UNIVERSITY OF FLORIDA

Integrated PV/Storage and PV/Storage/Lighting Systems

PI: Franky So **Co-PI**: Jiangeng Xue, Shirley Meng
Students: Ming-Che (Tim) Yang, William Hammond, Edward Wrzesniewski, Cephas Small, Fred Steffy (Ph.D.); Postdoctoral Associate: Jegadesan Subbian; Thomas McGilvray (undergrad);

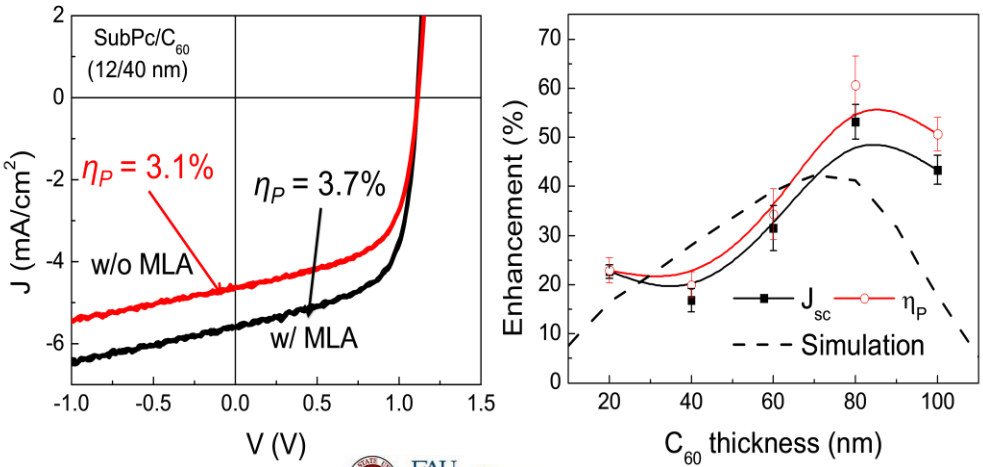
Description: The goal is to increase the efficiency and reduce the cost of solar power through the integration of PV, Li-battery, and LED lighting technologies. Since all components are in the form of thin films, the PV/battery/LED system can be integrated as a single module. Since half of the materials cost of each device is the substrate, integrated module will also reduce materials costs and processing steps. Importantly, their integration further eliminates the need for inverters since they are all low-voltage devices. Such an integrated device can be used to store energy during the day and power the LED panel for lighting in the evening. In addition, we will explore the possibility of fabricating a semi-transparent module. The success of this Task will lead to a novel solar-power lighting panel that can be used as a sky light during the day and a lighting panel during the night without using grid-power. We not only will develop the technologies, but also integrate devices and perform technology-economic evaluation, including life-cycle costs.

Budget: $576,000
Universities: UF

Progress Summary

Organic and hybrid organic-inorganic photovoltaic cells

We have developed novel optical structures for enhancing the efficiency of organic and hybrid organic-inorganic photovoltaic cells by allowing the active materials to more efficiently absorb the incident light. Two different optical structures were created and applied to the PV cells using a soft lithographic process, which could be easily implemented in large-scale high throughput manufacturing systems. Such enhancement mechanism could also be universally applied to any active materials or device platforms. Figure a shows the current density-voltage characteristics of a bilayer SubPc/C_{60} cell under 1 sun AM1.5G solar illumination, which shows a 20% enhancement in efficiency with the microlens array. Figure 1 shows that by varying the C_{60} layer thickness, a maximum enhancement of 60% could be achieved.

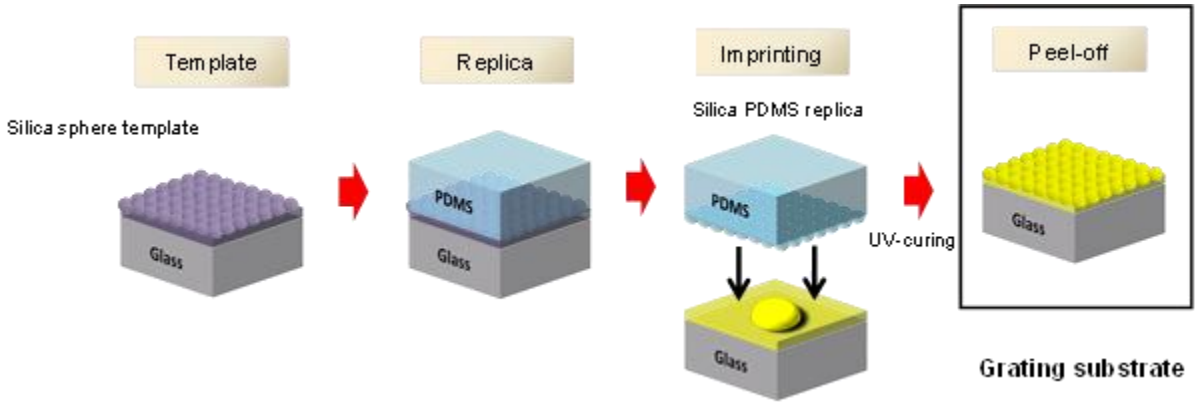


High Power and High Energy Spinel Based Electrode Materials

First-principles computation is carried out for investigating the electronic, structural and electrochemical properties of $LiM_{1/2}Mn_{3/2}O_4$ (M=Ti, V, Cr, Fe, Co, Ni and Cu). The computation results suggest that $LiM_{1/2}Mn_{3/2}O_4$ spinel materials family can have significantly different activation barriers for Li diffusion depending on the doping elements, and doping with Co or Cu can potentially lower Li diffusion barrier compared with Ni doping. We found that the amount of Cu will affect the lattice parameters, the cation disorder in the spinel lattice, the particle morphology, as well as the electrochemical properties. With detailed electrochemical measurements and in situ x-ray absorption spectroscopy (XAS) experiments of $LiNi_{0.25}Cu_{0.25}Mn_{1.50}O_4$, the proposed explanation of the voltage profile by the first-principles computation was proven. Ni, Cu and Mn are 2+, 2+ and 4+ respectively in the pristine sample and a second plateau at 4.2V originates from the oxidation of Cu2+ to Cu3+. Cu cannot be further oxidized to Cu4+ and the plateau at 4.95V originates from extra electrons provided by oxygen ions. Although the reversible discharge capacity decreases with increasing the Cu amount, optimized composition such as $LiCu_{0.25}Ni_{0.25}Mn_{1.5}O_4$ exhibits high capacities at high rates. The good rate capability of $LiCu_{0.25}Ni_{0.25}Mn_{1.5}O_4$ spinel oxide is attributed to the single phase reaction during charging, the lower Li diffusion barrier induced by Cu doping, and possibly higher electronic conductivity contributed by Cu doping.

OLED lighting

In collaboration with Dr. Nelson Tansu at Lehigh University, OLEDs were fabricated on grating substrates. These grating substrates were fabricated by coating 1 μm diameter SiO_2 microlens array on glass substrates. The 1-μm-diameter-microlens array pattern of the template was transferred to an epoxy layer by imprinting process. A 120-nm-thick ITO layer was subsequently deposited on the epoxy layer by sputtering and organic layers for OLEDs were subsequently deposited. With the grating structure, light extraction was enhanced by 1.6 times due to enhanced extraction of thin film guided modes. To extract the substrate modes, a hemisphere lens was attached on the back of the glass substrate to extract substrate modes. A further enhancement of 1.5 times was obtained. With our approach, a total enhancement of 2.4 times in OLED efficiency was achieved.



UNIVERSITY OF FLORIDA

Water-Use Efficiency and Feedstock Composition of Candidate Bioenergy Grasses in Florida

PI: Lynn E. Sollenberger **Co-PIs:** John Erickson, Joao Vendramini, Robert Gilbert
Students: Jeff Fedenko (M.S.); Pedro Korndorfer (M.S.); Xi Liang (Ph.D.), Chae-In Na (Ph.D.), Arkorn Soikiew (M.S.), Kenneth Woodard (postdoctoral research associate)

Description: Florida ranks first in the USA in annual growth of plant biomass because of a large cultivatable land area, high rainfall, and long growing season. In order to capitalize on these advantages, the agricultural production sector and biomass conversion industries require information regarding which crops are adapted to particular Florida regions and local environments, how much biomass can be produced during what times of the year, which crops produce the most biomass per unit of water used, and which crops have the desired yield and composition for particular bioenergy applications. Research conducted to date has quantified the seasonal biomass supply provided by the most likely crops for use in Florida, identified crops and management practices that result in most efficient water use, and described the chemical composition of these plants to allow estimates of potential energy production per unit of biomass. Florida growers and industry representatives have gained access to this information through on-line resources, presentations by several of the project investigators at the Florida Farm to Fuel Conference, and by attending the Bioenergy Crop Field Day at the University of Florida Plant Science Research and Education Unit. Seven graduate students are being trained through this project and undergraduate students are gaining invaluable research experience via internships mentored by project investigators. Faculty involved in the FESC project have formed collaborations regarding agronomic and breeding projects with Speedling, Inc., SERF, and BP. Both SERF and BP plan to construct ethanol facilities in Florida that would create an estimated 400 temporary construction jobs and 140 permanent jobs each.

Budget: $191,981
Universities: UF
External Collaborators: Speedling, Inc., Nutri-Turf, Inc., British Petroleum (BP), and Southeast Renewable Fuels (SERF)

Progress Summary

Characterization of water use occurred in sweet sorghum, elephantgrass, energycane, and giant reed during 2009 and 2010. Measures of plant transpiration allowed for direct measurement of crop water use under real-world conditions so as to assist producers in selecting crops that are most sustainable for Florida. Results indicate that energycane and elephantgrass produce more biomass per unit of water than giant reed. For sweet sorghum, planting date affects water use efficiency, and optimal planting dates have been identified at various locations in Florida.

Six potential perennial bioenergy grasses were compared at three regional (North-central, South-central, and South) locations in Florida. Species were miscanthus, giant reed, erianthus, sugarcane, elephantgrass, and energycane. All plots were fully established by early summer 2009, and biomass yield and composition of the grasses was quantified during 2009 and 2010. Miscanthus yielded least at each location (2-5 tons dry biomass per acre), giant reed was generally intermediate (6-12 tons/acre), and elephantgrass, energycane, erianthus, and sugarcane yielded the most (13-17 tons/acre). Maximum ethanol production was estimated to range from approximately 80-90 gallons/ton of dry biomass for elephantgrass, energycane and erianthus, and was 104 gallons/ton for sugarcane bagasse. Our data show

that elephantgrass, energycane, erianthus, and sugarcane outyield giant reed and miscanthus in terms of biomass and potential ethanol per acre, and elephantgrass and energycane possess the most favorable management characteristics including ease of planting, efficiency of water use, and ease of harvesting.

