Professorial Lecture

"Climate Change, Green Technology and Sustainable Buildings"

Azni Zain Ahmed
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CLIMATE CHANGE, GREEN TECHNOLOGY AND SUSTAINABLE BUILDINGS

ABSTRACT

This book introduces the causes of climate change that is presently being experienced by mankind. The reasons behind global warming as an effect of major greenhouse gas emissions and how world energy consumption contributes towards climate change are discussed. This book continues to explain how green technology can contribute towards the mitigation of greenhouse gases. Sustainable buildings in particular provide some solutions which are also presented in the book. The design of buildings which integrate sustainable technologies as a whole, create a positive impact on the environment. This book also presents the initiatives, policies as well as recent developments in terms of green technology that have been introduced by the Malaysian government in its effort to reduce the impact of energy use on the environment. The final part of the book discusses the current research and development in sustainable energy technologies applied to buildings which encompasses fundamental studies leading to design, systems, processes and new materials, particularly at Universiti Teknologi MARA.
INTRODUCTION

In recent years, many have realized that there has been a definite change in our environment. The obvious changes are physical development; rise in human population; increase in building structures especially tall buildings; increase in the number of vehicles leading to increase in traffic volume and thus congestion. These are just a few examples of how the immediate environment around us has changed in a few short years. As a result we have also witnessed the aggressive rape of hills and mountains in the name of development. Soil erosion, collapse of buildings, landslides, smog and haze seem to occur more often. What man is experiencing now is the gradual change in the climate, where snow, floods, droughts or heavy rainfalls that occur do not follow the normal average conditions. This paper presents the relationships between climate change and how green technology can address some of these issues and how buildings in particular can form solutions to the climate change.

HUMAN ACTIVITIES AND CLIMATE CHANGE

One cannot underestimate the seriousness of the negative changes in our world especially the climate surrounding us. It is normally not experienced immediately but the effects can only be seen and felt many years down the road, and not only that, not really obvious to the individual. However, many are alarmed by the daily news that appear in the media about disasters, drought and maybe unusual changes in the weather such as heavy rains recording readings that exceed more than 100 years of data or floods in places that have never occurred. Many too are not aware that these are the adverse effects of climate changes that will become gradually worse in time to come.

Scientists have argued on the actual degree of degradation of the climate but all agree that the main reason for climate change is the increase of the surface temperature of planet Earth over the last century by 0.8 °C (Henson, 2006). Examples of other evidences
that point towards climate change are melting ice on land and sea especially in Antarctica and Greenland; lengthening of growing season such as cherry blossoms in Japan blooming five days earlier than the average date and growing seasons extending up to two weeks longer in many places; insects, birds and other creatures moving towards higher altitudes and latitudes due to increasing warmth in their natural habitats. Worse still, some parts of the world experience heat waves in summer causing deaths by the thousands. Such incidents have occurred in Chicago in 1995 and Paris in 2003.

Global Warming

The increase in the Earth’s surface temperature, or in common terms global warming is partly due to the burning of fossil fuels (such as petroleum, coal, oil and gas). Other causes of global warming are results of cataclysmic volcanic eruptions, changes in solar output and variations in the Earth’s orbit. However, scientific research has proven that other types of volcanic eruptions actually cool down the Earth’s surface temperature, like the Mount Pinatubo in 1991 but the effect of greenhouse gases produced by the burning of fossil fuels is more pronounced on global warming (Henson, 2006).

Greenhouse gases and their effect on global warming

The Earth’s atmosphere is a thin layer of gases and particles which occur naturally. It actually acts as a so-called “blanket” around the Earth to maintain an average temperature of about 15 °C. Solar radiation (or solar energy) during the day time goes through a process of absorption, reflection and scattering by clouds and particles in the atmosphere. About 30% of the radiation is reflected to space, 20% absorbed by the atmosphere and the rest of the 50% reaches the Earth’s surface. During night time, the Earth reradiates the energy absorbed during the day resulting in a cooling of the Earth’s surface. Most of this energy is absorbed by the atmosphere and the rest escapes out of the atmosphere as well as reflected back to earth. This process retains some of the heat from solar radiation keeping the Earth comfortably warm.
Natural greenhouse gases – which have the capability to absorb heat in the atmosphere are well-known and the notable ones are Carbon dioxide (CO₂), Nitrous dioxide (NO₂), Methane and near-surface ozone. CO₂ is produced when humans burn fossil fuels, when humans and animals breathe and when plants decompose. However, CO₂ is absorbed by plants during photosynthesis and huge amounts of water like oceans. The energy equation becomes unbalanced when human activities produce more greenhouse gases than the natural absorption process takes place. Other greenhouse gases like Chloroflourocarbons (CFCs) and Hydroflourocarbons (HFCs), besides CO₂ and methane are also produced by vehicles, buildings and factories. The Industrial Revolution, modernisation, urbanisation and increasing world population are the main cases of the production of excess greenhouse gases. Human-produced CO₂ makes up 53% of the greenhouse gases while methane and NO₂ makes up 17% and 12% respectively. Figure 1 shows the relationship between Earths’ surface temperature and CO₂ emissions which clearly demonstrates the rise in temperature is almost proportional to the rise of CO₂ in the atmosphere (Zain-Ahmed, 2008b).
Energy Production, Consumption and Greenhouse Gases

Conventionally, the production of energy involves burning of fossil fuels. As mentioned in the above section, the main producers of excess CO$_2$ are fossil fuels used to provide energy in all sectors namely. Globally, the CO$_2$ emissions are from the following sectors: industry (40%), buildings (31%), transportation (22%) and agriculture (4%) (IPCC, 2001). The demand for energy will not decrease but instead increase dramatically. In fact, the increase in world energy consumption is expected to be 65% from 1996 to 2020. Ninety percent of the world’s energy comes from oil, a CO$_2$ producer. Although by 2020 other forms or alternative energy are expected to provide 30% of the world’s energy needed, electricity will still be the largest form of energy consumed.

In terms of energy demand, the projected growth in the Asia and the Pacific region alone is 2.75% a year until 2030 which is half of the global demand (Heyzer, 2008). More than 80% of the energy sources would come from fossil fuels such as coal, oil and gas.

In Malaysia, the largest consumer of energy is the transport sector accounting to almost half of the total commercial energy demand followed by the industrial sector and the residential and commercial sector (Table 1).

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<tbody>
<tr>
<td>Industrial</td>
<td>477.6</td>
<td>630.7</td>
<td>859.9</td>
<td>38.4</td>
<td>38.6</td>
<td>38.8</td>
</tr>
<tr>
<td>Transport</td>
<td>505.5</td>
<td>661.3</td>
<td>911.7</td>
<td>40.6</td>
<td>40.5</td>
<td>41.1</td>
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<tr>
<td>Residential &amp; Commercial</td>
<td>162.0</td>
<td>213.0</td>
<td>284.9</td>
<td>13.0</td>
<td>13.1</td>
<td>12.8</td>
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<tr>
<td>Non-Energy</td>
<td>94.2</td>
<td>118.7</td>
<td>144.7</td>
<td>7.6</td>
<td>7.3</td>
<td>6.5</td>
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<td>4.4</td>
<td>8.0</td>
<td>16.7</td>
<td>0.4</td>
<td>0.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Total</td>
<td>1243.7</td>
<td>1631.7</td>
<td>2217.9</td>
<td>100.0</td>
<td>100.0</td>
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Sources: Malaysia (2006)
GREEN TECHNOLOGY AND SUSTAINABLE BUILDINGS

By 2010 the transport and industrial sectors will still remain the largest consumer of energy accounting to 80% of the total energy consumed (Figure 2).

![Figure 2: Projected Energy Consumption in Malaysia by Sector in 2010 (Zain-Ahmed, 2008)](image)

The main source of energy in Malaysia is petroleum products and will remain so even after 2010. Figure 3 shows that the next important energy sources are natural gas and electricity. However, electricity is also generated from fossil fuels which are oil, gas and hydropower which contribute towards the emission of CO$_2$, SO$_2$ and NOx or collectively known as the greenhouse gases (GHGs).
Zainon Noor et al., (2008) has estimated that in parallel with the increased demand in energy, there will be an increase in CO₂ emissions for the period 2000 - 2020. The four main sectors would be in power generation, industrial, transportation and residential buildings. The power generation sector contributes 43.40% of all emissions, second from the industry sector (30.34%), third from the transportation sector (26.26%) and 0.03% from the residential sector. The transport sector relies heavily on petroleum fuels which produces 0.85 kg of CO₂ per kWh. Coal produces the most CO₂ at 1.18 kg per kWh as compared to natural gas at 0.53 kg of CO₂ per kWh, while hydro is cleanest with zero emission (Masjuki et al., 2002).
GREEN TECHNOLOGY

Broadly speaking, green technology refers to "clean technology which is the application of the environmental science to conserve the natural environment and resources, and to curb the negative impacts of human involvement. Green technology is also a low-carbon technology and is environmentally friendlier than a comparable existing technology (MEGTW, 2009)". Green technology may also be defined as "a diverse range of products, services, and processes that harness renewable materials and energy sources, dramatically reduce the use of natural resources, and cut or eliminate emissions and wastes (The New York Times, 2007)".

Green technology when related to climate change would of course means technology that involves applications, product development, services and processes that would produce less or no CO$_2$ and other greenhouse gases or simply put: "environmental-friendly". Green technology would inevitably requires the use of energy that is environmental-friendly and produces less pollution. This ultimately means that there should be less dependency on sources of energy from fossil fuels.

