GKI RESORT PTY LTD
GREAT KEPPEL ISLAND RESORT
RENEWABLE ENERGY ANALYSIS REPORT

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ARUP

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EXECUTIVE SUMMARY

This report has been undertaken by Arup on behalf of GKI Resort Pty Ltd to analyse a renewable energy target strategy based on a solar photovoltaic (PV) panel installation at the Great Keppel Island Resort.

The Island's Revitalisation Plan has adopted an ambitious sustainability strategy to position it as ***Australia's first carbon-positive resort island*** that will produce more energy than it consumes each year. While many eco-resort destinations around the world have embraced sustainability, there are very few that have established this ambitious environmental goal as the cornerstone of a comprehensive sustainability strategy. It will place the Great Keppel Island Resort in a rare category of developments that are redefining sustainable building performance.

Embracing one of Australia's most significant natural resources—its abundant sunshine—the Resort is committed to achieving a carbon positive status through the installation of solar photovoltaic panels on the rooftops of the eco-resort villas, hotel and apartment complexes that will generate enough electricity to offset and surpass the emissions resultant from the operation of the complex.

To be carbon positive, the Resort would have to generate electricity in excess of **11,851,681 kWh/ year** via its photovoltaic system to be able to offset and surpass the total amount of annual emissions. In order to achieve this carbon positive status, the following system is proposed:

►**Proposed PV System Size: 5.9 MW**

►**Proposed Number of Panels: 24,320**

►**Total Carbon Postive Resort-wide Buffer: 5%**

►**Total Carbon Emissions Offset: 12,693,150 kgCO2/ year**

►**Annual Generating Potential: 12,444 MWh/year**

This system will generate electricity during daylight hours and supply both the Resort site, other island residents and into the mainland grid via undersea cabling connections. During the evening hours, the Resort will draw electricity from the grid.

The proposed eco-resort villas play a critical role in the objective to reach carbon positive status, as many of the PV panels required will be installed on their roofs. It was estimated that each eco-resort villa unit would have approximately 45m² of available roof for the installation of PV panels, after discounting area for access and maintenance and for the installation of solar hot water panels. This represents 89% of the total area required for the installation of PVs.

The remaining PV panels will be installed on the rooftops of the eco -resort apartments and the hotel.

A key component of the Resort's sustainability strategy is to engage visitors with the generating capacity of the villa PV installations, making clean energy a visible part of the Great Keppel Island experience.

On Sunday, July 10, 2011 the Australian Government announced that from July 1, 2012 carbon polluters in Australia would be taxed at $23/tonne of carbon emission for the first year after being introduced. The new policy is expected by the Government to cut approximately 159 million tonnes of carbon pollution by 2020, reducing Australia's emissions by 5 percent. The GKI contribution to carbon emission reduction is expected to exceed this target by more than 100%.

1.0 INTRODUCTION

The proposed Great Keppel Island Resort is located approximately 12 kilometres from mainland Australia and within the Keppel group of islands. The Island's Revitalisation Plan has adopted an ambitious sustainability strategy to position it as ***Australia's first carbon-positive resort island*** that will produce more energy than it consumes each year. This goal will place the Great Keppel Island Resort amongst the most environmentally conscious tourism developments in the world and a model for future development in Australia and abroad.

This report has been undertaken by Arup on behalf of GKI Resort Pty Ltd to analyse a renewable energy target strategy based on a solar photovoltaic installation at the Resort. This strategy is presented as a model for how the development will proceed, in as much that this is not intended to be a design document, but rather as a methodology that establishes clear environmental targets that will be met by the Resort's development.

Project Description

The Resort will include four major components:

►750 free-standing, low-rise eco-resort villas;

►250-room, 2-3-storey luxury hotel and resort facilities;

►300 low-rise eco-resort apartments; and

►250-berth marina.

The Resort will embrace best practice in Environmentally Sustainable Design (ESD) principles and guidelines for hospitality facilities, including appropriate site orientation, passive design attributes like exterior shading and good-performing façade and glazing elements, as well as high-performance building services systems and resource-conserving systems for water, energy and waste. Assumptions regarding system efficiencies are documented in Section 3.0.

Carbon Positive Strategy

The achievement of a carbon positive status starts with reducing energy demand through enhanced passive building design strategies, enhanced energy management and commissioning as well as educational programs and target commitments from staff and guests. The remaining carbon emissions resultant from the Resort's operation should be offset by a renewable energy source.

