Science and technology for a low GHG emission world

http://gcep.stanford.edu/

New Directions for GCEP Research

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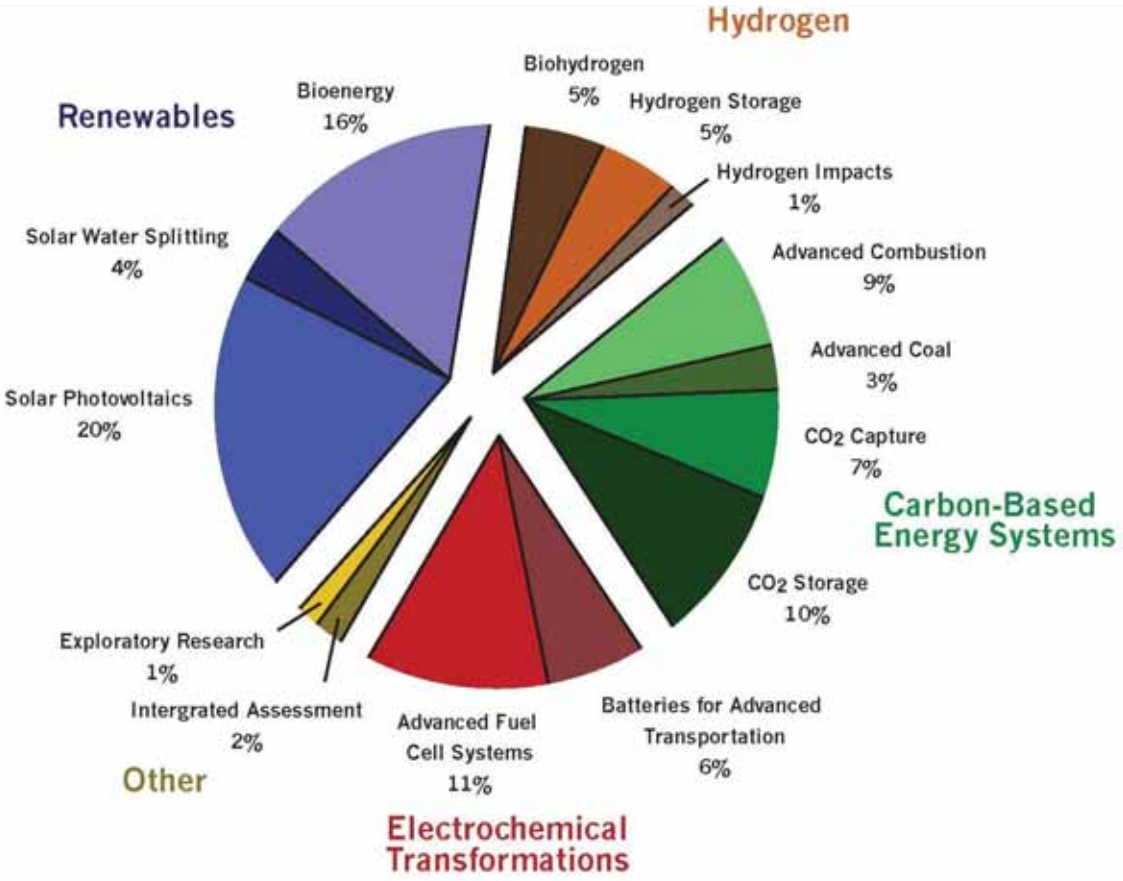
October 1, 2008

Global Climate and Energy Project
Stanford University

Research Portfolio Development Approach

- Annual solicitations to Stanford faculty – broad set of topics
- Targeted world-wide solicitations
  - New batteries for transportation
  - High efficiency solar PV
  - Lignin management in biofuels



What's Next?

GCEP Criteria

… excellent fundamental science and engineering science

… impact at scale on reducing greenhouse gas emissions

… step-out, game changing or disruptive approaches

and

… restore, protect and sustain our environment

… with a focus on primary energy supply

Targeted Portfolio Development

GCEP Theme Leaders

Solar Energy
Martin Green, UNSW

Biofuels
Chris Field, Stanford

Energy Storage
Chris Chidsey, Stanford

Carbon Dioxide Capture and Storage
Sally Benson, Stanford

Opportunity Area Idea Generation

GCEP Analysts

GCEP Analysts Assessment

Paolo Bosshard
Emilie Hung
Jennifer Milne

Opportunity Assessment

Workshops with Scientific Community and Industry Leaders

Opportunity Development

GCEP Team

GCEP Criteria for Lignin Management

- Two-fold increase in the amount of sugars produced
- 50% increase in cellulosic ethanol production
- Maintain the structural and vascular integrity of the plant
- Large-scale deployment in crops that minimize environmental stress and resources.

