

Report

Solar technology and building implementation in Malaysia: A national paradigm shift

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Received: 20 December 2010 / Accepted: 17 May 2012 / Published: 22 May 2012

Abstract: Solar technology is becoming increasingly popular. For example, the production of solar cells quadrupled in the 1999-2004 period, with a capacity of four gigawatts worldwide. Renewable energy including solar power produces few or no harmful emissions and it is becoming increasingly important to exploit it in the future. This paper presents a literature review of the application of numerous types of solar technology in buildings in Malaysia and identifies the challenges faced. Although several newly constructed green buildings use solar technology, Malaysia has yet to accept it wholesale. If solar technology is to be adopted widely, then both public and private sectors must cooperate to provide large-scale financial incentives and produce specialists in solar technology. As the first step, the government has established the Low Energy Office and the Green Energy Office, which use passive solar design and photovoltaic systems in their own buildings. However, the private sector has yet to follow suit. It is anticipated that the application of solar technology in buildings will encourage sustainable development when all non-renewable energy sources decrease significantly. If people do not recognise the potential of such technology in daily life, it will soon be too late.

Keywords: solar technology, photovoltaics, solar energy application, Malaysia, sustainable development.

INTRODUCTION

Solar energy is the most promising source of clean, renewable energy and it has the greatest potential of any power source to solve the world's energy problems [1, 2]. In Malaysia, the climatic

conditions are favourable to the development of solar energy, with abundant sunshine throughout the year. The annual average daily solar radiation is 4.21-5.56 kWh/m² [3]. The highest solar radiation is estimated at 6.8 kWh/m² in August and November, and the lowest is 0.61 kWh/m² in December. The northern region and a few places in eastern Malaysia have the highest potential for solar energy application, with particularly high solar radiation throughout the year.

A photovoltaic (PV) system, a source of solar power, consists of several solar cells that convert light energy into electricity [4]. It is an elegant means of producing electricity on site, directly from the sun without concern for fuel supply or environmental impact. Solar power is produced silently with minimum maintenance, no pollution and no resource depletion. The PV system is also exceedingly versatile and can be used to pump water, grind grain and provide communications and village electrification where electricity is unavailable [5]. Currently, most solar energy applications are for domestic hot water systems, water pumping and drying agricultural produce [6]. Most of the solar power used in Malaysia is at the domestic level; it is estimated that over 10,000 units of domestic systems are using the PV system at present while large-scale commercial use is insignificant. Although the PV system has tremendous potential, especially for remote areas in Malaysia, the cost of PV panels and associated technology is extremely high for mass power generation. The current market value of a PV system is about RM 28.00 (US\$ 8.40)/Wp [7]. Malaysia has no local solar cell manufacturers and all the PV modules and inverters are imported from countries such as Germany and Japan at a very high cost. As a result, PV systems are not an attractive option for the Malaysian public.

In 1995, a 100-kilowatt peak (kWp) demonstration photovoltaic project was implemented under the initiative of the Ministry of Energy, Water and Communications in Marak Parak, Sabah, heralding a good start for an effective and efficient transfer of PV power generation technology in Malaysia [6]. In order to reduce the cost of the PV systems, in 2005 Malaysia carried out the Malaysia building integrated photovoltaic (MBIPV) project, funded by the government, the global environment facility disbursed through the United Nations development programme (UNDP/GEF), and various private investors [8]. The principal objective of this project was to reduce the long-term cost of building-integrated photovoltaic (BIPV) technology within the Malaysian market, leading to sustainable and widespread BIPV technology applications that avoid greenhouse gas emissions. Over the lifetime of the project, the energy generated will prevent 65,100 tons of CO₂ emissions from the country's power sector [9]. The project is expected to result in a 330% increase in BIPV applications from the 2005 baseline. The full project addresses in an integrated manner the long-term cost reduction of BIPV technology and the adoption of supportive regulatory frameworks to establish the desired environment for a sustainable BIPV market [2]. After the BIPV programme was introduced in 2005, the cost of BIPV dropped to US\$ 6500/kWp—a reduction of 40% by 2010 compared to the 2005 cost, as shown in Figure 1.

