Stanford University

Global Climate & Energy Project

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

Richard Sassoon

Prevention First 2008
Long Beach, CA

September 9, 2008

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.

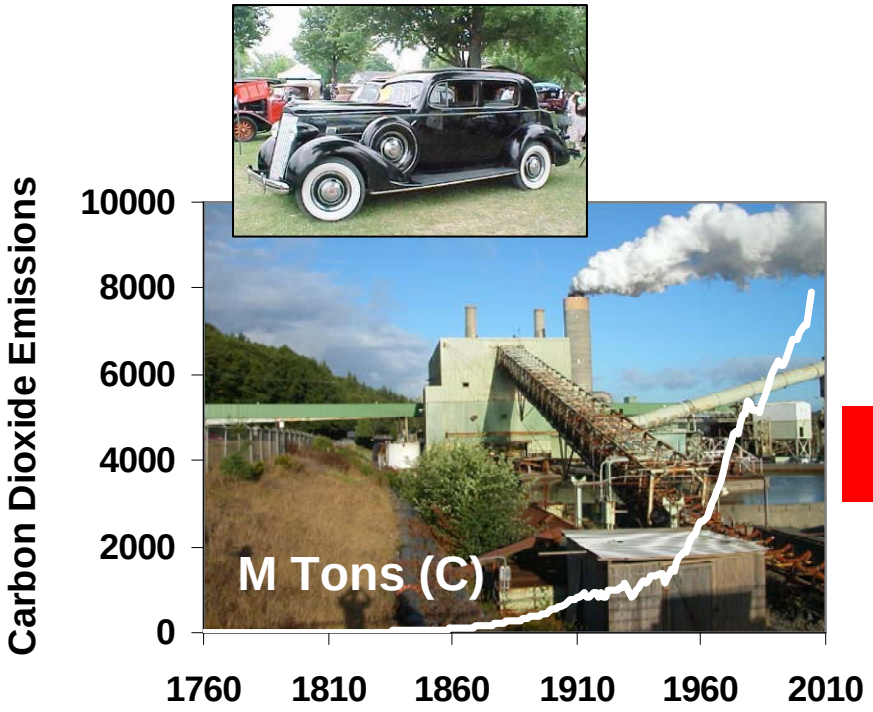
Protecting, Restoring, and Sustaining Global Biogeochemical Systems

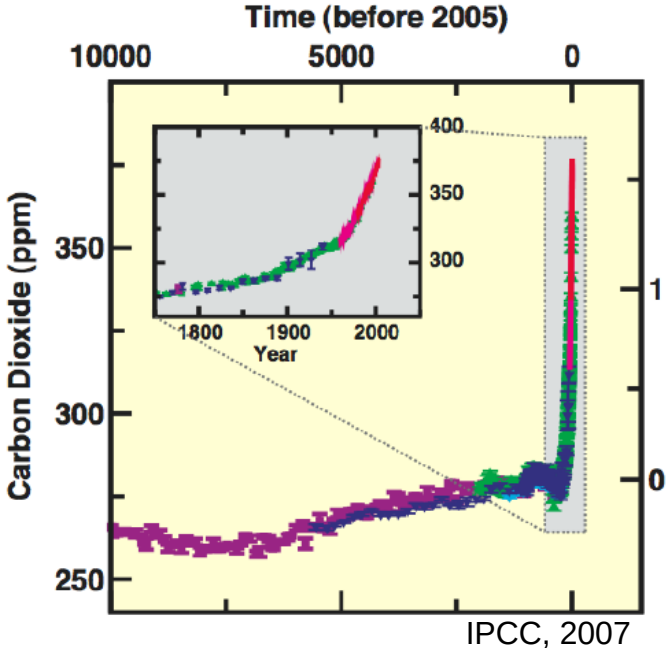
Component Challenges

- Water supply
- Food supply (strongly linked to water supply)
- **Energy – The Focus of GCEP**

Carbon Dioxide in the Atmosphere

Carbon dioxide emissions have risen dramatically over the past two hundred years…





IPCC, 2007

… leading to the buildup of carbon dioxide in the atmosphere,
… global warming, and
… ocean acidification.

