Shell Center for Sustainability

2011 Annual Report

Celebrating 10 years of Research, Education and Outreach

School of Social Sciences
6100 Main Street, MS-27
P. O. Box 1892
Houston, Texas 77251
(713) 348-2796
http://shellcenter.rice.edu

2011 Annual Report
The Shell Center for Sustainability (SCS) at Rice University is an inter-disciplinary program of research, outreach and education that addresses actions that can be taken to ensure the sustainable development of living standards, interpreted broadly, to encompass all factors affecting the quality of life, including environmental resources.

This year marks the ten-year anniversary for the Shell Center for Sustainability, a partnership between Rice University and Shell Oil Company.
A Word from the Academic Director

The Shell Center focused on enhancing interdisciplinary collaboration of faculty, staff and students for research and education in all areas of sustainability during 2011. We currently fund seven new research projects across campus and support 28 graduate and undergraduate students from six academic departments at Rice University, along with four external collaborations, working on a range of sustainability projects.

Our Web site continues to expand as a useful resource on campus sustainability endeavors and is currently being updated to include information on faculty and staff who are engaged in various aspects of sustainability research and education.

As part of our outreach efforts and under our new focus on sustainability of Gulf of Mexico coastal cities we published “Atlas of Sustainable Strategies for Galveston Island”, and “Measuring City Sustainability: Project Houston.”

Ongoing efforts are aimed at improving sustainability practices for the greater Houston area and the Gulf Coast.

John B. Anderson
Executive Summary

Research on low energy use and water purification is the focus of Drs. Jun Lou, Quilin Li and Pulickel Ayayan. These researchers work on a Self-sustaining portable capacitive deionization device for water purification project.

Drs. Douglas Schuler and Marcia O’Malley explore sterilization off the grid with a project previously funded by the Shell Center for Sustainability (SCS). This new initiative explores a medical application of the Solar-thermal powered autoclave for rural health services.

The tradeoffs between sustainability and performance are the focus of Drs. Marc Epstein and Kristi Yuthas as they develop performance metrics and methods for evaluating social impacts.

Drs Robert Griffin and Barry Lefer are conducting research to control strategies that can support future clean air legislation by measurement of atmospheric particle number concentrations in Houston.

Exploring the challenges of micro-cities at sea is the focus of the research project by Neeraj Bhatia and Fares El-Dahdah, The Petropolis of Tomorrow.

Maria Meza-Lopez and Dr. Evan Siemann will research non-native species impacts in their project, Effects of Anthropogenic Nutrient Enrichment and Climate Change on Invasion Success and Impacts On Native Freshwater Communities.

Drs. Rafael Verduzco and Seth Darling explore cheap and scalable solar energy via High Performance Polymer Voltaics.

The Houston Sustainability Indicators project, led by Dr. Lester King, will develop 30 indicators to measure sustainability in the Houston region.

Speakers from Shell Oil Company and the University of Chicago enhanced SCS collaborations, partnerships and invitations to share research and information within and beyond the Rice community.

Local activities included continued participation with the Center for Houston’s Future and Americas’ WETLAND Foundation.

Publications produced by SCS are, “Measuring City Sustainability: Project Houston”, and “Atlas of Sustainable Strategies for Galveston Island”.

SCS created an Advisors and a Technical Review Board to include regional experts in sustainable development to assist with strategies and technical direction.

Students continued to gain opportunities to work on sustainable development projects through internships offered by our partners and SCS.

SCS supported and advised students who decided to create a team to participate in the Shell Eco-Marathon, and the Glasscock School of Continuing Studies’ development of a new sustainability course.

SCS carried the sustainable development message to the community and abroad via participation in summits, visits, talks, competitions and planning initiatives.
In the fall of 2011, The Shell Center for Sustainability (SCS) funded projects with a broad focus. The objective was to attract more projects that focused on the Houston and Galveston urban areas and the Gulf of Mexico while meeting the criteria for research on sustainable development.

The SCS Operating Committee and members of the newly formed Technical Review Board reviewed submitted proposals. The selection committee sought the best projects among many interesting proposals.

