



Stanford University  
**Global Climate & Energy Project**

April 26, 2004

# **Introduction to the GCEP Wind Workshop**

Richard Sassoon



# Outline of Talk



- Workshop Objectives
- The Grand Challenge
- The GCEP Project
- GCEP Process for Identifying Research Opportunities
- Research Questions Concerning Wind Power



# Workshop Objectives



- Collect input on technology barriers and research opportunities from internationally recognized experts in the field of wind power
- Inform Stanford research community and other potential GCEP researchers on how they can apply their expertise in the area of wind energy
- Support GCEP in formulating future directions for the Project



# Agenda



- 8:30–9:00**      **Welcome and Introduction**
- 8:30              GCEP Introduction and Workshop Objective, Richard Sassoon, *GCEP*
- 9:00–10:30**      **Session 1: Wind as an Energy Source, Chair: Mark Jacobson**
- 9:00              Wind Power Technology, Robert Thresher, *NREL*
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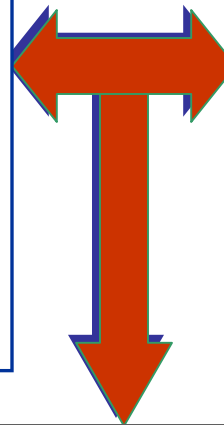
# The Grand Challenge



## Needs

- Growth in world population to 9 billion from 6 billion, of which 2 billion people currently have no access to modern energy systems
- Improved standard of living in growing economies of developing world
- Increased demands for energy, food, land, and materials.

Protection,  
Restoration, and  
Improvement of the  
Planetary  
Biogeochemical  
Systems

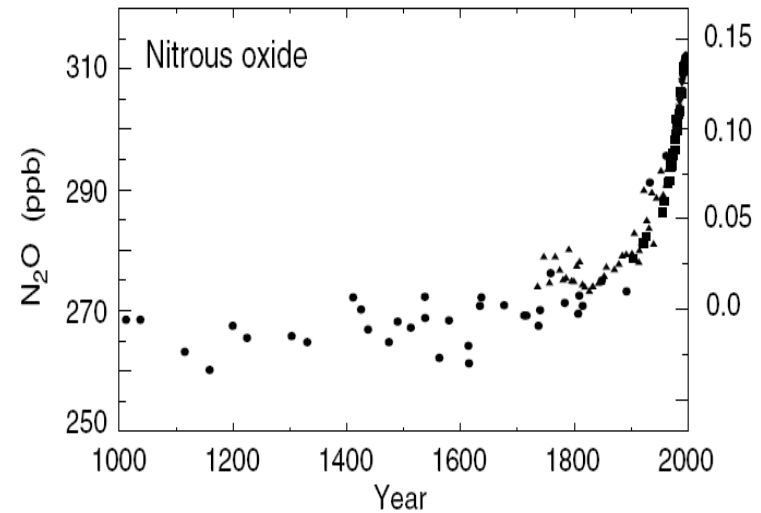
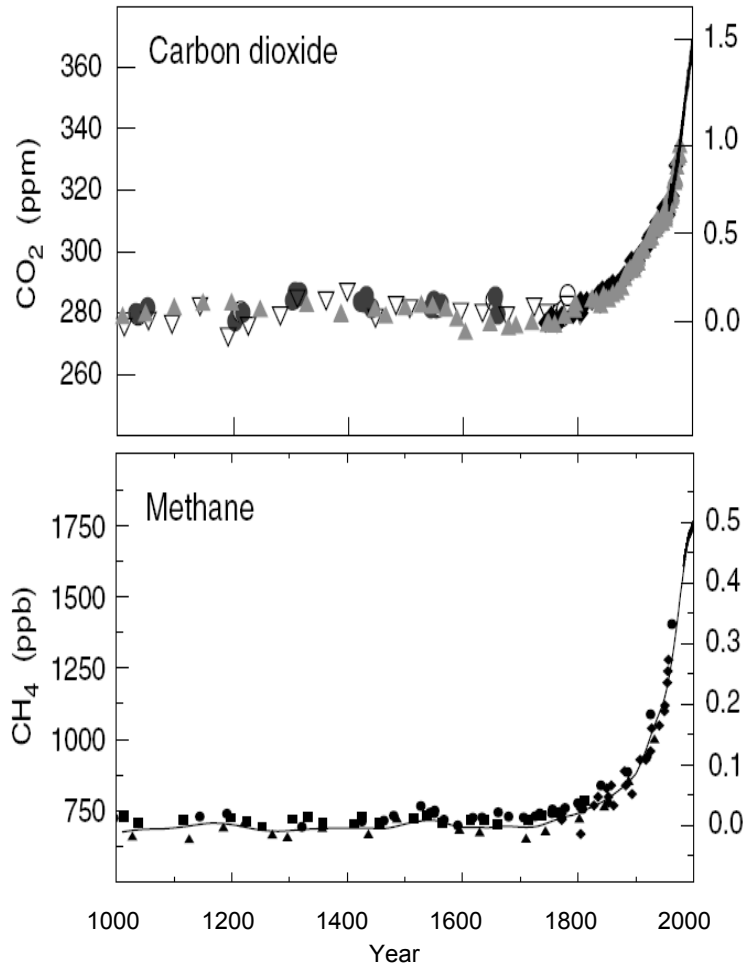


