National Renewable Energy Laboratory
Innovation for Our Energy Future

Renewable Energy Materials Needs—Frontiers of Research

Dr. Dan E. Arvizu

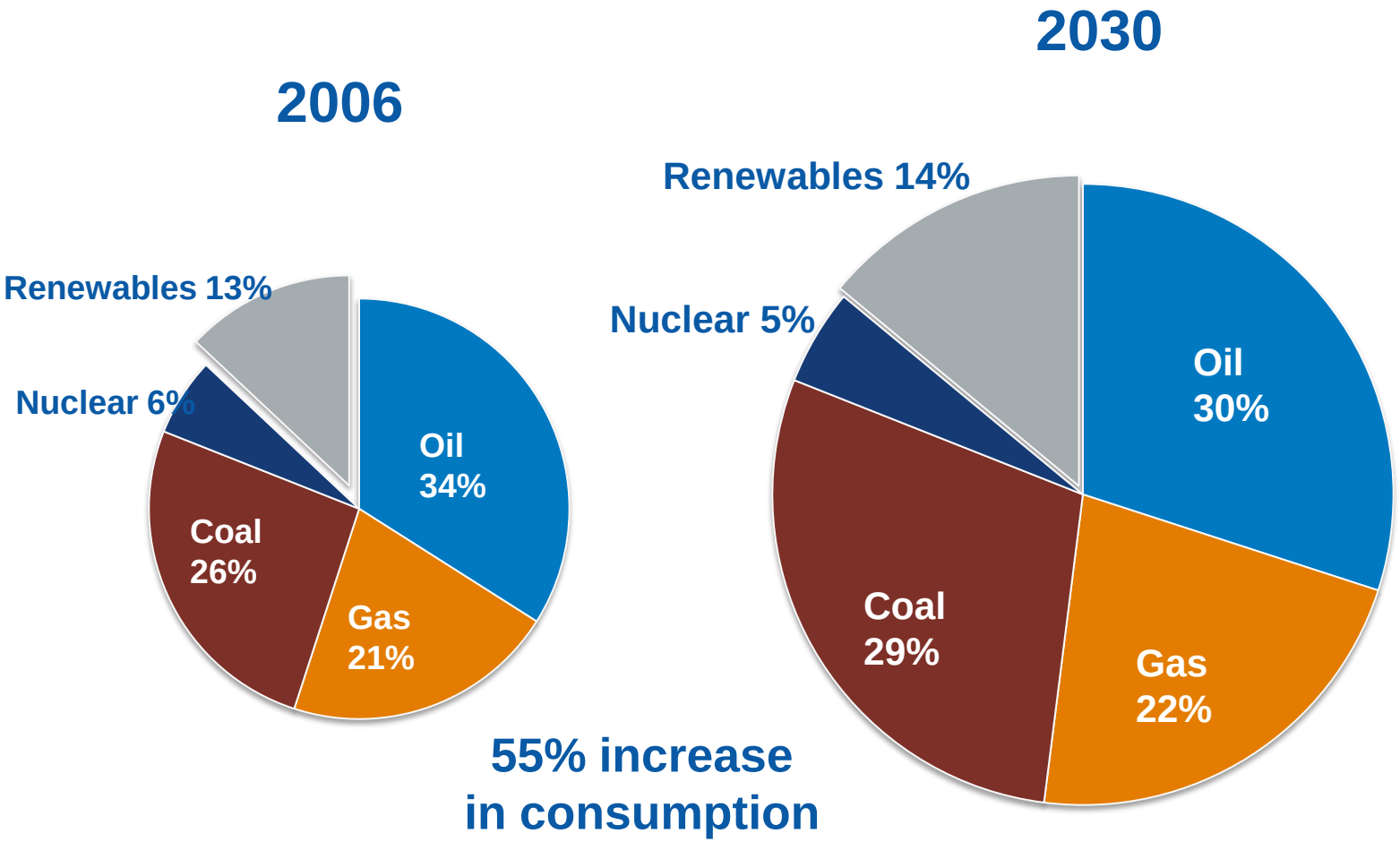
Director

National Renewable Energy Laboratory

Golden, Colorado USA

October 13, 2009

World Energy Supply and the Role of Renewable Energy



Units = Mtoe

Source: IEA/OECD, World Energy Outlook 2008, page 78, table 2.1

Looking Ahead with Optimism—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

Getting to “Speed and Scale”– Key Challenges

Implementing Renewable Gigawatts at Scale

BARRIERS

- Cost
- Reliability
- Infrastructure
- Dispatchability

Displacement of Petroleum-Based Fuels

BARRIERS

- Cost
- Life cycle sustainability
- Fuels infrastructure
- Demand and utilization

