TESTIMONY OF

ROBERT J. BIRGENEAU

CHANCELLOR

UNIVERSITY OF CALIFORNIA, BERKELEY

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

UNITED STATES SENATE

"EXAMINING STRATEGIES TO REDUCE GREENHOUSE GAS EMISSIONS AT U.S. COLLEGES AND UNIVERSITIES"

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Senator Boxer and members of the committee – thank you for giving me the opportunity to speak to you today on one of the most urgent issues facing our state, our nation and our globe. Climate change caused by our use of carbon fuels is one of the most significant and pressing challenges of our time. At UC Berkeley, the nation's leading public teaching and research university, we are aggressively addressing climate change through our teaching and research, as well as through policy and collective and individual action on our campus.

California has demonstrated national and international leadership in committing to reduce its green house gas emissions. It has legislated that the state's global warming emissions be reduced to 1990 levels by 2020 (a 25% Greenhouse Gas cut) and 80% below 1990 levels by 2050.

Berkeley is at the forefront of energy research, and specifically energy research and implementation to make these goals viable. This is fundamental to our public mission as a university. We received an important grant from the US Department of Energy Office of Science to create the Joint Bioenergy Institute (JBEI), through a 5 year $125 million grant. Another important effort is the creation of the Energy Biosciences Institute (EBI), a collaboration with the Lawrence Berkeley National Laboratory (LBNL) and the University of Illinois at Urbana-Champaign, funded by a $500 million, 10 year grant from BP awarded in 2007, to explore and develop biofuels.

Additionally, scientists from UC Berkeley and the LBNL have been developing a bold research agenda called "Helios" exploring solar energy devices from photovoltaics to microorganisms, including nanotechnologies to produce cheaper solar cells and improve their efficiency. Today, Berkeley has emerged as a leading world center on energy research and education, with an annual budget of $100 million through unprecedented public-private partnerships.

We have also been aggressive with measures to reduce greenhouse gas emissions on campus. Under the Cal Climate Action Partnership (a coalition of students, faculty and staff with the administration), we have undertaken a feasibility study, and based on sound analysis and actionable policy, have committed to a target of reducing greenhouse gas emissions on campus to 1990 levels by 2014. This is six years ahead of the State's mandated reduction. Our strategies for achieving this ambitious target include increasing the efficiency of our energy usage, greening our electricity supply, and promoting sustainable transportation.

Buildings account for over 70% of campus emissions. Projects to reduce emissions include large scale lighting retrofits, building re-commissioning, making our heating, ventilation, and air conditioning systems more efficient, and deploying additional on-site renewable energy production. Our plan also contains efforts that are indirectly related to energy usage and also have enormous impacts on resource conservation, such as water conservation, minimizing waste, and purchasing greener products. These actions are supported by a formal campus policy "statement of commitment to the environment" and the appointment of a Director of Sustainability.

Many of these efforts to mitigate UC Berkeley's climate footprint have been led by our students who are a new generation passionately committed to solving the world's energy needs in both a clean and socially responsible way. Berkeley students recently voted a $5 student fee increase to

fund sustainability projects on campus. The Berkeley Energy and Resources Collaborative is a unique student community that brings together hundreds of students, professors and industry and government leaders on issues of energy and resources at Berkeley. Our students are acutely aware that over one billion people live on 50 cents per day or less and that these populations will be disadvantaged even further if global climate change continues to progress at its current rate. They understand that how we deal with these challenges will transform humankind's relationship with the environment and change the way that we drive the global economy. Universities must lead this transformation.

Thank you for this opportunity to describe very briefly UC Berkeley's strategies for reducing greenhouse gases both on its campus and even more importantly, its strategies for contributing to greenhouse gas emission reduction world-wide.

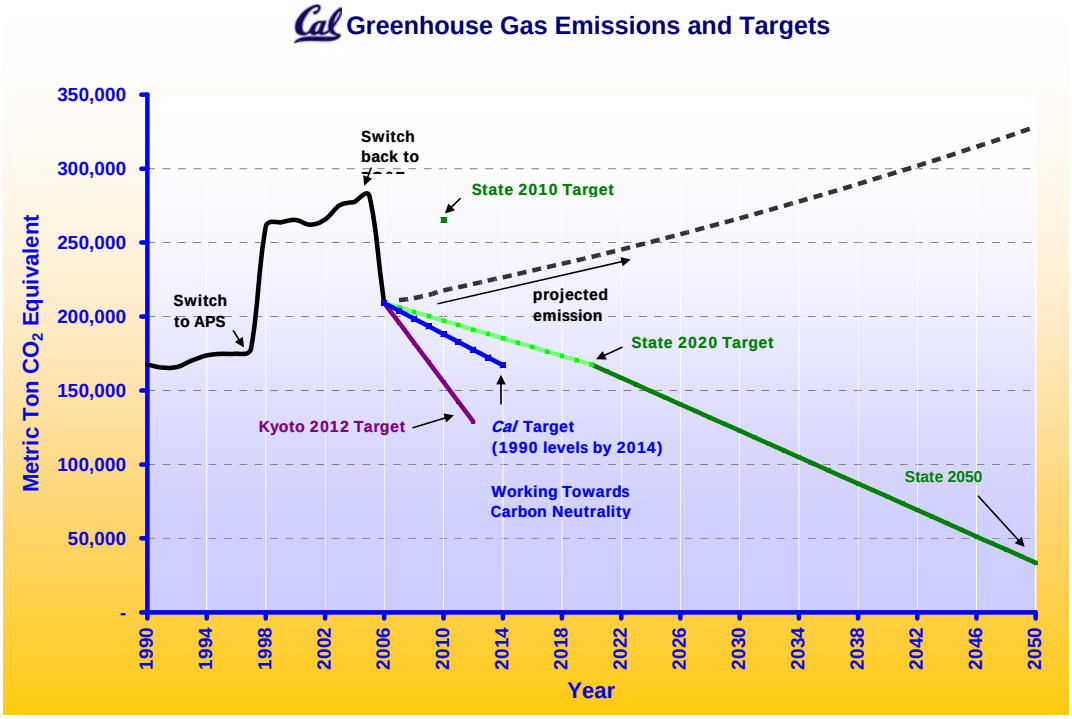
Finally, if you would allow me to comment on national policy, I feel strongly that while there is so much that universities and other local entities can do to reduce their carbon footprints, global warming really must be addressed at the national level if we as a nation are going to have the kind of impact we must have to prevent further destruction of our atmosphere. To that end, passage of the S.2191 or similar legislation to impose strict limits on greenhouse gas emissions, is absolutely critical.

