Lizard Research Station
Solar Power
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Introduction

The Australian Museum's Lizard Island Research Station (LIRS) supports research into coral reef biology and ecology (www.australianmuseum.net.au/Lizard-Island-Research-Station) in the remote north of Australia's Great Barrier Reef. It is recognized as one of the world's leading coral reef field research stations. It has infrastructure that supports over 8,000 person user days annually.

Corals reefs world-wide are under severe threat from many human induced stresses including warming seas and acidification of the world's oceans due to the burning of fossil fuels. The main objective for installing a green power system was to substantially reduce the Station's CO_2 emissions. Other significant benefits included a reduction in diesel generator maintenance and fuel costs, reducing staff time used to transport fuel and a quieter environment for visitors and staff.

This document is intended as a resource for others in remote locations who are interested in achieving similar benefits – i.e. reducing their carbon footprint through the installation of a solar photovoltaic (PV) power system and achieving a significant saving in the use of diesel fuel. It documents the journey the Australian Museum's Lizard Island Research Station took to achieve a 64% reduction in its CO_2 emissions and diesel fuel usage from the generation of electricity. This reduction was highly significant since LIRS already had a relatively small carbon footprint prior to the installation of its PV system.

Background

The Lizard Island Research Station was established in 1973 as a facility of the Australian Museum. It provides facilities that support scientific research and education on the northern part of the Great Barrier Reef. The Station is located about 270 km north of Cairns, Qld and it is about 30 km off the mainland coast. Visitor access to the island is generally by light aircraft from Cairns whereas food, fuel and other freight are shipped to the island on a fortnightly landing barge from Cairns that is chartered by the Lizard Island Resort.

The Station has developed from a collection of tents into a permanent research facility. Power is provided to facilities twenty-four hours a day, everyday of the year. These facilities include: four non air-conditioned visitor houses accommodating up to 38 people; two non air-conditioned staff houses; two laboratory blocks with eight air-conditioned rooms; air-conditioned office, library, seminar and computer room; a large aquarium system with saltwater and air pumps; laundry facilities; walk-in cool room; freezers; beach hut; workshop including drill press, lathe, welder, water blaster; pumps for the freshwater bore; and two scuba compressors. All of the Station's hot water is produced by solar hot water systems and its phone system is powered by solar panels charging a battery bank.

With funding from the Lizard Island Reef Research Foundation, the LIRS undertook a major upgrade to all aspects of its facilities from 2005 to early 2011. Sustainability was a central pillar in planning for the upgrade. Through thoughtful building design, LIRS maximised passive cooling and minimised airconditioning. The houses are not airconditioned. Instead they are well ventilated and have wide eaves and verandahs. The roof of the Ian Potter Centre for Tropical Marine Research acts as a venturi to draw hot air from the central research area so that airconditioners in the labs and offices do not have to work as hard. Technology played a part too as we incorporated high levels of insulation and energy efficient lighting and air-conditioning equipment into the design of new buildings.

There is a large body of scientific evidence supporting the contention that coral reefs are severely degraded by rising sea temperatures and ocean acidification which are caused by increasing levels of atmospheric CO_2. As one of the world's leading coral reef research stations it is important that

LIRS minimizes its output of CO_2. The station's primary source of CO_2 emissions is through burning diesel fuel for power generation. Before installation of a PV power system, the Station's annual carbon emissions from power generation was about 123 tones; based on an annual energy requirement of 86,870 kWh and CO_2 emissions of 1.418 kg per kWh.

Investigations into Alternative Power

Since its inception, LIRS has used diesel powered generators to produce 240 volt AC power. From the 1970s through to about the mid-1990s electricity was typically provided during daylight and evening hours only. Since the mid-1990s, usage of the Station and demands for power had increased such that electrical power was required 24/7.

The decision to install a solar/diesel hybrid power generating system was based on two major energy audits and one less thorough audit. Each audit provided a recommendation for green power supply. Simulation models using power load data from the audits clearly indicated that the most cost-effective way of significantly reducing the Station's carbon footprint was to install a system consisting of solar panels and battery bank that are integrated with the existing diesel generators.

The first energy audit was undertaken in 2001. It used loggers on the Station's generators over a four month period to measure power loads over different times of the day and between seasons. In addition, it included a calculation of the power requirements of every building based on its electrical equipment and an estimate of the equipment's daily run time. Reassuringly, the calculated power loads agreed well with the logged data from the generators.