Reducing Energy Demand of Buildings, Vehicles, and Industry

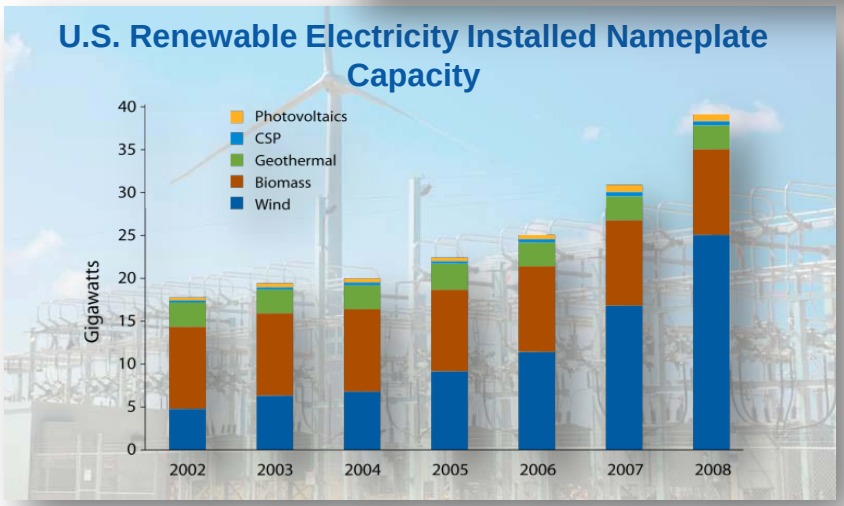
BARRIERS

- Coordinated implementation
- Valuing efficiency
- Cost
- Performance and reliability

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

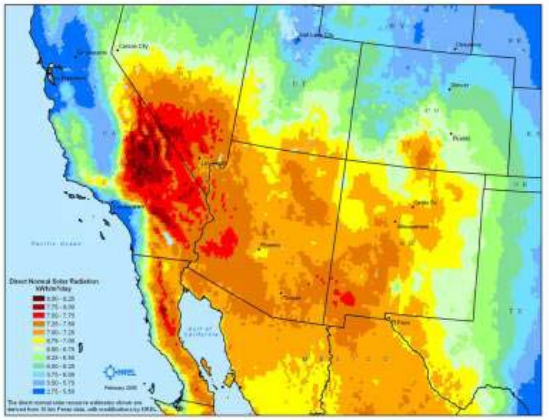
NREL Provides Data, Tools and Technical Assistance to:

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

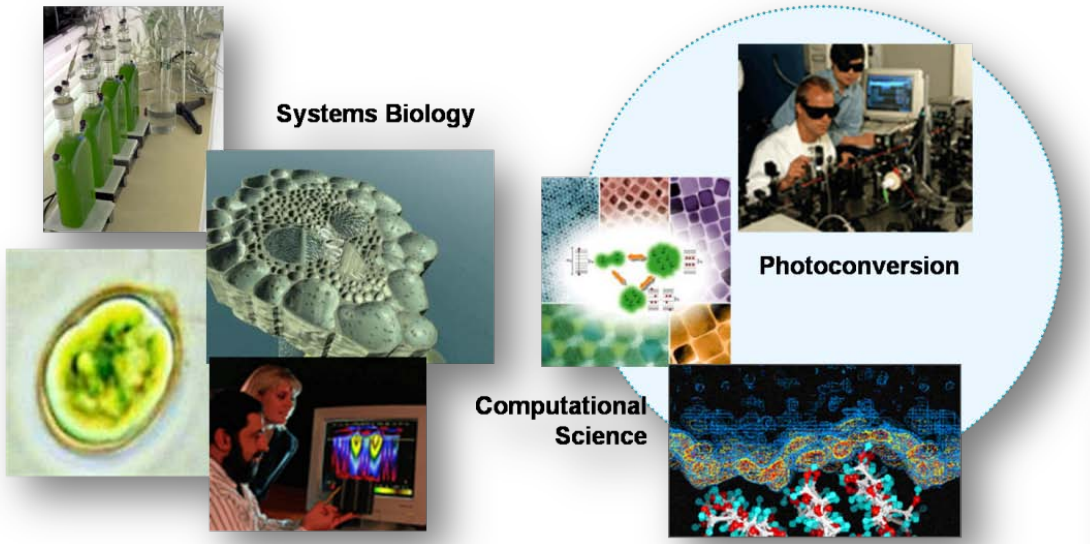
Unique Partnering Facilities

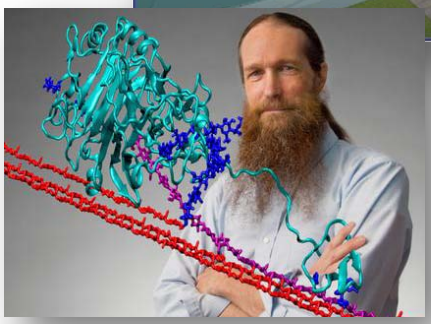
Testing and Validation Capabilities

Integrated Biorefinery Research Facility

Energy Systems Integration Facility

Long-Term Impact: Requires Breakthrough/Translational Science



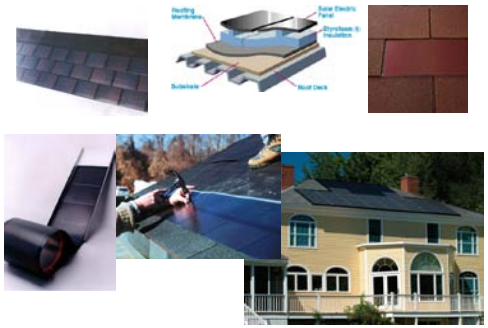


Managing the science-to-technology interface

Energy Efficiency

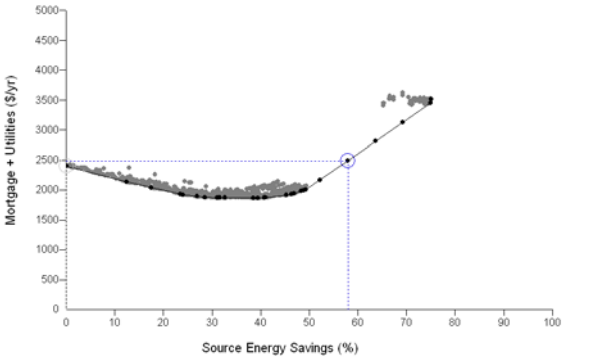
Technology for Cost Effective Zero Energy Buildings

