National Renewable Energy Laboratory
Innovation for Our Energy Future

NREL Overview

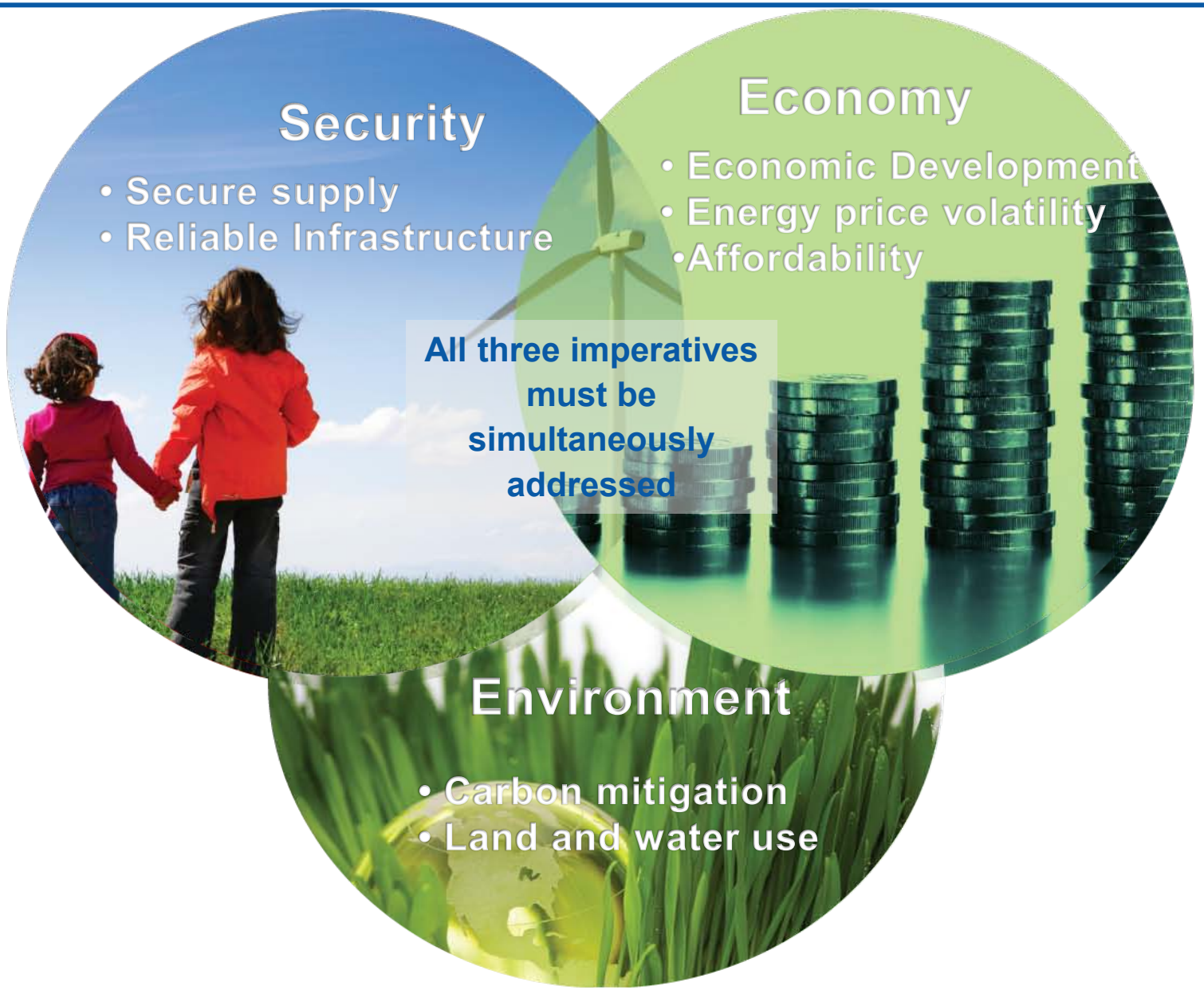
Dr. Dan E. Arvizu

Laboratory Director

March 23, 2010

NREL is a national laboratory of the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy operated by the Alliance for Sustainable Energy, LLC

Energy Challenges



Achieving a Sustainable Energy Economy

*Requires a National Energy Grand Challenge**

Lead Coordinated RD3E Strategy in Sustainable Energy

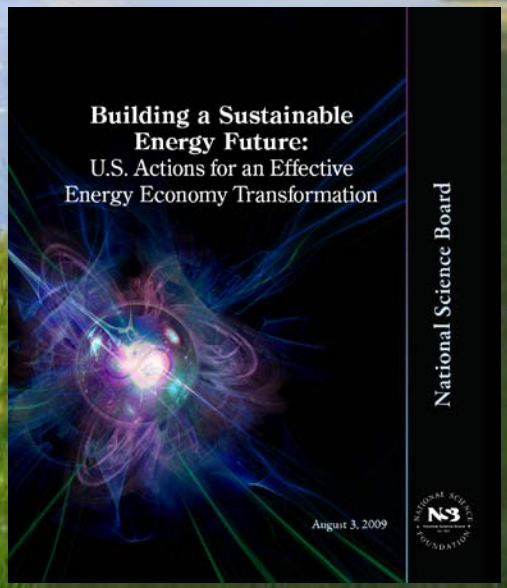
Boost R&D Investment

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

100 Quads

Oil 40%

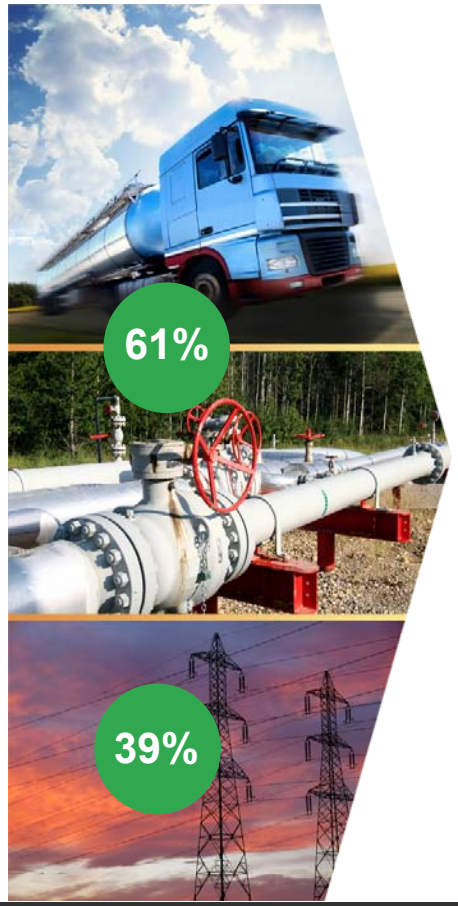
Coal 23%

Natural Gas 23%

Nuclear 8%

Hydro
Wind
Solar
Biomass
Geothermal
6%

Transmission & Distribution



Utilization

27%

40%

33%

Lost energy as inefficiencies – 62%

New National Priorities

Creating new Jobs in the Clean Energy Economy. Drive the development of new, green jobs that pay well and cannot be outsourced.

Investing in the Next Generation of Energy Technologies. Invest $150 billion over ten years in energy research and development to transition to a clean energy economy.

Breaking Dependence on Oil. Promote the next generation of cars and trucks and the fuels they run on.

Producing More Energy at Home. Enhance U.S. energy supplies through responsible development of domestic renewable energy, fossil fuels, advanced biofuels and nuclear energy.

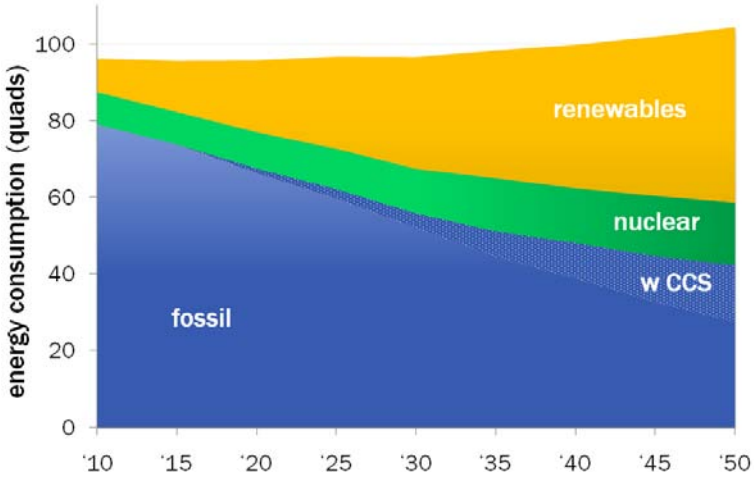
Promoting Energy Efficiency. Promote investments in the transportation, electricity, industrial, building and agricultural sectors that reduce energy bills.

