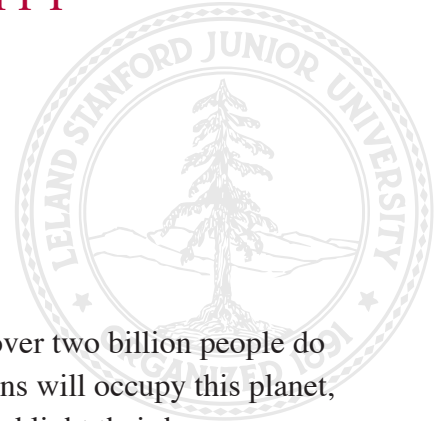




GCEP
Global Climate & Energy Project
STANFORD UNIVERSITY

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The Challenge

Energy is the lifeblood of modern societies. Yet even today, over two billion people do without basic energy services. Within 20 years, 7.5 billion humans will occupy this planet, about 25 percent more than do so now. They will want to heat and light their homes, power electrical devices, move from place to place, grow food, and drink clean water. Supplying the energy required to do all this is, by itself, a significant challenge, but it is only part of the challenge that we must face in this century. It is apparent that humans are interacting with the planet on a global scale. The concentration of carbon dioxide (CO₂) in the atmosphere has increased by a third from its preindustrial levels, and the pH (a measure of how acid or alkaline a solution is) of the upper ocean has also changed as the CO₂ from the atmosphere dissolves. While there is a lively ongoing debate about the magnitude and timing of the climate's response to the presence of more greenhouse gases (GHGs) in the atmosphere, there is no question that changes are occurring on a global scale, and hence there is a possibility that the world will need an energy system that has much lower emissions of CO₂ and other greenhouse materials to the atmosphere in the future. This project will help make that future possible.

*Imagine a global energy system
where greenhouse emissions to the atmosphere are a small
fraction of what they are today.*

Many questions arise as we try to foresee how such a system will operate. What will be the primary sources of energy supply? How will we deploy that supply? What technologies and systems could be applied as effectively in the developing countries as in North America and Europe? Will we use wind, solar, nuclear, hydrogen, fossil fuels, and in what combinations? Will currently unforeseen options emerge? How will such an energy system be created? What barriers prevent implementation of such systems today? How will we overcome questions of safety, adverse environmental impacts, market acceptance, legality, social responsibility, and cost in implementing these systems? What technologies will have to be developed to eliminate these barriers? How can the creative talents of the world's great universities be harnessed to invent such a future? Who will train the next generation of scientists and engineers? Who will make all this possible?

The Project

With the support and participation of a group of visionary international companies — ExxonMobil, GE, Schlumberger, and Toyota—the Global Climate and Energy Project (GCEP) at Stanford University will develop and manage a portfolio of pre-commercial research programs to explore low GHG-emission energy technologies of the future. It is unlikely that any one energy source will be able to meet the full range of future energy needs, and hence it is essential that the exploration of energy futures examine technologies across the full spectrum of globally significant energy sources and end uses. Clearly, investigation of a diversified portfolio of research topics is critical to success. Research conducted as part of the project will be performed at Stanford and at other universities and research institutions worldwide. Stanford will draw widely from energy expertise around the world to frame the discussion and to build and shape the portfolio over time. Results of the research will be made widely available to the science and engineering community through the GCEP website, workshops, presentations, and journal publications. Stanford and the sponsors anticipate that patents developed under the program will ultimately be available for license and are currently developing principles for licensing to third parties. A key objective of this project is to encourage future commercial application of the technologies that flow from the research. Stanford will apply its considerable experience in technology transfer to make sure that happens.

GCEP will focus the creativity of talented students and faculty to develop and carry out the research activities that cross-fertilize creative solutions to the complex interactions of climate and energy. Stanford's part of the research effort will be a sustained investigation in research groups that focus on problems with long-term payoffs, and it will produce well-trained graduates who can build on their university experience in industry. Stanford has world-class programs in engineering, earth sciences, conservation biology, law, economics, business, and public policy, and this project will encourage formation of interdisciplinary approaches to the complex problems that must be addressed if a new global energy system is to emerge.

