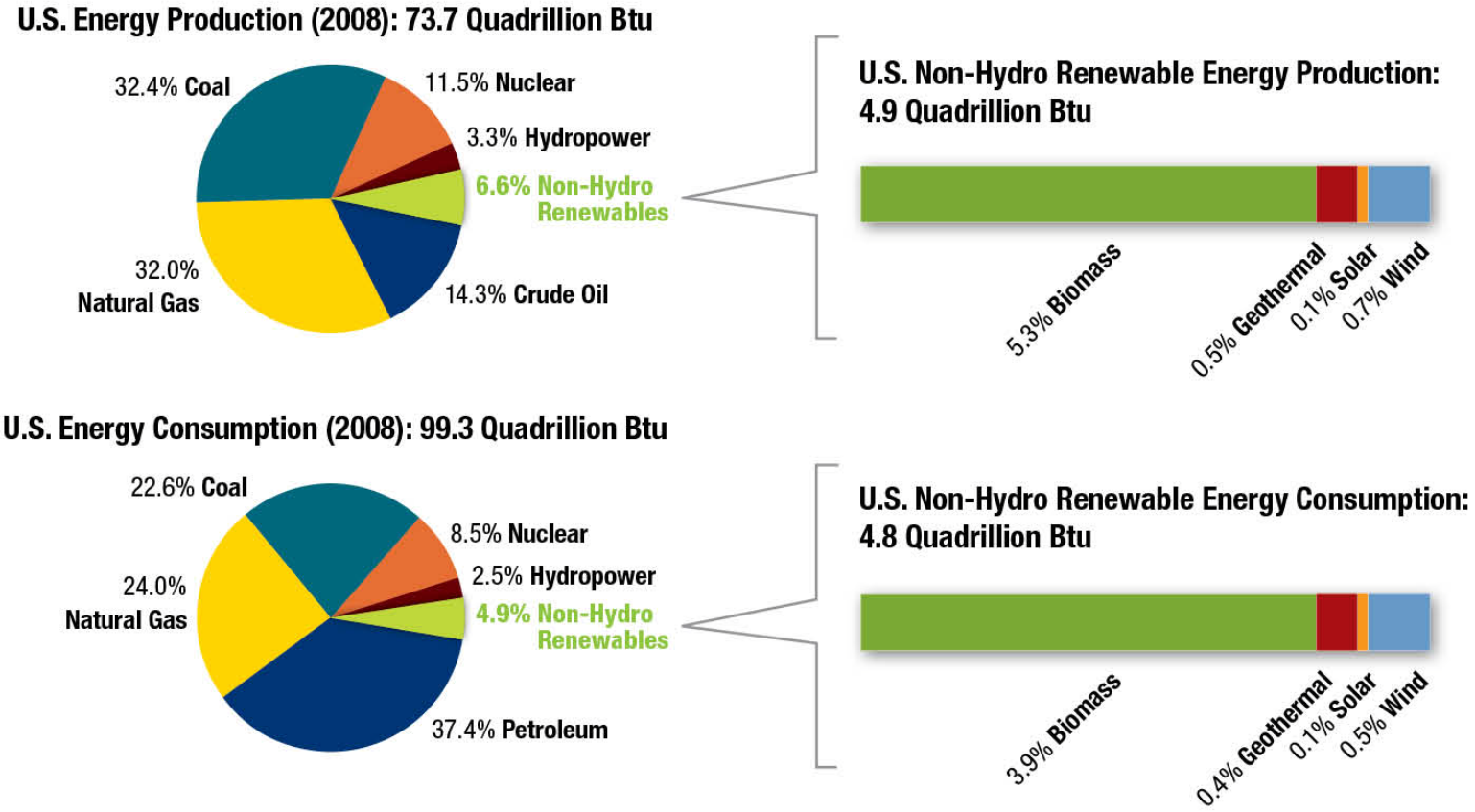
27%

40%

33%

Lost energy as inefficiencies – 62%

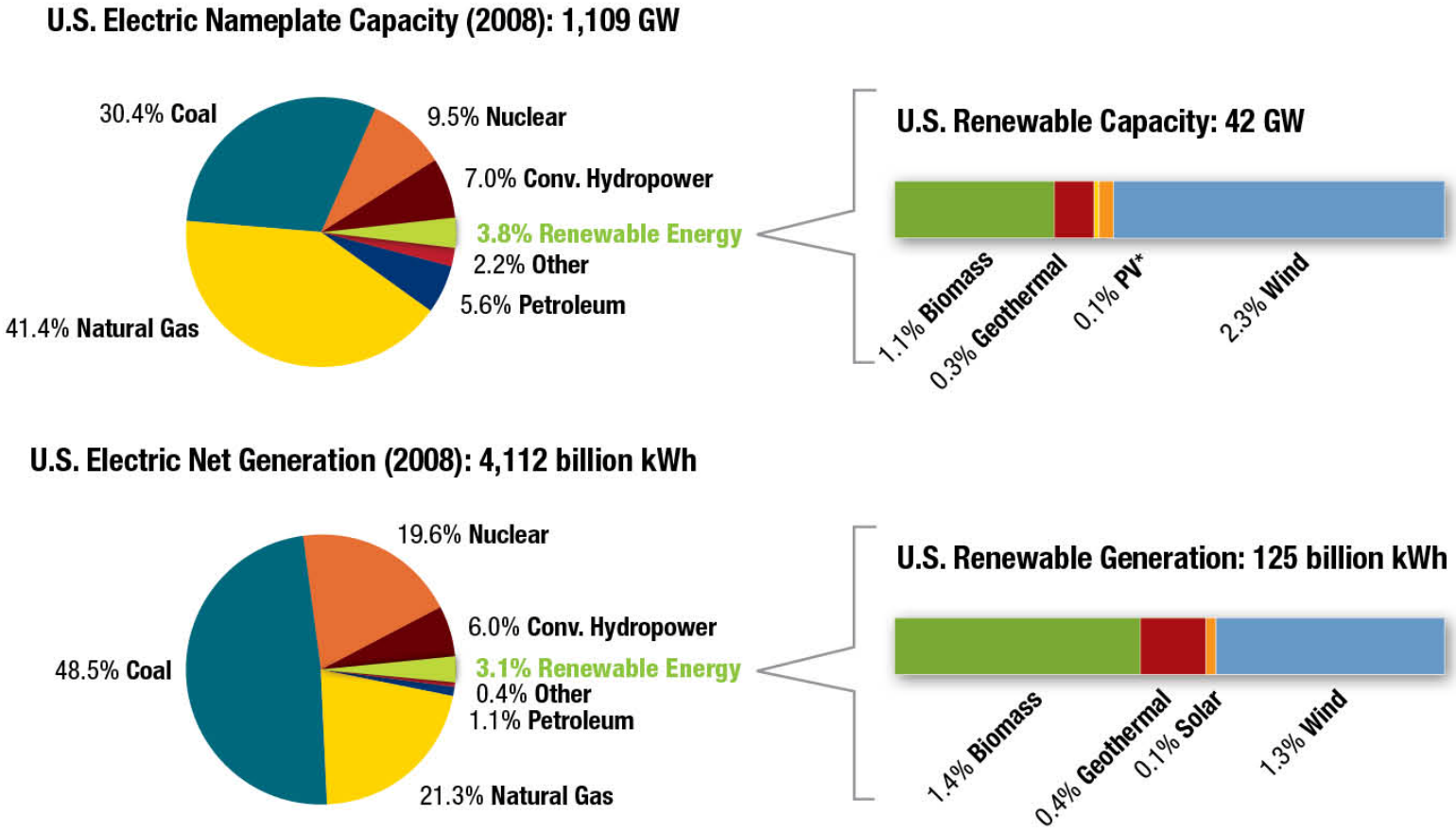
U.S. Energy Production and Consumption (2008)



Source: EIA; full references are provided starting on p. 122.

