THE PTM ZEO BUILDING

Poul E. Kristensen
IEN Consultants, Denmark and Malaysia
e-mail : poulekristensen@hotmail.com

Dato' Ruslan Khalid[2], C. K. Tang[3],Ahmad Zairin Ismail[4]
[2]Ruslan Khalid Associates
430 Jalan Tun Razak 50400 Kuala Lumpur, Malaysia
[3]Virtual Environment, Kuala Lumpur, Malaysia
e-mail : ckmail@pd.jaring.my

[4]Pusat Tenaga Malaysia, Bangunan SAPURA@MINES
The Mines Resort City, 43300 Seri Kembangan Malaysia

Abstract

The new headquarter for Pusat Tenaga Malaysia is designed to be a Zero Emission Office Building, or a ZEO Building. A full range of passive and active energy efficiency measures are implemented such that the building will need no more electricity than what can be produced via its own Building Integrated photo-voltaic (PV) system. The overall objective of the project is to achieve zero energy consumption at lowest possible initial investments. Advanced computer design tools have been used throughout the design process.

The paper highlights the implementation of the integrated design concepts in ZEO Building where active and passive energy systems are interwoven into the building itself, and where several building elements serve as energy systems. This integration helps to bring the extra costs of the building down, and hence the economic feasibility of the ZEO building concept is improved. A detailed description of the passive design features, energy efficiency measures and photo voltaic system is presented.

Keywords : Energy Efficiency. Photo-voltaic (PV), Zero Energy, Floor Slab Cooling, Radiant roof.

1. Introduction

The New PTM Zero Energy Office Building (ZEO Building) is presently being designed. Construction of the main building will start in June 2005, and completion is expected in August 2006. This 4000 m2 building in Banghi will be the new building for PTM, and in line with the scope for PTM, the new building will in itself be a research and demonstration building for new energy technologies in buildings in Malaysia. The new PTM building aims to demonstrate that an office building need not consume any electricity from fossil fuels. All electricity needed by the building will be produced by the buildings own Photo-Voltaic System (PV System).

The development of the PTM ZEO building is a logical continuation of the work behind the MEWC Low Energy Office Building(LEO Building) in Putrajaya. The LEO Building is designed to have an Energy Index of approximately 100 kWh/m^{2}year. The LEO building is aimed at demonstrating state of the art energy technologies that can be applied in new non-domestic buildings now, technologies that are both technically and economically feasible.

The computer modeling of the LEO building indicated that it was in fact technically possible to reduce the Energy Index of an office building to approximately 50 kWh/m^{2}year. The measures that would bring down the EI from 100 to 50 are not economically feasible in today's context, with relatively low electricity rates and with technologies that are still relatively expensive due to little market share and small volume productions. However, all these technologies, such as super energy efficient double glazing and super low energy office equipment are in the future likely to become economically feasible.

In Malaysia, Solar PV elements will produce approximately 150 kWh per m^2 roof per year. Therefore, if a three storey building with an Energy Index of 50 kWh/m^2year has a roof covered with Solar PV elements, the PV system will be able to produce all the electricity needed by the building. This is the simple logic of how to get to a Zero Energy Office Building, or ZEO Building.

The building will be powered only by the sun falling onto the roof and by the daylight entering the windows.

The climate in Malaysia is very appropriate for exploitation of renewable energies for climatisation and running of buildings. The largest renewable energy sources in Malaysia are daylight and solar energy. The PTM building shall utilize these renewable energy sources to the maximum.

The PTM ZEO Building will be the first building of its kind in SE Asia, and it will be a landmark building in the strive towards developing fully sustainable building that does not require fossil fuels at all. The PTM building will be a test bed for innovative energy technologies, for the benefit of Malaysian building industry and academia.

2. How Zero Energy Consumption is Achieved

In the Design Brief of the ZEO building, the overall energy design objective for the building is formulated as "achieving zero energy consumption at least construction costs". Since PV electricity is still quite expensive, this means that investments in energy saving technologies can be stretched much further than under normal economical conditions. Energy saving technologies that are relatively expensive can be applied. At present, where the building is under development, it seems that an Energy Index of approximately 40 kWh/m^2year and a resulting PV area of 85 kW_{peak} is close to the optimum. The area of this PV system is approximately 700 m^2, depending on the PV technology applied.

3. The key energy saving strategies

Reducing the energy consumption to approximately 40 kWh/m^2year is achieved by applying a host of energy saving strategies in building design, design of the mechanical and electric system and in choice of energy efficient office equipment. However, the following areas are the main contributors to the low energy consumption :

- An energy efficient building envelope with super energy efficient glazing and well insulated walls and roofs.
- Use of daylight as the only source of lighting during daytime.
- Use of energy efficient office equipment

The diagram above shows the influence of some of the design parameters of the building. To the left is the Energy Index of the present building design, a design that will be improved during the detailed design phase of the coming months. Each of the bars shows the influence of changing one parameter from the present building design.

