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An Assessment of Building Energy Efficiency Options at Horn Island Ranger Station, Gulf Islands National Seashore

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Contract Report

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through the Renew the Parks initiative
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Introduction

As requested by Joe Martin of the National Park Service (NPS), Southeast Support Office, researchers from the Florida Solar Energy Center (FSEC) conducted a building energy efficiency assessment for the ranger station on Horn Island, Mississippi. The assessment included audits and inspections of the energy systems, building thermal performance, appliances, and energy use patterns. FSEC researchers Stephen Barkaszi and John Harrison conducted the audits and on-site inspections June 29 and June 30, 1999.

The purpose of the assessment was to evaluate the facility and to present recommendations for improving the energy efficiency of the building. This report summarizes the information obtained during the site visit and presents recommendations for improving the energy utilization at the facility.

This work was funded by Sandia National Laboratories (SNL), in collaboration with Hal Post and Mike Thomas at SNL, through the Renew the Parks initiative.

Site Description

Horn Island is part of the Gulf Islands National Seashore and is located approximately 12 miles off the Mississippi coast, south of the city of Ocean Springs, MS. The island is accessible only by boat and visitors frequent the island year-round for camping, nature outings, and to enjoy the beaches. Park rangers are present on the island at all times to assist visitors and to enforce regulations. The park rangers and wildlife researchers live on the island, and the typical number of people on site varies during the year from two to six individuals. The number of individuals living at the site also varies, depending on whether the rangers have spouses and children residing with them.

Facilities Description

A ranger station has been established on the island and consists of living quarters, a storage/maintenance building, a generator building, a dock and small boardwalk, a water pumping station, and a newly installed photovoltaic system. The park facility and a National Guard communications facility are the only structures on the island; there are no accommodations for visitors.

The park facility was damaged during Hurricane Georges when the storm surge and excess rainfall caused the gulf waters to overwash the island. The majority of the damage was to the residential structure, the generators, and the boat dock. Repairs have been made to return the facility to the pre-storm condition, excluding the boat dock and diesel fuel delivery system.

A report published by Sandia National Laboratories (Post and Thomas, 1994) provides a detailed description of the Gulf Islands National Seashore facilities. This report also provided recommendations for the PV system design and requirements.

Horn Island Ranger Station Residence

Building Description

The residential structure at the ranger station was the focus of the energy audit. This single story, wood frame structure is constructed on a pile foundation. The exterior of the building is covered with T1-11 plywood siding and the roofing system is comprised of brown asphalt shingles over plywood decking and conventional trusses with a pitch of approximately 4:12. Attic insulation consists of fiberglass batts and the insulation was estimated to have a nominal R-value of 19. The flooring system is vinyl composition tile over plywood and pressure treated floor joists, with area rugs used in some rooms. No insulation was observed for the floor. Double-paned windows were installed throughout the house.

The gross area of the building is approximately 2650 $ft^{2,}$ with 2150 ft^2 of conditioned space. Three porches occupy approximately 500 ft^2. The T-shaped multi-family residence is divided into three distinct units, each with a kitchen, bathroom, living room, and dining room. Two of the units have one bedroom and one unit has two bedrooms. There is a single laundry/utility area for community use.

Appliance Audit

One central air conditioner serves all three units, a recently installed Carrier 38YCC 3.5 ton heat pump with a 10 SEER rating. The nameplate rating on the unit is 27.8 amps at 230 volts. An indoor unit for the heat pump is located centrally in the house and is situated on a return air plenum constructed of plywood and drywall. Ductwork for air distribution is located in the attic space and consists of a network of insulated ducts. A digital thermostat controls the heat pump and is capable of being programmed for multiple set points on a daily basis for both heating and cooling. It is unclear why a heat pump was installed when it had been reported that the space heating is supplied by a propane furnace.

A 30-gallon gas water heater (Rheem Rheemglas Fury, Model 21V30-7P) is located in the utility area in the ranger house and provides hot water for all of the units. The water heater is currently being fueled by propane supplied from a tank located in a shed adjacent to the residence. The water heater tank is rated at R-6.7 insulation value and according to the tank label, "This model uses 278 gallons per year ($272)." All visible plumbing was galvanized steel.

