NREL
NATIONAL RENEWABLE ENERGY LABORATORY

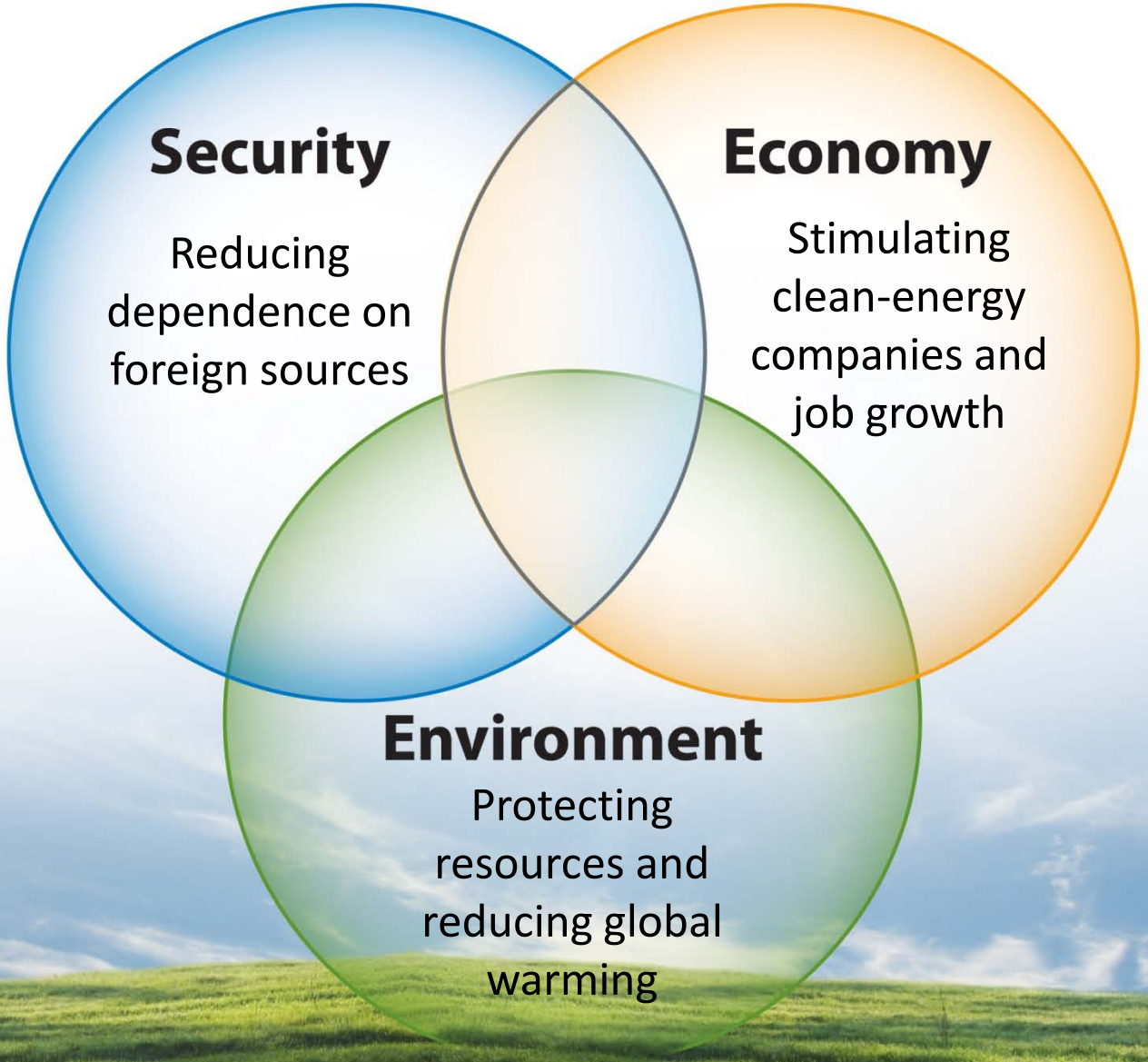
STEM Education and Achieving Our Clean Energy Goals for the Future

UCF 4th Annual Senior Design Symposium on Renewable & Sustainable Energy

April 13, 2012

Dr. Dan E. Arvizu
Laboratory Director

National Energy Imperatives



National Renewable Energy Laboratory—Who We Are

The DOE's only national lab dedicated to energy efficiency and renewable energy

- Leading clean-energy innovation for 34 years
- 2547 employees with $388.6M annual budget
- Several major world-class multi-million dollar partnering facilities, dozens of additional research labs
- Campus is a living model of sustainable energy
- Operated by Alliance for Sustainable Energy, LLC (MRIGlobal, Battelle, CU-Boulder, CSU, CSM, Stanford, MIT)

Scope of Mission

Energy Efficiency

- Residential Buildings
- Commercial Buildings
- Personal and Commercial Vehicles

Renewable Energy

- Solar
- Wind and Water
- Biomass
- Hydrogen
- Geothermal

Systems Integration

- Grid Infrastructure
- Distributed Energy Interconnection
- Battery and Thermal Storage
- Transportation

Market Focus

- Private Industry
- Federal Agencies
- Defense Dept.
- State/Local Govt.
- International

National Goals and NREL's Role

By 2035, 80% of America's electricity will come from clean energy sources

Support deployment of 1 million electric vehicles (EVs) on the road by 2015

Double renewable energy generation by 2012

Reduce our daily petroleum consumption in 2020 by 3.5 million barrels (18%) – from a 19 million-barrel baseline – and by 85% by 2050

Reduce energy-related greenhouse gas emissions by 17% by 2020 and 83% by 2050, from a 2005 baseline

NREL's Vision for the Energy System

By 2050, we will have a clean and sustainable energy system that contributes to economic prosperity, enhances national security, and maintains environmental quality

Sustainable Energy System

NREL Roles and Strategic Intents

Lead Strategic Analysis and Decision Support in Our Mission Space

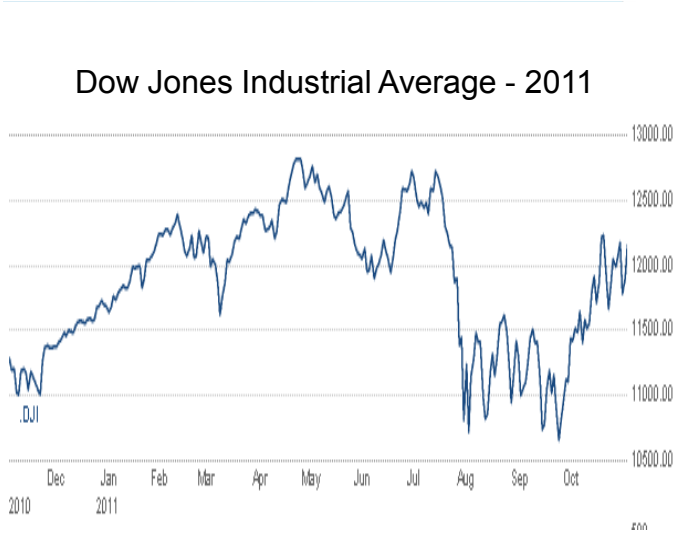
Deliver Market-Relevant Sustainable Energy Innovations