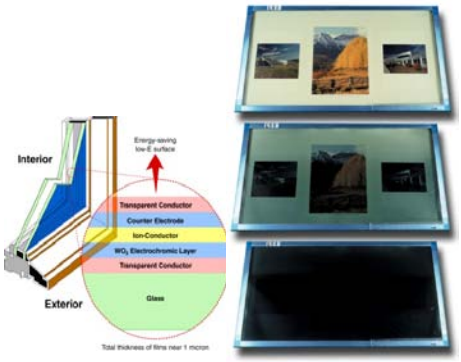
NREL Zero Energy Habitat House



BIPV Products & PV-T Array

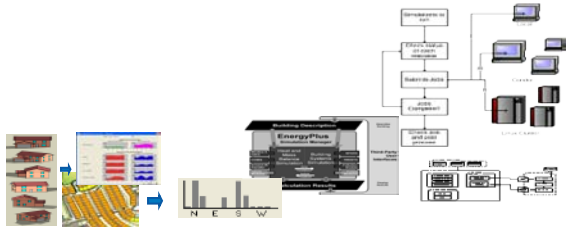
Compressorless Cooling





Electrochromic Windows

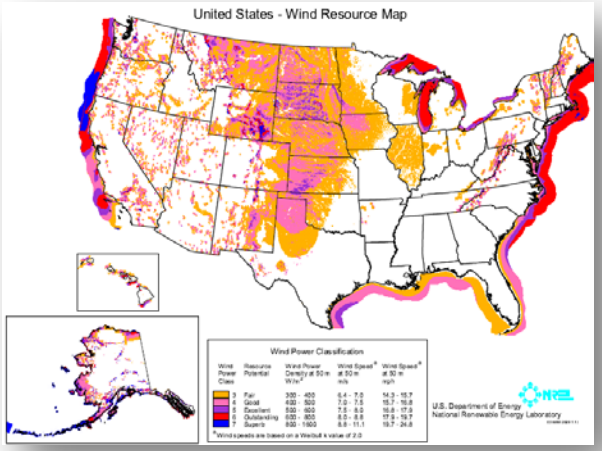
Polymer Solar Water Heaters



Computerized optimization & simulation Tools

Renewable Electricity Supply

Wind Energy Technology



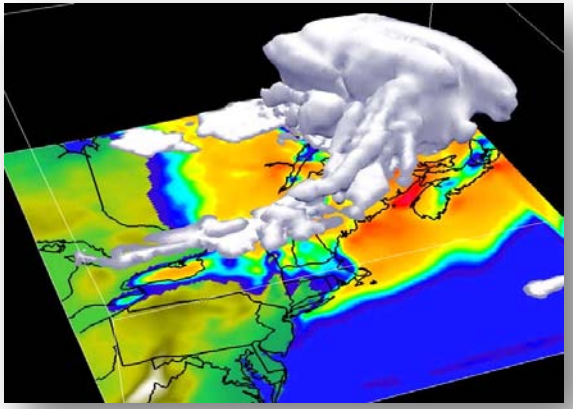
US Wind Resource Exceeds Total Electrical Demand

Offshore Wind

Advanced Blades

Innovative Tall Towers

Giant Multi-megawatt Turbines

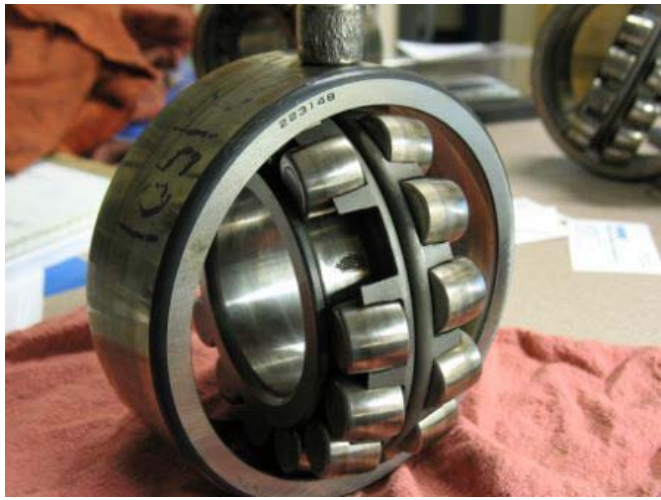


Courtesy:WindLogics, Inc. St. Paul, MN

Wind Forecasting

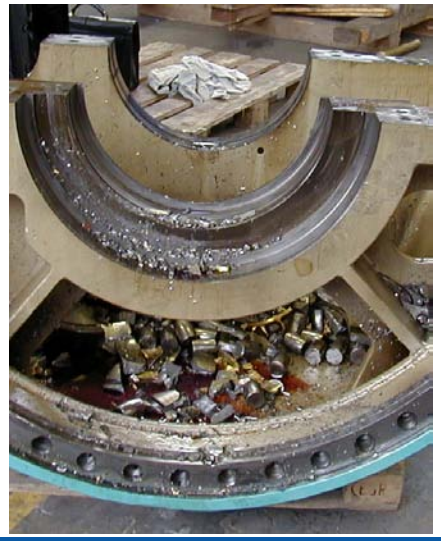

Horns Rev Offshore Wind Farm
North Sea, Denmark
Photo used by permission of Uni-Fly A/S

