FESC
Florida Energy Systems Consortium

2010 FESC Semi-Annual Report

Research, Education and Outreach Progress Reports

FESC
Florida Energy Systems Consortium

FLORIDA ATLANTIC UNIVERSITY

Center for Ocean Energy Technology

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Description: Ocean energy is an emerging technology that uses the power of ocean currents, waves, tides, and salinity gradient to create renewable energy. Tapping ocean energy resources will reduce our reliance on fossil fuels. Research areas of focus include ocean current and thermal differential systems, cold, deep ocean water-based air-conditioning, underwater hydrogen generation and storage, and environmental impact and mitigation.

The Center for Ocean Energy Technology's (COET) program is structured to be the catalyst that will enable the ocean energy industry in Florida toward determining solutions to answering the state's energy challenge. This project focuses on determining the potential of harnessing specifically the ocean current resource and ocean thermal energy conversion. The regulatory process at State and federal levels is not clearly defined nor the roles and interdependencies of the individual agencies clearly articulated. In addition, knowledge to make these decisions is more on a macro rather than micro level necessary to assess individual devices. COET's mission is to bridge the gap between concept and commercial deployment of ocean energy technologies by providing at-sea testing facilities for both ocean current and thermal energy research and for technology development. Research cuts across environmental, ecological, resource and technology.

Budget: $8,750,000.00

Universities: UCF, FSU, ERAU, University of Miami, Oregon State University, University of Washington, Pennsylvania State University, University of New Hampshire, University of Hawaii, University of Edinburgh, Heriot-Watt University, Nova Southeastern University, Virginia Polytechnical Institute, Florida Institute of Technology

External Collaborators: Numerous industry and State and federal government as well as FFRDCs, such as National Renewable Energy Laboratory, Woods Hole Oceanographic Institution, U.S. Department of Energy, U.S. Department of Interior (Minerals Management Service), U.S. Department of Commerce (National Oceanic and Atmospheric Administration), and Florida Department of Environmental, Protection, to name a few.

Progress Summary

Florida Atlantic University's Center for Ocean Energy Technology (COET) is focusing its research and development of ocean current and thermal energy. COET is conducting scientific and engineering research in the Florida Current off of Southeast Florida to determine ocean current and temperature profiles.

Progress on oceanographic research and assessment programs include:

1. Acoustic Doppler current profilers, capturing thirteen months of continuous resource characterization data, are being decommissioned and data assessment and analysis underway.
2. Ocean Thermal Energy Conversion measurement of Conductivity, Temperature, and Depth (CTD) conducted over one year to produce time series mapping of the temperature profile. Weekly assessments include more than 48 data sets of ocean thermal gradients offshore Ft. Lauderdale, FL and monthly more than 6 data sets of ocean thermal gradients in four locations stretching from Miami to Stuart, FL. The measurements are taken from nearshore Florida's SE coast to more than 30 nm offshore into the Florida Straits.
3. Prototype device (20kW) fabrication is underway for ocean current test and evaluation. An in-lab 20 kW coupled motor-generator dynamometer has been constructed to simulate ocean current rotor behavior with respect to motor/generator performance and setup. The 3-phase 240VAC system will provide a platform to fully test the offshore turbine control and monitoring system. In addition, a smaller 2-3 hp system is being integrated for mini-grid and heterogenous generation investigations.
4. Operational and testing requirements are being developed to provide a test and evaluation platform capabilities for ocean current device developers.
5. Participation on the U.S. Technical Advisory Group to the International Electrotechnical Commission in developing global standards for ocean energy convertors.
6. Draft Application for Lease under Interim Policy coordinated with Department of Interior, Minerals Management Service (MMS) and cognizant federal and state regulatory and permitting agencies, with final Application to be submitted in May. Pursuing both research and development in renewable energy on the Outer Continental Shelf (OCS) must comply with the federal Outer Continental Shelf Lands Act. With respect to the COET deployments of prototype devices/systems the major permits, approvals, and authorized actions necessary to construct, operate, maintain, and decommission project facilities while falling outside of State of Florida waters (i.e., the deployment and operations will be more than 3 miles offshore), will involve interaction with the Florida Fish and Wildlife Commission due to its agreements with the U.S. Fish and Wildlife Service. In addition, shore-side activities in support of the offshore deployment will be conducted within State waters, at a commercial marina under the purview of the Florida Department of Environmental Protection. These activities will also engage agencies such as the U.S. Army Corps of Engineers, the National Oceanic and Atmospheric Administration's Marine and Fisheries Service, the U.S. Coast Guard, the U.S. Navy, etc.
7. COET has worked closely with the MMS and other stakeholder agencies to draft and refine environmental/technical. Environmental effects assessments and analyses underway to include such areas as benthic habitat, acoustics, sea turtle and marine mammal migratory patterns.
8. COET hosted The Offshore Ocean Energy Dialogue on March 3-5, 2010 in Boca Raton, FL, bringing together 55 industry, university and federal and state agency participants to begin the conversation on a coordinated approach to meeting the research and development challenges of exploiting surface waves, tidal flows and open-ocean currents and the potential of the thermocline. The group approved seven consensus recommendations that will be helpful in addressing some of the challenges facing development of these important resources. Proceedings from the Dialogue will be made available publicly and be used to plan future topic specific events related to ocean energy development.

FLORIDA STATE UNIVERSITY

Biofuels Through Thermochemical Processes: Approach to Produce Bio-jet Fuel

PI: A. Krothapalli

Project Description:
The program addresses the emerging needs for aviation industry to have cost effective alternative liquid transportation biofuels. The main objectives are to produce bio-jet and bio-diesel fuels from cellulosic biomass and nonedible bio-oils and demonstrate that they have cost structure and product quality comparable to petroleum based fuels. Novel processing concepts, reactor design and catalyst systems are employed in this integrated approach to convert any cellulosic biomass and any nonedible bio-oils into bio-jet fuel. Feedstock flexibility offers significant cost and logistic advantages to this approach. Unlike other processes which use only the oil derived from a plant, the entire plant can be used as feedstock source. The proposed approach can also convert the more challenging lignocellulosic component. Through molecular manipulations, the proposed approach allows the production of "designer" biofuels. The technology offers a means to tailor product properties through saturation of double bonds to give better shelf life, cleaving long chain hydrocarbons to maximize the yield of the jet cut, controlling aromatics content of the jet cut for better combustion characteristics, and isomerization to improve ignition characteristics and for better cold flow properties of the fuel. Successful deployment of research program in biofuels can mean billions of dollars per year in fuel cost savings for aviation industry. It also opens the door for energy independence and distributed fuel generation capability.

Budget: $420,567

Progress Summary

An 11 kw Downdraft gasifier is installed and began its operation in April 2010. A prototype steam gasification with external heating module has been designed and built. The hydrodynamic testing of the proof of concept dual fluidized bed steam gasification process has been successfully tested.

FLORIDA STATE UNIVERSITY

Planning Grant: Constructual Optimization of Solar Photo-Bioreactors for Algae Growth

PI: Juan Ordonez
Students: Quinn Straub (MS), Tom Tracy (MS)

Description: This is a planning grant (15K, only). As such, the work proposed, will be targeted towards placing us in a more competitive position in future submissions in the area of bio-fuels. By the end of this one-year effort we expect to: (i) have a complete design of a small-scale photo-bioreactor for algae growth and, (ii) obtain additional funds that will allow us to build a large-scale photo-bioreactor and conduct the necessary research for its optimal design and operation. A technical report will be delivered by the end of the one-year period.

Budget: $15,000

Universities: Florida State University

External Collaborators: Federal University of Parana, Brazil

Progress Summary

Research Objectives for Current Reporting Period:
As a planning grant, the main objectives for the project are to enhance our laboratory capabilities and personnel qualifications to make us more competitive for other solicitations.

Progress Made Toward Objectives During Reporting Period:

Personnel training: Two students (T. Tracy and Q. Straub) were sent to a 2-day seminar hosted by the University of Texas at Austin. The seminar exposed the students to fundamentals of the biological interactions of micro-algae, culturing techniques, culture maintenance, as well as, proper use of lab equipment. They also toured a culture collection, that is one of the best in the world (0ver 3,000 species).

Laboratory enhancement: We acquired a Vernier photo-spectrometer, and a microscope. Simple experiments were conducted to familiarize mechanical engineering students with the use equipment typically found in a biology laboratory. The students learned how to grow Nannochloropsis Oculata, measure cell concentration with a Newbauer hemocytometer and a fixed volume micropipette, and measure sample's absorbance using the Vernier photo-spectrometer.

		
Day 2	Day 7	Day 20
Growth of Algae Species Nannochloropsis Oculata (left), Botryococcus Braunii (right)		

Synergistic Activities:

Collaborations:
Our group collaboration with Brazilian researchers for over 10 years has produced results that leverage the efforts of the current planning grant, some of those results are listed below.

Publications:
J.C.L Torrens, J.V.C. Vargas, E.C. Telles, A.B. Mariano, J.C. Ordonez, " Biodiesel From Microalgae: The Effect of Fuel Properties on Pollutant Emissions," COBEM, Gramados, Rs, Brazil, Nov. 2009.
R.L.L Ribeiro, A.B. Mariano, J.A.Souza, J.V.C. Vargas, J.C. Ordonez, "Numerical Simulation of the Biomass Concentration of Microalgae Cultivated in a Self-Sustainable Photobioreactor," COBEM, Gramados, Rs, Brazil, Nov. 2009.

Invited Talks:
J. C. Ordonez, "An Overview of Microalgal Biodiesel," Ubatuba, Brazil. Oct, 2009. Visit sponsored by the State of Sao Paulo.
J.C. Ordonez, Thermodynamic Optimization of Energy Systems, Manila, NEECC-IEEE, Philippines, Dec. 10, 2009. (as part of IESES-FSU delegation to Philippines)
Invention disclosure:

"Compact Photo Bioreactor for Microalgae Cultivation," J.V.C. Vargas, W. Balmant, A. Stall, A.B Mariano, J.C. Ordonez, Z. Hovsapian

Proposal Submissions:
Proposed work (over $500K budget) in micro-algae related work as part of the DOE ERIC program.
Participated in the writing of FSU position paper to USAID, which includes work in micro-algae.
Met with Philippine National Academy members from Ateneo and De La Salle Universities to discuss collaboration opportunities in microalgae efforts.

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Environmental Impacts of Energy Production Systems: Analysis, Evaluation, Training, and Outreach

PI: Amy B. Chan-Hilton (FSU) **Co-PI's:** Gang Chen (FSU), Wenrui Huang (FAMU), Michael Watts (FSU), Ming Ye (FSU), and Paul Lee (Florida Department of Environmental Protection)

Students (name/degree sought): Gustavo Munoz (B.S. Civil Engineering), Chandra McGee, Sandip Patil (Ph.D. Civil Engineering), Andres Lastra (M.S. Civil Engineering), (M.S. Scientific Computing)

As Florida develops its long-term energy strategy, multiple efforts are ongoing to develop and apply a wide range of energy technologies that are sustainable and carbon-neutral. But pragmatic issues related to environmental impact and sustainability need to be addressed before these technologies may be implemented. This project directly addresses the FESC's Thrust 6 on "Energy systems and their environmental and economic impacts." This project also directly addresses the IESES's Objective 4 on unique geographical challenges and Objective 5 on sustainable energy engineering, science and the sustainable energy economy.

The goal of this project is to develop tools and conduct research to objectively assess environmental and water resources needs and constraints while developing prudent energy strategies and policies. The focus of this research will be on fuel cycle and energy production systems. The objectives of this project are to:

1. Analyze the environmental and water resources demands and potential impacts, specific to Florida's unique geographical challenges, of fuel cycle systems.
2. Develop an objective environmental impact screening and evaluation tool (i.e. decision support system) for energy planning and policy making by Florida's industry, utilities, and government.
3. Provide outreach to industry, utilities, government to allow for discussion and better-informed decisions on energy strategy, regulation, and permitting.
4. Provide training on "Energy and the Environment" to ensure environmental stewardship without sacrificing energy production.

Budget: $87,417 (revised Feb 2010, total for 2-year period)
Universities: Florida State University, Florida A&M University
External Collaborators: Florida Department of Environmental Protection

Progress Summary

For the period November 2009 – May 2010.

Progress made in Tasks and Towards Deliverables:

- *Task 1: Analyze potential environmental impacts of energy production systems*. We have conducting extensive literature reviews on how biofuel production systems, with a focus on cellulosic ethanol, affect our environmental resources and quality. Approximately 500 journal papers, reports, and permit applications have been reviewed for this task to date. This includes impacts on the potential contamination of water, soil, and air, demands on water resources, ecosystem and human health, and emissions of greenhouse gases. We have found that the local

impacts and downstream issues (e.g. effluent and by-products) from biorefineries have largely been overlooked in the literature. However, these issues are relevant and are significant when siting and permitting these facilities. We also have investigated how state and federal policies, regulations, and permitting processes can affect the progress of establishing biorefineries in different regions of the U.S., including Florida. Two manuscripts to peer-reviewed journals were submitted in December 2009 and May 2010.

- *Task 2: Develop evaluation tool for energy production systems*. During the Summer 2010, we are exploring how a tool developed to investigate nitrate in groundwater and streams developed in a current project funded by FDEP may be extended to a biofuel production scenario in Florida.

Seeking External Funding:

- IDR - Engineering Solutions for Sustainable Algal Growth on Municipal Wastewater Effluent, National Science Foundation (NSF), PIs: Michael Watts, Michael Wetz, Amy Chan Hilton, William Cooper, requested budget $ 876,536, submitted December 2009, pending.
- DMUU: Collaborative Groups in Energy, the Environment, and Sustainability, National Science Foundation (NSF), PIs: Robert Isaac, Dmitry Ryvkin. Svetlana Pevnitskaya, Douglas Norton, Amy Chan Hilton, requested budget $ 2,794,206, submitted July 2009, declined.

Publications:

- McGee, C. and A. Chan Hilton, Analysis of Federal and State Policies and Environmental Regulations for Bioethanol Production Facilities, submitted to *Environmental Science & Technology*, 2010, under review.
- McGee, C. and A. Chan Hilton, Anticipating local effects of cellulosic biofuel production, submitted to *Science*, 2009, declined.

FLORIDA STATE UNIVERSITY

Visiting Scholar in Energy and Land Use Law, Florida State University College of Law

PI: JB Ruhl **Co-PIs**: Uma Outka (Visiting Scholar)

Description:
Two-year Visiting Scholar at the College of Law researching the interface between land use law and innovative energy solutions and delivering academic symposia and graduate student seminars on the research scope, comprising Sustainable Energy Research Project (SERP) within Environmental and Land Use Law Program.

Budget: $214,603
Universities: Florida State University, College of Law
External Collaborators: N/A

Progress Summary

Research and Presentations

In February 2010, I completed a lengthy written work, *Facility Siting for Renewable Energy: Land Use and Regulatory Context*. This work takes up the increasingly important land use question of siting for renewable energy. Historically, power plant siting has been the province of state and local governments, so the regulatory context into which renewables are being integrated varies, sometimes significantly, jurisdiction by jurisdiction. To examine this regulatory context, the article focuses on Florida – the third largest consumer of electricity in the U.S. with less than two percent of that power generated from renewable resources. The article first provides an overview of Florida's power supply sector and sets out the existing regulatory context for terrestrial siting of energy facilities. It then situates Florida's most promising renewable resources within that context, identifies regulatory barriers that implicate siting, and considers the siting issues unique to each resource. I argue that a window of opportunity exists in which state and local governments can plan for and guide renewable energy siting – an approach that contrasts with utility-driven planning and siting that has long been standard practice. I presented a this research at the University of Florida's interdisciplinary "U.S. Energy Policy in Transition" conference in March 2010, and the article is forthcoming in *Ecology Law Quarterly*, the environmental law journal of the UC – Berkeley Boalt Hall School of Law.

A second project is substantially underway: *Renewable Energy's Land Use Impacts: Emerging Approaches to Siting* (working title). This research is concerned with the implications of renewable energy development for land use and land use law, and conversely how the land use context might inform energy policy more broadly. Within the highly variable regulatory landscape for power plant siting across the states, a range of land use approaches tailored to renewable energy is developing responsively to changes in energy policy. Although land use decision-making is traditionally a local government function, we are seeing policies that touch upon siting in one way or another develop at the local, state, and federal levels. The article first addresses existing regulatory frameworks for power plant and transmission siting, with which new approaches necessarily interact. I argue that these frameworks' inadequacy in accommodating renewable energy is a key driver of new policy making in this area. The article then provides an overview of emerging approaches to siting, grouping them loosely in three categories based on the aspect of siting they address: (1) process/review, (2) jurisdiction/authority, and (3) site selection. Proceeding from this overview, the

article has two goals. First, it seeks to disentangle the innovative aspects of these approaches from the concerns they may raise – "energy sprawl," diminished opportunity for public participation, compromise of finite public land resources, to name a few – and evaluate the extent to which the spectrum of siting policies addresses those concerns. Second, the article seeks to advance the policy discourse promoting renewable energy in ways that better integrate consideration of land use impacts. I argue that the shift to renewable energy presents land use risks as well as opportunities that current energy policy and land use law do not meaningfully engage.

Graduate Seminar

At the end of 2009, my focus was on designing the graduate law seminar course, Sustainable Development Law. This course used as a base text *Agenda for a Sustainable America* (Dernbach, J., Environmental Law Institute, 2009), supplemented with additional readings. The seminar examines how the concept of sustainability is shaping policy dialogues and influencing the design of legal instruments and institutions, as well as the implementation of existing law. Students have the opportunity to evaluate the capacity of regulatory and legal frameworks to incorporate this overarching social and environmental goal in a broad range of contexts, including energy and land use. The course was full in the spring 2010 semester, with a total of 16 students, including two in the College of Law's new LLM program.

Student Involvement

A third-year law student, Andrew Fier, was involved in SERP as a research assistant during most of the academic year with a focus on renewable energy and siting issues. Another third-year law student, Sarah Berner, made progress toward completion of directed independent study in SERP on energy efficiency policy in Florida, but was forced to withdraw for personal reasons. A spring 2011 law symposium is in the early stages of planning, and I am in discussions with the student editors of the *Journal of Land Use and Environmental Law* about involving them in topic design and co-sponsoring the event.