Green technology is not really new. The greenhouse effect was actually discovered way back in the nineteenth century. The Earth’s rise in temperature was actually recorded in the 1950’s. But it was only in the 1970’s that real interest picked up about global warming coupled with the rise in price of oil during the tumultuous period between 1973 and 1982. There were also concerns the world over regarding the thinning of the ozone layer in the Earth’s atmosphere and the discovery of the ozone hole over Antarctica in 1985. Finally, in 1987, 46 countries felt compelled to ratify the Montreal Protocol and collectively agreed to reduce the CFCs in the atmosphere in an attempt to recover ozone.

Finally, in 1992 and 1999, more countries signed pacts to reduce CO$_2$, the major greenhouse gas at the United Nations’ Earth
Summit in Rio de Janeiro and Kyoto, respectively. Malaysia also signed the United Nations Framework Convention on Climate Change (UNFCCC) in 1993 to promote a cleaner environment and to address the issues of the reduction of GHGs. The Kyoto Protocol is a treaty that requires developed nations to reduce their emissions of six GHGs: CO$_2$, NOx, methane, sulphur hexafluoride, CFCs and perfluorocarbons. Each country that ratified the Protocol is required to reduce by varying percentages. For example 7% reduction in the US and 6% reduction in Canada and Japan. Incidentally, the largest producers of GHGs are US, China, Japan, Russia and India. The energy consumption by these countries derived from fossil fuels are US (24.3%), China (8.9%), Japan (5.9%), Russia (3.4%) and India (3.2%). The order of energy consumption is obviously proportional to greenhouse gas emissions (Nationmaster, 2009). The Kyoto Protocol has since become an international law in 2004. A secondary goal of the Kyoto Protocol is the promotion of clean technologies to emerging economies.

Solutions

There are several technologies that can be utilised to reduce GHGs. These include removing CO$_2$ from the atmosphere, reduction in the burning of fossil fuels and replacing them with cleaner fuels or energy sources, reduction of energy consumption, replacing conventional technologies with green technologies and re-engineering the Earth’s surface.

Carbon sequestration

Carbon sequestration is the capture of CO$_2$ before it is released into the atmosphere and storing it or carbon capture and storage (CCS) or commonly known as carbon sequestration. This involves removing GHGs directly from industrial or utility plant exhausts and storing them in secure reservoirs. Enhancing natural sinks like increasing uptake of CO$_2$ in soils and vegetation is one way or iron fertilization in oceans another way. In other words carbon sequestration may be viewed as emissions avoidance and yet delays the need to opt for alternative energy sources (Herzog, 2001).
**Energy efficiency**

Using energy efficiently is another way of reducing GHGs. This requires the use of less energy but maintaining the same output or outcome. However, using less energy does not necessarily mean less services but should at least maintain the same standard of living and productivity. Energy efficiency can be applied in many sectors and these are industry, transportation and buildings. Common appliances for daily use can be energy efficient such as lamps, bulbs, computers, washing machines and televisions. In the industrial sector, energy can be more efficiently used in combined heat and power (or cogeneration) systems. In building design, energy efficiency is applied in several areas. Energy efficiency in transportation would normally involve the design of vehicles and the type of fuel used. Improved aerodynamics, vehicle weight and materials, energy efficient engines would be the emphasis towards improving efficiency. Hybrid cars are now the most recent development under the green technology category. Nearer in the local scene biofuel such as biodiesel is a promising alternative energy to replace fossil fuels.

**Energy efficiency in buildings**

Energy efficiency in buildings require two basic components which are the design itself and the mechanical and electrical (M&E) component. The design component consists of the architectural, passive design and building envelope. The M&E component are roughly divided into the lighting, electrical power and distribution, air conditioning and mechanical ventilation system and energy management control system. The design itself has a large impact on the energy consumed as well as the amount of M&E components required to maintain the building at the required human comfort level.

**Renewable energy and solar technologies**

The use of renewable energy resources (or commonly known as renewables) involves the harnessing of the natural flows of energy in the environment. Energy is removed at a rate comparable to that of which energy is being replenished. Renewable energy is thus
inexhaustible and more environmentally-friendly as opposed to conventional sources of energy. Consequently, the use of renewables contribute to environmental protection for the present generation and the future. Therefore, there should be efforts to harness and develop ingenious methods of renewable energy conversion systems and to substitute renewables where fossil fuels applications are most vulnerable. Renewable energy technologies can secure and diversify the supply of energy resources. Renewable energy is widely distributed, available and indigenous to almost every region of the world (Yatim and Abdul Rahman, 2000).

Renewables produce less or even zero emissions, can be replenished and therefore are clean as far as the environment is concerned. Thus renewables have been known to be called sustainable energy. It can be said that renewables are also green energy which besfits the definition of the prefix “green”. It is widely known that the group of renewable energy resources are solar, wind, hydro, geothermal and tidal waves. All renewable energy resources are derived from the parent energy: solar. Therefore, in many cases renewable energy technology can also be termed solar technology or vice-versa. In some cases, too, renewable technology is also called “green technology”.

The Malaysian Government Initiatives

Malaysia has a well-established set of plans that are laid out for implementation every five years. Even the 9th Malaysia Plan 2006-2010 which covers strategies to be followed from 2006 up to 2010 had evidences of “green” elements embedded in the plans. The five thrust areas of which the 9th Malaysia plan aims to address were to (i) move the national economy up the value chain, (ii) raise the capacity for knowledge and innovation and nurture “first class” mentality, (iii) address persistent socio-economic inequalities constructively and productively, (iv) improve the standard and sustainability of the quality of life and (v) strengthen the institutional and implementation capacity. The Malaysian government is fully aware of the importance of sustaining the quality of life for the
needs of the population and at the same time to manage Malaysia’s resources wisely (Malaysia, 2006). This entails ensuring the protection of the environment, enhancing energy sufficiency and efficiency, diversification of energy resources, increasing water efficiency and providing better transport and reduction of fuel wastage, access to affordable housing and healthcare.

The energy sector plans outlines these strategies:

1. Ensuring sufficiency, security, reliability, quality and cost-effectiveness of energy supply;

2. Improving the productivity and efficiency of energy suppliers and promoting market-based approach in determining energy process;

3. Reducing the high dependence on petroleum products by increasing use of alternative fuels;

4. Promoting greater use of renewable energy for power generation by industries;

5. Intensifying energy efficiency initiatives in the industrial, transport and commercial sectors as well as in government buildings;

6. Expanding rural electricity coverage, particularly in Sabah and Sarawak; and

7. Developing new sources of growth in the energy sector including participation of local companies in energy-related industries and services abroad.

The development and utilisation of renewable energy will be further intensified. By 2010 about 300 MW is expected to be generated from new sources such as from municipal waste, solar
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hybrid systems and biomass based cogeneration. A roadmap for solar, fuel cells and hydrogen has been developed but has not yet taken off the ground. This roadmap extends activities up to 2050 and includes the installation of 1000 kWh of building integrated photovoltaics and the development of power generated from solar, fuel cells and hydrogen.

Other sources of energy such as wind, solar and biofuel from palm oil will be developed through intensive R&D. Financial initiatives have been introduced in the form of research funding via the Ministry of Science, Technology and Innovation (MOSTI) where alternative energy has been identified as a priority area in research.

In terms of energy efficiency (EE), the 9th Malaysia plan only focuses on the industrial and commercial sectors. EE features in both sectors are encouraged and the Malaysian standards department has produced a guideline for EE and the use of RE in non-domestic buildings called the MS 1525 introduced in 2007. It is planned that the MS 1525:2007 will be incorporated in the Uniform Building By Laws (UBBL).

The government's initiatives are based on the sustainable strategies and policies formulated to diversify the national energy mix. The government is committed to manage its energy resources, ranging from fossil fuels to renewable resources, on a sustainable basis to supplement the conventional sources of energy.

To achieve the national objectives, the Government is pursuing the following strategies:

1. Secure supply
   Diversification of fuel type and sources, technology, maximize use of indigenous energy resources, adequate reserve capacity to cater for contingencies adequate reserve margin for generation, upgrading transmission and distribution networks and distributed generation (islanding);
2. **Sufficient supply**  
Forecast demand, right energy pricing and formulate plans to meet demand;

3. **Efficient supply**  
Promote competition in the electricity supply industry;

4. **Cost-effective supply**  
Promote competition and provide indicative supply plan to meet demand based on least cost approach using power computer software such as WASP;

5. **Sustainable supply**  
Promote the development of renewable and co-generation as much as possible;

6. **Quality supply (low harmonics, no surges and spikes, minimal variation in voltage)**  
Match quality with customer demand with variable tariffs;

7. **Efficient utilization of energy**  
Benchmarking, auditing, financial and fiscal incentives, technology development, promotion of ESCOs, Labeling, Ratings, correct pricing, energy managers; and

8. **Minimizing Negative Environmental Impacts**  
Monitor the impacts, improve efficiency of utilization and conversion and promote renewable.

**Energy efficiency in buildings project**  
With regards to energy efficiency and the use of sustainable energy in buildings, a few projects have been initiated to act as demonstration, educational and enhance public awareness programmes.
1. The LEO Building

The LEO (Low Energy Office) Building in Putrajaya was built as a demonstration project by the Ministry of Energy, Water and Communication (MEWC) and was first occupied in 2004. Building energy management has been practised since then and the building energy index was aimed at a maximum of 100 kWh/m²/year. The building energy index in 2005 was 114 kWh/m²/year but the index had decreased to 104 kWh/m²/year in 2006. An energy audit was done on the Block E6 Ministry of Health and Block B6 Economic Planning Unit (EPU) of the Prime Minister's Department buildings in Putrajaya. The audit showed that the energy index of the LEO Building was lower than conventional buildings.


