

RURAL HONDURAN PV POWERED SCHOOLS AND COMMUNITY CENTERS

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ABSTRACT

The Honduran Science and Technology Council (COHCIT) installed innovative solar electric school projects with funding from the World Bank (WB) and the InterAmerican Development Bank (IDB). COHCIT implemented nine solar electric systems for rural schools and community centers between 2003-05. COHCIT partnered with New Mexico State University and Sandia National Laboratories, who assisted with technical specifications, bid review, design, training, and acceptance testing. This new electrification program for schools in Honduras has raised the bar for better quality code compliant solar electric installations in Central America.

1. BACKGROUND

Honduras is the third poorest country in Latin America with a per capita income of about US\$920. Access to the electrical grid and other services in rural areas is limited. In Honduras, 38 percent of the population has no electrical service, which includes 63 percent of the rural population. There are over 3,000 rural schools in the country without electric power. Grid extension is not a feasible alternative for many regions given the rugged mountainous terrain and dispersed populations. Photovoltaic (PV) systems offer the best short term solution to providing basic electricity needs for many rural communities and in providing basic services such as communications and education.

In 2003, with seed funding from the World Bank (WB) and technical assistance from New Mexico State University (NMSU), and Sandia National Laboratories (Sandia), through sponsorship from the US Department of Energy and

the US Agency for International Development, the Honduran Science and Technology Council (COHCIT – Consejo Hondureño de Ciencia y Tecnología) installed the first pilot PV powered telecenter for Central America in the community of Montaña Grande near the capital of Tegucigalpa. This project included internet service through packet radio. As a result of this successful pilot installation, and with IDB funds, COHCIT installed 5 more telecenters in 2004 and three additional installations in 2005.

These additional systems were funded by the IDB with COHCIT as part of their US\$10.5 million Community Teleservices Centers Project (Proyecto Centros Polivalentes de Teleservicios Comunitarios). This project has installed about 80 rural telecenters throughout the country, 90 percent of which have been through traditional grid-connection. However, for the most remote regions without grid service, nine off-grid solar-net installations were installed for selected rural communities without access to the electric grid. These remote installations serve as model for underdeveloped regions throughout the world.

2. TECHNICAL REQUIREMENTS OF SCHOOL SYSTEM

When designing off-grid solar electric systems, the first order of business is to select high efficiency appliances that reduce the electric loads. The options are to select multiple laptops or a system that reduces the loads by using only one computer and several energy efficient LCD terminals. A high efficiency system also eliminates the need for televisions since the computer can be used to play educational DVDs and CDs. While a laptop costs more than

a desktop, the savings by requiring a smaller PV system more than offset the additional costs of a high end computer.

For the COHCIT systems, a detailed technical specification was developed by NMSU to help ensure a high quality PV installation. While there is no legal electric code in Honduras, the National Electric Code, as used in Mexico, Nicaragua, El Salvador, and the U.S., served as the basic guide (Article 690). Specific objectives of the specifications were to:

- a) Normalize the evaluation criteria for bids;
- b) Establish good design and installation practices;
- c) Serve as a technical guide for the vendor;
- d) Form the basis for acceptance testing of installed equipment;

These criteria, when addressed early in a project cycle, help ensure long-lasting high-performance installations.

The PV systems were designed to provide ac power for the school loads. The electric system was designed with a photovoltaic array, solid state charge controller, battery bank, inverter, surge protection, grounding, cables, and bonded mounting structure.

4. CAPACITY BUILDING

Capacity building forms the backbone of any successful development program and must include local industry, planners, NGOs, and end-users to be successful. From 1994-2003, Sandia and NMSU conducted a series of six solar energy workshops with over 350 participants with various partners including COHCIT, WB, the Natural Resources and Environment Secretariat (SERNA, Secretaría de Recursos Naturales y Ambiente), Winrock International, Adesol/Enersol (a local based NGO), the Institute of International Education, the Honduran Ministry of Education, the National Rural Electric Cooperative Association (NRECA), and the US Agency for International Development (USAID). These workshops were the precursor for the program that COHCIT, WB and IDB wanted to develop. Two of these workshops, in 2001 and 2003 by COHCIT and WB, were focused on distance education and bridging the digital divide using solar energy. Both were part of an Energy Sector Management Assistance Program (ESMAP) technical assistance to COHCIT's Aldeas Solares program, which aims to establish urban telecenters and smaller, more basic "Infocenters" in remote rural areas.