FLORIDA STATE UNIVERSITY

Reliable and Resilient Electrical Energy Transmission and Delivery Systems

PI: Steinar Dale
Co-PIs: Tom Baldwin, Ph.D, Omar Faruque, Ph.D., James Langston, Peter McLaren, Ph.D., Rick Meeker, P.E., Mischa Steurer, Ph.D., Karl Schoder, Ph.D.
Students: Thamer Alquthami, Harsha Ravindra (MS Electrical Engineering)

Description: The project goal is to address the challenges of the reliable movement of electrical energy throughout the state as the power system is transformed to include far more renewable and alternative sources, increased use of distributed energy resources and microgrids, possible expansion of new very-large centralized baseload (nuclear), and incorporation of new power conversion, transmission, measurement, communication and control technologies.

Budget: $235,991
Universities: FSU
External Collaborators: Florida Reliability Coordinating Council (FRCC), City of Tallahassee Electric Utility

Progress Summary

Research Objectives and Progress made for the Current Reporting Period: The analysis of the Florida Power Grid Disturbance of February 2008 using an aggregated 14-Bus dynamic model was continued to refine the data and protection related switching events. The results from the aggregated FPL 14 bus system were found to match the recorded data observed in the incident report with minor discrepancies. The reason for minor mismatch can be attributed to the use of generic data due to the unavailability of actual data. The matching of simulation data with the recorded data indicates that the reduced FPL system can be used for representing the FPL network with reasonable assumptions for some simplistic studies. Work is underway to construct parametric studies to determine the parameters sensitivity in the simulation using factor screening and other statistical techniques.

Data collection and development of a 154 Bus Florida Grid Model for dynamic analysis were continued. Despite the fact that 14 Bus Florida grid model was sufficient for some initial studies, the project's objective require a more detailed benchmark system of the Florid grid. Therefore, a 154 bus notional electrical grid of Florida was built with detail representation using data available in the public domain. The comparison of power flow results with available sources revealed a very close agreement with negligible mismatch.

Since, our objective includes the dynamic analysis of the Florida grid, in the next step, efforts were made to develop a dynamic model for the 154 Bus system. The dynamic model requires data for each unit of generators, exciters, turbine governors, power system stabilizers, automatic generation controls and all the required protective devices with accurate settings. This task is complicated by the requirement of data that is not publicly available. Nevertheless, development of a notional dynamic model of the Florida gird in PSS/E is underway and most of the dynamic data were obtained from various public resources. In case of unavailability of the sufficient information on the details breakdown in each plant's generation units, models for generators, exciters, and governors were chosen for the large plant or known plant at that bus. If information is available, models for the exact type of generation units are chosen. Typical data were assigned for the specified dynamic models for parameters.

The development of a dynamic solar PV model with Maximum Power Point Tracking (MPPT) has been initiated and completed in this period. The model will contribute to the general power system modeling and simulation community as we intend to make it publically available and to the envisioned Florida Grid studies of future load and generation growth specifically. Initial studies of the impact of solar PV-based resources have been undertaken, and significant implications for power system operation and stability have been observed, see Figure 1. The depicted bus frequency traces after tripping of a solar PV-power plant at different penetration levels reveal unacceptable frequency deviations.

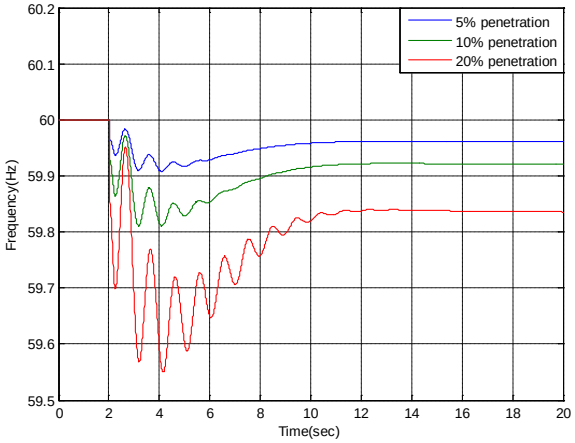


Figure 1. Frequency response after tripping PV

Research activities for the next reporting period: The next steps will focus on completing the dynamic model of the Florida grid, refining load and generation forecasting, and developing relevant case scenarios. Probabilistic analysis will be performed and uncertainty and sensitivity analyses will subsequently provide insight into the expected resiliency of the grid in the context of future developments in load and generation patterns.

FLORIDA STATE UNIVERSITY

Energy and Efficiency Video Public Service Announcements

PI: Andy Opel, **Co-PIs:** Phil Steinberg, Leslie France-Patterson, Laura Arpan, Ian Weir

Description: This interdisciplinary team will produce 6-8 short (30-second/one-minute) video public service announcements (PSAs) that address issues of energy and efficiency and one 12-15 minute informational documentary targeted to Florida legislators and the Governor's office. These videos will be tailored to reinforce existing IESES efforts.

Budget: $200,720

Progress Summary

Beginning in January 2009, our five member faculty team began meeting, with the addition of two quarter time doctoral graduate students funded by the grant; Jia Lu from Communication and Adam Keul from Geography. Laura Arpan and Jia Lu assembled an up to date literature review of research in the area of communication campaigns and environmental communication/persuasion. A summary of this work was presented to the group in late February 2009, with the goal of shaping the message strategy that would be emphasized in the PSAs.

Arpan and Lu then went on to develop a survey questionnaire to be administered to a random sample of Florida residents. This survey data will serve as baseline data as we begin message testing specific PSAs. Data from the survey was collected in May 2009 and analysis of that data is on-going. In addition, Arpan established partnerships with the Yale Project on Climate Change and the Center for Climate Change Communication at George Mason University. These partnerships include data sharing and survey question collaboration.

Based on the communication research aggregated by Arpan and Lu, Opel, Steinberg, France-Patterson, Weir, and Keul brainstormed PSA ideas resulting in over 20 potential PSA videos. This list was narrowed down to the top eight concepts through consultation with Arpan and Lu. Production plans were developed for each concept, including locations, costumes, cast, script, storyboards and props. Production plans included variations within each PSA that will allow for message testing in the fall of 2009.

In May 2009, four PSAs were shot. In June, rough cuts of 3 PSAs were assembled. In July and August, two more PSAs were shot, with post production scheduled for September.

Deliverables

Power point presentation summarizing recent research on influencing audience attitudes and behavior.
Three rough cuts of original PSAs.
Three PSAs in production or post-production.
Two PSA concepts in pre-production.
Energy efficiency attitudes data from 400 person survey of Florida residents.

Scholarship

Andy Opel attended the Full Frame Documentary Film Festival in Durham, NC, April 2-6, 2009 where he took part in the Full Frame Fellows Program that connects filmmakers with producers, funders and distributors.

Andy Opel presented rough cuts of two PSAs as well as some of our initial findings from the research literature at the Conference on Communication and the Environment, Portland, ME, June 27-30, 2009.

External Funding Initiatives

Opel, Arpan, and Steinberg have been in close contact with Scott Minos from the US Department of Energy over a proposed Center of Excellence in Energy Information and Communication. We have a revised draft of a proposal that we have developed with the assistance of Scott Minos and he recently circulated a white paper that will eventually serve as the basis for an RFP from the DOE. We also met with Chuck McClure and Chris Hinnant from the Information Institute in the College of Communication and Information and they have agreed to be active partners in pursuit of the CoE.

Adam Keul developed a list of potential funding sources, ranked by applicability. From the list, we submitted a grant application to the Mazda Foundation for $25,000 in June. We have not heard anything back on this application.

FLORIDA STATE UNIVERSITY

Planning Grant: Enhanced Thermal Performance and Microstructure Simulation of Nuclear Fuels

PI: Justin Schwartz

Description: The objective of this proposal is to perform preliminary investigations to determine the viability of improved oxide nuclear fuels through high thermal conductivity coatings such as "BeO." To meet Florida's sustainable energy demands, we will pursue the option of enhanced oxide nuclear fuel performance by considering the potential for improved thermal behavior through high thermal conductivity oxide coatings. This work will include a literature search of past investigations of the impact of enhanced thermal conductivity on nuclear fuel and reactor performance, the temperature and irradiation dependence of the thermal conductivity of BeO and other high thermal conductivity oxides, the chemical and thermal compatibility of BeO and nuclear fuels (UO2, PuO2, ThO2 and MOX), and initial studies into BeO coatings on HfO2 particles, where HfO2 serves as a benign surrogate for nuclear fuel oxides. We will conduct an evaluation of possible coating processes and measure their thermal behavior. We will use these findings to pursue external funding.

Budget: $15,000

Progress Summary

Project is complete.

FLORIDA STATE UNIVERSITY

Development of a Renewable Energy Research Web Portal

PI: Charles R. McClure, **Co-PIs**: Ian Douglas, Chris Hinnant

Description: This project will identify, organize, and make available via a web portal, research generated as part of the FESC effort as well as other selected related information resources and tools as identified by FESC participants. The primary tasks to be completed in this process include:

- Conduct needs assessment of IESES and FESC energy researchers and related experts to determine (1) the most important content to be included in the web portal, and (2) preferences to be considered in the design of and applications for the web portal;
- Identify and obtain relevant energy research information from IESES and FESC and other sources as appropriate;
- Develop a web portal such that identifies, organizes, and accesses energy research information;
- Field test and conduct usability, feasibility, and accessibility testing on web portal; The goal of this project is to provide IESES, FESC researchers, and others in the state of Florida with the research information they need to accomplish statewide energy goals and to help IESES meet the thirteen objectives it has undertaken by providing access to research information.

Budget: $194,542

Progress Summary

Project is complete.

The webportal is live and can be viewed at http://energyportal.cci.fsu.edu/.

The Renewable Energy Research Portal was used as a model for the Oil Spill Academic Task Force and can be viewed at http://oilspill.fsu.edu/expertfinder/#.

FLORIDA STATE UNIVERSITY

Promoting Energy and Land Use Through Land Use, Transportation and Green Infrastructure Polices

PI: Tim Chapin; **Co-PIs**: Ivonne Audirac, Chris Coutts, and Greg Thompson, Department of Urban & Regional Planning, and Mark Horner, Department of Geography

Description: In response to the many issues related to energy provision, energy sustainability, and GHGs, in 2007 Governor Crist created an Action Team on Energy and Climate Change. This group was tasked with investigating and recommending strategies for reducing GHG emissions, creating more sustainable energy systems in Florida, and for establishing Florida as an international leader in innovative energy provision. Related to this, the 2008 session saw the Florida Legislature pass HB 697 which, among many things, requires every local government in the state to address energy systems and GHG emissions explicitly within their comprehensive plans. Currently, the linkages between energy planning, environmental and economic sustainability, land use and transportation planning, and GHG reductions have never been stronger in Florida. This project is aimed at continuing the momentum in Florida for developing broad-based solutions to these problems by helping to develop a knowledge base for informing state policy in the areas of energy, sustainability, and land use and transportation planning.

We continue to work on generating a report similar to the *Tough Choices: Shaping Florida's Future and Facing Florida's Revenue Shortfall* document prepared by the Collins Institute. This report summarizes the literature on the links between urban development patterns and energy sustainability/ climate change and makes recommendations for state policies and programs to address these issues. The intention is to author a report that is easy-to-read, including graphics, and will highlight the key policies and programs the state should pursue to achieve its energy sustainability and climate change goals.

Budget: $168,185

Progress Summary

The project began in May 2009 and will continue through the end of the 2010 calendar year. During the Spring 2010 term the research team finalized its review the current state of knowledge in the issue areas. We have also finished our review of state and local energy and climate change policies and outlined the report. We have completed interviews with key informants at several state agencies and planners in local governments that have taken the lead on this issue in the state. We also continue to identify potential outside funding sources for continued work on this initiative.

Linkage to IESES Priorities and Core Mission

The IESES mission statement reads that the "primary mission is to provide Florida and the country with up-to-date and pragmatic tools and analysis to assist in meeting challenges, and to forge new opportunities for an unprecedented energy and climate constrained era." This research project directly serves this mission in that the project report will inform public officials and elected officials about the breadth and form of the policy options available to them. In terms of the objectives and thrusts of the IESES initiative, this project specifically targets Objective 2 (Assisting Florida's Governing Bodies) and Thrusts #5 and #6 (Enhancing Energy Efficiency and Energy System Environmental and Economic Impacts). This research project contributes directly to the IESES objective to "assist Florida's governing bodies in the successful development and implementation of a comprehensive, long-term, environmentally compatible, sustainable, and efficient energy strategic plan for the state".

Key Accomplishments to Date

- Project team populated our Blackboard website with project materials
  - Houses relevant reports, articles, and chapters
  - Houses summaries of key literatures
- Project team finalized our review of the substantial literatures revolving around transportation, land use, and green infrastructure
- Chapin worked with IESES staff to help organize the IESES Smart Mobility I symposium; Identified and secured two nationally-recognized transportation-land use planning faculty for the; Participated in symposium events
- Project team completed interviews with key informants at FDCA, FDOT, FDEP, FDOH, FDEA
- Project team completed interviews with local planners in Tallahassee-Leon County, Gainesville-Alachua County, Sarasota city and county, and in Miami-Dade County
- Horner and Chapin (with Tingting Zhao) submitted a paper to AAG
- Horner presented the Horner, Zhao, and Chapin paper at the AAG annual conference
- Project team developed a draft report layout
- Coutts and Audirac authored a Green Infrastructure "white paper", portions of which will be included in the Final Report
- Project team wrote draft sections of Final Report
- Chapin secured funding to travel to Griffith University in Brisbane, Australia during summer 2010 to work on a comparative study of Florida and Queensland planning responses to climate change and sea level rise.

FLORIDA STATE UNIVERSITY

Marketing Strategies to Incentives Entrepreneurship and Innovation in the Development of Sustainable Energy

PI: Joe Cronin
Faculty: Dr. Jeff Smith
Students: Mark Gleim (PhD), Stephanie Lawson (PhD), Jeremy Wolter (PhD), Jacqui Bybee (PhD), Ed Ramirez (PhD)

Description: The objective of this project is to investigate the role of market pull strategies in advancing sustainability goals. Specifically, the intent is to identify what "drives" consumers' attitudes and behaviors relative to sustainable products. This includes consumers' personal attitudes, opinions, and beliefs, their perceptions of their own and organizations' abilities to affect or change the environment in which they live, and their personal characteristics (e.g. demographics). In addition, in collaboration with the College of Communications, the strengths and weaknesses of the various modalities that can be used to deliver sustainability knowledge to consumers (e.g. advertisements, testimonials, expert word-of-mouth communications, public relations, publicity, etc) will be assessed. Specifically, the research will attempt to identify the optimal market pull modality; that is, the means by which to deliver to consumers the knowledge that drives the purchase of sustainable goods and services. The overall objective of the research is to provide much needed market pull information for organizations embarking on "green" marketing strategies; that is, firms in the process of developing or expanding their mix of environmentally friendly goods and services.

Budget: $278,778 (total), $102, 564 (yr 2)
Universities: FSU
External Collaborators: NA

Progress Summary

Research Objectives for Current Reporting Period: The main objectives for the current reporting period include the further development and search for outside grants for the recently formed Center for Sustainability Initiatives (CSI) in the College of Business at The Florida State University. Further, growing the online research panel created by the CSI is an important step in monitoring and evaluating consumers within the state of Florida. The main research objectives also aim to provide deliverables, including published conference papers, journal articles, presentations, and other modes of educational knowledge transfer.

Progress Made Toward Objectives During Reporting Period: The research team has made tremendous strides during the reporting period in meeting many of the goals we set. Currently six papers have been published in the proceedings of national or regional conferences, including our premiere American Marketing Association conferences. Further, twelve conference presentations have been given on sustainability related topics funded through the IESES grant. Numerous articles of research are also under review at various journals, or nearing the process of submission to select premiere marketing journals.

Securing additional funds has also been a priority for the CSI. As such, members of the research team were recently awarded a research grant from the Von Allmen Center for Green Marketing in the Gatton College of Business and Economics at the University of Kentucky. The proposal, entitled "The Adoption of Sustainable Practices: Overcoming Perceived Barriers to Socially Responsible Initiatives" won the highly competitive award.

In addition, Dr. Joe Cronin and his research recently team chaired a special session on sustainability at the American Marketing Association's Winter Educator's Conference entitled Sustainability in Action. World-renowned scholars in the field of sustainability in marketing not only attended the session, but many participated by presenting their own research as well. The session was well received by all that attended and was likely one of the most prominent events at the conference. Several members of the research team also attended the first annual Sustainability in Marketing Colloquium hosted by the University of Kentucky.

In addition, members of the CSI research team have been active within the FSU and local communities. Member of the research team have been invited to speak at a number professional and practitioner-oriented seminars at the state and local level. Within the university, the research team is exploring potential partnerships with other groups to incorporate a sustainability-oriented approach to business strategies. The development of a sustainability-oriented marketing class is also in the works, potentially as an undergraduate course or as a part of the MS in Marketing program. In addition, the undergraduate basic marketing course has gone green by requiring students to utilize an online textbook.

The online research panel housed in the CSI has made tremendous progress as well. The panel is quickly approaching 1,000 members and we hope to dramatically increase that number very soon with the help of the FSU Alumni Office. Current panel members are already actively engaged in our research and eager to participate in future endeavors.

FLORIDA STATE UNIVERSITY

Energy Sustainable Florida Communities

PI: Richard Fieock**, Co-PIs:** Ivonne Audirac, Keith Ihlanfeldt

Description: The objective of this proposal is to develop an energy sustainability index to measure local governments' adoption and capacity to implement energy policy innovations in response to the provisions of new energy legislation in Florida. This measure will be applied to investigating factors influencing local government energy policy decisions and be disseminated to research and governmental decision-makers. The following tasks are proposed to FSU for funding: archival data collection; survey of local governments; construction of a Florida Sustainable Communities web site; statistical analysis, hold a workshop on sustainable energy governance in local government; preparation of reports; papers journal manuscripts and grant proposals.