I have submitted a much fuller written submission describing in detail our many initiatives. I would be pleased to answer any questions that you may have.

Campus Activities to Reduce Emissions

The University of California at Berkeley is committed to reducing the greenhouse gas emissions associated with our campus activities. We have inventoried our emissions, set an ambitious target, and begun implementation. Our Cal Climate Action Partnership (CalCAP) program is an interdisciplinary research and implementation program and is the torchbearer of climate action on campus. In April 2007, based on recommendations from the CalCAP study, I committed the campus to reduce its greenhouse gas emissions to 1990 levels by the year 2014, which is equivalent to meeting California's AB-32 (Global Warming Solutions Act) six years early (see Figure 1).

Figure 1: Projected Emissions and Potential Targets



Emissions Sources and Reduction Feasibility

CalCAP started in the fall of 2006 by creating a climate action feasibility study. This study led to the development of a ten source greenhouse gas emissions inventory and the emissions reduction target, which included 14 possible projects as a starting point for implementation. Our target and inventory are based on both our direct emissions – like energy usage in buildings and our fleet vehicles – and optional categories like air travel, staff and student commute to campus, water consumption, and solid waste.

In order to achieve this ambitious emission reduction target, we will:

- Use aggregate emissions targets as a metric in campus communication and planning
- First implement infrastructure-related emissions reduction projects, starting with the most cost-effective (i.e., highest $/MTCO$_2$e) projects, and then use the savings from those projects to invest in additional projects or to purchase Renewable Energy Credits (RECs)
- Focus on identifying additional cost-effective GHG mitigation opportunities on campus, such as energy efficiency.

The campus joined the California Climate Action Registry and has certified its emissions inventory for 2005 and 2006 (see Figure 2). Of the 14 projects that have been initially associated with the CalCAP target, four projects are active and seven projects are in a small pilot phase. Investments of almost $2 million have already yielded an estimated one million KWH energy savings.

Figure 2: UC Berkeley GHG Emissions by Source in Calendar Year 2006

Emissions Sources (required & optional reporting)	CO_2 equivalent (metric tons)	Percentage Contribution
Steam (co-generation)	82,000	38.8%
Purchased Electricity	65,000	30.6%
Air Travel	24,000	11.3%
Faculty and Staff Auto Commute	19,000	8.6%
Natural Gas	13,000	6.1%
Student Commute	4,000	1.8%
Fugitive Emissions- Refrigeration	2,000	1.0%
Water Consumption	2,000	0.9%
Solid Waste	1,000	0.4%
Campus Fleet	1,000	0.4%
Total Emissions	209,000	100.0%
Required reporting emissions sources	160,000	76.5%
Optional Reporting emissions sources	50,000	23.5%

While our 2007 inventory calculations are not certified yet, we expect that our overall emissions will be lower (approximately 207,000 metric tons) than what we had originally projected. The relative percentage contribution by various emissions sources has not shifted by a significant portion.

The reasons for this year's reduction can be attributed to implementation of various energy efficiency projects on campus. Examples of these efficiency measures include lighting retrofits, building re-commissioning, and upgrades to heating and air conditioning systems. An additional factor is the increased use of cleaner electricity, as the campus has purchased more of its power from Pacific Gas and Electric. Other initiatives are discussed below.

Specific Initiatives

1. **Infrastructure projects** – The following types of projects enhance the energy efficiency of campus energy systems. They can have a significant upfront cost, but can also have a quick payback and generate savings that can be further invested.

a. Co-generation plant steam trap survey and repair (saving up over 1,000 tons of carbon a year)
b. Monitoring-based commissioning (all buildings over 50,000 square feet will be re-commissioned; energy savings of up to 15% are expected)
c. Automated lighting controls (for example, use of wireless lighting controls in a pilot study has yielded energy reductions of 65%)
d. Fluorescent lighting retrofits (for example, installation of more than 700 electronic ballasts and photoelectric control in five parking structures)
e. Fleet vehicle replacement plan (questionnaire and plan to convert the single-occupant fleet on campus to electric by 2014)

In addition, the campus is completing a Strategic Energy Plan (SEP) in partnership with PG&E. Consultants have started surveying almost 70 campus building to identify commissioning, retrofit, HVAC upgrade and other energy efficiency projects. Work is expected to begin in 2009. The campus also plans to purchase up to 1MW of solar power Solar through a power purchase agreement.