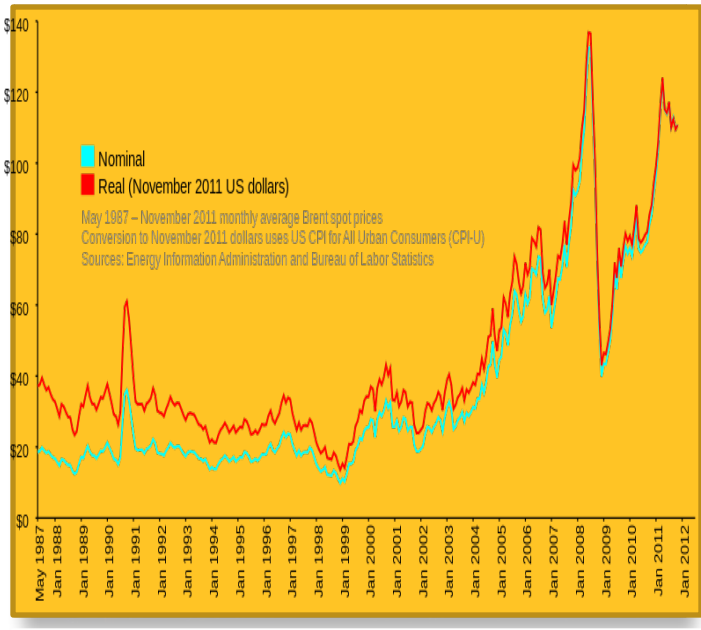
Lead Renewable Integration in Highly Efficient Systems at All Scales

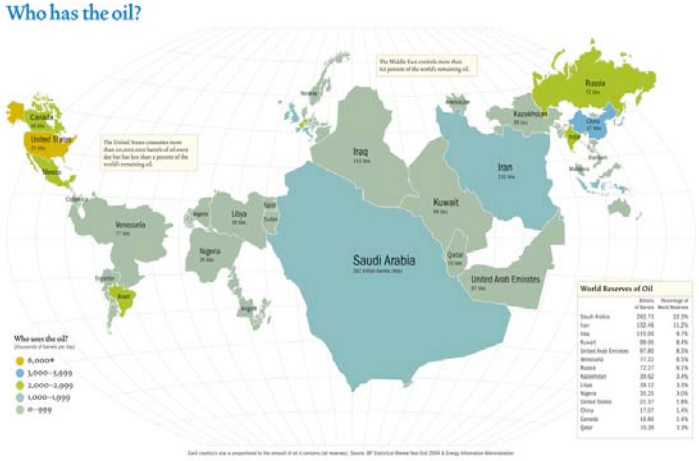
Increase the Speed of Commercialization and the Scale of Deployment

Develop the Laboratory of the Future

Mounting Evidence

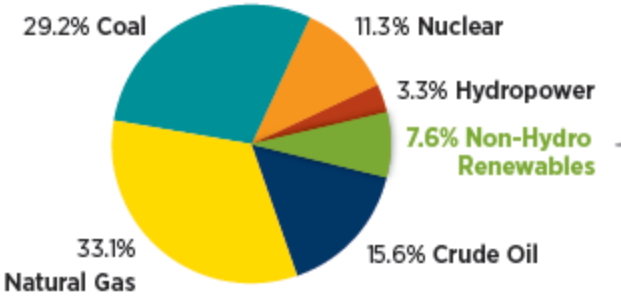


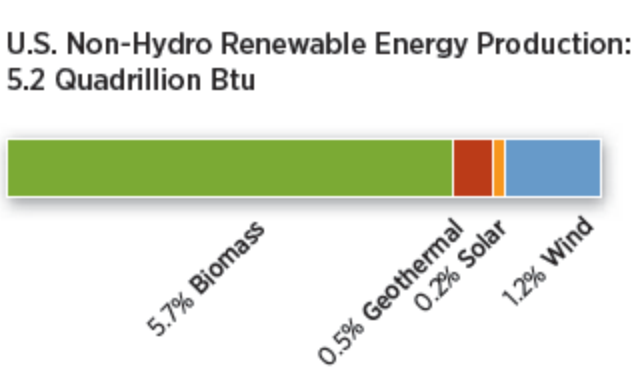




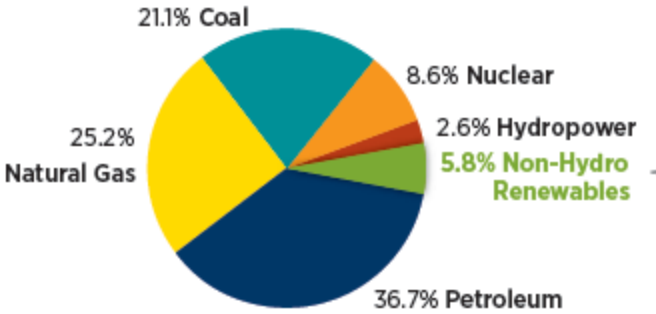
U.S. Energy Production and Consumption (2010)

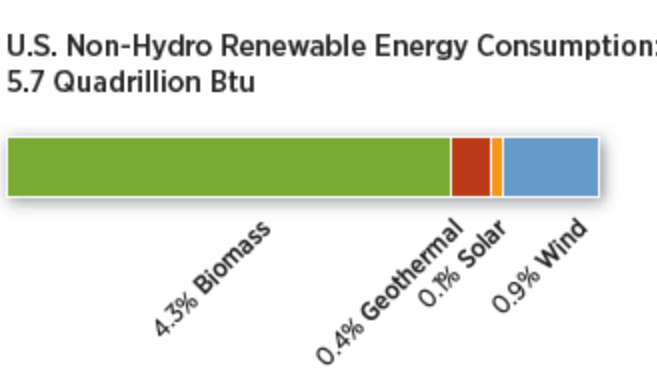
U.S. Energy Production (2010): 74.9 Quadrillion Btu