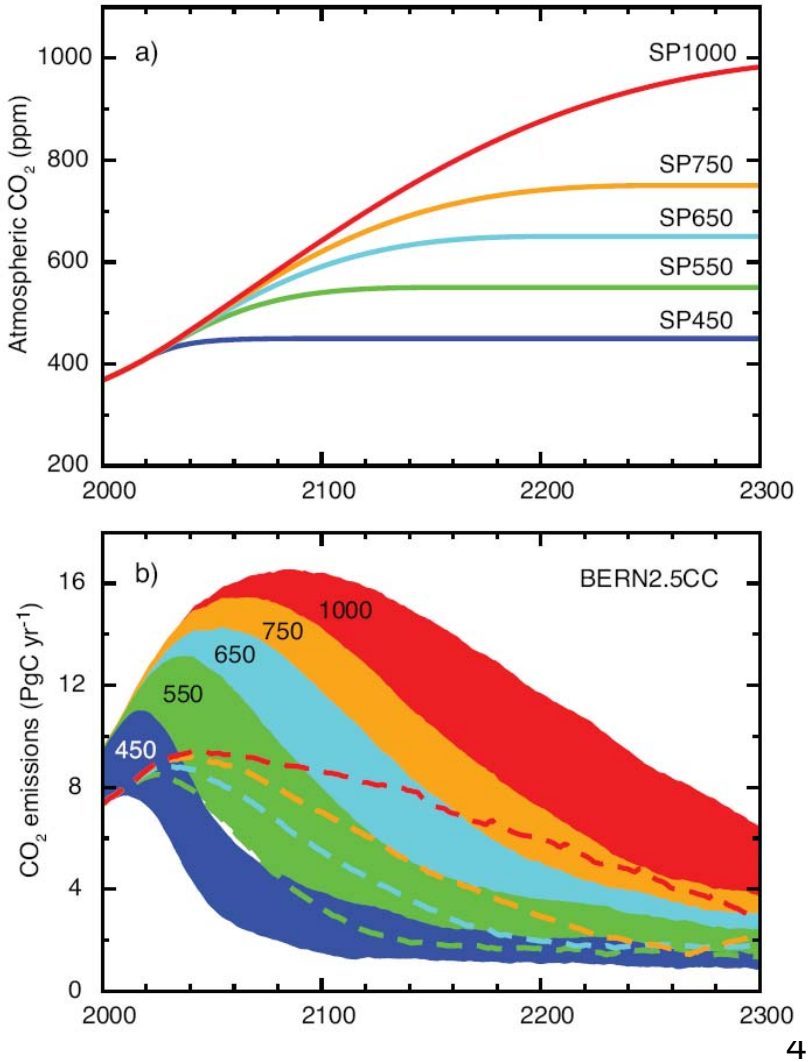
The Need for Technology

Concentrations of CO_2 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

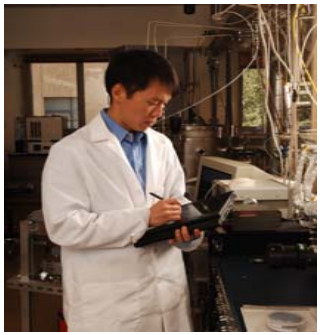
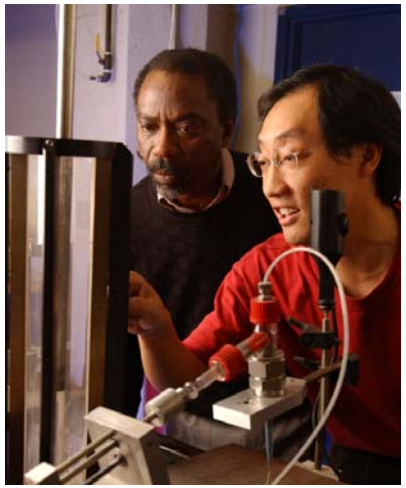
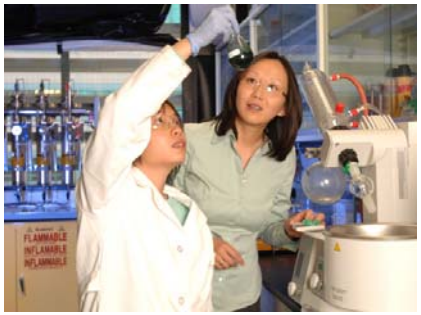
- 10 years (2003 – 2013+)
- $225 M