2. **Educational and Behavioral Projects** – These campus initiatives will encourage individuals to conserve more energy and educate the campus population to incorporate conservation into their daily activities. They require some capital investment and a significant dedication to coordination and planning. They have a quick payback and also contribute to establishing a culture of environmentally sustainable practices. Not all of these projects are currently funded.

    a. Introduce fleet biking
    b. Expand electric vehicle fleet
    c. Implement high priority bicycle plan projects & programs
    d. Reward department level energy reduction
    e. Increase utilization of videoconference room(s)
    f. Increasing occupant awareness and electricity curtailment
    g. Introduce Campus Composting program

3. **New Buildings** – We are using the Leadership in Energy Efficient Design guidelines for new buildings, supplemented by additional energy efficiency requirement: all new building projects on campus will be designed to exceed the required provisions of the California Energy Code (Title 24) energy-efficiency standards by at least 20 percent. Our first LEED certified building, the Haste Street Early Childcare Development Center, has been awarded Silver. The certification process was funded through a grant from Stopwaste.Org, procured by Capital Projects. Additional projects presently undergoing USGBC LEED certification include University Village Step 2 (housing); Clark Kerr

Renovation (housing); Li Ka Shing Biomedical Building (laboratory); and Durant Hall Renovation (historic/office).

In addition, LEED Equivalence submittal for the Underhill Parking Structure has been received and planning checklists for all major capital projects have been prepared. All projects are tracking at 20% or greater in outperforming the California Energy Code. We have modified its project approvals to assure that all renovation projects include sustainability measures, as required by policy. The Li Ka Shing Biomedical Building, a Labs 21 partner, has been identified as a Best Practice for Energy Efficient Laboratory Design from the PG&E Savings by Design program. The building will outperform energy code requirements by 33%, and is projected to receive almost $500,000 in energy efficiency incentive funding.

The Berkeley campus has incorporated expectations for internal LEED equivalent certification into all design professional agreements and contracting documents for major capital projects. Results thus far indicate that performance objectives are being met.

Started as a grassroots effort by students, CalCAP has since matured into a results-oriented sustainability program. Today, it is a partnership of various research and administrative departments, and it continues to add stakeholders. The culture of collaboration is rooted in its interdisciplinary steering committee with more than 25 active members from faculty, staff, administration, and students. The CalCAP model is now the University of California standard on climate action, and the program was showcased at the University of California-California State University- Community College annual summit in 2007.

Student Leadership and Ingenuity

Our students have pioneered many of our broader sustainability efforts. In addition to being the driving force behind our climate reduction target and the backbone of our implementation of many projects, they are "walking the walk." Last year, students passed a referendum known as The Green Initiative Fund (TGIF) to increase their fees by $5 per student per semester. This fee has raised about $170,000 so far and will be used to fund sustainability projects around campus. These grants are student controlled and have already generated around $1 million in grant proposals.

One successful student programs are the Green Campus Interns. The projects implemented by the Green Campus Interns, in partnership with the Alliance to Save Energy, have saved over 1500 MWh of energy, which equals $150,000 in avoided energy costs or 70,000 pounds of CO_2. Their projects have included dorm energy competitions ("Blackout Battles") and a fume hood campaign ("Shut the Sash").

Another is the Green Living Project, the first project in the nation to demonstrate that a room in a student resident hall can be environmentally friendly without costing huge sums or sacrificing a comfortable lifestyle. The project, organized by Campus Recycling and Refuse Services in close cooperation with Residential and Student Service Programs and Green Campus, is showing the campus community that it is not only possible but also easy to "go green."

There are unique student initiatives related green building. All our major building projects work to engage students during the process, through an eco-charette or having them assist on tracking LEED and green building performance measures. We employed students to assist with documenting LEED performance on the following projects: University Village Housing Step 2, Units 1 and 2 Infill Housing and Durant Hall Renovations, Hearst Memorial Mining Building. With the College of Civil and Environmental Engineering, we had students work on Life Cycle Cost Analysis tools for the design phase, using our CITRIS building as an example. In addition, there are Green Classroom Programs, where students work with the Registrar's Office and the Classroom Renovation Program to develop recycling in classrooms, energy efficiency lighting, and user satisfaction research tools.

Students have played a key role in integrating climate action into curricula to further elevate the campus' climate commitment. In the fall of 2007, the first student-led climate action course trained 14 undergraduate and graduate students on campus decision processes and emissions reduction options - an engagement that has inspired hundreds of students to integrate climate action into their research and activities. This student-led course – with guest lectures from staff, faculty and students – developed recommendations for holistic campus planning. They concluded that the CalCAP reduction target could potentially be achieved just by focusing on energy efficiency alone. Students are also running two additional courses that are producing an educational campaign and multiple building energy audits.

The CalCAP program also supported student projects that produced actionable recommendations on department and building level energy reduction, greening procurement, emissions inventory data gathering, project financing options and a design for sustainability programs on campus.

Broader Context

These actions to reduce our greenhouse gas emissions are grounded in a broader policy on sustainability. I have an Advisory Committee on Sustainability designed to promote environmental management and sustainable development at UC Berkeley. This Committee is charged with advising me on matters pertaining to the environment and sustainability and draws strength from its diverse composition of faculty, staff, students and alumni. Earlier this year, I approved a formal “Statement of Commitment to the Environment,” that commits our campus to being “responsible stewards of the physical environment and to using educational and research activities to promote environmental awareness, global thinking, and local action.” As part of this commitment, I recently formed an Office of Sustainability, which has been charged to identify and prioritize ways to improve environmental sustainability on campus and generate creative solutions.

