Stanford University

Global Climate & Energy Project

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Emerging and Paradigm Changing Energy Technologies

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Global Challenges – Global Solutions – Global Opportunities

The Global Climate and Energy Project at Stanford University

Mission

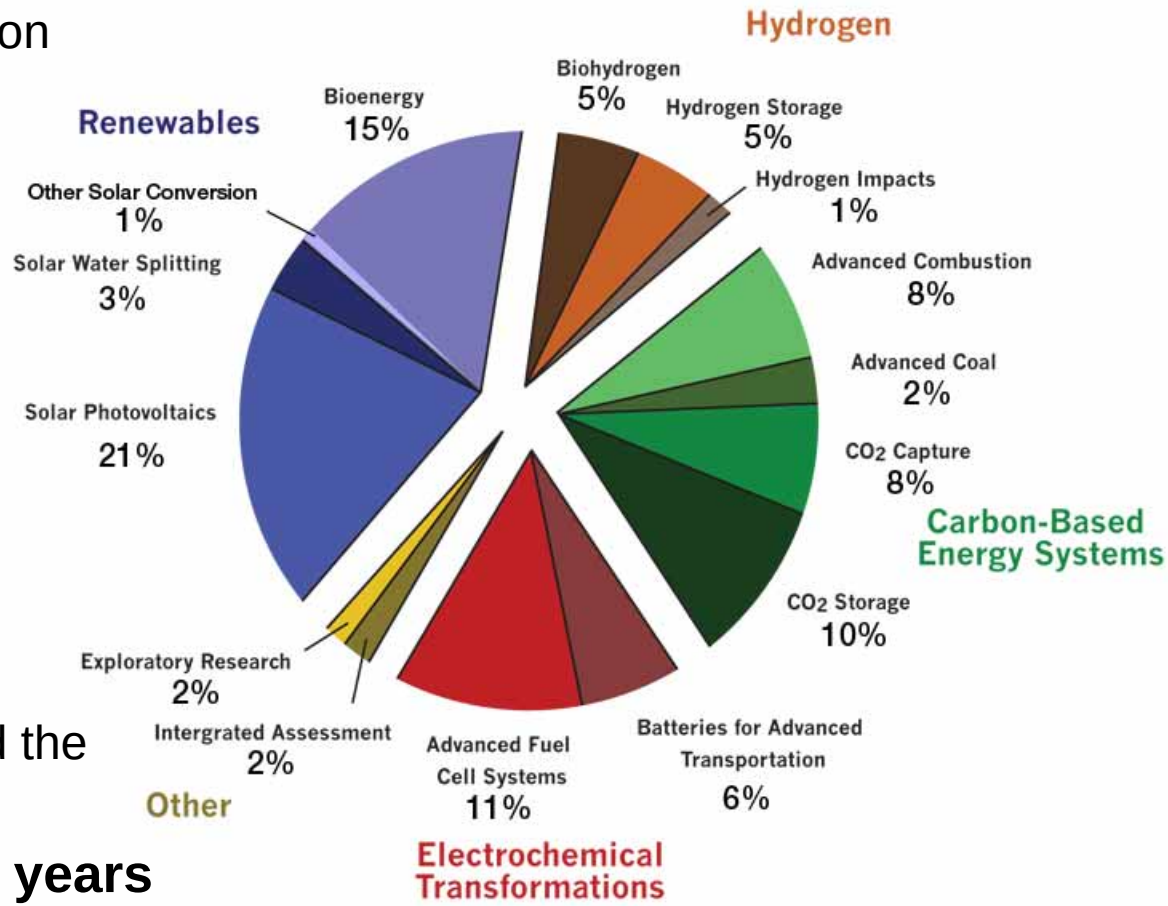
- Low-greenhouse gas emission energy conversions
- Fundamental research
- Applications in the 10-50 year timeframe

Strategy

- Potential for significant impact on reducing emissions
- High risk/high reward
- Research at Stanford and academic institutions around the world

