COOLTEK

RENEWABLE ENERGY WITH ENERGY EFFICIENCY

1 ORIGINALITY

1.1 Design

Moving from a temperate climate in England to a tropical climate in Malaysia, the need to use air conditioning to provide a comfortable environment was paramount. By the use of the most recent air-conditioning technology and proven methods of insulation, shading, high thermal performance windows and internal air-tightness together with constantly cooled, fresh air entering only from below ground, the electricity needed to run air conditioning was minimised. The subsequent installation of grid connected photovoltaic electricity generating system provides most of the electricity needs.

1.2 Application

Initial energy efficient design features of the building are shown here, which are the essential steps in maximising the use of the renewable energy generated.

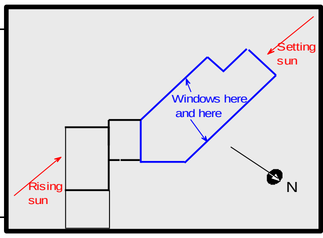
Protection provided from surrounding trees

Helps to reduce heat from the sun warming up the building.

Protection by the white steel roof, lined with high quality aluminium reflective foil

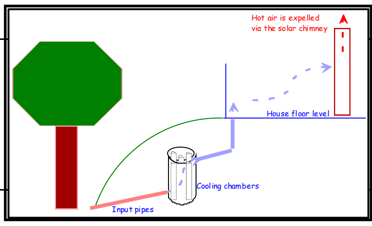
The white roof reflects much of the sun's heat, the wide roof overhangs shade the windows and walls and the steel roof structure quickly allows any heat to dissipate after the sun sets.

Orientation with windows facing north and south only



Avoids direct sun from entering the house through the windows.

Ventilation only from below the ground

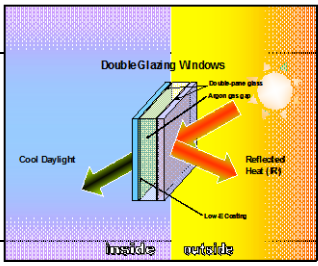


Brings cooled and filtered fresh air into the house, before venting through a chimney.

Insulated walls of 250mm thick lightweight blocks

Resisting much of the heat and sound from outside passing into the rooms, as well as keeping much of the air conditioned coolness from being lost.

Double glazed windows with low-E coating and argon filled gap



Ensuring that heat cannot pass easily though to the inside of the house and also resists sound, stops condensation and aids security.

Insulated ceiling with 50mm dense rockwool blanket

Resists heat from radiating down into the rooms.

Insulated flooring with under layer of 50mm thick polyurethane

Resisting the air conditioned coolness being lost into the concrete floor slab.

Energy efficient inverter air conditioning unit

A multi split unit, with just one outdoor rotary compressor and four internal units, chosen for its high energy efficiency and charged with ozone friendly R410A hydro fluorocarbon refrigerant gas.

Energy efficient equipment and appliances

For example microwave and induction cooking appliances; positioning of fridge/freezer

Energy efficient lighting

All lighting is fluorescent.

1.3 Approach for the introduction of renewable energy

Launched in 2006, the Malaysian Building Integrated Photovoltaic programme, SURIA 1000 aims to introduce photovoltaic generation of electricity to residential and commercial buildings to a nation blest by endless sunshine.

With the announcement of SURIA 1000 an immediate application was made by the owners of the energy efficient house, and approval granted in March 2007 with the installation completed in October 2007. The orientation of the house, with the longest sides of the roof facing both north and south, allows maximum solar collection throughout the year.

2 ENVIRONMENTAL AND SOCIAL CONSIDERATION

2.1 Emissions avoided (CO2 etc)

Although, the installation has been fully operational since 31 October 2007, the project reporting period is for the calendar year 2008. A total of **5,793 kWh** was generated during this time, with a direct saving of 3.5[1] metric tonnes of carbon dioxide, which equates to 3.73 metric tonnes per year when the avoidance of standard grid distribution losses are included[2].