Three sweet sorghum varieties (M81, Dale, and Topper 76-6) were planted at three dates during 2009 and 2010 at three locations in Florida to assess planting date and location effects on biomass production, sugar composition, and sugar yield. Planting occurred in March, May, and June. Across all sites, first crop green yields ranged from 21 to 33 wet tons/acre, with M81 yielding better than Topper 76-6 which yielded better than Dale. The May planting date yielded most. Regrowth crop green yields were affected by all treatments, ranging from 2 to 30 wet tons/acre with greater yields associated with earlier planting dates. Juice brix values ranged from 8 to 19% across all treatments, averaging 14.4 and 13.1% in the first and regrowth crops, respectively. Brix values were about 20% lower on the muck soil at Belle Glade compared to the sandy soil locations and about 20% lower in M81 compared to Dale and Topper 76-6. Combining first and regrowth harvests, this translates to estimated ethanol yields of 250 to 625 gallons/acre/year. Our results indicate that sweet sorghum production in Florida can be competitive with corn ethanol in the Midwest, but choice of variety, growing environment, and management practices will be critical to optimizing energy yields from sweet sorghum.

As a result of the studies conducted, we can now recommend bioenergy grass species and varieties for use throughout Florida based on adaptation to local environments, ease of establishment and harvest, water-use efficiency, and chemical composition. Agricultural producers and biomass conversion industries can use these data to guide site selection for production and conversion facilities, which plant species to grow, estimates of acreage needed to support a given conversion facility, and predictions of seasonal distribution of feedstock supply. Faculty involved in the FESC project have formed collaborations regarding agronomic and breeding projects with SERF and BP, both of whom plan to construct ethanol facilities in Florida that would create an estimated 140 permanent and 400 temporary construction jobs each.

New collaborations		
Partner name	**Title or short description of the collaboration**	**Funding, if applicable**
Southeast Renewable Fuels	Sweet Sorghum Agronomy and Breeding Program	Negotiations in progress
British Petroleum	Energycane Breeding Program	Negotiations in progress

Proposals						
Title	Agency	Ref #	Investigators/ Collaboraotors	Funding requested	Duration	Date submitted
An integrated systems approach to sustainable commercial production of biofuels and bio-based products for the southeast coastal region,	USDA-NIFA		Gallo, Sollenberger, Erickson, Vendramini, Gilbert, et al.	$43 million	5 years	October 2010
Woody biological nitrogen fixing plants for sustainable ligno-cellulosic biofuel feedstock	USDA/Sun Grant		James P. Muir, Joao Vendramini, et al.	$160,000	2 years	03/01/2011

Discovering The Desirable Alleles Contributing To The Lignocellulosic Biomass Traits In *Saccharum* Germplasm Collections For Energy Cane Improvement	DOE	DE-FOA-0000417	Jianping Wang, Robert Gilbert, and Neil Glynn Collaborators: Raymond Schnell, USDA-ARS, Joseph Binder, BP	$1,069,710	3 years	3/18/11

Grants Awarded					
Title	**Agency**	**Reference Number**	**Investigators/ Collaborators**	**Duration**	**Funding awarded**
Reproduction, Mechanisms of Spread, and Control Strategies for Elephantgrass, a Candidate Biomass Crop in the Caribbean Region	USDA		Sollenberger, Vendramini, and Erickson	9/1/2010 – 8/31/2012	$120,000
Sulfur, chloride and ash analyses of sweet sorghum for potential impacts of combustion on air quality	FDEP		Erickson	11/1/2010 – 10/31/2011	$3,081

UNIVERSITY OF FLORIDA

Biocatalytic Lignin Modification for Carbon Sequestration

PI: Jon Stewart
Students: Bradford Sullivan (postdoctoral fellow)

Description: After cellulose, lignin is the second most abundant forma of carbon in plants. Lignin's complex structure makes it difficult to use this material in value-added products, and ahte vast majority of lignin is currently burned to provide energy for factory operations. While burning plant derived lignin does not add to global greenhouse gas levels, having options to remove lignin from the global carbon cycle would lead to diminished atmospheric CO2 levels. This could be accomplished by chemically altering lignin's structure to facilitate long-term terrestrial sequestration or using it in value-added products that would not be discarded immediately. We will use Nature's catalysts (enzymes) to tailor the chemical structure of lignin for both deep-well injection (by using lignin derivatives as drilling "muds") and for materials that can be used in building, packaging, and other manufactured products.)

Budget: $200,000
Universities: UF

Progress Summary

Bradford Sullivan joined this project as a postdoctoral fellow in February 2010 with extensive experience in both organic synthesis and in dioxygenase enzymes. To the best of our knowledge, no one has applied dioxygenases to lignin and/or lignin model compounds. Enzymes such as toluene dioxygenase offer the possibility of converting this renewable feedstock into valuable building blocks. In preliminary studies, Brad has applied toluene dioxygenase to model compounds derivable from lignin to create small molecule mediators required by laccases for lignin breakdown. Some reaction was observed. We are also setting up a collaboration between our lab and those of Steven Sherman and Charles Turick (Savannah River National Laboratory), who have developed a simple method for lignin extraction from a variety of soft materials such as switchgrass as well as woody tissues. This will provide us with the material for exploring ionic liquids and deep eutectic solvents for laccase-catalyzed lignin conversions.

Funds leveraged/new partnerships created

New collaborations		
Steven Sherman, Charles Turick (Savannah River National Laboratory)	Steve and Chuck have agreed to supply us with lignin samples prepared in their lab using a newly-developed extraction method. This product stream will be employed for enzyme-catalyzed reactions in our lab using safe, non-volatile solvents (ionic liquids and deep eutectic solvents)	No external funding yet for this work

Proposals						
Title	**Agency**	**Ref #**	**Investigators/ Collaborators**	**Funding requested**	**Duration**	**Date submitted**
Adapting Kernel Metabolism to Enhance Cereal Yield Under Adverse Conditions	USDA	2011-67003-30215	L. Curtis Hannah (P.I.), Tracy Hennen-Bierwagen (co-P.I.), Karen Koch (co-P.I.), Don McCarty (co-P.I.), Alan Meyers (co-P.I.), Mark Settles (co-P.I.), Jon Stewart (co-P.I.), William Tracy (co-P.I.)	$5M	5 years	June 2010
Improving Alkene Reductases for Applications in Asymmetric Synthesis	NSF	NSF 10-1	Jon Stewart (P.I.)	T497,851	3 years	December 2010

Grants Awarded						
Title	**Agency**	**Ref #**	**Investigators/ Collaborators**	**Period of Performance**	**Funding awarded**	**Start Date**
Adapting Kernel Metabolism to Enhance Cereal Yield Under Adverse Conditions	USDA	2011-67003-30215	L. Curtis Hannah (P.I.), Tracy Hennen-Bierwagen (co-P.I.), Karen Koch (co-P.I.), Don McCarty (co-P.I.), Alan Meyers (co-P.I.), Mark Settles (co-P.I.), Jon Stewart (co-P.I.), William Tracy (co-P.I.)	5 years	$5M	June 2010

UNIVERSITY OF FLORIDA

An Integrated Sustainable Transportation System

PI: David Norton
Faculty Participant: KeithDuncan
Students: Dan Gostovic, Dong Jo Oh, Eric Armstrong, Byung Wook Lee, Kang Taek Lee, Nick Vito and Christopher, R. Fell (Ph.D.); Patrick Wanninkopf, Eric Klump, Nicholas Sexson, Kevin Seymor, and Thomas McGilvray (Undergrad)

Description: The proposed vehicle, operating on biofuel while in transit and charged by the sun while parked, is the ultimate sustainable transportation system operating completely on renewable American energy resources. Moreover, the use of solid oxide fuel cells (SOFCs) rather than an IC engine in this hybrid vehicle results in a dramatic improvement in efficiency and reduction in emissions. SOFCs are the most efficient technology for converting energy from hydrocarbon fuels to electricity on a "well to wheels" basis. In contrast, the more conventional fuel cells require hydrocarbon fuels to first be converted to H_2, with resultant efficiency losses, followed by losses due to H_2 transport and storage. Therefore, on a system-basis SOFCs hold the potential for producing the least CO_2/kWh from conventional fuels, and if designed to operate on biofuel would in effect be carbon neutral and operating on a renewable resource. *If developed this vehicle would be a transformational change in transportation technology.*

Budget: $594,000
Universities: UF
External Collaborators: Solid-State Energy Technology, Inc., Lynntech, Inc., Planar Energy Devices, Inc., CFX Battery, Inc.

Progress Summary

This project has ended. We made significant gains in the science of energy conversion, from fundamental studies of the atomistic underpinning for materials properties to the engineering of the highest performance solid oxide fuel cells in the literature.

Fundamental studies of the two most promising materials for solid electrolytes, using computational modeling, enabled us to determine the optimal potentials to use (the Gotte potential) in predicting materials properties for oxides of interest in this field.

Moreover, from a molecular dynamics study of bismuth oxide we were able to confirm that dopant polarizability was the key feature in determining oxygen vacancy mobility in the fluorite system. Undergirded by these results we are now positioned to use our computational tools to further optimize the material properties of known oxygen ion conductors as well as develop new ones with superior performance.

This year we have also expanded the application of our previously developed continuum-level electrochemical model to describe and predict the performance of SOFCs as a function of electrolyte thickness. We were able to show that, for maximum power density, mixed conducting electrolytes had an optimal thickness below which they were rapidly overwhelmed by electronic conduction and above which their ohmic losses grew. We also are the first ones to predict the drop in open circuit potential with decreasing thickness for these materials.

Our development of record conductivity materials also continued with the highest conductivity ceria based and bismuth oxide based materials reported. We further studied their stability and optimal temperature window for operation. In so doing we have established our institution as the clear leaders in this area.

We are also leading in the area of anode development as the first to develop SOFCs with anode functional layers, which enabled a quantum step in SOFC performance. By comparison, our work on cathode performance is set to take off. We have already developed one of the highest conductivity cathodes (a bismuth ruthenate-bismuth oxide composite) in the literature. However, our fundamental studies on the oxygen reduction reaction (ORR) have positioned us to break further ground towards making a significant performance jump using conventional cathode materials. We have used multiple techniques to investigate the factors governing the ORR and the results of those studies point to new electrode architectures that should both improve performance and increase stability (especially, with respect to chrome poisoning and secondary phase formation).