Seven projects were funded for research that will take place in 2012. They encompass a diverse set of interdisciplinary teams and covered the following areas of research:

- Low Energy Use Water Purification
- Solar Sterilization
- Metrics for Social Impact
- Measurement of Atmospheric Particles
- Offshore Living
- Effects of Climate Change and Nutrient Enrichment in Freshwater
- Photovoltaics
Self-sustained Portable Capacitive Deionization Device for Water Purification

Deionization at a low cost

Team

Project Investigator (PI): **Dr. Jun Lou**, Department of Mechanical Engineering and Materials Science.
Co-PI: **Dr. Qilin Li**, Department of Civil and Environmental Engineering.
Co-PI: **Dr. Pulickel Ajayan**, Department of Mechanical Engineering and Materials Science.

Project Background

Water is one of the most important problems facing human beings. A large proportion of the world’s population suffers from drinking water shortages. Meanwhile, 98% of the water on earth is sea water which is not drinkable because of high salt concentrations.

One possible solution lies in our ability to desalinate sea water. There are several mature technologies for sea or brackish water desalination. The most widely used are thermal processes and reverse osmosis (RO). However, both technologies are very energy intensive.

Capacitive deionization (CDI), however, is a desalination/purification technique with a promise as a cheaper and more efficient alternative. This makes this technology attractive for portable, point of use treatment devices.

In order for the CDI devices to work off-grid, which will be very important for their utilization in both remote areas and urban areas where minimum energy footprint is allowed, solar energy is a very attractive option. In this regard, dye sensitized solar cells (DSCs), an emerging low cost (~1/3 cost compared to silicone based solar cells) solar harvesting technique, is a perfect candidate for desalination.

The overall objective of this research is to create a self-sustained portable water purification system that integrates energy efficient CDI with low cost DSCs.

The team will develop innovative nano-carbon materials for high efficiency and versatile CDI electrodes. The off-grid operation and small footprint of the proposed portable system has minimum impact on overloaded aging urban energy and water infrastructures. CDI/DSC has great potential in military and domestic applications where more energy intensive water purification technologies are not viable.

For this one-year project, the team plans to explore this technology from both materials and system perspectives. The team will first fabricate high quality 3-D graphene/CNT composites that have desired surface and electrical properties with sufficient mechanical integrity. Utilization of the novel graphene/CNT composite as electrode material in both CDI and DSC devices for higher efficiency operations will occur. Finally, the team will directly connect a DSC module consisting of several individual cells with proper output voltage and current as an external DC power source for the fabricated CDI devices.

The team’s end-of-project goal is to successfully fabricate both CDI/DSC devices using novel 3-D graphene/CNT composite. They expect to have an operational lab demonstration of a well-integrated CDI-DSC system by the completion of the project.
Solar-thermal Powered Autoclave for Rural Health Services

Sterilization off the grid

Team

PI: Doug Schuler, Professor, Jones Graduate School of Business, Rice University.
Co-PI: Marcia O'Malley, Ph.D., Professor, Mechanical Engineering and Materials Science, Rice University.
Tremayne Kaseman, Student, Mechanical Engineering, Rice University.
Jean Boubour, Staff, Rice University.

Marcia O'Malley, Rice Engineering student Tremayne Kaseman and Rice staff member Jean Boubour.

"According to the United Nations' Millennium Development Goals, the lack of energy services is a major deterrent to socio-economic development," Schuler said. "Many health practitioners in these remote settings don't have access to clean medical instruments. The unfortunate result is a number of negative health outcomes, including post-maternal mortality and other infectious conditions."

The project is a continuation of research sponsored by the SCS a few years ago. Schuler and his students developed a solar-powered cooking device, which they tested in Haiti in 2009. Schuler calls their new project a "new application" of their previous research–“That may be scaleable through private-public-NGO partnerships and is expected to have a large public health impact.”