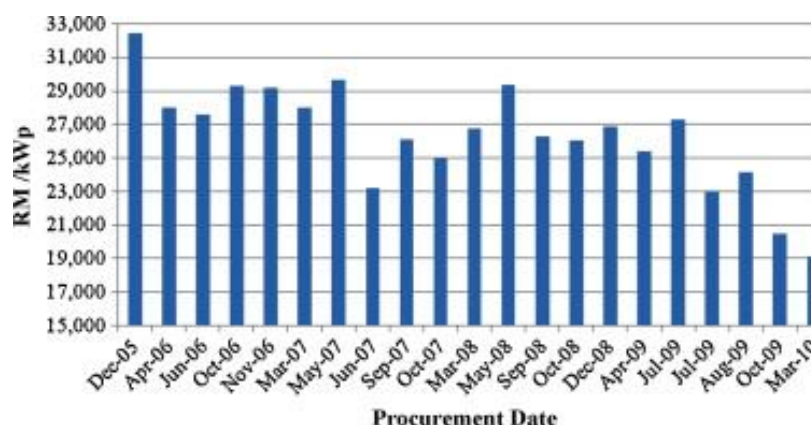


Figure 1. Average BIPV price/kWp from 2005 to 2010 in Malaysia [7]

Another national MBIPV programme, SURIA 1000 [9], which is targeting the residential and commercial sectors, will consolidate the new BIPV market. SURIA 1000 will enable the public and industry to be directly involved in renewable energy and environmental protection initiative. Since 2007, a limited number of grid-connected solar PV systems have been offered to the public through a bidding (auction) system, with a minimum BIPV capacity of 3 kWp per application. Successful bidders install the building-integrated PV system at their premises; the cost of each PV system is borne by the successful bidder at the bidding price and supplemented by the project. This programme is co-financed by the public, the Malaysia Energy Commission and the PV industry. It is expected that PV suppliers will finally offer BIPV system prices equivalent to those in Europe and Japan. Nowadays, the cost of a 5-kWp BIPV turn-key roof-top system in Malaysia is about RM 27,000/kWp; thus, a 5 kWp BIPV system is estimated to cost RM 135,000. This will facilitate the creation of a sustainable BIPV market upon the completion of the programme. The system will produce approximately 6,000 kWh of energy per annum [10].

SOLAR HEATING SYSTEMS IN MALAYSIA

Ali et al. [11] noted Malaysia's suitability for harnessing solar energy and developing solar technology due to the availability of sunshine. Domestic hot water systems are very popular in Malaysian households, but because of the high initial cost of solar water-heating systems, many are still opting for electric water heaters, which are affordable and easy to install. However, recent figures show that the annual cost of an electric water heater is greater than the cost of a solar water-heating system in a longer term, after 4-6 years. With Malaysia's increasing population, solar water-heating systems will have long-term economic benefits; they are environmentally friendly and play a role in reducing the country's increasing dependency on foreign oil.

The development of a solar-assisted heat pump (SAHP) for hot water supply was described by Hamllaoui et al. [12] and Chowa et al. [13]. The SAHP system [13] (as shown in Figure 2) adopts the vapour compression-refrigeration cycle. The working fluid (refrigerant) passes through the compressor, condenser, capillary tube, evaporator and solar collector in turn, with corresponding thermodynamic-state points denoted 1-5 respectively. The condenser is basically a water storage tank with a submerged heat transfer coil for refrigerant flow from state point 2 to 3. The liquid

refrigerant vapourises at the capillary tube to state 4 and evaporates at the evaporator-collector, where point 5 indicates the saturated vapour condition. The superheated refrigerant vapour at state 1 enters the reciprocating compressor and leaves at a higher temperature and pressure located at point 2 [13]. It was found that it is possible to heat water to 55°C at night with the energy available from the ambient surroundings. Figure 3 compares the annual costs of electric water heaters and solar water heating systems [11].

