University of Florida

Florida Advanced Technological Education Center (FLATE)

PI: Marilyn Barger, Hillsborough Community College

Description: FLATE (Florida Advanced Technological Education Center) is partnering with FESC to develop statewide curriculum frameworks for technical A.S./A.A.S. degree programs supporting existing and new energy business sectors. FLATE will develop and have processed through the FLDOE the industry-validated student competencies of the frameworks. FLATE will also develop new courses required for each new program of study. Additionally FLATE will help state and community colleges implement the new frameworks in their institutions. To support the new curriculum, FLATE will work closely with the FESC Public Outreach and Industry Partnership programs to provide professional development opportunities for teachers and faculty to upgrade and update their knowledge base.

Budget: $300,000
Universities: Hillsborough Community College
External Collaborators:
Brevard Community College
Tallahassee Community College
Daytona State College
Central Florida Community College
Polk State College
Florida State College at Jacksonville
Valencia Community College
School District Hillsborough County
Florida Department of Education – Division of Adult and Career Education
West Side Technical School
WFI Banner Center for Energy
Advanced Technology for Energy and Environment Center (ATEEC)
University of West Florida, Dept of Construction Technology
WFI Banner Center for Construction
WFI Banner Center for Alternative Energy
USF College of Engineering
Madison Area Technical College ATE project for Alternative Energy certifications
Milwaukee Area Technical College Energy Conservation and Advanced Manufacturing Center (ECAM)
Florida Energy Workforce Consortium (FEWC)
TECO
Progress Energy
ISTEC (Ibero Science and Technology Education Consortium

Progress Summary

During the current reporting period, FLATE partnered with 10 Florida community colleges and their local industry to define curriculum standards for alternative energy that support industry needs, made several presentations both within and outside of Florida, and is working with Brevard Community College for a fall implementation of the Alternative Energy Systems Certificate. In April, FLATE added Jorge Monreal to the team as Project Manager to help drive implementation of this FESC project.

Specific accomplishments during the period are:

9/29/09	Poster presentation at the 2009 FESC Summit; "Preparing the Technical Workforce to Meet Florida's 21st Century Needs" (Tampa, FL)
9/09-10/09	Conducted two workshops for curriculum framework development with faculty at Polk State College and Valencia Community College.
10/28/09	Gave energy education focused presentation at ISTEC (Albuquerque, NM)
11/18/09	Presentation on Energy Curriculum in Florida at Interstate Renewable Energy Council's (IREC) third "New Ideas in Educating a Workforce in Renewable Energy and Energy Efficiency" Conference. (Albany, NY)
2/2/10	Co-presented, with Drs. Tim Anderson and Pierce Jones, to the Florida House Committee for Public Universities and Private Colleges Policy
3/10/10	Facilitated the approval by FL DOE of the new curriculum framework for Alternative Energy Technology Specialist (CIP: 0615000003) as a College Credit Certificate program under the Engineering Technology AS/AAS degree program. Brevard Community College (BCC) will adopt in Fall 2010.
4/5/10	Added Jorge Monreal as Project Manager- FESC project
4/23/10	Presented overview of FESC and its interactions with two year A.S. programs at the spring state wide Engineering Technology Forum held at FSCJ at Jacksonville.
5/7/10	Meeting with Broward College Associate Dean for A.S. programs to discuss alternate energy specialization in the state wide Engineering Technology A.S. degree program

The immediate focus is to help BCC implement the new Alternative Energy Technology Specialist program for the Fall of 2010 by helping to develop curriculum for the introductory course, as well as providing any necessary aid in other courses. Additionally, FLATE is partnering with BCC on an NSF grant to support curriculum development and outreach for college energy programs and degrees.

In the next few months, FLATE in partnership with the FLDOE will conduct a survey to assess what, if any, alternative/renewable energy courses are currently being offered at public state and community colleges, private colleges and high schools. This follow-up to the 2009 Greensforce Florida survey will focus on specific courses currently offered at public and private 2-year degree granting institutions. It will also request enrollment data in courses and programs.

A list of Florida companies with products or services in the Alternative/Renewable energy sector is in the process of being compiled. The goal is to create industry focus groups to assess workforce education needs.

FLATE has partnered with FESC public outreach to develop a professional development workshop to be offered on July 27 at the Hi-TEC conference in Orlando.

UNIVERSITY OF FLORIDA

A Low Cost CIGS Thin Film Hot Carrier Solar Cells

PI: Gys Bosman; **Co-PI:** Tim Anderson
Students: Barrett Hicks, Yige Hu, Chris Muzillo

Description: PV has entered into a period of record growth. Most of the current production is based on crystalline Si technology. However, there are fundamental limits to the ultimate Si costs that may inhibit it from achieving the desired level of contribution to worldwide energy production. In contrast, thin-film PV technology can reach the desired outcome due to fast deposition rates and lower cost. USF, UCF and UF play a lead role in developing these technologies. The world record 16% efficiency for CdTe was set by USF and held for 10 yrs. The time has come to coordinate the leading-edge resources within the SUS and establish a Florida PV industry. To achieve the desired level of energy generation, efficiency has to be >13%, which has been achieved in the laboratory; however, there is an inability to transfer laboratory success into manufacturing success. The transfer process has been the purview of industry, with limited success. What is needed is a fundamental understanding of this process, which can best be done in a university environment with industry cooperation. It is proposed to combine SUS expertise with local industry to develop this foundation. We will build and operate a pilot line that includes all aspects of module fabrication and characterization for the SUS/industry partners to develop manufacturing processes.

Budget: $450,000

Universities: UF

External Collaborators: NA

Progress Summary

Research Objective: Low cost CIGS based hot carrier solar cells are studied for cell conversion efficiency improvement. To extract hot photogenerated carriers we plan on using phonon engineering in the absorber layer and device engineering for optimizing energy selective contacts. To increase throughput, a CVD approach is explored.

Progress: Phonon engineering in the CIS absorber layer was studied to reduce the thermalization of hot carriers. Hot photogenerated carriers transfer their excess energy to the lattice in the form of an optical phonon. Typically an optical phonon decays into two, equal energy, acoustic phonons, via what is known as the Klemens mechanism[1]. Optical phonons are high-energy stationary lattice waves and are actually able to transfer energy back to the carriers to keep them hot. Acoustic phonons on the other hand are low energy propagating waves. Once energy is in the form of an acoustic phonon, it cannot be recovered to re-heat carriers.

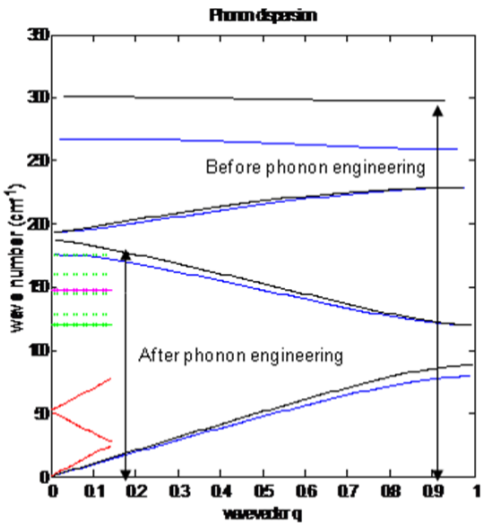


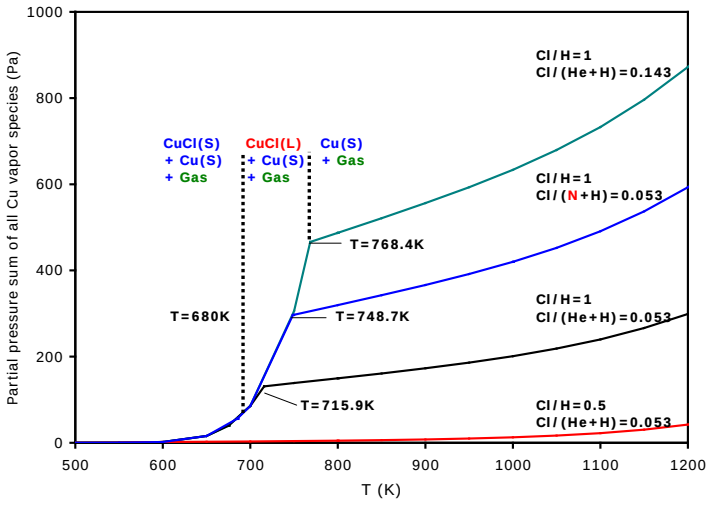
Fig.1 Phonon Dispersion Curve

[1] P. G. Klemens, "Anharmonic decay of optical phonons," Phys. Review, vol. 148, no. 2, 845 (1966)

Phonon engineering was studied in this period to block the Klemens mechanism so as to keep the high energy photoexited carriers hot until they reach the contacts. As an example the phonon dispersion curves of bulk CIS and CIGS and a CIS/CIGS super lattice with layer widths of 5 and 12.5 Å, respectively, were calculated as shown in Fig. 1. In the superlattice phonon mini gaps result in the acoustic phonon branch. Obviously optical phonon decay into acoustic phonons whose energy would fall into these gaps is forbidden since there is no allowed acoustic phonon state. By optimizing material composition and feature size, the Klemens mechanism can be blocked. Also the optical phonon branch of the superlattice becomes discrete, reducing the likelihood of Klemens transitions.

We are in the process to validate simulation results with experimental data. Raman and FTIR spectroscopy experiments to measure phonon energies are underway in collaboration with the Chemical Engineering and Physics Departments at UF, respectively.

Device engineering of energy selective contacts[22] was investigated for the purpose of extracting hot carriers at the contacts without energy loss. Firstly, the contacts are required to be very thin so that carriers are collected before they interact with the lattice. Secondly, the design should allow for the collection of carriers in an optimal energy range. Carriers having energies outside this range are rejected to prevent scattering loss. Energy confinement can be realized by quantum mechanism tunneling or interband resonant tunneling such as in Esaki diodes. Quantum dots also provide total energy confinement but it is hard to control the size uniformly[2]. Alternatively, Esaki tunneling junctions are easy to fabricate and provide energy selective properties. We are currently simulating germanium Esaki diodes to study how material properties (band gap, affinity and carrier density) affect the energy selective range. Subsequently Esaki diode contacts of material compositions compatible with the CIGS matrix will be integrated with a phonon engineered CIGS absorber. Via simulation optimal energy selection and device structures will be analyzed to achieve higher efficiencies.



The goal of this proposal is to evaluate the feasibility of the envisioned process. This will be accomplished in a 2-phase investigation supported by process modeling. The first phase aims to demonstrate the individual deposition stages in the envisioned process to understand their process characteristics and define the limits of operation. The next phase is to emulate the countercurrent process to grow a CIGS layer, fabricate devices, and characterize their performance. A complex chemical equilibrium description of the process has been completed to identify the feasible operating ranges. The figure to right shows the transport efficiencies for Cu as a function of temperature for 4 different inlet conditions. As can be seen there exists a minimum operating temperature for which Cu can be effectively transported. A reactor has been designed and constructed to explore this process and Cu transport and deposition has been verified.

[2] Gavin Conibeer, Nicholas Ekins-Daukes , Jean-Francois Guillemoles , Dirk Koenig , Eun-Chel Cho, Chu-Wei Jiang, Santosh Shrestha , and Martin Green, " Progress on hot carrier cells," Solar Energy Materials & Solar Cells 93, 713, (2009)

FESC
Florida Energy Systems Consortium

UNIVERSITY OF FLORIDA

UFTR Digital Control System Upgrade for Education and Training of Engineers and Operators

PI: Alireza Haghighat

Faculty Participants: James Baciak, Edward Dugan, Gabriel Ghita, Glenn Sjoden & DuWayne Schubring
Students: S. Brown (BS), G. Fekete (BS), A. Holcomb (BS/MS), D. Lago (BS/MS), M. Marzano (MS/PhD), J. Musgrave (MS)
Staff participants: Brian Shea and Matthew Berglund

Description: The goal of this project is to contribute to a major initiative on design, licensing and construction of a fully digital control system for the University of Florida Training Reactor (UFTR). This makes the UFTR the first operating nuclear power plant in the United States that uses a fully digital control system. This facility will provide for the training and education of the necessary workforce in the area of digital control and instrumentation for nuclear reactors. With this effort, a new focus/certificate on digital control and instrumentation will be developed at the Nuclear and Radiological Engineering (NRE) Department. Further, the UFTR facility will offer training courses for community colleges (Central Florida, Indian River, and Jacksonville) in the State of Florida, personnel from nuclear utilities and government agencies including the Nuclear Regulatory Commission (NRC). The project has already received significant funding from industry and government in form of grants, contracts, equipment/systems, and engineers' time.

Budget: $308,000
Universities: UF
External Collaborators: Several engineers from AREVA NP Inc & Siemens Corporation

Progress Summary

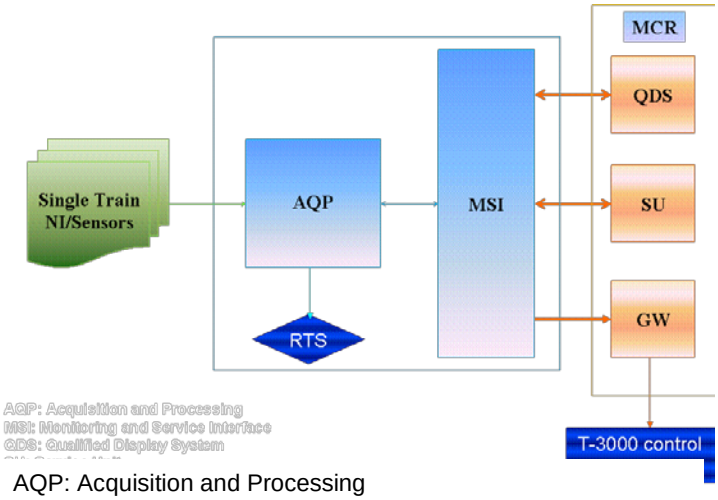
We have been working on the following two major areas:

i) Design of the new digital system

ii) Preparation and submission of licensing documentation to the NRC

i) Digital system design

Thus far, we have completed a design for the AREVA's TXS protection system. Figure 1 shows the components of this design. The UFTR-TXS system includes three major components: Acquisition and Processing (AQP), Monitoring Service Interface (MSI), and Main Control Room (MCR). This design will be housed into two cabinets as shown in Figures 2a and 2b. Cabinet 1 includes the AQP and all the signal processing units, and the Cabinet 2 includes the MSI and all the MCR components.



