



Low Carbon Economy and the Green Tech Revolution: The Role of Efficiency and Renewables



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Laboratory Director

A Profound Energy Transformation is Required

Today's Energy System



Sustainable Energy System

- **Innovation:** Reduce costs and increase reliable performance
- **System-Focused Solutions:**
 - Energy is a 'system of systems' challenge
 - Delivery of services should drive energy resource optimization
 - Existing infrastructure needs to be adapted and new infrastructure holistically designed to meet requirement
- **Partnerships:** Concerted, coordinated government and private sector efforts
- **Informed Decisions:** Analysis to understand options and their implications

Light, Heat and Power

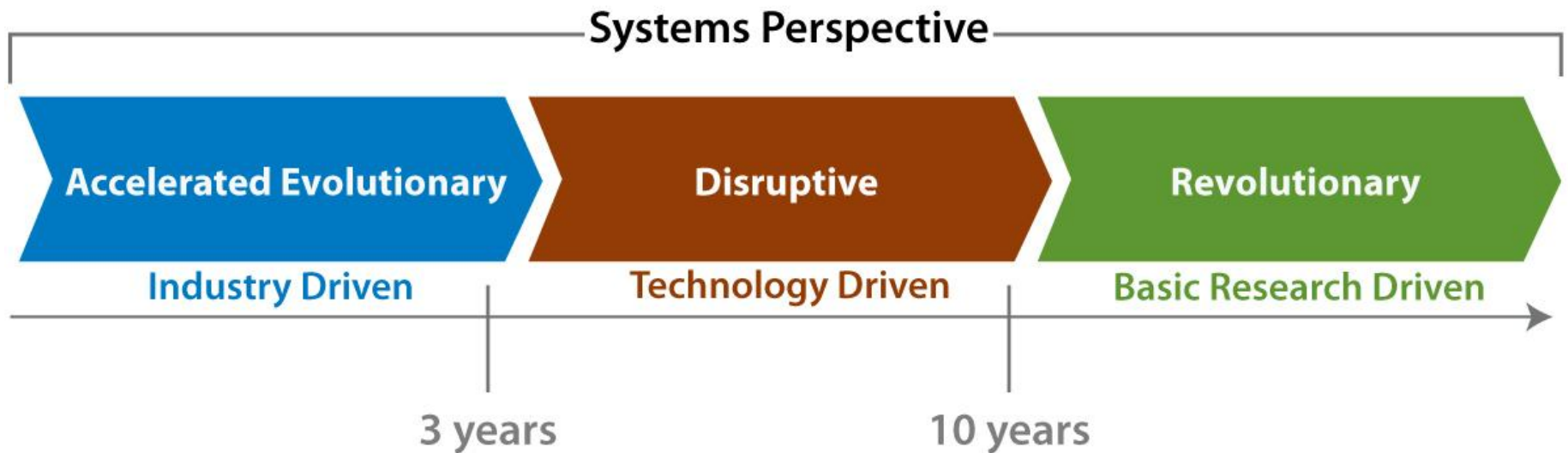


Mobility and Access



NREL is focused on transforming key systems

Achieving the Potential Requires A Balanced Portfolio



A Role for Clean Energy—A Decade of U.S. Progress

U.S. wind power generation increased more than **15 fold** to 80 terawatt-hours

Solar PV went from **20 MW/yr** to nearly **600 MW/yr** (2009)

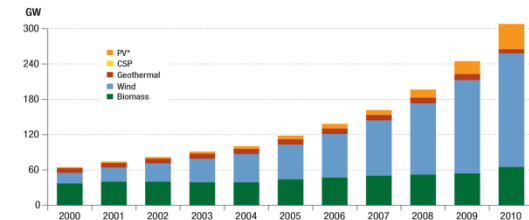
Biofuels emerged as a **major national and global industry** (~11 bgal/yr in US)

LEED-certified commercial buildings grew from 3 to more than 8,100

Costs have been significantly reduced and are **approaching grid parity**

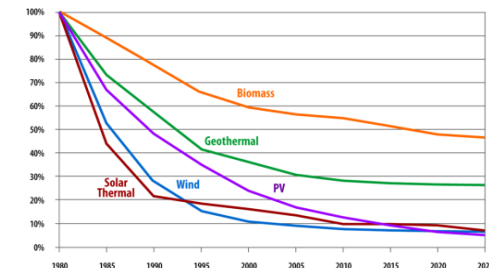
Clean energy grew from \$1B/year to a **\$34B/year market** in the U.S.

