

Final Report
**“Feasibility Study for Photovoltaics, Wind, Solar Hot Water for ON/OFF Grid-
Connected Power to SIPI Campus”**

Award # DE-FC36-00GO10629
Southwestern Indian Polytechnic Institute
October 1, 2000 - December 31, 2007

Summary

Southwestern Indian Polytechnic Institute (SIPI) located in Albuquerque New Mexico is a community college that serves American Indians and Alaska Natives. SIPI's student body represents over 100 Native American Tribes.

SIPI completed a renewable energy feasibility study program and established renewable energy hardware on the SIPI campus, which supplements and creates an educational resource to teach renewable energy courses. The SIPI campus is located, and has as student origins, areas, in which power is an issue in remote reservations. The following hardware was installed and integrated into the campus facilities: small wind turbine, large photovoltaic array that is grid-connected, two photovoltaic arrays, one thin film type, and one polycrystalline type, one dual-axis active tracker and one passive tracker, a hot air system for heating a small building, a portable hybrid photovoltaic system for remote power, and a hot water system to preheat water used in the SIPI Child Care facility. Educational curriculum has been developed for two renewable energy courses one being the study of energy production and use, and especially the roles renewable energy forms like solar, wind, geothermal, hydro, and biomass plays, and the second course being a more advanced in-depth study of renewable energy system design, maintenance, installation, and applications. Both courses rely heavily on experiential learning techniques so that installed renewable energy hardware is continuously utilized in hand-on laboratory activities and are part of the Electronics program of studies. Renewable energy technologies and science has also been included in other SIPI programs of study such as Environmental Science, Natural Resources, Agriculture, Engineering, Network Management, and Geospatial Technology.

Section I. Technical Concept:

Renewable Energy Hardware Installed

1. Install a relatively small wind turbine, off-grid, with an appropriate battery set on campus to provide real-time actual learning from an electrical generating wind turbine. While Albuquerque is located in a class 1 wind field, there are instances of usable wind speeds, and there are numerous mechanical windmills in the immediate vicinity. This on-campus wind turbine will provide a technical resource for laboratory experimentation, operational theory and maintenance. A Bergey XL1 24VDC Wind Turbine with a 42 ft. Tilt-up Tubular Tower w/ lift Kit, and Trace SW 4024 Inverter, Trace DC 250 Disconnect w/enclosure, and

2.

Trace C-40 Charge control was installed in the NW corner of the SIPI Greenhouse Complex in the spring of 2003 (Figure 1).



Figure 1. Bergey wind turbine installed at SIPI greenhouse complex.

2. Large, photovoltaic array that is grid-connected to the local: Public service Company of New Mexico (PNM). For New Mexico Public Regulatory Commissioning, the size is below 10,000 watts AC. Building a large array will give students first-hand experience with all aspects of PV arrays such as power conditioning equipment and theory, wind turbulence and analysis, structural engineering, cabling, and procurement. The array will supplement the electric utility grid for the Science and Technology building, giving students knowledge of electrical utility engineering, regulations, and laws. The large PV array carport was installed during the spring and summer of 2003, in the parking lot of the new 72,000 sq. ft. SIPI Science and Technology building. Photo shows 6kW ac tracking PV array from the Science and Technology building and the Sandia Mountains and Bosque with fall colors of cottonwood trees (Figure 2).



Figure 2. Large PV 6.kW Array.

3.

3. Photovoltaic arrays off-grid for powering separate stand-alone electrical devices such as lighting, or pumping water for irrigation, or small water treatment. Water is a scarce resource in the Southwest, where many of the SIPI student population are based. Most water resources lay in underground aquifers. The acquisition and management of the water resource is crucial for the continued existence of the Tribes. The PV arrays will be sized specifically to the depth of the potable water table and the flow rate required. The existing Agriculture program currently has a greenhouse, arboretum, and plans to teach traditional farming and irrigation methods to students. Equipment installed consists of 12 Matrix UL listed 100 watt PV modules, TSP 2000 submersible pump, and Watsum 12 module dual axis tracker (Figure 3).



