Title

The Transition to a Carbon-Neutral Energy Economy: Exploring UCSD's Role

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The Environment and Sustainability Initiative

The Transition to a Carbon-Neutral Energy Economy: Exploring UCSD's Role

Workshop Report
May 3-5, 2006
La Jolla, California

UCSD

University of California, San Diego

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Executive Summary

A workshop of UCSD faculty, researchers, and students, joined by representatives of industry, government and non-profit organizations, spent two days considering the role UCSD and its partners could and should play in addressing the challenges of energy and sustainability. As UCSD proceeds with developing a campus-wide Environment and Sustainability Initiative, it is clear that energy must be an important area of research, teaching, and partnership. The workshop succeeded in providing a forum for participants to share their expertise and explore the potential for UCSD to develop interdisciplinary sustainable energy projects. UCSD has a wide range of expertise, including ocean and atmospheric sciences, engineering, informatics, chemistry, biology, health sciences, economics, management, international relations, political science, and urban studies. UCSD is also part of the larger San Diego community, the border region, and has a role to play at the national and international level as well.

To effectively address the energy and sustainability challenges ahead, we will need to draw on the full range of academic research and practical knowledge found throughout UCSD and in our public and private sector partners. This integration and partnership will initially take shape in research and demonstration projects developing biological sources of energy on both short and long time horizons. At the same time, the challenges of growth and environmental stewardship in the southern California-Baja California region will be addressed. Work has already begun on the practical steps needed to turn these ideas into actions.

Our long-term vision includes the development of integrated observations and analysis tools to support decision-making at all scales as society addresses the challenges of transitioning to a carbon-neutral energy economy, taking into account technological, social, ecological, and political considerations. UCSD and its partners have an important role to play in making this vision into reality. The initial projects stimulated by the workshop will be developed with the longer-term vision in mind, and can be viewed as modules building toward a comprehensive capability.

As stated in a May 3, 2006, *New York Times* editorial, "…energy, broadly defined, has become the most important geostrategic and geoeconomic challenge of our time…" UCSD is applying its resources to contribute knowledge and practical solutions to meet this challenge.

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Introduction

Sustainability – meeting the needs of society while preserving the natural systems on which we all depend – is the most pressing challenge facing humankind in the twenty-first century.

Corporations, universities, and governments around the world now recognize the challenges of sustainability, and are responding to its obligations and opportunities. Together, we can harness the latest understanding of the complex interconnections that sustain life and growth to provide information for decision-makers and stimulate new products and services. UCSD is committed to providing knowledge, technology, and trained professionals, and to partner with the external community, to help achieve a more sustainable future. While there is no single definition of sustainability or sustainable development, it is clear that certain paths are not sustainable: continued depletion of natural resources and disruption of ecological systems and natural cycles to meet short-term economic needs cannot be continued indefinitely. Rather than debate specific targets or definitions, we are focused on moving in more sustainable directions. We can define paths that are more sustainable than others, while leaving the debate over specific goals or targets to individuals and to decision-makers in the public and private sector.

Dr. Charles Kennel, Director, UCSD Environment and Sustainability Initiative

Under the leadership of Dr. Charles Kennel, a large group of UCSD faculty has proposed the establishment of a UCSD Environment and Sustainability Institute (ESI) as a formal entity to oversee campus-wide interdisciplinary efforts in this area. The mission of the ESI is to:

- Develop practical solutions to local, regional, and global problems,
- Create innovative partnerships within UCSD and with industries, governments, and international organizations to ask the right questions and create effective solutions,
- Generate new research and teaching specifically aimed at sustainability challenges.

A UCSD Energy Research Vision:

- Develop a set of scenario computation tools that provide visualization of 21st century energy development trajectories.
- Link multi-disciplinary toolsets to provide consistent scenario computations based upon state-of-art understanding in all relevant fields.

A successful sustainability program must address energy as a fundamental component. The initial ESI planning workshop in February 2006 highlighted the value of having a focused workshop on energy. With financial support from Sempra Energy and several individual donors, a workshop was planned to design a UCSD research and education program in energy and sustainability, based on the question "How can we move toward a carbon-neutral energy economy?" In particular, consistent with the ESI theme of sustainability informatics, participants were asked to consider development of tools to define, model, and visualize scenarios integrating climate change, ecosystem processes, business innovation, technology development, local/regional/national/global economics, policy and regulatory processes, and possibly other factors to support decision-making. Participants were invited from UCSD, local energy companies, and relevant government and non-governmental organizations. A list of the workshop participants can be found in the Appendix (on pages 30-31).

The workshop began with words of welcome from UCSD Vice Chancellor for Marine Sciences, Charles Kennel, Director of the ESI, and Lisa Shaffer, Executive Director of the ESI. UCSD experts in engineering, climate science, atmospheric science, cyberinfrastructure, biology, management, urban studies, and geosciences gave opening presentations on current research directions at UCSD. Dr. Ari Patrinos, President of Synthetic Genomics, Inc., and former DOE

Green is the new red, white, and blue.

Thomas Friedman

official, gave a keynote address on future directions in biology and energy. Professor George Tynan of the UCSD Center for Energy Research presented a strawman vision of a comprehensive energy research program for UCSD.

UCSD is committed to providing knowledge, technology, and trained professionals, and to partner with the business community, to help achieve a more sustainable future.

With this foundation to build on, the participants met in smaller groups to develop ideas for new interdisciplinary initiatives in bioenergy and in border energy issues. The groups considered what would be appropriate activities for UCSD, given its strengths, and how to partner effectively with non-academic organizations, so that the work would have practical value and applicability. Particular attention was given to information technology, data, and tools that might help inform decision-makers considering complex issues related to energy and sustainability. Several specific initiatives were proposed and will provide the basis for further, more focused development.

As an early effort in the development of the campus-wide UCSD program, the workshop provided valuable outputs.

In addition to the specific project ideas, the ESI organizers gained insights into the needs and expectations of the participating non-academic organizations. Graduate and professional students from UCSD participated actively in the workshop and helped prepare this report. They provided important feedback as well on educational aspects of the issue, and useful connections were made for possible internships.