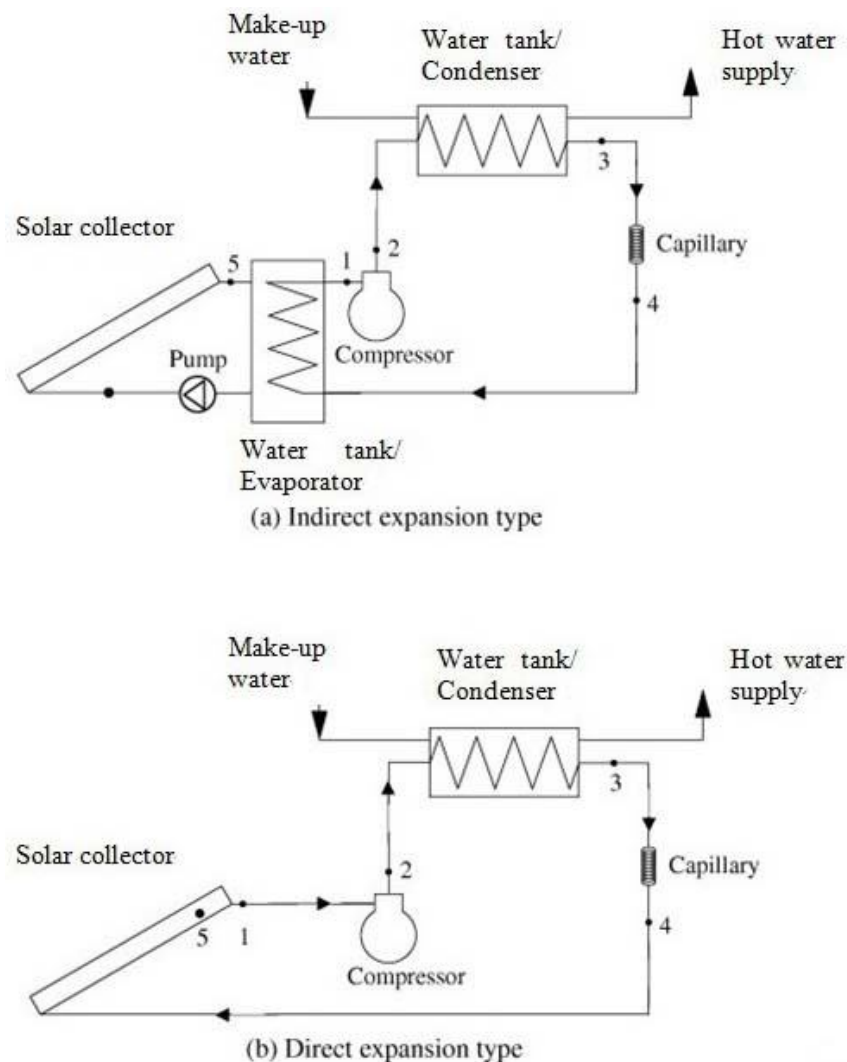


Figure 2. Diagram of SAHP [13]

PASSIVE SOLAR DESIGN IN MALAYSIA

Beggs [14] described a solar-assisted air-conditioning system, a 'mixed-mode' method of addressing the high energy consumption in Malaysia. This system used the heat from solar radiation to drive a thermally-driven chiller such as an absorption chiller, which produced chilled water for indoor cooling purposes. According to MS 1525 [15], a Malaysian standard for green building index, designing with an emphasis on natural daylight should be considered at the preliminary design stage. Conventional and innovative daylight systems that collect, transport and distribute