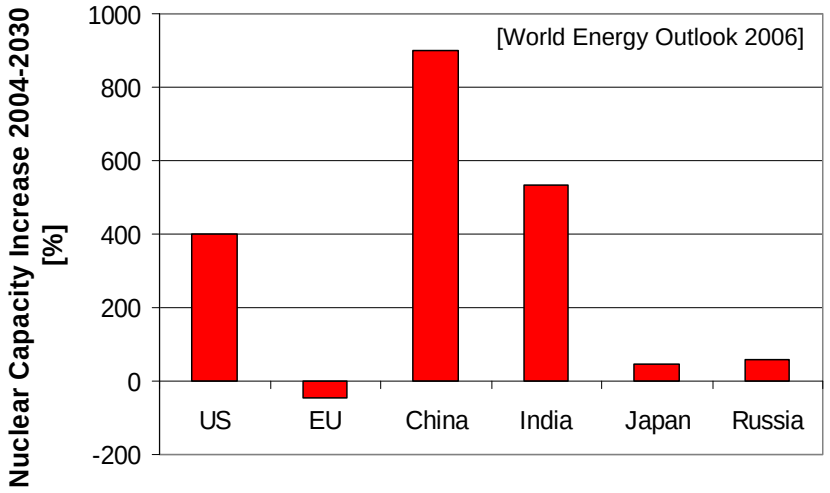
Targeted Requests for Proposals

Workshops: 2007-2008

- Fission Energy
  - Joint with MIT, Center for Advanced Nuclear Studies
  - http://gcep.stanford.edu/events/workshops_fissionenergy_11_07.html
- Advanced Electricity Infrastructure
  - http://gcep.stanford.edu/events/workshops_electricity_11_07.html
- Industrial Sources
  - http://gcep.stanford.edu/events/workshops_carbonmgmtmfgind.html
- Non-CO_2 Greenhouse Gases
  - http://gcep.stanford.edu/events/workshops_nonco2.html

GCEP/MIT Fission Energy Workshop

- Large potential for providing low-GHG emission base-load power
- Significant increase in the global nuclear power production during the next decades, particularly in fast-growing economies such as China and India.



- Challenges of nuclear power
  - Safety — aging fleet and slow progress in novel design concepts
  - Security — diversion of nuclear material
  - Sustainability — fuel availability; waste treatment and management
  - Economics — large capital costs
- 70 experts in a large spectrum of scientific and technical areas organized around the following sessions:
  - Design innovation in reactor technology
  - Advanced fuel cycles
  - Structural materials for future nuclear plants
  - Waste management

