

San Juanico Hybrid Power System Technical and Institutional Assessment

Preprint

Dave Corbus, Charles Newcomb and Zeke Yewdall

*To be presented at the World Renewable Energy Congress VIII
Denver, Colorado
August 29–September 3, 2004*



NREL

National Renewable Energy Laboratory
1617 Cole Boulevard, Golden, Colorado 80401-3393
303-275-3000 • www.nrel.gov

Operated for the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
by Midwest Research Institute • Battelle

Contract No. DE-AC36-99-GO10337

NOTICE

The submitted manuscript has been offered by an employee of the Midwest Research Institute (MRI), a contractor of the US Government under Contract No. DE-AC36-99GO10337. Accordingly, the US Government and MRI retain a nonexclusive royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for US Government purposes.

This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

Available electronically at <http://www.osti.gov/bridge>

Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: <mailto:reports@adonis.osti.gov>

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: <http://www.ntis.gov/ordering.htm>



San Juanico Hybrid Power System Technical and Institutional Assessment

World Renewable Energy Congress VIII (WREC VIII)

August 2004

Dave Corbus, Charles Newcomb,

Zeke Yewdall

National Renewable Energy Laboratory

1617 Cole Blvd. Golden Co 80401

303-384-6966, dcorbus@nrel.gov

Introduction

San Juanico is a fishing village with approximately 120 homes and more than 400 people in the Municipality of Comondu, Baja California Sur. San Juanico's first autonomous diesel generator began operating in 1980. The 205-kW generator supplied power for 3 to 4 hours a day. The average load was about 50 kilowatts (kW), and the observed peak demand was about 75 kW. During that time, customer energy use was not metered. Each customer paid the same fee (50 pesos/month). Additionally, 23 homes in the village were equipped with small gasoline-powered generators



that provided power for refrigerators and other appliances. In April 1999, the Arizona Public Service Company (APS) and Mexico's national electric utility – Comision Federal de Electricidad (CFE), installed a hybrid power system in San Juanico to provide 24-hour power. Before the installation of the hybrid power system, researchers from the National Renewable Energy Laboratory (NREL) conducted a field study to characterize San Juanico's electrical usage and its institutional and social framework. One year after the installation of the hybrid power system, researchers performed a "post-electrification" study to document the changes that had occurred as a result of the introduction of 24-hour power.

Because researchers monitored the technical aspects and the institutional issues regarding the hybrid power system and the electricity usage of San Juanico's residents, there is more information on this hybrid power system than any on other renewable energy village power system. In December of 2003, NREL researchers visited the site to conduct a technical assessment of the system, to upgrade the data acquisition system at the site, and to revisit the social/institutional issues as detailed in the original assessment (Boer, 2000).

The System

The system is composed of a Trace HY-100 inverter with an integrated peak power tracker for a 17-kW PV array. A nominal 240VDC flooded lead-acid battery bank consisting of 7 strings of 350 amp-hour batteries in parallel (nominal 2450 amp-hrs) provides energy storage. Ten Bergey

Excel wind turbines (about 70 kW total) are connected to the DC side of the electrical system. An 80-kW diesel generator carries the village load and charges the batteries when the renewable systems cannot meet the load. The diesel generator is dispatched by the Trace inverter controller and charges the batteries via a rectification circuit within the inverter. Approximately 20% - 35% of the village's electricity is supplied by the renewable energy systems, as shown in figure 1. The site is well maintained by two residents employed to perform routine operations and record system operational data points and issues for about 20 hours per day.

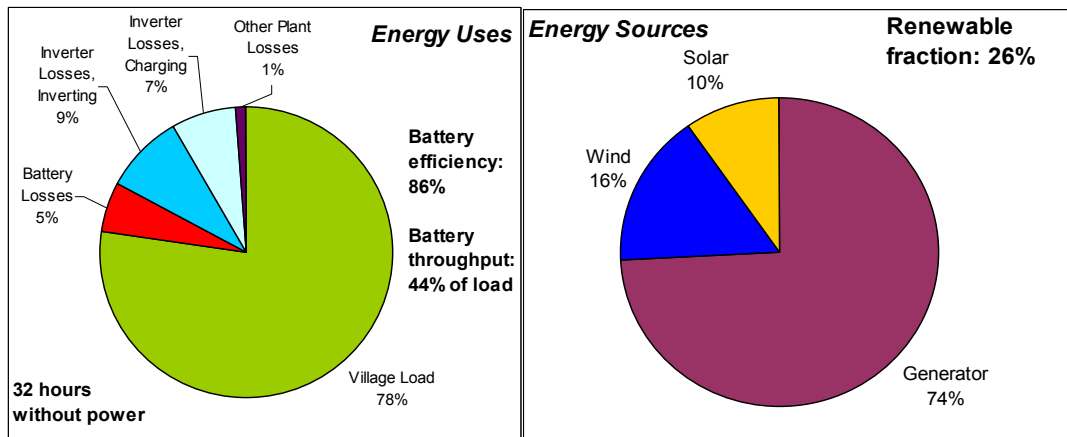


Figure 1 : Typical Energy Uses and Sources

Operational Issues

Several technical issues have been addressed since the system was installed. Three turbines experienced a failed alternator bearing. It is unclear whether this was a manufacturing related issue or was due to San Juanico's harsh environment (proximity to corrosive sea air in addition to prevalence of fine particulates characteristic of the desert dust). There were also several problems with the inverter. Although most of these can be characterized as nuisance problems, they kept the system down for long periods of time because CFE personnel were unfamiliar with the system.

