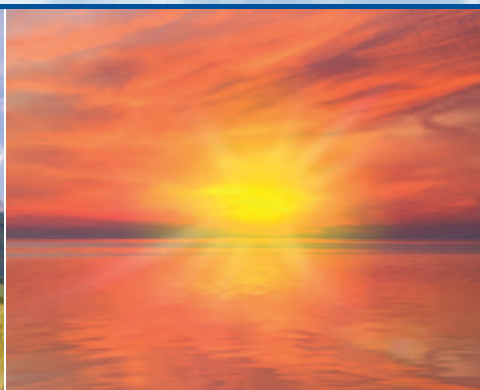




# Colorado Renewable Energy Collaboratory

Partners for Clean Energy



## Partnering with the Collaboratory

### What makes the Collaboratory the world's most powerful renewable energy research consortium?

The Colorado Renewable Energy Collaboratory is a research partnership among the National Renewable Energy Laboratory and Colorado's premier research universities—Colorado State University, the University of Colorado at Boulder, and Colorado School of Mines. Together, they comprise the world's most powerful renewable energy research consortium.

The Collaboratory works with industry partners, public agencies, and other universities and colleges to:

- Develop renewable energy technologies for rapid transfer to the marketplace
- Support economic growth with renewable energy industries
- Educate the finest energy researchers, technicians, and workforce.

The Collaboratory's research centers unite world class researchers with industry leaders, pursuing both shared (pre-competitive) and sponsored (exclusive) research.

**Shared Research** projects are selected by industry members from proposals offered by researchers at all four Collaboratory institutions, and are funded by industry members' annual fees and, initially, by matching funds from the State of Colorado.

**Sponsored Research** can be conducted at one or more of the four institutions under a single contract, with a single administrative point of contact.

Industry members may also sponsor fellowships for undergraduate, graduate, and postdoctoral students.

### **C2B2** Colorado Center for Biorefining and Biofuels

C2B2, a research venture between large and small businesses and the Collaboratory, performs cutting-edge research to develop new biofuels and biorefining technologies for rapid transfer to the private sector.

Fourteen private companies are supporting members of C2B2. They are Chevron, Cobalt Biofuels, ConocoPhillips, Ecopetrol-ICP, Flad Architects, Genencor, General Motors, Genesis Biofuel, Gevo, OPX Biotechnologies, Rentech, Shell Global Solutions, Sundrop Fuels, and Valero.

For more information, contact: Frannie Ray-Earle, Center Coordinator, C2B2@Colorado.edu, 303-492-7736



### **CRSP** Center for Revolutionary Solar Photoconversion

CRSP focuses on basic science and applied research to create new technologies for direct solar photoconversion into clean electricity and fuels. Under the scientific direction of Dr. Craig Taylor (Colorado School of Mines), CRSP partners and members create new materials and processes to lay the foundation for tomorrow's solar energy technologies. CRSP's members are Abengoa Solar, Applied Materials, DuPont, General Motors, Lockheed Martin, Sharp, Tokyo Electron, and Total.

For more information, contact: John Benner, Managing Director, john.benner@nrel.gov



### **CREW** Center for Research and Education in Wind

CREW offers to the wind power industry the capabilities of the four Collaboratory institutions plus the atmospheric science expertise of two additional Colorado-based federal research institutions—the National Center for Atmospheric Research (NCAR) and the National Oceanic and Atmospheric Administration (NOAA).

[www.coloradocollaboratory.org](http://www.coloradocollaboratory.org)

## Collaboratory Centers in Development:

### Carbon Management Center

Reducing greenhouse gases in the atmosphere through reuse of carbon and geologic and terrestrial sequestration can work in tandem with renewable energy strategies to combat climate change.

The Collaboratory will soon launch the Carbon Management Center to study and create technologies for carbon capture, beneficial reuse, and sequestration; to quantify and assess greenhouse gas "footprints;" and to analyze the broad-ranging policy issues presented by these alternatives. Membership invitations are now being issued.

For more information contact: Kevin Doran, [dorank@colorado.edu](mailto:dorank@colorado.edu)

### Energy Systems and Efficiency Center

To achieve our national goal of clean, sustainable, and secure energy, we must be more efficient in the production, distribution, management, and consumption of energy.