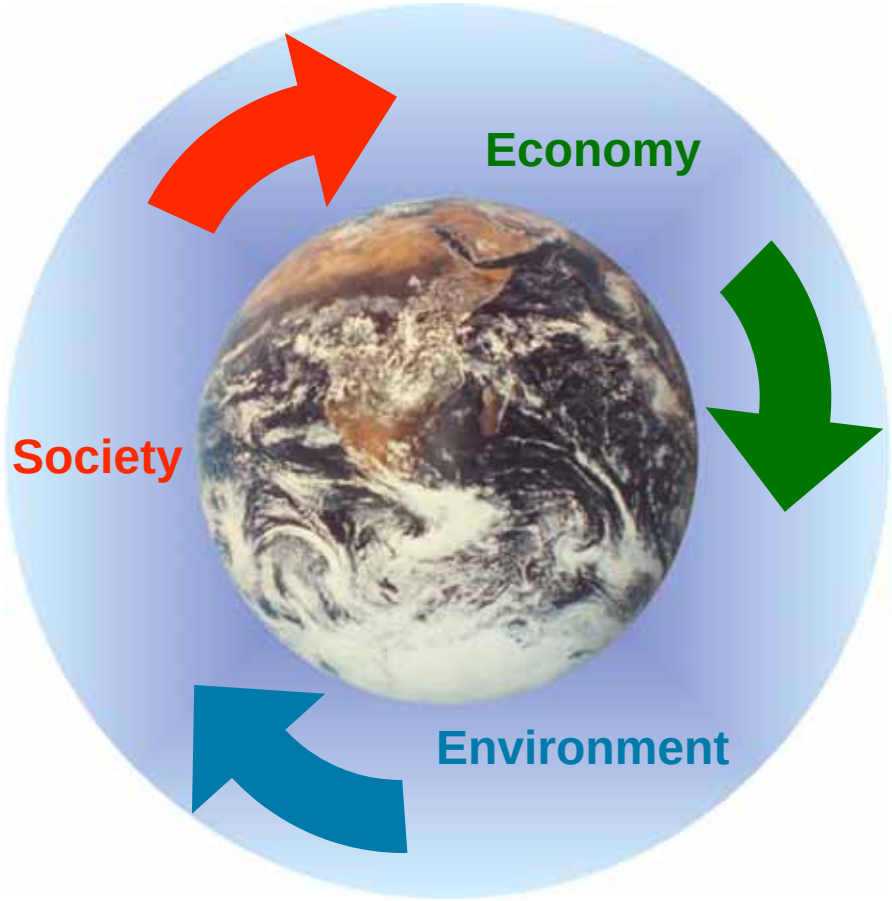
Support: $225 M over 10+ years

GCEP Research Portfolio



GCEP Perspective

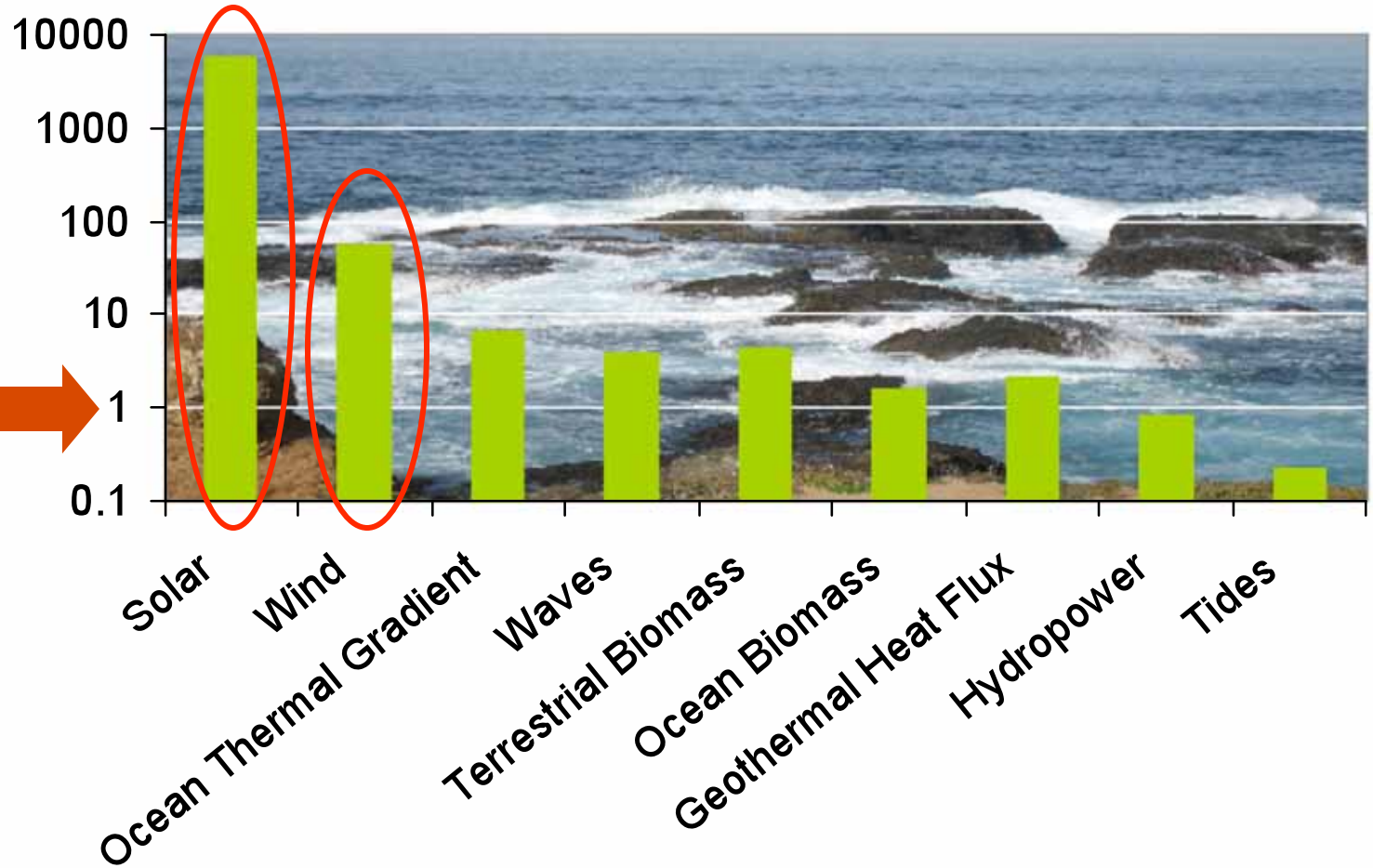
- Long term
- Large scale
- Low greenhouse gas emissions
- Efficient use of natural resources
- Earth abundant non-toxic materials
- Scalable manufacturing – gigawatts not megawatts



How Do We Meet Growing Demands for Energy While Protecting the Planet?