Figure 3. Polycrystalline 1.2 kW PV water pumping system with active tracker, and 10,000 gallon storage tank located at SIPI greenhouse complex. Pumps water for the arboretum, garden, and fruit orchard.

4. Photovoltaic 1 kW hybrid system that can be move to areas where electrical power is needed on a temporary basis. The system can be mounted on a trailer and moved to sites as required. The system has a backup propane generator that keeps the batteries charged during times of limited solar radiation(Figure 4).

4.



Figure 4. Stand-alone hybrid PV system for rural domestic electrification.

5. A hot air system has been installed on the Twelve Feathers double wide portable classroom/office complex. The system is a SolAire Solar Energy System that includes an Energy Control package to reduce the amount of natural gas required to heat the 28' x 32' portable building. The Energy Control Package incorporates a temperature setback function. This component will automatically reset the space temperature from 70 degrees to 55 degrees during unoccupied hours as a fuel saving feature.
6. A 340 watt Millennia thin film PV array has been installed at the water treatment laboratory. The system is mounted on an eight-module Zomework passive tracker system and powers a Dankoff Sunrise Submersible Model # 5218 water pump. The well is used to provide water to the Small Water Treatment system used in the Environmental Science program. This system is used to teach students how well depth and flow rate affect the design and sizing of the PV array, and pump motor sizing. Students in the renewable classes pull this pump and work closely with the array system.
7. A 64kBTU SP Sol-Aqua Domestic solar hot water system has been installed on the new SIPI Child Care Center. This system will be used to preheat water used in operating the Center, which will have a large demand for hot water. The system consists of 2 Heliodyne collectors and HP 16 AC double Wall Heat Transfer appliance package, and a B & W 120 gal Commercial water storage tank.
8. A 1 kW SP GTSol solar electric PV array system has also been installed on the SIPI Child Care Center. The system consists of 8 130 watt PV modules and a KACO PVI 1501i-1.5 kW. This system will be used to supplement the electrical needs of the Center. The Child Care Center is scheduled to open in the Spring 2009.

Section II. Educational Program Plan

Renewable Energy Curriculum Development

The first Renewable Energy class RENG 220 with lab was offered during the spring trimester of 2003, and was taught by Dr. Mike Thomas and Mr. Dean Pershall. Dr. Thomas did an excellent job, and helped bring in a number of outside experts to talk to the class. The basic curriculum developed by Mr. Pershall, continues to be a work in progress because of the rapid changes occurring in renewable energy.

Curriculum for the second renewable energy class (RENG 230) was developed by Mr. Pershall, but never offered because of low enrollment. Since SIPI has developed an AS degree Engineering Program and Renewable Energy will be a required course for students to take the numbers of students and renewable class offerings are expected to increase. Renewable energy has become of more importance in the last year because of high energy prices, and this has initiated a renewed interest in renewable energy systems. Copies of the renewable energy curriculum are included with this report.

SIPI campus energy load information has been recorded by students during the early classes, as part of the renewable class. During 2005 renewable energy students also accumulated energy load data on the Science and Technology building (which was first occupied in August 2003) and it's presented as follows.

1. The annual electrical consumption of 300,000 kWh for the S & T building equates to production of 600,000 lbs. of carbon dioxide and the loss of approximately 225,000 gallons of water.
2. The annual production of electricity by the Photovoltaic (PV) shade structure is 20,000 kWh/yr, which avoids production of 40,000 lbs of carbon dioxide and the loss of 15,000 gallons of water (Environmental Impacts).
3. Reduction in electricity payments to PNM on the PV shade system generation of \$1,200/yr for energy (all on-peak) and another \$750 in demand charges (Cost/economics).
4. The class projects were the first introduction of students to spreadsheet solutions, which was used to determine building heat losses and PV system performance evaluation (building technology).
5. These class projects were also the first introduction to field data collection and analysis for all students. Routine data collection of PV system was used to establish continuous database (Instrumentation and database management).
6. First introduction to hands-on small power system fabrication-PV, engine generator, energy storage (design and system manufacturing).
7. Introduced to indigenous campus natural resources and uses—water, wind, and sun not included in other parts of SIPI program curriculum.