Finally, we have also found time to complete our research efforts in hydrogen production, which is critical for the realization of a future hydrogen economy. In addition, we moved forward with our work on sensors, by indentifying the factors affecting the sensing process and developing high selectivity sensors with high signal-to-noise ratios. This has garnered interest from industry, leading to collaborations with General Electric (GE) and Energy Management Solutions (aka EPS) and RedOx Fuel Cells.

Recent publications:

Determination of Surface Exchange Coefficients of LSM, LSCF, YSZ, GDC Constituent Materials in Composite SOFC Cathodes *J. Electrochem. Soc*., 158, pp. (2011) B492. E. N. Armstrong, K. L. Duncan, D. J. Oh, J. F. Weaver and E. D. Wachsman,

Surface Exchange Coefficients of Composite Cathode Materials Using In Situ Isothermal Isotope Exchange*J. Electrochem. Soc.*, 158, pp. B283-B289 (2011) E. N. Armstrong, K. L. Duncan and E. D. Wachsman,

Dependence of open-circuit potential and power density on electrolyte thickness in solid oxide fuel cells with mixed conducting electrolytes *Journal of Power Sources, In Press, Accepted Manuscript, Available online 20 October 2010*Keith L. Duncan, Kang-Taek Lee, Eric D. Wachsman

UNIVERSITY OF FLORIDA

Secure Energy Systems - Vision and Architecture for Analysis and Design

PI: Pramod Khargonekar
Student: Tejaswini Akunuri

Description: The goal of this project is to investigate the concept of secure energy systems and formulate a concrete vision of a broad-based, comprehensive research program. An additional project goal is to develop architecture for modeling, analysis, and design of secure energy systems. An energy system consists of a collection of interconnected subsystems representing energy generation devices, energy consumption devices, transmission, distribution, and storage devices, and communications and computing devices. Such systems are dynamic and its operation is influenced by external perturbations. Definition of the system and it environment depends on the problem of interest. This project is motivated by strong interest among key decision makers in understanding and assuring security of energy systems in the face of various natural and man-made threats. Increasing penetration of renewable energy sources and capabilities offered by smart grid have the potential to enhance or degrade security of energy systems. Thus, these new developments present additional motivation for understanding of secure energy systems. Whereas there is an intuitive understanding of security and assurance, much work remains to be done in formulating precise definitions that cover problems of interest and devising an overall architecture that may facilitate a system level analysis and design of such secure energy systems. Taking into account rapid changes in the energy issues in a wide variety of private and public sectors, this project is a proactive effort to develop a vision and architecture for analysis and design of secure energy systems. It is expected that the results of this project will lead to future development and integration of specific analysis and design algorithms and software that will assist system designers in assessing and ensuring an appropriate level of system security.

The term security can take on different meanings depending upon the context. There are risks associated with intentional disruption of the system (sabotage) and operational risks of the system (whether from physical failure of the plant, human error, or market-based instability). Both can pose short- and long-term national security risks for the electric energy system which consists of the basic elements: generation, transmission, distribution, the load (users); and the control system. These elements are the choke points and can cause great harm by causing outages and moderate-term disabling of important elements in the energy system. We present the security issue by considering the various elements of the energy system one-by-one. At the generation end, we consider the security of the power plant. The attacks on the power plant are mainly physical i.e. the attack on the pipelines which carry the gas or oil (input to the turbine), attacks on the manual valves (which can be opened/closed physically), physical security of a nuclear power plant is in itself a topic which has been extensively researched. Thus we start with the generation system and move onto the transmission system (transmission towers and lines), the distribution system (local transmission lines and substations), and finally the control system which connects all these elements. Network security at the plant level (the connection of the control system and SCADA to the physical components) has also been considered.

Progress Summary

We have focused much of our efforts in two related directions: electric grid and a graphical user interface that can help visualize potential security analysis tools. In electric grid, we have worked on the new issues that arise in the smart grid from the cyber-security perspective. These issues are already central to the future of the electric grid. We have also investigated integration of intermittent renewable energy into the electric grid. This

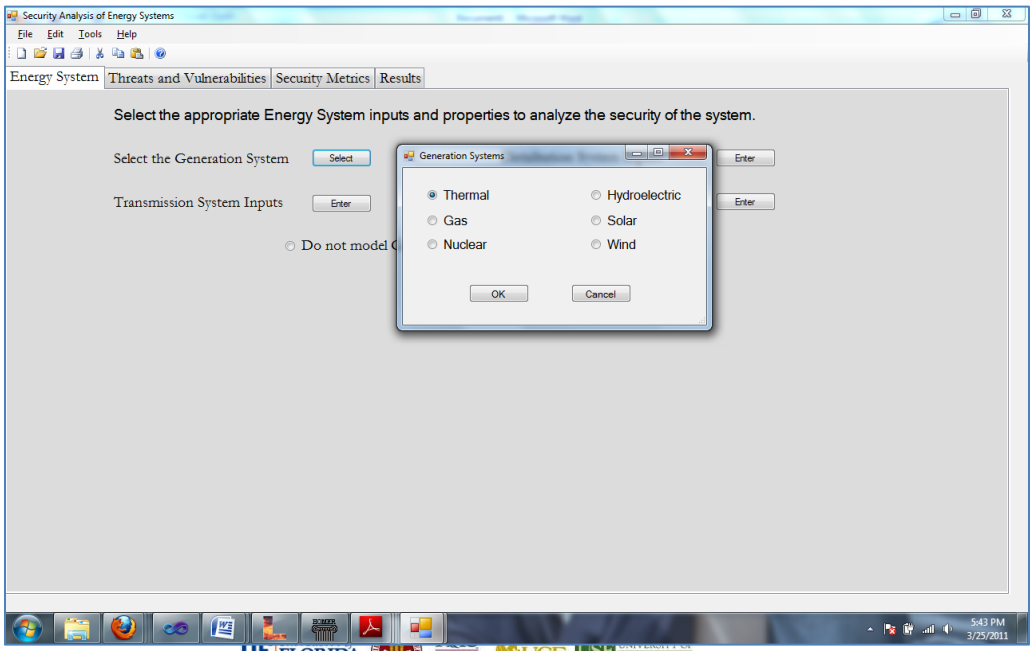
is one of the major goals for the smart grid. With distributed renewable generation and smart grid enabling components, the electric grid becomes much more open to cyber-attacks. Here we are investigating attacks on the SCADA based state estimation by cyber-attacks on the measurement system. We are working on optimal deployment of the new synchrophasors (which will be integrated using the new NASPInet framework) for thwarting attacks on the SCADA system. A paper based on this work is under preparation. This work is being done in collaboration with colleagues at the University of California at Berkeley and Idaho National Labs.

We next describe the outline of a graphical user interface which will form the external interface for the analysis system. This will serve as a framework for a tool which will be able to analyze the security situation of the energy system. The graphical user interface will consist of the various threats faced by the energy systems and the analysis of the situation in case of an attack. In the work conducted so far, we have found that there is no document or analysis present which takes a complete look at the energy system as a whole. We are hoping to develop a comprehensive view and research agenda for analysis and design of secure energy systems.

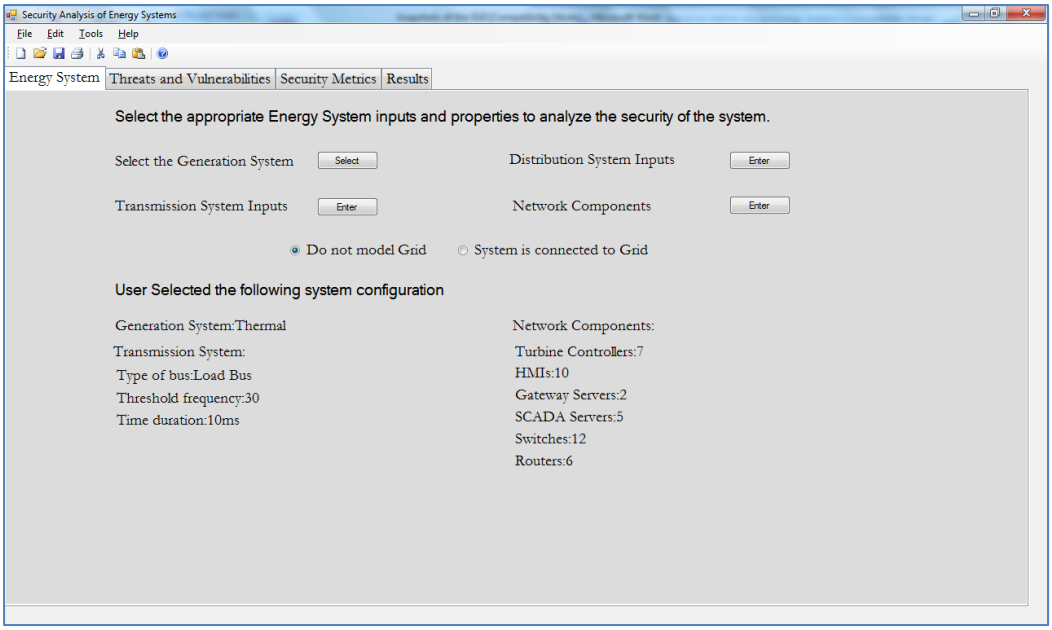
The initial framework for the Security Analysis GUI has been created. The salient features of the GUI include the user's inputs specifying the kind of generation system, transmission and generation system and the network architecture i.e., specifying the control system applications and network switches. The GUI has been created used C# language in Visual Studio 2010 tool. The concept of this framework has been based on the following elements:

- Degree of loss and damage due to the impact of the hazard.
- Degree of exposure to the hazard i.e., the likelihood of being exposed to the hazards of as certain degree and the susceptibility of an element at risk to suffer loss and damages.
- Degree of capacity of resilience i.e., the ability of a system to anticipate, cope with/absorb, resist and recover from the impact of a hazard or disaster. For example, the vulnerability of the electric power system might be assessed in terms of the frequency of major blackouts and the associated severity. A number of approaches can be undertaken for the vulnerability assessment depending on the type of system, the objective of the analysis and the available information.

