Description: Solar concentrating systems use direct beam solar energy focused to produce high temperatures for power production. They hold promise for Florida given a sufficient direct beam resource and assuming the technology can meet production and cost goals. Existing measurements of direct beam solar energy are limited to a few Florida locations. The objective of this R&D project is to advance concentrating technologies by conducting an analytical study of the Florida solar resource in order to predict performance and the amortized cost of energy from this technology in the Florida environment. Later years may include experimental tests for validation of the predicted results.

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

Progress Summary

The evaluation of solar concentration systems for performance and energy production requires as input, a prediction of the solar direct beam resource throughout the year for the anticipated installation location. These systems have been previously installed in the desert southwest where direct beam data has been accumulated over many years. A problem was identified – the lack of validated direct beam measurements for the State of Florida.

Literature Search Completed: Various methodologies to resolve the problem were investigated through literature search. Over 40 published papers were reviewed for information on the determination of the direct beam resource and the establishment and validation of predicting equations.

Method Selected: The Heliostat-2 method was selected as the most viable to provide validated direct beam historical data for Florida. This method (developed a few years ago by Ecole de Mines de Paris) basically consist of using two parameters, turbidity (atmospheric conditions), and elevation as input, to provide an estimation of the total, beam and diffuse radiation based on a “clear sky model”. That is, the amount of direct beam and diffuse radiation that would reach the ground for a totally clear sky, given location, time of year, and time of day. Then satellite images (visible band – grey level on the pixel/point of the image), are used to calculate a prediction of the cloudy level for each pixel of the satellite image. This level is then used by equation to modify the “clear sky” data to produce a predicted value of the beam and diffuse solar radiation. These values are validated with on-the-ground measurements. Once these values are calculated and validated they can be used to produce a historical data set of solar radiation for any given lat – long location across Florida. The data is also used to produce a statistically based 95% confidence interval for the expected solar radiation for any site. This information is a necessary input for existing performance/output models to determine projected cost per kWh of solar concentrating power plants in the Florida environment.

Proposals Written: One objective of the Consortium effort is to leverage the activity with funding from other sources and the model developed could be used in other locations. To this end, two proposals for outside funding were written and submitted in the previous review period to the Commonwealth of Puerto Rico. In this past review period, Puerto Rico determined not to fund these two proposals.

Programming of Algorithms Continues: It was determined to program the equations for each stage in the calculation sequence using the Excel calculation platform. Excel was selected to provide a step by step visualization of each calculation, for a single pixel and time, as a check on the programming...
that produces the direct beam matrix. Turbidity calculations have been completed and published for Europe, but are not available for the US or Florida. Thus, this must be part of the calculation sequence for the model. Programming for the model continues this review period. Turbidity as developed in Europe is a combination of three factors, Raleigh optical scattering (scattering due to molecular effects), Aerosol optical scattering (dust, ash, etc.), and the Absorption of gases (Water vapor, Ozone, NO2). For the Florida data base, the dominating factor is water vapor. Thus, Raleigh optical scattering will be used to determine the clear sky matrix data, and water vapor will be regressed via available RH data along with cloud cover data to create the predicting algorithms. Cloud cover data accumulation has begun this review period and continues. Six satellite photos per day at 13:15, 15:15, 17:15, 19:15, 21:15, and 23:15 Zulu time are being retrieved from the NOAA satellite archive of the GOES East Hurricane Sector in the visible spectrum. Each .gif file (with compression) is converted into a .bmp file to provide a consistent file size and map of brightness pixel values relating to a fixed lat-long matrix. The satellite photo data has been analyzed using the file descriptor tool NEO, which provides file internal locations and hexadecimal values within locations of the file. A program has been completed that provides the brightness value of the satellite image, given the latitude and longitude as input. Progress continues on the development of these predicting algorithms.

2010 Annual Progress Report

The general objective of this R&D project is to advance concentrating technologies that can be deployed in Florida for the near term and to develop advanced technologies that make future solar trough concentrating power plants more competitive with conventional power plant sources.

The project will consist of two phases as follows:

**Phase I:** Conduct analytical study of Florida solar resource and predict the performance of a concentrated solar power plant.