Nanotechnology Can Improve the Reliability and Lifetime of Wind and Ocean Power Systems



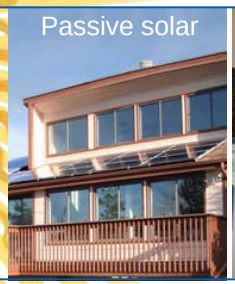
Advanced Material Coatings

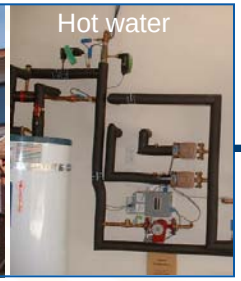
- Offshore high corrosion environment applications
- High stress drivetrain components including
  - Gearing; pinions; planet bearings
- Lubrication systems & surface wear
- Anti-fouling ocean energy systems
- Ice reduction on turbine blades
- Longevity



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

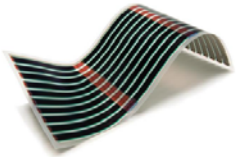
PV Conversion Technology Portfolio

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

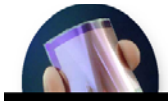
Thin Films (aSi)

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]

Crosscut

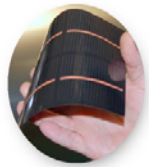
Synergistic technologies, evaluation approaches, and process engineering approaches applicable across multiple absorber materials and processes

Concentrating PV

Combining new, lower cost multijunction cells and innovative optical packages

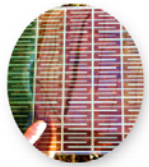
Thin Films (CIGS)