Developing Performance Metrics and Methods for Evaluating Social Impacts

The tradeoffs between sustainability and performance

Team

PI: Marc J. Epstein, Ph.D., Professor, Jones Graduate School of Business, Rice University
Co-PI: Kristi Yuthas, Ph.D., Professor, School of Business Administration, Portland State University

Project Background

Among the most critical challenges in the fields of sustainability and the management of non profit organizations is measurement of social impacts. Large corporations are often faced with tradeoffs between sustainability and financial performance as they evaluate proposals and face decisions re-
lated to job layoffs and other labor practices, environmental responsibility, community activities, and many others.

This issue is also common in governmental and non-governmental (NGO) organizations. Philanthropic organizations are commonly faced with resource allocation decisions that include choosing which projects to invest in to maximize the benefit to the community.

A sovereign wealth fund wants to maximize the benefit of its activities for the country’s residents. A foundation may have to decide whether to invest in a for-profit dairy, in non-profit primary schooling, or in non-profit or for-profit delivery of health programs in Africa. And, there are many others. Each of these choices requires an evaluation of social impacts that are challenging.

More guidance is needed about how to make investment decisions that maximize social impacts and monitor and evaluate how much social impact occurred. It is also necessary to monetize these benefits so that social impact per dollar invested is calculated which makes project comparisons more effective.

Building upon extensive research completed by Dr Marc Epstein, Distinguished Research Professor of Management at the Jones Graduate School at Rice University along with his co-author Dr Kristi Yuthas of Portland State University, this project will complete phone interviews and field research to:

1) identify existing practices that identify and measure social impact by various corporations, social enterprises, foundations, and other NGOs

2) identify best practices

3) develop a model and measures for social impact

4) provide practical guidance for individuals and organizations that need these measures to make more effective resource allocation decisions

This project will build on the authors’ work with major corporation sustainability programs along with their extensive work with non-profit organizations in developing countries in Africa, Asia, and South America.
Measurement of Atmospheric Particle Number Concentrations in Houston

Knowledge to support control strategies

Team

PI: Rob Griffin, Ph.D., Associate Professor, Civil and Environmental Engineering, Rice University.
Co-PI: Barry Lefer, Ph.D., Associate Professor of Atmospheric Science, University of Houston.
Yu Jun Leong, Graduate Student, Civil and Environmental Engineering, Rice University.

Project Background

Particulate matter (PM, also known as aerosol) consists of very small solid or liquid materials distributed in a background gas. Levels of atmospheric PM have been correlated to rates of illness and premature death among exposed populations based on the mass concentration of all particles that have diameters smaller than 2.5 millionths of a meter (PM$_{2.5}$). However, increasing evidence indicates that the smallest particles (generally in the range of a few to 100 billionths of a meter in diameter), which typically contribute very little to the particulate mass concentration but very strongly to the overall particulate number concentration (i.e., how many individual particles are present), have profound implications for exposed populations because they are small enough to cross tissue boundaries and enter the bloodstream directly. A continuous, high-quality, high time-resolution data set of particle number concentration in an urban area known to suffer from poor air quality is highly valuable. Generation of such a one-year data set in Houston is the primary objective of this project.

The generation of this data set will be by use of a condensation particle counter (CPC). A CPC operates by exposing particles in an ambient sample to saturated water vapor and then cooling the sample so that the water condenses onto the particles and makes them large enough to be detected by a laser.

Based on the frequency of detection of particles by the laser and air flow rate through the CPC, a concentration (# of particles/volume of air) can be determined. Typical particle number concentrations are on the order of thousands of particles per cubic centimeter of air.

The CPC will be deployed at the air quality monitoring station located atop the North Moody Tower on the University of Houston main campus. The planned date for initial deployment is February 1, 2012, and measurements will be taken for one calendar year at a frequency of one minute. This location is ideal for air quality measurements as it is influenced by many local and regional air pollution sources, including power generation facilities, highways, airports, and industrial facilities associated with the Houston Ship Channel.

Deployment of the CPC at this location will complement the existing meteorological and other air pollutant parameters that are measured and will be invaluable for the initial assessment and analysis of particle number concentration data. After quality checks are complete, data analysis techniques will be performed in conjunction with statistical analysis. Further analysis will focus on methods for determination of factors that control particle number concentrations in Houston. Data will be made available publicly.