U.S. Energy Consumption (2010): 98.0 Quadrillion Btu

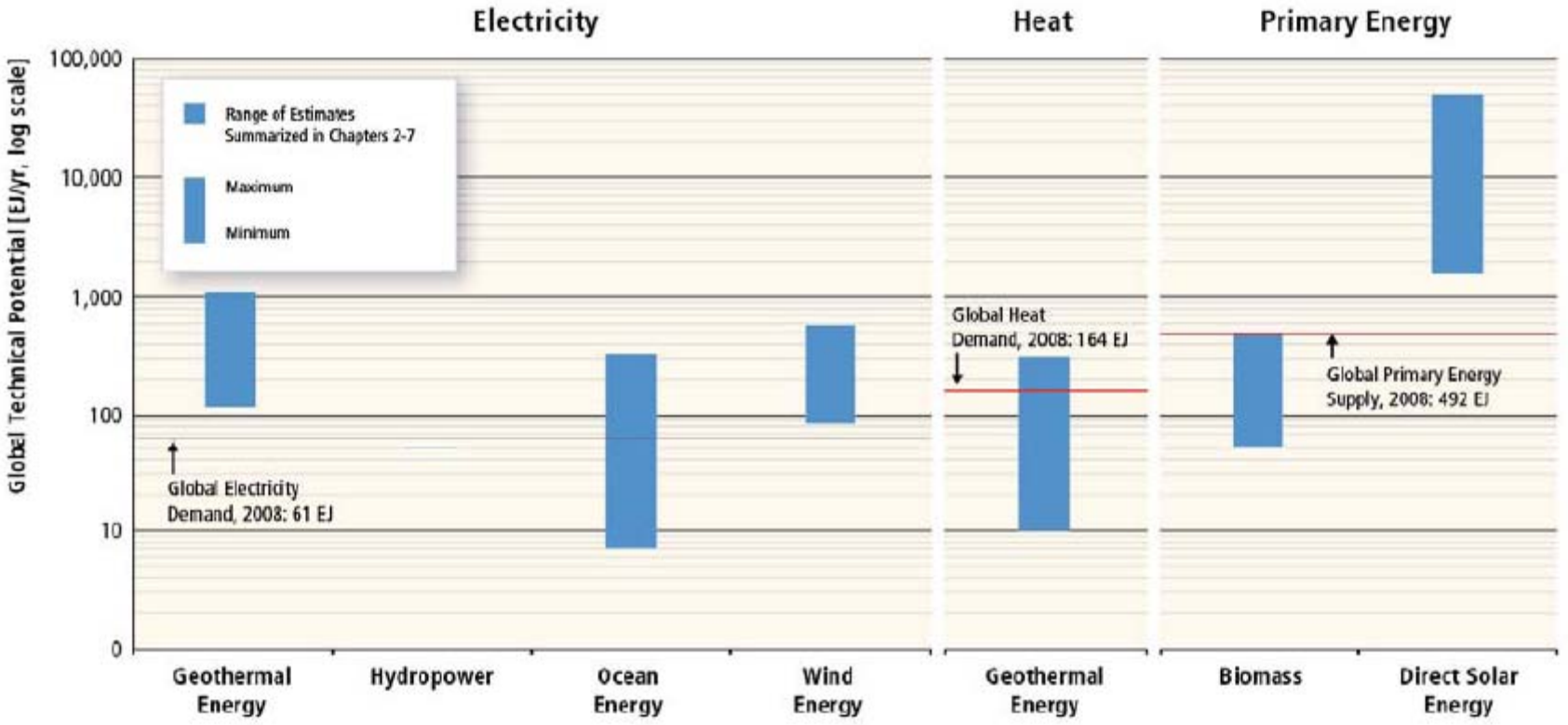




Source: EIA; full references are provided starting on p. 123.

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.

Ranges of global technical potentials of RE sources

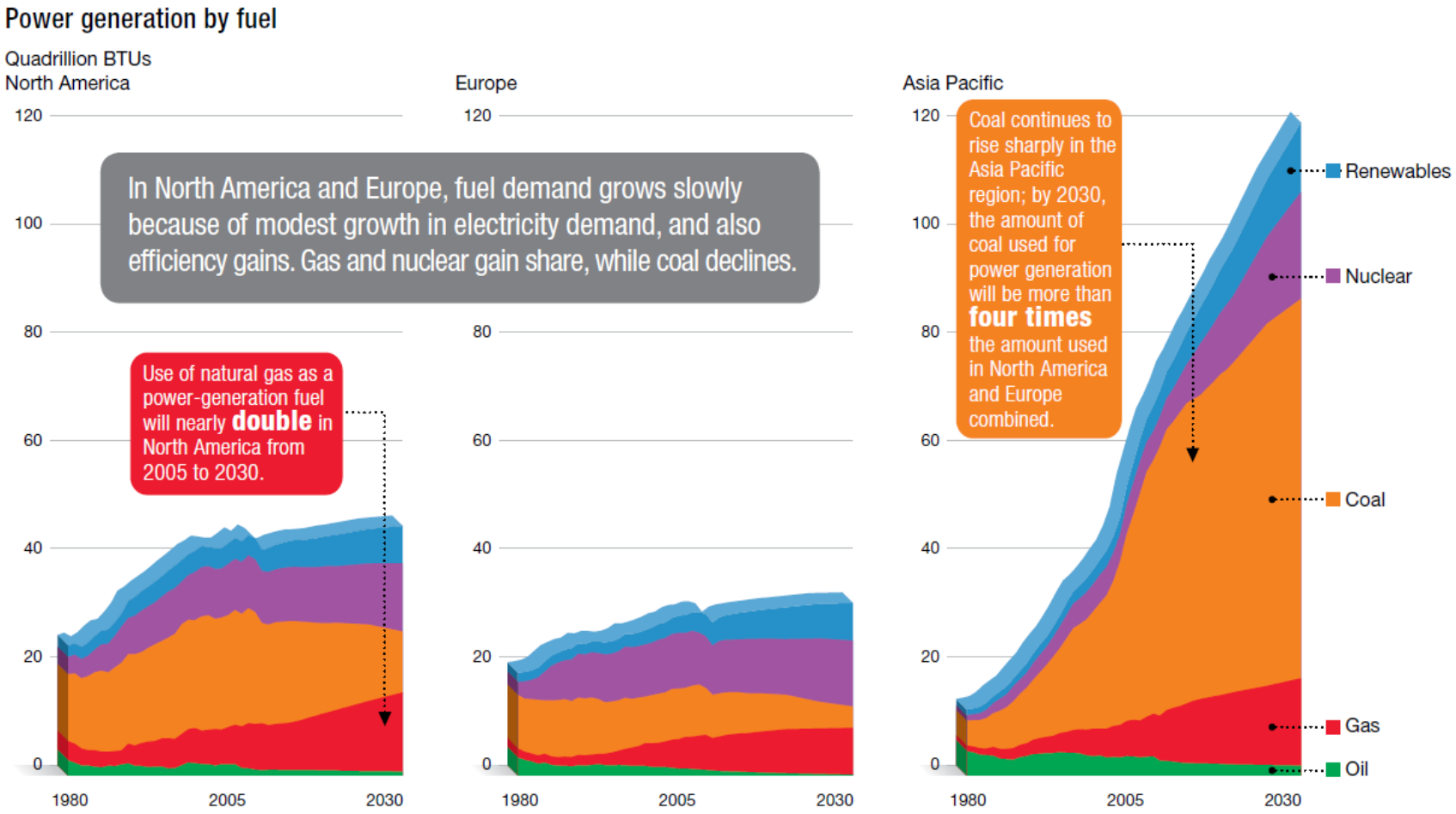


Range of Estimates of Global Technical Potentials

	Geothermal Energy	Hydropower	Ocean Energy	Wind Energy	Geothermal Energy	Biomass	Direct Solar Energy
Max (in EJ/yr)	1109	52	331	580	312	500	49837
Min (in EJ/yr)	118	50	7	85	10	50	1575