Renewable Energy Resources

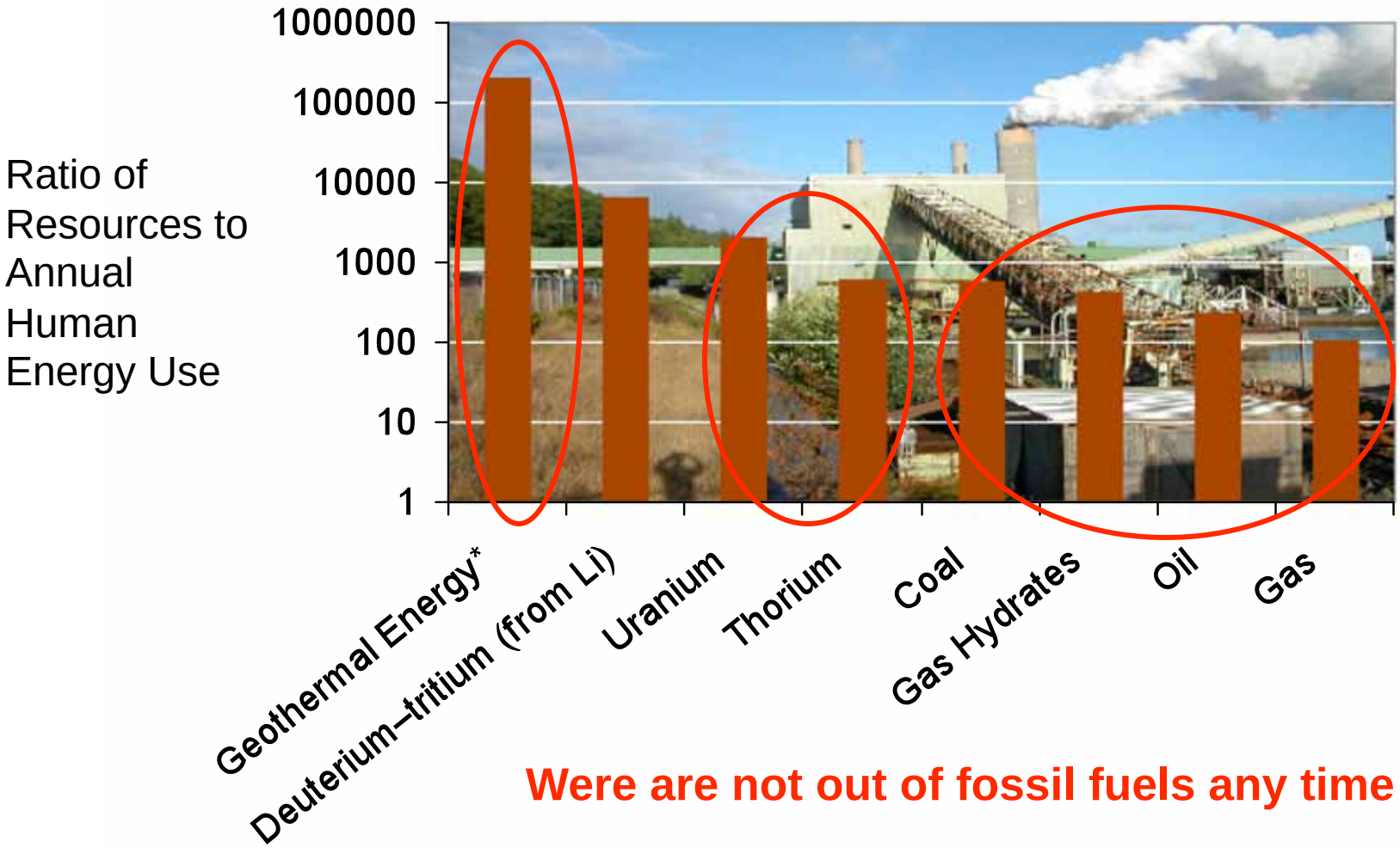
Ratio Between the Size of the Resource and Current Human Use of Energy (15 TW)



The sun and the wind are the two most significant energy resources.

Exergy sources scaled to average consumption in 2004 (15 TW)
From Hermann, 2006: Quantifying Global Exergy Resources, Energy 31 (2006) 1349–1366

Global Energy Stores



Were are not out of fossil fuels any time soon!

