Stanford University

Global Climate & Energy Project

March 15-16, 2005

Welcome and Introduction

Lynn Orr

GCEP Advanced Coal Workshop
Provo, UT

The Grand Challenge

Needs

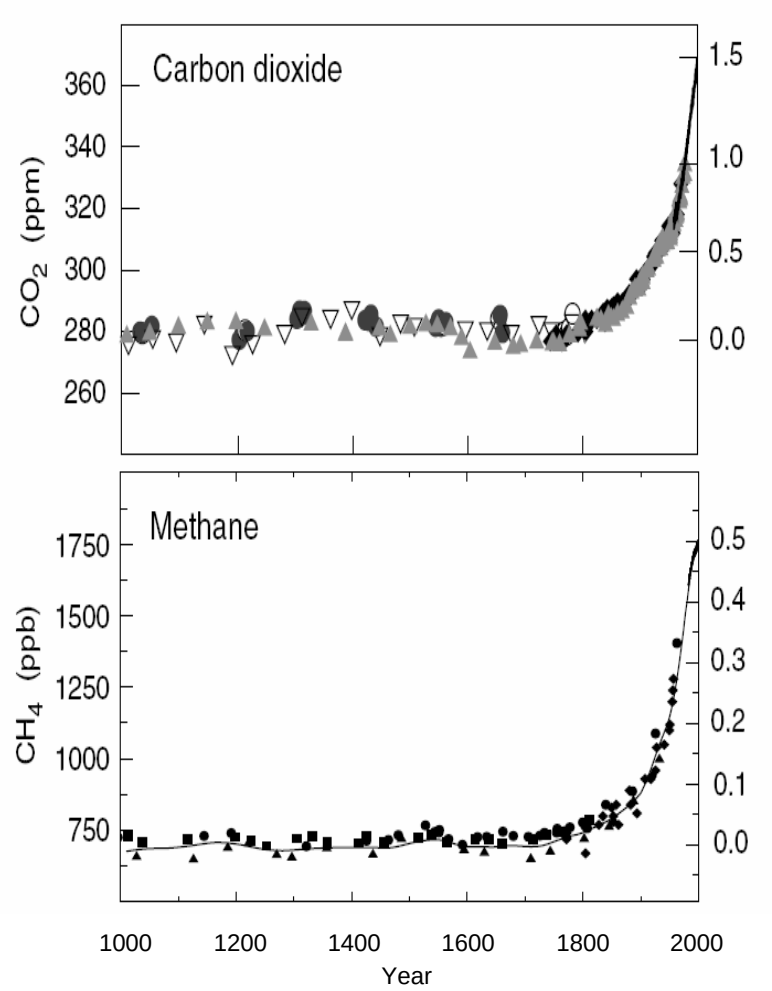
- Growth in world population to 9 billion from 6 billion, of which 2 billion people currently have no access to modern energy systems
- Improved standard of living in growing economies of developing world
- Increased demands for energy, food, land, and materials.

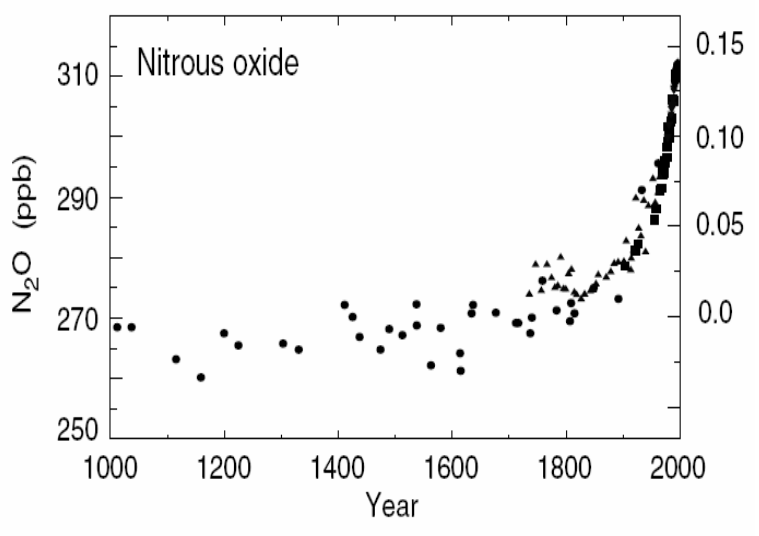
Protection, Restoration, and Improvement of the Planetary Biogeochemical Systems

Component Challenges

- Water supply
- Agricultural systems (strongly linked to water supply)
- **Energy (with possible limits on CO_2 emission)**