## Component Challenges

- Water supply
- Agricultural systems (strongly linked to water supply)
- **Energy (with possible limits on CO<sub>2</sub> emission)**



# Global Geochemical History



- Concentrations of GHGs have risen significantly over the preindustrial levels.
- Surface ocean pH has also declined by 0.1 as additional CO<sub>2</sub> dissolved.

Source: IPCC Third Assessment Report, 2001

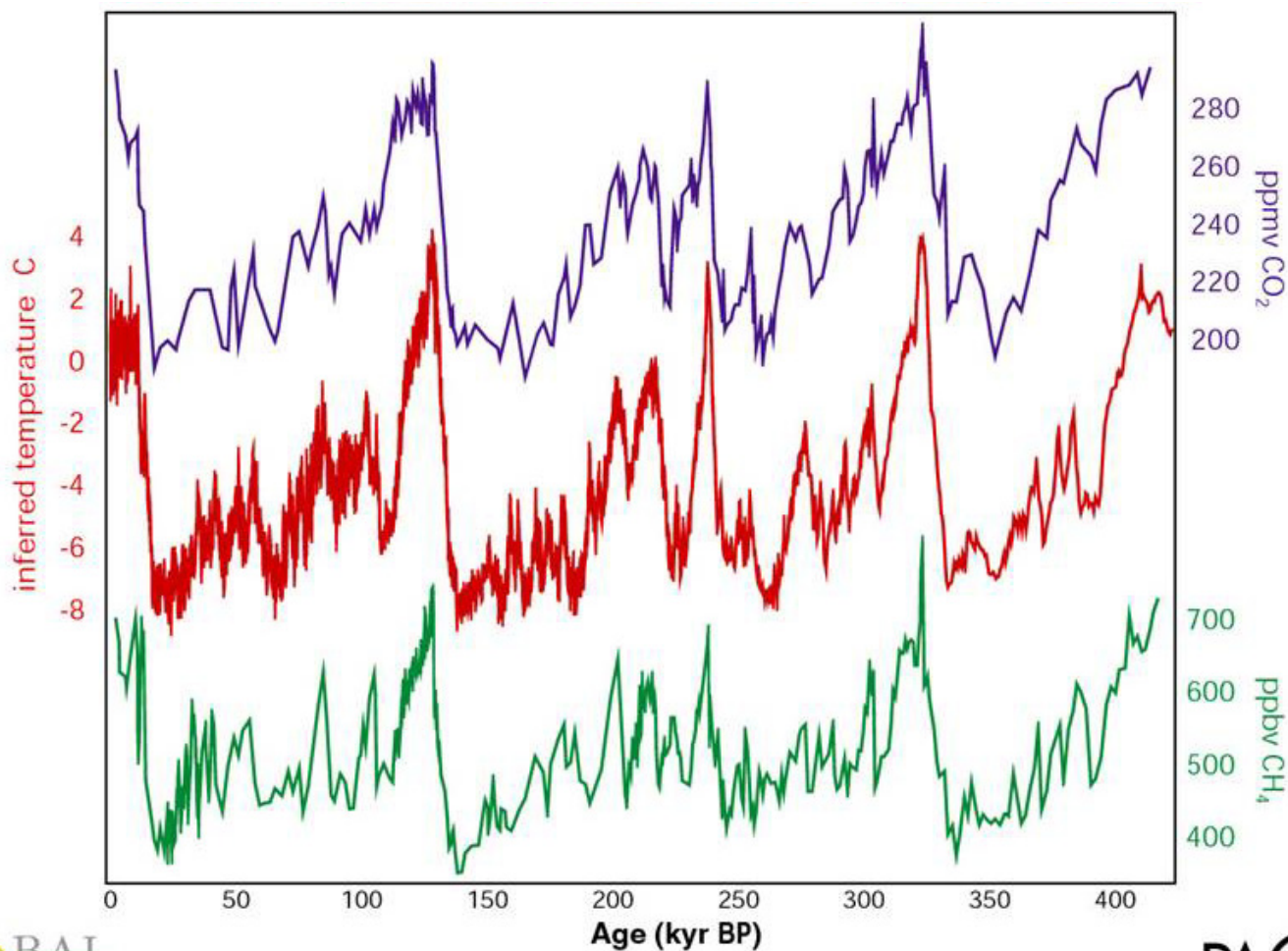
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# Four Glacial Cycles Recorded in the Vostok Ice Core