Future Renewable Energy classes will be able monitor the electricity production of the new PV roof on the SIPI gym. The gym roof system is rated at 75k Wh, but actual performance data will be collected and analyzed. The PV and hot water systems installed on the new Child Care Center will also be evaluated by future classes.

Outreach:

A tour for tribal members of SIPI's renewable energy hardware was conducted by Tom Corbitt, Mike Thomas and Roger Taylor of NREL on June 28, 2006. This tour gave tribal members a chance to see and ask questions about the renewable equipment.

BIA forestry is proposing a Biomass energy generation system to be tied to SIPI's heating system to supplement the use of natural gas for heating SIPI's boilers. A meeting with Arthur "Butch" Blazer NM State Forestry, and Jeffrey Hamley SIPI President was held in April, 2007 to discuss the possibility of the Biomass boiler unit, so that curriculum can be developed and added to the current Renewable energy and BIA boiler training classes. All tours of the SIPI include the Science and Technology building and tour members are exposed to the renewable systems associated with the building.

- Initial informational brochures/news letters were developed by students, with photos as a class project. Renewable energy is included in SIPI recruitment brochures. The new renewable courses developed under this project have been included in SIPI'S current catalog.
- SIPI students used renewable hardware such as solar powered cars, and solar cookers to show to visiting high school students and during college recruiting functions. SIPI's renewable hardware was used to recruit students who attend our summer science programs. Current SIPI students are used to recruit as much as possible.
- The Child Care Center is close to being accepted by SIPI and BIA. The center is renewable energy friendly. A roof mounted PV and solar hot water system is part of the Child Care Center. Mr. Otto Van Geet of NREL assisted the architects in designing a more energy efficient building within our limited budget.
- We are continuing to develop an introductory "Short Course" dealing with renewable energy applications and SIPI renewable hardware. A renewable energy "Short Course" will be offered June 9-July 3, 2008 as part of the summer technical workshops offered to STEM faculty from Salish Kootenai, Leech Lake Tribal College, Lac Courte Ojibwa Community College, Ogalala Lakota College, Sinte Gleska University, and Blackfeet Community College students and faculty. These workshops are funded by the Department of Defense.
- Renewable energy systems and concepts are continuing to be included in Natural Resources, Environmental, Engineering, Electronics and Agricultural Sciences courses. The SIPI research and demonstration farm was planted this summer for the first time. A micro sprinkler system will be installed during the summer of 2008. The sprinkler system drive motors will use solar energy to move the system across the field. This micro sprinkler system will conserve water and demonstrate the use of solar energy on remote reservation sites.

Individuals Who have made Major Contributions to the Success of this Project:

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|--|---|
| 1. Odes D. Armijio-Caster
Sacred Power Corporation
Albuquerque, NM | 2. Tom Corbitt, Instructor
Environmental Science
SIPI |
| 3. Bill Dawes, Engineer
Retired Consultant
Albuquerque, NM | 4. Carolyn Elgin, Retired
President, SIPI
Albuquerque, NM |
| 5. Al Green, Retired
Chair, SIPI
Albuquerque, NM | 6. Roger R. Hill, Retired
Sandia National Labs
Albuquerque, NM |
| 7. James Lujan, Retired
Dean, SIPI
Albuquerque, NM | 8. David S. Melton
Sacred Power Corp
Albuquerque, NM |
| 9. Valerie Montoya, Vice President
Academics, SIPI
Albuquerque, NM | 10. Fred Norwood, Instructor
Engineer, Retired, SIPI
Albuquerque, NM |
| 11. B. Dean Pershall, Instructor
Electronics, SIPI
Albuquerque, NM | 12. Lizana Pierce, Prog. Officer
DOE Golden Field Office
Golden, CO |
| 13. Richard Stephens, Retired
Sandia National Labs
Albuquerque, NM | 14. Mike Thomas, Instructor
Retired, Sandia Nat'l Lab
Albuquerque, NM |
| 15. Sandra Begay-Campbell, Engineer
Sandia National Labs
Albuquerque, NM | 16. Marlene Brown, Engineer
Sandia National Labs
Albuquerque, NM |