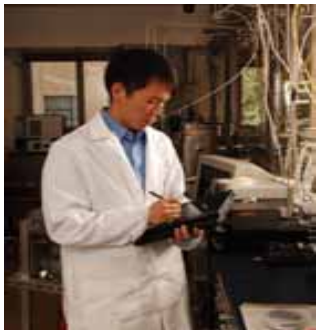
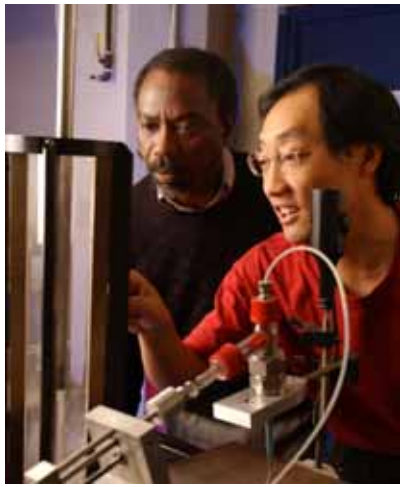
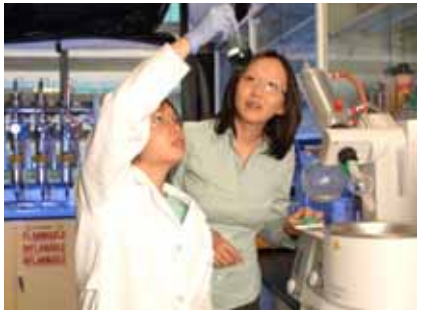
From Hermann, 2006: Quantifying Global Exergy Resources, Energy 31 (2006) 1349–1366

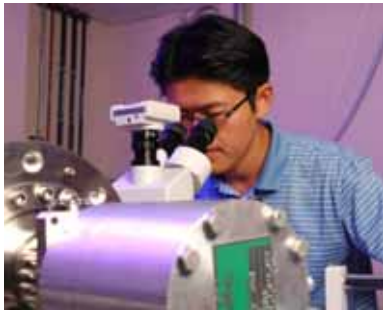
Paradigm Changing Energy Technologies

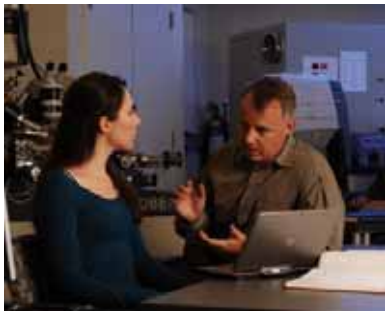
- Solar energy
  - Lower the cost and increase the efficiency of solar photovoltaics
  - Make fuels directly from sunlight
- Bioenergy
  - Increase the life-cycle efficiency of bioenergy production
  - Identify areas of land where biofuels can be grown and processed with large net greenhouse gas emission reductions
- Energy Storage
  - Improve the performance and lower the cost of grid-scale electricity storage to “firm” the intermittent renewable energy supplies
  - Increase energy and power density and lifetimes of batteries for light-duty vehicle transportation
- Advanced Energy Conversions
  - Increase the efficiency of exergy transformations to closer to their thermodynamic efficiency limit
  - Identify new exergy transformations with higher intrinsic efficiency
- Reduce emissions from fossil fuels with carbon Dioxide Capture and Storage
  - Reduce costs and energy requirements for CO_2 capture
  - Increase confidence in long term storage in saline aquifers
  - Identify novel options for CCS where capture and geologic storage in sedimentary basins is not possible
- Electricity Transmission and Distribution
  - Develop next-generation simulation tools and control technologies for electricity transmission and distribution with a large fraction of intermittent energy sources and grid-integrated storage

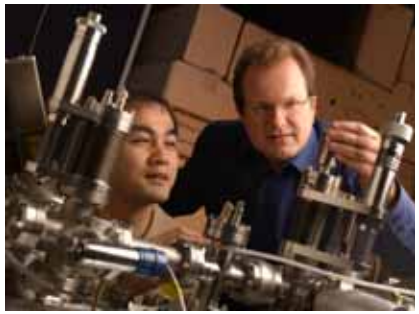
GCEP Researchers

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

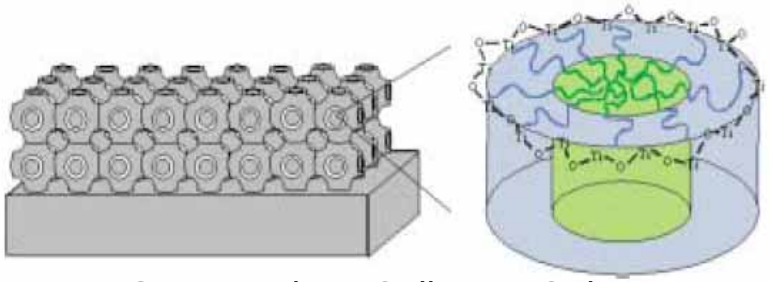






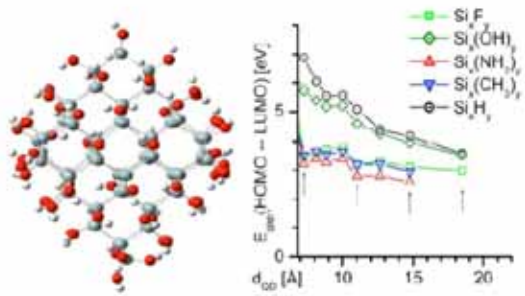




Research Projects in Solar Energy



Nano-Structured PV Cells - McGehee



Durable Nanostructured Cells
With Si Quantum Dots –
Green et al.