Note: Because hydropower is considered a conventional source of energy, it is accounted for separate from other new renewable sources of energy. Energy consumption is higher than energy production due to oil imports.

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

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

A Profound Transformation is Required

Today's Energy System

- Dependent on foreign sources
- Subject to price volatility
- Increasingly unreliable
- 2/3 of source energy is lost
- Produces 25% of the world's carbon emissions

Imperatives for Transformation

DEFINE THE END STATES

REDUCE NEW TECHNOLOGY RISK

ACCELERATE ADOPTION

Sustainable Energy System

- Carbon neutral
- Efficient
- Diverse supply options
- Minimal impact on resources
- Creates sustainable jobs
- Accessible, affordable and secure

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

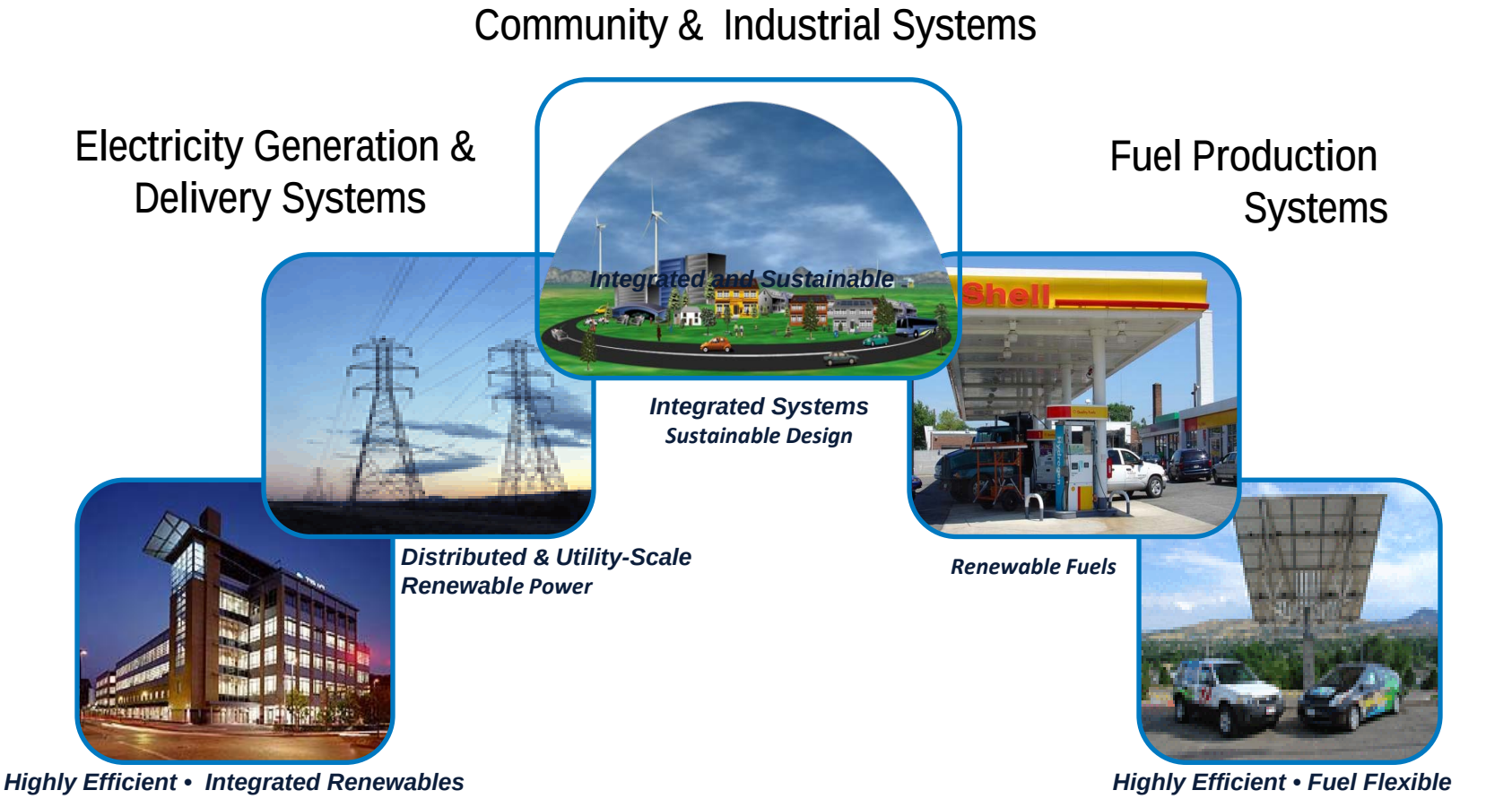
Heat and power for where we live and work