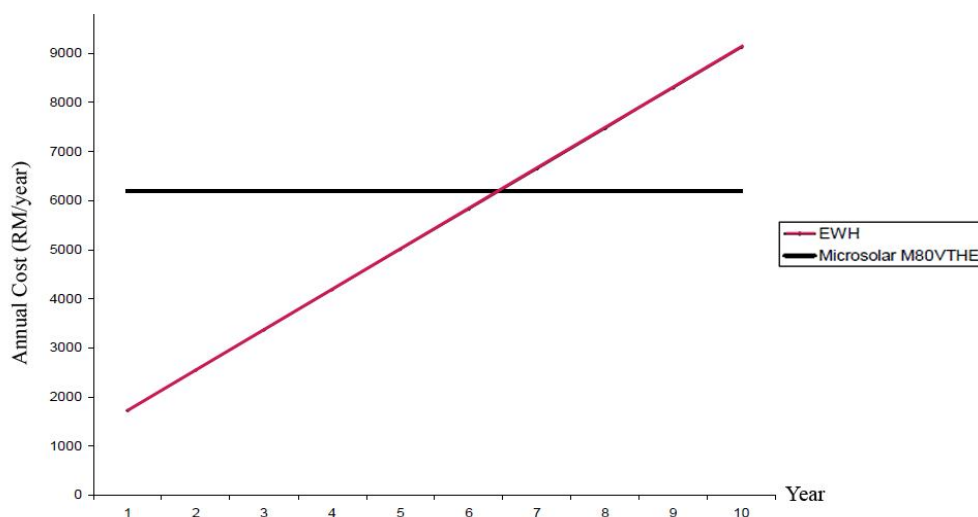


Figure 3. Comparison of annual costs of electric water heater and solar water heating system [11]. EWH stands for electric water heater and ‘M80VTHE’ is a common brand of solar water heater whose capacity is 0.285 m³ and 0.340 m³ respectively.

light deep into buildings to reduce the need for artificial lighting are recommended. The low energy office (LEO) building in Putrajaya, built as a demonstration project by the Ministry of Energy, Water and Communication, was first occupied in 2004. The building’s 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 but it decreased to 104 kWh/m² in 2006. An energy audit was done on Block E6 (Ministry of Health) and Block B6 (Economic Planning Unit) of the Prime Minister’s Department building in Putrajaya. The audit showed that the energy index of the LEO building was lower than in conventional buildings [16].

For the LEO building, the shade for various facades was optimised using sun charts for geometrical verification and later using ENERGY-10 (a computer application for energy management) for overall optimisation of the design including the effect of daylight on the overall energy balance. The ‘punched-hole window’ design incorporates a shade element-cum-‘light shelf’ in the middle of the window. This light shelf is painted with a light-diffusing colour on the upper surface in order to transfer diffuse light into the building through the upper part of the window. The light shelf must have the same depth as the rest of the ‘punched-hole’ window shade. The punched-window method is used for external windows on Levels 2 and 3, and a curtain wall with exterior shading is used on Levels 4 to 6.

As shown in Figure 4, shading of the atrium is provided by translucent canvas; this is adjusted automatically to reduce sunlight penetration into the atrium and avoid glare in the adjacent office areas. The canvas has a high shading coefficient. A solar sensor which senses the intensity of solar radiation on a horizontal surface is placed above the canvas to control shading. A manual override is provided. The shading and punched-hole windows for the various facades are summarised in Table 1.



Figure 4. Shading device for atrium

Table 1. Shading and punched-hole windows for various facades [17]

Orientation	Shading type	Depth of shading	Shading coefficient	Note
NE	Punched-hole windows	650 mm	0.7 – 0.8	For a 2400-mm-high window with light shelf in the middle
	Louvres / curtain wall	370 mm	0.7	For a distance between louvres of 1000 mm
SE	Punched-hole windows	1000 mm	0.59 – 0.8	For a 2400-mm-high window with light shelf in the middle
	Louvres / curtain wall	820 mm	0.59 – 0.8	For a distance between louvres of 1000 mm
South	Punched-hole windows	650 mm	0.59 - 0.8	For a 2400-mm-high window with light shelf in the middle
	Louvres / curtain wall	370 mm	0.59	For a distance between louvres of 1000 mm
North	Punched-hole windows	1000 mm	0.7 – 0.8	For a 2400-mm-high window with light shelf in the middle
	Louvres / curtain wall	370 mm	0.8	For a distance between louvres of 1000 mm
NW	Punched-hole windows	1000 mm	0.7 -0.8	For a 2400-mm-high window with light shelf in the middle
	Louvres / curtain wall	820 mm	0.7	For a distance between louvres of 1000 mm