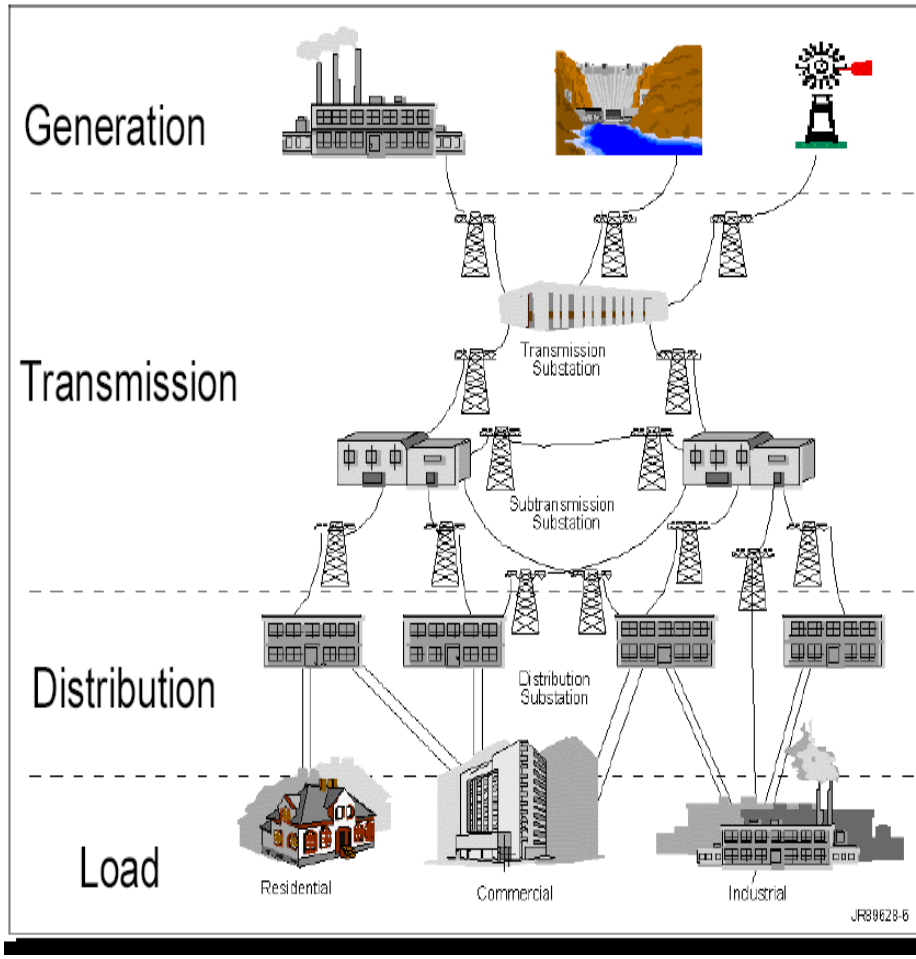
Fission Energy Research Opportunities

- Potential research opportunities
  - Novel approaches for multi-scale multi-physics simulation and modeling - Large spectrum of potential applications
    - reactor physics
    - radiation defects in structural materials for fission and fusion
    - long-term nuclear waste interactions with the environment
  - Novel high-temperature radiation-resistant materials (for fission and fusion)
  - Novel chemical separation techniques for minor actinides (e.g. Cs, Sr)
  - Reactor concepts for the future: look beyond Gen IV
- GCEP activities in this area
  - GCEP is still considering what areas would be most appropriate for GCEP-sponsored academic research that would create impact-full options complementary to research efforts pursued in national laboratories worldwide

Advanced Electricity Infrastructure Workshop

- Existing electrical grid is the legacy of a century of incremental development
- Stability and reliability are significant concerns
- Transition to integrate more intermittent renewable and distributed resources will create new and significant challenges
- Explored topics in electricity transmission, distribution and storage:
  - Advanced Transmission
  - Power Systems and Control
  - Distributed Generation
  - Storage for Distributed Resources

Current Legacy Infrastructure



Source: T. Overbye GCEP Workshop 2007

Grid Network Communication and Control

Characteristics and challenges of existing system

- Centralized, large generation
- Local disturbances can have wide area impacts due to elaborate interconnected networks
- Information processing is complex and biased
- Lack of information, operation and design at the distribution level
- Integration of intermittent and distributed generation sources like wind power can disrupt operations and destabilize the grid

Attributes for integration of renewable energy resources

- Grid-integrated storage to manage intermittency, peak shaving, power quality
- Multi-layer communication and control
- Bi-directional power flow at the distribution level
- Localized information and situational awareness

GCEP Request for Proposal: Grid Networks, Simulation and Control

Develop a set of models and/or tools to maintain system reliability and power quality for a system with *at least 50% renewable energy penetration and reduced GHG emissions*.

- Detail the methodologies and architectures proposed for communication, control, and optimization;
- Identify the extent to which hardware, such as the capacity and type of storage or power electronics, would need to be grid-integrated to contribute to the effectiveness of such a system;
- Provide intelligence and information at high granularity and small scale to maintain reliable and high quality power supply;
- Simulate reliability and stability of a power system under realistic mixed renewable energy generation scenarios;
- Address the opportunities and challenges posed by large-scale integration of plug-in vehicles into the grid; and
- Demonstrate the approach to optimal network communication and control at bench or small-scale.

RFP issued May 2008 and funding decision expected Dec 2008.