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

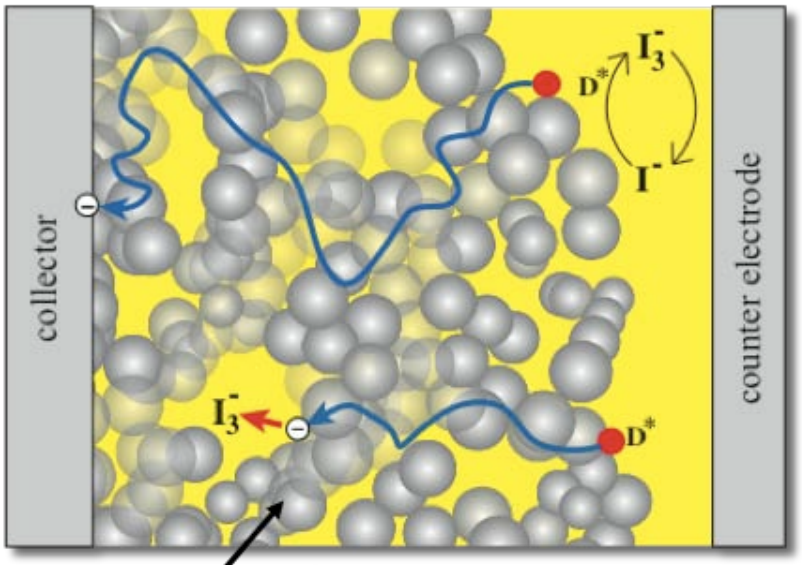


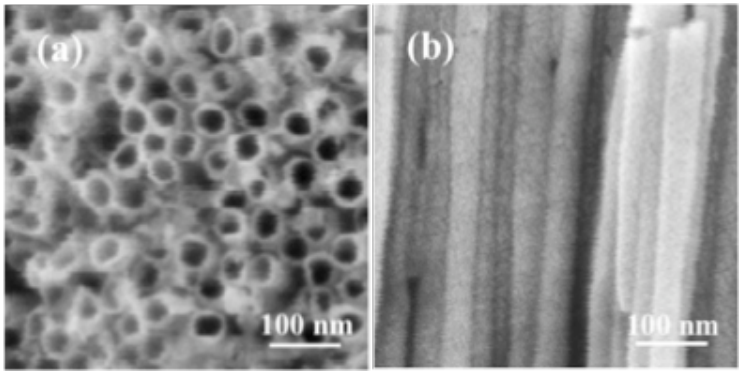
Building Integrated PV

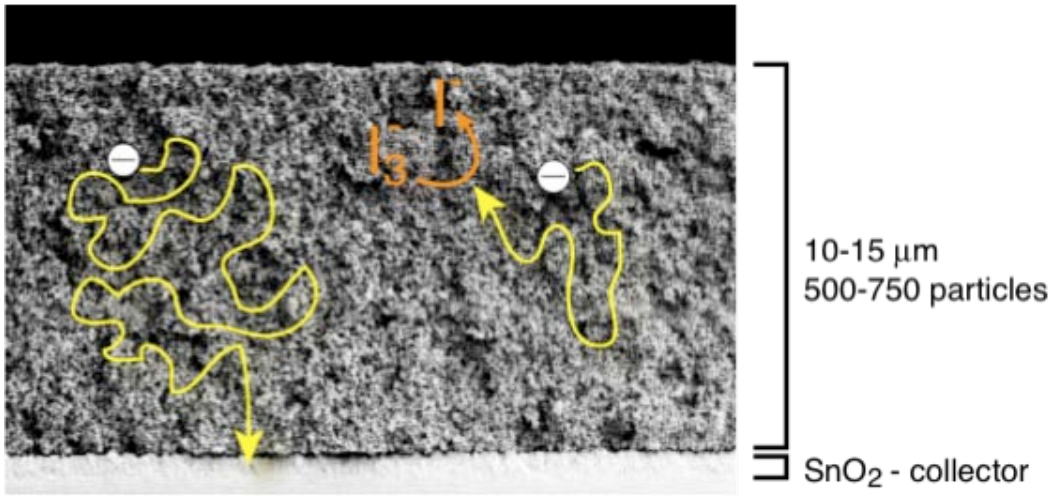
Creating module form factors

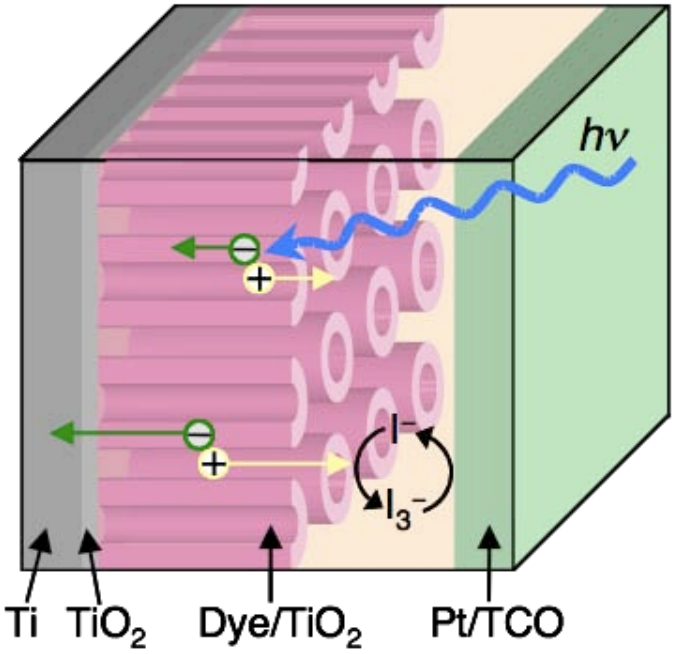
[redacted]

Current Research Moves from Nanoparticles to Nanotubes to Improve Electron Transport



