On the Cover: Cal Poly’s solar house (*left, and under construction, center*) at the 2005 Solar Decathlon, an international competition for solar-powered homes built and installed by university teams on the mall in Washinton, D.C., and *(right)* a grove of redwoods at Swanton Pacific Ranch, Cal Poly’s living laboratory for sustainable agriculture and natural resource management studies.
MAY 7-8, 2006

ACHIEVING SUSTAINABLE SOLUTIONS TO THE GLOBAL ENERGY AND ENVIRONMENTAL CHALLENGE
The Baker Forum was established by the Cal Poly President’s Cabinet* on the occasion of two decades of service to Cal Poly by President Warren J. Baker and his wife, Carly, to further the dialogue on critical public policy issues facing the nation and higher education. The forum gives particular attention to the special social and economic roles and responsibilities of polytechnic and science and technology universities.

The health and prosperity of humanity in the 21st century depend upon our ability to sustain and increase the pace of scientific and technical innovation. Polytechnic and science and technology universities must lead the way in ensuring that these innovations are applied broadly to serve the interests of society and in preparing new generations of innovators and problem-solvers.

The biennial Baker Forum provides an opportunity for polytechnic and science and technology university presidents and industry leaders to come together in an issue-focused, highly interactive setting designed to promote international dialogue, highlight issues of critical importance and stimulate creative responses.

Funding support from the President’s Cabinet, friends of the university and John Wiley & Sons, Inc., is gratefully acknowledged.

*The Cal Poly President’s Cabinet is a senior advisory group of state and national leaders in business, industry, government and the community.
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THE WILEY LIFETIME ACHIEVEMENT AWARD

With the creation of the Baker Forum in 2002, John Wiley & Sons, Inc., generously established the Wiley Lifetime Achievement Award. This award, presented at the Baker Forum, recognizes extraordinary leadership and lasting contributions in American higher education and public life.

David L. Goodstein, vice provost and professor of physics and applied physics at Caltech, is the recipient of the 2006 Wiley Lifetime Achievement Award.

Past recipients include: William C. Harris, director general, Science Foundation Ireland (2004), and Walter E. Massey, president, Morehouse College (2002).

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The theme of the 2006 Baker Forum, “Achieving Sustainable Solutions to the Global Energy and Environmental Challenge,” was timely and vitally important.

Caltech Vice Provost and Physics Professor David Goodstein’s thought-provoking keynote address, “Out of Gas: The End of the Age of Oil,” reviewed the scientific, technological and environmental challenges associated with continued reliance on nonrenewable petroleum energy resources. Afterward a distinguished panel discussed energy alternatives, and breakout groups considered sustainable solutions in the areas of transportation, the built environment, and natural and agricultural resource management.

Although the forum revealed a considerable diversity of viewpoints among the industry, government and education leaders in attendance, there was general agreement that the world community must lose no time in developing alternatives to dwindling (and polluting) petroleum energy resources or face severe economic and environmental consequences. Indeed, in his address Dr. Goodstein predicted that civilization as we know it will come to an end if we fail to act promptly, resolutely and comprehensively.

Many of us left the forum persuaded that a massive nationwide mobilization is needed to meet the global energy and environmental crisis. Dr. Goodstein’s urgent call for action reminded us of President Kennedy’s Apollo Project, a national initiative that took the United States to the moon. During World War II, there was the Manhattan Project, the crash program to build the atomic bomb.

These past achievements demonstrate that America is capable of solving daunting, complex problems if we summon the requisite will and marshal the needed resources.

In the wake of the forum, Cal Poly has undertaken further comprehensive reviews of its activities regarding energy sustainability. From these reviews we can see that students and faculty have already initiated a number of exciting programs to foster energy and environmental awareness and to develop sustainable energy solutions. The university administration is also working hard to implement principles of sustainability in its operations and capital facility initiatives. The President’s Cabinet is committed to assisting the university in identifying opportunities to expand and extend its educational, research and operational efforts.

The President’s Cabinet is pleased to share these proceedings of the 2006 Baker Forum as a resource to Cal Poly and to interested individuals and groups as together we seek to develop sustainable solutions to global energy and environmental problems.
KEYNOTE ADDRESS

OUT OF GAS: THE END OF THE AGE OF OIL

DAVID L. GOODSTEIN

VICE PROVOST AND PROFESSOR OF PHYSICS AND APPLIED PHYSICS

CALIFORNIA INSTITUTE OF TECHNOLOGY
In quiet but stark words summoning images reminiscent of an Old Testament prophet’s admonitions, Caltech Physicist and Vice Provost David L. Goodstein delivered both a harrowing warning and an urgent call to action as he forecast the coming end of the “Age of Oil” to an overflow 2006 Baker Forum audience.

As preface to his challenge to achieve sustainable solutions to global energy needs while preserving our precious environment and the advances of our oil-based civilization, Goodstein first sought to dispel seven commonly believed myths about energy:

- **Three-dollar-a-gallon gasoline is too expensive.** “Gasoline is one of the cheapest liquids in the United States—bottled water is twice as expensive as gasoline. The relatively low price of gasoline has helped create our overuse of and overdependence on oil.”
- **Oil companies produce oil.** “Oil companies can never produce oil—they extract oil from the ground. The sun and the Earth produced oil hundreds of millions of years ago.”
- **We must conserve energy.** “Energy is always conserved and can never be created or destroyed, as proven by the law of the conservation of energy. We need to conserve fuel, not energy.”
- **When we run out of oil, the marketplace will provide alternative energy sources.** “Replacing the energy we get from oil with sustainable, nonpolluting energy sources is not yet technologically feasible and will require a massive research and development effort more ambitious than President Kennedy’s space program that ultimately put a man on the moon in 1969.”
- **Fossil fuel still in the ground will provide us with fuel for hundreds of years.** “At our present level of consumption, we will run out of fossil fuels by the end of the 21st century.”
- **Nuclear energy is dangerous.** “Most technically trained people understand that nuclear energy is the safest and most dependable source of energy we have, despite the unsolved problem of radioactive waste disposal.”
- **The greenhouse effect and global warming are bad.** “A natural greenhouse effect and global warming trap heat from the sun and make the Earth warm enough to support human life. If there were no naturally occurring greenhouse gases, the Earth would reflect all light absorbed from the sun and Earth’s temperature would be approximately 0 degrees Celsius. However, in the last 200 years our burning of fossil fuels has almost doubled methane concentration in the Earth’s atmosphere and caused carbon dioxide to rise sharply—we are presently in the midst of an uncontrolled chemical experiment that could have disastrous effects for life on Earth.”

Before tracing the history of the Age of Oil and humanity’s dependence on petroleum, Goodstein quickly noted the forms of energy in our universe, first describing **organized kinetic energy**—the energy of motion, as when a car goes down a street—and **random kinetic energy**, the energy of atoms and molecules that move faster as temperature increases. The kind of energy that directly concerns us as the oil on which our civilization
Goodstein emphasized that there is only a finite amount of oil in the Earth—enough to last approximately 40 years at humanity’s current rate of consumption.

“At first the oil was used for illumination and lubrications,” Goodstein informed his audience, “but in 1861 Nicholas Otto, a German entrepreneur, invented the world’s first gasoline-burning engine, the direct ancestor to the engines in our cars today. Soon oil was in great demand for fuel and we began digging oil wells all over the world. The net result after 150 years is that we can no longer live on the light that we get from the sun. We are thoroughly addicted to oil, as our president stated in his State of the Union address. We have unwittingly created a trap for ourselves, because the oil will eventually run out.”

Goodstein emphasized that there is only a finite amount of oil in the Earth and that two-thirds of it is in the Middle East, a region that has 10 times as much oil as South and Central America, 10 times as much as Africa, 10 times as much as the former Soviet Union, and 10 times as much as the United States. The Earth still contains about 1 trillion barrels of oil in known reserves—enough oil to last approximately 40 years at humanity’s current rate of consumption.

The fact that oil deposits are not inexhaustible and will eventually run out was first voiced in 1956 by Marion King Hubbert, an oil geologist working for the Shell Oil Company. Hubbert was ridiculed when he predicted that U.S. oil production would soon reach a peak and begin an inevitable decline toward zero—his contemporaries assumed oil companies would continuously find new petroleum reservoirs. Hubbert’s computations, derived from a logistic equation used by population biologists, produced bell-shaped curves for domestic oil discovery and production, showing peak discovery in 1930 and a production peak in 1970.
Hubbert’s prediction was correct and his critics were dead wrong.

Goodstein summarized:

“Ken DeFrays, an oil man, said he knew that Hubbert was right and that the peak in domestic oil extraction had been reached when he read the following lines in the *San Francisco Chronicle* in the spring of 1971: ‘The Texas Railroad commissioner announced 100 percent allowable for next month.’ The Texas Railroad Commission was the quaintly named cartel that governed the oil industry in the United States by manipulating Texas’ excess capacity to pump oil. When the commission announced that 100 percent was allowable, it was acknowledging that there was no longer any excess capacity—everyone was pumping at maximum production and the United States had lost control of its domestic oil market.”

OPEC—the Organization of Petroleum Exporting Countries—was quickly formed to control world oil supplies and prices just as the Texas Railroad Commission had once controlled the oil market in the United States. The power of OPEC is based on manipulating the excess oil capacity of Saudi Arabia, and the end of Saudi Arabia’s excess capacity may have been announced on February 24, 2004, in a *New York Times* story that eerily echoed the *San Francisco Chronicle*’s 1971 report on domestic production.

In a *Times* front-page story titled “Forecast of Rising Oil Demands Challenges Tired Saudi Fields,” Jeff Gerth wrote, “The country’s (Saudi Arabia’s) oil fields are now in decline, prompting industry and government officials to raise serious questions as to whether the kingdom will be able to satisfy the world’s thirst for oil in the coming years.”

Hubbert’s peak for America’s oil production had apparently been duplicated by the world’s premier oil producer.

“I don’t know if someday we will look back on February 24, 2004, as the day the worldwide ‘Hubbert peak’ was reached,” Goodstein told Baker Forum listeners. “It may not be for another five years, 10 years or 20 years. The difference in time is very important to us, because we would like to go on living the comfortable life that we have been leading. But in the scale of human history, 20 years is nothing at all and the peak in world oil production will come in the foreseeable future.”

Humanity’s global dependence on oil falls into four general categories: petrochemicals for fertilizer and fuel for stationary electric power plants, home heating and transportation.

“There are 6.4 billion people living on the planet today,” Goodstein reminded his audience, “and most of them are reasonably well fed, as a consequence of the ‘Green Revolution’ that occurred in the second half of the 20th century. This revolution consisted largely of fertilizing land with petrochemicals—oil-based chemicals. I don’t think we can sustain present-day population levels, much less future population increases, without oil.”

Stationary power plants burn only a small portion of the world’s oil, and Goodstein suggested that coal or nuclear power can be substituted for oil to generate electricity. Many of our homes are heated by oil, and a skyrocketing oil price will be a major hardship for homeowners, but an
oil shortage’s most immediate and drastic effects will be felt in transportation.

“Cars, trucks, planes, ships and trains all run on oil and cannot run without it.”

Goodstein directed attention to a recent chart of global energy consumption. The graphic showed that yearly worldwide use of oil (4.52 trillion watts), natural gas (2.7 trillion watts) and coal (2.96 trillion watts) totals 10 terawatts (10 trillion watts) of the 13 terawatts humans use annually, with non-fossil-fuel energy sources making up only 3 terawatts (about 23 percent) of total energy use.

And American citizens, business and industry burn a tremendous portion of the world’s fossil fuels:

“The United States consumes one quarter of the world’s energy, although Americans make up only 5 percent of the world’s population—we’re using much too much energy.”

What is the likelihood that the marketplace will solve the global energy crisis, that the demand for energy will spur fuel producers to find new energy sources?

“I’ve been talking previously about light crude oil, but oil also comes in the form of heavy oil, from older oil fields and from oil sands and tar sands,” Goodstein explained. “Although new technologies make it possible to pump more crude from any given field, the more you pump, the heavier the oil gets and the more costly it becomes to refine.

“The tar sands of Alberta, Canada, have been named ‘the Oil Sands of Alberta’ because the description attracts investment. But to make oil from Alberta’s ‘oil sands’ you have to mine two tons of ore to extract one barrel of bitumen, a liquid that isn’t rich enough to distill into oil—hydrogen must be added, and as a consequence the world’s largest facilities for the production of hydrogen by using natural gas are in Alberta.

“As we go down the list of hydrocarbons in search of an oil source to replace the light crude pumped from wells, it becomes increasingly clear that oil production from alternative sources is expensive and requires massive inputs of energy—eventually the expense of the energy for production grows larger than the profit gained from the sale of the fuel produced.”

Natural gas is a good substitute for oil—it can be used in compressed form or liquefied into fuel—but Goodstein noted that Hubbert’s equation shows that the worldwide peak for natural gas production is only 10 years behind peak oil production. At best, natural gas can be only a temporary replacement for oil.

And reliance on oil shale, methane hydrate
or coal present economic, technological or environmental obstacles that make their use highly problematic:

“Harvesting shale by strip mining and then extracting the oil by heating the shale in a retort are environmentally damaging processes. People who have invested hundreds of millions of dollars in oil shale research and production have come to the conclusion that shale will never become ‘energy positive’ and an economically feasible source of energy.

“Methane hydrate is a solid that looks like ice but that burns when heated—it consists of methane trapped in a cage of water molecules. No one knows how much methane hydrate there is on Earth or where it can be found or whether it can be mined for human use.”

Many people believe coal offers the best alternative to the light crude oil we pump from wells, but Goodstein presented his audience with a series of disturbing facts as he argued that coal would be an unsatisfactory, short-lived and dangerous alternative to oil:

• “We are told that there is enough coal in the ground to last for hundreds or thousands of years at our present rate of use, but estimates of coal deposits vary by a factor of 10 and no one has any true knowledge of how much coal the Earth holds. (We do know that the United States has the world’s largest deposits and that China and Russia have extensive known reserves of coal.)”
• “Coal can be liquefied and used as a substitute for oil—this was done by the Germans in World War II because they had no petroleum—but the conversion process is inefficient and oil from coal is a very dirty fuel: It comes combined with mercury, arsenic, sulfur and other substances that are difficult to get rid of.”
• “Coal is the worst possible fuel in regard to the greenhouse effect—coal is essentially 100 percent carbon and every molecule burned turns into a molecule of carbon dioxide.”
• “To replace our present consumption of oil with coal, we would have to increase coal production by at least a factor of five—an increase that is almost unimaginable. And the five-fold increase doesn’t take into account the world’s rising population numbers or the fact that the world’s less advantaged populations want to duplicate the lifestyles enjoyed in First World countries, an advance that will require a sizeable increase in energy production.”
• “If we should blindly ignore the negative climatic consequences and burn coal as a substitute for oil, we would reach Hubbert’s peak for coal production sometime this century, and coal production would inevitably diminish forever.”

What does the future hold for our oil-addicted civilization, on our planet with over 6 billion human inhabitants, where fossil-fuel emissions have dramatically increased the carbon dioxide levels in our atmosphere during the 200 years since the beginning of the Industrial Revolution?

“There will be an oil crisis very soon,” Goodstein warned. “I don’t know if ‘very soon’ means that the crisis is upon us now or if the crisis will occur in the next five, 10 or 20 years. But the crisis will occur, fossil fuels will run out or start to run out by the end of this century, and switching from oil to fossil fuels other than natural gas will have negative consequences for the Earth’s climate.
“If we are able to have a civilization somewhat like the one we have now, that civilization will have to be based on sources of energy other than fossil fuels—and our only other energy resources are solar and nuclear. The dilemma of moving from oil to solar and nuclear power involves enormous social and political factors that I can’t say very much about—but I can address the technical problems we’ll have to solve as our civilization switches to new energy sources.”