A Vision for a UCSD Integrated Energy Program

Professor George Tynan
Jacobs School of Engineering

Access to an adequate supply of energy is correlated with a decrease in infant mortality, increase in literacy and education rates, increase in lifespan and decrease of population growth, all indicators of a higher quality of life. Areas with poor access to energy are increasing their energy production and as they do so, individuals living in these regions can expect improvements in their quality of life.

Currently the vast majority of the world's energy demand is provided by the combustion of fossil fuels, which emit large amounts of CO2, a greenhouse gas, into the atmosphere; with the increase in global energy consumption, the quantity of CO2 emitted into the atmosphere is expected to increase. Given the concern about global climate change, the question then arises: as the populations in developing regions increase their appetite for energy and a higher standard of living, how do we meet the global demand for energy and not induce unacceptable levels of climate change? In other words, can we stabilize carbon dioxide concentration in the atmosphere and meet the world's growing energy needs? Projections from Hoffert, et al show that by the mid-century the world will need about 15-20 TW of carbon-free power in order to stabilize atmospheric carbon dioxide and meet global development requirements. This rate of energy production is larger than the entire current global power production capacity, which is very carbon intensive. How are we going to make this transition, and are we moving quickly enough in the right direction?

In the past, transitions between different energy sources have taken roughly 40-50 years as our primary energy sources have moved from wood, to coal, then to oil, and more recently to natural gas. Given the expected increase in global energy demand and the constraints of climate change, what set of primary energy sources should the coming energy transition move towards? How well prepared are we for this transition? Are our current efforts, investments, and focus sufficient? If not, then how do we redirect our efforts?

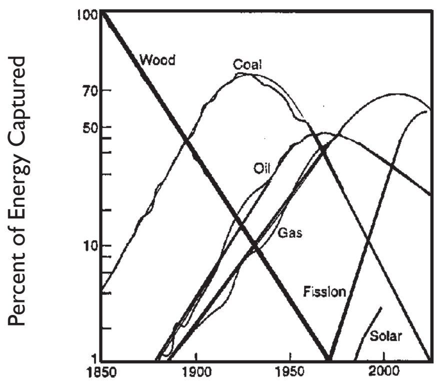


Fig 3: Market Penetration History and Projection for the U.S. (Marchetti Rule)

Ref: Marchetti, C., Nakicenovic,N. Energy in a Finite World, Ballinger Pub. Cambridge, MA 1979, pp.253-279

Creating visualization tools for the 21st century energy trajectories linking data from all relevant disciplines will help answer these questions. These visualization tools should include components from a wide variety of fields including: climate modeling, biological and ecosystem models, market, capital, and economic models, energy resources availability, advancement of technological and scientific breakthroughs, and demographic and social models. The tools would be used to then develop internally consistent scenarios which then be visualized in all their dimensions using state-of-the-art visualization tools and data representations. They would then be made available to researchers, public and private decision makers, and the general public in order to permit stakeholders to see the long-term impact of near-term choices and thus be able to make informed decisions about the development of appropriate energy sources and technologies. Example scenarios include how a large-scale biofuel production would impact the economy, environment, and climate in a specific region or how to modify policies to create the best market forces for a carbon-neutral energy system. This is envisioned as a multi-scale approach going from local to national to global.

Keynote Address: Biotechnology for Energy Needs

Dr. Aristides A.N. Patrinos

Genomic projects and fundamental biological investigations are not just about human medicine and health. These endeavors have much wider impacts. The US Department of Energy's Genomes to Life (GTL) program is one example of how genomics will likely have a significant impact on developing a sustainable energy future. Through the use of DNA sequencing and high-throughput technologies, GTL seeks biological solutions for our energy challenges by pursuing innovative approaches along unconventional paths. Central to the success of endeavors such as GTL is the continued advancement of automated DNA sequencing and high-performance computing. The application of automated research tools is new for biology, but it is a key step if we are to succeed in solving our most pressing challenges.

Most of the world around us is unicellular and invisible. In this invisible world we can find biotechnology solutions using the natural diversity of microbes and microbial communities. Until recently we could only culture a small percentage of the organisms around us and could only research what we could see. Genomics and genome sequencing change this. To date 320 genomes have been fully sequenced, with another 813 ongoing sequencing projects. But, when compared to the 1.7 million currently described species and estimates of the total number of species world wide in the tens of millions, we clearly have only begun to scratch the surface of solutions through biotechnology. Environmental genomics – the sequencing of all the genomes found in a sample of soil, water, air, rock, etc. – holds particular promise in finding and developing novel biological solutions to current and future needs.

Up to this point, sequencing of plant genomes has received little effort (three so far with 31 ongoing

Converting wood chips into biofuels.

> *…the greatest ultimate global impact of genomics will result from the manipulation of the DNA of plants. Ultimately, the world will obtain most of its food, fuel, fiber, chemical feedstocks, and some of its pharmaceuticals from genetically altered vegetation and trees.*
>
> *Philip H. Abelson, Editor, Science, March 1998*

projects) yet the development of sustainable energy solutions through advances in our understanding of plant biology/physiology is very promising. The sun delivers 120,000 terawatts (TW) of energy to the Earth's surface annually. Plants through photosynthesis have the ability to convert this energy into a wide variety of energy products such as sugars for ethanol and oils for ethyl/methyl esters (biodiesel). The world currently consumes approximately 13 terawatts of energy annually. At 1% energy conversion efficiency it would take only 3.86% of the Earth's total land area to agriculturally produce our current energy consumption of 13 TW. Many of the crops currently cultivated for biofuel production have proven 1% conversion efficiency is easily achievable, and newer crops such as miscanthus and oil palm have shown energy conversion efficiencies of 2% or greater are feasible. Given that terrestrial plants are largely composed of cellulose and lignin – materials which are currently not easily converted to fuel – and "energy crops" have not been subjected to human selection yet, large gains in productivity are likely in the near future. Genomics will play a significant role in achieving these gains and recent progress in basic and applied sciences should facilitate rapid progress.

Agriculturally produced fuels such as ethanol and biodiesel hold huge promise for using biomass to replace petroleum and meet US and world energy needs. Today, production of fuels such as ethanol is mostly a chemical engineering process. In the near future, production of ethanol and other biofuels will be bio-microbial process driven. Energy is an enabler in the world, but it has its costs and prices. The answer to our energy crisis is biology. If we do not place biology as central to finding the solutions, we will fail.