This project addresses a threat to clean air. Appropriate control strategies cannot be derived without knowledge of present day concentrations and sources of pollutants. In this case, the data collected
may provide the basis for future clean air legislation. This project also addresses concerns beyond air quality because PM deposits on surface waters (water quality) and because PM affects the amount of radiation that reaches the Earth’s surface (climate forcing).

Results will be presented at a national conference (American Association for Aerosol Research (AAAR) which will be held in Minneapolis, MN, in October 2012). At the end of the project, a manuscript which describes data collection and analysis will be submitted to a peer-reviewed scientific journal for publication.

The Petropolis of Tomorrow

Empowering the challenges

Team

PI: Neeraj Bhatia, Visiting Wortham Fellow, School of Architecture, Rice University.
Co-PI: Farès El-Dahdah, Associate Professor, Professor, School of Architecture, Rice University.

Project Background

The Petropolis of Tomorrow is a design and research project, which examines new Petropolises — cities formed from resource extraction — associated with offshore oil extraction in Brazil. The Libra oil field and newer discoveries are occurring at greater distances from shore. Being out of feasible helicopter range has prompted plans to develop a series of ‘floating frontier towns’. ‘Island hubs’ are being investigated which bridge distances and allow for efficient movement of people as well as storage of materials.

Laura Williams, An aquaculture-based island.

These hubs allow workers to be transported by boat to land, and connect to various rigs via helicopters. Perhaps most importantly, these hubs are not only operating as logistics centers, they are taking on larger core populations, which afford greater public amenities such as auditoriums, gyms, and libraries. As these frontier islands take on additional programs outside the production of oil, they act as micro-cities, yet little research has been afforded to this new type of water urbanism.

While often developed as temporary settlements with few amenities and with a series of social problems, these micro-cities in fact exist for at least twenty years. Plans to make hubs operational by 2017 provokes an investigation of how these new micro-cities could be designed to account for social and environmental sustainability as well as resource extraction. These new micro-cities are a form of water urbanism that creates a landscape that interfaces with both industry and marine environments.
The Petropolis of Tomorrow will develop these floating frontier micro-cities so they account for social and cultural concerns while simultaneously addressing environmental challenges and economic opportunities. Key research/design questions include:

— How can new landscape, architecture, and infrastructure be integrated to make the public realm more robust and sustainable?
— How can these micro-cities operate autonomously by harvesting food, fresh water, and energy from their local environment (both natural and constructed)?
— How can negative ecological effects of oil extraction be addressed in the design of these micro-cities to leave no footprint once extraction is complete?
— How can micro-cities be designed with long-term, holistic planning and create a healthy environment and culture for resource extraction?
— How can a symbiosis between resource extraction and sustainable urbanism be created?

To date, infrastructure tied to natural resource extraction has rarely been designed using long-term, holistic planning. Despite a growing use of floating cities, little effort has been afforded to the design of the landscape of these settlements.

The intention of The Petropolis of Tomorrow is to engage and empower the unique social, cultural, environmental, and economic challenges which face these new communities. The research/design work is organized into the following categories:

A) Culture (housing, arts, education, health).
B) Mobility (helicopters, boats).
C) Ecology (aquatic life, biology, effects of extraction).
D) Resources (energy, food, water).

The research will be presented via a blog, exhibition, and book.

Currently eight-six fixed and forty-six floating rigs serve as workplaces for over 45,000 people. It is evident that these new micro-cities are neither temporary nor small and must to be examined so we understand how both networks and islands can be deployed in a sustainable manner.

An estimated fifty new island platforms will be constructed in the future. This is an opportune moment to develop a new system of sustainable water-based micro-cities that use natural and constructed landscapes that create a robust public sphere.
Effects Of Anthropogenic Nutrient Enrichment And Climate Change On Invasion Success And Impacts On Native Freshwater Communities

Native species impact

Team

PI: Maria Meza-Lopez, Student, Ecology & Evolutionary Biology, Rice University.
Co-PI: Evan Siemann, Ph.D., Professor, Department Chair, Ecology & Evolutionary Biology.

