FLORIDA STATE UNIVERSITY

Real-Time Power Quality Study For Sustainable Energy Systems

PI: Dr. U. Meyer-Baese, **Co-PIs:** Helen LI, Simon Foo, Anke Meyer-Baese, Juan Ordonez
Students Supported: Jinglin Xu (Ph.D.), Indranil Bhattacharya (Ph.D.), Zhichao Wu (Ph.D.), Liming Liu (Ph.D.)

Description: The main objective of this project is the collection of preliminary data for IESES proposals that can be used to seek local, national and international sources of external funding from private and government sponsors. The overall project has been split up in several independent subprojects to allow a timely completion of the tasks. All tasks have been completed successfully.

Budget: $15,000
University: FSU

Progress Summary

A large amount of data ranging from photovoltaic, PWM, fuel cell to custom microprocessor design has been collected during the time of the award and will enable the Principal Investigators to submit proposals in these areas. The team produced seven refereed conference papers, one journal paper, and one book has been published with IESES support.

Proposals submitted:

Faculty	University	Source	Project Title	Date Submitted	Amount
S. Foo	FSU	CRC	Developing Super-High-Efficiency Multijunction Photovoltaics for Solar Energy Harvesting	Fall 2009	$15000

FLORIDA STATE UNIVERSITY

Sustainably Integrated Advanced Building Subsystems (OGZEB)

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

Students supported: Shannon Ingersoll

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

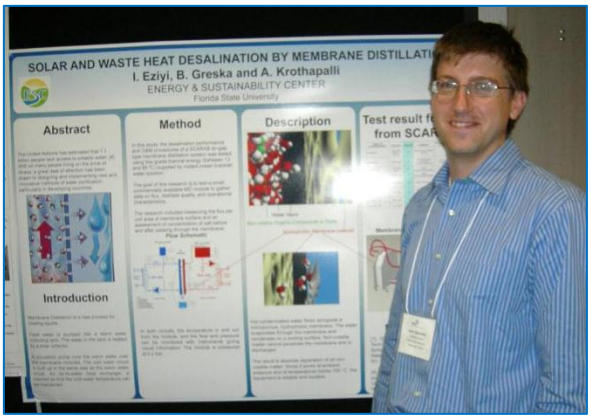
This team forms the engineering team participating in the Team Florida's Solar Decathlon Competition. Lessons learned from the Off-Grid Zero Emission Building are incorporated into Team Florida's design.

Budget: $503,168
University: FSU

Progress Summary

This project is complete.

Shannon Ingersoll at the FESC Summit.



Graduate student I. Eziyi also attended the FESC Summit representing the FSU Energy and Sustainability Center

FLORIDA STATE UNIVERSITY

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

PI: Jim Zheng, **Co-PIs**: Richard Liang, Chuck Zhang, Ben Wang
Student: Michael Greenleaf, a Ph.D. student at ECE department. He is currently working on development of equivalent circuit models for energy storage devices, and an investigation of Li-ion batteries safe due to over-charge conditions.

Description: The objective of this project is to provide an innovative approach to revolution of current energy storage and conversion technology and greatly leverage FSU position in the strategic important area for sustainable energy. The project was performed by Drs. Jim Zheng and Richard Liang at the Department of Electrical and Computer Engineering and Department of Industrial Engineering, respectively. First to demonstrate preliminary results in high performance of energy storage and conversion materials and devices in order to seek outside funding consistent with the vision of IESES. The deliverables were conference proceedings and journal papers and proposal submissions for additional funding.

Budget: $15,000
University: FSU
Research Integration (collaboration)

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

Progress Summary

The planning grant funds were used to travel to conferences, workshops, and seminars. Dr. Zheng was invited to give a seminar on High Performance Fuel Cells using Buckypaper, Louisiana State University, Baton Rouge, Louisiana. A site visit for proposal of "An International Collaboration Group on Solar Cell Technologies Development", sponsored by the Chinese Academy of Sciences. This trip developed an international collaboration on renewable energy researches and recruited international graduate students and postdoctors. Another invited paper in 2009 at the China-North America Workshop on Fuel Cell Science and Technology: Highly Efficient and Stable CNT Paper-Based Electrodes for PEMFCs was significant. At this meeting, Dr. Zheng met individuals that

Jim Zheng, left, receiving a token of appreciation for IESES Director, Dave Cartes

would license the fuel-cell technology. A start-up company called Bing Energy has relocated its world headquarters to Tallahassee Florida to manufacture the nanopartical fuel cell.

The catalytic electrode was developed using carbon nanotube film (buckypaper) as a supporting medium through use of the electrodeposition method. Buckypapers are free-standing thin films consisting of single-walled carbon nanotubes, carbon nanofibers held together by van der Waals forces without any chemical binders. Mixed buckypapers may be developed by layered microstructures with a dense and high-conducting SWNT networks at the surface, as well as large porous structures of CNF networks as supports. This unique microstructure may improve Pt catalyst accessibility and the mass exchange properties. Pt particles were uniformly deposited in porous buckypaper and had an average particle size of about 6 nm. A promising electrochemical surface area of about 40 m2g-1 was obtained from these electrodes.

Due to their unique microstructure, buckypaper-supported platinum (Pt) catalysts derived from carbon nanotube and carbon nanofiber have demonstrated a high utilization in proton exchange fuel cells. The durability of a buckypaper-supported catalyst was investigated using an accelerated degradationtest in a mimic cathode environment of PEMFC. Compared to commercial carbon black-supported buckypaper showed better catalyst durability after holding at 1.2 volts for 400 hours; specifically, almost 80% of electrochemical surface area was lost for carbon black, while only 43% loss for buckypaper. Transmission electron microscopy and cyclic voltammetry were used to study the Pt degradation mechanism. It was concluded that Pt coarsening and detachment from buckypaper support due to carbon corrosion make the major contribution to the Pt surface area loss under this condition. It is supposedly due to the higher corrosion resistance of buckypaper because of its high graphitization degree which is indicated by a slower formation rate of surface oxides in buckypaper than in carbon black.

FLORIDA STATE UNIVERSITY

Experimental Investigation of Economic Incentives of Policies, Institutions, and R&D in Environmental Conservation

PI: Svetlana Pevnitskaya, **Co-PI:** Dmitry Ryvkin
Students: Matt Cutillo

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

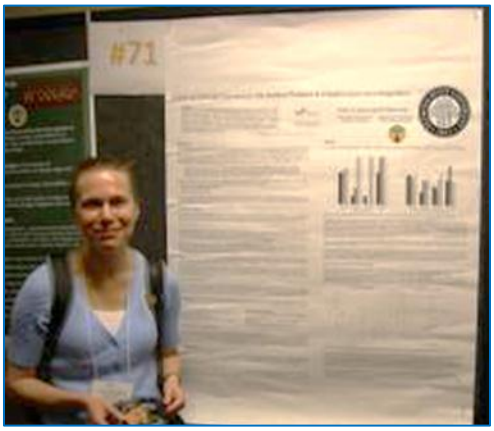
Budget: $43,168.00
Universities: FSU

Progress Summary

This project is the first, to the best of our knowledge, laboratory experimental study of the effects of environmental context, technological heterogeneity, and investment in clean technologies in an environment with a dynamic public bad. It also provides interesting and at times unexpected insights that have direct implications for policy or at least require a more detailed investigation. Specifically, we find that

- Environmental context and "green" framing, even if purely symbolic, have consequences for economic decisions.
- Under relatively low cost of pollution heterogeneous countries are less likely to achieve sustainability without external enforcement than under more severe costs of pollution and climate change.
- Common access to clean technology leads to higher investment in clean technology, lower levels of pollution and dominating payoffs. The results suggest that policies promoting research and development collaboration and technology sharing in combating environmental damage and climate change are effective.

Impact:
The results point at several important directions in which the research should be extended to gain better insights into why subjects behave in a certain way, and to make the experimental design more applicable to policy. The first limitation of the presented design is in the implementation of the dynamic public bad. One of the problems policy makers face is the uncertainty (and ambiguity) of the extent and timing of costs associated with environmental damage and climate change. An alternative implementation of the public bad as an uncertain catastrophic event would provide a robustness check to our results in this direction. The second limitation is the implementation of clean technology.



Svetlana Pevnitskaya at the 2010 FESC Summit

The important property of research and development is the uncertainty of its outcome, both in terms of the very existence and timing of innovations, and in terms of its cost and efficiency. Additionally, technologies are durable, in the sense that once a technology is implemented it does not require new research and development investments. The implementation of these features will constitute an important robustness check for the results related to research and development collaboration and sharing of technologies that we plan to focus on. For policy applications, it is also of interest to interact heterogeneity in initial conditions with clean technology investment. One of the reasons international environmental agreements fail is the difference in the levels of technological development between countries.

Funds leveraged/new partnerships:

Faculty	Source/ Agency	Project Title	Date Submitted	Amount
Pevnitskaya, S., Ryvkin, D.	NSF	Experimental Study of Games with a Dynamic Public Bad and Applications to Environmental Policy.	2010-08-18	$187,844

Also, a letter of intent was submitted for a DOE grant with UF scholars 3/25/2011.

University of Central Florida

Enhanced and Expanded PV Systems Testing Capabilities at FSEC

PI: Stephen Barkaszi, Robert Reedy

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

Budget: $132,398.
Universities: UCF/FSEC

Progress Summary

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

The new equipment purchased under this project has been in service for several months and has proven to be very valuable to the PV testing program. The capabilities have been leveraged to attract new funding from the public and private sectors.