All of the individuals listed above made major contributions to the success of this project. Some donated large amounts of their time meeting with SIPI on a regular basis to advise us on the proper equipment, critiquing developed curriculum, assisting with classes, recruited students, and taught classes. This project would not have succeeded without their dedicated service.

Lesson Learned from Project:

1. A project of this nature requires many dedicated support advisors. Renewable Energy like most science and technology programs is constantly evolving, so the help of experts in the field is a number one priority. Strong support and backing of the college administration is also needed.
2. Many students entering college are not prepared for “college level” science and technology classes, so entering students are being placed in developmental classes early in their college life, and this causes some students to drop out and look for employment. For a college program to survive early intervention at the elementary and high school level needs to be part of the program of recruitment. Students need to be “turned on” to science, technology, engineering and math (STEM courses) before they enter college. We thought that developing accelerated math classes would help move the students through faster, but this proved to only delay the students. SIPI now has in place agreements with local school districts to test and offer joint enrollment STEM classes to high school students. Hopefully these classes will “turn on” students in STEM areas and increase the number of college prepared students.
3. When renewable hardware is installed access to monitoring the functions and output must be included with the installation. SIPI class access to the installed systems was limited. Student experiential or “hands on” learning must be a part of any renewable energy curriculum.
4. Campus-wide education of renewable energy systems should be a part of the curriculum developed. Renewable energy students could be used to set up campus displays to educate their peers, faculty, and help with recruitment of high school students.
5. Renewable energy systems deserved to be a major unit in engineering and/or program and should not be looked at as electives in many STEM programs.
6. Renewable energy faculty release time for professional development needs to be a major part of the project. This would allow for faculty to stay current with all of the changes/improvements taking place in the renewable energy area. Summer renewable energy system tours for students and faculty should be incorporated into the curriculum.

Submitted by: Ronald F. Hooks, SIPI Project Director

Date Submitted: May 15, 2008

Southwestern Indian Polytechnic Institute
A National Indian Community College

Division of Instruction
Department of Advanced Technical Education
Electronics Technology

RENG 220 – Introduction to Renewable Energy
RENG 220L – Introduction to Renewable Energy Lab

B. Dean Pershall
October 1, 2008

Introduction to Renewable Energy and Lab RENG 220/220L

Introduction

The renewable energy technology (RET) industry is growing both on tribal lands and in private industry. More tribal governments are in the process of forming their own tribal utility authorities, which include large grid-tied renewable energy facilities as well as small single-dwelling systems for reservation families whose homes are too isolated to conveniently connect to the main power grid. Aside from the tribal interest, a growing number of homeowners wish to reduce or even eliminate their monthly energy costs or wish to locate their homes in sufficiently remote sites that connecting to the main power grid is too costly or inconvenient. However, there is a shortage of trained technical personnel knowledgeable in RET system design, installation, evaluation, troubleshooting, maintenance, and repair to meet the multiplicity of needs from the single-dwelling user to large commercial facilities.

Few training programs exist to meet these increasing needs for technical personnel. There are limited numbers of educational institutions that have comprehensive RET training programs. To date, each institution's RET training program is unique to that institution. No standardized curriculum exists to be shared between schools to enable the transfer of credits from one institution to another. Concerning the need on tribal lands, there are currently no other BIA tribal colleges that offer any kind of RET curriculum.