Global Geochemical History

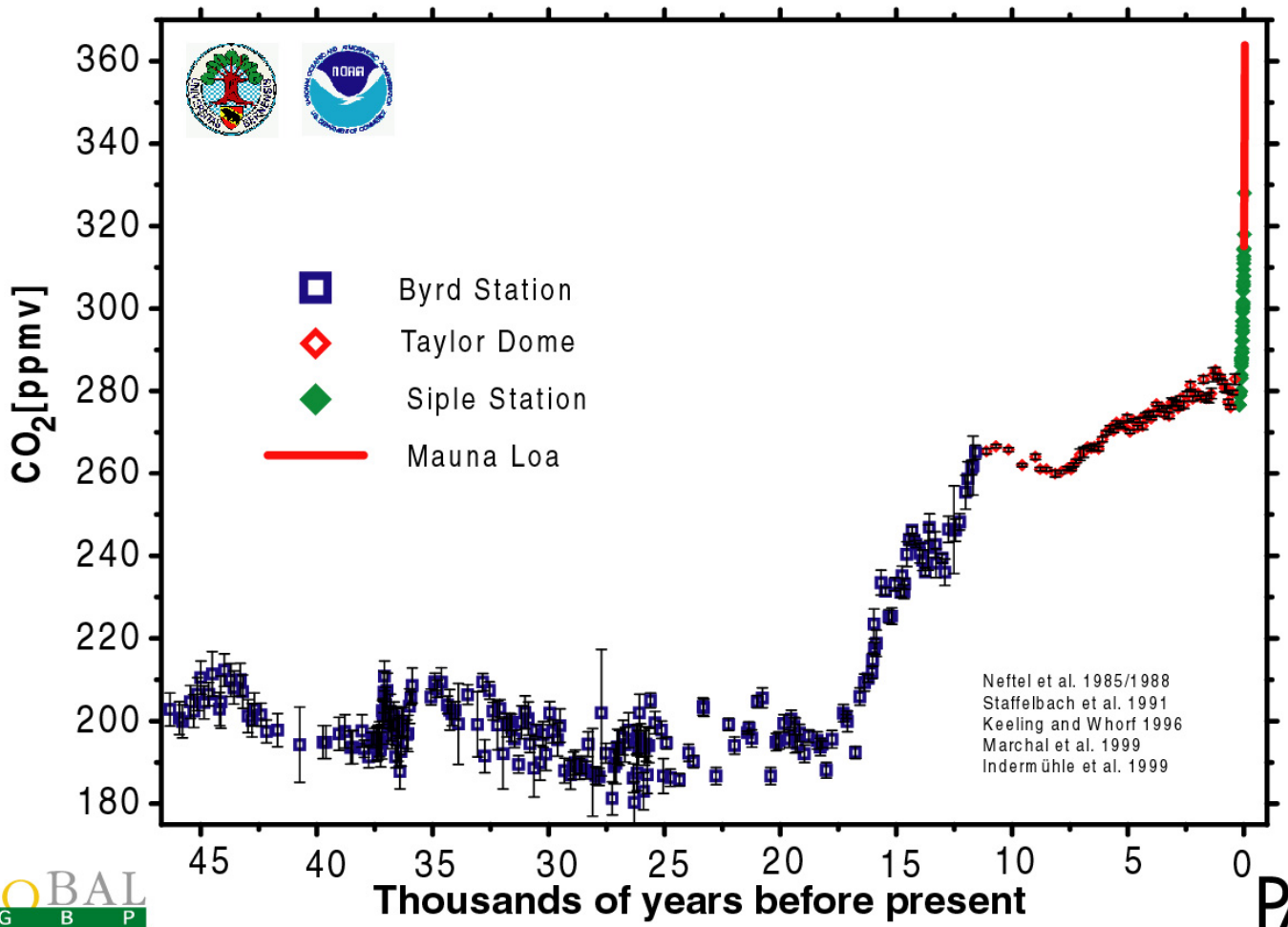




- Concentrations of GHGs have risen significantly over the preindustrial levels.