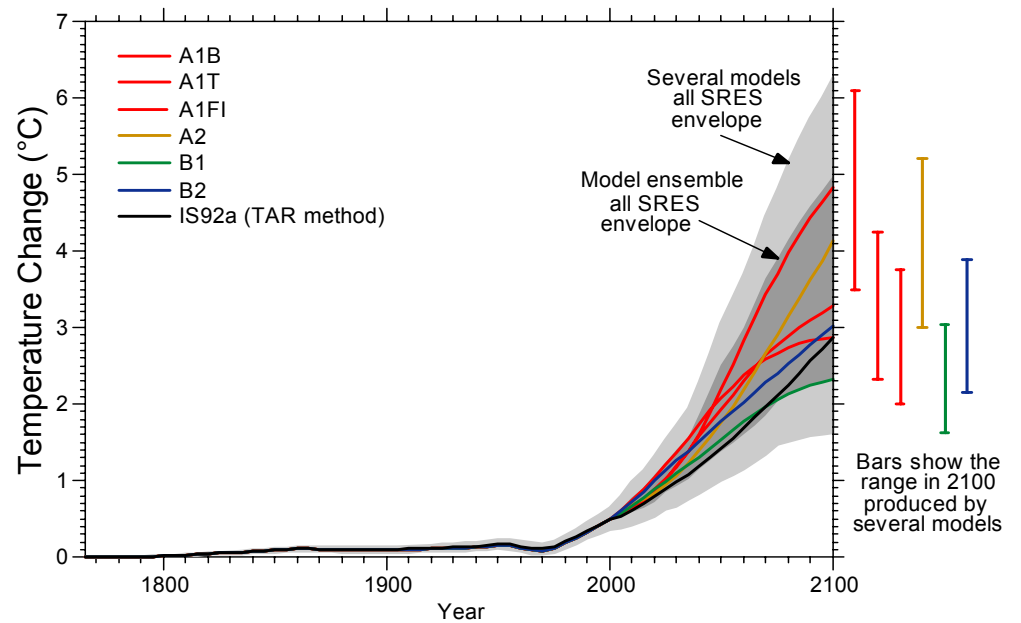
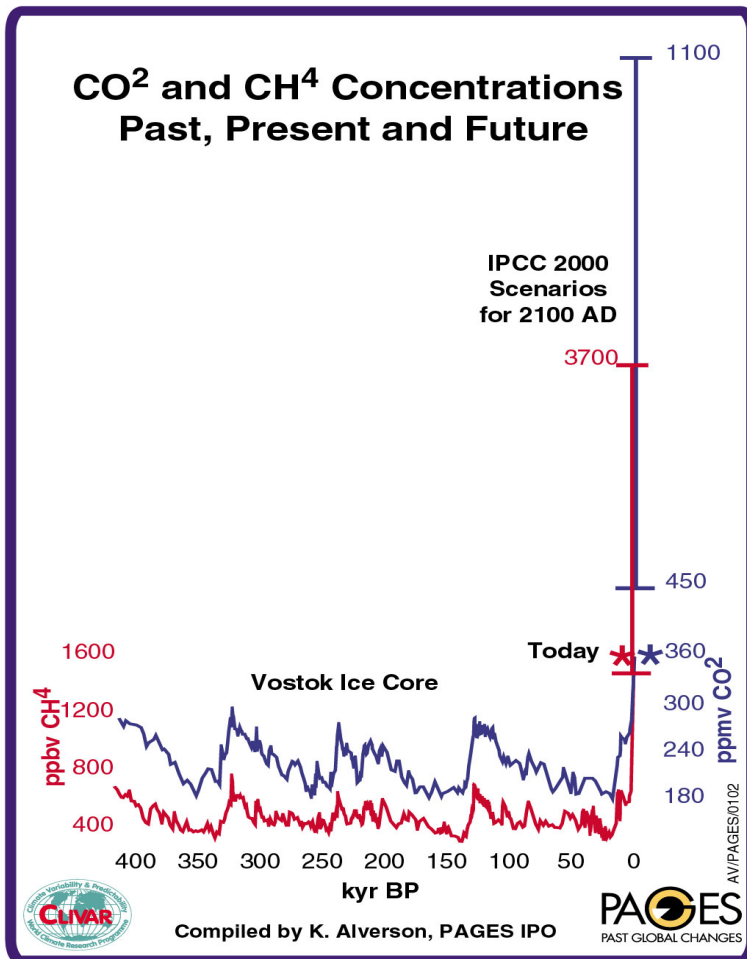


J.R. Petit et al., *Nature*, **399**, 429–36, 1999.





