CONGRESSIONAL HEARING

Regarding

Renewable Energy Technologies – Research Directions, Investment Opportunities, and Challenges to the Deployment in the United States and the Developing World

Statement of

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before the

Subcommittee on Energy
Committee on Science
U.S. House of Representatives

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Chairman Biggert, Ranking Member Honda,
and Members of the Committee,

I am Steve Chu, Director of Lawrence Berkeley National Laboratory, and it is again my pleasure to testify before the House Science Committee on an issue of such critical importance to the United States and to the world. The last time I appeared before your committee I was privileged to represent the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine's Committee on Prospering in the 21st Century and to discuss the recommendations of the committee's report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*.

Because of its direct bearing on this Hearing, I wanted to let you know that I am currently serving as Co-Chair of the InterAcademy Council's study panel on Transitions to Sustainable Energy. The InterAcademy Council was created by the world's academies of sciences to bring together the best scientists and engineers worldwide to provide high quality advice to international governmental and non-governmental organizations. It is the charge of the Transitions to Sustainable Energy panel to provide scientific advice to policymakers on moving toward adequately affordable, sustainable and clean energy supplies. My Co-Chair is Jose Goldemberg, formerly the Secretary of Science and Technology and the Secretary of the Environment for Brazil, and an expert in sustainable energy technologies who helped to shepherd Brazil's sugar cane-based energy phenomenon. The panel has given me a broad and varied view of the many energy challenges and opportunities facing our world. Our final report should be completed by early 2007 and I will make sure that a copy is transmitted to the Committee once available.

Today, I'm excited to share with you developments in science, particularly at Berkeley Lab, that I believe hold great promise for addressing the world's energy and environmental challenges. My comments or written testimony are not intended to represent the policies or positions of the Department of Energy.

The Challenge and the Opportunity

There is now general consensus that humanity faces an energy and environmental crisis. Global energy use has grown to the point where the by-products of man's energy consumption are significantly influencing the atmosphere and climate, with costly and potentially disastrous consequences. Experts forecast that the ability to locate viable sources of energy will increasingly determine the degree of economic and technological development. Motivated by a strong desire to provide solutions to these problems, and encouraged by the findings of the *Gathering Storm* report, the President's American Competitiveness and Advanced Energy Initiatives, and new research funding opportunities within the Department of Energy, concerned scientists and engineers from across a diverse range of disciplines and institutions are developing new and innovative approaches to energy research. This is what we are also doing at Berkeley Lab.

There has been an ongoing effort for decades on the part of the scientific community to find a solution to the renewable energy problem. So is there any reason to believe that the problem is more amenable to solution now? The answer is yes. Major recent advances in science and technology have dramatically improved the prospects for finding a technical solution. The multi-billion dollar investment in the National Nanotechnology Initiative that was so ardently proposed and supported by Congressman Honda and this committee has led to dramatic advances in the synthesis and control of materials that are crucial to the problem. Large scale advances in genomics have led to whole genome sequencing, as well as to the new field of synthetic biology, a new scientific discipline in which Berkeley Lab is a pioneer.

The Helios Project

Answering the call of the Congress and the Administration to discover new and cleaner energy sources, we at Berkeley Lab are embarking on an exciting new initiative called the Helios Project. Hoping to do for the supply-side of the equation what we've done at Berkeley Lab on the demand-side, the objective of Helios is to accelerate the development of renewable and sustainable sources of energy using sunlight. We are approaching this goal with a clear commitment, intent on developing solutions from basic science through to practical uses.

Although there is currently no "magic bullet" to solve the energy problem, we believe that utilization of the sun holds significant untapped promise for reducing the need for fossil fuels. Using Helios as an example, my testimony will describe exciting new scientific and technological opportunities that are available to researchers to address the fundamental barriers to developing sustainable energy alternatives.

The ultimate goal of Helios, simply stated, is to use sunlight to manufacture a transportation fuel. Transportation fuels would be the most costly form, but the most valuable form, of solar energy. Helios recognizes that there are several routes to accomplish this goal, and various approaches require materials and techniques that will have significant impact in other solar applications. For example, one approach is to use photovoltaics to capture sunlight that then can be used with photoelectric cells to convert carbon dioxide and water into liquid fuels or hydrogen. Scientists and engineers will collaborate to make more efficient and less-costly photovoltaic systems and electrochemical systems. Either of these new systems will have vast implications for other clean energy routes and stand-alone processes.