The Collaboratory is creating a research center to address these challenges, including the critical issues of grid management and the integration of increasing amounts of renewable energy into our electric grid, with special emphasis on grid security and reliability.

For more information contact: Tim Reeser, [tim.reeser@colostate.edu](mailto:tim.reeser@colostate.edu)



### Center for Research and Education in Wind *continued...*

CREW's areas of emphasis include: modeling, design and testing of wind turbines; short- and mid-term forecasting; and electrical and control systems. CREW offers the scientific and engineering research capabilities of three universities, two national research institutions, and NREL's National Wind Technology Center, located just south of Boulder, Colorado. CREW's members are Catch The Wind, Mitsubishi Power Systems Americas, NRG Systems, RES Americas, Vestas Wind Systems, and WindLogics.

For more information, contact: CREW Managing Director, Florence Bocquet, Ph.D., [florence.bocquet@colorado.edu](mailto:florence.bocquet@colorado.edu)

### SolarTAC Technology Acceleration Center

In addition to its own research centers, the Collaboratory provides broad research capabilities to the Solar Technology Acceleration Center (SolarTAC).

SolarTAC, one of the world's largest solar research, test, and evaluation facilities, is managed and operated by MRIGlobal. Its founding members are Xcel Energy, Abengoa Solar, and SunEdison. Additional sponsoring members are Amonix, EPRI, and the Alliance for Sustainable Energy.

Located in Aurora, Colorado (southeast of Denver International Airport), SolarTAC provides facilities where member companies can bring near-commercial or advanced solar technologies for testing and demonstration under actual field conditions. SolarTAC also offers flexible programs for research, monitoring, and evaluation.

The four Collaboratory institutions will conduct shared and sponsored research programs in support of SolarTAC's research, testing, and demonstration activities.

For more information, contact: Lindsey Matthews, [lmatthews@mriglobal.org](mailto:lmatthews@mriglobal.org)

### Collaboratory Education Task Force

The Collaboratory's Education Task Force works with Colorado state agencies, universities, colleges, community colleges, and private employers to accomplish two goals essential to the transition to a new energy economy:

1. The education of scientists and engineers for industry and academia
2. The training of workers needed by the private sector for manufacturing, deployment, and operation and maintenance of renewable energy technologies.

The Collaboratory is currently partnering with public and private partners, including the Colorado Community College System and the Colorado Department of Labor and Employment, to train workers in transition and students for solar, wind, and smart-grid industry jobs.

For more information, contact: David Hiller, [David.Hiller@ColoradoCollaboratory.org](mailto:David.Hiller@ColoradoCollaboratory.org)

## Colorado Center for Biorefining & Biofuels



C2B2 is a research center of the Colorado Renewable Energy Collaboratory, a unique research partnership of the:

- The National Renewable Energy Laboratory (NREL)

and Colorado's premier research universities:

- University of Colorado at Boulder (CU)
- Colorado State University (CSU)
- Colorado School of Mines (Mines)

The Collaboratory's primary goal is the development and rapid commercialization of renewable energy technologies. Working through the Collaboratory's unified administrative structure, the four world-class institutions are able to offer their broad research capabilities to private industry through a single point of contact.

C2B2's private members identify shared research areas and then help to select projects for funding. The State of Colorado has provided funds to the Collaboratory to match the investments of private members in initial shared research programs.

C2B2, the Colorado Center for Biorefining and Biofuels, represents four research/educational partner institutions devoted to the conversion of biomass to fuels and products. C2B2 provides private industry with easy access to the researchers, laboratories, students, and educators of these innovative institutions, each with unique strengths.

### Gain access to research spanning the full spectrum of bio-technologies:

- **Feedstock Engineering, Plant Biotechnology and Crop Science**, including genetic engineering and cultivation of plants with improved biorefining and biofuels characteristics.
- **Biochemical Engineering** develops new technologies for upstream bioprocess engineering.
- **Process Engineering** improves understanding of overall process issues, including solids transport, separations, reforming and purification of biofuels/biorefining processes/products, and integration of processes into existing refineries.
- **Thermochemical Engineering** develops new technologies for converting biomass into useful products for fuels and chemical applications.
- **Product Engineering** addresses the interaction of the structure of various biofuels and biochemicals and their impact on emissions, performance, and durability of engines.
- **Systems Engineering** addresses overall systems issues, including life-cycle issues, economics, energy efficiency, and the impact of biofuels/biorefining processes on society.