Budget: $125,424

Progress Summary

RESERACH ACIVITIES:
1) Local Government Institutions and Turnover. RAs Lee and Ha have been collecting longitudinal data from Florida League of Cities and FL Association of Counties, ICMA, and online municipal codes.
2) Compilation of Information of State Energy Policy Environment. PI Audirac and RA Spector have been working on a report on state energy policy relevant to local governments
3) Survey Instrument. The Project Team was met on a weekly basis for the past two months to design the first survey instrument that will be directed to city, county and school district planning officials.
4) Proposal Preparation. PI Feiock is preparing a proposal to the NSF Political Science Directorate August 15th target date. PI Audirac is preparing a proposal for the NSF Innovation and Organizational Sciences Program September 3rd target date.

OUTREARCH/INSTRUCTION ACTIVITIES:
1) Florida League of Cities and FLCIR. In June PI Feiock met with representatives of FLC and LCIR to brief them on our project and to coordinate activities.

2) Consultation with CGLFE. The Project Team met with Robert Lee, the Director of the of The Center for Florida Local Government Excellence. We discussed cooperative actions including a Webinar with on Local Government Sustainability and Energy Conservation and a workshop for local government managers on sustainability to be held in South Florida.
3) Mentoring. In addition to the funded RAs two fellowships supported doctoral students Yi (University Fellow) and Kassekert (DMC and NSF Dissertation Improvement Grant Awardee) have volunteered their time and are working closely with PI Feiock and the project and proposals and they are included as co-authors of forthcoming presentations at the American Political Science Association.

PUBLICATIONS/PRESENTATIONS
Mark Lubell, Richard Feiock and Edgar Ramierz. "Local Institutions and the Politics of Urban Growth," with Mark Lubell and Edgar Ramirez, American Journal of Political Science 53(3): 649-665, 2009.

FLORIDA STATE UNIVERSITY

Innovative Proton Conducting Membranes for Fuel Cell Applications & Protein Enhanced Proton Conduction Membranes for Advanced Fuel Cells

PI: Ongi Englander, **Co-PIs:** Anant Paravastu, Subramanian Ramakrishnian

Description: The objective of this proposal is to establish new research directions in the development of proton conducting materials for fuel cell applications. We will build novel high surface area silica particle based membranes as supports, and infuse in them newly discovered proton conducting protein nanomaterials as well as oxide-based nanocomposites. In order to test electrical transport mechanisms, we will build microfabricated electric testing structures, and subsequently integrate materials with fuel cell test setups.

Budget: $30,000

Progress Summary

Task 1: Fabrication of silica and latex-supported membranes and oxide-based nanocomposites

To help carry out this work, two students so far have been recruited – 1) Erin Holley: a graduate student (masters) has started school at FSU in the newly formed materials science and engineering department. Erin was an undergraduate at FSU in the department of chemical and biomedical engineering whom we have convinced to stay on and pursue graduate school due to her interest in the proposed research. 2) Mayra Gonzalez: A Junior in chemical and biomedical engineering has started working in our labs to help characterize the membranes and is working with Erin Holley. Recruiting these two students we feel is a key step forward in the project.

Experimental setup of equipment for gas and water permeability:
A considerable amount of time was spent by Erin in overcoming difficulties and in setting up the equipment for gas and water permeability measurements (Figure 1). Commercial membranes were then successfully characterized using the above equipment (Figure 2). Thus, we now have the capability to characterize membrane pore size and water permeability's in our capabilities and this will play an important role in characterizing the membranes.

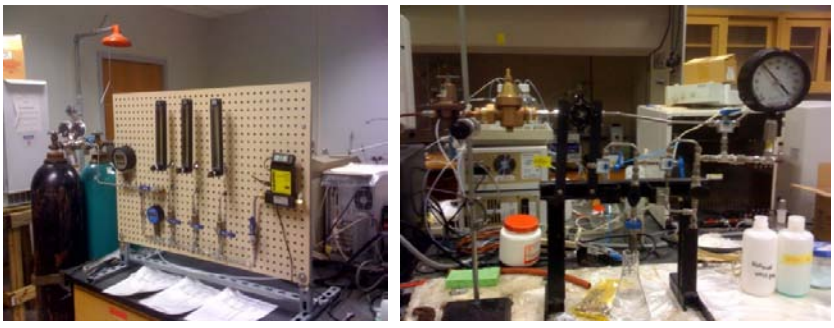


Figure 1: Experimental setup to measure pore size distribution and water permeability of membranes.

Future Work

- Integration of proteins & particle-based membranes
  - Protein infused silica →high porosity
  - Silica infused protein → low porosity
  - Assessment of adsorption and linking of proteins onto silica surfaces will be studied using Quartz Crystal Microbalance (QCM)
- Analysis of transport mechanisms in proteins

Future Funding

- Each PI submitted an NSF CAREER proposal (July 2009) building upon preliminary work enabled with IESES support
- DOE's Basic Energy Science (BES) program – 2010 submission
- NSF's Interdisciplinary Research (IDR) program – Dec 2009 submission is being considered

FLORIDA STATE UNIVERSITY

Planning Grant: Advancing Knowledge of Network Theory for Analysis and Design of Smart Power Grids

PI: Svetlana V. Poroseva **Co-PIs:** Yousuff Hussaini, Per Arne Rikvold

Description: With power grids evolving towards increasing size, complexity, and integration, it has become more difficult to describe and predict their behavior, even under normal operational conditions. With technological development, climate change, and activities in the political arena, adverse circumstances (natural disasters, intelligent adversary, software design errors, human errors, etc.) have become more probable and costly events. The Project seeks to provide industry and government with advanced analytical and computational tools necessary for the automated evaluation of the structural resilience and reliability of power grids. The potential applications of the Project's results go beyond power grids. Any infrastructure essential to our society and economy (e.g., computer, communication, transportation) can benefit from the Project's results.

Budget: $15,000

Progress Summary

Project is complete.

FLORIDA STATE UNIVERSITY

Establishment of the Center for Marine Bioenergy Research: Systems Approach to BioEnergy Research (SABER)

PI: Joel E. Kostka
Co-PIs: William Cooper, Ivonne Audirac, Amy Chan-Hilton, Ellen Granger

Description: This proposed SABER research center will blend fundamental and applied research to:
1. Develop sustainable, biologically-based fuel alternatives and renewable energy strategies.
2. Capture, recycle or clean up environmental pollution (greenhouse gases, excess nutrients) associated with energy production and use. Equally important to our research goals will be partnering with public and private institutions to immediately implement our research for the benefit of society. Biosolutions will be rapidly incorporated into the solid waste treatment and power plant industries. We will partner with the other IESES groups to promote awareness that the near-term realization of clean, cost-effective energy alternatives will occur only through a multidisciplinary systems-based approach from research to planning and implementation. We will assure sustainability by assessing the environmental impacts and promoting the mitigation of those impacts of alternative energy technologies on the geosphere.
The centerpiece of the proposed project will be the development of sustainable practices for the production of transportation fuels from algal biomass feed-stocks. Algal cultivation practices will also be incorporated into industrial processes such as CO2 capture and sequestration from coal-fired power plants and wastewater treatment.

Budget: $494,135

Progress Summary

The centerpiece of the SABER project is the development of state-of-the art technology to tap marine or aquatic algae as a biomass source for fuel production (Figure 1). A state-of-the-art, off-the-grid algal cultivation facility will allow us to produce algae with a minimal ecological footprint. Once cultivated, the algae yield lipids, carbohydrates, and protein, which can be processed into biofuels or used as biomass in animal feed. Wastewater from the process can then be reintroduced into the system during cultivation, making this a highly efficient, ecologically friendly alternative for producing fuel from the sun. A multidisciplinary team of faculty and students at FSU is covering biofuels R&D across the entire value chain, including algal strain selection and growth optimization, biomass analysis and conversion, and the use of green power in sustainable, carbon neutral algal cultivation. SABER is particularly focused on coupling algal cultivation to wastewater remediation.

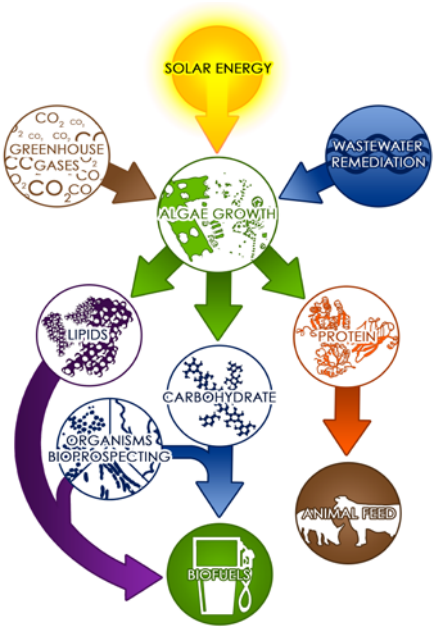


Figure 1.

In the first month, PI Kostka and co-PI Wetz visited the following Florida companies engaged in algal biofuels research throughout the state: the Midwest Research Institute (MRI) of Palm Bay, Petroalgae in Melbourne, Aurora Biofuels of Vero Beach, and Algenol of Bonita Springs. We toured facilities and discussed potential research collaborations.

Based on these discussions, we pursued further contacts with Petroalgae and MRI. Contact with MRI resulted in the submission of two research proposals. The partnership with Petroalage requires that we build an marine algal cultivation facility close to the ocean. Thus, we are currently in discussions with the Director of the FSU Coastal and Marine Laboratory, Dr. Felicia Coleman, to move forward on this partnership with Petroalgae.

SABER has entered into a partnership with the city of Tallahassee to optimize the growth of algal biomass for fuel from the city's nutrient-rich wastestream. See Figure 2 for details on the research plan. The city has offered the use of land at the plant to build a pilot scale algal cultivation facility. SABER will build the pilot scale facility and the city will offer some analytical services as a match. The city also has an operating biorefinery for transforming vegetable grease into biodiesel through a transesterification process. We are exploring the possibility of using this refinery to produce biodiesel from algal biomass. Secondly, we discussed the establishment of a recycling program on campus for oils from food waste to be used as a feedstock for the production of biofuels.

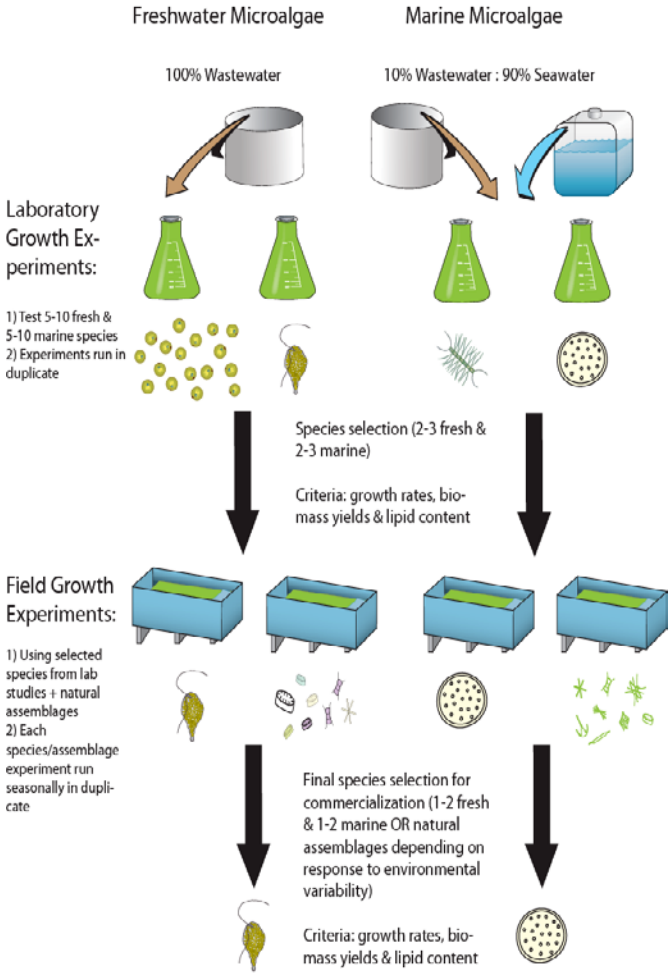


Figure 2.

A total of 9 proposals and white papers have been submitted to federal agencies for funding. A number of biofuels meetings were attended by the PIs. A principal investigator meeting for the SABER program was convened by the PI in September. The goal of the meeting was to report on research progress and discuss further collaborations within IESES at FSU. This meeting was a resounding success, and the presentations are available upon request. Numerous other meetings were attended by the PI with state and local officials that are not listed.

FLORIDA STATE UNIVERSITY

Microgrids for a Sustainable Energy Future

PI: Chris S. Edrington
Co-PIs: Jim Zheng, Mischa Steurer, Dave Cartes

Description: A microgrid strategy can provide a solution for meeting Florida's sustainable energy needs; this effort focuses on the following:

- Reduce the number of system-wide power outages by providing islanding capabilities allowing grids to separate from each other, providing for a more stable and reliable power delivery infrastructure.
- Provide a framework in which non-traditional, low-carbon footprint, energy sources such as: wind, solar, and fuel cells can be easily integrated into the existing power system.
- Provide for intelligent energy management and increased efficiency via high-penetration levels of power electronics and control strategies.
- Provide for streamlined integration of both stationary and non-stationary energy storage devices as well as future energy conversion resources such as: ocean current and tidal.
- Directly address greenhouse gas targets.

Budget: $719,333

Progress Summary

To meet Florida's renewable energy and greenhouse gas targets, there must be an aggressive sustainable energy plan. A microgrid strategy can provide a solution for meeting Florida's sustainable energy needs. Microgrids are an amalgam of: loads; distributed generation such as: photovoltaic, wind, fuel cells and other renewable energy sources; distributed energy storage devices which include: stationary (flywheels, ultracapacitors, and batteries) and non-stationary entities such as plug-in hybrid electric and electric vehicles. Possible benefits of microgrids are:

- Reduce the number of system-wide power outages by providing islanding capabilities allowing grids to separate from each other, providing for a more stable and reliable power delivery infrastructure.
- Provide a framework in which non-traditional, low-carbon footprint, energy sources such as: wind, solar, and fuel cells can be easily integrated into the existing power system.
- Provide for intelligent energy management and increased efficiency via high-penetration levels of power electronics and control strategies.
- Provide for streamlined integration of both stationary and non-stationary energy storage devices as well as future energy conversion resources such as: ocean current and tidal.
- Directly address greenhouse gas targets.

To this end, the PI and co-PIs formed a research proposal that was submitted to IESES and subsequently, after peer review, approved for an award. Appendix A contains the original full statement of work. The PI and co-PIs have put together a team of undergraduate, graduate, post-doctoral associates, and visiting scientists to achieve the outcomes of the statement of work.

PROPOSALS

Table IV shows a list of the proposals that are either submitted or are in the pre-proposal stage, based on the information provided to the PI by the co-PIs on this project. The purpose of the table is to give an indication of the effort by the PI and co-PIs to leverage the resources that this grant has provided to obtain further research funds to sustain the work. The participants are not a complete listing, but reflect only the involvement of the PIs from this project.

CONCLUSIONS

Due to budget cuts at the initial stage of the project, the original $1M that was awarded was cut to approximately $ 719K and additionally the 3rd year of the project was left unfunded. The original set of PIs included Dr. Farukh Alvi who at this initial stage decided to decline participation in the research effort since he could fund the same type of work under FCAAP. Due to this, the portion of the Statement of Work relating to Dr. Alvi's work will not be pursued and essentially does not impact the overall objectives of the project. It is envisioned that, due to importance of solar PV installations that are being proposed in the State of Florida, that a modification to the SOW is in order that will address control, stability, and integration of high levels of penetration of solar PV in existing and new grid topologies. A new student will begin working on this research area starting in the fall semester. Another modification to the SOW was proposed for the work that is responsible by Dr. Mischa Steurer. The original intent was to set up a Power Hardware in the Loop (PHIL) interface for experimental work. However, it is felt that a more important issue is to investigate where and how microgrids might be instantiated in the State of Florida. A student was placed on this research effort, but due to lack of interest and performance was not retained. In the fall semester a new student will start on this effort. It is felt that the burn rate is quite appropriate at the moment for this research award and that at the 6 month mark approximately 50% of the first year allotment has been spent. Of primary importance is the fact that: 1) all graduate students have been fully funded, 2) all support requests for summer support for faculty have been honored, 3) there has been a sufficient amount of travel to present research results and participate in workshops and proposal planning meetings, 4) support for undergraduate researchers has been available and utilized, and 5) stipends for visiting scholars has been made available. However, based on the current burn rate, it may be possible to pick up another visiting scholar, partially fund an additional post-doctoral researcher, and another graduate student starting this fall. This is primarily due to a vacancy created by Dr. Wenxin Liu who is leaving this fall to take an assistant professor position at New Mexico State University. In general the research team is making good progress toward the research goals that were set forth in the original SOW, as evidenced by the level of publications in national and international forums.

Additionally, the educational goals are being amply met and the funding is providing opportunities for undergraduate and graduate students to achieve an education in an area that is clearly of national importance. Moreover, the PIs have utilized the knowledge and opportunity provided for by the grant to write additional proposals that if funded will help support the initiatives of IESES and FSU.

FLORIDA STATE UNIVERSITY

Planning Grant: Hydrogen storage using carbon-based adsorbent materials

PI: Efstratios Manousakis

Description: We propose to theoretically investigate a variety of carbon based nano-porous materials, such as activated carbon or single-wall or multi-wall carbon nanotubes, which can be used to store and transport hydrogen. We find that by doping with metallic elements, the micro-surfaces of these carbon-based porous materials provide increased van der Waals forces to the adsorbed hydrogen molecules; this effect significantly enhances the volumetric energy density for hydrogen storage and we propose to carry out a full theoretical investigation to find the optimum conditions.

Budget: $15,000

Progress Summary

As a result of the realization that the originally proposed project has low funding priority we have recently turned our attention to a different idea which was not included in our original White Paper. The idea is to use a radically different class of materials to produce highly efficient solar cells. We have found that the photovoltaic effect, which as it is well known works with doped band insulators, works in addition, with a class of materials which are called Mott-Insulators. Namely, first, we can show that a p-n junction can be produced by making an interface between a p-doped and an n-doped Mott-insulator. Most importantly, we find that if we appropriately choose these materials to be narrow-band and narrow-gap Mott-insulators they give rise to very high quantum efficiency. We find, theoretically, that a solar photon when it is absorbed by the type of device produces several electron/hole pairs and only very little amount of energy is dissipated by photon emission or other dissipative processes. We are in the process of using Molecular Beam Epitaxy to produce the first such device.