The laundry facilities consist of a washing machine and clothes dryer. Both of these appliances are electric powered.

Each kitchen area contains basic appliances: stove, refrigerator, microwave oven, and coffee maker. The stove and refrigerator use propane and the microwave and coffee maker use electricity.

Lighting throughout the residence is provided by incandescent lamps and fixtures. Ceiling fans are installed in the bedrooms, living rooms, and several other rooms. Each of the ceiling fans has light fixtures with four or five 25- to 75-watt incandescent bulbs.

Water is supplied to the residence from a well located to the north of the building. The system utilizes a 1-hp pump and a 100-gallon pressurized tank located in the outdoor utility shed.

Site Inspection

It was noted during the inspection that there were large gaps in the return air plenum, and air was being drawn from the air handler closet. The air handler closet was not completely isolated from the unconditioned attic, resulting in hot humid air being introduced to the system. At the time of the inspection, the thermostat was set at 75 degrees and no program was entered. The occupants stated that they did not use the programmable features and typically leave the thermostat at this setting at all times during the cooling season. The cooling season is typically from April to October.

The water heater appeared to be in good condition and functioning properly. The hot out piping was not insulated nor was the cold in piping plumbed to the heater. At the time of the inspection, the water heater was set at "warm." The hot water usage was discussed with the current occupants, who stated the total number of showers per day were two per person, totaling four showers per day during normal activities (excluding increased occupancy and daily visits). The showers are usually taken in the morning and late afternoon. Hot water is also supplied to the kitchens. Approximately one gallon of hot water is used per day for cooking meals. There is no dishwasher at the facility. All dishes are typically washed by hand three times per day. Cold water is used for all clothes washing. Two loads are washed per week. There were no other stated uses of hot water at the facility.

An infrared camera was used to scan the building envelope during mid-day and early afternoon. No major hot spots or other anomalies could be observed. However, there was no way of determining the value of the wall insulation. It could only be assessed that the level of insulation appeared to be consistent throughout the house. There were several minor hot spots observed on the ceiling where the walls and ceiling met. This is not atypical for a house constructed in this manner, as it is often difficult to insulate these areas.

Solar access for the utilization of roof-mounted solar thermal collectors or photovoltaic panels is good. There are trees located to the west and south of the building, but these do not cause significant shading during peak hours.

Power Generation

Diesel Generators

Two 25kW diesel generators are the primary source of electrical energy for the facilities on Horn Island. These generators were relatively new (installed in early 1999), having replaced the two generators (25 and 20kW) that were destroyed during Hurricane Georges. Diesel fuel is stored in a large tank located on a concrete pad adjacent to the generator building. In the past, fuel was pumped directly from the fuel delivery ship docked near the beach. However, the pipeline from the boat dock to the storage tank was damaged during the hurricane. Currently a fuel tank must be towed approximately ½ mile across the beach and dunes to the storage tank and transferred locally.

PV System

A photovoltaic array was installed in July of 1999 to help offset some of the run time required for the diesel generators. The system is comprised of a 3.6-kW PV array, an 80-kWh battery bank, and sine wave inverters. The array faces due south and is tilted at approximately 45 degrees from horizontal. This configuration is optimized for maximum production during the winter season when the electrical demand for the facility is lowest. It is anticipated that the PV system will completely eliminate the need for diesel generators during the winter, with the exception of periods of inclement weather.

Recommendations

Solar Water Heating

The initial inspection of the site indicated that the site has good solar access and is quite suitable for the installation of a solar system. There is no shading of the probable collector mounting location. The roof is in good condition. The roofing material is asphalt shingle installed on standard roof sheathing with common trusses. This makes for an easy and well-sealed roof installation of collector mounting brackets and collector loop piping. A large area of roofing is facing close enough to south (25 degrees west of south) for flush mounting of the collectors. The roof tilt is 20 degrees. A tilt increase when the collectors are mounted would increase solar gain during the winter months. The horizontal distance from the probable collector mounting location on the roof to the existing water heater is 10 feet, while the vertical distance is 8 feet.