The Great Keppel Island Resort is committed to achieving a carbon positive status through the installation of solar photovoltaic panels on the rooftops of the villas and apartment complexes that will generate enough electricity to offset and surpass the emissions resultant from the operation of the complex.

Defining the Carbon Positive Framework

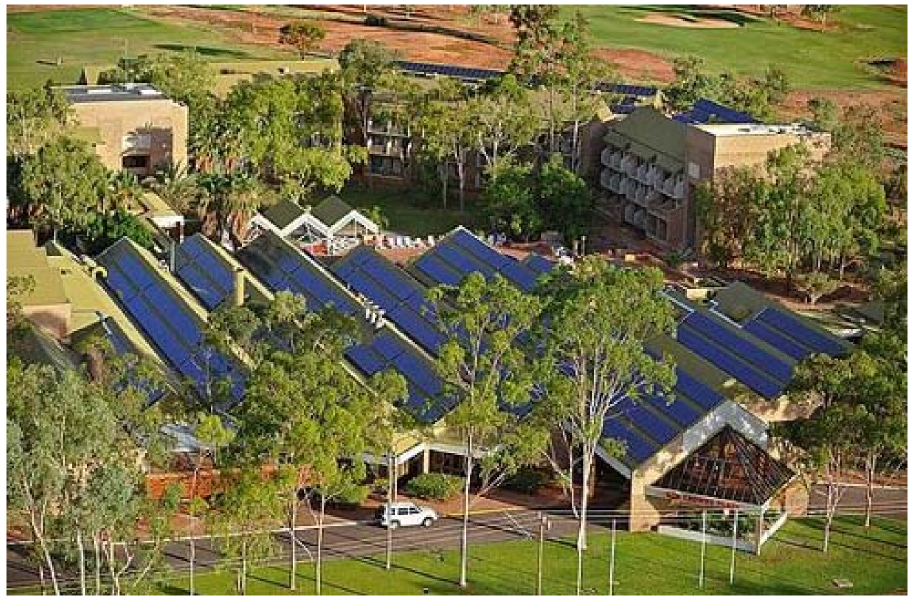
Prior to making environmental claims, it's important to define what we mean by "carbon positive." There are many developments throughout the world that claim "carbon neutrality" and other such goals, but many times these claims are dubious and based on spurious accounting and worthless carbon offsets. For the Great Keppel Island, we will approach the issue of carbon by considering the total energy use of the development's site, including both electricity and gas. In the design and construction industry, we would begin by understanding the Resort as a zero-energy building that would ultimately produce more energy than it consumes. Zero-energy buildings can be sub-classified into four schemes: net zero source energy, net zero site energy, net zero energy cost, and net zero energy emissions.

Net zero source energy compares the building's energy consumption and production to that of the utility source. Since utilities rely on multiple generation plants and transmission systems, this concept generally proves too difficult to quantify and is therefore rarely used in architecture. The net zero site energy concept measures energy consumption within the boundaries of the building's site, ignoring whether the utility source is coal or wind. This applies more generally to what architects try to achieve, since even so-called "off-the-grid" buildings loaded with photovoltaics and wind turbines still typically connect to utility transmission lines for backup power. The third element, net zero energy cost, relies on volatile energy rates—a notoriously difficult metric—to reach a balance between the energy generated on-site and sold to the utility versus the energy supplied by the utility. Finally, the concept of net zero energy emissions only measures the emissions produced by the generation of power to meet the building's total energy needs, which can also prove difficult with a utility company dependent on multiple sources at any given time.

The Great Keppel Island Resort will be designed to surpass the "net zero site carbon" classification, by having the potential to generate enough electricity to offset **100% + 5%** of the carbon emissions than is produced by the Resort's site-defined operations.

This report presents a model for how the development will proceed. It is not presented as a design document, but rather as a methodology that establishes clear environmental targets that will be met by the Resort's development. We must note there are significant assumptions built into this analysis which should be adjusted to fit actual program, areas and operation profiles and environmental targets of the Resort in future design stages.

2.0 PHOTOVOLTAIC ENERGY IN TOURISM RESORTS - CASE STUDIES



Crowne Plaza Hotel, Alice Springs

The Crowne Plaza has retro-fitted a 305kW solar photovoltaic array on its existing zig-zag rooftop in its Alice Springs resort. The installation generates an estimated 530MWh of electricity per year and helps the hotel reduce annual CO_2 emissions by 420 tonnes.

The array is oriented facing N-NE, which exposes the panels to significant amounts of direct sunlight in the morning and most of the afternoon. The zig-zag roof also ensures the panels do not experience overshadowing, which would significantly decrease their efficiency.