Current Research and Future Directions

UCSD experts were invited to give short presentations about current research and future directions related to energy and sustainability. Each presentation is summarized below. The visual materials from the presentations are available on the ESI website.

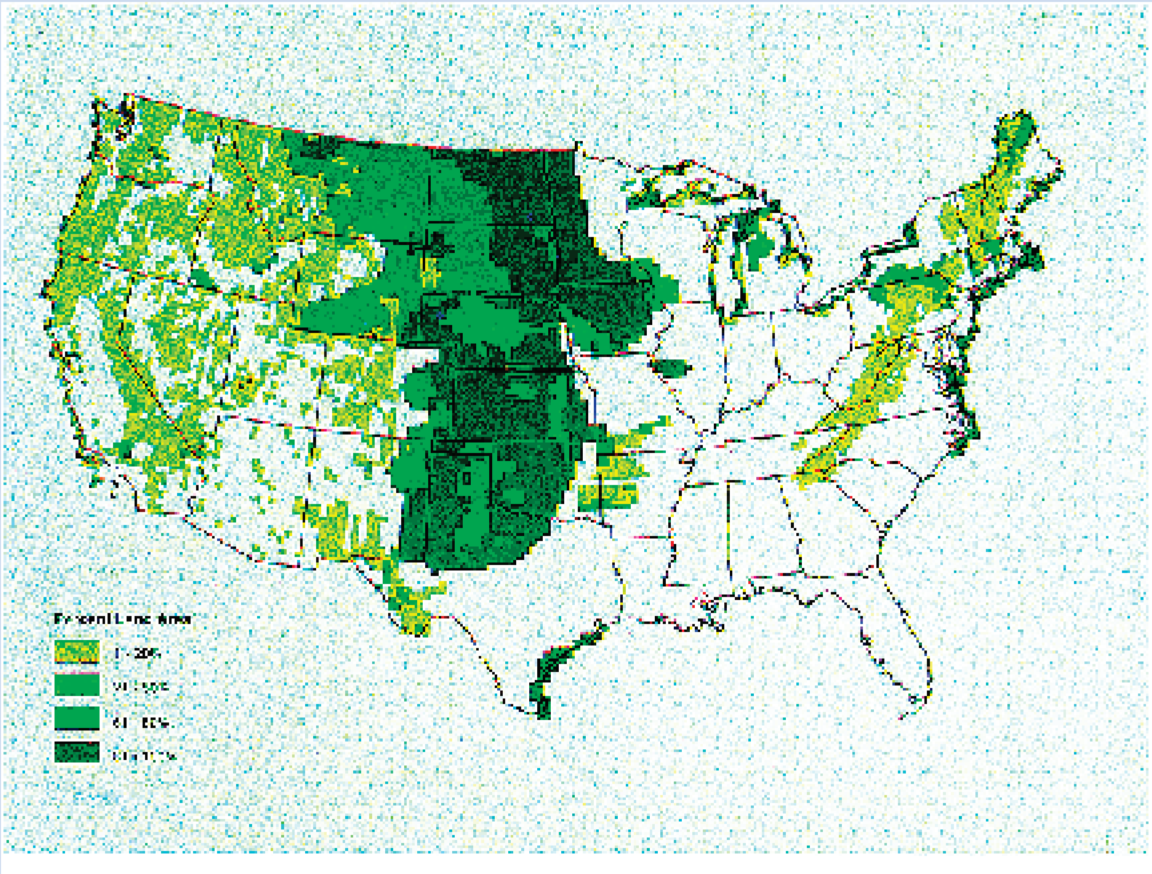
Energy Technology and Materials

Professor Steve Buckley
Jacobs School of Engineering

The Center for Energy Research (CER) has a strong technical program centered in combustion and fusion engineering. The Center wants to grow into other energy-relevant technical areas related to transitional technologies, such as biofuels and other alternative energies as well as energy systems and fire science. Currently based primarily in the Jacobs School, the CER would like to involve more chemistry, physics, business, economics, social sciences, and humanities collaborations. As UCSD educators, CER members view their role as producing energy technologists as well as communicating with policy makers. As researchers, they see their role as finding energy solutions beyond fossil fuels and developing new ways of storing and utilizing carbon-free energy.

There are several big questions in the energy field. How do we go from "here" to "there"? We know we have to move away from "here" – business as usual – due to the effect of our carbon-intensive energy infrastructure on climate and geo-politics, but where is "there"? Is "there" a place with only carbon-free energy or just reduced carbon intensity? Carbon intensity is the ratio of mass of carbon emitted to unit of power. We note that carbon intensity is not related to combustion efficiency, as when burned in a power plant, nearly all fuels have

How do we go from "here" to "there"? We know we have to move away from "here" – business as usual – due to the effect of our carbon-intensive energy infrastructure on climate and geo-politics, but where is "there"?



Percent of the land area estimated to have Class 3 or higher wind power in the contiguous United States.

an efficiency of 30-35%. The transition between "here" and "there" will be expensive.

Making renewable energy cost effective is an additional issue to consider. W.W. Nazaroff from UC Berkeley has compiled data showing that wind is the only renewable energy on par with coal on an economic basis, for substitution in the near-term. According to NREL wind potential maps, most of the Midwest has a great potential. One place that does not show potential is Ohio – but even in Ohio there has been great progress in wind energy. A non-profit from Ohio, Green Energy Ohio (GEO), has been finding suitable locations to place wind turbines since 1997. In 2004, they helped the local utilities place two wind turbines. The return on the turbines was such that the costs were recouped in a little over a year, so the utility company was excited to work with them to place more turbines. So far, they have placed four turbines in Ohio and have brought great excitement about renewable energy. If Ohio isn't an ideal place for wind energy but has been this successful, imagine the potential for the Midwest. And if a non-profit can do that on a shoestring budget, imagine what UCSD can do.

Climate, Energy and Sustainability

Dr. David Pierce
Scripps Institution of Oceanography

There is an important interaction between climate and energy, and variations in climate affect both the energy supply and demand. For example, the snow pack in the Pacific Northwest varies according to the severity of the winter, which has an impact on the amount of hydroelectric power that can be produced. Energy by-products such as CO_2 and particulate matter also affect climate, and this is perhaps the most familiar part of the relationship.