FESC
Florida Energy Systems Consortium

FLORIDA STATE UNIVERSITY

Multi-Generation Capable Solar Thermal Technologies

PI: A. Krothapalli**; Co-PI:** Brenton Greska
Students: John Dascomb (Ph.D.), Ifegwu Eziyi (Ph.D.), Jon Pandolfini (Ph.D.), Michael Gnos (M.S.)

Description: The objective of the proposed research is to develop and demonstrate small-scale solar thermal technologies that can be used separately, in conjunction with one another, or with existing waste heat producers, thus improving the overall system efficiency.

The development of an indoor solar simulator capable of providing and sustaining 1 kW/m2 over an area of 10 m2

The development of a Rankine cycle-based solar concentrating system that is capable of producing at least 2 kW of electricity adaptation and integration of small-scale absorption-based refrigeration systems that can employ the waste heat from the aforementioned Rankine system.

Integration of existing membrane distillation technology for waste heat recovery from either, or both, of the above-mentioned technologies. Demonstration of a multi-generation system that combines all of the above-mentioned technologies.

Budget: $544,226

Progress Summary

Task 1: Develop an indoor solar simulator

Testing of the solar simulator components has begun (Figure 1). The results from two of the test configurations are shown in Figure 2. It can be seen that there is uniform light distribution without the reflector but it is only 40% of the desired intensity. With the reflector the maximum intensity rises to 80% of the desired value but it is concentrated over an unacceptably small area. A number of configurations will be tested in an attempt to address these issues.

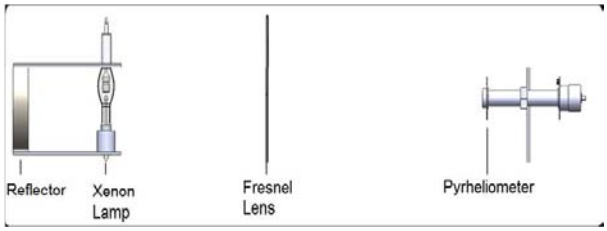


Figure 1. Experimental setup for solar simulator design development.

A low-cost pyreheliometer is under development at ESC for use with the simulator and other outdoor activities requiring direct beam radiation (Figure 2). Work on the tracking system for the low-cost unit is currently underway. Cost for pyrheliometer and tracking system ~$500

A first generation solar generator has been built to verify the basic design principles of solar steam generation using dish system. Figure 3 is the system installation picture on the FSU at ESC. The results of this work is described in a recent M.S thesis (John Dascomb, August 2009)

Figure 2. Pyreheliomoeter

Arrangements have been made to have a 15-foot diameter commercial concentrating dish donated by Infinia Inc. to ESC for use in the development of a small-scale cavity type steam boiler.

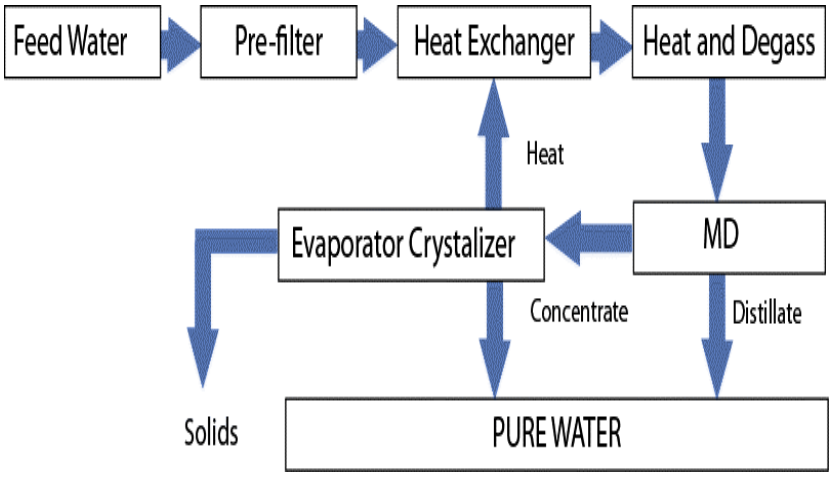
Task 5: Integration of existing membrane distillation technology for use with the waste heat from the Rankine cycle and the refrigeration system (unfunded). Because of the importance of efficiency improvement in solar thermal systems, ESC has been developing waste heat recovery methods with particular emphasis on a novel water purification system. This work is carried out in collaboration with the Royal Institute of Technology (KTH) in Sweden. A typical multi-generation solar power system is shown schematically below. Such systems are being studied currently with a goal of building a demonstration system during the second year of the program.

Figure 3. ESC 14 m2 parabolic dish concentrator with a steam boiler - solar steam generator.

A multi-generation solar thermal system. MD: membrane distillation unit; ORC: Organic Rankine Cycle.

A membrane distillation (MD) unit for water purification has been purchased.This unit is capable of utilizing waste heat to operate and understanding of itsoperation will allow for an optimal solar thermal system design.

Figure 4. Infinia 3 kW dish-Stirling system.(The dish is being donated to ESC for the steam generation project)



FLORIDA STATE UNIVERSITY

Planning Grant: Meteorological Factors Affecting Solar Energy Efficiency in the Tropics

PI: Paul Ruscher**, Co-PIs:** Yaw Owusu, Hans Chapman

We propose to develop meteorological guidance in support of engineers and others needing to estimate solar energy efficiency across the tropics by analyzing the required meteorological data as well as installing monitoring weather stations in three locations at cooperating sites in Jamaica, Trinidad & Tobago, and at a site to be determined in the northeastern Caribbean. In addition we will add components to an already existing site at Key West, Florida. The relevant meteorological parameters important for this work are summarized in Case et al. (2008). The meteorological parameters needed are routinely available from conventional government-operated weather stations in general, but lack some of the required details. In particular, measured solar radiation is usually absent. Some areas across the moist tropics in particular will exhibit substantial mesoscale variation (on the order of km to a few hundreds of km) due to local terrain, orographic circulation, and surface land use variations. Surface stations used for this part of the study routinely collect most of the required hourly data. A limited number of stations also collect upper air profile data from radiosonde balloons twice daily that can be used to assess directly the precipitable water in the atmosphere.

Budget: $15,000 (February 2009 – December 2010)

Universities: Florida State University

External Collaborators: NOAA/National Weather Service Key West, University of the West Indies and Caribbean Solar Energy Center (Trinidad & Tobago), University of Technology (Jamaica), NOAA Global Systems Division, Earth Science Resource Laboratory (Boulder, CO)

Progress Summary

We have identified two of our three partners in the Caribbean for data collection points, and purchased the necessary hardware to be installed in summer 2010 (July – September time frame). Either St. Lucia or St. Maarten will provide support for a third station. National Weather Service Key West also will be installing a pyranometer on their weather station to provide solar radiation data there. Data collection continues in Tallahassee and at several other locations in Florida, and will be part of the comprehensive data analysis provided.

The SMARTS version 2.9.5 software (Gueymard 2001) has been installed and is being used to develop calculations of the impacts of the various meteorological variables on available surface solar energy. Atmospheric factors generally limit efficiency of solar systems, with cloud cover playing a major role, but the other variables listed previously also contributing to reductions. Most problematic is that most solar systems are rated for an atmosphere of 1.5, characteristic of drier, higher altitude air of a continental origin, not appropriate for the tropics. By using a different model with higher air mass value and varying the parameters according to observed atmospheric variability, we will come up with a much more appropriate model for energy utilization and efficiency appropriate for the tropics in the Caribbean. It is hoped that this model could then find widespread use across the developing nations in the tropics and subtropics.

The table below summarizes the variability in some of the meteorological factors involved, for which gross oversimplifications are often made (if factored in at all) by designers and end users of solar systems

The educational value of this project and system is also tremendous. By utilizing existing scientific protocols for measuring these atmospheric variables in an educational setting (e.g., using GLOBE protocol measurements, we should be able to interest schools to get involved in energy efficiency projects while at the same time increasing public scientific literacy about the complexities involved in design and use of energy systems. Much of the data collected in this project come from relatively inexpensive measurement systems and we will demonstrate their utility in this educational context, as well.

Typical Meteorological and Surface Factors Affecting Calculations of Available Solar Energy Potential Tropics)

Variable	Surrogate/Description	Symbol	Range/Typical Values
Aerosol optical depth	aerosol optical depth	σ	
Air mass factor (latitude ϕ, zenith angle ζ)		AM	0-10 (1.5)
Air temperature	Dry-bulb temperature	T_a	0-40°C
Albedo		α	0.05 - 0.95
Barometric pressure		p	700-1040 hPa
Carbon dioxide	Ground concentration CO_2		370 (–390) ppm
Cloud cover	Cloud fraction (reduced set)	cc	0-1.0 (in tenths or oktas)
Irradiance		I	
Land surface type			Lookup table
Panel temperature	Brightness temperature	T_B	0-50°C
Precipitable water	Relative humidity, Dew point	PW	0-70 mm
Total ozone	(Column Total)		344 DU (0.344 atm cm)
Visibility	Runway visual range	VR	0-50 km
Wind speed		V	0-25 m s^{-1}

FLORIDA STATE UNIVERSITY

Political and Economic Institutions Regarding Siting of Energy Facilities: "Hold Out" and "NIMBY" problems, with concurrent developments in undergraduate education

PI: R. Mark Isaac; **Co-PIs:** Douglas Norton, Svetlana Pevnitskaya

Description: The "holdout" problem occurs when one economic agent attempts to construct a portfolio of economic assets (often land) from multiple sellers. When a public good has diffuse public benefits but costs concentrated on a few, a "NIMBY" problem (Not In My Back Yard) may exist.

Budget: $79,621

Progress Summary

1) **The "Hold-Out" project (with graduate student Sean Collins).** The experimental design is complete, the programming is complete, IRB approval has been obtained, and we have conducted two complete experimental treatments. This research was presented at one of the Presidential Sessions at the 2009 Meetings of the Southern Economics Association in November in San Antonio. Findings will be submitted to a major economics journal such as the *Journal of Law and Economics*.

The "hold-out" concept is discussed repeatedly in the context of public policies regarding land acquisition and facilities siting, but a clear definition is elusive. To economists, the most likely definition is that a profitable amalgamation of land parcels by one buyer from competing sellers does not obtain because of the failure of the private bargaining process. However, the term seems to be used more for delay instead of failure in bargaining, or even the very different concept of creation of any bilateral bargaining situation of the buyer and the "last" or "holding-out" seller, which may be inconvenient to the buyer but is immaterial in terms of economic efficiency unless efficient trades actually fail.

Our first task was to create a "best case" scenario to observe holdout, which could then serve as a test-bed to examine changes in institutions and/or information conditions to ameliorate hold-out. There was no possibility of eminent domain proceeding. The buyer would have to purchase all parcels in order to reap the synergistic gains from amalgamation. There would be no contingent contracting, so that the buyer would face the so-called "exposure problem" of having to pay for some of the parcels before knowing whether he/she could obtain all of them. The buyer would also be unable to borrow against the eventual value of the amalgamated properties. All of this would unfold in the context of valuations which made the amalgamation profitable to the buyer relative to the separate values placed on the parcels by the sellers. If hold-out existed, it would mean the failure of bargaining to capture mutually beneficial gains from exchange.

The design conditions above were good; however, we then had to choose certain information conditions, the effects of which on the "best case" objective were ambiguous. For example, should the terms of the contracts be common knowledge? Might that stoke the fires of "me last" among the sellers; on the other hand, it might be a vehicle for developing reasonable expectations among the sellers as to what to expect from the negotiations.

We realized that there was an array of these information conditions that, while ambiguous as to their propensity to promote holding-out, were clearly different from what one might recognize as the archetypal approach to the facilities siting problem when approached by governments or by private parties. In the contemporary era, governments often operate in the context of "Government in the Sunshine" and "Freedom of Information" provisions that promote transparency and common knowledge. Conversely, private acquirers of large parcels often resort to the opposite: non-disclosure agreements and dummy corporations to keep as little information as possible from affecting the negotiations. Therefore, even in our "best case" scenario, we began with two information conditions. One we call "government" in which sellers know how many units the buyer has purchased, all contract prices as they occur, and they can continue to communicate with one another throughout the negotiations. In the other, "private," information condition, sellers do not know how many of the parcels the buyer has purchased, they do not know the other contract prices, and there is an enforced non-disclosure condition.

Our results are unambiguous: we observe the hold-out problem in our baseline design. In half of the cases the contracting fails, so we have successfully created a test-bed which we can use to investigate institutional and information conditions that might ameliorate hold-out. Our second experimental treatment has been completed, and again the results are clear: contingent contracting significantly ameliorates the hold-out problem.

2) **The "NIMBY"project (with Co-PIs Doug Norton and Svetlana Pevnitskaya).** The experimental design and programming are complete, IRB approval was obtained, and the first twelve experimental sessions have been conducted. The first presentations of the design were at the 2009 Southern Economics Association meetings and the 2010 American Economics Association meetings. The first public presentation of the results will be at the 2010 World Meetings of the Economic Science Association in Stockholm in July.

To review, the NIMBY problem deals with siting issues in which external effects are "good" for some members of "society" and bad for others. Without the debate over the alternate energy bio-mass facility in Tallahassee, people might have questioned our hypothetical scenario. Even as our research was underway, a similar scenario played out with the cancellation of the bio-mass facility in Gadsden County. Different citizens with credentials as "environmentalists" viewed the plant as either "good" (due to development of an alternative energy infrastructure with an eye to global issues of sustainability and global warning) or "bad" (due to local environmental effects). Examination of public goods provision problems in such a heterogeneous-preferences situation opens a new direction for research in economics.

In initial presentations of the design, our decision mechanism, the generalized voluntary contributions mechanism (GVCM) will be received as an important institution in its own right.

We are now analyzing the data. Preliminary data suggests effects of the nature of the conflict ("censored" versus "uncensored" conflicts) and from the intensity of minority preferences either for or against the projects.

3) **The undergraduate course (The Economics of Sustainable Energy) with Doug Norton** was taught for the first time in the Spring Semester, 2010. We capped the enrollment at about 26 students, and about 19 of those remained in throughout the course.

FLORIDA STATE UNIVERSITY

Reducing Residential Carbon Emission in Florida: Optional Scenarios Based on Energy Consumption, Transportation, and Land Use

PI: Tingting Zhao**, Co-PI:** Mark Horner
Student: John Sulik (PhD)

Description: In 2007 the Governor of Florida established targets for greenhouse gas (GHG) emissions, which mandate that the State of Florida aims to reduce emissions to 2000 levels by 2017 and to 1990 levels by 2025. To fulfill these goals, not only is the development of renewable sources of energy and fuel needed, but it is also necessary to achieve more sustainable energy/fuel consumption patterns. The objective of this project is to explore energy and fuel sustainability as well as CO_2 mitigation in Florida by investigating the household-level energy and transportation fuel consumption and by analyzing changes in land use. The project consists of three major steps: 1) calculating the baseline Florida CO_2 emissions from residential energy and fuel consumption as well as human land uses; 2) developing models of household behavior regarding various energy/fuel conservation and efficiency options based on a residential survey; and 3) forecasting energy/fuel demand and CO_2 emission levels in 2017 and 2025 throughout the state of Florida based on the scenarios created in step two. This project helps identify and determine the efficacy of various proposed practical energy incentives for household energy consumption reduction and carbon mitigation. It provides insights into the possible effectiveness of economic and policy tools for sustainable energy consumption and greenhouse gas reduction.
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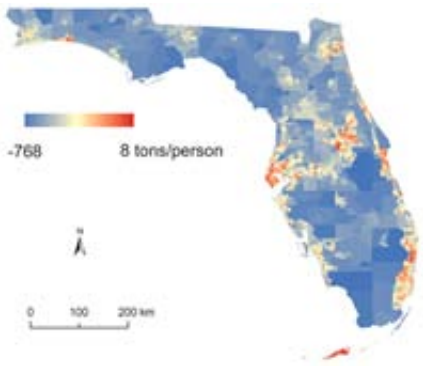
Budget: **$60,844**

Progress Summary

Objectives for Current Reporting Period include finishing the baseline carbon emissions estimation for Florida in 2000, conducting household survey on energy incentive behavior, and exploring modeling approaches that may be applied to building household behavior scenarios.

Progress to Date: We investigated the Florida carbon balance between household emissions and vegetation carbon assimilation (Zhao, Horner, and Sulik, journal manuscript submitted to *the Annals of the Association of American Geographers*). Household carbon emissions are composed of CO_2 released through residential consumption of energy and transportation fuels. Vegetation carbon assimilation is measured as plant net photosynthesis using biophysical remote sensing techniques. We found that vegetation in Florida was able to offset the state's residential energy and transportation fuel related carbon emissions in 2000. The balance of household carbon emissions and vegetation carbon sinks, however, varied significantly across the state (Figure to the left). The consumption-based carbon emission sources tend to be spatially separated from vegetation carbon sinks. The urban and suburban densities were associated with the highest per capita energy consumption, whereas exurban densities were associated with the highest per capita transportation fuel usage.



Both exurban and rural densities were associated with significant vegetation carbon sinks.

We developed survey questionnaire for the investigation of household energy incentive behavior. This questionnaire includes 32 questions covering four major household socioeconomic and energy behavior aspects. These include the present household conservation/efficiency methods, household decisions on adopting alternative energy-saving approaches driven by incentives, housing characteristics, and household characteristics such as ownership, education level, and income level. We have been working on the sampling strategy. We decided to sample 400 residential households across Leon County as a pilot survey study. The mailing list has been acquired (Figure to the left shows an example of residential mailing locations in a residential neighborhood at the parcel scale). We plan to test effectiveness of two survey modes – half of the residents will receive mail interviews and the other half postcard invitation to Internet survey. The survey framework is presently under the FSU Institutional Research Board (IRB) review. FSU Survey Research Laboratory will facilitate the conduction of survey upon the IRB approval.

We have conducted literature review on energy sustainability and carbon mitigation in the new era of climate change, with a specific focus on synergy between energy and Geographic Information Science (Horner, Zhao, and Chapin, journal manuscript submitted to *the Annals of the Association of American Geographers*). Several research challenges have been identified, which include the spatially explicit modeling of energy consumption that take into account the complex nature of social networks and environmental heterogeneity. The agent-based models (ABMs) may help us to overcome these difficulties, and we plan to focus on developing an ABM of household energy consumption behavior towards energy conservation and efficiency incentives based on our survey results during the next research development stage.

