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University of Colorado Boulder. Center for Energy & Environmental Security

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CEES

the center for energy & environmental security

also in issue four:

EESI TO CEES:
FROM INITIATIVE TO CENTER

Lakshman Guruswamy, Ph.D
Nicholas Doman Professor of International Environmental Law
Director of the Center for Energy and Environmental Security

The Energy and Environmental Security Initiative (EESI) has now become the Center for Energy and Environmental Security (CEES)—pronounced "cease." While some have rightly acclaimed this change as a milestone, others have been puzzled, nonchalant, and indifferent to this important news. So let me try and explain why being transformed from EESI to CEES is so central to our mission. In brief, Center status gives us greater rank and standing to propagate our ideas, attract additional funding, conduct research and teaching, involve more students, and advance our mission of finding sustainable energy solutions to global and local energy challenges.

CEES originally began as an exchange of ideas between Kevin Doran and myself for spreading sustainable energy solutions. We thought it was something worth pursuing, and we expanded these concepts in our first White Paper. But all new inventions and ideas—whether they take the form of new photovoltaic cells or proposals for policies and laws to advance sustainable energy—will remain academic concepts unless they become commercially or politically viable. We realized that our ideas and plans would remain cabined within academia unless they were purveyed, reviewed, discussed and adopted by city, local, state, or national governments. Promoting our ideas called for institutional or focused organizational backing, and this led to the creation of the Energy and Environmental Security Initiative (EESI).

We began with no funds at all, and remain deeply indebted to Provost Phil DiStefano for starting us off with a small but very important seed grant, and to Regent Cindy Carlisle for her enormous help.

See CEES, Page 2

CEES Profile: Katherine Peters, Research Associate

James Lamb, CEES 1L Volunteer

For Katherine Peters, a full-time research associate at CEES, academic pursuits are practically second nature. "Imagine using the word pico-second when you're seven," she says, recalling growing up with a mother and father who were both chemistry professors at CU Boulder. Besides the early introduction to scientific lingo, Katherine's childhood in Boulder gave her plenty of opportunities to cycle and hike. In addition to an appreciation of the outdoors, she gained an early awareness of the importance of environmental issues. "It was always something I wanted to do," she says of working in the environmental field.

See Peters, Page 5

Heading Photos: CEES Staff and Volunteers

CEES: (continued...)

Along with their help and the encouragement of Law School Dean David Getches, we succeeded beyond expectations by winning significant gifts and grants. The first was from the Renewable Energy and Energy Efficiency Partnership (REEEP)—perhaps the most prestigious international renewable energy partnership of governments and non-governmental organizations. We won many other gifts, grants, and contracts that enabled us to hire great students who have done and continue to do excellent work on these externally funded projects.

Our reputation and profile as a non-partisan, interdisciplinary think tank on sustainable energy grew surprisingly quickly. The steady stream of funding we have received from the State of Colorado, private philanthropic organizations, and other institutions has enabled us to undertake very important research projects spanning state, national, and international issues pertaining to sustainable energy. Furthermore, we have been able to present outstanding public service programs, seminars, and other activities that attract large and informed audiences. EESI was a remarkable success.

Nonetheless, we understood the need to expand our activities—and cast our financial nets even further—if we were to grow to our optimal size. We also realized that we remained an initiative and did not enjoy the more recognized and prestigious university status of a Center. The University of Colorado boasts a wide variety of centers, institutes, laboratories, and bureaus. A sizable portion of them attract external funding. These entities generally combine a number of functions. They expand opportunities for student research and learning, faculty research and teaching, and public service. But obtaining Center status is not a quick or easy procedure. It involves a strenuous and time-consuming process of assessment and evaluation both within the Law School and the University of Colorado as a whole, without any guarantee of success.

Moving toward Center status entailed the preparation of numerous plans, and involved frequent consultations and meetings. It also included the drafting of By-Laws. We were required to present a general five-year plan covering objectives, activities, and programs, structure and organization, and long-term sustainability. We were also obliged to address our financial outlook, and draw up a five-year business plan and a five-year financial plan. These were reviewed by the law school as well as at the highest echelons of the University administration. Finally, we needed to receive an affirmative vote from the Law Faculty. It is a testament to the superb work done by the students and staff of EESI that we received affirmative and enthusiastic support at each and every one of these stages. To our great joy, the process was capped by a unanimous affirmation vote by the Law Faculty.