First, Goodstein focused on solar energy:

- “We already use a great deal of solar energy in the form of hydroelectric power—the water in reservoirs turns a turbine that produces electricity, the water evaporates and returns as rain to fill the reservoir. This renewable form of energy seemed a good idea a century ago and dams were built in most of the feasible locations, with a consequence that 25 percent of the world’s electricity and 10 percent of the United States’ electric power is generated by falling water. Unfortunately, we’ve reached the saturation point—hydroelectric plants are everywhere and few likely sites remain for building new reservoirs and dams.”

- “The sun’s light creates wind, and wind power will obviously be increasingly important. Advances in technology and tax credits to encourage the use of renewable energy sources have made wind power almost as cost-effective as coal-fired power plants. But wind is too undependable, too intermittent to be an energy source we can rely on for a steady, unbroken transmission of energy.”

- “Biomass is a time-tested energy source—until the 1800s, human existence depended on the burning of vegetable matter. But trees and plants are an inefficient source of fuel and at maximum productivity can turn only two-tenths of a percent of falling sunlight into potential chemical energy.”

- “The Earth is awash in solar energy, but solar technology remains in its infancy. Although the annual energy from the sun is 20,000 times greater than the 10 terawatts of energy we currently extract from fossil fuels each year, we would have to cover a land area half the size of California with photovoltaic cells operating at 10-percent efficiency—the ‘gold standard’ for solar batteries—to equal the energy we get from oil, coal and natural gas.”

Goodstein then cautioned his audience that using nuclear energy to fuel our civilization also presents problems and limitations:

- “Geothermal energy, which is created inside the Earth by radioactive decay, provides space heating in a number of locales but using it for generating power is difficult. The Earth has few areas where the geothermal source is close enough to the surface to allow for drilling, and the steam extracted from the ground for power generation would be used too swiftly for the Earth to replace the lost steam.”

- “Fission—the splitting of atoms—is the form of nuclear energy that we currently use in nuclear power plants. No fission plants have been built in the United States in the last 20 years and few have been constructed in the rest of the world, although France receives 80 percent of its energy from...
keynote address

nuclear plants, and India and other countries are increasingly relying on nuclear power. However, the largest fission plant can produce only one gigawatt (1 billion watts) of power, so that 10,000 nuclear plants would be required to replace the 10 terawatts of energy from fossil fuels humans consume each year.

- "Fusion"—the fusing of atoms—was used in the H-bomb and is the kind of nuclear energy burned by the sun. Harnessing fusion would provide human civilization sufficient energy forever—the deuterium in one gallon of seawater has the potential energy of 300 gallons of gasoline. Unfortunately, the use of fusion for power generation on Earth remains highly problematic: The process involves the use of gases so hot that no surrounding substance can withstand the high temperature, so fusion must be contained in a 'magnetic bottle' or by other means. In experiments, fusion has been made to produce one-half of the energy externally applied—the energy 'break-even point' has not yet been reached."

Fuel for transportation is a critical area for concern as we move from fossil fuels to solar and nuclear energy—Goodstein acknowledged that sun- or nuclear-powered cars will not appear in the foreseeable future and that we must address our transportation problem as a separate energy issue. Someday our cars may use batteries charged from stationary power sources, or run on fuel cells or internal combustion engines powered by hydrogen produced from water by electrolysis. Hydrogen combined with carbon dioxide could provide a liquid-fuel substitute for gasoline, but hydrogen is presently made from fossil fuel—it takes about six gallons of gasoline to produce enough hydrogen to replace one gallon of gasoline. In some future civilization where fusion power exists, hydrogen from electrolysis may become a viable energy source.

Any successful transition from fossil fuels to alternate energy sources will of course require conservation. Goodstein gave special mention to Amory Lovins of the Rocky Mountain Institute and his recent, well-documented article on fuel conservation as he outlined several important ways to reduce energy consumption:

- Strong, ultra-light materials developed in the last 20 years can reduce the weight of cars and trucks and increase fuel mileage.
- We can produce and drive more hybrid cars that burn less fuel.
- Politicians can enact regulations that grant tax rebates to drivers who give up gas-guzzling cars for hybrids and other fuel-efficient cars.
- Fuels can be made from switch grass and poplar. (Unfortunately, U.S. production of ethanol from corn may be 'energy negative'—the corn first has to be distilled into sugar, then the sugar turned into ethanol, a difficult and expensive two-step process. Ethanol made from sugar cane in Brazil is 'energy positive,' but potential growing areas for sugar cane within the United States are limited and our current transportation needs vastly exceed Brazil’s.)
- Electricity can be used more effectively and factories and buildings can be made more energy efficient.

"We understand the fundamental energy principles," Goodstein told his audience in his unflinching and stirring conclusion.
"The real question remains: Do we have the will, the courage and the vision to advance down the path before us?"

As a scientist and a physicist, I am supposed to make predictions based on my analysis of the situation before me, and from the evidence at hand predict some new phenomenon that hasn’t yet occurred and then hope that the prediction turns out to be correct, proving what a clever person I am.

But I am now going to make a prediction of a different kind—I am going to predict that civilization as we know it will come to an end sometime in this century, when our fossil fuels run out.

I hope my prediction is wrong, and that by my merely making this dire prophecy many members of this audience will start or accelerate work on technological innovations that will solve our critical energy dilemma. Energy projects are presently under way at virtually every university in America, as they are at my own university, Caltech, and at Stanford University, where the Global Climate and Energy Project, America’s largest energy research effort, is based.

Although I am a mere physicist, I have tried to make what contribution I could in moving our civilization away from fossil fuels and toward other sources of energy as our Age of Oil nears its end. I thought of what I might do to aid the effort to harness alternative, nonpolluting energy sources, and I decided the most valuable work I could perform was to write a book of warning. I have written that book—Out of Gas: The End of the Age of Oil—and in my talk to you I’ve presented my book’s central ideas and main conclusions.

I regret to acknowledge that presently we have no national or global energy policy. When I wrote my book two years ago, mine was a voice in the wilderness. Now the points I’ve made are part of the mainstream discussion—as I previously mentioned, the president’s State of the Union address highlighted our addiction to oil. But so far the discussion about energy has not led to any policy or to the informed, swift, concerted action necessary to save our civilization.

The truth is that we have no choice: We must make the transition from the Age of Oil to a new age with new sources of energy if we are to preserve our planet and our advanced culture for ourselves and for future generations of Earth’s human inhabitants.”

In the occasion of the 2006 Baker Forum, Cal Poly is pleased to join with John Wiley & Sons, Inc., to honor David L. Goodstein’s outstanding contributions to higher education and his distinguished leadership in science education, research and policy.

In 2002, John Wiley & Sons, Inc., generously established the Wiley Lifetime Achievement Award to recognize national leaders whose work exemplifies extraordinary leadership and lasting contributions in American higher education and public life.

David L. Goodstein, Ph.D., is vice provost and professor of physics and applied physics at Caltech, where he has been on the faculty for more than 35 years. In 1995, he was named the Frank J. Gilloon Distinguished Teaching and Service Professor.

In 1999, Goodstein was awarded the Oersted Medal by the American Association of Physics Teachers and, in 2000, the John P. McGovern Medal by the Sigma Xi Society. He has served on and chaired numerous scientific and academic panels, including the National Advisory Committee to the Mathematical and Physical Sciences Directorate of the National Science Foundation. He is a founding member of the board of directors of the California Council on Science and Technology.

Goodstein’s books include *States of Matter* (Prentice Hall, 1975; Dover, 1985), and *Feynman’s Lost Lecture* (Norton, 1996), written with his wife, Judith Goodstein, Ph.D. In the 1980s he was director and host of “The Mechanical Universe,” an educational television series that has been viewed by millions of students throughout the world.

In recent years, while continuing to teach and conduct research in experimental condensed matter physics, Goodstein has turned his attention to the relationship between science and society. In articles, speeches and colloquia he has addressed conduct and misconduct in science, the end of exponential growth in the scientific enterprise, and issues related to fossil fuel and the climate of planet Earth.
PANEL PRESENTATIONS
As preface to the panel presentations on the transition from what David L. Goodstein has termed the “Age of Oil” to a new world supported by different sources of energy, panel moderator Tom Jones, dean of Cal Poly’s College of Architecture and Environmental Design, introduced the four panelists:

- Martha Krebs, deputy director for research and development for the California Energy Commission
- Linda Trocki, a Bechtel Fellow and project manager for Bechtel National, Inc.
- Paul J. Turinsky, professor and department head, Department of Nuclear Engineering, North Carolina State University
- Jan Hamrin, president of the Center for Resource Solutions in San Francisco

Jones noted that the panelists would not only address the daunting challenges of harnessing adequate, safe and clean energy sources in a post-oil civilization but also explore important emerging energy opportunities for the United States and California.

Martha Krebs

Martha Krebs began her presentation on renewable energy and California’s current and future energy profile by reminding her audience that, despite restrictions on offshore drilling, California ranks third in domestic oil production, after Louisiana and Texas, and that the state’s electrical generation consumes as much natural gas as California’s homes and workplaces, a fact that accounts for cleaner power generation than in states that depend on coal for electricity.

“We also derive electric power from nuclear plants—we’re sixth in the nation in nuclear generation of electricity. Eleven percent of our power is from increasingly important renewable sources. And, surprisingly, we receive a portion of our power from coal, although most of our coal-generated electricity is imported from other states.”

While California’s consumption of electric power has steadily increased, its per capita electricity use has remained constant since the Middle East oil embargo of the early 1970s. Krebs described the factors that are responsible for the unchanging rate of individual energy consumption: statewide regulations for electric appliances and for house and business construction; and changes in the industrial sector that involve improvements in production efficiency and a shift from manufacturing to service industries. However, a booming increase in the number of California residents has meant that total electricity use has not gone down.

“California’s 1970 population of 20 million has now grown to 35 million, and will continue to grow. In addition to providing electricity to vast numbers of consumers, California must supply extra power during the ‘summer peak,’ when demand skyrockets. In inland areas of Southern California, and in the Central Valley, where a great portion of
the state’s population growth is occurring, summer temperatures require nearly constant air conditioning. The summer peak, and the state’s transmission system’s inability to move electricity efficiently from region to region, caused the 2000-2001 energy crisis. Conservation efforts by individual users helped ensure that an unmanageable peak didn’t occur in 2002.”

California’s energy and conservation policies are tightly intertwined, Krebs explained, pointing out that efforts to improve transportation energy efficiency are linked to the state’s concern with air quality. Emissions standards and the regulatory work of the California Air Resources Board, the Bureau of Automotive Repair, and air quality management districts have not only enabled California to achieve some improvement in air quality but also prepared for the introduction of new fuels and fuel-saving, less-polluting transportation technologies.

“One of California’s most controversial measures has been the legislature’s passage of a bill that would require a 30-percent reduction in greenhouse gas emissions from light-duty vehicles by 2016. The automotive industry challenged the law in court and the case is presently wending its way toward the U.S. Supreme Court.”

Krebs emphasized that a close study of California’s emissions of carbon dioxide and other greenhouse gases shows that the great majority of contaminants are produced by the transportation sector. In 2002 the California Energy Commission (CEC) was tasked to produce a biennial Integrated Energy Policy Report, based on consultation with the Public Utility Commission (PUC), the California Environmental Protection Agency (CalEPA) and other state agencies. The CEC’s second report, released in November 2005, focuses on transportation fuels, reflecting the emphasis California places on decreasing pollution from cars and trucks and procuring dependable supplies of cleaner fuels.

In seeking to protect its natural environment, California is also aiming energy strategies in the direction of renewable sources of energy and is one of the few states that have established renewable portfolio standards. Krebs observed that state law requires that by 2010 at least 20 percent of electric power must be generated by renewables, and that the governor has set a target of 33
percent by 2020. A new solar initiative established by the PUC and the CEC calls for a million roofs fitted with photovoltaic cells that together can produce 3,000 megawatts. The governor has recently affirmed an interagency working group’s report that describes the state’s biomass resources and their potential for producing both electric power and alternate fuels.

But despite these encouraging efforts, the renewables’ share of the state’s total power generation has remained at about 11 percent since 2002, a fact that Krebs attributed to the technical and market challenges that hamper wider use of renewable energy sources.

“Achieving California’s renewable portfolio standard by the target dates will require a special emphasis on widely expanding the use of our state’s already substantial solar power capacities. We do have wind power resources in the Tehachapi Mountains southeast of Bakersfield, and geothermal resources in the Imperial Valley, but tapping these renewables for electricity generation is limited by the absence of transmission lines to link these areas with the state’s backbone transmission system. A similar lack of infrastructure, as well as attendant legal, regulatory and funding issues, presently limits our ability to import wind-generated power from Wyoming. That state’s existing low-power wind turbines could be replaced by 3-megawatt turbines, but installing new technologies as well as interstate transmission lines is expensive and gaining the approvals from the Federal Energy Resources Commission will be complicated and time-consuming.”

Solar energy remains California’s best immediate source of renewable energy, but Krebs underscored some of the technical and monetary difficulties in providing dependable electricity delivery using solar power.

“The amount of generated electricity needs to be predicted a day before delivery, to allow Cal ISO (California Independent Systems Operator, the not-for-profit, public-benefit corporation charged with operating the majority of the state’s wholesale power grid) to confirm its procurement of the electric power and guarantee that it can be sent through transmission lines or into the main transmission system. The sale of electricity generated by the state’s solar initiative for rooftop photovoltaic cells could help reduce the cost of the new solar technology, but technical improvements in design are required to make solar cells a completely reliable, day-to-day source of power, and the metering that joins individual homes and commercial structures with the utilities requires the installation of adequate equipment. And then there’s the challenge of ‘distributed generation’—interconnecting individual generation sites with local distribution systems, then integrating local systems with larger utility grids. Using biomass for power generation presents similar difficulties in delivering electricity to greater transmission and distribution systems.”

Krebs next focused on the unique nexus between California’s energy consumption and its water supplies as she outlined how the state’s unequal distribution of rain and snow is linked with its growing need for electrical power.

“Two-thirds of precipitation falls in Northern California, but Southern California requires two-thirds of the 

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“The California water system requires 19 percent of the state’s electrical power to deliver water to Californians.”

Martha Krebs
California Energy Commission
state’s water, a reality that requires the costly transfer of water from the north to the drier, more populated south. And in the near future, this expensive and complex water supply system will have to serve vastly more customers—the state’s population is expected to grow to 48 million by 2030, an increase of 13 million people in 24 years. Water resource experts warn that such a drastic increase in population will severely tax our water resources and that water consumption cannot continue to grow at its current rate. The interesting and disturbing connection between water supply and electricity is that the California water system requires 19 percent of the state’s electrical power—which means 32 percent of the state’s yearly use of natural gas—to deliver water to Californians.

“There are a number of aspects involved in collecting and transporting water in California. Gravity-fed water from our mountains collects in reservoirs and is relatively inexpensive to manage, but increasingly, especially during warm summers when the winter snowpack has not been adequate, groundwater pumping—from ever-greater depths—has been necessary to meet demand. And once the water is collected, by gravity or expensive pumping, it has to be moved around the state. Motorists who travel north and south along Highway 5 can see the extensive network of canals and the large pumping facilities that are part of state and federal water projects. It isn’t difficult to imagine the great energy that is required to move such enormous quantities of water over such distances, or how much power it takes to lift water over the Tehachapi Mountains so it can flow down into the L. A. basin. And after the water is used, we have the problem of water treatment and the energy required for water purification.