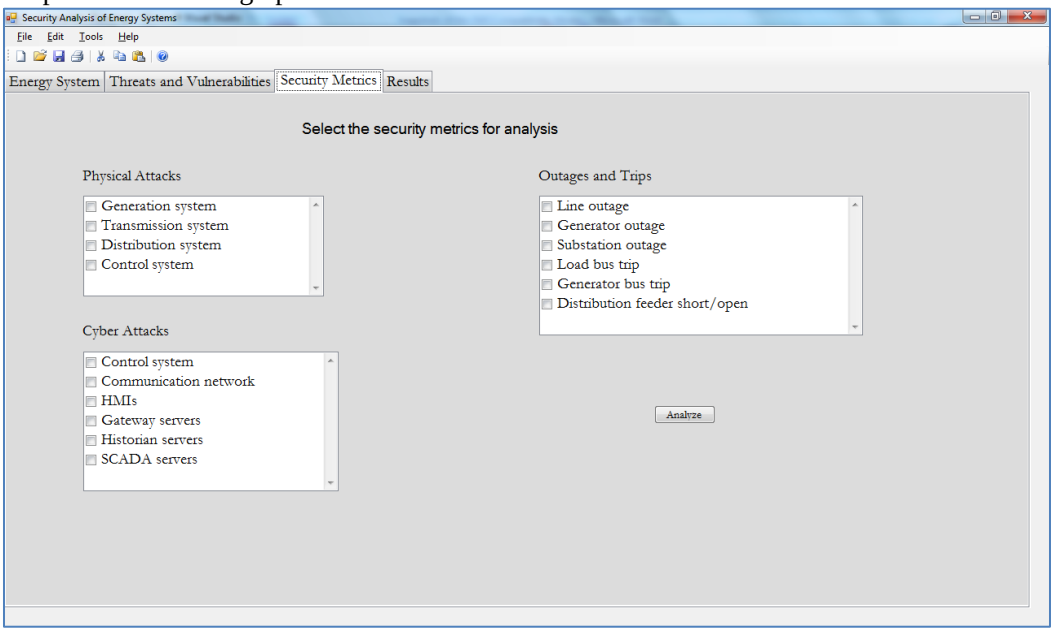
The GUI developed has the functionalities for analyzing the energy system as a complete system, including the generation, transmission, distribution and the control system; the snapshots of the GUI are as follows:

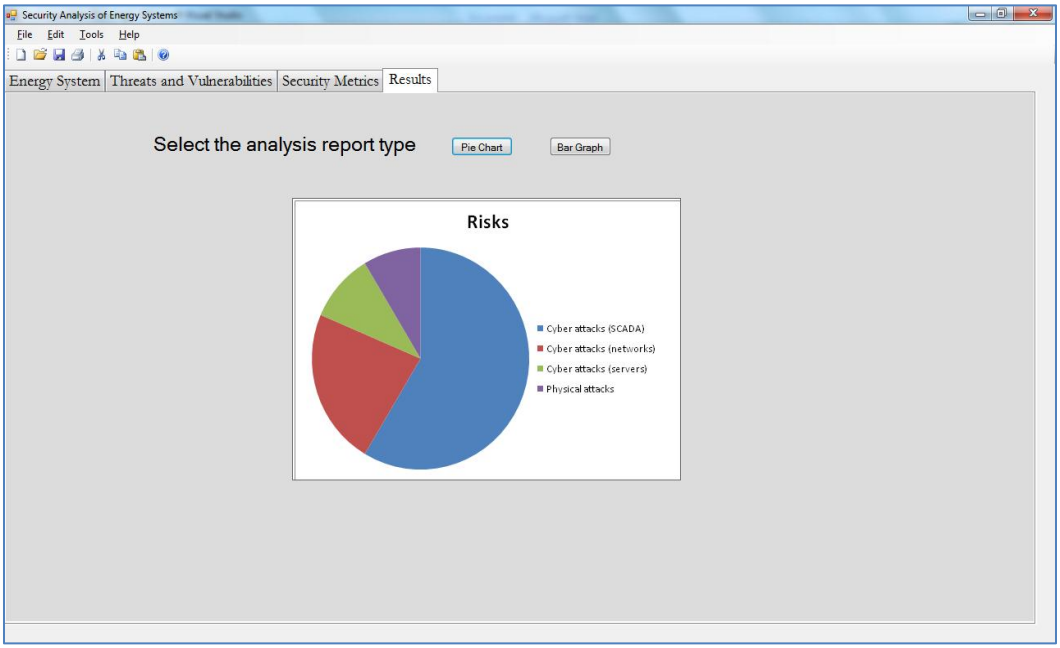


By clicking the Select button, the user can select the type of generation system. This would give the user the ability to analyze the selected energy system. The database at the back-end would contain the elements which are contained in the generation system. Similarly, the user can select the transmission, distribution and control system elements. The inputs are reflected back for the user to review and make changes if needed.



The threats and security metrics for the analysis are then selected and the analysis yields results which can be viewed as a pie chart or a bar graph.





Next Steps:

The research on the security of energy systems has made a clear point that the threats and attacks on the energy system are very dangerous and can cause serious damages to the systems and people globally as well as in the country. The security measures for physical, cyber and the various other kinds of attacks mentioned above need to be in place for the impact of the attacks to be minimal. This needs to be done effectively and efficiently so as to avoid major damages. The next steps would be to complete the GUI with additional functionalities as needed and make it a complete tool for the analysis of security of energy systems.

New collaborations		
Partner name	**Title or short description of the collaboration**	**Funding, if applicable**
Poolla, Varaiya UC Berkeley	Smart Grid	None

University of South Florida

Power Generation Expansion under a CO_2 Cap-and-Trade Program

PI: Tapas Das, USF; **Co-PI:** Ralph Fehr, USF

Students: Patricio Rocha (Ph. D. Candidate), Felipe Feijoo (Ph. D. Student). Industrial and Management Systems Engineering Department

Description: The objectives of the proposed research include: 1) developing a comprehensive generation technology based portfolio optimization methodology, 2) developing carbon revenue redistribution strategies to achieve goals of emissions control policies (cap-and-trade), and 3) develop educational resources to enhance training of scientific workforce for the state of Florida. The research will directly address three major challenges: fulfillment of the growing power demand, meeting the emissions control targets, and supply of technology workforce. The potential economic impact of the proposed research on the State of Florida is expected to be very high, since an energy-secure environment is a basic necessity to support the current trend of explosive growth both in industry and human resources.

Budget: $71,906
Universities: USF
External Collaborators: Argonne National Lab

Progress Summary

During the initial phase of the project, our efforts were focused on developing a generation capacity expansion model that incorporates the implications of the implementation of a CO_2 cap-and-trade program in the U.S. A CO_2 cap-and-trade program will change the way generators make capacity expansion decisions, especially if the allowances (or pollution permits) created with the program are distributed via auction (as opposed to be given away for free based on historical emissions). In fact, the profitability of a particular expansion plan is measured by adding the profits obtained by the generator in the allowance and electricity markets. Furthermore, the generators' bids and profits in the electricity market are directly impacted by the additional cost generators incur in purchasing allowances.

We have been working on expanding our problem scope by including the issue of optimal redistribution of the revenue collected from the CO_2 allowances. It is anticipated that the implementation of a CO_2 emissions control scheme, either a cap-and-trade program with auctioned permits or a carbon tax, will provide the government with an important new source of revenue. Several economists advocate for the redistribution of this carbon revenue i.e., for the emissions control schemes to be revenue neutral. We have developed an optimization model to obtain redistribution strategies of the carbon revenue collected by an electricity-sector emissions control scheme. We consider two types of subsidies through which the redistribution is accomplished: i) bid subsidies for low-emission generators, which are directed at lowering locational marginal prices throughout the power network, and ii) R & D subsidies, whose purpose is to improve the competitiveness of low-emission generators against fossil-fuel generators. We use empirical curves found in the literature to model the potential effect of R & D subsidies on the cost reduction of low-emission technologies. The optimization model that we have developed attempts to strike a balance between the allocations of these two types of subsidies for a given planning horizon. In addition, by considering the OPF as the basis for our formulation, we intend to address some of the regional (locational) equity issues that may arise if an equal per capita revenue redistribution rule (as proposed in the literature) is implemented.

We are currently conducting numerical analysis of the mathematical model via a 4-node sample problem. With the objective of examining the effect of network location in the results, we are examinning two subsidy-scenarios: discriminatory and non-discriminatory allocation. Our goal is to better understand the leverage that redistribution has on achieving the goals of CO_2 emissions control strategies.

UNIVERSITY OF SOUTH FLORIDA

Production of Liquid Fuels Biomass via Thermo-Chemical Conversion Processes

PI: B. Joseph, USF; **Co-PI's:** Y. Goswami, V. Bhethanabotla, J. Wolan, V. Gupta
Students: Ali Gardezi, Nianthrini Balakrishnan, Bijith Mankidy

Description: The objective of this project is to develop technology for the economical thermo-chemical conversion of lingocellulosic biomass (non-food grade biomass such as agricultural waste, bagasse from sugar mills, citrus peels, switch grass, municipal green waste, etc.) to clean burning liquid fuels. Five of the major advantages of this process over a biochemical route to production of ethanol are: (i) it does not utilize food-grade feed stocks and therefore complements and does not compete with the agricultural food production in the state, (ii) the fuel produced is similar to those derived from petroleum unlike ethanol derived fuels which have at least a 25% lower energy content, (iii) the conversion is accomplished in using fast chemical reactions unlike the slow biological reactions for fermenting alcohol, (iv) the process does not require large amounts of water and associated energy costs of separating the water from the fuel as in bioethanol processes, (v) it can utilize a wide variety of biomass sources unlike the biochemical route which cannot work with high lignin containing biomass.
Budget: $554,447
Universities: USF
External Collaborators: Prado & Associates

Progress Summary

To advance Fischer Tropsch conversion of synthesis gas from biomass, we have shown that we can synthesize cobalt (Co) nanoparticles with precise size control (1-14nm) to establish the effect of nanosized catalyst. By immobilizing these Co nanoparticles on sub-micron sized SiO_2 supports, we have recently focused on utilizing an in situ AABSPEC reactor to study the dependency of size on catalytic activity. Since chemical interaction of CO gas on the catalyst surface is a primary step in FTS, we investigated an elementary reaction such as CO oxidation on Co-oxide nanoparticle surface. CO dissociation energy has been calculated from its dissociation profiles measured during temperature programmed reaction studies at different heating rates. Figure 1 shows that by increasing the heating rate, CO dissociation temperature shifts towards higher temperatures. These temperature values can be used to calculate activation energy for CO dissociation. Figure 2 shows the turnover frequency of CO_2 formation as a function of temperature for different nanoparticle sizes. Activation energies for CO_2 formation on cobalt nanoparticles were also calculated based on plotting Arrhenius plots (figure 3) from turnover frequency data.