The actual design has double glazing with low emissive coating and spectrally selective coating. This glazing has a shading coefficient of 25% only, that is only 25% of the solar radiation is transmitted through the glazing. The daylight transmission coefficient is 50%, and this favorable difference in transmission coefficient of sun and daylight creates the spectrally selective glazing, glazing that lets in more daylight than sunlight.

If the glazing would not have been spectrally selective, and had let in 50% radiation, the energy consumption increases by 8%. If the glazing would only be single glazing, the energy consumption would increase by 22% compared to case 1. It is also seen that if there was no exterior shading in the form of an exterior overhang over the windows, then the energy consumption would increase by 3%, similar to if the building had windows to the east and west instead of to the north and south.

It should be noted, that the influence of orientation and shading would have been much more profound if the base case was not a building with super efficient glazing but a building with single glazing. The high performance glazing reduces the penalty of having a non-ideal orientation or having no exterior shading.

It is noted that if the building did not use 100% daylight during daytime, but had to rely on electric lighting (energy efficient), then the energy index would increase by 35% !! If traditional office equipment were used instead of energy efficient office equipment, then the energy index would increase by 30%.

These results of the computer modeling clearly demonstrates the importance of having high performance glazing, using daylight instead of electric lighting and using energy efficient office equipment. Without these key energy saving measures, it would be impossible to reduce the energy consumption of the building to around 41 kWh/m2year, and thus it would be impossible to cover that energy consumption with a PV system integrated in the roof. The necessary PV area would simply be exorbitantly large and very expensive.

4. Overall design

4.1 Building Integrated PV

The building will have a Solar PV system integrated in the roof of the building, a Building Integrated PV System (BIPV System). The BIPV system is designed to cover all the electricity load of the building. The BIPV system of the new PTM ZEO building will become one of the National Demonstration projects for BIPV under the coming program for the promotion of grid connected BIPV in Malaysia. This program is funded by the United Nations Development Program, the Global Environmental Facility, the Government of Malaysia and PV companies in cooperation. This 5 year program starts in 2005 and runs until 2009.

The production of electricity from PV elements is fully sustainable and based on the abundant amount of solar energy available as a renewable energy source. Furthermore, the production of electricity from PV in Malaysia fits very well with the demand curve for electricity, which is shown in the diagram below.
It is seen that the maximum electricity demand occurs between 10.00 in the morning and 05.00 in the afternoon. This is also the period where the performance of the PV system will be largest. The PV system of the PTM building will be inclined 15 degrees to the west. Therefore, production will be slightly larger in the afternoon.

PV power is therefore ideal as a peak shaving measure, input of PV occurs when it is mostly needed. This is the main strategy in the coming UNDP/GEF program on BIPV in Malaysia.

However, in the PTM building, the positive effect of using PV is double. Firstly, the building will need very little electricity during daytime because the necessary load is covered by the buildings own PV system. Secondly, most of the PV power produced by the PV system is fed into the electricity grid during daytime. This is possible because the chiller of the building will operate only during night time. During daytime, chilled water for cooling of the building is sourced from a system of chilled water storage, as explained later. The electricity used by the chillers during nighttime is drawn from the grid, and the amount will be equivalent to the electricity exported to the grid during daytime. This makes the building into a Zero Energy building, which in addition shown how PV can be coupled to the electric grid to provide further advantages to the utilities.

4.2 High Performance Glazing

Electric lighting is a major source of electricity consumption in office buildings. Furthermore, the heat generated from the electric lighting also increases the electricity consumption for cooling.

The diagram shown the energy content of daylight/sunlight for varying wavelength. Visible light occurs between 750 and 400 nm, and visible light accounts for approximately 50% of the energy in daylight. The rest of the radiation, ultraviolet and infrared radiation is invisible, and in energy terms it is “heat only”.
It is preferable to let only the visible light into the building, and not to let the heat only part in. This is possible with a new generation of advanced glazing, so-called Spectrally Selective Glazing.

Spectrally selective glazing is sealed double glazing, where one of the surfaces towards the cavity has a thin invisible coating which reflects the major part of IR and UV light back to the ambient. The PTM building will use this new advanced glazing type, and this glazing is key to use natural daylight and at the same time to avoid unnecessary radiation into the building.