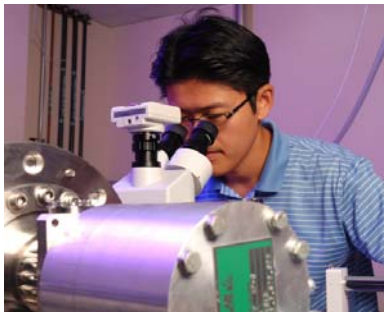
Status

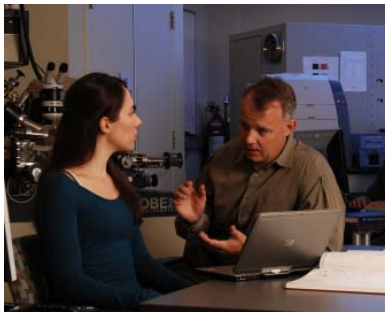
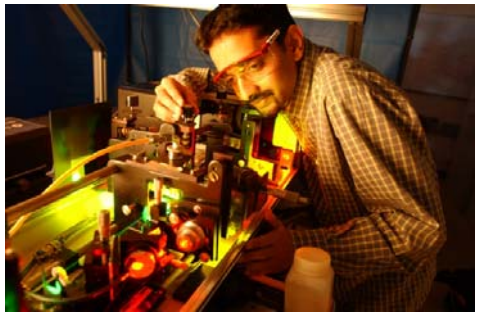
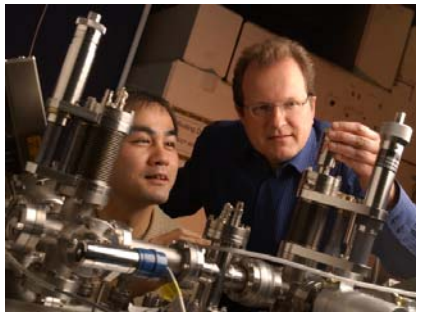
- 44 research programs
- 24 institutions
- 70 investigators
- Over 300 graduate students and post-doctoral fellows
- 6 patent applications

GCEP Researchers

- 70 Principal Investigators
- Over 300 graduate students and post-doctoral fellows



GCEP Institutions Around the World

GCEP Institutions

Japan
RITE

Australia
UNSW
University of Sydney

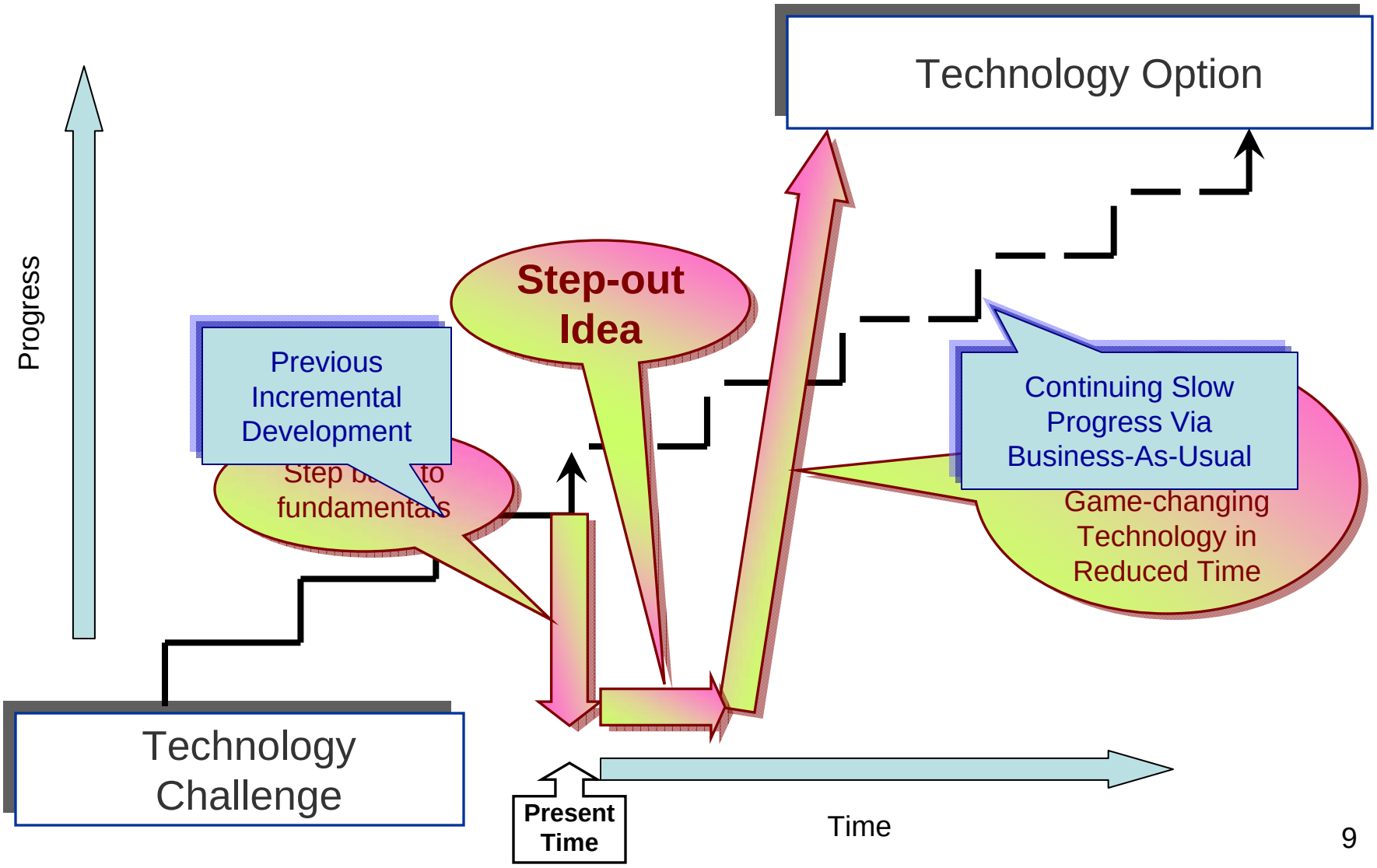
USA
Stanford University
Boise State University
Brigham Young University
California Institute of Technology
Carnegie Institution of Washington
Harvard University
Purdue University
SRI International
UC Santa Cruz
University of Montana
University of Wisconsin