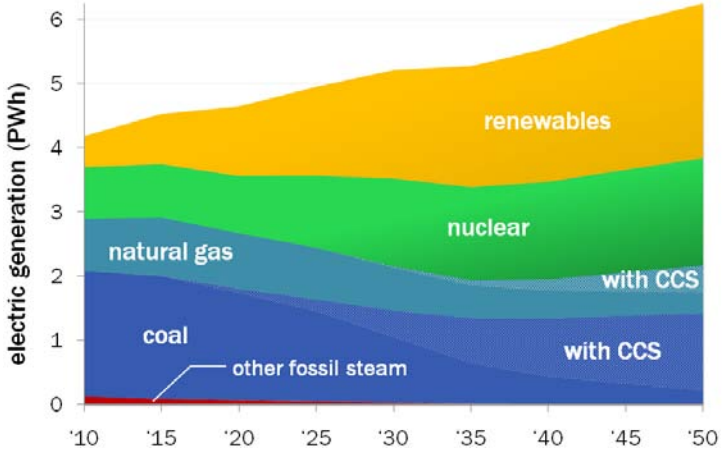
Closing the Carbon Loophole. By stemming carbon pollution through a market-based cap, we can address in a systematic way all the energy challenges that we face: curbing our dependence on foreign oil, reducing our use of fossil fuels, and promoting new industries right here in America.

G8Website/ANSA Photo: Alessandro Di Meo

Strategic Technology for Energy Plan (STEP) to Frame FY12 Budget

Minimal Case: (a) total US energy consumption, and (b) electric generation (hydropower counted in renewables)





Business Sensitive – Do Not Cite

A Profound Transformation is Required

Today's Energy System

- Dependent on foreign sources
- Subject to price volatility
- Increasingly vulnerable energy delivery systems
- 2/3 of source energy is wasted
- Produces 25% of the world's carbon emissions
- Role of electricity increasing

Sustainable Energy System

- Carbon neutral
- Highly efficient
- Diverse supply options
- Sustainable use of natural resources
- Creates American jobs
- Accessible, affordable and secure

A Profound Transformation Requires…

Light, heat, power

Mobility and access

- Continuing advances in science and technology to reduce cost and enable impact at scale
- A much stronger *systems focus*
  - Recognize the energy system is a energy 'system of systems'
  - Focus on efficiently delivering future energy services
  - Make optimal use of all energy resources
  - Adapt existing infrastructure
  - Holistically design new infrastructure
- Concerted and coordinated efforts between government and private sector
- Greater understanding of options and their implications to guide decisions

NREL's impact will be delivered through commercialization and deployment of innovations designed to be integrated in five key systems

Focused on Sustainable Systems

Today's Energy System

Sustainable Energy System

Community & Industrial Systems

Integrated Systems
Sustainable Design

Electricity Generation & Delivery Systems

Distributed & Utility-Scale Renewable Power

Highly Efficient • Integrated Renewables

The Built Environment

Fuel Production Systems

Renewable Fuels

Highly Efficient • Fuel Flexible

Transportation Systems

Aligned with System Outcomes

2050 Reduce oil use to <15% of current levels and CO_2 emissions by >80%

System of Systems

2030 System Outcomes

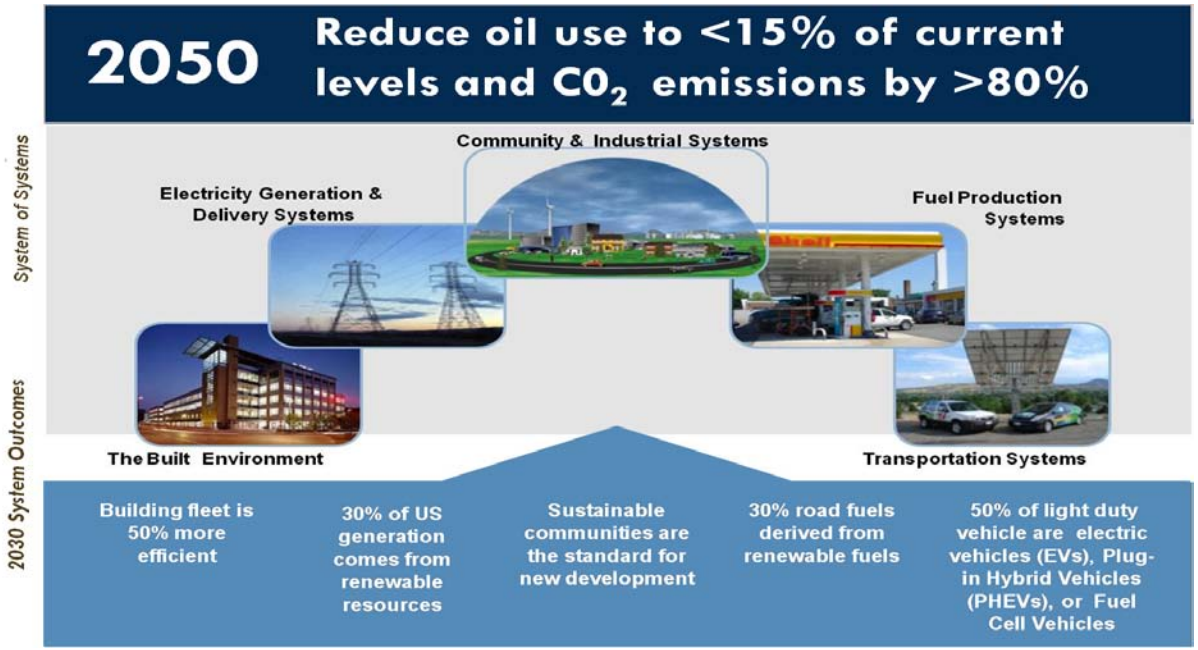
- Building fleet is 50% more efficient
- 30% of US generation comes from renewable resources
- Sustainable communities are the standard for new development
- 30% road fuels derived from renewable fuels
- 50% of light duty vehicle are electric vehicles (EVs), Plug-in Hybrid Vehicles (PHEVs), or Fuel Cell Vehicles

The Revised Strategy Construct

National Context

NREL Mission Focus

Intended Strategic Approach



NREL Strategy for Impact

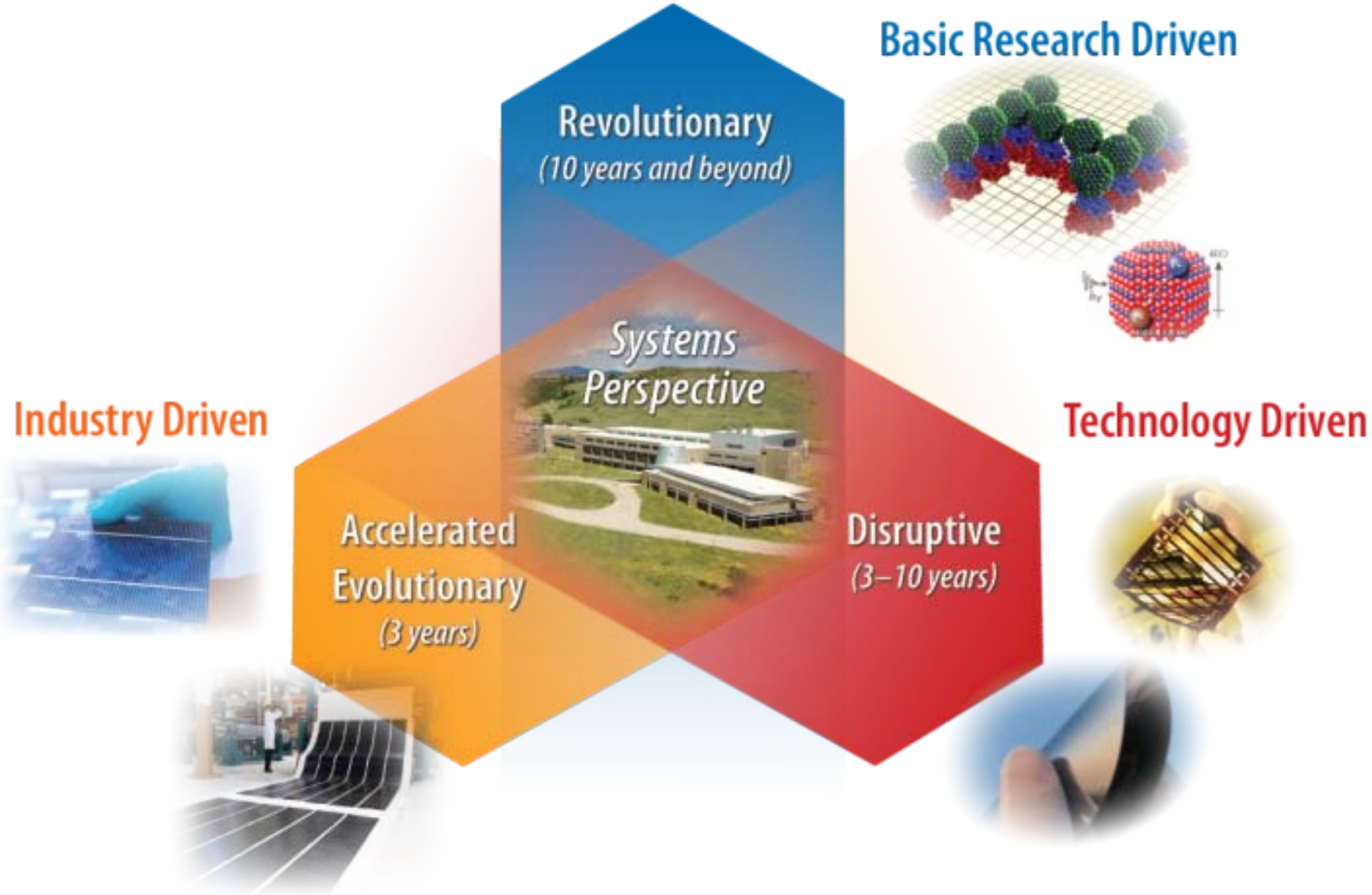
Focused on the What it Takes to Transform Each System