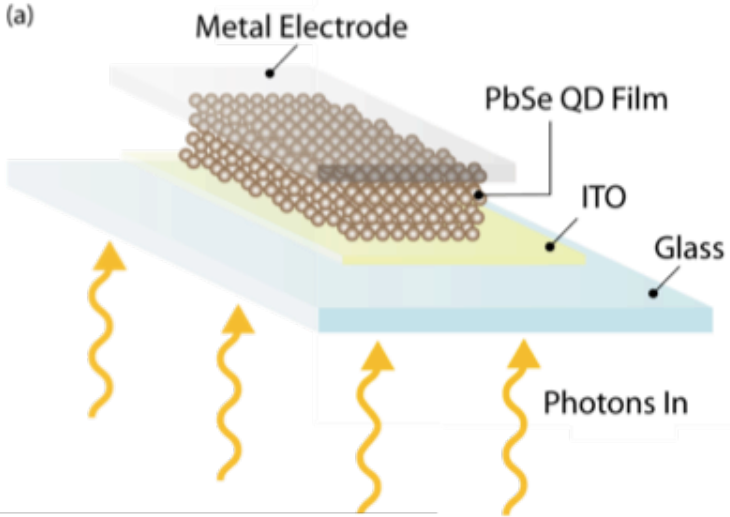


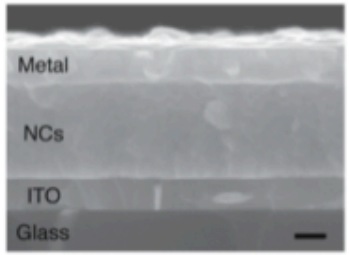


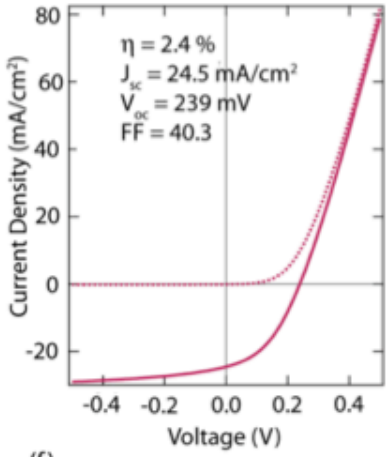


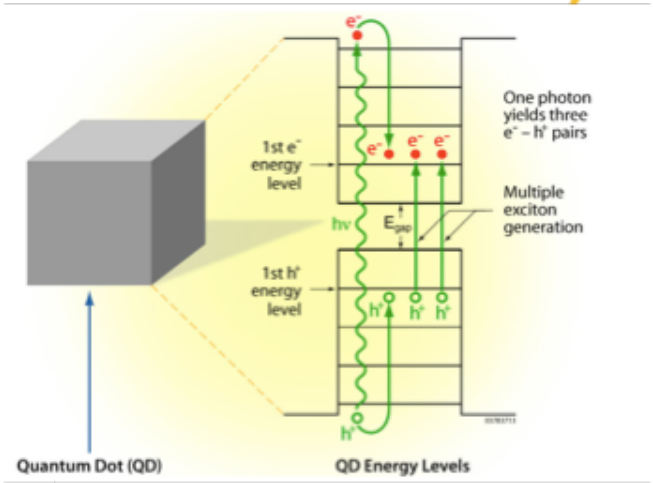
Credits: Art Frank

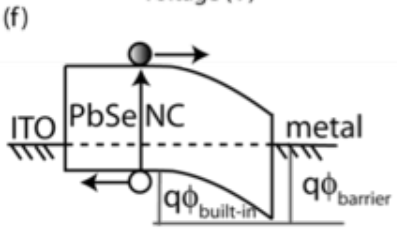
Connecting the Dots: Moving to the 3rd Generation







