october 16-17, 2004

Energy & Nanotechnology Workshop II
Prospects for Solar Energy in the 21st Century

The James A. Baker III Institute for Public Policy
Rice University

hosted by

James A. Baker III Institute for Public Policy
Energy & Environmental Systems Institute
Center for Nanoscale Science and Technology
Shell Center for Sustainability

Agenda

Saturday, October 16, 2004

Morning Session: Policy and the State of the Solar Industry

8:00-8:10 am	Welcome **Dr. Richard Smalley** *Director, Carbon Nanotechnology Laboratory; Gene and Norman Hackerman Professor of Chemistry, and Professor of Physics, Rice University*

Opening Keynotes: The State of the Solar Industry

Moderator: Ms. Amy Myers Jaffe, Wallace S. Wilson Fellow for Energy Studies, James A. Baker III Institute for Public Policy; Associate Director, Rice Energy Program, Rice University

8:10-8:30 am	**Dr. William Beckenbaugh** *Chairman of the Scientific Advisory Council, Konarka Technologies*
8:30-8:50 am	**Dr. Franz King** *Director, Global R&D and Technology, Shell Solar*
8:50-9:10 am	**Dr. Jean Posbic** *Manager of Product Development, BP Solar*
9:10-9:45 am	Discussion
9:45-10:00 am	Introductions and Workshop Overview **Dr. Wade Adams** *Director, Center for Nanoscale Science and Technology, Rice University*
10:00-10:30 am	An Assessment of Federally Funded Solar Energy Research **Mr. Kenneth Zweibel** *Manager, Thin Film Partnership, National Renewable Energy Laboratory*
10:30-10:45 am	Discussion
10:45-11:00 am	Break
11:00-11:30 am	A Renewable Energy Rationale **Dr. Martin Hoffert** *Professor of Physics, New York University*
11:30-12:30 pm	Discussion
12:30-1:30 pm	Lunch

Afternoon Session I: Economics and Public Policy Panel

Moderator: Ms. Amy Myers Jaffe, Wallace S. Wilson Fellow for Energy Studies, James A. Baker III Institute for Public Policy; Associate Director, Rice Energy Program, Rice University

1:30-1:50 pm	The Potential Role of Solar Power in the Southwest **Dr. Peter R. Hartley** *Chair, Department of Economics, Rice University*

1:50-2:10 pm — A Bright Future for Solar Power and Renewable Energy in the United States and Europe
Dr. Dagobert Brito
Peterkin Professor of Political Economy, Rice University

2:10-2:30 pm — Obstacles for Solar Energy in the United States
Dr. Alexander E. Farrell
Assistant Professor, Energy and Resources Group, University of California, Berkeley

2:30-3:00 pm — Low Cost but Totally Renewable Electricity Supply for a Huge Supply Area—A European/Transeuropean Example
Dr. Gregor Czisch
Institute for Solar Energy Technology, Kassel University

3:00-3:30 pm — Discussion

3:30-4:00 pm — Break

Afternoon Session II: Thermal Solar

Moderator: Dr. Howard Schmidt, Executive Director, Carbon Nanotechnology Laboratory, Rice University

4:00-4:20 pm — Thermal Solar
Mr. Frank Wilkins
U.S. Department of Energy

4:20-4:40 pm — Thermal Solar
Dr. Jacob Kami
Professor, Department of Environmental Sciences and Energy Research; Director, Center for Energy Research, the Weizmann Institute of Science, Israel

4:40-5:15 pm — Discussion and Wrap-up of Day 1

Sunday, October 17, 2004

Morning Session: Photocatalytics and Photovoltaics

Moderator: Dr. Robert Hauge, Distinguished Faculty Fellow in Chemistry, Rice University

8:00-8:30 am — Photocatalytic Solar Energy
Dr. Nathan Lewis
George L. Argyros Professor and Professor of Chemistry, California Institute of Technology