To maximise daylight, space in the LEO building is divided into three zones: the daylight zone, no-daylight zone and semi-daylight zone, which are used for different purposes. The office rooms in the daylight zone make good use of daylight and artificial lighting is not needed most of the time. Glare is minimised by the light shelves, especially in the south- and north-orientated offices. The building is deep and artificial lighting is needed in the inner zones where most of the staff work. The atrium provides a certain amount of daylight but not enough to avoid artificial lighting. The light is on constantly during working hours but a lighting control system reduces the electricity demand

considerably. The energy demand for lighting is more than double that of the estimated load. On the east facade the morning sun shines directly into the offices and to avoid discomfort blinds are used. Later in the day the direct sun does not enter the offices but the blinds tend not to be removed and the daylight is not used to advantage. Utilisation of daylight is excellent in the offices along the south and north facades and poor in the inner zones of the building.

According to MS1525 [15], the average daylight factors may be obtained by using nomograms, computer simulation or architectural modelling of a building design. Scaled models or computer simulations of buildings with more than 4000 m² of air-conditioned space are used to model daylight performance. Daylight factors were measured in several rooms in the LEO building. The rooms were selected to represent different orientations of the building façade. It was found that in general, without the use of blinds, a daylight factor of more than 2% is available for up to 3-m depth from the perimeter of the glazing, while a daylight factor of 1% is available for up to 6-m depth in the office space of all orientations. Figure 5 provides a view of the lighting effect with blinds.



Figure 5. Lighting effect with blinds

The daylight lux level measurement of various rooms indicates that daylight distribution is even for the first 2 m of depth, gradually decreasing beyond that. The change in the daylight factor of 1-2% between 3-6 m shows that the daylight is well distributed and provides an even daylight environment for rooms less than 7 m deep. The light shelf seems to produce the necessary even light distribution by reflecting some of the light further into the room and reducing the light nearer the glazing. It is interesting to note that a daylight factor of 1% seems adequate for office work here. This may indicate that a high level of daylight is available outside or that people are more willing to accept a lower lighting level when they can see that the outside light level is also low. Further analysis of the available daylight outside the hours of 8 a.m. - 5 p.m. is recommended for further

academic research. A study of the occupants' preferences and tolerance of light levels in space lit by natural light where they can see the outside daylight at the same time is also proposed.

Daylight was measured on the afternoon of 14 November 2005 and it was found that blinds were in use in approximately 50% of the rooms, necessitating the use of artificial light. Most of the rooms facing east and some of the rooms facing north and south had the blinds in use. The east facade received direct sunshine in the morning, creating glare and causing the occupants to use the blinds. However, once the blinds were drawn they were rarely opened again, even when the sun had moved away and would no longer cause glare. Some of the blinds in use in the north- and south-facing rooms were to prevent glare on computer screens to the occupants sitting with the window behind them. This practice warrants comprehensive research to gain an understanding of the occupants' behaviour in relation to blind use, visual comfort and energy efficiency.

BIPV TECHNOLOGY IN MALAYSIA

In 2005, the Malaysian government launched its first collaborative effort in using renewable energy technology, specifically PV technology, in its buildings in the Malaysian BIPV project. Unlike in the UK, the BIPV system used in Malaysia is grid-connected. Subsequently, in 2006 the government launched the SURIA1000 project focusing on residential BIPV systems. In the 9th Malaysian Plan, the government made a substantial allocation for solar technology application, especially in the east Malaysia region [18]. Figure 6 presents a diagram of a basic grid-connected PV system and Figure 7 illustrates the grid-connected BIPV system concept.