*C2B2 is a research center of the*

**Colorado Renewable Energy Collaboratory**

*Partners for Clean Energy*

**Profit from our innovations. Work with world-class researchers at C2B2.**



*C2B2 operations are administered by*  
**The Center Executive Board:**

Executive Director: Dr. Al Weimer (CU)

Managing Director: Dr. Ryan Gill (CU)

CU Site Director: Dr. Will Medlin

CSU Site Director: Dr. Ken Reardon

Mines Site Director: Dr. John Dorgan

NREL Site Director: Dr. Mike Cleary

### Sponsors

Chevron

Cobalt Biofuels

ConocoPhillips

Ecopetrol-ICP

Flad Architects

Genencor

General Motors

Genesis Biofuel

Gevo, Inc.

OPX Biotechnologies

Rentech

Shell Global Solutions

Sundrop Fuels

Valero

### Programming and Benefits

C2B2 sponsors obtain access to the following programming and benefits of membership:

- Benefits:
  - Semiannual Member Meetings
  - Networking Receptions
  - Center Newsletters
  - PRIME Research Innovation Re-Cap
  - Members Only Website
  - Researcher Resume Database
  - Research Report Archives
  - Intellectual Property Development in Shared or Sponsored Research Opportunities
- Sponsor On-Site Training Opportunities
- Postdoctoral Fellowships
- Graduate Assistantships
- National Science Foundation Research Experience for Undergraduates Site Program in Biofuels and Biorefining
- Facilitation:
  - Recruitment and Hiring
  - Sponsored Research Agreement Development and Solicitations
  - Analytical Equipment Usage Facilitation
- Research and Training:
  - Seed Scholar Program
  - Professional Short Course

### Contact us

*Partner with our world-class researchers.*

Frannie Ray-Earle,  
Center Coordinator

Call: 303-492-7736

Visit: [www.C2B2web.org](http://www.C2B2web.org)

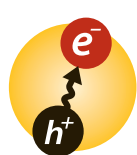
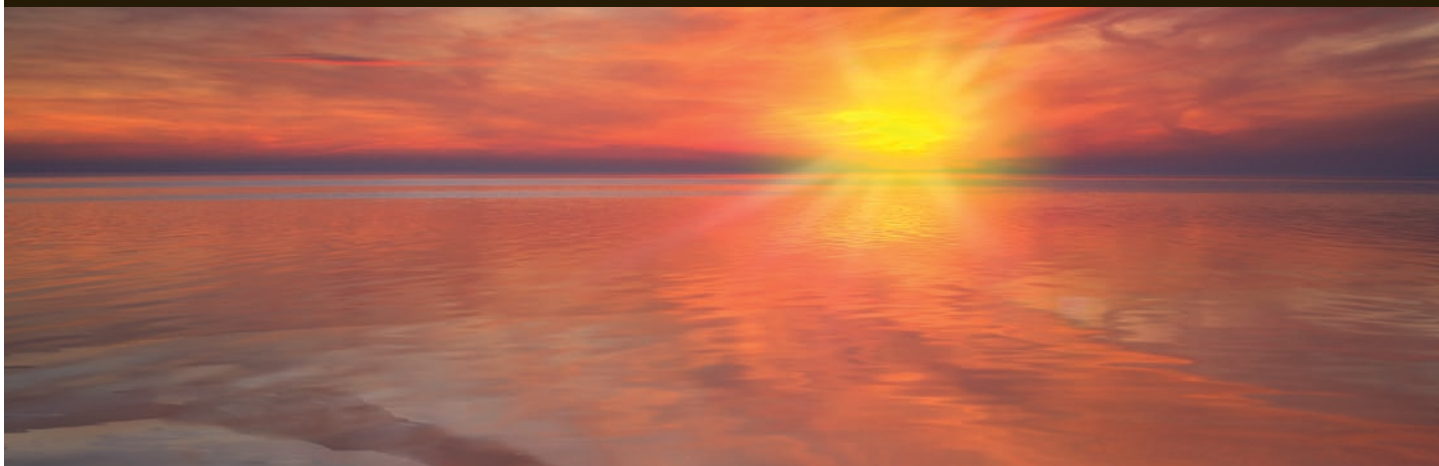
E-mail: [C2B2@colorado.edu](mailto:C2B2@colorado.edu)