“The California Energy Commission has made substantial efforts to make pumps and water treatment processes more energy efficient, but one important lesson has become abundantly clear: The less water we use, the less energy we use. Conserving water means consuming less electricity and the natural gas that generates it. This important insight was emphasized in California’s most recent energy policy report, and we are beginning a program that will closely study water and energy efficiency in the state water system. Cal Poly has had a long involvement with the Energy Commission’s PIER program (the Public Interest Energy Research program) on energy efficiency in irrigation and the wise use of water and energy in agriculture, and I expect the university to play an important role in developing strategies for better conserving these closely linked resources.”

Krebs highlighted two important areas for further investigation in addressing the difficult water supply/electric power equation:

- The need for more widespread and sophisticated water metering that registers and links water use, price and usage times, and allows better communication between customers and the utilities that supply water and
power

- Improved water-storage strategies, and especially new techniques in water and wastewater treatment, including the use of on-site, naturally generated methane at sewage treatment plants to produce electricity and make plants energy self-sufficient.

In conclusion, Martha Krebs offered encouragement and a challenge to America’s, California’s and Cal Poly’s technical communities. While acknowledging that conservation and energy problems remain daunting—and that the governor’s announced target dates for drastically reducing greenhouse gases are highly ambitious and will be difficult to meet—she emphasized that California is one of the few states that has an energy research-and-development program, and that the state’s monetary resources are being invested in new and exciting areas of conservation and energy study and application.

“One of the most interesting scientific investments California has recently made has been with the Scripps Oceanographic Institute, to downscale the global climate models so that the detailed impacts of climate change on our state can be assessed with sharper, higher resolution. The depth and volume of the snowpack and its melting rates can be examined with more precision; this is critical information to have for hydroelectric power production, flood control and agricultural irrigation. The models are also able to register changes in the size and distribution of areas of vegetation in the context of a myriad of potential changes in temperature and other climatic factors. Californians now have a better understanding of the effects of climate change on our topography—and our economy—and a clearer vision of what the coming years will bring. We can better see the future, and now we must decide how we will respond to it.”

Linda Trocki

Linda Trocki, the panel’s next presenter, addressed the need for practical incentives to foster industry investment in sustainable, environment-friendly energy technologies, then described energy strategies and fuels that will play an important role in the world’s transition from oil to other energy sources.

First, Trocki posed a rhetorical question: Is industry purposely investing in technologies whose energy requirements and environmental impacts are unsustainable? Her answer was no, but she stressed that industry needed both encouragement and prodding for a successful transition to cleaner, more energy-efficient processes and infrastructure.

“One of the most interesting scientific investments California has recently made has been with the Scripps Oceanographic Institute, to downscale the global climate models so that the detailed impacts of climate change on our state can be assessed with sharper, higher resolution. The depth and volume of the snowpack and its melting rates can be examined with more precision; this is critical information to have for hydroelectric power production, flood control and agricultural irrigation. The models are also able to register changes in the size and distribution of areas of vegetation in the context of a myriad of potential changes in temperature and other climatic factors. Californians now have a better understanding of the effects of climate change on our topography—and our economy—and a clearer vision of what the coming years will bring. We can better see the future, and now we must decide how we will respond to it.”

Linda Trocki
additional investment to make them fully commercial. I would characterize incentives to industry as ‘carrots,’ which should include stable research-and-development tax credits, like those recently legislated by Congress, as well as production tax credits and cost-share support for designing and building ‘demonstrations,’ those working prototypes on which future commercial technologies are based.”

New energy technologies, Trocki emphasized, require time for development and patient, long-term funding commitments.

“Over a span of years, the U.S. Department of Energy has put billions of dollars into promising technologies that are still not yet commercial but may become important as designs are perfected and the price of oil increases. A large federal investment is needed and justified, because breakthroughs in energy technology are a public good and provide energy and environmental solutions that our country and the world desperately need.”

“Sticks” are also required, Trocki suggested, underlining the importance of a stable regulatory environment.

“I’ve heard CEOs of major oil companies say that they would be happy to invest in reducing greenhouse gases if they knew that there were going to be predictable regulations with clearly stated targets and timelines. Without legal requirements, industry may not voluntarily take the necessary steps to convert to cleaner energy technologies, improve fuel conservation and phase out practices that damage the environment.”

Trocki acknowledged that industry’s reluctance to institute changes in energy technology can be tempered or even reversed by pressure from stakeholders.

“The stakeholders of American Electric Power, one of the largest coal-based utilities in the country, organized themselves and with their votes forced the company to reduce greenhouse gas emissions. Growing public opinion and concern may have an influence on industries and their energy practices. Another ‘stick’ is the inevitable long-term rise in oil and gas prices, which will force industry to invest in different energy solutions.”

In outlining near-term options for electricity generation, Trocki discussed the advantages and drawbacks of the new natural gas combined-cycle power plants. She explained that combined-cycle technology is relatively clean and capital costs are low. However, plants are currently experiencing high fuel costs and combined-cycle plants are not a carbon dioxide (CO2)-neutral technology, although their greenhouse gas emissions are approximately half those of coal-fired plants. Even if there were sufficient supplies of natural gas to generate all of our electricity, combined-cycle plants would increase the concentration of CO2 in the atmosphere.

At present, Trocki pointed out, pulverized coal remains the standard fuel for producing electric power and in the
foreseeable future coal will remain a vital energy source, with coal-fired generation evolving toward a cleaner, less-polluting energy technology.

“America has lots of coal and 55 percent of our electricity is generated by burning coal. In any examination of sustainable energy technologies, at least those that will carry us through the end of the 21st century, we have to acknowledge that we’re going to rely on coal. Our challenge is to make the burning of coal a cleaner operation. In a process called integrated gasification combined cycle (IGCC), the coal is gasified and the CO2 is separated out. Although generating electricity with this technique is more expensive than using pulverized coal, IGCC is favored by many as the environmentally desirable coal technology of the future. Bechtel has just formed an alliance with General Electric and hopes to greatly reduce the capital cost of IGCC electricity generation while improving the efficiency and reliability of the technology.”

In defending coal as an indispensable energy resource, Trocki highlighted new coal gasification and CO2-sequestration processes that she believes will drastically reduce greenhouse gas emissions and allow coal to be widely used without damaging the environment.

“Coal gasification produces a gas containing hydrogen, carbon monoxide and carbon dioxide. The addition of water vapor to carbon monoxide produces a mixture of CO2 and hydrogen. The CO2 can then be captured and sequestered. The U.S. Department of Energy has invested billions of dollars in developing this process and we have built many of the electric generation plants that gasify coal, including the Coolwater and Polk power plants. Again, a sustained investment is required to commercialize these new technologies.”

Trocki described a new demonstration called FutureGen that the U.S. Department of Energy has proposed, a large IGCC plant that will separate CO2 and sequester it under the surface of the Earth. The CO2 sequestration is not a simple series of procedures, Trocki acknowledged, and will probably require another Energy Department-sponsored demonstration project equal in magnitude to the government investment that has already underwritten clean-coal technology demonstration programs.

“Billions of dollars and at least 10 to 20 years of research and development will be required to prove that CO2 can be...
"The several energy options for hydrogen production—coal, petroleum, natural gas, biomass and solar—make hydrogen a very attractive fuel for the future."

Linda Trocki

effectively sequestered underground, most likely in deep saline aquifers where the gas will remain. The process will require careful monitoring, there will be public concerns about the environment, about the safety and long-term effects of subterranean storage of CO2 emissions, but as a technologist I believe sequestration is achievable.

As Martha Krebs pointed out, the transportation sector produces a large portion of CO2 greenhouse emissions, and Trocki next discussed alternative, cleaner-burning fuels that can replace oil as gasoline prices rise and the new energy technologies become increasingly reliable and commercially feasible.

"Hydrogen is a very promising fuel because it burns so cleanly, but producing hydrogen fuel cells that will fit easily into cars is extremely challenging, and at present such fuel cells are very expensive. Another technical difficulty involves the safe on-board storage of hydrogen. The several energy options for hydrogen production—coal, petroleum, natural gas, biomass and solar—make hydrogen a very attractive fuel for the future. I estimate a research-and-development commitment of between 10 and 20 years to make hydrogen fuel cells commercially viable and to build the infrastructure to supply hydrogen for the new cars and trucks."

Trocki next described the role bio-fuels might play as oil becomes scarcer and more expensive and increasing environmental concerns dictate the need for less-polluting cars that release smaller amounts of CO2 into the atmosphere. Bio-fuels are derived from either animal waste or living organisms, and crops especially suited for bio-fuel production can be selected and grown. Trocki pointed out that because plants absorb CO2 and release oxygen, using bio-fuels as a source of energy can also balance the amount of CO2 in the environment.

"Plants take in CO2 to produce sugars we can use for bio-fuels. Even though burning plant matter gives off CO2, the increased planting of crops for bio-fuels will mean many more plants to take in CO2. The CO2/bio-fuel cycle is not quite a closed loop because more gas will be released than plants can absorb, but using bio-fuels will substantially decrease net greenhouse gas emissions from cars."

Bio-fuel production can follow two paths, Trocki explained:

"Ethanol can be made from corn or sugar cane, but using cellulose to produce ethanol may prove the better sustainable energy solution for the future. Agriculture waste or switch grass or crops specifically grown for bio-fuels can supply plentiful amounts of cellulose at low cost. It’s true that the biomass in agricultural waste is much harder to break down than the biomass of corn or sugar cane, but there are a number of engineers across the country trying to make cellulosic ethanol production more efficient. The Department of Energy is working on the problem, and Bill Roberts at North Carolina State University is studying the chemistry that allows cattle to digest straw and other roughage. Dr. Roberts’ ultimate aim is to engineer similar enzymes and duplicate on a large scale the cow’s digestion and fermentation processes to efficiently produce bio-fuels from the energy locked in cellulose. This ‘bio-refinery’ concept might someday transform the energy market. In the future, cellulose biomass could feed
refineries that produce vital chemicals and fuels, and gasified cellulose could be burned to generate electricity.”

Linda Trocki concluded by stressing that there is no single “silver bullet” to solve the energy dilemma caused by decreasing oil supplies, a decrease that she sees not as a single enormous bell curve spelling the end of all fossil fuels, but as a series of smaller bell curves that will allow time for the free enterprise system to develop other energy sources and technologies as the world shifts from oil to a variety of cleaner, more sustainable fuels.

“I have a great deal of optimism that the market is going to answer our energy challenges and provide sustainable technology solutions for the future. There is not going to be one solution, but many solutions, an array of alternatives that my fellow panelists and many others are investigating.”

Paul J. Turinsky

Paul Turinsky prefaced his presentation on the importance of nuclear power in a post-oil world by admitting that many people do not view nuclear energy as part of the solution to the world’s growing energy needs. Before arguing for the vital need for nuclear-generated electrical power, Turinsky emphasized the importance of considering the rising demand for dwindling oil supplies as not just a national but a global problem.

“The energy policies of other countries are having a great impact not only on the United States’ economy but also on its environmental health. The rapidly growing economies of China and India have caused world oil prices to rise as supplies decline, and the solutions these countries choose in meeting their expanding energy needs will dramatically affect the world’s climate. For example, if China proceeds with vast coal production for coal-fed generating plants, the ill effects on our atmosphere and world environment could be severe.”

As a computational reactor physicist, Turinsky explained, he has become involved in national energy policy issues, as have many scientists in the field of nuclear power. He is presently doing research with the Idaho National Laboratory to develop predictive models that will guide energy policy decision-makers in Washington, D.C., and he summarized the current status of nuclear-power electricity generation in the United States and the world.

“We have 103 reactors currently running in the United States, the approximate number in operation a few years after the accident at Three Mile Island (TMI), which had a major, negative impact on the development of nuclear power in this country and a smaller effect worldwide. There are now 444 reactors in the world, with most of the new installations being built in Asia, especially in Korea, Japan and China. The United States is playing a major role in these new plants—Korean and Japanese companies are former licensees of American companies.
"The number of nuclear plants in the United States will increase after the end of this decade."

Paul Turinsky
North Carolina State University

and use American technology, and China’s nuclear technology purchased from the French comes from Westinghouse, which was recently purchased by Toshiba."

Although the total number of nuclear power plants in America has remained almost unchanged since Three Mile Island, the amount of electricity produced by these plants has dramatically increased.

“Nuclear power generates about 20 percent of the electric energy used in the United States, an increase of 50 percent from the days soon after TMI, when our nuclear installations were running at 61-percent capacity. American plants now run at approximately 91-percent capacity. The need to periodically shut down and refuel prevents 100-percent capacity, which would require that plants operate constantly, day and night, at full power. Some regions and states receive a higher percentage of their total electricity from nuclear reactors, well exceeding the nationwide percentage: South Carolina receives 70 percent and North Carolina 45 percent of their electricity from nuclear fission.”

In most of the world’s developed countries, as in the United States, nuclear power accounts for about 20 percent of total electric power generation. Turinsky noted that France and Belgium receive about 80 percent of their electricity from nuclear plants, and that Switzerland’s nuclear electricity production is relatively high. All countries supplement nuclear power with other sources of energy, and in the United States the reliance is on coal.

“In the United States it’s coal, coal, coal for generating electrical energy. Since TMI the American nuclear power industry has not sold a new plant, and about 100 proposed domestic nuclear power installations have been cancelled. Instead of the 103 units that are presently running, we might have had a total of 220 units online. Nuclear power plants are ‘cash cows’ because they have low generating costs: In the last few years the price of nuclear electric power has been marginally below the cost of coal-generated electricity, and nuclear plants have become the utility companies’ ‘baseload units,’ operating around the clock. (Baseload units provide all or part of the minimum energy requirements of customers, usually run continuously to produce electricity and are typically shut down only for maintenance.) In the United States, nuclear plants have been used exclusively for electricity, while in Russia and a few other countries— noting that nuclear plants run at lower temperatures and about 32-percent efficiency because of material limits on core fuel—the substantial waste heat produced has been used to warm local homes and factories. These plants compare unfavorably with coal-powered electric plants, whose efficiency is above 40 percent.”

The number of nuclear plants in the United States will increase after the end of this decade, Turinsky predicted, as a result of a Department of Energy (DOE) program called Nuclear Power 2010 (NP2010) and a changing governmental and public perception of nuclear energy.

“DOE’s target date for having a new plant in place and running was originally 2010, but that goal has apparently become the ‘sale date,’ when final agreements will be settled and construction can begin. Plans for approximately 15 nuclear plants..."
have been announced, in part because of a number of incentives set forth by the National Energy Policy Act, which has motivated utilities to reexamine nuclear power. The legislation provides substantial tax breaks for the first 2 gigawatts produced, while additional generation of up to 4 gigawatts brings companies a slightly lower tax reduction. In addition, the Price Anderson Nuclear Industries Indemnity Act was renewed, providing limited-liability protection for the nuclear power industry.

“Except for one plant in the mid-Atlantic region, and the Clinton plant in Illinois, the new nuclear installations will be located in the Southeast, where population growth has increased electricity demand and public acceptance for nuclear power is greater than in other parts of the nation. All but two of the plants slated for the Southeast will be built at existing sites.”

Two other factors accounting for American utility companies’ renewed interest in nuclear power include three new nuclear power plant designs that have recently entered the market and regulatory changes streamlining licensing procedures for nuclear plant construction and operation.

Turinsky briefly described the new nuclear reactors available to American utilities.

“The Westinghouse AP1000 is an approximately 1,100-megawatt unit that is about the size of Diablo Canyon, the Pacific Gas and Electric plant just a few miles from Cal Poly. The new Westinghouse design is based on a comprehensive, sophisticated, passive safety system and offers an array of technological improvements that should make power generation more economical than in older plants. Toshiba now owns Westinghouse, and significant manufacture of large components will need to take place outside the United States due to decay of U.S. manufacturing capabilities.