CEES is only the third center approved by the Law School in its 115-year history. Our application was shepherded with skill and dexterity by Associate Dean Dayna Matthew and Dean David Getches to whom we remain deeply indebted. The good ship CEES now proudly floats with its peer institutions, and we are privileged to fly the flags of the Law School and the University of Colorado at Boulder. We are about to set sail on a new and exciting voyage and look forward to an even brighter future.

Breakthroughs in Vehicle Technology: The Race is On!

Gabriella Stockmayer, CEES 1L Volunteer

RMI's Michael Ogburn

On the evening of October 22, 2007 at the University of Colorado Law School, change was in the air. Before CEES and their co-hosts, the Rocky Mountain Institute (RMI), presented an array of key advancements in vehicle technology, they publicly recognized each other's most recent advancements. EESI had acquired center status within the University (please see *EESI to CEES* in this issue). And, after twenty-five years, the nationally recognized "think and do tank" RMI had gained a new CEO, Michael Potts. At the intersection of the respective mission statements of CEES and RMI lay the driving force behind the event—the use of technological innovation to address the world's energy crisis. At this event the focus was on advancing vehicle technology.

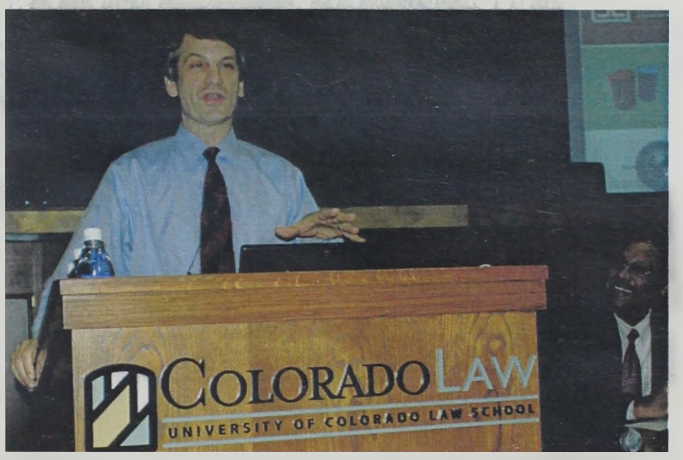
First, Michael Ogburn, a product design engineer with RMI's Transportation Innovation Group, uncovered an interesting truth—some of the most important energy efficiency technologies may be only as glamorous as wide-base tires and base flaps. How do you put a dent in the twenty-five trillion gallons of gas per year, twelve percent of U.S. oil, or $1 billion per day, that heavy trucks burn through? Along with engine and transmission technologies, it is necessary to think of trucks outside of their 80,000-pound boxes and chisel away at excessive drag, weight, and fuel usage. On the ground, Ogburn explained, new efficient dual tires decrease rolling resistance while use of wide-base tires reduces total truck weight by up to 1000 pounds. Next, reducing airflow between the tractor and trailer with side skirts, gap farings, and base flaps can add up to fifteen percent increased efficiency. Finally, heating the sleeping cabin by use of power units instead of idling can reduce fuel usage five-fold. With these changes trucks can become twenty-five percent more efficient. Along with the six trillion gallons of gas that can be saved per year from such efficiency upgrades, companies like Wal-Mart, who have invested in such changes, can attest to huge savings in overall capital costs.

Next, Jeff Ronning of RMI's Plug-In Hybrid Electric Team gave a run-down on modern technologies available for cars. Ronning echoed the importance of a "whole systems engineering" approach that strives to maximize separate parameters such as drag, mass, and power train efficiency for maximum overall efficiency.

See Breakthroughs, Page 8

Freedom From Oil

Mike Kopp, CEES 1L Volunteer



David Sandalow addresses a packed audience as CEES Director Lakshman Guruswamy looks on.

David Sandalow began his November 12, 2007 address by promoting his new book, *Freedom from Oil*, and outlining the problem: oil leads to rising temperatures and ensnares the United States in messy wars. But the U.S. keeps consuming oil because there is no alternative—the entire U.S. transportation system depends on it. Even if the U.S. could produce enough oil domestically, consumption of the fuel would still cause severe problems. Cars would continue to spew climate-altering CO_2 and worldwide jumps in oil prices could still make prices skyrocket at the gas pump. "We need alternatives," Sandalow said.