Project Background

Freshwater ecosystems are often invaded by exotic species. Native biodiversity in freshwater ecosystems has declined at a higher rate than biodiversity in marine and terrestrial environments. Exotic plant and animal invasions, habitat modification by nutrient pollution and climate change each impact native species and ecosystems. Understanding the effects that nutrient pollution, and climate change (anthropogenic factors) have on interactions between native and exotic species in food webs is necessary to predict the effects of these factors on Gulf Coast freshwater ecosystems.

In southeast Texas, common native plants cattail (*Typha latifolia*), pennywort (*Hydrocotyle umbellata*), frog’s bit (*Limnobium spongia*), and pickerelweed (*Pontederia cordata*) together with native snails Physa spp. and ramhorn (*Planorbarius spp.*) co-occur with the exotic plant water hyacinth (*Eichhornia crassipes*) and the ex-otic island apple snail (*Pomacea insularum*). These exotic species invade freshwater ecosystems and co-occur in their native (South America) and in their introduced ranges (US). The team will conduct experiments that determine:

1) the responses of freshwater ecosystems to nutrient pollution and to climate change

2) the effects of exotic plant and animal species on these ecosystems

3) how the presence of exotic species modifies the vulnerability of these ecosystems to nutrient pollution and to climate change

The team will establish native freshwater communities composed of native plants and snails, invaded by an exotic plant and/or an exotic snail, to investigate the impacts of nutrients and the impacts of warming on native communities and the interaction of exotic species.

These experiments will increase the team’s knowledge of how exotic species invasion and anthropogenic factors such as nutrient pollution and/or climate change alter the interaction between multiple exotic species and their impact on native communities.
High Performance Polymer Voltaics

Cheap and scalable solar energy

Team

PI: Rafael Verduzco, Ph.D., Louis Owen Assistant Professor, Department of Chemical and Biomolecular Engineering, Rice University.
Co-PI: Seth Darling, Ph.D., Scientist, Center for Nanoscale Materials, Argonne National Laboratory.
Kendall Smith, Graduate Student, Chemical Engineering, Rice University.
Yen-Hao Lin, Graduate Student, Chemical Engineering, Rice University.

Project Background

The energy contained in 1 hour of sunlight is sufficient to power the world for an entire year. Nevertheless, a cost-effective method to harness solar energy has not been developed. With current technology, the cost of electricity from solar cells, also known as photovoltaics (PVs), is 4 - 10 times that of fossil-fuel based energy. This is due in part to costly high-temperature and high-vacuum process methods that are needed to fabricate silicon PVs.

Polymer-based PVs represent an emerging technology with significant potential for the provision of cheap and scalable solar energy. Flexible, large-area polymer PV arrays can be made by the use of liquid-based methods such as ink-jet printing and roll-to-roll coating. These techniques are used by the plastic industry to fabricate a variety of inexpensive consumer materials.

Polymeric-based PVs therefore offer the prospect of significantly cheaper solar energy as well as potentially recyclable and portable solar cells. However, the solar conversion efficiencies of the best polymeric PVs are insufficient to make these devices economically competitive.

While current materials should theoretically be capable of converting 20% of incident sunlight into electricity, only 8% conversion has been achieved. The team’s goal in this project is to prepare polymeric PVs that result in a better understanding of this limitation and perform better than materials currently being studied.

The team believes that nanotechnology provides a path to better polymeric solar cells. Polymeric PVs require at least two components to function properly: an electron-conductor and a hole-conductor for transporting negative and positive charges. In state-of-the art polymer PVs, the hole conductor is a semiconductive polymer and the electron-conductor is a C60 fullerene. While these components provide good charge transport, a practical challenge arises when attempting to blend the two components in the active layer of a polymer solar cell. The components do not mix uniformly, and as a result the active layer is heterogeneous and contains non-ideal pathways for photon absorption and charge transport.

Instead of blending two components, the team will use advanced chemical synthesis techniques to link the two molecules together at
the nanoscale. The researchers hypothesize that by doing so, they can not only prevent the two components from separating, but through a process known in the nanotechnology field as “self-assembly”, generate controlled nanoscale patterns of the electron-conducting and hole-conducting components.