Fig. 1. Bridging the digital divide with solar energy workshop for 80 participants with World Bank, COHCIT, Sandia, NMSU, and SERNA in Santa Lucia, Honduras in November, 2003.

5. MONTAÑA GRANDE PILOT SYSTEM

The first rural pilot PV powered telecenter with internet connection in Honduras, indeed all of Central America, was installed in late 2003. WB-ESMAP collaborated with the International Telecommunications Union (ITU), Hondutel, Sandia, and NMSU to demonstrate the use of PV powered telecommunications providing internet access to remote areas via radio transmission spread-spectrum technology.

In the case of the pilot installation at Montaña Grande, a small rural community with 50 homes located near Tegucigalpa, the radio link is between the Infocenter and a Telecenter at the nearby town of Santa Lucia. This Infocenter demonstrates a less-expensive alternative to internet access via satellite.

ESMAP financed the PV power system at Montaña Grande, including a TV and VCR, several laptop computers, and a fax machine. Hondutel, ITU, and COHCIT financed the telecom equipment and infrastructure, and provided administration for the project. School children use the computers to augment their classroom sessions, while after school hours anyone can pay a small fee to use the computers and send emails.

For the Montaña Grande system, the PV array is inclined at 20° tilt (Lat ~14°N). The PV array is composed of eight UL listed 75 Wp BP monocrystalline PV modules (2s x 4p), totaling 600 Wp. The module array frame is bonded to ground with 8 AWG copper conductor.



Fig. 2. Montaña Grande 600 Wp PV array. The PV array is connected through a listed Trace TCB6 PV Source Circuit Combiner box, with each string leg fused. Two Square D 30 A AC breakers rated at 120/240 V are used as a disconnect for the PV array; this represents about 17 A per leg of dc power from the modules.

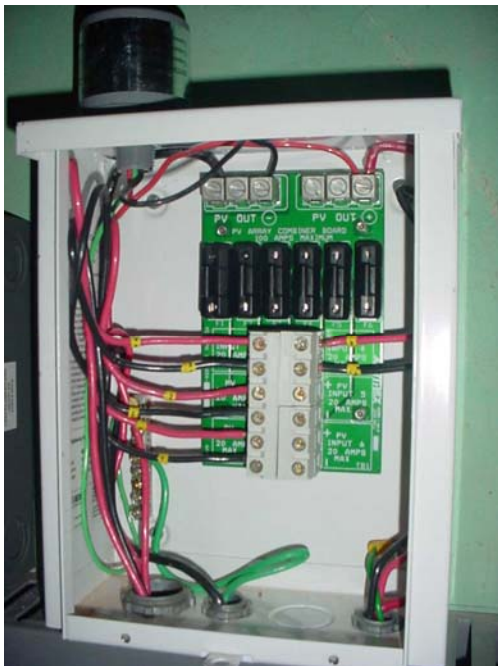


Fig. 2. PV array combiner box for Montaña Grande.

The battery bank consists of six GNB Absolyte IIP batteries at 2 V each. The total battery bank has 800 Ah capacity at

12 V. A listed Trace C60 charge controller charges the battery bank with temperature compensation. The battery bank has a listed Trace DC disconnect rated at 175 A.



Fig. 3. GNB sealed batteries providing 800 Ah of energy storage at 12V for the Montaña Grande school complex.

Three 15 A circuit breakers rated for 120/240 V AC are used to disconnect the dc loads, which consist of fluorescent and LED lamp lights. Each circuit breaker leg has about a 5 A dc lighting load running through it.

AC loads are supplied through a Trace DR series inverter 1512 rated at 1500 W maximum continuous load. The ac loads are run through a Square D circuit breaker rated at 20 A 120/240 V AC for the laptop computers. Load wires used in the system are run through conduit and are 8 AWG. The equipment grounding wire is 10 AWG. The AC loads run through 20 A Square D breakers listed for 120/240V ac usage, as is the case.

There are two 20 W ThinLite fluorescent lights, and one Steca LED 7 W light per classroom. Outside on the porch there is also one LED light per classroom (two total). Also, there are two 20 W fluorescent lights used in the computer classroom, as well as an LED light for the machine room and a LED light for the computer classroom porch. These were the first LED lights used for schools in Honduras and should have lifetimes five times or more of the fluorescent lights.