Renewable Electricity Generating Capacity Worldwide (excluding hydropower)

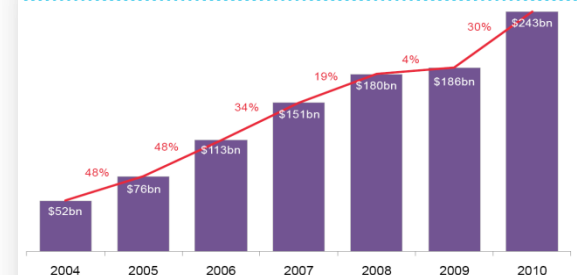


*Grid-tied capacity.
Sources: REN21, GWEC, IEA, SEIA, EIA

History of R&D builds confidence in continued investment



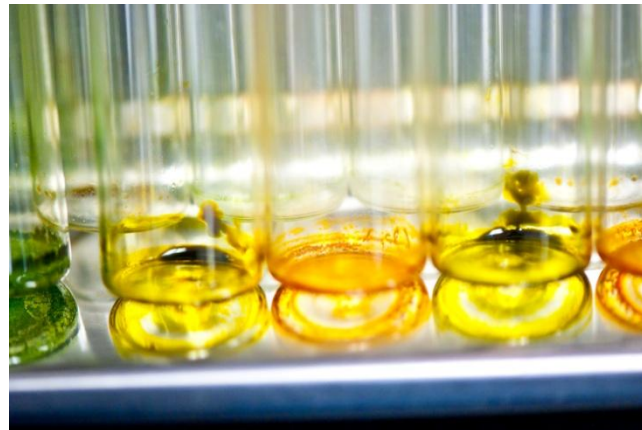
GLOBAL TOTAL NEW INVESTMENT IN CLEAN ENERGY 2004–10 (\$Bn)



Note: Includes corporate and government R&D, and small distributed capacity. Adjusted for re-invested equity. Does not include proceeds from acquisition transactions. Source: Bloomberg New Energy Finance

Bloomberg // GLOBAL TRENDS IN CLEAN ENERGY INVESTMENT, 11 JANUARY 2011

Next generation technologies are key



R&D Partnering to Reduce Investment Risk



innovation Impact



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ALSTOM



JOHNSON
MATTHEY



FedEx

JCPenney



PHOTON SOLAR POWER
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MiaSolé
Thin-film solar

Pardee Homes
Where smart solutions live.



Energy Efficiency



Buildings

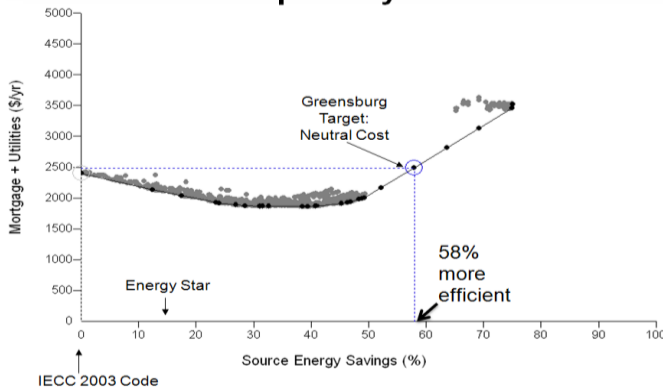


Current Status

U.S. Buildings

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

Neutral Cost Point: Greensburg BEopt Analysis



Major Technology Directions

Whole building systems integration

- Computerized building energy optimization tools
- Advanced HVAC (Heating Ventilating and air conditioning)
- Cost effective ultra energy efficient retrofits and new buildings