The expansion of capabilities has attracted to additional requests for certification of equipment,

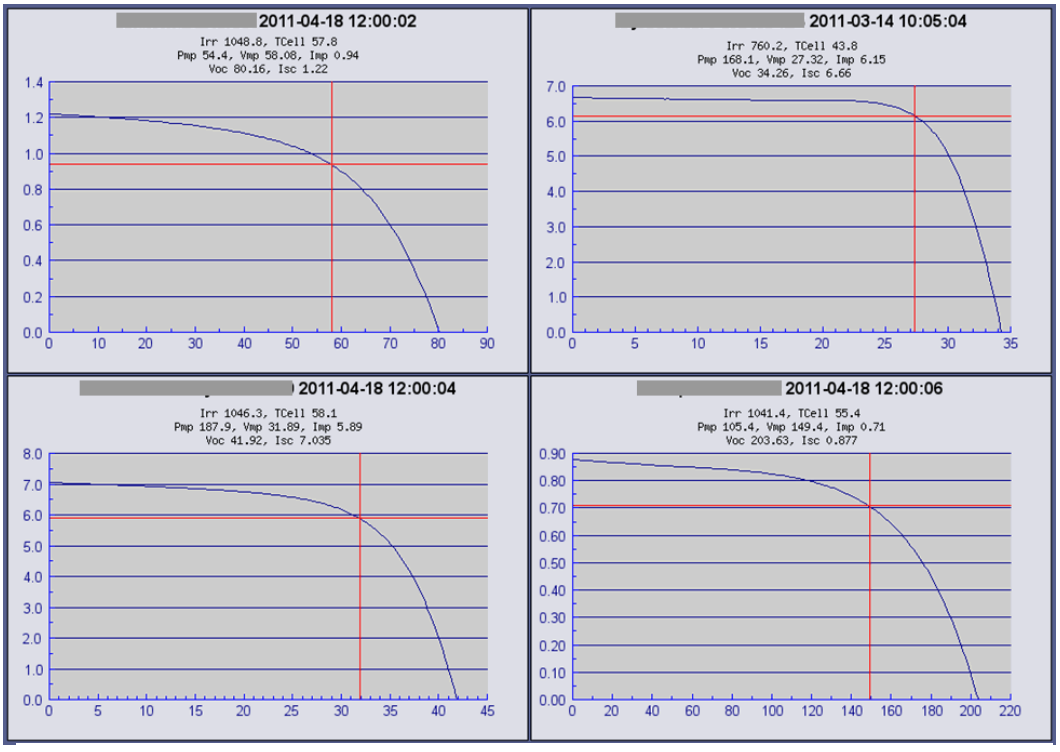


Figure 1.Sample data from a side-by-side comparison of PV modules

calibration of references, and prototype testing. System integrators and manufacturers are also interested in longer term bankability studies to validate performance and potential value of the electricity generated by the solar equipment. One of these studies is currently underway and two additional studies are proposed. The ability to perform these tests is a direct result of this project.

A sun-tracking system for testing PV modules has been identified and the procurement process has begun. It is anticipated to have the equipment in service during the second quarter of 2011. This highly accurate tracker will improve the accuracy of the data acquisition process.

Deliverables:

Expanded Testing Facilities for PV modules and systems, with proven capabilities:

- Long-pulse solar simulator for new multi-junction cell designs
- One 3-axis tracking platforms for maximum exposure and aging testing
- Stationary I-V curve tracers, with flexible connection systems
- Doubling of fixed test rack space
- Improve certification process and minimize time requirements

Industry Support:

This task will be strongly supported by the PV manufacturers. Many such companies have already contracted with FSEC for testing in our uniquely hot, humid and lightning-prone environment. Further, the US DOE is expected to continue support FSEC's PV test program with contract work for accelerated aging, high voltage and generalized testing.

UNIVERSITY OF CENTRAL FLORIDA

PV Manufacturing Data Base and Florida Applications

PI: David Block, Robert Reedy

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

Budget: $81,120
Universities: UCF/FSEC

Progress Summary

This project's goal to establish a PV manufacturing database has approached the database by separating the PV manufacturing information into three areas – world-wide statistics, U. S. statistics and Florida activities. The database was established in 2008, was updated for 2009 and some statistics are available for 2010.

World-wide Statistics

At this time, the world-wide statistics data for 2010 has yet to be published. The present results for world-wide production for 2008 and 2009 in megawatts (Mw) are as follows:

	2008	2009	08-09 change	2009 Market share
China	1848.4	3946	113.5%	37.0%
Europe	1906.6	1930	1.2%	18.1%
Japan	1224	1508	23.2%	14.1%
Taiwan	853.9	1245	45.8%	11.7%
U.S.	412	595	44.4%	5.6%
ROW	*696.2*	*1436*	*106.3%*	*13.5%*
Total	**6941.1**	**10660**	**53.6%**	**100.0%**

Notes:

- PV production increased by 53.6% from 2008 to 2009.
- China leads production at 3946 Mw with 37% market share.
- U. S. production is 595 Mw showing a 44.4% increase from the previous year.
- U. S. market share for 2009 was 5.6% and preliminary figures for 2010 show the U. S. market share remains about the same.

U. S. Statistics

U. S. installations per year by state (includes data for 2010) are as follows:

State	2008	2009	2010	09-10 Change	2010 Market Share
CA	178.7	212.1	258.9	22.1%	29.5%
NJ	22.5	57.3	137.1	139.3%	15.6%
NV	14.9	3	61.4	1946.7%	7.0%
AR	6.4	21.1	54	155.9%	6.1%
CO	21.7	23.4	53.6	129.1%	6.1%
PA	--	3	46.8	1460.0%	5.3%
NM	--	1	42.8	4180.0%	4.9%
FL	0.5	35.7	35.2	-1.4%	4.0%
NC	4	7.8	30.7	293.6%	3.5%
TX	--	4	22.6	465.0%	2.6%
Others	38.6	34.7	135.2	289.6%	15.4%
Total	287.3	403.1	878.3	117.9%	100.0%

Notes:

- California remains number one at 258.9 Mw or 29.6% of total.
- Florida is ranked 8th with a large increase in 2009 because of FPL
- Florida remains close to its 2009 number with 35.2 Mw installed in 2010.
- U. S. installed capacity in 2010 more than doubled from 2009 with a 118% increase.
- Sixteen states now have over 10 Mw installed capacity in 2010, up from four states in 2008.
- Utility installations showed the major increase for 2010 going from 113 Mw to 242 Mw. Reference 1 has also noted that over 700 Mw of utility PV is already contracted for 2011.

U. S. based PV manufacturers for 2008 and 2009 are as follows:

Company	State	2008	2009
First Solar	AZ	147	147
United Solar	MI	113	120
Evergreen Solar	MA	26.5	104.6
Solarworld	CA	61	71.8
Solyndra	CA		30
BP Solar	MD	27.7	
Schott Solar	NM	11	
Global Solar	AZ	7.2	
Other		18.7	121.6
Totals		412.1	595

Notes:

- First Solar is the world's largest PV producer with a total of 1011 Mw.
- No other U.S. manufacturer is in the top 15.

From Reference 1, the following comments were made with respect to PV manufacturers in the U. S.

The highly impressive top-line results, however, mask continuing turbulence in the field of domestic PV manufacturing. Manufacturing is a global industry, and competition from producers in low-cost regions such as China and Taiwan has introduced significant challenges for manufacturers in the U. S., Europe, and Japan over the past eighteen months. As a consequence, 2010 saw closure announcements at no fewer than three domestic PV manufacturing facilities: BP Solar's wafer-cell palnt in Maryland, Spectrawatt's just-opened cell plant in New York, and Evergreen Solar's integrated 160 MW wafer-cell-module plant in Massachusetts. Cost pressure on domestic plants is

expected to continue to be an issue through 2011, meaning that additional plant closures will not come as a surprise. At the same time, however, 2011 should also see new plants being built, notably Wacker Chemie AG's polysilicon plant in Tennessee, Flextronics' crystalline silicon module plant in California, and Stion's CIGS (Copper Indidum Gallim Selenide) facility in Mississippi.

Of the more than 2,000 companies in the U. S. solar value chain, there are at least 39 active facilities manufacturing PV components (polysilicon, wafers, cells, modules, inverters) spread across 17 states in the U. S. A great many of these are located in California due to its leadership position as an end-market, as well as the adjacent states of Oregon and Arizona, which offer skilled labor and strong policy support for PV manufacturers. While the Midwest has historically been dormant on the PV manufacturing front, recent plant announcements in Wisconsin, Indiana, and Illinois suggest that this is changing quickly. The geographic shift towards the Midwest seems to be taking place at the expense of states on the Eastern seaboard such as Massachusetts, Maryland, New York, and New Jersey, which have seen a total of five plant closures since mid-2009.

On April 8, 2011 and on the positive side, General Electric announced that it will build the largest PV manufacturing plant in the U.S. The plant size is 400 Mw and is budgeted at $600 million. The plant locations are said to be in NY, CO or SC.

In addition, Reference 1 presents information on PV costs. The data is presented by market type and the average is as follows:

National weighted-average systems prices fell by 20.5% over the course of 2010, from $6.45/W to $5.13/W. Much of this decline was due to a shift toward larger systems, particularly utility systems.

PV Manufacturers in Florida

- Advanced Solar Photonics (ASP), Lake Mary, FL, is a manufacturer and R&D center for monocrystalline solar panels and racking systems for residential, commercial, and utility applications. ASP focus is high power solar modules ranging from 190 watts to 400 watts. Associated with ASP is BlueChip Energy, LLC (BCE) a fully-integrated solar PV power generator, occupying all segments of the solar power value chain, from manufacturing of solar panels and balance of systems components, to the sale of turnkey solar power plants – and solar electricity — to residential, commercial, and industrial customers.
- On March 7, 2011, BlueChip Energy™ (BCE), announced that it has signed an agreement to acquire land in central Florida for the development of the third largest US PV installation, a 40 megawatt (MW) capacity solar farm called Sorrento Solar Farm. The solar farm will be a ground-mount system covering 140 acres of open field in Lake County, Florida. The proposed site is located 50 miles northwest of Orlando adjacent to two utility substations.
- Mustang Vacuum Systems, LLC, of Sarasota County, FL is a company that has received $577,636 from the Florida Renewable Energy Grants Program in May 2009. The company offers tools and technology for producing PV. It is not a PV manufacturing company.
- In 2008, Blue Sky Solar, Inc. made preliminary comments concerning the location of a PV manufacturing plant in Orlando. It has a website at www.blueskysolar.com which states that Blue Sky Solar is a U.S. based manufacturer of large utility-sized solar modules, but no location is given and the website appears to be out-dated.
- Willary & Kelsey Solar Group, an Ohio company, was coming to Florida, but due to incentives changed its mind and stayed in Ohio.

References

Solar Energy Industries Association. (2010). U. S. Solar Market Insight – 2010 Year in Review: Executive Summary.

UNIVERSITY OF CENTRAL FLORIDA

Concentrating Solar Power Program

PI: Charles Cromer **Co PI:** Robert Reedy
Students: Pablo Izquierdo (Ph.D.)

Description: The objective of this effort is to produce a detailed Florida map of the solar direct beam and global resource available for use in Florida whereby a potential user of solar energy can enter their location latitude and longitude and receive a table of solar energy monthly averages for that specific site as derived from the past eleven years of data. The concept is to use NOAA satellite photos and utilize the brightness of the cloud cover as a clearness factor predictor of the solar energy that gets through to the ground below.

Past progress: A literature search was completed and the equations to predict theoretical optimum clear sky daily insolation (Hc) were programmed. The clearness value (x) of each pixel in satellite photos was used to mediate the clear sky insolation values to produce ground level predicted values (H) for that pixel area (5 miles x 5 miles) by the general equation:

$$H = Hc\ (a + bEXP(-x/c))$$

Where a , b, and c are correlation coefficients. The hypothesis was tested by using NOAA weather satellite data from summer and fall of 2010 retrieved over the internet, and real irradiance values measured at FSEC. Correlations (r sq) of predicted vs. real values were found to be above 0.90 at the 95% confidence level. This work validated the concept.