The original batteries lasted about 2.5 years, and after that their capacity degraded to less than 80% of rated. All of the batteries were replaced in the fall of 2003, and the battery bank was upgraded from 5 to 7 strings for a total of 280 Trojan L-16 batteries.

Impacts of 24-Hour Power

The most significant impact of 24-hour power for San Juanico's residents has been refrigeration. Whereas before, only those residents with gasoline-powered generators had refrigerators, now everybody connected to the hybrid power system owns a refrigerator, thereby increasing their ability to store food and for shops to preserve food. However, this did not help the fishermen to preserve their fish, as the electricity is not used for fish preservation or storage and this does not appear to be an option for the near future. While electric refrigeration would be an improvement over insulated trucks using ice, it is unclear whether the benefits from improved storage quality and capacity would outweigh the costs. The impact of 24-hour power on the tourist economy in San Juanico has been modest. Tourist numbers over the year are similar to previous years and continue to be influenced by San Juanico's surfing.

Local businesses connected to the system include 5 – 7 grocery shops, a few mechanics, a couple of restaurants, a couple of beer depositories, and a variety of part-time home businesses. Several families provide laundry services. There are also three schools in San Juanico: a kindergarten, a primary, and a secondary school. The secondary school is a “telesecondary,” which uses satellite television programming to administer lessons. All the schools are connected to the hybrid power system, but their energy use is low. According to the electrification study (Boer, 2000), only the telesecondary school realized significant benefits from using 24-hour power. Although 24-hour power replaced the health clinic’s previous energy source – a PV system – it has had minimal impact, because the clinic has few electrical appliances. At night, street lighting represents as much as 15% of the village load. Street lighting is provided by as many as 75 45-w fluorescent lamps, but not all of these were working at the time of the study.

Households experienced notable short-term (within one year after the system was installed) impacts from the hybrid power system. Every home connected to the grid obtained at least one electric appliance. With the increase in the number of appliances a significant modification in behavior occurred. Domestic tasks and some productive uses moved from the evenings to the daytime. Boer notes that 73% of respondents reported moving domestic tasks from the evening to the day within one year after the installation of the system. Leisure use of electricity, including radio and television use, increased throughout the day and evenings (Boer, 2000).

Appliance use, estimated from data provided by the local electrification panel of seven members known as the Patronato, is listed below for six major appliances. Other popular appliances, not included in the table, include blenders, coffee makers, stereos, VCRs, and electric tools.

Table 1 – Appliance Use

Appliance	Estimated users
Refrigerator	100%
Washing Machines	60%
Irons	25-30%
Microwave	20-30%
Television	90%
Satellite Television	50%
Floor Fans	100% (Mostly summer use)

Because the power provided by the hybrid system is intermittent, some of San Juanico’s residents use battery chargers to charge batteries that power small battery inverter systems to power appliances during the outages.

Load and Load Growth

The hourly average community load shows a rather typical usage pattern for a village the size of San Juanico (Figure 2). Base loads are composed of refrigerators, energy losses in the system, and miscellaneous uses. There is a brief, moderate increase during early morning hours as the fishermen wake up and villagers prepare for the day. Although the streetlights turn off at 8:00 a.m., some productive use loads start up. The loads increase during the midday and throughout

the afternoon as households use more electricity for domestic, recreational, and productive activities. Evening loads are higher as villagers use lights and televisions, and the streetlights switch on. By 11:00 p.m. the load decreases as families go to bed. The seasonal load is highest in the summer when floor fans are used for cooling and tourism is higher. The highest summer loads occur during the Saint Johns Day festival, with a peak load of 63 kW in June of 2001. The rest of the year the load experiences little change.

Load growth for the village grid from 1999 to 2003 is shown in Fig 2. Grid load growth from 2000 to 2003 was approximately 10%. Users have increased from 110 to 130, with 18 new residential users and 2 new stores. This is the primary contribution to load growth. The average residential kWh usage per month has remained steady while the average commercial kWh usage has grown 14%. The residential energy usage accounts for approximately 78% of the total energy usage, while the commercial energy usage is about 21% of the total energy use.