Links between climate and energy demand are well known. For example, in California, 40% of the demand for energy in the summer goes to air conditioning, which leads to enormous price increases in electricity on hot days when the demand cannot be met. This is a concern for both consumers and producers, as it can potentially lead to electrical blackouts. Reducing energy consumption on peak load days can help to decrease the price of electricity, as even a modest reduction in demand can reduce electricity prices significantly on the peak demand days. The effect of climate on energy supply is less appreciated. As changes in climate affect the supply of energy, the amount of variance in the climate has important implications. Supply changes in one area can affect consumers in other areas. The Pacific Northwest, for example, doesn't export electrical power to California if it doesn't have an excess supply of hydropower. Hydroelectric power has significant variance from year to year. Better reservoir management based on seasonal climate forecasts could increase efficiency and save money; thus improved forecasting of seasonal streamflow and reservoir water levels would be very valuable.

The effect of energy emissions such as CO_2 and aerosols on the climate, resulting in an overall warming, is an important problem that has received a great deal of scientific and media

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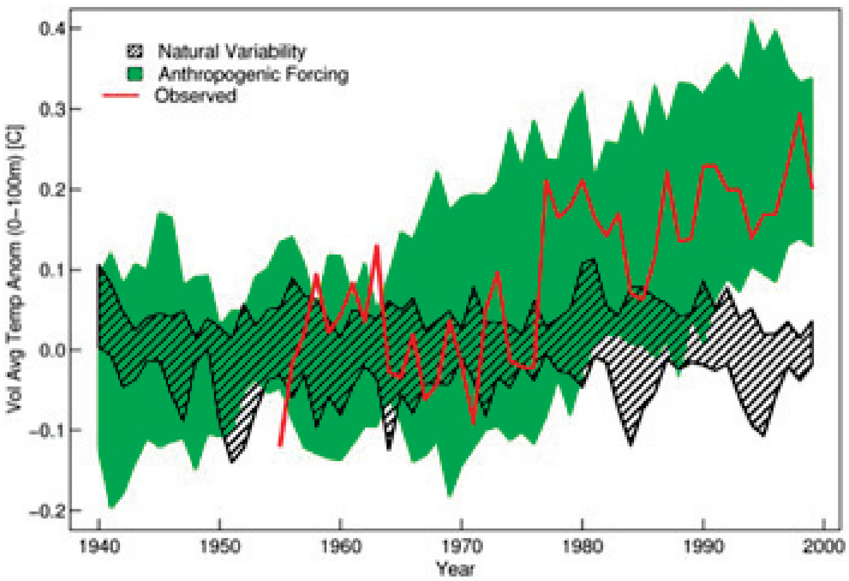
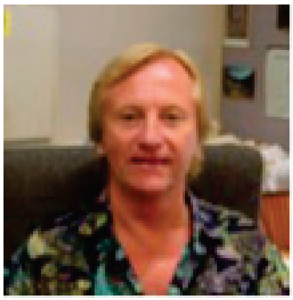


Impact of human activity on ocean temperatures.



Sustainable Energy in the California/Baja California Border Region

Jim Adams
California Energy Commission

No matter what we do, we use energy. Every two years the California Energy Commission compiles the Integrated Energy Policy Report (IEPR) to assess energy use in California, including the California/Baja California border region.

In 2003, there was more than $30 billion in trade transport across the border. Trade has contributed to air and water pollution in and around the border region, and the CEC staff is doing an in-depth analysis of transportation, energy efficiency, and air quality.

What is the potential for rail use, non-petroleum based fuels, and alternative energy at the ports, among others? Southern California is one of the most dynamic areas in terms of vehicles and goods movements, and energy use and environmental impacts must be examined at both the micro and macro levels.

....Pierce, continued from previous page

attention. The increase in global average surface temperature over recent decades has manifested itself in many ways: arctic sea ice extent is shrinking, loss of shoreline ice has resulted in worsened coastal erosion (as there is less ice to buffer winter storms), glaciers are undergoing systematic change (most are retreating), and the timing of blooms, egg laying and migration is speeding up at rate of five days per decade. The Keeling curve indicates increasing levels of CO_2 due to human activity, and there is a relationship between CO_2 levels and surface temperatures. Ocean temperature data, which show a pronounced warming in recent decades, also match models of the warming expected due to human forcing. (Ocean temperatures are not well explained by natural variation at all).

There is a close relationship between these temperature changes and energy use and supply. Increased temperatures result in longer and hotter heat waves and hence higher needs for air conditioning, while at the same time lead to diminished snow pack and less hydroelectric energy supply. In addition to the climate change we are experiencing now, there is a certain amount of committed climate change, i.e. the amount that will occur due to the gasses and aerosols already emitted even if we stop emitting CO_2 today. Climate change is complicated, and one issue confronting potential users of climate information is its probabilistic nature. Not all energy industry management structures are set up to utilize this type of information – but models can help them shift their behaviors, or help them set up financial hedges.

Air Pollution and Climate Change

Professor V. Ramanathan

Scripps Institution of Oceanography

Air pollution and climate are interconnected at regional and global scales. The effect of greenhouse gases on global warming is the most important environmental issue facing the world today. The history of climate change research goes back to Svante Arrhenius in the late 1800s, and includes the pioneering measurements of atmospheric CO_2 by Dave Keeling, and Ramanathan's own work identifying the greenhouse effect of CFCs and subsequent identification of other greenhouse gases.