This audit identified that the most significant individual loads in terms of daily energy use included the four salt water pumps (3 kW each) that supply sea water to the aquarium system, the two scuba compressors (7.5 kW each), laboratory and office air conditioners and other pumps such as those pumping fresh water from the Station's bore. Lower consumption of power during Winter is primarily due to: cooler temperatures resulting in less running time for air conditioners, refrigerators and freezers; less use of the aquarium system meaning that the saltwater pumps don't run as much; and significantly less diving resulting in reduced usage of the scuba compressors.

A report resulting from the 2001 energy audit considered two options – solar and wind power. Although this report only considered these two options the Station undertook its own investigations into other types of green energy such as wave power. However, options other than solar or wind power were found to have at least one of the following major drawbacks: unproven technology, large engineering challenges, very high capital costs or high maintenance. Given that LIRS has a small staff with a high work-load it was imperative that its alternative energy source was of proven technology and low maintenance.

Although Lizard Island is a windy location, wind power was eventually dismissed because: 1) due to its sheltered location the average wind speed on the station's lease is only 4.5m/s; 2) the closest optimal site is off the lease area and there was little chance of Qld Parks and Wildlife Service granting an extension of the lease onto a better site; 3) there were concerns with visual and noise amenities and harm to birds; and 4) it was advised that a large cleared site immediately adjacent to the wind generator was desirable so that the tower can be lowered to the ground during cyclone threats.

The 2001 audit recommended a hybrid solar/diesel system. This recommendation was never acted upon due to negative comments received from others about the system. In particular, LIRS management were not confident repairs, if and when required, would be affordable.

In 2008, the same company again supplied data loggers to record power loads. Once again, a hybrid solar/diesel system coupled to a battery bank was proposed. Simulation models predicted that this system would reduce 2008 CO_2 emission levels by about 30%. The system was estimated to cost about $660,000 although this amount could probably have been reduced by 50% due to a Federal Government Rebate that was applicable at the time. This proposal was also not acted upon due to concerns over potential maintenance cost blowouts and because a 30% reduction in CO_2 emissions was not considered enough to warrant the capital outlay. Coincidentally, the government 50% rebate program was disbanded just as the Station received the 2008 recommendation. The axing of this rebate substantially increased the cost of achieving a meaningful reduction in CO_2 emissions.

Selection of a Hybrid Solar/Diesel power generating system

A third energy audit and model simulation undertaken by the Research Institute for Sustainable Energy (RISE) at Murdoch University, WA, provided the data that finally enabled a decision to be made. Details of the audit and simulations are set out below. The good news is that LIRS commissioned its 30KW solar/diesel power generating system on 24th February 2011.

After about five months of operation the new system has proven to be reliable while enabling a meaningful (~70%) reduction in CO_2 emissions. Importantly, at about the time of the RISE energy audit a LIRS staff member (Robert Lamb) gained his qualifications to design and install remote power systems. Having a staff member knowledgeable about solar power enabled LIRS to better evaluate and eventually implement the RISE recommendations.

Sizing of the solar-hybrid electrical power system recommended by RISE was based on load profiles generated from three periods of logging power usage namely: 16 September to 6 October 2008; 9 – 26 December 2008 & 26 June to 7 August 2009. Simulation models based on power loads from these logging periods clearly indicated that the most cost-effective way of significantly reducing the Station's carbon footprint was to install a system consisting of solar panels and battery bank that are integrated with the existing diesel generators. The average load of the system over a year was estimated at 238 kWh/day with a peak load of 40kW. These findings and recommendation were in general agreement with those from the 2001 and 2008 audits. Wind power was not seriously considered in the RISE report due to drawbacks previously outlined.

Power configurations considered in the RISE study included:

a. Diesel generator only
b. Diesel generator, PV array and inverter (no battery)
c. Diesel generator, PV array, interactive inverter, and battery bank

For option c, an interactive bi-directional inverter is required since it must control the diesel generator set and manage the battery charging from both the PV array and the generator. Additionally, it must supply power to the station load in parallel with the diesel generator.

Model simulations done by RISE used HOMER software (ver. 2.67). A large number of assumptions were used in the simulations with some of the main ones including:

- Logged summer loads were increased by 5% to account for future growth.
- The winter load profile was increased by 10% since the logging period corresponded to an unusually quiet period at the Station.
- Cost analysis is based on a system lifetime of 20 years.
- The lifetime of the PV modules is estimated as 20 years.
- The lifetime of the inverters is estimated as 12 years.
- Diesel generator operational life is assumed to be 24,000 hours.
- Battery life is assumed to be 6,390 cycles at 25% depth of discharge.
- The interest rate was set at 6% with inflation being factored into this rate.
- Capital costs for all system components (PV module, inverter, battery, etc.) were based on quotes from PV system suppliers in Australia.
- Net cost of diesel in late 2009 was $1.06/litre.
- Generator maintenance costs were set at $0.57 per running hour.
- No government solar rebates were included in the calculations.
- Costs are in Australian dollars and are GST inclusive.