8:30-9:00 am — Discussion

9:00-9:30 am — Overview of the State of Play in the Field if Photovoltaics
Dr. Lawrence Kazmerski
Technology Manager, Solar Energy Technologies, National Renewable Energy Laboratory

9:30-10:00 am — Discussion

10:00-10:30 am	Overview of Breakthrough Possibilities in the Science of Photovoltaics **Dr. Paul Alivisatos** *Department of Chemistry, University of California, Berkeley*
10:30-11:00 am	Discussion
11:00-11:30 am	Break
11:30-12:00 pm	Dye-Based Photovoltaics **Dr. Michael Gratzel** *Laboratory for Photonics and Interfaces, Swiss Federal Institute of Technology*
12:00-12:30 pm	Discussion
12:30-1:30 pm	Lunch

Afternoon Session: Science and Technology for the Future

Moderator: Dr. Alex Ignatiev, Director, Texas Center for Superconductivity and Advanced Materials; Distinguished University Professor of Physics, Chemistry, and Electrical Engineering, University of Houston

1:30-2:00 pm	Road Map for Solar Energy Research: Third-Generation Efforts and Strategic Challenges **Dr. Arthur Nozik** *Senior Research Fellow, National Renewable Energy Laboratory*
2:00-2:30 pm	Discussion
2:30-3:00 pm	The Potential of New Materials to Advance the Science of Solar Power **Dr. Alex Ignatiev** *Director, Texas Center for Superconductivity and Advanced Materials; Distinguished University Professor of Physics, Chemistry, and Electrical Engineering, University of Houston*
3:00-3:30 pm	Discussion
3:30-4:00 pm	Break
4:00-4:30 pm	Wrap-up Discussion Moderators: Dr. Richard Smalley, Dr. Wade Adams, Ms. Amy Myers Jaffe

Speaker Biographies

Dr. Wade Adams
Director of the Center for Nanoscale Science and Technology, Rice University

Dr. Adams is chairman of the board of the Texas Nanotechnology Initiative and director of CNST. He retired from the U.S. Air Force in 2002 as a chief scientist at the Air Force Research Laboratory at Wright-Patterson Air Force Base. Dr. Adams's research specialty is polymer physics. He is internationally known for his research and writings on high-performance rigid-rod polymer fibers, X-ray scattering studies of fibers and liquid crystalline films, polymer-dispersed liquid crystals, and theoretical studies of ultimate polymer properties

Dr. Paul Alivisatos
Department of Chemistry, University of California, Berkeley

Dr. Alivisatos is Director of the Materials Sciences Division and Molecular Foundry at the Lawrence Berkeley National Laboratory. He has served as a member of the Defense Sciences Study Group and is a member of the Department of Energy Council on Materials Sciences. His research investigates the structural, thermodynamic, optical, and electrical properties of nanocrystals. He received a bachelor's degree from the University of Chicago and a Ph.D. in Physical Chemistry under the supervision of Charles Harris from the University of California, Berkeley, in 1986. He was a postdoctoral fellow with Louis Brus at AT&T Bell Labs.

Dr. William Beckenbaugh
Chairman of the Scientific Advisory Council, Konarka Technologies

Dr. Beckenbaugh provides senior leadership in microelectronics products development and manufacturing. In addition, he has been issued eighteen patents and has published nine technical papers. He received his B.A. in Chemistry from MacMurray College and his Ph.D. in Physical Chemistry from Rice University. He has served on the boards of the National Electronics Manufacturing Initiative and IPC.

Dr. Dagobert Brito
Peterkin Professor of Political Economy, Rice University

Dr. Brito is Peterkin Professor of Political Economy and Baker Institute Scholar at Rice University. He also holds a faculty appointment at Centro de Investigación y Docencia Económicas (CIDE) in Mexico. His work with the Baker Institute involves the allocation of resources in the West Bank and Gaza, Hispanic assimilation in the United States, and solar energy. His work with CIDE involves the pricing of natural gas and operation of natural gas pipelines. He is also working on land tenure and thirteenth-century inflation in England. He has served on the faculties of the University of Wisconsin, Madison, The Ohio State University, and Tulane University, and as a visiting professor at Instituto Tecnologico Autonomo de Mexico and a visiting scholar at the Center for International Studies, Massachusetts Institute of Technology.