An Integrated Strategy Across S&T, C&D, Analysis (Focus & Accomplishments)

Distinctive Competencies: Building on Technology-Specific Strengths to Address Integrated Systems of All Scales and Across Disciplines and Institutions

Enabling Environment: Lab of the Future

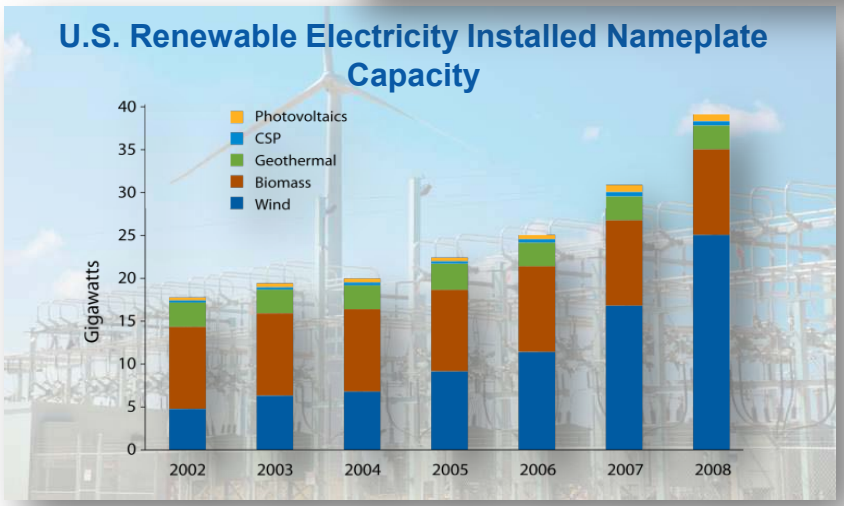
Achieving the Potential Requires A Balanced Portfolio



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

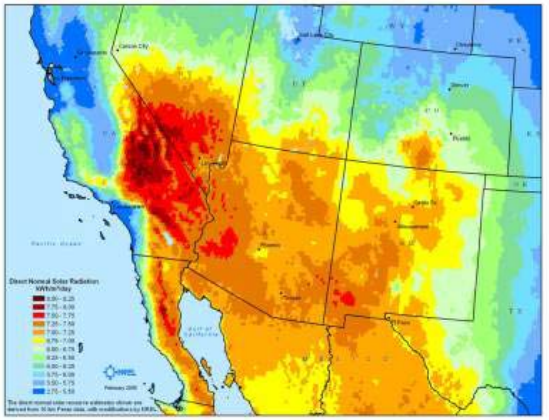
NREL Provides Data, Tools and Technical Assistance to:

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

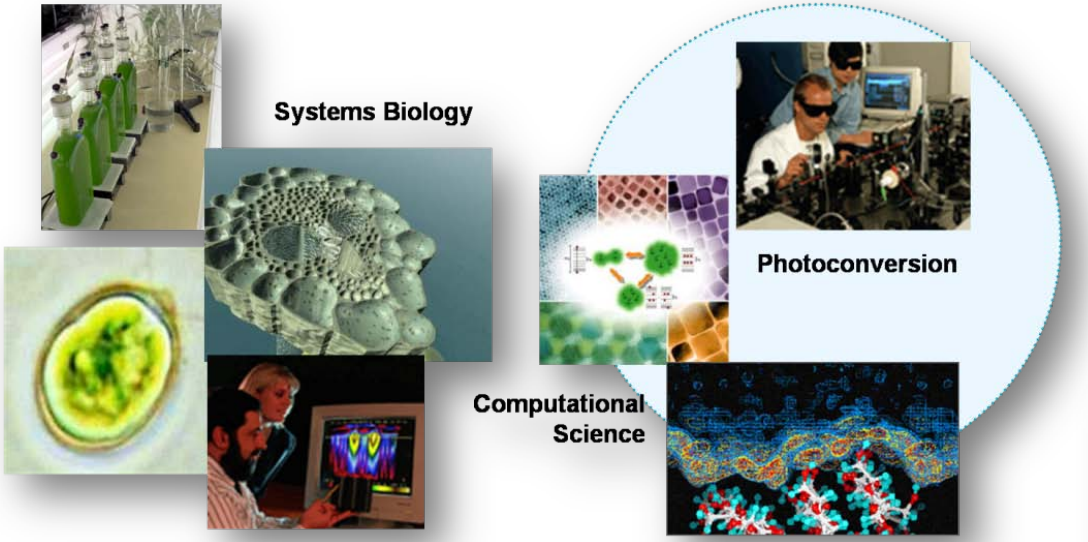
Unique Partnering Facilities

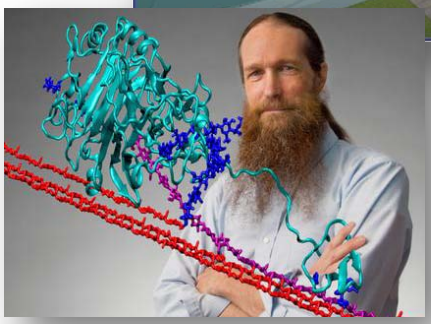
Testing and Validation Capabilities

Integrated Biorefinery Research Facility

Energy Systems Integration Facility

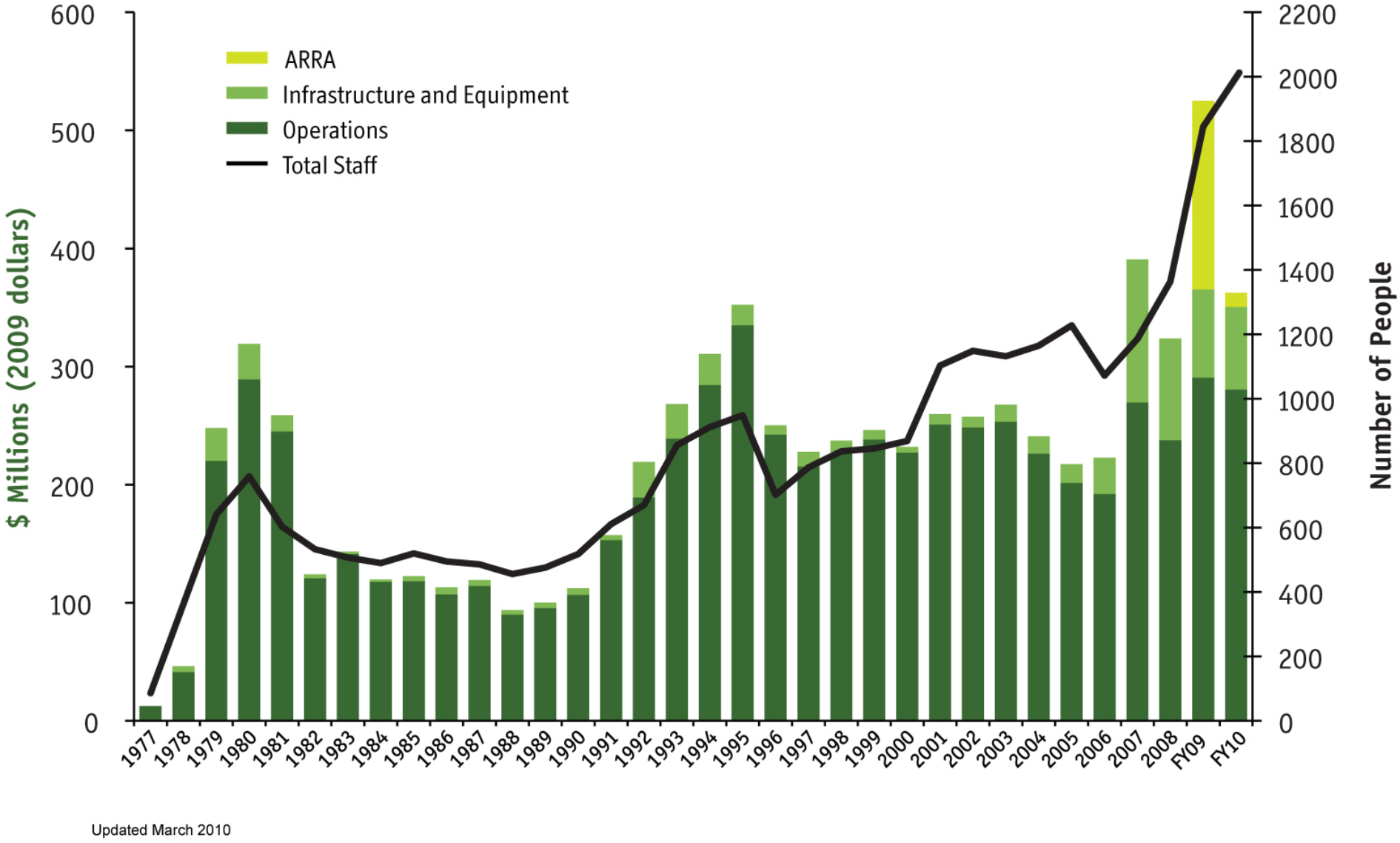
Long-Term Impact: Requires Breakthrough/Translational Science