AQP: Acquisition and Processing
MSI: Monitoring and System Interface
MCR: Main Control Room; RTS: Reactor Trip System
QDS: Qualified Display System
SU: Service Unit; GW: GateWay

Fig. 1 - Schematic of the UFTR-TXS Protection System

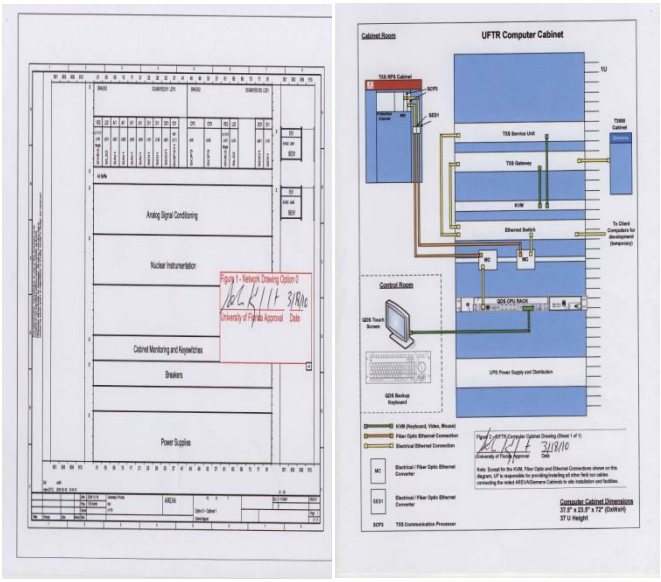
ii) Preparation and submission of licensing documentation

With support from AREVA, we have prepared several important documents, and since Jan 2010, we have submitted seven documents to the NRC. Table 1 presents the list of documents and indicates their status.

Table 1 – List of Documents[1] & Their Status

UFTR Quality Assurance Program[2]
Conduct of Quality Assurance[2]
Quality Assurance Project Plan (QAPP)[2]
Safety System Design Basis[3]
Diversity and Defense in Depth Analysis (D3)[3]
Software Verification and Validation (SVVP)[4]
TXS Cyber Security[4]
Software Quality Assurance Plan (SQAP)[4]
Software Configuration Management Plan (SCMP)[4]
Software Safety Plan (SSP)[4]
Software Test Plan – SIVAT Plan[4]
Factor Acceptance Test (FAT)[4]
Functional Requirements Specification (FRS)[3]

[1]Software related documents are listed here
[2]Does not need the NRC approval
[3]Being completed
[4]Completed and submitted to the NRC



a) Cabinet 1 **b) Cabinet 2**

Fig. 2 – Schematic of UFTR-TXS protection system in two cabinets

UNIVERSITY OF FLORIDA

Solar Thermal Power for Bulk Power and Distributed Generation

PI: David Hahn, James Klausner, Renwei Mei, Joerg Petrasch, and Helena Weaver

Students: Richard Stehle (PhD); Michael Bobek (PhD); Kyle Allen (PhD); Justin Dodson (PhD), Like Li (PhD)

Description: While there are many different approaches to hydrogen generation, the most attractive means is to split water molecules using solar energy. The current approach is to develop highly reactive metal oxide materials to produce intermediary reactions that result in the splitting of water to produce hydrogen at moderate temperatures (<1000 K). It is envisioned that the metal oxide reactors will ultimately be mounted within a solar concentrating reactor, and irradiated via heliostats. This Task is structured toward the overall goals of solar-driven, thermochemical hydrogen production, with associated efforts toward the enabling surface science, catalysis, particle science, material synthesis, nano-structures, multiscale-multiphase physics modeling, and process simulation that will enable the realization of solar hydrogen-based fuels to power the transportation economy. Successful efforts as targeted in this project are a critical step toward increased renewable-resource based fuels and energy, reduction of GHG emissions, and establishment of a new power industry in Florida.

Budget: $446,400

Universities: UF

Progress Summary

Research Objectives for Current Reporting Period: The main research objectives for the current reporting period include setting up a high temperature iron powder fluidized bed reactor facility for the measurement of hydrogen production rates at various operating conditions, the development of a high temperature bench-scale reactor for fundamental kinetic studies, the preliminary testing of experimental facilities, and the development of fundamental reactor design methodologies.

Progress Made Toward Objectives During Reporting Period: A bench scale hydrogen production process that utilizes a fluidized bed reactor was fabricated and tested at temperatures of 450, 650, and 850^{o}C. The reaction utilizes porous iron powder with a mean particle diameter of 91 μm. The reaction chamber includes a 0.6 m long fused quartz tube, capable of operating up to temperatures of 1200^{o}C. The quartz fluidization chamber extends through an electric furnace with a range of 100 to 1200^{o}C. A steam generator, consisting of four 200W (maximum) cartridge heaters inside an aluminum chamber, is used in a boiling mode to produce superheated steam at 200 ^{o}C. The mass flow rate of steam to the reactor is 0.075 g/s for all experiments considered.

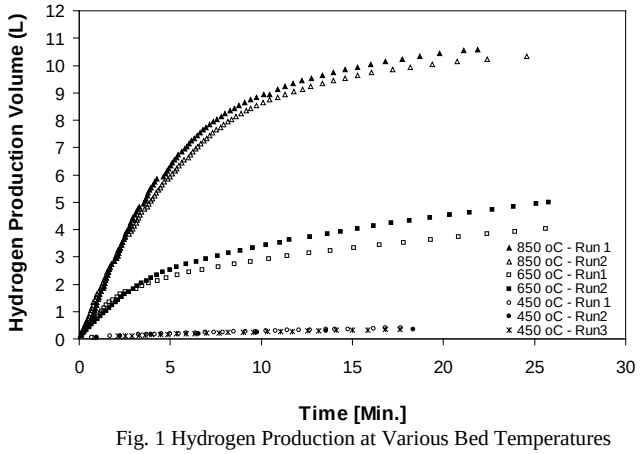


Fig. 1 Hydrogen Production at Various Bed Temperatures

For the current reactor configuration steam is introduced to a fluidized bed of iron particles. These particles are porous and have a mean particle size of 91 µm.

The powder has a particle density of 7800 kg/m^3 and an estimated surface area of 60 cm^2/g. This powder is classified as Geldart B and 25 g of powder are used for each experiment.

The measured volumetric hydrogen production at three different reaction temperatures is shown in Figure 1. As the temperature of the reactor increases, the amount of hydrogen produced increases. The total volume of hydrogen produced for 25g of iron is 0.35, 4.5 and 10.5 L for 450, 650 and 850 ^{o}C respectively. All volumes are measured at atmospheric conditions. The hydrogen production for different powder batches is shown to be repeatable. The trend of increasing hydrogen production with increasing temperature is expected since the reaction rate increases exponentially with temperature, according to the Arrhenius equation. Clearly, the rate of hydrogen production decreases exponentially, and this is due to the fact that an iron oxide (magnetite) layer forms over the particles as hydrogen is liberated from the steam, thus reducing available surface area for reaction.

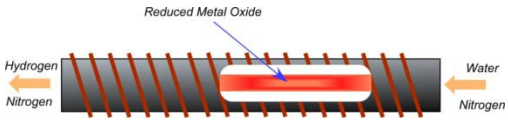


Fig. 2 Monolithic Reactor for Fundamental Reaction Kinetic Studies

In order to develop a scaling methodology and analytical reactor design tool, conservation of species and energy transport equations have been derived for the current fluidized bed reactor configuration. Evolution of the hydrogen concentration and bed temperature with time are described by the resulting partial differential equations. A necessary input to the species conservation equation is the intrinsic heterogeneous reaction rate law and accompanying reaction rate constant. Figure 2 shows a diagram of the monolithic reactor that is used to measure the intrinsic reaction rate constant for different operating temperatures. A cylindrical iron rod with a precisely known surface area is situated at the centerline of the reactor. Due to the slow rate of reaction, a quasi-steady plug flow analysis is used to extract the precise reaction rate constants from the rate of hydrogen production, measured with a mass spectrometer.

Research activities for the next reporting period will focus on making extensive measurements of the reaction rate constants and scale-up of the fluidized bed reactor for testing within the solar simulator, which is under construction.

UNIVERSITY OF FLORIDA

Joint Optimization of Urban Energy-Water Systems in Florida

PI: James P. Heaney
Student: Miguel Morales (M.E.)

Description: Urban water infrastructure systems for providing water supply, collecting and treating wastewater, collecting and managing stormwater, and reusing wastewater and stormwater require major energy inputs. End users of the water require even more energy to heat this water for showers and baths, clothes washing, cooking and other uses. Increasingly, cities will rely on alternative water supplies such as desalination that require much more energy per gallon of water produced. Conservation is the ideal way to save energy and water by managing the demand for these precious commodities. Major strides have been made in reducing indoor water use from about 75 gallons per person per day to as low as 40 gallons per person per day. However, these gains are being offset by concurrent increases in outdoor water use for irrigation that range from 30 to 300 gallons per person per day depending on irrigation practices and the size of the landscape. From a water use perspective, perhaps the greatest challenge will be the expected growing competition for water if certain energy options are implemented in order to reduce our current dependence on foreign oil. Several recent national studies warn of this impending energy-water crisis. This project will build on our extensive experience in evaluating urban water conservation options to include the implications for energy use and to develop integrated energy-water management systems that are compatible.

Budget: $72,000

Universities: UF

External Collaborators: NA

Progress Summary

Research Objectives for Current Reporting Period: The research objectives during this period were to develop and test databases that we have developed that provide physical and economic attributes for each of the 8.8 million parcels of land in the state of Florida. A related objective was to develop a database on monthly water use for each public water utility in the state of Florida. This information on land and water use was then to be combined with other data to develop advanced software called EZ Guide 2 Beta that can be used to develop cost-effective water conservation plans for water utilities.

Progress Made Toward Objectives During Reporting Period:

Water use analysis is typically done using utility-wide data since it is to difficult to organize and evaluate customer level attribute and water billing data. A major breakthrough in the research of the CFWC has been the acquisition and use of customer level attributes including land use information, and utility level monthly water use data for every utility in the State of Florida. Annually updated attribute and GIS data for nine million parcels in Florida were downloaded from the Florida Department of Revenue (FDOR) web site (ftp://sdrftp03.dor.state.fl.us/). The key land use information for a parcel is its impervious and pervious areas. This information can be extracted directly from the FDOR and selected county tax assessors' databases. The type of land use is available for 66 separate land uses. Population information

was obtained from US Census data at the Census Block level of aggregation. Water utility service areas may not be contiguous with the political boundaries of the cities. Water utility boundaries were obtained from four water management districts. Eleven years of monthly water use data for each utility were obtained from the Florida Department of Environmental Protection web site. This information is used to evaluate historical trends and to project future growth patterns.

A detailed analysis of monthly water use has been done for all of the customers served by Gainesville Regional Utilities using data for a recent year. A customer's water use pattern provides a signature of the nature of their water use. Our research indicates that indoor water use is constant throughout the year whereas outdoor water use varies widely based on the lot size, type of irrigation system, and customer preferences. Thus, it is possible to partition the total water use signal into its indoor and outdoor components. Our EZ Guide 2 Beta software uses the above data along with information on the expected cost effectiveness of conservation devices to generate a conservation plan. This software has been tested by several utilities during the past four months.

The next phase of the study will incorporate the water-energy nexus into the model so that it simultaneously optimizes both energy and water efficiency.

UNIVERSITY OF FLORIDA

Outreach Activities for the Florida Energy Systems Consortium

PIs: Pierce Jones, Kathleen C. Ruppert, Hal S. Knowles III, Nicholas Taylor, Barbra Larson, Craig Miller

Description: Developing educational outreach programs and materials designed to deliver practical, applicable information and knowledge on energy-related topics to the general public as well as targeted to specific audiences such as builders, planners, engineers, architects, small businesses, local governments, and utilities through the Cooperative Extension Service and others. By focusing educational programming on climate and efficient use of energy and water, the program aims to provide the knowledge needed by building and energy professionals, local governments, and the general public, to significantly reduce greenhouse gas emissions in Florida.

Budget: $497,671

Universities: UF

External Collaborators: Primarily DCA, FSU, UCF (FSEC), USF, and DEP with many others as well.

Progress Summary

Energy/Climate Awareness Fact Sheets: Completed four fact sheets for the FESC website with eight more currently in various stages of completion. Additional topics have been determined.

Energy Extension Service: Offered two homeowner classes on energy efficient building construction in Florida. Natural Resources and Florida Yards and Neighborhoods faculty were informed about FESC opportunities and information via articles in their respective state-wide newsletters. Held *Emerging Energy Issues and Topics* in-service training in Gainesville on 3/18 for county faculty representing 16 counties in which the emphasis was updating them on information and activities in support of FESC and to increase their knowledge on specific energy related topics of current and future interest to them and their clientele. This training primarily centered on alternatively fueled vehicles, including viewing of same. The panel discussion on alternatively fueled vehicles was repeated on the same day for the general public. Promoted county activities in three counties hosting green-related activities of local interest. Gave two presentations as part of in-service training program for Family and Community Sciences faculty. A number of other energy and climate related presentations have been conducted around the state. Barbra Larson is a member of the Climate Variability and Change Focus Team that has an in-service training set for June 16-17.

Demand Side Management: Creating protocol to accurately quantify consumption reductions due to various energy efficiency programs. Analyzing energy implications of ENEGY STAR qualified new homes program. Analyzing programmatic effects of DSM programs from various utilities. Working with utilities to streamline DSM programs based on analysis results. Creating documents that will include implications of analysis results for policy makers and the general public. Working with utilities to design and implement a performance based demand side management program that uses smart controllers to reduce potable water use for irrigation. Worked with Tampa Bay Water to assess the carbon footprint of alternative water supplies. Presented poster on same at Water Institute Symposium on 2/24 as well as a lecture titled *Land Development, Water and Accounting for Greenhouse Gas Emissions in Florida*.

Continuing Education: Offered continuing education classes on *Energy Efficient Building Construction in Florida, Low Impact Development, HVAC and IEQ, and Green Advantage* during this reporting period. Additional classes are being scheduled for this summer—see http://buildgreen.ufl.edu as they are scheduled.

Greenhouse Gas Reduction and Energy Conservation: Development Impacts Under Florida's HB 697 is a 110+ page manual published in October 2009 and used as a workbook in the first continuing education class conducted. This for sale manual is under revision and will be used in the next series of CEU classes in May with the goal to present local officials, planners and development professionals with the new requirements of growth management regulations.

Demonstration House: Continued work with Pinellas County Extension on structuring their $475,000 earmarked grant to build a demonstration facility.

Workforce Development: Working with Osceola County Extension and the Technical Education Center-Osceola on the Osceola Energy Initiative (EECBG) project that received funding through the Florida Energy and Climate Commission. Exploring collaborative opportunities for grant funding for Weatherization Innovation Pilot Program with Sarasota County and the Community Weatherization Coalition.

Alternatively Fueled Vehicles: Held in-service training and panel discussion for the public on PHEV Prius and charging station, potential for PHEV and EVs in Florida, Solar Electric Low Speed Vehicles, Solar Bicycle ASES Photon, Compressed Natural Gas, Liquefied Natural Gas and Liquefied Petroleum Gas, and Bio-diesel 3/18 in Gainesville. Working with Progress Energy to evaluate performance of PHEV using converted Toyota Prius equipped with GPS tracking system and software to monitor performance. FESC publications on AFVs are planned.