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

Progress Summary

Daytime satellite photos of the past eleven years were purchased from NOAA archives. In each photo, a pixel covers a 5 mile x 5 mile square and there are 10,272 pixels over the Florida area in each photo. Using printed NOAA navigational charts, latitude-longitude values were assigned to each pixel. The 20,075 photos were reviewed and if any anomalies (blank areas or bands across the photo) were found, the photo was corrected. Because the gray scale map varied among photos, a program was written to correct all photos to represent a standard gray scale map and all photos' pixels were adjusted to this gray scale base with this program. A program was written that searched the pixel files to determine the darkest and lightest tone recorded for each location and these were determined. A program was written that calculated the normalized brightness value (value x in the equation above) for each pixel of each photo and these were loaded into master "clearness" files. A program was written that calculated and output the theoretical clear sky direct beam solar energy available for each day of the year for each Florida location (value Hc in the equation above).

Effort Remaining to Be Completed:

Using the NOAA historical data sets now developed and actual data taken at FSEC, new correlations need to be developed that calculate the ground measured direct beam and direct diffuse solar daily insolation. Using these correlations, solar direct beam and direct diffuse radiation values need to be calculated for each day of the eleven year data base for each of the 10,272 Florida locations. Each daily value for each location needs to be averaged across the 11 years of data. Daily values need to be averaged to produce direct beam and direct diffuse monthly averages for each of the Florida locations into a master table. A program needs to be written that will run on the internet that when given a Florida latitude and longitude, will provide a table of the expected monthly direct beam and direct diffuse averages for that location.

UNIVERSITY OF CENTRAL FLORIDA

Development of High Throughput CIGS Manufacturing Process

PI: Neelkanth Dhere
Students: Shirish A. Pethe (PhD), Ashwani Kaul (PhD), Eric Schneller (M.S)

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

Budget: $141,611
Universities: UCF/FSEC

Progress Summary

Molybdenum back contact deposition is a bottleneck in high volume manufacturing due to the current state of art where molybdenum back-contact film consisting of multiple layers must be deposited to achieve the required properties. Experiments were carried out in order to understand and solve this problem. The effect of working distance (distance between the target and the substrate) on film properties was studied and is being presented here. The main goal in reducing the working distance was to determine the increase in the deposition rate that would be very essential in order to reduce the deposition time and eventually the manufacturing cost. Earlier work carried out on molybdenum films reflected on the effect of the sputtering power and working gas pressure on the film properties. This work is continuation of that effort in understanding effects of various sputtering parameters and determining the route to develop a composite molybdenum film with the required properties of near zero stress, low resistivity and good adhesion to substrate.

The effect of varying the sputtering power on the residual stress in the films deposited at working gas pressure of 1 mTorr was studied. Also, the effect of working gas pressure on the residual stress in the films deposited while keeping sputtering power constant at 200 W was also investigated. It was found that lower sputtering power of 200 W yielded tensile stresses in the molybdenum films. At higher sputtering power of 275 W some compressive stresses were developed in the molybdenum film.

Variation of residual stress with varying working gas pressure suggests an inverted U shaped curve where the tensile stress reaches maximum and then the tensile stress is reduced with the increase of working pressure. Beyond a certain higher pressure the residual stress crosses into the compressive stress regime. As compared to earlier work, at working distance of 6.5 cm the dependence of residual stress on the processing conditions is significantly different. It may be noted that the properties of the plasma change with changing working distance. Moreover, the discharge voltage required to achieve the same sputtering conditions of power and pressure for working distance of 6.5 cm was higher as compared to that required for working distance of 9 cm. This higher discharge voltage results in higher kinetic energy of the sputtered atoms as well as of the back-scattered and neutralized argon atoms. Four point probe technique was used to measure the sheet resistance of the films and the resistivity of the films was calculated. Figures 1 and 2 show the variation of resistivity with varying sputtering power and working gas pressure respectively.

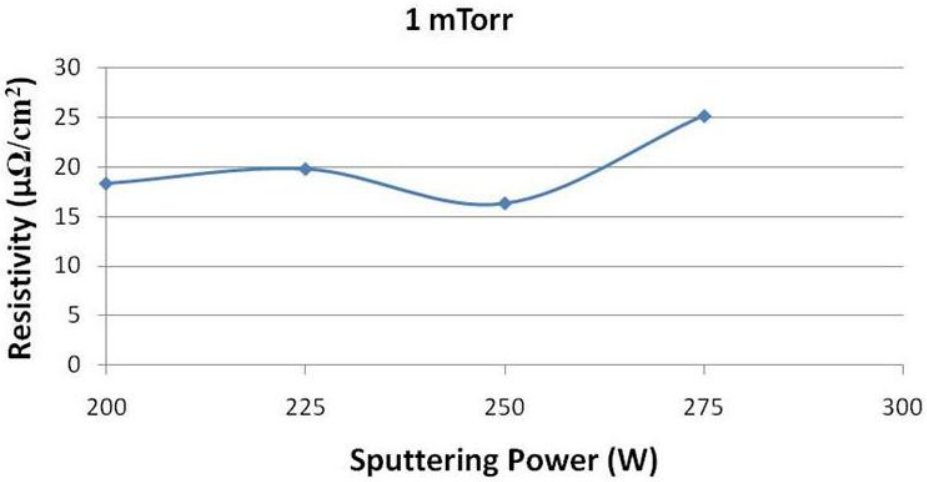


Figure 1: Variation of Resistivity with varying sputtering power for working distance of 6.5 cm

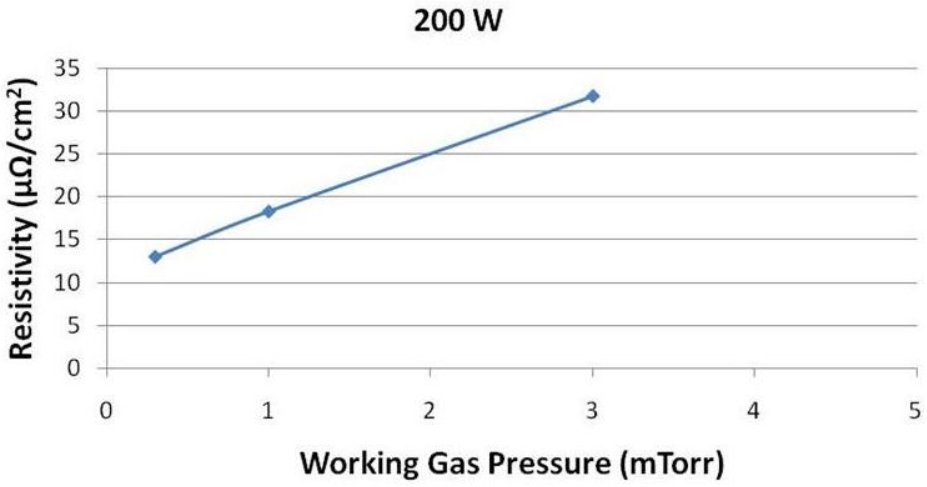


Figure 2: Variation of Resistivity with varying working gas pressure for working distance of 6.5 cm

The variation in the resistivity of the molybdenum films with varying process conditions is not significant. The resistivity increases with increasing gas pressure because as the pressure increases the sputtered atoms and the neutralized argon atoms are scattered more frequently. Consequently, the incident kinetic energy of the sputtered atoms and the neutralized argon atoms is reduced which in turn can lead to a slightly more open structure causing an increase in resistivity.

Student Accomplishments:

Shirish Pethe (PhD in Electrical Engineering) graduated in fall 2010 and Ashwani Kaul (PhD in Material Science) will be graduating in Fall 2011. Eric Schneller (M.S in Material Science) joined the group in Fall 2010.

Publications:

S. A. Pethe, A. Kaul and N. G. Dhere, "Effect of working distance on properties of sputtered molybdenum films", submitted for presentation and publication at the upcoming MRS-Spring 2011 conference.

UNIVERSITY OF CENTRAL FLORIDA

PV Devices Research and Development Laboratory

PI: Robert Reedy
Co-PIs: Nicoleta Hickman, Neelkanth Dhere,
Student: Kristopher Davis, Ph. D CREOL-UCF

Description: The goal from this project is to develop and equip a PV devices R & D laboratory which would then be open to industry, research institutions and academic partners for the purposes of planning, designing, deploying and operating PV systems. Scientifically supported by the experts in PV from FSEC/UCF, the PV Devices Research and Development laboratory is a comprehensive suite of scientific tools for the fabrication and characterization of materials and PV devices. The laboratory is designed specifically to reduce time delays associated with transferring technology from the academic research laboratory to industry. Furthermore, the PV laboratory will also facilitate undergraduate and graduate internship programs to train chemists, physicists and engineers in photovoltaic processing, characterization and testing.

Budget: $450,250
Universities: UCF/FSEC

Progress Summary

Although reliable PV systems are commercially available and widely deployed, further development of PV technology is crucial to enable PV to become a major source of electricity. The current price of PV systems is not low enough for PV electricity to compete with the price of peak power in grid-connected applications and with alternatives like diesel generators in stand-alone applications. It also cannot rival consumer or wholesale electricity prices. A drastic further reduction of turn-key system prices is therefore needed. For these reasons, research and development is crucial for the advancement of PV. Performing joint PV research and addressing well-chosen research issues can play an important role in achieving the critical mass and effectiveness required to meet the sector's ambitions for technology implementation and industry competitiveness.

At FSEC/UCF, there is a long history of partnering with manufacturers, integrators, and other researchers, all working together to make advancements in the photovoltaic industry. This history includes a proactive role through investment, research and partnerships with the purpose to design, characterize, test and deliver new solutions to meet the needs of a growing PV market. From early-stage process development to full scale mass production, FSEC's PV research program can help to create new jobs and save both time and money. FSEC's PV research and development program and its laboratory can be a resource for the solar industry and Florida universities for the advancement of solar technology.

In the FSEC PV Devices Research and Development laboratory, researchers collaborate with other research teams in using established fabrication and characterization techniques and to develop new in-situ diagnostics tailored for the specific growth and processing steps used in PV manufacturing.

The following customized capabilities distinguish FSEC's Devices Research and Development PV Laboratory:

1. Customized Oriel Quantum Efficiency System

The quantum efficiency (QE) system is an essential tool for any laboratory working on PV materials and devices. With the help of Oriel's product engineers, FSEC's researchers have

configured this system to measure internal quantum efficiency (IQE). The difference between IQE and EQE is that IQE measurements account for any EM radiation reflected from or transmitted through the PV cell under test. By doing this, one can infer more about the internal workings of the active semiconductor layer, without concern regarding the cell's external optical properties (e.g. anti-reflection coatings). This allows the determination of whether bad performance comes from the active semiconductor itself or simply from high reflection losses at the surface of the cell.