FLORIDA STATE UNIVERSITY

Investigating the Effect of Appliance Interface Design on Energy-use Behavior

PI: Paul Ward; **Co-PIs:** Ian Douglas, David Eccles
Students:
Avner Dachoach / Ph.D., Psychology (Cognitive)
Jarrett Evans / Ph.D., Psychology (Cognitive)
Jason Torof / Post-bacc. Psychology / Masters, Educational Psychology & Learning Systems
Jackie Kott / Undergraduate. Psychology
Stephanie Robertson / Ph.D., Educational Psychology & Learning Systems
Katerina Kudlockova / Ph.D., Educational Psychology & Learning Systems
Guler Arsal / Ph.D., Educational Psychology & Learning Systems

Description: The primary objective of this research project is to identify the behavioral factors that contribute to energy in/efficiency in the home. In particular, this project was designed to (a) examine current state-of the science on behavioral factors that affect energy efficiency, (b) report on the efficiency of typical energy consuming technology used in the home as well as existing programs designed to improve efficiency, and (b) investigate the types of human-technology interactions and other behavioral factors that lead to in/efficient energy use. To achieve these objectives this project uses laboratory-based experimental and field-based methods to (i) identify interface-design factors that constrain individuals to behave in locally optimal but globally sub-optimal ways, and (ii) survey how cognitive, technological, and motivational behavioral issues affect use in the home environment.

Budget: $247,720
Universities: Florida State University
External Collaborators: None

Progress Summary

Original Objectives for Current Reporting Period
The primary objectives for the current reporting period were to identify the existing energy efficiency initiatives (Task 3), produce the first part of an online design review/guide (Task 4), seek human subjects approval and identify households for inclusion in research (Task 5), and to pilot the cognitive task analysis (CTA)/inventory procedures (Task 6).

Progress Made Towards Objectives During Reporting Period
Compilation of the information necessary for Task 3 (identify the existing energy efficiency initiatives) was completed in the prior reporting period. Due to the revision of the project budget, tasks 4 (Design Review) and 9 (Online Recommendations) have now been integrated and replaced by a new task (Task 10), which involves producing an online project and data summary/design recommendations (to be produced by Dec 31). Information from Task 3 will be incorporated into this online guide.

Two applications for use of humans as participants in research (part of Task 5) were submitted to, and approved by, the Florida State University Institutional Review Board.

These included an application for a survey of behavioral and technology factors influencing energy efficiency (part of original Task 6, see below), and one for experimental research examining the design-related and behavioral factors that constrain use and efficiency (a new task added to this project—Task 11—described below).

Tasks 6 (pilot CTA), 7 (data collection using CTA), and 8 (data analysis of CTA) originally consisted of three primary sources of data: Survey, Interview, and Inventory data. Due to the revision of the project budget, only the survey component of the CTA (which now includes some household inventory data) will be collected. This information, together with the laboratory-based experimental data (Task 11), will enable us to provide a detailed report of human-technology (i.e., cognitive, behavioral and design-related) factors that constrain and influence energy in/efficiency. The (online) survey (Task 6) has now been fully developed and piloted. This survey takes approximately 1 hr to complete and obtains the following information from participants: Household demographics, technology use audit, device feedback, consumption feedback, energy savings behaviors, conceptions and misconceptions. Advertisements for participants in the survey have been distributed throughout the locale and/or published in regional newspapers, and internal mechanisms have been established for remunerating human participants for completing the survey. Two experimental data sets (Task 11) have also been partially collected (11a—the effects of access cost on efficiency; 11b—the effects of feedback and time pressure on efficiency) and, based on the data, a follow-on study is in development for one of these experiments (11a).

FLORIDA STATE UNIVERSITY

Planning Grant: Real-Time Power Quality Study For Sustainable Energy Systems

PI: Dr. U. Meyer-Baese, **Co-PIs:** Helen Li, Simon Foo, Anke Meyer-Baese, Juan Ordonez
Students: Bhattacharya (Ph.D.), J. Xu (Ph.D.)

Description: The main objective of this project is the collection of preliminary data for IESES proposals that can be used to seek local, national and international sources of external funding from private and government sponsors. The overall project has been split up in several independent subprojects to allow a timely completion of the tasks. Four tasks have been completed and one task is still ongoing. The remaining task will be performed by the CO-PIs and their graduate students at Florida State University.

Budget: $15,000

Progress Summary

Task 1: "Sustainable Energy White Paper Development" has been completed. Two proposals have been submitted and one conference paper has been published: Indranil Bhattacharya and Simon Foo, "Indium Phosphide, Indium-Gallium-Arsenide and Indium-Gallium-Antimonide based High Efficiency Multijunction Photovoltaics for Solar Energy Harvesting," 1st Asia Symposium on Quality Electronic Design (ASQED '09), Kuala Lumpur, Malaysia, July 15-16, 2009.

Task 2: "IESES Collaboration within State of Florida" to develop dynamic models for fuel cell, battery and ultra-capacitors has nor been completed. We will travel to seek collaborations with the University of Miami and write proposals in the near future. Project funds will be used for travel expenses seeking collaboration opportunities within the State of Florida. This task is still ongoing.

Fig. 1 Instrumented PEM fuel cell station. 1.2 kW.

Task 3: "IESES International Collaborations" has been completed. To meet Florida's sustainable energy demands, we have addressed the important problems on power quality. The preliminary study showed that a custom microprocessor should be favored. Currently the leader in ESL design of microprocessors is the Processor Designer (PD) by Coware Inc. These tools have been originally developed at RWTH Aachen in Germany and are now commercial products. To learn the use of these tools, the PI visited the RWTH Aachen in the summer of 2009 for 2 month (June and July) and was trained on using the various design tools. In the following, we have successfully installed the Pocessor Designer tools at FSU College of Engineering computers and became member of the CoWare University program. The tools (16 seats having a total commercial value of 16x$120K=$1.920 MUSD) are in use in the Fall 2009 ASIC System design course (EEL5707). 3 students in this course were MS students from CAPS. Data produced during the research stay at RWTH Aachen resulted in the submission of 2 journal publications and will be used later to submit proposal in related calls.

Task 4: "Power Quality Preliminary Data Production" is complete. We have compared the preliminary study from the FSU Ph.D. thesis "FPGA-Based Real-time Processing of Time-varying waveform Distortions and Power Disturbances in Power Systems" by Jinglin Xu with current state-of-the art systems. It turns out that commercial switching to an alternative source after detecting a power distortion is done within 2ms. As a result the narrow band filter approach used in harmonic analysis cannot be used. The study of low latency, robust, and efficient systems uncover that a zero or first order Hilbert Transformer. We have successfully designed, built in MatLab/Simulink, simulated and tested on an FPGA board such a system using first and second order Hilbert transformers and could successfully implement a sag/swell detection under the 2 ms requirements. We have included this MatLab/Simulink experiments in the "DSP with FPGAs" CCLI phase II proposal to NSF in the spring 2010.

Task 5: "Power quality analysis of PEM fuel cell system" has been completed. We have made available to the team PEM fuel cell systems to evaluated prototypes of power quality control systems. In particular we collaborated with Dr. Li's group in the testing of hybrid energy storage systems for fuel cell applications. Our group provided a 1.2kW fuel cell which was integrated with the hybrid energy storage and power conversion systems. Our teams tested different load profiles representative of transportation applications. The imposed load profile resulted in the FC power output and fuel consumption was measured. The power management strategy target was to keep the FC output nearly constant and have the storage elements respond to load variations. Different control strategies were tested trying to identify the one that leads to minimum fuel consumption for a given mission (load characteristics).

FLORIDA STATE UNIVERSITY

Sustainably Integrated Advanced Building Subsystems (OGZEB)

PI: A. "Yulu" Krothapalli, **Co-PI:** Justin Kramer

Description: This project focuses on the development of building subsystems that minimize the use of natural resources and carbon-based energy in Florida while also using materials that are renewable and sustainable. A key component of this project is the Off-Grid Zero Emissions Building, which will allow for the testing of these subsystems.

Budget: $503,168

Progress Summary

This project is complete.

FLORIDA STATE UNIVERSITY

Planning Grant: High Performance and Low Cost Fuel Cells for Future Vehicles

PI: Jim Zheng, Co-PIs: Richard Liang, Chuck Zhang, Ben Wang
Student: Michael Greenleaf, Ph.D.

Description: The objective of this project is to provide an innovative approach to revolution of current energy storage and conversion technology and greatly leverage FSU position in the strategic important area for sustainable energy. The following tasks are proposed to FSU for funding of the planning grant "High Performance and Low Cost Fuel Cells for Future Vehicles". The proposed tasks will be performed by Drs. Jim Zheng and Richard Liang at the Department of Electrical and Computer Engineering and Department of Industrial Engineering, respectively. First to demonstrate preliminary results in high performance of energy storage and conversion materials and devices in order to seek outside funding consistent with the vision of IESES. The deliverables will be conference proceedings and journal papers and proposal submissions for additional funding.

Budget: $15,000

Research Integration (collaboration)

- NCSU and NHMFL on advantage batteries
- Industrial Engineering on fuel cells
- Maxwell Technologies, Inc. and Ionova Technologies, Inc. on supercapacitors
- CAPS on microgrids
- MARTECH on thermoelectric
- Shanghai Institute of Technical Physics on photovoltaic
    - N. Dai, F.Y. Huang, S.L. Wang, X.N. Li, J.P. Zheng (co-PI), and D. Wei, "An International Collaboration Group on Solar Cell Technologies Development", Sponsor: Chinese Academy of Sciences, Budget: $877,193 (￥6,000,000 RMB), Project Dates: 4/09-4/14.

Progress Summary

To meet Florida's renewable energy and greenhouse gas targets, there must be an aggressive sustainable energy plan. A microgrid strategy can provide a solution for meeting Florida's sustainable energy needs. Microgrids are an amalgam of: loads; distributed generation such as: photovoltaic, wind, fuel cells and other renewable energy sources; distributed energy storage devices which include: stationary (flywheels, ultracapacitors, and batteries) and non-stationary entities such as plug-in hybrid electric and electric vehicles. Possible benefits of microgrids are:

- Reduce the number of system-wide power outages by providing islanding capabilities allowing grids to separate from each other, providing for a more stable and reliable power delivery infrastructure.
- Provide a framework in which non-traditional, low-carbon footprint, energy sources such as: wind, solar, and fuel cells can be easily integrated into the existing power system.
- Provide for intelligent energy management and increased efficiency via high-penetration levels of power electronics and control strategies.
- Provide for streamlined integration of both stationary and non-stationary energy storage devices as well as future energy conversion resources such as: ocean current and tidal.
- Directly address greenhouse gas targets.

To this end, the PI and co-PIs formed a research proposal that was submitted to IESES and subsequently, after peer review, approved for an award. The PI and co-PIs then put together a team of undergraduate, graduate, post-doctoral associates, and visiting scientists to achieve the outcomes of the statement of work.

CONCLUSIONS

Due to budget cuts at the initial stage of the project, the original $1M that was awarded was cut to approximately $719K and additionally the 3rd year of the project was left unfunded. The original set of PIs included Dr. Farukh Alvi who at this initial stage decided to decline participation in the research effort since he could fund the same type of work under FCAAP. Due to this, the portion of the Statement of Work relating to Dr. Alvi's work will not be pursued and essentially does not impact the overall objectives of the project. It is envisioned that, due to importance of solar PV installations that are being proposed in the State of Florida, that a modification to the SOW is in order that will address control, stability, and integration of high levels of penetration of solar PV in existing and new grid topologies. A new student will begin working on this research area starting in the fall semester. Another modification to the SOW was proposed for the work that is responsible by Dr. Mischa Steurer. The original intent was to set up a Power Hardware in the Loop (PHIL) interface for experimental work. However, it is felt that a more important issue is to investigate where and how microgrids might be instantiated in the State of Florida. A student was placed on this research effort, but due to lack of interest and performance was not retained. In the fall semester a new student will start on this effort. It is felt that the burn rate is quite appropriate at the moment for this research award and that at the 6 month mark approximately 50% of the first year allotment has been spent. Of primary importance is the fact that: 1) all graduate students have been fully funded, 2) all support requests for summer support for faculty have been honored, 3) there has been a sufficient amount of travel to present research results and participate in workshops and proposal planning meetings, 4) support for undergraduate researchers has been available and utilized, and 5) stipends for visiting scholars has been made available. However, based on the current burn rate, it may be possible to pick up another visiting scholar, partially fund an additional post-doctoral researcher, and another graduate student starting this fall. This is primarily due to a vacancy created by Dr. Wenxin Liu who is leaving this fall to take an assistant professor position at New Mexico State University. In general the research team is making good progress toward the research goals that were set forth in the original SOW, as evidenced by the level of publications in national and international forums.

Additionally, the educational goals are being amply met and the funding is providing opportunities for undergraduate and graduate students to achieve an education in an area that is clearly of national importance. Moreover, the PIs have utilized the knowledge and opportunity provided for by the grant to write additional proposals that if funded will help support the initiatives of IESES and FSU.

FLORIDA STATE UNIVERSITY

Planning Grant: Climate Modeling and Outreach Activities

PI: Shawn R. Smith, Co-PI: Steve Cocke
Student: Cristina Collier / B.S. Meteorology

Description: The objective of the planning grant is to develop at least one external funding proposal that focuses on areas of climate modeling and/or climate outreach that support the activities of the Institute for Energy Systems, Economics, and Sustainability (IESES). The focus of our activities has centered on evaluating the potential offshore wind resource in the northeastern Gulf of Mexico. Preliminary research has been completed using observations from instrumented Air Force towers and confirms the existence of wind power capacity at the assessed locations. Due to the sparseness of in-situ wind data in the region, a numerical modeling approach will need to be pursued to develop a wind climatology with sufficient spatial and temporal scales to further define the offshore wind power capacity. We seek interested collaborators from academia, industry, and government.

Budget: $15,000

Universities: FSU

External Collaborators: Mark Powell (National Oceanographic and Atmospheric Administation)

Progress Summary

Overview:
The project team has assessed available information regarding offshore wind power generation potential around Florida and in the Eastern Gulf of Mexico. According to previous research conducted by the Lawrence Berkeley National Laboratory and Navigant Consulting at the request of Florida's Public Service Commission, offshore wind has "large technical potential" in Florida, and certain sections off the northeast and northwest panhandle are economically sustainable. About 40,000 Megawatts (MW) of offshore power were identified, enough to power ~2.6 million homes and about four times the current installed capacity of wind energy in the U.S.

Previous studies have largely been based on climate data from land-surface and upper air meteorological observations, and little information is known about offshore wind power and its dependence on mesoscale processes or the impact of coastal circulations (e.g., sea and land breezes). Taking advantage of COAPS expertise in marine climatology and our access to a number of offshore observing sites, we conducted a pilot study to assess the potential for wind power on the shallow West Florida Continental Shelf. One key data source was tower N7 – with a suite of weather instrumentation deployed by FSU as part of the Northern Gulf of Mexico Institute – which collects wind measurements at a height closer to most standard offshore turbines heights than most surface moorings (thus reducing errors in corrections to turbine hub heights).

Progress:
In Fall 2009, we initiated a pilot study that to examine the offshore climate data to compute the annual wind resource and its seasonal variability at a select sites. The study focused on (1) examining the differences in methods used to adjust winds from an observation height (30 m for examined locations) to a nominal hub height of 85 m, (2) computation of wind power density and wind power capacity at each location, and (3) assessing the suitability of one regional climate model's wind output for spatially expanding the wind power study beyond the few in-situ sites.

The hourly wind speed must be estimated at the turbine hub height so we used three different adjustment methods, the power law, log law, and a stability-dependent surface boundary layer model developed by FSU professor Mark Bourassa (and colleagues). Preliminary results show the effects of atmospheric stability to reduce the wind at hub height by ~0.5 m/s as compared to values adjusted using the power law (in common use by engineering firms). Although the stability does reduce the wind at hub height, the results for two towers offshore of the Florida panhandle reveal wind power capacities between 25% and 31%. Background research by Dr. Mark Powell from NOAA's Atlantic Oceanographic and Marine Laboratory (currently stationed at COAPS) have shown that capacities over 20% have proven economically viable for other wind farms. Finally, assessing offshore wind using the North American Regional Reanalysis (a numerical weather prediction model) revealed the model winds to be wholly inadequate for assessing wind power resources. The model lacks any indication of the seasonal wind variability that exists in the in-situ data for the region studied.

Results from the pilot study confirm the need for a high-quality wind climatology for the offshore regions of Florida. A full proposal is under development. Determining the viability of offshore wind power will target FESC and IESES goals to expand economic development in sustainable energy industry in Florida. The results will provide policy makers with essential information to determine which offshore regions are suitable for wind energy production.

FLORIDA STATE UNIVERSITY

An Experimental Investigation of Economic Incentives of Policies, Institutions and R&D in Environmental Conservation, Sustainability and Renewable Energy

PI: Svetlana Pevnitskaya, **Co-PI:** Dmitry Ryvkin
Students (name/degree sought): Sean Collins (Ph.D.), Matthew Cutillo (Ph.D.)

Description: Policies and institutions aiming at reducing pollution and battling climate change often do not reach desirable results because actual decisions of governments and economic agents deviate from those predicted by theory. The methods of experimental economics allow for finding such deviations and their causes, and use the findings to modify theory and design better policies and institutions. In this project we construct a theoretical model of decisions in a dynamic environment with costs of pollution and climate change and employ laboratory experiments with human subjects to study actual behavior and explore responses to changes in the environment, production technologies, investment in clean technology and institutions.

Budget: **$43,217**

Progress Summary

Research Objectives for Current Reporting Period: For the current reporting period, the first goal was to complete the analysis of experimental results from the first phase of the project – the development of an experimental testbed for the analysis of policies and institutions in an environment with dynamic costs of pollution. The second goal was to design and describe theoretically the more complicated experimental treatments involving a possibility for economic agents to invest in clean technologies and allow for different types of access to clean technology by other agents. The third objective was to produce, on the basis of the results of the first phase of the study, two manuscripts for submission to refereed journals.