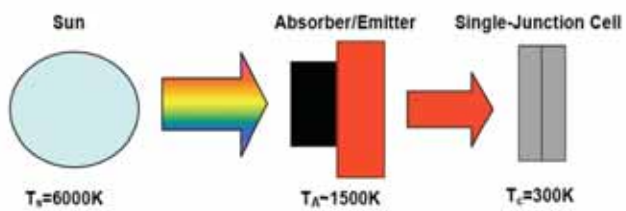
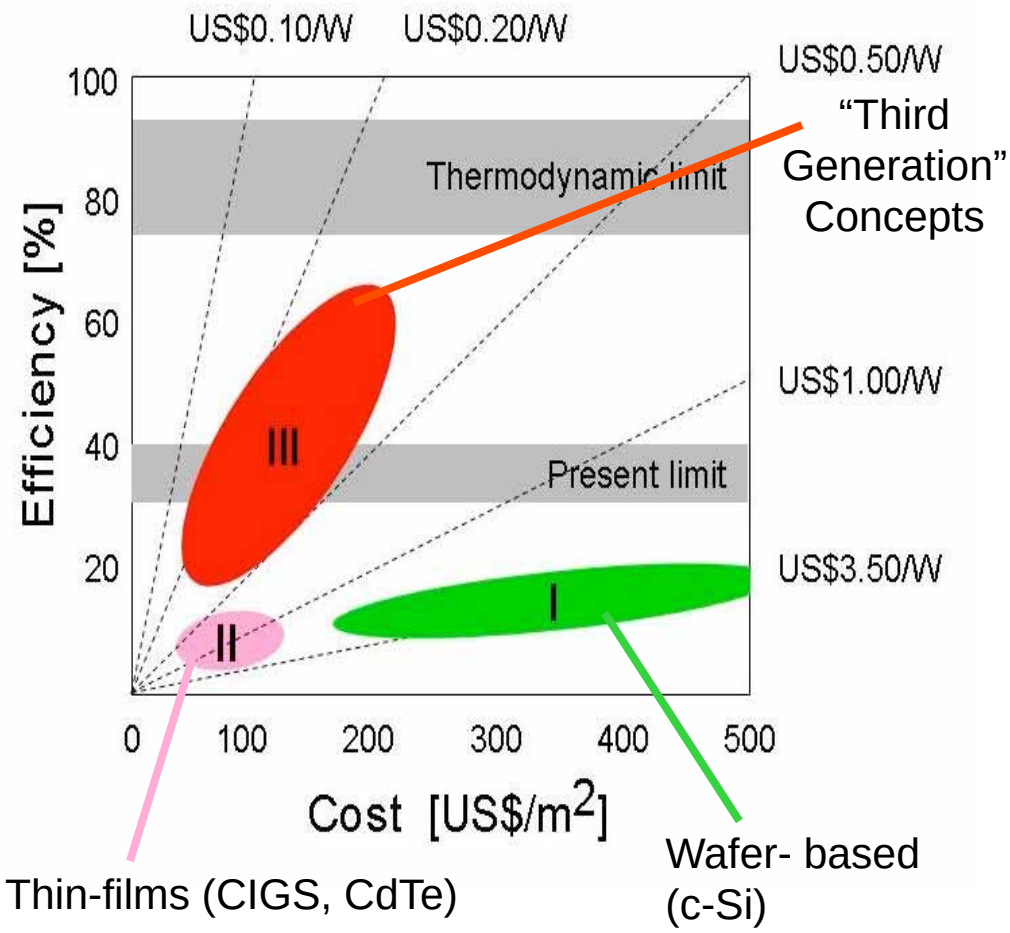
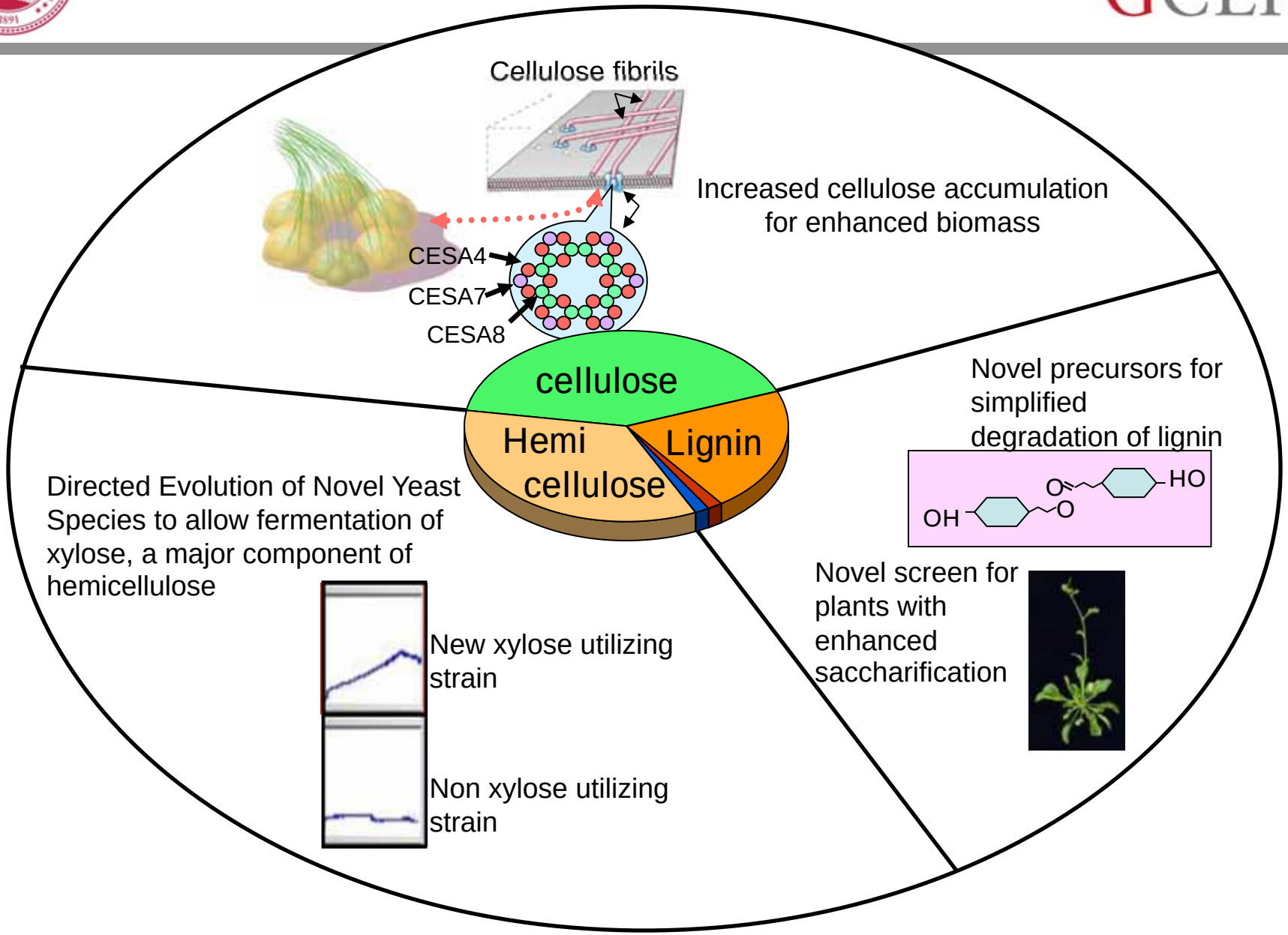