Note 1: Most Malaysian electricity is generated using natural gas, so a figure of 600grammes of CO_2 per kilowatt hour has been used.
Note 2: A figure of 7.3% for grid distribution losses has been used, which is given as the percentage distribution loss in the UK.

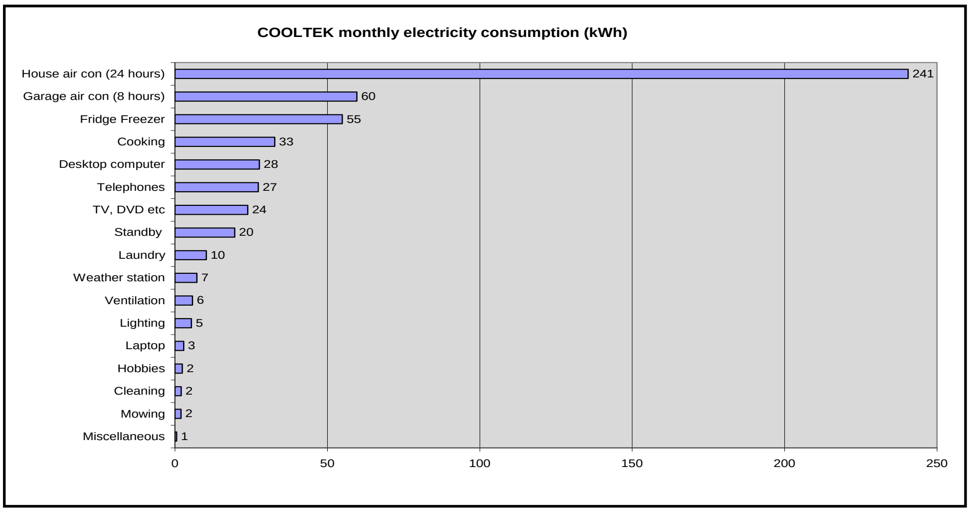
2.2 Community and people participation

Since its completion in October 2005,COOLTEK as an example of energy efficiency, has been widely reported in the Malaysian press. The additional of a renewable energy generating system has only increased its efficiency and its profile.

Many hundreds of Malaysians have visited the building for many different reasons. Visitors include government officers, architects, builders, teachers, students or homeowners. It has shown to them that homes in the tropics can be more comfortable without increasing the use of fossil fuels or increasing the pollution of the atmosphere.

2.3 Benefit to user

The main benefit to the owners and users of COOLTEK is providing a clean, comfortable and affordable home. As can be seen from the graph[3] below, most electricity is consumed by the air conditioning which runs twenty-four hours during occupation. Fortunately, most solar electricity is generated during the hottest time of the day exactly when required for air conditioning.



Note 3: an energy audit was conducted on the building from 2 to 31 July 2008.

Based on the ground floor area of 232 sq m and a yearly occupation of 350 days with the air conditioning running continuously for twenty hours, the electricity consumed in 2008 was a total of 8,636 kWh, giving an energy index of just **37.2 kWh/m^2/yr (due to energy efficiency),** and **an amazing 12.3 kWh/m^2/yr (with renewable energy included**) with the net consumption of 2,843kWh, see Appendix I.

2.4 Benefit to Community

Spare green energy that is generated by the photovoltaic installation but not consumed by the building is made available to other local consumers, thereby reducing their distribution losses as well.

The photovoltaic installation was one of the first to be installed and commissioned under the Malaysian BIPV SURIA 1000 programme and as such has promoted this programme to other private houseowners. Many initial problems, including some financial aspects, with the grid connectivity have been resolved by the owners of COOLTEK for the benefit of all future participants of SURIA 1000.

More broadly, the energy efficient and renewable energy features have been included into the national curriculum for primary schools, as an example to future generations.