Sandalow, a senior fellow at the Brookings Institute and chair of the Clinton Global Initiative's Energy and Climate Change Working Group, described to a packed audience how we can free ourselves from oil by reducing consumption and using biofuels. Ninety-six percent of our transportation energy comes from oil, but for electricity production it is only three percent. Thus, the key to eliminating oil is using electricity for transportation by switching to plug-in hybrid vehicles. "We have a great electric grid," Sandalow declared, "but the grid is no good if we can't connect our cars to it."

Plug-in hybrids get over 120 miles per gallon on most trips, so their widespread use could dramatically decrease oil consumption. Even using coal-generated electricity, plug-in hybrids can reduce CO2 emissions because running cars on electricity is more efficient than oil. Plug-in hybrids will also increase demand for wind power, which is mostly generated at night, when most plug-ins will be charging.

Sandalow acknowledged that plug-in hybrids won't solve our oil problem, but they are a good start—especially if combined with biofuel use. Sandalow noted that cellulosic ethanol, made from fast-growing trees and grass rather than a food source like corn, could potentially provide much of our fuel in the future. And decreasing oil use by telecommuting, planning smarter communities, and building better public transportation will stretch biofuels even further.

Sandalow also noted that there is widespread consensus on this issue from conservatives and liberals alike. The Pentagon, noting the vulnerability of fuel convoys, has also been increasing its use of renewable energy. Sandalow concluded by describing unprecedented technologies developed in the last thirty years, like GPS receivers. "What will happen," he wondered, "with renewable energy?"

Dr. Joel Swisher of RMI

Following Sandalow's remarks, Dr. Joel Swisher, a team leader at the Rocky Mountain Institute (RMI) and professor of civil and environmental engineering at Stanford University, agreed that conservation, technology, and biofuel use could potentially eliminate our oil consumption within the next three decades. Swisher emphasized that people don't want energy—they want the services energy provides, like convenient transportation. The challenge is to provide such services with less energy.

Swisher stated that we could easily reduce oil consumption by fifty percent by using lighter, more efficient vehicles. "The purpose of transportation," he noted, "is to move people and cargo, not heavy vehicles." By using materials like aluminum, carbon fiber, and new steel alloys, we can make vehicles lighter while at the same time maintaining safety. Swisher indicated that size does not have to be compromised in this equation so long as the vehicles are lighter. Lighter cars also require less power, meaning the power train can be smaller, thus making the car even lighter—a situation that Swisher calls "a virtuous circle."

Swisher also saw biofuels as the next step to reducing oil consumption, agreeing that cellulosic ethanol is the future of biofuel and that eliminating the current tariff on ethanol imports could help jump start this technology. Swisher argues that if we reduce oil consumption by fifty percent through greater efficiency, we could use biofuels for the remaining fifty percent, thus reducing our oil use to almost nothing.

Swisher finished his address by describing a hypothetical smart garage that integrates plug-in hybrids with the electric grid to store excess power and moderate heavy loads. This could help the grid become cleaner and more efficient. Concepts like the smart garage, Swisher said, will help us use energy to get the services we desire in cleaner, better ways while at the same time freeing us from the burdens of oil. 3E

CU/CSU Collaboration

Mariah Zebrowski, CEES News Editor-In-Chief

On September 4, 2007, under the guidance of Colorado Representative Randy Fischer, a meeting to discuss collaboration between two Colorado universities took place in Ft. Collins. In attendance for the University of Colorado were CEES Director and Nicholas Doman Professor of International Law Lakshman Guruswamy, CEES Senior Research Fellow Kevin Doran, Distinguished Professor of Electrical and Computer Engineering Frank Barnes, Master's candidate in telecommunications Jonah Levine, and dual degree student and CEES Events Coordinator Mariah Zebrowski. In attendance for Colorado State University were Vice President for Research Bill Farland, Vice Provost for Outreach and Strategic Partnerships Lou Swanson, Associate Dean of the College of Engineering Wade Troxell, Associate Professor of Construction Management Brian Dunbar, Associate Professor of History Mark Fiege, Professor in the School of Education Bill Timpson, Professor of Chemistry Tony Rappe, and Recording Secretary Margaret Saldana.