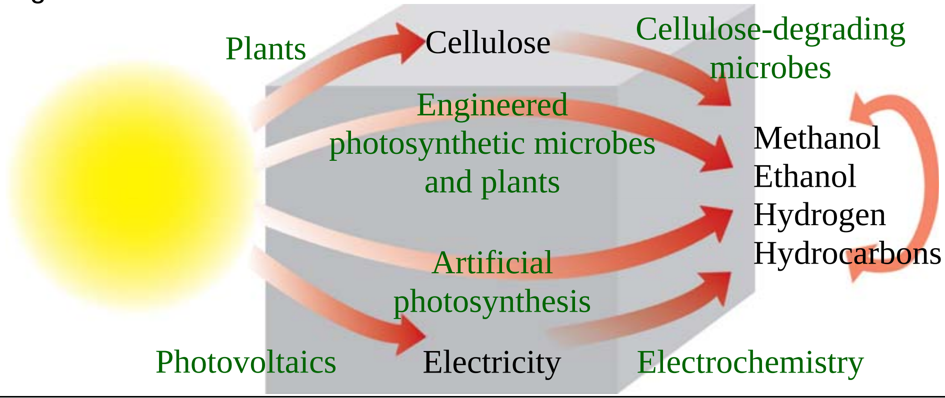
A comprehensive and accelerated program of basic science and technology development, such as Helios, can make great strides. Much like the development of the transistor at Bell Laboratories, Helios will be managed in a way that ensures progress toward its applied technology goals. Because of the ability to marshal resources, focus scientific research and build broad teams of multidisciplinary expertise, a national laboratory is uniquely organized to attack big scientific challenges like the present energy crisis. Berkeley Lab is well suited for this task because of our long history in biological and chemical systems research such as photosynthesis, as well as our world-leading and pioneering work in nanotechnology and synthetic biology.

Even so, the scientific problems to solve and the technological barriers to overcome are huge and other Labs and research universities, along with an engaged and proactive commercial sector, will be required to ensure the successful translation of science and technological achievement into the marketplace.

The Four Pathways

The overarching goal of the Helios Project is to revolutionize the means by which we harvest the energy of sunlight, so that this source will satisfy a majority of our energy needs. Figure 1 illustrates the four major pathways for going from sunlight to fuel that Helios will explore: two based on living systems, and two based on artificial systems. A great advantage of the Helios Project is that all programs and research pathways will be closely integrated. We have analyzed each of the four pathways, to determine the present status, the requirements, the major roadblocks, and the benefits that may arise as each roadblock in each path is solved.

Fig. 1. Helios research will break down roadblocks on four routes to solar fuels development



Path I: Sunlight to Fuel via Biomass

Biomass is the most abundant renewable carbon source on the planet and has long been a major combustible fuel for mankind. While biomass has the potential to meet most, if not all, of the transportation fuel needs, there are several difficulties in using biomass for production of fuels. The first problem is that current biomass crops are far from optimal for energy- and water-efficient production. The second problem is the expense and inefficiency of the process for converting biomass to fuels. Helios will address both problems.

Currently ethanol for transportation is produced primarily from sugar cane and corn. Possibly we can find a way to create new plants that will "grow energy" by incorporating genes that will make the plants self-fertilizing, and drought- and pest-resistant. The creation of crops efficiently raised for energy will also take full advantage of our great American agricultural capacity. Also, by designing microbes which will behave in new ways, our scientists hope to convert cellulose into chemical fuel more efficiently, so that biomass fuel can be obtained at a cost-effective price, and to keep the overall cycle as carbon-neutral as possible.

Path II: Microbial synthesis of biofuels using photosynthesis

Another approach is to skip production of the intermediate biomass and produce the fuels directly from sunlight using photosynthetic microorganisms. This model will use nature's mechanism as the refinery. While there are microbes and plants that utilize sunlight directly to produce oils and alcohols, they are not efficient enough to supply a significant fraction of U.S. energy need. They need to be optimized for their fuel production role. Berkeley Lab's strengths in photosynthesis since the early discoveries by Nobel Laureate Chemist Melvin Calvin will be put to use to increase photosynthetic efficiencies. DOE's Joint Genome Institute (JGI) and the Berkeley Lab Genomics Division will also play integral roles in this endeavor.

Path III: Sunlight to Electricity: Nanotechnology-enabled solar cells

There are many possible routes to achieve solar energy utilization. However, all known potential routes are limited now by two types of serious roadblocks: one is the need for fundamentally new and optimized materials for use in solar collectors, efficient processing steps, and energy handling. The other is that because of daily, seasonal, and other variations, the use of solar energy must involve the development of efficient storage strategies. The Helios Project is devoted to developing the basic science needed to overcome these roadblocks.

Because the elementary steps of conversion of sunlight to electricity in either biological or non-biological pathways takes place on the nanometer scale, the advent of new methods to control and pattern matter on the nanoscale has created tremendous new opportunities for solar cell design. Two broad areas of activity will be pursued: with new nanotechnology-based solar cells, it is possible to explore concepts for how to dramatically increase the power efficiency of solar cells; second, low-cost high volume solar cell fabrication techniques will be enabled. By controlling the size, shape, dimensions, and connectivity of nanoscale building blocks, it is possible to control the basic energy levels of a system, allowing for the design a new type of solar cell.

