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RENEWABLE ENERGY FOR PROTECTED AREAS OF THE YUCATAN PENINSULA

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ABSTRACT

Renewable energy technologies have been widely applied to support diverse protected areas in the Yucatan Peninsula in Mexico. Under the U.S. Agency for International Development (USAID) and the U.S. Department of Energy (DOE) collaborative Mexico Renewable Energy Program (MREP), over 70 renewable energy systems have been installed in Mexico. These projects have been installed in collaboration with the Mexican Secretariat of Environment and Natural Resources (SEMARNAT), the Nature Conservancy (TNC), World Wildlife Fund (WWF), and Conservation International (CI). Technical assistance for protected areas projects in Mexico has been provided by Sandia National Laboratories which manages MREP, as well as Ecoturismo y Nuevas Tecnologías (Mexico City) and New Mexico State University. Projects have been installed in the Mexican states of Quintana Roo, Yucatán, Chiapas, Chihuahua, and Oaxaca. This paper discusses some of the key system installations in the protected areas of the Yucatan Peninsula between 1995 and 2002.

1.0 INTRODUCTION

Use of renewable energy in protected areas directly benefits the living conditions of researchers, technicians, and rangers working in the reserves, as well as providing energy for environmental training centers. The biologists and other researchers often stay for extended periods of time and are more effective in their work by having more comfortable living conditions and power for laboratory instruments and computers. The renewable energy systems also have the advantage of providing power without the noise or pollution associated with conventional fossil-fueled generators, while reducing the risk of fuel spills in these sensitive areas. Up front design decisions, user operation, and long-term maintenance issues play an important role for overall system reliability.

Another benefit of using renewables is that they can also provide an environmentally appropriate example to neighboring buffer communities surrounding reserves (often without electrical service themselves) which can likewise benefit by replicating the protected areas example of employing renewable energy (RE) technologies. Likewise, RE systems provides a useful example to visitors and tourists to take back home.

In addition, the remote protected area research and visitor facilities also benefit economically from RE installations through reduced operation and maintenance costs associated with more conventional electrification approaches (e.g., diesel gen-sets). Actual system life-cycle costs for any particular RE system varies and is a function of design, usage, application, and maintenance. With proper system operation and maintenance, the expected RE system lifetimes should exceed 20 or more years (with appropriate battery replacements, etc.). Following are some of the key MREP protected areas RE projects in the Yucatan Peninsula:

2.0 ISLA CONTOY NATIONAL PARK

This island park (PNIC) is part of the nationwide network of reserves maintained by the Mexican government (SEMARNAT). It was designated a park only in 1998, although it had been protected since 1961. PNIC is located 47 km. north of Cancun in Quintana Roo State with an area of 5,126 hectares. It is informally known as "Bird Island" due to the extensive population of over 5,000 frigates among the 151 bird species found at PNIC. It is also important site for protecting marine turtles, crocodiles, as well as 31 coral species and 98 indigenous plant species.

An assessment on the feasibility of renewables electrification for the Park was initiated in 1995 by Sandia under MREP. Since PNIC is not designated a threatened area, the Park was burning gasoline transported by boat from nearby Cancun for a 3.5 kW generator, with significant noise pollution that disturbed birds, as well as the constant threat of fuel spills.

Two years later, US$35,000 in funding was secured from USAID to support the installation of a hybrid renewable energy system. An anemometer was installed by EyNT to determine the wind resource for wind system design purposes. During the planning process, the Park director met with local fishermen, NGOs, and other interested parties. Of particular concern was the potential impact of wind turbines on the large bird sanctuary (i.e., threat of bird kills). Since small wind turbines spin very fast and are quite visible, it is unlikely that a bird will fly into the spinning blades. It was agreed that any wind turbines installed would not be done so on any of the key bird transit routes over the island (typically right along the coastline), nor in critical nesting areas (which are off limits to all visitors as well). There have been just two bird killed after five years.