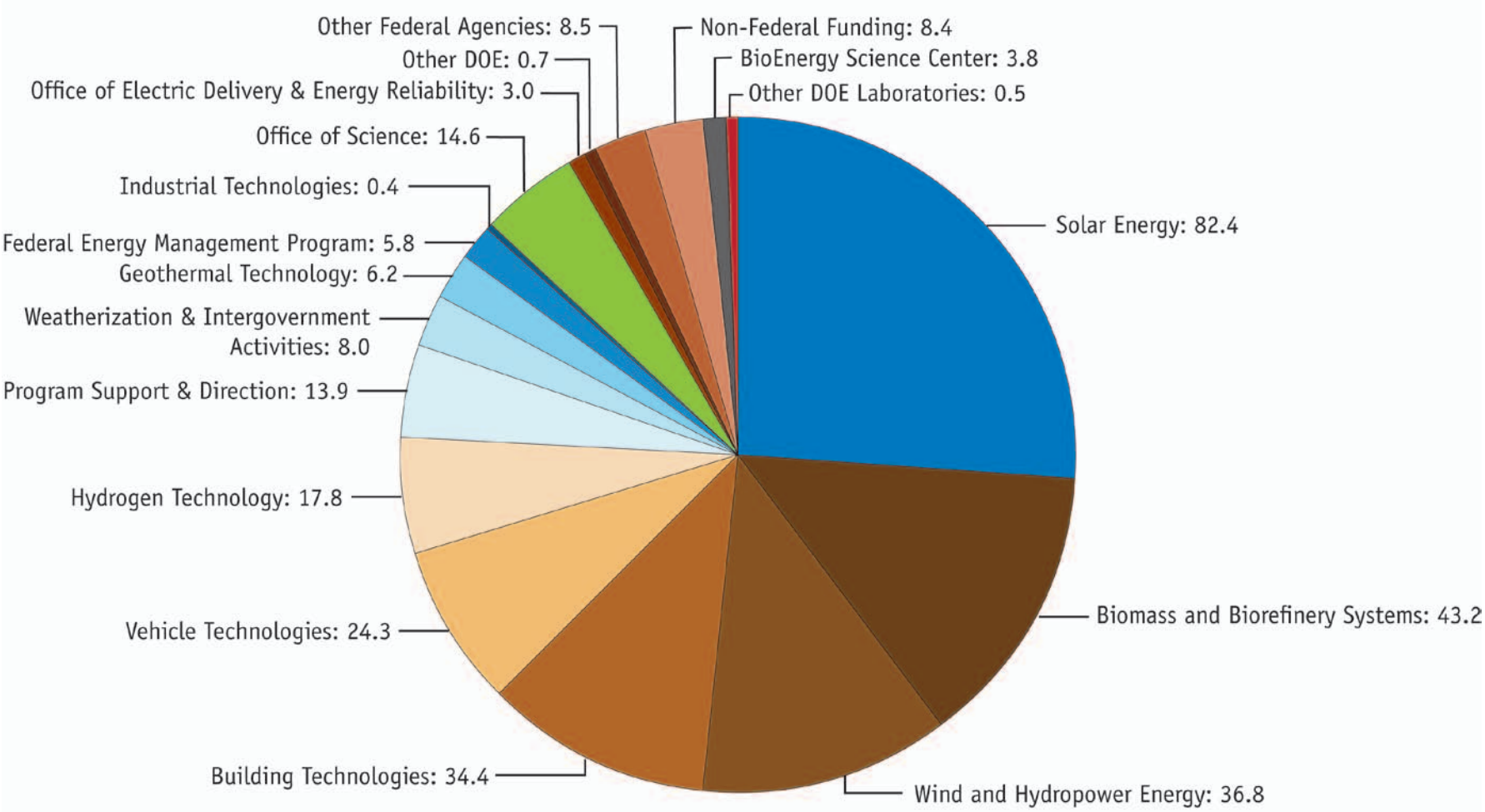
Managing the science-to-technology interface

NREL Funding and Staffing



Updated March 2010

NREL FY2010 Program Portfolio $312.7M*
(Est)



Recovery Act Funds Included above:	2010
EERE Research Programs	*$ 16.0*
Office of Science	*0.0*
Other Federal Agencies	*0.0*

*Does not include Construction & Infrastructure = $63.7M

Energy Efficiency

Buildings

Status U.S. Buildings:
- 39% of primary energy
- 71% of electricity
- 38% of carbon emissions

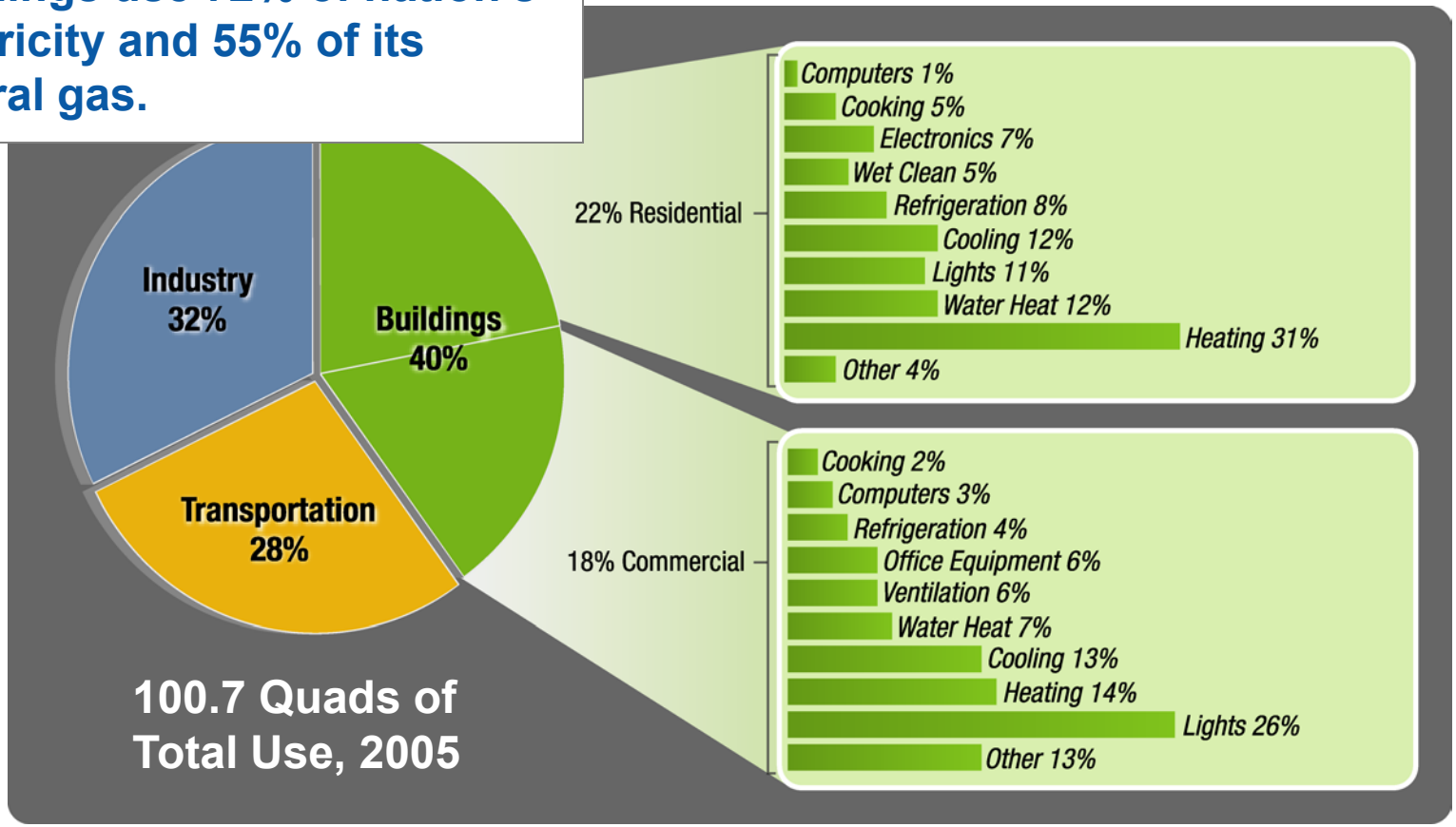
DOE Goal:
- Cost effective, marketable zero energy buildings by 2025
- Value of energy savings exceeds cost of energy features on a cash flow basis

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

April 10, 2008

Energy Used in Buildings

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

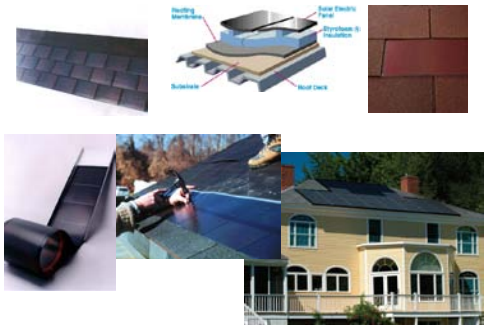


Buildings use 72% of the nation's electricity and 55% of its natural gas.