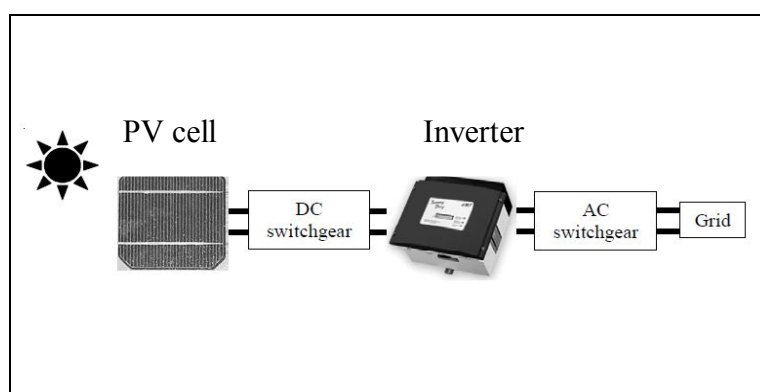


Figure 6. Diagram of basic grid-connected PV system [18]

Sunlight is converted by the PV module into direct current, which is fed into an inverter that converts it into alternating current transferable to the grid. The system responds by importing energy from the grid when energy from the PV system is insufficient, or exporting excess energy to the grid. Apart from government buildings such as the Centre for Environment, Technology and Development and Green Energy Office (GEO) of Pusat Tenaga Malaysia (PTM) as well as Monash University (Sunway), residential areas such as those in Cheras, Semenyih, Bukit Sebukor (Malacca), Setia Eco Park, Putrajaya and Bangsar have also incorporated PV modules into their buildings under the MBIPV project.

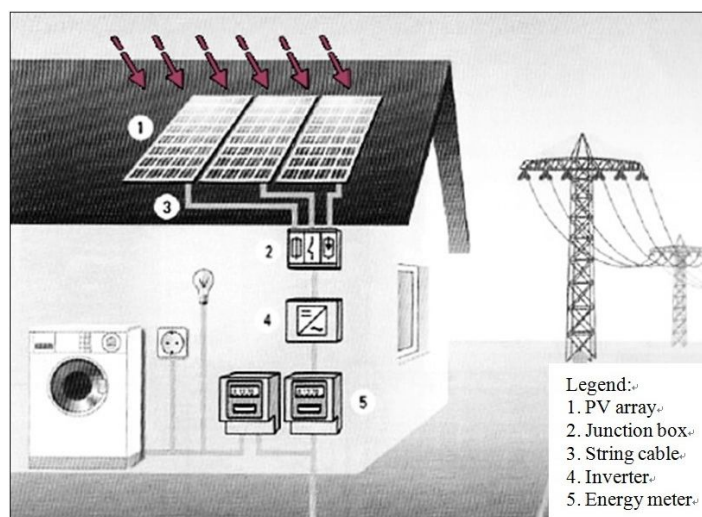


Figure 7. Grid-connected BIPV system concept [18]

The PTM GEO building was developed following the success of the LEO building in Putrajaya. Table 2 summarises some of the project data for the GEO building. It demonstrates that the Zero Energy Building concept can be realised using technologies already available today and taking advantage of a climate where solar radiation and daylight can be used as the energy sources, at the same time reducing fossil fuel consumption. This building promotes advanced energy technologies for use in buildings in Malaysia, technologies that will ultimately make buildings self-sustaining in energy supply.

Pre-programmed into the building's 'DNA' are energy-efficient features and the BIPV system, which make up the backbone of this self-sufficient, fully sustainable landmark. The PTM's GEO building does not use fossil fuels, driving home the point that an office building need not consume electricity derived from this source. Instead, all the electricity needed by the building is generated by its own solar BIPV systems. Four different systems utilising four different technologies have been installed, as shown in Figure 8. The first and biggest component features a 47.28-kWp polycrystalline BIPV system on the main roof; the second component is a 6.08-kWp amorphous silicon BIPV system incorporated into the second main roof; the third system stored in the atrium of the building highlights the use of a 11.64-kWp monocrystalline glass-glass BIPV system; and lastly, the car park roof is fitted with a 27-kWp monocrystalline BIPV system.