Research on atmospheric brown clouds started with the Indian Ocean Experiment (INDOEX). If greenhouse gases are the ultimate end product of fossil fuel and CO_2, then particulates in the air represent an intermediate phase. A brown haze is generally associated with urban areas, but in 1999, INDOEX focused on a brown cloud that spans an entire continent and ocean and found that biomass burning and fossil fuel combustion contribute as much as 75% to the observed aerosol. Black carbon is probably the most insidious component of the haze as far as health is concerned; it is also the most important factor in terms of climate change. The investigators discovered that black carbon and other absorbing particles in the brown haze over the Indian Ocean and the Arabian Sea reduced sunlight by as much as 10–15%. The sunlight reduction effect at the surface was larger by a factor of two or more than estimated by climate models. In terms of the ocean surface, black carbon in the brown haze reduces the average radiative heating by as much as 10% and enhances atmospheric solar radiative heating by as much as 50–100%. The link between aerosols and precipitation represents an added complication. As emissions from fossil fuel and black carbon have increased, monsoonal rainfall and surface sunlight have decreased. The brown haze appears to slow summer monsoonal circulation, leading to a reduction in precipitation over South Asia. Long-range wind transport means that pollution on the East Coast of the United States is going across the Atlantic to Europe, European pollution is traveling to Asia, and Asian pollution is coming back to America. To better understand how atmospheric brown

Our knowledge of the underlying causes of climate change is growing, but the problem brims with uncertainties, raising serious scientific and ethical questions.

clouds impact the environment, climate, and the quality of life, the Atmospheric Brown Clouds (ABC) project was launched to develop a system of strategically located ground-based observatories in the Indo-Asian and Pacific regions to monitor atmospheric pollution.

There are unsolved questions surrounding the rate and masking of global warming. The extent of global warming is not fully reflected in the Earth's surface temperatures. Some of this warming has been masked by the dimming due to brown clouds, and the remaining heat is stored in the depths of the ocean to be released later. Every decade we delay in taking action, we are committing the planet to additional warming that future generations have to deal with. The masking effect is equally troubling. We now know that the surface cooling effect of aerosols may have masked as much as 50% of the global warming caused by greenhouse gases, presenting a serious dilemma for the global community: if we attempt to reduce air pollution because of its effect on health, we may see an explosion in global warming. At the same time, if greenhouse gases are curbed because of our concerns about global warming, the brown clouds may weaken the Earth's water cycle, particularly the monsoonal rainfall in East Asia, leaving us with conflicting options involving those regions negatively impacted by global warming and those negatively impacted by air pollution.

Energy Sustainability Informatics

Dr. Chaitanya Baru

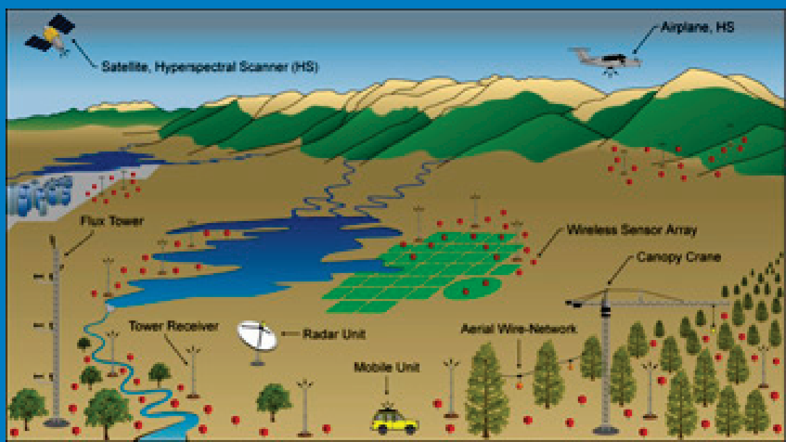
San Diego Supercomputer Center

Cyberinfrastructure can be simply described as computational technology that brings remote resources together. The energy problem is a multifaceted issue that involves science and information from many disciplines in many forms. Cyberinfrastructure includes the computational resources to combine massive amounts of heterogenous scientific data, knowledge, and information. It involves data storage, management, manipulation, and presentation and could act as the connecting architecture in the energy science community. It would include four domains: the instruments and facilities which collect the data in the "physical world"; a knowledge management activity to collect, build and curate the data; high performance computing systems for modeling, simulating, and processing; and interfaces that provide individual or group users access. Portals would provide authenticated, role-based access to cyber resources such as raw data, tools for manipulating the data, derived data products, models built with the data, and collaboration spaces for remote user interaction.

Similar example projects include the Geoscience Network (GEON; http://www.geongrid.org), which is a collaboration between Information Technology (IT) and Geoscience researchers, with the goal of developing a platform to facilitate the next generation of Geoscience research; and the Long Term Ecological Research network (LTER; http://www.lternet.edu). Other programs that are currently under consideration include the National Ecological Observatory Network (NEON; http://www.neoninc.org/related), the Ocean Research Interactive Observatory Networks (ORION; http://www.orionprogram.org), and the Consortium of Universities for the Advancement of Hydrologic Science Hydrologic Information System (HIS) (CUAHSI; http://www.cuahsi.org).

To begin building a cyberinfrastructure for energy and sustainability science at UCSD and SDSC, a UCSD energy portal should be developed, including online access to data sets and models, discussion space or digests of information on various energy related topics, and point of access data collected by current observation systems or web crawls.

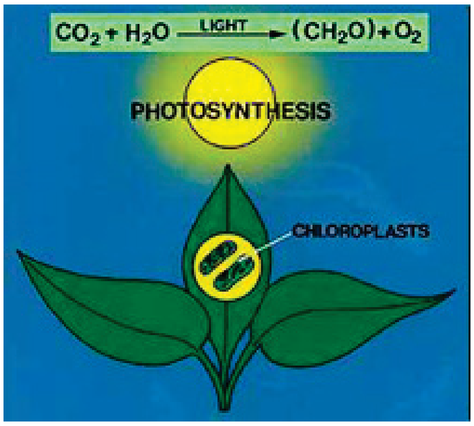
NEON Infrastructure Overview



Renewable Energy from Biofuels

Professor Julian Schroeder
Division of Biological Sciences

Plant biotechnology offers many intriguing opportunities to address important environmental challenges. Currently, a plateau has been reached in world grain production per capita. The population in water-scarce and water-stressed countries is projected to increase dramatically (a situation which could be even worse due to the impact of climate change.) Two-thirds of the water we use is for agricultural purposes, and the high volumes of pesticides used create runoff that has a negative impact on water quality. Plant biotechnology can contribute to addressing these problems by increasing yields, providing drought-resistant and salt-tolerant varieties, and making decreased pesticide use possible through engineered plants that are pest-resistant. Research in the Schroeder lab at UCSD is revealing genes and mechanisms through which plants could be engineered to show enhanced drought and salt resistance.