Fig. 1. Schematic of a solar thermo-photovoltaic cell.

Themo-Photovoltaic Cell –
Fan et al.

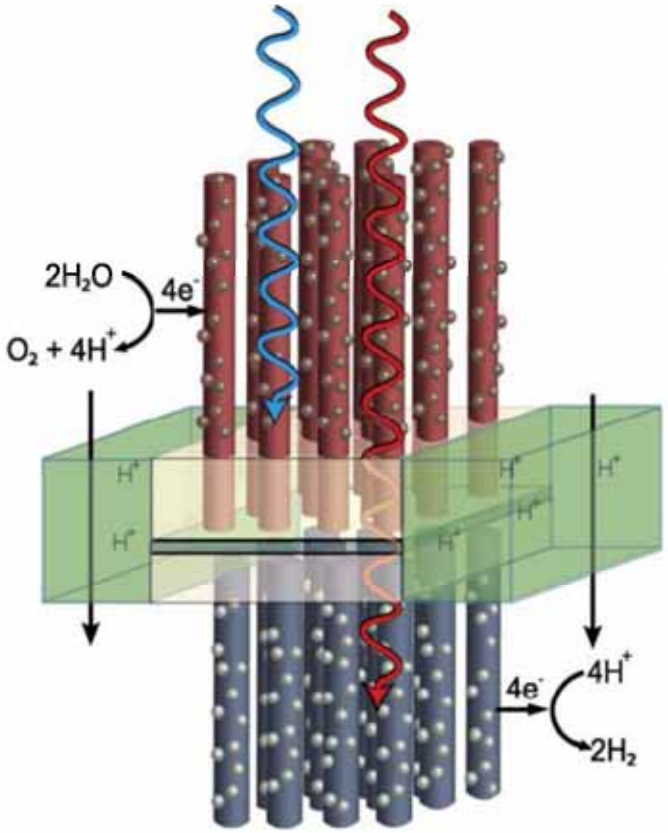


Research Projects in Biofuels

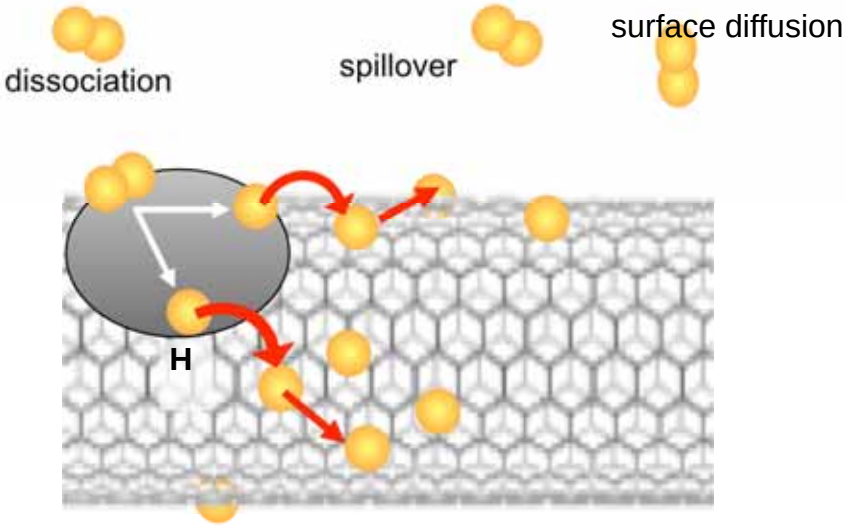


Research Projects in Hydrogen

Photo-activated Water Splitting at an Artificial Membrane – *Lewis et al.*