# Future Projections



IPCC 3<sup>rd</sup> Assessment Report (2001) – Projected Global Temperature Change



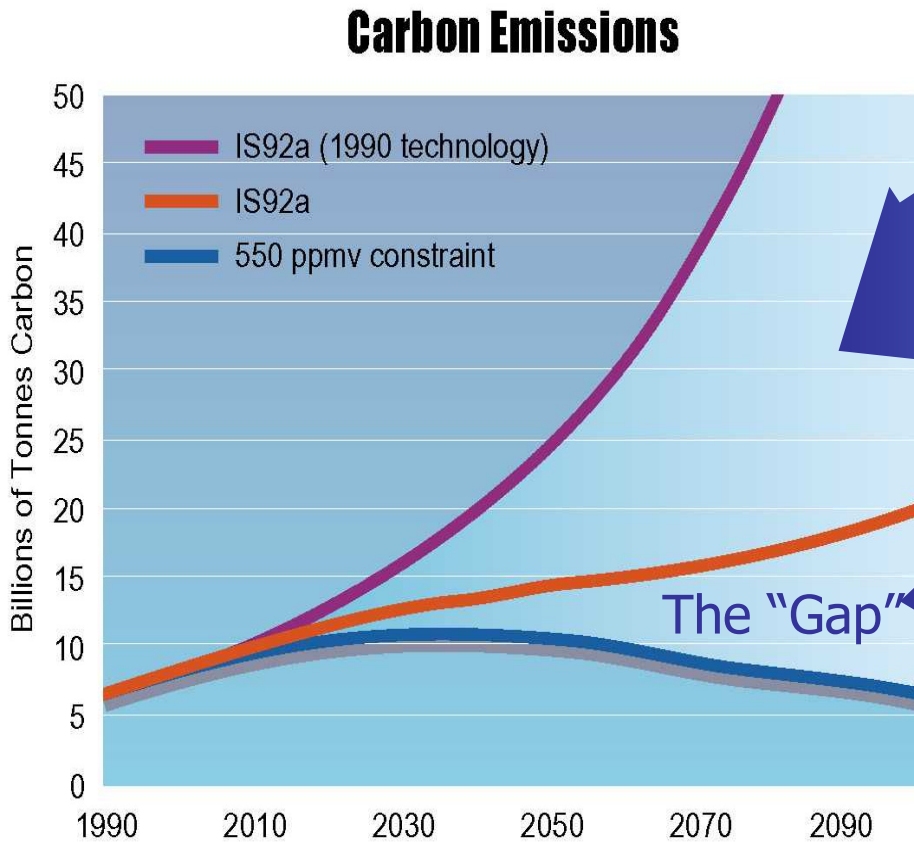
# Global Geochemical Impact



- CO<sub>2</sub> concentration in the atmosphere has increased from 280 to 370 ppm since 1860.
- pH of the upper ocean has decreased by 0.1
- Continuing debate about the magnitude and timing of impacts of greenhouse gases on global climate.
- No doubt that human activities are interacting with planetary geochemistry on a global scale.
- Major need for research to create energy options with very low greenhouse emissions.



# The Need for Technology



## Assumed Advances In:

- Fossil Fuels
- Energy intensity
- Nuclear
- Renewables

## Gap Technologies:

- Carbon capture & disposal
  - Adv. fossil
- H<sub>2</sub> and Adv. Transportation
- Biotechnologies
  - Soils, Bioenergy, Adv. Biological Energy

Source: J. Edmonds, PNNL



# The Need for a Major R&D Effort



Consider a set of global energy systems that emit very small amounts of greenhouse materials ( $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{N}_2\text{O}$ , black soot, and others) to eliminate the “gap”:

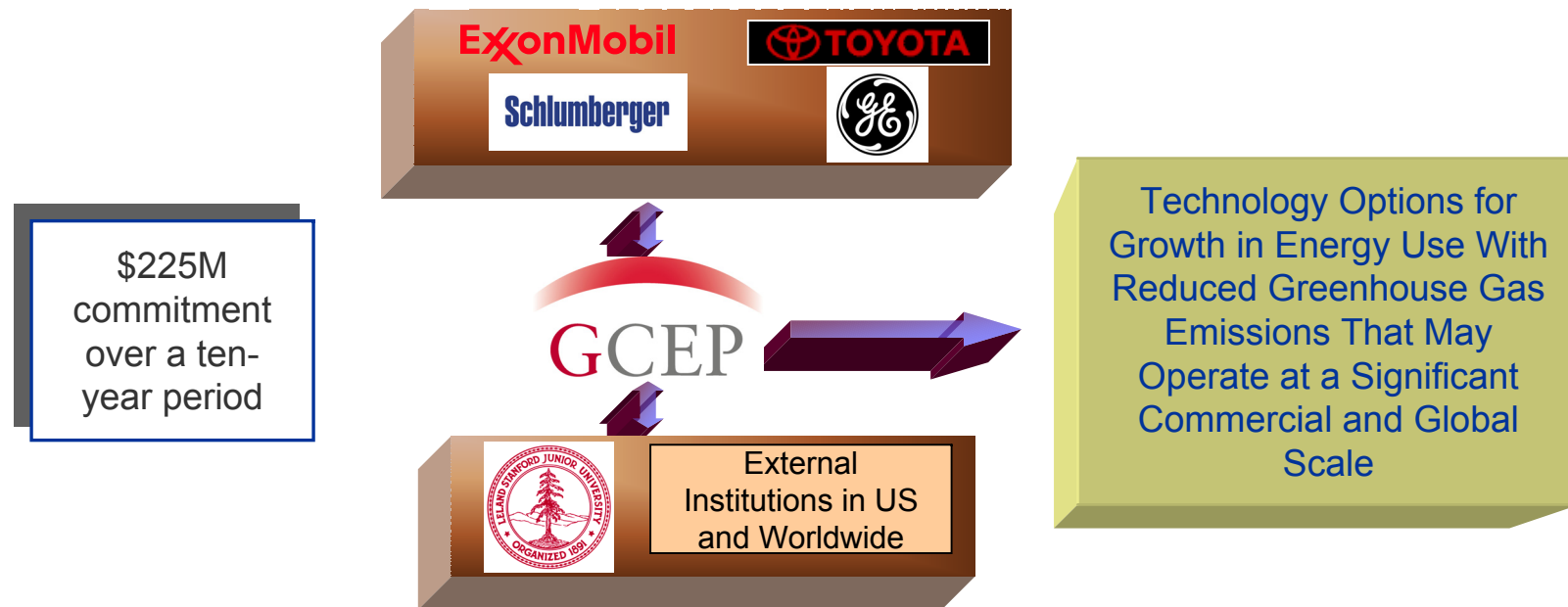
- What will be the primary energy sources?
- How will supplies be deployed, distributed?
- What technologies and systems can be applied effectively in developing countries?
- What barriers to implementation will have to be overcome and how long will it take?
- What infrastructure will be required?
- How will we deal with questions of safety, environmental impact, market acceptance, cost?
- What research on technologies can help eliminate these barriers?



# The GCEP R&D Program to Generate Technology Options



- The Global Climate and Energy Project (GCEP) was established to conduct pre-commercial research necessary to develop the technology options needed to address the “gap”
- It represents a long-term commitment to developing groundbreaking technologies that may have a significant impact on a global scale





# Mission and Objectives



## Mission

- Fundamental, Pre-Commercial Research into Technologies for Growth in Energy Use with Reduced Greenhouse Gas Emissions

## Objectives

- Identify options for technologies with impact at a global level
- Identify barriers to large-scale use
- Identify potential solutions to these barriers
- Conduct pre-commercial research to explore options, barriers and potential solutions
- Communicate options, barriers, solutions, and research