Europe
ECN
ETH Zürich
IRDEP/CNRS
TU Delft
University of Dundee
Ghent University
Universite de Picardie Jules Verne
Universidad Politécnica de Madrid
Uppsala University
Utrecht University/FOM

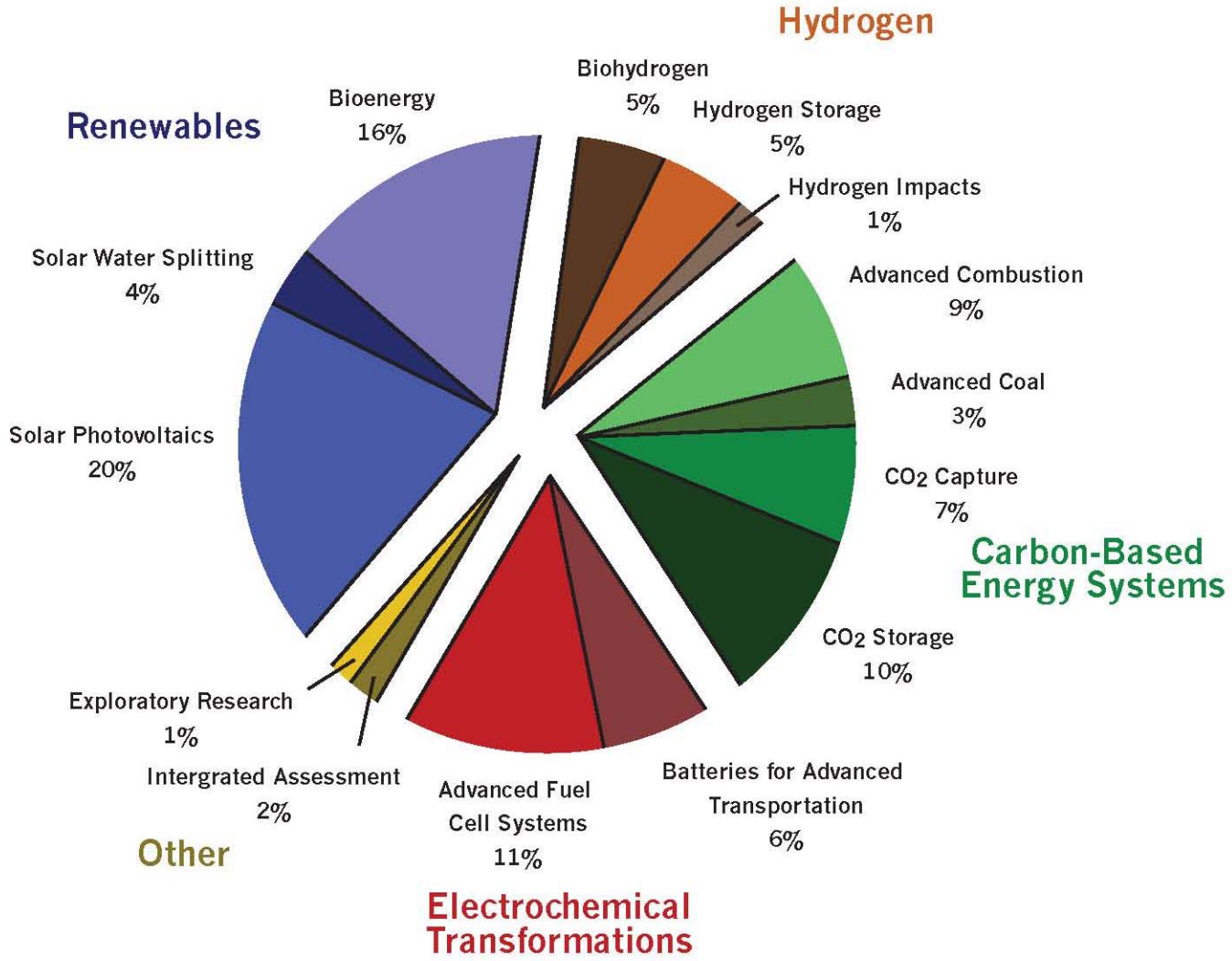
GCEP Strategy

