STATE ENERGY CONSERVATION OFFICE
Contract No. CM615 - Entry Level PV Installer Training
Final Report

Project Summary

Overall the project has achieved a level of success well beyond the expectations of the ACC Continuing Education management team that directed the project, the Texas State Energy Conservation Office (SECO) that supported the development and implementation of the project, and team of course designers and instructors who brought the course concept to the Austin Community College (ACC).

Market Response:
We were confident that our course would find enough student interest to make it worthwhile to offer the course. We actually received an overwhelming response. The course filled up to capacity and we immediately added a second class for the first semester of the course which also filled to capacity. Each semester we had a waiting list. We found that the course would fill without advertising through the Austin Chronicle as we did in the beginning. Word of mouth and placement in the ACC course catalog was sufficient and we still had a waiting list. Overall, 50 students completed the course during the term of the grant and $25,000 was collected in course tuition and lab fees.

Student Appreciation:
We found that the evaluations were always very positive and several students continue to be in contact with the course instructors as they pursue their careers in solar energy. Additional evaluation detail is included later in this report.

Impact on the Local Industry:
Solar contractors have asked for recommendations from the instructors as they interview for open positions for their companies. Several graduates of the course are now working for local solar companies or starting their own solar company.

Continuing and Future Training Needs:
There will continue to be demand for this Entry-Level NABCEP-based course both as a college credit course and as a continuing education course. In addition, there is demand for the Professional-Level NABCEP-based course in solar photovoltaics as well as solar thermal technologies. This demand for advanced training has been articulated both by students of the Entry-Level course as well as others in the area who were hopeful that the current course offering would be the Professional-Level course.

Deliverable Outcomes

1. ***Review learning requirements for the Entry Level Certificate and the Test and Administrative Process of the North American Board of Certified Energy Practitioners (NABCEP) and develop compatible weekly learning objectives.***

58 Learning Objectives have been grouped into 10 Course Sections. The Course Sections have been scheduled over a 13 week period. There are 48 total class hours. These hours are used for Regular Classes (held in the evenings) and for Saturday Classes.

22 Regular Classes for 1.5 hours each (33 hours)

- 1 Class for Mid-Term Exam;
- 1 Class for de-briefing the solar installation and conducting a general review;
- 1 Class for Final Exam;
- 1 Class for Final Exam review and prep for the NABCEP Certification Test;
- 18 classes for instruction, quizzes, and homework review

3 Saturday Classes for 5 hours each (15 hours)

The certification test to gain the NABCEP Photovoltaic Entry Level Certificate of Knowledge is not administered during the 48 hours of this course. It is available through the ACC Business Assessment Center.

2. ***Review and incorporate the existing PV installer training materials and improve with additional materials needed to develop the program into a full semester of workforce development training.***

<u>Overall Course Outline</u>

Section 1. PV Markets and Applications

- 1.1 Describe history of PV technology and industry
- 1.2 Describe markets and applications for PV (grid-tie, remote homes, telecom, etc.)
- 1.3 Identify types of PV systems (direct motor, standalone with storage, grid-backup, etc.)
- 1.4 Associate key features and benefits of PV with applications

Section 2. Electricity Basics

- 2.1 Explain difference between energy and power
- 2.2 Define basic electrical terms
- 2.3 Describe the use of digital multi-meter
- 2.4 Calculate simple circuit values

Section 3. Solar Energy Fundamentals

- 3.1 Define basic solar terms (e.g., irradiation, Langley, azimuth)

3.2 Determine true (solar) south from magnetic (compass) south given a declination map
3.3 Describe Basic solar movement and effect of earth tilt
3.4 Predict solar position using solar path diagrams
3.5 Describe angular effects on the irradiance of array
3.6 Identify factors that reduce/enhance solar irradiation
3.7 Determine average solar irradiation on various surfaces
3.8 Convert solar irradiation into a variety of units
3.9 Determine effect of horizon on solar irradiation (shading)
3.10 Demonstrate use of Solar Pathfinder or sun charts

Section 4. PV Module Fundamentals

4.1 Explain how a solar cell converts sunlight into electric power
4.2 Label key points on a typical IV curve
4.3 Identify key output values of solar modules using manufacturer literature
4.4 Illustrate effect of environmental conditions on IV curve
4.5 Illustrate effect of series/parallel connections on IV curve
4.6 Define measurement conditions for solar cells and modules (STC, NOCT, and PTC)
4.7 Compute expected output values of solar module under variety of environmental conditions
4.8 Compare the construction of solar cells of various manufacturing technologies
4.9 Compare the performance and characteristics of various cell technologies
4.10 Describe the components and construction of a typical flat plate solar module
4.11 Calculate efficiency of solar module
4.12 Explain purpose and operation of bypass diode
4.13 Describe typical deterioration/failure modes of solar modules
4.14 Describe the major qualification tests and standards for solar modules