We are also reaching out beyond the edges of campus. In a wholly new and innovative collaboration, the mayors of Berkeley, Oakland, Richmond and Emeryville have joined forces with me and LBNL director Steve Chu to form the East Bay Green Corridor Partnership — aimed at "establishing our region as one of the world's leading centers" of environmental innovation, alternative-energy research, and green business, green job development and industry. After several months of negotiations, a formal *Statement of Principles* was developed that outlines the cooperative agreement between the East Bay cities, UC Berkeley and LBNL. This unique partnership brings the expertise of all the entities together to contribute to emerging green and sustainable industries, alternative energy research and green workforce development throughout the region. This new alliance is intended to position the East Bay to become one of the nation's green economic engines that also looks to keep California competitive and the nation energy independent.

The CalCAP program offers many benefits to the local community, including local emissions reductions information, informed participation in the process of climate change mitigation, and a forum for discussion of ideas, strategies, and best practices. The City of Berkeley and community action groups are involved participants in the group's steering committee to jointly work on community based carbon reduction opportunities. In January 2008, our campus observed Focus the Nation – Global Warming Solutions for America, that brought together over 500 students, staff and local community members to jointly discuss solutions for climate change at a regional scale.

Additional information is available at our websites: www.sustainability.berkeley.edu and www.climateaction.berkeley.edu.

Research on Global Climate Change at UC Berkeley

California and its academic institutions have a unique history in addressing climate change, which includes path-breaking scientific and technological research, as well as the development of new economic techniques and assessments of social impacts of changing environmental conditions. Researchers at UC Berkeley have been at the forefront of national and international research efforts that have found there can be significant local benefits to confronting climate change, including energy savings from "greening" buildings and industries, creating job growth, and building export opportunities in some of the fastest growing economic sectors.

UC Berkeley has a long and rich history of pioneering knowledge and action on the most urgent issues facing our state, our nation, and our globe, and climate change is no exception. A hallmark of our campus is a tradition of not only training the next generation of research and political leaders, but also in engaging in real world mission-oriented projects to meet the needs of the state, nation, and the world. We recognize that as a society, we must discover how and how fast the climate is changing, what degree of climate protection we can implement through low-carbon energy systems, and how can adapt to the climate change we can not prevent. Across the campus, we are deeply engaged in research that focuses not only on the science of climate change, but also on developing new practices to lower energy demand, and the emerging economic and legal frameworks that can help manage our energy demand and impacts that change will have on the planet.

At UC Berkeley more than 300 faculty are already working on issues related to energy, the environment and global warming. We are particularly fortunate in our close association with the Department of Energy funded Lawrence Berkeley National Laboratory. Berkeley Lab is a multidisciplinary scientific research lab that is home to some of the world's best scientific tools and research expertise. Approximately 300 of Berkeley Lab's scientists are also UC professors, and close to 1,000 UC Berkeley students do scientific work and training at Berkeley Lab. It is a remarkable alliance.

Berkeley Lab Director Steve Chu and I have brought together the great resources of our institutions to address the energy and environmental challenges head on. UC Berkeley and Berkeley Lab are pooling our vast experience in energy technology, policy and transportation to help achieve an affordable, sustainable, and clean supply of global energy. From the BP-funded, campus-led Energy Biosciences Institute, to the Berkeley Lab-led, DOE-funded Joint BioEnergy Institute, Berkeley is becoming a world center for sustainable energy research.

These are some of the major research initiatives already underway on our campus:

The **Energy Biosciences Institute (EBI)** is a new research and development organization that brings advanced knowledge in biology, physical sciences, engineering, and environmental and social sciences to bear on problems related to global energy production, particularly the development of next-generation, carbon-neutral transportation fuels.

EBI represents a collaboration between the University of California, Berkeley, Lawrence Berkeley National Laboratory, the University of Illinois at Urbana-Champaign, and BP, which will support the Institute with a 10-year $500 million grant. EBI's multidisciplinary teams will collectively explore total-system approaches to problems that include the sustainable production of cellulosic biofuels, enhanced biological carbon sequestration, bioprocessing of fossil fuels and biologically-enhanced petroleum recovery. A hallmark of EBI will be the attention to the social and environmental impacts of fuel pathways, and the 'life-cycle' impacts of a bio-energy infrastructure.

The Joint Bioenergy Institute (JBEI) is a new organization funded by a $125 million, five-year grant from the US Department of Energy Office of Science to Lawrence Berkeley National Laboratory (LBNL), the University of California, Berkeley, and four other partners to develop better biofuels.

Research at JBEI centers on improvements to current technology for producing ethanol, in particular cellulosic technology for producing ethanol from biomass, and new technologies for producing other biofuels. Research will find out how plant cell walls – the hard lignocelluose that makes plants sturdy – are put together, so that scientists can find a way to take them apart and access the simple sugars they're made from. These sugars could then be fermented along with the simple starches in the plant to produce much more energy than currently possible.

JBEI scientists will also develop the tools and infrastructure to accelerate future biofuel research and production efforts, and help transition new technologies into the commercial sector.