2. Oriel Class 3A Solar Simulator

In the context of PV materials and device research, a solar simulator allows for a dependable measure of device performance under broadband radiation that is spectrally similar to that coming from the sun. The configuration and operation of this system has included the fabrication of a suitable structure for safely mounting the simulator on the laboratory bench, installing individual components (e.g. light source, power supplies, optical filters, etc.), verifying proper beam alignment and light throughput, and testing the unit with actual PV cells with known current-voltage characteristics. The Oriel Sol3A simulator is certified to IEC 60904-9 Edition 2 (2007), JIS C 8912, and ASTM E 927-05 standards for Spectral Match, Non-Uniformity of Irradiance, and Temporal Instability of Irradiance. The Oriel Sol3A simulator use a single lamp design to meet all three performance criteria without compromising the 1 Sun output
power and, thus, providing true Class AAA performance. The Oriel Sol3A uses a black non-reflective finish to minimize stray light and incorporates captive screws for all panels requiring user access to facilitate lamp replacement, alignment, and filter changes. (Newport website). See below figure for device and irradiance.

3. Laurell Technologies Spin Processor

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

- Organic and inorganic thin films can be deposited onto any kind of substrates,
- The deposited film can be dense or porous after sintering, depending on requirements for the film,
- The deposition rate and the spinning rate are high,

The process can be done in under a minute.

4. Dimatix DMP-2831 Materials Printing System

The largest and most expensive item of fabrication equipment is the material printing system (Dimatix, Inc). It is a system used for inkjet- printed quantum dot and nanostructure hybrid PV and TE materials and devices. The system provides a high degree of fabrication accuracy and reliability of fabrication when operated and maintained correctly.

The DMP-2831 is a state of the art printing system which will generate new research capabilities that include experiments with inkjet deposition of organic semiconductors, inorganic solution based semiconductors, and patterned conductive layers. The configuration and operation of this printing system has included the installation of individual components, installation and operation of the system software, fluid transfer to printer cartridge, and troubleshooting to overcome non-jetting nozzles.

5. Spraying system

Inkjet printing is used to create the actual solar absorber, which is the layer in a solar cell in which the sunlight's energy generates free electrons. The inkjet printing technique can be applied to any thin-film materials or organic photovoltaics. For example, cadmium telluride, Si, organic-inorganic materials are absorber layer materials which are being developed for deposition by a liquid precursor. Also, nanoparticulate-based ink is spray-deposited to form a film. Work has successfully produced optically dense thick films—up to 10 micrometers with no cracks. Many solar cell technologies collect freed electrons using a thin layer of transparent conducting oxide rather than metallic grid lines. This work uses special inks, fabricated in our laboratory with spray deposition, to lay down thin, high-quality transparent graphene and carbon nanotubes based layers. Continuing work is expected to improve this technique so that conductivities will rival those of conventionally deposited.

Conclusions

The above systems were acquired and configured for operation last year. In the Annual Report of last year these five systems were described in detail with photos of the scientific equipment. The work for this year has been the use of this equipment in the ongoing PV R&D being conducted at FSEC.

UNIVERSITY OF CENTRAL FLORIDA

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

PI: Nicoleta Sorloaica-Hickman**,** Robert Reedy
Students: Kris Davis, Ph.D. CREOL-UCF

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

Budget: $161,200
Universities: UCF/FSEC

Progress Summary

Photovoltaic/Optical/ Thermoelectric Device- Unconventional architectures for low cost solar device with high efficiency due to the light capture and conversion

FSEC researchers have fabricated high efficiency and low cost unconventional cylindrical architecture solar devices for terrestrial applications by combining the solar cell design with a novel optical design and a thermoelectric element. . This approach allows multiple benefits including: decreasing the amount of active semiconducting materials to less than 5%, increasing the light absorption and conversion, improved performance with non-ideal (lower cost) materials, increased flexibility of the material choices and increase the overall efficiency. The concept has been demonstrated using organic materials and a similar platform as used for high performance inorganic solar cells. The process uses inexpensive fabrication technologies which could define a new direction in the PV large-scale fabrication of this PV/optical/TE device.

The realization of a high efficiency/low cost solar hybrid device which is easily manufactured is one of the defining problems of photovoltaics. Our innovation is to design an integrated optical/PV/TE cell hybrid system allowing efficiency improvements while decreasing the costs, and hence expand the applications for solar energy. It utilizes a design approach which focuses first on performance, enabling the use of old or new photovoltaic materials. The flexibility of these architectures allows a wide portal to accommodate new breakthrough concepts because the device accepts light at wide angles from a large fraction of the sky and it is therefore able to capture most of the diffuse light, which makes up ~10% of the incident power in the solar spectrum, in the most populated regions of the world.

Unconventional architectures: Photovoltaic/Optical Device

The PV/Optical cell consists of four layers deposited on a very thin glass or polymer fiber: a transparent anode shell, a positively charged/doped shell; a negatively charged/doped shell and a transparent cathode shell. [1] (fig.1) The light is incident on the fiber and cell and it is transmitted down the fiber and reflected multiple times from its interior surface, until passing through the active layers and absorbed or passed through the transparent electrodes, thus allowing for multiple passes through active layers of the incident or adjacent cells. Two metal layers separated by a dielectric material are used to collect the photo-generated charges. They constitute the device back side of the

PV/optical hybrid device. The electrode shells of each cell are of different length, with the outer and shorter electrode shell connected to the upper metal layer, and the longer inner electrode shell passing through the dielectric layer and connecting to the lower metal layer. One of the metal layers is connected to the positively charged transport electrode and the second metal is connected to the negatively charged transport electron.

The PV device consists of many cylindrical cells imbedded into a polymeric matrix with nanoparticles which scatter the light back into the cells.[2] (fig.2)The key optical elements which enhance the light capture are: light trapped by the glass/polymer fiber, light transmitted through the transparent electrodes (ITO and graphene), light absorbed and scattered by the nanoparticles imbedded into the polymeric matrix and, light reflected back into the device by the metallic substrate

The key electrical elements which enhance the light conversion are: photo-excited electrons and holes traveling very short distances before being collected by the electrodes, which could decrease the electronic recombination caused by impurities, high anti-reflection, high surface energy which could increase EQE. [3]

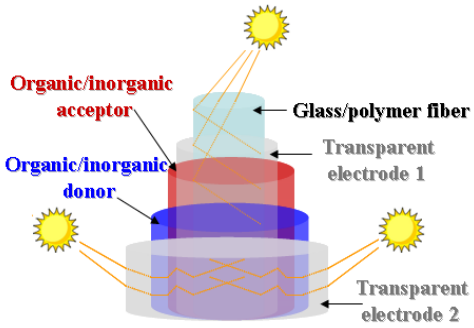


Figure 1. PV cell

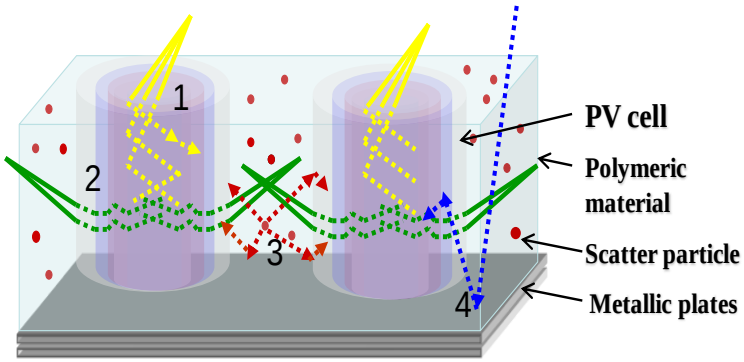


Figure 2. Schematic of the PV/optical device

Transparent electrodes fabrication:

The ITO electrode was deposited using a sputtering machine for thin-film followed by a cure process. The film thickness, optical transparency and electrical conductivity were modified by the deposition time. Graphene oxide (GO) was obtained from exfoliation of graphite through oxidation. A stable 1 mg/mL GO aqueous dispersion was obtained by adding GO into DI water followed by 1 h sonication. In order to achieve a highly uniform deposition, we employed a motor controlled two-dimension spraying system. The prepared GO coatings were reduced by hydrazine vapor and followed by annealing under Ar atmosphere at 400 ^{o}C for 30 min. This room-temperature solution process is completely compatible with polymeric substrates and does not require a sophisticated transfer process.

Donor-acceptor fabrication (PEDOT-PSS, P3HT/PCBM):

For standard devices a layer of 0.45 µm filtered PEDOT:PSS was sprayed in a temperature controlled environment onto ITO coated glass fibers which were then annealed at a temperature of 125 °C for 1 minute. A layer of 0.45 µm filtered 1:0.8 P3HT:PCBM was then sprayed forming the active layer of the devices and following that the devices were solvent annealed for 5 minutes. Studies of the thickness and thermal annealing were performed in order to optimize the power conversion efficiency.[4]

1. Yuan Li, Eric D. Peterson, Huihui Huang, Mingjun Wang, Dan Xue, Wanyi Nie, Wei Zhou, and David L. Carroll, *Tube-based geometries for organic photovoltaics*, Appl. Phys. Lett. 96, 243505 (2010);

2. Joseph Lik Hang Chau, Ruei-Tang Chen, Gan-Lin Hwang, Ping-Yuan Tsai, and Chien-Chu Lin, *Transparent solar cell window module*, Solar Energy Materials and Solar Cells, Volume 94, Issue 3, March 2010, Pages 588-591

3. Hsin-Cheng Lee, Shich-Chuan Wu, Tien-Chung Yang and Ta-Jen Yen, *Efficiently Harvesting Sun Light for Silicon Solar Cells through Advanced Optical Couplers and A Radial p-n Junction Structure*, Energies 2010, *3*, 784-802;

4. Youngkyoo Kim, Amy M. Ballantyneb, Jenny Nelsonb and Donal D.C. Bradleyb, *Effects of thickness and thermal annealing of the PEDOT:PSS layer on the performance of polymer solar cells*, Organic Electronics, Volume 10, Issue 1, February 2009, Pages 205-209

UNIVERSITY OF CENTRAL FLORIDA

PV Energy Conversion and System Integration

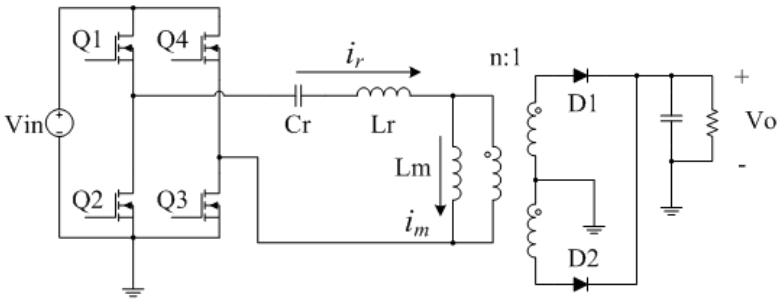
PI: I. Batarseh
Co-PI's: J. Shen, I. Batarseh, Z. Qu, X. Wu, W. Mikhael, L. Chow
Post Docs: H. Hu (PhD), R. Ranganathan (PhD), N. Kutkut (PhD)
Students: Kejiu Zhang (PhD), Souhaib Harb (PhD),
Karthik Padmanabhan (PhD), Xiang Fang (PhD), Ala Alsaeed (PhD)