“The General Electric ESBWR, usually referred to as BWR, is also a complete passive safety design. At full power, the 1,500-megawatt unit operates as a natural-circulation reactor, actual water circulation through the reactor being accomplished by the buoyancy effect produced by boiling. GE remains an American-owned company and is located in Wilmington, North Carolina.

“Areva offers a 1,500-megawatt European Pressurized Reactor (EPR) built by Areva NP, a French/German venture. A new Finnish reactor that’s in construction is based on the EPR design and in Normandy the Electricité de France reactor is also an EPR-style installation.”

Turinsky noted the similarities in new reactor designs.

“The trend is toward extremely large units, to take advantage of the ‘economy of scale’ that makes nuclear-power electricity generation profitable. The companies selling these new reactors insist that they will be safer and less expensive to run than older models, but a final verdict will have to wait until these reactors are built and running. An interesting common aspect of the three new designs is their use of very large forgings, which are so immense that only one facility in the world, a plant in Japan, is able to make them, a fact which may postpone delivery when reactors are sold to customers.”
The final factor that has encouraged American utilities to return to nuclear power is licensing reform—what Turinsky calls “one-stop licensing.” In the past, companies needed both construction and operating permits. Delays in obtaining building permits were a hindrance, but delays in receiving operating permits for the completed plants cost the utilities great amounts of money. Interest payments on their huge investments continued as they waited for permission to generate electricity to sell to their customers. Under the new regulations, a nuclear plant can go online immediately after completion if the company has already met the agreed-upon specifications for construction.

“One-stop licensing has streamlined and speeded the process and is now the final step in getting a nuclear plant up and running—pre-site approval, the initial permission to build a plant at a designated site, of course precedes the licensing phase, and the three new reactors now on the market can receive the required design certification before they’re ever sold to the utility company.”

Nuclear power plant construction within the United States will become a faster process, and the new reactors built by Westinghouse, GE and Areva will enable utilities to standardize the nation’s nuclear power industry, which has been hampered by the large number of customized plants—traditional utilities that were used to refitting their fossil-fuel units often carried over this practice to nuclear plant construction. Individualized plans for nearly every nuclear installation in America lengthened construction schedules and increased costs. In France, which has only one utility company, the government-owned Electricité de France, there are 53 reactors but only three reactor designs. In the United States a survey of 53 nuclear plants might identify as many as 35 different reactors, and some plants, like Diablo Canyon, are “twin stations” that use differing reactor designs to counter site-specific seismic conditions or other geological or environmental concerns. The new line of reactors, Turinsky emphasized, can be built in a wide range of geographic locales without special customizing, an important aspect of their design that will help begin the needed standardization of America’s nuclear industry.

Turinsky acknowledged that the planned increase in the number of domestic nuclear plants and the speed at which they may come online has also been influenced by the companies that build the reactors, which are becoming more adept in gaining rapid certification for their new models.

“The Westinghouse AP1000 received approval from the United States’ Nuclear Regulatory Commission (NRC) last fall, a process that spanned several years but was far shorter than the nearly 10 years required to certify Westinghouse’s earlier reactor, the AP600. GE submitted its new ESBWR for certification last fall, and Areva, which has hired 200 engineers in the last 12 months, will be applying for NRC licensing of its EPR in approximately two years. The NRC’s certification is the world’s ‘gold standard’ for reactors and very important to reactor manufacturers, who have become increasingly skilled in working with the NRC and meeting its requirements. Most countries accept the authority of NRC licensing, with the sole exception of Germany, which may phase out nuclear energy pending an internal political debate.”
As he began his description of the future use of nuclear power in the United States and the world, Turinsky acknowledged that the unrestricted spread of nuclear materials, know-how and equipment remains a major issue for concern, although the danger is less formidable than might be expected.

“In some sense, it’s amazing how well the world has done in limiting the spread of nuclear technology. The present worry concerns a few rogue nations, a relatively small number of countries when we consider that nuclear technology has been around for 60 years.”

Turinsky next analyzed nuclear power in terms of the long-term availability of nuclear-fuel sources.

“At present, we don’t have a closed nuclear fuel cycle. We’re reaping only .7 percent of the potential energy content of the nuclear fields we create in reactors. Where does the remaining, unused energy go? Right now it’s going into spent-fuel pools, and may one day be stored under Yucca Mountain in Nevada. The long-term use of nuclear power will depend on a reliable fuel source, which depends on closing the fuel cycle. If the cycle can’t be closed, nuclear power will have only a temporary existence as a means of electricity production and will disappear by the end of this century. However, if a closed-cycle solution is found, the nuclear power industry will be revolutionized. For example, we could generate immense amounts of electricity from the plutonium and the minor actinides that otherwise would be stored at Yucca Mountain, reducing nuclear waste by over 99 percent and vastly lessening current concerns about the heat those waste materials now emit.”

The open nuclear fuel cycle’s production of radioactive waste poses an immediate as well as an ongoing difficulty for sustainable nuclear power, Turinsky stressed.

“The large amounts of nuclear waste produced by American nuclear plants, and the proposed use of Yucca Mountain as a repository, present thorny problems. Yucca Mountain is a heat-load-limited, drip-wall temperature-limited repository—by 2010 our current nuclear plants will have generated all the fuel that Yucca Mountain can accommodate, given the target licensed capacity. And Yucca Mountain won’t even be licensed by 2010, even though the area is very close to an atomic test site and has already been exposed to some radiation.”

The continuing debate over Yucca Mountain reflects resistance among some Nevada residents and other Americans who doubt the safety of waste storage as well as nuclear power and its importance for the future. However, Turinsky pointed out, polls show that two-thirds of the people in the United States are now in favor of nuclear energy for electricity generation, a sea change in sentiment over the last few decades based on three major factors:

- Since Three Mile Island, the absence of nuclear plant accidents to galvanize negative opinion
- The growing public concern with our dependency on petrochemicals and on the countries that supply us with oil
- Environmental worries about the continued use of carbon-based fuels

Turinsky described the likely nature of nuclear power use over the next 30 to 50 years, predicting the appearance of
what he calls “Generation IV” reactors that will replace the Generation II reactors operating now and the Generation III reactors (the Westinghouse AP1000, General Electric’s ESBWR and Areva’s EPR) that will probably be installed in the United States after the end of this decade.

“Generation IV reactors will be based on one of six concepts now being developed at labs around the world. In the United States, two of these concepts have received limited governmental funding: high-temperature gas-cooled thermal reactors, and liquid-metal sodium reactors, on which the United States has recently signed accords with France and Japan. The sodium reactor is an idea that was heavily researched a number of years ago and is now receiving renewed interest. Both of these approaches aim at tightening the nuclear fuel cycle. Unfortunately, the American Generation IV project is under-funded at $40 million a year, an insignificant amount in terms of the scope and complexity of needed research and development.”

One American research effort, the Advanced Fuel Cycle Initiative (AFCI), is an outgrowth of earlier programs and is also aimed at closing the nuclear fuel cycle. The AFCI project receives $80 million a year and its mission is to address problems concerning Yucca Mountain, to minimize the need for that site and other nuclear waste repositories.

A new initiative in the president’s budget for the 2007 fiscal year is the Global Nuclear Energy Partnership (GNEP), which is designed to develop a worldwide consensus on the expanded use of nuclear power as world culture shifts from carbon fuels. As part of the Advanced Energy Initiative, the GNEP’s mission is to enhance the safety, efficiency, proliferation resistance and economics of nuclear power.

“We now have passive safety systems. Core melt probabilities have declined by another factor of 100, to a probability of 10^-6 per reactor year, so the chance of a core melt is very, very low. And passive safety systems are being further enhanced. The long-term economics of nuclear power will continue to depend on a reliable fuel source, which depends on closing the fuel cycle. And improving nonproliferation efforts remains a priority. If we’re going to deploy nuclear technology worldwide, we have to make sure we’re deploying it carefully, with safeguards that prevent nuclear expertise and materials from falling into the wrong hands and being used for destructive purposes.”

Unfortunately, Turinsky emphasized, there is no such thing as a proliferation-proof nuclear cycle.

“All we can do is harden the cycle, turn more of the nuclear fuel into energy, and produce less nuclear waste. Present efforts in this direction include work on hydrogen production based upon electrolysis and thermochemistry. All of these approaches require very high reactor temperatures, which accounts for
the avid interest in the high-temperature gas-cooled reactor. Some researchers believe that 850 degrees centigrade are sufficient, while others argue that 1,000 degrees are required, a temperature that brings into play arcane metallurgical issues and the integrity of the pressure vessel. The Department of Energy has set a goal of 1,000 degrees centigrade.”

Turinsky stressed that one important element of this GNEP fuel-cycle effort is the advanced burner reactor, which is a sodium-cooled fast reactor.

“The earlier Clinch River Breeder Reactor Project (CRBRP) involved a sodium-cooled fast reactor, and several billions of dollars were expended on the project before it was abandoned. The Clinch River reactor was designed to breed fuel, it had breeding ratios greater than one, so that more fuel came out of the reactor than was put in. The new burner reactors have conversion ratios that are less than one and nuclear scientists are in debate concerning what the proper ratio should be. The burner reactor is designed to use the stockpile of light-water reactor fuel we’ve created over the years. The idea is to take hot, high-energy waste and transform it through nuclear reactions into energy, leaving a nuclear waste that is very short-lived, free of the plutonium and the minor actinides such as the neptuniums and the curiums responsible for high heat loads and the safety concerns surrounding Yucca Mountain. The sodium reactors run at high-energy fission spectra that are needed to thoroughly burn waste products and convert them into high-energy fuel sources.”

Small capsule tests that explore the sodium reactor idea and other reactor concepts are being conducted around the world, often with the use of the French Phoenix reactor and air-core reactors designed for testing purposes. Negotiations are presently under way with the Russians and Japanese, who have testing capabilities that are lacking in the United States.

“We do not have any fast reactors in production—the single demonstration reactor at the Fermi plant was operated for only a short time before it was shut down. The Fast Flux Test Facility at the Hanford Nuclear Reservation and the Experimental Breeder Reactor-II (EBR2) no longer exist, so American nuclear research programs are very dependent on testing facilities in other countries.”

Another aspect of the Global Nuclear Energy Partnership proposes that nations with nuclear weapons provide nuclear fuel and technology to non-weapons nations, which would in turn return the used fuel to the weapons nations. Turinsky described the sharing plan, which involves the use of nuclear cores similar to naval reactors that could be plugged in and then taken out of service in 20 to 25 years.

“All enrichment services would be provided by the supplier nations—those countries with weapons technology, as well as Japan. The user nations would never own the fuel, and would pay for the energy the fuel produced. Nuclear energy installations in user nations need to be of modest size to prevent power
grids from going down when one big plant trips off line or has to be shut down for maintenance. The current focus is on smaller plants that offer higher levels of inherent safety, that can operate for many years, and that match the technical infrastructure and nuclear expertise of countries new to nuclear power. The extended longevity of these nuclear cores will require improvements in current fuel reliability—several ideas have emerged, including an interesting concept stemming from the IRIS reactor that Westinghouse is promoting, but so far no consensus has been reached.”

Turinsky once again acknowledged that there is substantial resistance from many quarters to the spread of nuclear power to non-nuclear nations. The International Atomic Energy Agency plays a major role in monitoring nuclear energy use in America and across the world and in preventing unregulated proliferation of nuclear materials and technology. The task is multifaceted and challenging, Turinsky admitted—illegal proliferation can occur at many levels, ranging from the activities of rogue nations to individual perpetrators who discover how nuclear fuel can be diverted from reactors.

In concluding his presentation on the current and future status of nuclear energy as a source of electrical power and an alternative to oil and other fossil fuels, Paul Turinsky briefly described the new reactor scheduled to be built at the Idaho National Laboratory.

“The Global Nuclear Energy Partnership initiative calls for a new-generation, high-temperature reactor to be installed at the Idaho Laboratory. The Idaho facility is mandated to become the lead nuclear-technology development laboratory in the Department of Energy’s complex of laboratories. North Carolina State University is a partner with Battelle and four other universities, a consortium that won a $5 billion contract to operate the lab for the next 10 years. The GNEP’s mission is to use nuclear energy to produce electricity and hydrogen, decreasing and ultimately ending U.S. dependency on oil.

“Whether nuclear energy will be an economically feasible replacement for oil and other fossil fuels is not yet certain, but safe, highly advanced nuclear power technology could theoretically accomplish amazing things. At night, when customer electricity demands decrease, a helium-cooled reactor could shift the thermal energy it produces from electrical power generation to increased hydrogen production, to provide more fuel for cars that run on hydrogen cells. I believe that the key is to first design better thermal reactors, and after that build new, fast reactors.”

Jan Hamrin

Jan Hamrin, the panel’s final speaker, presented some of the dramatic national and international developments in renewable resources technology and policy for electricity generation as she highlighted the important role of governmental, corporate and institutional partnerships in promoting cost-effective solutions to the growing energy and environmental crisis.

As an introduction to her discussion of
practical strategies for promoting green-energy alternatives to oil and other fossil fuels, Hamrin gave a brief background of her work at the Center for Resource Solutions.

“The center is a nonprofit institution based in San Francisco that focuses exclusively on clean-energy policy and design and the implementation of the most promising renewable energy practices. One of the center’s important activities has been the administration of the Green-e program, which verifies and certifies renewables sold in retail markets. We also produced the report for the governor on the feasibility of meeting a 33-percent renewable portfolio standard by the year 2020. I am not a technologist but someone trained in policy work—I’ve specialized in learning how to structure, propose and advance practical energy initiatives with the goal of achieving their acceptance and effective operation.”

Hamrin stressed that her vision of a world that runs on clean, alternative energy sources relies not on one all-encompassing solution but on a whole spectrum of renewable energies and technologies.

“In describing global efforts in sustainable energy technology, I want to emphasize that an effective evolution toward renewables means the use of a whole family of technologies that includes solar, wind, geothermal and biomass, as well as tidal, ocean-thermal and ocean-wave technologies that are in research and development. The introduction of biofuels for transportation, which will require no drastic changes in infrastructure, is an especially important aspect of sustainable energy policy, as is solar energy for water heating. Today, however, I want to focus on electricity generation technologies currently in use that are cost-effective now and are becoming more economically attractive every day.”

Hamrin began her discussion of sustainable electricity generation by noting that the use of fossil fuels to produce electric power is becoming increasingly expensive, not only because of the growing scarcity of oil but also because fossil-fuel plants require more and more retrofitting to reduce the quantity and toxicity of emissions in order to address air quality concerns. Increasingly, the older fossil-fuel technologies are becoming more costly, while the newer sustainable technologies continue to decrease in cost.

Hamrin then offered some recent statistics concerning global renewable energy use.

“Worldwide, $30 billion have been invested in renewable energy research, development and installation, and the amount of investment is growing rapidly. In the years 2003 and 2004, 160 gigawatts of electricity were generated by renewable power, and when the numbers are compiled for 2005 and 2006 the amount should be substantially higher. Photovoltaic (PV) is the fastest-growing energy technology in the world, with a growth rate of 60 percent. In addition, 40 million solar water heaters are in operation, with China leading all nations in the manufacture and use of solar water heating systems.”

Green power, Hamrin emphasized, is still in its infancy but is swiftly expanding its international presence and reach. “Green power” is defined as the voluntary purchase of renewable energy that supplements or replaces the electricity
Across the globe 4.5 million customers buy green power electricity, and many of these users are in the United States, where reliance on green power is increasing, particularly in industry. Renewables-generated electricity is also spreading in the world’s rural areas, where local feed stocks and other resources are available and the construction of long transmission lines is impractical and too costly.”