Sustainable Electricity System

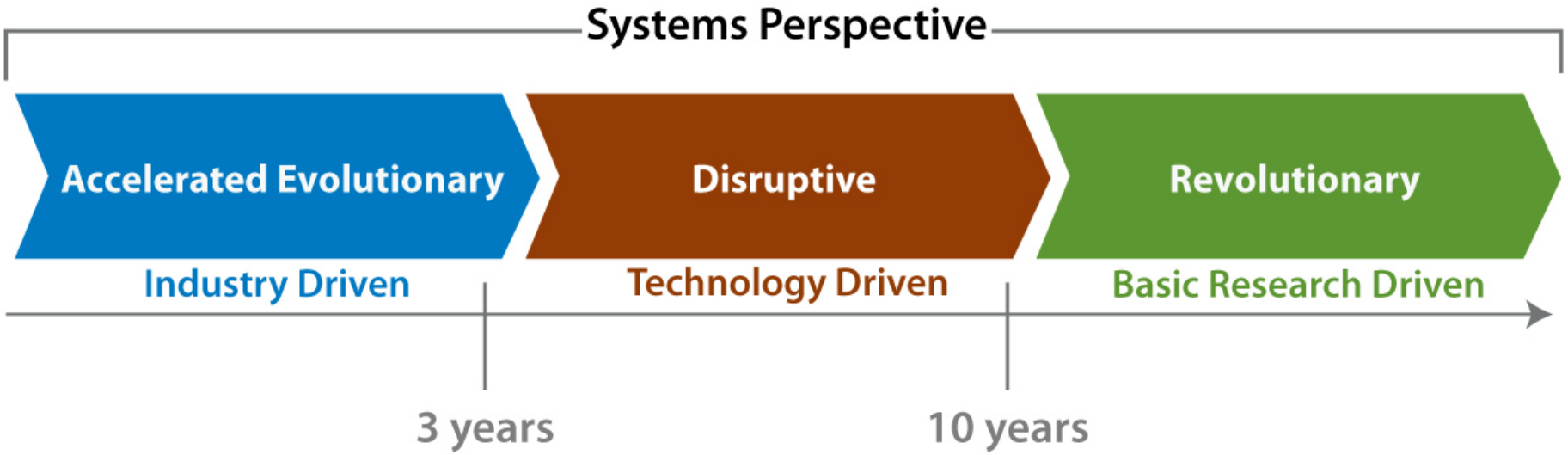
Fuel and power for mobility and access

Sustainable Transportation System

Need a Sustainable "System of Systems"



Achieving the Potential Requires A Balanced Portfolio



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

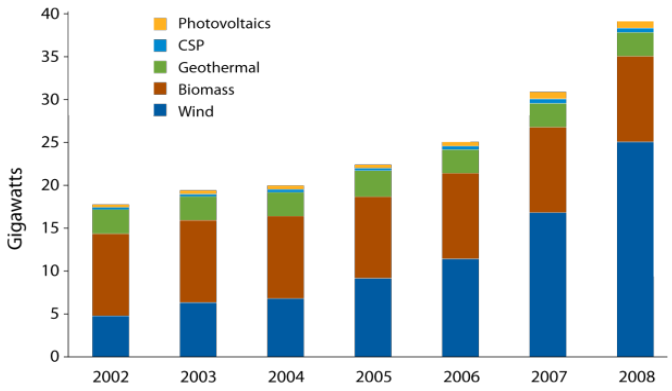
Remove Barriers to Broad Deployment

- Fuels Economic Recovery
- Creates Jobs

NREL Provides Data, Tools and Technical Assistance

- Educate and inform
- Develop codes and standards
- Inform policy options, program design, and investment choices
  - Resource Assessment
  - Technology Analysis
  - Policy Analysis

U.S. Renewable Electricity Installed Nameplate Capacity



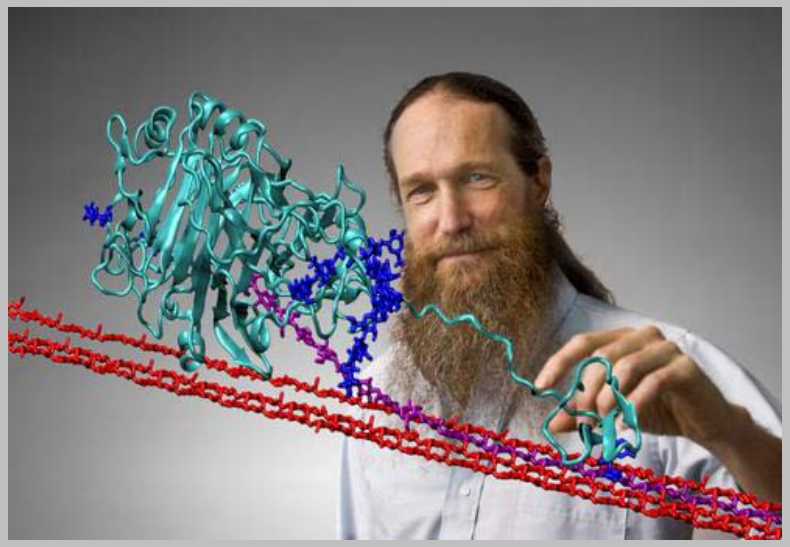
Source: EIA Annual Energy Outlook 2009 Early Release

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

- NREL Focus on Technology and Systems Development
- Unique Partnering Facilities
- Testing and Validation Capabilities

Long-Term Impact: Requires Breakthrough/ Translational Science

Translational science at NREL focuses on renewable energy and energy efficiency innovations that will most benefit the nation in practical applications.