4.3 100% Day Lit During Daytime

Electricity for lighting in an office building may consume 30 – 40 kWh/m2year. In Malaysia, daylight can potentially cover most of that lighting load, as daylight is abundantly available outside the building throughout normal office hours 08.00 – 18.00. However there are a number of constraints that means that this potential for free daylight is not used in buildings today.

Daylight is easily available near the windows, whereas it is more difficult to provide daylight deep in a building. Furthermore, admission of daylight into a room often causes glare and discomfort due to the high radiation level in Malaysia.

However, the energy saving potential using daylight is as shown very large, and the occurrence of advanced spectrally selective glazing that transmits only “cool daylight” has led to that use of daylight has been defined as one of the key energy saving technologies to be implemented in the PTM ZEO building.

In order to develop the right design that will transmit daylight deep into the building, and in order to achieve a design that does not cause glare, a full scale test cell for testing daylight will be constructed. In this 6x6 meter test room various window and shading systems will be installed and tested, in order to arrive at the optimal system to be installed in the ZEO building.

4.4 Concrete Floor Slabs with Thermal Storage and Radiant Cooling

The chiller of the building will run only during nighttime in order not to use electricity for cooling during daytime where the pressure for electricity consumption is largest. Here the concrete floor slabs will play a key role in storing cooling from nighttime to daytime.

The concrete floor slabs will have embedded tubes that allow the floor slabs to be cooled down at night. The cooling will be released from the floor slabs to the rooms above and below during daytime. Due to the thermal capacity of the concrete, there is a delay between active input of cooling and passive release of cooling.

The concrete floor slabs will provide part of the cooling load to the rooms during daytime. This cooling will be supplemented by cooling provided by a conventional air cooling system. The performance of the air cooling system will be regulated so that the sum of cooling released from the floor slabs and from the air system is adequate to cover the cooling load needed for the actual room or zone of the building. In some rooms, such as on the top floor, a hydro radiant ceiling cooling system will be installed, and there will be no concrete floor slab above the top floor.

The floor slabs provide part of the storage needed for cooling, and they transmit part of the cooling load to the rooms. The advantages are that storage is provided without using storage tanks with chilled water. Furthermore, providing cooling using water as heat transfer medium instead of air is much more effective. Pumping water requires only a fraction of the electricity compared to pumping air.

The air handling system is still needed, but it can be reduced in size. The air handling system will provide dehumidification of the air, and it will balance the passive output of cooling from the floor slabs with active cooling input, so that the required room temperature is achieved.

The part of the cooling which is provided by the air handling units during daytime will come from storage tanks using chilled water as storage medium. So storage of cooling from night to day is provided partially by the floor slabs and partially by the water storage tanks.

4.5 Trickling Night Cooling Roof

The release of heat from the chillers will normally be via cooling towers. However, for the PTM building, another system is being considered. The chillers will run only during night time, and the heat may be released from the PV roof by trickling water over the slope of the roof. Water will be added at the ridge of the roof, and will be collected at gutter. Heat will be released from the wet room through radiation to the night sky, through convection and through evaporation.

Initial calculations suggest that such a trickling roof system is interesting, as enough heat can be released at relatively low water temperatures (25 – 35 ^{o}C). It has to be noted that as the cooling load of the ZEO building is very low compared to a traditional building, so is the amount of heat that has to be released. For a conventional building with a much higher cooling load, it would normally not be possible to use the roof as the “cooling tower”. Also, during daytime a wet roof is not useful as a “cooling tower”, as solar energy will heat up the water.

As part of the design of the trickling roof, a small mock up of a roof will be built, and the performance of a trickling roof during night time will be tested.

4.6 Fresh Air and Dehumidification.

Dehumidification of the air is as important in this building as in any building, in order to provide comfort for the users. Furthermore, effective dehumidification is necessary to avoid condensation on cold surfaces, such as the cool concrete floor slabs.

Dehumidification of the air in the building is expensive in electricity consumption. Therefore several measures will be implemented to reduce the load caused by dehumidification. It will be considered to use a so-called desiccant heat wheel, that is a heat wheel that will cool and dehumidify the incoming hot and humid fresh air by exchanging to the relatively cool and dry exhaust air. Furthermore, the amount of fresh air will be controlled according to the CO2 level of the air in the building. This allows the amount of fresh air to be controlled according to the number of occupants in the building. The more occupants, the more CO2 emission and the more fresh air will be provided. Finally, it is important to build and to keep the building very airtight, so that hot and humid air does not enter the building through cracks and openings.