2.5 Benefit to Country / Nation

Following visits from many different governmental departments, this example of energy efficiency with renewable energy has allowed many lessons to be learnt which have allowed policies to be discussed and formulated. Reductions in the Malaysian taxation of photovoltaic equipment and energy efficient building materials has been introduced in 2009.

2.6 Other features

The installation of photovoltaic panels on the roof of an energy efficient designed and built house has shown that the percentage saving is considerably higher than for a standard Malaysian house (see section 3.3 below). As energy efficiency can be achieved at a much lower cost than expensive photovoltaic panels and associated equipment, clearly, renewable energy should only be encouraged or considered once energy efficiency has been thoroughly utilised within the building structure.

3 TECHNICAL, ECONOMIC AND MARKET CONSIDERATIONS

3.1 Installed capacity

The project installation consists of 40 Mitsubishi 120watt peak polycrystalline panels mounted on the roof of the house, making of total capacity of 4.8 kilowatt peak. Each panel is approximately one metre square and has a rated efficiency of 11.9%.

The roof area shaded by the panels amounts to just over 40 square metres, and is 10% of the total roof area.

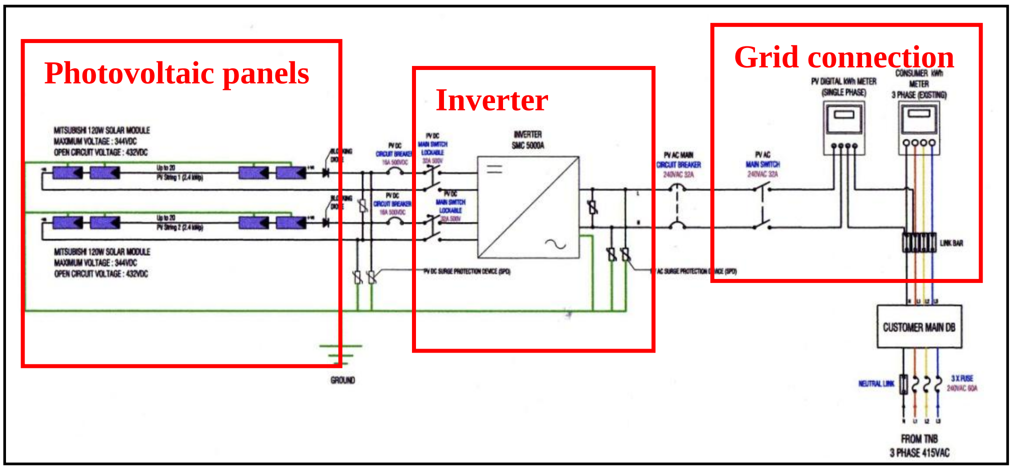
3.2 Technical design

The main part of the house is orientated with its longest sides facing North and South. Thus, the area of the roof where the photovoltaic panels are mounted, allow 50% of the panels to face due North and 50% to face due South. This takes advantage of the sun's tracking at this location, just two degrees north of the equator. The installation therefore benefits from greater solar collection efficiency throughout the year.

The roof has a very shallow 15% slope, which as the sun at this latitude is almost directly overhead during much of the day, allows greater collection of the solar energy.