The **Helios** project is a clean energy initiative at LBNL designed to address the challenges of climate change by developing new, clean energy alternatives with low carbon emissions. Its goal is to harness the sun's energy for a secure, sustainable, and prosperous future.

Helios research will concentrate on developing transportation fuel from biomass and from solar energy driven electrochemistry. It will also target solar technologies, including a new generation of solar photovoltaic cells, and the conversion of electricity into chemical storage to meet future energy demands.

The Energy and Resources Group (http://erg.berkeley.edu) is an interdisciplinary academic unit of the University of California, Berkeley whose mission is to develop, transmit and apply critical knowledge to enable a future in which human material needs and a healthy environment are mutually and sustainably satisfied. ERB pursues its mission through education, research, and service. Established in 1973, ERG offers programs of study in Energy and Resources for graduate students leading to MA, MS, and PhD degrees.

The University of California Energy Institute (http://www.ucei.berkeley.edu/), located on the Berkeley campus, is a multi-campus research unit of the University of California system. Since its inception in 1980, UCEI's mission has been to foster research and educate students and policy makers on energy issues that are crucial to the future of California, the nation, and the world.

The **Renewable and Appropriate Energy Laboratory (RAEL)** is a unique research, development, project implementation, and community outreach facility based at UCB. RAEL focuses on designing, testing, and disseminating renewable and appropriate energy systems. The laboratory's mission is to help these technologies realize their full potential to contribute to environmentally sustainable development in both industrialized and developing nations while also addressing the cultural context and range of potential social impacts of any new technology or resource management system. RAEL projects range from theoretical analysis of low-carbon energy futures, to engineering-based efforts to develop new solar, small-scale wind, and biomass gasification technologies, and to work with partner groups in Nicaragua, Kenya, South Africa, Tanzania, China, and elsewhere, to put these projects into operation.

Berkeley Water Center. The nation's water resources are certain to be affected by global climate change. Effective water management is not purely a scientific problem, a political problem, a technological problem, a computer science problem nor a socioeconomic problem; it is a complex, 21st Century problem that demands collaborative coordination between all of these disciplines. The Berkeley Water Center has been developed to integrate expertise across disciplines in support of a new research mode for water investigations.

Center for Fire Research and Outreach. The impact of global warming on our climate is already being felt in our nation's wooded areas. Given the importance of fire in many ecosystems, along with our dependence on and development into inherently fire-prone

landscapes, we need to reach a sustainable coexistence with wildfire. The mission of the Center for Fire Research and Outreach is to develop and disseminate science-based solutions to wildfire-related challenges.

Center for Forestry. The Mission of the Center for Forestry is to sustain forested ecosystems through scientific inquiry. Our approach is comprehensive. We seek to create and disseminate knowledge concerning ecosystem processes, human interactions and value systems, and restoration and operational management practices.

Center for Sustainable Resource Development. The Center for Sustainable Resource Development brings together UC Berkeley's leading environmental and social scientists with other experts and stakeholders from industry, government, and environmental organizations to address complex resource-use issues such as global climate change, sustainable agriculture, water reliability, and population, poverty and the environment.

Center for the Assessment and Monitoring of Forest and Environmental Resources at UC Berkeley (CAMFER). CAMFER is dedicated to providing innovative, state-of-the-art monitoring of environment using geospatial technologies. CAMFER research and outreach staff conduct studies in wetland monitoring and modeling, atmospheric emissions, forest biometrics, and watershed modeling.

CITRIS. The Center for Information Technology Research in the Interest of Society creates information technology solutions for many of our most pressing social, environmental and healthcare problems, including global climate change.

The first public-private partnership created to use IT in this way, CITRIS partners more than 300 faculty and thousands of students from myriad departments at four UC campuses (Berkeley, Davis, Merced and Santa Cruz) with industrial researchers from over 60 corporations. Together they are thinking about IT in ways that have not been thought of before. They see solutions to many of the concerns that face all of us today, including the environment and finding viable sustainable energy alternatives.

Energy and the Environment

As climate change continues and the world population expands at a rapid rate, we must find energy solutions that improve the quality of life while not adversely affecting the environment. CITRIS researchers are engaged in a variety of projects in renewable energy; nuclear energy; and carbon capture and storage, to name a few.

- Modeling Electric Usage in Residential Areas. Because electricity cannot be practically or economically stored in large quantities, the electricity generation and distribution system must match supply and demand on a minute-by-minute basis. Delivery of electricity for residential use has traditionally been done by matching the supply to the demand, with little or no control over the demand. This causes severe distortions in the system operation and economics when the demand hits unusually high peak values.
- Energy Efficiency and Reliability in Dense Sensor Networks. This research addresses some important components in the theoretical and algorithmic signal processing machinery needed to make low-power, ubiquitous sensor networks a reality. The physical and hardware attributes as well as the computing and communication capabilities of these low-power, low-cost sensors, particularly those based on high-density low-cost MEMS devices, have the potential to revolutionize next-generation information technology.
- Window Performance for Human Thermal Comfort. Anyone who has ever sat near a cold window on a winter day or in direct sunlight on a hot day recognizes that windows can cause thermal discomfort. In spite of this broad recognition there is no straightforward method to quantify the extent of such discomfort. HVAC designers specify dedicated perimeter heating and cooling systems to mitigate window-related comfort problems, yet they use simplified assumptions that may not solve the comfort problems or that might lead to designs that are energy-inefficient.
- Solar Reflecting Film. The Center for the Built Environment (CBE) at UC Berkeley has developed a sophisticated thermal comfort capable of modeling non-uniform, transient conditions. This model has been used to study occupant comfort in buildings and automobiles. SRF has unique properties that reduce transmitted solar heat gain and lower the glass surface temperature.