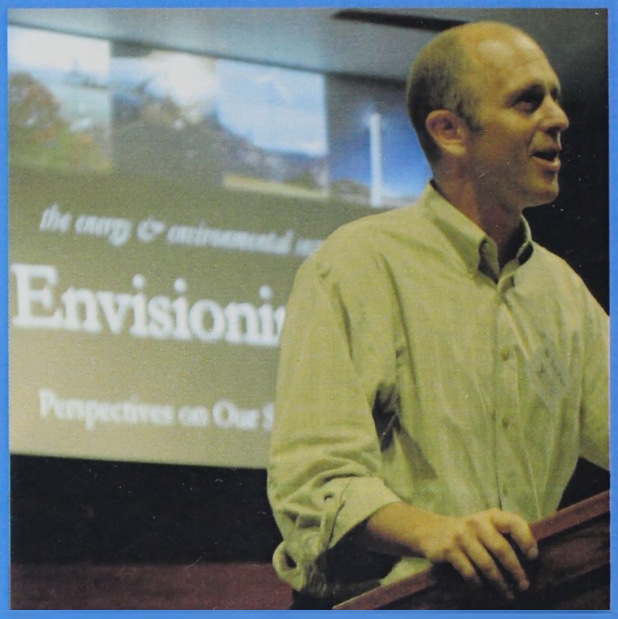
The meeting began with a discussion of CEES' Colorado Energy Profile (CEP) [please see *Project Profile: CEP* in this issue for more information.]. Doran explained that the goals of CEP are to pool all energy information from the state of Colorado, normalizing the data so comparative assessments are possible. CEP also endeavors to generate energy information where it is missing. Members of the CSU Sustainability Committee asked pertinent questions and offered valuable advice for the further development of CEP. Guruswamy suggested that CSU could collaborate in finding the energy information that is currently missing or unavailable. He also suggested that although CEES' current funding is not sufficient to turn CEP into a forecasting project, CEES is open to ideas from CSU to help take this project to the next level in the future.

The discussion then turned to interdisciplinary education to promote environmental awareness among students. Doran explained the interdisciplinary graduate course on energy and the environment that CEES is designing. Farland described the faculty education program at CSU, where faculty members are invited to workshops pertaining to environmental issues to brainstorm about how to build environmental case studies into courses across every discipline. There was agreement that ideas and collaboration could be exchanged concerning interdisciplinary teaching and learning.

Although several other projects were discussed, time was too short to make much progress at this "kickoff" meeting. However, there was unanimous agreement that collaboration attempts should continue in the future. Representative Fischer closed the meeting by saying, "Thank you everyone for making this happen – it is a really good starting point. Some of these issues that we talked about are really good ways that we might collaborate in the future. Programs like this give me great hope about work in these fields legislatively. I would love to see this continue in the future, and I hope to be involved." 3E

Interview with Tom Plant

Katherine Peters, CEES Research Associate



Tom Plant, Director of the Governor's Energy Office

During the 20th Century, Americans were concerned about the environment, but not in a way that spurred much long lasting change in energy policy. At times, bold energy policy would succeed, but little of it endured. President Carter installed solar panels on the White House, only to have them removed by his successor. However, in Colorado we are seeing renewed interest in energy policy. Tom Plant, Director of the Governor's Energy Office (GEO), thinks that there has been a "profound shift" in public thinking and that this time the policy will stick.

"I think we have hit that tipping point," says Plant, who attributes the change in the public's attitude to "a combination of serious concern about climactic impacts of our methods of energy consumption, the higher prices [of gas and oil], various public media, like 'An Inconvenient Truth,' becoming popular in the mainstream, and the leadership of people like Governor Ritter."

"We are seeing much broader coalitions of people who are coming together around this same goal of being more responsible stewards of the environment for our future generations. We are seeing this not just from the usual suspects in the environmental community and the political community, but we are seeing it within the business community."

See Plant, Page 7

Peters: (continued...)

However, Katherine didn't take a direct path to her environmental work. While an undergraduate studying physics at the University of Maryland, Katherine became interested in Quantum Mechanics, something she continued to pursue while working toward a Master's degree in Physics and Philosophy at Columbia University. Later, at the University of California at Irvine—where she obtained her second Master's in Logic and the Philosophy of Science—Katherine studied the philosophy of general relativity, working with faculty advisor David Malament, who is a leader in this field. Since then, Katherine has completed most of the research for a book she hopes will make quantum mechanics more comprehensible to lay people—to convey the craziness of it without delving too deeply into its complexities.