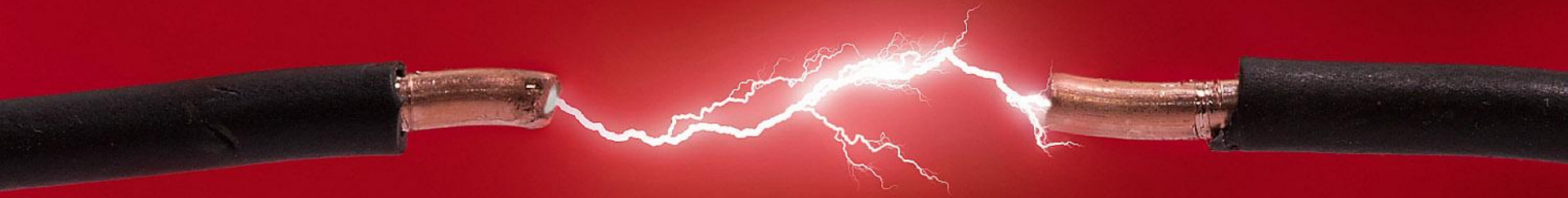
Updated 9/10



Key Design Strategies

- Optimal orientation and office space layout
- Fully daylit office wings with high-performance electrical lighting
- Continuous insulation precast wall panels with thermal mass
- Operable windows for natural ventilation
- Radiant heating and cooling
- Outdoor air preheating
 - Transpired solar collector
 - Data Center waste heat
 - Exhaust air heat recovery
 - Crawl space thermal storage
- Aggressive plug load control strategies
- Data Center outdoor air economizer with hot aisle containment
- Roof top- and parking lot-based PV

Renewable Electricity Supply



Wind Energy



The Siemens 2.3 MW turbine at NREL is among the largest land-based turbines deployed in the United States

Current Status (2010)

- 39.2 GW of installed capacity
- <2% of total U.S. electricity generation
- Cost 6-9¢/kWh at good wind sites

Major Technology Directions

- Wind Turbine System and Component Reliability
- Wind Resource Modeling and Forecasting
- Grid Integration
- Offshore Wind /Small Wind Siting and Testing

4/7/11



Solar Energy



Current U.S. Status (2010)

Photovoltaics

- 2,096 MW installed solar photovoltaic (PV) capacity
- Cost 16.5¢/kWh*

Concentrating Solar Power

- 431 MW installed capacity
- Cost 13.5¢/kWh*

Major Technology Directions

Concentrating Solar Power

- Low-cost, high-performance thermal storage
- Advanced absorbers, reflectors, and heat transfer fluids
- Next generation solar concentrators

Photovoltaics

- Thin-film cells/modules & scale-up
- Nanomaterials enabled technologies
- Advanced manufacturing techniques
- Improved reliability
- Closing gaps between cell & module efficiencies

Grid integration, systems performance and reliability

*Source: Photon International , 3/11
CSP assumes trough technology.

5/18/11



Biofuels



Biofuels



Current Status (2009):

U.S. produced 10.8 billion gallons of ethanol and 0.5 billion gallons of biodiesel

- 210 commercial corn ethanol plants
- 150 biodiesel refineries
- 26 cellulosic ethanol demonstration plants

Cost goal:

Cellulosic ethanol—cost parity with gasoline by 2012

Major Technology Directions:

- **Foundational Science:** Enzymes, fermentation, understanding biomass and cell composition
- **Feedstocks:** Sustainable feedstock production systems
- **Pretreatment & Conversion R&D:** Biochemical and thermochemical conversion processes
- **Advanced Biofuels and Algae:** Broadening RD&D beyond cellulosic ethanol to address “drop in’ and high-energy content fuels from algae and other biomass resources

Updated 10/10

Sustainable Transportation



Alternative Vehicles

Current U.S. Status

- 133 million light duty gas/diesel vehicles
- 111 million heavy duty gas/diesel trucks
- 2 million hybrid electric vehicles

NREL Research Thrusts

- **Fuels utilization**
 - Advanced fuels chemistry and testing
 - Engine- alternative fuels interactions
- **Component technologies**
 - Advanced materials for lithium ion batteries
 - Energy storage and power electronics thermal management
 - Advanced heating & cooling
 - Vehicle thermal management
- **Electric vehicle-to-grid interface**
 - Codes and standards
 - Charging Infrastructure tie to renewables
 - Analysis of advanced concepts
- **Deployment and Outreach**
 - Clean Cities, Alternative Fuels Data Center



Updated 9/10

Fuel Cells/Hydrogen



Current U.S. Status

- >200 fuel cell vehicles on the road
- ~60 hydrogen fueling stations
- Commercial fuel cell electric vehicle launch expected in 2015
- Fuel cells having market success in forklift and backup power applications
- > 2000 fuel cells shipped by U.S. companies in 2009
- 9 million metric tons of H₂ produced annually for a variety of uses



Major Technology Directions

- Renewable H₂ production
- H₂ storage
- Fuel cells
- Safety/codes/standards
- Integration of H₂-electricity systems
- Technology validation