Table 2. Summary of project data for the GEO building [19]

Project name:	Malaysia Energy Centre: Green Energy Office
Location:	Section 9, Bandar Baru Bangi, Bangi, Selangor
Completion:	July 2007
Site area:	2 hectares
Gross floor area:	4,000 m ²
Number of rooms:	41 rooms
Building height:	47.50 metres
Client/Owner:	Malaysia Energy Centre (Pusat Tenaga Malaysia)



Figure 8. Four types of solar panel and their locations on the GEO building [20]

The solar BIPV systems are all linked to grid-connected inverters that convert DC produced into AC. The amount of electricity generated is recorded by a meter. In this case, no battery is installed as the generated solar electricity is consumed directly and the net surplus sold to Tenaga Nasional Berhad (TNB) on a net meter basis. At a total BIPV capacity of 92 kWp, the anticipated target for electricity generated annually by solar BIPV systems stands at 102 MWh [17]. To date, the BIPV systems have produced an estimated 103 MWh/year on average, based on actual output over three months. Buildings that are not energy efficient would need more than the GEO's 92 kWp because the super energy efficient features of the GEO reduce the energy consumption of the building. The total payback time for the whole GEO system should be less than 22 years [20], based on the current subsidised electricity tariff and imported technologies. It is acknowledged that future electricity costs will increase while the cost of energy efficient features and solar technologies will decrease. However, it is important to bear in mind that there is no payback price for the environment.

ENERGY LEGISLATION AND POLICY IN MALAYSIA

Malaysia is a strong supporter of the ASEAN countries' renewable energy development programme, implementing a Five Fuel Strategy under the 8th Malaysian Plan, and regarding renewable energy as the fifth fuel. However, Malaysia is still far from achieving the desired target.

The Malaysia Energy Centre was launched with the aim of playing a major role in developing energy efficiency and renewable energy. Its message was reinforced through its GEO (formerly known as the zero-energy office) and its building was certified as Malaysia's first completed green-rated office building. It was inspired by another energy-efficient building, the LEO building, which is now the Ministry of Energy, Green Technology and Water. Malaysia has set the standards for energy efficiency through these remarkable buildings. The GEO building incorporates solar technology such

as BIPV panels, at the same time exploiting solar radiance in the building design for cooling and air convection. The LEO also uses PV systems, although they operate in parallel with the grid supply. The Malaysian government has introduced codes of practice for energy efficiency, hoping to encourage more 'green' buildings in the country. These are MS 1525:2001[15], specifying the minimum criteria for being a low energy building, and MS 1837:2005 [21] which is used as guidelines for BIPV-system projects.

Recently, the prime minister of Malaysia, Datuk Seri Mohd Najib, launched the Green Technology Policy 2009, stressing energy efficiency and green building design. Some of the approaches taken were setting up a green technology agency, promoting foreign investments, allocating incentives for students pursuing green technology, and provision for R&D.

Malaysia's development is tied to three key national policy frameworks: new economic policy (NEP), 1971-1990; national development policy (NDP), 1991-2000, and national vision policy (NVP), 2001-2010. The framework for developing energy is outlined in the national energy policy 1979, national depletion policy 1980 and fuel diversification policy (four-fuel diversification policy 1981 and renewable energy as the fifth-fuel policy 2000). The four-fuel diversification policy 1981 identifies the country's energy mix as oil, natural gas, coal and hydro power. Due to increasing oil prices and environmental degradation, in 2001 the government of Malaysia introduced the fifth- fuel policy, adding renewable resources to the energy mix with emphasis on sustainability and efficiency. Since then, the government has concentrated on energy efficiency in industrial and commercial sectors as well as residential sectors, and on the utilisation of renewable energy by promoting new renewable energy resources, e.g. biofuel, landfill gas, mini-hydro power and solar energy, and sustainable development of all energy resources [22]. Table 3 traces the history of various energy policies/acts in Malaysia's national energy development.

