New Energy Technologies for the Global Climate Change Problem
- The Global Climate and Energy Project

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Prevention First 2008
Long Beach, CA

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Motivation for GCEP: The Challenge

Meeting Needs

- World population of 6.5 billion growing to 9 billion. 2 billion people currently have no access to modern energy systems
- Improving standard of living in growing economies of developing world
- Increasing demand for energy, food, land, and materials.

Component Challenges

- Water supply
- Food supply (strongly linked to water supply)
- **Energy – The Focus of GCEP**
Carbon dioxide emissions have risen dramatically over the past two hundred years…

… leading to the buildup of carbon dioxide in the atmosphere, … global warming, and … ocean acidification.
Concentrations of CO₂ will rise above current values (380 ppm), even under the most optimistic scenarios.

Stabilization will require that emissions peak and then decline. Peak timing depends on the stabilized concentration.

Improvements in efficiency, introduction of renewables, nuclear power, … all help.

New technology will be needed for the really deep reductions.

Source: IPCC 2007
The Global Climate and Energy Project

Mission
- Research on low-GHG emission energy conversions
- Focus on fundamental and pre-commercial research
- Applications in the 10-50 years timeframe

Schedule and Budget
- 10 years (2003 – 2013+)
- $225 M

Status
- 44 research programs
- 24 institutions
- 70 investigators
- Over 300 graduate students and post-doctoral fellows
- 6 patent applications
70 Principal Investigators
Over 300 graduate students and post-doctoral fellows
GCEP Institutions Around the World

GCEP Institutions

USA
- Stanford University
- Boise State University
- Brigham Young University
- California Institute of Technology
- Carnegie Institution of Washington
- Harvard University

Purdue University
- SRI International
- UC Santa Cruz
- University of Montana
- University of Wisconsin

Europe
- ECN
- ETH Zürich
- IRDEP/CNRS
- TU Delft
- University of Dundee
- Ghent University

Japan
- RITE

Australia
- UNSW
- University of Sydney

Université de Picardie Jules Verne
- Universidad Politécnica de Madrid
- Uppsala University
- Utrecht University/FOM
GCEP Strategy

- Focus on potential energy technologies that may be game-changing with respect to greenhouse gas emissions
- Encourage high risk/high reward research
- Seek opportunities across a portfolio of technical areas
- Address questions appropriate to pre-commercial research that may have an impact in the 10-50 year timeframe
- Use the best research talent available
- Make all data, results, and other information generated from the project open and available to all
- Involve institutions from countries with potential high levels of future greenhouse gas emissions
Step-Out Technology

Technology Option

Scientific Advance to Enable Development of a Game-changing Technology in Reduced Time

Previous Incremental Development

Step back to fundamentals

Continuing Slow Progress Via Business-As-Usual

Game-changing Technology in Reduced Time

Technology Challenge

Present Time

Time

Step-out Idea
GCEP Research Portfolio

Renewables
- Solar Water Splitting 4%
- Solar Photovoltaics 20%
- Exploratory Research 1%
- Integrated Assessment 2%

Electrochemical Transformations
- Advanced Fuel Cell Systems 11%
- Batteries for Advanced Transportation 6%

Carbon-Based Energy Systems
- Advanced Combustion 9%
- Advanced Coal 3%
- CO₂ Capture 7%
- CO₂ Storage 10%

Hydrogen
- Biohydrogen 5%
- Hydrogen Storage 5%
- Hydrogen Impacts 1%

Other
- 16%
Increasing Efficiency and Lowering Costs of Solar PV

GCEP research efforts include a broad array of new approaches to reducing the cost and enhancing efficiency of solar energy conversion.

**Third Generation** Concepts

- **Hot carrier**
- TPVs, thermionics
- Intermediate band, up-converters, tandem (n=3)
- Multiple exciton generation
- Tandem (n=2)
- Down-converters

**GCEP High Efficiency PV Program**

**Single-junction limit**

- 31%

**Thermodynamic limit**

- 68%

**Present limit**

- Thin-films (CIGS, CdTe, a-Si, ...)

**Wafer-based (c-Si)**

(M. Green, UNSW)
Directed Evolution of Novel Yeast Species to allow fermentation of xylose, a major component of hemicellulose.

Novel precursors for simplified degradation of lignin.

Novel screen for plants with enhanced saccharification.

Increased cellulose accumulation for enhanced biomass.

Cellulose fibrils

Directed Evolution of Novel Yeast Species to allow fermentation of xylose, a major component of hemicellulose.

New xylose utilizing strain

Non xylose utilizing strain

Engineering pathways in *E. coli* for Biodiesel production.
C-H Bonds in C Nanotubes as an Energy Carrier  
Anders Nilsson, Bruce Clemens, Hongjie Dai

- Investigated storage of hydrogen and its reversibility in carbon nanotubes
- Observed formation of C-H bonds with X-ray spectroscopy techniques
- Demonstrated ability to achieve up to 7 wt% hydrogen storage capacity
- Optimal C-H bond energetics can be tuned by selecting nanotube curvature range to minimize energy losses of the hydrogen desorption/adsorption process

Offers opportunity to reduce efficiency penalties for electrochemical energy storage by using C-H bonds in carbon nanotubes rather than molecular hydrogen as the energy carrier.
Carbon Dioxide Capture and Geologic Storage
• Goals
  ➢ Zero matter release to atmosphere
  ➢ Intrinsically safe storage with CO₂ pre-equilibrated in brine
Outreach

- Annual symposium
- International symposia
- Workshops and roundtables
- Community college information outreach
- Energy data resource website
- Sabbatical program
- GCEP Distinguished Lecturers

http://gcep.stanford.edu/
Expected Impact of GCEP

- A research-base for technologies that would permit substantial reductions in greenhouse gas emissions due to energy use
- A highly trained pool of researchers to address the remaining technological issues
- A better-informed technical community concerning the technical barriers and potential solutions concerning greenhouse gas emissions from energy production and utilization
- A unique model of a university-industry alliance for conducting research to address global technological issues
Conclusions

• There is no single solution to addressing the energy/GHG challenge
• Fundamental research is needed to create novel, more efficient technology options with potential for large-scale impact
• GCEP is a leader in the development of step-out fundamental science that will generate breakthrough energy technologies in the 10-50 year timeframe
• We are especially grateful for the opportunity to unleash the creativity of Stanford faculty and students, and talented researchers worldwide, to work on one of the grand challenges of this century