Progress Made toward Objectives During Reporting Period: Theoretical models of behavior were developed for corresponding environments and total of 22 experimental sessions have been conducted.
The first set of experiments aimed at the investigation of the effects of termination uncertainty and meaningful environmental context in dynamic games with accumulating costs of pollution and climate change. We find that termination uncertainty has practically no effect in the absence of experience, with the exception of a strong end-game effect in the treatment with certain termination. Environmental context and experience, on the other hand, have a strong impact on behavior, reducing pollution and increasing payoff.

In the second set of experiments, we studied the effect of technological heterogeneity on production decisions and the level of pollution. We do not observe heterogeneity in behavior across types, however find that treatments with largest average pollution propensity lead to strongest adjustment in curbing pollution for all types.

In the third part, we allow subjects to invest in clean technology. The goal was, first, to see whether the presence of this option changes behavior as compared to the no-investment benchmark.

Secondly, we compare the impact of two different institutions regulating access to the developed clean technology: the *private access* institution only allowed for the technology to be used by the corresponding investor, whereas the *public access* institution allowed the benefits of the technology to spread around the entire society. Although theoretically the expected amount of investment and pollution under both institutions are the same, we found that agents invest more and pollute less in the public access treatment.

We completed data analysis for the first phase of the project and produced the following two manuscripts:
1. Pevnitskaya, S., Ryvkin, D. Behavior in a dynamic environment with costs of climate change and heterogeneous technologies: an experiment (under review).
2. Pevnitskaya, S., Ryvkin, D. The role of context and termination uncertainty in dynamic climate change games (in preparation for submission)

We also presented our results at multiple conferences and invited engagements.

During the next reporting period we plan to complete experimental sessions and data analysis for the treatments with investment in clean technology and institutions and generate one more manuscript.

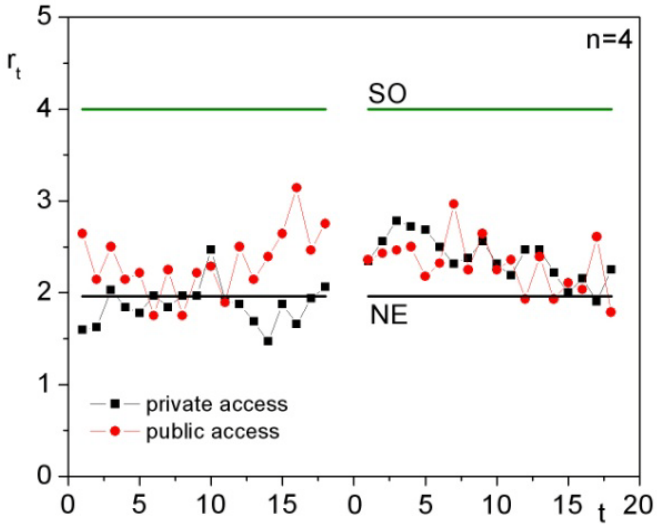


FIGURE 1. INVESTMENT IN CLEAN TECHNOLOGY

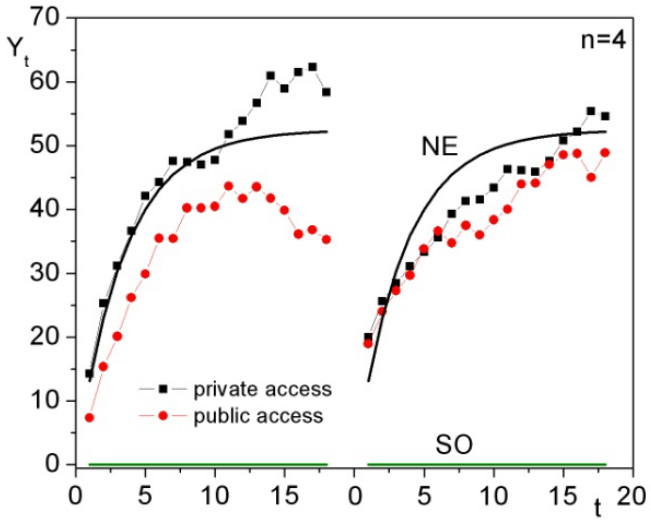


FIGURE 2. POLLUTION LEVEL

University of Central Florida

Enhanced and Expanded PV Systems Testing Capabilities at FSEC

PI: Stephen Barkaszi, Robert Reedy

Description: An important FSEC function is consumer protection from poorly designed and manufactured PV modules and systems. FSEC's test capabilities were established over 10 years ago and were adequate at the time to test and certify PV modules for certification. However, PV costs have fallen and competing electric utility rates have risen. In the last two years, these curves have crossed under some economic scenarios and incentive programs, and the demand for PV module testing and system certification has jumped. Thus, this task will provide for enhanced and expanded PV testing and certification capabilities. The task will also be done in close coordination with FSEC's work with the U.S. Department of Energy PV program.

Budget: $196,018

Universities: UCF/FSEC

Progress Summary

The objective of this project is to provide for enhanced and expanded PV testing and certification capabilities at the Florida Solar Energy Center (FSEC). Funding from the Consortium has been used to either purchase or leverage the purchase of photovoltaic testing equipment that will be used to expand the research and commercial testing programs at FSEC.

A state of the art long-pulse simulator has been purchased and delivered to FSEC. This simulator increases the speed of testing and expands the capabilities to test different PV materials. The same equipment is utilized by the National Renewable Energy Lab (NREL) for reference module calibrations and characterizations for industry.

Figure 1. Long-pulse solar simulator for PV module testing

Additional testing equipment added to the program includes multi-channel I-V curve tracing hardware for automated testing of PV modules under natural sunlight. The new equipment allows for the reliable testing of new high voltage and high power modules.

Figure 2. Multi-channel I-V curve tracer (left) capable of continuous testing of multiple PV modules

The test facility expansion will increase the small systems and inverter test areas to allow for side-by-side comparisons of inverters, modules, complete systems and balance of system (BOS) components.

As a result of FSEC's expanded capabilities, the PV test program has attracted funding projected to exceed $250k for 2010. Funding sources are both public and private.

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PV Manufacturing Data Base and Florida Applications

PI: David Block, Robert Reedy

Description: The overall goal of this project is to assist in the stimulation of the development of a photovoltaic (PV) manufacturing industry in Florida. The project objective is to conduct a review of the national and international PV manufacturing data for the purposes of establishing industry practices and an industry data base. The data base will then be available to assist Florida in establishing PV manufacturing firm(s).

Budget: $81,120

Universities: UCF/FSEC

Progress Summary

This project has established a data base for assisting in the establishment of PV manufacturing facilities in Florida. The following information has been determined:

Worldwide Statistics

- In 2008, the worldwide PV industry produced 6,941 M2 and experienced its strongest growth – an increase of 87%.
- Europe leads in world production with 1909 M2 at 27.5%, closely followed by China with 1848 Mw at 26%.
- The U.S. only accounts for 412 Mw or 5.9%.
- The U.S. installed 6.4% of world installations in 2008.
- The U.S. has only one manufacturer in the top 15 world companies – First Solar is at number 2.

U.S. Statistics

- The top seven U.S. manufacturers supply 96% of the U.S. total.
- The two largest U.S. producers use thin film technologies and these producers account for 65% of the U.S.'s capacity – First Solar and United Solar.
- For the seven U.S. manufacturers, 2 are located in Arizona, and one each in Maryland, Massachusetts, Michigan and New Mexico.
- California leads in PV installations with 178.7 Mw or 62% of the U.S. total followed by New Jersey with 22.5 Mw or 8% of total.
- Because of four installations completed or started in 2009, Florida is now ranked second in installations. Thus, in six months, Florida went from last to second in the U.S.

Key Florida Results

- Two PV installations by FPL in DeSoto County (25 Mw) and south of Kennedy Space Center (1.1 Mw) are now completed and in operation.
- 140 M2 of Florida PV installations are now in planning for the next 5 years – GRU, FMEA, OUC, and Lakeland.
- Three PV manufacturers now have or have proposed Florida locations – Advanced Solar Photonics, Mustang Vacuum Systems, and Blue Sky Solar.
- Willard and Kelsey withdrew Florida as a possible location and stayed in Ohio.
- Spire of Boston has established an equipment manufacturing plant in St. Petersburg, FL

Update: The database will be updated once the manufacturing date for 2009 is published.

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Concentrating Solar Power Program

PI: Charles Cromer **Co PI:** Robert Reedy

Description: Solar concentrating systems use mirrors to focus sunlight onto receiver pipes at the focal point of the mirrors and are one of the lowest-cost centralized solar power options. After many years of applications, solar concentrating technology has the ability to produce electricity for about $0.10/kWh in the desert southwest. This technology holds high promise for Florida and could also produce low cost solar electricity assuming it can meet production goals. The objective of this R&D project is to advance concentrating technologies by conducting an analytical study of Florida solar resource in order to predict the performance of the concentrating solar application and then to perform experimental test and evaluation of the predicted results.

Budget: $52,000
Universities: UCF/FSEC
External Collaborators: FPL

Progress Summary

The project consists of two tasks:
Task 1. Determine the solar resource for any designated installation site in Florida.
Task 2. Calculate the expected amortized cost of energy that would be produced from that site given its location and the solar concentrator equipment anticipated to be installed at that site.

The effort of the past months has focused on the completion of Task 1: The determination of the solar resource for any designated installation site in Florida. These systems have been previously installed in the desert southwest where direct beam data has been accumulated over many years. A problem was identified – the lack of validated direct beam measurements for the State of Florida.

Literature Search Completed: Various methodologies to resolve the problem were investigated through literature search. Over 40 published papers were reviewed for information on the determination of the direct beam resource and the establishment and validation of predicting equations. The five most appropriate to the task, providing validated equations, were used to select the most appropriate analytical approach for Florida.

Method Selected: The Heliostat-2 method was selected as the most viable to provide validated direct beam historical data for Florida. This method (developed a few years ago by Ecole de Mines de Paris) basically consist of using two parameters, turbidity (atmospheric conditions), and elevation as input, to provide an estimation of the total, beam and diffuse radiation based on a “clear sky model”. That is, the amount of direct beam and diffuse radiation that would reach the ground for a totally clear sky, given location, time of year, and time of day. The calculation protocol begins with a calculation for the “extra terrestrial insolation value.” The air mass is then calculated given the altitude of the site and surface barometric pressure. The turbidity (absorption and scattering) of the air mass is then calculated based on ground temperature and humidity which is used to derive the “clear sky” data. Satellite weather data is then used to modify the clear sky data to provide monthly direct beam averages.

Programming of Algorithms Underway: It was determined to program the equations for each stage in the calculation sequence into two separate calculation platforms: Matlab and Excel. Matlab was selected for its ability to handle and manipulate the very large number of matrices needed to make the calculations for the entire data base. Excel was selected to provide a step by step visualization of each calculation, for a single pixel and time, as a check on the programming and matrix manipulations of Matlab. Turbidity calculations have been completed and published for Europe, but are not available for the US or Florida. Thus, this must be part of the calculation sequence for the model. Programming for the model on these two platforms has been the predominate effort of the past months.

The Excel main file has been created. This program has as input the variables of: year, month, day and hour, latitude and longitude, turbidity and elevation. It calculates from the external radiation values, clear sky values of direct beam, global, and diffuse radiation values. This model now uses generalized turbidity values. The next step is to develop a localized turbidity model for input to this algorithm.

Development of High Throughput CIGS Manufacturing Process

PI: Neelkanth Dhere
Students: Shirish A. Pethe (PhD), Ashwani Kaul (PhD) and Eigo Takahashi (M.S)

Description: A reduction in the cost of CIGS and other thin PV film modules is required for large-scale PV applications. The goal of this project is to attract a PV manufacturing company to Florida by developing a high-rate manufacturing process for $CuIn_xGa_{1-x}Se_2$ (CIGS) solar cells. The objective is to develop a high-rate deposition process for synthesis of CIGS absorbers and other layers by employing in-line and batch deposition techniques.

Budget: $141,620

Universities: UCF/FSEC

Progress Summary

The main objective of the current reporting period was elucidating the relation between the sputtering parameters such as working pressure, sputtering power and the working distance and the properties of the molybdenum back contact film. Experiments were carried out with various combinations of sputtering power and working gas pressure. The sheet resistance of the film was measured by four probe technique using an in-house built four probe measurement setup. Residual stress analysis was conducted with beam bending test with very thin glass strips that were specially procured for these experiments. Average roughness and thickness of the film were determined using a Dektak profilometer. X-ray diffraction (XRD) was carried out to estimate the crystallite size.

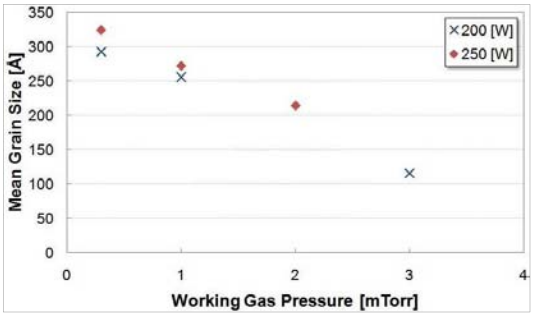

FIGURE 1: VARIATION OF MEAN GRAIN SIZE WITH WORKING GAS PRESSURE

The sputtering power was varied from 200 W to 300 W in 25 W increments and the working gas pressure was varied from 5 mTorr to 0.1 mTorr. It was observed that the deposition rate increased with increasing sputtering power and the working gas pressure did not have a significant effect. A very good agreement is observed between experimental data and the fast atom model by Ekpe which indicates that the deposition of the fast sputtering atom is dominant mechanism in this system. The XRD of Mo films deposited using various process parameters suggest that the lattice parameter variation was not significant with changes in sputter power and pressure. It was found out that the lattice parameter was in the range of 3.141 to 3.148 Å. From the XRD analysis, the mean grain size was estimated using the Scherrer's equation.

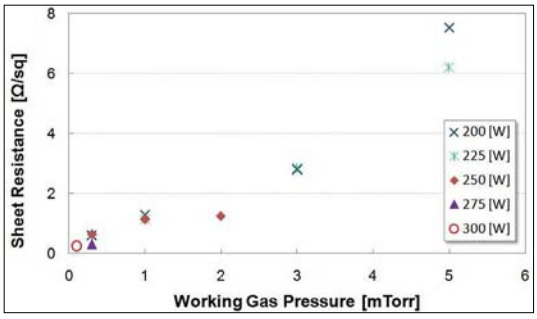

FIGURE 2: VARIATION OF SHEET RESISTANCE WITH WORKING GAS PRESSURE AND SPUTTERING POWER

The variation of mean grain size with respect to sputtering power and working gas pressure is shown in figure 1. From the figure it can be clearly seen that the mean grain size increased with increasing power and decreasing pressure. It is suggested that grain growth was facilitated by the atomic peening effect at lower pressure, hence grain coarsening occurred. The energetic incident atoms provide the energy to the Mo film to grow in ordered manner as well as enhance the growth rate, resulting in large grains. Sheet resistance of the film was measured and it was found out that the sheet resistance of the Mo films is strongly influenced by the gas pressure as compared to the sputtering power (Figure 2). The sheet resistance of the Mo thin films with thickness of about 7000 Å was found to be in range of 0.036 to 7.53Ω/□. With decreasing pressure and less scattering of sputtered atoms, the films become less porous and more tightly packed. This results in the decrease in film resistivity. Residual stress state was found to be strongly dependent on the kinetic energy of incident Mo atoms and backscattered Ar atoms to the substrate. At lower gas pressure and higher discharge voltage, incident atoms are more energetic and incident to the substrate normally because of their longer mean free path and higher flying speed. These energetic incident atoms cause the atomic peening effect, resulting in densely packed microstructure. By increasing the gas pressure or decreasing the voltage, incident atoms become less energetic and atomic peening diminishes. As a result, interglanular and interatomic spacing increase to develop tensile stress which is exerted by attractive force among the grains and atoms. Further increment of pressure or decrement of voltage makes the film more porous. When the spacing exceeds certain value so that the attractive force is not effective the film exhibits no stress.

The future work in the next reporting period would be concentrated on verifying the effect of working distance on properties of Mo films. Moreover, experiments will be carried out to determine the effect of metallic ratios of the absorber film on device performance. Experiments will also be performed to improve the efficiency of CIGS thin film solar cells.

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Research to Improve Photovoltaic (PV) Cell Efficiency by Hybrid Combination of PV and Thermoelectric Cell Elements

PI: Nicoleta Sorloaica-Hickman**,** Robert Reedy

Description: Photovoltaic/thermoelectric (PV/TE) cell integration is a promising technology to improved performance and increase the cell life of PV cells. The TE element can be used to cool and heat the PV element, which increases the PV efficiency for applications in real-world conditions. Conversely, the TE materials can be optimized to convert heat dissipated by the PV element into useful electric energy, particularly in locations where the PV cell experiences large temperature gradients, i.e. use the thermoelectric module for cooling, heating and energy generation depending on the ambient weather conditions. Thus, the goal of this research effort is to research and develop nanoscale design of efficient thermoelectric material through a fundamental understanding of the materials properties and to design and build a photovoltaic thermoelectric (PV/TE) hybrid system.

Budget: $167,820

Universities: UCF/FSEC

Progress Summary

There has been one primary approach taken in our laboratory in order to improve the efficiency of the n-type PbTe and p-type TAGS: create controlled shape and size nanostructured materials. By using the bulk materials n-type PbTe and p-type TAGS in a nanostructured form, it could be possible to modify thermoelectric properties in ways that are not possible with bulk materials, which can lead to an improvement in ZT.

Reports of enhanced ZT on thin film structures and nanowires have demonstrated the principle of nanostructuring to improve ZT, although questions remain regarding the accuracy of the ZT reported due to experimental difficulties in measuring the properties accurately.[(1)] Our preliminary theoretical calculation of the phonon and electron transport in PbTe and TAGS superlattices indicated that the primary benefit from nanostructures, a reduced lattice thermal conductivity, require an atomically high density of interfaces and good geometry. Because of these requirements the fabrication process could be laborious and complicated. In order to improve the figure of merit ZT it is required that, the nanostructures should have a size smaller than the phonon mean free path but greater than the electron or hole mean free path, phonons are more strongly scattered by the interfaces than are electrons or holes, resulting in a net increase of the efficiency.