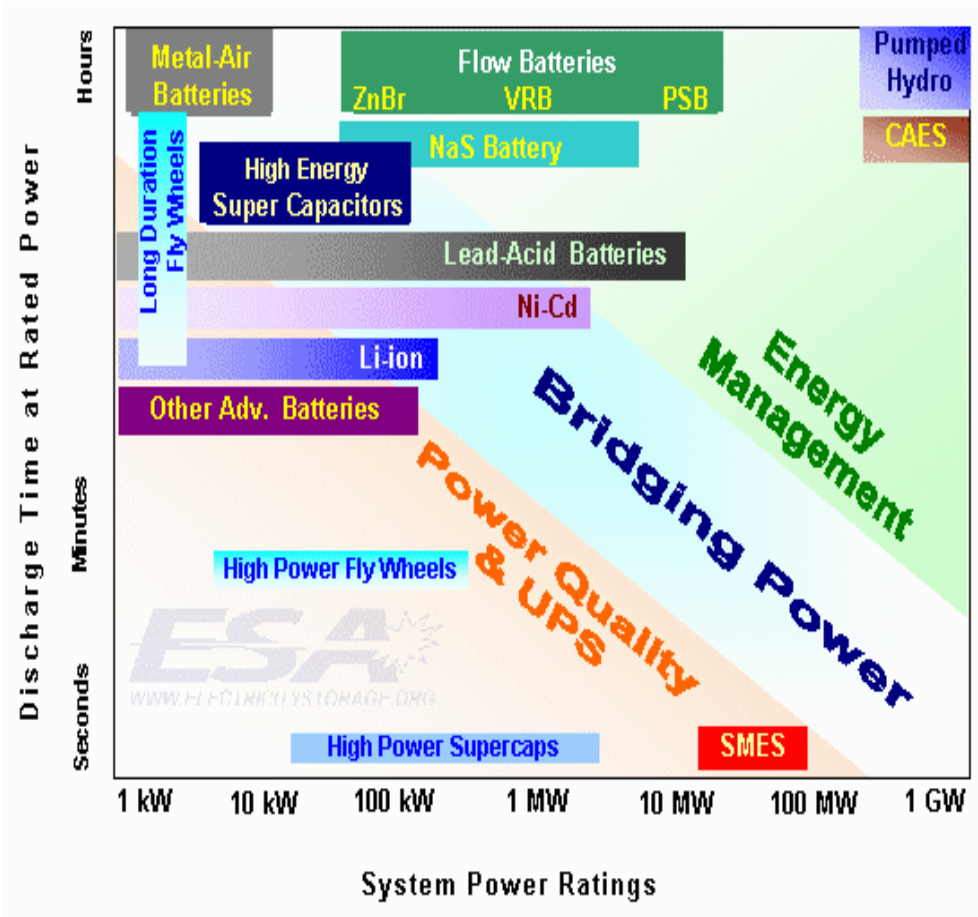
Energy Storage

Balance intermittency and off-peak generation from renewables

- Energy management such as peak shaving
- Manage supply intermittency
- Power system support in maintaining power quality and stability

Plan to issue an RFP in Energy Storage in 2009

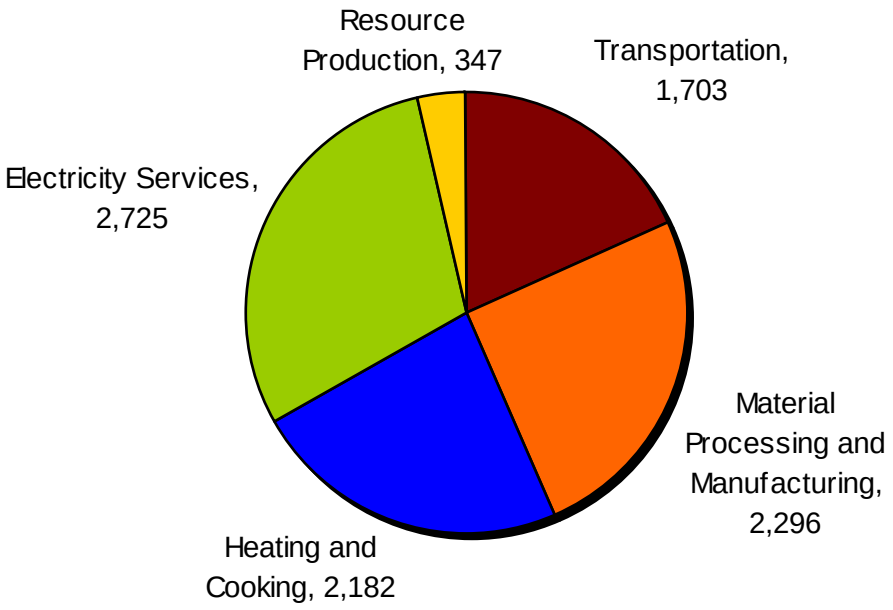
- High performance and carbon roundtrip efficiency
- Long lifetime and cycle life
- Durable and reliable- low maintenance
- Low cost