There is also potential for plant biotechnology to play a role in the move to renewable energy sources. Recently, there has been growing interest in the possibilities offered by biofuels made from agricultural products. For example, through microbiology, cellulose compounds can be degraded and converted into ethanol allowing more efficient use of a very abundant fuel source. Plants have tremendous potential because they turn sunlight into fuel, and we receive much more light from the sun than we need – if we could harness the sun's energy even at 1% efficiency, then we would only need 3.86% of the land to meet the entire planet's energy needs. With improved technology, the energy inputs necessary are decreasing. Currently it is estimated that for each unit of energy put in it is possible to get out 1.4 units of biofuel. In other countries the ratio is even better. In Brazil the ratio is very high because by-products are recycled for use in the process. A 2005 DOE USDA study predicted that even at present conversion efficiencies, the excess biomass produced by US agriculture could be converted to 100 billion gallons of ethanol, which could replace 30% of the U.S. annual oil consumption. Biotechnology also has the potential to greatly increase the yield of biofuel through plant and microbe engineering. In another example, biodiesel is extracted from seed oils, and through the use of biotechnology, UCSD scientists have developed methods through which seed dispersal can be inhibited, resulting in more seeds available for fuel production and increased yields.

Business and Innovation

Professor Vish Krishnan
Rady School of Management

The new Rady School is a work in progress, with only six full-time faculty and its inaugural classes of full-time and executive MBA students currently enrolled. A large portion of students (about 33%) already hold PhD or MD degrees. At Rady the emphasis is on "Lab to Market": taking technologies and developing commercialization paths.

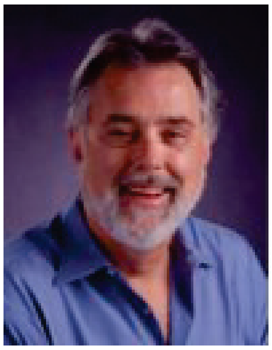
Ultimately, it comes down to consumption. Are we trying to sustain today's consumption?

Issues of both supply and demand influence how a business relates to sustainability. To be sustainable, businesses must minimize inputs for a given level of outputs. In terms of energy, it is not enough to reduce the carbon-intensity of the energy that is used – companies must work to reduce energy use overall. Sustainability can be a factor in all aspects of efficiency, growth, and productivity relating to design, manufacturing, re-manufacturing (i.e., what happens to the products after their initial use), logistics, procurement, and services and customer support.

Businesses naturally care about inputs because of their impact on the bottom line. Despite popular perception, businesses care about reducing inputs and increasing efficiency. However, to go from efficiency to sustainability, we need to look at overall consumption. Using hybrid engines not for increased fuel efficiency, but rather for improved acceleration, is not sustainable enterprise. At present, is appears that customers only care about performance, and their willingness to pay has not increased for "green" product attributes.

What is sustainability – what are we trying to sustain? Who is paying for environmental costs? There are companies working on solar panels who have resisted moving towards newer, more sustainable technologies because investors seek short-term results and present technology is good enough, even though long-term there are greater benefits to seeking technological advance.

There are examples of sustainability market mechanisms: the Chicago Climate Exchange for trading emissions credits for greenhouse gases, and a retail service allowing individuals to purchase offsets for their emission, Terrapass.com. Another example is a solar company interested in technology that is moving away from separate solar panels, and integrating energy production into the building materials so all the exterior surfaces contribute to energy production. Several students and groups at the Rady School are involved with initiatives in sustainability.



Political Potential: Challenges and Opportunities for Sustainable Energy

Professor Steve Erie
Urban Studies and Planning, Political Science

In Los Angeles, the timing is right for green politics. The environmental consequences of L.A.'s massive trade infrastructure complex are devastating. The San Pedro Bay Ports are the most toxic hot spot in Southern California, and LAX emissions significantly contribute to substandard air quality. This is not a new phenomenon, and yet more than ever before it is high on the political agenda. West Side Angelenos (a key political support group), residents of the harbor area, and local health policy academics have made environmental concerns and quality of life top political priorities. As a result, the L.A. mayor has pledged no net increase in emissions at the Port of Los Angeles, and has halted LAX expansion.

It is often thought that a crisis is necessary to prompt political action. However, this new agenda in Los Angeles is not a response to crisis, but reflects leadership responding to scholarly research and political pressure. The Haynes Foundation funds academic research on public policy issues in the Los Angeles region. Environmentalists and community residents are driving the new L.A. green agenda through

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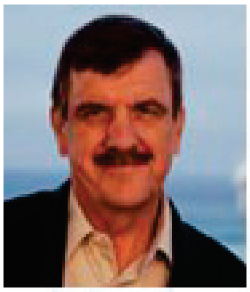

Geosciences

Professor John Orcutt
Scripps Institution of Oceanography
UCSD Center for Earth Observations and Applications

Geoscience is a broad field representing areas from biology to meteorology, and there are many different programs being developed both domestically and abroad. For example, the Center for Earth Observations and Applications (CEOA) at UCSD promotes programs that provide data and information and make continuous awareness of the environment possible, an essential component of moving toward a more sustainable future. An example of a regional program is the Southern California Coastal Ocean Observing System (SCCOOS), connecting eleven universities and laboratories integrating observations such as high frequency radar and ocean color satellite data to monitor river outflow transport and supply continuous surface current maps 100-200 km off the coast.