The Introduction to Renewable Energy course provides an introduction to electricity and an overview of various renewable energy technologies compared to existing conventional power systems. The basic physics of energy conversion will be covered along with power conditioning and storage, system sizing, and power economics. Technologies presented in the course include passive and active solar thermal, photovoltaics (PV), wind turbines, small-scale hydropower generation, biomass, geothermal, and fuel cells. The SIPI campus renewable energy installations are integrated into modules on **Resource Assessment, System Design, and Long-Term Benefits**. Upon completion of this course, the student will have a firm understanding of PV theory, DC electrical energy production from PV modules and wind turbines, inversion of DC to AC electrical energy, and DC electrical energy storage.

The target population for this introductory renewable energy technology course is any SIPI student interested in acquiring a more thorough understanding of RET systems for any of the following reasons:

- Provide irrigation on family ranch/farm
- Create private system on one's own home
- Create private system on the home of a family member
- Securing internship position or future professional employment within the

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- renewable energy industry private sector
- Future professional employment within a tribal utility authority
 - Supplemental knowledge and skill in addition to one's primary discipline

Introduction to Renewable Energy and Lab RENG 220/220L

Course Syllabus

Introduction

This course is designed to provide the student with an understanding of the fundamental principles of electricity and renewable energy technologies along with intensive reinforcement through lab coursework. In this course, the theoretical concepts of basic energy conversion will be explored with special emphasis on specific renewable energy applications and integrated renewable energy systems. Students are required to provide written and oral descriptions of their work to the class. The format includes individual, team, and class discussions and exercises. Classroom presentation will be through lecture, audio/visual aids, and hands-on interactive demonstrations. Monitoring of the student's progress and comprehension will be through standard testing procedures, with major evaluations at mid-term and trimester-end (final).

Prerequisites

The prerequisite for this course is the satisfactory completion (C or better) of MATH 120, Intermediate Algebra.

Terminal Objectives

Upon completion of this course, the student should be able to define energy and discriminate between renewable and non-renewable types, anticipate and identify potential environmental and sociological impacts of energy development, positive and negative, determine individual and community benefits, measure voltage and current, perform basic electrical calculations utilizing Ohm's Law and Watt's Law, describe PV theory of operation, quantify available solar and wind energy using reference tables both seasonally and annually, calculate power, energy, and costs for resource use and energy generation, estimate the required DC electrical energy production by PV modules for a particular electrical load given current and voltage characteristics, determine the equipment required for inversion of DC to AC, calculate the required energy storage capacity for renewable energy systems, operate and maintain systems, and, utilizing the above skills, independently analyze an integrated renewable energy system implementing power conditioning and storage.

Course Outline

The course will be outlined as follows:

1. Introduction to Electricity
 - a. Basic definition of electricity
 - b. Electrical quantities and units
 - c. Difference between DC and AC
 - d. Electronic Laws
 - e. Series and parallel circuits
2. Energy and the Environment
 - a. The relationship between power and energy
 - b. Energy mechanics
 - c. Energy from fossil fuels
 - d. Air pollution and energy use
 - e. Global warming, ozone depletion, and waste heat
 - f. Individual energy consumption
 - g. Comparative costs of options
 - h. Consistency with modern and traditional values
 - i. Benefits of legislative and public policy changes
3. Resource Assessment
 - a. Solar energy: characteristics and heating
 - b. Electricity from solar, wind, and hydro
 - c. Fuel cells
 - d. Conservation of energy
 - e. Nuclear power: fission
 - f. Fusion
 - g. Biomass
 - h. Geothermal energy
4. System Design
 - a. Remote residential
 - b. Engine-PV hybrid
 - c. Water pumping
 - d. Campus systems
 - e. Solar golf cart
5. System Sustainability
 - a. Operation and maintenance activities
 - b. Evaluation of system output under various operating conditions
6. Long-term Benefits
 - a. Develop community outreach program ideas
 - b. Field trip to Laguna Pueblo Major's Ranch

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- c. Student recommendations for course change
- d. Develop Campus Outreach Program ideas

Textbook

The primary textbook for this course is Energy: Its Use and the Environment, 3rd Edition, by Roger A. Hinrichs and Merlin Kleinbach. Additional texts used in this course are Stand-Alone Photovoltaic Systems - A Handbook of Recommended Design Practices, SAND87-7023, by the Photovoltaic Design Assistance Center, Sandia National Laboratories and Working Safely with Photovoltaic Systems by Daystar, Inc.