Colorado Center for  
Biorefining and Biofuels,  
Department of Chemical and  
Biological Engineering  
University of Colorado, 523 UCB  
Boulder, CO 80309-0424

Learn more about the Colorado  
Collaboratory at:  
[www.coloradocollaboratory.org](http://www.coloradocollaboratory.org)

September 2011

# Center for Revolutionary Solar Photoconversion



## CRSP

Center for Revolutionary  
Solar Photoconversion

*Third-Generation Solar Photon Conversion*

CRSP is a research center of the Colorado Renewable Energy Collaboratory. The Collaboratory is a unique research partnership between the National Renewable Energy Laboratory (NREL) and Colorado's premier research universities—the University of Colorado at Boulder (CU), Colorado State University (CSU), and Colorado School of Mines (Mines).

### CRSP Member Companies:

Abengoa Solar

Applied Materials, Inc.\*

DuPont\*

General Motors

Sharp\*

Tokyo Electron

Total

\*Founding members of CRSP

**Visit the CRSP website  
for more information:**

[www.coloradocollaboratory.org/crsp](http://www.coloradocollaboratory.org/crsp)

**CRSP is dedicated to the basic and applied research necessary to create revolutionary new solar energy technologies as well as educational and training opportunities. The research underpins renewable energy technologies, commonly called third-generation solar photon conversion, for the highly efficient and cost-competitive production of both electricity and fuels via direct solar processes.**

CRSP institutions make available their capabilities for shared and sponsored research projects with CRSP members, as well as for federally funded research. CRSP is a joint effort among the four Collaboratory research institutions and other research institutions that may be added in the future. Membership in CRSP allows companies and other organizations to learn about and participate in advances in solar cell science and technology and to guide shared research programs. The areas of research being pursued include:

- Photovoltaics (inorganic and organic)
- Photochemistry
- Photophysics
- Photobiology
- Photoelectrochemistry
- Nanoscience

CRSP research is divided among three programs:

- *Shared Research.* CRSP members help select precompetitive shared research projects and receive nonexclusive licenses to the resulting technologies. Shared research projects are supported by a pool of funds created from membership fees and, initially, by matching funds from the State of Colorado.
- *Sponsored Research.* Any member may contract with one or more of the CRSP institutions for an independently funded sponsored research project that focuses on specific areas of interest, including results of shared research projects. In addition, exclusive licensing is available.
- *Federally Funded Research.* The CRSP institutions compete for funding from the U.S. Department of Energy (DOE) to conduct basic research on novel approaches to solar photon conversion. For example, CRSP is part of a 5-year federally funded Energy Frontier Research Center under a DOE Office of Science award.



CRSP is a research center of the

## Colorado Renewable Energy Collaboratory

*Partners for clean energy*

The ultimate and ambitious long-term goal of CRSP is to produce electricity and liquid and gaseous fuels at costs competitive with energy produced from coal. CRSP researchers see these technologies grouped into various categories including:

- *Electricity Production (Photovoltaics)*: Photoconversion processes yield electricity, as in solid-state photovoltaic solar cells based on bulk semiconductor p-n junctions, but also include technologies based on the absorption of solar photons in molecular or polymeric chromophores, or in semiconductors in contact with electrochemical redox systems.
- *Photoconversion into Liquid and Gaseous Fuels*: This is a one-step direct process in which the fuel (for example hydrogen, hydrocarbons, or alcohols) is the initial product of a direct photoelectrochemical, photochemical, or photobiological process driven by solar photons.
- *Novel Nanostructures and Advances in Nanoscience*: These technologies play a major role in the science of third-generation solar photon conversion.

