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LOW ENERGY OFFICE BUILDING IN PUTRAJAYA, MALAYSIA. CASE STUDIES AND INNOVATIONS

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Figure 1: East facade of the LEO Building

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Summary

The Ministry of Energy, Water & Communications (MEWC) have moved into their new Low Energy Office Building, LEO Building, in Putrajaya Malaysia in September 2004. This building is a National Demonstration project aimed at promoting energy efficiency (EE) in buildings, and the project is part of a wider program aimed at developing the capacity of the Malaysian building industry in EE building design.

The target for the Energy Index of the 17,800m² building (A/C area) is an equivalent electricity consumption of 100kWh/m2year. Among the energy saving features are well insulated walls and roof, exterior window shading, energy efficient lighting controlled according to occupancy and daylight availability, energy efficient office equipment, a comprehensive energy management system, and implementation of a series of best practice solutions for the mechanical and electrical systems. The building also demonstrates use of renewable energy, as a 3-kWp grid connected photovoltaic system is installed on the roof.

The building is designed to meet and in some area exceed the standard of MS 1525: Code of Practice for Energy Efficiency and Renewable Energy in non-domestic building. This entails, that the building is designed for an illumination level of 300 – 400lux. Installed lighting and small power loads are each reduced to approximately 8 W/m², compared to a typical load of 15 – 20W/m² for each respectively.

The extra cost for the energy efficiency features in the LEO building is 10% on top of the normal construction costs, or RM 5 million. The energy savings compared to traditional design without energy efficiency features are 100 – 150kWh/m²year. The estimated payback time is thus less than 10 years, with the current price of electricity in Malaysia of 0.29 RM/kWh.

During 2004 - 2005, with the assistances of DANIDA, the energy performance of this building will be monitored and evaluated, and results will be disseminated to academia and practitioners. The experience from the LEO building monitoring programme will be used in developing a new building code and standards for the private and public building sector in Malaysia. The building will also be made available to visitors from the public, academia and professionals as part of the capacity building and promotion programme on energy efficiency in buildings in Malaysia.

1. Introduction

In September 2004, the Ministry of Energy, Water & Communications (MEWC) have moved to its own 17,800 m² building in the Federal Government Administrative Capital, Putrajaya, situated between Kuala Lumpur and the new Kuala Lumpur International Airport.

The Government of Malaysia wants their new MEWC building to be a showcase building for energy efficiency and low environmental impact, and design support from the Danish International Development Assistance – DANIDA program was requested and granted. The building demonstrated integration of the best energy efficiency measures, optimised towards achieving the overall best cost-effective solution.

The Danish and local experts have since January 2001, in cooperation with Malaysian architects and engineers, optimised the overall design of the building and its energy systems for minimum energy consumption. A computerized design tool was introduced as a key instrument in the optimization of the building design and the design input of the energy systems. In August 2002 the detailed design of the building has been finalised, and the turnkey contractor, Putra Perdana Construction Sdn Bhd has started construction.

An ambitious goal was set for the energy efficiency of the building: Energy savings of more than 50% compared to conventional design. The energy saving features is achieved at an extra construction cost of less than 10% of the total building costs, giving a payback time of less than 10 years.

The cost target of maximum 10% extra costs for the energy efficiency measures have been confirmed through the design and build tender. The computer modelling using the Energy-10 computer software has predicted more than 50% energy savings. A subsequent energy monitoring follow up program is in progress. The energy monitoring during use will add vital credibility to the predictions, that major energy savings and environmental benefits can be achieved in the building sector of Malaysia.

The new MEWC LEO building demonstrates the feasibility of the energy efficiency measures according to the new Malaysian Standard MS 1525:2001 "Code of Practice on Energy Efficiency and use of Renewable Energy for Non-residential Buildings". Following this code, the LEO building must have an energy consumption less than 135kWh/m²year. The predictions are, that the LEO building will have an energy index close to 100kWh/m²year. This is a very good performance compared to typical new office buildings in Malaysia and the ASEAN region, having an Energy Index of 200 – 300kWh/m²year.