Collaboration on New Initiatives: Extending energy analysis techniques to assist utilities across the state. PREC will be working with Florida DCA on analysis of the Federal Weatherization Assistance program. This project will quantify energy savings for up to 19,000 participating households across the State of Florida. Results of this analysis will provide valuable feedback about post consumer impacts of various common demand side management techniques.

The Florida Legislature recently passed enabling legislation allowing local political jurisdictions to establish property assessed clean energy (PACE) financing programs. PREC is developing a manual for Florida to help guide these jurisdictions in the process for energy efficient retrofits of existing housing and applying for a grant from the Doris Duke Charitable Foundation to establish a pilot PACE program with the city of St. Cloud.

UNIVERSITY OF FLORIDA

Solar Driven Desalination

PIs: James Klausner and Skip Ingley
Students: Fadi Alnaimat (PhD) and Gabriel Espinosa (PhD)

Description: With the advancement of renewable energy utilization for seawater desalination, solar energy is projected to be a promising energy source for seawater distillation. The current approach is to develop a low temperature solar energy driven distillation process that is based on direct evaporation and condensation of water vapor through a packed bed using an air stream. Transient one-dimensional conservation equations have been developed to analyze the heat and mass transfer within direct-contact evaporators and condensers. Closure models have been specified. The conservation equations are solved numerically using a finite difference scheme to predict water, air/vapor mixture and packed bed temperatures in the evaporator and the condenser. The heat and mass transport model accounts for the transient variations within the packed-bed due to changes in the inlet air and water temperature over the course of the experiment. Set of experiments are conducted and used to validate the transient models. The developed model will be used to predict fresh water production at various operating conditions. The transient computer model will be used to design solar driven desalination plants and analyze the economics of construction and operation.

Budget: $252,000

Universities: UF

Progress Summary

Research Objectives: The research objective for the current reporting period is to set up an experimental diffusion driven desalination facility and experimentally validate a computer models developed for the transient evaporation and condensation processes based on solar heating.

Progress Made Toward Objectives During Reporting Period: An experimental diffusion driven desalination facility that operates in a transient mode has been fabricated. The facility operates in a recirculation mode, and the discharge brine from the diffusion tower circulates through a simulated solar water heater. The 15 kW simulated solar water heated is computer controlled so that the transient heating of the water matches that of a solar water heater for various sky conditions over an eight hour period. The main body of the evaporator and condenser is a transparent column constructed with 24.1 cm ID acrylic tubing with wall thickness of 0.64 cm and 1 m height. Experimental desalination experiments are done for the evaporator operating at water inlet mass fluxes of 1.0, and 2.15 kg/m^2-s and air mass fluxes of 0.5, and 1.0 kg/m^2-s. The experimental condenser facility operates with water mass fluxes of 1.0, and 2.0 kg/m^2-s and air mass fluxes of 0.5, and 1.0 kg/m^2-s. The heights of the packed bed within the evaporator and condenser are 0.91 m, and 0.7 m, respectively.

Figure 1(a) shows a comparison of the measured and computed exit air and water temperatures discharging the diffusion tower for different air mass fluxes. Figure 1(b) shows the comparison for the condenser. The computed exit water and air temperatures are in good agreement with those measured. For a 2.0 m^2 solar collector area, the predicted fresh water production per number of collectors per day is 14 L/collector-day. It is believed that the water production can be improved further by optimizing the system operating conditions.

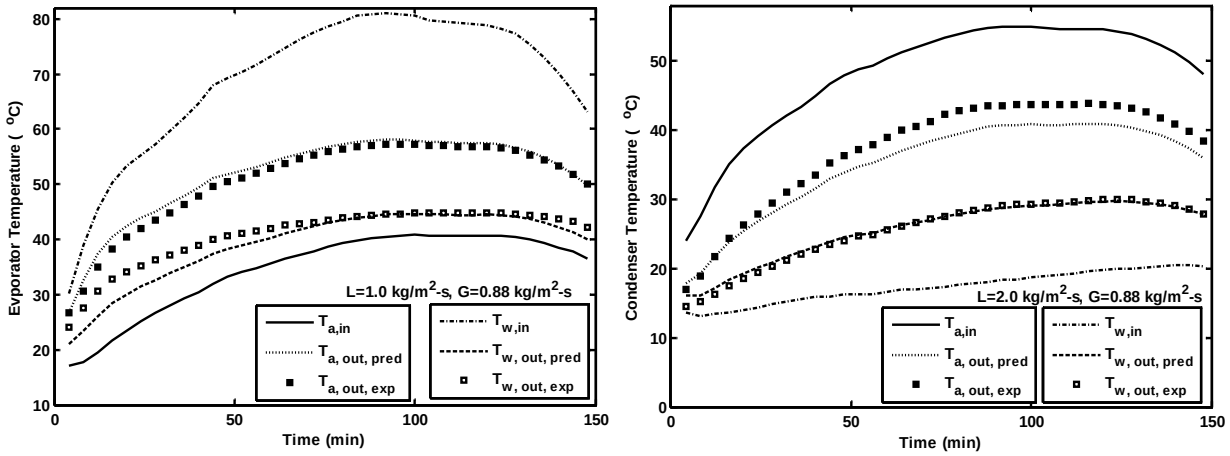


Figure 1 Exit air and water temperature variation from the a) diffusion tower and b) condenser.

The computer model appears to provide a very good predictive capability for the thermal and mass transport within the diffusion tower and condenser. The computer model will be utilized as a design tool to identify the optimal operating conditions and analyze the performance of the desalination processes for various size solar collector facilities. In addition, a comprehensive economic analysis of the solar driven desalination process will be undertaken. Particular attention will be paid to the cost of construction, and the break even point for an initial investment. The computer model will also be used to guide the scale-up of the facility for both large and small scale applications.

UNIVERSITY OF FLORIDA

Combined Cooling, Heat, Power, and Biofuel from Biomass and Solid Waste

PI: William Lear
Students: Minki Kim (PhD); Elango Balu (PhD); Harsh Khandelwal(MS)

Description: The goal of this project is to provide the underlying research and demonstration of a novel technology which would enable the economic utilization of dispersed biomass and solid waste resources to produce electric power, cooling, heat, and transportation fuels. This integrated gasification and power generation system combines University of Florida advances in high-temperature gasification, hydrogen generation and separation, and advanced gas turbine systems. Their integration is expected to result in significant improvements in the cost, emissions, feedstock flexibility, and water requirements, all in a relatively compact, modular plant system. This in turn will enable much greater utilization of renewable energy supplies, helping the development of a sustainable energy supply infrastructure.
Budget: $576,000
Universities: UF
External Collaborators: Siemens Power Generation, Florida Turbine Technologies, Energy Concepts Co., Alturdyne, Inc., LPP Combustion, Planet Green Solutions.

Progress Summary

Continuing progress has been made in three areas: development of a system architecture and thermodynamic model, development of models and system-level experiments for the PoWER gas turbine unit, and exploration of the underlying science and demonstration of the high temperature steam gasification subsystem. These activities are structured in such a way as to allow stepwise research and development of the overall plant in outlying years.

The system architecture includes the full integration of waste heat and water produced in the gas turbine module with the gasification subsystem. This in turn allows efficiency gains, reducing the proportion of hydrogen utilized internally, and allows zero net usage of external water resources. A thermodynamic system model is operable, though more sophisitcation is needed for full optimization of the system and accurate prediction of performance.

The PoWER system has been validated as an early demonstration unit in previous programs. Experimental results from the combustion process have been obtained, allowing the quantification of soot and other emissions in flameless combustion, including the effect of biofuels. Combustion modeling supports the experimental findings. System thermodynamic models have shown the potential of the PoWER system to improve efficiency and produce fresh water. These models are being integrated into the overall system model for improved fidelity.

On the gasification side, we have primarily been working on the development of the experimental systems. Two different sized units are under development, one a laboratory-scale system and the larger one installed on a trailer. Both systems have been designed and constructed under FESC support. The characterization and evaluation of both systems have been undergoing.

The laboratory-scale system that was designed for high-temperature pure steam gasification research has been completely built and is undergoing calibration evaluations. The system will be ready for gasification experiments at the beginning of June, 2010.

For the trailer-scale system, we have performed six test runs and found that the system can produce 12 kW of power with a biomass (wood chip) consumption rate of 20 kg/hr. This result is consistent with the theoretical model prediction. We also discovered that the gasifier produced excessive amount of tars that condensed on the inside of the syngas paths, as expected for the initial downdraft combustion design. The system has been under repair and modification to operate at higher temperature to avoid tars, and will be available for next phase of experiments in the middle of May, 2010.

UNIVERSITY OF FLORIDA

Non-Contact Energy Delivery for PV System and Wireless Charging Applications

PI: Jenshan Lin
Students: Zhen Ning Low (PhD), Joaquin Casanova (PhD), Raul Chinga (PhD), Jason Taylor (MS), Yan Yan (PhD), Xiaogang Yu (PhD)

Description: Innovative non-contact energy delivery method will be used in photovoltaic energy generation system to accelerate the system deployment. Instead of delivering electric power using cables penetrating through building structures, magnetic field coupling allows power to be transferred wirelessly through building walls and roofs. In the meantime, the DC electric energy from photovoltaic cells is converted to AC energy. This enables the photovoltaic system to be quickly set up or relocated, and the collected solar energy from outdoor system can be conveniently delivered to indoor appliances. Techniques to achieve high efficiency at high power delivery through different building structures will be studied for this plug-and-play architecture.

In addition, the technique and the system can also be used for non-contact charging of electric vehicles. The transmitter/charger can be placed as a mat on garage floor or parking space. The receiver inside vehicle will pick up the energy delivery through magnetic coupling. This eliminates the need of connecting charging wires to vehicles and exposed metal contacts, which is a safer method of charging electric vehicles.

Budget: $252,000

Universities: UF

External Collaborators: NA

Progress Summary

In the previous report, we described the design and experimental results of extending the magnetic induction electric energy delivery system from a close distance of 1 cm to 50 cm. The results demonstrated that 50% efficiency can be achieved when the two coils are separated by 50 cm. In this report, the distance is further extended to 1 m, and the peak efficiency reaches 58%.

I. Design of the System

Fig. 1 shows the block diagram of the system and a picture of test setup. The DC-AC inverter provides the AC power to be transmitted to the receiver. The inverter is a class E switch-mode power amplifier. Following the inverter is an impedance transformation network, the purpose of which is to maximize power transfer and efficiency by transforming the impedance looking into the transmitting coil. The transmitting coil follows, which is in turn inductively coupled to the receiving coil. Both transmitter and receiver coils were constructed using Litz wire to reduce resistive losses from proximity and skin effects. The receiving coil is connected to the second half of the transformation network, a series or parallel capacitor, and followed by a rectifier and a receiver load. It is found that the series-series topology is best for midrange power transfer. Both coils have the same size of 1 m x 1 m and use six turns of 48 AWG Litz wire on each.

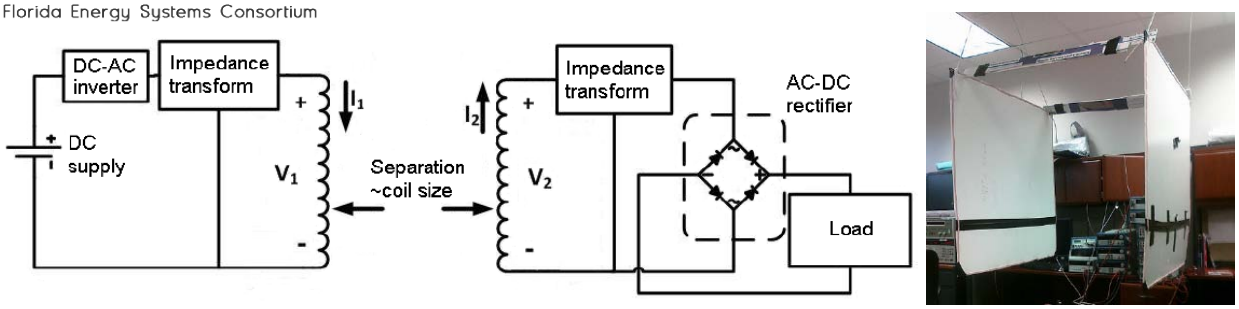


Fig. 1: Wireless electric energy delivery system diagram and picture of test setup (coils are wound around the while cardboards separated by 1 m).

II. Test Results

Fig. 2 shows measured efficiency versus delivered power when load resistance changes from 75Ω to 18Ω. The peak efficiency is about 57.9% and the peak power delivery is about 3.78 W. Transmitted power was measured using a current probe (Agilent N2783A), a voltage probe (Agilent N2863A), and an oscilloscope (Agilent DSO 5034A). The accuracy is estimated to be around 5%. Received power was measured using a DC electronic load (BK 8500). The estimated accuracy for received power is about 0.8%.

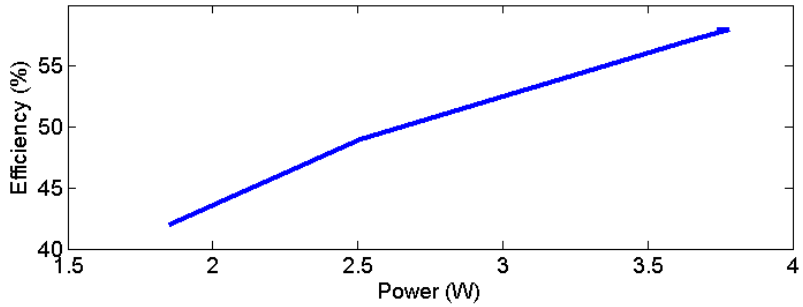


Fig. 2: Efficiency versus power of wireless electric energy delivery system.

FESC
Florida Energy Systems Consortium

UNIVERSITY OF FLORIDA

Carbon Capture and Sequestration

PI: Sabine Grunwald, Tim Martin
Students: Post-Doc: Biao Zhong; Programmer: Brandon Hoover; student support: C.W. Ross, X. Xiong

Description: Rising CO_2 concentrations in the atmosphere and effects on global climate change have been well documented, and future impacts are uncertain but potentially devastating. Florida's natural and agro-forest ecosystems have much potential to sequester carbon in biomass and soils due to unique climatic and landscape conditions. However, research gaps exist to accurately assess carbon pools and fluxes at coarse scales, ranging from county to the region and larger. The overarching objective of this project is to address these obstacles by creating a terrestrial carbon information system (called "TerraC") for the carbon science community, focused on ecosystems in Florida. The information system will be administered through the UF Carbon Resources Science Center (http://carboncenter.ifas.ufl.edu), a multi-disciplinary Center dedicated to research in support of enhanced agricultural and natural resource carbon management.