Advances in basic and applied science at CRSP will be readily and efficiently transferred into marketable solar technologies. This will occur through NREL's strong renewable energy relationships with industry and the three research universities' commitments and strong track records in technology transfer.

CRSP is uniquely positioned to support the research that will revolutionize solar energy technologies. NREL houses both the applied and near-term solar R&D programs supported by the DOE Office of Energy Efficiency and Renewable Energy and longer-term basic solar research programs supported by the DOE Office of Science. The three Colorado research universities offer internationally recognized faculties and world-class research facilities, and Mines is the home of the National Science Foundation's only Renewable Energy Materials Research Science and Engineering Center.

The scientific skills and market understanding of CRSP's private-sector partners will combine with the resources of the four Collaboratory institutions to focus CRSP's research efforts in areas that will truly impact global solar energy utilization.

#### Executive Board and Management

Scientific Director: Dr. Craig Taylor, REMRSEC, CSM  
Co-Directors: Dr. C. Michael Elliott, CSU; Dr. David Jonas, CU; Dr. Colin Wolden, CSM  
Managing Director: Kaitlyn VanSant, NREL  
Senior Scientific Advisor: Dr. Arthur Nozik, NREL  
Senior Advisor: Paul Nelson

#### Company Advisory Panel

The panel includes one representative from each member company, who play a key role in identifying shared research thrust

#### CRSP Shared Research Thrust Areas for 2011

As the word "revolutionary" in our name suggests, we are interested in research that is potentially transformative, compared to current technologies for solar energy conversion to electricity and fuels. Research proposals should also provide a credible pathway for achieving significant market penetration by ultimately meeting appropriate cost and reliability targets.

##### Photoconversion into Electricity

1. Inorganic materials and novel device architectures for advanced solar cells  
*Thin-film Si, new low-cost Si substrates, nanocrystalline semiconductors, CdTe and CIGS solar cells, new polycrystalline thin films, new transparent conductors, and new multijunction and other novel device concepts, plasmonics.*
2. Novel organic/polymeric/hybrid inorganic-organic solar cells  
*Molecular semiconductor and polymeric solar cells, nanocrystalline dye-sensitized solar cells.*
3. Third-Generation Photovoltaics  
*Quantum-confined structures for solar cells (quantum dots, quantum films/wells, quantum wires/rods), intermediate-band solar cells, up- and down-conversion of incident photons, thermophotonics.*

##### Photoconversion into Fuels

1. New materials and approaches for efficient solar water splitting for hydrogen production  
*Bioinspired materials, novel thermal chemical processes (lower temperature, less corrosive chemicals), novel photoelectrochemical processes (coupling light harvesting with efficient catalysts, improved water oxidation component durability).*
2. Photoreduction of CO<sub>2</sub> with water to fuel (artificial photosynthesis)  
*New catalysts for CO<sub>2</sub> reduction and water oxidation based on abundant elements, increased catalyst durability, light-harvesting units with catalytic site and biological assemblies; system integration and analysis.*

areas, selecting projects for funding, and in other functions of CRSP.

#### Scientific Advisory Board

Dr. Thomas J. Meyer, University of North Carolina at Chapel Hill, chairs this board of external experts; the board's role is to evaluate and monitor the quality of the science performed by CRSP researchers.

#### For more information

Contact Kaitlyn VanSant at +1 (303) 384-7863 or kaitlyn.vansant@nrel.gov

September 2011



## Center for Research and Education in Wind (CREW)



Visit CREW at <http://crew.colorado.edu>

CREW is a research center of the Colorado Renewable Energy Collaboratory, a unique research partnership between:

- The National Renewable Energy Laboratory (NREL) and Colorado's premier universities:
- The University of Colorado at Boulder (CU)
- Colorado State University (CSU)
- Colorado School of Mines (Mines)

In CREW, the National Oceanic and Atmospheric Administration (NOAA) and the National Center for Atmospheric Research (NCAR) partner with the four Collaboratory institutions. Working through the Collaboratory's unified administrative structure, these six world-class institutions are able to offer their broad research capabilities to private industry through a single point of contact.

CREW's private members identify shared research areas and select projects for funding. The State of Colorado provided funds to the Collaboratory to match the investments of our private members in initial shared research programs.