The energy efficiency measures that are expected to contribute to achieving the goal of an Energy Index of 100kWh/m²year are:

- Creation of a green environment around and on top of the building.
- Optimisation of building orientation, with preference to south and north facing windows, where solar heat is less than for other orientations.
- Energy efficient space planning.
- A well insulated building facade and building roof.
- Protection of windows from direct sunshine and protection of the roof by a double roof
- Natural ventilation in the atrium
- Energy efficient cooling system, where the air volume for each building zone is controlled individually according to demand

- Maximise use of diffuse daylight and use of high efficiency lighting, controlled according to daylight availability and occupancy
- Energy Efficient office equipment (less electricity use and less cooling demand)
- Implementation of an Energy Management System, where the performances of the climatic systems are continuously optimised to meet optimal comfort criteria at least energy costs

2. Site & Climate

The climate in Malaysia is hot and humid. Temperatures over the year and day varies typically between 24^{o}C and 35^{o}C, and the humidity is high. This has important implications for the design of modern energy efficient, air conditioned office buildings. In the office working areas, a controlled, conducive environment is essential for occupant comfort and for productive output.

The local temperature outside the building can be reduced by using the cooling effect of trees, greenery and water areas. In cities with little greenery, the "heat island effect" occurs, means causing air temperature to be several degrees higher than in green areas. An air temperature of 35^{o}C instead of 28^{o}C is critical to both comfort in the city and cooling load of its buildings. The green layout and the large water areas of Putrajaya help to create optimal comfortable, local micro-climatic conditions for buildings and people.

In Malaysia, daylight is plentiful during the normal office hours throughout the year. Therefore, daylight can be an important light source to help reduce energy use for artificial lighting, provided adequate building design, as discussed later in this paper is incorporated in the project development.

3. Comfort & Indoor Air Quality

Human thermal comfort depends on a range of climatologically and physiologically related parameters. In a tropical climate context, a person will be increasingly uncomfortable with increased air temperature, humidity and radiant temperature (temperature of the surfaces surrounding the person). Increased air velocity and reduction of the clothing level can help in improving the comfort level.

The recommended indoor temperature range is from 23^{o}C to 26^{o}C and the recommended relative humidity is 60% - 70%. As both the required temperature and humidity parameters are lower than outside air, full climatization is normally required for the working areas, in order to satisfy optimal human comfort and working condition. Buildings therefore have to be tight, and the fresh air intake has to be controlled for optimum quality of the indoor air. In the LEO Building, intake of outside air is controlled according to CO_2 level of the indoor air, and thereby controlled according to the occupancy level. The more people in the building, the more fresh air intake required.

It is noted that low temperature and low humidity is uncomfortable, unhealthy and expensive. Office air temperatures lower than 22^{o}C to 23^{o}C mean that people will have to dress up with warmer clothes, and the cooling load of the building increases. In the LEO Building, a reduction of the office air temperature from design level of 24^{o}C to 20^{o}C increases the energy consumption by 33%!

In the LEO Building, the quality of the indoor air is further improved by the use of electronic air cleaners, instead of normal fibre filter to clean the incoming air from particle pollutants.

4. Daylight

Natural light is the preferred light source for the human beings. This perception has now also been scientifically proven: People prefer daylight, be it in the offices or in shops, as our children learn more and better in daylight schools. Furthermore, daylight is a free source, which is available throughout the normal office hour.

The challenge in daylight design of buildings is to design windows and shading which lets daylight in, prevent sunlight to enter the building, and reduces glare problems from the windows. In the LEO building, these criteria are achieved through a combination of exterior shading and a glazing, which allows 65% of the light through, and allows only 51% of the heat through. The atrium allows daylight access to deeper parts of the building, thereby improving energy savings and user comfort.

In order to fully utilise daylight to offset artificial lighting, the artificial lighting has to be controlled so that it is automatically shut off when daylight is sufficient to satisfy the lighting need, which is an illumination level of 300

– 400 lux. In the LEO building, a daylight responsive control system on lighting system is combined with a motion detector, which automatically shuts off lighting and reduces cooling once an office is unoccupied.

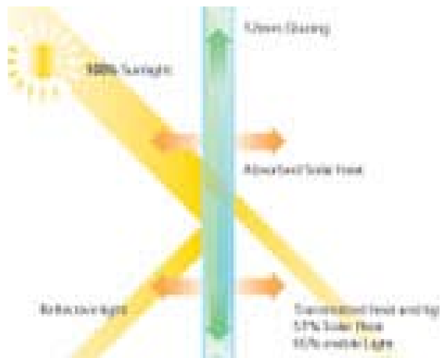

Figure 2: Illustration of heat and light transmission through a glass

In the future, advanced glazing will become available. Glazing that filters the sunlight such that visible light has preference and the solar heat is avoided. These spectrally selective glazing reflect the invisible infrared and ultraviolet and heat away from the building. Such spectrally reflected glazing, which normally will be combined with sealed double windows will significantly improve energy efficiency of buildings, and more architectural freedom with respect to façade design will be possible.