Center for the Built Environment. Research is being conducted to improve the design, operation, and environmental quality of buildings by providing timely, unbiased information on building technologies and design techniques.

CBE projects fall into two broad program areas: First, developing ways to "take the pulse" of occupied buildings - looking at how people use space, asking them what they like and don't like about their indoor environment, and linking these responses to physical measurements of indoor

environmental quality. This feedback is highly valuable those who manage, operate, and design buildings.

Secondly, studying technologies that hold promise for making buildings more environmentally friendly, more productive to work in, and more economical to operate. This helps manufacturers target their product offerings, and facility management and design partners to apply these new technologies effectively. Some current research projects include

Indoor Environmental Quality (IEQ). CBE has developed methods to measure the performance of occupied buildings in terms of occupant comfort, workplace efficiency, and building operations.

Building HVAC Systems. Advanced HVAC systems provide opportunities for energy savings and benefits to occupants.

Building Envelope Systems. CBE is developing tools and criteria for evaluating facade performance in terms of occupant comfort and energy efficiency.

Controls and Information Technology. New information technologies provide ways to optimize the performance of building systems.

The Berkeley Institute of the Environment

BIE is a nexus for research on environmental issues that brings together campus teams in a number of thematic areas, that currently include: low-energy buildings; sustainable fuels; environmental history; and life-cycle analyses of materials.

One of the many areas of research related to global warming being conducted at BIE is the Zero Energy Commercial Buildings Initiative. ZECBI will transform the energy use of commercial buildings in the US to routinely achieve carbon-neutral building performance within a generation. The building sector remains responsible for about 40% of energy use and carbon emissions, and over 70% of electricity use. Research at ZECBI will transform the energy use of commercial buildings in the US to routinely achieve carbon-neutral building performance within a generation by addressing industry institutional inertia, fostering technological innovation in equipment, materials, and controls, developing innovative tools and predictive models to support innovative design, enhancing the education of design and engineering professionals, fostering technology transfer from labs to industry, developing innovative processes for delivering and operating high performance buildings, identifying deployment policies that will ensure widespread adoption of high performance buildings, and developing metrics and a framework to track long term progress toward goals.

Environmental Energy Technologies Division (EETD)

UC Berkeley partners closely with the Lawrence Berkeley National Lab on a wide range of research, including research done at the EETD. Together, the LBNL and UC Berkeley

researchers work to find better energy technologies and market mechanisms that reduce adverse energy-related environmental impacts. EETD's work increases the efficiency of energy use, reduces its environmental effects, provides the nation with economic benefits, and helps developing nations achieve similar goals through technical advice. EETD carries out its work through the support of the U.S. Department of Energy other federal entities, state governments, and the private sector. Our staff of 300 represents a diverse cross-section of fields and skills, ranging from architecture, physics, and mechanical engineering to economics and public policy. Many areas of research are directly related to global warming:

Energy efficiency in buildings
• Energy-efficient windows and daylighting systems
• Energy-efficient lighting concepts and systems
• Simulation tools for energy use in buildings
• Information technology for energy efficiency in commercial buildings
• Application of advanced concepts to testbed buildings
Advanced energy technologies
• Electrochemical research on batteries
• Combustion and emissions
• Laser and other spectroscopic tools: development and application
International energy issues
• Energy efficiency in developing countries (special emphasis:China and India)
• Energy efficiency and global climate change
US energy issues
• Appliance and equipment energy-efficiency standards
• Energy efficiency programs to promote market transformation
• Energy utility deregulation
• End-use energy demand forecasting and policy analysis
Indoor environment
• Advanced ventilation, infiltration, and thermal distribution systems
• Sources, emissions, and transport of indoor pollutants
• Air pollutant exposures and health risks
• Control strategies for indoor air quality

Other areas of research and development

- air pollution: from science to public policy
- electricity reliability: distributed energy systems, real-time control, and markets
- industrial energy efficiency: U.S. and international perspectives

BUILDING TECHNOLOGIES

Division researchers work closely with industry to develop efficient technologies for buildings that reduce energy bills while improving the comfort, health, and safety of building occupants.

Technology efforts focus on windows, daylighting, lighting systems, building simulation research, and commercial building systems.

Windows and daylighting

Every year, heat worth billions of dollars flows through windows in American homes and businesses. In hot climates, the heat radiates into homes, requiring expensive air conditioning. In cold climates, it leaks out, requiring more energy to keep the occupants warm. Thermally efficient windows save consumers and businesses energy and money. The Division's researchers develop advanced optical coatings and materials for future windows; study the energy performance of windows and window systems (windows, glazings, and their frames, blinds, louvers, etc.); and create computer tools to improve window energy performance and aid product rating and labeling. In the 1980s, EETD researchers worked with window manufacturers to develop special "low emissivity" window coatings to reduce heat loss through windows. These windows, which reduce energy loss by 20% to 50% depending on the design, now account for 35% of the market and have saved more than $1 billion in energy costs. Current windows research includes developing new tools and measurement techniques to assess energy performance and comfort; advanced electrochromic coatings that automatically change the level of transparency depending on exterior lighting conditions; and technologies and design strategies for commercial buildings that maximize daylighting benefits. In addition, EETD works with industry partners in developing standards for rating windows.