Source: IPCC Third Assessment Report, 2001

Atmospheric CO_2 Concentration
- Last Glacial Maximum to Present



Adapted from: http://www.climate.unibe.ch/gallery_co2.html

The Oceans in a High CO_2 World

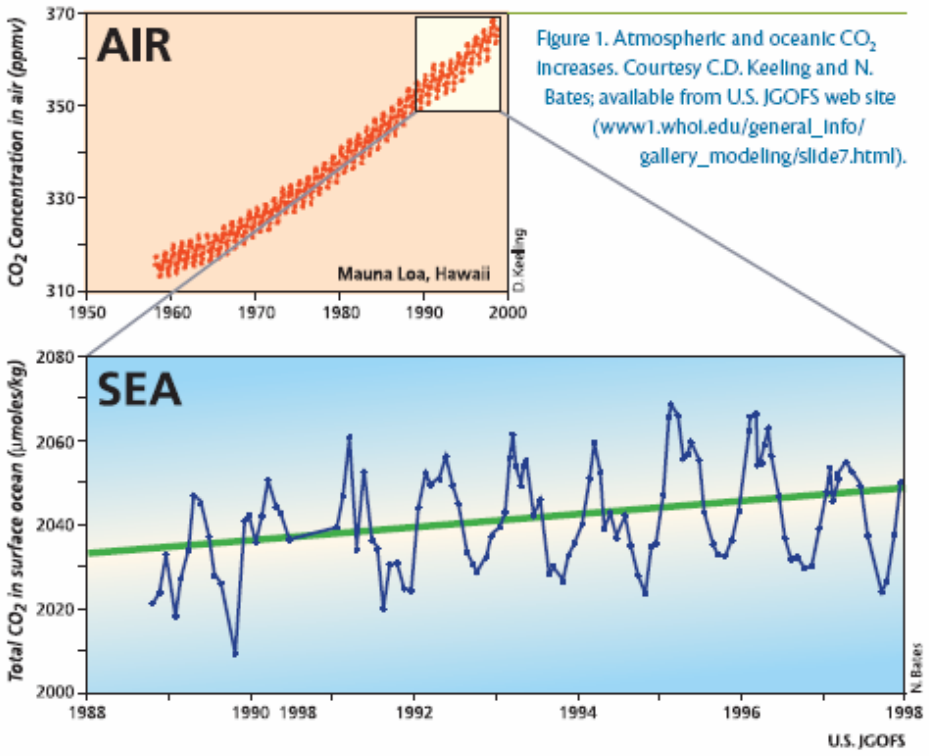


Figure 1. Atmospheric and oceanic CO_2 increases. Courtesy C.D. Keeling and N. Bates; available from U.S. JGOFS web site (www1.whoi.edu/general_info/gallery_modeling/slide7.html).

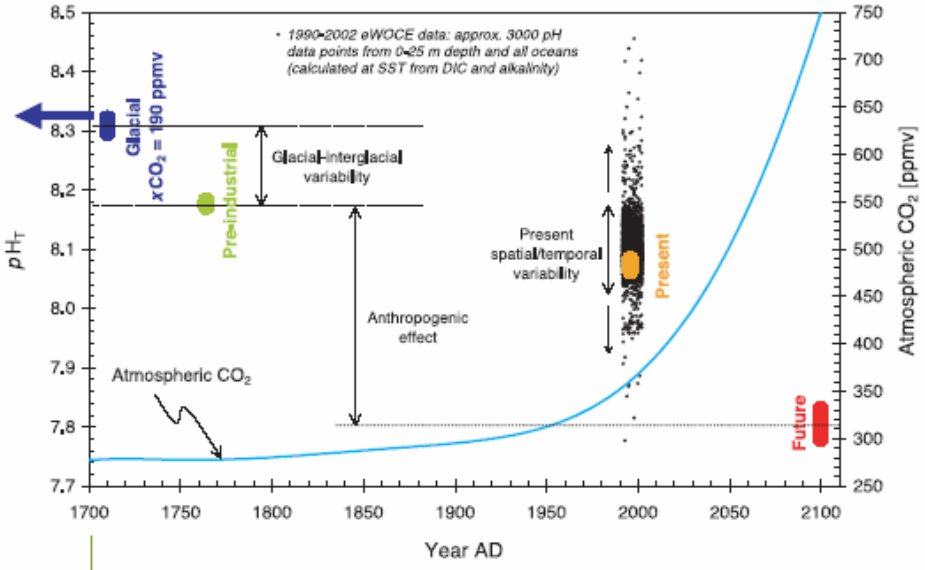
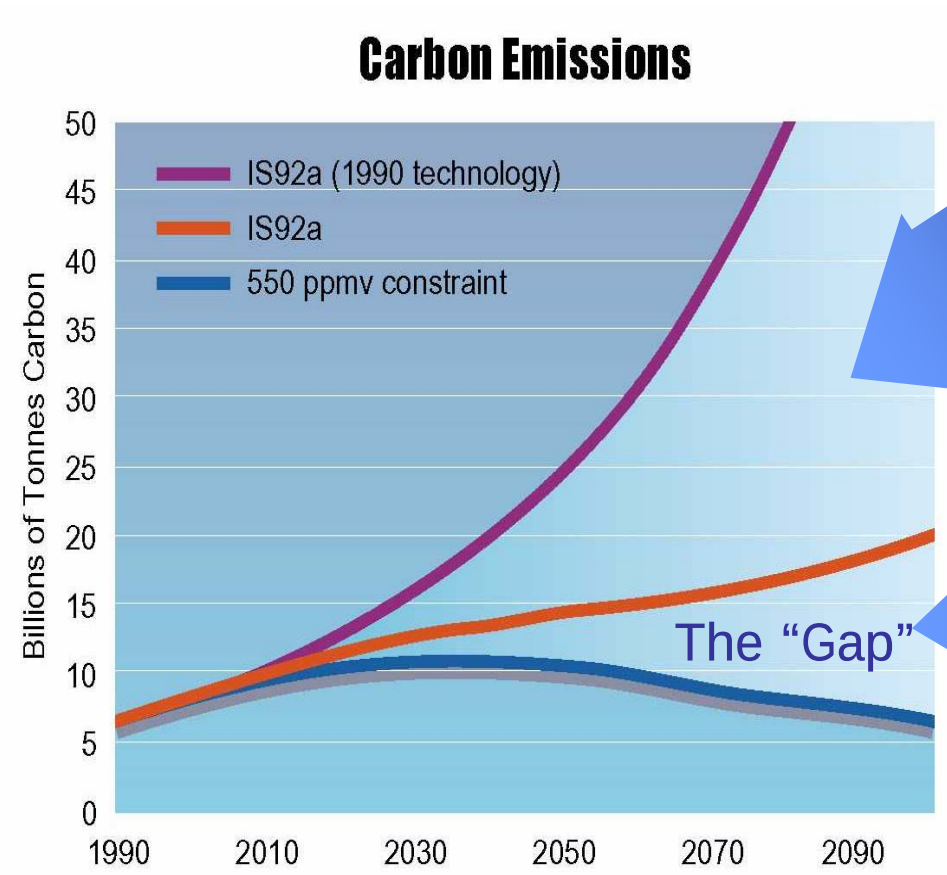