The system is described and its operation is reported at a sustainability exhibition installation in the hotel's lobby.

System Details:

Number of panels: 1,326, with 54 DC-AC inverters

Panel sizes: SunPower 230W panels

Annual generating capacity: 530MWh

Grid connection: Yes

Cost: $3.3 million

Year of completion: 2007

ABOVE The Crowne Plaza's photovoltaic installation is installed in a prominent location at the front porte-cochere, where arriving guests can easily view it.

LEFT The installation takes advantage of the existing sloped roof for optimal orientation.

BELOW Inside the lobby, the hotel has installed an exhibition of the sustainable attributes of the resort. The flat screen TV reports outside climate conditions, as well as the real-time generating capacity of the photovoltaic system.

Xanterra Parks and Resorts, Death Valley, USA

Xanterra is a hotel operator in national parks in the United States with a diverse array of properties and a significant environmental sustainability strategy. To help the company meet its carbon emissions reduction commitments, they installed a 1MW solar photovoltaic array on land within Death Valley National Park in California, one of the sunniest places in the U.S., to reduce emissions associated with two resorts they operate within the park.

The system tracks the sun, so panels are always optimally oriented to increase generating capacity. The installation saves 750 tonnes of CO_2 emissions per year.

The cost of the system was offset significantly by 30% tax incentive grants from the California State and U.S. Federal governments. The company estimates the payback time to be within five years.

System Details:

Number of panels: 5,740, with 2 DC-AC inverters

Panel sizes: Sharp 208W panels

Annual generating capacity: 2200MWh

Grid connection: Yes

Cost: $8.8 million

Year of completion: 2008

2.0 CASE STUDIES (CONTINUED)

Mauna Lani Resort, Hawaii, USA

This Hawaiian island resort installed a 674kW solar photovoltaic system on its rooftop and grounds in order to reduce its operating costs and avoid future fuel price volatility, in addition to contributing to the hotel's sustainability strategy. The system currently meets 30% of the resort's electricity needs each year.

In one innovative approach, the resort uses the PV system to charge all of its golf carts.

The system will help the hotel reduce its CO_2 emission by 430 tonnes per year and estimated a system payback in only five years.

System Details:

Number of panels: 2,900 panels

Panel sizes: SunPower 230W panels

Annual generating capacity: 1150MWh

Grid connection: Yes

Cost: $5.5 million (estimated)

Year of completion: 2003

Zira Island, Azerbaijan

This resort, which includes hotel and residential villa accommodation, is currently in development and seeks to achieve "carbon neutrality" through the use of wind power and solar photovoltaics.

Target Zero, Zanzibar

This resort, which consists of 35 villas, is currently in development and seeks to achieve "carbon neutrality" through the use of wind power and solar photovoltaics.

3.0 ENERGY DEMAND AND CARBON CALCULATIONS

Energy Load Densities

Predicted electricity demand figures used in this study are based on Aecom's GKI Power and Telecomunications Infrastructure Report– Rev 5.

Calculations assume that Gas is only used for cooking purposes at the 5 proposed kitchens (1 hotel kitchen and 4 retail restaurants). Predicted gas consumption figures (not included in Aecom's calculations) are suggested by Arup based on experience and are representative of typical commercial kitchen gas consumption.

It is recommended that a project specific gas demand calculation is undertaken to present a scenario compatible with the development's intended operation.

Diesel consumption calculations uses Aecom's recommendation based on preventive maintenance usage. This is 689L of diesel used 1 hour per month for test and maintenance.

Occupancy Diversity Factors

These are based on assumptions presented by Aecom's report.

Other Assumptions

For using a single electricity demand figure proposed by Aecom for the basis of PV calculations, this report follows all assumptions adopted by Aecom in regards of domestic hot water systems, air conditioning systems, lighting, and breakdown of spaces.

Carbon Calculations

Between electricity and gas, it is estimated that the Resort will operate with an energy demand at around **13,550,000 kWh/year** (For detailed calculations on electricity demand please refere to Aecom's GKI Power and Telecomunications Infrastructure Report– Rev 5)

To transform this value into the electricity needed to be generated by the PV system to offset the emissions, we used the GHG Coefficient for Queensland from the NABERS Energy tool. Gas and electricity have different intensity factors, 0.2 and 1.02, respectively. This means that each kWh of electricity will produce 1.02 $kgCO_2$, whilst every kWh of gas will produce only 0.2 $kgCO_2$.