Project Atmospheric Brown Cloud (ABC), which was described in more depth by Professor Ramanathan, demonstrates the value of integrated observations using ships, ground-based observatories, aircraft, satellites, and unmanned aerial vehicles (UAV) to measure Earth's albedo and absorption of solar radiation. Several UCSD programs, including HPWREN,

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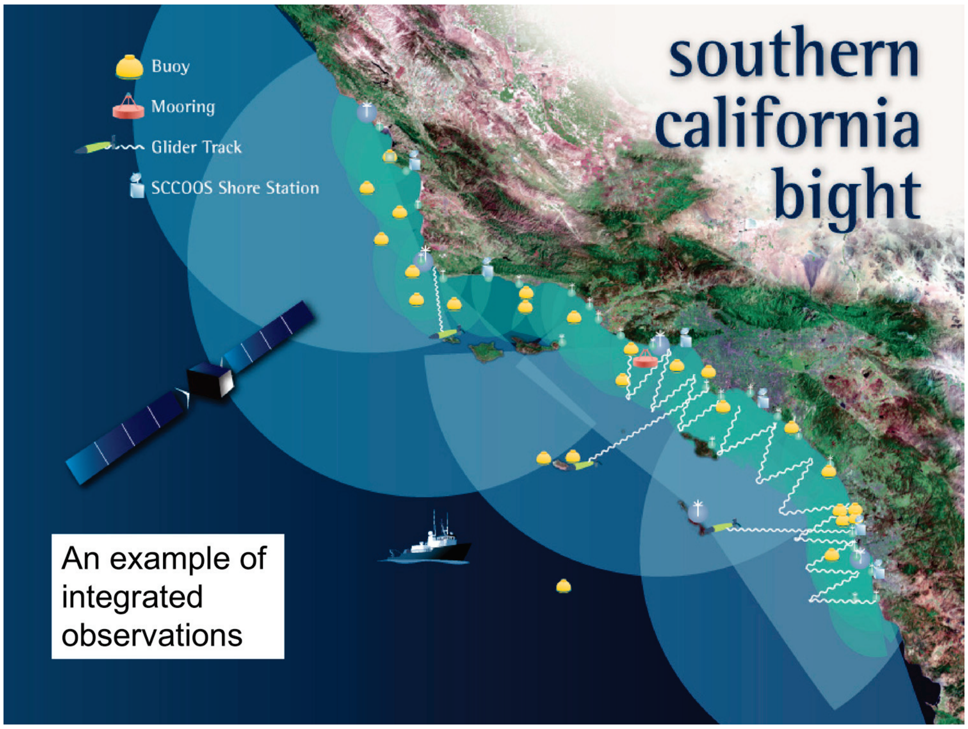

An example of integrated observations

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ROADNet, and HiSeasNet, exploit wireless and satellite networks to allow data communication of seismology, meteorology, imagery, surface current, and geodetic data in real time from sensor networks and research ships. The data are open to everyone, making the ships at sea a continuous "local observatory." Earthscope is an NSF program supplying continuous data from seismic stations in the US.

ARGO is a program led by Scripps involving close to 3000 free-drifting profiling floats that measure the temperature and salinity of the upper 2000 m of the ocean. This allows, for the first time, continuous monitoring of the temperature, salinity, and velocity of the upper ocean, with all data being relayed and made publicly available within hours after collection. As of January 2006, there are 2236 ARGO floats around the world recording continuously. One-third of the Global Seismic Network (GSN) is run by Scripps Institution of Oceanography at UCSD. In a major initiative linking cyberinfrastructure to marine genomic analysis, the Community Cyberinfrastructure for Advanced Marine Microbial Ecology Research and Analysis (CAMERA) project was awarded a $24.5 million grant over six years to better understand the phylogenic tree of life.

As a final example, the Ocean Observatory Initiative (OOI) is the NSF's contribution to the U.S. Integrated Ocean Observatory System (IOOS) to establish a permanent presence in the oceans. The ocean subsystems are monitored continuously on global, coastal and regional scales and cyberinfrastructure ties it in with the Ocean Research Interactive Observatory Network (ORION).

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political action. The environmental costs of most infrastructure projects are concentrated, while the economic benefits are dispersed, which encourages group organization to mitigate the adverse effects of L.A.'s ports and airports.

San Diego is on the same deteriorating quality-of-life trajectory as Los Angeles. Yet once-strong environmentalists no longer drive the San Diego political agenda. "Prevent Los Angelization," was once a popular phrase. But San Diego is now sprawling haphazardly, and traffic and pollution are worsening. The local growth machine is firmly entrenched in city and county government.

There is a great need for regional policy research on environmental, infrastructure and energy issues in San Diego. But the local political situation is not favorable, and there is no regional policy research funding. Government agencies are separate and narrowly focused on their missions. Environmental problems require a broad vision and perspective, and the capacity to organize coalitions. This is where the Environment and Sustainability Initiative can be of assistance. ESI can support sustainable energy research and initiatives in the San Diego region, and can serve as an honest broker between government, industry, the community, and academia on such critical issues as regional carrying capacity, sustainable energy technologies and policies, and comparative regional assessments.

Breakout Groups

The workshop participants divided into two breakout groups, one on biology and energy; the other on air quality, climate, health, and border energy issues. A summary of each group's discussions follows. The breakout groups identified several specific projects that the ESI could stimulate, and the details of these ideas are incorporated into a separate "Action Plan" which will provide the basis to further develop strategies and move ahead on implementation.

Breakout Group I:

Biology, Genomics and Alternative Energy Scenarios

The Biology, Genomics and Alternative Energy Scenarios breakout group had an exhilarating discussion that focused on the topic of bioenergy.

The session began with a motivating message from Ari Patrino's presentation on the essential role of biotechnology in alternative energy development for a sustainable future. The question thereafter was how the Environment and Sustainability Initiative could focus the University's strengths in the natural and social sciences on alternative energy solutions. The resounding answer from both the academic and industry participants was bioenergy! Bioenergy can take numerous forms other than the production of ethanol or biodiesel from terrestrial agriculture (from products such as corn, sugarcane and soybeans). Biofuels can also be harvested from aquatic agriculture. Algae and other microbial feedstocks can produce oils for biodiesel, sugars for ethanol, and even have the potential of producing hydrogen with continued development. Harvesting oils for biodiesel is a particularly promising near-term solution with many advantages over terrestrial crops including increased conversion efficiency. Bacteria and fungi are intriguing, but as yet undeveloped, sources of biofuels such as methane. The Rhodobacter bacterium is the first known biological source of electricity, although traditional biofuels are being successfully converted into electricity in places such as Brazil. Finally biology can be used to motivate biomimetic devices and improve non-biological alternative energy technologies.