TerraC
Terrestrial Carbon Information System

Budget: $398,880

Universities: UF

Progress Summary

A conceptual design for the Terra Carbon Information System (Terra C) was developed. The core database structure, variable types, names, data types and meta data fields were established. The workflow steps to use the Terra C system are the following: A template is generated by the user that is then downloaded and populated with carbon data, which may include carbon measured in soils, plants/biomass, roots, water or air. Carbon data may be provided as totals, fluxes or as fractions (pools). In addition other data associated with carbon (e.g. bulk density in soils, nutrients, or environmental data) may be added to the data template. After the template is populated by the user it is uploaded into the core database (SQL) of the Terra C system. The template ensures data compatibility with data already stored in the database, while it allows adding additional data to the template. Thus, the template (and database structure) will grow with time as more users use the Terra C system.

After reviewing other public data sharing platforms, we developed a data sharing policy, data quality standards, and a usage policy. We also assembled material and resources to build the Terra C web site (http://terrac.ifas.ufl.edu), which is in development since all material will need to be carefully reviewed before release to the live web site. The data sharing policy will be based on the *Creative Commons Licensing* scheme and includes: (i) Attribution (the data user must give credit to the project leader (or project) in the manner specified by the him/her (but not in any way that suggests that the project leader endorses the data user or his/her use of the data); (ii) Noncommercial: The data user may not use TerraC data for commercial purposes; and (iii)

Share Alike: If the data is modified in any manner or used to derive other products, the data user may distribute the resulting work only under the same or similar license to this one. Data stored in TerraC can be shared at three access levels. The access levels are chosen by the project leader to control access to their projects by different users.

Different access levels can be assigned to different users, the level being project- and user-specific. Levels 1 and 2 mirror the roles of data user and data manager, respectively. Level 3 in the most restricted access level.

Level 1 – Public with read-only access: Access to the data is open to all TerraC users. Any person that has a TerraC user account (i.e. data user) can view the data, but not modify it directly from the TerraC database.

Level 2 – Private read/write access: Access to the data is open to the users data were assigned manager status (i.e. data managers), who can view and modify the data directly from TerraC. *Private read/write access* is password-protected.

Level 3 – Private read-only access: Access to the data is restricted to the project leader and users selected by the project leader, who in turn can only view the data, but not modify it directly from TerraC.

The project leader controls the sharing of data in TerraC. He/she provides leadership for collaboration with new partners on behalf of the project teams. The project leader can switch sharing levels from Level 3 to 2 and 1, but not vice versa, meaning if the data are released to other users or the general public this right cannot be reversed.

Data users who wish to access a protected dataset can contact the project leader and negotiate a data use agreement. The project leader may agree to share data with the data user to collaborate on a joint project, work on a co-authored research publication, or other purpose.

In addition, test carbon data sets from projects in the Soil and Water Science Department and School of Forest Resources and Conservation, UF have been acquired to be streamlined into the Terra C system. However, this process is time consuming since all meta data for carbon and environmental data need to be documented.

A new Post-Doc, Biao Zhong, started to work on the project May 1, 2010. The previous Post-Doc, Gustavo Vasques, accepted another position elsewhere; and thus there was a transition period in the first quarter of this year to make the new project team member familiar with the project.

University of Florida

Energy Intensive Crop Development

PIs: Gary Peter, Matias Kirst, Don Rockwood
Students: Juan Acosta, (Ph.D.), Alejandro Riveros-Walker, (Ph.D.), Jianxing Zhang, (Ph.D.), Patricio Munoz (M.S.)

Description: To build a commercially viable, industrial scale system to produce transportation fuels and electricity from biomass requires both efficient conversion technologies and environmentally sustainable, cost effective supplies of biomass. In the US, Florida ranks first in its annual growth of plant biomass, because of its large cultivable land area and its subtropical climate, even though substantial land areas that can be planted are not currently in agricultural or forest production. The development of high yielding production systems for dedicated energy crops is considered essential for a sustainable, biomass to energy industry to be established, because the long-term availability of sufficient amounts of reasonably priced biomass is one of the most important factors in the site selection for new biofuel and bioenergy facilities. Dedicated energy crops are ones that 1) have high yields with minimum energy inputs in terms of agronomic practices, water and nutrient applications, 2) can be harvested, transported and processed efficiently into fuel or power, and 3) can be grown sustainably for generations without adverse environmental affects, or significantly impacting the food supply. We will evaluate likely energy crop species, *Eucalyptus* and southern pine to provide important yield and best management practices for growing these species for bioenergy conversion. We will also provide important chemical composition information that will impact the conversion efficiency of this biomass to ethanol, and identify and characterize important genes that regulate wood chemical composition.

Budget: $240,000

Universities: University of Florida

External Collaborators: N/A

Progress Summary

Research Objectives for Current Reporting Period: 1) To develop rapid methods for determining wood and grass (in collaboration with the team from Agronomy) cell wall chemical composition, and 2) to establish field plantings of Eucalyptus for testing agronomic practices acquiring yield information.

Progress Made Toward Objectives During Reporting Period: Objective 1: A near and mid-infrared spectrometer was purchased from Perkin-Elmer. The instrument is capable of collecting reflectance near and mid IR spectra from 96-well plates as well as individual sample near infrared (NIR) spectra with an integrating sphere and mid IR spectra with an attenuated reflectance probe. Calibration models have been built for predicting the lignin, cellulose and hemicellulose chemical composition of grass, loblolly pine and poplar wood biomass samples. A variety of spectra collection and analytical methods have been tested and the results show that NIR reflectance spectra collected with the 96 well plate reader gave good calibration models using the 2nd derivative of the spectra and partial least squares for grass and poplar biomass samples. For the grass biomass, calibrations were performed with a total of 116 samples, spanning 4 sites and 4 species. Strong calibration regression coefficients (r^2) were obtained with recovered glucose (0.92), xylose (0.93), fiber-glucose (0.90), total recovered (0.93) and total potential sugar (0.91).

With 396 poplar samples, the calibration regression models gave strong coefficients for total lignin (0.87), guaiacyl lignin (0.81) and syringyl lignin (0.91) and cellulose (0.80). In contrast, the calibration coefficient was moderate for xylan (0.68). These poplar calibration models gave strong prediction regression coefficients with new wood samples for total lignin (0.875), syringyl-lignin (0.83), guaiacyl lignin (0.69), and cellulose (0.74) content (Figure 1) while xylan (0.59) was only moderately well predicted. We are currently quantifying the ability of grass and pine calibration models to predict biomass lignin, cellulose and hemicelluloses content in grass and pine. The grass work is being done with the UF team led by L. Sollenberger, funded from the FESC. In addition, we are testing how well these calibration equations predict *Eucalyptus* wood chemical content.

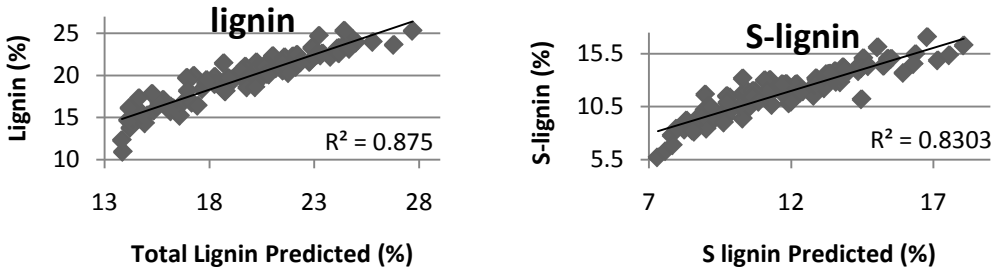


Figure 1: Prediction of total and syringyl lignin content of 100 poplar wood samples using NIR spectra with multivariate calibration equations developed from 396 samples.

Objective 2: In 2009, field plantings were established in central Florida with half-sib seedlings and the four locally adapted UF-IFAS *Eucalyptus grandis* cultivars and in north Florida with half-sib seedlings and clones of *Eucalyptus amplifolia* cultivar. The north Florida planting is about 16 acres and was put in by Buckeye Cellulose. The central Florida planting was about 3 acres and was put in by Mosaic Corp. This planting tested the genetic material at 3 initial tree spacings 3 x 3 ft, 3 x 4.5 ft, and 3 x 6 ft. In addition, it contained a Nelder design to identify the most productive tree spacing. Height, diameter and biomass sampling will occur this fall and will provide the data for growth and yield estimates.

UNIVERSITY OF FLORIDA

Solar Fuels for Thermochemical Cycles at Low Pressures

PI: Jörg Petrasch
Students Ben Erickson M.S (from July 2010)

Description: Using concentrated solar energy to produce hydrogen-rich, carbon-neutral energy carriers via two-step thermochemical cycles is an intriguing concept for tomorrow's energy economy. Concentrated solar energy drives high temperature endothermic metal oxide (MO) reduction reactions. Reaction products are used to produce hydrogen from water or CO from CO_2. In turn, hydrogen and CO may be used to synthesize carbon neutral methanol or methane. At atmospheric pressures, temperatures above 2000 K are necessary for the MO reduction reactions, causing a range of material and design issues. This project aims at lowering the MO reduction temperature by reducing the reaction pressure. M/MO redox reactions at low pressures will be experimentally investigated in a state-of-the art high flux solar simulator. Furthermore, undesired product recombination is less likely under rarefied conditions. Associated efforts will be directed at developing chemical kinetics and multi-phase, multi-scale process models. Process temperature reduction and a better understanding of the underlying physicochemical phenomena will move solar thermochemistry towards commercialization and make it attractive for Florida's high-technology and energy industry.

Budget: $ 100,000
Universities: UF
External Collaborators: NA

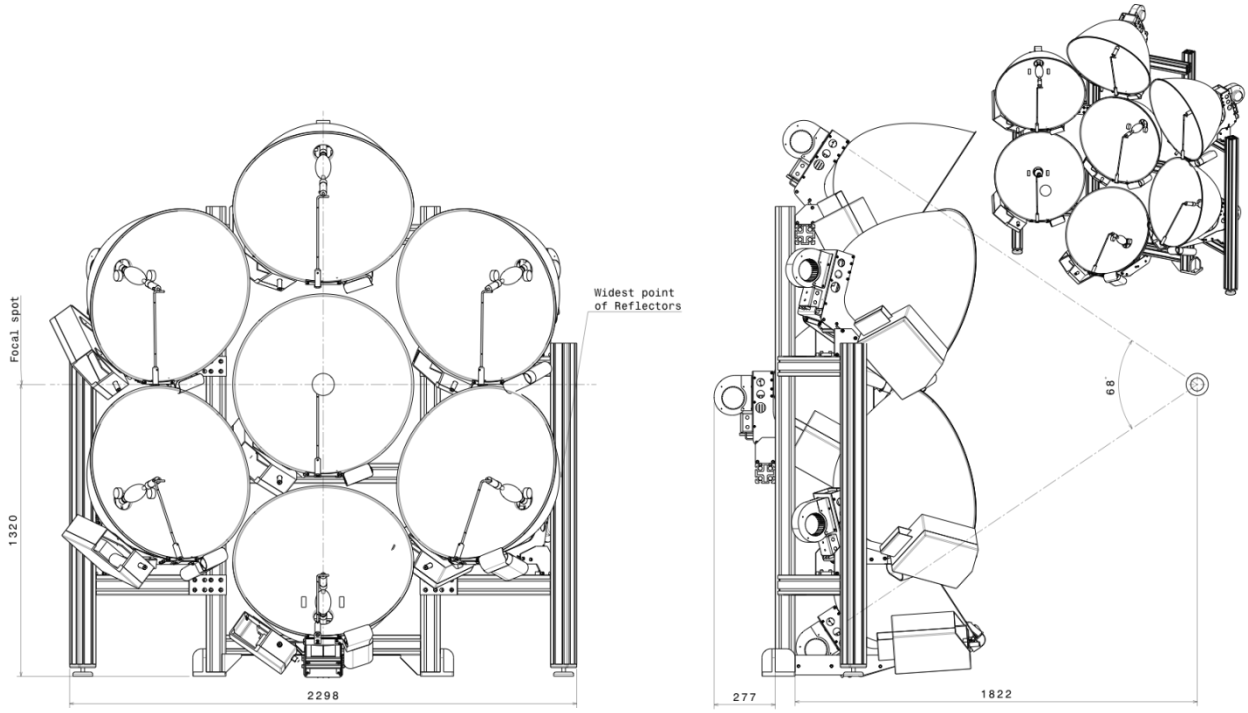
Progress Summary

Research Objectives for Current Reporting Period: The main research objective of the current report period was designing and manufacturing a high flux solar simulator for the experimental investigation of metal/metal oxide cycles at low pressures. The solar simulator must provide peak flux levels exceeding 5000 kW/ m^2 and be compatible with low pressure experimentation. Furthermore, a literature review and thermodynamic calculations were carried out to come up with a shortlist of redox pairs for further investigation.

Progress Made Toward Objectives During Reporting Period: A high flux solar simulator consisting of seven 6 kWe Xenon arc lamps (Osram XBO 6000 HSLA), each close-coupled to an ellipsoidal mirror has been modeled and designed. The mirrors are arranged in a hexagonal grid. The mirrors have a diameter of 0.8 m, a focal distance of 1.8 m, and an opening cone angle of 50°. Each Xenon arc lamp is positioned at the focal point of one mirror.

The mirrors are oriented such that their second focal points coincide in a single point. The overall cone angle of the arrangement is 52°. Monte Carlo ray tracing simulations have been carried out to predict flux levels at the common focal point. Peak fluxes exceeding 5000 kW/m^2 are predicted, this is equivalent to blackbody stagnation temperatures exceeding 3000 K.

Currently, components are being manufactured. The mirrors are spun from Aluminum sheet metal, polished, vacuum plated, and equipped with a high temperature resistant protective polymer coating to minimize degradation of the optical surface during experimentation. Each lamp-mirror assembly is equipped with a fan that provides cooling air, ensuring that the bulb temperature remains below 1000 K.



UNIVERSITY OF FLORIDA

Development of Biofuel Production Processes from Synthetic and Biomass Wastes

PI: Pratap Pullammanappallil
Students Diane Chaulic, PhD, Microbiology and Cell Science; Zhuoli Tian, PhD, Agricultural and Biological Engineering; Gayathri Ram Mohan, MS, Agricultural and Biological Engineering

Description: With the ever-increasing price of petroleum and its finite supply, it is of high priority to develop domestic sources of transportation fuel, as well as other chemicals. Ethanol is an attractive alternate fuel that is being produced from corn starch. It is necessary to target other feedstocks for biofuel production and develop processes that have a minimal environmental impact. There is considerable ongoing research on developing processes and catalysts for conversion of biomass to biofuels like ethanol (called cellulosic ethanol process). But this project addresses other feedstocks with the following objectives: 1) development of biocatalysts for the conversion of waste biodegradable poly lactic acid based plastics to ethanol and 2) development of processes that processes for the production of additional fuels like biogas, bio-oil and biochar from the waste and byproducts of a cellulosic ethanol plant for the clean up and reuse of these waste streams

Budget: $192,000

Universities: UF

External Collaborators: UCF

Progress Summary

Process development for biogasification and clean up of cellulosic ethanol stillage

- Biochemical methane potential assays were conducted on stillage obtained from the biofuels pilot plant. Stillages derived from hardwoods and sugarcane bagasse were assayed for its biochemical methane potential.
- It was found that about 5 to 7 L of methane (at STP) can be produced per liter of stillage. Typically this amount of methane can displace 25-30% of fuel consumption in a cellulosic ethanol facility.
- A continuous biogasification process design to efficiently produce methane from cellulosic ethanol stillage is being developed and tested.
- The stillage contained ammonia and phosphate which can be recovered for application as slow release fertilizer.
- The residual organic carbon along with the nitrogen and phosphorous in stillage can be captured for land application and treated effluent (water) can be recycled.