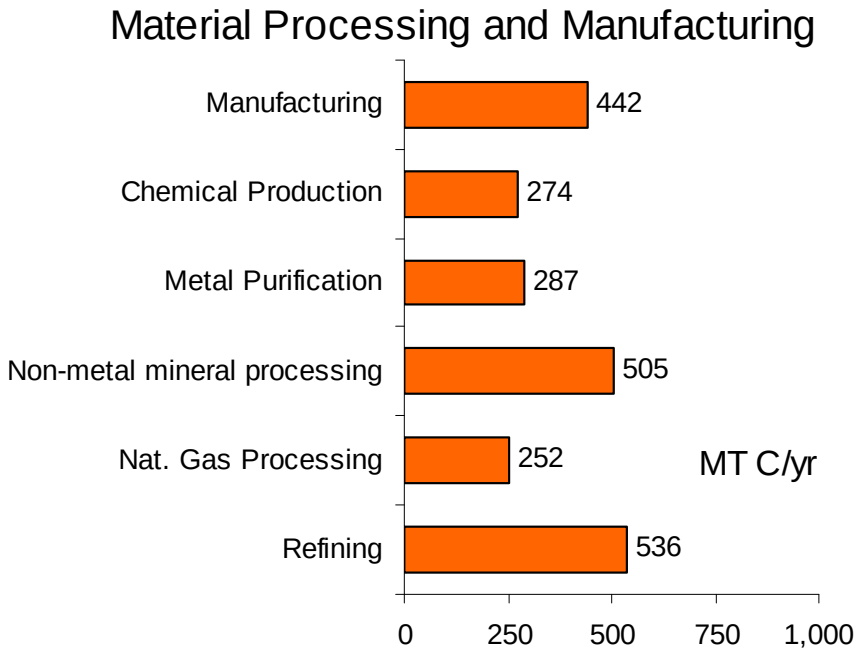


Source: Electricity Storage Association

Emissions Reductions from Industrial Sources

2004 Global CO_2 Emissions (Mt C)





~ 25% of CO_2 emissions come from manufacturing
-- and can be expected to grow

Six industries account for the majority of emissions

Industrial Emission Sources

- Carbon Management in Manufacturing Industries Workshop
  - Explored challenges in reducing greenhouse gas emissions from cement production, iron-making, refining, and other industries
- Opportunities for large emissions reductions
  - High efficiency oxygen production
  - Post combustion CO_2 capture
  - Low-emission material substitution
  - CO_2 as feedstock