This is an ideal site for the use of solar water heating. The solar access and structure of the roof, attic, and water heater area present no immediate problems regarding the installation of a solar system. This would be a relatively easy installation.

There are several system options available for this site, depending on whether the propane tanks are removed or kept. The island maintenance supervisor would like to have the propane tanks removed because having to haul in the propane tanks periodically creates logistical hardships and is time consuming. The type of system chosen depends on this decision, which needs to be made by the facilities' rangers/area maintenance supervisor.

Propane tanks are also used at this facility for space heating and refrigeration. Therefore, it is anticipated that propane will always be required. The use of solar, in conjunction with propane, could reduce somewhat the amount of propane used, especially in the ideal solar months.

If the propane tanks are removed and an electric water heater is retrofitted to serve as back up for an active direct system, the back-up electricity will have to be provided by either the diesel generators or the photovoltaic system. The diesel generators will provide electricity to the facility during the summer months, while the photovoltaic system will provide electricity during the winter months. Therefore, during the winter months, the generators would have to be activated to provide back-up electricity for the water heater in the event there is no solar gain (and therefore no solar heated water). Having to turn on the generators periodically for a short period of time to heat a tank of water and then turn them off again does not seem reasonable, and would possibly create mechanical problems for the generators. It is doubtful that the photovoltaic system was designed to provide sufficient power for the water heater elements, which could range from 4500W to 6000W. Therefore, it makes sense to keep the propane tanks for back-up water heating.

Nevertheless, if the Park staff decides to eliminate the propane tanks, the above strategy would have to be employed. The ideal system in this case would be either a direct active photovoltaic controlled water heating system or a passive integral collector storage (ICS) system.

An active direct pumped solar water heating system cannot be used with a single-tank gas water heating system for the following reason. Every time hot water is used in the residence, cold water from the well tank replaces the hot water used. This introduction of well tank water causes the gas water heater's thermostat control (located at the bottom of the tank) to activate the burner, since cold water from the well tank would undoubtedly be colder than the temperature set at the thermostat.

One option for solar water heating is the installation of an *active photovoltaic-powered system*. This system (shown below) differs from other direct-pumped systems in that the energy to power the pump is provided by a photovoltaic (PV) panel. The PV panel converts sunlight into electricity, which in turn drives the direct-current (dc) pump. Water flows through the collector only when the sun is shining. The dc pump and PV panel must be suitably matched to ensure proper performance. The pump starts when there is sufficient solar radiation available to heat the solar collector. It shuts off later in the day when the available solar energy diminishes. A thermally operated valve provides freeze protection. Freeze protection can also be achieved by manual draindown of the collectors.