**Phase II:** Using Potential Follow on Funding - Perform experimental tests and evaluations of the analytical results from Phase I.

**Project Impact:**

Solar concentrating systems use mirrors to focus sunlight onto receiver pipes located at the focal point of the parabolic mirrors. The fluid is then stored and used to generate electricity from a conventional steam turbine. Given a sufficient input of direct beam solar energy, concentrating solar system plants are one of the lowest-cost centralized solar power options, with great potential to become directly competitive with conventional power sources. After many years of applications, solar concentrating technology has the ability to produce electricity for about $0.10/kWh in the desert southwest environment. The technology holds promise for
Florida and could also produce low cost solar electricity in Florida assuming the direct beam resource is sufficient and the technology can meet production goals.

Solar concentrating technology has been successfully applied in the U.S. desert southwest. To use the same southwest desert technology in Florida may not be applicable because Florida’s solar resource (amount of direct solar radiation) is significantly less than the desert southwest, and because of Florida’s harsher environment conditions of high humidity and salt air.

Trough Concentrating System in Arizona.

In the first phase, this project has conducted an extensive literature search, and developed a model to produce a historically based solar resource set of tables for locations across Florida. These tables are in the process of being constructed and will be validated by comparison with the direct solar radiation data collected at FSEC as part of the solar collection testing program. This data has been collected for longer than 10 years at FSEC’s location and was also collected at FSEC’s old location in Cape Canaveral. The first outcome of this effort will be validated values for the solar direct beam and diffuse resource available across Florida. The data will be available by the entry of latitude and longitude of the Florida location. This solar resource data will then be used to predict the power output performance of a solar trough system, given the potential location of installation.

Assuming that Phase I results are satisfactory and ongoing funds are available, Phase II will perform an experimental test in order to evaluate the analytical predictions. In addition, this project will test complete prototype systems and each of the system components for their application, durability and reliability. Without a durable and reliable system, the solar concentration project has the potential of not providing the energy it was design to produce. The research plan is to install one solar concentrator pilot system and collect the operating and performance data.

Project Description:

The goal of this program is to analytically evaluate and then develop and test concentrating solar thermal power systems as they are applied to the solar radiation and the environment conditions of the state of Florida. The specific project goals are:

**Phase I**
- Analytically evaluate the solar radiation resource for Florida.
- Evaluate concentrator performance for potential Florida locations.

**Phase II (With follow-on funds)**
- Evaluate collector support pylons
- Field test collector support bearings
- Deploy, test and evaluate hydraulic drive mechanisms
- Implement and check ball joint assemblies
- Field test tracking controller (sun tracking)
- Collect operating and performance data

In achieving these goals, the project is designed to increase the potential of U.S. solar collector technology, improve concentrating receivers and support development of advanced thermal storage technologies. The project will also improve computer simulation tools and testing capabilities and improve the technological knowledge base necessary to support the growth of a new solar concentrating industry in the southeast.

For Phase II, this project will be closely coordinated effort with FPL and will use FPL’s solar concentrators that are to be used for the Florida solar power project. FPL support will be required. One of the technologies to be studied is the Ivanpah Solar Electric Generating System. The Ivanpah System is presently planed to be used on three solar thermal power plants near Ivanpah Dry Lake in California on land managed by the Bureau of Land Management. The proposed California project is to be constructed
in three phases: two 100-megawatt (MW) phases (known as Ivanpah 1 and Ivanpah 2) and a 200-MW phase (Ivanpah 3). The three plants are collectively referred to as the Ivanpah Solar Electric Generating System and would be located in the Mojave Desert close to the California-Nevada border.

The intent of this project is obtain the initial groundwork technical data needed for implementing FPL’s recently announced 300 mega-watt solar power plant for Florida. Performance and durability data will be taken in collaboration with FPL.

Industry Support:

After many years of applications, solar concentrator technology has the ability to produce electricity for about $0.10/kWh in the southwest desert. The technology holds high promise for Florida assuming it can meet production and cost goals. The technology also has large potential to generate electrical power and to produce the local jobs that support this form of power production. The electrical mega-watt power needs for Florida far exceeds the ability to build enough solar concentrator plants to meet the state’s demand.