5. Building Envelope

In the LEO Building, the windows are primarily orientated to the North and the South. This orientation receives less direct sunshine, and only shallow out shading is required to shade off the sun. East and west orientation receives more sun, and the sun is more difficult to shade off due to the low sun angles for the radiation in the morning and in the afternoon.

Exterior shading is most efficient, as the sun is stopped before it enters the building. In the LEO Building, two types of window façade are used: The punch hole window facades in the lower floors, and curtain wall windows with exterior shading louvers in the upper floors. Towards the east, shading is deeper to protect against the low morning sun. The windows constitute 25 – 39% of the façade area, depending on orientation. The western façade has virtually no windows. The window glazing is a 12mm thick light green tinted glazing with visible light transmission of 65% and a shadow coefficient of 0.59.

Figure 3: The "Punch Hole" windows provide shading to the windows

The walls of the LEO building consists of 200mm aerated concrete and exterior surface have light colors to reduce solar heating of the walls. The lightweight concrete wall has an insulation value which is 2.5 times better compared to traditional brick wall.

The roof of the building is insulated with 100mm of insulation, compared to normally only 25mm of insulation. Furthermore, the roof surface is protected by a second canopy roof, which prevents direct solar radiation onto the roof. Along the perimeter of the roof, green landscaping provides shading and improves the aesthetics of the roof areas, which can be used for various functions.

On top of the atrium, there is a two storey high thermal flue (solar chimney). The air in the glazed cavity is heated by the sun, and the rising hot air pulls air out of the atrium, and fresh air is entered at the bottom of the atrium.

6. Office Appliances

Office equipment such as computers, printers and copy machines, are responsible for increased electricity consumption and thereby also responsible for additional increase in cooling load. Therefore, special emphasis has been made in the LEO Building to reduce the electricity consumption for equipment, and a guideline for procurement of energy efficient office equipment has been produced.

Simulation with the Energy-10 computer tool confirms the significance of office equipment on the overall energy consumption. Using energy efficient office equipment, the electricity consumption for the equipment can be reduced from 25 to only 10kWh per m^2 per year. In addition to this, the cooling load is reduced by further 10kWh per m^2 per year.

Figure 4: Energy consumption of office equipments

The main energy consuming office equipment in modern office is the Personal Computer, with its screen. Energy consumption is reduced by purchase of energy labelled computers with software that automatically reduces energy consumption during idle periods. Furthermore, LCD screens are much more energy efficient than the traditional bulky CRT screen. Also, LCD screens provide better user comfort with less reflection than the CRT screens, and they take up much less space on the desk. Therefore, all in all, the extra cost of flat screen, now typically less than RM 1,000 can easily be defended from an overall perspective.

Portable laptop computers are much more energy efficient than stationary computers because they are optimised for maximum battery life. The extra price for a laptop compared to a desktop computer with LCD screen is now less than RM 1,000. This extra investment is very attractive given an extra flexibility and the energy consumption per PC is reduces to approximately to 30W for a laptop. For comparison, energy consumption for stationary computer with CRT screen is around 150W.

7. Cooling, Lighting & Transport

The largest energy consumption for an office in Malaysia is for its cooling and lighting, which normally accounts for 60% - 70% and 25% - 30% of total energy consumption respectively. The rest of energy use is for pumps, motors and lifts for vertical transport. Finally, energy is used for office equipment, the plug loads.

Apart from being free, daylight is also a very efficient light source, measured in light (lumen) received compared to the unwanted heat (watts) that accompanies the light. Diffuse daylight with an efficiency of around 120lumen/watt is twice as good as traditional fluorescent lighting around 60lumen/watt.

In the LEO Building, high efficiency light fixtures are installed. This, in combination with a reduction of the illumination in offices according to the new standard, reduces the installed lighting load from typically 20W/m² to only around 10W/m². The illumination level is reduced from 500lux to approximately 335lux in the office space.

The mechanical and electrical (M&E) equipment for the building also include high efficiency motors (HEMs) for pumps and fans, with variable speed drives (VSDs) for optimum operational efficiency. The VSD's reduce motor power and electricity consumption drastically for part load condition, which is the normal load condition.