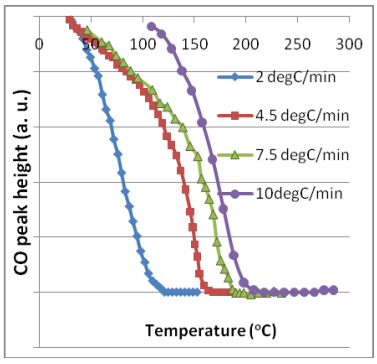


Figure 1

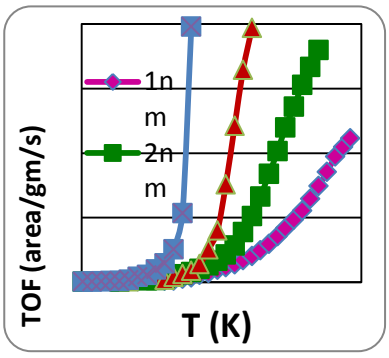


Figure 2

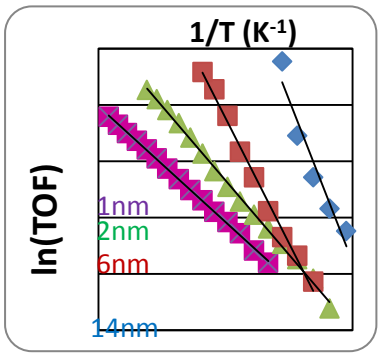


Figure 3

In summary, we have established a strong Co nanoparticle size effect and the trend in the activation energy for CO dissociation and CO_2 formation is $E_{14nm} > E_{6nm} > E_{2nm} > E_{1nm}$. We propose to use these techniques next to establish a size dependency relationship in FTS reaction of CO with H_2.

DFT studies: Here the objective was to determine the role of promoters in FTS. The economics of the Fischer-Tropsch process strongly depends on the performance of the catalyst used. Few desired properties of a catalyst are improved selectivity, higher activity and longer catalyst life and promoters are often added to improve these properties. Promoters can increase reducibility, dispersion of catalyst thereby improving the activity and/or selectivity. It can also prevent the deactivation of catalysts caused by oxidation or carbidization.
In this work, the effect of Pt promoter on the reduction of cobalt oxides to metallic cobalt was studied on both flat and stepped surfaces using surface alloy models where the promoter metal was dispersed on the top surface of the catalyst. We found that the activation barrier for the removal of O on promoted catalyst was reduced compared to that on the unpromoted catalyst by about 0.3 eV. We also found that on the promoted catalyst, CO dissociation was difficult. A kinetic model was developed for the removal of O and TOF was higher for the promoted surface compared to the unpromoted Co surface. We also evaluated the activation barrier for CO hydrogenation on the stepped surfaces using the same model surface and found that the promoted surface had lower activation energy for the hydrogenation of CO. This reduction in activation barrier is due to the change in the electronic structure of the cobalt surface due to the presence of Pt promoter. The change in the electronic structure changes the most favorable sites on the promoted surface and leads to a reduced barrier.

Reaction Studies:
Fischer Tropsch synthesis run using pine chips derived biomass gas has been planned. One of the pending issues was removing the contaminants from the syngas. For this purpose, pine chips derived syngas was analyzed using mass spectrometer. Its results show the presence of contaminants like benzene, toluene, ammonia and high moisture content. For this purpose, scrubbing filters have been installed in series and performance tested. Complete removal of contaminants has been ensured.

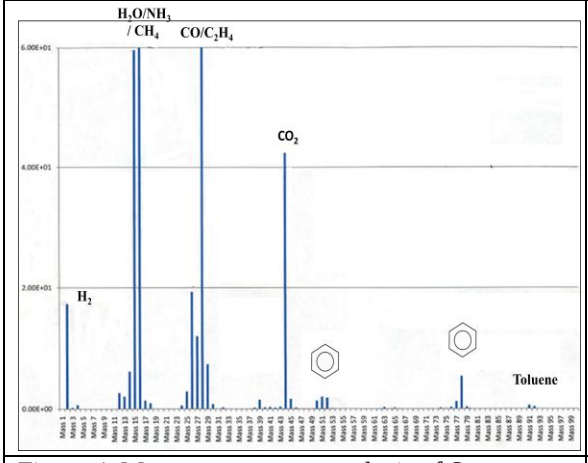


Figure 4. Mass spectrometer analysis of Syngas

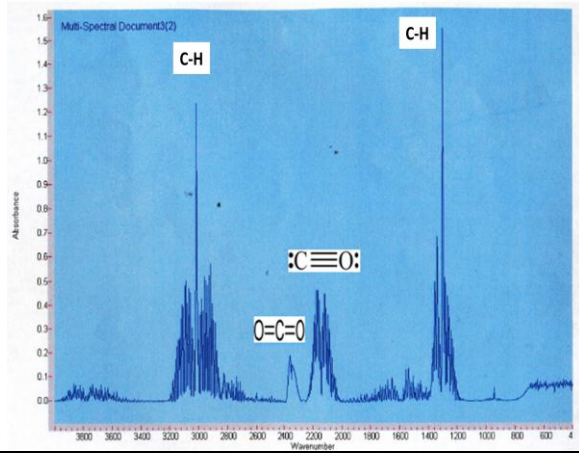


Figure 5. FTIR analysis of cleansed gas

In conjunction with analytic studies, FTS modeling is being performed on MATLAB. The focus is on the startup non-steady state process. Efficient heat removal has been a constant problem during our analytical work. In this regard we have developed the reactant conversion model, product pore filling duration and axial/radial temperature profile. By using this model we have successfully controlled the heat transfer in

our fixed bed reactor. In addition to the ongoing analytical work, this model will also help in the scale up of Fischer Tropsch process.

New collaborations:		
Partner name	**Title or short description of the collaboration**	**Funding, if applicable**
Pearson Ass.	We have started discussion on the submission of a new DOE proposal for building a pilot plant for FTS	Proposal preparation in progress

Proposals					
Title	**Agency**	**Investigators/ Collaborators**	**Funding requested**	**Duration**	**Date submitted**
FTS catalyst studies	NSF	B. Joseph	$480,000	3 years	Mar, 2011

UNIVERSITY OF SOUTH FLORIDA

Solar Photovoltaic Manufacturing Facility to Enable a Significant Manufacturing Enterprise within the State and Provide Clean Renewable Energy

PI: Don Morel **Co-PI's:** Chris Ferekides, Lee Stefanakos
Students: S. Bendapudi (MS) K. Jayadevan (MS), R. Anders (Ph.D.), Y. Wang (Ph.D.), B. Turnbull (BS)

Description: The primary goal of this project is to enable the establishment and success of local solar photovoltaic manufacturing companies to produce clean energy products for use within the state and beyond and to generate jobs and the skilled workforce needed for them. Thin film technologies have shown record efficiencies of 20%, and present tremendous opportunities for new Florida start-up companies. USF, UCF, and UF are collaborating to develop a pilot line facility for thin film solar technologies, which will serve as a test bed for making ongoing improvements in productivity and performance of solar modules, develop advanced manufacturing protocols, and help train a skilled workforce to ensure the success of new companies.
Budget: $1.6M
Universities: USF, UCF, UF
External Collaborators: Mustang Solar, a Division of Mustang Vacuum Systems

Progress Summary

During the reporting period we continued progress in both thrust areas of the project. Development of the thin Film Pilot line is awaiting completion and delivery of the deposition system. The components are being assembled at Mustang Solar, and delivery is expected by June 1. Meanwhile we have been conducting extensive laboratory experiments as part of our preparations for the pilot line. These experiments address both near-term and long term issues. Since the line will be processing CIGS technology, main emphasis is in that direction.

We are using our 25 year processing experience with CIGS to develop new pathways for processing. These pathways are a compromise between those that produce the best laboratory cells and those that are necessary for commercial success. The process that we are developing is termed 2SSS, "2 Step Solid State" processing. The advantages are that the process uses solid Se as the Se source instead of the highly poisonous gas H_2Se, and simultaneous control of multiple deposition sources is relaxed. Our primary focus initially is in controlling the material composition with the new process. A particular concern from a manufacturing perspective is the effective utilization of source materials. We discovered an interrelationship between the selenization of the metal layers and the loss of Ga. This issue was observed in applying the 2SSS process to the first step of the two step process that we are developing. In this step we form a Cu-rich CuGaSe layer which provides a larger grain platform for growth of the second step layer containing all four elements. For the simplified 2SSS process we found that in order to achieve full selenization Ga was being lost from the precursor layer. This lead to development of a modified 2SSS process that overcame this difficulty. Through further development of the process we demonstrated that the film composition using this process is the same as that produced by the highly controlled co-deposition process that produces 20% cells. This new approach is now being utilized in both steps of the 2 step process and initial results are indicating that we can produce the same film quality as with co-deposition while keeping the process time the same. We also have reduced Group III loss to the same level as co-deposition.

An important longer term issue for CIGS technology is the potential for scarce and expensive In. Efforts are underway in many labs to find a solution to this problem. A new material, $Cu_2ZnSnSe_4$ holds promise. In is replaced by the Zn/Sn couple and both are earth abundant. The new material structure(kesterite) is similar to CIGS, but adds additional complications. There is ongoing debate as to what the bandgap is, and cell efficiencies are only about 5%. We have developed a new fabrication pathway for the material that may lead to improved performance. By judicious tuning of the kinetics and thermodynamics of film growth we are able to produce films with the same properties as those produced under more tightly controlled deposition conditions. This is again an attempt to find a manufacturable pathway for this material. Our results are also contributing important insights to the structure of the material and its ensuing electronic properties. If these can be understood and controlled, the material could replace CIGS as a more sustainable material for large scale application.

UNIVERSITY OF SOUTH FLORIDA

Design, Construction and Operation of CSP Solar Thermal Power Plants in Florida

PI: Yogi Goswami, USF; **Co-PI's:** Lee Stefanakos, Mohammed Rahman USF, D. Hahn,UF, R. Reedy, FSEC

Description: Florida utilities are mandated to achieve 20% renewable energy contribution to their generation mix by 2020. While technologically feasible with solar energy, the capital costs are high – presently, capital costs range from $6,000-$7,000/kW for PV and $3,500-$4,000/kW for concentrating solar thermal power. This project targets the development of solar thermal power technology for bulk power and distributed generation, which will diversify energy resources in Florida and reduce greenhouse emissions by utilizing renewable sources. Also, there will be economic impacts with the establishment of new power industry in Florida, which will help the electrical utilities of the state to meet the renewable portfolio standards. The project has three main tasks; the first one is to develop design methodologies and standards for the proven solar thermal power technologies in combination with bio or fossil fuels based on Florida conditions and resources. Secondly, the project aims to set up demonstration and test facilities for these technologies for optimization for Florida conditions, and the final task is to develop and commercialize innovative technologies based on new thermodynamic cycles.

Budget: $882,000
Universities: USF, UF, UCF
External Collaborators: Sopogy Inc. and Gulf Coast Green Energy.

Progress Summary

Research Objectives for Current Reporting Period: The main research objectives for the current reporting period include the development of a test facility and pilot demonstration systems based on parabolic trough technology.