Biocatalyst development for conversion of waste PLA based plastics to ethanol

- Hydrothermolysis experiments have been conducted in which different amount of PLA (7.5%, 25%, 50% (w/w)) plastic have been inserted into a stainless steel canister in presence of water, and heated for different heating time (15 min to 720min), at different temperatures (120C and 160C) to dissolve the PLA and produce lactic acid syrup. Higher temperatures gave faster recovery of lactate. The longer the heating time, the less solid that remains in the

canister at the end of the treatment. 50% PLA content and 160C are the two parameters that give the highest recovery of lactate with approximately 7M solution recovered after 2hours of treatment. In a more recent study, only 75 min were enough to recover the same amount of soluble lactate.

- *E. coli* cells can directly grow and utilize the lactic acid syrup with no further purification necessary.

- Toxicity of the lactic acid syrup on cell growth was investigated. Results show that at least 400mM of syrup (≈4%) is necessary to observe a toxicity induced by the components of the syrup other than lactic acid itself. Lactic acid toxicity can be observed when it is present at concentration higher than 2%. No growth is observed in cultures containing 8% lactic acid that is either PLA derived or lactic acid bought from sigma in form of sodium salts.

- Ongoing work: Construction of *E.coli* mutant that can convert lactic acid to ethanol.

UNIVERSITY OF FLORIDA

Engineering Biocatalysts for Hemicelluloses Hydrolysis and Fermentation

PI: James F. Preston
Students: Changhao Bi (Ph.D.)

Project Description:

Our goal is to develop biocatalysts for the cost-effective production of fuel alcohols and chemical feedstocks from underutilized sources of renewable biomass and evolving energy crops. To reach this goal protocols for efficient saccharification of hemicellulose fractions from these resources will be developed.
Objectives are to:

1. Develop improved enzyme-mediated saccharification protocols of hemicelluloses with existing bacterial biocatalysts for production of biofuels and chemical feedstocks.
2. Develop Gram positive biocatalysts for direct conversion of hemicelluloses to biobased products.
3. Develop systems with bacterial biocatalysts for efficient bioconversion of the hemicellulose fractions of perennial energy crops (poplar, eucalyptus, switchgrass, energy cane) to targeted products.

Budget: $192,000

Universities: UF

External Collaborators: Collaborations are in various units within the University of Florida: L.O. Ingram and K.T. Shanmugam, Microbiology and Cell Science; F. Altpeter, Agronomy; G. Peter, Forest Resources and Conservation

Progress Summary

1. **Development of a bacterial biocatalyst for the complete conversion of hemicellulose hydrolysates to biobased ptoducts.**

This support allowed Changhao Bi to complete his Ph.D. and contributed to the development of a new strains of *Enterobacter asburiae* JDR-1 that efficiently converted hemicelluloses hydrolysates to either D-lactate or to ethanol. Relevant publications from this effort include:

Bi, C., X. Zhang, J.D. Rice, L.O. Ingram, J.F. Preston. 2009. Genetic engineering of *Enterobacter asburiae* strain JDR-1 for efficient D(-) lactic acid production from hemicellulose hydrolysate. Biotechnol. Lett. 31:1551-1557.
Bi, C., X. Zhang, L.O. Ingram, J.F. Preston. 2009. Genetic engineering of *Enterobacter asburiae* strain JDR-1 for efficient ethanol production from hemicellulose hydrolysates. Appl. Environ. Microbiol. 75:5743-5749.

A relevant patent application from this effort is:

U.S. Provisional Application SN 61/115, 722 UF #12617 “Biocatalyst for complete conversion of hemicellulose to biobased products”. Preston, J.F., C. Bi, and J.D. Rice. Filed 11/18/2008.

2. **Develop improved enzyme-mediated saccharification protocols of hemicelluloses with existing bacterial biocatalysts for production of biofuels and chemical feedstocks**

Endoxylanases and alpha-glucuronidases encoded by genes from mesophilic *Paenibacillus* sp. JDR-2 and the extreme thermophile *Thermotoga maritima* have been produced as recombinant enzymes in *E. coli* the provide catalysts for the efficient conversion of the xylans of hemicelluloses to ethanol using the biocatalysts *Klebsiella oxytoca* P2 and *Enterobacter asburiae* E1. Additional studies are in progress to refine the conditions to maximize the conversion of hemicelluloses from forest resources and agricultural residues to ethanol as a biofuel and D-lactate as a chemical feedstock for bioplastics.

3. **Develop Gram positive biocatalysts for direct conversion of hemicelluloses to biobased products**

The definition of the xylan-utilization regulon in *Paenibacillus* sp. JDR-2 has been further refined with the recently completed sequence of the genome of this bacterium. This has identified the combination of the transcriptional regulators, transporters and intracellular enzymes that collectively assimilate the products of extracellular depolymerization of xylans and convert these to fermentable xylose. This has provided evidence for a process in which assimilation and of metabolism of the products of depolymerization is coupled to the depolymerization process that is catalyzed by a cell-associated endoxylanase, allowing efficient and rapid conversion of xylans to fermentable xylose by single bacterial biocatalysts. The results of this discovery are the subject of a publication:

Nong. G., J.D. Rice, V. Chow, and J.F. Preston. 2009. Aldouronate utilization in *Paenibacillus* sp. JDR-2: Physiological and enzymatic evidence for coupling of extracellular depolymerization with intracellular metabolism. Appl. Environ. Microbiol. 75:4410-4418.

and also provided supporting information for a provisional patent application:

U.S. Provisional Application SN 60/982,623. UF# 12619. Xylan-Utilization Regulon for Efficient Bioprocessing of Hemicellulose and Uses Thereof. Preston, J.F., V. Chow, G. Nong, J.D. Rice, and F.J. St. John. Filed 10/22/2008.

.

UNIVERSITY OF FLORIDA

Thermophilic Biocatalysts for the Conversion of Cellulosic Substrates to Fuels and Chemicals

PI: K.T. Shanmugam
Students: Brelan Moritz (Ph. D.)

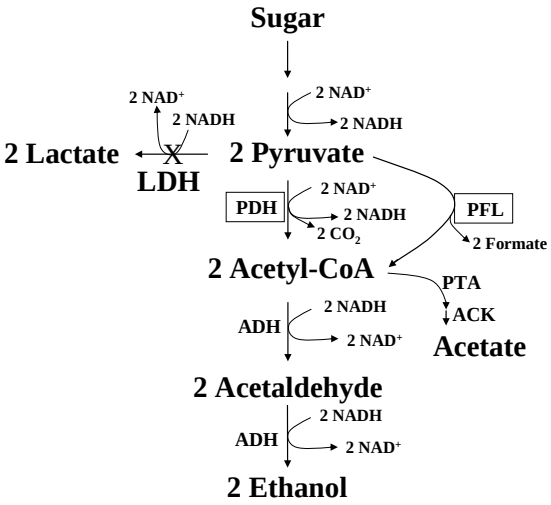
Description: Biomass is an attractive source of sugars for a state like Florida that produces very limited amount of corn for fermentation to produce ethanol as transportation fuel or other products such as lactic acid that can be converted to bioplastics. Florida currently generates about 8.7 million tons of dry cellulosic biomass per year (US-DOE) that can be converted to about 0.7 billion gallons of ethanol. With specific energy crops and short rotation trees cultivated for energy production using the abundant sunshine and water resources, the ethanol produced from biomass can be significantly increased to meet the demand for transportation fuel in the State of Florida. Before biomass-based fuels and chemicals become an economic reality, several key steps in the depolymerization of biomass to constituent sugars need to be addressed. One is depolymerization of cellulose to glucose by fungal cellulases before fermentation to ethanol by microbes. The current estimated cost of fungal cellulases is $0.32 per gallon ethanol produced and this cost is targeted for reduction to $0.10 or less by year 2012 (DOE). We have demonstrated that by increasing the temperature of Simultaneous Saccharification and Fermentation (SSF) of cellulose from 30-35 ºC to 50-55 ºC, the amount (and associated cost) of cellulases can be reduced by the required 3-fold with the current commercial enzyme preparations. A microbial biocatalyst that produces ethanol or other chemicals as the main fermentation product and can also function at this higher temperature and pH 5.0 in conjunction with the fungal cellulases in the SSF process is a critical component of this process. We have identified a thermophilic facultative anaerobe, *Bacillus coagulans*, with versatile metabolic capability as the microbial platform for the SSF of biomass to products and engineering this L(+)-lactic acid producing bacterium to produce ethanol. *The primary objective of this proposed study is to construct a B. coagulans derivative that produces ethanol as primary product of fermentation and to enhance the ethanol productivity of the engineered derivative.*

Budget: $192,000

Universities: UF

Progress Summary

As a first step towards developing thermotolerant *B. coagulans* as an ethanologenic microbial biocatalyst, activity of the primary fermentation enzyme L-lactate dehydrogenase was removed by mutation (strain Suy27). Strain Suy27 produced ethanol as the main fermentation product from glucose during growth at pH 7.0 (0.39 g ethanol per g glucose fermented). Pyruvate dehydrogenase (PDH) and alcohol dehydrogenase (ADH) acting in series contributed to about 55% of the ethanol produced by this mutant while pyruvate formate-lyase and ADH were responsible for the remainder. Due to the absence of PDH activity in *B. coagulans* during fermentative growth at pH 5.0, the *l-ldh* mutant failed to grow anaerobically at pH 5.0. Strain Suy27-13, a derivative of the *l-ldh* mutant strain Suy27, that produced PDH activity during anaerobic growth at pH 5.0 grew at this pH and also produced ethanol as the fermentation product. These results show that construction of an ethanologenic *B. coagulans* requires optimal expression of PDH activity in addition to removal of LDH activity to support growth and ethanol production.



Fermentation pathways of *B. coagulans l-ldh* mutants.
PDH, pyruvate dehydrogenase complex; ADH, alcohol dehydrogenase; PFL, pyruvate formate-lyase; PTA, phosphotransacetylase; ACK, acetate kinase; LDH, lactate dehydrogenase

B. coagulans strains Suy27 and Suy27-13 lack LDH activity and produce ethanol using the indicated pathways.

We also evaluated the potential of *B. coagulans* for production of lactic acid from non-food carbohydrates. Lactic acid is used as an additive in foods, pharmaceuticals and cosmetics as well as an industrial chemical. Optically pure lactic acid is increasingly used as a renewable bio-based product to replace petroleum-based plastics. However, current production of lactic acid depends on carbohydrate feedstocks that have alternate uses as foods. The use of non-food feedstocks by current commercial biocatalysts is limited by inefficient pathways for pentose utilization. *B. coagulans* strain 36D1 is a thermotolerant bacterium that can grow and efficiently ferment pentoses using pentose-phosphate pathway and all other sugar constituents of lignocellulosic biomass at 50°C and pH 5.0, conditions that also favor simultaneous enzymatic saccharification and fermentation (SSF) of cellulose. Using this bacterial biocatalyst, high levels (150-180 g L^{-1}) of lactic acid was produced from xylose and glucose by trapping the lactic acid as calcium salt. In a fed-batch SSF of crystalline cellulose, $CaCO_3$ addition also improved lactic acid production by *B. coagulans* with a yield of near 80% based on a final titer of about 80 g L^{-1}. These results demonstrate that *B. coagulans* can effectively ferment non-food carbohydrates from lignocellulose to L(+)-lactic acid at sufficient concentrations for commercial application.

UNIVERSITY OF FLORIDA

Integrated PV/Storage and PV/Storage/Lighting Systems

PI: Franky So **Co-PIs**: Jiangeng Xue and Shirley Meng
Students: Ming-Che (Tim) Yang (PhD), William Hammond (PhD), Sang-Hyun Eom (PhD), Cephas Small (PhD) and Fred Steffy (PhD)

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

Research Objectives for Current Reporting Period: The main research objectives for the current reporting period include have optimize the synthesis process, understand the critical role on stoichiometries of the precursors on the electrochemical properties of the proposed lithium excess manganese nickel oxide materials, and investigate the change of crystal structure during electrochemical processes and its impact on cycling stability of the high energy lithium ion cells.

Progress Made Toward Objectives During Reporting Period:
In the area of lithium ion cells, we focus on studying the effect of synthesis conditions on the electrochemical properties of $Li[Ni_xLi_{1/3-2x/3}Mn_{2/3-x/3}]O_2$. During the co-precipitation, an excess amount of $LiOH{\cdot}H_2O$ solution was used to ensure complete precipitation of the transition metal double hydroxide. Intentional surface modifications of $xLi_2MnO_3{\cdot}(1\text{-}x)LiMO_2$ (M=Mn, Ni and/or Co) can significantly improve the electrochemical performance compared to bare-surface materials. The stoichiometric materials had well defined clean crystalline surfaces as shown in Figure 1a, while the LiOH excess materials showed different surface characteristics from the bulk, see Figure 1b. We also found that the electrochemical performance of the material sintered at 1000°C shows consistently better reversible capacity compared to that synthesized at 900°C.

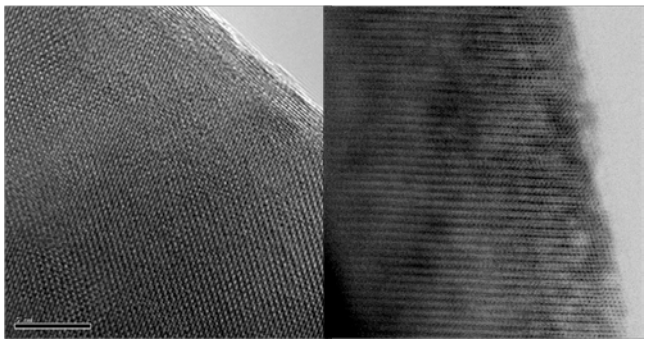


Figure 3. TEM images of a) stoichiometric b) LiOH excess $Li[Ni_{1/5}Li_{1/5}Mn_{3/5}]O_2$ synthesized at 1000°C with furnace cooling.

In the PV area, we have been studying the effect of anode interlayer on the device performance. In our previous report, we used MoO_3 as an anode interlayer to enhance charge extraction. We have recently found that the device performance can further be enhanced by inserting an electron blocker at the anode interface in addition to the MoO_3 interlayer. For MDMO-PPV cells, a 50% enhancement in power conversion efficiency was observed.