Each floor has its own air handling unit (AHU) and it is subdivided into smaller zones, where the provision of chilled air is controlled with a Variable Air Volume (VAV) damper. The VAV damper controls the chilled air volume to the zone according to the temperature setpoint.

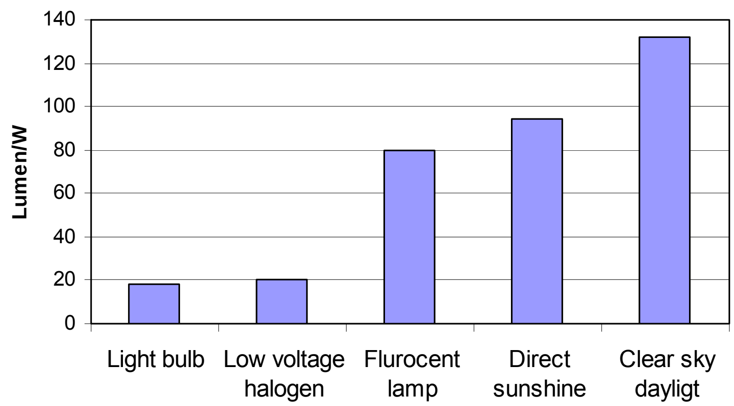

Figure 5: The light intensity of different light sources

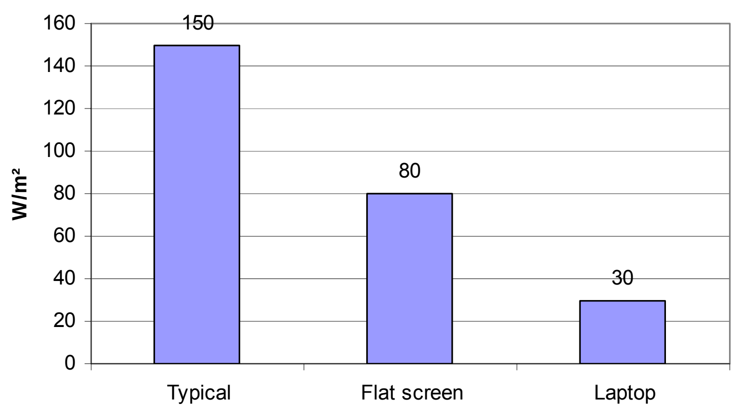

Figure 6: Power index of various services in office buildings

8. Energy Management

A comprehensive energy management system (EMS) is a prerequisite for actually achieving the low energy consumption, for which the building has been designed. The energy management system monitors on a continuous basis the energy consumption of the building. This allows for the comparison of actual energy consumption with predicted consumption and with typical previous consumption, and action can be taken if abnormal high energy consumption is registered.

Energy management requires the installation of adequate metering as a means of measuring the energy used and temperatures archive. As the saying goes "you cannot manage what you cannot measure". In addition, the

EMS shall incorporate a computer software tool, which helps the building energy management to optimise the performance of various energy systems for cooling and lighting, such that optimal user comfort is achieved at least costs in purchase of energy.

The LEO Building will be equipped with a comprehensive Energy Management System. For each floor and each section (east or west wing), energy consumption for cooling, lighting and plug loads is monitored individually. Furthermore, temperatures in various parts of the zone are monitored. The detailed monitoring data of the LEO Building will be made available for further study by academia and professionals.

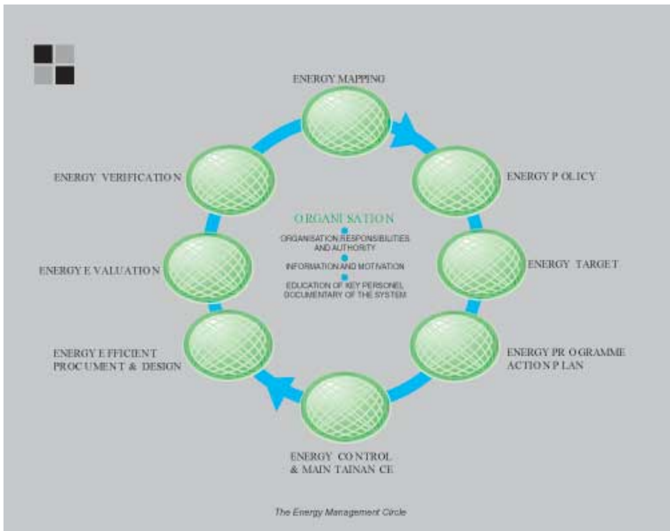

Figure 7: Energy management cycle

Successful energy management can only be achieved if there is a competent energy management authority in additional to the traditional building management services. The Ministry has therefore created a special position for energy manager. He will be responsible for the day to day energy management activities including advising the organisation related on energy management activities.