Source: *Buildings Energy Data Book 2007*

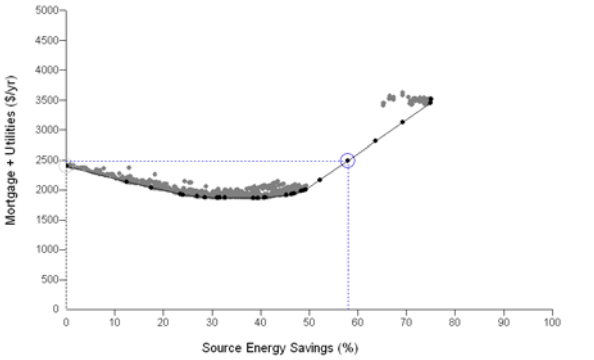
Technology for Cost Effective Zero Energy Buildings

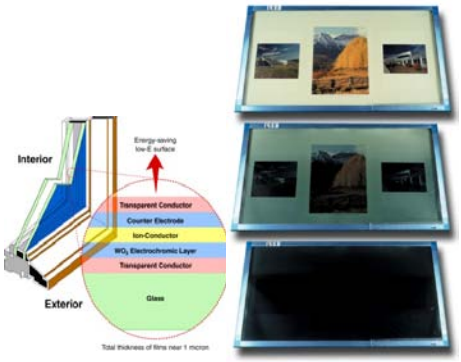
NREL Zero Energy Habitat House



BIPV Products & PV-T Array

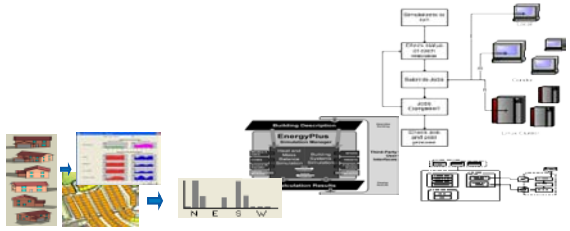
Compressorless Cooling





Electrochromic Windows

Polymer Solar Water Heaters



Computerized optimization & simulation Tools

Renewable Electricity Supply

Wind

Today's Status in U.S.

- 35,000 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

At least 20% of the nation's electricity supply

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.

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

Updated 1/10

The “20% Wind Report” Informs Our RD&D

The 20% Wind Energy by 2030 Scenario

How it began:

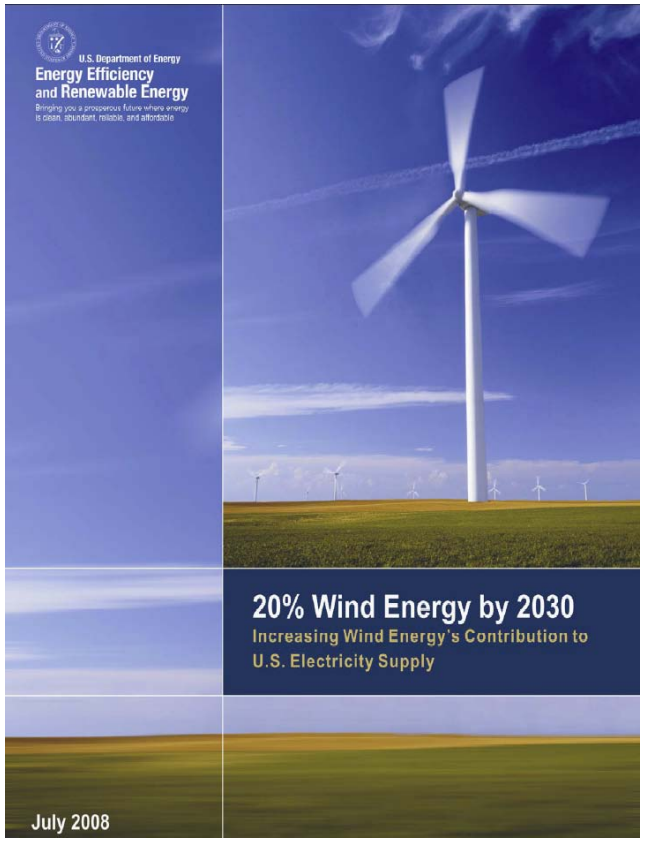
- 2006 State of the Union and Advanced Energy Initiative
- Collaborative effort of government and industry (DOE, NREL, AWEA) to explore modeled energy scenario where wind provides 20% of U.S. electricity by 2030

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 15% by 2030
- Wind turbine costs decrease 10% by 2030
- No major breakthroughs in wind technology

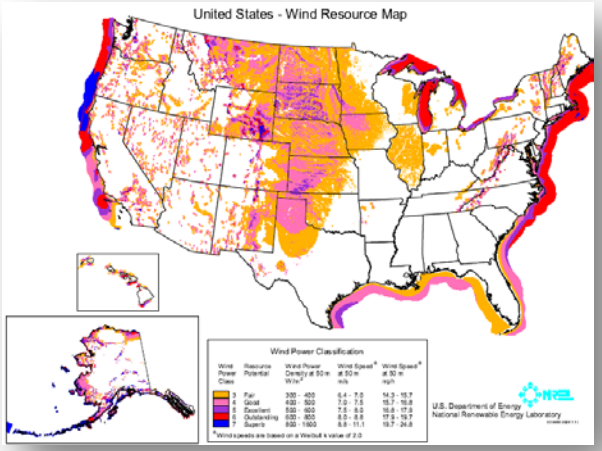
Primary Findings:

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



www.eere.energy.gov/windandhydro

Wind Energy Technology



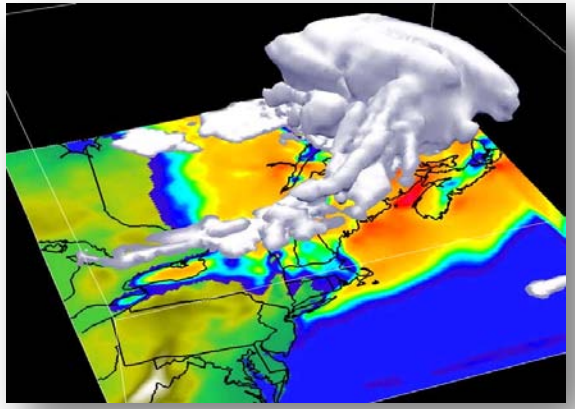
US Wind Resource Exceeds Total Electrical Demand

Offshore Wind

Advanced Blades

Innovative Tall Towers

Giant Multi-megawatt Turbines



Courtesy:WindLogics, Inc. St. Paul, MN

Wind Forecasting

NREL Research Thrusts

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

Photo credit: Megavind

Solar – Photovoltaics and CSP

Status in U.S.

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

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

Potential:

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

CSP
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).