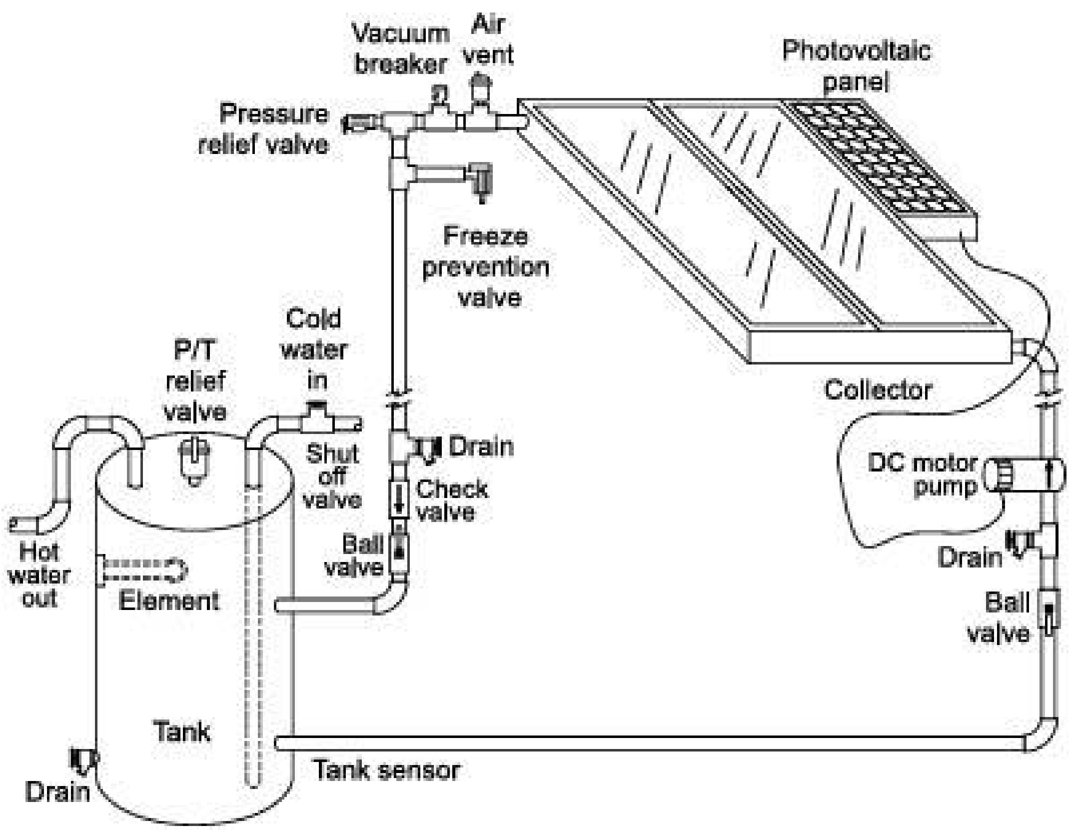

Figure 1. Active PV-Powered Solar Water Heating System

The second option for solar water heating is an *integral collector storage solar system.* In this system, the hot water storage system consists of relatively large diameter tubes located within the collector. Cold water flows progressively through the collector where it is heated by the sun. Hot water is drawn from the top, which is the hottest, and replacement water flows into the bottom. This system is simple because pumps and controllers are not required. On demand, cold water from the house flows into the collector and hot water from the collector flows to a standard hot water auxiliary tank within the house.