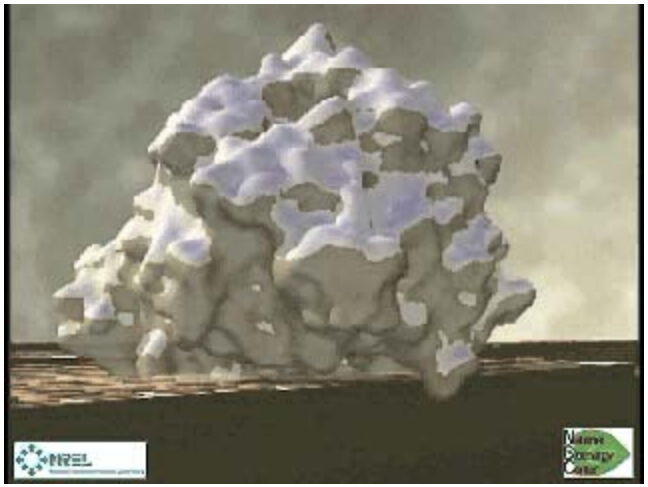


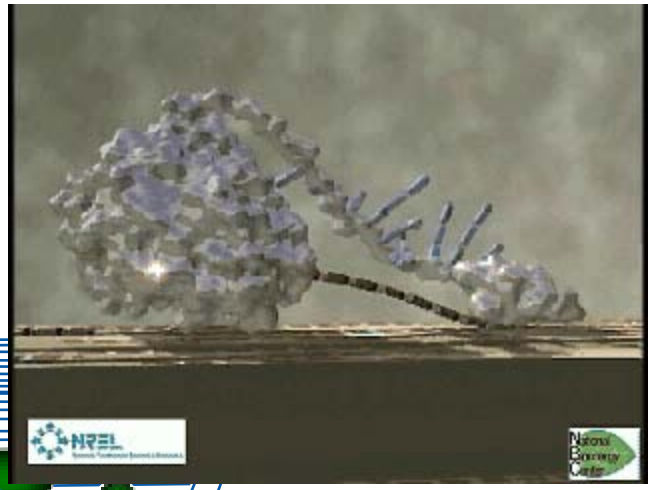


Credits: Art Nozik, Matt Beard – NREL

Biofuels

Action of Fungal Cellulases





endoglucanase

cellobiose

exoglucanaseNR

exoglucanaseR

NR

R

cellulose

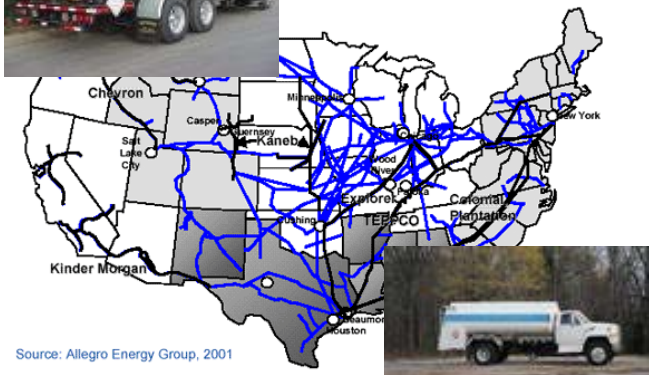
β-glucosidase

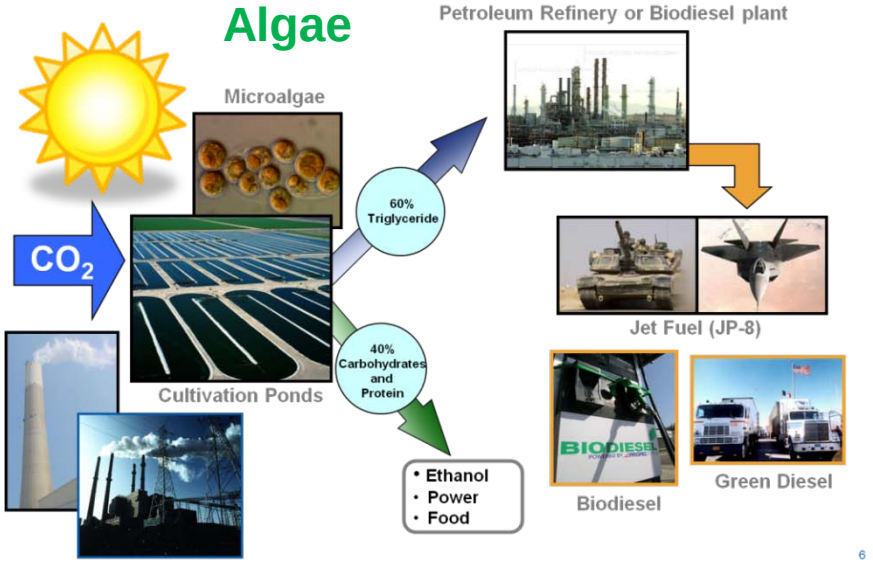
glucose

Why Follow-On Generations?

3rd & 4th Generations – "beyond ethanol"

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





Sustainable Transportation

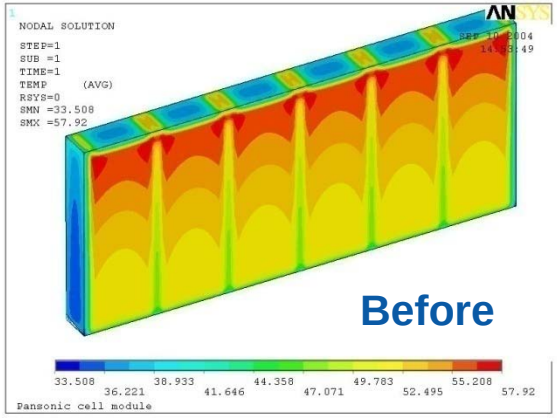
Advanced Vehicle Technologies

Energy Storage

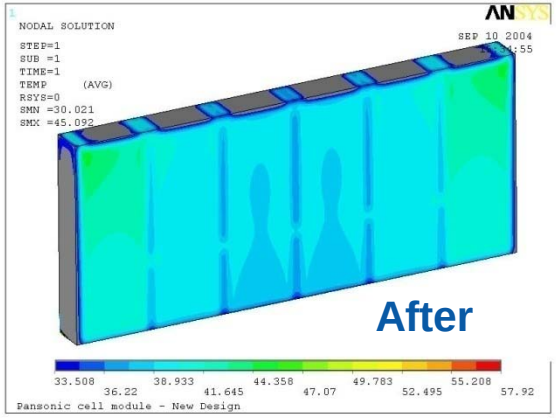
UltraCaps

Advanced Power Electronics

Vehicle Ancillary Loads Reduction

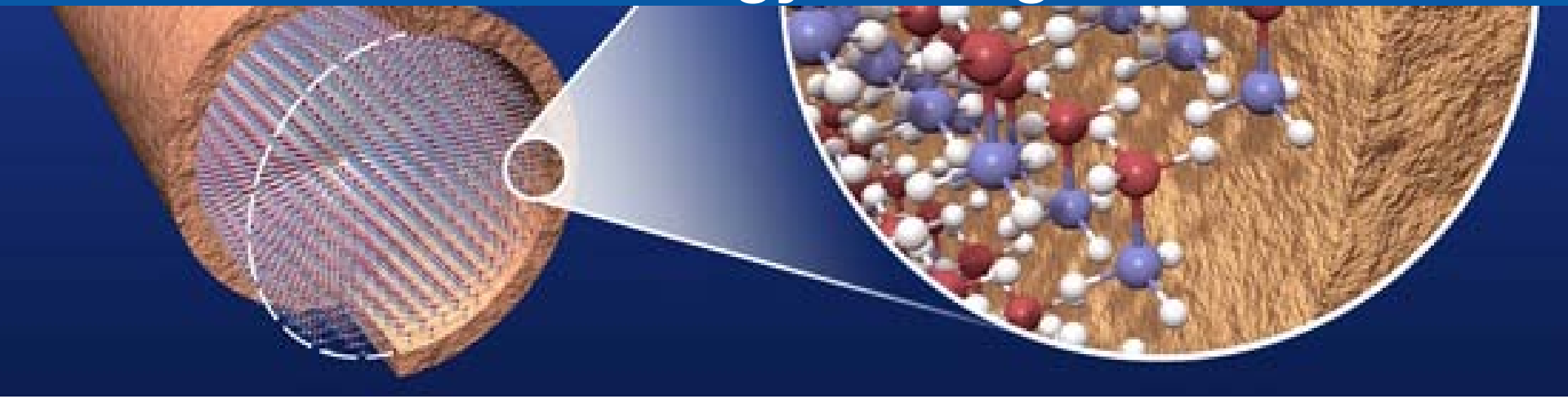


Before



After

Energy Storage



Designer Nanostructured Materials are Critical to Enabling Energy Storage Systems for Renewables

Organometallic Buckyballs for Hydrogen Storage

State-of-the-art processing to create novel nanomaterials for energy storage:

- Hydrogen storage: porous carbons, boro-carbons, metcars, macromolecules
- Batteries: novel electrolytes and metal oxides for cathodes and anodes
- Ultracapacitors: nanotubes and high dielectric materials
- Dynamic smart windows

NREL leads DOEs hydrogen sorption Center of Excellence

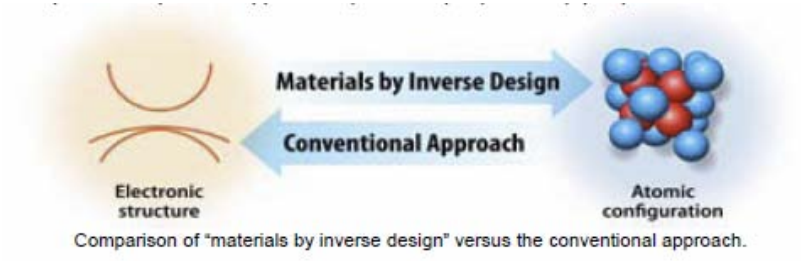
- Develops high surface area, low-weight and low-cst materials
- 15 projects: 4 national labs, 10 universities, and on industrial parnter

New Directions

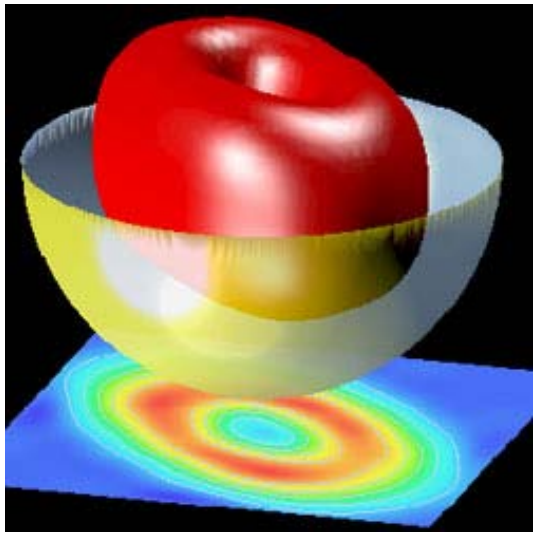
Enabling Innovation—Centers, Hubs and Clusters

New NREL Related Energy Frontier Research Centers:

- Center for Inverse Design
- Molecularly Assembled Material Architectures
- Materials for Energy Efficiency
- Hybrid Solar-Electric Materials
- Direct Catalytic Conversion
- Polymer-Based Solar Materials
- Solar Photophysics

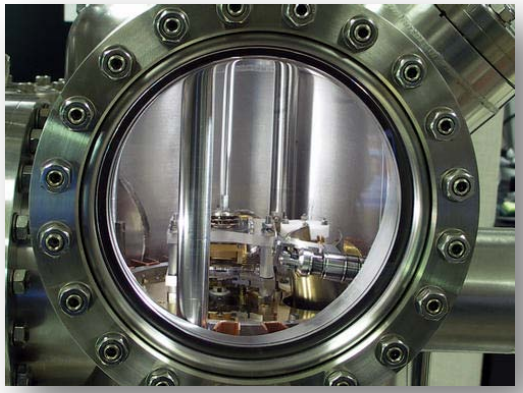


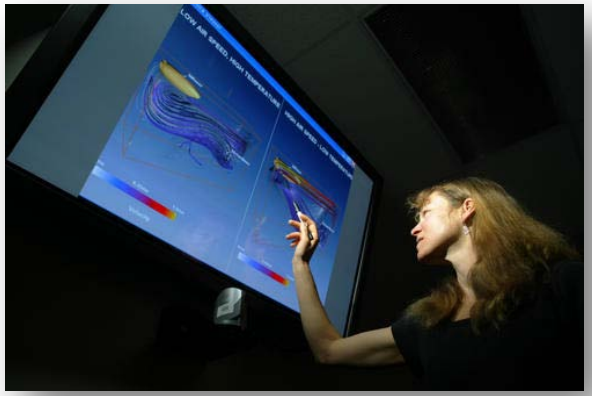
Comparison of "materials by inverse design" versus the conventional approach.

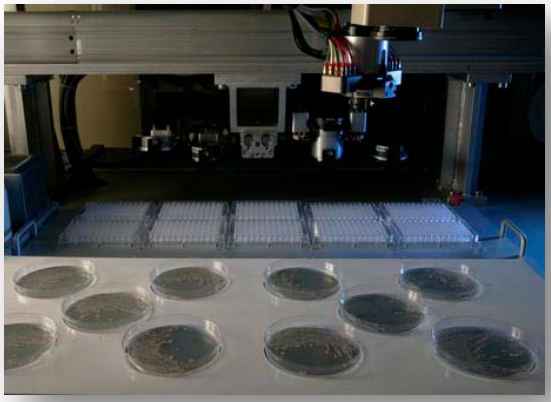


Energy Solutions Require a New Approach

- Multi-disciplinary/multi-institutional collaboration
  - Chemistry, materials science
  - Computational modeling
  - Biology
- Translational science—bridge basic to applied







Making Transformational Change

The opportunity for making renewable energy transformational change is now before us as a solution to a global crisis.

We must seize the moment.


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 the Alliance for Sustainable Energy, LLC