4.7 Energy Efficient Office Equipment

The use of energy efficient office equipment has proven to be crucial to achieve the very low electricity load of the building, in the region of 40 – 50 kWh/m^{2}year. In a modern office where most people have their own computer, the installed capacity for office equipment can easily be corresponding to 10 W/m^2 office space. This is equivalent to an annual electricity consumption of 25 kWh/m^{2}year. Adding the cooling load caused by the office equipment, the total electricity load caused by office equipment amounts to 30 – 35 kWh/m^{2}year, depending on the efficiency of the chiller installed.

However, using only the most energy efficient office equipment available, the installed load can be reduced to around 2.5 W/m^2. It has therefore been decided by the management of PTM that purchase of new office equipment from now on will be predominantly buying the most energy efficient equipment. This means that when PTM will migrate the new building in less than two years time, most office equipment will be super energy efficient, suitable to the scope for the new building.

A feasibility study was performed, comparing the use of the more energy efficient laptop computers to traditional desktop computers, with the energy efficient flat screens. The extra costs of a laptop PC compared to a desktop of similar performance was found to be ~ RM 1, 100 per unit. However, providing extra PV power to cater for the increased energy consumption of the desktop was found to be more expensive, ~ RM 2,600 per PC. Hence it is more feasible to opt for the more costly and more energy efficient laptop PCs.

It should be noted that this result is obviously triggered by the relatively expensive PV power. However, with the reduction in costs for energy efficient flat screens and energy efficient laptops, the trend will be that flat screen computers or laptops are to be preferred in any case.

4.8 Integrated Design Development of the Building and Its Energy Systems.

The development of the PTM ZEO building is done using the approach of integrated design development, using advanced computer design tools in the process.

By using computer modeling from day 1 in the design process, strategic design decisions can be made early in the design, where this is possible. One example is that the benefits of using high performance windows can be predicted early on, benefits of reduced cooling load and also benefits of reduced size of the chiller and reduced size of the cooling system. The computer design tools are thus used to optimise the architectural design of the building in harmony with the optimal design of the mechanical and electrical systems, in order to achieve the goal of zero energy consumption at the least investment cost.

4.9 Other Measures to Improve Energy Efficiency.

Beyond the various innovative energy solutions mentioned above, a host of good practice and good housekeeping measures are implemented in the design to reduce energy consumption. However, compared to a traditional well designed building, such as the MEWC LEO building, in this case these good practice measures are being evaluated very carefully, and their performance typically be chosen to be the best possible on the market. This is because the PV electricity is expensive, and more investments in better performance can be justified.

These good practice solutions include on the architectural side use of external window shading, and use of well insulated walls and roofs. Within the regime of M&E systems, pumps and fans will have very high efficiencies, and pipes and ducts will be designed for very low resistances.

The chillers will be designed to take advantage of a high off coil temperature and a low condenser temperature, in order to improve the efficiency of the chiller and reduce electricity consumption. The air cooling system will be of the Variable Air Volume type, and all pumps and fans will have Variable Speed Drives, measures that are now finding its way also in more conventional buildings.

The electric lighting system will not be on to the same level as in a conventional office building. However, the most energy efficient equipment will be used in order to reduce the electricity bill for lighting even further, beyond what is achieved by the use of daylight as the prime light source. In order to optimise the performance of the electric lighting system, lighting will be controlled according to demand in all zones of the building. Occupancy sensors and daylight sensors will see to that electric lighting is only on when daylight is insufficient and only in those rooms that are occupied.

5. Conclusions

The energy design of the PTM Zero Energy Office Building (ZEO Building) rely on comprehensive use of renewable energies and on building integrated design technologies. The ZEO building is “designed as an energy system, thereby reducing the need for active energy systems in the building”. The key energy efficiency strategies include use of high performance glazing, N/S orientation of the building and use of high efficiency lighting and office equipment. Daylight provides nearly all lighting needed during daytime.

The innovative floor slab cooling system means that floors and ceilings are cool, thereby allowing the air temperature to be higher, up to 25 – 27 ^{O}C, without compromising user comfort. The sensible heat load can be removed using off coil temperatures of 18 – 22 ^{O}C, which improves chiller efficiency drastically compared to the normal off coil temperatures of 6 – 8 ^{O}C. Furthermore, the sensible cooling load itself is reduced because of the higher air temperatures in the building.

The building is driven by renewable energy only: daylight falling through the windows and solar radiation falling onto the roof.

The ZEO Building aims to demonstrate that it is indeed possible today to build buildings in the tropics that do not need any fossil fuel, yet buildings that still meet the highest standards on indoor climate. All the technologies that are used to achieve this are off the shelf products that are technically feasible today. The ZEO Building project aims to stimulate further development of building components and systems such that in the near future, buildings that do not consume any fossil fuels are also the right choice in an overall economic context.