Diesel consumption by the 1 generator for preventive maintenance was calculated to be 8,376 L per year by Aecom. The amount of carbon dioxide resultant from that was calculated based on 1 gallon of diesel = 2.78 $kgCO_2$ (data from the United States Environmental Protection Agency website), corresponding to a conversion factor of approximately 0.73 $kgCO_2$ per litre of diesel.

The aim is to offset 105% of all carbon generated by the use of gas. Electricity and diesel.

Achieving a Carbon Positive Status

To achieve a carbon positive status, the resort must generate enough electricity to offset more than 100% of the total carbon emissions resultant from its operation.

We have taken the carbon emissions of the projected electricity, gas and diesel use into account by converting the annual energy consumption figures into kilograms of CO_2 per m^2 per year. We then calculated the number of PV panels that would be required to offset these emissions based on the electrical output of the panels proposed by Aecom.

To be carbon positive, the Resort would have to generate electricity in excess of **11,851,681kWh/ year** via its photovoltaic system to be able to offset and surpass the total amount of annual emissions.

It is noticeable that the energy generated by the PV system is less than the energy demand of the Resort. This is explained because as electricity is more carbon intense than gas, to compensate for the carbon emissions resultant from the Resort's operation (which also includes gas), the PV system can produce less energy than the development consumes. Whilst the PV system will generate only electricity, the Resort will consume electricity and gas. Carbon generated by diesel consumption is also accounted for, however it was found to be marginal when compared to gas and electricity.

A diagram found in Appendix A demonstrates the methodology for these calculations.

5.0 PHOTOVOLTAIC SYSTEM SIZING

Total Resort Energy Load

We have sized the solar photovoltaic system for the Great Keppel Island Resort based on the site-wide energy demand load:

► **Total Resort (gas + electricity) : 13,550,000 kWh/year**

► **Total Resort (diesel) : 8,376 L/year**

Achieving a Carbon Positive Status

To achieve "carbon positive" status, the Resort has proposed to install a photovoltaic system of the following size:

► **Proposed PV System Size: 5.9 MW**

► **Proposed Number of Panels: 24,320**

► **Total Carbon Positive Resort-wide Buffer: 5%**

► **Total Carbon Emissions Offset: 12,693,150 kgCO2/ year**

► **Annual Generating Potential: 12,444 MWh/year**

Photovoltaic System Details

This analysis is based on Photovoltaic panels proposed by Aecom , the SunPower E20/327 Solar Panel, which provides an efficiency of 20.1%—that is, it converts available sunlight energy to usable electricity by that order. With photovoltaic panels, the majority of energy is lost as waste heat. These panels are approximately 1.63m² in area.

PV Installation within the Resort

The proposed system will be integrated into the Resort with most of the PV panels installed on the villas, with the remaining panels installed on the roof of the apartments and hotel. It is estimated that the eco-resort villas would provide 89% (or 33,602 m²) of the total area required for the installation of PVs.

► **Area of PVs per villa unit: 45 m²**

► **Number of panels per Villa unit: 27**

FIGURE 5.1 SunPower E20/ 327 photovoltaic panel (Source:SunPower)

ELECTRICAL DATA Measured at Standard Test Conditions (STC): Irradiance 1000W/m², AM 1.5, and cell temperature 25° C		
Nominal Power (+5/-0%)	P_{nom}	327 W
Panel Efficiency	η	20.1 %

ELECTRICAL DATA Measured at Nominal Operating Cell Temperature (NOCT): Irradiance 800W/m², 20° C, wind 1 m/s		
Nominal Power	P_{nom}	243 W

FIGURE 5.2 SunPower E20/ 327 photovoltaic panel efficiencies.

PV capacity (from manufacturer)	Sun Power E20/ 327W		
0.243	kW PV plate equals	1.63	sqm of PV

FIGURE 5.3 The insolation, or available sunlight energy on a given site, is provided at the left and is based on values provided by Aecom for Rockhampton. The panel efficiency was given by SunPower as noted in Figure 5.2, to which we have applied a de-rating factor (76%) to achieve the final energy generation capacity per area of PV per year. We used this value in the calculation shown in Figure 5.5 below.