Overall the Montaña Grande PV system represents one of the better installed systems in Central America and shows great innovation using LED lights as part of the design. SOLARIS from Tegucigalpa won the competitive WB bid and was the system installer working closely with NMSU on design details.



Fig. 4. Bridging the digital divide means supplying computers for rural students like these in Montaña Grande.

6. LEMPIRA DEPARTMENT PV TELECENTERS

One of the most inaccessible and remote regions of Honduras is the western Lempira Department, typified by rugged mountainous terrain with only a few unpaved roads. Five PV systems were installed in this Department by COHCIT with IDB funds. Overall, the PV systems represent some of the better quality PV installations in Central America. All systems are similar in design and workmanship and were installed by SOLARIS.



Fig. 5. San Manuel Colohete 700 Wp PV array and satellite communication system in Lempira Department.

The project was well planned, starting with an energy requirements assessment for the schools. NMSU assisted COHCIT in developing a minimum technical specification that met the National Electrical Code for PV installation. As a public institution, COHCIT had to follow rigid IDB and Honduran government bidding rules. After the final bid was awarded, NMSU worked with the Honduran vendor

(SOLARIS) to help refine the PV system design to be sure that it met code requirements. The PV system was sized to provide 5 days autonomy under normal use in central Honduras (about 4 kWh/m²/day average). Metal enclosures and frames were bonded and grounded. The system disconnects, inverter, and battery bank were placed in a room inaccessible to students. The system has appropriate overcurrent protection. All interior wire runs were placed in conduit. All of these details help ensure a safe and quality PV installation. The total PV system installed cost for the first system in San Manuel Colohete was US\$12,150 utilizing a total of 700 Wp PV.

For all the systems, the PV arrays are inclined between 17-24° tilt, which is an acceptable inclination for Honduras. The arrays are installed with an orientation between 161 – 195 ° magnetic. Generally, in mountainous regions of western Honduras, it is more productive to orient arrays slightly east than west to take advantage of typically sunnier mornings since afternoons are often cloudy.

Two systems consist of fourteen 50 WP Isofoton I-50 monocrystalline PV modules (1s x 14p), totaling 700 Wp. The other three 700 Wp systems use seven 50 WP Isofoton I-100 monocrystalline PV modules (1s x 7p). Isofoton PV modules are UL 1703 listed and meet code requirements. Array interconnects use THWH AWG 12 copper wire. Module frames are bonded to ground with 8 AWG copper conductor.



Fig. 6. Sosoal PV telecenter components with expert SOLARIS PV installer Ethel Enamorado.

The four PV array strings are connected through a listed Trace TCB6 PV Source Circuit Combiner box, with each

leg fused at 15A. Two Siemens C32 breakers rated at 220/380 V are used to disconnect the PV array.



Fig. 7. San Francisco telecenter with 700 W PV array.

All battery banks for the Lempira systems consist of five Concorde SunExtender PVX-2580L Absorbed Glass Matte (AGM) batteries. For each telecenter, the battery bank has 1290 Ah capacity at 12 V. Battery banks are installed in locked and ventilated equipment rooms which, as mentioned previously, are not accessible to students. The battery bank uses a UL listed Xantrex JLE-1 disconnect rated at 250 A for dc use.

A listed Morningstar TCB60 charge controller is used to charge the battery bank. 15 A and 20 A Square D circuit breakers are used to disconnect the dc loads, which consist of fluorescent and LED lamp lights. An additional 600V Delta Surge arrestor is also used on the dc side. Two 30 A Square D circuit breakers are used for the ac loads. A Myers Protector surge arrestor is used. Load wires used in the system are run through conduit and are 10 AWG.



Fig. 8. San Francisco telecenter components and 20W fluorescent light. Note the Trace 1500 W DR 1512 series sine wave inverter on the far wall.

Alternating current loads are supplied through a Trace DR 1512 series inverter rated at 1500 W maximum continuous load for 60 Hz at 12 V. The inverter is used to operate ac loads, mostly the computers and satellite receivers. All systems meet National Electrical Code requirements, even though there is no such legal requirement in Honduras at present. The five COHCIT PV installations in Lempira were finished in November, 2004.