- 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

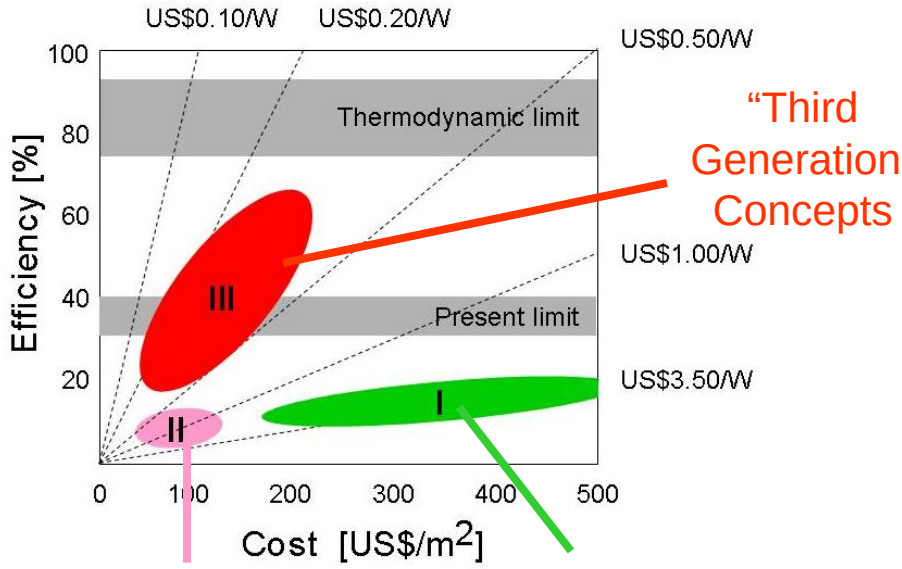
Step-Out Technology



GCEP Research Portfolio



Increasing Efficiency and Lowering Costs of Solar PV



"Third Generation" Concepts

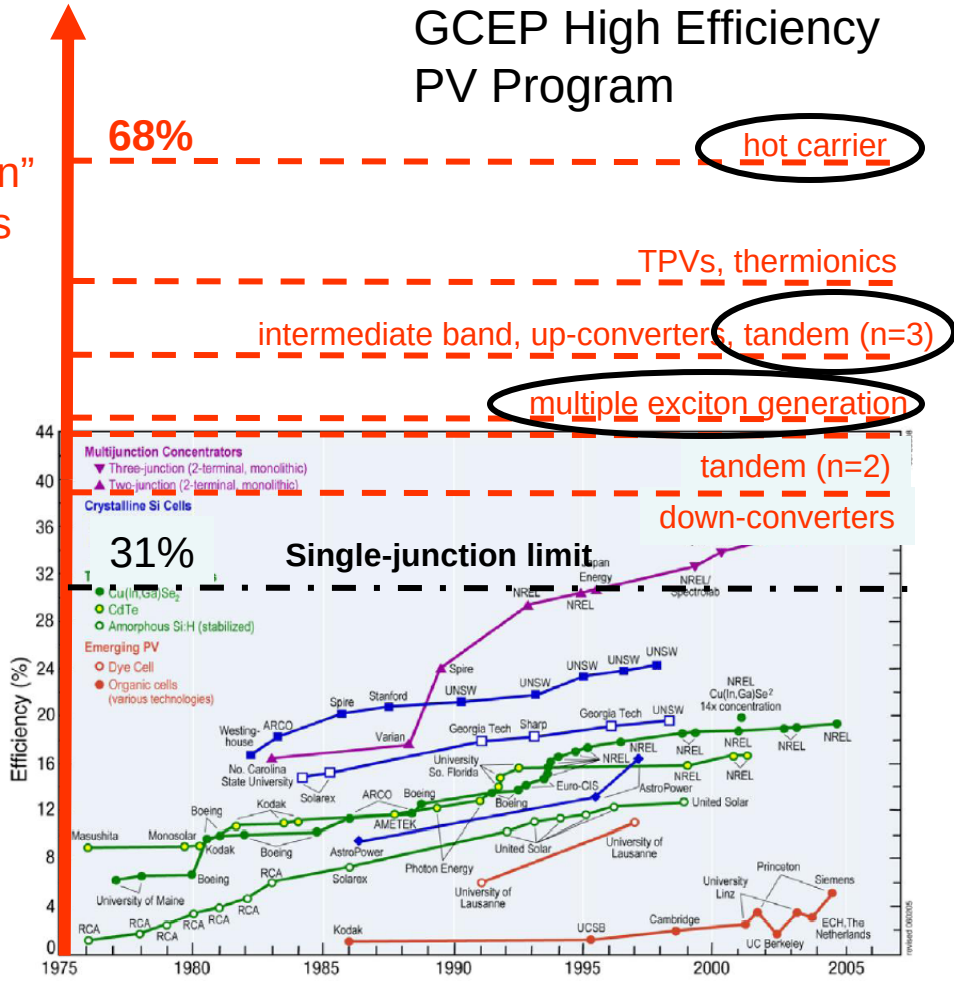
(M. Green, UNSW)