Out first challenge is to create a material with nanoscale structures throughout using inexpensive, fast bulk procedure. Once the bulk material has been fabricated, the next challenge is to optimize the fabrication conditions so that the efficiency is improved. In our case it is difficult because the effects of the fabrication conditions on the nanostructures formed and the material's thermoelectric properties are not always clear. Finally we have to fabricate a thermodynamically stable material which can retain its nanoscale structures while being used in a practical device. If the nanostructures dissolve during the course of operation the thermoelectric properties will return to those of the bulk material, removing any increase in efficiency that the nanostructured material was supposed to give.

For this work we are using the inkjet printing technique to fabricate the bulk materials of nanostructure. This method is a simple method in theory, but is rather involved in many areas.

Some of the main things that need to be controlled during the printing process are drop volume, drop shape and formation, printing distance and its impact on print quality, evaporation kinetics of the droplet, surface energy of the substrate and surface tension of the droplet, penetration or spreading parameters and film thickness. Furthermore, ink rheology varies and one must be able to print liquids ranging from low to relatively high viscosity, hot melts, phase-changing inks, etc. However, viscosity range is rather limited. The phase separation kinetics can be controlled by the drop size and substrate temperature which affects the annealing time. Upper limit for viscosity is dictated by the printer: in this research printer used have upper limit for viscosity of 15 cP and the surface tension 30 ~ 32dynes/cm. Despite these difficulties, several inks processes have been developed which we hope will successfully create stable nanocomposites with improved properties over those of their bulk counterparts.

1. R. Venkatasubramanian, E. Siivola, T. Colpitts and B. O'Quinn, *Nature*, 2001, **413**, 597

UNIVERSITY OF CENTRAL FLORIDA

Research and Develop PV Devices Science and Laboratories

PI: Robert Reedy **Co-PIs:** Nicoleta Sorloaica-Hickman**,** Kris Davis

Description: The primary challenge facing the PV industry is to dramatically reduce the cost/watt of delivered solar electricity by approximately a factor of 2 to 3, to increase the manufacturing volume by a factor of 10 and to improve the cell efficiencies by a factor of 2 to 3. This task will conduct R&D on basic science of PV cells and develop a world class PV cell laboratory for future cell research. The R&D will focus on developing new and improved PV cells such as organic PV, nano-architectures, multiple excitation generation, plasmonics, and tandem/multi-junction cells.

Budget: $882,507

Universities: UCF/FSEC

Progress Summary

The following are the PV measurement and evaluation systems procured and configured at FSEC during the last year and put into operation the last six months.

1. Customized Oriel Quantum Efficiency System

A quantum efficiency (QE) system is an essential tool for any laboratory working on photovoltaic (PV) materials and devices. With the help of Oriel's product engineers, our research group has configured this system to measure internal quantum efficiency (IQE). The difference between IQE and EQE is that IQE measurements account for any EM radiation reflected from or transmitted through the PV cell under test. By doing this, one can infer more about the internal workings of the active semiconductor layer, without concern regarding the cell's external optical properties (e.g. anti-reflection coatings). This allows one to determine whether bad performance comes from the active semiconductor itself or simply from high reflection losses at the surface of the cell.

The configuration and operation of this system has included many tasks, including installation of the individual components, optical beam alignment, integration of the LabView based software, several rounds of troubleshooting relating to both hardware and software complications, procedure development, adaptation of test procedures to novel materials and device architectures (e.g. organic PV, multi-junction devices), and development of analytical techniques for processing data. A large part of the effort was placed in customizing this system to measure transmission, absorption, and reflection measurements of samples, which is required for IQE. Working with Sphere Optics, a manufacturer of integrating spheres, our research group was successful in achieving this new functionality.

2. Oriel Class AAA Solar Simulator

In the context of PV materials and device research, a solar simulator allows for a dependable measure of device performance under broadband radiation that is spectrally similar to that coming from the sun.

The configuration and operation of this system has included the fabrication of a suitable structure for safely mounting the simulator on the laboratory bench, installing individual components (e.g. light source, power supplies, optical filters, etc.), verifying proper beam alignment and light throughput, and testing the unit with actual PV cells with known current-voltage characteristics.

3. Laurell Technologies Spin Processor

Spin coating systems are a common tool in semiconductor fabrication labs and facilities. They allow for a controlled deposition of liquid phase materials. The Laurell Technologies system features an automated dispense system, which allows for better control of the fluid during deposition, therefore better control of the final thickness, which is very important for PV devices which features individual layers smaller than 100 nm in some cases. The configuration and operation of this system has involved the fabrication of a structure to house the system, installation of individual components (e.g. vacuum pump for the substrate chuck, compressed nitrogen cylinder and regulator for system's pressure inlet), integration of the system software, and final verification of proper operation.

4. Dimatix DMP-2831 Materials Printing System

The largest and most expensive item of fabrication equipment is the Material printing system (Dimatix, Inc.). It is a system used for Inkjet- printed quantum dot and nanostructure hybrid PV and TE materials and devices towards solar energy application. This system provides a high degree of accuracy and reliability of fabrication when operated and maintained correctly. The DMP-2831 is a state of the art printing system which will generate new research capabilities for the FSEC, including experimentation with inkjet deposition of organic semiconductors, inorganic solution based semiconductors, and patterned conductive layers. The configuration and operation of this printing system has included the installation of individual components, installation and operation of the system software, fluid transfer to printer cartridge, and troubleshooting to overcome non-jetting nozzles.

Work will continue on developing advanced PV cells using the above experimental measuring systems.

UNIVERSITY OF CENTRAL FLORIDA

PV Energy Conversion and System Integration

PI: N. Kutkut
Co-PI's: J. Shen, I. Batarseh, Z. Qu, X. Wu, W. Mikhael, L. Chow
Students: Kejiu Zhang (PhD), Souhaib Harb (PhD),
Karthik Padmanabhan (PhD), Xiang Fang (PhD), Ala Alsaeed (PhD)

Description: The objective of this project is to develop a system-driven Plug'N'Gen solar power system demonstrating architecture of decentralized, low-cost, mass-produced, PV panel-mounted micro-inverters. This system will be able to compete with today's centralized multi-kW PV inverters that require cost prohibitive professional installation. The project tasks are: 1) novel inverter topology and control concepts; 2) advanced digital control algorithms; 3) SmartTie interface with the utility grid; and 4) low cost and ultra-compact PV inverter in package.
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Budget: $1,267,000

Universities: UCF

Progress Summary

- **Advanced Digital Control Algorithms**

  a. Pulse skipping control strategy development

  To verify the performance of the previously developed pulse skipping techniques, an experimental setup was built and the performance of the 200W micro-inverter was measured using the maximum efficiency criteria developed earlier. The experimental results (Fig. 1) match the predicted calculation fairly accurately, where the inverter efficiency is greatly improved to above 90% even at light loads resulting in an overall CEC (weighted) efficiency improvement of 0.5%.

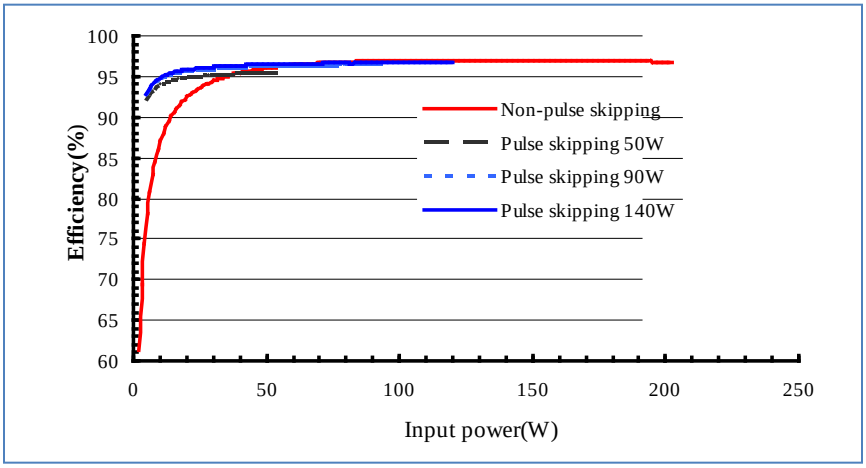

Fig. 1: Efficiency improvement using pulse skipping

  2) Adaptive PV Sun Tracking System

  An experimental setup is being built to verify the mathematical model that has been developed. The experimental setup utilizes a dsPICDEM MCSM development board, 12V 85W solar panel, and a 6V 2A 361 oz-in stepper motor. Over the peats few months, the effort was focused on spent pn testing the developed sun tracking algorithm on the 16 bit dsPIC33FJ32MC204 Digital Signal Controller, constructing the frame and mounts for the solar panel, and developing motor control code for the 6V 2A 361 oz-in stepper motor. Presently, the team is involved in designing the power measurement sensor board containing the voltage and current sensors.

- **SmartTie Interface with the Utility Grid**

  A novel control strategy that enables PV inverters to absorb little active power from the grid when the renewable source (e.g. the sun) is not available to compensate for the inverters' internal losses, regulate the DC bus voltage to keep it within limits, and operate the inverters in VAR mode wa s developed. This will extend the utilization of PV inverters beyond active power generation and will help improving grid stability and voltage regulation. Detailed simulation and experimental measurements were conducted to verify the proposed scheme (experimenntal results during VAR mode operation are shown in Fig. 2).

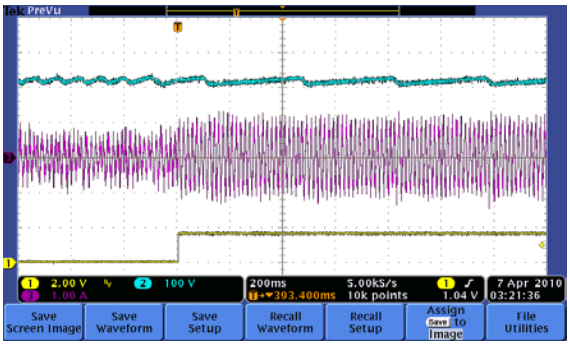

Fig. 2: VAR mode operation (No Sun)

- **Ultra Compact PV Inverter Packaging**

  Thermal Design and Optimization

  An optimal heat sink design, based on the optimization design process developed earlier, was built and tested. A micro inverter power board was assembled using the optimized heatsink and the thermal performance of the inverter and the heat sink was measured. The measurements show that the averaged temperature of current design is merely 2.3 ^{o}C higher than the previous design (Fig. 3). Note that the heat sink of the optimal design is more than 55% lighter and smaller than the original design.

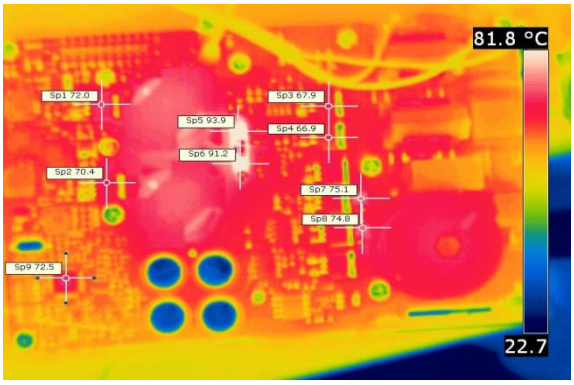

Fig. 3: Thermal performance with optimal heat sink design

UNIVERSITY OF CENTRAL FLORIDA

Buoy Array for Ocean Wave Power Generation

PI: Zhihua Qu **Co-PI**: Kuo-Chi Lin
Students: Shiyuan Jin (Ph.D), Steven Helkin (M.S.), Carlos Velez (B.S.), Karan Kutty (MS)

Description: The objective of this project is to develop a novel design that can extract ocean wave energy for commercial consumption. The design detailed herein is unique in that it is a wave point energy harvester that is small in size and contains all of the mechanical components directly within the buoy. As such, the buoy would simply need to be moored to the ocean floor and have cables to transport power to the shore, making it ideal for use in a multiple-unit wave farm. The project focuses mainly on the mechanical system within the buoy as well as methods to control the electrical load on the system. Different mechanical systems have been developed and tested on a motion platform to simulate a vertical wave motion—these systems have been analyzed and compared in order to provide an ever-increasingly effective design. Mathematical simulations have been developed to help optimize design parameters for use in subsequent prototype designs that will be able to be implemented in a wave pool or saltwater environment.

Budget: $150,000

Universities: UCF

Progress Summary

A Wave Energy Conversion (WEC) simulation model (see Fig. 1) was developed. The proposed model will be used to stabilize the variable frequency and voltage output and to satisfy the grid requirements of constant voltage, frequency, and power. It will also be used for future preparation once the buoy power system is deployed in an ocean environment.

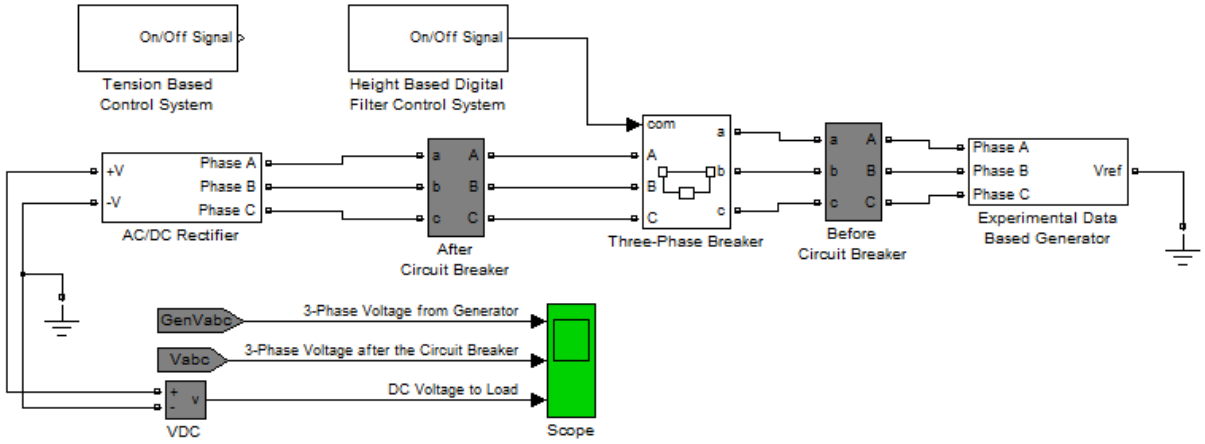

Fig. 1 Schematic for Wave Energy Conversion (WEC) system

The first alternative prototype (see Fig. 2) was built with the following characteristics:

- A cable is used instead of a chain to improve reliability
- A two-shaft system is used that allows motion on both upstroke and down-stroke without need of additional pulleys to be mounted to the floor
- A large size aluminum flywheel is used to increase the inertia of the rotating system
- A 4:1 gear set increases the RPM and power output

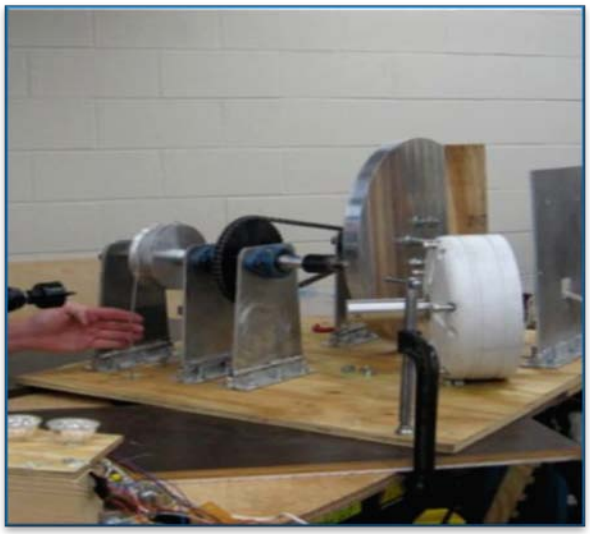

Fig. 2 Alternative prototype 1

The second alternative prototype (see Fig. 3) was built with the following characteristics:

- Replaces the pulley and cable system with a rack-and-pinion to drive the shaft
- Also uses a two-shaft power drive system with ratchets on each to generate consistent power in both upward and downward motions

Due to the lack of information regarding several important generator parameters provided by the manufacturer, a performance analysis was carried out.

- Developed a function to relate voltage produced by the generator with the moment applied to the shaft
- Determined a relation between the RPM of the shaft, the load acting on the generator, and the back-torque developed

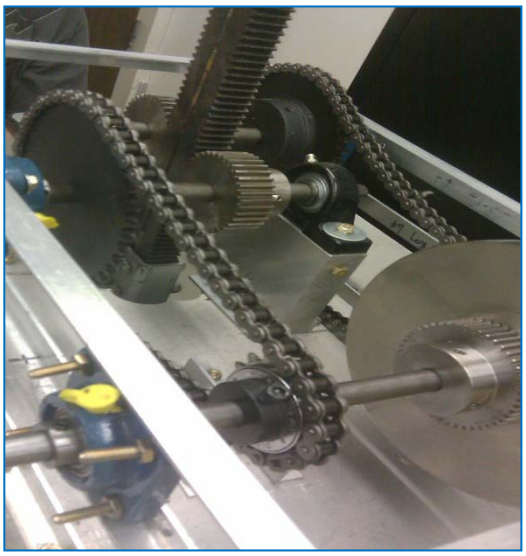

Fig. 3 Alternative prototype 2

An updated mathematical model was designed to simulate buoy motion on an ocean wave.

- Can be used to estimate power output for given conditions
- Allows for different design parameters to be varied to optimize design
- Will be used to prepare for next-generation, optimized design

UNIVERSITY OF CENTRAL FLORIDA

Solar Water Heating Systems Facility

PI: James Roland, David Block

Description: The objective of the task was to design with air conditioning (A/C), develop construction drawings, obtain permits and then hire a construction firm to add the walls, windows, doors and A/C to an existing FSEC roof facility. The enclosing of this existing space was done for the purpose of increasing laboratory space and to allow for conducting tests on solar water heating systems and PV inverters. The action was taken following a study which determined this project was the most cost effective means of adding valuable laboratory space.

Budget: $600,609

Universities: UCF/FSEC

Progress Summary

In 2005, FSEC constructed a slab and roof only facility on the west side of its Cocoa site. Due to the increase in testing and certification requirements, the need for conditioned laboratory space has become a critical requirement. Following a study, the most cost-effective program that could be done to add laboratory space was to design an enclosure for an existing roof facility located at FSEC. This facility is called the Applications Testing Facility (Bldg. #1940). The following photograph shows this existing facility before any renovation has begun.