While sustainable, green-energy production remains a relatively small percentage of the world’s total electricity generation, the numbers for renewables are rising at an accelerating rate. To illustrate the growing international emphasis on using sustainable energy to produce electricity, Hamrin outlined parallel efforts under way in California and in China, where for almost six years she worked with the Chinese on sustainable energy issues.

“In California, the governor’s 33-percent renewable energy target for 2020 reflects the direction that the state is moving in energy policy, while in China some ambitious new goals for renewable energy have recently been set. The Chinese passed a sweeping renewable energy law in February 2004 that became effective in January 2006.

“In China, I worked for five years to develop renewable energy strategies and policies, but when the government made the decision in favor of renewables a law was written and approved within a span of 12 months, an accomplishment that for many reasons would be unlikely in the United States. The Chinese have now set a 2020 goal of 30,000 megawatts from wind, 30,000 megawatts from biomass and 70,000 megawatts from small-capacity hydroelectric installations. Targets for electricity generation from other renewable sources remain to be established, but those technologies are in development, and goals and dates for implementation will be announced in the future. Overall, China has set a goal of generating 20 percent of its electricity from renewable sources by 2020.”

Exciting progress in sustainable energy technology, especially using wind, is well under way in several European nations, Hamrin pointed out.

“The European emphasis is on utility-scale wind projects, much larger than the small wind turbines that might be found in rural areas or beside houses. Germany is very involved in developing wind power technology to supply its national energy needs. Spain also is investing heavily in large wind power projects, and both Germany and Spain have very aggressive renewable energy policies called ‘feed-in’ tariffs—the government sets a price and agrees to buy all the electricity green suppliers can generate. The tariffs have strongly stimulated the renewables industry, especially the wind power sector.”

### Renewable Energy: Contribution to Electric Generation Capacity

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<th>2003</th>
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<tr>
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<td>0.5%</td>
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<tr>
<td>Wind</td>
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<tr>
<td>All renewables</td>
<td>9%</td>
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Source: Center for Resource Solutions

### World Wind Energy Capacity

Source: Center for Resource Solutions
Hamrin emphasized the importance of expanding photovoltaic manufacture and installation, especially in China, where a 600-percent increase in PV production has been reported.

“In China’s rural areas, PV modules are sold in hardware stores as packaged, ready-to-use sets. China is among many countries that are gearing up for mass production and wide use of large, sophisticated PV units, and China will likely become one of the world’s major manufacturers and exporters of PV modules.”

At the present time, Hamrin explained, the rapid increase in world PV production has been hampered by the insufficient supply of refined silicon, particularly for fabrication of crystalline PV systems.

“I expect a large increase in manufacturing facilities for processing much larger quantities of silicon, and a steady development and expansion of thin-film PV technologies that don’t require the large amounts of purified silicon needed to produce crystalline PVs.”

Hamrin pointed out that worldwide electricity production from PV and wind power is increasing at a similar rate, despite the fact that PV development for electricity began more slowly.

“Photovoltaic electricity generation is more costly per kilowatt hour than electric power produced by other renewables, but PVs have the advantage of generating power at the site where the electricity is consumed. The cost of transmission lines as well as controlling the flow and direction of the electricity is avoided—many PV users are attracted by the independence from an outside electricity provider and its infrastructure. Like all renewables, PVs have a high initial capital cost but very low variable costs. Over time, the cost of PV-generated electricity will remain nearly constant, allowing rate payers to avoid abrupt double or triple increases in power bills, which is especially important to businesses and manufacturers budgeting future energy costs as part of their operating strategies. The promise of relatively stable electricity prices makes PVs, as well as wind and other renewables, increasingly appealing, cost-effective investments for both commercial and residential use.”

As an adjunct to her description of the convenience and attractive economics of on-site PV electricity production, Hamrin paused to underline the pressing need to harness solar energy for water heating.

“Using the sun for heating water is so cost-effective that all of us should be placing much more emphasis on solar technology as a replacement for the expensive, dwindling and polluting fuels that directly heat water or generate electricity for water heaters. Natural gas is an important but very costly fuel and burning it to raise the temperature of water a few degrees isn’t sensible. As the world leader in using solar energy for heating water, China has recently introduced some new designs for solar water heaters that are much better integrated into building designs than the old, cumbersome technology that often
“A tremendous number of businesses, industries and universities such as Cal Poly are becoming involved in sustainable energy alternatives.”

Jan Hamrin  
Center for Resource Solutions

took the unattractive form of a big tank sitting on a roof.”

Hamrin went on to stress that although corporations, businesses and universities have usually been ahead of government in developing and implementing renewable energy solutions, a “silent revolution” in renewables is rapidly gaining momentum and attracting adherents from a wide spectrum of our cultural and governmental institutions as the world evolves from fossil-fuel technologies to sustainable alternatives.

“It is a very exciting time and most people remain unaware of the rapid changes that are taking place. A tremendous number of businesses, industries and universities such as Cal Poly are becoming involved in sustainable energy alternatives. California’s government buildings and offices and even federal government facilities are shifting to renewable power sources. One of America’s largest purchasers of renewable energy is the United States Air Force, followed closely by the other branches of the armed services. Large American corporations, businesses and institutions are all buying renewable-generated energy, and new customers are appearing every day. The renewables market has evolved well beyond a ‘boutique’ clientele and increasingly involves our country’s biggest companies, government agencies and universities.”

“At the Center for Resource Solutions, we felt that companies and corporations that use renewable energy deserved ‘bragging rights,’ that potential customers should know that these businesses use and support sustainable energy sources and technologies. And so we developed labels, ‘Made with Renewables,’ and ‘We Buy Renewables,’ that are beginning to appear on commercial products. When we launched the program with a 2004 press release, we hoped that we’d have one or two dozen products to bear the labels. By the end of 2005, 142 products from 68 companies were for sale with our logo, and more companies are calling us every day.”

Many of the first items with the renewables label were organic foods, but the list now includes clothing, textiles, carpeting and paper products.

“Mohawk Papers, a very large company, is using renewables for their recycled paper line. Customer response to our logo has been so good that Mohawk is labeling other paper lines made from renewable materials or with renewable energy. And wine and beer producers, as well as the makers of a number of other products, are using renewables and requesting our ‘Made with Renewables’ label. Public awareness of renewable products helps raise support for the kinds of green policies we need as our country continues its evolution away from oil and other fossil fuels.”

Jan Hamrin ended her presentation by underscoring the importance of “green buildings” and urging her audience to join in the green architecture revolution.

“The Leadership in Energy and Environmental Design (LEED) Green Building Standards set by the United States Green Building Council (USGBC) include a renewable energy component that brings a higher level of green certification, and many, many companies that build LEED-certified buildings are now incorporating renewable energy technology. But I want to stress
that green architecture is about even more than renewable materials and technologies. I feel strongly that the new, environmentally aware architecture is also about exciting developments in aesthetics. I hope that many Cal Poly departments will increasingly encourage young people to discover designs—for home and business owners and for builders—that are aesthetically pleasing as well as energy efficient and cost-effective. I encourage all of you to help make our residential and commercial architecture not only greener but more beautiful, so that ‘green’ and ‘beauty’ increasingly become synonyms that express the essence of the growing movement toward clean, affordable, renewable energies.”

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**QUESTIONS AND ANSWERS**

Panel moderator Tom Jones thanked the four panel presenters, then introduced the discussion period by suggesting that the presentations could be viewed from at least three important perspectives that each offered opportunities for Cal Poly to play an important role in helping solve America’s and the world’s growing energy and environmental crisis:

- **Public policy:** What can we do at the local, state and federal levels of government to advance sustainable and safe energy solutions?
- **Technology:** How can we produce, distribute and use energy more efficiently?
- **Public education:** How can we bring increasing numbers of our citizens to an informed, balanced understanding of energy issues?

“I believe that in each of these three distinct but closely related areas Cal Poly has valuable contributions to make,” Jones told Baker Forum participants before opening the question-and-answer period.

The first questioner was Jaime Oaxaca, chairman of the Oaxaca Group-Grupo Oaxaca.

**Oaxaca:** “I’ve been very involved in the U.S./Mexico Foundation for Science, an organization which now includes Canada. We’ve been having many discussions about ways to make commerce regulated by NAFTA (the North American Free Trade Agreement) more efficient. As I listened to the Baker Forum panelists’ excellent presentations I was reminded of an important energy issue that arose at the last board meeting of the foundation.

“Mexico is very quickly running out of what is called ‘sweet oil,’ the prime thin oil that is more easily produced and refined. The Mexicans do have huge reserves of ‘thick oil,’ oil that requires different, special handling for recovery and processing. The Mexicans tell us that when compared with other oil-exporting countries, Mexico now has a 22- to 26-percent disadvantage in the cost of producing energy.

“As we attempt to keep the United States, Mexico and Canada strong exporting countries in the increasing global trade competition from China and India, the problem arises as to how the North American trading partners can efficiently share new and needed technology without impeding their own country’s commercial interests. Mexico is ceasing to be a country of low-cost labor and has lost a million jobs to China, Nicaragua and Guatemala. The Mexicans have concluded that their manufacturing sector must move toward higher-end,
value-added products, but presently Mexico is graduating many more chemical engineers than the country can employ, while the United States is producing far fewer engineers than our domestic economy and chemical industry require.

“How do you experts address the problems involved with the three North American countries effectively sharing their resources and technologies and their trained professionals, for the benefit of their own national economic interest as well as the interests of their trading partners and neighbors?”

Trocki: “With respect to effectively sharing technology in the marketplace, I think there are a number of privately and publicly held American companies that have petroleum-technology solutions and can work with entities such as Pemex to improve Mexican oil recovery. At Bechtel we have a subsidiary that’s working now with Pemex. I think the efficient transfer of needed technology depends on the rapid commercialization and marketing of that technology, especially in the area of oil production, where I don’t believe there’s any real impediment to sharing techniques and expertise. And of course the universities are producing available literature, publishing research journals and reports that allow new knowledge to be shared among countries.”

Jones asked Martha Krebs for her perspective.

Krebs: “You may remember that I showed you a PowerPoint slide regarding the California Energy Commission’s Integrated Energy Policy Report that was released in November 2005. The slide depicted the different aspects of California’s energy planning and one item was entitled ‘Border Energy,’ a category that focuses on our energy relationship with Mexico. On a practical level, ‘Border Energy’ considers a number of factors, among them natural gas and particularly liquefied natural gas, but on the level of policy this category reflects California’s recognition of the importance of the state’s interaction with Mexico and the need to share technology and human resources to maintain the energy security and independence of both Mexico and California. The importance of Mexico in California’s overall energy planning is acknowledged by members of the CEC and, I think, by the governor’s office.”

Jones asked Jan Hamrin to respond.

Hamrin: “There are several interesting changes occurring in the electricity sector, which is the Mexican energy area I know best. Presently, a movement is under way in Mexico to use more natural gas to generate electricity, which I think is unfortunate, a poor use of a valuable, limited resource. Mexico does have its own natural gas reserves, although it is beginning to import more natural gas, when it could be exporting gas and receiving hard currency in exchange if it were using other energy sources for electricity generation. Mexico has some excellent renewable resources that could be mobilized—outstanding wind resources, as well as some geothermal, hydro and biomass resources. In this context, I’d like to touch very briefly on renewable energy certificates, which are part of a new electric-power valuing system that quantifies the environmental benefits of green power electricity.

“These certificates represent the ‘environmental value’ (separate from the kilowatt value) of power generated from renewable energy and can be sold as an option to purchase a certain amount of green power. They have the economic incentive of allowing some or all of the environmental benefits of the green power to be separated from the kilowatt. They are particularly important in Mexico where the encouragement to improve the environment and reduce pollution is strong.”
renewable electric plants. Renewable energy producers offer these certificates as a way for customers to help replace the environmental impacts of ‘dirty’ generation with clean, renewable energy and increase the production of green power electricity. These green certificates can be sold and offer a way for Mexico as well as developing countries in Central and South America to earn revenues by increasing renewable electric power.

“Renewable energy certificates are attractive to companies in the United States and Canada, who value them for a variety of reasons, including for tax benefits and for meeting environmental requirements. We’re increasingly living in a single world with a single environment and a single economy, where a green advance anywhere is a green advance everywhere. The viability of the certificate system rests on building a credible, standardized method of measurement and verification. At the Center for Resource Solutions we’re putting together for the western United States a system called WREGIS (Western Renewable Energy Generation Information System), for tracking renewable energy generation and issuing green-energy certificates. The WREGIS system will reach down into Northern Mexico and Baja California, giving Mexico an opportunity to begin renewable energy trading with the United States and helping to offset the initial extra cost of constructing renewable facilities. I’m hopeful that the renewable energy certificate program will aid Mexico environmentally and economically and encourage a shift to renewable electricity in both countries.”

The next questioner was Douglas Austin, chairman and chief executive officer of Austin Veum Robbins Partners.

**Austin:** “I want to ask Dr. Hamrin three questions about the slide she showed of the flat roof that was completely covered by voltaics:

- With a flat roof, how important is it that the panels are tilted in the right direction?
- Can you estimate the cost per square foot to cover a large area with photovoltaics?
- If you sign a long-term contract, are there companies that will pay the infrastructure cost of the voltaics and guarantee that the PV-produced energy will cost less than the current rate offered by utility companies?”

**Hamrin:** “As I said earlier, I’m not a technologist, and I’m not sure I can answer all of your questions, but I’ll try. Let me take them in order:

- It’s true that some efficiency is lost when photovoltaics are placed on a flat roof. There are companies that are now coming out with slightly tilted sets of panels for use on horizontal surfaces. The advantage of the flat-roof installation, as I understand it, is that there’s no penetration of the roof itself. A large portion of the price of PV systems is the installation cost, so ease of installation brings economic advantages, even if you have to add a few more PV panels to gain the same efficiency of PVs on pitched roofs.
- The cost for covering an area with photovoltaic cells is usually calculated in ‘peak watts.’ A peak watt is the maximum-rated output of a PV device, such as a solar cell or array, under standardized test conditions, which is usually about 1,000 watts per square meter of sunlight, with specifications for temperature and other atmospheric conditions. The price of PVs has been approximately
$7 per peak watt but there are systems now on the market that are selling for about $5 per peak watt. These prices include deductions for tax credits. There is talk in the PV industry that in the next decade PVs will go down drastically in price, to around a dollar a peak watt. That reduced cost would mean a dramatic breakthrough for PV installation and would reflect the increased scale of PV manufacturing we’ve been hearing about. Present plants produce between 10 and 30 megawatts of PVs a year, but apparently there are plants now on the drawing board that will manufacture 100 or even 500 megawatts per year. Such a large jump in production would substantially lower PV prices.

There are a number of companies that are offering customers the opportunity to amortize the initial cost of the PV system over a long period of time, rather than paying the entire amount up front. I do think that it is important that when comparing the price of PV-generated electricity with the utility company’s rate you remember to figure in the cost of the PV system and not just the PV’s maintenance cost of generating electricity.”

Bob Leach, a private investor, asked the panel a question concerning hydroelectric power and renewables.

**Leach:** “I noticed that all of the panelists failed to classify hydroelectric power as a renewable source of energy, and that strikes me as peculiar, considering that snow and rain fill the reservoirs and spin the electric turbines. I’m a suspicious person and I wonder if politicians are holding hydroelectric in reserve, in case the shift to renewables doesn’t go smoothly, so they can suddenly include hydroelectric to meet the mandated increase in renewable energy’s share of California’s total energy production. Why isn’t hydro classified now as a renewable energy source?”