The seminar on Energy Efficiency in Buildings was targeted at Government agencies and departments, local authorities, building owners and maintenance, and professional bodies in the energy industry. The “MEWC Low Energy Office: Lessons Learnt” seminar was attended by 300 people from Government agencies and the private sector. By creating awareness with such programmes, the Ministry hopes to increase the effectiveness of energy usage among members of the public.

Other continuous activities implemented under this project include monitoring the energy usage index on a monthly basis, receiving visitors, and delivering talks and preparing brochures on the LEO Building. The LEO building won first place in the “Energy Efficient Building Best Practices Competition 2006” at the ASEAN level under the “New and Existing Building”
category. The award was presented at a special ceremony organised on 27\textsuperscript{th} July 2006 in conjunction with the 24\textsuperscript{th} ASEAN Energy Ministers meeting in Vientiane, Lao PDR. (MEWC, 2008).

![Figure 4: The LEO Building in Putrajaya, Malaysia](image)

2. The PTM GEO (Green Office) Building

The GEO building belongs to Pusat Tenaga Malaysia (PTM) or the Malaysia Energy Centre which is a demonstration project for commercially viable examples of sustainable initiatives for modern buildings in Malaysia and the region (Anon, 2007). PTM was established in 1998 aimed at coordinating and managing energy-related R&D programmes and promote
the development of renewable energy in Malaysia. The GEO Building was formerly known as the Zero Emission Office (ZEO) building but the present Prime Minister, The Honorable Dato’ Seri Mohd Najib Abdul Razak, renamed it the GEO Building during the launching of the National Green technology Policy on 23rd July 2009.

The GEO building is equipped with the state-of-the-art facilities for energy research in the country. It has also helped in the capacity building of local architects, engineers, consultants, academia and building managers. The building is aimed to have a BEI of less than 50 kWh/m²/yr. The design incorporates a combination of energy efficiency measures and sustainable technologies. For example, natural daylight is used for daytime and intelligent lighting is used for low illumination levels. The building utilizes high insulation in facade and roof and spectrally selective glazing or double-glazing on all of the windows installed. The energy efficient measures are energy efficient office equipment and an Energy Management System. In summary, the building design and initial concepts have incorporated almost all of the ideas and principles recommended in the MS 1525:2007 although both were developed around the same period of time.
3. **The Energy Commission Diamond Building**

The Energy Commission Malaysia is also building an energy efficient office to house its headquarters. It will be the third showcase energy efficient and sustainable building or "green" building in Malaysia. The ground-breaking ceremony was held on 28\textsuperscript{th} June 2007. The diamond-shaped building is slanted downwards and inwards to provide self-shading as a passive design strategy (Figure 6).

An atrium is being built at the centre of the building but designed in such a way that the heat gain and thermal impact are kept at a minimum while ensuring sufficient daylight to penetrate for natural lighting purposes simultaneously in the atrium and in the office zone around the atrium.

![Figure 6: The Energy Commission Diamond Building](image)

The facade is integrated with internal light shelves to direct natural daylight deep into the office space whilst the glazing is specially coated with low-energy coating to address the heat.
To further reduce the latent and sensible load, the building will incorporate floor slab cooling as one of the means to improve the comfort of its office space. The building energy index is designed to be 85 kWh/m²/yr. The building houses a sunken garden which is filled with lush landscape to act as a heat sink as well as daylighting into the basement.

The sustainable strategies include rainwater harvesting (which is not employed in the LEO nor the GEO buildings). The system is located on the roof and the water used for toilets and irrigation. Another plus factor for the Diamond Building is that it will be rated under the Green Mark Building Sustainability Assessment Scheme, which is aimed at the highest rating, the Green Mark Platinum (Suruhanjaya Tenaga, 2008).

4. The Malaysian Building Integrated PV Project

The UNDP-GEF with the support of the Malaysian Ministry of Energy, Communication and Water and the private sector, established the building integrated photovoltaic (BIPV) project in 2005. The objective of the MBIPV is to promote renewable energy to supplement the current fossil fuel consumption for power generation in Malaysia. It proposes to provide a solution in the utilization of alternative source of energy and which would contributes towards the reduction of greenhouse gas emissions particularly in the power generation industry.

The BIPV project budget amounts to some US$25 million of which UNDP-GEF contributes almost 20% of the total amount. Although BIPV technologies have considerable potential to support initiatives to promote renewable energy, these technologies have yet to penetrate the Malaysian market due largely to their high cost. This project therefore also aims to reduce the costs of BIPV technology within the Malaysian market.
BIPV technology has been demonstrated at selected premises. The GEO Building is a fine example of the MBIPV project being implemented. BIPV systems and technologies have been aesthetically integrated into the building envelopes used as building elements on the roof and glass.

Moreover, the BIPV project also provides additional advantages to other projects such as demand side management and energy efficiency programs. Finally, the project aims to increase BIPV applications to about 330% with a cost reduction of 20% by the year 2010 (ABCSE, 2005).

5. **Suria 1000**

On 22nd June 2007, The Prime Minister of Malaysia launched the Suria 1000 Programme under the Malaysian Building Integrated PV project supported by MEWC, UNDP and the GEF. The aim of Suria 100 is to install 1000 kWp of BIPV in the country over 5 years to promote RE and EE. It provides privileged opportunities to successful applicants to own BIPV systems at discounted prices (Abdul Rahman, 2007). The incentives provided were in the form of a discount price at decreasing percentages as follows: 75%-70% in 2007, 65%-60% in 2009 and 45%-40% in 2010. The installed capacity for each consecutive year is respectively 100 kWp, 260 kWp and 340 kWp. The BIPV systems are grid-connected and owners are able to sell excess solar electricity generated by the systems. This programme has been very successful thus far.

**Other Initiatives**

1. **Energy Efficiency Incentives**

For companies that provide energy conversion services (MEWC, 2008):

Pioneer status with tax exemption of 70% of statutory income for a period of 5 years or Investment Tax Allowance of 60% on
the qualifying capital expenditure incurred within a period of 5 years with the allowance deducted in each year of assessment be set-off against 70% of statutory income; and import duty and sales tax exemption for equipment used in the related project which are not produced locally. Equipment purchased from local manufacturers is given sales tax exemption.

These incentives are for applications received from 28th October 2000 until 31st December 2010. Companies are required to implement their projects within one year from the date of approval of the incentive.

For Companies Which Incur Capital Expenditure For Conserving Energy For Own Consumption:

Investment Tax Allowance of 60% on the qualifying capital expenditure incurred within a period of 5 years with the allowance to be set off against 70% of statutory income for each year of assessment. Incentive is applicable for applications received by the Malaysian Industrial Development Authority (MIDA) from 1st October 2005 until 31st December 2010; and import duty and sales tax exemption on equipment used in energy conservation which are not produced locally. Equipment purchased from local manufacturers is given sales tax exemption.

2. **Incentives for the use of renewable energy resources**

Incentives are also provided to companies for utilizing biomass as a source of energy. For companies generating energy from renewable sources such as biomass, hydro power (not exceeding 10 MW) and solar power are eligible for the following incentives:

Pioneer status with tax exemption of statutory income for a period of 10 years or Investment Tax Allowance of 100% on the qualifying capital expenditure incurred within a period of
5 years with the allowance deducted each year of assessment to be set off against 100% of statutory income for each year of assessment; and Pioneer status with tax exemption of statutory income for a period of 10 years or Investment Tax Allowance of 100% on the qualifying capital expenditure incurred within a period of 5 years with the allowance deducted each year of assessment to be set off against 100% of statutory income for each year of assessment; and Equipment used for the project will be given import duty and sales tax exemption if not produced locally. Equipment purchased from local manufacturers will be given sales tax exemption.

These incentives are effective for applications received from 28th October 2000 until 31st December 2010. Companies are required to implement their projects within one year from the date of approval of the incentive.

3. Accelerated capital allowance on equipment to maintain quality of power supply

In order to reduce the cost of doing business caused by interruptions in the power supply, companies which incur capital expenses on equipment to ensure quality of power supply is given Accelerated Capital Allowance for a period of 2 years. Thus, the annual allowance is increased from between 10 and 20% to 40%. The equipment eligible for Accelerated Capital Allowance shall be determined by the Minister of Finance. This incentive is effective from year of assessment 2005.

The National Green Technology Policy

The National Green Technology Policy was launched by the Honorable Prime Minister, Dato’ Seri Najib Tun Razak on 23rd July 2009. The policy was predicated on four primary pillars of energy, environment, economy and social perspectives (Anon, 2009). Under the policy, five strategic thrusts will be given emphasis and they are:
1. Establishment of a national green technology council for high-level coordination among ministries, agencies, private sector and key stakeholders;

2. Provision of a conducive environment for Green Technology development;

3. Intensification of human capital development by availing training and educational programmes;

4. Intensification of Green Technology research and innovation towards commercialization;

5. Strong promotion and public awareness of Green Technology.

The Honorable Dato’ Seri Najib also reiterated that the government would continue support for the development of solar energy in the country. This is certainly good news for solar and environment enthusiasts in the country as the support for green technology has become stronger than ever. The research community is also celebrating this recent development and fervently hopes that there will be more funds for research and development in this area.

SUSTAINABLE BUILDINGS

The Malaysian Standards MS 1525:2007 describes the sustainable building that is designed to combine “architectural, engineering, site planning and landscaping (multidisciplinary) approaches” that would “optimize the energy efficiency of a building especially when employing combined passive and active devices”. The microclimate of a location must be taken into consideration, natural resources are used such as solar, wind, water and materials. The ultimate goal is to reduce energy consumption from fossil fuels and to protect the environment. For example, natural daylight is maximised in the
design while solar gains are minimised to reduce energy consumption for cooling. The use of wind for induced air movement for natural ventilation is advocated, again to minimise energy consumption from mechanical cooling. The building design solutions must also strive to optimise the benefits provided by the specific environment and to use environmentally friendly materials of high quality and durability in order to decrease waste. As such it is also most appropriate to describe sustainable buildings as “green” buildings.