Results of simulation models for three system configurations with the above assumptions are shown in Table 1.

Table 1. Economic and performance parameters for three system configurations

Description	**Simulation Results PV-Diesel-Gel Battery**	**Simulation Results PV-Diesel (No Battery)**	**Simulation Results PV-Diesel (No Battery)**
System Component Sizes			
Diesel generator	40 or 58 kW	40 or 58 kW	40 or 58 kW
Battery	288 kWh	N.A.	N.A.
Inverter	30 kW	15 kW	N.A.
PV array	25 kWp	25 kWp	N.A.
Capital Costs			
Diesel generator	$68,000	$68,000	$68,000
Battery	$145,920	N.A.	N.A.
Inverter	$60,000	$15,000	N.A.
PV array	$150,000	$150,000	N.A.
Project infrastructure	$164,000	$120,000	$0
Total capital cost	$587,920	$397,000	$68,000
Diesel Generator Operation			
Fuel consumption (L/yr)	16,684	34,707	46,786
Operating time (Hrs/yr)	1,573	6,957	8,756

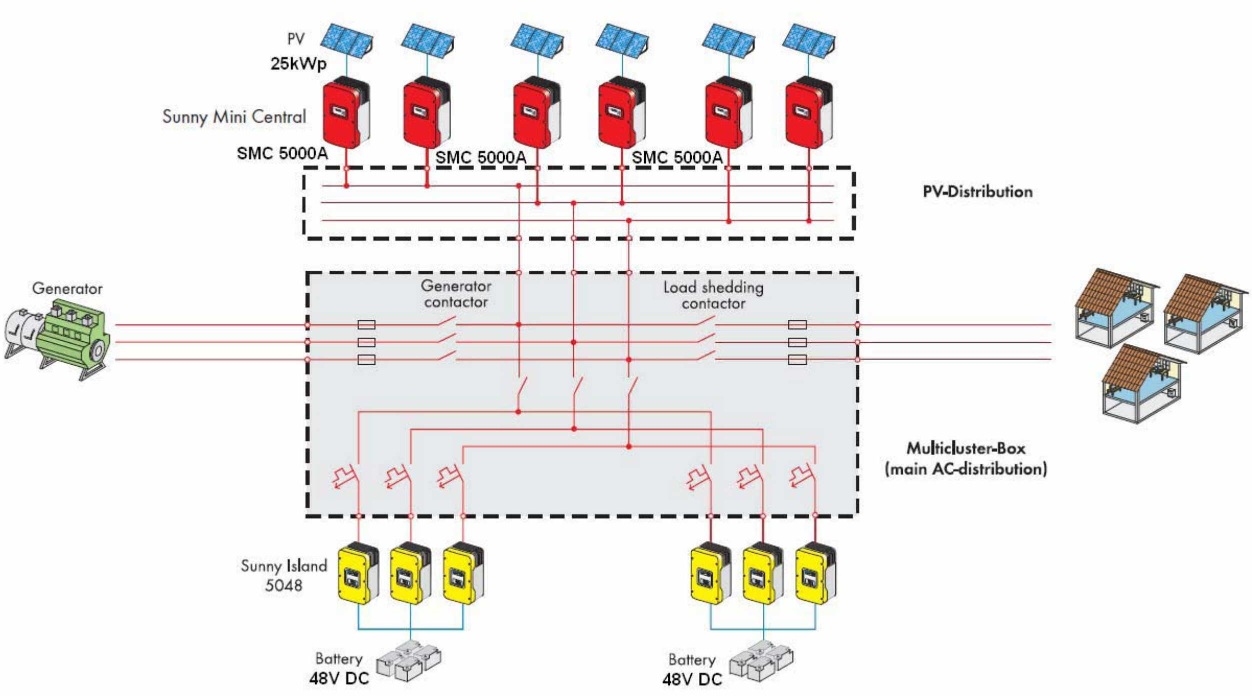
Life Cycle Costs			
Levelised cost of energy ($/kWh)	$0.903	$0.926	$0.888
Net present cost	$899,448	$922,880	$884,532
CO_2 Emissions			
Tonnes/year	43.933	91.395	123.203

The main recommendation from the simulation model was that LIRS should install a PV-diesel system with 25 kW PV array, 288 kWh batteries and 30 kW inverter. Table 1 shows that the cost of energy under this recommendation is about 1.5C/kWh higher than the cost of electricity supplied from the diesel only option. However, if potential government solar rebates are factored in then the cost of electricity under the PV-diesel-gel battery option is similar or slightly less than the cost of electricity under the diesel only option.