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

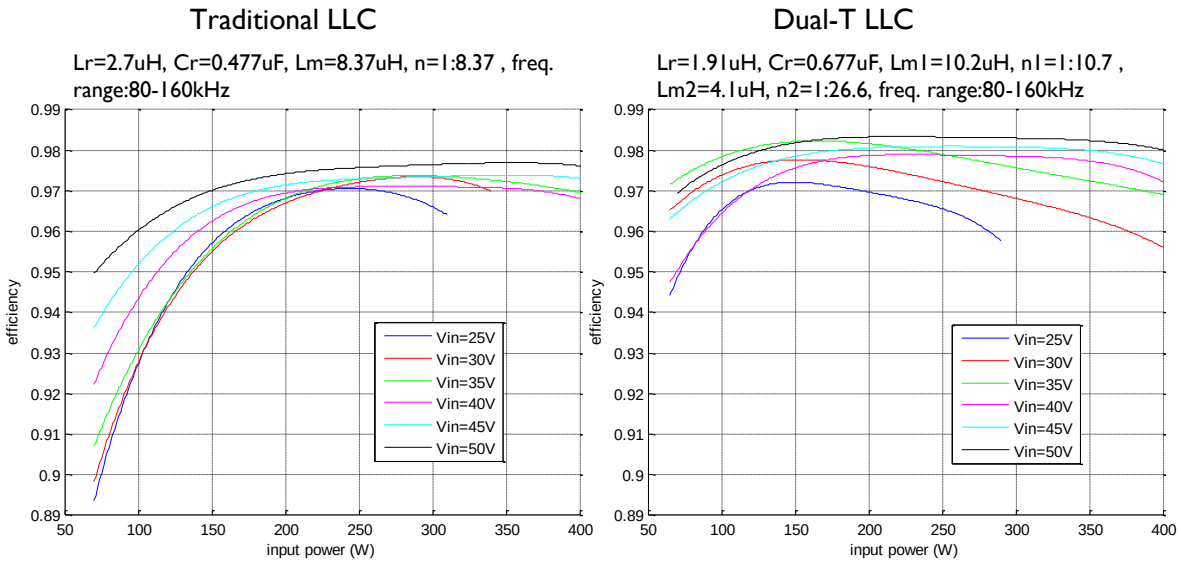
Budget: $1,267,000
Universities: UCF

Progress Summary

The focus of this period was on developing very high efficiency LLC resonant DC/DC converter stage for the PV inverters



LLC is a 3-resonant-component converter topology with high efficiency and high power density. It has advantages of achieving ZVS for wide input voltage and load range, which makes it ideal candidate for PV applications. LLC's operation is complicated. A systematic analysis and modeling based on its operating modes are proposed and verified by experiments. The model provides high accuracy in DC gain prediction comparing to traditional approaches (FHA method). And the model is used to optimize LLC design. A modified LLC topology with dual transformers is proposed. The modified topology has better efficiency than traditional one. A prototype board was built to perform comparative tests.



LLC optimal design is to find the circuit parameters that minimize the power loss while maintaining a desired DC gain level to adapt the wide input range. An optimal design procedure is developed based on the mode model. The experiments validate our LLC model study and show promising results of the dual-T LLC topology. A power loss model will be built to further improve the converter efficiency. We will finalize the circuit for its implementation in the mico-inverter prototype

Grants Awarded					
Title	**Agency**	**Ref. #**	**PI, Co-PI, Collaborators**	**Period of performance**	**Funding Awarded**
Photovoltaic Power Electronics Initiative (PERI)	DOE	DE-EE0003176	I. Batarseh, J. Shen, T. Wu	24 months	$1,400,000

UNIVERSITY OF CENTRAL FLORIDA

Buoy Array for Ocean Wave Power Generation

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

Description: The objective of this project is to develop a novel design that can extract ocean wave energy for commercial consumption. The design detailed herein is unique in that it is a wave point energy harvester that is small in size and contains all of the mechanical components directly within the buoy. The project focuses mainly on the mechanical system within the buoy as well as methods to control the electrical load on the system. Different mechanical systems have been developed and tested on a motion platform to simulate a vertical wave motion—these systems have been analyzed and compared in order to provide an ever-increasingly effective design. The Harris Corp. have acted as new collaborators with the project since October 1st 2010, funding four UCF senior design teams in the development of a buoy for wave power generation.

Budget: $150,000
Universities: UCF

Progress Summary

In collaboration with Dr. Zhihua Qu's wave energy research the Harris Corp. funded the work of four UCF senior design teams. The four teams were directed by Carlos Velez, Dr. Qu's graduate researcher in wave energy, to design, construct and optimize four components of an innovative wave energy application. The four teams were split in half with two teams working on creating a wave-energy converter mechanical system and buoy. The other two teams worked on an automated abandoned oil well monitoring system which would be powered by the surface buoy. A small project description and accomplishments for each team are described below.

Ocean Oil Well Monitoring System Team

The team designed a large cap that when placed on top of a pre-existing or newly abandoned ocean oil well can detect any oil leakage from the abandoned well. If oil is detected a wired signal is transmitted to the surface buoy which then sends a wireless transmission of the detection data. The team constructed two prototypes and tested the performance of the sensor system in a ten foot deep water tank. The experiment simulated oil flow emanating from the bottom of the tank for various different scenarios. The performance of the sensor system was very successful in detecting a variety of leaks. The sensor data was collected and will be used to improve upon the prototypes design. Shown below in figure 1 is the oil well monitoring system.

Figure 1. Illustration of oil well monitoring system

Electrical Systems Team

This team designed an electrical system which converts the electricity produced by the wave energy buoy into a usable and consistent power source for the oil well monitoring system. The team's goal was to efficiently convert the AC electricity created by the generator, which runs at a variable RPM, due to the inconsistent nature of the ocean waves. This fluctuating output was properly rectified to a DC signal and then stored in a battery for use by the oil well monitoring system. Additionally, the teams created an automated load control board which varies the generator load to minimize the range of the generator RPM. This

benefits both the energy conversion and the overall efficiency of the wave energy system. The conversion system is soon to be tested with the current PMG generator available.

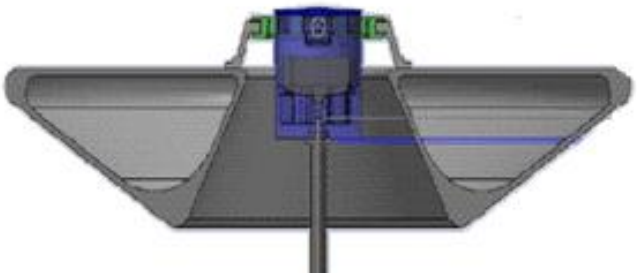


Figure 2 - Illustration ocean buoy

Wave Energy – Turbine Team

This team designed, constructed and tested two different wave energy mechanisms. The design consists of a novel bi-directional turbine which allows a generator to be spun in a single direction regardless of the direction of the wave motion. This allows for power generation on the up and down stroke of the wave and provides a more continuous force input. The Harris Corp. built the turbine design and two different converging diverging shells for the team. The prototypes were tested with the use of Dr. Qu's motion platform to simulate the oscillating motion of the buoy. Data was collected on the performance of the system and a mathematical model was created which agrees with the experimental results. The data and model will be used to improve upon the design and predict the performance of a full scale model.

Figure 3 – Prototype turbine and channel system

Wave Energy- Buoy Team

The buoy team designed, built and tested a 1/3 scale buoy which would drive the turbine when the buoy rises or falls with the ocean waves. This buoy also houses the electrical equipment created by the electrical team and sensor team. The team used CFD simulations to design the optimal buoy shape for large power generation and stability. The buoy was tested at the UCF pool and the results agreed with those found in the simulation.

Aside from directing the senior design projects the graduate student has developed various high quality CFD simulations which analyze the performance of this bi-directional turbine in various unexplored transient scenarios. His thesis is based on this turbine design and from his results he has published two conference papers for this year's ASME OMAE offshore structures conference. Currently, the work from the senior design teams is being collected to be published in a multi-disciplinary journal this summer.

Funds leveraged

The Harris Corp. funded $10,000 for the four senior design teams. Three thousand was given to each wave energy team and the remaining four thousand was used jointly by the electrical and sensor teams. The funds were used to construct prototypes and purchase the sensors and equipment required for each team to perform experiments to test and document the performance of each prototype. An account has yet to be established from the 5K awarded to Dr. Qu's research by the FESC Energy Tech Commercialization Program, so none of the funds have been used as of yet.

UNIVERSITY OF CENTRAL FLORIDA

Solar Systems Testing Facility

PI: James Roland, David Block

Description: Over the past four years, the Florida Solar Energy Center (FSEC) has received a significant increase in demand for solar and PV systems testing and certification. This occurrence has resulted in requiring the Center to correspondingly amplify its capabilities to respond to the increased demand. Thus, the objective of this task was to construct a solar and PV systems testing facility by adding walls, windows, doors and A/C to an existing Florida Solar Energy Center roof only facility. The enclosing of this existing space was done for the purpose of increasing laboratory space and to allow for laboratory testing of solar water heating systems and PV modules and inverters. The action was taken following a study which determined this project was the most cost effective means of adding valuable indoor laboratory space.

Budget: $600,609
Universities: UCF/FSEC

Progress Summary

The building renovation has been completed. This facility is now called the Solar Systems Testing Facility (Bldg. #1940). The following photograph shows this existing facility before any renovation was begun (Figure 1) and the exterior and interior views after renovation (Figures 2 to 4).

Figure 1: Ground Level Front View

Figure 2: Exterior View after completion

Figures 3 and 4: Interior views – ready for laboratory installation.

At present, work continues inside the building to install solar water heating laboratory equipment for testing and certification of solar systems and the installation, development and operation of a Spire PV simulator. Both of the laboratory development projects are part of the FESC and are reported under the following two projects:

1. Enhanced and Expanded Solar Thermal Testing Capabilities, PI: Joe Walters
2. Enhanced and Expanded PV Systems Testing Capabilities at FSEC, PI: Stephen Barkaszi

Industry Support:

This task is supported by the solar thermal and PV manufacturers who must have certification to effectively sell their products and qualify those products for various state and federal incentives and rebates. The Solar Rating and Certification Corporation (SRCC) currently contracts with FSEC for $500,000 of annual work in solar testing and certification. However, this DOE and industry support is directed to labor and other operating expenses, and will not provide for the capital expansion and enhancements conducted under this task.

UNIVERSITY OF CENTRAL FLORIDA

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

PI: J. Shen **Co-PI's:** I. Batarseh, N. Kutkut
Students: Michael Islas, John Elmes

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

Budget: $380,816
Universities: UCF
External Collaborators: City of Tavares, FL

Progress Summary

Research Objectives for Current Reporting Period: The main research objectives for the current reporting period include the development of power electronics hardware and fine tuning of control software.