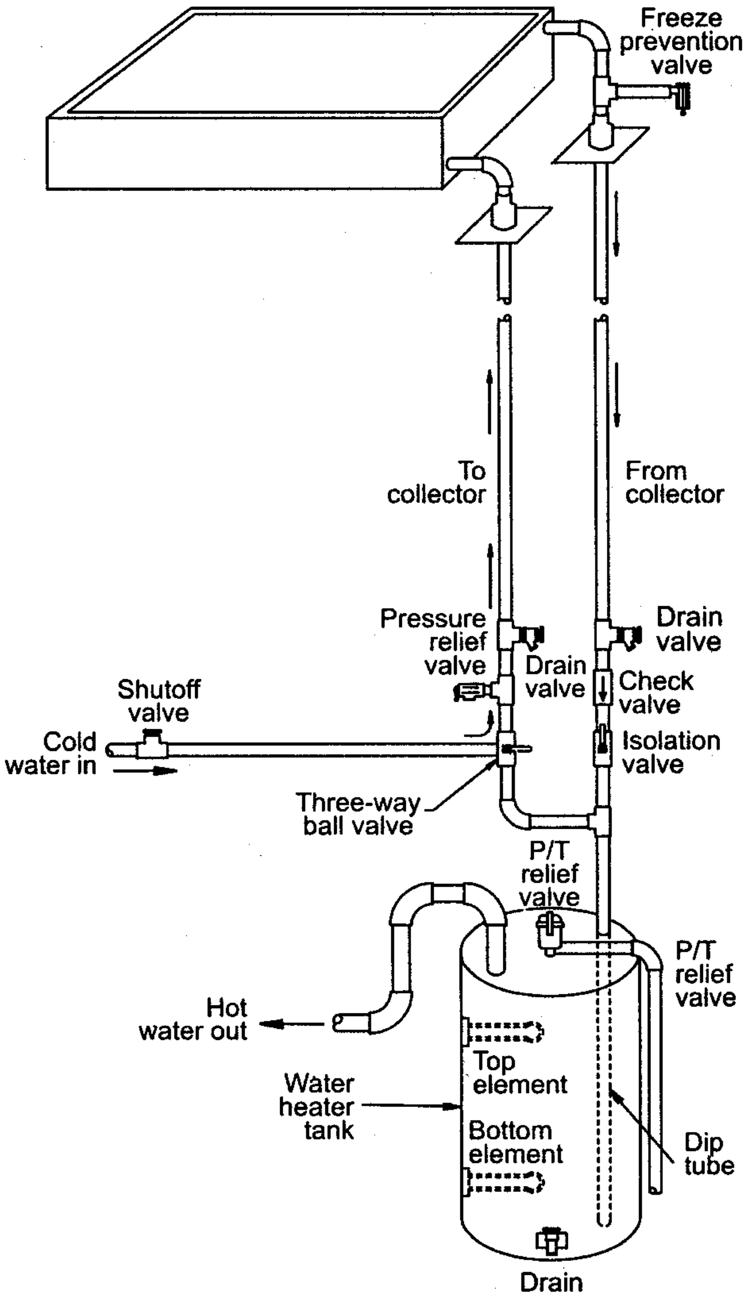

Figure 2. Integral Collector Storage Solar Water Heating System

A flush-type freeze protection valve is installed in the top plumbing near the collector. As temperatures near freezing, this valve opens to allow relatively warm water to flow through the collector to prevent freezing. In temperate climates, the thermal mass of the water in the ICS tubes serves as a freeze protection method. Of course, exterior and attic piping have to be covered with 3/4" thick pipe insulation.

If the propane power source is not removed, then the most feasible option would be to install a two-tank active system or retrofit the ICS system to the existing propane water heater. The solar storage tank would serve as a solar pre-heat tank for the active system, while the ICS collector would serve as a pre-heater to the gas water heater.

Once the Park staff decides whether to keep or remove the propane tanks, the next step is to decide on the type of system and develop system design and sizing guidelines.

System Cost

The price range of a solar water heating system installed at Horn Island is somewhat difficult to determine at this stage since the type of system influences the cost, as well as other decisions, such as whether new tanks would have to be included. At this point, a roughly estimated cost for a solar water heating system falls in the range of $2,000 to $3,500. Once the type of system has been decided, more accurate prices can be obtained from solar vendors.

Air Conditioning System

The ranger station on Horn Island is located in a cooling dominated climate. This is demonstrated by the energy use records, which indicate the cooling season is from April to October. The air conditioning system represents the single largest electrical load for the building. The efficient operation of this system is critical if the goal of reducing the diesel fuel consumption to a minimum is to be met.

The Carrier 38CYY has a SEER rating of 10.0. This unit is considered an entry-level builder model and is one of the most basic units available from this manufacturer. While the unit is typically very reliable, it is the minimum efficiency required by most building codes. There are many units with SEER values of 14 or greater available from this and other manufacturers. Replacing the existing unit with a high efficiency unit (14 SEER or greater) should result in a decrease in cooling system energy use of 30% or more.

Some serious problems were identified with the return plenum and air handler closet for the air conditioning system. Due to the gaps in the construction of the plenum and the closet, hot, humid air is drawn from the attic and is introduced to the conditioned air. This situation has a tremendous impact on both the sensible and latent loads that the air conditioner experiences. In addition, the comfort level of the occupants is affected because the air may not be properly dehumidified. Correcting the air infiltration problem will significantly reduce the air conditioner run time and should improve the comfort level of the occupants. Repairs to the air handler closet coupled with the installation of a high SEER unit, could reduce cooling energy use by 50% or more.

To further reduce the cooling energy needs, other components of the HVAC and building systems can be upgraded to operate more efficiently. Placing the air distribution ductwork inside the conditioned space can significantly reduce the heat gain to the conditioned air and, in turn, reduce the compressor run time. Reworking the air distribution system can be very costly and may not be feasible. However, heat gain to the ductwork can be reduced by lowering the attic air temperature. This can be accomplished by installing a highly reflective roofing system such as a white metal roof. Studies at FSEC have shown that a reflective roof surface can reduce cooling energy use up to 40% in hot, humid climates.