Thin-films (CIGS, CdTe, a-Si, …)

Wafer-based (c-Si)

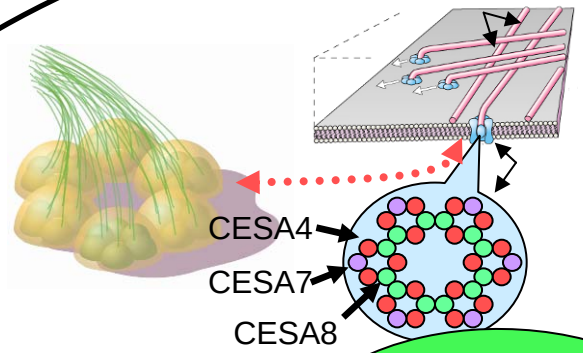
GCEP research efforts include a broad array of new approaches to reducing the cost and enhancing efficiency of solar energy conversion

GCEP High Efficiency PV Program

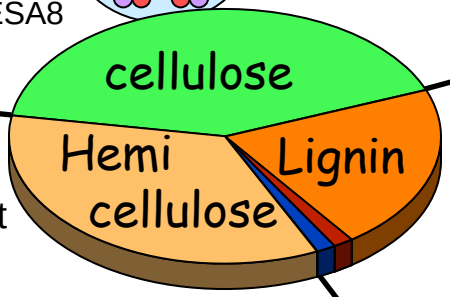


GCEP Research Projects in Biofuels

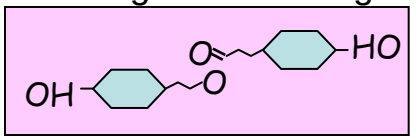
Cellulose fibrils



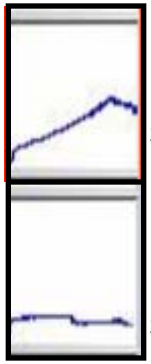
Increased cellulose accumulation for enhanced biomass



Novel precursors for simplified degradation of lignin



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

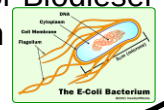


New xylose utilizing strain

Non xylose utilizing strain

Novel screen for plants with enhanced saccharification

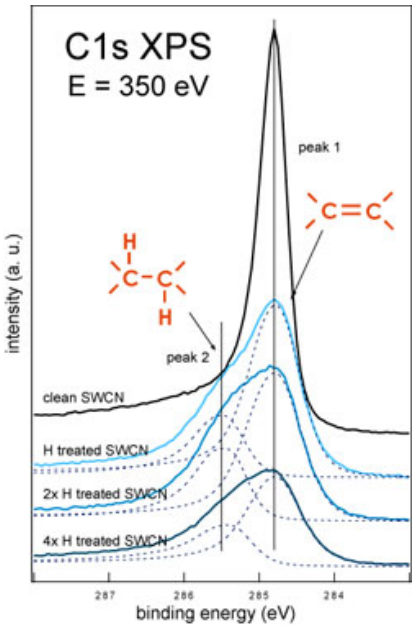
Engineering pathways in *E.coli* for Biodiesel production