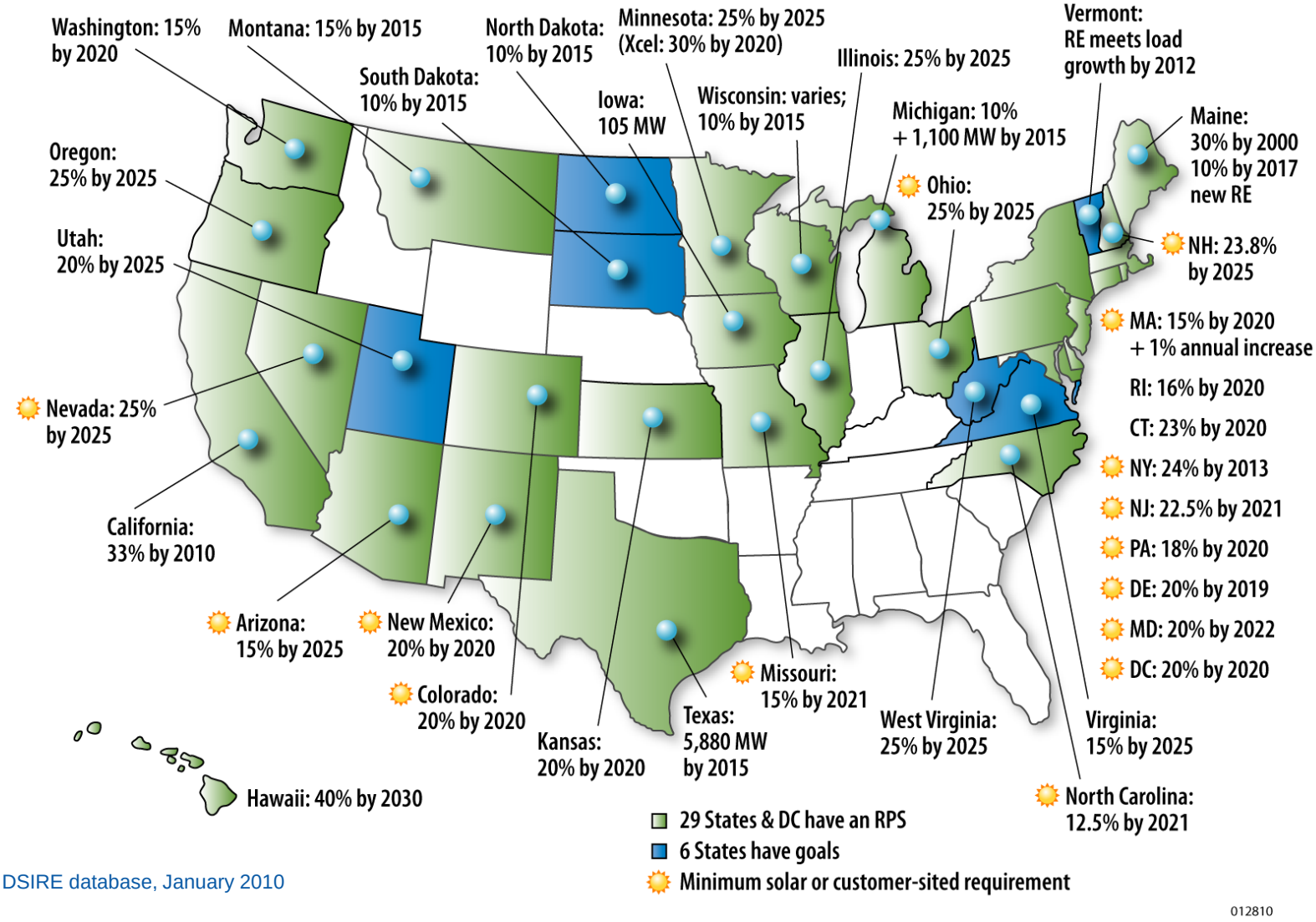


Michael Crowley, a senior scientist with the Chemical and Biosciences Center, created an animated model of Cel7A, nature's primary enzyme for decaying plants.

NREL: Managing the science-to-technology interface

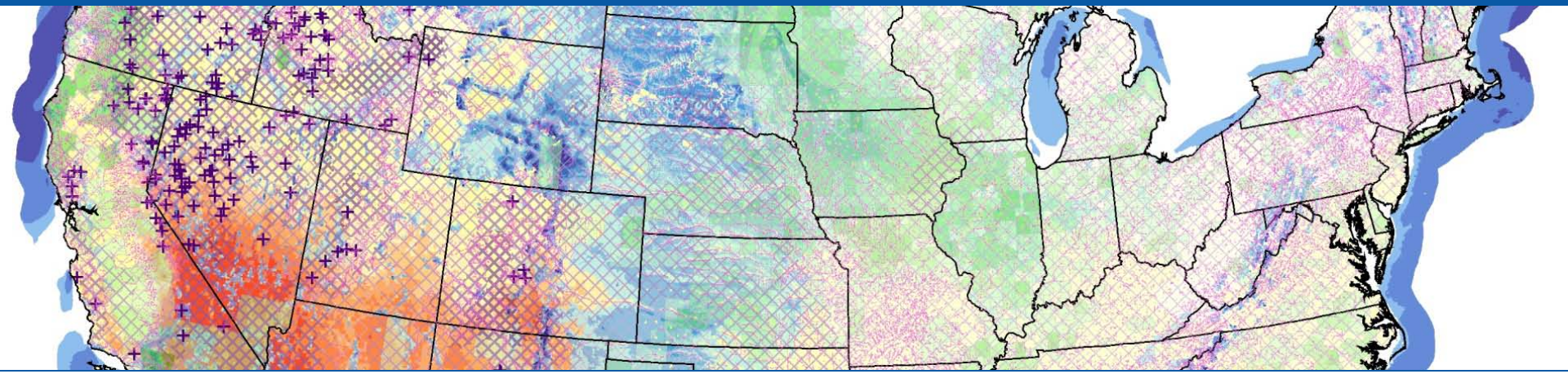
State Policy Framework

Renewable Portfolio Standards



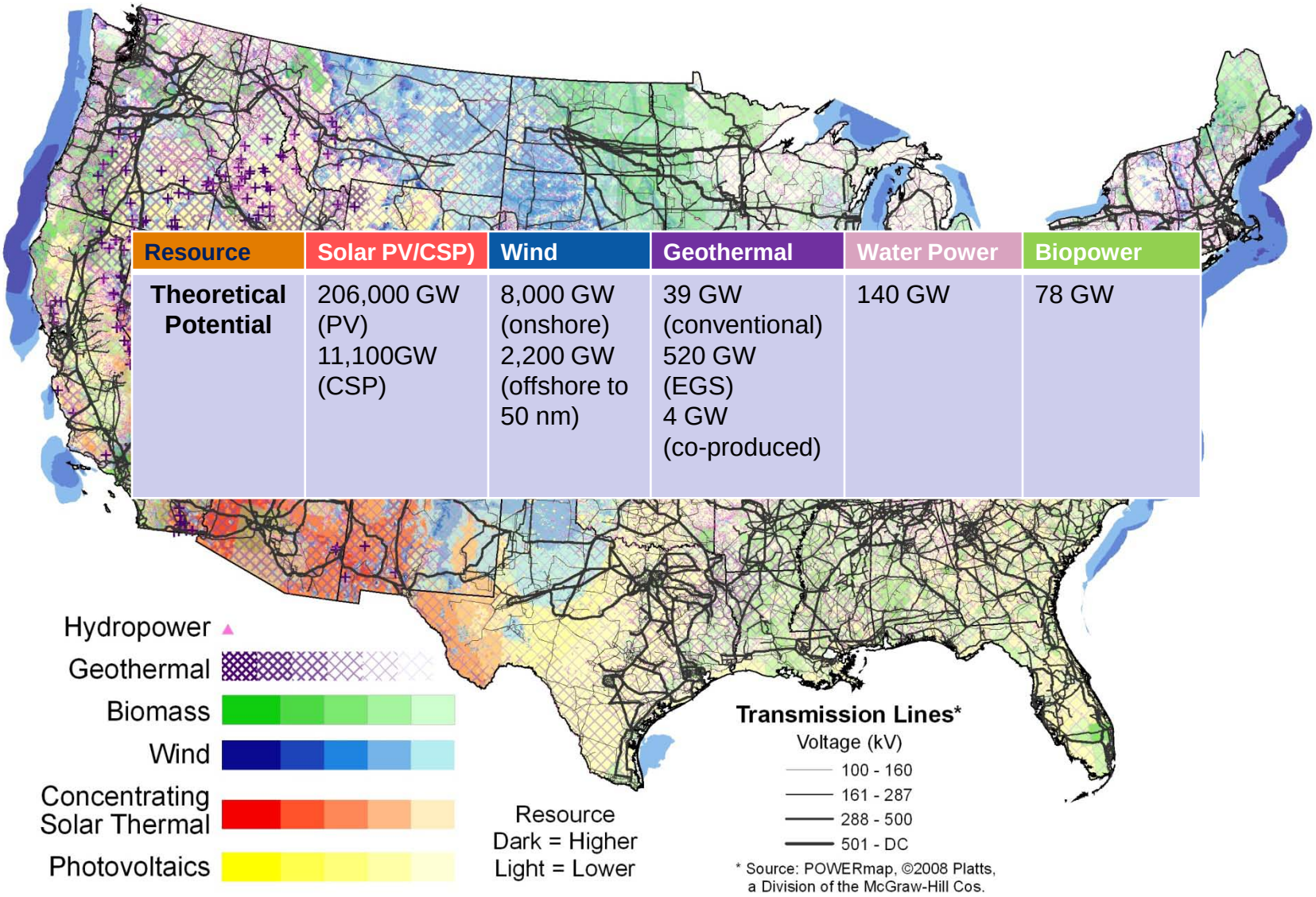
Source: DSIRE database, January 2010

Resource Potential



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



Energy Efficiency

Buildings

Status U.S. Buildings:

- 39% of primary energy
- 71% of electricity
- 38% of carbon emissions

DOE Goal:

- Cost effective, marketable zero energy buildings by 2025
- Value of energy savings exceeds cost of energy features on a cash flow basis

NREL Research Thrusts

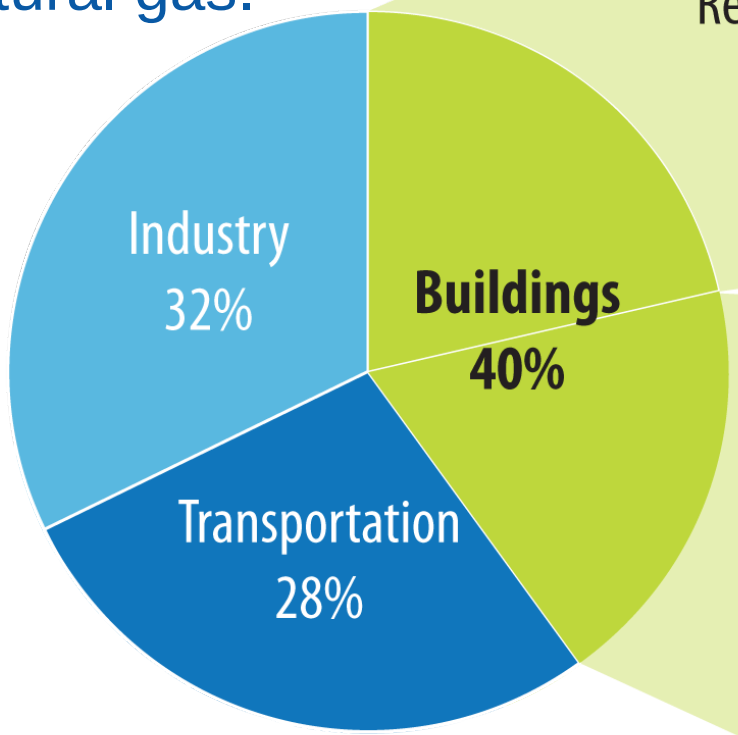
- Whole building systems integration of efficiency and renewable features
- Computerized building energy optimization tools
- Building integrated PV

Updated 7/09

Energy Used in Buildings

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

100.7 Quads of Total Use, 2005



Residential 22%

Computers	1%
Other	4%
Cooking	5%
Wet Clean	5%
Electronics	7%
Refrigeration	8%
Lights	11%
Cooling	12%
Water Heat	12%
Heating	32%

Commercial 18%

Cooking	2%
Computers	3%
Refrigeration	4%
Office Equipment	6%
Ventilation	6%
Water Heat	7%
Cooling	13%
Other	13%
Heating	14%
Lights	26%

Source: Buildings Energy Data Book 2007

Technology for Cost Effective Zero Energy Buildings

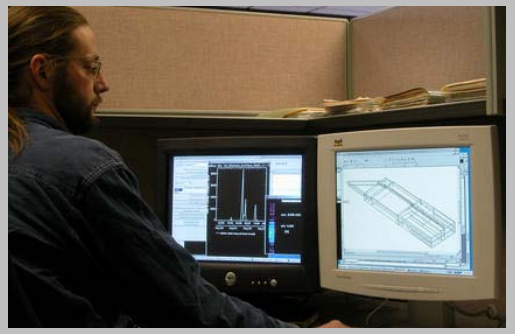
NREL Zero Energy Habitat House

BIPV Products & PV-T Array

Compressorless Cooling

Electrochromic Windows

Polymer Solar Water Heaters



Computerized optimization & simulation Tools

The Laboratory of the Future

Renewable Electricity Supply

Wind

Current Status in the U.S.

- 35,000 MW installed capacity
- Cost 6-9¢/kWh at good wind sites*

Long Term Potential

- At least 20% of the nation's electricity supply

DOE Cost Goals

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

*With no Production Tax Credit
Source: DOE, American Wind Energy Association

Updated 1/2010

Wind Energy Technology

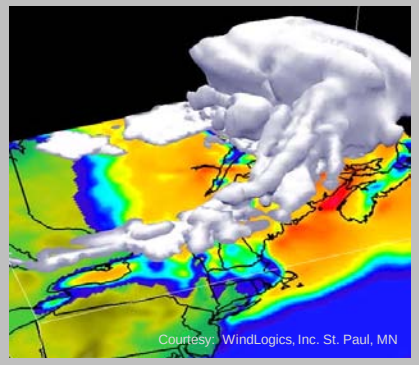
US Wind Resource Exceeds Total Electrical Demand

Offshore Wind

Innovative Tall Towers

Advanced Blades

Giant Multi-megawatt Turbines



Wind Forecasting

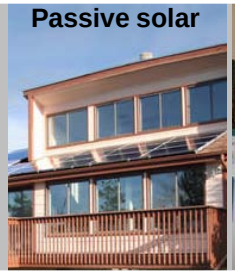
Wind Research Thrusts

- Improved performance and reliability
- Advanced rotor development
- Utility grid integration

The Siemens 2.3 MW turbine is among the largest land-based turbines deployed in the United States and is the largest at the NWTC site.