But Katherine's research interests are not limited to the somewhat obscure realm of Quantum Mechanics. Katherine's interest in working at CEES stems also from a desire to affect a wide range of people. "I've always been excited about how policy makes such a big difference in people's everyday lives," she says.

Kevin Doran, Senior Research Fellow at CEES, remembers that Katherine began working at CEES (when it was still EESI) as a volunteer, putting in 20-hour weeks on complex research. The high quality of her work soon led CEES to offer her a position as a full-time researcher. "She has, I think, the enviable and brilliant ability to digest material and concepts she's never seen before and to master them very quickly," Doran says.

Doran's impressions of Katherine are mirrored by those of CEES Director Dr. Lakshman Guruswamy. "Soon after she arrived," Guruswamy recalls, "we recognized Katherine's leadership potential and made her the Project Leader for our International Project on Energy Commitments and Compliance (IPECC). She has successfully managed a team of researchers and kept the energy of IPECC going. She is charming, shows great maturity, and interacts well with her co-workers. Despite her own daunting amount of work, she always volunteers to help when help is needed, such as when we host special events or need an article for the newsletter." (For example, please see Katherine's *Student Comment* and her *Interview With Tom Plant* in this issue!)

In addition to her work on IPECC, Katherine is involved in several other projects at CEES. One of her favorite tasks was writing a paper for the Presidential Climate Action Plan (PCAP), an initiative to provide the next U.S. President with a package of near, middle, and long-term policy options on climate change that he or she can implement once in office. Katherine's paper dealt with one of the President's most significant channels of power—executive orders—and the philosophical approaches three different presidents brought to their uses of these orders. Additionally, Katherine is doing research with Dr. Guruswamy on ways to bring renewable energy technology to people living on less than a dollar a day. Much of this research involves geographically specific applications of technology, one example being a study of the viability of hybrid wind/photovoltaic systems in western, rural China.

One of the best aspects of CEES, Katherine says, is the way that it has been able to tap into the Colorado legislature and increasingly, the international community. She thinks this is partly a result of the Center's emphasis on an unbiased research perspective concentrated on providing policy makers with the tools to implement more effective initiatives. And the Center has also given Katherine a new perspective on what she might want to do with the rest of her life. She has applied to law school for next fall and feels that working at CEES has already given her "a year's worth of prep." In particular, she has gotten a better idea of how law interfaces with science and policy, as well as plenty of opportunities to do legal research.

Given her accomplishments to date, whichever law school Katherine chooses will be fortunate indeed to have her as a student.

CEES/EcoArts Events

Michelle Stoll, CEES 1L Volunteer

ecoarts

During September and October of 2007, CEES co-hosted four events focusing on climate change with EcoArts, a non-profit collaboration between artistic and scientific entities. The annual EcoArts festival investigates the realities of climate change and a sustainable future through artistic expression based upon scientific research. EcoArts uses artistic media to connect emotionally with the spectre of climate change—to inspire, educate, and empower people to act constructively.

CEES co-hosted four panels of scientists and artists discussing their collaboration. The participants' dialogue elaborated upon how their inspiration could be used to combat apathy on climate change.

The first discussion, held on September 17th, was entitled *Art Meets Science.* It featured digital media artist Andrea Polli, acting director of CU's Institute of Arctic and Alpine Research (INSTAAR) Dr. James White, and ecological artist Aviva Rahmani. Polli's project combined sonifications of storm, heat, air quality, and wave data with abstract visualizations to evoke emotion related to climate change. Contemplating the ramifications of reaching a tipping point in baseline climate change, White and Rahmani shared collaboration using GIS mapping to address environmental and geopolitical impacts around the Nile, Ganges, and Mississippi Rivers.

On September 24th, Dr. Kevin Trenberth, head of the climate analysis section at the National Center for Atmospheric Research (NCAR) and lead author for the Intergovernmental Panel on Climate Change (IPCC), presented *Global Warming Affects Us All: What Must Be Done?* Dr. Trenberth asserted that global warming is unequivocal, and that most of what will occur in the next thirty years is already determined. Trenberth emphasized that without a substantial shift in attitude and political will, the effects of polluting the "global commons" are unlikely to abate—instead we will have to adapt. Trenberth believes that sustainable management of the environmental system will be our primary challenge.