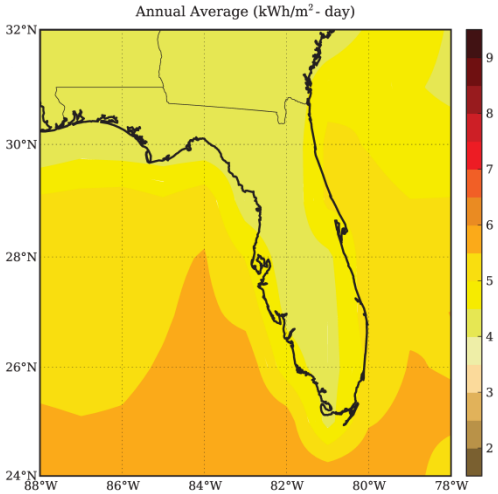


Fig. 1 Direct Normal Radiation for Florida

Progress Made Toward Objectives During Reporting Period (from November 2010):
Daily integration (DI) approach was used to obtain the average direct normal solar radiation for the location of the pilot demonstration solar plant (USF, Tampa, Fl). The direct normal solar radiation obtained for Florida is shown in Fig. 1. The annual average for Tampa Fl. is 4.6 kWh/m^2-day. These solar radiation values and the solar shading analysis for solar collector rows were used for the solar field calculation. The Soponova 4.0, Sopogy Inc., (See Figure 2.) parabolic trough collectors will be used in the solar field for providing 430 W/m^2 of thermal energy after losses. The solar field is being designed to work in conjunction with a thermal energy storage system which will use phase change material (PCM) as a storage material. USF has signed contract with Sopogy Inc. for installation of 50 KWe Solar Power Plant. Sopogy is currently preparing the final drawings for the permit and installation.

Fig. 2 Solar Collector

The remaining thermal energy will be provided by a natural gas boiler, which will work in series with the solar field and supply thermal energy to the power block when the solar energy is not available.

The power block that will convert the thermal energy to electricity is based on Organic Rankine Cycle. This power block will have a nominal capacity of 50 kW_e. A preliminary study on condensation methods for solar thermal plants is also conducted and more research will be devoted to the development of cost effective dry cooling technology.

A heat transfer model for PTC solar receiver was performed. The results showed that the new model has good agreement with experimental data. The numerical heat transfer model integrated with the solar radiation model can be used for evaluating the performance of solar collectors for any location. Also, a solar piping model was developed to calculate the parasitic (pumping requirement) and thermal losses in the solar field. The research activities for the next period will be focused on thermal energy storage design and modeling of the parabolic trough solar power plant.

UNIVERSITY OF SOUTH FLORIDA

Beyond Photovoltaics: Nanoscale Rectenna for Conversion of Solar and Thermal Energy to Electricity

PI: Shekhar Bhansali **Co-PI's:** Elias Stefanakos, Yogi Goswami, Subramanian Krishnan
Students: Rudran Ratnadurai, Electrical Engineering, Ph.D.
Michael Celestin, Chemical Engineering, Ph.D.
Samantha Wijewardane, Mechanical Engineering, Ph.D.
Justin Boone, Electrical Engineering, Ph.D.

Description: The main objective of the proposal is to commercialize and scale up a new technology, rectenna to convert waste heat energy to electricity. Although the prediction of highly efficient (~85%) solar rectennas was published almost 30 years ago, serious technological challenges have prevented such devices from becoming a reality. Since the ultimate goal of a direct optical frequency rectenna photovoltaic power converter is still likely a decade away, we plan to convert optical solar radiation to thermal radiation (~30 THz regime) using an innovative blackbody source. Leveraging the research efforts of the world-class team members, we plan to further develop the rectenna technology that is within reach of efficient radiation conversion at 30 THz. A fully integrated, blackbody converter and 30 THz rectenna system will be capable of converting at least 50% of solar and thermal energy into usable electrical power, clearly demonstrating a truly transformational new technology in the renewable energy technology sector.

Budget: $598,500
Universities: USF
External Collaborators: Bhabha Atomic Research Center, India

Progress Summary

Research Objectives for Current Reporting Period: The main research objectives for the current reporting period includes; (a) testing and characterizing of an organic MIM tunnel junction using Gallium as a liquid contact, (b) characterizing the solid-state MIM junction using tunneling AFM technique, and (c) fabrication of a dipole fed slot antenna.

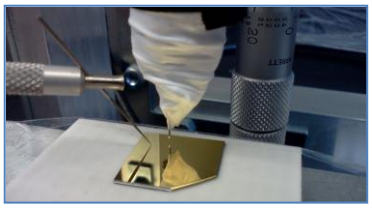


Figure 1: Test set-up for measuring SAM with Ga

Progress Made Toward Objectives During Reporting Period: (a) In this research task, MIM junctions have been developed with SAM films. One of the main challenges in fabricating a SAM based tunnel junction is the inability to deposit a top electrode. In order to overcome this challenge, a liquid metal contact is used to form a top contact, which was suspended from a needle probe. The test set-up used for measuring the I-V characteristics of the tunnel junction is shown in Figure 1. The I-V characteristic was measured using a Keithley 2400 source meter. The bias voltage was swept from -1V to +1V and the corresponding current was measured. Figure 2 shows the I-V characteristics of the SAM junction. As shown in the

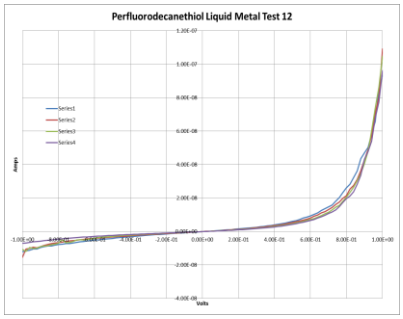


Figure 2: I-V response of SAM junction

figure, the tunnel junctions exhibited a high degree of asymmetry. The rectification ratio of the organic tunnel junctions was 1:19, suggesting a better performing rectifier.

(b) In this task, thin film dielectric was characterized using tunneling AFM technique. Ni and NiO were deposited on a silicon substrate and AFM tip was used as the top electrode to measure the tunneling current. Figure 3 shows an optical image of the AFM probe on NiO film. A sample bias voltage of -3V was applied and the tunneling current was measured. Figure 4 shows the I-V characteristics of the Ni/NiO/AFM probe. The I-V response exhibited an asymmetric curve with 1:7 rectification ratio. However, the current was in the order of few uA. This is due to the film thickness. The current can be improved by reducing the NiO thickness. Based on the above experimentation, the NiO is being characterized for use in MIM stack.

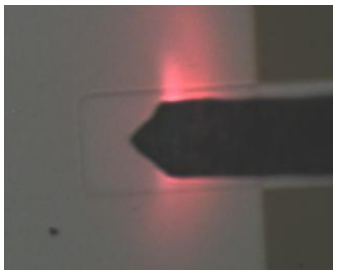


Figure 3: Optical image of MIM with AFM probe

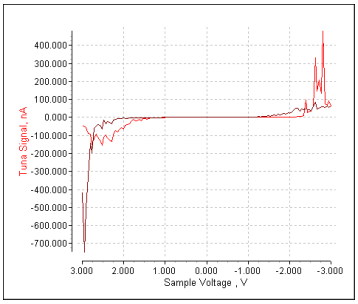


Figure 4: I-V measurement using AFM probe passivation

(c) In this task the modeling, simulation and fabrication of a single element antenna operating at 60GHz was accomplished. The modeling and simulation was done using Agilent Technologies' Momentum Electromagnetic Simulator. This software uses an efficient meshing approach and adaptive frequency sampling to reduce simulation time. The single element antenna design was modeled in the software using a substrate thickness of 50um. Based on the design, a 60 GHz antenna was fabricated on a 50um silicon diaphragm using bulk micromachining technique. Figure 5 shows the fabricated antenna and the simulated return loss. Currently, the antenna is being measured experimentally to determine the radiation pattern and the reflection co-efficient using a network analyzer.

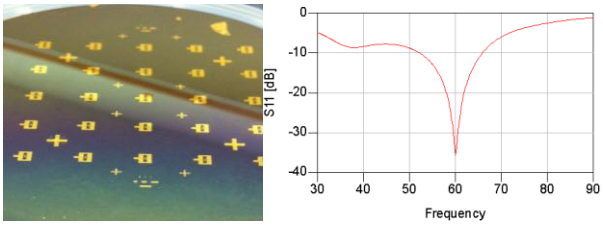


Figure 5: Optical image of fabricated dipole antenna and simulated return loss

New collaborations		
Partner name	**Title or short description of the collaboration**	**Funding**
Bhabha Atomic Research Center, Mumbai, India	Provide guidance and expertise on developing an organic tunnel junction to improve the rectification ratio	None at this time

Proposals						
Title	**Agency**	**Ref #**	**Investigators/ Collaborators**	**Funding requested**	**Duration**	**Date submitted**
Development of an Automated Engineering Test Bed to Evaluate Terahertz Devices	NSF	1126700	Yogi Goswami Shekhar Bhansali Subbu Krishnan Susan Allen Lee Stefanakos	$504,365	3 years	Jan 27, 2011
Nanoscale Organic Dielectric based Planar Tunnel Junctions as High Frequency Rectifiers	NSF	1128604	Shekhar Bhansali Lee Stefanakos Subbu Krishnan	$394,790	3 years	Feb 7, 2011
Development of Plasmon Emitter for High Efficiency Solar Energy Conversion	NSF	1134342	Yogi Goswami Lee Stefanakos Subbu Krishnan	$296,057	3 years	Mar 3, 2011

UNIVERSITY OF SOUTH FLORIDA

Energy Efficient Technologies and The Zero Energy Home Learning Center

PI: Stanley Russell, USF; **Co-PI:** Yogi Goswami, USF
Students: Mario Rodriguez (MS), Jon Brannon (MS), Jean Frederic Monod (MS)

Description: The project is to create and evaluate an affordable residential scale Zero Energy building that will function as an exhibition of energy efficiency and Zero Energy Home [ZEH] technology on or near the University of South Florida campus. The project will feature the most cost-effective combination of renewable solar energy with high levels of building energy efficiency. The building will incorporate a carefully chosen package of the latest energy-.efficiency technologies and renewable energy systems to achieve the most successful and reliable results.

The building will utilize Photovoltaic solar electricity and solar domestic hot water heating systems using the grid as an energy storage system, producing more energy than needed during the day and relying on the grid at night. Plug-in hybrid automobile technology offers a promising means of providing distributed energy storage for such homes but has not been sufficiently tested. Using a systems approach to couple zero energy home technology with PHEVs we will explore opportunities to develop marketable products that meet Florida's energy and environmental goals.