Figure 2. Present (1990-2002) surface seawater pH_T values from all oceans (3000 data points from the upper 25 m, pH_T were calculated from measured dissolved inorganic carbon and alkalinity). The majority of the data fall into a rather narrow pH range of 8.1 ± 0.1. Also shown are typical pH ranges of glacial, pre-industrial, present, and future (year 2100) surface seawaters resulting from the observed and predicted increase in atmospheric CO_2 levels (blue line with exponential increase) as obtained by simple scenario calculation. Figure prepared by Arne Körtzinger on the basis of WOCE data (Schlitzer, 2000). From IMBER (in prep.).

The oceans have taken up ~400 Gt of fossil fuel CO_2. Global surface oceans now remove 20-25 Mt CO_2/day.

Decline in pH (0.1 since industrial revolution) affects bicarbonate, carbonate ion concentrations, rates of fixation of $CaCO_3$ by assorted critters in the trophic chain, potential for feedbacks with temperature change. Source: Oceanography Vol.17, No.3, Sept. 2004

The Need for Technology



Assumed Advances In:

- Fossil Fuels
- Energy intensity
- Nuclear
- Renewables

Gap Technologies:

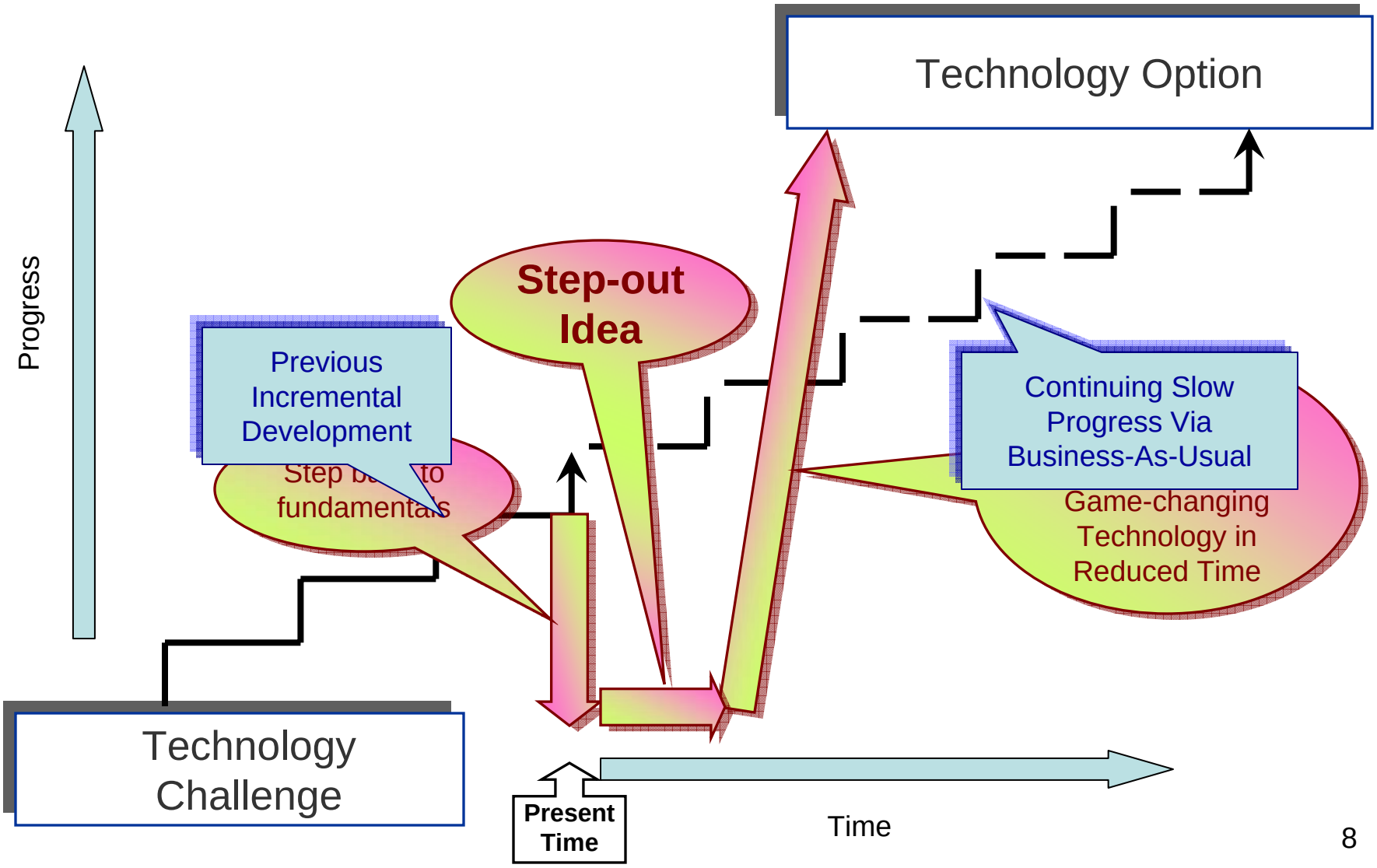
- Carbon capture & disposal
  - Adv. fossil
- H_2 and Adv. Transportation
- Biotechnologies
  - Soils, Bioenergy, Adv. Biological Energy