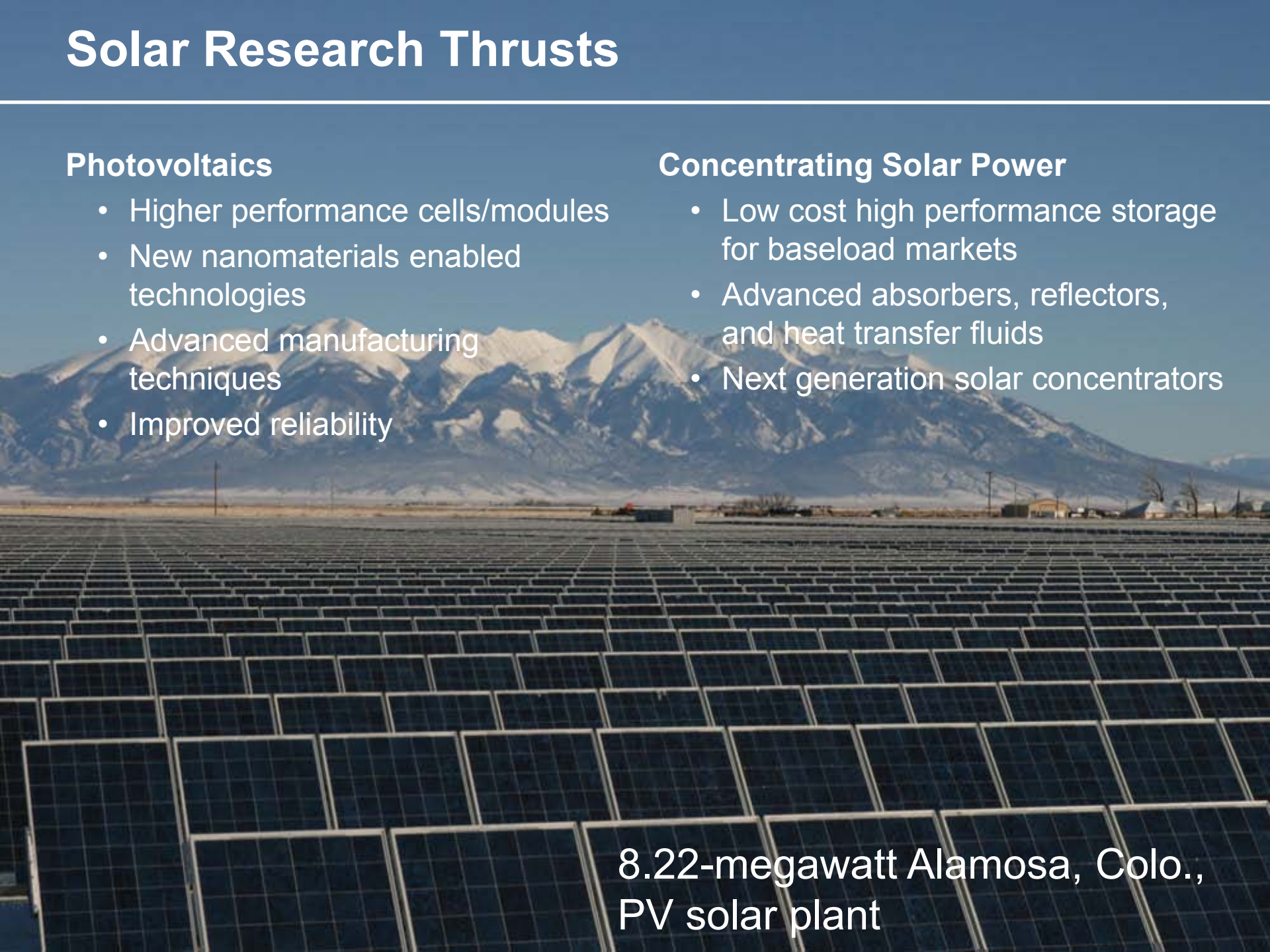
Solar Research Thrusts

Photovoltaics

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

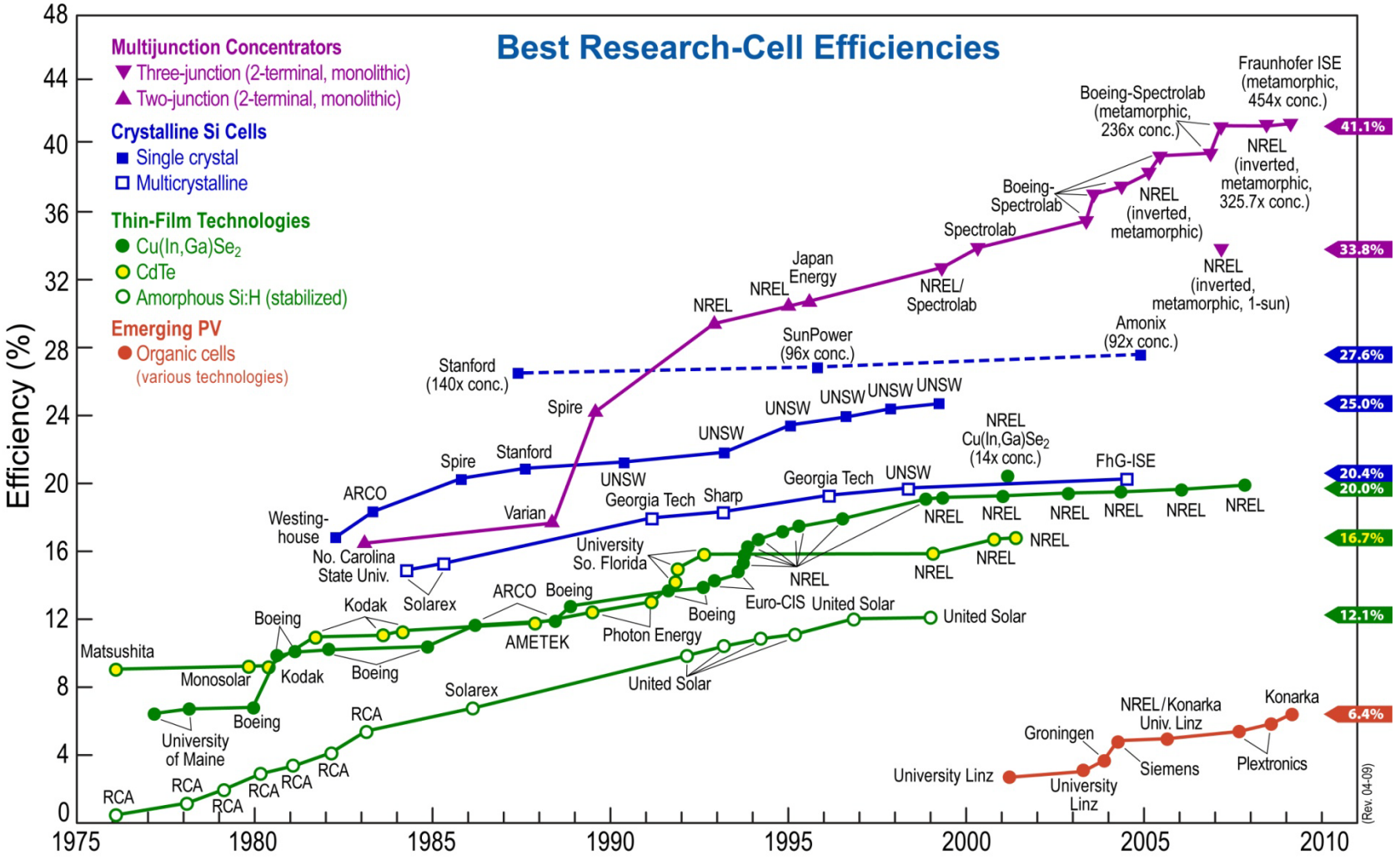
Concentrating Solar Power

- 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 Technologies—Decades of NREL Leadership



Geothermal

Today's Status in U.S.

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

Future Energy Cost

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

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

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

Updated 1/10

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)