# GCEP Strategy



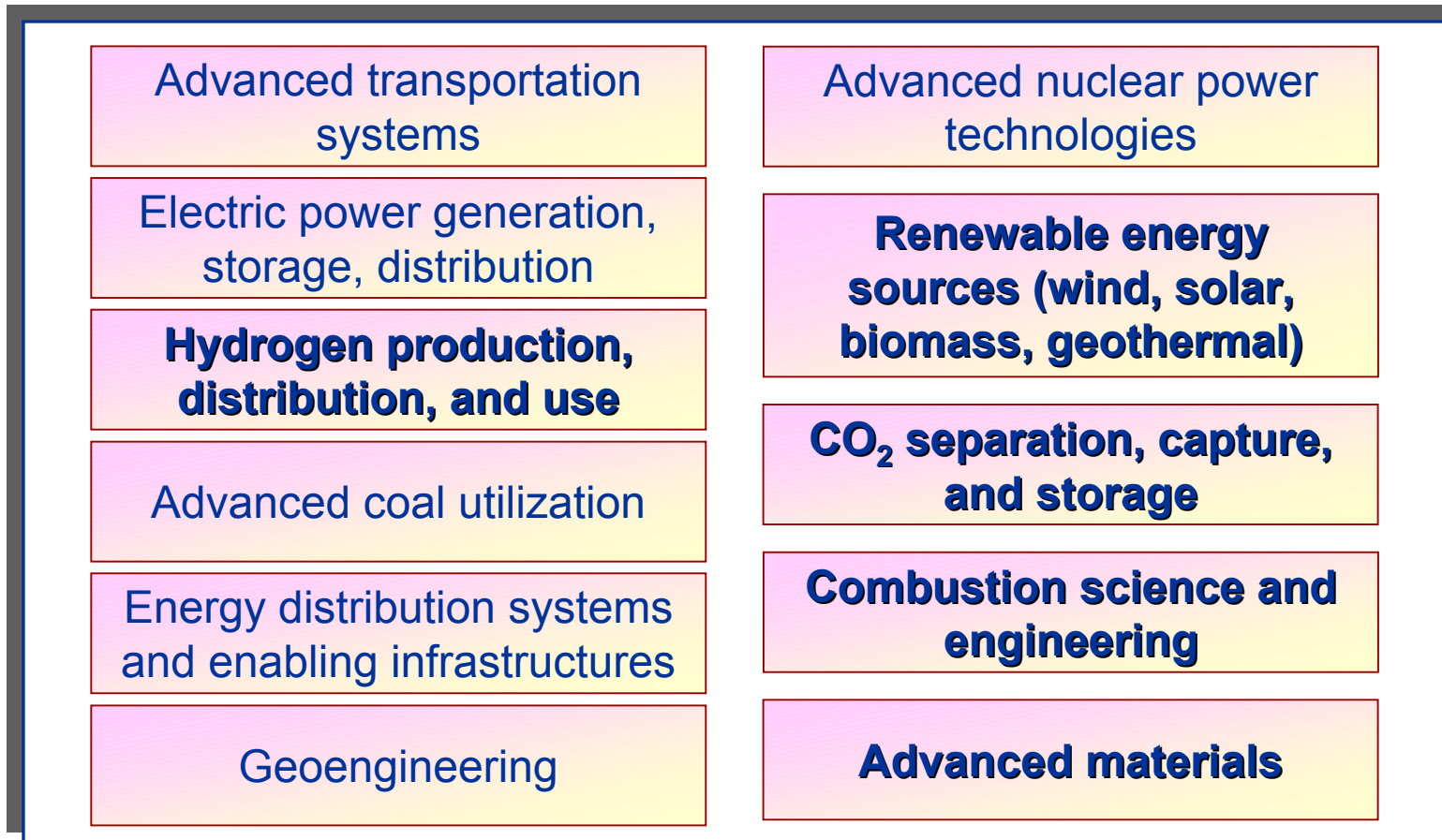
- Focus on potential energy technologies that may be truly game-changing with respect to greenhouse gas emissions
- Encourage high risk/high reward research
- Address questions appropriate to pre-commercial research
- Operate independently at Stanford with oversight from Sponsors
- Use the best research talent available either at Stanford or at institutions around the world
- Make all data, results, and other information generated from the project open and available to all
- Involve institutions from developing countries with potential high levels of future greenhouse gas emissions