Based on the recommendations provided by RISE, LIRS decided to install a hybrid solar/diesel system with battery storage. This system was calculated to meet about 44% of the Station's average annual electrical load with a 64% reduction in both diesel use and CO_2 emissions compared to the diesel only option. It was designed in accordance with the recommendations made by RISE except that a 30 kW PV array was installed instead of the 25 kW array upon which the model was based. This change, done in consultation with RISE, was undertaken because it was desirable to balance the PV array with the 30 KW inverters, we wanted more solar production during summer when our peak load is highest, and an anticipated drop in the cost of solar panels indicated we could acquire the larger array for about the same price as the smaller one. Component specifications of the system are given in Table 2 and a schematic drawing is shown below.

Table 2. Specifications of 30 KW solar-diesel-battery system

Hardware	Description
Solar panels	144 x Sanyo 210 watt panels (Model HIP-210NKHE6)
Batteries	48 x 2 volt sealed Exide Sonnenschein Solar (Rating – 288 kWh)
Central inverters	6 x 5000 A SMA inverters (Type SMC5000A)
Interactive inverters	6 x Sunny Island 5040 (Type S15048)
System Control	1 x SMA multi-cluster box (Type MC-Box 12.3)
Data Logging	1 x SMA web box
Fuses	2 x SMA BATFUSE-B.03 (Type 388)



Construction of the building infrastructure supporting the hybrid solar-diesel system occurred mainly in October 2010 while installation of solar hardware was from January to February 2011. The solar panels are supported on a purpose-built frame made of hard wood measuring 32 metres long x 6 metres wide. The side of the frame with panels faces North at 15 degrees to horizontal. The general configuration of the frame is based on a design used by the resort on Lady Elliott Island. Underneath the frame are two rooms (each 2.4 m wide x 7.4 m long) on a concrete slab with one room housing the batteries and the other containing inverters and multi-cluster box that interface the solar power with the batteries and the diesel generators.

Sanyo solar panels were chosen based on quality and because of their good performance in a hot environment. The 30 kW PV array consists of 144 Sanyo 210 watt panels. Light shining on the solar panels generates electricity in the form of direct current (dc). This dc current goes into one of six central inverters that transform the electricity into 240 volt alternating current (ac) which is suitable for using in the Station's existing electrical network. The Station can typically run on the electricity produced by the solar panels during daylight hours with excess electricity shunted to the battery bank for use later.

The 288 kWh battery bank consists of 48 – 2 volt gel cell batteries. Management of charging and discharging of the batteries is by six Sunny Island 5048 interactive, bi-directional inverters. The batteries are charged from the solar panels, a diesel generator or a combination of both depending on load requirements, season and whether the day is overcast or sunny. Electricity from the batteries powers the Station during much of the night when power demands are generally lowest. To optimize battery life cycle economics we try to limit the batteries to one discharge cycle per day. The multicluster box facilitates the switching of the above equipment. A web-box is utilized to monitor the system and collect data for maximizing operations.

The Station's existing diesel generators are used to supplement power requirements during daylight periods of low light and at night when battery storage levels reach a pre-set level of discharge. Operation of the duty generator is generally controlled automatically by the interactive inverters. LIRS has chosen to over-ride this automatic control by integrating a digital timer into the system. This ensures the diesel generator is only run at specified times in order to provide a quiet period when most people are sleeping. Under the new system, the duty generator is always running under high load and therefore its output of energy per litre of diesel fuel used has greatly improved.

The Station incorporated two (40 kW & 58 kW) of its three existing diesel powered generators into the solar-diesel system. These two generators are run alternatively for about two weeks at a time. The Station's third generator (58 kW) is independent of the solar-diesel system and it can quickly be brought on line in the event of a failure with the hybrid system.

A typical 24 hour time line of the Station's production of electricity is shown in Table 3.