See EcoArts, Page 8

Student Comment: Katherine Peters

CEES Research Associate

General Relativity and the Folly of Artificial Distinctions

I recently came across an article in the *Harvard Law Review* written by Lawrence Tribe entitled, "The Curvature of Constitutional Space: What Lawyers Can Learn From Modern Physics." *See* Lawrence H. Tribe, *The Curvature of Constitutional Space: What Lawyers Can Learn from Modern Physics*, 103 HVLR 1 (Nov. 1989). At first, I balked at the title because too often analogies to physics are used badly to bolster an argument where they have no place. But in the introduction, Tribe assures the reader that this is not his intent. Instead, the essay argues, "the central conceptual shifts represented in modern physics provide useful new ways of thinking and talking about law, legal argument and legal practice." *Id.* at 3. So I read on.

Tribe describes the shift from Newtonian Mechanics to General Relativity. In the Newtonian world, spacetime is a static background upon which bodies are moved by forces. In General Relativity, spacetime is active. The mass of bodies upon spacetime cause it to curve and in turn, its curvature determines how bodies can move.

In the "Newtonian" view of jurisprudence, the law is a static background entity. Judges look at it and apply it, their actions causing no change to the law itself. A post-Newtonian view of the law, based on insights from General Relativity, better fits our modern intuitions about the law. Tribe argues:

> *Just as space cannot extricate itself from the unfolding story of physical reality, so also the law cannot extract itself from social structures; it cannot "step back," establish an "Archimedean" reference point of detached neutrality, and selectively reach in, as though from the outside, to make fine-tuned adjustments to highly particularized conflicts. Each legal decision restructures the law itself, as well as the social setting in which law operates, because, like all human activity, the law is inevitably embroiled in the dialectical process whereby society is constantly recreating itself.* Id. at 7-8.

See Student Comment, Page 7

The Colorado Energy Profile (CEP): Meeting the Energy Challenges of the Future, One Data Point at a Time

Adam Reed, CEES Research Associate

Fifty years ago, everyone knew that Colorado's energy lay deep in its mountains, and its food roamed the plains and grew from irrigated soil. That old geography lesson about coal and cows now seems as tattered as the schoolbook out of which it came. In its place are more new energy options, in more places, than ever: biofuels, biomass, demand side management, geothermal, hydropower, nuclear, solar, wind, and more. But how do we craft the new energy economy in Colorado; what mix of technologies is "right" economically, socially, and environmentally?

High-country coal veins and gas pockets still yield energy, but at what cost? Greenhouse gas emissions from traditional energy use threaten the prosperity of our descendants and their global neighbors, while the ecological damage of extraction raises deep questions about our role as caretakers of the wondrous landscape we inhabit. And yet the new options, while exciting, are no panacea. All renewable energy technologies and strategies have economic, social, and environmental drawbacks. To name a few: biofuels displace food supply; demand side management is more "tourniquet" than "surgery;" geothermal technology injects toxins close to aquifers; hydropower destroys endangered species' habitat; nuclear power is still frightening to many; and solar and wind are too costly to compete as-is with a heavily-subsidized fossil fuel industry and also raise land use concerns because of their need for massive amounts of space. No one method or technology appears optimal. The allocation of social and economic capital to the new energy economy falls on policy experts to direct the development of a cleaner, greener, and more sustainable future for Colorado.

Accurate, timely data about renewable resource potential, production and generation capacity, transmission infrastructure, consumption patterns, and environmental impacts is crucial to good decision-making. Equally crucial is an understanding of what renewable energy and energy efficiency policies and laws are currently in place at the federal, state, and local levels, and what effects they have produced. Over the next two years, CEES will work with the Governor's Energy Office and its research partners at the Renewable Resource Generation Development Area Task Force, Colorado State University's Natural Resources Ecology Laboratory, Xcel Energy, the Colorado Public Utilities Commission, and the Rocky Mountain Climate Organization to create a free, comprehensive, and public database of energy data and policies: the Colorado Energy Profile (CEP).