In the OLED area, we have been working on enhancing the light outcoupling efficiency in OLEDs by attaching a microlens array to the light-emitting surface of the glass substrate. The nearly close-packed hemispherical microlens array was made out of an optical adhesive using a molding process (with a concave mold of PDMS). Arrays up to 4" wafer size can be easily made. Figure 2 shows the optical microscope image of 100 μm diameter microlenses over a few mm size. The inset shows the cross-section image of a microlens under scanning electron microscope. Applying such a microlens array to an OLED leads to an enhancement of 50-70% of the overall efficiency of the OLED.

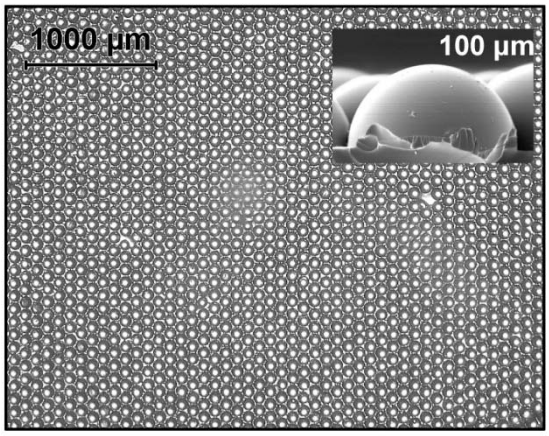


Figure 4. Optical micrograph of microlenses fabricated. The inset shows the cross-sectional SEM image.

UNIVERSITY OF FLORIDA

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

PI: Lynn E. Sollenberger
Co-PI's: John Erickson, Joao Vendramini, Robert Gilbert
Students: Arkorn Soikiew (M.S.), Chae-In Na (Ph.D.), Jeff Fedenko (M.S.)

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 seasons. The development of high yielding production systems for energy crops that can be grown in Florida is considered essential for establishment of a sustainable biomass to energy industry. This is the case because long-term availability of sufficient amounts of reasonably priced biomass will be an important determinant of if and where new biofuel and bioenergy facilities will be built. Because of its size and large number of climatic zones, there will be large regional differences in what energy crops can be used at various locations in Florida and how they will perform. In this project, we are conducting applied research at locations throughout Florida with sweet sorghum, sugarcane, energycane, giant reed, miscanthus, erianthus, and elephantgrass to provide important agronomic practice, yield, water use, and chemical composition information for Florida growers, bioenergy producers, and policy makers. This information will support decision making regarding which crops are adapted to specific environments, which are best suited to particular management practices (e.g., irrigation or none), and which have the desired chemical composition for the intended bioenergy use.

Investigators in the project include Dr. Lynn Sollenberger and Dr. John Erickson (agronomists at University of Florida), Dr. Joao Vendramini (agronomist at the Range Cattle Research and Education Center at Ona, FL), and Dr. Robert Gilbert (agronomist at the Everglades Research and Education Center at Belle Glade, FL). Graduate students involved in carrying out project research include Jeff Fedenko, Arkorn Soikiew, and Chae-In Na, all of whom started their grazduate programs in August 2009. External collaborators include Speedling, Inc., which has provided planting material of miscanthus.

Budget: $191,981

Universities: UF

External Collaborators: Speedling, Inc.

Progress Summary

Miscanthus, giant reed, erianthus, sugarcane, elephantgrass, and energycane are being compared in regional trials throughout Florida. All plots were fully established by early summer 2009. Biomass yield of the grasses was quantified at the end of the growing season in December 2009.

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 based on carbohydrate content. This ranged from approximately 80-90 gallons per ton of dry biomass for giant reed, elephantgrass, energycane and erianthus, but was 104 gal/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.

Three sweet sorghums varieties including M81, Dale, and Topper 76-6 were planted at three dates during 2009 at three locations in Florida to assess the effects of planting date and location on biomass production, sugar composition, and sugar yield. Planting occurred on 13 March, 27 May, and 12 June 2009 at Belle Glade, 31 March, 5 May, and 9 June 2009 at Citra, and 7 April, 12 May, and 16 June 2009 at Ona. Across all sites, plant crop green yields ranged from 48 to 73.2 Mg ha^{-1}, with M81-E yielding better than Topper 76-6 which yielded better than Dale. The May planting date yielded most. Ratoon crop green yields were affected by all treatments, ranging from 5 to 67 Mg ha^{-1} with greater yields generally correlating to earlier initiation of ratoon. Juice brix values ranged from 8 to 19% across all treatments, averaging 14.4 and 13.1% in the plant and ratoon crops, respectively. Brix values were about 20% lower on the muck soil location compared to the sand soil locations and about 20% lower in M81-E compared to Dale and Topper 76-6. Combining plant and ratoon harvests, this translates to estimated ETOH yields of 2350 to 6780 L ha^{-1} yr^{-1}. Our results indicated that sweet sorghum production in Florida can be competitive with corn ethanol yields in the Midwest, but understanding genotype, environment and management will all be critical to optimizing sugar yields from sweet sorghum in Florida.

Characterization of water use occurred in sweet sorghum, elephantgrass, energycane, and giant reed during summer of 2009 and will continue in 2010. Measures of plant transpiration allow for direct measurement of crop water use under real-world field conditions. These data will be combined with stem density measurements, leaf area index measurements, and/or stem basal diameter measurements to calculate water use by each plot. These daily measurements will be integrated with climate data (measured at the site) to calculate seasonal water use by each crop. Thus, we will be able to directly compare crop water use during the growing season which will assist producers in selecting crops that are most sustainable for Florida. In addition, we will be able to couple seasonal crop water use data with yield data (e.g., biomass, lignocellulose and/or simple sugars) to estimate ethanol produced per unit of water used by the crop during production. Results from 2009 indicate that energycane and elephantgrass produce more biomass per unit of water than does giant reed.

The projects described above have been initiated for a second year in 2010 at all locations. Feedstock composition of samples collected in 2009 is currently being analyzed and will be available for presentation in the next several months.

UNIVERSITY OF FLORIDA

Biocatalytic Lignin Modification for Carbon Sequestration

PI: Jon Stewart

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. He has 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 addition, by adding catechol functionalities to the aromatic rings of lignin, the materials will form highly stable complexes with iron that may enhance sequestration significantly.

UNIVERSITY OF FLORIDA

An Integrated Sustainable Transportation System

PI: Eric Wachsman **Co-PI:** Shirley Meng
Students: Dong Jo Oh (PhD), Eric Armstrong (PhD), Kang Taek Lee (PhD), Byung Wook Lee (PhD), Nick Vito (PhD), and Christopher R. Fell (PhD)

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

Anode Supported Cell Development

For high performance SOFCs at lower temperature operation, a simple method was developed to dramatically improve anode functional layer (AFL) performance by dispersion of nano-precursors into a conventional colloidally-deposited AFL. (Fig 1) The composition used for the anode substrate, the colloidal AFL, and the nano-precursor integrated into the AFL was Ni and Gd-doped ceria (GDC). The electrolyte composition was GDC, a system that has received much attention for its potential use for IT-SOFCs. The novel AFL exhibited over 1.3 W/cm^2 at 650 °C—a 107% increase in maximum power density compared a similar cell with no AFL and a 26% increase for a cell with a colloidal AFL. (Fig 2) This AFL can be applied on various anode-supported SOFCs, such as the ESB/GDC bilayered electrolyte cell. Due to the simple fabrication procedure, this AFL can be easily applied to large planar cells for stack cell fabrication.

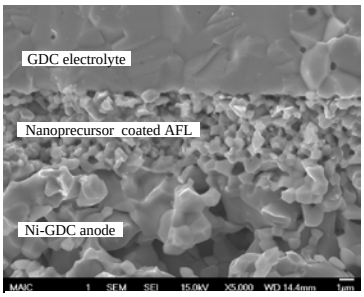


Figure 1. SEM image of cross sectional SOFC structure with novel AFL.

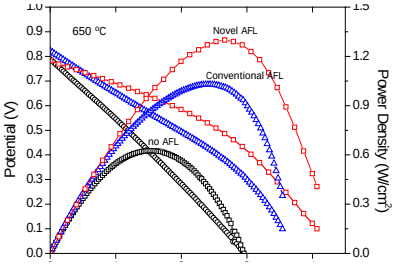


Figure 2. Performance of novel AFL compared to colloidal AFL and no AFL at 650 °C (30 sccm of H_2/Air.

Further studies are being done to optimize performance in relation to microsturcture and AFL composition using a dual beam focus ion beam / scanning electron microscope (FIB/SEM). Initial results show that a NiO to GDC ratio of 6 to 4 yields the highest triple phase boundary density of ~10 / μm^2 along with the highest maximum power density in the study. A 3D reconstruction of the anode and colloidal AFL are shown side by side in figure 3.

Cathode Development

A high performance cathode was developed with one of the lowest reported area specific resistances (ASR) ever reported, especially

at the low temperature range of 500 – 600 °C. The cathode is a composite composed of stabilized bismuth oxide as an ionic conductor and nano-sized high-temperature pyrochlore bismuth ruthenate as an electronic conductor. The nano-sized bismuth ruthenate was successfully synthesized for the first time using the glycine-nitrate combustion (GNC) method, enabling a further decrease in activation polarization losses by expanding specific surface area for oxygen reduction.

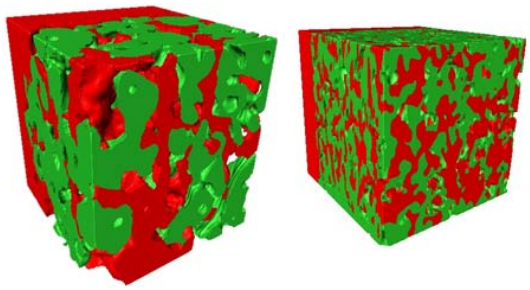


Figure 3. Bulk anode (left) and colloidal AFL (right) reconstructions—GDC (red) and Ni (green)

Initial results also show a unique behavior in the 500 – 600 °C temperature range where resistance decreases with decreasing temperature, supposedly related to metallic behavior from the coating of bismuth ruthenate nanoparticles. (Fig 4) Other synthesis methods such as amorphous citrate, Pechini type, and polymerized complex methods failed to create high purity bismuth ruthenate nanoparticles due to the lower synthesis temperature and longer reaction time.

Energy storage in the integrated sustainable transportation system

$LiMn_2O_4$ spinel material is an attractive compound as a cathode material in lithium-ion batteries, due to its economical and environment advantages over $LiCoO_2$. However, $LiMn_2O_4$ tends to exhibit capacity fade in the 4V region, particularly at elevated temperatures. Factors such as manganese dissolution into the electrolyte and development of micro-strain during cycling have been suggested to be the main sources of capacity fade. The poor cycling performance could be improved by partial substitution of manganese with other metals, an approach of making the $LiM_xMn_{2-X}O_4$ (M = Co, Mg, Cr, Ni, Fe, Al, Ti, Cu, Zn etc.) electrode materials. It has been found a high voltage plateau that can be achieved in spinel materials accompanies the transition metal doping. Among all $LiM_xMn_{2-X}O_4$ materials, $LiNi_{0.5}Mn_{1.5}O_4$ is an attractive high voltage cathode material since it offers a flat voltage plateau at 4.7 V and demonstrates a reversible capacity >135mAh/g. First principles computation based on density functional theory (DFT) is used to examine the voltage profile and electronic structures of the $LiM_xMn_{2-x}O_4$ (M =, Cr, Fe, Co, Ni, Cu,).The Li diffusion activation barriers in each material are also calculated and compared. The computation results suggest that $LiM_{1/2}Mn_{3/2}O_4$ spinel can have quite different activation barrier for Li diffusion depending on the doping elements, and doping with Cu and/or Co can potentially lower Li diffusion barrier compared with Ni doping. Our experimental research was focused on $LiNi_xCu_yMn_{2-x-y}O_4$ ($0<x<0.5$, $0<y<0.5$). Previous studies show that the Cu-rich spinel electrodes are significantly more stable during electrochemical cycling than the Ni-rich electrodes. The $LiNi_xCu_yMn_{2-x-y}O_4$ oxide materials have the potential to achieve high rate, high voltage, high discharge capacity and excellent cycling performance. In order to systematically study the composition, crystal structure, electronic structure and electrochemical property relations of the spinel oxide, $LiNi_xCu_yMn_{2-x-y}O_4$ ($0<x<0.5$, $0<y<0.5$) are experimentally synthesized by sol-gel method. We have found that the amount of Cu will affect the lattice parameters, the cation disorder in the spinel lattice, the particle morphology and electrochemical properties. Although the reversible discharge capacity decreases with increasing Cu amount, optimized materials such as $LiCu_{0.25}Ni_{0.25}Mn_{1.5}O_4$ exhibits high capacities at high rates. (See Figure 4.)

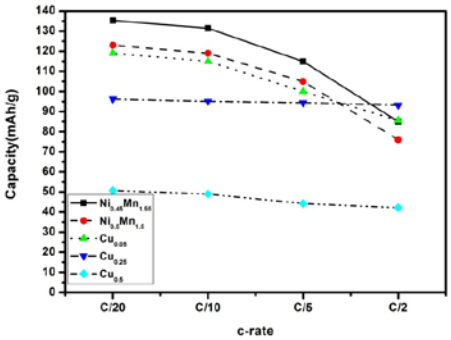


Figure 4: Rate Capability of $LiNi_xCu_yMn_{2-x-y}O_4$

FESC
Florida Energy Systems Consortium

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), Ehsan Salimi (Ph. D. Student). Industrial and Management Systems Engineering Department

Description: The objectives of the proposed research are to 1) develop a comprehensive generation technology based portfolio optimization (GTPO) model and its solution algorithm, and 2) 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 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: $92,442
Universities: USF
External Collaborators: Argonne National Lab

Progress Summary

Summary of Progress: Our team, in collaboration with Argonne National Lab and Iowa State University, submitted a NSF proposal for $400,000 this past February. The title of the proposal is "Impact Analysis of Alternative CO_2 Emissions Control Schemes on Future Power Generation" and its main objectives are: 1) Build a modeling framework to assess the impact of CO_2 cap-and-trade and carbon tax programs on future generation expansion. 2) Develop a computational solution methodology for the model. 3) Analyze and compare the impact of alternative CO_2 cap-and-trade and carbon tax programs on emissions reductions and social welfare. 4) Build a test bed using Illinois electricity market data and assess the impact of cap-and-trade and carbon tax programs. 5) Train a cadre of graduate and undergraduate students, especially from underrepresented minority groups, and develops support programs for science education of K-12 teachers.

Progress Made Toward Objectives During Reporting Period: Additionally, we are about to submit a paper to the European Journal of Operations Research titled Generation Capacity Expansion in Restructured Power Markets under a CO_2 Cap-and-Trade Program. In the paper, we present a game-theoretic capacity expansion model and its solution algorithm to obtain equilibrium capacity expansion plans for a number of generators under different CO_2 cap-and-trade designs. The game theoretic model is applied to a sample network constructed based on the power market conditions of the state of Illinois. This work was presented at the past INFORMS Conference in San Diego on October 2009.