Source: J. Edmonds, PNNL

GCEP Approach

- Focus on potential energy technologies that could be game-changing with respect to greenhouse gas emissions
- Encourage high risk/high reward research
- Apply within 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 developing countries with potential high levels of future greenhouse gas emissions

Step-Out Technology



Portfolio Areas

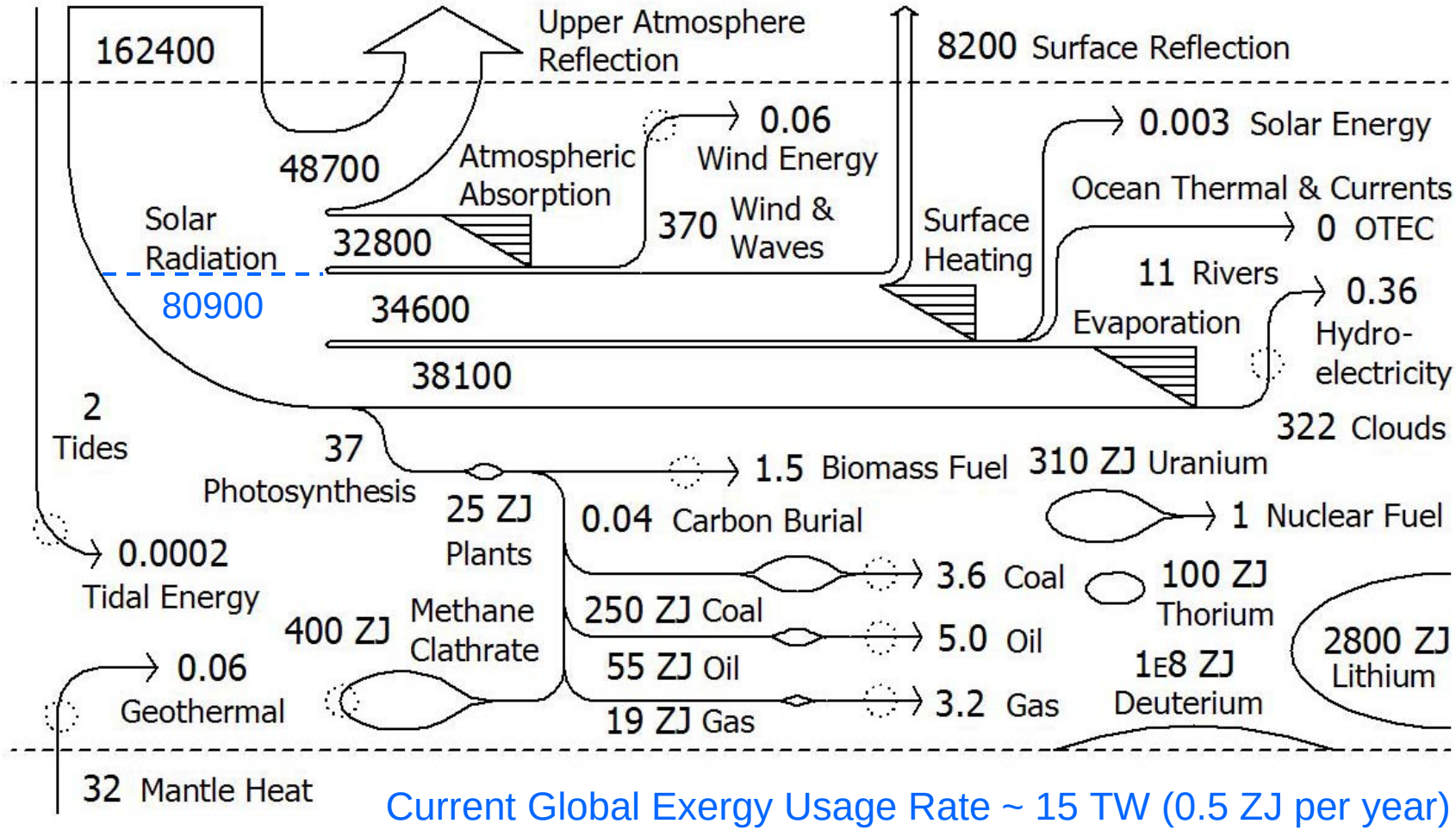
- GCEP portfolio currently includes 11 technical areas:

Advanced transportation systems	Advanced nuclear power technologies
Electric power generation, storage, distribution	**Renewable energy sources (wind, solar, biomass, geothermal)**
Hydrogen production, distribution, and use	**CO_2 separation, capture, and storage**
Advanced coal utilization	**Combustion science and engineering**
Energy distribution systems and enabling infrastructures	**Advanced materials**
Geoengineering	

Technical Areas with Projects currently underway

- Portfolio development and maintenance is supported by thorough assessment and analysis efforts

Exergy Flow of Planet Earth (TW)



Current Global Exergy Usage Rate ~ 15 TW (0.5 ZJ per year)

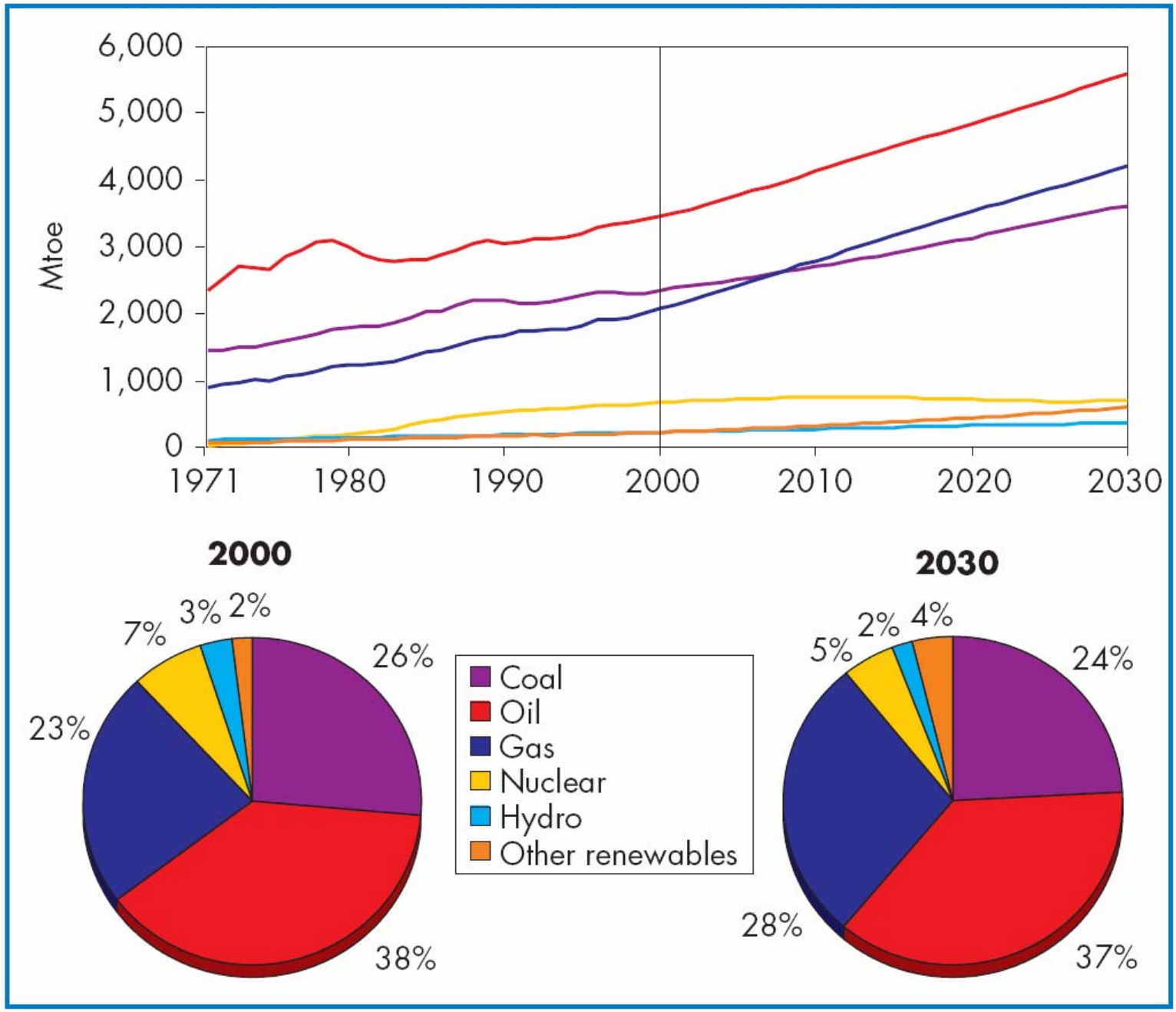