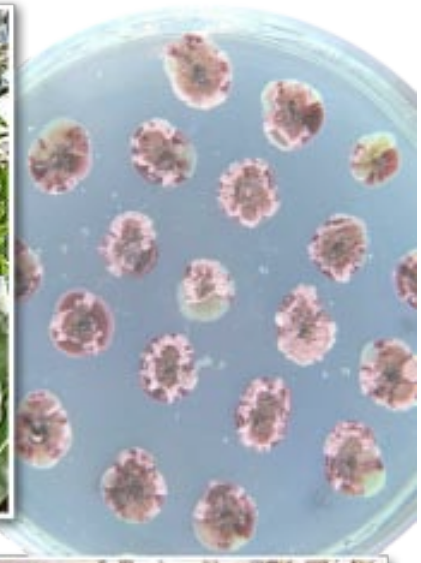
1/2010

Biofuels

Biofuels

Current Biofuels Status in 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



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

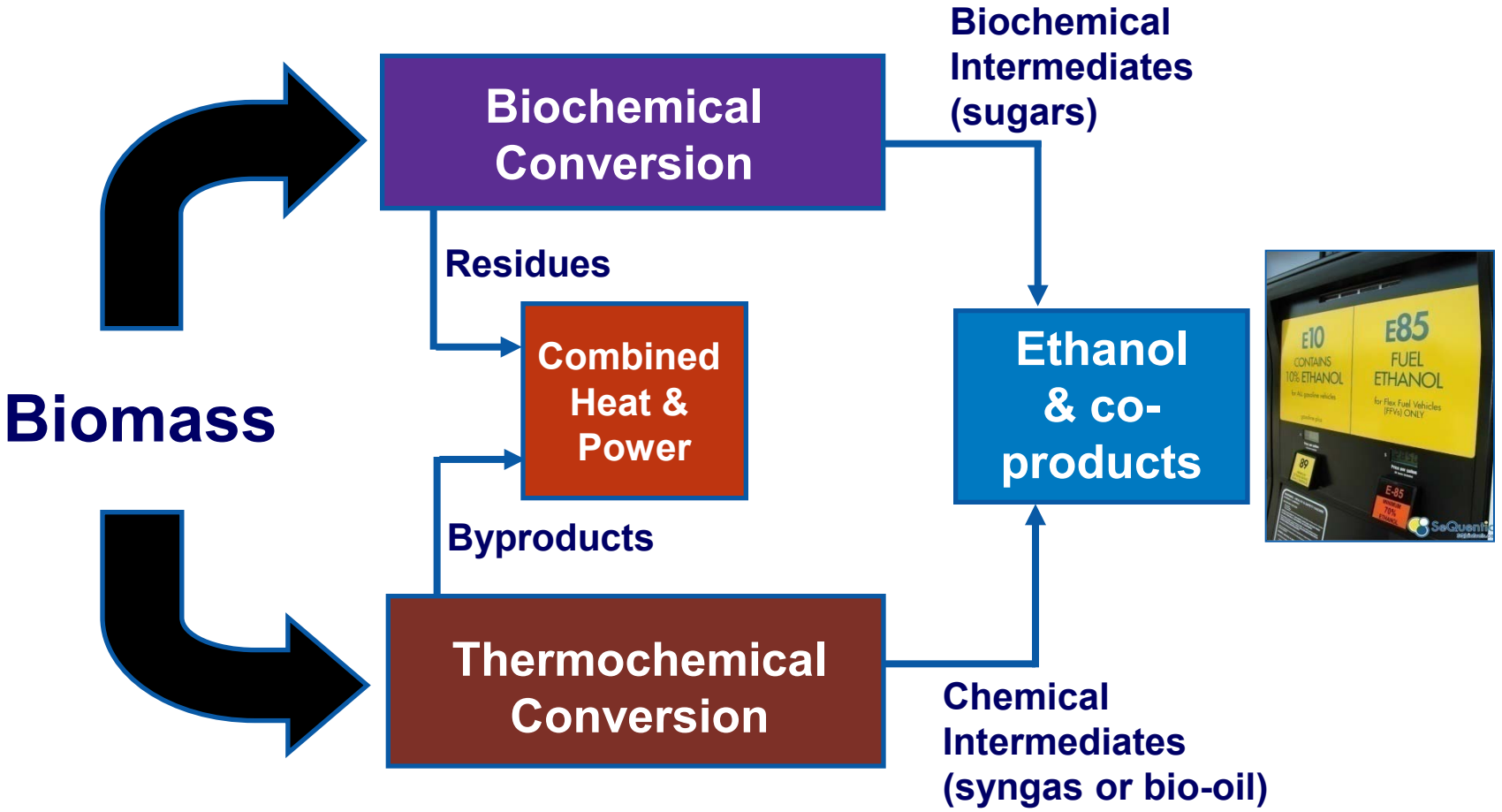
NREL Research Thrusts

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

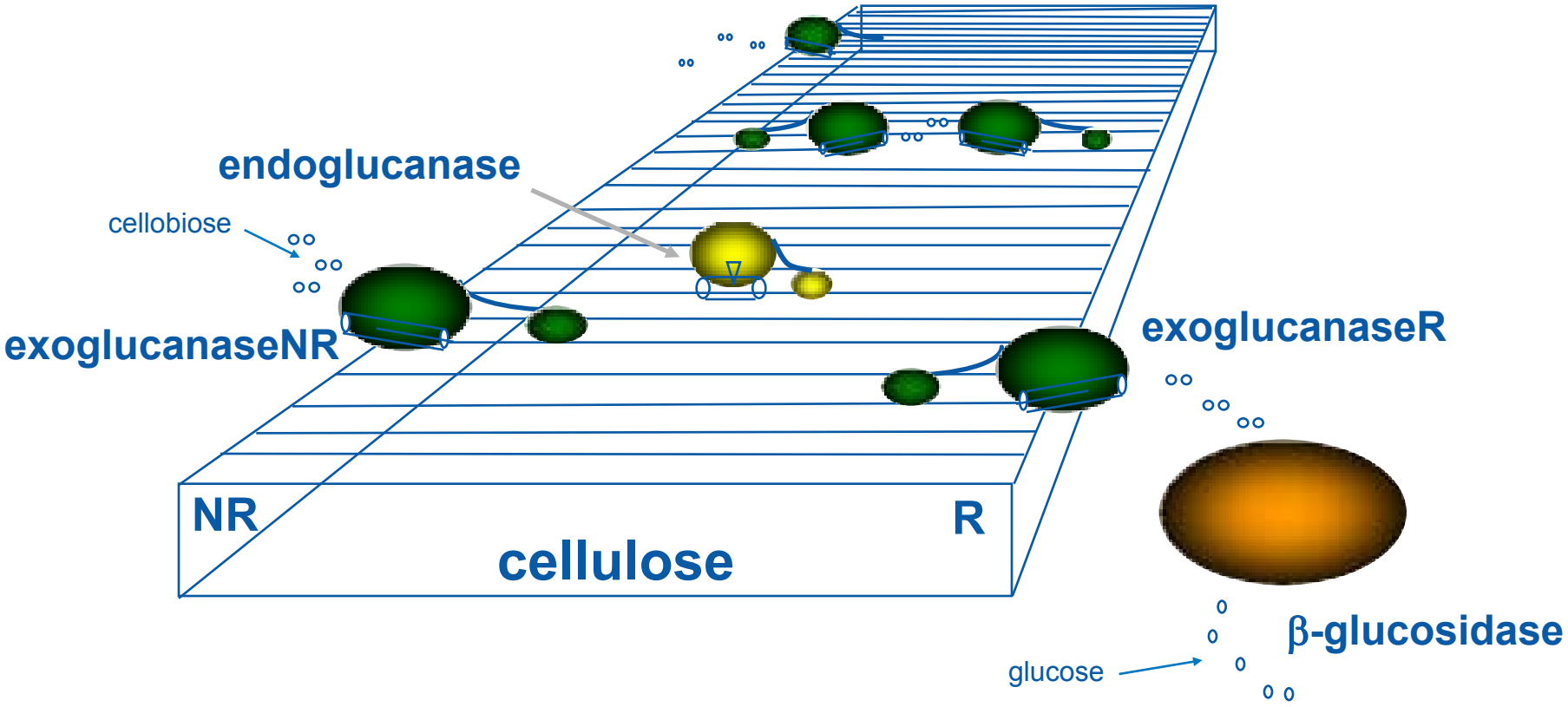
Updated January 2010
Sources: 1- National Biodiesel Board
2 - Renewable Fuels Association,
all other information based on DOE and USDA sources

Generation 2—Cellulosic Ethanol

2nd generation—from lignocellulosic biomass materials, primarily producing ethanol via biochemical or thermochemical conversion



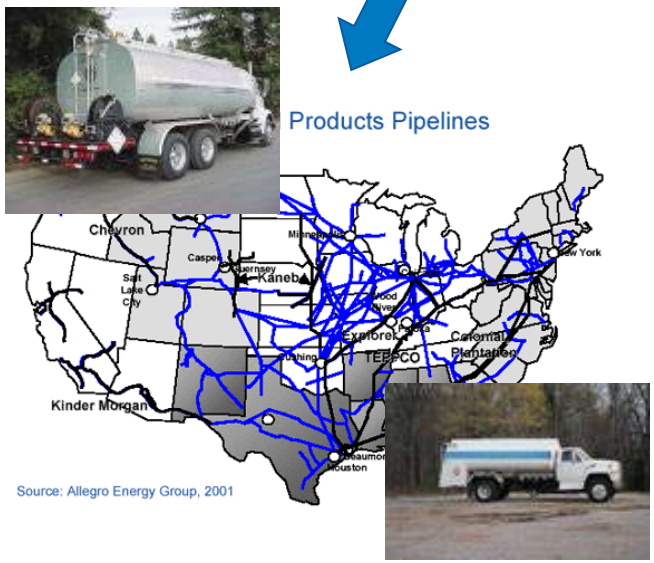
Action of Fungal Cellulases

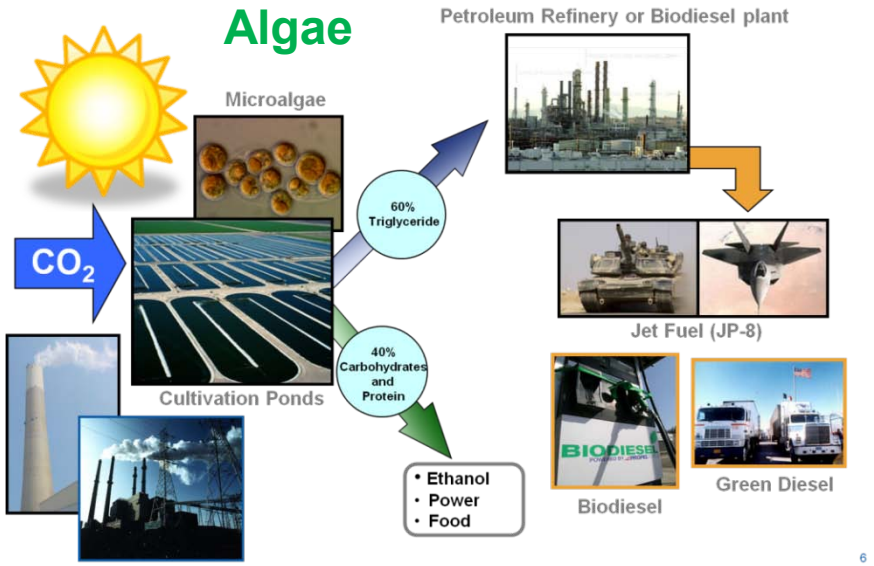


Why Follow-On Generations?