**CREW, the Center for Research and Education in Wind, advances fundamental understanding and develops new technologies in areas that can improve the reliability and efficiency of wind power generation under a wide range of conditions. The ultimate goal of CREW is to enable widespread deployment of wind infrastructure and to contribute to a reduction in the cost of wind energy through scientific, technological, regulatory, and political advances in the current state of the art in wind energy systems.**

### CREW is structured to reach these goals by:

- Offering wind industry companies access to six powerful research institutions through a single point of contact
- Conducting both shared (pre-competitive) and sponsored (exclusive) research programs
- Partnering with other public and private research efforts
- Creating educational programs that support wind industry research, outreach, and professional and technical training.

### Additional Partners

To offer unique capabilities in wind and climate forecasting, modeling, and related disciplines, CREW, the National Oceanic and Atmospheric Administration (NOAA), and the National Center for Atmospheric Research (NCAR) have forged an official partnership. Both NOAA and NCAR operate laboratories and research centers in Boulder, Colorado, in close proximity to the four Collaboratory campuses.

### Faculty

CREW faculty membership continues to grow, and presently includes more than 70 researchers from the six CREW research institutions. CREW has faculty expertise in most areas of wind energy and growing educational programs focused on wind energy.



CREW is a research center of the

**Colorado Renewable Energy Collaboratory**

*Partners for clean energy*

## Profit from our wind research. Make CREW your partner.



### CREW's Five Areas of Emphasis

Based on input from leading wind energy companies, CREW has identified these five areas for special research emphasis:

**1. Turbine Modeling** develops models for all aspects of wind turbines including: mechanical components, aerodynamics, aeroelasticity, aeroacoustics, load prediction, wind farm effects, electrical systems, grid interactions, wind inflow, and hydrodynamics for offshore wind turbines. Models may employ a range of complexity—from empirical engineering codes to high-fidelity, physics-based codes.

**2. Electrical Systems** research includes grid modeling, power converter research, and the InteGRID Laboratory. Grid modeling research covers power quality, fault tolerance, islanding, and stability analysis with high wind penetration. The power converter area includes advanced control of converters, modular converters for improved utilization of wind power, and generators. The InteGRID Laboratory includes a megawatt-scale physical grid simulation capability and is used to test, validate, and develop solutions via grid simulations with actual physical system dynamics, including renewable sources.

**3. Control Systems** can reduce the cost of wind energy by using advanced turbine controllers. Research falls into two categories: individual turbine control and coordinated wind farm control. Individual turbine control can increase energy capture and/or reduce turbine loads. Coordinated wind farm control may also achieve both objectives.

**4. Turbine Testing and Certification** is performed by CREW at NREL's National Wind Technology Center. Blades are tested for fatigue and strength at the Blade Test Facility; drivetrains and generators are tested at the Dynamometer Facility; and turbines are installed in the field for power quality and acoustics tests.

**5. Atmospheric Science** capabilities include environmental sensing and measurement technology using meteorological towers, lidar and sodar, high-resolution numerical wind and inflow forecasting, and hybrid numerical wind models.

### Additional Research Capabilities

In addition to the five areas defined above, CREW's engineers and scientists also offer expertise in blade materials, energy storage and dispatchability, hybrid systems, interaction between wind farms and local ecosystems, and offshore wind farms. CREW researchers are also working on policy and outreach tasks, such as defining relevant IEC standards and developing wind energy classes at CREW-affiliated universities. All of these capabilities are available to private members of CREW.

September 2011

#### Managing Director:

Dr. Florence Bocquet (CU)

#### Mines Site Director:

Prof. Katie Johnson

#### CSU Site Director:

Prof. Sid Suryanarayanan

#### CU Site Director:

Prof. Kurt Maute

#### NREL Site Director:

Dr. Pat Moriarty

CREW's members are Catch The Wind, Mitsubishi Power Systems Americas,\* NRG Systems, RES Americas,\* Vestas Wind Systems,\* and WindLogics.\*

*\*Founding Members*

### Contact us

For information about membership, contact the CREW Managing Director:

Florence Bocquet at  
florence.bocquet@colorado.edu

**Visit CREW at <http://crew.colorado.edu>**