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

campus. The interactive system also allows for non-sunlit period vehicle charging. On an annual net metering basis, the carport is anticipated to be a net exporter of power to the grid as there will be a significant number of sunlit hours during a year when the majority of electric vehicles parked at the facility are fully charged, and during semester breaks and weekends. A communication link will be established between the system and the power grid to facilitate intelligent control.

Several hardware prototypes have been built to facilitate the three-way energy flow control. Final prototyping for the DC/DC converter is shown here. Each converter consists of a power board, a power supply board, and a controller board. The power supply board is designed to supply 12V from an input between 100V and 400V. The controller board is a generalized design with built-in sensing amplifiers. These boards are mounted vertically in the power board of each DC/DC converter included in the carport charging station. In order to increase the efficiency, soft switching was implemented in both converters (1.2kW solar DC/DC and 4kW DC/DC converters). These prototypes operate at a high overall efficiency (above 95%). Research activities for the next reporting period will focus on fine tuning of the hardware and the software control algorithms, and make efficiency comparison between the new system and the convention configuration over a wide range of conditions.

UNIVERSITY OF CENTRAL FLORIDA

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

PI: Darlene Slattery **Co-PI's**: Len Bonville, Marianne Rodgers
Students: W. Rigdon (Ph.D); Paul Brooker (Post Doctoral Associate)

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

Budget: $351,518
Universities: UCF/FSEC

Progress Summary

In order to better determine the impact of fuel cell testing on membranes, it is necessary to examine cross-sections of the tested membranes using a transmission electron microscope (TEM). The Materials Characterization Facility (MCF) at UCF has an excellent TEM but it was determined that the existing microtome, used for preparing the cross-sections, was not adequate for this purpose. This instrument must be capable of preparing slices of the sample that are 80-100 nm thick in order for the TEM to obtain clear images of fuel cell membranes. With the MCF microtome, a diamond knife could not be used and as a result slices were either too thick or were shredded. It was therefore decided that a new microtome would be purchased. It was determined that the Leica EM UC7 possessed all of the required characteristics and so was purchased under this program. It was also determined that before the microtome could be used, a trimmer was required to perform the rough trimming of the samples. Leica carried this instrument and it was purchased to be used in conjunction with the microtome. The instruments, which were installed in the MCF facility for use by all UCF faculties, can be seen below. This Leica microtome provided samples that were far superior to any obtained previously with the old instrument.

Fig 1. Leica Trimmer

Fig 2. Leica EM UC7 installed at MCF

The capability to acquire publication quality TEM images has been greatly enhanced with the acquisition of both the trimmer and the microtome.

An example of the images obtained after sample preparation using the new instruments can be seen in Figure 3.

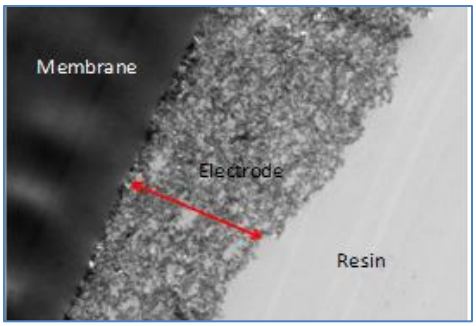


Fig 3. Partial cross-section image of an MEA

UNIVERSITY OF CENTRAL FLORIDA

Energy Efficient Building Technologies and Zero Energy Homes

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

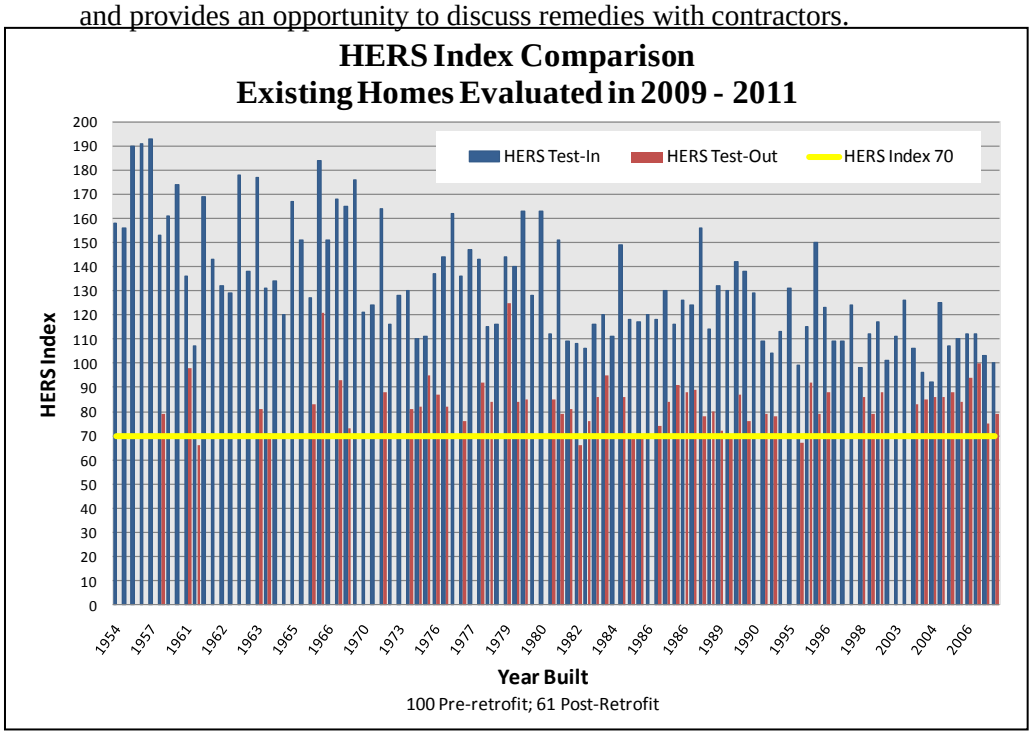
Description: The project consists of two elements: 1) the construction of two flexible research homes at FSEC to conduct research on advanced building energy efficiency technologies under controlled conditions; and 2) a staged, field retrofit study in a small number of unoccupied homes to measure and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

Budget: $ 1,224,000
Universities: UCF/FSEC

Progress Summary

April 2011 status:

A. Technical assistance for government and non-profit residential retrofits, with the FSEC technical support largely funded through Building America, and local retrofits funded by block grants. Key findings:
   - 100 Homes Analyzed
     - 65 Retrofits completed
     - 27 Retrofits in progress
     - 8 Lost from study after initial analysis
   - Mostly: single family detached, cmu or frame, single story, built 1954 - 2006, 754 – 2408 sf, split-system forced air mechanical systems are the norm.
   - Poor HERS results were largely related to duct leakage.
   - Ducts were leakier at post retrofit in 12% of the cases.
   - Average annual projected whole house energy savings is 24%, $467.
   - Lack of return air ducts in the bedrooms creating depressurized main bodies is common and provides an opportunity to discuss remedies with contractors.

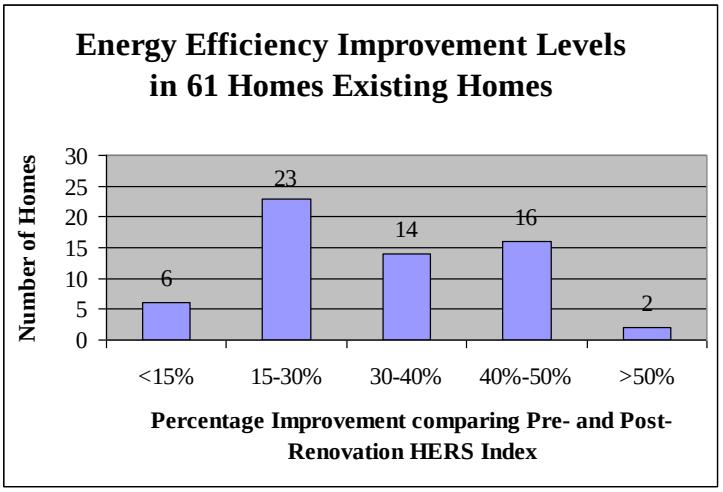


- 32 Homes Achieved 30% or more improvement in HERS Index

B. Flexible residential test structures:

Construction of the flexible residential test structures was completed in December. Instrumentation was ordered and will be installed next quarter. A preliminary measurement of temperature during passive load conditions indicates the buildings track each other well. A number of DOE staff toured the facility when they visited the Florida Solar Energy Center in January, after FSEC had been awarded a four year research contract in which the facility will play a significant role.

"As we address greenhouse gas emissions, we have to look at retrofitting existing homes. This facility will be instrumental in researching the impacts of home energy efficiency improvements in hot climates," said Mr. David Lee, U.S. Department of Energy's Director of Residential Building Programs.



HERS index (the lower the better) for before and after retrofits by year of construction

Right: Cutting the ribbon at the opening of the Flexible Residential Test Facility are (left to right) Robin Vieira, Director, Buildings Research at Florida Solar Energy Center; David Lee, U.S. Department of Energy's Director of Residential Building Programs; James Fenton, Director, Florida Solar Energy Center.

Completed flexible residential test Structures on FSEC campus

UNIVERSITY OF CENTRAL FLORIDA

Enhanced and Expanded Solar Thermal Test Capabilities

PI: Joseph Walters**,** Robert Reedy

Description: The Florida Solar Energy Center (FSEC) serves the State of Florida by providing independent, third-party testing and certification of solar equipment for the main purposes of providing product value in the marketplace, especially for products that are not widely "proven" with consumers such as solar water heating systems and solar electrical (photovoltaic) systems. Even more important, third-party certification provides protection to reputable manufacturers, ensuring that lower quality products, often from foreign markets, do not compete head-to-head with Florida and U.S. products unless they meet the same standards.

In addition, due to the resurgence of the solar industry, FSEC has received a significant increase in demand for solar collector and solar system testing and certification. This occurrence has resulted in requiring the Center to correspondingly amplify its capabilities to respond to the increased demand This project has the objective of increasing FSEC's solar thermal testing and certification activities by upgrading and expansion of testing and analysis equipment and software, integration of the solar collector and system laboratories, enhancing documentation and reporting methods and streamlining and devising more comprehensive client test and certification application documents.

Budget: $809,295
Universities: UCF/FSEC

Progress Summary

The enhanced and expanded solar thermal testing capabilities are close to completion and significant progress has been achieved. The project's objective was to improve the capabilities and output of the thermal test facility by improving the testing equipment and procedures and by increasing the number of test platforms. This objective was achieved by the purchase of equipment and the setting up of data collection procedures. Accomplished during the past year are as follows.

Ten (10) major sub-tasks were identified to attain the objective. A brief sub-task summary is as follows.