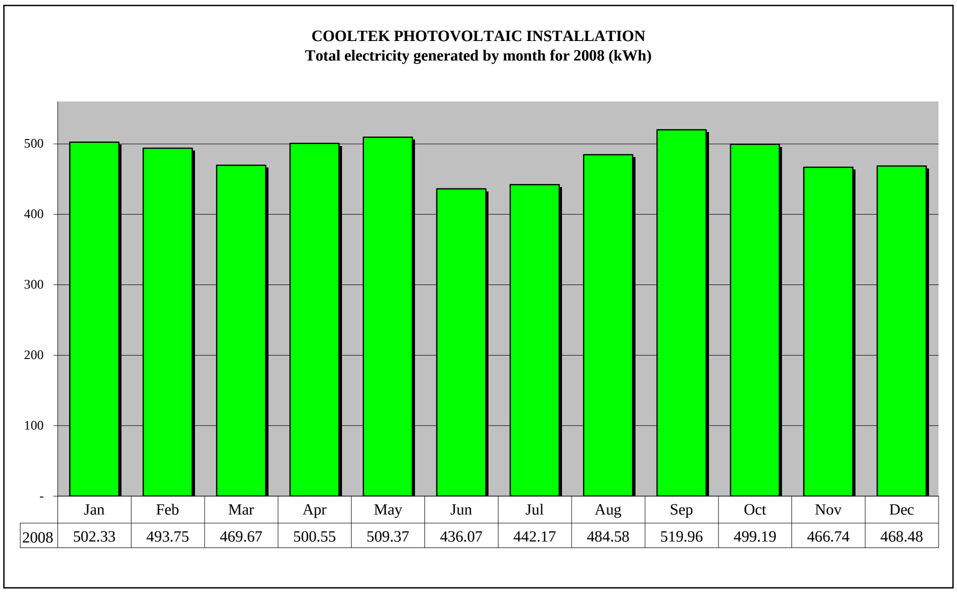
The SMA 5000A inverter used has a 96.1% efficiency rating. The two sets of twenty panels have been wired separately, but in a ring configuration to minimise cable losses. Surge protectors on both the AC and DC sides of the inverter were fitted to reduce the risk of damage from lightning strikes.

An additional feed-in meter has been installed to enable electricity generated by the installation to be recorded, while total electricity consumed by the building is still recorded by a standard meter. A wireless data logger linked to the inverter allows easy remote data collection of electricity solar generated on an hourly and daily basis.



3.3 Technical performance

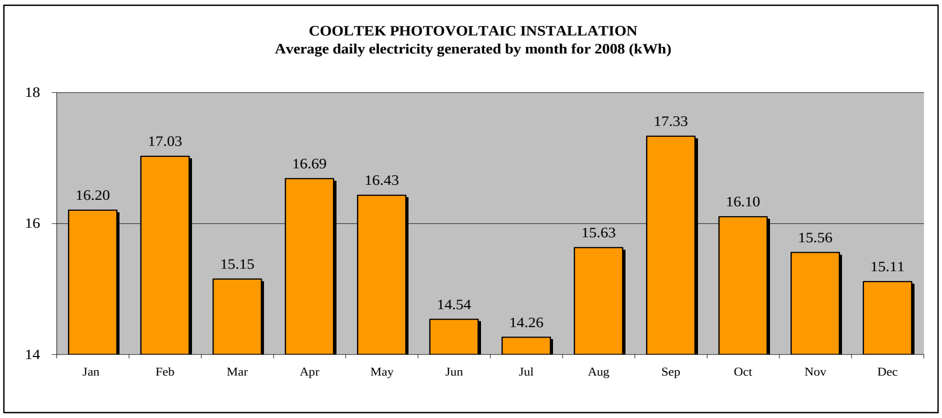
Since the completion of the installation in October 2007, daily recordings have been taken of generated electricity and total consumed electricity. The graph below shows the electricity that has been generated each month by the project installation for the reporting period during the year 2008.