Figure 1: Ground Level Front View

Figure 2: Exterior View After Completion

Figures 3 and 4: Interior Views – Ready for Laboratory Installation

Results to Date

The building has been completed and accepted. Work is underway inside the building to install the laboratory equipment for testing and certification of solar systems and solar panels. Work is also underway to provide work stations for five technical personnel.

UNIVERSITY OF CENTRAL FLORIDA

PV Power Generation Using Plug-in Hybrid Vehicles as Energy Storage

PI: J. Shen **Co-PI's:** I. Batarseh, N. Kutkut
Students: Michael Islas (MS), John Elmes (PhD), Chris Hamilton (MS)

Description: The objective of this project is to develop and demonstrate an alternative PV power generation architecture that uses plug-in hybrid vehicle as the energy storage and transfer element with a total system cost target of $3.50/W. The tasks include developing efficient, reliable, and inexpensive maximum power tracking DC/DC battery chargers and 3-phase converters. A 10kW demonstration solar carport charging station will be built on UCF campus. A plug-in hybrid vehicle with a 25kWh battery bank (battery-only driving range of 50-100 miles) and onboard bidirectional AC charging system will be demonstrated

Budget: $380,816

Universities: UCF

External Collaborators: City of Tavares, FL

Progress Summary

Research Objectives for Current Reporting Period: The main research objectives for the current reporting period include actual construction of the smart solar plug-in vehicle charging station, and the development of power electronics hardware.

Progress Made Toward Objectives During Reporting Period: A 10kW smart solar plug-in electric vehicle charging station was constructed on UCF campus. The PHEV Smart Solar Carport is configured as two 5 kilowatt systems providing a total power output of 10 kilowatts. Most PHEVs currently available today are configured to receive standard "household" 120 volt Alternating Current (AC), so an inverter converts the DC into the required AC power for the vehicle chargers. The new system not only offers this feature but also facilitate future deployment of experimental technologies that will interface the DC produced by the photovoltaic modules directly with the DC batteries in the electric vehicles. This would allow direct DC transfer to the vehicle batteries, thereby eliminating losses associated with converting the DC to AC, and then back to DC power. A unique control strategy is implemented, allowing efficient energy transfer while reducing the conversion stages between the source and the load. All of the pedestals are reconfigurable and include provisions to accommodate future vehicle charging configurations.

The solar carport system is "grid interactive" in that the inverters produce AC voltage that is synchronized with the electrical grid. This means that power produced from the PV panels in excess of what is needed to charge the electric vehicles will "go back" into the University's electrical grid. This allows the campus grid to act as an energy "bank" in which the excess capacity from the solar carport can be used to power other electrical demands on the campus. The interactive system also allows for non-sunlit period vehicle charging. On an annual net metering basis, the carport is anticipated to be a net exporter of power to the grid as there will be a significant number of sunlit hours during a year when the majority of electric vehicles parked at the facility are fully charged, and during semester breaks and weekends. A communication link will be established between the system and the power grid to facilitate intelligent control.

Several hardware prototypes have been built to facilitate the three-way energy flow control. They are being tested and evaluated for their performance. Research activities for the next reporting period will focus on fine tuning of the hardware and the software control algorithms, and make efficiency comparison between the new system and the convention configuration over a wide range of conditions.

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Insight into Membrane Degradation Mechanisms Through Verification of Chemical and Mechanical Degradation Test Capabilities

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Students: W. Rigdon (Ph.D), Paul Brooker (Post Doctoral Associate)

Description: The objectives of the program are to gain insight into fuel cell membrane degradation mechanisms including both chemical and mechanical degradations. In order to achieve this objective, the Membrane Electrode Assembly Durability Test System, MEADS, was verified, after which chemical degradation tests were conducted. By performing post mechanical testing and analyzing the data, the impact of accelerated degradation tests on the cell performance decay, chemical decomposition and mechanical weakening of the membranes will be revealed.

Budget: $324,000

Universities: UCF/FSEC

Progress Summary

Progress Made Toward Objectives During Reporting Period: Axial load is a critical parameter for cell assembly because components must be in intimate contact to achieve low proton and electrical resistance but too much compression will decrease porosity of the catalyst layers and the gas diffusion layers and add stress to the membrane, resulting in decreased performance and increased degradation.

To examine the effect of axial load on performance and durability, cells were built with pinches of 5-6, 8-10, and 13-14 mil. Adjusting the thickness of the gaskets around the MEAs controlled the amount of pinch each cell experienced. All cells were humidified, performance tested, durability tested and finally performance tested again.

To evaluate the level of degradation, the OCV and fluoride emission rates were monitored during the degradation test, Figure 1, and the pre- and post-test performances were compared. The initial OCV for all cells ranged from 1.028-1.045 V. The changes in OCV were very similar for all cells. The fluoride emission rate values and trends were also very similar. However, when the performance curves before and after durability testing are plotted, not only is it apparent that all cells decreased in performance after testing, but it appears that the cells with pinches of 8-10 mils decreased in performance the most, Figure 2.

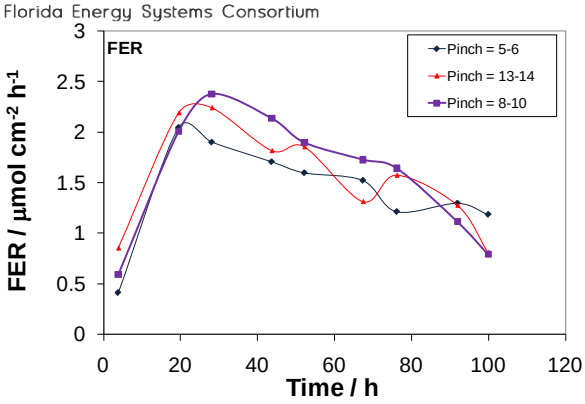

Figure 1. Average Fluoride Emission Rates.

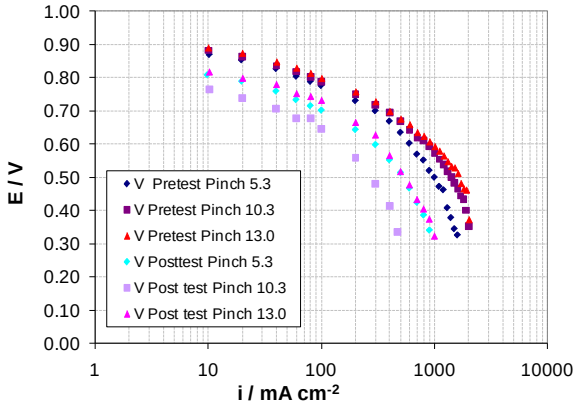

Figure 2. Performance curves of cells with varying pitch.

Additional cells were run on the MEADS in order to acquire enough data for meaningful analysis to estimate the characteristics associated with the chemical and the mechanical degradation mechanisms. Eight cells were prepared to be run simultaneously. Three of these cells contained FSEC-3; two of the cells contained FSEC-3 + 0% PTA; two of the cells contained NRE211. One cell contained an Ion Power CCM. All eight cells were assembled, and OCV tested for 100 h under 0.2 L/min H_2/Air at 90 ^oC and 30% RH. The data obtained was recorded and analyzed.

An apparatus for the testing the mechanical strength of membranes was transferred from the University to the lab at FSEC. It was installed, verified to be functioning correctly and calibrated. This apparatus will be used to determine loss of mechanical strength in samples that have been subjected to durability testing.

Additional experiments for determining the presence of pinholes in an MEA lead to the conclusion that the method developed last reporting period did not generate data that was adequately reproducible. Other methods for locating pinholes are being reviewed and will be evaluated under an alternate program.

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Energy Efficient Building Technologies and Zero Energy Homes

PI: Robin Vieira
Co-PIs: Philip Fairey, Jeffery Sonne

Description: The project consists of two elements: 1) the construction of two flexible research homes at FSEC to conduct research on advanced building energy efficiency technologies under controlled conditions; and 2) a staged, field retrofit study in a small number of unoccupied homes to measure and document the effectiveness of a series of retrofit measures that can be deployed using current technology. The project will also conduct an annual meeting where other FESC participants, other university members and utility, industry, the U.S. Department of Energy and other stake holders who will be briefed on plans and progress. Inputs from meeting participants will be sought.

Budget: $1,224,000

Universities: UCF/FSEC

Progress Summary

A. Technical assistance for government and non-profit residential retrofits in conjunction with Building America:
   a. Added new partners Volusia County, City of Palm Bay, Habitat Mobile, Habitat Lake Sumter
   b. Conducted energy audits and analysis of 33 homes
      i. Five homes have been retrofitted
      ii. One Sarasota County home, of the five homes retrofitted, has met the Builders Challenge level for new homes with a HERS index of 66. Other homes have HERS indexes of 73, 79, 86, 87.
      iii. Fifteen other homes in process of retrofits, others just beginning process

Sarasota County home before retrofit

…and after

B. Side-by-side residential test structures
    a. Designs of the test structures were completed. Decision was made to use concrete block construction and not make walls flexible as previously planned.
    b. Final site selection was made and the structures will sit next to one another with 60' between the structures. A shade analysis was completed indicating minimal shading at that distance.
    c. Documents were put out to bid in April 2010.
    d. Pre-bidders meeting was held.
    e. Three contractors submitted pre-qualification interest.
    f. Bids are due in June. Construction expected to be completed by December 2010.

C. Led proposal effort for FESC to four federal funded agencies with the $120+ million Energy Efficiency Hub Regional Innovation Cluster (E-RIC) proposal. Teamed with UF, FSU, USF, FIU, U of Illinois, GTI, American Council for an Energy-Efficient Economy, Lighting Science Group, and Sunovia. Also had economic co-applicants Seminole State College, Florida High Tech Corridor Council, Small Business Development Center, and the Florida Manufacturing Extension Partnership. With the help of the Florida MEP, reached partnership projects with a number of manufacturers in the region.

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Enhanced and Expanded Solar Thermal Test Capabilities

PI: Joseph Walters **Co-PI:** Robert Reedy

Description: The project focus was to increase the collector testing reliability, efficiency and capability to meet the market demands for 3rd party independent testing. The project focused on eight (8) projects

- Implement interim testing/certification protocol to streamline quality products to market.
- Design, install and qualify wind systems for collector test platforms
- Convert test platforms to allow all 3 type of collector testing on one platform.
- Automate portions of qualification tests for improved reliability and efficiency
- Increase capability by adding more test stands
- Convert to new control system for improved test reliability and data storage
- Develop automated testing protocol to increase efficiency.
- Design and implement information control system to improve efficiency in record capture, data capture and report generation.

Budget: $654,295
Universities: UCF/FSEC
External Collaborators: Solar thermal manufacturers

Progress Summary

Following is the summary for each project.

1. Implement interim testing/certification protocol to streamline quality products to market.
   The interim testing and certification was released in May of 2009. It allows thermal collectors to be certified with an interim rating as long as the unit passed the quality testing as described in the test standard (ISO 9806-2). Twenty thermal collectors have been processed since the release. Seventeen of those units have passed through for certification.
2. Design, install and qualify wind systems for test platforms
   The wind system was developed and qualified on a single test stand and then propagated to the other 2 test stands. The wind system has increased test capability by creating acceptable test conditions for collector testing when wind speed were low. The low wind speed condition was present about 50% of the time.
3. Convert test platforms to allow all 3 type of collector testing on one platform.
   Designed and implemented the required hardware set that allows a test stand to test either unglazed, glazed flat plate or evacuated tube style thermal collectors. The increased flexibility will increase overall throughput at the test center.
4. Automate portions of qualification tests for improved reliability and efficiency.
   Differential pressure test and flow calibration tests were automated with LabVIEW software and National Instrument hardware. The tests are currently undergoing qualification.
5. Increase capability by adding more test stands
   A 3rd test stand was built with National Instrument data acquisition and LabVIEW software control. It is currently undergoing qualification testing.

6. Convert to new control system for improved test reliability and data storage.
   The National Instrument data acquisition and LabVIEW software control will be propagate to other 2 test stands once the initial unit is qualified for production.
7. Develop automated testing protocol to increase efficiency.
   Automated testing algorithms have been written and are currently in qualification testing. The semi-autonomous program provides efficiency improvement by having the computer monitor the progress of testing and move to the next stage in the test process without the need for human intervention. Previously the testing required significant human intervention.
8. Design and implement information control system to improve efficiency in record capture, data capture and report generation.
   The flow diagram of the test and certification process has been developed. The database structure has been developed. The new collector testing software is writing the database.

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Integrated Florida Bio-Energy Production with Carbon Capture and Sequestration

PI: Ali T. Raissi **Co-PI**: Nazim Muradov
Students: Nathaniel Garceau (BS-Ch.E.), James Pardue (BS-M.E.)

Description: The aim of this project is to produce liquid hydrocarbon fuels derived from Florida based biomass utilizing a two-step process. In the first step, biomass or biomass-derived pyrolysis oils are gasified with oxygen and steam to synthesis gas (syngas) comprised of mostly hydrogen, carbon monoxide and carbon dioxide gas. For this step, an oxygen source is employed (e.g. oxygen concentrator, electrolytic unit, etc.) for biomass gasification. Use of pure (or nearly pure) oxygen for gasification of biomass allows higher overall process energy conversion efficiency by eliminating nitrogen dilution in the syngas. In the second step, syngas from step 1 is fed into a Fischer Tropsch (FT) synthesis unit and converted to liquid hydrocarbon fuels, *e.g.*, diesel fuel. The process can be employed with any lignocellulosic material including crop residues, forest waste, yard clippings, and energy crops. The technology also provides a means for sequestering carbon in the form of a high-value soil enhancing bio-char (terra preta) by simple modification of the gasification step 1.

Budget: $648,000

Universities: UCF/FSEC

Progress Summary

In this reporting period, we designed and built a larger scale Fischer-Tropsch (FT) synthesis reactor using a cobalt based catalyst. A large number of bench-scale screening of various Fe, Co and Mo based FT catalysts had been conduced prior to choosing cobalt as the FT catalyst of choice.

The larger scale reactor was fabricated out of a 1" OD, 3.5' long stainless steel tube. Fig. 1 shows the schematic of the FT reactor having several heating mantles and five thermocouples placed in various locations inside the reactor for monitoring and controlling the reaction bed temperatures. A total of 20g of 20%Co-SiO_2 (20-35 mesh) mixed with 500g of SiC (30 mesh) particles was used as bed material. The bed material was placed inside the reactor in ten small batches to allow a more even distribution of cobalt catalyst throughout. The catalyst bed was reduced in pure H_2 for a day before each experimental run.

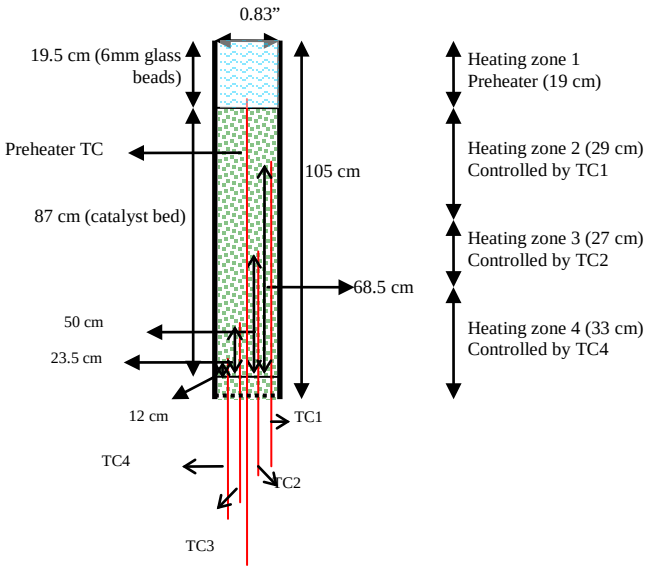

Fig. 1. Schematic diagram of the FT reactor.

Fig. 2 shows the effect of flow rate of the gas (H_2:CO ratio of 2:1) on conversion, selectivity and space-time yields at 220°C and 100 psig reactor temperature and pressure, respectively. Syngas flow rates above 652 mL/min give higher concentration of CH_4 and light gases and lower liquid hydrocarbon yields. The increased CH_4 and light gas selectivity appears to be due to the development of hot spots in the catalyst bed.

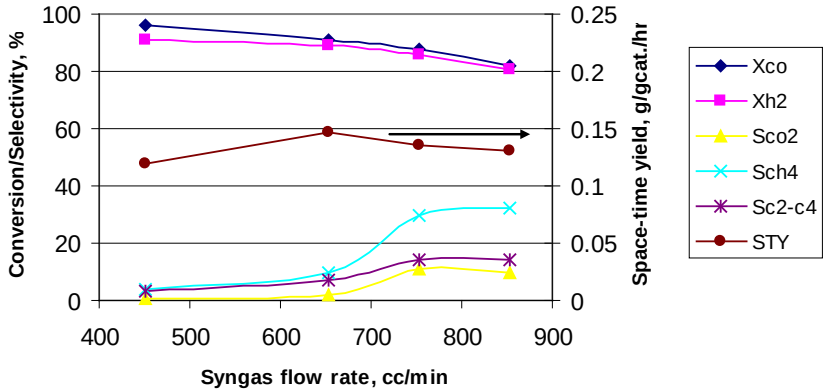

Fig. 2. Effect of syngas flow rate on the conversion, selectivity and space-time yields for H_2:CO ratio of 2:1 and at 220°C and 100 psig.

Several tests were conducted with syngas H_2:CO ratio of 1:1. It was possible to increase the syngas flow rate substantially without any increase in CH_4, light gas and CO_2 selectivity – resulting in space-time yields of liquid hydrocarbons greater than the ones obtained with syngas of H_2:CO ratio of 2:1. To date, the maximum liquid hydro-carbon yield obtained has been about 5.1 g/hr.

We also tested a syngas composition containing CO_2. Results obtained to-date indicates that the presence of CO_2 has the effect of reducing the partial pressure of the reactants leading to lower liquid hydrocarbon yields. This can be compensated by increasing the total pressure of the reactor. The presence of CO_2 also led to lower CH_4 and light gas selectivity.