Section 5. Safety Basics

5.1 Identify safety hazards of operational and non-operational PV systems
5.2 Identify safety hazards, practices and protective equipment during PV system installation and maintenance (electricity, batteries, roof work)

First Lab Day

Lab Experiment 1: Testing and Measuring Solar Cell Characteristics
Lab Experiment 2: Connecting Modules in Series and Parallel
Lab Experiment 3: Connecting Modules to Batteries and Loads
Lab Experiment 4: PV Module I-V Measurements
Lab Experiment 5: Setting up the Pathfinder
Lab Experiment 6: Conducting a Site Survey: Evaluating the storage building for a Solar Installation
Lab Experiment 7: Conducting a Site Survey: Evaluating the simulated roof for a Solar Installation
Lab Experiment 8: Final Site Evaluation

Section 6. System Components

6.1 Describe purpose and operation of main electrical BOS components (inverter, charge controller, combiner, ground fault protection, battery, and generator)
6.2 Identify key specifications of main electrical BOS components (inverter, charge controller, combiner, battery, and generator)

Section 7. PV System Sizing

7.1 Illustrate interaction of typical loads with IV curve (battery, MPPT, dc motor)
7.2 Analyze load demand for stand-alone and grid interactive service
7.3 Identify typical system electrical output de-rating factors
7.4 Calculate estimated peak power output (dc and ac)
7.5 Calculate array and inverter size for grid-connected system
7.6 Calculate estimated monthly and annual energy output of grid-connected system
7.7 Explain relationship between array and battery size for stand-alone systems
7.8 Calculate array, battery and inverter size for stand-alone system

Section 8. PV System Electrical Design

8.1 Determine series/parallel PV array arrangement based on module and inverter specifications
8.2 Select BOS components appropriate for specific system requirements
8.3 Determine voltage drop between major components

Section 9. PV System Mechanical Design

9.1 Describe most common solar module mounting techniques (ground, roof, and pole)
9.2 Compare features and benefits of different solar mounting techniques
9.3 Explain the relationship between solar module cell temperature and environmental conditions, given mounting method (e.g., NOCT)
9.4 Describe the relationship between row spacing of tilted modules and sun angle
9.5 Describe the mechanical loads on a PV array (e.g., wind, snow, seismic)

Section 10. Performance Analysis and Troubleshooting

10.1. Describe typical system design errors
10.2. Describe typical system performance problems
10.3. Associate performance problems with typical causes
10.4. List equipment needed for typical system performance analysis
10.5. Compare actual system power output to expected
10.6. Identify typical locations for electrical/mechanical failure

Second Lab Day: Solar PV System Installation

Physically mount all components
Electrically connect all components
Conduct a system checkout and inspection

3. ***Develop in-class exercises to include: a) Interactive whiteboard explanations; b) Individual student, team, and hands-on lab exercises; c) and Identify and select textbook and reading materials.***

The methods of instruction include hands-on equipment training, in-classroom team-oriented table-top experiments, classroom instruction, homework assignments, and outside lab days.

The outside lab days include experiments, use of equipment, safety instruction, and the installation of an actual grid-tied solar photovoltaic system.

Classroom instruction consists of interactive lectures, class discussions, in-class exercises, PowerPoint presentations, and video illustrations. The classroom agenda is based on the assumption that the students have done the reading assignments before class.

The overall goal for this course is to conduct the training in such a way so that all who have the aptitude can successfully pass the NABCEP certification test at the end of the semester. Instructors need feedback from the students in order to judge if they are being adequately prepared. This feedback is in the form of written quizzes, hands-on exercises, verbal responses, homework problem sets, a mid-term exam, and a final exam. Instructors conduct the two full class exams prior to the actual NABCEP certification test so that the student will know where they stand in their potential to be successful on the actual certification test and can prepare accordingly.

The following course textbook is required:

> *Photovoltaics: Design and Installation Manual*
> Solar Energy International
> New Society Publishers; 2004.

It is available from www.solarenergy.org, www.newsociety.com, and www.amazon.com.

The course also includes supplemental study materials that are detailed in the Instructor's Binder (Teaching Guide).

4. ***Develop class homework assignments that include: a) Reading assignments; b) Problem Sets.***

Homework assignments include reading chapters in the textbook, completing problems in the textbook, completing exercises created by the instructors, reading supplemental materials, and conducting research on the Internet for solar equipment specifications. Also, there are homework exercises that require using Internet-based solar industry calculators for determining solar electric system performance and for system design.