80900/15 = 5400

Source: W. Hermann, GCEP Systems Analysis Group 2004. (1 ZJ = 10^{21}J)

Summary of Progress to Date

- GCEP agreement signed between Stanford University and Sponsors on February 21, 2003
- 22 research projects in five technical areas are either underway or being initiated at Stanford and five outside institutions
- Total awards are ~$42.5M out to 2007
- Examined five topics in three technical areas through assessments and workshops
  - Hydrogen
  - Carbon Capture and Separation
  - Wind
  - Solar
  - Biomass

Figure 2.1: **World Primary Energy Demand**



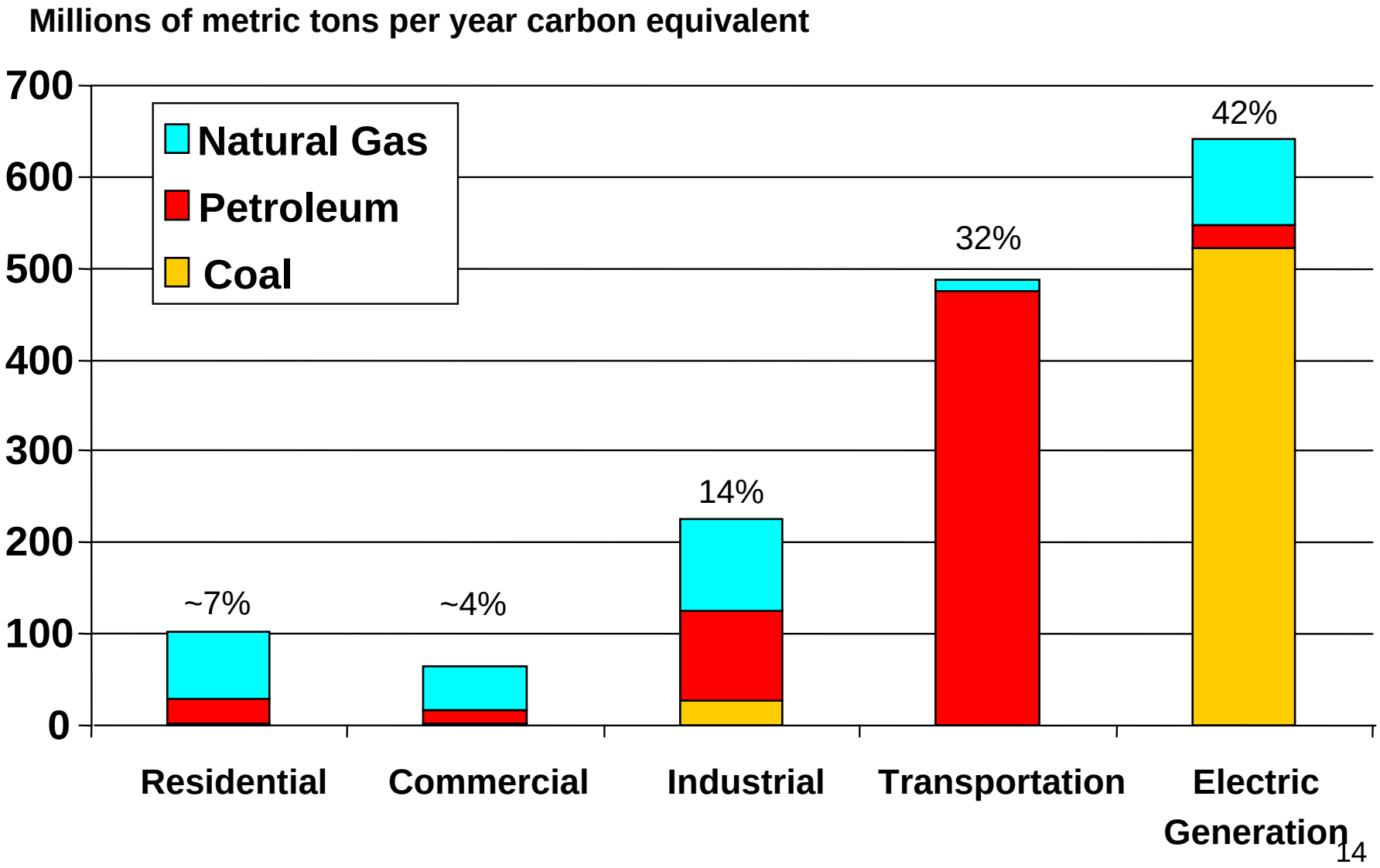
Source: OECD/ IEA, Paris, *World Energy Outlook 2002*, Second Edition, November (2002)