Lighting

Lighting accounts for 25% of all electricity consumed in the United States, at a cost of more than $35 billion per year. Researchers here develop advanced light sources, optimize lighting fixtures and control systems for energy efficiency, design computer tools to quantify the energy performance of lighting systems, and test system performance in the field, including the impacts on human performance and health. The Division's lighting team worked with manufacturers to develop electronic ballasts, a more efficient replacement for the magnetic ballasts used to control the current in fluorescent lamps. Electronic ballasts now account for 32% of the market, saving consumers hundreds of millions of dollars per year. Working with industry, the group developed a torchiere floor fixture based on the compact fluorescent lamp—an energy-efficient, lower-temperature alternative to the hot 300-watt halogen torchieres that are blamed for starting hundreds of fires.

Building simulation

Architecture and engineering firms use DOE-2—a computer program developed by Division researchers that analyzes the energy performance of buildings— to increase the energy efficiency of their designs. According to a DOE-2 user survey, buildings designed with DOE-2 save an average of 20% of building energy use. EnergyPlus, now under development, will replace DOE-2 and offer many new features. Radiance—a computer program for lighting analyses, also developed by Division researchers—allows lighting and daylighting designers to assess the quantitative and qualitative performance of their designs. Desktop Radiance, now under development, will greatly facilitate the use of Radiance and increase its user base. In addition to analytical tools, Division researchers are developing tools, like the Buildng Design Advisor, which change the way architects design buildings, by providing quick and easy access to multiple analysis tools linked to a single building database. In the first-ever such use of the

Internet, a program called Home Energy Saver is available to anyone with Web access (http://HES.lbl.gov). The user inputs information about a home, and HES (using DOE-2) calculates total energy use and cost, and suggests economic ways of reducing the energy bill.

Commercial building systems

The commercial building sector spends $80 billion per year on energy. Maximizing efficiency can cut billions from this cost. Researchers have launched a major effort to address this opportunity, developing tools to benchmark energy performance. Such tools let designers, owners, and operators access data throughout the building lifecycle and ensure that building operations meet performance targets.

The Division's energy analysts gather and interpret information about energy, including supply and consumption, energy technologies, management practices, government policies, and economic and environmental impacts. These studies examine the performance of energy-efficient technology in the marketplace; the impact of various regulatory policies; the feasibility of different approaches to designing energy-efficient standards and building codes; and technology options for reducing the emissions of greenhouse gases. The work provides local, state, and national governments, as well as regulatory agencies and international institutions with information to help them formulate effective energy and environmental policies.

ENERGY ANALYSIS

Standards, codes, and policy analysis

Appliance energy-efficiency standards and provisions in building codes in the United States save consumers billions of dollars a year. Often inspired by the U.S. experience, dozens of nations have adopted or are currently developing appliance standards and building codes. Division research provides impartial technical information on the energy use of appliance technologies to the Department of Energy's standards development process. In addition, studies of building codes help code officials formulate and fine-tune energy-efficiency measures. Division researchers conduct studies of utility-related public policy issues, from transmission pricing and market power to the role of renewables and energy efficiency. As the electric utility industry undergoes restructuring in some states, Division studies provide useful information to the industry and the regulatory community charged with guiding this evolution.

Energy-efficient procurement and labeling

An important approach to improving energy efficiency is to provide large buyers with information about energy-efficient products. The President directed federal agencies—collectively the world's largest customer of most energy-using products—to buy products that are among the top 25% most energy-efficient options on the market. Researchers in Berkeley and the Division's Washington D.C. Office are involved in projects to help federal, state, and local agencies procure energy-efficient products. EETD researchers also provide analytical support for the voluntary ENERGY STAR programs in appliance labeling and new homes, administered jointly by the U.S. Environmental Protection Agency and its partner, the U.S. Department of Energy. The government harnesses market forces to promote energy efficiency and pollution prevention by inducing manufacturers to put ENERGY STAR labels on their products.

Reducing greenhouse gas emissions

EETD's studies of energy use and greenhouse gas (GHG) emissions have made the Division an important source of information on global climate change for policymakers. Researchers have analyzed the potential of energy-efficient technologies to reduce GHG emissions, and have evaluated the emissions of the world's buildings and industrial sectors. Our efforts include co-managing the policy study "Scenarios of U.S. Carbon Reductions," a cooperative effort of five U.S. Department of Energy national laboratories. Internationally, our contributions appear prominently in the United Nations-sponsored Intergovernmental Panel on Climate Change Scientific Assessments. Division researchers also provide technical support to developing nations creating programs, energy codes, and standards to reduce GHG emissions and encourage efficiency. A China energy group works extensively with the Chinese government to exchange information on energy use and energy-efficiency practices.

Urban heat islands

Cities are urban heat islands, zones of higher temperature relative to the surrounding countryside. The heat island effect intensifies the use of expensive air conditioning. Higher outdoor air temperatures also increase smog formation. Division researchers have pioneered an effective, simple approach to keeping cities cooler—the use of shade trees and solar reflective roofing and paving materials. EETD studies have found that the cooling effect from wide application of these measures could save billions of dollars and reduce smog in large cities nationwide.