The team is also working on developing an optimization model to obtain redistribution (recycling) strategies for the revenue collected from emissions control schemes. We currently have a preliminary formulation, a quadratic non-convex optimization model, and its corresponding solution. This work was one of the recipients of the 2009 College of Engineering Research Week Poster Award. We are planning to present this work at the upcoming INFORMS Conference 2010.

Last but not least, we have started to work on developing a model to obtain an optimal cap-and-trade program design for a given power network and given emissions reductions targets. This work is in the literature review phase.

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, USF
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

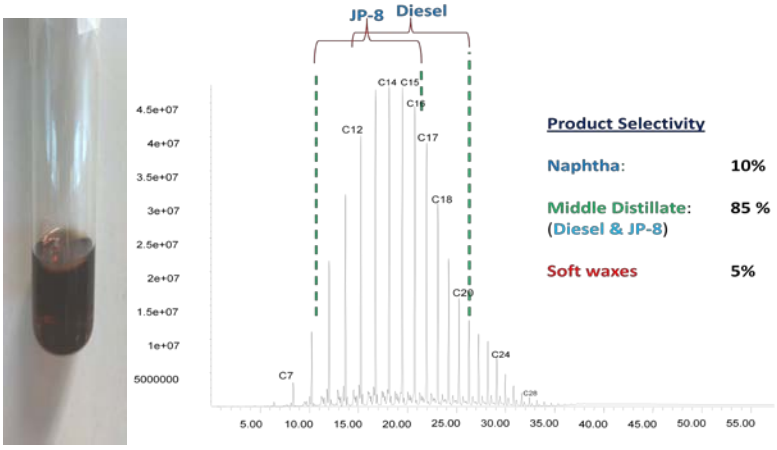
External Collaborators: Prado & Associates

Progress Summary

During the past six months, we made progress on four fronts: Biomass conversion process design, Reactor testing for synthesis of liquid fuels from bio syngas, catalyst synthesis and catalyst testing.

In the area of process design, we have been evaluating alternative strategies to combine the energy intensive biomass gasification step with the energy producing Fisher-Tropsch synthesis of clean liquid fuels from syngas produced in the gasification step. We are exploring ways of recycling energy by using the methane off gas produced in the FTS to fuel the steam pyrolysis of biomass. Another avenue we are exploring is a novel strategy to combine solar thermal powered steam pyrolysis with the syngas production step.

We successfully tested egg-shell catalysts in our fixed bed reactor setup using both mixtures of CO and H2 as well as Biosyngas produced from poplar wood. The product liquid produced have been analyzed and report good yield in the diesel and jet fuel range. The figure below shows sample of fuel made and its chemical composition.



We also continue with our catalyst characterization process. We are continuing to study the mechanisms of CO dissociation on the catalyst surface using density functional theory calculations. Current focus of this effort is on the effect of catalyst nanoparticle size on the adsorption and dissociation energies.

Catalyst synthesis efforts continue. We have successfully synthesized cobalt nanoparticles and placed them on silica Microparticles. These are currently being characterized and tested for activity.

Our DFT study focuses on the influence of cobalt particle size on CO adsorption and the effect of platinum promoter on the reduction of cobalt in a CoPt bimetallic catalyst. Cobalt catalysts exhibit particle size dependent activity. CO adsorption was studied, as it is the rate-limiting step in Fischer-Tropsch reaction. Studies on the effect of cobalt particle size on CO adsorption showed particle size dependence. Facets cut from a model icosahedral nanocluster was used for this purpose and two different adsorption sites, face centered cubic (fcc) and hexagonal closed packed (hcp) sites were explored depending on the size of the cluster. Back-donation of electrons from cobalt to carbon atoms was observed along with the weakening of CO bond length.

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, USF; **Co-PI's:** Chris Ferekides, USF, Lee Stefanakos, USF, Tim Anderson, UF, Neelkanth Dhere, FSEC
Students: Currently one Ph.D. and two MS Electrical Engineering students are being supported by the project

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

External Collaborators: NovaRay Solar, Bedford, MA; Brightwats, Inc., Ft. Lauderdale, FL; US Department of Energy, National Renewable Energy Lab

Progress Summary

Thin Film Pilot Line

The base upgrade build-out of the lab facility has been completed. Of greatest significance is the installation of electrical power to handle the power demands of the processing equipment. The air supply and exhaust systems were upgraded to allow installation of two large walk in hoods, and provisions for a third hood have been included in the ducting. An overhead raceway has been installed to accommodate distribution of the utility services to the processing equipment. Lab specific upgrades are still underway. These include compressed air, distilled water and chilled water supplies. The primary pace setter is the chilled water unit. It is on order and delivery is expected shortly. The plumbing and wiring for the unit have been installed. Once the unit is received it will be installed and the lab upgrade by the outside contractor will be completed. This should occur before the end of June.

The central processing unit for CIGS has been designed. Further progress in building the unit is awaiting completion of a partnership agreement with a local company. Once the agreement is signed we will work with the company to refine the design to include vacuum processing capabilities that they will contribute to the partnership. We are nearing the last stages of negotiating the partnership agreement and expect sign-off to also occur by June.

Lab Scale Experiments

In designing a large area processing unit one of the primary concerns is the efficient use of raw materials. In this regard In and Ga are a particular concern for CIGS because of potential price increases as manufacturing gets scaled up to Gigawatt levels. To address this concern we have been conducting lab scale experiments to help guide our design of the large processing unit. Another concern that we are addressing is Se utilization. While it is not nearly as expensive as In and Ga, as shown in the figure, to incorporate the needed 50 atomic per cent Se in the growing film can require Se flux levels in large multiples of the metal flux. This is not only wasteful, but also results in rapid buildup of condensed Se in the processing unit requiring frequent cleaning which will limit uptime in a production environment. The experiments that we are conducting are aimed at understanding and controlling the Se incorporation mechanism so that better management of Se can be designed into the processing unit. Similar experiments directed toward optimizing use of In and Ga are also under way.

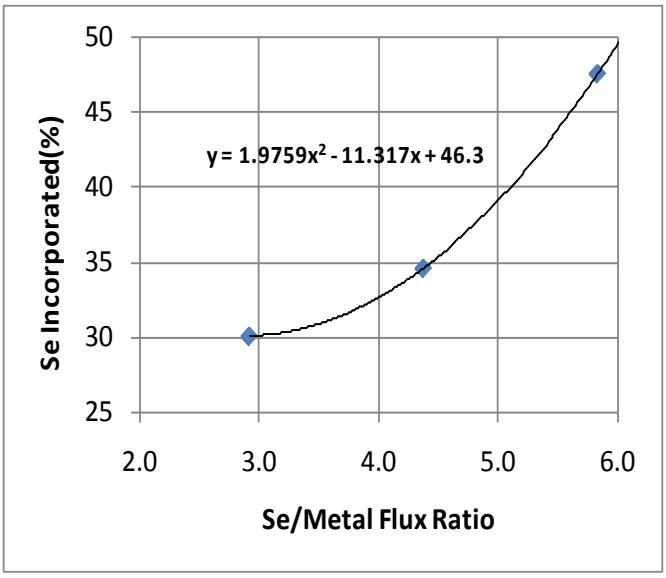


FIGURE 5. SE INCORPORATION AS A FUNCTION OF THE SE TO METAL FLUX RATIO IN A GROWING CIGS FILM.

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: Calnetix Power Solutions

Progress Summary

Summary of Progress: 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.

Progress Made Toward Objectives During Reporting Period: 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 Tampa is shown in Fig. 1. The annual average for this location 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 solar field layout proposed for 50 kW$_e$ is shown is Fig. 2. The Soponova 4.0 (Sopogy Inc.) 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.

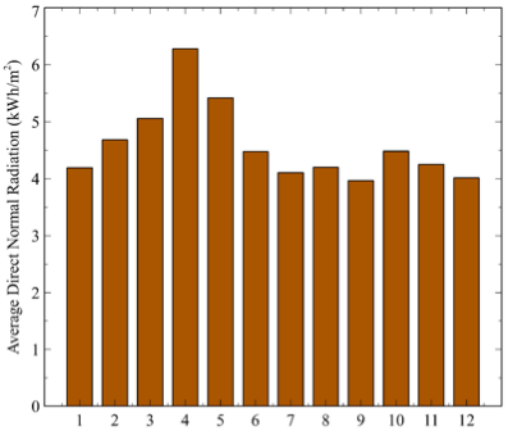


FIGURE 1: DIRECT NORMAL RADIATION FOR TAMPA

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 120 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.

Research activities for the next reporting period will focus on the modeling of heat transfer losses through the solar receiver and field piping, pressure drops pumping requirement and thermal energy storage system design.

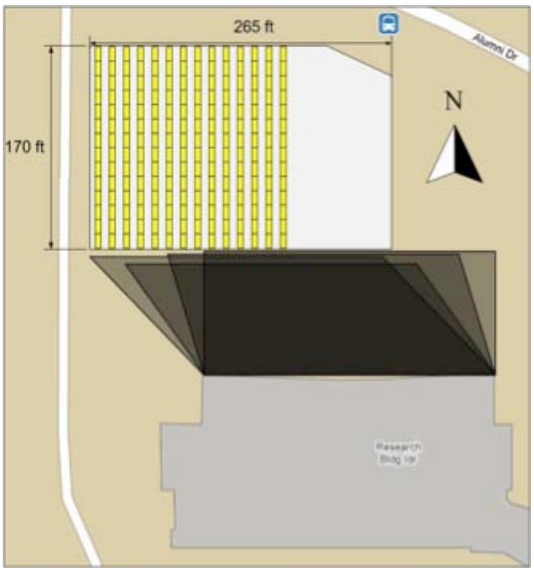


FIGURE 2: SOLAR FIELD LAYOUT

UNIVERSITY OF SOUTH FLORIDA

Beyond Photovoltaics: Productionizing of Rectenna Technology for Conversion of Solar Radiation to Electrical Energy

PI: S. Bhansali, USF; **Co-PI's:** L. Stefanakos, Y.Goswami, Subramanian Krishnan, USF
Students: Justin Boone (Ph.D.), Rudran Ratnadurai (Ph.D.)
Michael Celestin (Ph.D.), Samantha Wijewardane (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: Sandia National Laboratory

Progress Summary

Summary of Progress: The main research objectives for the current reporting period include development of a MIM tunnel junction based on self-assembled monolayers (SAM), testing and characterizing of the solid-state insulator layer, and design/optimization of novel dipole fed slot antenna.

Progress Made Toward Objectives During Reporting Period: High frequency MIM junctions have been typically developed using solid-state materials. In this research task, MIM junctions have been developed with SAM films. Several alkanethiols were procured and a thiol with smallest chain length was used for junction development. Specifically, 1-dodecanethiol (DDT) was used as the organic dielectric. The devices have been fabricated on a silicon substrate through photolithography and E-beam lithography (EBL). Fig. 1 shows the schematic of the SAM MIM junction design. Initially, a ground plane metal (gold) was deposited and patterned to form the bottom electrode as well as the contact pad for electrical testing. Then a window was patterned using EBL to deposit the thiol. A 1 mM solution of 1-Dodecanethiol was created in ethanol and the sample was immersion coated in the pre-opened window. A metal layer was deposited on top of the SAM layer to form a MIM structure.

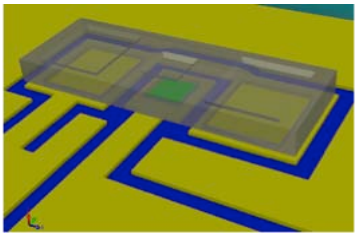


Figure 1: A schematic of the SAM MIM design

Fig. 2 shows an optical micrograph of the fabricated SAM array. The device will be developed for IR detection in collaboration with Sandia National Laboratories.

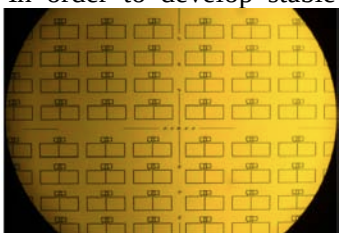


Figure 2: Rectifier array fabricated on silicon substrate

In order to develop stable MIM junctions with inorganic dielectric, the nickel oxide dielectric was characterized by varying the oxygen content during the deposition process. The dielectric layer deposited with low oxygen (1:3 O_2:Ar) content yielded a smoother film. However, the phase of the crystal structure was modified. It was also determined that the devices fabricated with 1:1 O_2:Ar ratio yielded a higher tunneling current of the order of 10^{-4}A. However, these devices were unstable over a period. Upon further analysis, Nickel oxide deposited with 1:2 O_2:Ar ratio was determined to be the most stable dielectric suited for the MIM fabrication. Later, the NiO samples were subjected to annealing to determine the charge dissipation. NiO was annealed at temperature of 900°C for 3 different soak intervals 30s, 1min & 1min 30s. When compared to un-annealed samples, the annealed samples showed conduction at a faster rate due to the increased crystallinity of the films. Furthermore, to improve the reliability of the tunnel junctions the sidewall of the bottom electrodes were passivated using a thick SiO_2 layer. This increased the breakdown voltage of the tunnel junction. Fig. 3 shows the schematic of the MIM junction with a passivation layer.

Previously a 94 GHz slot antenna was designed and fabricated. In order to develop a THz antenna, design and simulation needs to be performed using HFSS. As a preliminary step, the 94 GHz antenna was optimized to be coupled with a dipole fed slot configuration. The return loss of the antenna was determined to be -36dB as shown in Fig 4. Research activities for the next reporting period will focus on making extensive measurements on the SAM based as well as the inorganic MIM junction and scale-up the operating frequency of the device. The antenna structure will also be scaled and fabricated to operate at 1 THz.

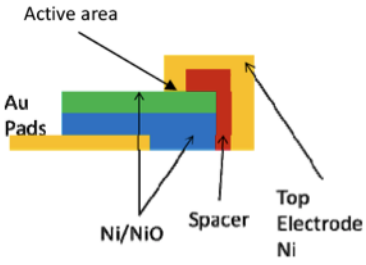


Figure 3: A schematic of the MIM with passivation layer

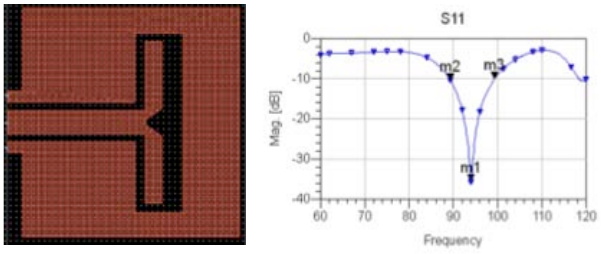


Figure 4: A schematic of the dipole antenna and return loss at 94 GHz

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)

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 Zero Energy Home Learning Center [ZEHLC] 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

External Collaborators: FSU, UF, UCF

Progress Summary

Research Objectives for Current Reporting Period: Our research objective for this reporting period were to develop proposals for innovations and improvements in ZEH technology; build and test full scale mock-ups of ZEH Technologies intended for use in the ZEHLC; assemble a package of ZEH strategies for the design and construction of the ZEHLC with an interdisciplinary team; Schematic design of the ZEHLC.