Budget: $344,600
Universities: USF, FSU, UF, UCF
Student support: Mario Rodriguez continued as a Student Assistant from 10/1 until the present
Sean Smith began as a Student assistant from January 2011
Jean Frederic Monod began as a Student assistant from January 2011

External Collaborators: Palm Harbor Homes, Hees and Associates Structural Engineers, David Young Landscape Architect

Progress Summary

Design Development was completed in November of 2010. The 889 square foot Zero Energy House Learning Center is a flexible, modular, pre-fabricated, net zero energy prototype that can adapt easily to different site situations and client needs. The key factor shaping the design approach is Florida's mild climate and an indoor outdoor lifestyle. FLeX House combines the wisdom of vernacular Florida houses, ZEH research, with cutting edge technologies to make a holistic systems engineering based, zero energy building package. The project will feature the most cost-effective combination of energy-.efficiency technologies and renewable energy systems. The ZEHLC will serve as a teaching and learning tool on campus while promoting the use of ZEH technologies throughout the southeastern US.
The prefabrication process maximizes efficiency and quality control and reduces waste when compared to the site built counterpart. Once fabricated, the main body of the house can be shipped to the site on a single truck minimizing transportation costs. The main body contains sliding modules that are deployed from the main body to complete setup at the site quickly with a minimum use of equipment and labor. The modular system is easily expandable and reconfigurable according to the wants and needs of the client and the site situation.

The plan is laid out on the east west axis to maximize shading and natural ventilation and minimize direct solar gain. Because of the hot climate, the living spaces focus on the cooler, north side of the site. The

entire north wall, composed of sliding glass panels can be opened combining the interior living spaces, the exterior deck and the garden into one continuous indoor/outdoor space. The interior space can be left open with a continuous flow from the kitchen to the master suite/office area, or it can be partitioned to separate the living and bedroom areas for privacy and to create two separate thermal zones for energy conservation.

Building Envelope- Designing an envelope that works equally well throughout the year combining an optimum level of insulation, resistance to air infiltration, transparency for daylight, and flexibility, is a challenge in Florida's hot humid climate. Flex house incorporates a double skin system. The outer skin or "umbrella" is composed of cypress [a locally grown wood] louvers that provide complete shade for the building envelope for most of the year and allow the sun in for passive heating on a selective basis. The umbrella is also the support structure for the solar array that consists of Photovoltaic panels for electrical generation and solar thermal panels for water heating. The inner skin, the building envelope, is composed of structural insulated panels with a corrugated metal exterior finish. Metal is an ideal material for this climate because of its high reflectivity and low thermal mass. Because the umbrella provides complete shade and there is a relatively low average indoor-outdoor temperature differential in Florida, the envelope is relatively thin with a modest insulation value. All of the glazed surfaces are double pane, low e glass insulating glass.

Clean Renewable Energy- As a net zero energy house FLeX House utilizes Photovoltaic panels for site based, clean renewable energy generation. The grid tied 5 kW array will send electricity back to the municipal electric utility grid during peak hours of generation and FLeX House will take electricity from the grid in the evening or on cloudy days. Over the course of a year the net consumption from the grid will equal zero.

Water conservation and collection- Flex House is equipped with low flow fixtures to conserve water. Rain water is diverted from the roof into a cistern where it is stored and used for irrigating the organic vegetable garden.

Energy efficiency- To keep energy consumption to a minimum FLeX House includes high efficiency energy star rated appliances. To reduce the amount of energy required for lighting, FLeX House was designed to make the best use of natural day light for its interior spaces with large glazed areas on the north and south facades and light colored interior finishes that reflect the light and brighten the interior spaces. At night highly efficient LED and compact fluorescent lights will provide illumination. Shading devices are designed to control the amount of direct sunlight that hits the glazing system reducing heat gain through windows and doors. Energy efficiency is also related to the operation and monitoring of building systems. The house employs whole building systems control and diagnostic software that monitors more than 35 channels of data (i.e. temperature, humidity, power, occupancy schedules, window operation incidences, etc.) to make the owners aware of when and where energy is being used and when systems are malfunctioning resulting in excessive energy usage.

Mechanical Systems- The HVAC system consists of a heat pump and solar thermal panels that circulate chilled or heated water to two interior fan coils to cool or heat the house. The energy recovery ventilator [ERV], by precooling the outside supply air, allows the chilled water system to run more efficiently. The ERV combined with a liquid desiccant dehumidifying system allows the fan coil temperatures to exceed the dew point while still maintaining good indoor air quality.

Durability- Flex house is designed to meet Florida's demanding hurricane code. All exterior finish materials have been tested for impact in hurricane winds and have obtained the required Florida product

approvals. The building skin is durable, galvanized corrugated metal and the wood lovers are made from cypress which has a natural resistance to rotting and intrusion from insects. In the off season the bedroom and entry modules can be slid back into the main body of the house and the entire exterior can be shuttered to protect the house from the weather and vandalism.

Construction Documents were completed in March and a contract between Beck Construction and USF was finalized. Beck construction is currently lining up subcontractors and ordering materials. Construction will begin on 4/19 and last until the first week of August.

New collaborations		
Florida Power and Light	Sponsor	$10,000
TECO		
OUC	Sponsor	$10,000
Progress Energy	Sponsor	$10,000
USF COE	Sponsor	$10,000
UCF	Sponsor	$20,000
Wells Fargo	Sponsor	$16,000
CSI	Sponsor	$15,000
Solar World	Sponsor	$500
Bosch	Sponsor	Gift in Kind
Sothern Cypress Manufacturers	Sponsor	Gift in Kind
Simpson Strongtie	Sponsor	Gift in Kind
Kohler	Sponsor	
Dupont	Sponsor	Gift in Kind
Pella, CWS	Sponsor	Gift in Kind
Lithonia	Sponsor	Gift in Kind
Beck Construction	Industry Partner	

Proposals					
Title	**Agency**	**Investigators/ Collaborators**	**Funding requested**	**Duration**	**Date submitted**
TechnologyFee Grant	USF	Stanley Russell Mark Weston Yogi Goswami	$223,462	1 year	3/15/2011

UNIVERSITY OF SOUTH FLORIDA

Energy Delivery Infrastructures

PI: Alex Domijan, USF; **Co-PI:** Arif Islam, USF

Description: The Power Center for Utility Explorations (PCUE) proposes to simulate the effects of a renewable energy generation system in a microgrid context to the distribution grid system. The proposed project is to simulate the combination of renewable distributed generation and a battery system to assess the effects during critical conditions such as power system peak.

A research opportunity is to investigate how existing tools can be applied to properly representing dynamic and transient behaviors of microgrids. Therefore, in this project we propose using simulation tools to model a microgrid and investigate how well we can reproduce its measured behavior in the field.

Budget: $485,184

Universities: USF

Progress Summary

Dr. Domijan has left USF and this project has been suspended. USF is undergoing an internal process to find a new PI to lead the research.

UNIVERSITY OF SOUTH FLORIDA

Creation of Carbon Sequestration Data, Technologies and Professional Cohorts for Florida

PI: Mark Stewart, USF; **Co-PI's:** Jeffrey Cunningham, Yogi Goswami, Maya Trotz
Students: Shadab Anwar, Post-doctoral researcher
Saeb Besarati, MS Chemical & Biomedical Engineering
Arlin Briley, MEVE Civil & Environmental Engineering
Drupatie Latchman, MS Chemical & Biomedical Engineering
Roland Okwen PhD Civil & Environmental Engineering
Douglas Oti, PhD Civil & Environmental Engineering
Tina Roberts-Ashby, PhD Geology
Mark Thomas, MS / PhD Civil & Environmental Engineering

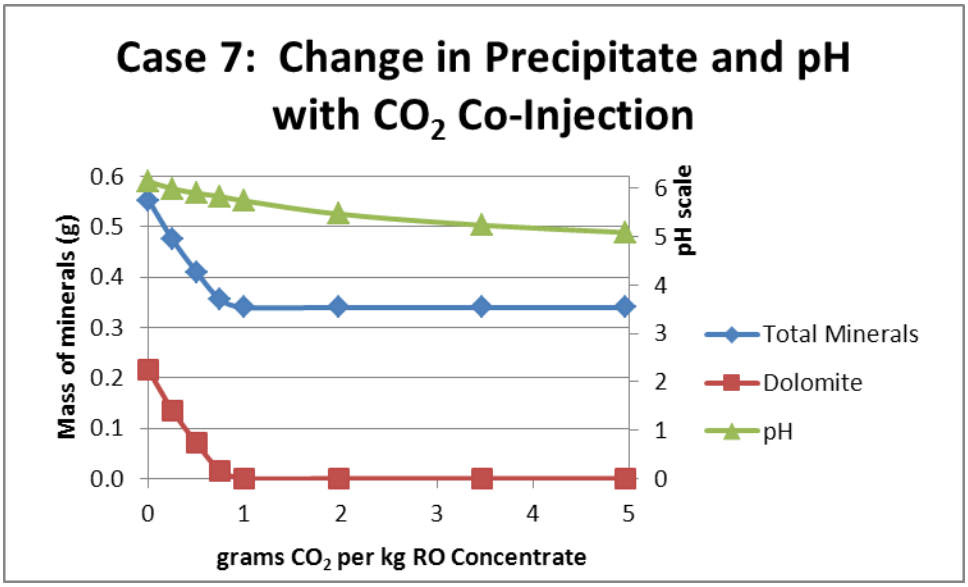
Description: Rising concerns over increasing levels of green house gases, especially carbon dioxide, have led to suggestions to capture carbon dioxide at fixed sources, such as fossil fuel power plants, and sequester the carbon for millennia by injecting it underground. Florida overlies many thousands of feet of carbonate rocks which may be suitable for geologic sequestration of carbon dioxide. This project will investigate the potential for geologic sequestration of carbon dioxide in Florida, the physical and chemical changes that may occur as a result of injection, assess the potential for escape of injected carbon dioxide, determine the risk, if any, to aquifer systems used for water supplies, develop methodologies for Florida utilities to predict the performance and risks of proposed sequestration projects, and educate a cohort of geologic sequestration professionals to create a carbon sequestration industry in Florida.