GCEP

Global Climate & Energy Project

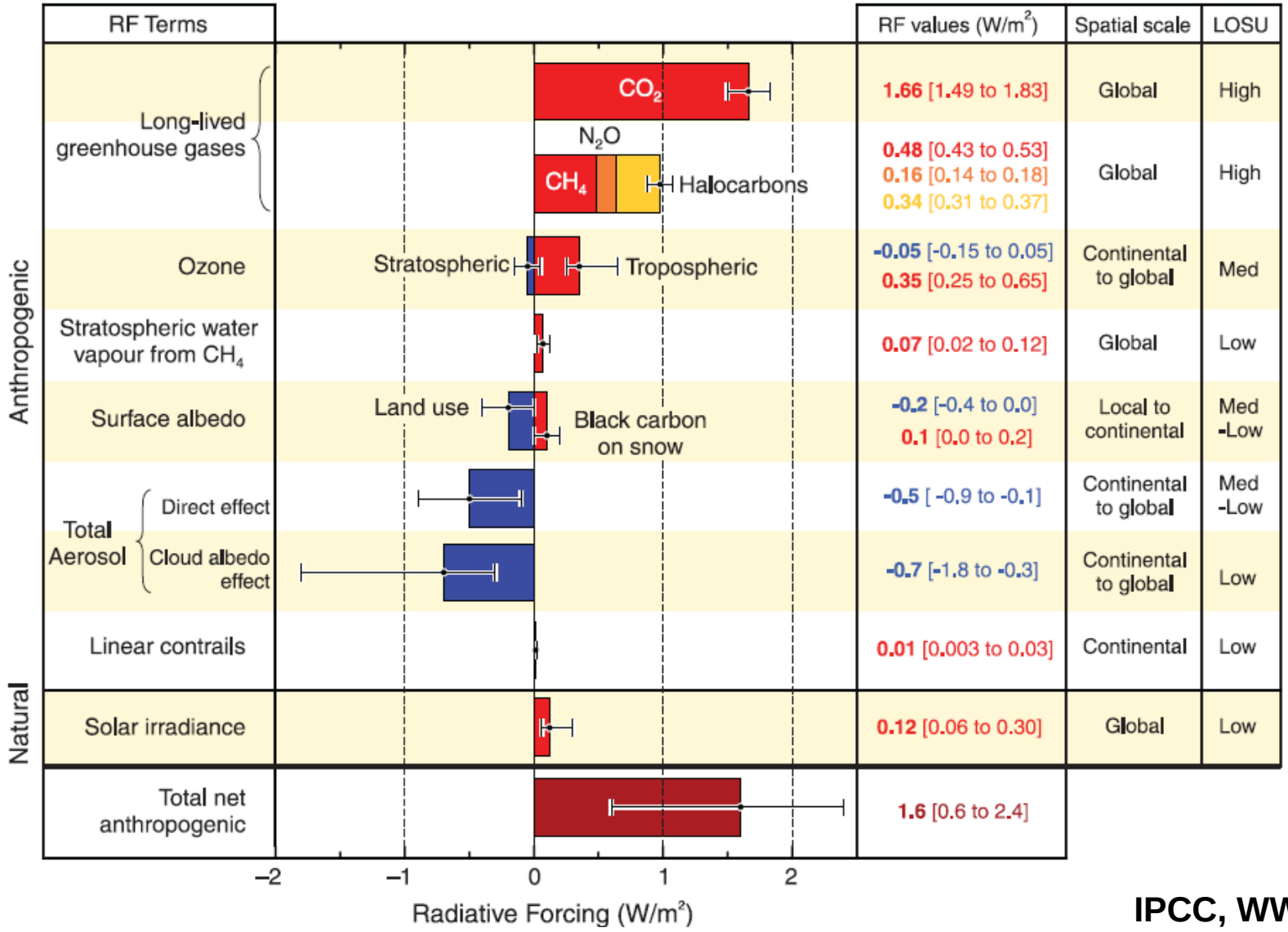
STANFORD UNIVERSITY

GCEP Workshop

Non-CO_2 Greenhouse Gas Emissions

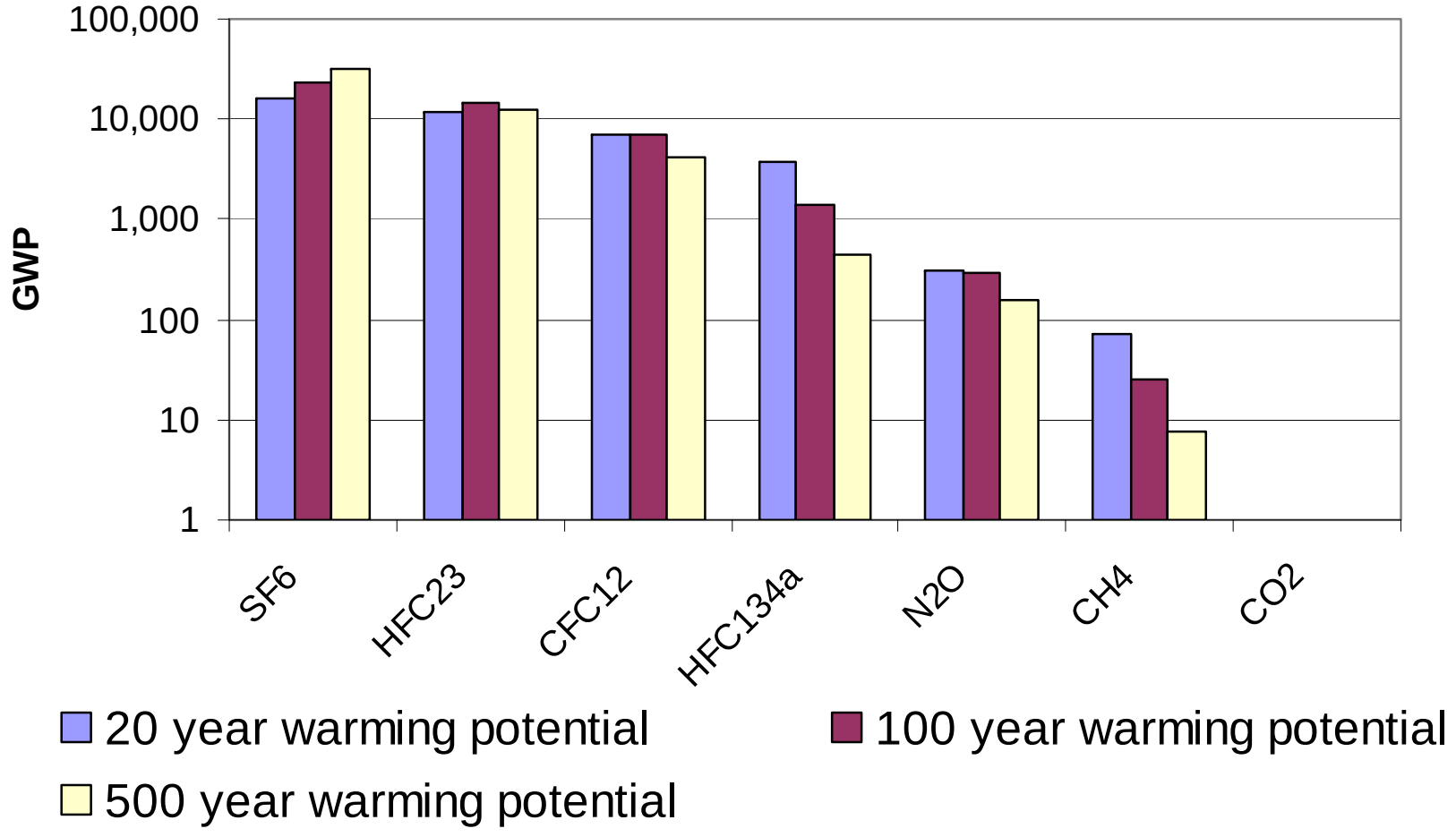