1. Tasks that are completed:

   - Interim Test and Report for Certification – Provides a process that allows collectors to get to market quickly while maintaining consumer protection for quality.
   - Mobile Tracking Platform (MTP) Unit 2 Wind System – Provides wind source for collector testing to meet wind requirements on demand.
   - MTP Unit 1 Wind System – Provides wind source for collector testing to meet wind requirements on demand.
   - MTP Unit 1 Conversion to Dual Flow – Provides for test platform to have the capability to process the predominant collector type like the other platforms.
   - LabVIEW® based Collector Testing – Provides updated data logging automation for improved reliability and data transfer and automated testing for differential pressure testing, RTD calibration & flow calibration.
   - Sensor Improvement – Provides implement of new sensors and applications of sensors for more reliable and precise data measurement.

- MTP Unit 4 – capacity increase – Brings into production a new test platform that has all the improvements to date with respect to sensors, automation, and wind systems.

2. Tasks that were discontinued:
   - MTP Unit 3 – The unit was to increase capacity, but 15 U. S. test facilities have come on-line in the last year. This fact has significantly reduced the industry demand for FSEC's thermal test services, thus, the unit was not built.
   - Fixed Stand Configuration – This task was to provide a permanent or semi-permanent test platform to improve throughput by reducing the set up and take down time associated with mobile platforms. Demand has reduced need for configuration, thus, the unit was not built.

3. Remaining task:

   - Finish the development of an information control system by creating application for storage and retrieval of test data in a database. The Test Application Data Analysis system provides a more efficient method for data review and generation of summary data related to the tests. Also under development is an information control system that allows customer and user access to determine material status and report on material testing with the ultimate goal of automatically generating the test reports and certifications. This task is approximately 50% completed.
   - The other sub-task of this project is the disassembly and moving of FSEC's solar thermal system test facilities. The solar systems test facilities are located in FSEC's fuel cell laboratory and for space and research needs, the systems test equipment is being moved to the newly enclosed Solar Systems Testing Facility. The Solar Systems Testing Facility is reported in a separate FESC project of the same name. For this equipment move, new storage tanks and test stands have been constructed, but the disassembly part of the old lab is not yet completed. The estimated indicator of completion of the move is 35%.

With the above equipment and new procedures in place, the measurable results are:

Year	Test Rate	Report Rate	Certification Rate
2008 (before project)	4 collectors/year	4 reports/year	4 per year
2009	14 collectors/year*	22 reports/year*	-
2010	27 collectors/year*	20 reports/year*	195 per year †

* These rates include the interim test and report category which allows collectors to get to market prior to performance testing while still protecting the consumer from poor quality product. For 2010 the rate is based on number of units through end of September projected for the year.

† The certification rate was actually the number of certification for FY2010. Thus the absence of data in year 2009. The rate is expected to increase as the information control system is implemented.

Industry Support:

This task will be strongly supported by the solar thermal manufacturers, who must have certification (FSEC within Florida, and FSEC-contracted SRCC nationwide) to effectively sell their products and qualify those products for various state and federal incentives and rebates. The Solar Rating and Certification Corporation (SRCC) currently contracts with FSEC for $500,000 of annual work in testing and certification.

UNIVERSITY OF CENTRAL FLORIDA

Integrated Florida Bio-Energy Production with Carbon Capture and Sequestration

PI: Ali T. Raissi
Co-PI: : N.Z. Muradov (PhD-Chemist), D.L. Block (PhD)
Research Team: Amit Gujar (PhD-ChE), Jong Baik (PhD-ME), Nathaniel Garceau (MS-ChE) and Suzanne Fenton (PhD-ChE)

Description: The aim of this project continues to be production of liquid hydrocarbon fuels derived from lignocellulosic and aquatic biomass employing a two-step thermocatalytic process. In the first step, pre-treated biomass is gasified with oxygen (or air) and steam yielding synthesis gas (syngas) containing hydrogen and carbon monoxide. In the second step, syngas generated by the gasifier enters a Fischer Tropsch (FT) synthesis unit where it reacts to form a range of liquid hydrocarbon fuels – including diesel.

Budget: $425,506
Universities: UCF/FSEC

Progress Summary

We have completed fabrication and testing of new updraft oxygen blown gasifier (see Fig. 1). A fuel chamber with two gate valves can be seen at the top of the reactor. A high pressure water pump and an oxygen feed line connect to the bottom of gasifier supplying oxidants at elevated pressures. Syngas from gasifier is routed into a condenser placed in a chilled ice bath which then passed through a gas-liquid separator. The gas then passed through a bed of activated charcoal and through a bed of drierite. A three way-valve was setup so that the syngas produced can be used to pressurize and purge the lock hopper chamber. The fuel chamber can accommodate several kilograms of biomass feed. In a typical experiment, biomass is feed to the gasifier at approximately 110 g batches, in regular intervals.

Fig. 1. Continuous flow gasifier.

The gasifier was operated with oxygen flow of 3 L/min and 5 g/min of added steam – giving an input $[H_2O]_0/[O_2]_0$ ratio of 2.23. The gasifier was initially charged with 200g of pine wood charcoal pellets. The lock hopper was filled with 100g of pine wood charcoal which was fed into the gasifier (using the valves) at 20 min intervals. The gasifier was run continuously for approximately 3.8 hrs.

The gas concentration and syngas flow rate profiles are shown in Fig. 2.

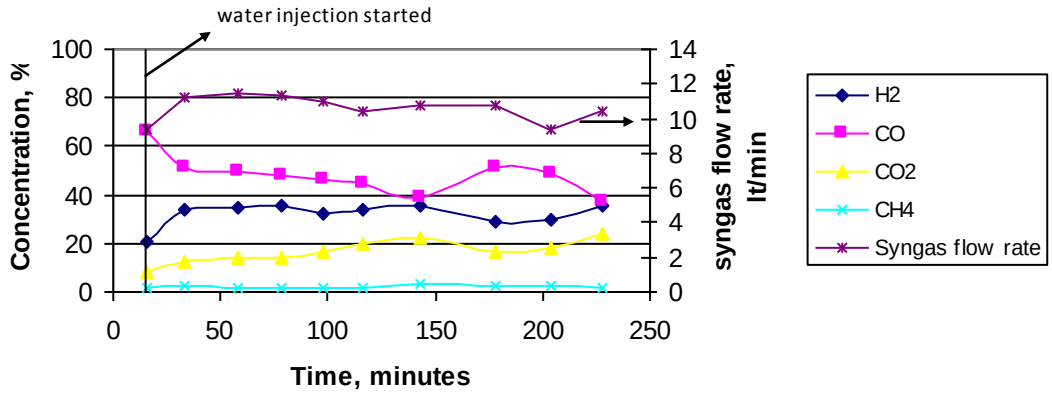


Fig. 2. Syngas composition and flow rate profile with time.

No oxygen bypass was observed. The exit syngas flow rate was around 10 L/min and the CO_2 concentrations were consistently below 25%. The H_2/CO ratios are also lower than that obtained for previous runs (at similar $[H_2O]/[O_2]$ ratios).

New collaborations		
R.J. Saxton	Chevron Energy Technology Company	FT catalyst development and evaluation
H. Chen	Bing Energy Inc.	Fuel reformation for PEMFC

Proposals						
Title	**Agency**	**Solicitation No.**	**Role**	**Funding requested**	**Duration**	**Date submitted**
Conversion of Biomass into Liquid Fuel with CO_2 Capture	U.S. Dept of Energy	DE-FOA-0000337	Co-PI Lead: Dr. Steve Xiao, Savannah River National Laboratory, Aiken, SC	UCF share: $300,000	3 years	February 4, 2011
Fuel-flexible Reformers for Converting Raw High-Sulfur Fuels to Fuel Cell-grade Hydrogen	U.S. Dept of Energy	DE-FOA-0000360	PI Collaborator: Bing Energy Inc., BEI	$1,012,020	3 years	March 3, 2011

University of Florida

Florida Advanced Technological Education Center (FLATE)

PI: Marilyn Barger, Hillsborough Community College

Description: FLATE (Florida Advanced Technological Education Center) is FESC's partner to develop statewide curriculum frameworks for technical A.S./A.A.S. degree programs supporting existing and new energy business sectors. FLATE develops the frameworks and facilitates their progress through the multiple sequential industry-validation, student competencies based, FLDOE procedure. FLATE also develops new courses and provides faculty professional development as required for each new program of study. Additionally FLATE helps colleges in the State College System 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 additional professional development opportunities for teachers and faculty to upgrade and update their STEM 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 continued to work with several community colleges and their local industry to define curriculum standards for alternative energy to support industry needs, made several presentations both within and outside of Florida, and is continuing to work with Brevard Community College, Tallahassee Community College, and Florida State College at Jacksonville for implementation of an Alternative Energy Systems Specialization. FLATE also conducted a state-wide survey to assess Florida's current Alternative Energy course offerings at State and Community colleges for the FESC education portal.

Specific accomplishments during the period are:

A. October 2010 to December 2010

- Participated as Advisory Council Member for the Banner Center for Energy's Focus Group meeting to assess future educational needs from industry within the Indian River State College area. (Orlando, FL)
- Attended presentation from the Sustainability Education & Economic Development (SEED) on application of Nanotechnology to Solar Cells. (Brandon, FL)
- Reviewed proposed course curriculum and frameworks in the Florida Energy Workforce Consortium (FEWC) quarterly meeting. (Orlando, FL)

- Jointly with Brevard CC, Tallahassee CC, FSCJ and University of Florida's Industrial Assessment Center discussed possibilities of establishing new educational programs at the three colleges that would prepare a new workforce in commercial building and residential energy efficiency. (Gainesville, FL)
- Focus group participant for the Second Annual Gathering of Tampa Bay Sustainability Educators for idea generation and implementation plans to improve sustainability efforts in the Tampa Bay area. (Tampa, FL)
- Initiated discussions with Hillsborough CC on partnership arrangements with other Florida colleges for participation in an exchange course with Denmark for Sustainability Studies where see towns that utilize distributed power generation facilities such as CHP plant with trash as fuel source. Obtained partnership with SCF in Sarasota. (Tampa, FL)
- Completed and distributed a survey to all State/Community colleges throughout Florida to assess the state's current educational offerings in alternative/sustainable energy.