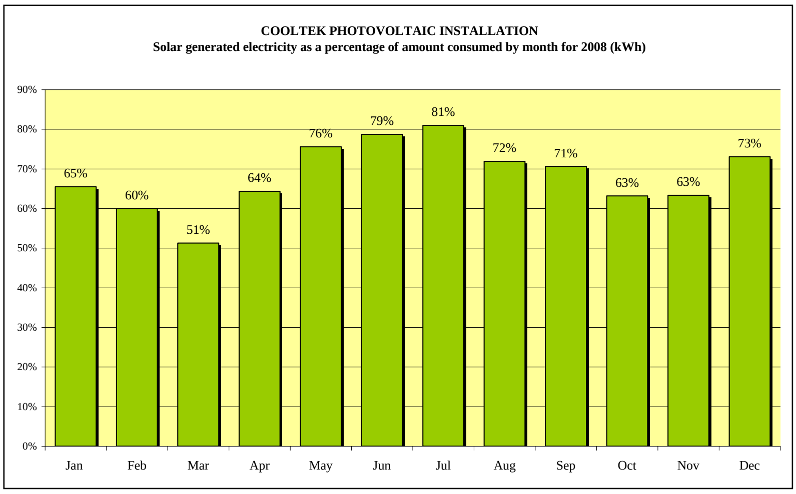


For comparison purposes between other photovoltaic installations, a rate of kilowatt hours per installed kilowatt peak is often used. The following table shows this result; the average monthly rate for this installation is 100.57 kWh per kWp.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
104.65	102.86	97.85	104.28	106.12	90.85	92.12	100.95	108.33	104.00	97.24	97.60

For a clearer indication of the performance of the installation, a record of the average daily electricity for each month is computed as shown below. At the time of year when the sun is more directly overhead it provides greater generation, apart from March 2008. A weather station is installed at the site, recording temperature, rainfall, barometric pressure and humidity. March was a particularly cloudy month and would explain the lower figure shown on the graph. On average, **15.84kWh** were produced on each day in 2008.





The graph above shows for each month, the amount of electricity generated as a percentage of the total electricity consumed. Overall, for the reporting year 2008, of the total 8,636 kWh of electricity consumed, 5,793 kWh was generated from the photovoltaic installation and this high proportion of **67% is** only achievable by the employing extensive energy efficient features within the house.

3.4 Investment cost

The renewable energy part of this project was financed under the recently introduced Malaysia BIPV SURIA 1000 programme. Starting in December 2006, Bidding Calls are held every six months, when hopeful participants can apply for funding.

The total cost of this project installation, including all parts, installation labour and grid connection was RM125,000 (US$34,237[4]). The cost per kilowatt peak of this installation was RM26,042 (US$7,132), less than the average for the first Bidding Call under SURIA 1000 which was RM28,020 (US$7,765). The average cost per kWp of later Bidding Calls under SURIA 1000 have varied, but the last Call had an average price of RM26,044 (US$7,133), very similar to this particular installation.

Note 4: Exchange rate used US$1 = RM3.651.

3.5 Funder (government / non-government)

RM55,000 (US$15,064) or 44% of the total cost of the project was contributed by the owners of COOLTEK with the remaining 56% or RM70,000 (US$19,173) provided by the SURIA 1000 programme. This funding was made jointly by the Ministry of Energy, Water & Communications (Malaysia), Suruhanjaya Tenaga (Malaysia), United Nations Development Programme and the Global Environment Facility (UN).

3.6 Financial scheme / livelihood projects

Current credit for green solar electricity generated is given by the appropriate Malaysian utility company, Tenaga Nasional Berhad. Credits are based on a **net kilowatt-hour** calculation, where each month the number of kilowatt-hours generated are subtracted from the total kilowatt-hours consumed during the month, before the applicable domestic tariff is applied. **No premium feed-in tariff is paid in Malaysia.**

The normal domestic tariff[5] used to calculate charges for net kilowatts-hours of electricity consumed is shown below:

If net units consumed is less than 401 kWh,		
– First 200 units at	RM0.218 per kWh	(US$0.059) per kWh
– Remaining units at	RM0.345 per kWh	(US$0.094) per kWh
If net units consumed is greater than 400 kWh,		
– First 500 units at	RM0.300 per kWh	(US$0.082) per kWh
– Next 100 units at	RM0.390 per kWh	(US$0.107) per kWh
– Next 100 units at	RM0.400 per kWh	(US$0.110) per kWh
– Next 100 units at	RM0.410 per kWh	(US$0.112) per kWh
– Next 100 units at	RM0.430 per kWh	(US$0.118) per kWh
– All remaining units at	RM0.460 per kWh	(US$0.126) per kWh

Note 5: effective from 1 July 2008. Before this date the domestic tariff charge was first 200 units at RM0.218, per kWh, next 800 units at RM0.289 per kWh and the remainder at RM0.312 per kWh.