Progress Made Toward Objectives During Reporting Period: Based on our research from the first year and together with engineers from USF, FSU and the Florida Solar Energy Center, construction and interior design experts from UF, and industry partners we looked at architectural and engineering innovations that can improve on current ZEH technology and construction practices. The closed nature of recent Florida houses and early attempts at ZEH was identified as a challenge. Contemporary houses can significantly reduce their annual energy consumption by incorporating the passive solar strategies that were commonly used in Florida homes before the advent of air conditioning.

Our proposal is to design a building envelope that is well sealed and insulated and that can be opened during the cooler/dryer months of the year and closed when temperature and humidity levels are too high to achieve an acceptable comfort range in the house. Furthermore, studies at FSEC have shown that the majority of heat gain comes through the roof of Florida homes and attic spaces reach extremely high temperatures. We propose the use of a shading device that covers the entire roof and east and west walls to significantly reduce or eliminate direct solar radiation coming in contact with the building envelope. The ventilated space between the shading device and the house would prevent the buildup of hot air that commonly occurs in the attic space of Florida houses. According to a life cycle assessment of energy use, we propose a modular factory built house to minimize construction waste and maximize efficiency in labor and energy used during the construction process. Innovations in mechanical systems include an innovative liquid desiccant system for controlling humidity levels and reducing latent heat load; a solar thermal system that takes advantage of a high thermal conversion of solar radiation and uses it for a variety of energy end uses; a heat pump tied to the solar thermal system to increase efficiency in both systems.

We built 3- 8'x8' test modules using structural insulated panels to monitor relative temperature fluctuations with different building envelope treatments. One module is a control case with no additional treatment of the envelope. The second module has a 3/4" ventilated airspace on the exterior skin of the roof and walls of the module. The third module has a shading device covering the roof and east and west walls of the module. The 3 modules will be monitored under identical conditions simultaneously with a Campbell Scientific PS100 Data logger and 3 temperature and relative humidity sensors attached. Results of this test will help us decide on the most efficient and economical configuration of the building envelope.

Together with an interdisciplinary team we applied our research from the first 11/2 years of the grant period to a design concept. To maximize industry involvement in our project, and media exposure to our team's research efforts, we began the application process to the 2011 Solar Decathlon in the early fall of 2009 and learned of "Team Florida's" acceptance in April of 2010. Advertising opportunities encourage many companies to sponsor teams in the Solar Decathlon and we feel that entering the ZEHLC in this competition will be beneficial to our efforts at securing industry support for the ZEHLC.

Activities for the next reporting period are developing the ZEHLC design, creating a set of construction documents, building the ZEHLC in the factory of our industry partner Palm Harbor Homes and monitoring the building for energy performance.

UNIVERSITY OF SOUTH FLORIDA

Energy Delivery Infrastructures

PI: Alex Domijan, USF; **Co-PI:** Arif Islam, USF
Students: Adedamola Omole (PhD), Mujahidul Islam (PhD), Bhavya Siddalingaiah, Nenad Damnjanovic

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 represent dynamic and transient behaviors of microgrids. We use test beds to study integrated systems of revolutionary distributed green generation, improved grid and home efficiency, and automated energy conservation technologies for residential, substation, and distribution scale energy systems.

Budget: $485,184

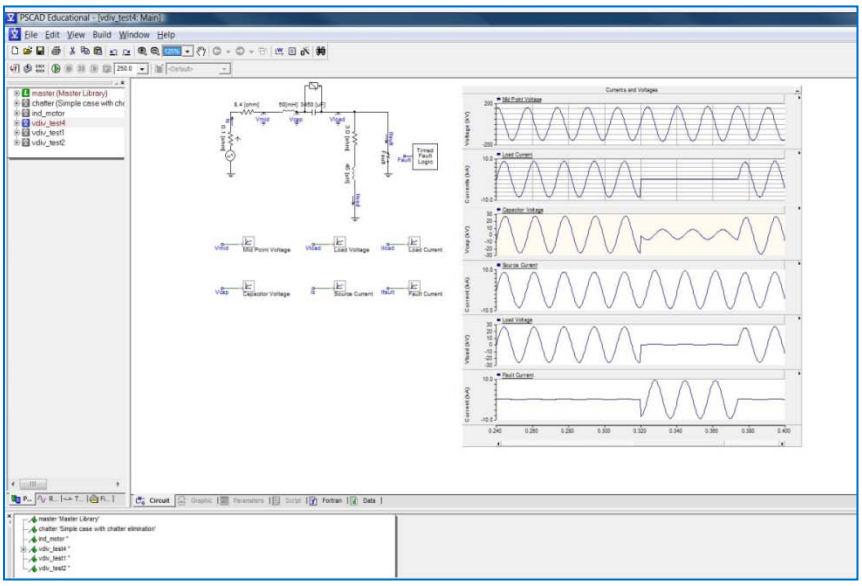
Universities: USF

External Collaborators: N/A

Progress Summary

An important aspect of a microgrid is to find a suitable control strategy that will take advantage of the inherent scalability and robustness benefits of distributed energy. This gives an opportunity to investigate how existing tools can be applied to properly represent dynamic and transient behaviors of microgrids. We have completed identifying simulation tools and different software's which will be useful for analysis of microgrids.

We have collected various parameters to the simulation tool.



We have performed testing and trail of various network models, generator models, transmission and cable models, load models. Implemented the EDSA and the Simulink software were used to analyze the system and have been validated. The control system for a micro grid embedded grid is modeled here. With the implementation of a controller, the microgrid system is able to switch between islanding and grid-connected modes without disturbing the critical loads connected to it.

One of the main challenges was obtaining a more detailed model network and components; this will be useful to investigate the dynamic response of renewable generation sources. As most of the renewable energy resources are intermittent in nature like the sun which is available to us during sunlight and wind only during strong currents; this gives a more challenging platform to analyze the behavior of renewable energy resources with the grid. The control system will be better observed in more detailed source and load models.

FESC
Florida Energy Systems Consortium

UNIVERSITY OF SOUTH FLORIDA

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

PI: Mark Stewart, USF; **Co-PI's:** Jeffrey Cunningham, Maya Trotz, Yogi Goswami
Students: Shadab Anwar (Post-doctoral scholar) Drupatie Latchman (MS, Chemical & Biomedical Engineering), Mark Thomas, MSEV, Civil and Environmental Engineering, Arlin Briley, MEVE, Civil and Environmental Engineering, Tina Roberts-Ashby, Ph.D., Geology, Drupatie Latchman, MSChE, Chemical and Biomedical Engineering

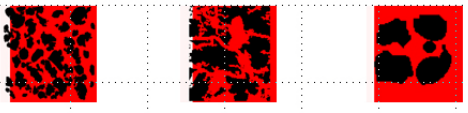
Description: Rising concerns over increasing levels of green house gases, especially carbon dioxide, have led to suggestions to capture carbon dioxide at fixed sources, such as fossil fuel power plants, and sequester the carbon for millennia by injecting it underground. Florida overlies many thousands 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: $479,640
Universities: USF
External Collaborators: TECO; USGS; Environmental Consulting & Technology, Inc.

Progress Summary

Summary of Progress: Physical and Geochemical processes at multiple scales are yet to be understand for the mitigation of Carbon concentration in the atmosphere by capture and storage of CO2 in aquifers. The pores in the potential aquifers for CO2 storage are most likely filled with saline water (brine aquifers) or oil, and gas (depleted hydrocarbon reservoirs). There are some major questions, which need to be answered before the deployment of any sequestration project. How much CO2 a potential aquifer can hold? How long it can hold? What will happen to the surrounding porous media after injection of CO2 in the saline aquifer? How much and how far CO2 will rise by buoyancy? How much will be trapped by viscous-fingering? The linkage of flow and geochemical models investigated these questions. Lattice Boltzmann method (LBM) is a recently developed numerical tool for the pore-scale modeling of single/multi-phase, miscible/immiscible fluid mixtures in complex geometry as observed in porous media. The pore scale flow model combined with geochemical models can predict the precipitation or dissolution of porous media, which can be a potential cause for the clogging of injection wells or development of new fractures/pores in the aquifer that can lead to leakage of CO2 back into the atmosphere.

How much minerals dissolve or precipitate?



Minerals/CO_2	Case1	Case2	Case3
Calcite (L/L of aquifer)	-1.133E-04	-1.23E-06	-1.3E-04
Dolomite (L/L of aquifer)	-7.1E-06	-7.7E-08	-8.29E-06
Gypsum (L/L of aquifer)	8.2E-05	9.E-07	9.6E-05
CO_2 dissolved (L/L of aquifer)	0.0257	0.00028	0.03

Graphical Processing Units (GPU's) are used to meet the high-performance-computing requirement for the modeling project. Geochemical reaction models were evaluated for their sensitivity under saline conditions as well as the availability of thermodynamic data applicable to reaction conditions. Various calcite, dolomite and gypsum configurations were evaluated for changes in solubility, amount of CO2 dissolved, and porosity.

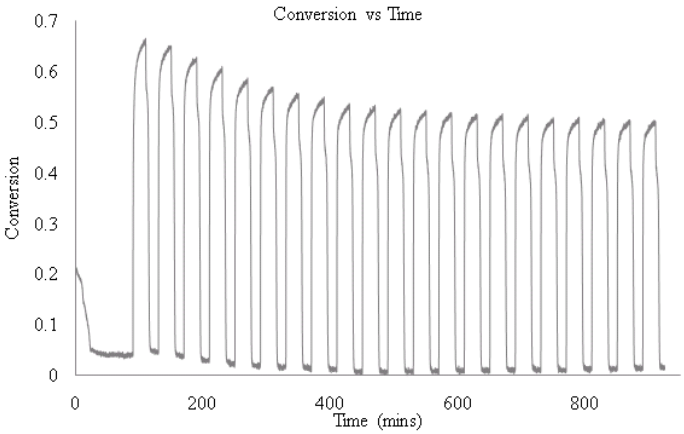


Figure 1: Conversion Cycles for Calcium-magnesium Carbonate Sorbent

Another goal of this research is to develop a sorbent that will effectively and inexpensively capture carbon dioxide from power plant flue gas. Current efforts include investigating the metal oxide to develop a sorbent with a better conversion stability and higher conversion rate. This was done by applying calcium-magnesium carbonate mixture to alumina fabric and conditioning it for 12 hours. Results show that the conversion becomes stable at 50% for a sorbent that has been conditioned for 12 hours as seen in Fig.1. At first carbonation/calcination cycles, the sorbent has a conversion higher than 60%, however has cycling continues the sorbent degrades and stabilizes at 50% after 21 cycles. Future investigations aim at increasing the conversion by changing the conditioning parameters, for example, conditioning time and weight of calcium- magnesium oxide deposited on the alumina fabric.

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: M Mohammad Abutayeh (Ph.D), O. Kofi Dalrymple (Ph.D)

Description: The availability of fresh water is a big problem facing Florida. In many locations, Florida's water is contaminated from leaky underground tanks and agricultural pesticides. Although salt-water desalination is possible, conventional systems are too energy intensive. Solar energy can supply the power, and innovative vacuum and humidification/dehumidification desalination systems can provide adequate fresh water for the state's needs. This team will develop water desalination for small community needs and also in bulk. Another goal is to develop photocatalytic disinfection to remove contaminants and integrate these technologies with solar PV for complete water supply systems. Projects include: Natural Vacuum Solar Flash Desalination: Creating vacuum conditions above liquids increase their evaporation rates. This phenomenon can be integrated into a practical continuous desalination process by repeatedly flashing seawater in vacuumed chambers to produce water vapor that will be condensed producing fresh water. Solar PV Assisted Photocatalysis for Air/Water Disinfection: Improving titanium dioxide photocatalysts for purification and disinfection of water and air contaminated with organic, heavy metal and microbiological species, using solar energy. This can be integrated into a practical continuous desalination process by flashing seawater in vacuum chambers to produce water vapor that will be condensed, producing fresh water.

Budget: $326,756
Universities: USF
External Collaborators: NA

Project Summary

Natural Vacuum Solar Flash Desalination: A flash desalination process sustainable by the natural forces of solar radiation and gravity has been proposed. Experimental and theoretical simulations of the proposed desalination process have been carried out. The process includes a start–up procedure and a continuous operation consisting of pumping seawater through a solar heater before flashing it under vacuum in an elevated chamber. The vacuum is passively created and subsequently maintained by the hydrostatic balance between the pressure inside the elevated flash chamber and the outdoor atmospheric pressure. Theoretical simulations were performed using a computer code comprising the fundamental physical and thermodynamic laws plus numerous correlations and parameters. Experimental and theoretical simulations were run at varying operating conditions but at analogous circumstances and their results were compared and analyzed to validate the developed model. The feasibility of the proposed system rapidly increased with flash temperature due to increased fresh water production and improved heat recovery.

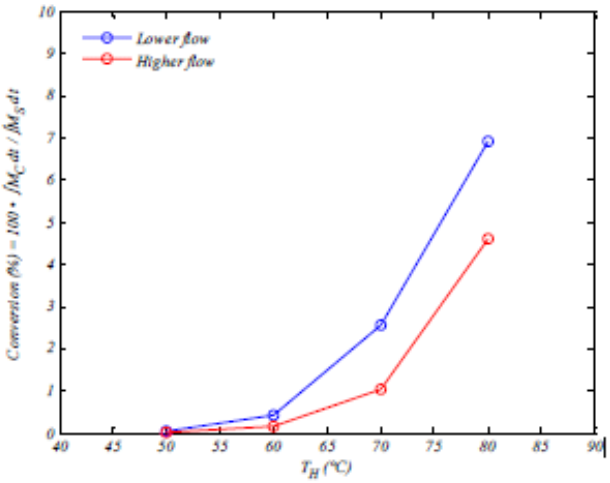


Figure 1. Seawater conversion dependence on flash temperature

The results suggest that the proposed process becomes more feasible if operated at higher temperatures and more moderate flow rates. It was found that that most fresh water production occurs in the beginning of the operation, where vacuum pressure is lowest.

Solar PV Assisted Photocatalysis for Air/Water Disinfection: 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 that are not applicable to photocatalysis. Therefore, the major goal of this research focus 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. The progress achieved in the current reporting period is as follows:

Model Development

- We have developed a theoretical model for disinfection of microorganisms for slurry and immobilized catalyst systems.
- The theoretical model and a thorough review have been accepted for publication in a high-impact-factor journal, the Journal of Applied Catalysis B: Environmental.

Bench-scale Experiments

- A series of bench-scale experiments have been conducted to test the following which feeds directly into the model:
  - The influence and physiological significance of cell membrane fatty acids in the disinfection process
  - The influence of light intensity of disinfection
  - The influence of catalyst concentration on disinfection
  - The difference in disinfection kinetics for slurry and immobilized catalyst systems