**Energy Consumption in Buildings**

The energy consumed in Malaysia is 90% in the form of electricity and when these trends continue, buildings will consume almost as much as industry and transport combined. It has also been reported that Malaysia has one of the fastest growing building industry in the world (ABCSE, 2007). Where energy consumption in buildings is concerned, buildings can be roughly be divided into residential and non-residential buildings. Commercial buildings in the ASEAN countries consume more than 30% of all the electricity and will demand at least 40% of the additional generating capacity in the near future. However, more than 40% of the energy consumed can be reduced if energy efficiency is practiced and sustainable technologies are applied to buildings (Zain-Ahmed, 2008a).

In 2002, 44% of the total energy used in the residential sector in Malaysia was in the form of electricity. In the commercial sector which includes commercial buildings, 75% of the energy consumed is in the form of electricity. Commercial buildings consume more than 50% of energy for lighting and air-conditioning (Ramatha, 1994). There is, therefore, enormous potential in energy savings from energy efficiency practices in buildings.

The energy demand can be reduced by applying energy efficiency measures coupled with the use of alternative energy sources or renewable energy for hot water systems, drying systems, water pumping and the application of photovoltaic systems for the production of electricity. The following building energy efficiency
potentials are attainable (Kannan, 2001), such as 40% to 50% reduction of energy consumption of new buildings; 15% to 25% in reduction in energy consumption of existing buildings and a shift of electricity demand for buildings from day to night, thus improving the load factor on electricity generating equipment for some ASEAN countries.

In the Malaysian residential housing sector, the housing stock is made up of terrace or linked houses (61%), apartments (27%) and detached (12%). More than 70% of the detached houses are air conditioned while 62% of the terrace houses and 36% apartments are air conditioned (Kubota, 2006). The current trend indicates that the bigger houses tend to be air conditioned than the smaller houses and further suggests that the purchasing power of occupants is proportional to the installed air conditioners.

Building Energy Index and Building Codes of Practice

The energy consumption in buildings is normally given in terms of the Building Energy Index or BEI. The South East Average BEI is 233 kWh/m²/yr whereby the Malaysian and Singaporean average are 269 kWh/m²/yr and 230 kWh/m²/yr respectively. The Malaysian Ministry of Energy, Green Technology and Water or previously known as the Ministry of Energy, Water and Communication (MEWC) before the year 2009; first introduced the Guidelines for Energy Efficiency in Non-Domestic Buildings in 1989 (Malaysia, 1989) which was meant to be a building code of practice. In the first version, the BEI was recommended to be not more than 135 kWh/m²/yr. In 2001, it was improved to include revised equations based on the latest research work on local buildings. As the energy efficiency awareness was beginning to set in at the time, the BEI of several new buildings began to demonstrate a decrease in value. The guidelines now were renamed as the Malaysian Standard MS 1525:2001 (Malaysia, 2001). The purpose of the MS were as follows: to encourage the design of new and existing buildings so that they may be constructed, operated and maintained in a manner that reduces the use of energy without constraining the building function.
nor the comfort or productivity of the occupants and with appropriate regard for cost considerations; to provide the criteria and minimum standards for energy efficiency in the design of new buildings, retrofit of existing buildings and methods for determining compliance with these criteria and minimum standards and to provide guidance for energy efficiency designs that demonstrate good professional judgment and exceeds minimum standards criteria. The standards were later improved in 2007 to include the following:

“To encourage the application of renewable energy in new and existing buildings to minimize non-renewable energy sources, pollution and energy consumption whilst maintaining comfort, health and safety of the occupants” (Malaysia, 2007).

As mentioned in the above sections, in Malaysia, building design is guided through the Malaysian standards MS 1525:2007 which sets out minimum standards for designers to design and select equipment above those stipulated in the code in the following areas (Zain-Ahmed, 2008b):

1. Architectural and passive design
2. Building Envelope
3. Lighting
4. Electric power and distribution
5. Air conditioning and mechanical ventilation (ACMV) system
6. Energy management control system

The architectural and passive design component provides further guidelines for the following:

1. Sustainable design approach
2. Passive design strategy
3. Site planning and orientation
4. Daylighting
5. Facade design  
6. Natural Ventilation  
7. Strategic landscaping  
8. Use of Renewable Energy  

In addition to energy efficient and passive design considerations, the MS 1525:2007 has included the applications of renewable energy relevant to buildings that should be incorporated are as follows:

1. Solar energy for heating, cooling, ventilation and lighting (daylighting)  
2. Photovoltaics for electricity  
3. Building integrated photovoltaics (BiPV)  
4. Integrated building devices such as photovoltaic shading devices  
5. Integrated passive solar and active systems for heating/cooling/lighting  

The inclusion of this particular section of the MS 1525:2007 which was not in the 2001 version was truly a milestone in the guidelines for actually taking into consideration the applications of “green technology”.

Green Building Index (GBI)

It is heartening to note that since the issues of climate change, global warming and the need to protect the environment, awareness among the public, researchers and professionals and policy makers has been steadily increasing from year to year. As recent as in the earlier part of 2009, a group of professionals in the building, construction and property industry got together to found the Green Building Index (GBI) (GBI Malaysia, 2009). Persatuan Arkitek Malaysia (PAM) and the Association of Consulting Engineers (ACEM) developed and introduced GBI on 3rd January 2009 and was officially launched by the Minister of Works, Malaysia; the Honorable Dato’ Shaziman Abu Mansor on 21st May 2009 (Abu Mansor, 2009). GBI, is a tool to classify green buildings using six
GREEN TECHNOLOGY AND SUSTAINABLE BUILDINGS

criteria: energy efficiency, indoor environment quality, sustainable site planning and management, materials and resources, water efficiency and innovation (ENSEARCH, 2009). The present GBI was developed specifically for commercial and residential buildings which will be rated as Certified, Silver, Gold or Platinum (GBI Malaysia, 2009). The rating of buildings is actually not novel as many countries have developed similar tools since the 1990's such as LEED and Energy Star in the USA, BREEAM in Great Britain, CASBEE in Japan, GREENSTAR in Australia and GREENMARK in Singapore (Tan, 2008). The only rating tool developed for tropical buildings is GREENMARK but it was customised for local consumption. Therefore, GBI Malaysia has been developed specifically for buildings in Malaysia. With GBI Malaysia being introduced in the local industry, it is envisaged that the greening of Malaysian buildings will escalate in the very near future as it has received tremendous response from the industrial players.

CURRENT R&D IN SUSTAINABLE BUILDINGS

Research and development (R&D) in Malaysian universities is heavily dependent on government funding. On the other hand, funding is dependent on the research area priorities and policies that are set to achieve national socio-economic and development goals. The current R&D funding is based on the national science and Technology Policy 2.

National Science and Technology Policy 2

The national policy states that the advancement of science and technology (S&T) must be maximized and utilised as a tool for sustaining economic development, the improvement of quality of life and national security. In relation to this, the policy is aimed at accelerating the development of S&T capability and capacity for national competitiveness by increasing the R&D expenditure to at least 1.5% of the Gross Domestic Product (GDP) and to achieve a
Green Technology and Sustainable Buildings

A competent workforce of at least 60 RSEs (researchers, scientists and engineers) per 10,000 labour force by 2010 especially in the science and technology fields. The investment in R&D up to 2000 was only 0.5% of the Malaysian GDP and this figure is grossly less than other developing countries. In order to address this discrepancy, the Malaysian Government set aside over RM 2 billion for R&D and commercialisation activities of R&D products to increase the country’s competitiveness. Among the many initiatives that have been taken under the S&T Policy is the development of a secure knowledge base in the key technology areas to sustain technology support for Malaysian industry namely: Advanced Manufacturing, Advanced Materials, Microelectronics, Biotechnology, Information and Communication Technology, Multimedia Technology, Energy, Aerospace, Nanotechnology, Photonics and Pharmaceuticals. These areas have been given priority status in terms of granting research awards to researchers and scientists. As a result, the research focus have been steered towards these areas and today, we now see an increase in R&D activities and outputs in the areas mentioned and notably in energy. In seminars around the country, researchers who have been recipients of such funding, disseminate their findings and results. These research outputs however, may find some difficulty in putting their products in the market as most of them are initiated by public and private universities. More efforts need to be taken to assist these researchers to mould them into technopreneurs or be given a helping hand in the process of commercialisation. At the same time, the private sector needs to invest or create smart partnerships with universities and the research institutions to create new products, designs, processes or services that can be quickly accepted by the public. Most R&D work in public universities is carried out without much help from the private sector or the industry. Perhaps in the area of R&D, more investment need to be made in the energy sector, be in for the discovery of new and alternative energy sources or in energy efficiency or in the design of sustainable buildings and townships (Zain-Ahmed, 2008b).
Sustainable Buildings R&D at Universiti Teknologi MARA

Presently, many public and private universities have embarked on various research and development work in sustainable buildings or energy-efficient building technologies for future applications in buildings. As an example, the Centre for Research and Innovation in Sustainable Energy (RISE) at Universiti Teknologi MARA was established to conduct research in the development and innovation of new technologies and its research fellows have embarked on several major projects. The major findings are outlined below:

Solar Energy Fundamentals

One can never underestimate the power of studying fundamentals as they shall determine whether certain technologies can work in climates such as in Malaysia. In order to develop solar technologies or innovate, one needs to measure or estimate empirically the energy received at any location. The author has done much work in solar modeling as reported here and elsewhere.