Industry collaboration and participation in the research activities will also be critical if promising technologies are to move beyond the stage of initial demonstration to commercialization. Industry perspectives can illuminate the university research process in very important ways, posing questions, challenging researchers, and helping the research groups understand real-world barriers that limit technology implementation. This project will create a sustained university/industry collaboration on the technical issues of climate and energy that frames a long-term research agenda, investigates a portfolio of energy solutions, and brings together industry and university researchers across technical disciplines.

Stanford University has a long, rich history of developing strategic relationships with the world's leading technology companies to solve the important problems of the future. Stanford's participation in the research that led to the information technology revolution is an example of the kind of impact this project is intended to have. The areas of energy and the environment are important not only to the future of this country, but indeed to all mankind, and Stanford is committed to investing its resources and energies to develop a significant and relevant presence in these domains.

Research Areas

Among the energy sources, systems, and uses that will be considered are:

- Hydrogen Production, Storage, and Utilization
- Renewable Energy Sources (wind, solar, biomass, and others)
- CO₂ Separation, Capture, and Storage Methods
- Advanced Materials
- Advanced Transportation Systems
- Electricity Generation
- Advanced Coal Utilization
- Combustion Science and Engineering
- Distribution Systems and Infrastructures
- Geoengineering
- Advanced Nuclear Power Technologies



The mix of future energy technologies will interact in complex ways with technology advances across these areas. Suppose, for example, that hydrogen becomes the preferred transportation fuel of the future. The development of an advanced infrastructure for hydrogen distribution could favor generation of the hydrogen at central facilities, while the absence of such an infrastructure would favor distributed generation of hydrogen. If hydrogen were made centrally from methane, coal, or other fossil fuel sources, then CO₂ will also be generated as a by-product. If low GHG emissions are to be achieved in that scenario, it would be necessary to separate, capture, and store the CO₂ generated (in depleted oil and gas reservoirs, aquifers, and unmineable coal beds, or in the ocean, for example). On the other hand, if sufficient electricity could be generated by solar, wind, or nuclear power to make hydrogen from water, then no CO₂ would be created in the hydrogen generation step, and CO₂ sequestration technologies would be less important. Advances in wind or solar generation technologies or in efficient, low-cost energy storage technologies that make renewable energy sources more attractive would alter the demand for CO₂ capture and storage technologies. Many more interactions among all the other technologies will be considered as part of the portfolio development. The linked performance of energy technologies and systems will mean that the diversified portfolio will evolve with time as more progress is made in some areas and less in others. GCEP will build tools to assess progress and manage the research portfolio as it evolves by evaluating these interactions among technologies.

Roles of Participants

The Stanford team will evaluate the opportunities and barriers in the areas listed above. When the evaluation of each area is far enough along that an initial research agenda can be formulated, GCEP will propose to its sponsors that funding be committed for research in that area. Of course, relevant research capabilities exist at a number of outstanding universities and research institutions around the world. The project will identify and develop collaborations that engage talent from well-qualified institutions around the globe to pursue research in specific projects that fit within the overall portfolio.

The process of evaluating opportunities and assessing barriers and progress for the research portfolio in a specific area will be an open one that involves contributions from Stanford, other institutions, and industry. International participation in these evaluations will be an important element. Successful energy technologies for the future must function both in the developed and developing economies. Broad-based participation in these discussions will be essential to identify safety, environmental, and market concerns, as well as ways to mitigate those concerns.

Summary

Supplying energy to a growing world population is a critical challenge for this century. A long-term commitment to research and significant resources will be required to lay the foundation for innovative future energy technologies. GCEP will harness the talent and creativity of the students and faculty of some of the world's great universities to identify and conduct the research that will enable development of innovative, commercially viable energy systems that will be essential to the well-being of the world's growing population. It will educate talented people who can build the world's new energy systems, and it will bring together representatives of academia, government, and industry to create the shared vision that will be required. There is much to do, but there is much that can be done, and the time to start is now.

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