CEES has two primary responsibilities in the joint project. First, drawing on its unique position as a law-based sustainability center, it will create a database of laws and policies regarding renewable energy and energy efficiency in Colorado, from federal initiatives to municipal outreach programs. Second, CEES will compile the legal database with the energy supply, demand, and environmental data collected by its research partners into the CEP itself. Currently, CEES is working with Colorado cities to compile renewable energy and energy efficiency policies implemented at the municipal level, such as photovoltaic solar panel rebates, water conservation measures, residential and commercial energy efficiency audit and upgrade programs, and green building codes that are mandatory for new structures. At the same time, CEES is communicating with research partners to prepare a database structure for all of the information to be gathered over the project's two-year timeline.

Plant: (continued...)
"Once you start to get those kinds of divergent interests all focused on one common goal, that's when you hit a real tipping point and things start to change."

Further evidence that there has been a real shift in public thinking is the success of the GEO, an office created by Governor Ritter on April 16, 2007. The GEO is helping to transfer technology from research labs into the marketplace, accruing new technology from various research projects, and stimulating "this emerging economic opportunity of renewable energy and energy efficiency," says Plant.

"Overall we have the much larger focus of really changing the paradigm of how we consume energy and how we emit pollutants into the air. We realize that we cannot continue down this same road. So there need to be some very profound shifts in the amount of pollutants we are putting into the air. It's going to come through a variety of things, but primarily we are seeing it come through conservation going on across the state and renewable energy taking the place of more traditional fossil fuels, so that we end up with more of a mix of energy resources as opposed to having a large reliance on one very polluting form of energy."

Plant believes that CEES plays an important role in this change. "I think House Bill-1203 [which provided CEES with a grant to study Colorado's energy use, please see EESI News Issue One for more information] was a very important step for the state in recognizing that if we are going to make changes in all the ways we have been talking about, we need to first quantify what the best ways are to get there, what our current resources are, what our current opportunities are, and what we need to do so that we can develop that well integrated plan. It's a fairly large challenge, but the work of CEES is going to really help us be able to achieve that."

Plant is in favor of CEES's policy of educating both politicians and the general public. "People care enough that if they are given information they are going to want change…Making that kind of information available to the public can help [the public] to lead even those politicians who may be resistant to change." EE

Student Comment: (continued...)
One of the advantages to a post-Newtonian view of the law is that it would spare lawmakers from making artificial distinctions. Tribe continues:

> *The most basic substantive principles affecting the kinds of things that government may do in its dealings with people should not depend on accidents of form and appearance—like the accident of whether the government exerts pressure through a single administrative regulation instead of through a series of judicial rulings, or by imposing a fine on those who do something instead of offering a benefit only to those who agree not to do it. Id.* at 37.

The purpose of this student comment is to provide an example from General Relativity to further illustrate the folly of artificial distinctions. According to Newtonian Mechanics, gravity is a force which pulls massive objects together. But, because the Earth has not gone crashing into the Sun, Newtonians had to posit the existence of a force that counteracts gravity when one object is circling the other. This force, the centrifugal force, differs from other forces in that no object seems to cause it. It simply appears when needed. Alternatively, according to General Relativity, the Earth stays in its orbit because it is traveling a geodesic, the shortest path given the curvature of spacetime. It is not necessary to invoke the centrifugal force as a way of balancing gravity because gravity is not a force—it's the result of spacetime curvature.

Marek Abramowicz, a professor of astrophysics at Göteborg University, one of the major universities in Europe, likes the idea of the centrifugal force because when we drive around in a circle it feels like a force is pushing us outward. So he extended the concept of centrifugal force to the arena of General Relativity. *See* Marek Abramowicz, *Black Holes and the Centrifugal Force Paradox*, SCIENTIFIC AMERICAN (March 1993). He took the curvature of spacetime and carved its effects into "gravity" and "centrifugal force."

Unfortunately, when an object is in orbit close enough to a black hole, the "centrifugal force" pushes in the same direction as gravity, rather than against it. In order to save intuitions about the "centrifugal force," Abramowicz proposed that we change what we mean by "outward" and "straight" so that it sounds like the centrifugal force always points in the right direction. However, the definitions he devised for these terms are artificial, designed only to fit the case of an object moving in a circle around a black hole. It turns out that if the object orbits in an ellipse instead of a circle, his new definitions fall apart. (To see the mathematics behind this statement, please contact me at: kkpeters@colorado.edu).

The problem with redefining terms to suit a specific situation is that the definitions are unlikely to behave well everywhere. It is not surprising that Abramowicz's attempt to save the relativistic version of centrifugal force failed when considering alternative situations given that his new definitions of "outward" and "straight" were introduced to save "centrifugal force" from clashing with intuition.