5. ***Develop 4 written tests, a preliminary and final for each session.***

Tests developed for each semester included a Mid-Term Exam, a Final Exam, and a Quiz. The format was the same as the NABCEP Entry-Level Certificate of Knowledge certification exam for the Mid-Term and the Final Exams.

In terms of format, they consist of 60 multiple choice questions that need to be completed within a two hour time period. Also, a Sun Chart, equipment specifications, and a formula sheet are given to the students and they must refer to these documents to answer several of the questions.

In terms of content, the questions are the instructor's best guess as to the content of the NABCEP Entry-Level Certificate of Knowledge certification exam and are not the same questions. NABCEP does not supply example questions for the entry-level certificate. However, the exams do focus on verifying the knowledge required to satisfy the 58 learning objectives as defined by NABCEP for the Entry-Level Certificate of Knowledge.

6. ***Develop Instructor's Binder.***

The course Instructor's Binder is available through the SECO office. This binder includes the following for each of the course sections:

Learning Objectives
Presentations
In-Class Exercises
Class Handouts/Worksheets
Class Video Selection
Homework Reading Assignments both Required and Supplemental
Homework Problem Set

Also, the Instructor's Binder contains the following:

Mid-Term Exam
Final Exam
Quiz
First Lab Day Experiments
Second Lab Day Materials

7. ***Deliver a comprehensive class integrating all necessary materials.***

Three course sections were delivered. This is one more than what was originally required per the contract with SECO. The instructors agreed to teach an additional course section given the large demand for the course. Two class sections were offered in spring 2006 with 14 students in each class. One class section was offered in fall 2006 with 22 students.

8. *Develop and deliver student evaluations of class content, materials, and labs as well as instructor effectiveness.*

Copies of actual student course evaluations are available through the SECO office. Course evaluation questions included:

a) rating the instructors on being prepared, being knowledgeable about the subject matter, presentation style and manner, able to answer questions confidently and completely, and encourages class interaction
b) rating the course content on clarity and understandability, relevance to the objectives, assisting the student on achieving their personal objectives, and title and description accurately describing the class
c) an overall class rating
d) current place of employment
e) how the student heard about the program
f) other comments and suggestions

9. *Review student evaluations. Review and change class dynamics and edit materials if necessary.*

Overall course evaluation results included:

Student course evaluation data collected from all courses sections (2 in Spring 2006, one in Fall 2006) reflect a high rate of student satisfaction for: the course instructors; the course content; and the course overall. There was a slight increase in satisfaction rates in the fall 2006 evaluations, after the Instructors had time to update and improve upon the course from the spring 2006 sections. More specifically, of the students that completed the student course evaluation (31) on a scale from 1 (low) to 5 (high): 81% of students rated the instructors on all criteria at a 4 or higher; 84% of students rated the course content on all criteria at 4 or higher; and 84% of students rated the overall course at 4 or higher, with 71% of students rating the overall course at a 5. Additional written comments on student course evaluations included suggestions for improvement in course delivery, as well as praise such as "course was very helpful", "great experience", and "I feel I am properly prepared for my upcoming NABCEP certification", "very well educated instructors", and "I had a great time learning and am walking away feeling very excited about my future in solar".

For the "Your Employment" section of the student course evaluation, the breakdown is as follows:
1% - Large Employer
16% - Small Employer
23% - Self-Employed
16% - Government Agency
19% - Looking for New Employment

Suggestions for "other programs" received on the student course evaluations included "an internship", "wind & solar", "advanced photovoltaic courses", "HVAC and building efficiency", "more alternative energy courses", and "more solar integrating, other green building technologies", "continuing education courses", "solar thermal", NABCEP small wind power system installer", and "hydrogen fuel cells".

Finally, the student evaluations praised the hands-on equipment exercises and asked for more. In response, the instructors added more experiential training in the form of hands-on equipment exercises that can be done in the classroom as table-top experiments. The instructors also added more homework problems in addition to the reading assignments.

10. Deliver a comprehensive class integrating all necessary materials.

22 students registered and completed the fall 2006 class. Of these, 20 choose to take the NABCEP Entry-Level Certificate of Knowledge exam. 17 successfully passed resulting in an 85% pass rate which was a significant increase compared to the spring 2006 results of a 71% pass rate.