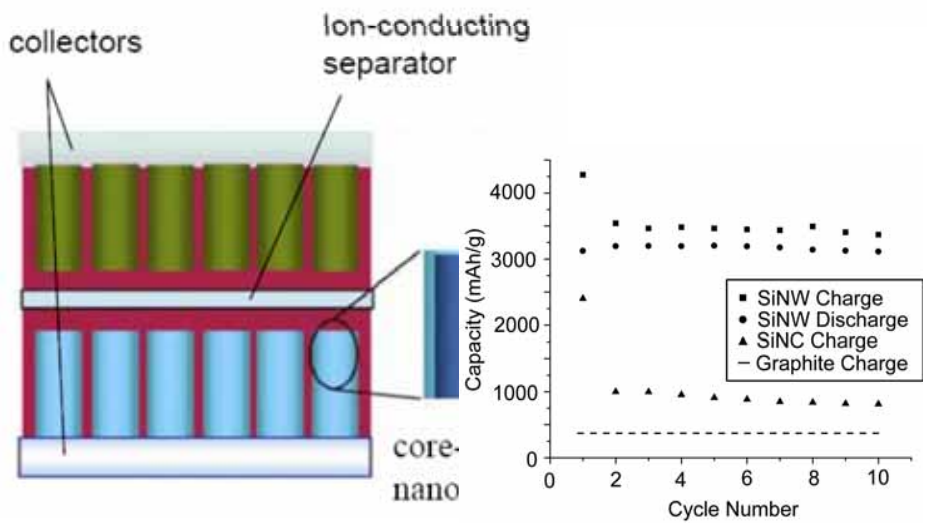


Hydrogen Storage in C-H bonds on Carbon Nanotubes – *Nilsson et al.*

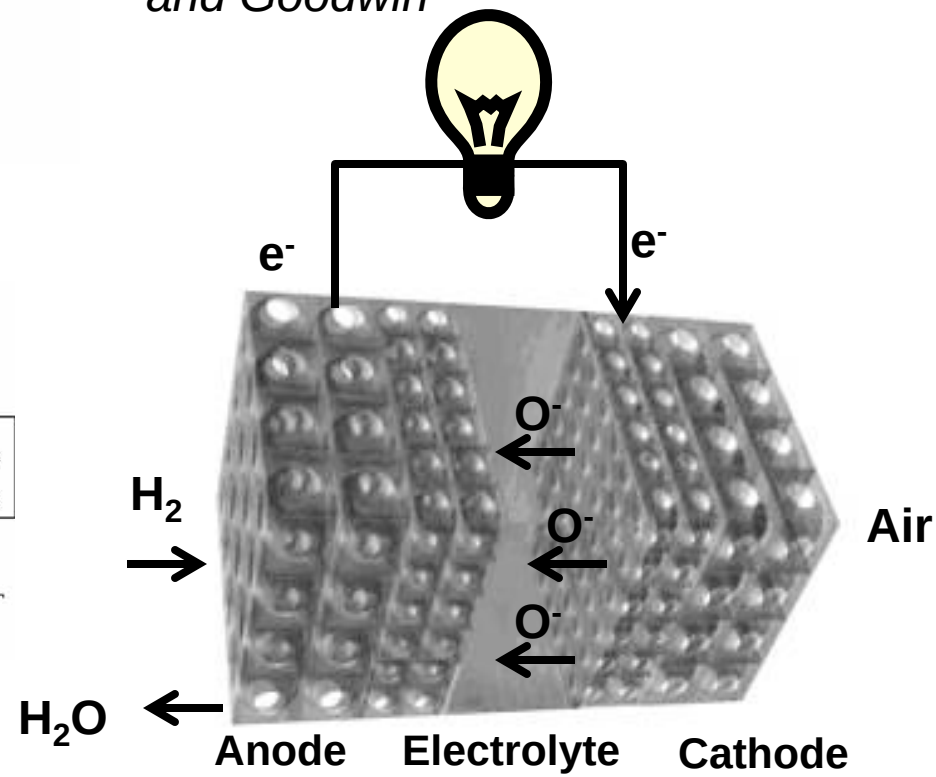


GCEP Research Projects in Electrochemical Transformations

Innovative Battery Technologies for Improved Energy Densities Based on Nanowire Architectures - *Cui*