August 26–27, 2008

Global Average Radiative Forcing (RF) in 2005



IPCC, WWG I, 2007

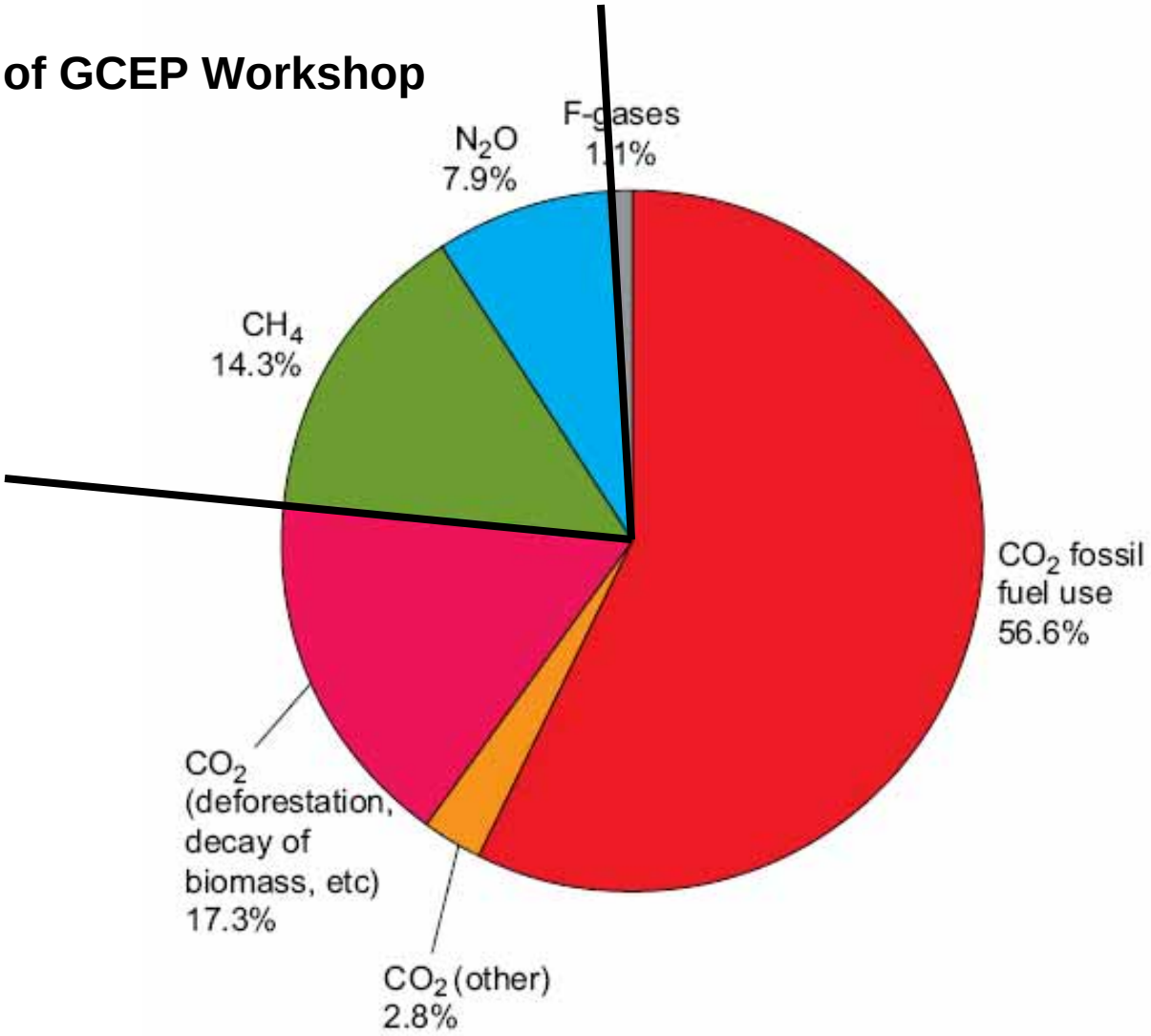
Global Warming Potentials for Some Non-CO_2 Greenhouse Gases