All of the solar-net telecenters use a combination of 20 W fluorescent lights, and Steca LED 7 W lights. The Lempira solar-net telecenter also uses one desktop and three laptop computers. Since these sites are so remote, radio links are not feasible and these schools are linked via satellite to the internet.



Fig. 9. Concorde SunExtender AGM batteries with 1290 Ah capacity for Sosoal telecenter.

These rural PV telecenters are helping revolutionize education in rural Honduras. They allow schoolchildren, as well as local families, access to the outside world. Many of these rural Honduran families have family members who work overseas as agricultural workers, etc. and send funds back home to help their families survive. Communication in these rural areas helps keep families connected across great distances. Likewise, the rural students are learning the modern computer skills that can help them enter the modern world and thrive in the future.

TABLE 1. SUMMARY OF SELECTED COHCIT LEMPIRA PV TELECENTERS

ITEM	San Manuel Colohete Mpo. San Sebastian 14° 26.505 'N 88° 44.698 'W	San Francisco Mpo. San Sebastian 14° 23.107 'N 88° 43.641 'W	Sosoal Mpo. San Andres 14° 15.285 'N 88° 35.385 'W
Array Size (Wp)	700 Wp	700 Wp	700 Wp
PV Array Configuration	1s x 14p	1s x 14p	1s x 7p
System Cost	US\$12,150	US\$11,334	US\$11,334
Module Type	Isofoton I-50	Isofoton I-50	Isofoton I-100
Ip @ STC	2.87 A	2.87 A	5.74 A
Array Orientation, S = 182°	161° mag	170° mag	195° mag
Array Tilt	20°	24°	17°
Batteries	5 Concorde SunXtender PVX-2580L, 258 Ah	5 Concorde SunXtender PVX-2580L, 258 Ah	5 Concorde SunXtender PVX-2580L, 258 Ah
Battery Bank Configuration	12V, 1s x 5p, 1290 Ah	12V, 1s x 5p, 1290 Ah	12V, 1s x 5p, 1290 Ah
Battery Disconnect	250 A Xantrex JLE-1	250 A Xantrex JLE-1	250 A Xantrex JLE-1
Charge Control	Morningstar Tri-Star 60	Morningstar Tri-Star 60	Morningstar Tri-Star 60
Inverter	Xantrex DR 1512	Xantrex DR 1512	Xantrex DR 1512
Array Combiner Box	Trace TCB6 15A fuses	Trace TCB6 15A fuses	Trace TCB6 15A fuses
Array Disconnect	Siemens C32	Siemens C32	Siemens C32
DC Load Disconnect	Square D 15 A & 20 A	Square D 15 A & 20 A	Square D 15 A & 20 A
AC Load Disconnect	Two Square D 30 A breakers	Two Square D 30 A breakers	Two Square D 30 A breakers
Cables – Array	THWH AWG 12 w/conduit	THWH AWG 12 w/conduit	THWH AWG 12 w/conduit
Cables – Battery	2/0 cable	2/0 cable	2/0 cable
Cables – Loads	THHN AWG 10 w/conduit	THHN AWG 10 w/conduit	THHN AWG 10 w/conduit

6. CONCLUSIONS AND SUMMARY

Over 3,000 rural schools in Honduras do not have grid power. Fossil fuel generators could be used to provide power, but they require frequent maintenance, are loud and polluting, and disrupt teaching. Thus, Honduran schools are turning to alternative technologies such as solar power to meet their energy needs. COHCIT has helped lead the way in Honduras in using quality PV systems to meet rural school energy needs and even in providing rural internet connectivity via satellite to selected schools.

The objective of these efforts was to contribute to the sustainable development process in Honduras, and support the strengthening of associated organizational capacity. There is a large economic and development gap between rural and urban Honduras. This project helps reduce this gap by introducing 21st Century technologies that give the rural communities a competitive edge and communication with an increasingly complex outside world. These projects provide empowerment for rural communities.

These remote photovoltaic systems have now been in operation for nearly two years with no major problems encountered. Young students quickly adapt and learn how to use computers. These rural PV powered centers have opened up new and modern technological opportunities for the many rural students, some of whom will become the future solar energy engineers and technicians that eventually electrify all of rural Honduras.

7. ACKNOWLEDGMENTS

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