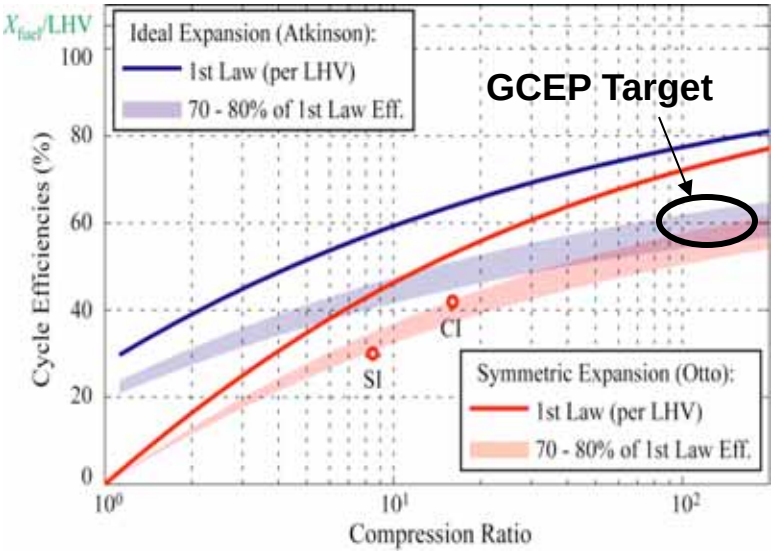


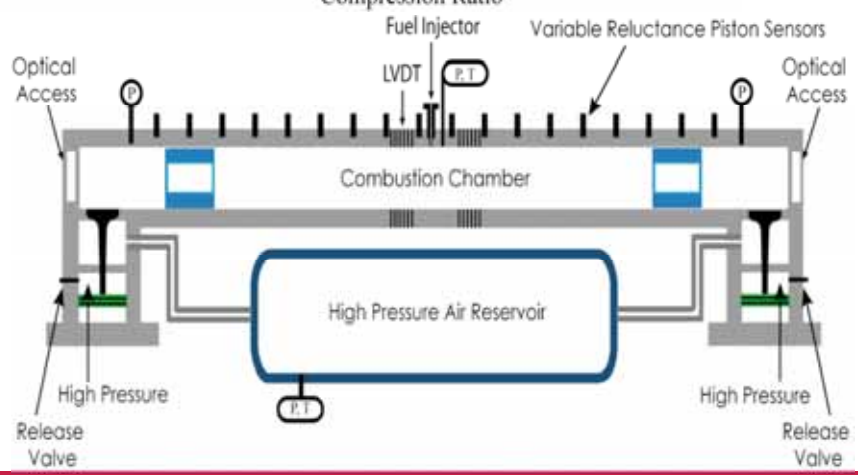
Novel Approaches to Fuel Cell Design and Chemistry Nanoscale Architectural Engineering – *Haile and Goodwin*



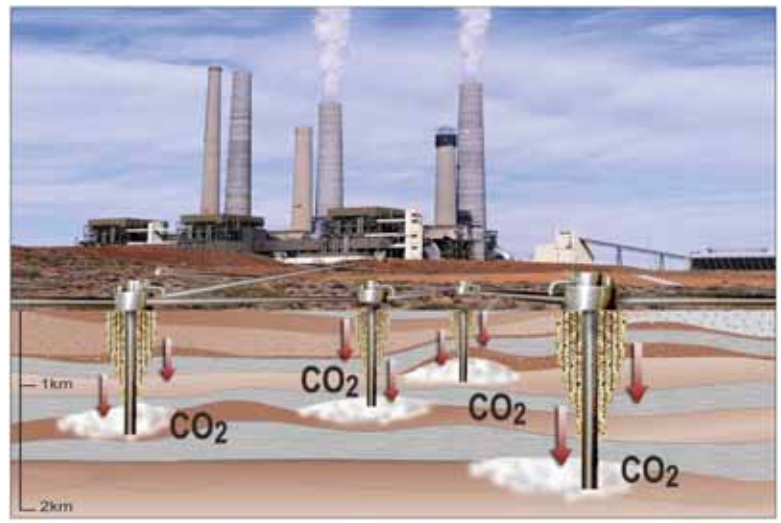
GCEP Research Projects in Carbon-Based Energy Systems

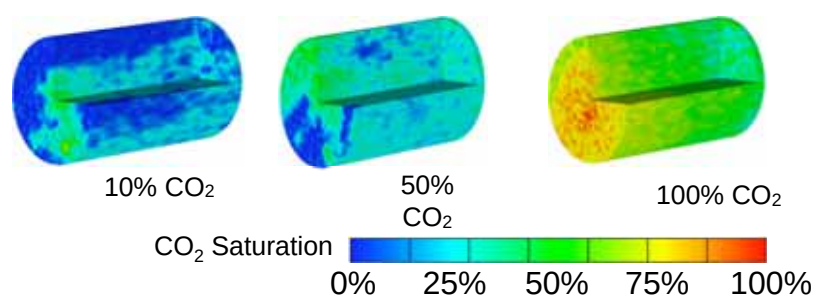
Advanced Combustion through Exergy Management – *Edwards*





Carbon Dioxide Capture and Sequestration - *Benson*





Summary

- The transition to energy systems with much lower GHG emissions is one of the greatest challenges we humans must face in this century.
- There is no single solution to this challenge. We need to work on a broad portfolio of approaches, with a spectrum of time scales and sources of support.
- GCEP is one example of fundamental research to create novel, more efficient energy conversion options with potential for large-scale impact. It should be one of many. There is plenty to do!
- Let's get started now:
  - Now: Energy efficiency, cost effective solar and wind, and conservation
  - Soon: Low carbon base-load electricity generation
  - Ongoing: Steady stream of invention and innovation.