The daily global solar irradiation is the sum of the beam and diffuse irradiation

\[ H_g = H_b + H_d \]  \hspace{1cm} (1)

The hourly global irradiation may be determined by the equation (Whillier, 1956, Collares-Pereira and Rable, 1979);

\[ \frac{I_g}{H_g} = \frac{I_o}{H_o} (a_3 + b_3 \cos \omega_i) \]  \hspace{1cm} (2)

where

\[ \omega_i = \text{mid-hour angle} \]
\[ a_3 = 0.409 + 0.5016 \sin (\omega_i - 60^\circ) \]
\[ b_3 = 0.6609 - 0.4767 \sin (\omega_i - 60^\circ) \]
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The solar constant is the extraterrestrial solar radiation when the distance between the sun and the earth is one astronomical unit (1 Å). The value taken in this work is 1367 W/m² which is the value recommended by the World Radiation Center (WRC) (Iqbal, 1987).

\[ I_{sc} = 1367 \text{ W/m}^2 \] (3)

The extraterrestrial solar irradiation incident on the earth’s surface is

\[ I_{sc} = I_{sc} \times 3.6 = 4921 \text{ kJ/m}^2 \] (4)

Hourly Extraterrestrial Solar Irradiation

\[ I_o = I_{sc} E_o (\sin \delta \cos \phi + \cos \delta \cos \phi \cos \omega) \] (5)

Daily Extraterrestrial Solar Irradiation

\[ H_o = \frac{24}{\pi} I_{sc} E_o \left[ \frac{\pi}{180} \omega_s (\sin \delta \sin \phi) + (\cos \delta \cos \phi \sin \omega_s) \right] \] (6)

These equations have been validated (Zain-Ahmed, 1991) and found to be accurate to less than 5% error for the location of Petaling Jaya, Malaysia.

The characteristic day is the day number in a particular month when the daily extraterrestrial irradiation equals that of the monthly average daily value of that month. For Malaysia the characteristic day for each month from January until December are respectively 17, 15, 16, 15, 16, 11, 17, 16, 16, 16, 14 and 11 (Zain-Ahmed et al., 1992). The solar angles and the corresponding irradiation values were then calculated based on these day numbers to represent the average values for a particular month. Similarly, the characteristic day numbers were also used to select the hourly cloud cover (CC) values in the succeeding modelling process.
Page (1961) produced a mean regression equation for data from 10 stations worldwide and suitable for locations between latitudes between 40° N and 40° S for the monthly average daily solar irradiation. This equation is

\[ \frac{H_d}{H_g} = 1.00 - 1.13 \frac{H_g}{H_o} \]  

(7)

The three components of solar irradiation which are required to estimate daylight availability are the diffuse, beam (direct) and global components. The diffuse and beam components have been measured only at the Petaling Jaya (3° 6' N) meteorological station during the periods from 1990 to June 1995 and these data were used in the modeling process. A regression analysis was done on these measured data and this model was subsequently used to estimate solar irradiation values for Subang (3° 7' N) because of their proximity.

The monthly average daily global solar irradiation \( (H_g) \) values used were taken from the Model Year Climate (MYC) data. The monthly average daily extraterrestrial solar irradiation \( H_o \) was calculated from standard equations (Zain-Ahmed, 1993). The daily diffuse solar irradiation, beam and global solar irradiation have been analysed and their correlation was found to be

\[ K = 0.705 - 0.633 K_t \]  

(8)

where \( K = \frac{H_d}{H_g} \) and \( K_t = \frac{H_g}{H_o} \) for \( 0.40 < K_t < 0.51 \)

This model has been tested against the measured data and found to be 1.91% accurate. A previous study (Zain-Ahmed, 1991) was done based on 14 months of data from the same station and compared against the new model.

The 1991 model is given as

\[ \frac{H_d}{H_g} = 1.007 - 1.119 \frac{H_g}{H_o} \]  

(9)
The data available used for the study was made up of only 12 months of data (July 1989-June 1990) and therefore it was decided that the new model be used using the latest data for better accuracy.

The old model produces more than 10% error against the latest data, the Page (1961) model was only 16.88% accurate while Rao (1983) model underestimated the data. The Page model was developed for locations between 40°N and 40°S and the Rao model was based on 4 years of measured data in Singapore. This analysis shows that data accumulated during a longer period of time produces greater accuracy in estimation models.

The hourly global solar irradiation, $I_g$, was estimated using the Collares, Pereira and Rabl model (1983) and has been reported in detail by Zain-Ahmed. The hourly diffuse solar irradiation was estimated from

$$r_d = - 0.0005 + 1.2926(r_t) - 2.5283(r_t)^2$$  \hspace{0.5cm} (10)

where

$$r_d = \frac{I_d}{H_d} \text{ and } r_t = \frac{I_g}{H_g}$$

This model was produced using the Gauss Elimination with Partial Pivoting Technique (Zain-Ahmed and Bahari, 1992) with 2% accuracy. Alternatively, the equation below can be used to estimate the monthly average hourly diffuse solar irradiation (Whillier, 1956, Liu and Jordan, 1960):

$$\frac{I_d}{H_d} = \left[ \frac{\pi \cos \omega_t - \cos \omega_s}{24 \sin \omega_s - \frac{\pi}{180} \omega_s \cos \omega_s} \right]$$  \hspace{0.5cm} (11)

where Equation 9 was used to estimate $H_d$.
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The predicted monthly mean hourly solar irradiation on horizontal surfaces for the month of March (month with maximum peak values), December (the month with minimum peak values) and June (month with peak mean value) are shown in Figure 7. The sun is over the equator in March and September and furthest from the equator in June and December. The heavy rainy season occurs towards the end of the year making November and December the coolest months or the months with the least solar irradiation. As a result the highest solar irradiation falls at the beginning of the year, during the drier months, especially in February.

Solar irradiation on inclined surfaces is extremely important for thermal analyses on building walls. The estimation and simulation are as follows:

The hourly extraterrestrial solar irradiation on inclined surfaces with tilt angle $\beta$ and at arbitrary orientation $\gamma$ is given by
\[ I_{\text{o}_\beta\gamma} = I_{\text{sc}} E_0 \left( \sin \phi \cos \beta - \cos \phi \sin \beta \cos \gamma \right) \sin \delta + \left( \cos \phi \cos \beta + \sin \phi \sin \beta \cos \gamma \right) \cos \delta \cos \omega_1 + \cos \delta \sin \beta \sin \gamma \sin \omega_1 \]

(12)

The daily extraterrestrial solar irradiation on slopes is estimated using Equation 12 and integrated from 7 hours to 19 hours to produce

\[
H_{\text{off}} = \frac{12}{\pi} I_{\text{sc}} E_0 \left( \cos \beta \sin \delta \sin \phi \left| \omega_{ss} - \omega_{sr} \right| \frac{\pi}{180} \right) - \sin \delta \cos \phi \sin \beta \sin \gamma \left| \omega_{ss} - \omega_{sr} \right| \frac{\pi}{180} \\
+ \cos \phi \cos \delta \cos \beta \left| \sin \omega_{ss} - \sin \omega_{sr} \right| \\
+ \cos \delta \cos \gamma \sin \phi \sin \beta \left| \sin \omega_{ss} - \sin \omega_{sr} \right| \\
+ \cos \delta \sin \beta \sin \gamma \left| \cos \omega_{ss} - \cos \omega_{sr} \right| 
\]

(13)

where
\[
\omega_{ss} = \text{sunset angle} \\
\omega_{sr} = \text{sunrise angle}
\]

The sunset and sunrise angles may be solved using trigonometry (Klein, 1979).

The radiation ratio is used to convert irradiation data on horizontal surfaces onto inclined surfaces. The hourly ratio \( r_b \) and the daily ratio \( R_b \) are the ratio of the hourly irradiation on a slope to the hourly irradiation on a horizontal surface and the daily ratio is the ratio of the daily irradiation on a slope to the daily irradiation on a horizontal surface.
\[ r_b = \frac{I_{o\theta \gamma}}{I_o} = \frac{\cos \theta}{\cos \theta_z} \tag{14} \]

\[ R_b = \frac{H_{o\theta \gamma}}{H_o} \tag{15} \]

Diffuse solar radiation on slopes may be estimated using hourly diffuse solar irradiation or daily diffuse solar irradiation. The anisotropic model (Hay, 1979) gives the hourly diffuse irradiation as

\[ I_{o\theta \gamma} = I_d \left[ \frac{(I_g - I_d)}{I_o} r_b + \frac{1}{2} (1 + \cos \beta) \left\{ 1 - \frac{(I_g - I_d)}{I_o} \right\} \right] \tag{16} \]

The isotropic model (Klucher, 1979) gives

\[ I_{o\theta \gamma} = \frac{1}{2} I_\rho (1 - \cos \beta) \tag{17} \]

where \( \rho \) = ground albedo

The Hay and Klucher models may be integrated to produce the diffuse irradiation on slopes and the respective equations obtained as below:

\[ H_{d\theta \gamma} = H_d \left[ \frac{(H_g - H_d)}{H_o} R_b + \frac{1}{2} (1 + \cos \beta) \left\{ 1 - \frac{(H_g - H_d)}{H_o} \right\} \right] \tag{18} \]

and

\[ H_{d\theta \gamma} = \frac{1}{2} H_\rho (1 - \cos \beta) \tag{19} \]
Similarly, the global solar irradiation on slopes may be estimated via hourly global solar irradiation or daily global solar irradiation. The hourly global irradiation on slopes is the sum of the hourly diffuse and hourly beam irradiation to gives:

\[
I_{gb} = (I_g - I_d) r_b + I_d \left[ \frac{(I_g - I_d)}{I_o} r_b + \frac{1}{2} (1 + \cos \beta) \right] + \frac{1}{2} I_g \rho (1 - \cos \beta)
\]

(20)

And the daily global solar irradiation on slopes is shown below:

\[
H_{gb} = H_d \left( \frac{H_g - H_d}{H_o} \right) R_b + \frac{1}{2} (1 + \cos \beta) \left[ 1 - \frac{(H_g - H_d)}{H_o} \right] + \frac{1}{2} H_g \rho (1 - \cos \beta)
\]

(21)

The hourly solar irradiation on slopes can then be used to estimate the incident solar irradiation on vertical surfaces and windows for thermal analyses. If the inclination of the plane is taken as 90°, therefore \( \cos \beta \) becomes zero. The results of the simulation of solar irradiation on vertical surfaces are shown in Figures 8 to 11.
Figure 8: Solar Irradiation on Vertical Surfaces Facing NE, SE, SW and NW in March.