During the system design process, it was determined by Sandia that a hybrid solar and wind energy system would be the best option for PNIC. The average annual wind speed was found by EyNT to be about 6.5 m/sec. Loads were sized for an average daily usage of 5,000 Wh/day, mostly for lighting, communications, radio, fans, and TV/VCR , as well as a LCD projector (for workshops), shop equipment, kitchen appliances, and a water pump.

After a competitive bid process, Golden Genesis of Arizona (now Kyocera America) was awarded a contract to install a solar/wind hybrid energy system, which was completed in December, 1998. The architecture of the original hybrid system consisted of two 500 W wind turbines, a 256 Wp amorphous PV array, a 4500 W Trace sine-wave inverter, and 19.2 kWh battery bank. The wind machines were originally installed on a tall dune on the east-side of the small island. A three day training course was then conducted for 23 persons from area institutions including PNIC on renewable energy systems design, operation, and maintenance. Also individual training was provided to the three key PNIC maintenance personnel on appropriate RE system operation and maintenance (O&M).

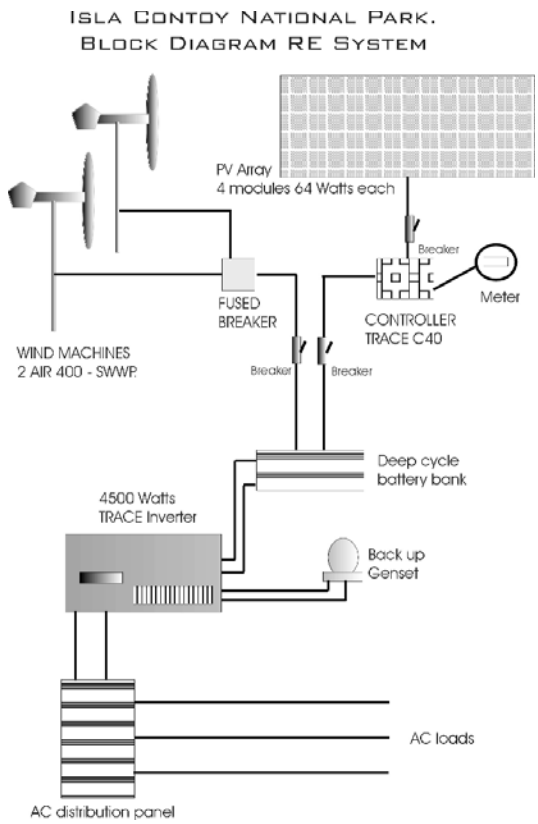

Fig. 1. Isla Contoy RE hybrid system

The hybrid system has evolved since installation, adjusting to expanding energy needs and operational conditions. After the first year of operation, the original wind machines had suffered from severe corrosion problems due to the salt spray environment and were replaced by the installer under warranty. Two Southwest WindPower (SWWP) Marine Air 400 Wp units (more corrosion tolerant) were installed at the top of the park's observation tower, and one H80 wind machine was left on the original dune site.

The PNIC station was completely remodeled in 2000 by SEMARNAT. A 40 kW diesel plant was installed to operate a reverse osmosis desalination unit, as well as vapor compression air-conditioning systems. However, the desalination plant was never operated and the diesel plant is used just few hours per month. Subsequently the battery bank and the PV array were further expanded thanks to a donation from the European Union (EU); the bank grew 300 percent in size (to 2,400 Ah) while an additional PV sub-array was added for a total of 1.5 kWp. This is one of the most complex renewable energy systems installed in Quntana Roo.

The two 400 Watt wind machines are working but with some slight abnormalities. They both have had much of the powder proof paint coat literally sand-blasted off due to the occasional high winds and blowing sand. They also produce a somewhat loud noise when operating together under load.

In September 2002 Hurricane Isidore caused substantial damage to the Isla Contoy hybrid system. The hurricane destroyed the dune mounted H80 wind turbine due to a unique tower failure mode. While the galvanized NRG tower had been guyed with stainless steel guys due to the severe corrosion of the area, the guys did not fail, nor the tower tubes, but rather the actual tower base failed. The base had corroded to the point that the high hurricane winds caused it to fail where the tower and base meet. The wind turbine itself did suffer some damage at its mounting base due to the fall. There was no damage to the actual rotor, but 2 of the 3 rotor blades were damaged when the tower collapsed. The smaller SWWP units had been lowered for the hurricane and did not suffer any damage.