The group discussed numerous resources that UCSD has to contribute to the research and development of bioenergy. The strong natural sciences at UCSD, including SIO, would play central roles. For example, researchers at SIO could continue developing micro and macro

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Jay Brandeis	Jessica Swanson
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algae sustainable feedstocks for large-scale energy production. A number of UCSD industry partners have expressed similar interests. The Division of Biological Sciences could contribute the botanical and agricultural research that will be essential for scaling up terrestrial biofuel production to levels sufficient to replace fossil fuels. The Jacobs School of Engineering, and in particular its Center for Energy Research, could address engineering challenges around biofuel production, storage and infrastructure. Atmospheric chemistry and human health faculty could address the effects of large-scale biofuel use on human health and pollution.

Discussants agreed that transitioning to alternative bioenergy would involve all facets of society. Therefore, a complete biofuel program would include a broad spectrum of UCSD's exceptional academic resources, such as the departments of Economics and Political Science, the Graduate School of International Relations and Pacific Studies, and the Rady School of Management. The San Diego Supercomputer Center (SDSC) could provide a linking architecture between this multi-department and institutional effort. The SDSC could be utilized not only for data management and analysis within separate disciplines, but as a meeting ground where the cumulative effects of science, engineering, social patterns, policy decisions, and market decisions could be explored.

Given this suite of talents, the group concluded that UCSD would be ideally suited to establish a Bioenergy Research Institute. This effort could be greatly bolstered through private industry partnerships to support test projects and facilitate the conversion of academic knowledge and lab-based research to practical applications, market products, and societal benefit. Sempra and Diversa expressed strong interest in socio-economic cost-benefit analysis of different alternative energy scenarios, and potential pilot projects in which cutting edge bioenergy research could be linked to the electric grid for real world testing and development. All companies present (Diversa Corp., Genomatica, Kyocera Solar, Sempra Energy, and Synthetic Genomics) expressed the need for community education and outreach.

Breakout Group 2:

Air Quality, Environment, Health, and Energy: Southern California/ Baja California Region

UCSD has many assets to bring to the question of air pollution, climate, and health on a global and local/regional scale. On the research side, some of the world's leading atmospheric scientists are at SIO and the main UCSD campus. We have a vibrant health sciences faculty working on the impact of environmental conditions on human health. We are also located in a border region with many scholars working on border issues including environment and energy. The workshop breakout group decided to focus initially on the southern California-Baja California region and to develop projects and analytical capabilities that could be applied in other geographic areas and scaled as needed. The approach was to develop integrated informatics tools that would support analysis of alternative scenarios such as changes in fuel sources, border crossing times, economic development, and other policy interventions, in a broad perspective, taking into account such impacts as ecosystem changes, coastal conditions, and human health, as well as economic and air quality implications. To the extent possible, this "regional sustainability portal" would integrate the many existing programs, data sources, and organizational interests that already are addressing specific elements of this challenge.

Once that framework was developed, specific research and policy questions could be posed and evaluated, guided by a bi-national leadership group. Before committing to a specific configuration or project design, the ESI will build on available information and the contributions of workshop participants to collect additional information and make additional contacts to encompass as much as possible of the relevant activities in the region. Then, based on that background research, we will develop a proposal for a bi-national leadership group and a complementary bi-national analysis group.

With SDSC leadership, the ESI proposes to develop an inventory of existing and desired data for the region, along with existing analysis tools or models to determine what added value ESI can provide. We plan to establish an energy informatics working group to collect requirements from researchers and decision-makers that can be used in defining the integrated sustainability informatics portal.

Participants

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V. Ramanathan
Lynn Russell
Sheila Sarkar
Lisa Shaffer

The group proposed to structure its activities around the goal of documenting change over past 10 years and developing the capability to project change over the next 20 years on a broad and integrated basis. We would strive to create a common knowledge base and portal for use by scholars, business leaders, and public officials, to study a wide range of specific questions.

The breakout group also discussed interest in developing tools for scenario building – using as an example the computer game "SimCity". We want to develop the capability to evaluate different trajectories and scenarios across different policy and technology changes, and to do so in a modular way. We would start with business as usual projections, look at the atmospheric quality component, then add transportation, congestion, urban growth, etc. and look at the challenges of cross-border policy harmonization.

In all the discussions, there was a desire to ensure that we can identify a clear value added by any undertaking. Among the areas where we believed the UCSD ESI could add value were in convening existing groups that are each more narrowly focused to provide a higher-level of integration and collaboration; integrating disparate data and information in a set of decision-support tools; filling research and observational gaps; serving as "honest broker" of knowledge without a policy agenda; devising common indicators and metrics; and in providing an objective peer review process for work in this area.

Workshop Summary and Conclusions

As UCSD proceeds with developing a campus-wide Environment and Sustainability Initiative, it is clear that energy must be an important area of research, teaching, and partnership. The workshop succeeded in providing a forum for participants to share their expertise and explore the potential for UCSD to develop interdisciplinary energy sustainability projects. UCSD has a wide range of expertise, including engineering, informatics, biology, chemistry, ocean and atmospheric sciences, health sciences, economics, management, international relations, political science, and urban studies. UCSD is also part of the larger San Diego community, the border region, and has a role to play at the national and international level as well.

To effectively address the energy and sustainability challenges ahead, we will need to draw on the full range of academic research and practical knowledge found throughout UCSD and in our public and private sector partners. This integration and partnership will take shape for issues related to energy and sustainability initially in research and demonstration projects involving the development of biological sources of energy on both short and long time horizons; and in addressing the challenges of growth and environmental stewardship in the southern California-Baja California region. Work has already begun on the practical steps needed to turn the ideas into action.

Our long-term vision includes the development of integrated observations and analysis tools to support decision-making at all scales as society addresses the challenges of transitioning to a carbon-neutral energy economy, taking into account technological, social, ecological, and political considerations. UCSD and its partners have an important role to play in making this vision into reality. The initial projects stimulated by the workshop will be developed with the longer-term vision in mind, and can viewed as modules building toward a comprehensive capability.

UCSD is applying its resources to contribute knowledge and practical solutions to meet the challenges of energy and sustainability.

Appendix: Participants

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The mission of the ESI is to:

- Develop practical solutions to local, regional, and global problems

- Create innovative partnerships within UCSD and with industries, governments, and other organizations to ask the right questions and create effective solutions

- Generate new research and teaching specifically aimed at sustainability challenges

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