If true, this will lead to a significant improvement in the efficiency of solar energy conversion and provide an approach for still-unanswered fundamental questions about how polymeric PVs function. In the long run, the team believes that its work will lead to much better power conversion efficiencies in polymer PVs and an improved understanding of how nanoscale properties affect the conversion of sunlight to electricity in polymeric PVs.

Houston Sustainability Indicators

Team & Background

Lester O. King, Ph.D., Sustainability Fellow

The Houston Sustainability Indicators (HSI) project was approved as a long-range effort for SCS. A fellow has been hired to lead Phase II of the project. Phase I, of the project, was completed by Jim Blackbrun and Stephen Klineberg, Ph.D. (See Measuring City Sustainability: Project Houston, in the Outreach & Education Chapter).

The first step under this fellowship was to establish a two year plan of action. The preliminary work developed a draft list of Sustainability Indicators and data collection and analysis for selected metrics.

The fellowship has advisors in the areas of environment, economics, and sociology. These advisors are Jim Blackburn, Ronald Soligo, Ph.D., and Stephen Klineberg, Ph.D respectively. The HSI Set, now in draft format, was chosen to measure and characterize the sustainability of Houston. After consultation with experts and advisors on the Draft Indicator Set, a Final Indicator Set will be identified and reported. Metrics for the chosen indicators will be defined and measured based on literature review; expert and advisory consultation; and data availability.

The framework used to structure the HSI Set is the Theme – Sub-Theme Framework. The Category Framework is also utilized to ensure balance between the pillars of sustainability. The Theme – Sub-Theme Framework is suitable for establish of links between important normative contributions of experts and advisors to the sustainability model and to the statistical components of the model.

Twenty seven (27) sustainability indicators have been chosen based on extensive literature review and criteria. Criteria used include data availability; data quality; update schedule of issuing agency, and characterization of sustainability priorities. The indicators were selected to equally cover the three (3) pillars of sustainability. Data was collected for the years 1990, 2000, 2010. Trends will be projected for 2015, 2020, 2030, and 2040.
Outreach & Education

Through outreach and education activities, the Shell Center for Sustainability shares scientific data. Collaborations, partnerships and invitations to share research are some of the ways that SCS shares science information at Rice University and delivers this information beyond the hedges.

Events and activities that took place in 2011 include:

Rigs to Reef: Decommissioning of Shell’s Eugene Island Platform, was a lunch colloquium co-sponsored with the Center for the Study of Environment and Society (CSES). The presentation was to talk about the decommissioning of obsolete and non productive offshore oil and gas structures and facilities for Shell Oil Company in the Gulf of Mexico. The talk focused on how these structures can be used to create habitat for marine life.

The Long Thaw was a public lecture co-sponsored with CSES and Green Team America at Rice University. Professor David Archer, from the University of Chicago, highlighted how humans are changing the Earth’s climate through the next 100,000 years.

SCS continued its partnership with the Center for Houston’s Future by presentation of the Quality of Place Symposium. The SCS participation continued through funding support of
the symposium. The theme of this year’s report focused on Water Quality, Water Supply and Green Buildings in the Houston region.

The Blue Ribbon Forum with The America’s WETLAND Foundation was hosted by SCS at Rice University. Blue Ribbon Resilient Communities: Envisioning The Future of America’s Energy Coast, was the 3rd of 13 leadership forums held across the five Gulf States of Texas, Louisiana, Mississippi, Alabama and Florida over 15 months. The forum focused on sustaining critical infrastructure and Houston's role as the center for the nation’s energy security.

The goal of the forum was to assess local vulnerabilities and empower individual communities in the region to envision, plan and act to ensure resiliency and sustain cultural, economic and ecological values in the face of growing coastal degradation. The forums’ objective is to strengthen the local voice. Through individual interviews, focus groups, and the forums, communities receive new data about vulnerabilities from Entergy Corporation’s recent "Gulf Coast Adaptation Study", and meaningful input from state and Federal partners that help participants identify actions needed to ensure a sustainable future.