Figure 9: Solar Irradiation on Vertical Surfaces Facing NE, SE, SW and NW in June.
Figure 10: Solar Irradiation on Vertical Surfaces Facing NE, SE, SW and NW in December

Figure 11: Solar Irradiation on Vertical Surfaces Facing N, S, E and W in March
Figure 12: Solar Irradiation on Vertical Surfaces Facing N, S, E and W in June

Figure 13: Solar Irradiation on Vertical Surfaces Facing N, S, E and W in December
It can be seen from the above figures that southwest and southeast facing vertical walls are exposed to a maximum of at least 300 Wh/m$^2$ in December, northeast and northwest facing walls in June. In March, the walls that face southeast, southwest, northwest and northeast directions can receive a maximum of solar irradiation of at least 250 Wh/m$^2$. The east and west walls receive a maximum of 250 Wh/m$^2$ in December and June and 200 Wh/m$^2$ in March. Solar irradiation data may then be used in the estimation of illumination for daylighting studies and applications.

**Daylight modelling**

In the design of sustainable buildings, an area of importance is the use of natural light from solar radiation (i.e. daylight from the sky dome) to complement, supplement or even replace electric lighting. Although the use of daylight is nothing new, man has almost forgotten its use in modern buildings. Daylighting in buildings can actually enhance its aesthetic value and at the same time reduce the need for artificial lighting. In the long run daylight is natural, clean and environmental-friendly as it does not produce GHGs. To design effectively, one needs to know the amount of light available from the sky at any time. It was only in the last ten years that some information about the conditions of the Malaysian sky is known as far as daylighting is concerned. Many researchers have studied the amount of solar radiation that reaches the ground and these data have been used in the design of solar thermal and photovoltaic systems. Such climatic data are also required for simulations of thermal loads in buildings. Design for daylight also requires climatic data but unfortunately, the sky luminance and illumination that is received on surfaces are not measured systematically anywhere in Malaysia. As such, mathematical methods had to be searched that enabled the estimation of illumination values. The authors have used established semi-empirical equations to produce hourly illumination data from measured hourly solar radiation and cloud cover data. Fortunately, these data are measured at most meteorological stations in Malaysia. These illumination values were then checked for accuracy using real data measured during a short period of time and found to be satisfactory. However, we recommend that for future research and
Our studies established that the Malaysian sky is mostly cloudy, but not necessarily overcast. The sky is overcast only during the early part of the morning, before 8 am and late in the evening around 6 pm and after. The sky is also overcast just before and during rain. The sky is only sometimes clear when there are no or minimum clouds. The Malaysian sky is therefore, predominantly intermediate in nature as defined by most daylighting literature. The Commissione Internationale l’Eclairage (CIE, 1973) or International Daylighting Commission sets the range of illuminances for this type of sky as between 20,000 to 100,000 lux. The author has produced a daylight availability chart for the Klang Valley as shown below. These values indicate that there is plenty of daylight to be utilised for visual comfort. For example, in the months of February, March and April, the outdoor illumination can reach above 80,000 lux at mid-day. Even during the hours from 7:00-8:00 am and between 4:00-5:00 pm, the illuminance range between 20,000-40,000 lux.

Figure 14: Hourly Global Illuminance in Malaysia
The estimation of outdoor illuminance is aimed at producing site specific mean global luminous efficacy. The Klang Valley uses meteorological data from the Subang station which is about 10 km away from the city of Shah Alam and 15 km from Kuala Lumpur. Global solar irradiation data is available from this station and global illuminance may be derived from solar irradiation data using global luminous efficacy, $K_G$.

The global luminous efficacy is best determined using field measurements of illuminance and irradiance simultaneously. However, it is not always possible to capture illuminance data routinely as illuminance data are not commonly used by many. Similarly, direct and diffuse irradiation data are not standard measurements in Malaysia. Although it is possible to use the DPP Model (Du Mortier, 1994) to estimate illuminance in Malaysia, the unavailability of direct and diffuse irradiation data makes this exercise difficult.

It is therefore recommended that the global efficacy value can now be used to estimate the global illuminance from global irradiance data that are available from most major meteorological stations in Malaysia (Zain-Ahmed, 2007). Architects especially, require such data for daylighting considerations in their designs.

The luminance and global illuminance data may be estimated by

$$L = 112 \times R$$  \hspace{1cm} (22)

$$IL_g = 112 \times I_g$$  \hspace{1cm} (23)

Where $L$ is the luminance, $R$ is the radiance and $IL_g$ is global illuminance.

The estimation of interior illumination is not simple, however. The western countries have developed their own design aids to calculate indoor illumination levels and they may be divided into...
two categories namely mathematical and graphical. Mathematical equations have been established for the clear and the overcast skies. A sophisticated mathematical model has been developed by Perez et al., (1990) for all skies but it still requires some input climate parameters that are not easily available in Malaysia. Other than those, the design aids such as protractors, nomograms, charts and tables exist only for the two mentioned sky types. Sophisticated computer simulation tools are also available, but some are not suitable for daylighting design under Malaysian skies, while others are more difficult, but not impossible, to use. Physical simulation of daylighting performance may be done by using sky simulators and other modelling methods. All these techniques aid the designer to analyse and visualise daylight performance in buildings early at the design stage.

Malaysian designers need such tools or aids to make use of daylight in architecture. The researchers in UiTM have produced a nomogram, tables and overlays but they are limited to unglazed window openings.

1. **Daylight footprints**
   An example of an overlay consisting of daylight footprints, is given in Figure 15. This overlay represents the daylight footprint of a window with 10% window opening to floor area. In daylighting design, the overlay can be placed over a room plan with the centre of the overlay over the centre of the intended position of the window. Several overlays to represent illuminance levels produced by several other windows can be used simultaneously. The total illuminance at a point on the work plane (normal table level) is the algebraic sum of the illuminance from each window at that point.

2. **Charts**
   Examples of illuminance charts are given in Figure 14. These are hourly illuminance levels produced in each month of the year on vertical surfaces in the Klang Valley. These charts
may be used with standard equations to predict the average indoor due to windows. The normal input parameters would be room surface reflectances, transmittance value of the glazing, window area and total wall and floor areas.

![Figure 15: Sample Design Overlay of Two Daylight Footprints](image)

3. **Distribution Table**

   Distribution tables are also useful in the determination of window opening sizes in the form of window-to-wall ratio (wwr) and glass types for making decisions in designs incorporating daylighting in buildings. An example of a distribution table for daylight factors (DF) has been developed by Ibrahim and Zain-Ahmed (2006) using established modeling tools.
Sustainable Building Technologies

These projects have produced a few innovative technologies such as a fiber optic daylighting system (Sulaiman et al., 2005), solar assisted integrated lighting and ventilation system (Ahmed et al., 2006) as shown in Figure 17, an insulation material based on oil palm empty fruit bunches (Figure 18) for roofing and potential building materials (Mohd Noor et al., 2006). Currently, an advanced polymer for energy efficient glazing material is being developed, its properties tested and in the near future to be laminated and tested on the field. Advanced solar cells using nanotechnology is also being studied using local organic materials as a base (Mohamad et al., 2007). RISE has also collaborated with a local construction company (Putra Perdana Sdn Bhd) to build twin test cells for energy performance tests of building materials and new technologies. During the time of writing, the test cells are being used in collaboration with a manufacturing association to test roofing insulation materials. In future the Twin Energy Efficiency Test Cells (Figure 19) shall become part of a research facility for tropical buildings which would be the first in the ASEAN region.
Integrated Daylighting and Natural Ventilation System (LiteVent)

Achieving thermal comfort without the use of mechanical means in hot and humid climates is a great challenge. Bioclimatic analyses of this type of climate have indicated that there is a need for both ventilation and dehumidification besides cooling (Zain-Ahmed, 1998b). Passive solar systems utilizes natural resources such as solar and wind and these may be used for lighting and cooling of buildings. Passive solar systems are therefore “green”. The use of natural ventilation itself may not lead to the reduction of air temperatures but at least a cooling effect can be produced from the air movement. The movement of air also assists in the reduction of air humidity. In the case of lighting, the visual spectrum of the solar radiation is actually the best source of natural lighting and careful use of this renewable source can reduce the dependence on electrical lighting. The system developed was based on a daylighting tube but modified to include a channel for natural ventilation to occur. The result of this innovation system consists of a ventilation component and a daylighting component (Figure 17).

Figure 17: Integrated Daylighting and Ventilation System
Figure 18: EFB Based Insulation Material

Figure 19: Twin Energy Efficiency Test Cells
1. The Ventilation System

The ventilation channel is a rectangular tube of width 10 cm and height 1.65 m. It is made up of a hollow concentric interior of 20 cm in diameter designed to provide natural light into spaces. The study was conducted with these particular dimensions as they were found to be the most optimum dimensions in providing air flow to the interior, without negative aesthetic impact (Abdul Rahman et al., 2004). The channel is easily placed through a normal roofing structure and is made from a light metal material. The upper end protrudes through the top of the roof while the lower end is exposed to the building space below as shown in Figure 20.