The Trace inverter also failed during Hurricane Isidore due to rainwater entering the inverter through a conduit leak which caused a circuit failure. The Ecovertice company sent two technicians to repair the inverter failure, which took about four weeks to complete. An additional floor fan is now necessary to provide cooling as the original inverter fans failed.

The battery bank is somewhat undersized given current loads and should be further expanded to about 4,000 Ah. This will reduce cycling and extend the battery lifetime. The expanded EU portion of the battery bank did not include spark arrestors unlike the original USAID portion, thus presenting a safety hazard for such a large bank.

Fig. 2. Isla Contoy solar and wind energy power center, inverter, controls, and batteries.

One problem the PNIC has had to contend with is ever changing park technicians and maintenance personnel who make various adaptations to the hybrid system configuration that are never documented. This complicates future maintenance actions by new personnel who have to spend a great deal of time trying to understand undocumented system changes, which exacerbate accident or failure potential if components are incorrectly connected due to poor system documentation.

In summary, the PNIC RE hybrid system has satisfactorily met park energy needs. Since the tower collapse of the H80 wind turbine, most of the energy is generated from the PV array. Despite systems ups and downs, the PNIC staff have been able to maintain the solar/wind hybrid system successfully. The system has survived several major storms and hurricanes over the past five years. The system clearly shows that an important component for successful application of RE technologies are the institutional aspects related to follow-up support and maintenance.

3.0 EL EDEN ECOLOGICAL RESERVE

El Eden is Mexico's first privately managed biological research reserve and is located 25 Km. northeast of the small community of Leona Vicario in northern Quintana Roo. The reserve is managed by an NGO called El Eden Reserva Biologica, A.C., which was established in 1990 by a scientific group and Mexican businessman. El Eden is part of a bioregion known as "Yalahau" located in the northeast portion of the Yucatan peninsula that is comprised of forests, swamps, and savannahs. The reserve protects many indigenous plant and bird species, and also has many rare animal species including pumas, jaguars, and ocelots.

An initial feasibility assessment and field visit was made by Sandia in 1995. The research station is comprised of individual cabins for workers and visiting researchers, a central station and laboratory, and a greenhouse. For this reason the project was subdivided into various systems. Solar energy projects were installed by MREP at the reserve in cooperation with WWF in 1997. A central PV 1,500 Wp system was installed for the main base station for total estimated loads of about 26,550 Wh/week.

A 15kWh, battery bank was installed as well as a 2.6 kW inverter for ac loads. The two identical 140 Wp PV cabin lighting systems each use a small 400 W inverter a 200 AH 12 V battery bank. A 100 Wp solar water pumping system was also installed using a 1/3 hp diaphragm pump to provide 1,500 lpd under a total dynamic head of 24 m (includes elevated tank storage).

USAID provided US$25,000 for all the installations. It was estimated that the reserve will need about US$400/year for future O&M expenses. Training was provided to 25 persons including El Eden users and staff, as well as other area NGOs and industry.

The solar systems have operated fairly well since installation, although the original centralized system was reduced by half in 1998, as new anticipated loads were delayed in coming on-line. One cabin system in 2002 became inoperable after nobody remembered to water the batteries, but was easily restored. Later a gasoline powered water pump was also added to the Reserve. The solar pump is working properly, but is only used for the central building and the gasoline pump provides water to the more distant and higher head cabins.

An additional refrigerator load was added to the central PV system using an energy intensive "Frigo-Bar." A new research building is being constructed which will be completed in 2003. The electric loads will increase and the PV system will need to restored to its original concept size to deliver sufficient energy to meet new demands.

After 5 years of systems operation, the RE systems are in good condition. The effort made by staff to maintain these systems are a good sign that renewable energy in El Eden is valued. The only consideration that the Park has had to really contend with is rotating personnel and the subsequent need to train each new generation of Reserve staff on how to properly operate and maintain the solar energy systems.