SUNPOWER	315' Solar Panel			
Insolation (kWh/m2/day)	No of days/ year	Panel Efficiency	Derate Factor	kWh/m2 of PV/ year
5.63	365	20.10%	76%	314

PV capacity (from manufacturer)	Sun Power E20/ 327W		
0.243	kW PV plate equals	1.63	sqm of PV

Energy Generated (kWh/m2 of PV /yr)			314	
Resort's estimated Energy demand			Resultant Carbon Emissions (kgCO2/ year)	carbon factor
11,430,000.00	(kWh/ year of elec)		11,658,600.00	1.02
2,120,000.00	(kWh/ year of gas)		424,000.00	0.2
8,376.00	(L/ year ofdiesel)		6,114.48	0.7
Carbon to offset (kgCO2/ yr)			12,088,714.48	
Electricity (kWh/yr) to be generated by PVs to offset carbon		carbon factor 1.02	11,851,681	
Area of PV required to offset electricity (m2)			37,755	
Number of panels			23,162.3	panels
Number of panels with buffer of:	5%		24,320.4	panels
system size (MW)		5.9 MW		

FIGURE 5.4 Photovoltaic system sizing calculation.

6.0 ELECTRICITY GRID CONNECTIONS

Since solar power is dependent on available sunlight to generate electricity, photovoltaic installations cannot provide electricity during night time hours without the use of battery storage. While battery storage can be appropriate for totally off-grid installations in remote areas or for small-scale residential, they often do not make financial or environmental sense for large-scale developments due to the significant size of batteries required to meet potential electrical demands. This is certainly the case with the Great Keppel Island Resort, which would be expected to have significant night time electrical demands for cooling and lighting.

In lieu of a battery storage facility, the Resort will include a connection to the mainland electrical grid. During sunlight hours, the Resort's expansive solar photovoltaic system will feed excess electricity into the national electrical grid, in effect providing carbon-free electricity to Australian customers. This "feed-in" operation is made possible through synchronizing the Resort's electrical infrastructure to the same voltage frequency as that of the national electrical grid connection. Once the sun sets, the Resort will then draw power in reverse to supply its electrical loads at night.

The "carbon positive" aspect of the design is based on the goal of ensuring that the quantity of "feed-in" electricity provided to the grid is greater than the electricity drawn from the grid at night.

In addition, the Resort seeks to provide solar photovoltaic-generated electricity to other residents on Great Keppel Island to achieve a "carbon positive" status.