**Hamrin:** “Hydro is absolutely classified as a renewable energy. But from the point of view of public policy and what can be done to increase our reliance on renewable energy, almost all of our resources for large-scale hydroelectric production are being used and have been used since the beginning of the era of widespread electricity generation. Large hydroelectric generation is relatively low in cost because of the economies of scale, and in the United States and the rest of North America most of the promising, large hydro sites have already been developed. Although you may see some ‘re-powering’ and other adjustments in the hydroelectric sector, these polices are not going to stimulate any more large hydroelectric projects.

“However, small hydroelectric generation is another matter and is being widely employed in China with micro- or mini-hydroelectric generators that don’t require dam sites. Where water for irrigation or domestic purposes falls by gravity, the water can be run through a turbine before it continues on its way. Again, these small generators are extremely popular in China—the Chinese manufacture some of the most beautiful mini-hydro turbines you’ve ever seen. They’re about this size [Hamrin measured a span with open arms] and are perfect for rural and small applications.

“Let me conclude my answer by emphasizing that when you study
California’s renewable portfolio standard you won’t find target increases for large hydroelectric generation because we’re already at or near capacity and we’re not going to develop any more big hydroelectric plants in our state. The targets we have for increased hydroelectric generation usually involve small hydroelectric installations, if they’re practically feasible. We need also to remember that there are environmental issues surrounding hydroelectric development and that in setting energy policy it is more difficult to get support for hydroelectric power than for many other renewables, because the proponents of renewable energy are very sensitive to any projects that might have the potential of causing ecological damage.”

Robert Caren, a California Council on Science and Technology Fellow, asked the next question.

Caren: “Could the panel address the problems in creating a hydrogen economy, especially in terms of moving hydrogen around the country in liquid or gaseous form, by pipeline or by other means?”

Jones asked Linda Trocki to respond.

Trocki: “Hydrogen could be piped or trucked. There is also extensive research being done on solid storage mechanisms that contain substances that can hold hydrogen, such as carbon buckey-balls or nano-tubes. To transport hydrogen by truck we would need seven times the number of fuel trucks that are currently transporting gasoline and diesel, which would probably mean seven times the current accident rate. I don’t think the transportation issue has been thoroughly studied. The research is moving ahead of the curve in terms of designing plants for hydrogen production but the problem of distribution hasn’t been sufficiently addressed.

“In terms of hydrogen car and truck manufacture, I believe that at first we’re going to see some relatively inefficient methods for developing hydrogen fuel-cell technology. And it will take time for economic incentives to grow strong enough to encourage industry to start producing hydrogen. The whole concept of hydrogen as a fuel needs to be seen as an entire system that includes production, storage and distribution.”

Turinsky: “The articles I’ve read suggest that converting our present oil-based transportation infrastructure to one that runs on hydrogen would take 40 to 50 years. A number of Department of Energy labs are working now on hydrogen transportation and storage. For years, our weapons scientists worked on a much more difficult storage problem involving tritium. The laboratories that worked on tritium storage are now working on how best to store hydrogen. The Savannah River lab has a very, very large hydrogen storage program because of its technology developed for handling tritium.”

Jones asked Martha Krebs for her perspective on hydrogen-fueled transportation.

Krebs: “I think that the governor’s hydrogen highway concept is a ‘big-step’ approach similar to Dr. Trocki’s descriptions of simultaneous development of infrastructure and hydrogen-fueled vehicles. In the near term, hydrogen development involves local production of hydrogen through methane steam reforming, then an evolution to renewables, probably solar thermal...”
"We’ve got to find ways to motivate our population toward conservation while we work to find technological solutions to our energy situation."

William Swanson
Raytheon Company

William Swanson, chairman and chief executive officer of the Raytheon Company, asked the next question.

Swanson: “I appreciate the panel presentations and the panel’s conclusion that there is no single answer to the energy crisis. But one element that I think has been missing in our discussion is the issue of human behavior, the energy problem’s immediate human component that perhaps Cal Poly can help address. By nature, most of us don’t conserve fuel or other natural resources. I think institutions can do more to educate Americans about the energy shortage, to emphasize that the problem is real and growing.

“What I’m talking about is the need to develop more of a ‘pull’ than a ‘push’ strategy in facing the dilemma of dwindling energy supplies. What I’ve heard today seems largely a ‘push’ that involves new energy technology outside the scope of the individual’s personal behavior. I think we’ve got to work harder to involve our citizens firsthand in conservation. We continue to go down the road, one person to a car, the lights in our houses burn all night long, we’re letting the water in our sinks and yards run too much. We’ve got to find ways to motivate our population toward conservation while we work to find technological solutions to our energy situation.”

Hamrin: “I think the Center for Resource Solutions’ Green-e program that labels renewable products promotes ‘pull’ behavior in the consumer. Anything we can do to encourage informed action concerning energy issues is a plus and I agree that we have to do more in education. However, informing the public about the reality of our predicament can be very dicey and requires careful thought. A week ago I attended a forum at UC Berkeley on climate change, at which the top scientists in the country talked candidly before a small, invitation-only audience. I was so depressed that the next day I could hardly get out of bed. The scientists’ bottom line is that we have 10 years to turn around the worsening climatic changes. If we don’t drastically alter our behavior, we’ll face irreversible changes that will cost us billions and billions of dollars and may result in the loss of many of our coastal cities and bring on a whole host of other huge, huge environmental and economic problems.

“But I don’t think that the dire message that I received is the message that we want to present to the public. We don’t want to make people feel more helpless than ever, that the problem is so overwhelming that there’s nothing we can do. We don’t want people to think that there’s no tomorrow and that they might as well consume all the remaining energy and resources now.

“An important part of the energy and environmental challenge is in crafting a message that communicates the seriousness of the problem but also presents alternatives that people can employ now as we continue working toward more sweeping and effective future energy alternatives. It’s a difficult thing to do, to keep that balance between delivering frightening warnings and encouraging practical behavior changes that will make an immediate improvement..."
and help forestall the coming crisis. We all need to send the right message, so people will have hope and a sense of purpose and will act in positive ways."

Swanson: “I mention the importance of education and individual involvement and responsibility because in a large organization it is very difficult to alter direction if you don’t have alignment along a single path and a burning platform for change. It’s very hard to reach a new goal if you don’t have numbers of people coming together in support of a clear-cut strategy for a change everyone agrees is necessary.”

Hamrin: “I agree.”

Tylor Middlestadt, president of Associated Students, Inc., at Cal Poly, asked the next question, after a brief description of his work in mobilizing fellow students in support of sustainable energy and conservation solutions.

Middlestadt: “I have a special interest in the role students can play in addressing the energy and environmental crisis and appreciate Mr. Swanson’s emphasis on the importance of changes in individual behavior. I was very honored that the Cal Poly president’s office included the booklet that my fellow students and I just completed, ‘The Student Guide to Sustainable Living,’ in your Baker Forum binders. We’re aware that our final product doesn’t address every pressing problem or find adequate resolutions for all the issues we focused on, but it’s the first attempt of our student volunteer project, which is funded by partners of the university and by supporters across the country. I was a founding member of Energy Action, the group that established the Campus Climate Challenge, and I was pleased to see Energy Action included in Dr. Hamrin’s list of sustainable energy and environmental organizations. There are literally tens of thousands of students nationwide who are eager to discover technological and policy solutions to the problems of shrinking oil supplies and a threatened global environment. That said, I would like to ask the panel a two-part question:

• As concerned students eager to work for energy and environmental answers, our biggest challenge is understanding why at some universities there is a shortfall in institutional and private-sector support for the students’ passion to pursue technical and policy solutions to the energy crisis. What should be the role of students in encouraging the university and private business to join forces in funding and supporting student efforts to address energy and ecology problems?
• How can we encourage privately and publicly owned businesses to invest more in research and development? I’m particularly interested in a recent action by Goldman Sachs, one of the largest banking institutions in America. Goldman Sachs has revised its entire environmental policy, earmarking billions of dollars for what it calls ‘Marginal Returns for Environmental Service Investment.’ Under this program Goldman Sachs finances businesses that return as little as 1- to 3-percent profit on investments, if the businesses are performing a service for the environment. Goldman Sachs is supporting Sun Edison—a company we’re working with on our Cal Poly campus—with a $60-million guarantee for photovoltaic-site lease agreements, and recently purchased

"What should be the role of students in encouraging the university and private business to join forces in funding and supporting student efforts to address energy and ecology problems?"

Tylor Middlestadt
Associated Students, Inc.
one of the largest remaining old-growth forests in Chile, then gave the forest to the Chilean government for preservation in perpetuity.

“I suppose my real question is: How can students use their enormous but still largely untapped potential for research and development as a means of inspiring positive changes in the business sector?”

Jones: “Who would like to respond to Tylor’s challenge that the university and business community enlist him and his fellow students to help find solutions to the serious energy problems we’ve all been discussing?”

Hamrin: “I think Tylor has already begun answering a part of his own question. With the Campus Climate Challenge you are moving forward in ways that are in the best tradition of committed student activism and that are valuable for the health of our culture. You’re bringing neglected vital issues to the attention of the university and demanding institutional behavior changes. As human beings, we all have a tendency to rationalize after the fact the reasons that we worked for a needed change, to tell ourselves that any number of moral principles dictated our actions whether or not we were actually noble or even receptive at the time the cultural change first began. But in the end, it’s not terribly important what exact conditions motivated any of us to start in a new and wiser direction, or whether we moved voluntarily or eagerly or instead felt pressured or harassed into action. The essential point is that we get the right things moving down the right road and I think university students in the United States will continue to play a really crucial role in raising public awareness about pressing issues and possible solutions.

“Part of the Campus Climate Challenge is to encourage the inclusion of solar energy concepts in new buildings and I know Cal Poly has won awards for innovative architectural designs that integrate solar power. Now it would be nice to have some of these new buildings constructed right here on the Cal Poly campus, so students and local residents could not only read newspaper articles about the university winning an architectural or sustainable energy prize but actually observe these buildings firsthand and see how they function and that people are living and working in these new designs. Tylor has already done a great job here at Cal Poly and now it’s time to take the effort to the next level and find creative ways to make important new ideas concrete local realities. People need to be able to ‘kick the tires,’ to see that we have real options that can be built and used, and I think students and teachers and administrators within the university have an opportunity to make sustainable energy technology something that our citizens can see and touch and imagine as a workable and even attractive alternative.

“Finally, let me say that if my friend Nancy Floyd were here I think she would tell you that financial investment in renewables is one of America’s rapidly expanding areas of economic activity, that now there is more money searching for good projects than there are good projects without funding. A shift has begun within the investment community, a growing awareness that clean energy is the way of the future and that those who invest at the beginning of this move to sustainable energy sources will be the ones who make the large profits.

“This change in outlook among investors started slowly, because the dimensions
of the market weren’t clear, and now the market is swiftly evolving. Investment could be further encouraged if we had positive and stable long-term government policies that assured the new market’s future development and profitability. But clean energy will remain an increasingly attractive financial opportunity in this country as well as around the globe. In fact, investment in alternative energy technology is currently greater in Europe and Japan than it is in the United States. Japan and Germany are each out-investing America in clean energy, an area of technology that the U.S. and California were leaders in during the ‘80s and early ‘90s before we lost our momentum. Those people who are interested both in investment profits and in ensuring that our state and nation return to the forefront of the sustainable energy wave need to make sure money continues to be available so that our domestic effort moves to the fast track again.”

Jones: “Do other panelists want to comment on Tylor’s call to action or add to Dr. Hamrin’s response?”

Krebs: “I think the course that Dr. Hamrin is describing is embodied in the mantra ‘Think Globally, Act Locally,’ a perspective that I agree with and believe is terribly important. I think that the development of new technologies is crucial in successfully confronting the energy crisis, and that improving and streamlining energy technologies and reducing their costs will ultimately bring them into wide use.

“In the meantime, as Bill Swanson has indicated, too many of us are ignoring our growing energy and environmental problems and not taking personal responsibility to do our part in lessening them. I think we’re talking about the need for social and political activism, for institution building. For students this means working hard to build more responsive institutions while you’re here at the university, then maintaining connections with your college after you’ve entered the larger society. You have to build something now, so that the students who follow you will continue your activism and the important interactions with faculty, who also have an obligation to help sustain the causes that students have championed. And when students graduate and work for companies or businesses and become members of communities, they need to carry on their activism and speak to the people who are going to be making the local decisions and investments.

“There are no simple answers to the ongoing problems that confront us, but the underlining theme has to be our commitment to larger-scale goals, the global through the local. I’ve worked in the federal sector for most of my career and understand how very hard it is to set at a national level the kinds of goals that California has been able to establish and expand. California’s effort to maintain manageable levels of per capita electricity use is an example of successful goal setting, of committing to a goal and then setting even more ambitious goals and striving to reach them. Difficult goals aren’t easy to reach and in my presentation I tried to acknowledge the real challenges we face. But we need to insist that our political and organizational leaders establish needed goals and then work continuously at the hard institutional problems to at least make progress, before we are faced with an energy or environmental disaster. For students, setting goals and working to achieve them begins at places like Cal Poly and will have

When students graduate and work for companies or businesses and become members of communities, they need to carry on their activism and speak to the people who are going to be making the local decisions and investments.”

Martha Krebs
"We need to insist that our political and organizational leaders establish needed goals and then work continuously to at least make progress, before we are faced with an energy or environmental disaster."

Martha Krebs

Jones called on Bob Leach, who posed a question to Martha Krebs.

**Leach:** “You emphasized in your presentation the relative fragility of California’s electricity distribution network, that it’s presently ‘tapped out’ and that even if we had more sustainable energy production we wouldn’t be able to move the clean electricity efficiently between the point of generation and the point of use. You also mentioned that one of the state’s largest consumers of electricity is the pumping plant south of Bakersfield, the one that pushes water over the Tehachapi Mountains to the Los Angeles basin. I know that there are obvious political issues involved, but has anyone thought of building a nuclear power plant beside the pumping station, to remove the station’s large electricity demand from the distribution grid?”

**Krebs:** “Absolutely. At the level of both policy and systems engineering, the Energy Commission, with consultation from the Public Utilities Commission, has taken up the issue of ‘distributed’ energy generation (also known as ‘regional’ generation or ‘systems dispatch’), the on-site production of electricity by consumers to meet their own energy needs. An important part of the discussion on how to relieve congestion of the transmission system concerns whether we should have generating facilities near large consumers of electricity like major pumping stations, and if so, how do we both site and build these generating facilities.

“The question goes beyond whether to locate a generating facility next to a pumping station and involves the general use of distributed electricity generation, particularly in Southern California, where there are especially serious air quality concerns. Within the California Energy Commission’s PIER program—the Public Interest Energy Research program—we’ve been looking at issues surrounding distributed generation, which include the need to lessen the negative impact on air quality of some current distributed-generation technology. We’re using air emissions computer modeling and developing new computer modeling techniques to examine the potential impact of distributed power generation on the L.A. basin and other areas.

“We’ve also been investigating ways that we might increase the capacity of the existing transmission right-of-ways, for example, by using new, better transmission lines that can withstand the high temperatures that are usually the cause of power outages.”

**Turinsky:** “In reference to locating a nuclear plant by the pumping station in the Tehachapi Mountains, I would say that for a facility like a major pumping plant that needs baseload power—a large, steady, minimum energy supply—on-site nuclear power makes sense. Nuclear power could be used to move water in large water projects or to pump water for storage in reservoirs for hydroelectric use. But in the United States it has become impossible to get nuclear plants approved at pumping sites. We used to be able to site-pump water to build hydroelectric storage capability but that practice is no longer a reality in the United States.”