# Portfolio Areas



- GCEP mandate includes 11 technical areas



## Technical Areas with Projects currently underway



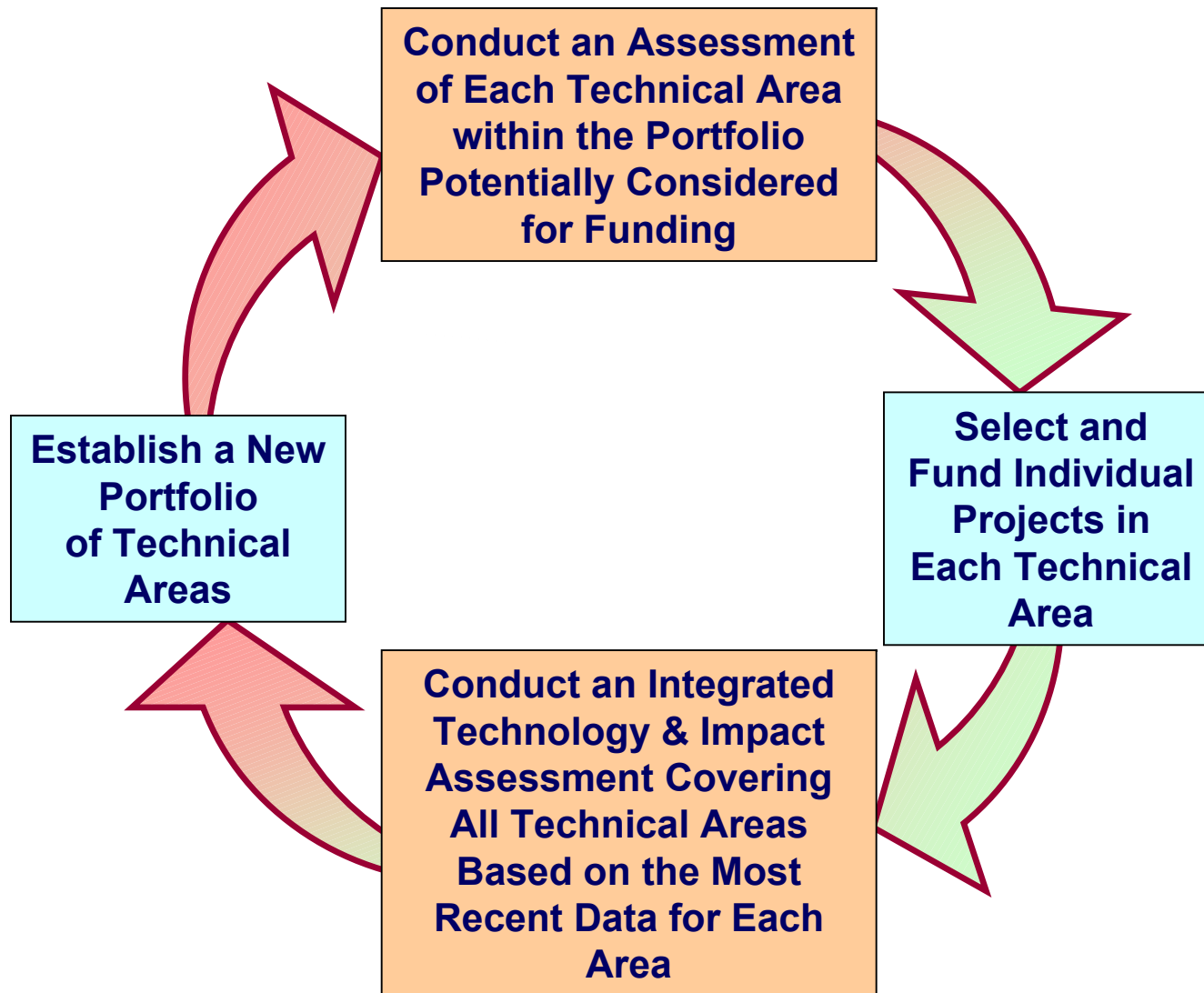
# Building the Portfolio



- Conduct an integrated assessment of energy areas to:
  - Estimate their significance on global scale
  - Evaluate the potential reduction in GHG emissions
- For each of the energy areas, assess:
  - Opportunities for reductions in greenhouse emissions
  - Barriers to implementation
  - Opportunities for university research to reduce barriers
- Identify research groups inside and outside of Stanford active in the area and review coverage of area by DOE and other programs
- Estimate magnitude of funding allocation appropriate to the area
- Request and select proposals that:
  - Demonstrate pathway for significant reductions in GHG emissions
  - Address barriers to eventual use of energy technologies
  - Are appropriate for university-based, pre-commercial research
- Construct a set of projects and obtain Management Committee approval for funding



# Application of Assessments to the Funding Disbursement Process





# GCEP Accomplishments



- GCEP agreement signed between Stanford University and Sponsors on February 21, 2003
- 15 research projects in five technical areas are underway
- Renovated and moved to GCEP office space, and staffed GCEP central management and administration
- Held Hydrogen workshop in April, 2003
- Requested, reviewed, and awarded four projects in hydrogen and renewables technical areas
- Visited 11 institutions in Europe, four in Japan, and one in US to learn about research efforts and consider potential GCEP sponsorship of work at those institutions
- Established GCEP Advisory Board and held first meeting on April 6



# GCEP Participation



## Stanford Faculty:

- 21 PIs lead GCEP supported research
- 10 departments in Earth Sciences, Engineering, and Humanities and Sciences (Geology, Pet Eng, Geophysics, Management Science & Eng, Materials Science & Eng, Chem Eng, Civil and Env Eng, Mech Eng, SSRL, Chemistry)