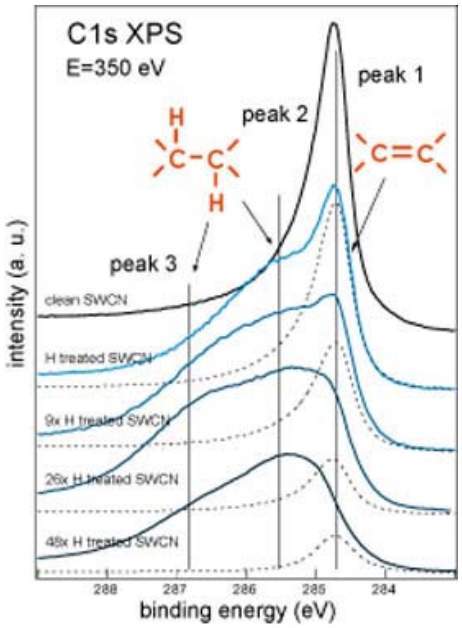


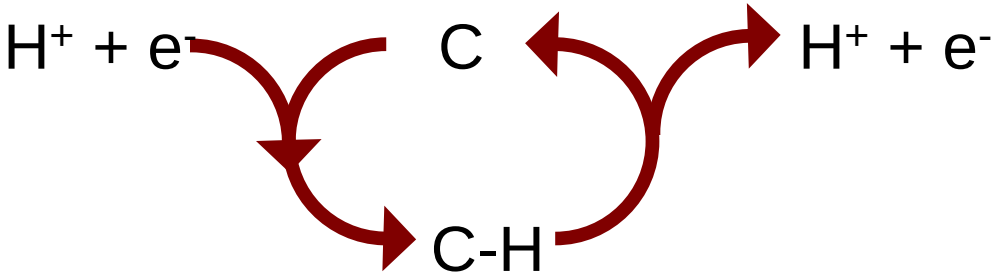
C-H Bonds in C Nanotubes as an Energy Carrier

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

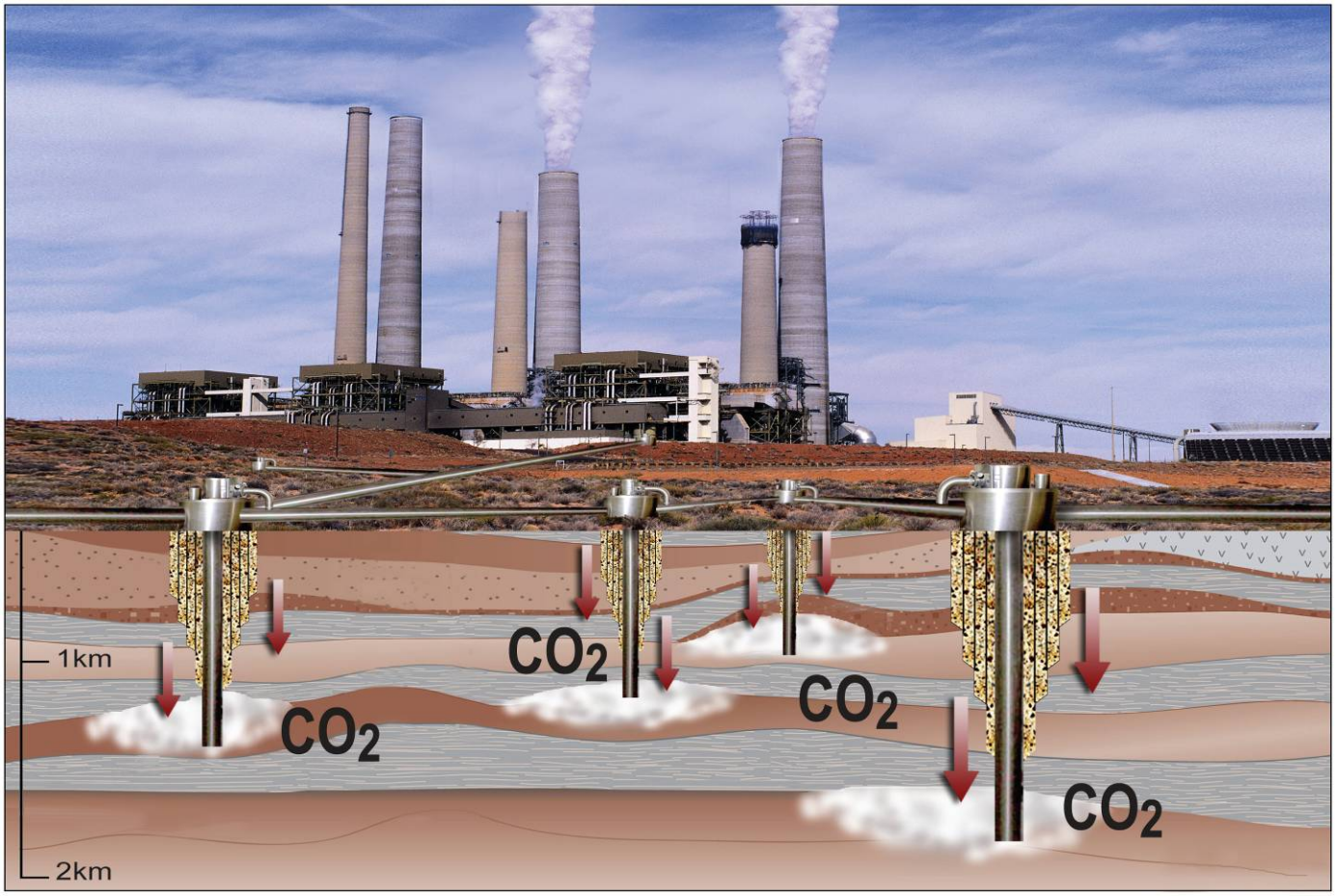






Offers opportunity to reduce efficiency penalties for electrochemical energy storage by using C-H bonds in carbon nanotubes rather than molecular hydrogen as the energy carrier.