9. Discussions

The use of computer design tools means that an overall optimisation of the building energy design can happen at the drawing table. Extra costs for some energy saving building elements can be offset by reduced costs for other elements, such as reduced investment costs for the cooling system caused by a more efficient design building envelope, that reduces the maximum cooling load. Furthermore, using life cycle calculations, extra costs for energy saving features can be offset by savings in energy costs over the life cycle of the building.

The LEO Building has been optimised using the *Energy-10* computer software from National Renewable Energy Laboratory, Denver US. Among the many computer design tools available, Energy-10 was chosen, as it is very user-friendly, yet sophisticated, calculating the energy balance of the building hour by hour throughout a year.

Figure 8 shows the effect of applying the main energy saving features, one by one. It is seen, that reduction of the internal heat gains from lighting and office equipment is of major importance. It is noted, that the increase of the room temperature by only one degree reduces energy consumption by 10%. Therefore it is also very costly to have too low room temperatures in the 20 - 22^{o}C region.

The extra costs for the energy efficiency features of the LEO building have been RM 5.0 million, or 10% of the total building costs. With an electricity price presently at 29 cent per kWh, the extra costs will be paid back within the first 10 years of the building lifespan. Energy efficiency is very cost-effective, it should be applied throughout the building sector, and the implementation of *Malaysian Standard 1525:2001 Code of Practice the Use of Energy Efficiency and Renewable Energy for non-domestic buildings,* is seen to be well justified.

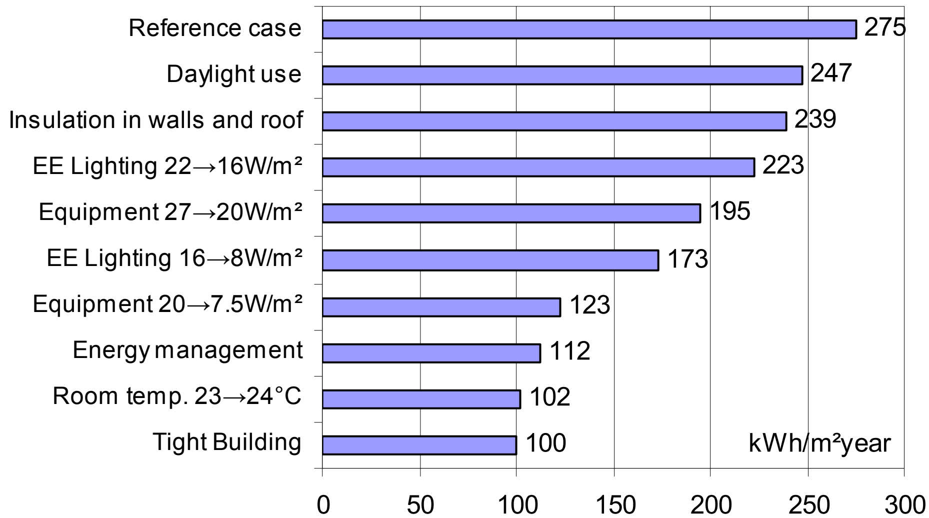

Figure 8: Energy saving features applied one by one

10. Conclusions

The building and the system design were analyzed and optimized. A comprehensive list of EE features was integrated in the project tender. The results of the computer simulations of the LEO building is shown in the figure below.

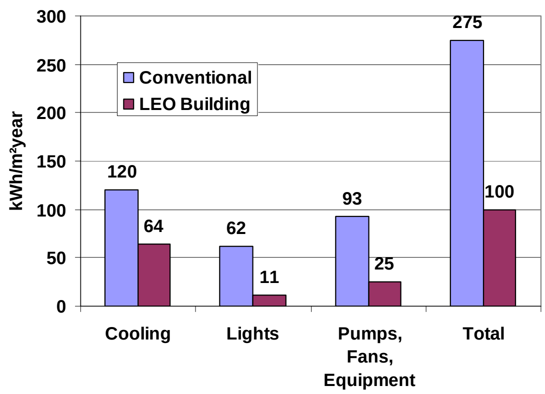

Figure 9: Predicted overall energy saving for the LEO Building

11. ACKNOWLEDGEMENTS

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