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 Concentrating Solar Power

U.S. Status

Photovoltaics

- 1,106 MW installed capacity
- Cost 16-32¢/kWh*

Concentrating Solar Power

- 419 MW installed capacity
- Cost 10-14¢/kWh*

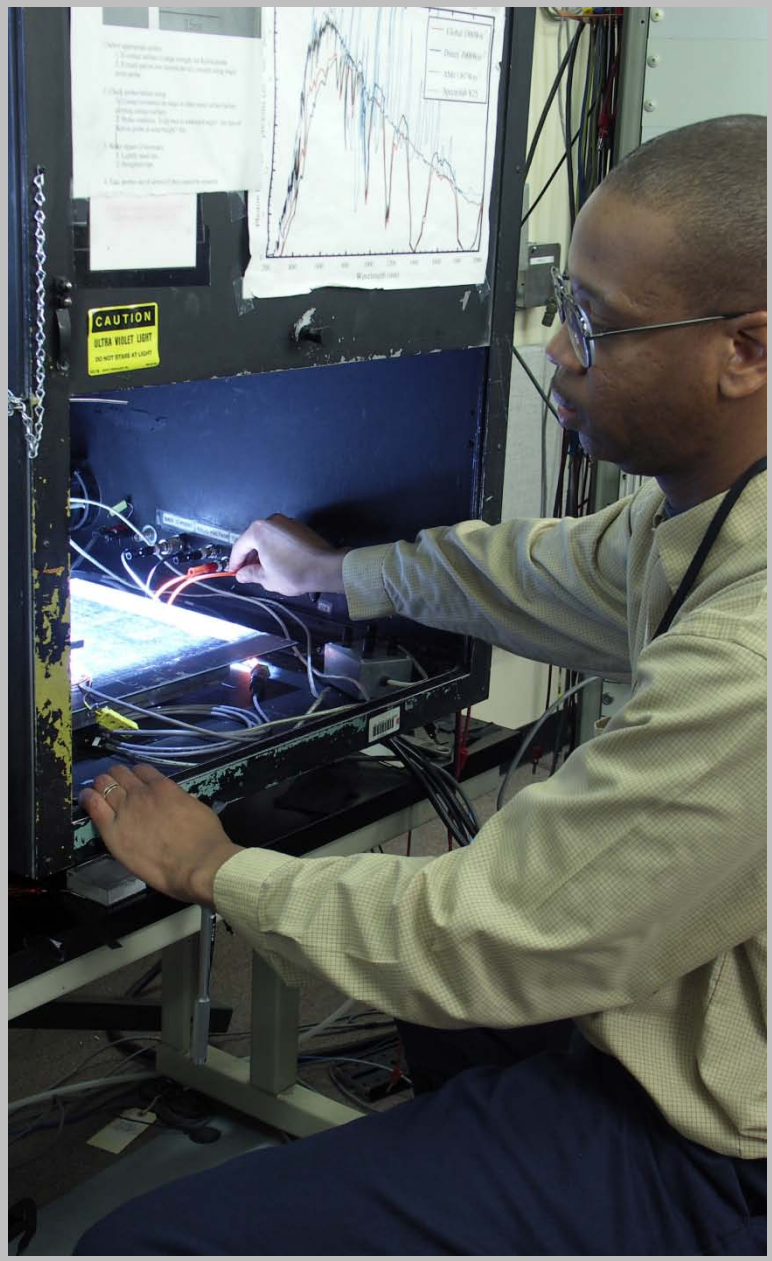
Potential

Photovoltaics

- 6-13 ¢/kWh by 2015*
- 6-15 ¢/kWh by 2030**

Concentrating Solar Power

- 8-11 ¢/kWh by 2015*
- 7-11 ¢/kWh by 2030**



* With 30% ITC
** With 10% ITC
Source: DOE/NREL 2010 program targets (currently under revision)

Updated 1/2010

Solar Research Thrusts

Photovoltaics

- Higher performance cells/modules
- New nanomaterials enabled technologies
- Advanced manufacturing techniques
- Improved reliability

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 solar plant

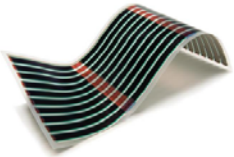
PV Conversion Technology Portfolio

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

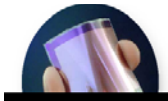
Thin Films (aSi)

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

[redacted]

[redacted]

Crosscut

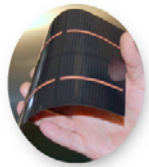
Synergistic technologies, evaluation approaches, and process engineering approaches applicable across multiple absorber materials and processes

Concentrating PV

Combining new, lower cost multijunction cells and innovative optical packages

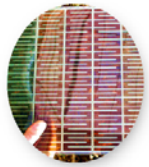
Thin Films (CIGS)

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

[redacted]

Geothermal

Current Status in the U.S.

- 3,153 MWe installed, 6443 MWe under development
- Cost 5-8¢/kWh with no PTC
- Capacity factor typically > 90%, base load power

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

Updated 1/2010

Geothermal

NREL Research Thrusts

- DOE lead for Low Temperature R&D
  - Oil/gas coproduction of electricity, direct use, geothermal heat pumps
- Analysis to define pathways for broad commercial impact of geothermal systems
- R&D in advanced power conversion systems
- Systems engineering/integration

DOE's Future Energy Cost Goals

- Near term: Hydrothermal sites at 5¢/kWh
- Longer term: Enhanced geothermal systems, huge resource at 5-10¢/kWh with mature technology

Drilling rig on South Table Mountain, testing for installation of geothermal heat pump showcase system at NREL.

Biomass Power

Current Status in the 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)

Biofuels

Biofuels

Current Status in the U.S.

- **Biodiesel**
  - 175 companies; 2.7 billion gallons/yr capacity[1]
  - 0.5 billion gallons produced in 2009
- **Corn ethanol**
  - 200 commercial plants[2]
  - 13.0 billion gal/yr capacity[2] (+1.4 billion gal/yr planned)
  - 10.5 billion gal produced in 2009
- **Cellulosic ethanol**
  - 30 demonstration plants funded and under construction

Sources: 1- National Biodiesel Board
2 - Renewable Fuels Association,
all other information based on DOE and USDA sources

Updated 1/2010

Biofuels

Key DOE Goals

- 2012 goal: cellulosic ethanol $1.49/gallon or ~$2.22/gge
- 2022 goal: 36B gal Renewable Fuel; 21B gal “Advanced Renewable Fuel,” 2007 Energy Independence and Security Act RFS

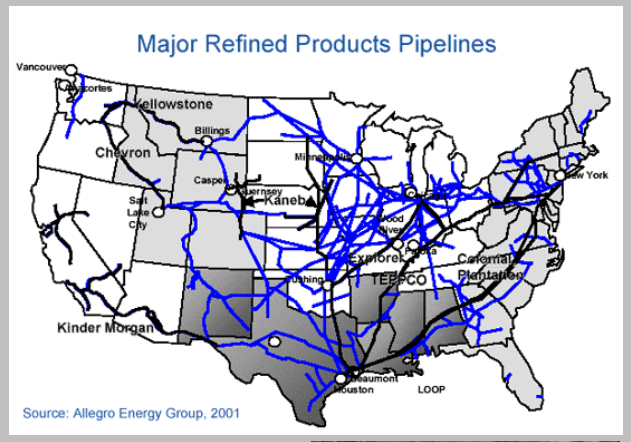
NREL Research Thrusts

- Cellulosic biomass conversion to cellulosic ethanol
- Advanced biofuels
- Algal biofuels
- Biofuels sustainability and technoeconomic analysis

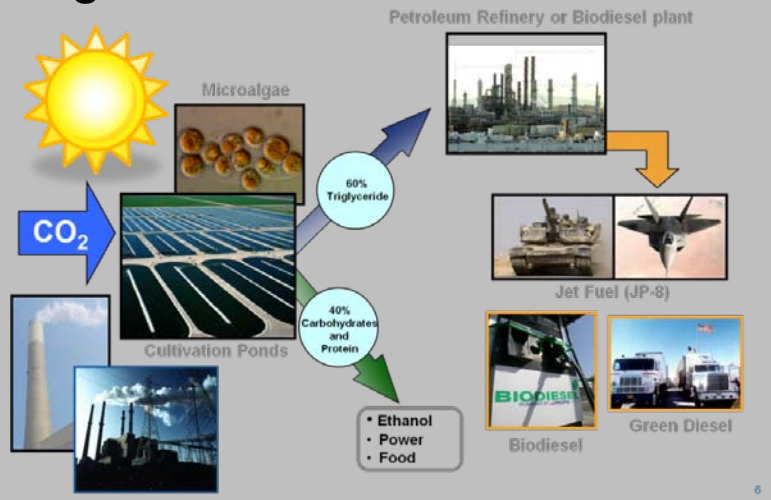
Why Follow-On Generations?