## Stanford Students:

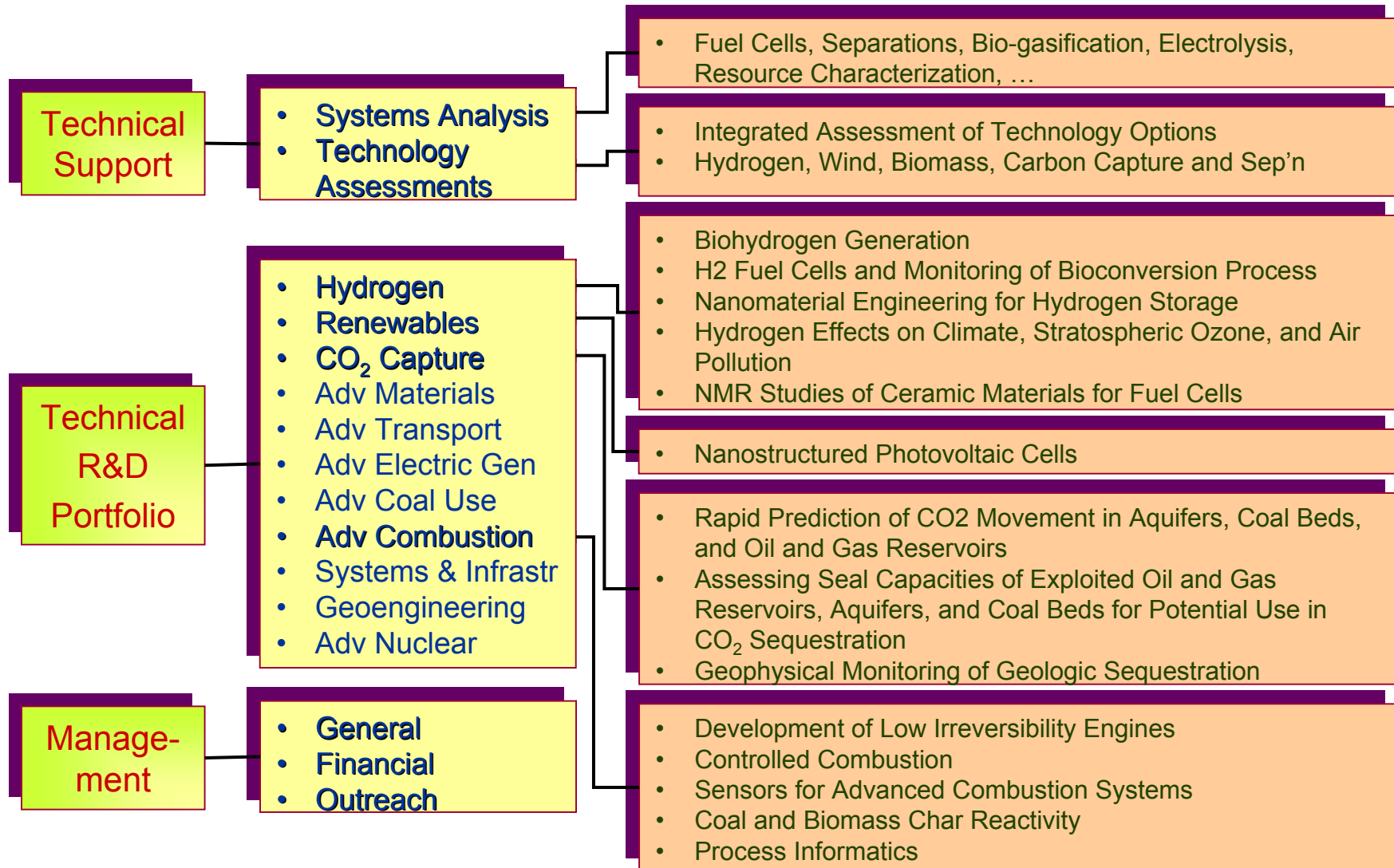
- 14 post-docs
- 42 graduate students

## Other GCEP Staff:

- 7 Central Staff
- 3 Consultants



# Current GCEP Projects





# Long-Term Future



- GCEP will ramp up to full capacity as additional projects and portfolio areas are put in place
- A novel, dynamic research portfolio will be established as the full suite of technology research opportunities is determined and continuously tracked
  - Manage multiple research projects in each technical area
  - Involve multiple institutions
- Outreach activities will include:
  - Issue full set of technical area assessment reports
  - Hold annual technical area workshops and GCEP symposia
- Educational courses and other materials will be developed on energy technologies that may lead to reductions in greenhouse gas emissions



# Research Questions Concerning Wind Power



- What is the potential impact to the climate if we fully exploit all practical wind energy sources?
- What are the technological barriers and limitations to greater implementation of wind energy?
- Which technologies, if developed, could change the game for wind power?
- What are the research opportunities for developing these technologies?
- What level of resources and financial investment is required to develop these technologies?



# Acknowledgements



- Speakers
- Chairs
- Emilie Hung
- Kersti Miller and Nancy Sandoval
- Other GCEP staff and students
- Sponsors
  - ExxonMobil, GE, Schlumberger, Toyota



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