The last questioner was Keith Fox, founder and former CEO of Brandsoft, Inc.

**Fox:** “Before I put my question to the panelists I’d first like to briefly present
an analogy. In the world of computers, two basic philosophies competed for dominance, and the advantages and disadvantages of the opposing approaches were compared and debated. The contest was between the mainframe computer and the personal computer, between centralized and distributed computer power. When personal computers appeared on the market there were disagreements about how much computing power was required for a business, for the macro-level of operation, which might be compared to the large-scale electricity generation and distribution we’ve been discussing. Over time the choice between the large, central computer and the many smaller, personal computers was resolved—it was agreed that we needed both approaches. However, it seems to me that when you have to build an ‘architecture,’ a practical, working system, you’re making a philosophical choice for one approach or the other. I would like to ask our panelists if they are ‘centralists’ who favor a small number of large power plants that supply a central power grid or ‘distributionists’ who favor many small power-generation stations located at any number of sites?"

**Jones:** “I think that’s a good question for our panelists and a good way to end our question-and-answer session.”

**Trocki:** “In the energy industry we don’t operate under a Moore’s Law, which holds that the number of transistors on a chip will double about every two years. The choice between centralized and distributed power generation is not easy to address, although I do think that we need a mixture of large and small electricity producers. Bechtel, my company, excels at building large, complex projects—while we’re very supportive of distributed generation we’re not necessarily going to enter that market but we will be building nuclear power plants or coal-fired power plants or other large, central facilities.”

**Turinsky:** “I’m not sure the computer/power generation analogy works. Packets—the small pieces of a message for transmission through a computer network—and electric rays are quite different. Computers use queuing theory—the mathematical study of waiting lines or queues—and generators run on dynamic principles of electrical engineering, so I think the basic analogy may not be applicable to power generation.”

**Krebs:** “I’m in favor of a mixed system. I think that’s what we’ll have during the transition from oil as a primary energy source as well as in the long run, when we’ll rely on a number of energy production technologies.”

**Hamrin:** “We obviously have to have a mixed system, because that’s what we’re building from now, but I do think we’ll see the growing development of the distributed system. We now have central power plants, centralized electricity generation and distribution, but we don’t yet have a system of distributed generation. I believe that the area of growth in electricity production will be in decentralized facilities, particularly in on-site generation from photovoltaics and other sustainable technologies. Decentralized power is where we’ll be going in the future, but because of the longevity of stocks for traditional power plants already in existence it is not likely that we will see a completely decentralized system. For the foreseeable future we’ll have a mixed system, but the
big changes in power generation over the next couple of decades will come from the side of distributed energy production."

**Krebs:** “I want to say a final word about electricity generation, but in terms of how electricity is distributed through the power grid. I want to mention ‘demand response’ and ‘load shedding,’ terms that refer to electricity customers reducing their power consumption during periods of peak demand and/or in response to fluctuating market prices. I think we need a more sophisticated electricity distribution system that allows for better communication with individual customers, so that when necessary we can efficiently coordinate load shedding in a way that makes more power available to the grid without interference with commercial production or the quality of life of residential electricity users. There are important systems issues to analyze and work out but our goal is to begin looking at load shedding as a ‘generating source,’ as a new power resource for the grid rather than as a response to its vulnerability. We’re now exploring load shedding as a positive aspect rather than as the reflection of an electricity deficit, an approach which requires a new and different way of thinking about our electricity system.”
BREAKOUT SESSIONS
Cabinet Chairman Richard F. Hartung, of the Sonoma Consulting Group, thanked participants in the three breakout sessions for their efforts to identify energy and environmental policy proposals for Cal Poly, in response to David Goodstein’s keynote speech and the four panel presentations.

Hartung then asked Ronald Smith, sector vice president, Six Sigma, Northrop Grumman, to provide a report on sustainable transportation options from Breakout Session #1.

**BREAKOUT SESSION #1: SUSTAINABLE OPTIONS FOR TRANSPORTATION**

“Our team agreed that there is no single, universally applicable solution to the energy/transportation problem, that the solution will necessarily be multi-tiered and require the efforts of many different disciplines. The complex solution to this complex problem will involve more than new technologies and include work in politics and policy that will affect a whole range of energy, environmental and infrastructure decisions.

“We believe that the transportation problem has both short- and long-term implications and that we need to consider both short- and long-term solutions. For example, there are probably some ‘efficiencies,’ what we called ‘quick hits,’ that can be implemented in the near term to reduce our dependency on foreign oil and conserve our domestic energy reserves, while we work on more long-term solutions based on alternative fuel and energy systems.

“In terms of priorities and approaches for Cal Poly, we suggest the following:

- Enhancing Cal Poly facilities and infrastructure and mobilizing students and faculty for a joint effort with private industry to develop prototype energy technologies and further develop the university’s learn-by-doing environment. Consistent with Cal Poly’s hands-on philosophy, our suggestion is to create an educational setting that encourages transportation research and development by allowing industry access to the university so that companies can work with students and professors to discover and test new energy-technology solutions. Our conception includes not only the ‘thought’ aspects of creation but also the testing phases, a complete path from idea to demonstration with the goal of finding practical, technical transportation breakthroughs in response to the ongoing energy crisis.

- Employing Cal Poly’s multi-disciplinary resources to support and expand projects like the Solar Decathlon and to increase collaboration with private companies and industry. Cal Poly’s applied professional programs offer opportunities for the university to bring to bear a range of skills and expertise to solve both near- and long-term transportation, energy and environmental problems. For example, we’ve discussed the possible establishment of a new cross-disciplinary department or center, something that might be called the Cal Poly Energy Department—or perhaps a Cal Poly ‘Energy Track’ course of study—to engage different schools in focusing
BREAKOUT SESSION #2: SUSTAINABLE OPTIONS FOR THE BUILT ENVIRONMENT

“Facts concerning Cal Poly and sustainability then evolved into broader, more fundamental questions:

• Do we need to change our approach?
to energy and the environment?
• Do we really accept that this change is a pressing need?

“The team’s answer to both questions was yes, for the reason that we need to protect the future—the future of our students and our children and our children’s children and of every generation.

“We then began posing even wider questions:
• What is our vision for a better future?
• Is our vision realistic?

“As our conversations developed and became more far-ranging, we became aware of the importance of semantics, of how the words we used to speak about energy and environmental issues influenced the direction and emphasis of our discussion. We soon realized that even the term ‘sustainability’ could be a lightning rod for controversy and mean different things to different people—our team comprised a broad spectrum of professionals, including representatives from industry and business as well as academics from the university. We discovered that the word ‘sustainability’ has accrued different connotations, that many varied and sometimes conflicting implications have become attached to the word. It is apparent that communication is going to be a key element in working on and solving energy and environmental questions, that words are going to be very important because their practical definitions and references differ from one person and profession to another.

“The topic of semantics and effective communication seemed especially pertinent because Cal Poly is a polytechnic institution that focuses on solutions. Our team felt that we needed to look beyond the different disciplines at Cal Poly and reach out to the broader community beyond the university. Rob Rossi, a San Luis Obispo businessman and developer and a member of the Cal Poly President’s Cabinet, echoed earlier remarks made by President Baker concerning the frustration attendant in recognizing a problem but being unable to gain a consensus for a solution—as exemplified by the continued scarcity of affordable housing for faculty members Cal Poly must attract to the university. Rush Hill, chairman of The Hill Partnership, Inc., Architects, and chair of the Orfalea College of Business Dean’s Advisory Council, also voiced his concern about the availability of faculty housing, a problem that was recognized as early as 1978.

“The local housing dilemma, which involves overlapping concerns that have been difficult to address in a way satisfactory to a number of different interests, can serve as a metaphor for our need to reach out beyond our own community within the university to the greater community beyond the campus. To find effective solutions for any number of issues, we’re going to have to understand a diverse range of perspectives held by people from many backgrounds and philosophical points of view and learn to communicate in language that is sensitive to our differences and a medium for agreement.

“In terms of conclusions and specific suggestions, our team determined that our own built environment on
the Cal Poly campus should be our pedagogy, our strategy in teaching Cal Poly students about building sustainable environments. We believe we should practice what we preach—the buildings that we’re constructing now and will construct in the future should be among the best examples of sustainable built environments, as we continue to increase our commitment to building and operating our facilities with renewable resources. And we think that there should be a Cal Poly policy on renewables that is in alignment with and goes beyond the broader policy that has recently been established within the California State University system.

“A large portion of our discussion that concerned reducing our consumption of nonrenewable resources dealt with changing our habits of energy use. The conversation included student participation that helped us to acknowledge that most of us aren’t doing enough to conserve vital energy resources, that we often fail to practice routine, ‘small’ acts of conservation such as turning our lights off at night. We learned that each Cal Poly student arrives on campus with approximately 16 electrical devices, and in considering that some of these machines run all night we began to conceive of the vast amount of energy used at the university. We agreed that we need to develop guidelines to encourage a greater reliance on renewable energy, but that we should also increase our efforts to use less of the nonrenewable energy that we presently consume. We’re all members of a ‘generation of waste’ and we all have to make a number of fundamental changes in the way we use valuable resources.

“With the buildings about to be constructed on campus and the resulting changes in the environment the new buildings will bring, Cal Poly has immediate opportunities to conserve resources as well as to teach our students firsthand those sustainable built-environment techniques and approaches that our society will have to incorporate. Our team emphasized the importance of understanding Cal Poly’s ecological footprint, of studying and assessing the university’s impact on and relationship with the environment, and then committing ourselves in intelligent and practical ways to creating a green environment. We will need to set specific building standards that include U.S. Green Building Council’s Leadership in Energy and Environmental Design (LEED) certification for new construction projects.

“Finally, our team came to two general conclusions, to guide us into the future:

• We should study and remember previous cultures and their successful relationship to the environment—especially the American Indian community that preceded us here on the Central Coast. The Chumash lived in tune with nature, and their heritage provides abiding environmental lessons we can learn despite the span of time that separates our world from theirs.

• Communication is of utmost importance in bringing different constituencies together in protecting our environment, and Cal Poly students may be the most effective spokespeople in convincing all of us that we have to improve the ways we interact with our natural world, if we are going to conserve the resources
we depend upon for our survival and that of our children and their children."

Tom Jones, dean of Cal Poly’s College of Architecture and Environmental Design, next offered concluding remarks.

“Let me add a few brief, but think important, points that reflect the underpinning of our team’s conversations and conclusions:

• We need to acknowledge, share and celebrate the many very good things that Cal Poly faculty and students are already doing in the areas of transportation and built-environment study and practical research. When we speak of promoting campus best practices and of fostering greater communication and cooperation among the different Cal Poly colleges and with the world beyond the university, we first need to educate ourselves—our students and faculty, members of the Cal Poly President’s Cabinet, friends and alumni of the university, and the surrounding community beyond our campus—about the many things that Cal Poly already does well.

• We have to admit the impediments we face at Cal Poly in seeking sustainability solutions: an overburdened physical facility, overworked faculty and staff, and inadequate state resources. As sometimes occurs in the corporate sector, Cal Poly lacks adequate financial resources to ‘front end’ investments in energy-saving, sustainable projects and to pay for research to discover new energy technologies.

• To overcome our financial shortfall for pursuing sustainability solutions, we must involve everyone on the Cal Poly campus in a discussion that identifies the most promising sustainability projects and the most likely ways to fund them. Increased communication across different disciplines and collaboration around a few selected projects will provide a breakthrough for Cal Poly faculty and students in better understanding and valuing the work done in other areas of study and in realizing the important contributions other disciplines can contribute toward reaching a common goal.

• We’re all involved in a truly campuswide endeavor. We should remember that every college has students interested in the built environment and that the concerted effort to find sustainable ways to interact with our natural surroundings is necessarily wide in scope and reaches beyond the important work being done at the College of Architecture and Environmental Design.”

Hartung next introduced the speaker for Breakout Session #3, Elin D. Miller, former president and CEO, Arvesta Corporation, Arysta LifeScience, who commented on sustainable options for natural and agricultural resource management.

BREAKOUT SESSION #3: SUSTAINABLE OPTIONS FOR NATURAL AND AGRICULTURAL RESOURCE MANAGEMENT

“Our focus began with Cal Poly’s College of Agriculture and broadened to consider sustainable solutions for global energy and agriculture issues and the environmental
challenges to creating sustainable agricultural policies and practices.

“First, David Wehner, dean of the College of Agriculture, and his associates outlined the work on sustainable agriculture presently under way at their college. Their presentation described:

- Restoration and stabilization activities that include water-quality management and the handling of waste waters, particularly from dairy, as well as improved grazing practices for erosion control
- Organic farming and ranching methods employed to raise and sell to the community organically grown produce and meat
- A sustainable agriculture resource consortium that consists of faculty members working on sustainability projects with the community and industry and integrating these projects into instructional activities
- A land exchange program that emphasizes the importance of riparian filters for water quality and addresses related agricultural environmental issues
- Intensive studies in improving irrigation efficiency to conserve water resources and reduce energy consumption for water production
- Cal Poly’s Swanton Pacific Ranch near Santa Cruz, which offers hands-on study in sustainable forestry and farming practices
- The college’s earth management and protection major and the earth sciences major, as well as extensive class offerings in sustainable agriculture

“Our team’s ensuing discussion then led to two major, general propositions:

- Cal Poly’s sustainability efforts should focus on solving the big, industry-related problems first.
- Sustainability solutions are complex and will require an approach that integrates the efforts of Cal Poly’s colleges of Agriculture, Science and Mathematics, Engineering, and Architecture and Environmental Design, and increases cooperation among the university, government and private industry.

“Under the rubric of these two guiding ideas for achieving sustainability, our team prepared the following recommendations that we hope the university will consider:

- Agree upon a complete, clearly stated definition of ‘sustainability’ as a branding identification to promote Cal Poly sustainability programs, policies and ideas
- Increase communication between Cal Poly and the farmers in the Central Valley, California’s major agricultural region, perhaps through the creation of a forum in the Valley where farmers and Cal Poly faculty can exchange vital energy and environmental information and discuss the main sustainability issues that need to be confronted and solved
- Work with farmers on issues concerning utilities and California’s Public Utility Commission
- Schedule professional sustainability conferences, not only technical forums but also gatherings of executives from industry and business, that will create opportunities for Cal Poly to develop partnerships and clearly define real-world applications of academic study and research
- Seek opportunities to work with business and industry in the area of alternative energy production,
emphasizing Cal Poly as a potential leader in discovering ways to use agricultural waste as a sustainable and money-saving source of energy
• Establish curriculum and programs that emphasize sustainable agricultural practices and the wise use of energy and other natural resources as a basic aspect of food production and a key element in the economics of agriculture
• Foster partnerships with Latin American universities—like Cal Poly’s partnership with EARTH University in Costa Rica—to encourage sustainability practices and policies throughout the Americas
• Research nonpolluting methods for turning rangeland biomass into energy
• Encourage multiple, sustainable uses for agricultural land, especially energy generation using wind and solar resources
• Apply Cal Poly’s effective learn-by-doing approach to the study of bio-fuel technology, especially the use of soy and other vegetable oils, to help reduce our reliance on petroleum products
• Create teams made up of Cal Poly faculty and the faculty from other universities to explore the development of bio-based fuels and products
• Engage faculty and students from the College of Science and Mathematics in the development of sustainable agricultural practices and technologies
• Encourage and support student enterprise projects that involve new bio-technologies and sustainable agricultural methods
• Create demonstration projects like the dairy project, which uses algae in biomass production
• Investigate opportunities for Cal Poly to play a role in studying and helping resolve issues concerning the levee system in the Sacramento River Delta
• Encourage the use of Radio Frequency Identification (RFID) technologies to aid the cattle industry in tracking cattle and identifying organic beef
• Develop pilot programs like the five-week Cal Poly course in sustainable forestry at Swanton Pacific Ranch taught by leaders from government, industry and public-interest groups
• Underline in course offerings and in partnerships among Cal Poly colleges the importance of clean energy.”