An additional cooling system option is to install a two-speed outdoor unit. These units typically operate at half their total capacity unless the demand for cooling cannot be met. Then the system operates at full capacity. This type of unit can be very efficient and will draw only half of the power that a single speed unit will for a significant amount of run time. This is especially true during transitional months and during unoccupied periods and nights when the loads on a cooling system are typically lower. Manual J calculations should be performed for this residence if the cooling system is to be replaced. Ensuring that the unit is properly sized will provide the appropriate comfort level for the occupants and will avoid excess energy use.

Building Envelope

Changes made to the building envelope can help the Park staff attain its goal of lowering diesel fuel consumption by reducing the mechanical cooling requirements and extending the natural ventilation period when cooling is not required. In a cooling dominated climate, one main source of heat gain to the building interior is through the roof. Currently the roof surface is covered with brown asphalt shingles in good condition. However, asphalt shingles do not reflect sunlight, they absorb it and convert it to heat energy, which is transferred to the building interior. By replacing the shingles with a highly reflective roofing material, such as light-colored metal panels, much of the sunlight is reflected and less is converted to heat. This will help reduce the run time of the air conditioner during the cooling season and extend the amount of time during the fall and spring when natural ventilation is sufficient. Changes to the roof can be made easily when the asphalt shingles need to be replaced in the future.

There was no insulation observed under the floor throughout the house. While the heat gain through the floor is not as great as the gain through the roof, a temperature differential of 20 to 25 degrees F can exist between the interior and exterior air spaces during the summer months. With very little resistance to heat flow, the resulting load on the AC system can be significant. It is recommended that a rigid foam or spray-applied insulation system be installed in this location due to the potential for damage from water or animals.

Lighting

Lighting throughout the house had been identified as primarily incandescent bulbs in conventional fixtures and lamps. A typical residence will use 1 kW of electricity per year, per square foot of floor area with incandescent lighting. The consumption can be reduced by 60 to 70% by replacing the standard bulbs with compact fluorescent bulbs. This would equate to approximate savings of 135 kWh per month. This is significant at this site, especially during the winter months when the PV system is to provide the majority of the electrical power requirements. The percentage of power used for lighting can be reduced from 35% of the total PV production to 11% of the PV system output by completing this simple retrofit.

Water Pumping

Water pumping power use at the residence was estimated to be 2 kWh per day. The possibility of installing a separate PV array for water pumping may be explored to eliminate an additional load on the main PV system. This would only be feasible if the diesel generators were eliminated completely or there was a critical need to shed more load from the PV system and all other energy efficient measures had been employed.

Occupant Habits

The energy use habits of the occupants will need to be assessed and possibly altered slightly for the transition to a PV-powered or PV/generator power system to operate at peak efficiency. Some habits that were observed during the site audit that can be altered to conserve energy are as follows:

Clothes Drying

Clothes that had been recently washed were hanging on clotheslines in the house. It was possible that the occupants felt that they were saving energy by not running the clothes dryer. However, the additional moisture introduced to the indoor air increases the latent load on the air conditioner and decreases the comfort level for the occupants. If possible, clothes should be hung on a line outside to dry. During periods of high humidity, the clothes may need to be run through the dryer on a short cycle after they are removed from the line.

Thermostat Usage

Utilizing the programmable thermostat is very important for conserving energy and can significantly reduce the power consumption for conditioning. If the occupants are on a regular schedule of leaving the residence, the setpoint should be raised to 85 degrees during unoccupied periods. This will reduce the run time of the unit and still provide acceptable dehumidification. The setpoint can be programmed to return to a comfortable temperature level one half to one hour before the occupants typically return. If the occupants are not on a regular schedule, the thermostat should be set to 85 degrees by the last person leaving each day and can be returned to a comfortable setpoint by the first person returning. The building may be slightly uncomfortable for a short period of time after the first person returns, but the energy savings will be very significant.

Appliance Usage

Appliances should be turned off when not in use. Radios, lights, televisions, etc., have a significant cumulative effect on the total power use for the building.

References

Post, H. and Thomas, M., “An Engineering Assessment of the Potential for Renewable Energy Power Systems at Gulf Islands National Seashore,” Draft Report, November 1994, Sandia National Laboratories, Photovoltaic Design Assistance Center, Albuquerque, NM 87185-0753.