With these rates, the average credit over the reporting period has been RM 0.312 per kWh (US$0.085) or a total of RM1,807 (US$494.93) for the year. With this rate of return, the payback period on just the RM55,000 (US$15,064), subsidised cost paid by the owners, is almost thirty- one years and for the full cost of the installation of RM125,000 (US$34,237), the payback period would be almost seventy years.

3.7 Market size in five years

As can be seen from section above, at the moment this project is not financially healthy and does little to encourage participation by the general population. Development of more efficient equipment at lower unit cost, better funding options and the realisation of its need, are the only hopes for the future widespread use of photovoltaic technology for generating electricity in sunny Malaysia. With a premium feed-in tariff, of say RM2 per kWh for solar electricity generated, the payback periods could be reduced to a more acceptable five years for the RM55,000 paid by the owners and less than eleven years for the total true cost of the installation.

3.8 Local manufacturing content of system

Many of the major expensive parts of this installation, such as panels and the inverter, were imported from Japan and Germany, respectively, and on which import tax was paid. In the Malaysian 2009 Budget changes, these products have now been exempted from import tax. All labour was provided locally.

3.9 Energy avoided

The production of **5,793kWh** of green solar electricity in the year 2008, has saved the consumption of almost **20 million BTU** of the limited national resource of natural gas.

4 OPERATION AND MAINTENANCE SCHEME

4.1 Operational hours (per day/per month/per year)

With the location of this photovoltaic installation being two degrees north of the equator, there is little seasonal difference in its operation. During the 366 days of 2008 (leap year), the installation was operational for a total of 4,168 hours and the table below shows the hours of operation for each month.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
349	325	351	344	362	342	359	356	343	351	337	349

The average daily length of operation was 11.73 hours, with a maximum of 12 hours 10 minutes on 27th May. Overall, 324 days had an operational time of over eleven hours, which is 88.5% of the time.

On the 28th February, the installation was only operational for 4 hours 55 minutes, as Tenaga Nasional Berhad replaced the local mains supply by a generator, whilst maintenance was being carried out nearby. The generator frequency of 52Hz was incompatible with the inverter therefore the installation automatically shut down. Otherwise, the lowest operational daily time was 9 hours 50 minutes on 7th December due to heavy rain falling from 1pm onwards.

4.2 Maintenance scheme (in-house, contracted out service)

As the photovoltaic installation is a passive system with no moving parts, little maintenance is required. The sole important requirement to ensure maximum efficiency is cleaning of the roof top mounted photovoltaic panels; this was carried out by the owners three times during 2008 on 3rd April, 9th July and 30th December. As the building is single storey and the roof has a slope of just 15^o, this is a comparatively safe, easy and quick task.

4.3 Other maintenance measures (training, after sales service)

Although not occurring in the reporting year, on 17th February 2009 the installation was subjected to a lightning surge during a violent electrical storm. The resulting destruction of the surge protection equipment, although expensive to replace, protected the panels and inverter from damage. The installation was not operating for five and a half days, while waiting for replacement parts to be installed. These replacements are now held on site, so that should such an event occur in the future, little generating time would be lost.

4.4 Local service content

All maintenance is carried out by local personnel, either the owners themselves or the original installer.

5 REPLICABIILTY

5.1 Replicability project

Under the Malaysian BIPV SURIA 1000 programme, still currently being promoted by the Malaysian Ministry of Energy, Green Technology and Water, more Building Integrated Photovoltaic installations will be completed. The project will run until April 2010 when it is hoped 1000 kWp of solar energy generation will be installed.

The Energy Efficiency aspects of the reported project could be easily duplicated with little additional cost.