4.0 SIAN KA'AN BIOSPHERE RESERVE

Established in 1986, this reserve has 528,148 hectares and helps protect the Sian Ka'an and Uaymil coral reefs, as well as many over 800 flora, 1,719 invertebrate, 339 bird, and 103 mammal species including jaguars, tapirs, and manatees. The Sian Ka'an reserve has unique landforms including Petenes (small palm islands located in marshy regions) and Cenotes (huge natural limestone wells).

There are a variety of solar and wind energy systems used throughout the park for ranger and research stations. After initial feasibility assessments by Sandia in 1994, over US$60,000 of USAID funds were allocated to the Sian Ka'an Association in collaboration with TNC for renewables hardware for these projects beginning in 1996. Key systems installed are:

4.1 The Mayan Arch (or San Eric Station)

This is the most transited and key entry point into the Reserve and the Punta Allen fishing community. There are three PV systems installed five years ago under Sandia/USAID auspices: for outdoor lighting at the gate, for water pumping, and for the ranger station.

The outdoor streetlight is important for the Reserve's entry gate and is designed to operate for 7 hours each night utilizing a low pressure sodium vapor 66 W lamp powered by a 150 Wp PV array and a 200 Ah battery bank. This system automatically turns on in the evening and shuts itself off after a specified number of hours of operation (e.g., 7 hours). The outdoor streetlight was repaired in 2002. Unfortunately, the English manufactured bulb had burned out and it took three months to replace since no similar bulbs were available in Mexico.

The ranger station PV system for lights and radio communication is in good condition having gone through one battery bank refurbishment (flooded lead acid batteries that were not watered sufficiently). Twice the system has been hit by lightning, which has caused damage to the radio, battery bank, and control system. In addition, the original flooded batteries were not well maintained by reserve personnel and the series type charge controllers with relays from Condumex eventually failed and had to be replaced in 2000. The failed batteries were likewise replaced with sealed batteries that did not need to be watered. However, the new management has been over-attentive about maintenance. Maintenance personnel in 2002 were found to be adding water to the maintenance free batteries, thus breaking their seals and severely reducing battery lifetimes. Sometime you just can't win in that inevitably someone waters a sealed battery, while somebody forgets to water a flooded battery.

The 110 Wp PV diaphragm water pumping system suffered a failure in 2002. Terminals had corroded to the point that operation had ceased (the site is only a few meters from the ocean and the electrical junction boxes were not properly sealed). A simple fix but it had been mis-diagnosed originally as a controller problem by the staff until NMSU and EyNT troubleshooted the system.

4.2 Muyil Station

Muyil is a new site and was not part of the original MREP installations in Sian Ka'an and represents a further replication of original Sandia efforts. The system is unique in that it is 100 percent wind powered, although additional PV outdoor light is scheduled to be added in 2003.

This station has a wind energy system using two AIR 400 Wp wind machines, a 12V battery bank, and a 1500 Watt inverter. For the station's present load demands, the inverter is actually about 300 percent larger than necessary, thus running inefficiently. However, it is also quite likely that additional loads will be added in the future. The users are happy with the system.

4.3 Santa Teresa Research Station

This is the largest station in the Reserve with also the largest renewable energy systems. It receives large groups of visiting researchers most every moth. The original estimated loads have been greatly surpassed due to a large increase in usage and number of visitors, visitor days, and newly utilized research equipment. This station has only one 1,100 Wp PV system with an adequately sized battery bank. Sometimes there are reports of power failures caused by low battery voltage insufficient to operate the inverter. During low visitation periods, a refrigerator is connected to the solar system. Additional PV modules have been procured for installation in 2003 to increase the total array power production.

Once again, the Park's maintenance personnel went from one extreme of not sufficiently watering flooded lead-acid batteries, to another by watering sealed lead-acid batteries. Again, these sealed lead-acid batteries are maintenance free and thus no water should be added. Breaking the seal causes a loss of electrolyte and the battery lifetime is greatly reduced.