Updated 9/10



New Directions



Smart Grid/Grid Integration

Current U.S. Status

The Grid

- 30,000 transmission paths; >180K miles of transmission lines
- 14,000 transmission substations
- Distribution grid connects substations to over 100 million loads

Utility Sector

- 3,170 traditional electric utilities (239 investor-owned, 2,009 publicly owned, 912 consumer-owned rural cooperatives, and 10 Federal electric utilities)



Artist Rendering of the Energy System Integration Facility

NREL Research Thrusts

DG Interconnection Standards

- IEEE Standards Development
- Standards Testing and Validation

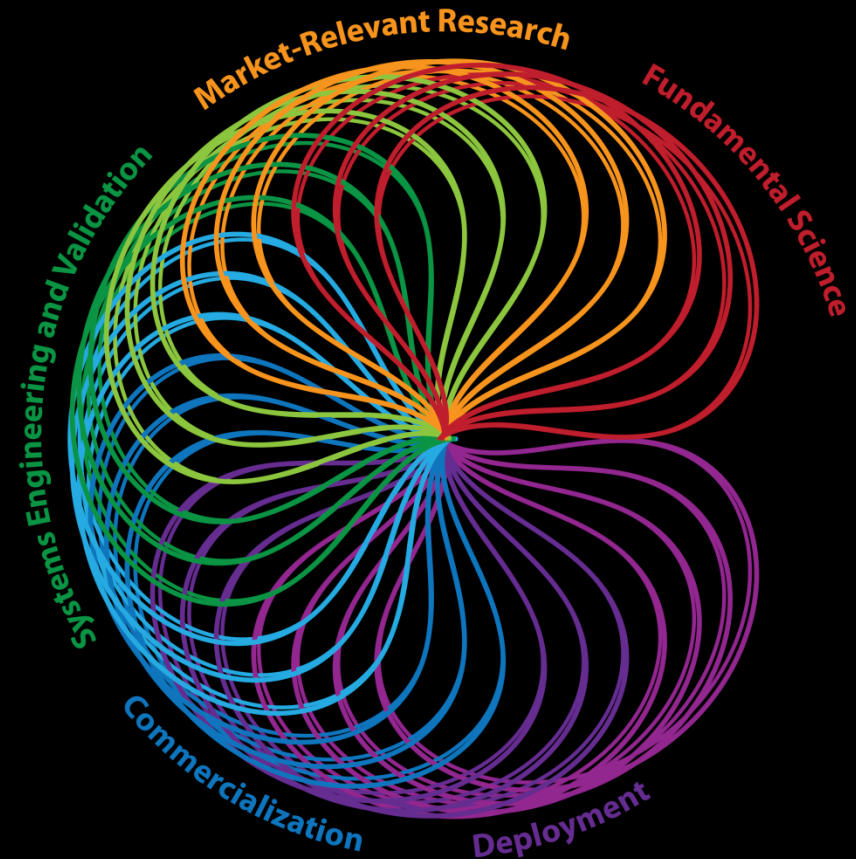
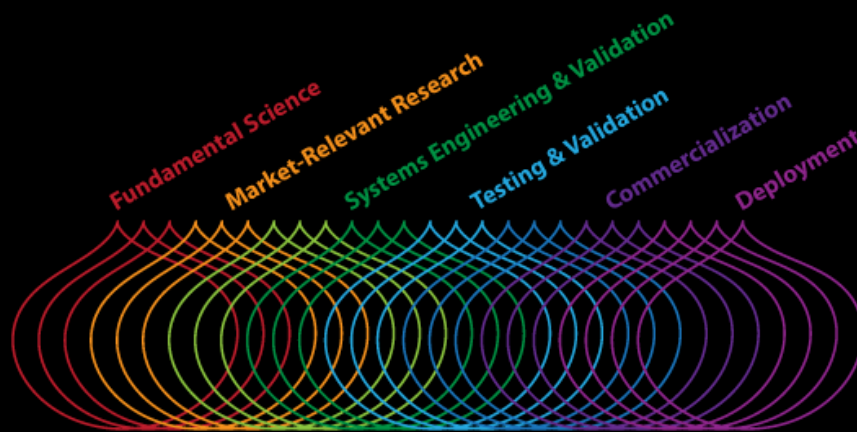
Smart-Grid Data Hub

RE Grid Integration

- Power Electronics for Interconnection monitoring and control
- Grid-to-vehicle interface