Advanced Biofuels – "beyond ethanol"

- Higher energy density/suitability
- Better temp and cold start ability
- Energy and tailored feedstocks
- Infrastructure compatibility



Algae



New Directions

Strategic Energy Analysis

Wind Research

Wind Integration Datasets

Wind Integration Datasets Home

- About the Datasets
- Eastern Wind Dataset
- Western Wind Dataset
- Help

About the Wind Integration Datasets

Here you can learn more about the Eastern and Western Wind Integration Datasets including the similarities and differences between the datasets. Both datasets provide time-series wind data for 2004, 2005, and 2006.

The Eastern Wind Dataset was originally created for the Eastern Wind Integration and Transmission Study and the Western Wind Dataset was originally created for the Western Wind and Solar Integration Study.

These Wind Integration Datasets are intended to be used by energy professionals such as transmission planners, utility planners, project developers, and university researchers.

The datasets were designed to help energy professionals:

- Perform spatial and temporal comparisons of sites including
  - Geographic diversity, and
  - Load correlation, and
- Estimate power production from hypothetical wind plants including
  - Needs for storage based on wind variability
  - Potential transmission line loadings, and
  - Simple economic calculations comparing in-state versus out-of-state costs of delivered energy.

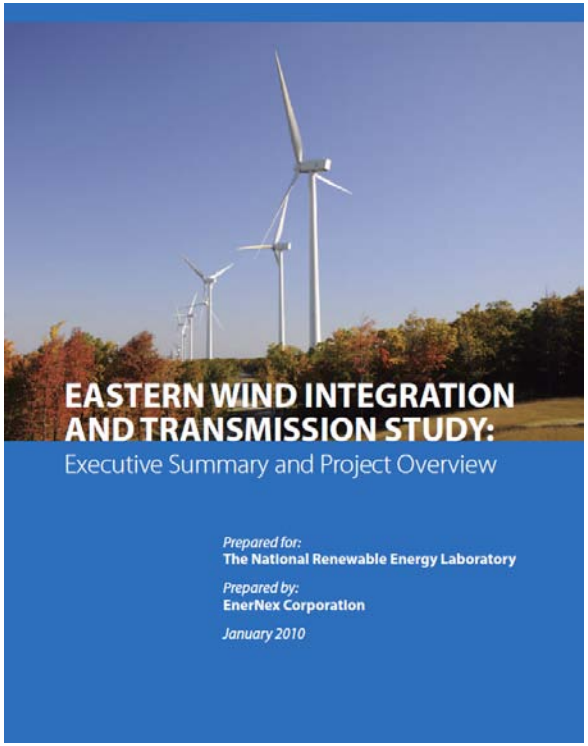
These datasets were NOT designed for:

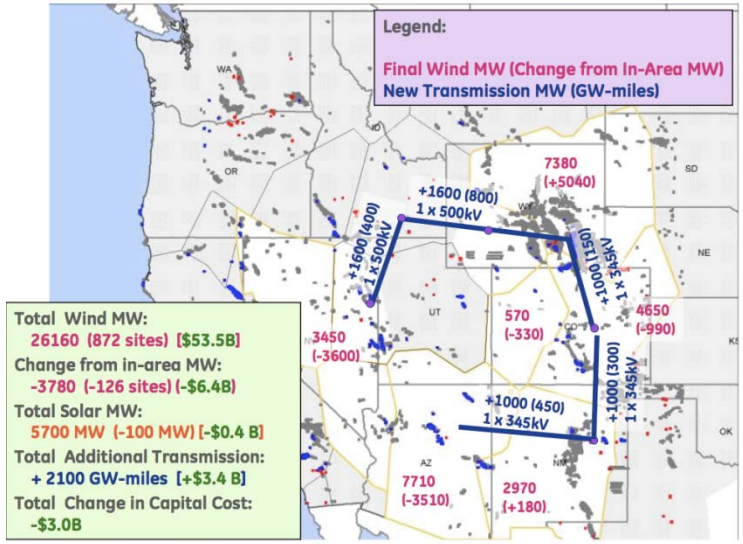
- Long-term average wind speed or wind power output
- Absolute accuracy of wind speed or power output for a particular site
- Use as the sole basis for a project investment.

Differences Between the Eastern and Western Datasets

The Eastern Dataset and the Western Dataset were created for very similar purposes and have the same period of record (1/1/2004-12/31/2006), but the data files and the methodology used to create them are not the same. The following table summarizes some of the differences between them.

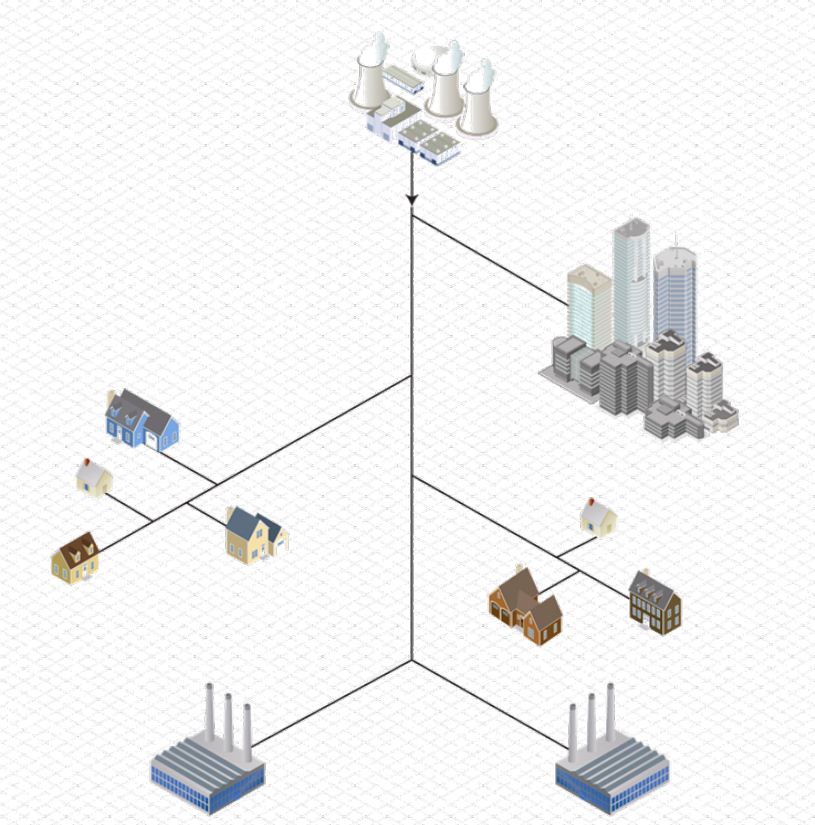
	Eastern Dataset	Western Dataset
Produced by	AWS-Truewind	3Tier
Mesoscale Model	MASS	WRF
Number of Output Points	1,326	32,043
Size of Output Point	5 km² to 160 km²	1 arc-minute²
Output Point Capacity (MW)	100 MW to 1435 MW	30
Model Output Heights (m agl)	80 m, 100 m	100 m
Turbine Power Curves	3 composite curves (each is the average of 2 or 3 commercial turbine power curves)	Vestas V-90 3MW