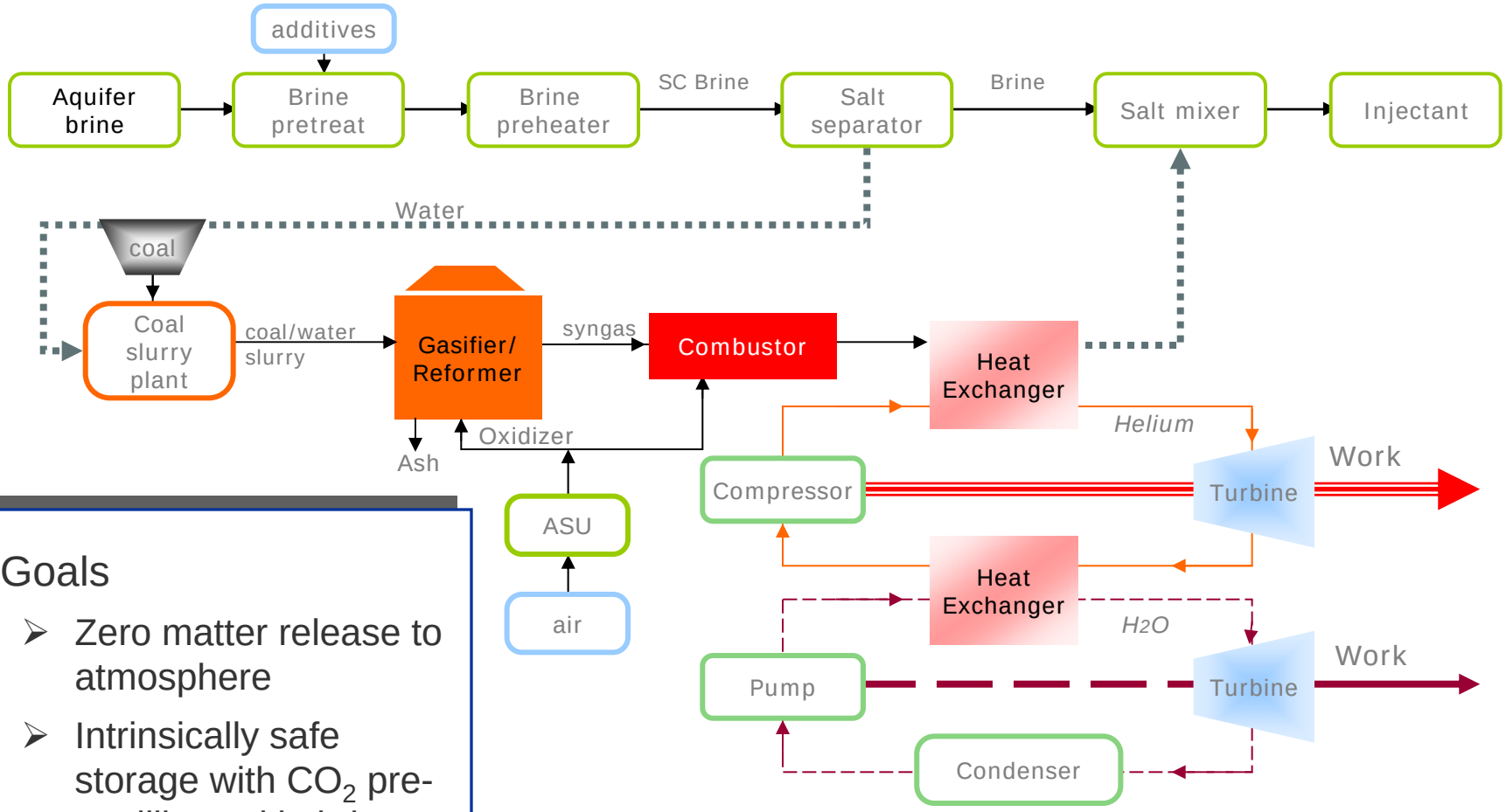
Carbon Dioxide Capture and Geologic Storage



Capture → **Compression** → **Pipeline Transport** → **Underground Injection**

Coal Energy Conversion with Aquifer Based Carbon Sequestration

Reginald Mitchell, Chris Edwards, Scott Fendorf, Stanford University



- Goals
  - Zero matter release to atmosphere
  - Intrinsically safe storage with CO_2 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