Lifetime of gases (Years): N_2O = 114; CH_4 = 12

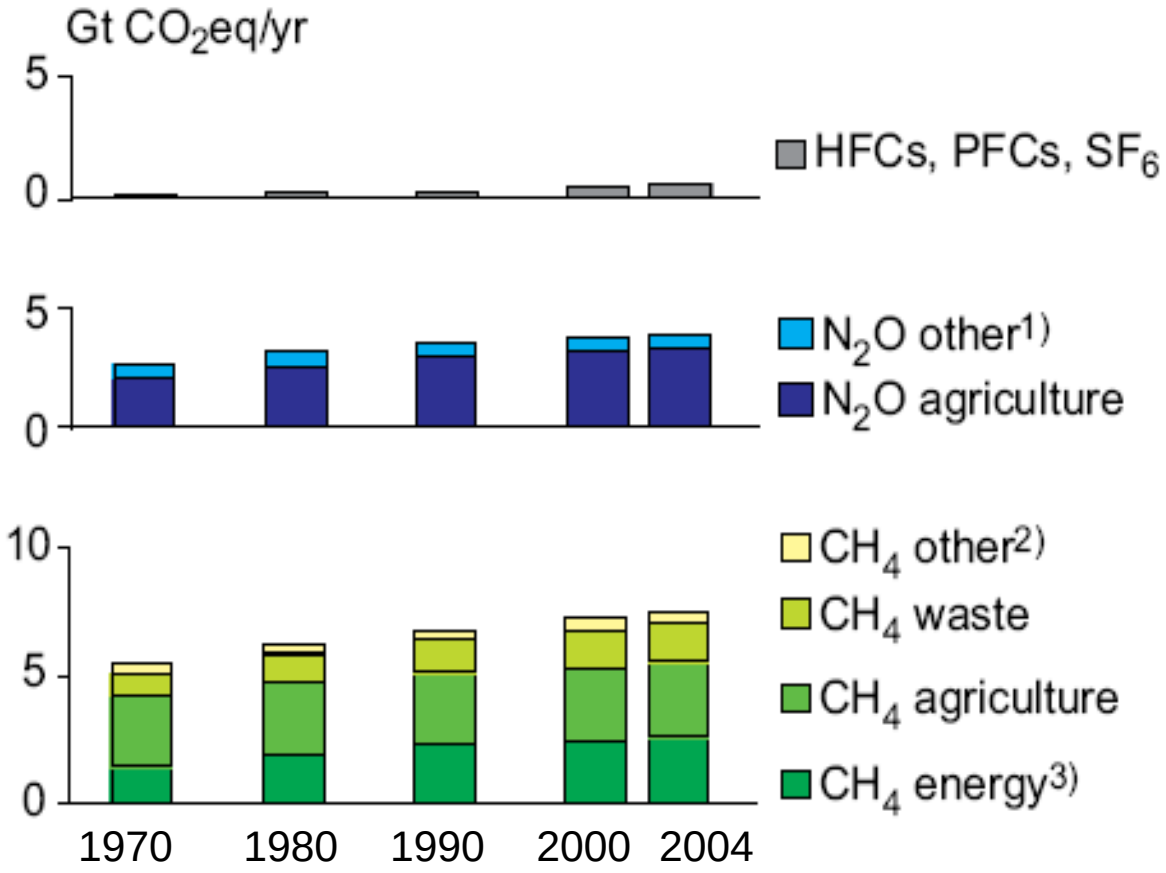
Global Anthropogenic Greenhouse Gas Emissions in 2004

Focus of GCEP Workshop



From IPCC Fourth Assessment Report: Working group III Report “Mitigation of Climate Change”

Global Anthropogenic Greenhouse Gas Trends 1970-2004



From IPCC Fourth Assessment Report: Working group III Report “Mitigation of Climate Change”

Research Needs Identified so far…

- Fundamental research to optimize cellulose degradation and methanogenesis
- Applying current molecular and genetic tools to microbial communities involved in methane production/utilization and the nitrogen cycle to control emissions
- Making plants more efficient utilizers of nitrogen
- Converting methane to liquid fuel/ higher alkanes/ use as a chemical feedstock for biomaterials

Summary

- GCEP continues to expand its portfolio

  … excellent fundamental science and engineering science

  … impact at scale on reducing greenhouse gas emissions

  … step-out, game changing or disruptive approaches

  and

  … restore, protect and sustain our environment

  … with a focus on primary energy supply

- Pursuing opportunities
  - Electrical grid to support intermittent distributed resources
  - Grid-integrated storage
- Evaluating potential for GCEP
  - Fission energy
  - Industrial sources
  - Non-CO_2 greenhouse gases
- More workshops and assessments planned for next year
  - Workshops publicized through mailing list and website