Table 3. Timeline of electricity production

Time	System producing electricity
Midnight to 6:00 AM	Running off the battery bank.
6:00 AM TO 7:00 AM	Diesel generator supplies power to Station and partially recharges the battery bank.
7:00 AM to 5:00 PM	All the electricity comes from the solar panels. On sunny days excess electricity is stored in the battery bank. On cloudy days, electricity might be drawn off the battery bank. If the battery bank drops to a pre-set discharge level the generator will automatically cut in

	to supply power to the Station and to charge the batteries.
5:00 PM to 8:00 PM	Running off the battery bank.
8:00 PM to 11:00 PM	Diesel generator supplies power to the Station with excess power charging the batteries. By 11:00 PM the battery bank is typically 95% charged.

A comparison of model predictions and actual results after five months of operation is shown in Table 4. Cost of the new solar-diesel system was in close agreement with model estimates. Performance after five months is better than the model prediction. However, it is estimated that daily fuel usage will increase during summer when more load is placed on the generator in order to fully charge the battery bank. If this is the case, then predicted and actual performance will probably be similar after a year of operation.

Table 4. Comparison of model predictions and actual results.

Description	**RISE Simulation Results PV-Diesel-Gel Battery**	**Actual Results PV-Diesel-Gel Battery**
System Component Sizes		
Diesel generator	40 or 58 kW	40 or 58 kW
Battery	288 kWh	288 kWh
Inverter	30 kW	30 kW
PV array	25 kWp	30 kWp
Capital Costs		
Diesel generator	\$68,000	\$68,000 Note 1
Battery	\$145,920	\$126,720
Inverters	\$60,000	\$83,435
PV array	\$150,000	\$120,571
Project infrastructure	\$164,000	179,274 Note 2
Total capital cost	\$587,920	\$578,000 Note 3
Diesel Generator Operation and CO_2 Emissions		
Fuel consumption (L/yr)	16,684	12,775 Note 4
Operating time (Hrs/yr)	1,573	1,460 Note 5
CO_2 Emissions (Tonnes/year)	43.933	33.726 Note 6

Note 1: This was not a new capital outlay since LIRS used its existing generators in the new solar-diesel system.

Note 2: Includes supply and construction of frame for PV panels, battery and inverter rooms (\$120,000), other electrical and infrastructure materials and labour (\$59,274).

Note 3: Includes GST. Figure does not include the value of 2,280 Small-scale Technology Certificates.

Note 4: Based on 35 litres per day. This is the estimated daily usage from March to July 2011. More data is required to determine if usage of diesel fuel increases during summer when electrical loads are higher.
Note 5: Based on the diesel generator running 4 hours per day (0600 – 0700 hrs, 2000 – 2300 hrs)
Note 6: Based on using 12,775 litres of diesel per annum with CO_2 emissions of 2.64 kg per litre.

Summary

The LIRS hybrid solar/diesel power system was commissioned on 24 February 2011. Although in operation for less than six months, the new system has operated with few problems. Its early performance is better than model predictions although it is expected to come back to model predictions as diesel fuel consumption increases due to higher power loads over summer. The smooth transition to a hybrid solar-diesel- battery system was due primarily to: 1) recommendations from the 2009 simulation model and 2) detailed planning of system hardware components and their installation by LIRS staff member, Robert Lamb.

The main benefit of the solar power system is an estimated reduction of 64% per annum in CO_2 emissions and diesel fuel usage from power generation. Another important benefit that wasn't fully appreciated until after the solar system was commissioned was how much both visitors and staff enjoyed the silence created by not having generators running. Finally, and somewhat counter intuitively, both visitors and staff are more conscious of conserving power once it is being supplied by a renewable source.

A decade of consulting with renewable energy experts and investigating renewable systems has led to the following main conclusions:

- The most cost-effective means of reducing CO_2 emissions due to power generation is to make your establishment as energy efficient as possible (i.e. solar hot water systems, energy efficient lighting, good building design, effective building insulation, energy efficient airconditioners).
- Make your establishment energy efficient first and then bring in experts to model your power loads. The simulation model will obviously not be very accurate if you alter major parameters after the model has been developed.
- To avoid conflicts of interest it is preferable that the company undertaking the energy audit and system recommendations be independent of hardware suppliers.
- Before acquiring a system, discuss the successes and problems that establishments with similar systems have experienced.
- Buy the best quality hardware that you can afford.

Future plans for LIRS power generation include installing monitoring equipment on the current system for at least a year or more. Results from this monitoring should indicate whether additional PV panels, a wind turbine or a combination of both is the best option for further reducing the Stations CO_2 emissions and diesel fuel costs.