Equipment/Materials

Portable PV system
Grid-intertied PV system
Load-direct PV water pumping systems
Solar water heating systems
Solar space heating system
Stand-alone wind energy generator

Assessment System

Homework is assigned for each unit to provide practical experience in applying the concepts presented during lecture. Periodic quizzes covering two or more units are given to insure complete understanding of the material. There are two major evaluations during the trimester, one at mid-term and another at the end of the trimester (final).

The Total Overall Grade is computed on the following basis:

Attendance/Attitude: 5%
Homework/Quizzes: 25%
Mid-Term Exam: 30%
Final Exam: 40%

In accordance with **SIPI's** grading policy the final letter grade is based on the following scale:

90 to 100 = A
80 to 89 = B
70 to 79 = C
60 to 69 = D
59 and Below = F

Students in this course are required to maintain a 2.0 GPA (C). Any student receiving the grade of D or F will have to repeat the course.

Evaluation:

Evaluations are accomplished in three categories:

1. Objective type: In this area, the student's recall ability is explored. The student will be required to respond with single answers such as True/False, Matching, and/or Multiple Choice statements.
2. Subjective Type: In this area, the student's critical thinking ability is explored. On written examinations, the student will be required to respond with an essay on procedures, functions, operations, or development of a single topic.

Written reports are graded on the student's comprehension, originality, and accuracy.

3. Performance Type:
 - A. Formal - The student will correctly complete a functional system from a schematic diagram, complete all measurements, and calculate all values for their comparability.
 - B. Informal – The student will be observed on daily performance in the areas of class participation, assignment completion, and attendance.

Attendance Policy

The formal attendance policy is defined on pages 32 and 33 of the 2001-2002 Student Handbook. There are five (5) allowable absences for both RENG 220 and RENG 220L. Any student exceeding this limit will be disenrolled according to the aforementioned procedures.

Course/Instructor Expectations

In order to obtain the highest possible grade, the student is required to attend classes regularly (classes meet MWF for a one-hour lecture and TTH for a one-and-a-half-hour lab), excel on all quizzes, exams, and homework assignments, and finish any given assignments on time including quizzes. No late homework is accepted without prior instructor approval.

Introduction to Renewable Energy and Lab
RENG 220/220L

Course Outline

<u>Unit #</u>	<u>Unit Title/Description</u>
1.	<p>INTRODUCTION TO ELECTRICITY</p> <p>Students will develop a comprehensive understanding of the basic definition of electricity starting at the atomic level and the relation of electron movement to current. Students will apply the basic electrical quantities of voltage, current, resistance, and power with their associated units of measure. Students will relate the difference between DC and AC and will apply the basic electronic laws to series, parallel, and series/parallel circuits.</p>
2.	<p>ENERGY AND THE ENVIRONMENT</p> <p>The relationships between power and energy will be explored using standard scientific/engineering definitions. Students will perform an exercise on their individual energy consumption and describe how each perceives energy as an issue for them and the community in which they live. This individual audit of energy consumption will provide a methodology and basis for discussions on cost and conservation. The class will look at comparative costs of options and consistency with modern and traditional values. A natural history approach, focusing on North America, will be used to compare cause-and-effect relationships. Benefits of legislative and public policy changes will be reviewed.</p>
3.	<p>RESOURCE ASSESSMENT</p> <p>The distribution of energy resources throughout the world and in North America will be discussed in terms of worldwide use and economic growth. Other topics include national security within the U.S.A. and potential development of energy resources in Indian Country. The effects of weather, geography, population, transportation, and availability of other resources like water will be used to understand elements of resource development and economics. The SIPI campus will be used as a model for defining resources, while students will work on self-directed activities to determine the resources for their tribe.</p>
4.	<p>SYSTEM DESIGN</p> <p>The point designs in <u>Stand-Alone Photovoltaic Systems - A Handbook of Recommended Design Practices</u> will serve as a text for discussing remote residential, engine-PV hybrid, and water pumping system design issues. The SIPI campus renewable energy system designs will also be reviewed and evaluated, and students will get hands-on experience in the operation of some of the systems</p>

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including hot air space heating, PV water pumping, small wind generator, and small commercial power production. Laboratory activities will include assembling and measuring the performance of small systems.