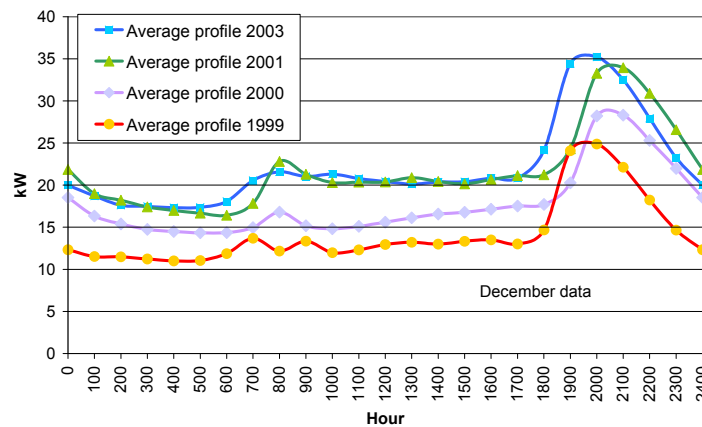


Figure 2: Daily load profile growth

The two major commercial load contributors are the comodu (the city itself), which uses electricity mainly for street lighting, and the Rattlesnake Restaurant Bar and Grill, which uses electricity mainly for refrigeration. The comodu and Rattlesnake Bar account for about two-thirds of the total commercial load.

According to the Patronato, there are about 40 people not connected to the village grid electrical system. These people, made up of both Americans and Mexicans, usually have their own source of power, typically a small stand-alone PV or a small diesel-battery-inverter system, because they do not trust the reliability of the village system.

Table 2 – Electricity Use

Average Residential Use (105 customers)	
kWh/month	85
Monthly cost	\$176 pesos
Average Commercial Use (20 customers)	
kWh/month	120
Monthly cost	\$406 pesos

Source: Patronato

The tariff structure for San Juanico is shown in table 3. Prices were raised for the first time since the beginning of the hybrid power system (i.e., 3.5 years) by 10 pesos as of 12/3/2003. It was noted by the Patronato that the ability to pay depended on the season, as fishermen make more money during seasons with high fish value (e.g., lobster season). Note 10 pesos is equal to about a dollar as of 2003.

Table 3 – Electricity Rates

Residential Use	\$50.00 peso fixed charge plus,
first 50 kWh	\$1.55 pesos/kWh
Next 100 kWh	\$1.85 pesos/kWh
Over 150 kWh	\$2.60 pesos/kWh
Commercial Use	\$80.00 peso fixed charge plus,
All use	\$2.70 pesos/kWh

Source: Patronato

System Reliability and Operation

In October and November of 2003 the town went without 24-hour power for 6-7 weeks because of a problem with the inverter that was easily corrected during the site visit. These types of outages have an adverse effect on the people's opinion of the hybrid power system and can cause monetary losses for the businesses that rely on the system for refrigeration throughout the day.

The system is maintained through monthly visits by CFE engineers that correct any problems and to perform detailed assessments of the battery bank. The seven-member local electrification council (Patronato) administers the daily operation of the plant, including regular maintenance, fuel provision, and meter reading and billing. The system is operated by two village residents employed by the village.

Conclusions

The San Juanico hybrid system is a good example of a successful hybrid system. While the assessment team discovered some problems and shortcomings during their visit, they believe the system is in good operating condition. The villagers tolerate system problems because they recognize the complexity and appreciate the savings the renewable system provides. Although they would like the system to be more reliable, in general, they are very grateful to have 24-hour power. The San Juanico system continues to provide valuable insights into village power systems from both a technical and institutional standpoint because of the wealth of available information.

Reference: Boer, Dereck, Unpublished National Renewable Energy Laboratory Report, 2000.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Executive Services and Communications Directorate (0704-0188). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.

1. REPORT DATE (DD-MM-YYYY) July 2004		2. REPORT TYPE Conference Paper		3. DATES COVERED (From - To) August 29 - September 3, 2004	
4. TITLE AND SUBTITLE San Juanico Hybrid Power System Technical and Institutional Assessment: Preprint				5a. CONTRACT NUMBER DE-AC36-99-GO10337	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Dave Corbus, Charles Newcomb, and Zeke Yewdall				5d. PROJECT NUMBER NREL/CP-500-36270	
				5e. TASK NUMBER IGIN 4530	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) National Renewable Energy Laboratory 1617 Cole Blvd. Golden, CO 80401-3393				8. PERFORMING ORGANIZATION REPORT NUMBER NREL/CP-500-36270	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S) NREL	
				11. SPONSORING/MONITORING AGENCY REPORT NUMBER	
12. DISTRIBUTION AVAILABILITY STATEMENT National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT (Maximum 200 Words) San Juanico is a fishing village of approximately 120 homes in the Municipality of Comondu, Baja California. In April, 1999, a hybrid power system was installed in San Juanico to provide 24-hour power, which was not previously available. Before the installation of the hybrid power system, a field study was conducted to characterize the electrical usage and institutional and social framework of San Juanico. One year after the installation of the hybrid power system a "post-electrification" study was performed to document the changes that had occurred after the installation. In December of 2003, NREL visited the site to conduct a technical assessment of the system.					
15. SUBJECT TERMS San Juanico; hybrid power system					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UL	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER (Include area code)

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18