B. January 2011 to March 2011

- Worked with HCC's Sustainability Council towards its goal of reducing greenhouse gas (GHG) emissions on a yearly basis. Energy audits are to be conducted by TRANE across all campus locations as well as implementation of GHG emission mitigation projects.
- Began planning phase on a professional development summer energy workshop for middle school/high school teachers.
- Discussed with a local development company, HCC leadership, and District's House Representative, Rachel Burgin, future development of a CHP site in the Valrico, FL area and the possibility of using a portion of the site as a training facility for hands-on alternative energy education.
- Presented a poster entitled "Building the Technician Workforce for Florida's Energy Future" at the Green Energy Summit in Milwaukee, WI.
- Presented "Developing an Alternative Energy Credit Certificate for Florida" at the IREC 2011 Clean Energy Workforce Education Conference in Saratoga Springs, NY.
- Compiled data from 14 State/Community colleges that replied to the survey of alternative/renewable energy courses offered in Florida. Following up with non-respondents.
- Completed upload onto FLATE's Wiki of course curriculum EST1830 Introduction to Alternative and Renewable Energy made up of 16 individual instructional "modules". Course content is made freely available to self-learners, students and educators. Material is available here: http://flate.pbworks.com/w/page/35326400/EST1830-Introduction-to-Alternative-Energy-Course-Content

3. Funds leveraged/new partnerships created

a. Please document how you have leveraged your FESC funds by listing any grant proposals/funding received or new collaborations. For each project/collaboration, you should include the following information, if applicable:

UNIVERSITY OF FLORIDA

Development of Low Cost Low Cost CIGS Thin Film Hot Carrier Solar Cells

PI: Gijs Bosman, Yige Hu (Ph.D.)

Description: Our study is focused on hot carrier solar cells for cell conversion efficiency improvement in a low cost, high throughput CIGS system. The rapid thermalization loss of hot photoexited carriers interacting with the lattice can potentially be reduced through phonon engineering in the absorber layer; the subsequent extraction of the hot carriers may be realized through device engineering of energy selective contacts.

Budget: $450,000
Universities: UF

Progress Summary

Our research for this period was focused on modeling energy selective contacts to collect the hot carriers generated in the solar cell absorber without energy loss and prevent cold carriers from the contacts to flow into the hot absorber. The proposed contact configuration borrows a structure used to increase the responsivity of photodetectors and has a double barrier quantum well (DBQW) configuration, which consists of ultrathin barriers on either side of a quantum well as depicted in figure 1. This is a resonant tunneling structure where the transmission probability goes towards one within the resonant energy band and falls towards zero outside the band. The energy range is optimized to match the most likely energy of the hot carriers, so that existing carriers will be collected as quickly and efficiently as possible and cold carriers from the contact are prevented to flow into the absorber. The key is to select an appropriate materials system.

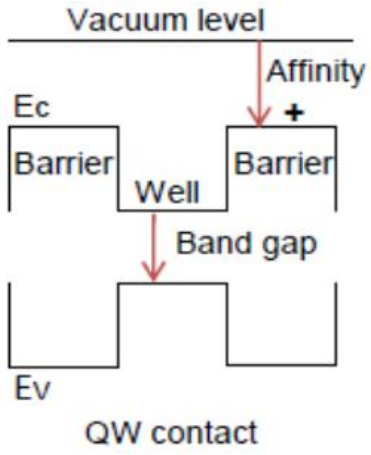


Figure 1. Band diagram of double barrier quantum well contact

Of the materials considered, AlN is a very good candidate for adapting to the CIGS absorber, as the material is used in a number of applications requiring very thin films. Furthermore, the high bandgap of AlN and the thin layer of the well material make it transparent for photon transport. Two reasonable well material candidates for the QW are $CuGaSe_2$ and GaN. $CuGaSe_2$ is compatible with the absorber and also has a high electron affinity to form a suitable well between two AlN cladding films. GaN has a wider band gap (3.4 eV) then CGS and thus more transparent. GaN also shows a type I band alignment with AlN with the valence and conduction band offsets about equal.

Preliminary simulations were performed on a AlN/$CuGaSe_2$/AlN structure for selected thicknesses (see Figure 2). The simulated electron transmission probability is shown in the Figure 2(a) and (b). Calculations performed as a function of barrier and well widths result in different resonant band locations. In Figure 2(a), the thickness of the AlN barrier is 4nm and the thickness of $CuGaSe_2$ well is 2nm. Seven resonant bands appear for electrons with energies ranging from 0 to 3 eV. In Figure 2(b), the thickness of the AlN and $CuGaSe_2$ layers are 2nm and 4nm, respectively. There are still seven resonant bands for incident energies ranging from 0 to 3 eV. More resonant bands, however, are located below 2 eV. The resonant bands located above 2eV are narrower and better separated. Hence, tuning the DBQW structure

gives desirable energy selections for the hot carrier solar cell domain of operation. The hole transmission probability of the respective AlN DBQW contacts are shown in Figures 2(c) and (d). The energy selection property is not obvious for holes because the barrier potentials for holes are small. Also the relatively heavy mass of the holes works to reduce the resonance. Candidates for hole ESCs will still have to be identified. The results of above simulation are encouraging and simulations will be performed using GaN as the QW material.

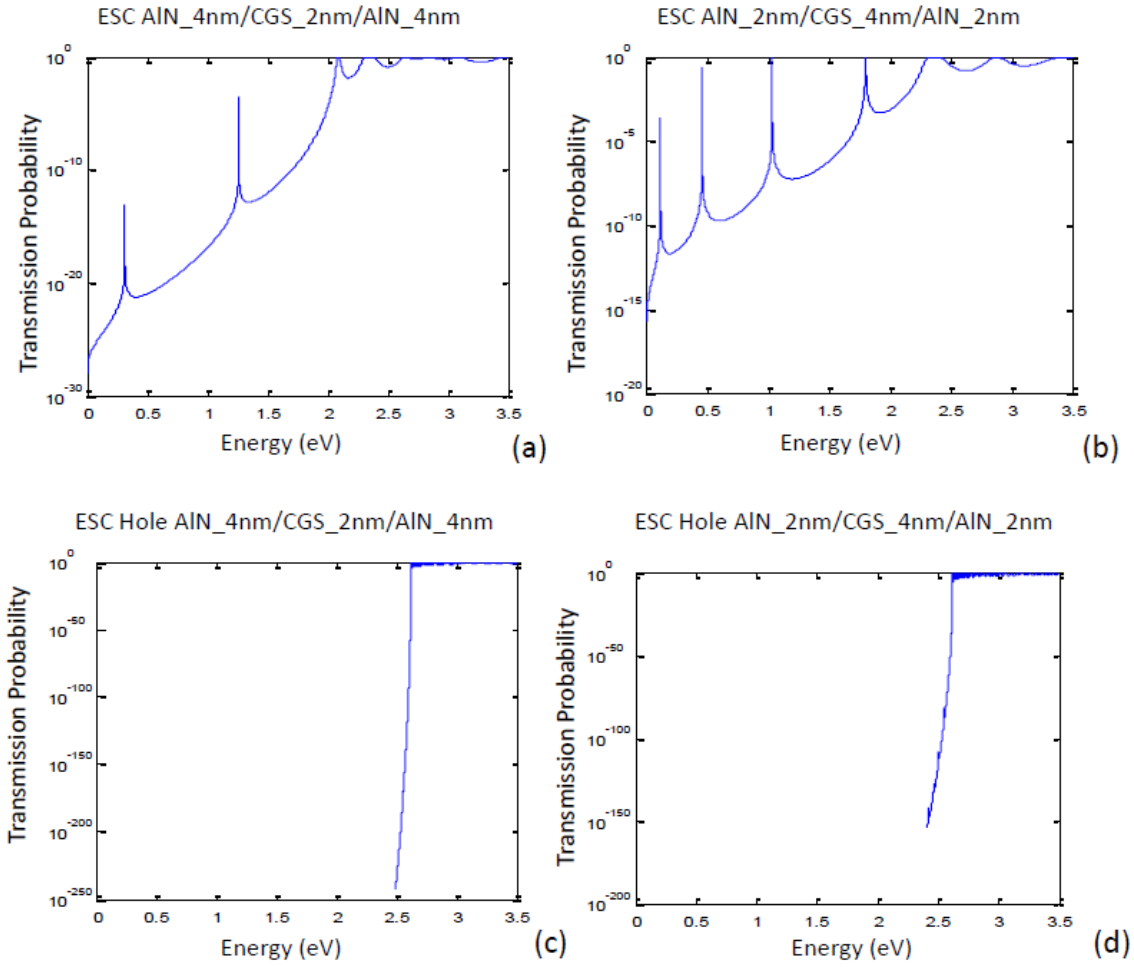


Figure 2. Transmission probability of an AlN DBQW contact: (a)electron transmission probability of AlN/CGS/AlN DBQW with 4nm AlN and 2nm CGS layers, (b)electron transmission probability of AlN/CGS/AlN DBQW with 2nm AlN and 4nm CGS layers, (c)hole transmission probability of AlN/CGS/AlN DBQW with 4nm AlN and 2nm CGS layers, and (d)hole transmission probability of AlN/CGS/AlN DBQW with 2nm AlN and 4nm CGS layers.

UNIVERSITY OF FLORIDA

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

PI: Gabriel Ghita

Faculty Participants: DuWayne Schubring

Students: S. Brown (BS), G. Fekete (BS), A. Holcomb (BS), D. Lago (BS), M. Marzano (MS), J. Musgrave (MS)

Staff participants: 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

In order to make the UFTR capable of offering training to engineers and operators, it is necessary to receive approval from NRC on reactor relicensing application and on the Licensing Amendment Request (LAR) for the digital control upgrade. Then install and test the new digital system. Thus far, we have been working on:

i) Licensing applications (submitted to NRC)
   a. UFTR Relicensing Application
   b. LAR for digital protection system
ii) Basic Design Documentation (submitted/to be submitted to AREVA)
iii) Application Software Development

i) a. UFTR Relicensing Application

This work was completed and we still are waiting for the license renewal.

i) b. LAR for the digital protection system

We are following the following licensing approach for which we have submitted a modified Final Safety Analysis Report (FSAR) based on NUEREG 1537, and referenced various documents related to licensing of a digital protection system. Figure 1 depicts this process:

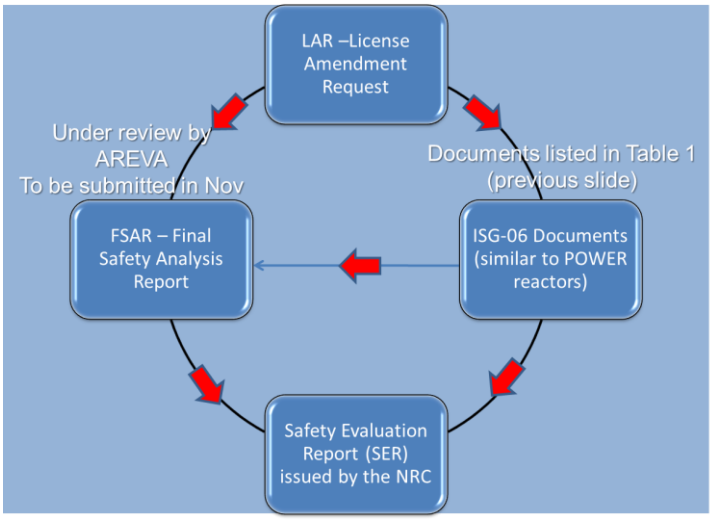


Fig. 1 - New licensing process for the UFTR Digital Control upgrade