Path IV: Direct Photochemical or Photoelectrochemical Solar to Fuel Conversion

Finally, nature's photosynthetic machinery constitutes proof of principle that solar fuels can be generated by direct chemical conversion in a single device. However, there are energy costs in the production and handling of huge amounts of biomass. The goal of this research is to develop single devices that mimic the pathways of natural plants in producing fuel from water and sunlight but which are stable and have significantly greater efficiency. The recent progress in the understanding of the design principles of natural photosynthesis coupled with the rapid emergence of new nanostructured inorganic, organic and biological/non-biological hybrid materials has opened up opportunities to develop engineered solar to fuel systems that will meet the efficiency and durability requirements of a practical system. In many ways this path may hold the greatest long term promise, but is consequently probably the most difficult research objective.

Cross-Cutting Areas

In addition to the four pathways, we have identified cross-cutting areas of fundamental science and engineering which will be further developed for the Helios Project to succeed. Breakthroughs in these crosscutting areas will have a positive impact on more than one of the four paths. The cross-cutting areas are: Catalysis, Separations, Theory, Synthetic Biology, and Manufacturing.

As an example, synthetic biology is an emerging field that will play a tremendous role in the success of the Helios Project and other alternative fuel research initiatives. In July 2003, Berkeley Lab established the world's first Synthetic Biology Department, which seeks to understand and design biological systems and their components to address a host of problems that cannot be solved using naturally-occurring entities. University of California at Berkeley Professor and Lab Scientist Jay Keasling heads this department and is one of the pioneers of synthetic biology. He is also one of the leaders of the Helios Project.

The overarching role of the cross-cutting synthetic biology component of Helios is to create biological components that can be used across the whole spectrum of Helios activities. For example, this approach will enable us to rapidly and reproducibly engineer cells to convert renewable resources (sunlight, cellulose, starch, and lignin) into fuels.

The discipline's specific aims are 1) to develop the foundational understanding and standard, interchangeable, biological components (parts, devices, and chassis) that will allow us to routinely build large numbers of useful biological systems; 2) to develop mathematical models and computing methods to organize and analyze data, predict the behavior of biological components, and design new biological components and large integrated systems; and 3) to utilize state-of-the-art molecular profiling technologies to better understand biological systems and to optimize their function.

When will the Helios Project produce results?

Helios is focused on revolutionary research to accomplish significant advances. The risk for any individual project is substantial, but with all approaches taken together the probability of making significant advances in the overall goal of developing sustainable energy alternatives is high. We cannot know in advance which approach or research area will be most valuable, and which will pay off earliest. So we have given great thought to our management plan, and have built in the flexibility to respond to new results and the freedom to veer toward something new, away from the current approach, if that seems to be the more promising route.

We realize that timeliness is essential. To ensure the timely success of the Helios Project, we have adopted an active management strategy. The technical requirements for each path have been clearly defined, as are the known major bottlenecks. These will be re-examined twice yearly. Helios investigators will be required to develop core research areas but also to directly contribute to advancing at least one of the four paths. As the project advances, it will be necessary to focus the effort into those directions that appear most promising. With a tightly managed program, the Helios Project will produce a range of advances in specific sectors (like improved photovoltaics or a better way to break down cellulose) within five years, with the goal of a major breakthrough within ten years.

Conclusion

The mission of the Department of Energy is to advance basic science and to explore energy solutions and promote environmental stewardship. Because of increased funding scheduled for basic sciences and energy research at DOE and with the public's growing awareness of the energy crisis and the environmental consequences of inaction, we believe that now is the right time for Helios.

Over the past three decades, Berkeley Lab has been a leader in developing energy efficient technologies, standards and practices that have a significant impact on the demand side of the energy equation. Technologies developed at Berkeley Lab have saved the US economy tens of billions of dollars in energy costs - these technologies include the development of dual-paned, gas-filled energy-efficient windows; the now ubiquitous energy-efficient electronic ballasts for lighting; software tools for better building design; and the development of appliance standards to save energy and water.

I strongly believe that the most immediate and substantive gains in addressing the energy challenge are available through energy efficiency and conservation.

However, addressing the demand side alone will not fully provide the solutions necessary to address the energy and environmental crisis we face today. You must also address the supply side.

It has been my pleasure to describe our initiative to you today, and I look forward to keeping you updated as we work to build a systematic and well-focused program of transformational energy technologies development.

Chairman Biggert, Ranking Member Honda, and Members of the Committee, thank you for the opportunity to provide testimony on this critical topic.

I would be glad to respond to any questions.