In General Relativity, "gravity" and "centrifugal force" are really two sides of the same thing. It's possible to make the distinction between them and treat them differently, but doing so can have bad consequences. Similarly, in law, imposing a fine for doing something is just the other side of offering a benefit for not doing it. As Tribe concludes:

> *In law just as in physics, the goal of freeing constitutional analysis from such entirely artificial distinctions is best achieved if we think of law, and of governmental action, as changing the social landscape and redirecting the 'geometry' of human interactions, instead of regarding government as a physical entity that, through the 'forces' exerted by its component parts, tugs and pulls at people who are 'out there' in a 'state of nature.*' Tribe at 37. EE

EcoArts: (continued...)

Dr. Kevin Trenberth of NCAR addresses a packed audience at a CEES/EcoArts

On October 4th, in *Music Meets Science*, musician and founder of Ensemble Galilei Carolyn Anderson Surrick, CU Boulder College of Music faculty and Associate Dean of Graduate Studies Dr. Steven Bruns, and National Oceanic and Atmospheric Administration (NOAA) scientist Dr. James Butler engaged in a discussion about the ability of music to inspire action on climate change. Surrick shared a musical presentation by Ensemble Galilei, combinding imagery from National Geographic's "Exploration and Discovery," Celtic music, poetry, and text. The piece evoked the mystery, sorrow, elation, and hilarity experienced by famous explorers, introspection on the optimism of humanity, and love for this world. Bruns and Butler rejected the division between art and science, noting that each is based upon technical foundations, insights, discoveries, and emotional intensity. The panelists urged the audience to embrace idealism, like that experienced during World War II and the preparations for the first moon walk, to vigorously combat climate change.

On October 25th, Lucy Lippard, curator of the "Weather Report: Art and Climate Change" exhibit, concluded the CEES/EcoArts discussions with *Art and Climate Change*. She urged artists and scientists to work together for social justice regarding climate change, leveraging their synergy to translate scientific knowledge into something comprehensible. Lippard believes it's the "artists' job to teach us how to see." Indeed, the exhibition harnessed art's potential to inspire and move, contemplating a vision for a sustainable future. EE

Breakthroughs: (continued...)

Cars like the new Volkswagen tandem-seat diesel car, which gets 235 miles per gallon, exemplify this approach.

More commonly, people look to electric technology for maximum fuel efficiency in the form of electric vehicles, hybrids, and hybrid plug-ins. Today, an electric vehicle can go from zero to sixty miles per hour in six seconds and get six miles per kilowatt-hour of electricity. Growing in popularity, hybrids yield forty percent more efficiency than gas-powered cars by utilizing their electrical systems during regenerative braking and deceleration. For both hybrid and electric cars, the largest impacts on overall efficiency likely will come with the technological advancements of plug-ins. Charging batteries from the grid, with the promise of eventually leveraging renewable energy sources, will cut U.S. dependency on oil as well as transform the transportation sector as we know it.

RMI's Jeff Ronning

Integral to prompting business investment in vehicle technologies is having policy mechanisms that explicitly favor resource efficiency. One of RMI's policy analysts, Natalie Mims, described the basics behind one such mechanism, the Feebate. Instead of strict regulations which punish inefficiency and incentives which reward efficiency, the Feebate model works on an ever-changing pivot point in each size category of vehicle to reward those pushing efficiency ahead and charging those who fall behind. RMI's study of this dynamic model indicates that the combination of incentives and rewards could phase out inefficient vehicles, while maintaining consumer choices across all size classes. Though one of the major goals of implementing this policy mechanism is to reduce U.S. dependency on oil, RMI specifically supports this mechanism because it falls directly in line with the motto as put forth by Michael Ogburn: "Green because we think it will make green in your pocket."

RMI's Natalie Mims

Besides sharing vehicle technology advancements, RMI's team drove home that innovation, so necessary to solving the world's energy crisis, often proceeds in relatively simple steps. RMI will continue to work on increasing energy efficiency, bit by bit, with a whole systems engineering approach. EE

Questions? Comments? Please Contact:

Mariah Zebrowski, Editor-in-Chief
Mariah.Zebrowski@Colorado.edu

Paris Lumb, Assistant Editor
Paris.Lumb@Colorado.edu