Source: IPCC Special Report Renewable Energy Sources (SRREN)

Many expect electricity demand to grow faster than renewable energy generation



Source: ExxonMobile
http://www.exxonmobil.com/corporate/files/news_pub_eo_2010.pdf

The Outlook for Energy: A View to 2030 31

A Profound Transformation is Required

Today's U.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

TRANSFORMATION

Sustainable Energy System

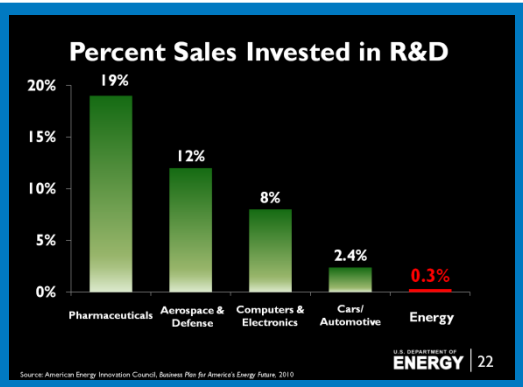
- Carbon neutral
- Efficient
- Diverse supply options
- Sustainable use of natural resource
- Creates American jobs
- Accessible, affordable and secure

Innovation, Integration & Adoption

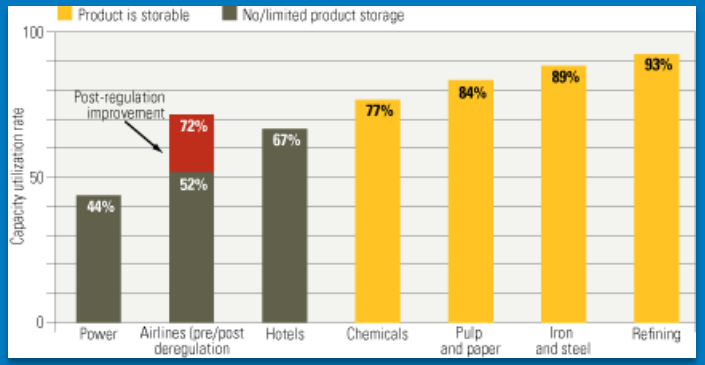
Reducing Investment Risk

- Enable basic and applied clean energy technology innovation
- Accelerate technology market introduction and adoption
- Integrate technology at scale
- Encourage collaboration in unique research and testing “partnering” facilities
- Provide analysis and expertise to inform decisions

Energy Sector Challenges



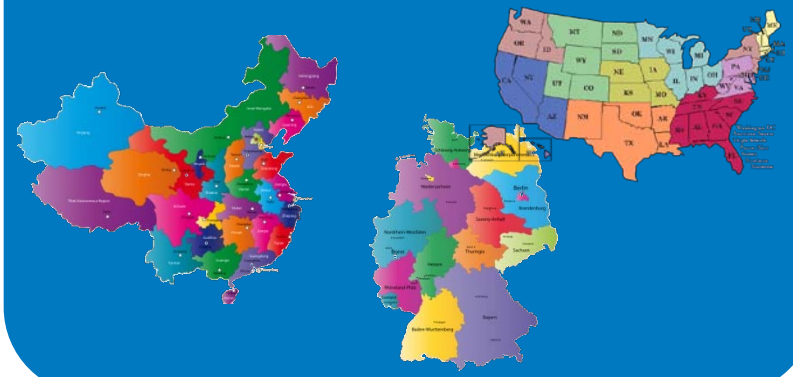
R&D Investment Drives Innovation



Asset Utilization

Capital Intensive with Long Life Cycles

National Strategies Driving Energy Market



Innovation for the Future

Integration:

- Integrating renewable energy at all scales

Solar:

- Lowering cost of solar energy systems by 75% by 2020

Biofuels:

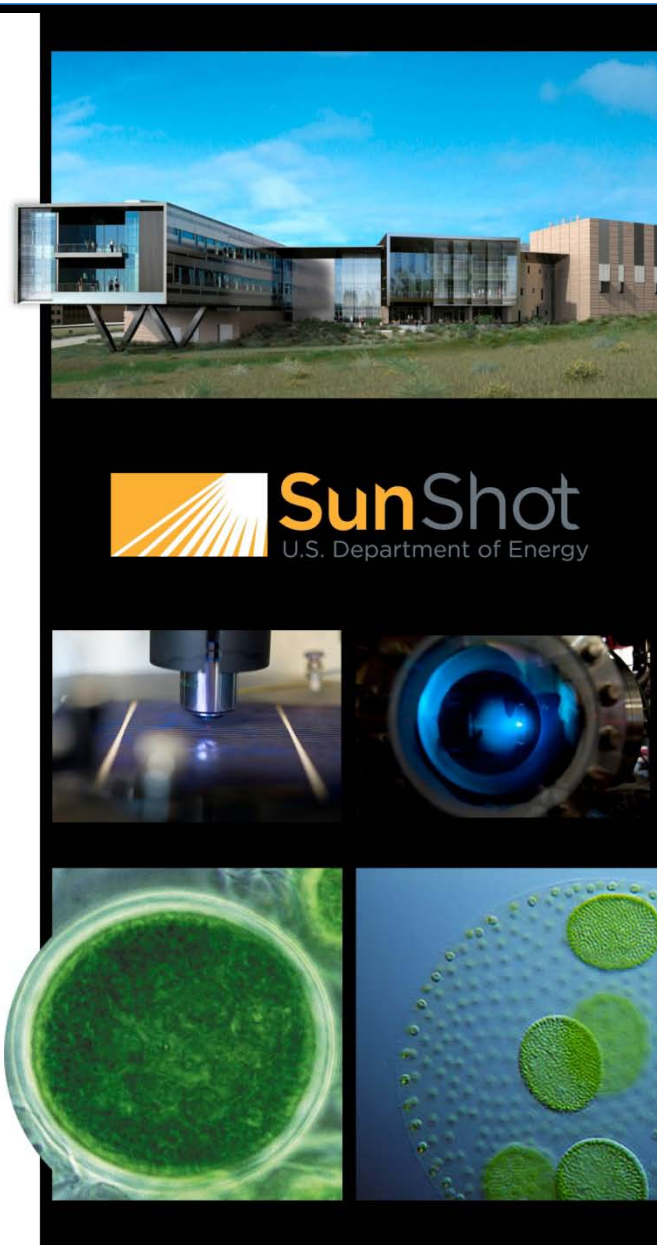
- Advanced biofuels – enabling cost-effective refining into transportation fuels

Wind:

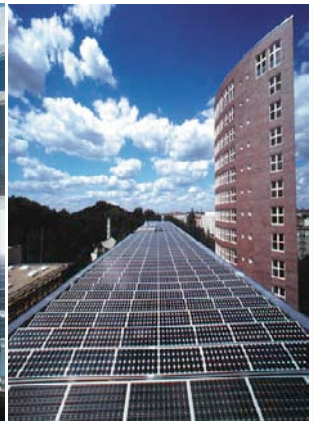
- System and component reliability, resource modeling and forecasting