Dr. Gregor Czisch
Institute for Solar Energy Technology, Kassel University

Agriculturist and physicist Gregor Czisch has worked since 1997 in the research and development division Information and Energy Economy at the Institute for Solor Energy Technology of the University of Kassel. His focus is on the analyses of worldwide potential of renewable energy and the development of scenarios for a CO2-neutral electricity supply. He has studied energy supply at the Technical University of Munich, in the Summer Science Program of the German Center for Air and Space in Stuttgart, the Fraunhofer Insti-

tute for Solar Energy Systems in Freiberg, and the Max Planck Institute for Plasma Physics in Garching. His research topics have included the engineering of solar buildings, biomass, wind energy, hydroelectric power, primary energy analyses, emission analyses, high-temperature heat storage, and solar-thermal power plants.

Dr. Michael Graetzel
Laboratory for Photonics and Interfaces, Swiss Federal Institute of Technology

Dr. Graetzel is a professor at the Swiss Federal Institute of Technology in Lausanne, where he directs the Laboratory of Photonics and Interfaces. He has pioneered research in nanomaterials, in particular semiconductor nanocrystallites and mesoscopic oxide films and their energy and display-related applications. His research and development projects include development of new ionic liquids, used as "green" electrolytes, and high-power lithium ion batteries based on mesoporous films. Dr. Graetzel has also discovered a new type of solar cell based on dye-sensitized nanocrystalline oxide particles. He has written more than 500 publications, including two books, and received more than forty patents. His numerous awards include the Millennium 2000 European Prize of Innovation and Technology, the 2001 Faraday Medal of the British Royal Society of Chemistry, and the 2001 Dutch Havinga Lecture Award and Medal. Dr. Graetzel holds a Ph.D. in Natural Science from the Technical University, Berlin.

Dr. Alexander E. Farrell
Assistant Professor, Energy and Resources Group, University of California, Berkeley

Dr. Farrell is an Assistant Professor in the Energy and Resources Group at the University of California, Berkeley. He has a B.S. in Systems Engineering from the U.S. Naval Academy and a Ph.D. in Energy Management and Policy from the University of Pennsylvania. He has studied and taught at Carnegie Mellon University (the Electricity Industry Center and the Department of Engineering and Public Policy), Harvard University (the John F. Kennedy School of Government), the American Association for the Advancement of Science, and the University of Pennsylvania. His research focuses on the technologies, economics, and politics of energy and the environment.

Dr. Peter R. Hartley
Chair, Department of Economics, Rice University

Dr. Hartley is widely published on such theoretical and applied economic issues as money and banking; business cycles; utilities and airlines regulation; international finance; and energy, environmental, health, and labor economics. His current research at Rice University involves financial intermediaries, liquidity and borrowing constraints, and applied microeconomics. He gained policy experience as a member of a team of economists that advised the Australian government on reform of the Australian electricity supply industry.

Dr. Robert Hauge
Distinguished Faculty Fellow in Chemistry, Rice University

Dr. Hauge served as Executive Director of Rice University's Carbon Nanotechnology Laboratory from 2001 to 2003 and now serves as Technology Director for the laboratory. His research interests include high-temperature chemistry, zero valent metal atom reactions, CVD thin film diamond growth, and the production and chemistry of single-wall carbon nanotubes. He has published more than 200 papers in refereed journals. Dr. Hauge received his bachelor's degree in chemistry from Loras College, Dubuque, Iowa, and his Ph.D. in high-temperature chemistry from the University of California, Berkeley. He joined Rice University in 1965 as a research fellow and in 1992 was named a distinguished faculty fellow.