Figure 20: The integrated Daylighting and Natural Ventilation System
Preliminary simulation results using a computational fluid dynamics software have shown that the mean temperature inside the air channel was found to be relatively higher and sufficient to create the necessary stack effect for the creation of air movement within the interior, even as early as 0800 hrs local time (Figure 21).

Results also show that as the temperature in the air channel increases, so does the pressure difference between the occupied space and the air channel, consequently increasing the air change rates (ACH). The mean air change rate throughout the day was found to be about 2.8 ACH, with a minimum of 0.7 ACH at 0800 hrs as shown in Figure 22.
On the average, the airspeed inside the occupied spaces of the room was found to be about 0.04 m/s (Figure 23) when there is no wind (ambient air speed is 0 m/s). The minimum airflow needed for cooling sensation of the skin is 0.2 m/s therefore, if there is no wind, the indoor air speed is very low. The indoor air speed should increase when there is a presence of wind.
2. **The Daylighting System**

The inner surface of the hollow cylinder is laminated with polycarbonate, a highly reflecting material. This is the most crucial part of the daylighting system incorporated in the natural ventilation channel. The top is covered by a specially-designed plastic dome exposed to the sun. The bottom part of the tube acts as a light emitter, also made of plastic material similar to lighting fixtures.

The daylighting system, which is also called a light pipe, was tested for its performance in real room conditions. The skylight was installed in a test room with a floor area of 4.5 m x 4.5 m and wall height of 3.05 m. The floor was divided into 9 x 9 grids with each division measures an area of 0.5 m x 0.5 m.
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The room has two windows, one each on two perpendicular walls (north and east-facing). The room also has a door which was kept closed during experiments. Measurements of indoor illuminance were made in the study to assess its performance under normal sky conditions.

The study was divided into three cases. In the first case, the measurement of the illuminance was taken with both windows closed, so that the illuminance was totally from the light pipe. In the second case, the measurements were done on the illuminance from the widely opened windows only, with the light pipe temporarily blocked. In the final part, the measurements were carried out with the light pipe and both windows wide open. The exterior or outdoor illuminance was measured simultaneously to obtain the daylight factors for each point measured.

From these daylight factors, the indoor illuminance can be estimated by substituting the outdoor illuminance values from Climate Model Year data (Zain-Ahmed et al., 1998a). Some of the results are shown in the graphs of the illuminance (or daylight) distribution on a typical day in July at 1200 hrs as in Figures 24 and 25.

The results show that sufficient daylight is provided by such a system in combination with open windows. The illuminance levels exceed 500 lx on most positions. Better illumination can be provided if more of the systems are installed. This study shows that even in hot, humid climates where the skies are mostly cloudy, there is sufficient supply of natural light.
Figure 24: Daylight Distribution from Light Pipe Alone at 1200 Hrs in July

Figure 25: Daylight Distribution from Combination of Light Pipe and Windows at 1200 Hrs in July
3. Integration of daylighting and ventilation

When the ventilation system is integrated with the daylighting system, several problems can be solved simultaneously without additional cost. The above system provides indoor comfort which include thermal and visual aspects.

**Fibre optic daylighting system**

Another way of providing natural light into buildings is the use of fiber optic systems. Innovative daylighting systems that use light pipes or glass fiber optics to channel light captured with sun-tracking mirrors are not very economical. A cost-effective optical fibre daylighting system uses passive (i.e. non-tracking) daylight collector to concentrate sunlight into inexpensive large core polymer optical fibers; transmitting through and finally dispersion through end-emitters using the same material. This is one of the most direct methods of sunlight utilisation for passive indoor lighting. (Zain Ahmad et al., 2005)

1. **Passive daylight collector**

The passive daylight collector is simply made up of a perfectly-shaped hemisphere (Figure 26) either of single, double-glazed clear glass or translucent glass. The collector may also be made from the same material as the fiber optic which is highly polished at one end to create a hemisphere.

A simulation software, MATLAB version 6.0 was used to predict the equivalent transmittance, absorptance and reflectance of the dome daylight collector using various materials and solar incident angles (Sulaiman et al., 2003).
The mathematical model showed that transparent dome daylight collectors have the ability to gather less daylight at low sun incidence angles and more daylight at high sun incidence angles. Simulations such as these are important to designers as they provide tools to solve the trade-off between daylighting and thermal performance of passive daylight collector. From this study, it was found that the most practical size of the collector is 16 cm in diameter.

2. Transmission

After the daylight is collected, several options exist for transmitting light to the interior of buildings but for the tropical building studies, large-core optical fibers were used which transmit light via total internal reflection and are typically fabricated using flexible materials such as solid polymers, gels, and liquids. In this case the large core plastic optical fibers (LCPOF) were used as they are cheaper than glass optical fibers (Sulaiman et al., 2004).
The LCPOF consists of concentric double-layer structure consisting of a core of high purity poly-methyl-meth-acrylate (PMMA) resin and a thin clad of special fluoropolymer. Since the refractive index of clad is lower than that of core, the light that enters from one end is transmitted through the core by total reflection at the core-clad interface and is emitted from the opposite end (step index profile, multi-mode optical fiber). The refractive index of core used in the study is 1.475 and that of clad is 1.34. The numerical aperture, an angle at which an optical fiber can receive (or emit) the light at the end, is 0.6 with a light acceptance angle of 75°. Luminaires were then attached to the optical fibers where light exits from the system.

![Figure 27: Schematics of the Large Core Plastic Optical Fiber (Total Internal Reflection Occur at Points a, b and c)](image)

3. End-emitters

A model room of size 27 cm by 27 cm and height 32 cm was built to study the illumination performances of 1 m length end lit optical fiber (diameter 6 mm) connected to end piece luminaries. The end-emitters were fitted at the centre of the ceiling in model room.
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A light engine was used as the light source and the daylight factor method was used in the measuring process. The interior illuminance was measured at every 3 cm on the floorboard of the model room while the exterior illuminance from the light engine produced 200,000 lx. The experiments were repeated for different diameters of luminaires acting as emitters. The luminaire models and dimensions are shown in Table 2.

**Table 2: Luminaire Models and Sizes**

<table>
<thead>
<tr>
<th>Luminaire Model</th>
<th>Size</th>
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<tbody>
<tr>
<td>FO-015</td>
<td>26 mm x 50 mm</td>
</tr>
<tr>
<td>FO-016</td>
<td>22 mm x 46 mm</td>
</tr>
<tr>
<td>FO-017</td>
<td>12 mm x 32 mm</td>
</tr>
<tr>
<td>FO-010</td>
<td>50 mm x 57 mm</td>
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</table>

![Figure 28: Illuminance Due to Luminaire Size at 1200 Hrs in March](image)
From the experimental results, the daylight factors were calculated for each point measured. Then the indoor illuminance was estimated by using outdoor illuminance from the Model Year Climate data as input. It is shown that models FO-017 and FO-010 provide indoor illuminance of more than 200 lx at distances between 60 cm and 110 cm away from the plane perpendicular to the position of the emitter. This is just sufficient for infrequent reading and writing. If more illumination is required, it is suggested that more numbers of luminaires must be fitted.

The experiment was repeated with various diameters of fibers with polished ends as at the time of writing, luminaires of larger than 6 mm were not available. The sample results of the illumination distribution for a 14 mm fiber with polished end acting as the emitter during the months of March, August and December are shown in Figure 29. The peak indoor illuminance exceeds 500 lx for all months.

![Figure 29: Illuminance along Centre of Room at 1200 Hrs Due to 14 mm Fiber](image)
Experiments were also conducted for fiber diameters of 10 mm, 11 mm and 14 mm. The results are shown in Figure 30. Obviously, the 10 mm, 11 mm and 14 mm fibers can provide more than sufficient indoor illumination. However, the outdoor illuminance values used for the estimation indoor illumination are the maximum possible intensities at 1200 hrs during the month of March. The minimum outdoor values which occur during the month of December are about 75% of the March values. The month of December still provides sufficient indoor illuminance.

An economic evaluation of the fiber optic daylighting has been done and was found to be able to save more than 50% of the total energy consumed (Sulaiman et al., 2005). When the use of fiber optics become more popular and when the price of the fiber optic components is reduced, the total cost savings would be considerably reduced as well.
Daylighting is used in architecture for several reasons: to humanise the visual environment so that the building occupants could perform their tasks well; to reduce the energy demand for lighting and to reduce the cooling loads by influencing the ventilation and air conditioning plant size and peak electrical demand leading to energy savings and efficiency.

Daylight is desirable over artificial light because the quality and colour rendering produced by daylight is far superior. Human vision is adaptable and responds to the effects of colour, texture and light in architectural space. The human eye can then help the mind to orderly shape the environment in accordance to how it is perceived. As a result, daylighting can produce architecture of great beauty besides reducing the need for artificial lighting which generate heat and increase the cooling loads of buildings (Baker et al., 1993).

Innovative daylighting systems can also reduce heat gains and glare. In Southeast Asia, studies have shown that the use of daylighting can reduce overall energy consumption by 20% and also reduce the sensible heat load on air-conditioning (Jiraratatananon, 1987 and Hopkirk, 1994).

In toplighting techniques, daylight penetrates from apertures located above the ceiling line, usually as part of the roof. Toplighting is used in deep buildings such as warehouses, workshops, factories, markets and other public and single-storey buildings as shown in Figure 31.
Atria that have the roof part that allows daylight to penetrate through also use toplighting as a daylighting technique (Figure 32). Atria are now becoming very popular in tropical architecture. A recent post-occupancy daylighting performance study of more than 50 atria in Kuala Lumpur, Malaysia has contributed to the understanding of the suitability of atria built in hot, humid climates.