Indoor Environment

Approximately one-third of the energy consumed in the United States is used in buildings. Energy for ventilation and thermal distribution in buildings accounts for roughly one-sixth of this total (4 to 5 Quadrillion Btu/year) and is valued at about $40 to $50 billion annually. Reducing a building's infiltration and mechanical ventilation can save energy. However, this strategy may produce undesirable side effects, because building energy use, ventilation, indoor environmental quality, and occupant health, comfort, and productivity are interrelated. Buildings can be designed and operated to protect human health and enhance productivity, while using energy as efficiently as possible. EETD researchers have estimated that improvements in U.S. building environments could decrease annual health care costs by $4 to $10 billion and increase worker productivity by $40 to $240 billion.

Ventilation technologies

Division research on air infiltration and ventilation in commercial and residential buildings has led to significant advances in modeling and measuring ventilation and its energy requirements. The work has contributed to the development of many ASHRAE (Association of Heating, Refrigerating and Air-Conditioning Engineers) and state standards, as well as building codes governing ventilation and indoor air quality. EETD research includes developing new methods of measuring ventilation rates and their spatial distribution and evaluating new ventilation technologies with potential to improve indoor air quality and reduce energy use. Sealing leaky, energy-wasting ducts is one way to reduce energy use substantially. An EETD study showed that a typical house with ducts located in the attic or crawlspace wastes approximately 20% to 40% of heating and cooling energy through duct leaks, and draws approximately 0.5 kilowatts more electricity during peak cooling periods. Sealing leaks could save close to 1 Quadrillion Btu of energy per year nationwide. Division research has led to the development of a major new duct sealant technology that uses aerosols to reach and seal areas of ducts inaccessible to humans. Its commercialization is underway

Batteries and fuel cells

A major goal of the Division's electrochemistry research is to develop electrochemical power sources suitable for applications in electric and hybrid electric vehicles. Battery systems are expensive and don't hold enough electric charge to drive a vehicle the same distance as a comparable gasoline-powered automobile. EETD is undertaking research that will lead to the development of low-cost, rechargeable, advanced electrochemical batteries with the high-performance potential to compete with the combustion engine. Current work focuses on lithium-polymer and lithium-ion batteries.

Cleaner combustion

Combustion research generates the fundamental physical and chemical knowledge necessary to reduce emissions and increase efficiency. Experimental and modeling studies lead to the design of better combustion devices. EETD researchers work with Berkeley Lab's National Energy Research Scientific Computing Center (NERSC) to model combustion processes using high-performance supercomputers. Turbulent combustion takes place in all heat and power generating systems, including combustion engines in automobiles and industrial boilers and furnaces. By studying the properties of turbulent fluid motion in combustion chambers, Division researchers have devised a low-swirl burner that emits 20 times less nitrogen oxide than current technology. (Nitrogen oxides are greenhouse gases, and when exposed to sunlight, also generate smog.) The burner could be used in the residential and commercial sectors in water heaters and boilers.

POLICY RECOMMENDATIONS

While there is so much that universities and other local entities can do to reduce their carbon footprints, global warming really must be addressed at the national level if we as a nation are going to have the kind of impact we must have to prevent further destruction of our atmosphere. To that end, passage of the S.2191 or similar legislation to impose strict limits on greenhouse gas emissions, is absolutely critical.

In even more specific terms, Congress can approve legislation that would address the following:

Buildings.

Two-thirds of all US energy is consumed in buildings, and the standing stock as well as the design of new buildings is a vital issue to address to meet national climate goals. Universities are ideal laboratories for new, 'best practices', because they bring public and private sector funds, challenge and evolve green energy standards (e.g. LEED ratings), and can be monitored with unusual detail.

Support for universities to commission, design, and evaluate the best practices in green buildings would have important, and relatively rapid impacts on the sector.

Climate Goals

As took place at UC Berkeley, climate protection goals, can both evolve rapidly on campuses, and can then feed back to the wider set of professional groups (construction industry, electrical work, water/civil engineering) who provide services and build infrastructure for campuses. A cost-effective set of federal initiatives exist to accelerate this process. Among the initiatives that could be considered are:

i) Demonstration projects for Plug-in hybrid vehicles are well-suited to campus deployment due to the central motor-pool and fleets that campuses maintain.

ii) Carbon pricing
Campuses are very good test-beds for novel accounting and economic schemes, including carbon footprint analysis, and direct pricing. More than half of the states in the union now have (or are completing) comprehensive “climate action plans” that align them with the level of effort expected if they were separate nations under the Kyoto Accord.

At present 30 of 50 states have adopted 'Renewable Energy Portfolio Standards' that call for 10 to almost 30% of their energy to come from low- and no-carbon sources over the next two decades. These state-level efforts have been driven in many cases by important research and demonstration efforts at universities. One direct area of interaction at the federal level is to consider assessments of the economic costs and benefits of federal clean-energy standards, and to examine how US DoE, HUD, and US EPA funds could be used to support these state efforts.

These states have also formed three regional cap-and-trade alliances and trading in GHG credits, comparable to the system already in operation in Europe, will begin in the US as early as the third quarter of 2008.

Support for graduate research

The most important aspect of facilitating universities to be the laboratories for innovation is graduate students conducting research and implementation projects on campus and beyond. One way to facilitate this is to expand the pool of graduate fellowships, such as the NSF and EPA (STAR) awards. A new category of 'sustainable energy' fellowships, or added slots within the existing NSF and EPA programs would be another way to do this. These positions are also among the most cost-effective ways to build the intellectual capital needed to meet the nation's long-term energy challenges.