The prime supporter of this project is FPL. All of the other Florida and Southeast utilities will be interested in the project’s outcome and the data produced.

Estimated Budget:

Annual budget for this task is $52,000 to be allocated for 0.5 FTE faculty member. Continuation of this task will depend upon securing of federal or industry support.

Phase I Effort:

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

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

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

Translated from the Russian by R. B. Rodman. LCCN 65011345
Method Selected: The Heliostat-2 method was selected as the most viable to provide validated direct beam historical data for Florida. This method (developed a few years ago by Ecole de Mines de Paris) basically consist of using two parameters, turbidity (atmospheric conditions), and elevation as input, to provide an estimation of the total, beam and diffuse radiation based on a “clear sky model”. That is, the amount of direct beam and diffuse radiation that would reach the ground for a totally clear sky, given location, time of year, and time of day. The calculation protocol begins with a calculation for the “extra terrestrial insolation value.” The air mass is then calculated given the altitude of the site and surface barometric pressure. The turbidity (absorption and scattering) of the air mass is then calculated based on ground temperature and humidity which is used to derive the “clear sky” data.

GOES – STATIONARY SATELLITE IMAGE OF FLORIDA (FROM NOAA)

Then satellite images (visible band – grey level on the pixel/point of the image), are used to calculate a prediction of the cloudy level for each pixel of the satellite image. This level is then used by equation to modify the “clear sky” data to produce a predicted value of the beam and diffuse solar radiation. These values are validated with on-the-ground measurements. Once these values are calculated and validated they can be used to produce a historical data set of solar radiation for any given lat – long location across Florida. The data is also used to produce a statistically based 95% confidence interval for the expected solar radiation for any site. This information is a necessary input for existing performance/output models to determine projected cost per kWh of solar concentrating power plants in the Florida environment.

Proposals Written: One objective of the Consortium effort is to leverage the activity with funding from other sources and the model that is in development under this effort could be used in other locations. To this end, two proposals for outside funding were written and submitted in the previous review period. The Commonwealth of Puerto Rico is also interested in the viability of concentrating solar power production. They have the same difficulty as Florida, the lack of validated historical data on the direct beam solar resource needed to evaluate this opportunity. The two proposals were: a. $208,000 Determination of the Solar Resource for Puerto Rico, submitted to the Puerto Rico Energy Office for an island wide study, and b. $35,000 Determination of the Solar Resource at the Phillips Plant, submitted to the Puerto Rico Electric Power Authority (PREPA), to do a resource evaluation for a specific site. In the last review period, word was received that these proposals were not funded.

Programming of Algorithms Continues: It was determined to program the equations for each stage in the calculation sequence using the Excel calculation platform. Excel was selected to provide a step by step visualization of each calculation, for a single pixel and time, as a check on the programming that produces the direct beam matrix. Turbidity calculations have been completed and published for Europe, but are not available for the US or Florida. Thus, this must be part of the calculation sequence for the model. Programming for the model continues this review period. Turbidity as developed in Europe is a combination of three factors, Raleigh optical scattering (scattering due to molecular effects), Aerosol optical scattering (dust, ash, etc.), and the Absorption of gases (Water vapor, Ozone, NO2). For the
Florida database, the dominating factor is water vapor. Thus, Raleigh optical scattering will be used to determine the clear sky matrix data, and water vapor will be regressed via available RH data along with cloud cover data to create the predicting algorithms. Cloud cover data accumulation has begun this review period and continues. Six satellite photos per day at 13:15, 15:15, 17:15, 19:15, 21:15, and 23:15 Zulu time are being retrieved from the NOAA satellite archive of the GOES East Hurricane Sector in the visible spectrum. Each .gif file (with compression) is converted into a .bmp file to provide a consistent file size and map of brightness pixel values relating to a fixed lat-long matrix. The satellite photo data has been analyzed using the file descriptor tool NEO, which provides file internal locations and hexadecimal values within locations of the file. A program has been completed that provides the brightness value of the satellite image, given the latitude and longitude as input. Progress continues on the development of these predicting algorithms.