SCS Publications for 2011 included the release of the, “Atlas of Sustainable Strategies for Galveston”, a report based on the project, “Developing A Long-range Sustainability Plan for the Upper Texas Coast”. The project, by John Anderson, Ph.D., from the Department of Earth Sciences, and Christopher Hight, Ph.D., from the School of Architecture, examines various development and socio-econo-

momic strategies in light of current information on sea-level rise, subsidence, sand budget analyses, and potential hurricane impact.

“Measuring City Sustainability: Project Houston”, a project led by Jim Blackburn, was published. This report proposed a group of indicators to measure sustainability and presented data to demonstrate how Houston performs in relation to these indicators. This project was the basis for the current HSI Project.

A Sustainability Fellow was appointed by SCS to lead the Houston Sustainability Indicators Project for the next two years. (See the Research chapter for more information).

SCS joined other members of the National Council for Science and the Environment for the 2011 National Conference on Science, Policy, and the Environment, “Our Changing Oceans”, held in Washington, D.C. The conference addressed the health of the Gulf, post BP spill; focused on changing climate and what it means for our oceans; and included a youth outlook for 2030.

The Glasscock School of Continuing Studies’ proposal for a sustainable development course with SCS continued to move forward.
SCS appointed an Advisors Board. The Advisors are a group of executives in the field of sustainable development. The board reviews objectives and advises on the best strategies to achieve SCS goals.

SCS also formed a Technical Review Board (TRB). Made up of technical experts in various fields of sustainable development, the TRB members review and advise on technical direction, project proposals, and report reviews.

Internship opportunities were offered to Rice University students through our community partners. Students with an interest in sustainability learned and gained experience by participating in a sustainable development project.

SCS interns, Angeleah Cleek and Tatyana Luttenschlager advanced their Fall research projects and gained opportunities to work with faculty at Rice and other institutions. Products from this effort generated data for the SCS Sustainability Experts Directory created by Matthias Jung.

SCS continued as advisor to students working on the Rice University solar car project. Students formed working groups and attended the Shell Eco-Marathon to gather information for their project.

SCS also judged the NASA Future of Flight International Student Art Competition; made sustainability presentations such as the pecha-kucha sustainability inaugural presentation hosted by Herman Miller; and received visitors to Rice University from other cities and countries such as delegations from Nankai University and the University of Yucatan.

SCS also joined the Houston-Galveston Area Council in the Coastal Transect Group to develop the Regional Plan for Sustainability. SCS participated on a panel of Sustainable Transportation hosted by the Women in Transportation Seminar (WTS) Diversity Program and joined other Gulf stakeholders at the State of the Gulf Summit 2011 hosted by the HARTE Research Institute and Texas A&M University.
Acknowledgements

As we celebrate this ten year partnership between Shell Oil Company and Rice University in support of sustainable development research, education and outreach, we acknowledge our Shell partners for their ongoing participation in SCS activities. We thank our Rice and external collaborators for their help in achieving our objectives through their support and contribution. We look forward to the ongoing partnerships and collaborations of the coming years.

The Shell Center for Sustainability recognizes that the work presented here can only be accomplished with the participation of our dedicated committee and board members.

Dr. John Anderson
Ms. Lilibeth André
Dr. William Arnold
Dr. Greg Biddinger
Dr. Walter G. Chapman
Mr. Claude Griffin
Ms. Mary M. Hamilton
Dr. Christopher Hight
Mr. Richard R. Johnson
Mr. Mark Juedeman
Dr. Lester King
Dr. Stephen L. Klineberg
Mr. Charles Lyons, P. E.

Mr. Andrew Mangum
Ms. Debra M. Marshal
Ms. Suzanne Mayne
Ms. Ann McAdam Griffin
Mr. David McDonald
Dr. Donald Morrison
Dr. Lyn Ragsdale
Dr. Ron Sass
Dr. Evan Siemann
Dr. Ron Soligo
Ms. Laura Spanjian
Mr. Brian Tippens
Mr. Charlie Williams, P.E.
Mr. Frazier Wilson, Ed.D.