Efficiency:

- Whole building systems integration
- Battery performance



Solar Electricity: *State of the Technology*

Photovoltaics (PV)

- Market: Residential; Commercial, Utility
- Geographically diverse
- kWs to MWs to GWs
- U.S. Capacity: 4.0 GW
- U.S. Forecast: 22+ GWs in pipeline
- Costs. $3 to $7/W: *LCOE 7 to 16¢/kWr
- Technologies: Conversion; thin-films, crystalline silicon. Storage; battery

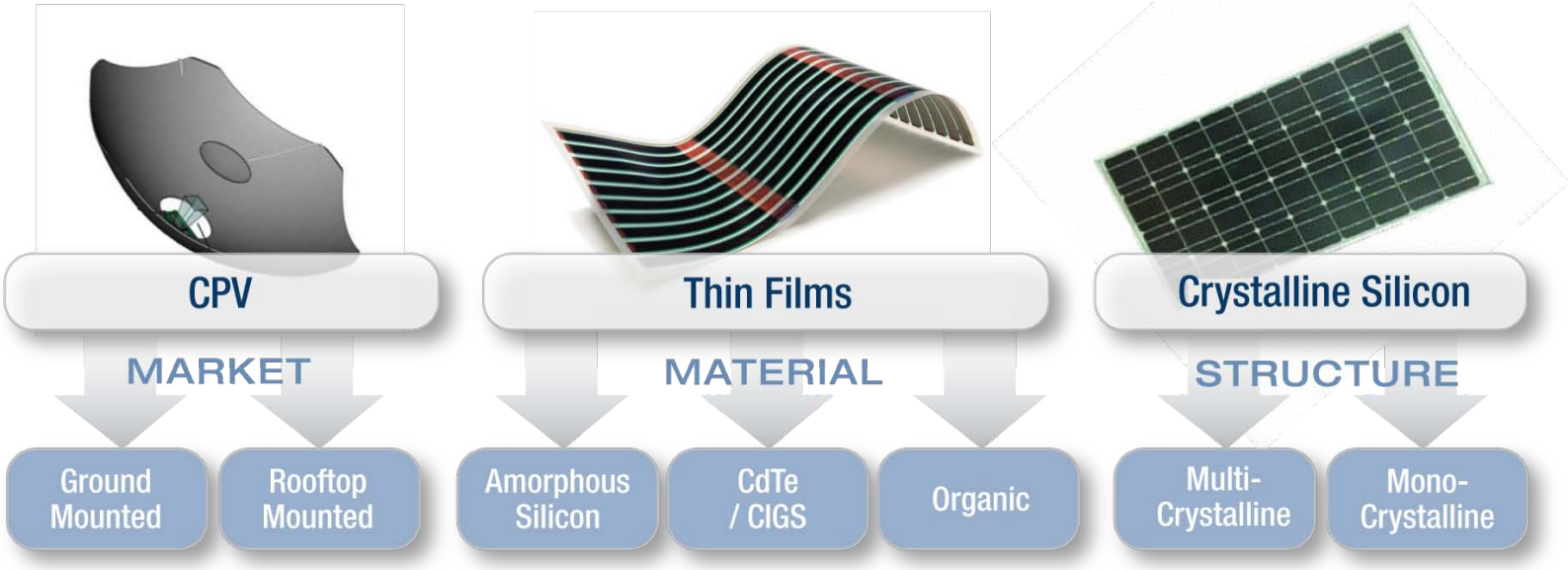
*With federal incentives; e.g. the FTC.

Solar Thermal Electric (CSP)

- Market: Commercial; Utility
- Geographically confined to “sun bowls”
- MWs to GWs
- U.S Capacity: 0.5 GW
- U.S. Forecast: ~6 GWs in pipeline
- Costs. $4 to $8/W: *LCOE 12 to 20 ¢/kWr
- Technologies: Conversion; parabolic troughs, central receivers, dish. Storage; thermal, up to 15 hours.

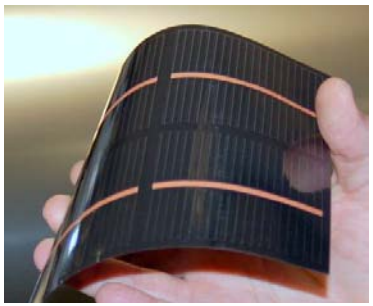
Updated: April 2012
Source: GTM/SEIA : U.S. Solar Market Insight Q4 2011 & 2011 Year-in-Review

Pursuing a Range of Promising PV Technologies

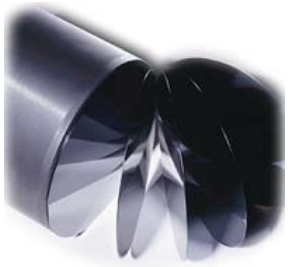


20x-100x

500x



Cu(In,Ga)Se_2 ~ 1-2 um



c-Si ~ 180 um

Market Relevant Process Innovation

"Black Silicon" Nanocatalytic Wet-Chemical Etch

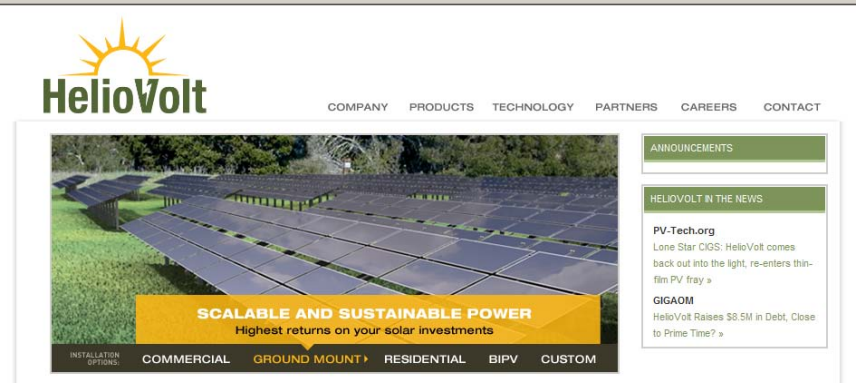
natcoretechnology
advancing solar science