Dr. Martin Hoffert
Professor of Physics, New York University

Dr. Hoffert's research interests include energy science and technologies, global climate change, oceanography, biogeochemical cycles, fluids and plasmas, and wireless power transmission. His recent work focuses on technology paths for transitioning away from fossil fuels to alternative sources. Major collaborative studies in which he has been lead author include, "Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet" (Science 2002) and "Energy Implications of Future Stabilization of Atmospheric CO2 Content" (Nature 1998).

Dr. Alex Ignatiev
Professor of Physics and Chemistry, University of Houston

Dr. Ignatiev originated the Wake Shield Facility Program, which uses the vacuum of space to grow and fabricate advanced thin film materials and devices. His research interests have been focused on advanced thin film materials and device development and surface chemical interactions that form the basis for thin film growth. He received a B.S. in Physics and Applied Mathematics from the University of Wisconsin and a Ph.D. in Materials Science from Cornell University. Dr. Ignatiev has published more than 280 articles, holds fourteen patents, is on the editorial boards of three journals, is a member of twelve scientific societies, and has been elected to the International Academy of Astronautics.

Dr. Franz Karg
Director, Global R&D and Technology, Shell Solar

Since 2002, Dr. Karg has been Head of Technology at Shell Solar, reporting to the chief executive officer and supervising the research and development department. He previously headed thin film development at Siemens Solar and, before that, helped develop amorphous silicon and germanium solar cells and sensors at Siemens Corporate Research Laboratory. In 1995, he set up the Solar Energy Research Association, funded by the Bavarian Research Foundation and consisting of ten research and industrial institutions. Dr. Karg received his Ph.D. in semiconductor physics at the Technical University of Munich and Osaka University.

Dr. Jacob Karni
Professor, Environmental Science and Energy Research Department, and Head of The Energy Center, The Weizmann Institute of Science, Israel

Prof. Karni studies the use of concentrated solar energy at high temperatures. He has helped develop a concentrated sunlight absorber, a high-pressure receiver window, a volumetric solar receiver, a non-imaging secondary optics device, and a concept for a non-isothermal high-temperature solar receiver. Current projects include solar-driven hydrogen production and a new concept for integrating solar and energy storage. Dr. Karni has been at the Weizmann Institute since 1989 and has headed the Energy Center since 2002. He previously taught at the State University of New York at Stony Brook, the University of Minnesota, and Johns Hopkins University. Dr. Karni has published more than seventy scientific articles, and holds eight international patents. He earned a B.S., M.S., and Ph.D. degrees at the University of Minnesota.

Dr. Lawrence Kazmerski
Technology Manager, Solar Energy Technologies, National Renewable Energy Laboratory

Dr. Kazmerski studies photovoltaic materials and devices and the electrical and chemical properties of interfaces in polycrystalline materials and devices. Development projects include measurement techniques for device diagnostic investigations and manufacturing-environment measurements for photovoltaics. Dr.

Kazmerski has published more than 240 scientific and technical papers, reviews, and book chapters on solar cells, thin films, semiconductor materials and devices, surface and interface analysis, molecular beam epitaxy, scanning tunneling microscopy, nanoscale technology, high-temperature superconductivity, and semiconductor defects. Dr. Kamerski holds B.S., M.S., and Ph.D. degrees from Notre Dame University. He did postdoctoral work at Notre Dame Research Laboratory, then taught at the University of Maine.

Dr. Nathan S. Lewis
George L. Agyros Professor and Professor of Chemistry, California Institute of Technology

The research interests of Dr. Lewis and his group (the Nathan S. Lewis Research Group of Caltech's Division of Chemistry and Chemical Engineering) deal with light-induced electron transfer reactions, both at surfaces and in transition metal complexes. In the area of surface chemistry, Dr. Lewis's studies have concentrated on the photochemistry of semiconductor-liquid interfaces. Another major research area involves the novel uses of conducting organic polymers. Current research efforts are directed toward construction of an "electronic nose" that can yield chemical insight into the sense of smell. Dr. Lewis earned his B.S. and M.S. degrees from Caltech and his Ph.D. from Massachusetts Institute of Technology.