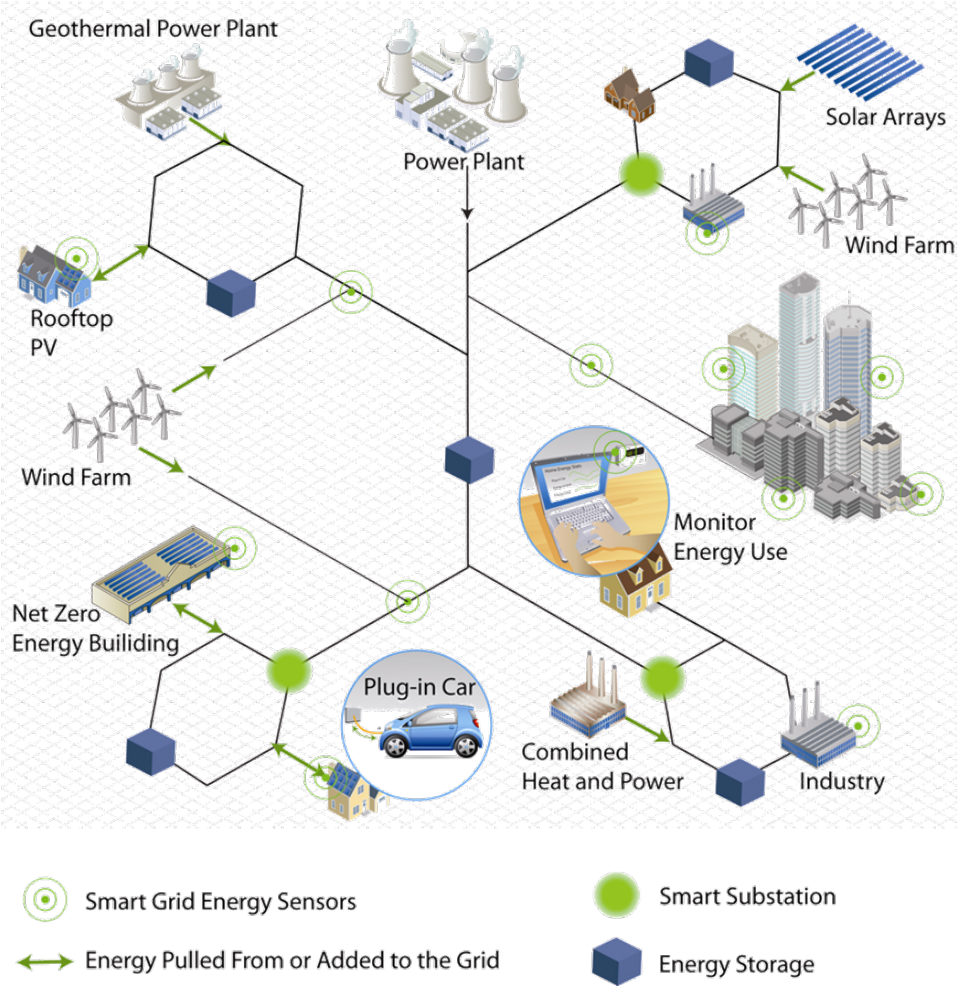


Smart Grid – Renewable Energy Integration in Systems at All Scales

Today

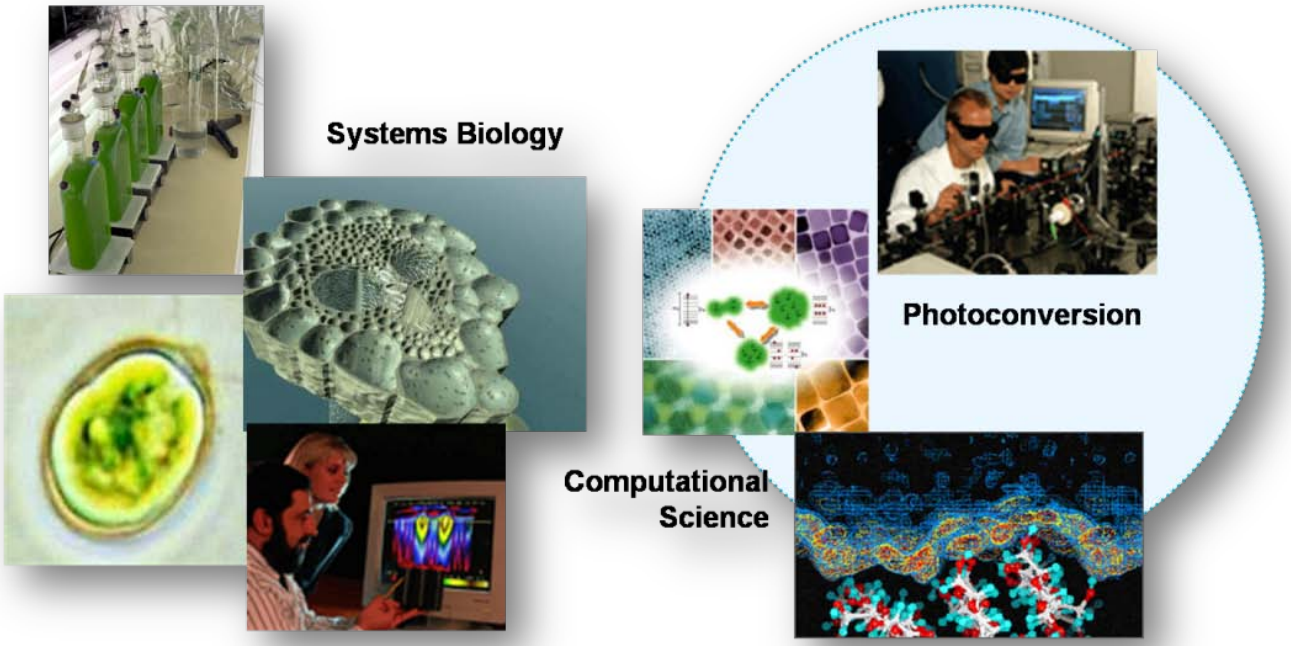


Future



Energy Systems Integration Facility

Commitment to Breakthrough Innovation



Managing the science-to-technology interface

An Integrated Approach is Required

Making Transformational Change

NREL Ten Year Site Plan

Visit us online at www.nrel.gov