A study on tropical atria (Zain-Ahmed et al., 2004a) shows that there is a significant relationship between daylighting from skylights and indoor thermal comfort in top-lit atria for controlled environments. The indoor environment can be modified by using innovative designs that reduce the solar gains yet distribute sufficient lighting.

This section reports on three sample atria that are incorporated in a large, six-storey commercial building in the heart of Kuala Lumpur, the Suria Kuala Lumpur Commercial Centre or Suria KLCC, which forms part of the famed Kuala Lumpur Twin Towers.
The KLCC has five atria, the North and South Courts, the Centre Court and the Connecting Courts. All the atria are of the top-lit variety. In this study, three atria were chosen: the Centre Court, Connecting Court and North Court.

The Centre Court has a hexagonal skylight with "rays" diverging from its centre (Figure 33). The Connecting Courts are two top-lit atria that run between the Centre Court and North Court and between the Centre Court and South Court. They are not flat but hemispherical in cross-section as shown in Figure 34. The North Court has a simple circular skylight as shown in Figure 35. The three atria were chosen as they represent top-lit atria are similar in height and are similarly environmentally controlled. Top-lit atria are more exposed to direct solar penetration as opposed to other types such as side-lit atria or monitor skylights.
Figure 33: Centre Court Atrium

Figure 34: North Court Atrium
The daylighting performance of each atrium was determined by measuring hourly external (outdoor) illumination and indoor illumination every minute from 9 am till 6 pm.
Figure 37: Hourly Illumination at Centre Court

Figure 38: External Illumination during Connecting Court Experiment
Figure 39: Hourly Illumination at Connecting Court

Figure 40: External Illumination during North Court Experiment
The mean indoor illuminance and the mean outdoor illuminance were obtained and the daylight factor (DF) calculated for each atrium. Table 2 shows the mean DF% for each atrium.

<table>
<thead>
<tr>
<th>Atrium</th>
<th>Centre Court</th>
<th>Connecting Court</th>
<th>North Court</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean DF%</td>
<td>0.422</td>
<td>0.098</td>
<td>0.064</td>
</tr>
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In terms of daylight factors, the Centre Court performs best and the North Court worse. Although the Centre Court skylight has a smaller surface area than the Connecting Court, the light penetrating through the diverging "rays" design contributed to additional illumination on the atrium floor. However, despite the relatively low DFs produced by the skylights, the overall illumination provided is considered sufficient as it exceeds the minimum intensity for normal vision.

Figures 42-44 demonstrate that the indoor illumination is proportional to the outdoor illumination and fluctuations in the indoor illumination reflects the dynamic nature of daylighting.
Figure 42: Comparison of Outdoor and Indoor Illumination in Centre Court Atrium

Figure 43: Comparison of Outdoor and Indoor Illumination in Connecting Court Atrium
This study shows that passive solar systems and design applications can reduce the dependence on artificial or mechanical means for lighting and cooling of buildings. The first example showed that two systems can be integrated to provide lighting and cooling simultaneously. In addition to that, the system can be integrated into the roof without disturbing much of the aesthetics.

Similarly, the fiber optic daylight system can be easily be integrated into a building without major disturbances to the building construction itself while providing healthy natural light which is beneficial to both humans and the environment.

The third example of a passive solar system is not only a beautiful feature in the architecture of a building, but provides more than sufficient light into the space where lighting is a paramount importance. Further work in this area will include the evaluation of daylight and thermal performances of side-lit and naturally-ventilated atria.
Understanding the performance of buildings which are integrated with passive solar systems is vital in tropical regions in order to maintain indoor quality visual and thermal environments while preserving the outdoor environment and conserving depleting resources.

Indoor Air Quality

Indoor air pollution is one of the top four environmental risks to public health. Indoor air pollution, in fact is consistently reported to be two to five times and occasionally more than one hundred times higher than outdoor levels. There is reason for concern as the average person usually spends approximately 90% of their time indoors, 60% of which is spent at home (Hess-Kosa, 2002 and Meyer, 1983). Indoor air quality (IAQ) however is still a largely unexplored topic in Malaysia. This is regrettable because IAQ studies are in fact necessary in order to determine the health and thermal comfort levels of Malaysian buildings. To rectify this situation, a study on the IAQ in Malaysian homes was conducted (Zain-Ahmed et al., 2004b). Sustainable building design has a role in the alleviation of indoor gas emissions.

Three Klang Valley area homes were selected in this study to provide different IAQ environments. All the houses are 2 storeys high and have an average built-up area of 160 m². They have one master bedroom with an attached bathroom, 2 bedrooms with shared bathroom, storeroom, living room, family room, dining room and a kitchen. All the houses chosen have louvred windows and the main rooms have ceiling fans for cooling and ventilation.

Indoor air measurements were taken in the living room, bathroom, kitchen, family room and bedroom of each home. The indoor air parameters selected for this study were CO₂, CO and air velocity which are the most basic and critical factors for IAQ. CO₂ and air velocity are indicators for the ventilation system’s effectiveness; and relative humidity and temperature are thermal comfort indicators.
The continuous CO₂ data collection for each room in all four homes were compared with the completed time activity diaries. The highest peaks were observed in the bathroom of the Shah Alam bungalow early in the morning and in the family room of the Klang terrace house late at night (Figure 45). Internationally accepted standards recommend CO₂ air quality guideline of 1000 ppm. This guideline value was exceeded on two occasions: (i) early in the morning in the bathroom of the Shah Alam bungalow and (ii) late at night in the family room of the Klang terrace house. The high CO₂ indoor level in both situations were due to poor ventilation since both rooms lacked windows and ventilation fans, which allowed the build-up of unhealthy levels of CO₂ following a period of heavy use of both rooms by the occupants.

The highest concentration of CO₂ was also recorded in the family room of the terrace house. It was also noted that the size of the room was smaller as compared to that in the other types of houses. CO₂ levels were generally highest in the bathroom and bedroom in all four monitored homes. More research is definitely required regarding IAQ to help us understand about the impact of building design on the indoor environment.

Figure 45: Variation of CO₂ Concentrations at the (i) Family Room of Klang Terrace House and (ii) Bathroom of Shah Alam Bungalow
Energy Performance of Buildings

Twin Test Cells have been built in the main campus of Universiti Teknologi MARA in Shah Alam (as shown in Figure 19). It is meant to be multi-purpose experimental outdoor laboratory using typical building materials. The Test Cells are modular in nature where their roof and wall orientations are flexible. Turntables are built under the two cells so that the building orientation may be varied according to the needs of the experiments. Currently experiments are being conducted in collaboration with a local manufacturing conglomerate. A well-known insulation material to reduce energy consumption in buildings is being conducted. The study seeks to evaluate the whole-building building thermal and energy performance insulated roof at several roof pitch angles. One Test Cell was used as a control unit while the second Test Cell was modified with the installation of insulation of thickness 75 mm at roof pitch angles of 10°, 15° and 20° respectively. Both cells were installed with a 750 W split unit air-conditioning system. Identical automated outdoor and indoor data logging systems were installed to measure the thermal and energy performance of the insulated cell (Syiful Irwan et al., undated). Interestingly, it was found that the optimum roof pitch is 10°. At this roof angle the energy saved per day is almost 0.8 kWh or 4% as shown in Figure 46. These figures may seem small but if calculated for one month’s savings, the amount is certainly significant.
Current work being carried out is the development of insulation material using Oil Palm Empty Fruit Fiber (EFB) (see Figure 18) of which the objective is to surpass the energy and thermal performance of this material against established materials. EFB is biowaste and therefore turning EFB into a useful thermal barrier to reduce air conditioning needs is a “green” process. Preliminary results of this new material is very promising and the current research team hopes to develop the product even further to convert the EFB into building walls, floors and other energy efficient material.

CONCLUSION

This paper has briefly explained the main cause of climate change and in particular the resulting phenomenon of global warming. Suggestions on the possible solutions have been made through the samples of R&D carried out by researchers at Universiti Teknologi MARA. The present critical mass is already capable of conducting research in critical areas coupled with strong knowledge in the fundamentals. R&D shall flourish if more academics indulge in these important areas especially when supported by funds and in collaboration with the industry.
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At the national level, barriers that hinder the development of sustainable sources and technologies need to be removed. More appropriate incentives (i.e. tax deduction on renewable energy technology, improved financing and green fund) need to be introduced to promote the utilization of renewable energy. Other than that, the capacity of key players needs to be enhanced as well. These key players include government decision-makers, industries, utilities, financial institutions and universities.

In the energy sector, the policies and strategies are already in place to diversify energy sources and power in general. Incentives have been given to various sectors especially in the development of biofuels, solar and photovoltaics. In the building sector, there needs a firmer policy and focused strategies to increase the acceptance of energy efficiency measures and the use of sustainable approach to building design and construction. The only strategies that have been out in place is the MS 1525:2007 which in reality is not mandatory and the introduction of the Green Building Index Malaysia. It has also been suggested that innovative financing from international bodies need to be solicited.

Finally, perhaps there is an urgent need to create a National Energy and Environment R&D Policy to strengthen or consolidate current policies where there exist weaknesses or lacks specific initiatives to improve the energy solutions. The introduction of the National Green Technology policy is a promising step forward for this nation. For researchers, more emphasis must be given to R&D funding for the energy and environment area. With these added incentives, R&D shall grow faster and be more productive in the long run. SIRIM Berhad has taken a positive step forward by bringing together academics, researchers, policy makers and industry players to a Technology Foresight Workshop on Clean and Sustainable Energy Roadmap from 27th to 28th July 2009. The main objective of the workshop was to brainstorm on the priority areas for the development of green technology. The rest lies on the government and the industry to stimulate growth in Green Technology R&D.
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