Dr. Arthur J. Nozik
Senior Research Fellow, National Renewable Energy Laboratory

Dr. Nozik has been a senior research fellow at the U.S. Department of Energy's National Renewable Energy Laboratory (previously known as the Solar Energy Research Institute) since 1978 and is Professor Adjoint in the Chemistry Department at the University of Colorado, Boulder. He is a fellow of both the American Association for the Advancement of Science and the American Physical Society. He has served as senior editor of the Journal of Physical Chemistry since 1993, and has authored or co-authored more than 160 papers, five books, and many book chapters, and he holds eleven U.S. patents. Dr. Nozik's research interests include size quantization effects, including exciton multiplication and carrier relaxation dynamics, in semiconductor quantum dots and quantum wells, and the applications of these nanostructures to solar photon conversion, charge transfer dynamics in semiconductor structures, photoelectrochemistry of semiconductor-molecule interfaces, novel approaches to solar energy conversion, photocatalysis, optical, magnetic and electrical properties of solids, and Mössbauer spectroscopy. He has served on numerous national and international scientific review and advisory panels and received several awards in solar energy research, including the research award of the Electrochemical Society in 2002. Dr. Nozik earned his BChE from Cornell University and his Ph.D. from Yale University.

Dr. Jean Posbic
Manager of Product Development, BP Solar

Dr. Posbic, who heads BP Solar's global product development department, has extensive field experience in energy-related domains, including solar photovoltaic modules and related systems. He received M.S. and Ph.D. degrees from Claude Bernard University in Lyon, France, and an MBA from Mount St. Mary's University, Emmitsburg, Maryland. Dr. Posbic has published numerous technical papers, spoken frequently at conferences, and traveled extensively. He is also an avid glider pilot.

Dr. Howard Schmidt
Executive Director, Carbon Nanotechnology Laboratory, Rice University

Dr. Schmidt has more than seventeen years' experience in senior management, business development, and sponsored research. In 1986, he helped launch Ionwerks, Inc., a Houston-based company that provided contract research and development services. In 1988, he founded Schmidt Instruments, which focused

on time-of-flight mass spectrometry, materials process research, and applications of diamond thin films. He took the company public in 1993 as SI Diamond Technology, Inc. In 2003, he joined Rice's Carbon Nanotechnology Laboratory as Executive Director. Dr. Schmidt received his B.S., M.S., and Ph.D. degrees from Rice University.

Dr. Richard Smalley
Nobel Laureate (Chemistry, 1996); Director, Carbon Nanotechnology Laboratory; University Professor, Gene and Norman Hackerman Professor of Chemistry, and Professor of Physics, Rice University

Dr. Smalley was awarded the Nobel Prize for chemistry in 1996, sharing the honors for the discovery of fullerenes, a new class of carbon molecule. His current research combines traditional methods and approaches from chemistry and physics to address problems and opportunities in the burgeoning field of nanoscale science and technology. Through his leadership, Rice established the Center for Nanoscale Science and Technology (CNST). Professor Smalley holds a B.S. from the University of Michigan, Ann Arbor. He earned M.A. and Ph.D. degrees from Princeton.

Mr. Frank Wilkins
U.S. Department of Energy

Mr. Wilkins works with industry, universities, national laboratories, and state agencies to promote the use of solar energy. He is responsible for two programs: solar heating and lighting, and concentrating solar power, which work with technologies ranging from solar water heaters to multi-megawatt solar power plants. He received B.S. and M.S. degrees from the University of Maryland.

Mr. Kenneth Zweibel
Manager, Thin Film PV Partnership, National Renewable Energy Laboratory

Mr. Zweibel has written two books on photovoltaics, the most recent of which was Harnessing Solar Power: The PV Challenge. He has been at the National Renewable Energy Laboratory for twenty-five years and now manages the Thin Film PV Partnership program, which coordinates the activities of the NREL, universities, and industry to promote the development of thin film photovoltaic technologies. Mr. Zweibel participates frequently in DOE technology assessments and is active in the solar policy arena. He holds a B.S. in physics from the University of Chicago.