2010 R&D 100

Flash Quantum Efficiency System

2011 R&D 100

FlashQE



Revolutionary CIGS thin-film manufacturing process using inket printing

HelioVolt

R&D 100
2008

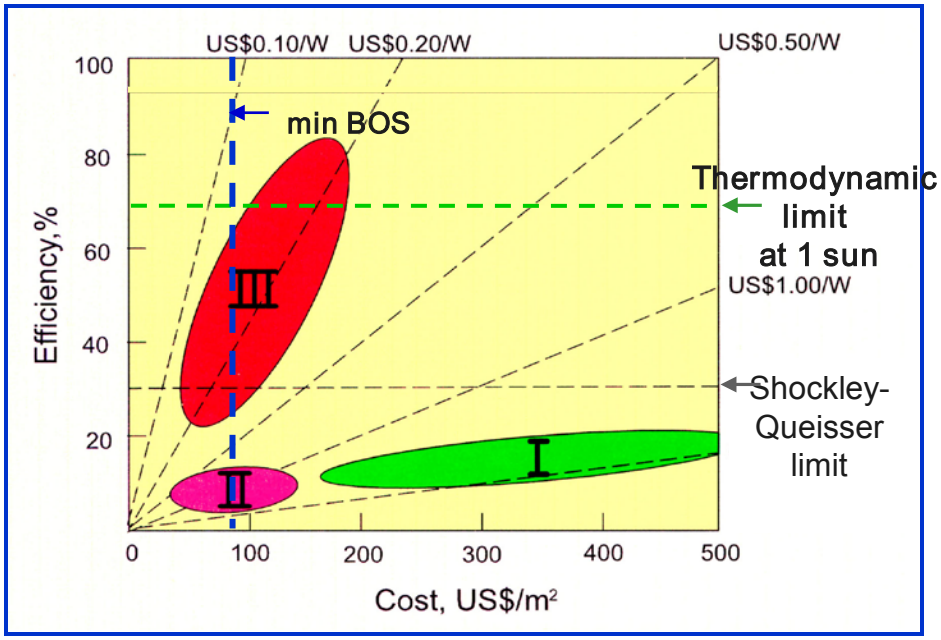
DUPONT innovaLIGHT

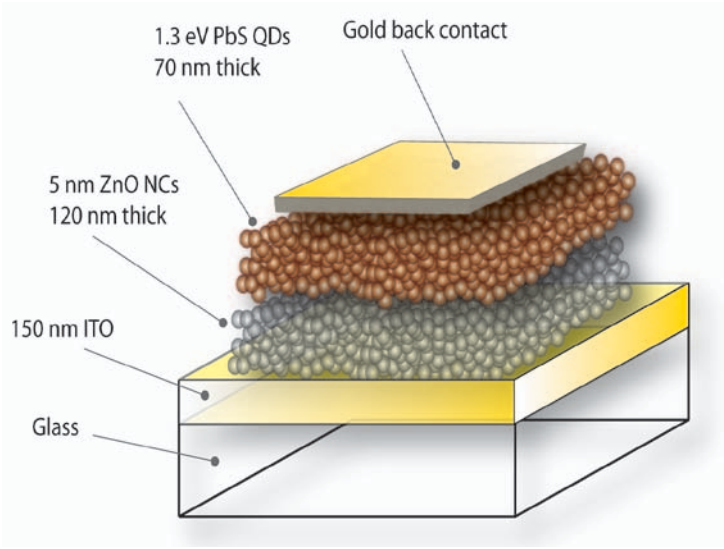
English | 中文

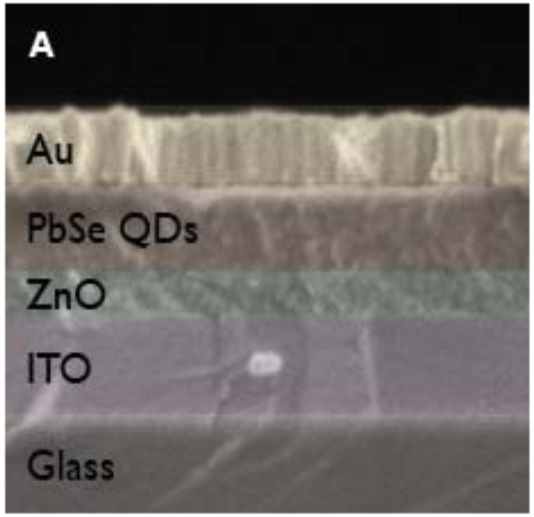
Silicon Ink NREL Incubator Project

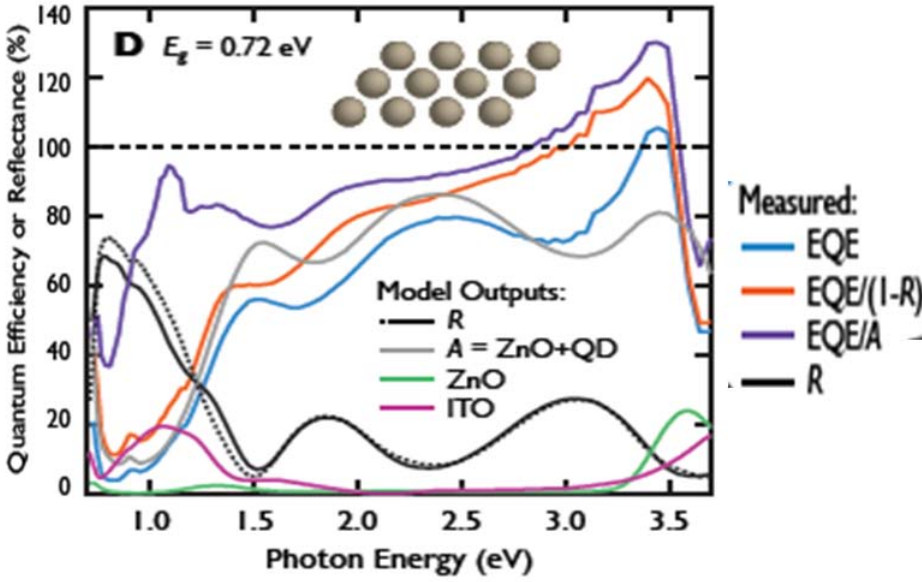
2011 R&D 100

Solar Science Innovation

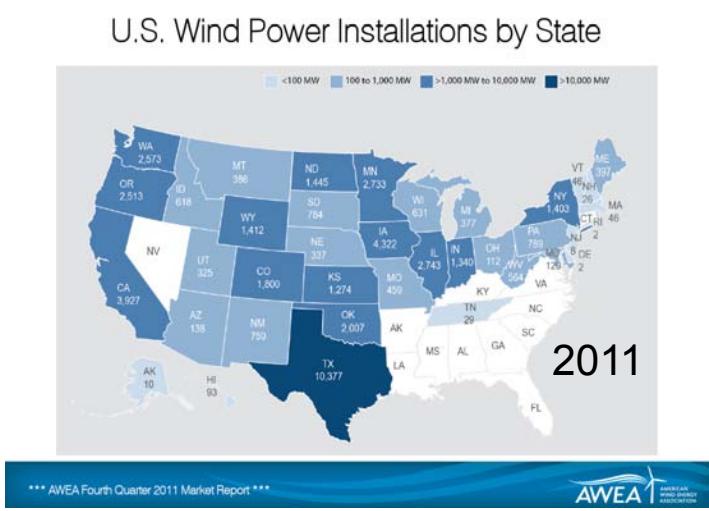








Wind Energy: *State of the Technology*



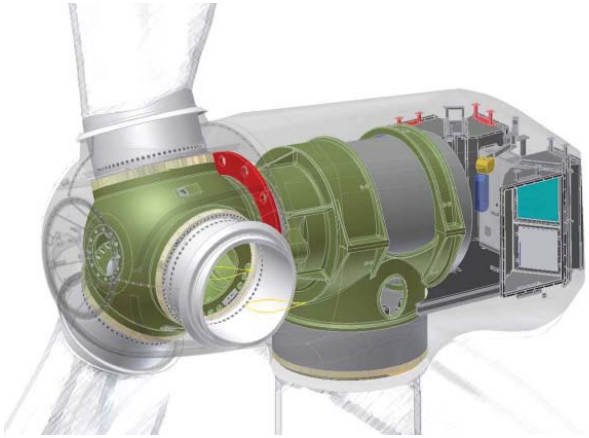
- Costs: 7-10 cents/kWh LCOE*
- Installed wind project cost = $2,155/kW
- 1.5-3.0 MW commercial turbines are typical
- 10 MW prototype machines in development
- Direct drive generators more common
- Variable speed and grid-friendly operation
- Technologies targeting offshore wind markets