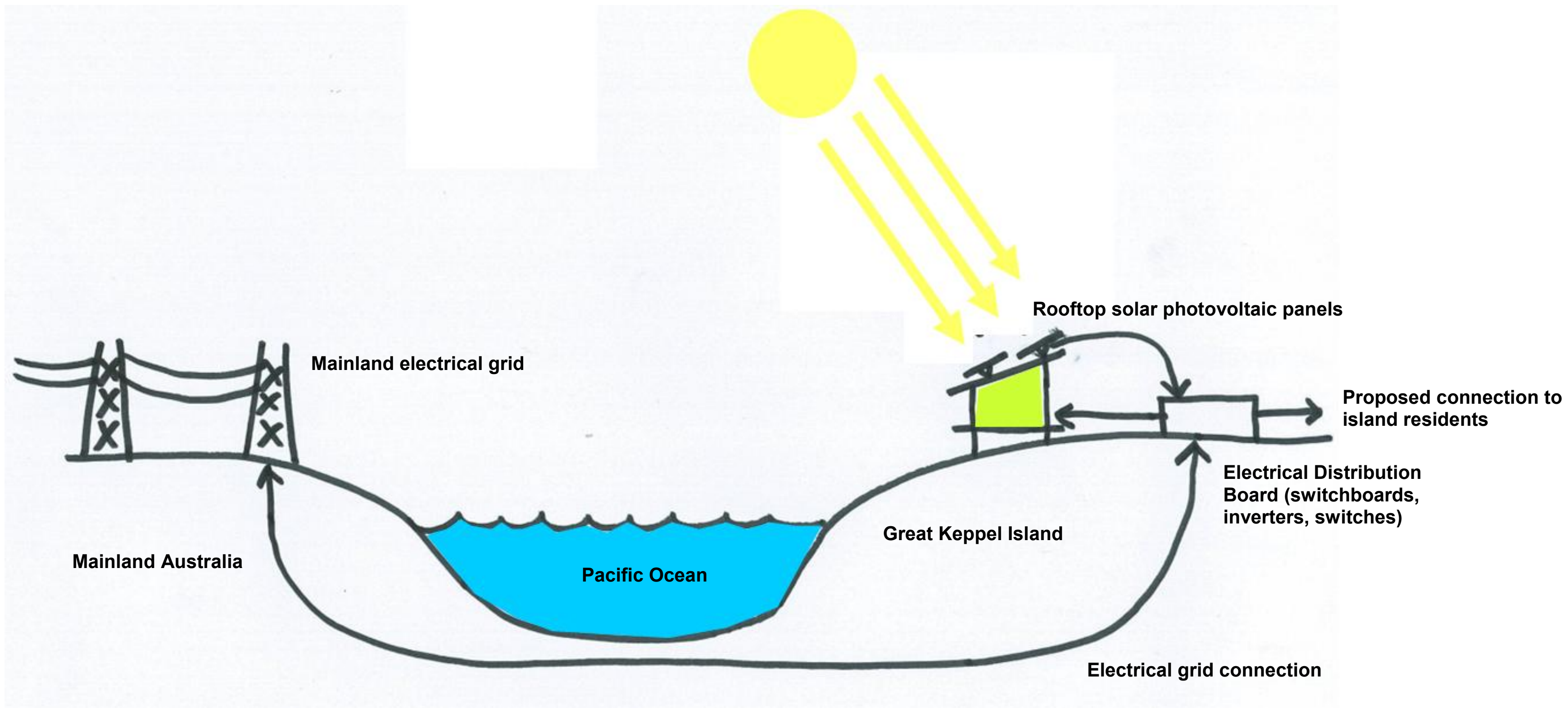


FIGURE 6.1 Electrical grid connection for the proposed solar photovoltaic installation for the Great Keppel Island Resort.

7.0 CONCLUSIONS

Our analysis of the proposed photovoltaic system for the Great Keppel Island Resort indicates the project has high likelihood of exceeding all existing environmental benchmarks for energy performance and could operate at 5% above carbon neutral, or carbon positive, if the following PV system were installed:

►**Proposed PV System Size: 5.9 MW**

►**Proposed Number of Panels: 24,320**

►**Total Carbon Postive Resort-wide Buffer: 5%**

►**Total Carbon Emissions Offset: 12,693,150 kgCO2/ year**

►**Annual Generating Potential: 12,444MWh/year**

We must note there are significant assumptions built into this analysis which should be adjusted to fit actual program, areas and operation profiles and environmental targets of the Resort in future design stages.

It is estimated that the eco-resort villas would provide 89% (or 33,602 m²) of the total area required for the installation of PVs. The remaining will be installed on the rooftops of the eco-resort apartments and hotel.

GKI and the Carbon Tax Scheme

On Sunday, July 10, 2011 the Australian Government announced that from July 1, 2012 carbon polluters in Australia would be taxed at $23/tonne of carbon emission for the first year after being introduced. The new policy is expected by the Government to cut approximately 159 million tonnes of carbon pollution by 2020, reducing Australia's emissions by 5 percent. The GKI contribution to carbon emission reduction is expected to exceed this target by more than 100%.

Supporting the development and deployment of low carbon technology, is considered an efficient and effective way of reducing emissions to meet this target. It also builds a strong business case for the investment in renewable technology when it is estimated that electricity cost may rise **30% in the next three years and could rise further (**Source: *Australian Financial Review 19 May 2011).*

By understanding the Resort's energy consumption through a carbon-positive PV system, the design team can effectively consider the current price of each kg of carbon and measure all design initiatives in terms of their carbon payback. This will likely encourage a high-level of sustainable design elements to be incorporated site-wide, without resorting to conventions of commercially available green building rating tools.

APPENDIX A
METHODOLOGY FOR CALCULATING PV SYSTEM SIZE TO OFFSET EMISSIONS

Total Energy Demand
13,550,000 (kWh/year)

						Carbon Emissions
	Electricity*	11,430,000.00	x	1.02	=	11,658,600.00 kgCO2/ year
						+
	Gas	2,120,000.00	x	0.2	=	424,000.00 kgCO2/ year
						+
Generators Preventive Maintanance	Diesel (L/year)	8376	x	0.73	=	6,114.48 kgCO2/ year

TOTAL EMISSIONS PER YEAR TO OFFSET (to achieve carbon neutrality) **12,088,714** kgCO2/ year

If we provide a PV system that generates: **11,851,681** (kWh/year) x 1.02 = **12,088,714** kgCO2/ year (We would be saving)

Demand (elec.+gas)
13,550,000.00 kWh/year

Generator diesel
8,376.00 L/year

12,088,714 kgCO2/ year

Carbon neutral Status

11,851,680.86
PV generation (elec.)
+ 5%

Carbon Positive Status

* Predicted electricity demand figures are based on Aecom's GKI Power and Telecomunications Infrastructure Report– Rev 5