India, China, & the USA in 2002
(with world rankings)

	India	*China*	*USA*
Population, millions	1050 (2)	1280 (1)	288 (3)
GDP, trillion 2002$ (ppp)	3.1 (3)	5.4 (2)	10.4 (1)
Total energy use, EJ	26 (4)	55 (2)	105 (1)
Coal consumption, EJ	8 (3)	30 (1)	25 (2)
Oil imports (net), EJ	3.3 (9)	3.6 (8)	23 (1)
Electricity generation, TWh	580 (5)	1650 (2)	4050 (1)
Electricity from coal, TWh	480 (3)	1200 (2)	2000 (1)
C emitted in CO_2, MtC	265 (5)	900 (2)	1640 (1)

Source: John Holdren, US-India Energy R&D Workshop, New Delhi, August, 2004

United States CO_2 Emissions in 2000



Source: U.S. EPA Inventory of Greenhouse Gas Emissions, April 2002

Research Questions Concerning Advanced Coal Technologies

- What are the technological barriers and challenges to coal utilization with reduced greenhouse emissions and other environmental impacts?
- Which key technologies, if developed, could change the game for future coal use in both the developed and developing world?
- What are the research opportunities for developing these technologies?
- How can GCEP best contribute to solving these problems and expanding the opportunities and benefits?

Thank You!

Larry Baxter and Reggie Mitchell

- for selecting the topics and bringing this group together

BYU

- for hosting this meeting

Emilie Hung

- for working hard to arrange this meeting

Kersti Miller and Nancy Sandoval

- for organizing everything else!

Our Sponsors

- for making this project possible

Our Speakers

- for sharing your time, expertise, and opinions with us

The Energy Community

- for taking time to participate in our discussions

Workshop Agenda
- Day 1

	Welcome and Introduction		
8:30	GCEP Introduction and Workshop Purpose		*Lynn Orr*
9:00	Coal Utilization and Overview		*Stephen Gehl*
	Gasification and IGCC	Chair: *Douglas Smoot*	
9:30	Overview of Gasification Technologies		*Gary Stiegel*
10:00	*Break*		
10:15	Producer Gas Products		*Eric van de Venter*
10:45	Gasification Design Issues		*Neville Holt*
11:15	Panel Discussion		
11:45	*Lunch*		
	Oxy-Fuel Combustion	Chair: *Philip Smith*	
12:45	Oxy-Fuel Combustion in the GHG Context		*Rajender Parshad Gupta*
1:15	Large Scale Oxy-Fuel Systems: The Role of Laboratory Combustor Research		*Jost Wendt*
1:45	CO_2 Reduction by Oxy-Fuel Combustion: Economics and Opportunities		*Sho Kobayashi*
2:15	*Break*		
	Fuels and Fundamentals	Chair: *Reginald Mitchell*	
2:30	Relationships Between Particle Chemistry and Decomposition Products		*Thomas Fletcher*
3:00	Review of Condensed-Phase Reaction Kinetics		*Stephen Niksa*
3:30	Panel Discussion		
	China Perspectives Panel		*Zhongyang Luo and Ni Weidou*
5:00	*Reception*		

Workshop Agenda
- Day 2

	Liquid Fuels Chair: *Ronald Pugmire*	
8:30	System Analysis of Liquid Fuels from Coal and Biomass with CCS	*Robert Williams*
9:00	Coal and Liquid Fuels	*Richard Bajura*
9:30	*Break*	
9:45	Direct Coal Liquefaction: Lessons Learned	*Ripudaman Malhotra*
10:15	Biological Utilization of CO, H2, and CO2	*Randy Lewis*
10:45	Panel Discussion	
11:15	*Lunch*	
	Co-Firing Chair: *Dale Tree*	
12:15	Co-Firing Switch Grass	*Gary Walling*
12:45	Attractions and challenges in Co-Firing	*Larry Baxter*
1:15	Biomass Co-Firing—Technology, Barriers and Experiences in Europe	*Gerrit Brem*
1:45	Panel Discussion	
	Closing Remarks	