5. SYSTEM SUSTAINABILITY

Power producing systems must meet customer expectations over their expected lifetime. Operation and maintenance activities include periodic checks on power output, identification of poorly performing components, and possible replacement of failed parts. Supervised maintenance of the SIPI campus renewable energy systems will be performed and modified as required. The output of each system will also be evaluated under various operating conditions. Documentation procedures will be developed and a report written on each of the systems, which will include costs and benefits. Designs will be reviewed on the basis of installed costs, system lifetime, convenience, and long-term performance.

6. LONG-TERM BENEFITS

A major interactive element of the course will be the development of outreach programs; package(s) for visitors to SIPI and for the tribes or communities that the students represent. The purpose of this module is to encourage the student to think beyond the course into what it would really take to adopt or advance renewable energy technology. A field trip to Laguna Pueblo Major's Ranch where renewable energy technology is being evaluated is included in this module. A class activity will be to document recommendations for changes to RENG 220/220L. A second class activity will be to recommend approaches for a Campus Outreach Program for SIPI to reach the larger part of the student body not enrolled in the course. (This could include a campus energy fair, an open house, tours, etc.) Lastly, each student will be required to document and present their recommendations on an outreach program (educational or business development) for their tribe or community

Information on new Building Integrated Photovoltaics (BIPV) on SIPI Gym Largest PV array in New Mexico.

69.9kW Building Integrated Photovoltaics (BIPV) at Southwest Indian Polytechnic Institute.

Customer:

BIA -Southwest Regional Office
Judith A. Bodo, Contracting Officer
Andrew Robinson, COTR

Contractor:

Sacred Power Corporation, Contract Number: CBK66070002
 Odes Armijo-Caster, Co-Owner/VP-COO
 Michael Elliott, Project Manager
 Tim Lambariski, Project Engineer
 Jonathan Begay, Leadman

Performance Impacts:

- $69,900 \text{ watts/hr} \times 5.5 \text{ hrs/day} \times 320 \text{ sunny days/yr} \times 90\% \text{ efficiency} = 110,721,600 \text{ wH/yr.}$
- Money Saved: $110,721,600 \text{ wH/yr} / 1000 = 110,721 \text{ kWh} \times \$0.10 \text{ kWh} = \$11,072/\text{yr saved}$
- Coal Saved: $727 \text{ watts per pound. } 110,721,600 / 727 = 152,299 \text{ lbs./yr} / 2000 = 76.15 \text{ tons coal/yr saved.}$
- Water Saved: $110,721 \text{ kWh/yr} \times 3 \text{ gals/kWh} = 332,163 \text{ gals. Saved/yr.}$
- Carbon Dioxide Avoided: $110,721 \text{ kWh} \times 2.12 \text{ lbs CO}_2/\text{kWh} = 234,728 / 2000 = 117.36 \text{ tons avoided annually.}$
- Nitrogen Oxides Avoided: $110,721 \text{ kWh} \times 0.0079 \text{ NO}_x/\text{kWh} = 874.7 \text{ lbs/yr avoided annually.}$
- Sulfur Dioxides: $110,721 \text{ kWh} \times 0.0136 \text{ SO}_x/\text{kWh} = 1,505.8 \text{ lbs/yr avoided annually.}$



Cross Section of Solar Roof

1. Flexible photovoltaic roofing panel
2. Gypsum board fire barrier
3. Rigid foam insulation
4. Electrical wiring conduit
5. Existing roof deck