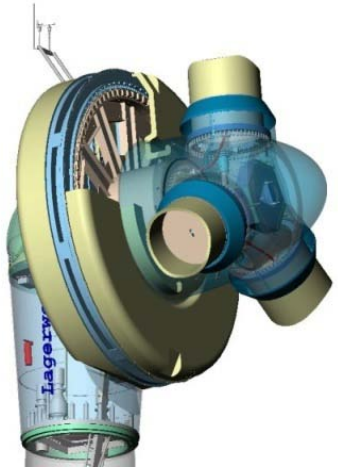
- U.S. installed capacity = 46.9 GW (12/2011)
- 38 of 50 states have utility-scale wind with 14 states > 1,000 MW installed
- Over 8.3 GW currently under construction
- U.S. wind capacity represents more than 20% of the world's installed wind power
- U.S. wind percentage of electricity is over 2.3%
- Over 400 manufacturing facilities across the U.S. make components for wind turbines

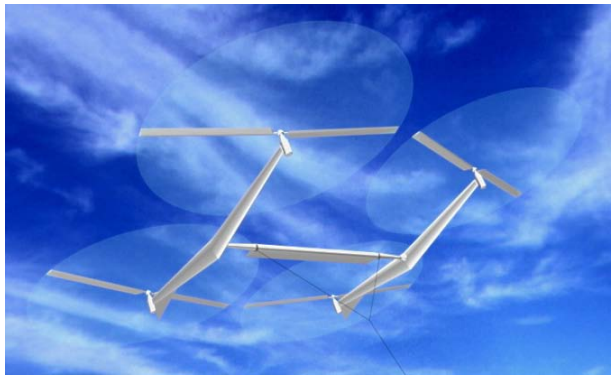
Updated: April 2012
* Estimate for utility-scale wind, class 4 wind sites, no subsidies

Wind Technology Innovation

- Modular large components – blades, drivetrains, and tall towers
- Advanced drivetrain power conversion systems – superconducting direct drive generators
- Flexible, ultra-large rotors and systems
- Active controls for structural load reduction, improved wind plant performance, and grid-friendly operation
- Floating offshore wind turbines
- Airborne wind power systems