- ✓ Reducing energy consumption by the use of low energy light bulbs and appliances available to all households.
- ✓ Energy efficient air conditioning equipment now widely available.
- ✓ Orientation to avoid direct sunlight passing through windows can be designed into all new buildings.
- ✓ Using shading from trees or extended roofing can reduce the heat in buildings.
- ✓ Introduction of insulation for walls, ceiling and floors will reduce air conditioning energy consumption.
- ✓ Energy efficient building materials and methods can replace present ones.
- ✓ New standards for sealing homes with underground 'pre-cooled' ventilation could be encouraged.
- ✓ Thermally efficient double glazed windows can be used for all air conditioned areas.

Some of the above methods may need government incentives and legislation to promote them to a level which may then guarantee Malaysia as a leading environmentally conscious nation within the ASEAN countries.

5.2 Life of project

The reported project, consisting of an energy efficient home with a photovoltaic installation, will last, in its present form, as long as the photovoltaic installation functions well and efficiently.

The Mitsubishi photovoltaic panels are guaranteed for twenty years while the SMA 5000A inverter has a five year guarantee. If the inverter was to fail during the twenty year life span of the panels, it could be replaced but this would affect the financial viability of the project.

The energy efficient home should be standing for many years after the useful life of the present photovoltaic installation, but newer and more efficient equipment could replace the existing installation or be added as only 10% of the roof is now covered by the panels.

5.3 Cost effectiveness

As some of the energy efficient aspects of the building, such as orientation and shading from trees, have no additional cost, their application to new buildings is desirable. The replacement of old, worn-out or broken equipment with energy efficient appliances, lighting or air conditioning will require little extra cost but could bring immediate savings.

The substitution of energy efficient building materials may carry a small additional cost, but their payback is rapid as the cost of running air conditioning is high.

The use of insulation and double glazing is an additional cost in buildings but the savings made will quickly pay back this extra investment.

Altogether, the energy efficient house COOLTEK, ignoring the electricity generated from the photovoltaic installation, uses around 19% of the electricity of a conventionally built Malaysian house (see Appendix I). Based on the reported period and the electricity tariffs current at the time, this translates to a return of RM12,268 (US$3,360) per annum, or almost RM43,000 (US$11,760) since the building was completed in October 2005.

As discussed under section 3.5 the photovoltaic installation is not cost effective and has been undertaken by the owners as a pioneering project to help pave the way for the wider introduction and development of solar electricity generation in Malaysia.

5.4 Sustainability of project

With the location of the building in the tropics and constant resource of solar energy, this project is fully sustainable in its present form. The option to increase the amount of electricity generated from photovoltaic equipment exists and once the amount of electricity generated equals the amount consumed, then the building could be classified as carbon neutral and totally sustainable.

APPENDIX I

COMPARITIVE ENERGY INDEX FOR THE YEAR 2008

For comparison purposes a standard built Malaysian house was used, which had no insulation or other energy efficiency features. It was occupied by a European family, who used the air conditioning for twenty-hours each day.

The first comparison is with the total energy consumed by COOLTEK, which takes into account only its Energy Efficiency features. The Energy Index shows that it uses around **81%** less electricity than the comparison house.

In the second comparison, which includes the renewable solar electricity generated on site, the Energy Index shows that COOLTEK uses just over **6%** that of a standard house, a total saving of non-renewable energy of **94%**.

	Comparative house	1. COOLTEK (gross kWh)	2. COOLTEK (net kWh)
Daily consumption (kWh)	280	25	8
No of days	350	350	350
Annual consumption (kWh)	97,920	8,636	2,843
Ground Floor Area m^2	500	232	232
Energy index ($kWh/m^2/yr$)	195.8	37.2	12.3
Comparison result		19%	6.3%

References

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www.ien.dk/cooltek

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UK electricity distribution losses
http://en.wikipedia.org/wiki/Electric_power_transmission