From Fundamental Science to Deployment

A comprehensive approach to innovation bridges scientific research to the market



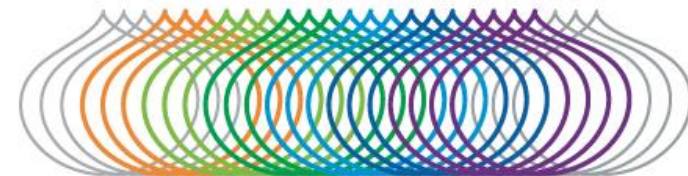
The NREL Spectrum of Clean Energy Innovation

NREL Innovations Improve Small Wind Turbine Efficiency



- 2.4 kW Skystream 3.7 wind turbine
- Unique blade design makes wind turbine more efficient and quieter
- **Essential for growth in the small wind turbine market;** 7,500 Skystream systems installed

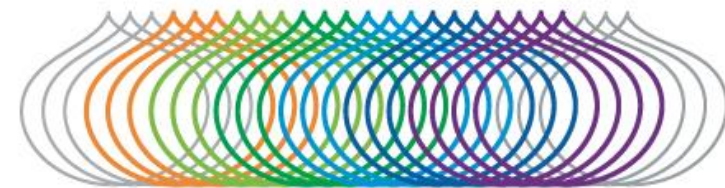
Southwest Windpower
Renewable Energy Made Simple



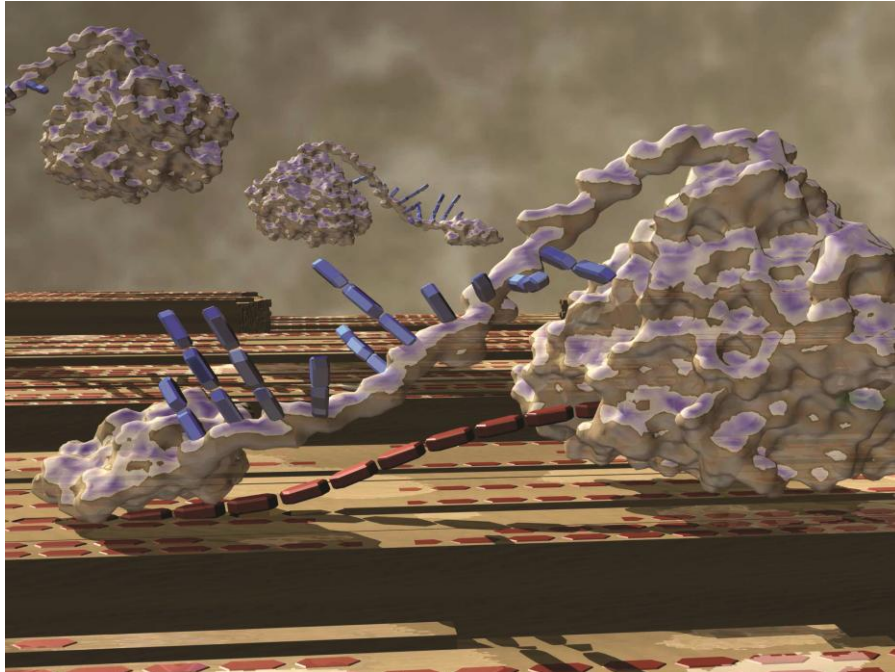
Rapid Deposition Technology Revolutionizes Thin-Film PV Manufacturing



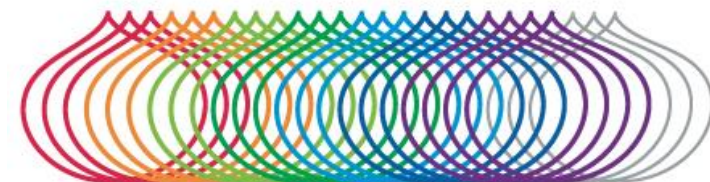
- Thin-film solar technology
- Long-term collaboration to discover less expensive materials for solar solutions
- First Solar has grown from start-up company to one of the world's largest solar manufacturer, with a production capacity of nearly 1,400 MW per year



Reducing Enzyme Costs Increases Market Potential on Biofuels



- New cellulase enzymes
- Reduced cellulase enzyme production cost by more than 10x
- Major step toward **commercializing large-scale biomass-to-ethanol production**



An Integrated Approach is Required





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