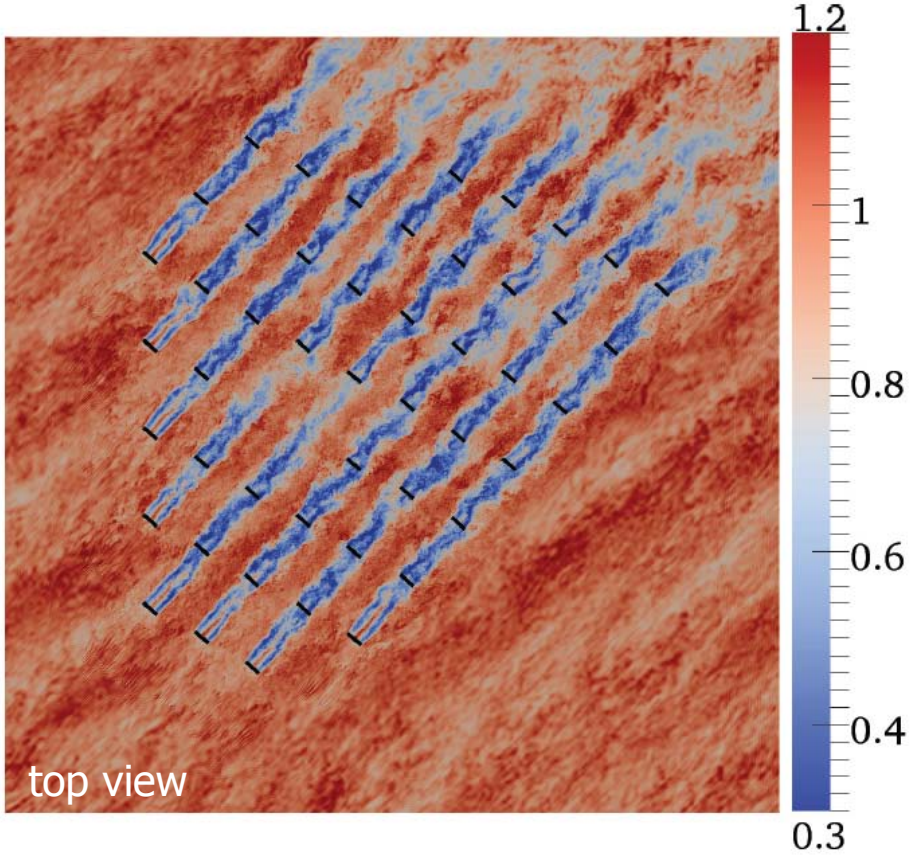




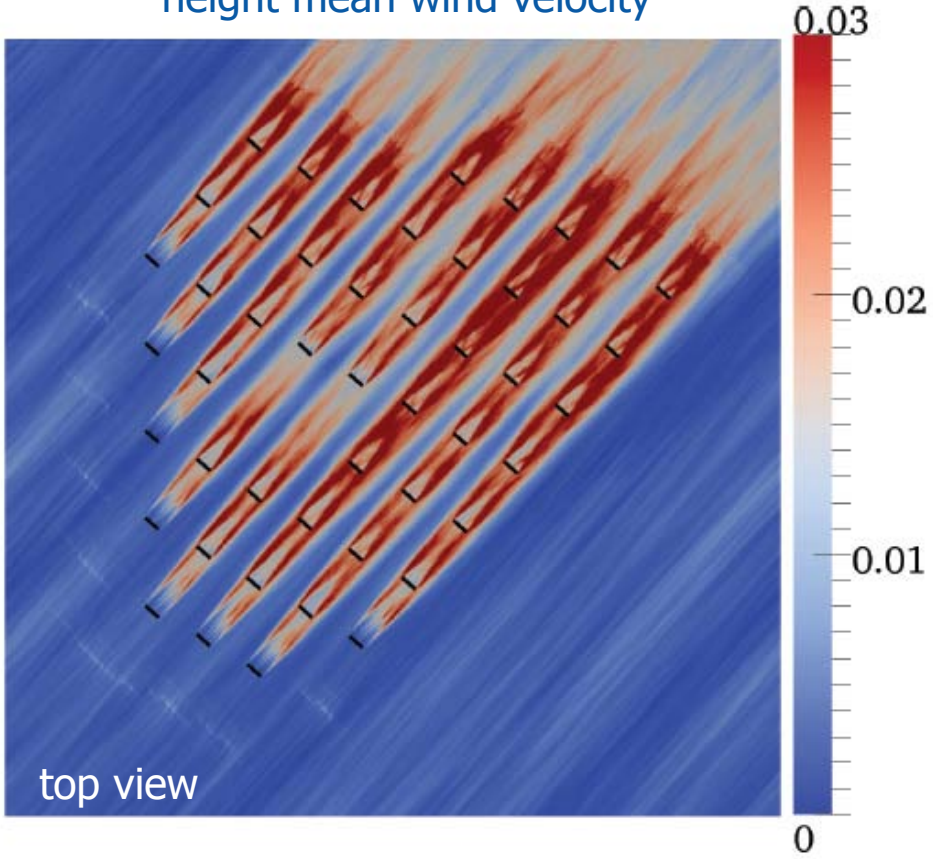


Wind Plant Simulation

Instantaneous velocity normalized by hub height mean wind velocity



Resolved-scale turbulent kinetic energy normalized by square of hub height mean wind velocity



Meandering shows up in resolved turbulent kinetic energy

Biofuels: *State of the Technology*

Current Status:

U.S. produced 13.5 billion gallons of ethanol and 1.1 billion gallons of biodiesel (2011)

Biorefineries:

- 219 commercial corn ethanol plants
- 180 biodiesel refineries
- 28 cellulosic ethan

Cost goal:

Cellulosic ethanol—cost parity with gasoline by 2012

Updated: 4/2012

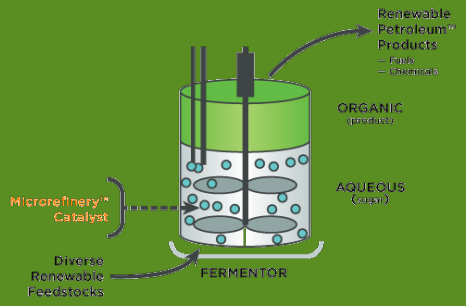
Major Technology Directions:

- 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

Biofuels Innovation

New conversion technologies are being developed, offering the possibility of revolutionary, high volume methods for producing biofuel hydrocarbon fuels for our trucks, trains, ships, and aircraft . . .

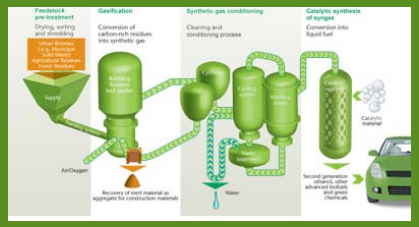
Biological Conversion



LS9

AMYRIS

Chemical Catalytic Conversion



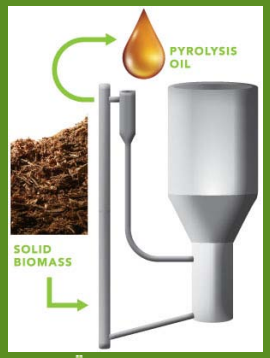
VIRENT
IT'S ABOUT TIME

RENTECH®

ClearFuels®
TECHNOLOGY, INC.

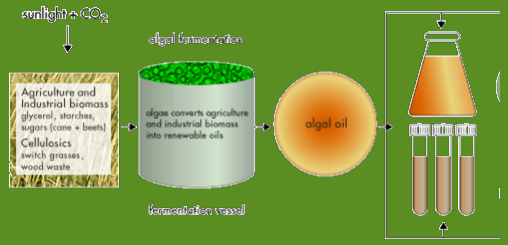
Enerkem

Pyrolysis/Bio-Oil Pathways



Envergent
TECHNOLOGIES
A Honeywell Company

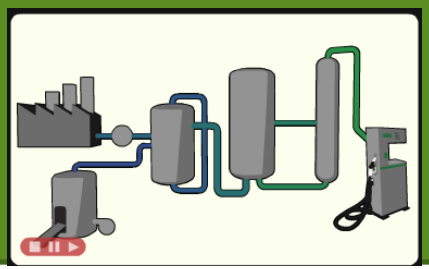
Heterotrophic Algae Conversion



solazyme®

MARTEK
life enriched™

Hybrid Conversion Technologies



LanzaTech

coskata

Efficiency/Integration Innovation

Buildings

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


High Performance Buildings


BIPV Products & PV-T Array


Compressorless Cooling


Electrochromic Windows


Polymer Solar Water Heaters


Computerized optimization & simulation Tools

Grid Integration

Interconnection Standards

- IEEE Standards Development
- Standards Testing and Validation

Smart-Grid Data Hub

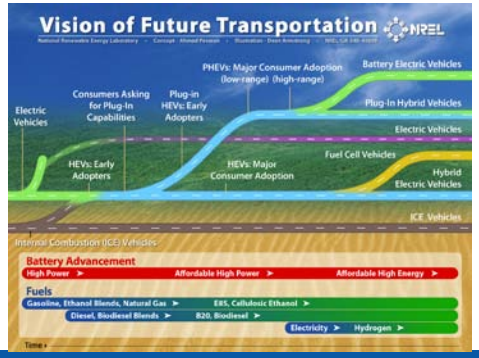
RE Grid Integration

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


Artist Rendering of the Energy System Integration Facility

Advanced Vehicles

- Fuels utilization
- Component technologies
- Electric vehicle-to-grid interface



innovation Impact: Partnering is Key















NREL Opportunities

- **Employment**
  - http://www.nrel.gov/employment/
- **DOE's Science Undergraduate Laboratory Internship (SULI) Program**
  - http://science.energy.gov/wdts/suli/
- **Graduate Fellowship Program—U.S. Department of Energy (DOE) has established the DOE Office of Science Graduate Fellowship Program**
  - http://scgf.orau.gov/
- **NREL's Research Participant Program**
  - http://www.nrel.gov/rpp/student_internships.html
- **For more information on NREL's education programs**
  - http://www.nrel.gov/rpp/
  - Linda.Lung@nrel.gov

NREL's Energy Vision

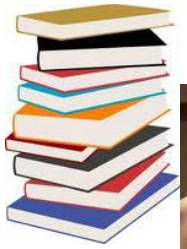
A clean and sustainable energy system contributing to economic prosperity, enhancing national security, and maintaining environmental quality

Ingredients for Success*

*My View

Dimensions of Professional Careers*

- Economic  Live
- Social 

Love
- Psychological   Learn
- Spiritual  Leave a Legacy

*Steven R. Covey

My Personal Passions

NREL

NSB

GMiS

Ingredients for Success

- Find something that really interests you
- Understand your own life balance
- Learn from everyone
- Be committed / dedicated
- Take risks and prepare for success

  •••
- Give back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May 2011