Advanced Biofuels – "beyond ethanol"

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





Sustainable Transportation

Plug-In Hybrid Electric Vehicles (PHEV)

Status:

- PHEV-only conversion vehicles available
- OEMs building prototypes, and several about to come to showrooms
- NREL PHEV Test Bed

NREL Research Thrusts

- Energy storage
- Advanced power electronics
- Vehicle ancillary loads reduction
- Vehicle thermal management
- Utility interconnection
- Vehicle-to-grid

Key Challenges

- Energy storage – life and cost
- Utility impacts
- Vehicle cost
- Recharging locations
- Tailpipe emissions/cold starts
- Cabin heating/cooling
- ~33% put cars in garage

Updated January 2010

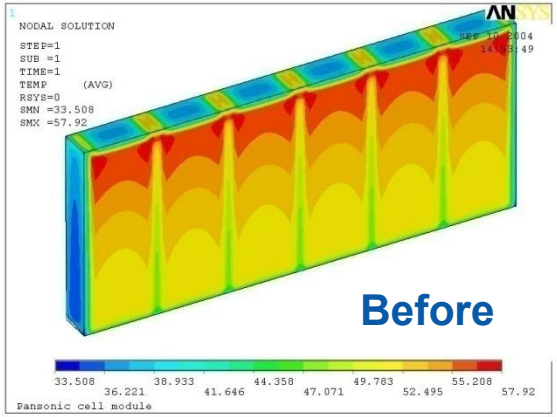
Advanced Vehicle Technologies

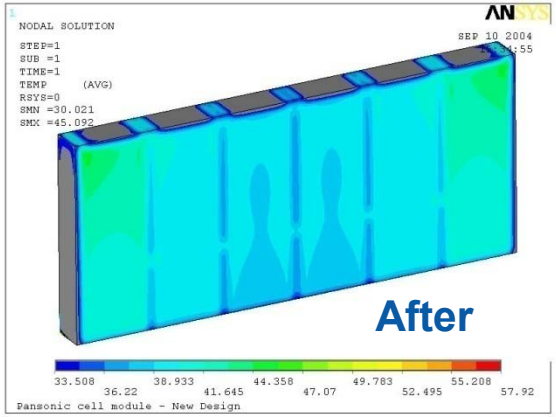
Energy Storage

Batteries & UltraCaps

Advanced Power Electronics

Vehicle Ancillary Loads Reduction





Hydrogen and Fuel Cells

Fuel Cells and Hydrogen

U.S. Status

- 400+ fuel cell vehicles on the road
- > 60 hydrogen fueling stations

2015 Goals

Hydrogen Production

- $2-3/Kg for all pathways
- Renewables in $5-10/Kg range

Fuel Cells

- $30/kW for transportation fuel cells
- 5,000 hour stack life

NREL Research Thrusts

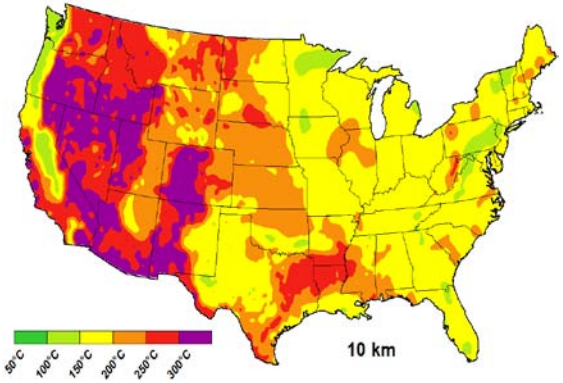
- Renewable H_2 production
- Fuel Cell
- Safety/codes/standards
- Early market introduction

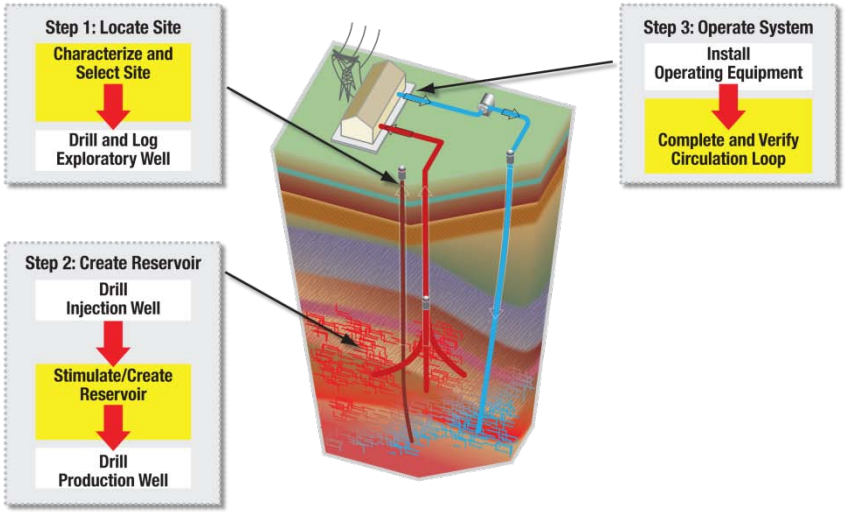
Updated January 2010

New Directions

Evaluating Potential New Directions

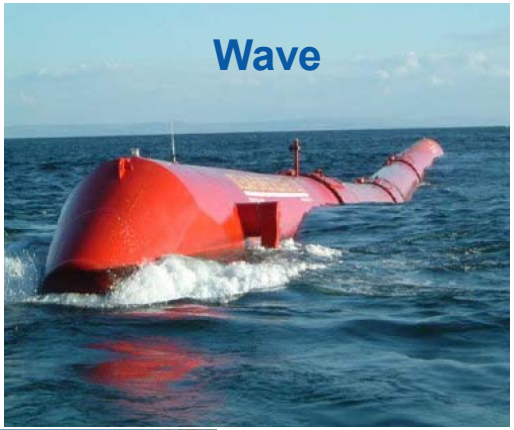
Enhanced Geothermal Systems





Ocean Kinetic Energy

Wave



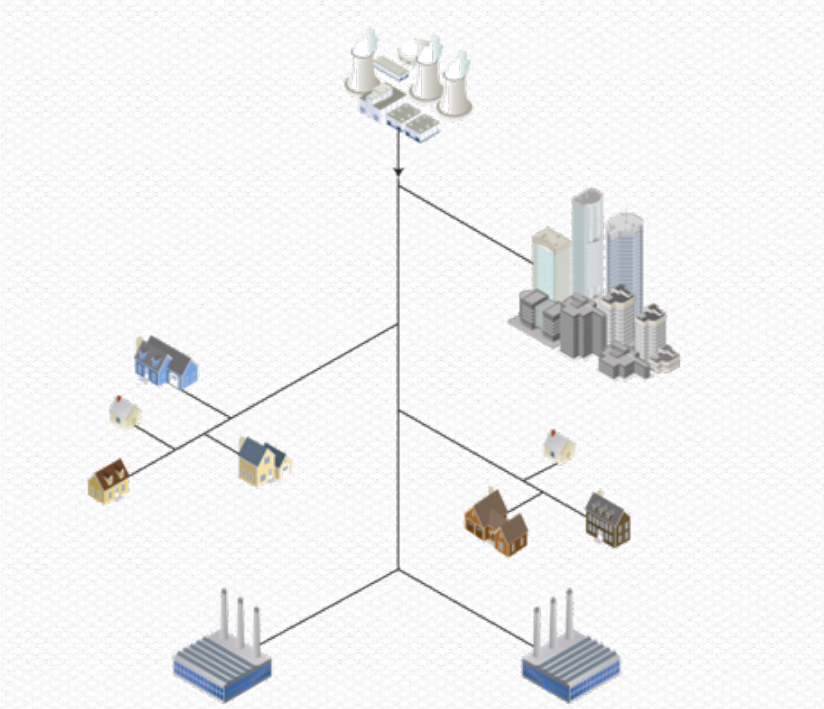
Tidal

Pelamis—Ocean Power Delivery

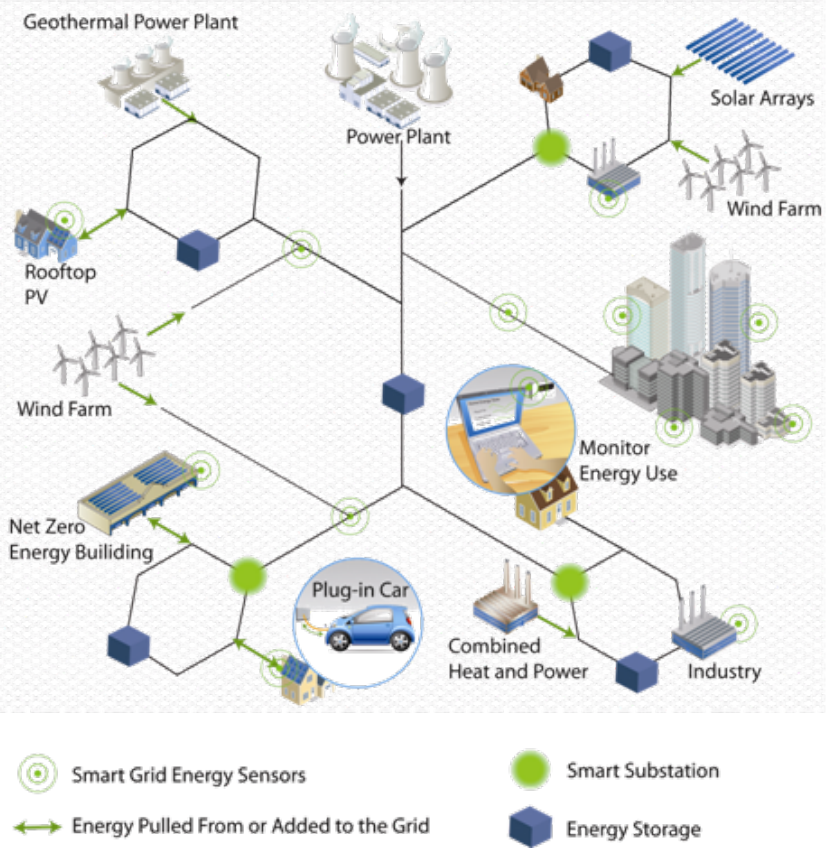
Verdant—Power RITE Turbine

Smart Grid – Renewable Energy Integration in Systems at All Scales

Today



Future



An Integrated Approach is Required

Making Transformational Change

Laboratory of the Future – Research Support Facility