Project Highlights

1) Student Success: Overall, 50 students completed the course in 2006 through 3 class sessions. Of those 50 students, 41 students chose to sit for the NABCEP Entry-Level Certificate of Knowledge exam. Of those 41 students, 32 students passed the exam and received their certificate. This is an overall pass rate of 78% for the year 2006. The pass rate improved from the spring 2006 specific rate of 71% to the fall 2006 specific pass rate of 85%. The national average pass rate (which would include our results) has been 57%.

2) Reproducibility: This project has produced a college level continuing education based course that will be offered on a semester basis at Austin Community College. This course is self-sustaining based on student tuition, and qualifies for state reimbursement from the Texas Higher Education Coordinating Board as an approved Workforce Education Course Manual course. The course can be easily replicated at other community colleges around the state of Texas that can support the facilities needed to effectively deliver the training. The success of this course has prompted ACC to investigate the development of a college credit certificate or degree in "renewable energy". The current ACC course is as follows:

HART 1011 Solar Electricity (Photovoltaics) System Installer (48.0 hours)
A course in the study of solar photovoltaic (PV) cells, modules, electrical circuits and systems; sizing and designing for usage in homes and commercial businesses: Solar electric products, applications and the market place; and understanding energy conversion from sunlight to electricity, and working with solar conversion equipment. The 48-hour course is designed for students to be eligible to obtain the North American Board of Certified Energy Practitioners (NABCEP) Photovoltaic (PV) Entry Level Certificate of Knowledge. *NOTE: Course meets on Wed from 6pm to 9pm for 12 weeks and meets on two Saturdays- from 9am-4pm. Instructors will provide dates of the Saturday classes. Prerequisites: Required: basic math skills (addition, subtraction, multiplication, division, fractions and decimals, use of formulas) and problem solving skills; Preferred: use of a calculator, some knowledge of electricity concepts. See the NABCEP website, for details about the examination.

3) Recognition: The course has been recognized in both the national and local media and promoted by the North American Board of Certified Energy Practitioners and the Interstate Renewable Energy Council www.irecusa.org.

4) Workforce Impact: Several students who completed the course are now working for solar energy companies in the Austin area. They look forward to further training as they gain work experience so that they may sit for the Professional-Level NABCEP certification exam.

Challenges Encountered

Few major challenges were encountered. The ACC staff and students have been supportive and enthusiastic about this new course offering. ACC constructed a storage shed for the outside lab days as well as an excellent outside area for conducting the labs. We have had the support of ACC staff ranging from management, to administration, to the Campus Police.

It is recommended that the course be held in a "dedicated" classroom that contains all of the following: Internet access, computer projector, and locking cabinets for the equipment and tools used for the in-class hands-on table-top experiments. Without this dedicated space, moving and securing of equipment is problematic. A classroom was not available that provided all of these features. It is difficult and time-consuming for the instructors to set-up and bring into the classroom all of the equipment, tools, computer projector, etc. in order to conduct the class. It is recommended that a classroom be available where the in-class experiment equipment can be securely stored and the class can have a "home base." It is preferable to share a classroom with other electronics-related courses.

Lessons Learned

1) Train the Trainer Sessions - The course is intended to be an entry-level course and there are direct ties in the course design to the NABCEP-based learning objectives so that the students are prepared to take the entry-level NABCEP certification exam. It was discovered that focusing the instructor's knowledge to produce entry-level material in alignment with the NABCEP-based learning objectives had to be very deliberate. There is a strong tendency on behalf of the instructors to elaborate well beyond the entry-level. Unfortunately, this can become overwhelming for a student class where we do not have pre-requisite course work. Also, it can be difficult for the student to comprehend what they need to know as an entry-level practitioner-to-be versus an experienced practitioner. Therefore, it is recommended to hold Train-the-Trainer sessions to insure that subsequent instructors for ACC and for other colleges understand the course objectives and the proper level of training for this course versus more advanced courses.

2) Tuition - The course tuition of $475 plus $25 lab fee is very competitive with the only other alternative in the Austin area which is a one-week workshop priced at $750. The full semester college course approach brings much higher value for students and is the best approach to achieve quality workforce development under NABCEP expectations. A course tuition increase should be considered by ACC Continuing Education as well as other colleges in order to insure a sustainable program and a continuation of both the quality of the course and the excellent results seen in the student's NABCEP certification testing.

3) Dual Instructor Approach - We found that the dual instructor approach works best now that the instructors have tried both the dual and the single instructor approaches. There is a high level of in-class interactivity and experimentation that is served well by the dual instructor approach particularly regarding team exercises where multiple experiments and exercises are happening concurrently. Also, the Lab Days require dual instructors for the setup, for monitoring the student team performance, for ensuring safety of the students, and for tear down and storage of the equipment.