Santa Teresa also has two outdoor 150 Wp PV streetlights, one that has worked fine while the other suffered a failure in 2002 due to a dead charge controller that had to be replaced (relay failure). In addition, there is a 110 Wp water pumping system that has had no problems.

Fig. 3. Central American renewables training held by NMSU, EyNT, and Winrock at the Santa Teresa Research Station in Sian Ka'an (2002).

5.0 CHINCHORRO BANKS

The 144,360 hectare biosphere reserve of the Chinchorro bank is managed by SEMARNAT. The banks are located in the Caribbean sea, 31 km. east of the Mexican mainland coastal village of Mahahual, along the southern coast of Quintana Roo. The Chinchorro bank are part of the Mesoamerican Reef System, the second largest in the world. The reefs are an ecologically significant ecosystem and contain a many marine and terrestrial species including marine turtles, tropical fish, corral, sponges, and bird species.

There is a base station in Mahahual and a remote island camp station. The camp station uses PV modules and small wind turbines to provide power for lighting, communications, computers, and laboratory test equipment. One SunDanzer direct drive PV refrigerator was installed at the Mahahual Station with the Amigos de Si'an Ka'an in July 2002. This refrigerator is used for food preservation since there are many difficulties in maintaining fresh supplies. A second PV direct drive refrigerator with thermal storage will be installed on Chinchorro Bank island itself by the summer of 2003.

The direct drive PV refrigerator technology was developed by NASA with SunDanze Refrigeration and displaces the need for batteries. The photovoltaic direct-drive or "PV direct" solar refrigerator uses thermal storage, and a direct connection is made between the vapor compression cooling system and the PV panel. This is accomplished by integrating a phase-change material into a well-insulated refrigerator cabinet and by developing a microprocessor-based control system that allows direct connection of a PV panel to a variable-speed DC compressor. This allows for peak power-point tracking and elimination of batteries. This is a very cost-effective approach.

6.0 LESSONS LEARNED

From the Yucatan RE projects, key lessons are:

• **Size Appropriately** since capital investment is relatively high for RE systems. Thus, RE system sizing and design needs to be focused and realistic as to user needs and loads to avoid unnecessary expenditures on larger systems than required. The system needs to be able to meet the loads now and be expandable for the future.

• **Obtain user input** on project implementation to help clearly identify needs and develop appropriate technical specifications for a system to meet those needs. Consider technical and cultural needs as well as economic constraints.

• **Develop a professional system design,** which is critical and should be undertaken by experienced engineers. Design parameters should include realistic system usage, climatic conditions, component selection, O&M considerations, safety, and reliability.

• **Insist on quality** installations done by experienced technicians that exhibits good workmanship. Acceptance testing of installed systems should be conducted to verify that contractual obligations have been met.

• **Conduct user and technician training** that includes detailed analysis and O&M reference manuals. Contingencies should be developed to train future operators when staff attrition occurs so as not to lose institutional knowledge.

• **Conduct preventive and regular maintenance** for long-term successful system operation. There are diverse maintenance levels, some actions done by the user, while more complex tasks requiring a skilled technician. Proper tools must be provided. An O&M actions journal is recommended.

• **Anticipate future growth** and design a system accordingly for relatively seamless expansion.

• **Maintain parts supply inventory** for components that are likely may need to be replaced (e.g., fuses). Try to use appropriate local components as much as possible to avoid delays in replacement parts.

• **Consider safety and security** installed for systems. Design the system with safety in mind, meet all applicable codes and standards. Likewise, be vigilant as to potential theft, vandalism, etc., and plan accordingly.

• **Demand guarantees and warranties** from the vendor and know what these are. Consider long-term preventive maintenance contracts for system support with the equipment vendor.

• **Think sustainability** for any project. All of these points lead to this end and it is important that the institution using the renewables system have a true commitment and interest (often demonstrated by their willingness to pay) for the long term operation and sustainability of the system). The ultimate goal is to have a well designed and installed system that will provide many years of reliable and satisfactory service.

7.0 REFERENCES

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