Budget: $147.360
Universities: USF
External Collaborators:
Tampa Electric Company (TECO)
Florida Power and Light (FPL)
Environmental Consulting and Technology (ECT), Inc.
Los Alamos National Laboratory

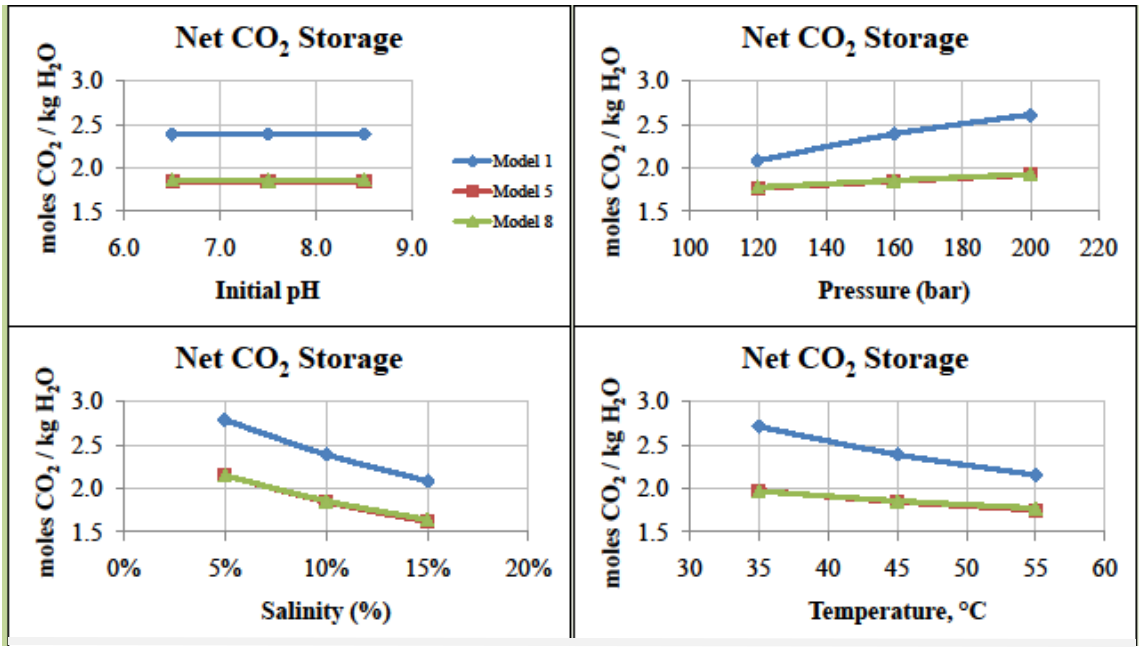
Progress Summary

In late 2010, we leveraged our project to obtain additional funding from Environmental Consulting and Technology (ECT), Inc. ECT is working with Tampa Electric Company (TECO) to drill and develop wells at the Polk Power Station approximately 2400 m (8000 ft) deep. These wells will be used to test the injection of wastewater and, pending the acquisition of appropriate permits, may be used to test the injection of supercritical CO_2. Our team at USF is performing modeling work to predict how injected wastewater and/or CO_2 streams will behave above-ground and below-ground.

The following figure demonstrates how the co-injection of CO_2 along with process wastewater can prevent the formation of mineral precipitation and therefore reduce or prevent clogging of pipelines and wells. (Note that several scenarios were considered as part of this work; the figure presented here represents results of one of those scenarios, named Case 7.) Thus we have concluded that co-injection of certain levels CO_2 has a beneficial effect.



We also have continued the development of models to predict the physical and chemical effects of CO_2 storage in deep saline aquifers, such as that underlying the Polk Power Station. The following figure shows how CO_2 storage capacity depends on environmental conditions.



Finally, two presentations were delivered at the 2010 Fall Meeting of the American Geophysical Union in San Francisco, California:

Anwar S, Cunningham JA, Trotz M, Thomas MW, Stewart M. Pore-scale modeling of reactive-multiphase-buoyant flow for carbon capture and storage. Presentation # H13C-0969. American Geophysical Union (AGU) Fall Meeting, San Francisco, CA, December 13–17, 2010.

Thomas MW, Briley A, Trotz M, Stewart M, Cunningham JA. Geochemical modeling of CO2 sequestration in deep saline aquifers in Florida. Presentation # H13C-0985. American Geophysical Union (AGU) Fall Meeting, San Francisco, CA, December 13–17, 2010.

Funds Leveraged / Partnerships Created

Grants Awarded					
Title	**Agency**	**Reference Number**	**Investigators/ Collaborators**	**Period of Performance**	**Funding awarded**
Geochemical modeling of waste stream injection into deep aquifers	Environmental Consulting and Technology (ECT), Inc.	Work Order 01-CO2, subcontract S-090299-0300	PI: Maya Trotz Co-PIs: Mark Stewart, Jeffrey Cunningham	Dec 2010 – June 2011	$ 29,201

UNIVERSITY OF SOUTH FLORIDA

Clean Drinking Water using Advanced Solar Energy Technologies

PI: Lee Stefanakos; **Co-PI's:** Yogi Goswami, Matthias Batzill, Maya Trotz, Sesha Srinivasan
Graduate Students: K. Dalrymple

Description: Availability of fresh water is one of the biggest problems facing the world and Florida is one of the most vulnerable to fresh water shortages. Moreover, Florida ground water is contaminated in many locations from leaky underground tanks, agricultural pesticides, and other chemicals. Although it is possible to desalinate abundant seawater, conventional systems are too energy intensive. Solar energy can provide the needed energy, and innovative new solar vacuum (USF) and humidification/dehumidification (UF) desalination systems can provide adequate fresh water for the state's needs. Systems are being developed for both bulk water desalination and small community needs/disaster response. We will also develop photocatalytic disinfection to remove contaminants and integrate these technologies with solar PV for complete water supply systems.

Photocatalysis is a promising water treatment technology capable of utilizing solar light. However, the construction of an effective photocatalytic disinfection system for water purification is currently limited by the lack of reliable models to aid in the design and testing of these systems. Simplified models have been proposed, but most are inadequate because they rely on traditional disinfection theories which are not applicable to photocatalysis. Therefore, the major goal of this research is to develop a model for photocatalytic disinfection based on fundamental processes which may then be used to design water treatment systems in the state of Florida.

Budget: $326,756
Universities: USF

Project Summary

A comprehensive mechanistic model for photocatalytic disinfection was proposed to optimize the design of treatment systems. A major benefit of a mechanistic model is the significant cost reduction associated with performing fewer preliminary experiments to determine the effectiveness of various combinations of catalyst concentration and light intensity for a given organism. The model simulates the effect of light intensity and catalyst concentration on the disinfection process and shows good agreement with the experimental data for stable colloidal suspensions, that is, suspensions in which rapid aggregation of cells and TiO_2 do not occur.

The following summarizes the main findings of the study:

- Most efficient disinfection achieved at high light intensity and lowest catalyst concentration
- Model predicted disinfection rate constants (k_{dis}) within 2 orders of magnitude, with less variation at lower TiO_2 concentration (within an order of magnitude)
- Disinfection has log-linear relationship with light intensity within the range in our research
- Small variation in disinfection efficiency for 0.10-0.50 g L^{-1}, especially at low and medium light intensity

- Generation rate per mass of catalyst reduces exponentially with catalyst concentration
- Colloidal interactions play a significant role in the disinfection process
- TiO_2 appears to be strongly and specifically adsorbed to cells
- Model shows disinfection does not vary significantly from pH 6-8

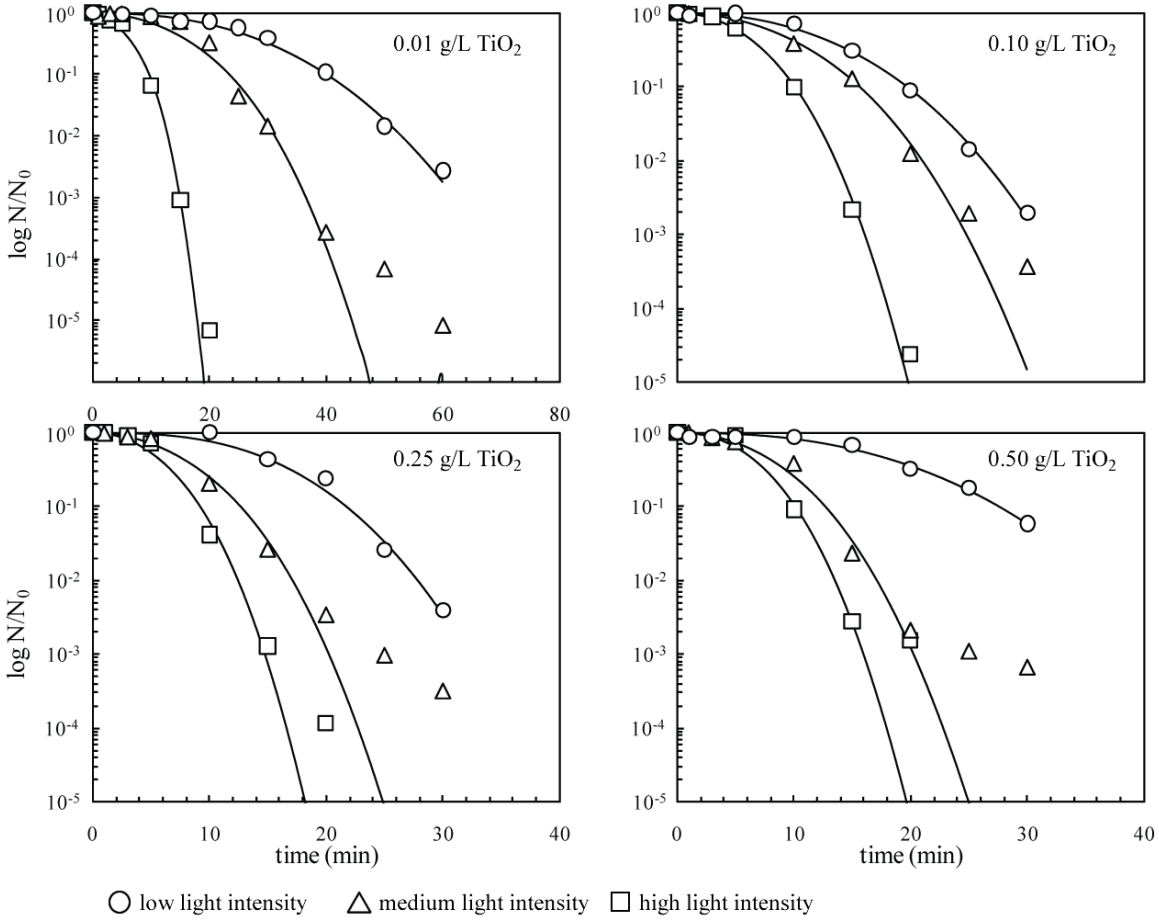


Figure 1 Disinfection curves showing the reduction in *E. coli* with time after photocatalytic exposure to different combinations of light intensity and TiO_2 concentration. The continuous lines are the results of the model simulation matching the data (geometric shapes).