Hartung thanked the presenters for their reports and next invited questions from forum participants.

QUESTIONS AND ANSWERS

Jaime Oaxaca: “Once again Cal Poly—and the President’s Cabinet and the university’s excellent faculty—has shown itself a national pacesetter in confronting crucial national and global challenges. This very special Baker Forum will allow Cal Poly to take its place as a leader in the conversation on energy that will continue in other states and regions across the country. I suggest that the university make a concerted effort to widely communicate the forum’s proceedings through the media so that the larger public can learn what we’ve learned.”

Douglas Austin: “I’d like to make a comment about the challenge we received last night from Dr. Goodstein. I don’t know if the challenge was aimed directly at us but I think we should accept it, especially in terms of Dr. Goodstein’s hope that we might find a national leader who in the area of new energy technology would duplicate John Kennedy’s commitment
to reach the moon within the decade of the 1960s. I think we need to accept our portion of responsibility for finding sustainable energy alternatives and discover how Cal Poly as an institution can lead in this effort. We’re unique here at Cal Poly, and we are watched by the wider world—we shouldn’t take this opportunity lightly but should formulate some very specific energy goals and then set a practical example for others. By setting the right tone at Cal Poly and influencing other institutions and individuals beyond the university, we can help create the atmosphere that will allow the right national leader on energy issues to emerge. Informed leadership is very necessary because, in answer to Breakout Session #2’s question as to whether we need to change our approach to energy and the environment, I believe we do. That’s my personal view.”

Hartung: “I think what’s lacking in our efforts to confront the energy and environmental dilemma is political will, not at Cal Poly but in the country as a whole. As Americans, we don’t have the political will, we don’t have the committed national leader to whom you referred, and we don’t have a political party willing to openly identify itself with the promotion of sustainable energy and environmental measures. In the realm of politics, we hear much talk about energy sustainability but the positions taken by politicians and their parties and the ensuing public discussion involve only tactical, short-term approaches, instead of long-term strategies that address our country’s long-term energy problems and that might provide real solutions.

“I think it is incumbent upon all of us to turn up the heat on the politicians. When a politician says, for example, ‘This is what I’m going to do about preschool,’ we need to answer, ‘Yes, that’s very important, but what are you going to do about energy?’ We need to keep telling politicians that we’re very concerned about energy issues and that we want to know what their energy policies are. If we can pressure one political party to take a stand on energy, the public will become attracted, and the other party will have to take up energy as a serious issue. We need both parties to understand the importance of the energy problem and work for intelligent solutions, so that in energy matters the fate of our country doesn’t depend on which party is in office.

“In Dr. Goodstein’s address there was reference to President Kennedy’s Apollo Project that took the United States to the moon. Americans were motivated by the fact that the Russians might beat us to the moon, and suddenly we all decided we needed to get there first and supported the space program. And before Kennedy’s race to the moon there was the Manhattan Project, the crash program to build the atomic bomb. Perhaps a similar massive effort could be undertaken now to develop sustainable energy technologies, if we could summon wide public support that would demand government commitment and funding.

“Now, how do we build public support for a national effort to achieve sustainable energy technology? Earlier today, one of our Cal Poly undergraduates asked, ‘As students, how can we work for sustainable energy and protect our environment?’ One of the best things that the university can do is to produce graduates who are ‘energy zealots,’ not irrational extremists that hurt the cause of sustainability but informed and committed people who will insist on the importance of clean
energy and do everything they can in their professional lives to promote sustainable technologies and practices.

“We need Cal Poly graduates who will say to their political representatives, ‘Energy issues are important to me. I want to hear what you’re going to do to help our country shift from a reliance on oil to sustainable energy sources. I’m not interested in hearing that you’re going to give me a hundred-dollar rebate because the price of gasoline has gone up. In the months ahead, what actions will you take to address the energy problem?’

“And all of us in the room can do something. Many of you are leaders, chairpersons and presidents who are listened to by your boards of directors and by your employees. If we all preach the message of sustainability, if we all really believe that we need to change our destructive habits of energy consumption, then we can exert a powerful influence in getting people to acknowledge the reality of the energy and environmental crisis.

“Earlier, Dr. Hamrin mentioned that at a recent UC Berkeley conference on climate she had learned that we have only 10 years to stop polluting the atmosphere before we cause irreversible damage to our environment that will endanger our coastal cities and ruin our economy. Our response to such a dire warning can be, ‘Oh yes, I’ve heard this doomsday talk before, another 10 years and everything will fall apart,’ or we can really take the informed scientists at their word, believe what they’re telling us, and work to avoid the catastrophe.

“If all of us at this forum have the desire to save our environment and move our country from oil to sustainable energy sources, and if we talk to our family and friends and fellow students and associates about the importance of developing sustainable technologies and policies, perhaps we can begin to mobilize public opinion and awaken the political will that is necessary to make the energy crisis a pressing national issue.”

Bob Leach: “There’s an important piece of implementation work that Cal Poly can perform and that’s to produce a position paper on sustainable energy. As those of us who work in the commercial world know, if you’re going to present a product or policy that will dramatically change a portion of your industry or the way your company addresses the marketplace, you need a well-defined position paper so that everyone in your organization can speak with a consistent point of view in business negotiations, promotion work and in interacting with the media. The consistency in the way we deliver our message and refer to its specific details helps create a brand recognition, a sense among the public that we speak with authority and informed knowledge. Suddenly we own the topic, the market for our service or commodity or idea.

“I think that producing a position paper on energy and the environment would educate our students and provide them with a clearly stated and comprehensive point of view on sustainability issues that they could take with them when they leave Cal Poly and enter the world of the marketplace. If we don’t construct a position paper, then all of us are left to offer our individual ideas and proposals, and the chances of our presenting a consistent strategy for effective action to the wider public are zero. I believe that if we’re going to succeed at mobilizing public opinion on energy issues we have to persuasively deliver a consistent message that has real impact.”

Robert Leach
Private Investor

"If we’re going to succeed at mobilizing public opinion on energy issues, we have to persuasively deliver a consistent message that has real impact."

Robert Leach
Private Investor
persuasively deliver a consistent message that has real impact, and repeat the same points again and again until they gain acceptance. If we can create a position paper that we can each make our own and then deliver as our own, I think that we would generate the beginning of the kind of political influence that we’ve been talking about.”

Keith Fox: “I think a position paper would lend support to the approach that Doug Austin suggested, which would implement sustainability and conservation technology in every new building at Cal Poly, so that the university would become a model for the ideas that it teaches and promotes. Our campus should be a perfect example of the sustainable techniques and policies we’ve learned about at this forum. A position paper would not only present our ideas on sustainable energy and the environment but also point to the Cal Poly campus as an example of these ideas put into practice. We would not have to wait for politicians or public opinion but could immediately begin making decisions on sustainability here at Cal Poly, so that the university’s position on energy and the environment would become self-evident and everyone could see that Cal Poly’s learn-by-doing philosophy and its polytechnic structure had become a model of energy sustainability. A position paper would then both promote and reflect Cal Poly’s commitment to clean sources of energy and a sustainable environment.”

Hartung: “Maybe the Cal Poly President’s Cabinet could work with the student body to implement the idea.”

Tylor Middlestadt: “In answering a question about financial investment in alternative-energy research and development, Dr. Hamrin said that she believed that there was more money available for good sustainability projects than there were good sustainability projects in need of funding. At Cal Poly we have a unique opportunity with our intellectual resources and our laboratories and other facilities to gain the attention of foundations, government agencies, investors or business partners and persuade them that Cal Poly could become a model environment where sustainable energy technology is both developed and implemented.”

Hartung: “President Baker, may I ask for your comments on the points we’ve been discussing?”

Warren Baker: “Let me first express my appreciation to all of you who have taken part in our third forum. In response to our present conversation, I want to note that among the many benefits of the two previous forums was the production of action agendas.

“The first forum focused on critical path analysis concerning the math, science and technology environment in California and had a number of dimensions, including the cultivation of human resources—the training of future scientists, engineers, technicians and science and math teachers—and the current state of innovative research and development within the United States. That forum led to a number of conclusions that helped shape decisions within Cal Poly and impacted the ways we conduct our outreach to future students, how we manage our enrollment in terms of academic disciplines, and our selection of new programs we need to develop. For example, we began a biomedical engineering program and placed greater emphasis on biotechnology, joining the efforts of several of our
colleges in an interdisciplinary fashion. The new awareness stimulated by the forum and the adjustments we then put in place resulted in a number of public and private partnerships in the middle-ground, applied-research arena that have successfully engaged our faculty and students.

“Participants at the second forum analyzed in greater detail some of the root issues surrounding the ‘pipeline,’ our country’s supply of future scientists and mathematicians and engineers. We looked closely at math and science education, discovered where the serious concerns were, and discussed possible solutions and means for reaching them. This second forum resulted in Cal Poly’s development of the Center for Excellence in Science and Math Education, which will devote special emphasis to innovation in science and math instruction. One of the unique features that we’re trying to develop as one of the center’s planned areas of focus is a partnership with the business community. This partnership will help train teachers who understand how to excite and inform their students about the range of careers that are available in science and mathematics and the opportunities that they can look forward to in working in business and industry.

“This year’s forum has been very exciting to me, especially because here at Cal Poly we’ve been conducting an ongoing conversation for well over a year about sustainability. Students and faculty have been engaged in dialogue concerning Cal Poly’s own particular sustainable energy issues, about how sustainability ideas interact with technology and culture here on campus and about the kinds of adjustments we should make within our curriculum to better respond to our country’s and the world’s pressing energy and environmental concerns. Our wide-ranging discussions have begun to come together and crystallize. And the advice and counsel forum participants have presented today are in many ways similar to lines of thought we’ve been following.

“At Cal Poly, we’ve been asking ourselves how best to develop public and private partnerships to pursue energy and environmental solutions."

Warren J. Baker
Cal Poly President
I’d like to ask that in the next year or two someone assess the positive actions that result from this forum and share them with us.

Neal MacDougall
Cal Poly
College of Agriculture

Departments in our colleges of Agriculture and Engineering, and the College of Architecture and Environmental Design is directly addressing the subject of the built environment. These areas of study are underpinned by Cal Poly’s College of Science and Mathematics. And we have the ability to mobilize the liberal arts—earlier today I mentioned a Center for Practical Politics, because reaching solutions to the energy and environmental crisis will require strenuous, patient and imaginative efforts in practical politics. Once more, I expect positive action will be the result of this forum and I appreciate very much the contributions all of you have made.

Bob Detweiler: “I don’t want to miss the opportunity for promoting a longer-term result from what’s been an excellent Baker Forum. I suggest that we produce a white paper that could be endorsed by the Cal Poly President’s Cabinet and the leaders of the university, a position paper for the Cal Poly campus that would lay out a policy and a strategy for dealing with energy and sustainability issues. I recommend that a subgroup of the cabinet be appointed to draft a white paper that can be submitted to the cabinet at large for its approval and support.”

Hartung: “I think your idea is a good way to concretely follow up on the previous position paper proposal.”

Neal MacDougall: “President Baker mentioned the positive follow-through efforts after the previous Baker Forums. I didn’t attend the first two forums and wasn’t aware of all the Cal Poly programs in different disciplines that have been set in motion. I’d like to ask that in the next year or two someone assess the positive actions that result from this forum and share them with us. As a member of the College of Agriculture, I’d like to know what the College of Architecture and Environmental Design, the College of Business, the College of Engineering and the other colleges have achieved since we met together at the forum. I think that sharing that information is important, so that we all know the successes in the different disciplines. Sharing each college’s progress makes our work a Cal Poly rather than a college-specific effort.”

Hartung: “Are you looking specifically for the follow-up on the previous forums?”

MacDougall: “I suppose I’m emphasizing the importance of recording and analyzing the actual follow-through from this and future forums. After participating in this year’s forum I would like to know and be able to tell other people the concrete goals and efforts and accomplishments that resulted from our meeting and dialogue. If a white paper is written, I’d like to know if its suggested policies and goals were successfully put into action.”

Hartung: “That’s a fair response.

“If there aren’t any other final comments, I’d like to say that like Jaime Oaxaca I’ve attended all three of the Baker Forums and I think this one has been very, very good, beginning with a very inspirational keynote speaker who I’m sure has motivated many in his audience. I don’t know if you’re aware that between 50 and 60 people were unable to find seats inside the auditorium and stood outside the doors, listening from the lobby. Dr. Goodstein was an excellent choice and his cogent speech that addressed pressing and difficult global energy and environmental issues had a powerful impact.

“I also want to say that our forum...
panelists were especially good this year. All of the presenters are obviously very knowledgeable and their different perspectives fit together nicely to give the audience a wide view of our energy and sustainability challenges and their possible solutions. I thought the discussion period after the panelists’ presentations was excellent—the many informed questions helped lay out the groundwork for the breakout sessions that followed.

“Now, if we can set to work on the follow-up efforts—agree upon our specific goals and then meet them and allow others to see and benefit from the positive outcome of our dialogue—we will all be proud of our participation in this year’s important Baker Forum. Once again, the concrete results of our meeting will determine its ultimate worth: I am committed to achieving our objectives on sustainable energy and environmental issues and I know President Baker and his staff will aid our efforts in every way possible.”

"If we can set to work on the follow-up efforts —agree upon our specific goals and then meet them—we will all be proud of our participation in this year’s important Baker Forum."

Richard Hartung
Among the many benefits of the three public policy forums the President’s Cabinet has convened to date at Cal Poly has been the production of action agendas that provide specific recommendations for Cal Poly, for other polytechnic and science and technology universities, and for their partners in industry, government and education.

The inaugural Baker Forum in 2002 focused on the challenge of educating sufficient numbers of students in science, technology, engineering and mathematics (STEM) to meet the needs of California’s high-tech economy. This forum encouraged a “total systems” approach for strengthening the pre-kindergarten through university STEM educational pipeline and outlined steps that might be taken by private industry, governmental agencies and public education to increase the ranks of graduates ready to enter the high-tech workplace.

The 2004 Baker Forum considered strategies for expanding the educational pathways to STEM careers and determined that strengthening the teaching and learning of science and mathematics in the K-12 schools is a crucial starting point. This forum identified roles for higher education, commerce and industry, and state and federal government in support of the K-12 system’s efforts to improve science and mathematics education.

After each forum, Cal Poly redoubled its efforts on behalf of STEM education: We implemented an ambitious billion-dollar master plan to strengthen and expand our undergraduate and graduate polytechnic programs, and established a new Center for Excellence in Science and Mathematics Education.

The 2006 Baker Forum gave us an opportunity to consider the best current thinking concerning the present and future uses of petroleum resources and the need for alternative forms of energy. Cal Poly initiated a review of the university’s current activities regarding energy sustainability in transportation, in the built environment, and in the management of natural and agricultural resources, reports of these efforts were presented during the breakout sessions of the 2006 forum. Cal Poly has since extended this review, developing a more comprehensive inventory of its applied research, education and operational activities. The university is also exploring opportunities for expanded corporate and governmental partnerships on initiatives to develop, test and evaluate energy alternatives.

In closing, I would like to express my sincere appreciation to the 2006 Baker Forum participants. The 2006 forum dialogue provided inspiration and encouragement for us at Cal Poly. We hope these published proceedings will help others to advance their understanding of the global energy and environmental challenge and the importance of achieving sustainable solutions.
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