To further show its commitment to promoting low-carbon technologies and ensuring sustainable development while conserving the natural environment and resources, the Malaysian government launched its national green-technology policy (NGTP) on 24 July 2009 [23]. Green technology refers to the development and application of products, equipment and systems used to conserve the natural environment and resources, minimising the negative impact of human activities and satisfying the following criteria: (i) green technology minimises environmental degradation; (ii) it has zero or low greenhouse-gas emissions; (iii) it is safe to use and promotes a healthy environment for all forms of life; (iv) it conserves energy and natural resources; and (v) it promotes the use of renewable resources [24]. The NGTP has five strategic thrusts as follows: (i) strengthen the institutional frameworks; (ii) provide an environment conducive to green technology development; (iii) intensify human capital development in green technology; (iv) intensify green technology research and innovations; and (v) promote public awareness. The aim of the NGTP is to foster progress and make improvements in major sectors such as energy, buildings, water and waste management, and transportation as detailed in Table 4.

Table 3. Malaysia's policies/acts on national energy development [22]

Policy/act	Key emphasis
National Petroleum Policy (1975)	Introduced to ensure optimal use of petroleum resources, regulation of ownership, management and operation, and economic, social and environmental safeguards in the exploitation of petroleum due to fast growing petroleum industry in Malaysia.
National Energy Policy (1979)	Formulated with broad guidelines on long-term energy objectives and strategies to ensure efficient, secure and environmentally sustainable supplies of energy. Three main objectives: 1. Supply objective: To ensure provision of adequate, secure and cost-effective energy supplies through developing indigenous energy resources, both non-renewable and renewable, using the least cost options and diversification of supply sources both from within and outside the country. 2. Utilisation objective: To promote efficient utilisation of energy and to discourage wasteful and non-productive patterns of energy consumption. 3. Environmental objective: To minimise negative impacts of energy production, transportation, conversion, utilisation and consumption on the environment
National Depletion Policy (1980)	Introduced to safeguard against over-exploitation of oil and gas reserves. Thus, it is a production control policy.
Four-Fuel Diversification Policy (1981)	Fuel diversification is designed to avoid over-dependence on oil as main energy supply and aimed at placing increased emphasis on gas, hydro power and coal in the energy mix.
Electricity Supply Act (1990)	Regulates licensing of electricity generation, transmission and distribution.
Gas Supply Act (1993)	Regulates licensing of gas supply to consumers, pricing, installations and appliances as well as safety aspects.
Fifth-Fuel Policy (2000)	Introduced in recognition of the potential of biomass, biogas, municipal waste, solar and mini-hydro power as potential renewable energy sources for electricity generation.
Energy Commission Act (2001)	The Energy Commission was established to provide technical and performance regulation for electricity and piped gas supply industries, and to advise the government on matters related to electricity and piped gas supply including energy efficiency and renewable energy issues. The Electricity Supply Act 1990 and Gas Supply Act 1993 have both been amended to allow the Energy Commission to take over these responsibilities.
National Biofuel Policy (2006)	Supports the five-fuel diversification policy. Aimed at reducing the country's dependence on depleting fossil fuels and promoting demand for palm oil. Five key thrusts: transport, industry, technology, exports and cleaner environment. Highlights: 1. Producing biodiesel fuel blend of 5% processed palm oil with 95% petroleum diesel; 2. Encouraging the use of biofuel by giving incentives for providing biodiesel pumps at fuelling stations; 3. Establishing industrial standards for biodiesel quality under standards and industrial research institute of Malaysia (SIRIM); 4. Setting up of palm oil biodiesel plants.

The prime minister of Malaysia, Datuk Seri Najib Razak, in his keynote speech on 24 July 2009 [25] during the launching of the NGTP, stated that between 2009-2030 global primary energy consumption is expected to rise by 1.6% annually. Malaysia's electricity demand is forecasted to reach 18,947 MW by 2020 and 23,092 MW by 2030, a 35% increase from 14,007 MW in 2008. Currently, Malaysian electricity capacity through renewable energy stands at 50 MW and it is

Table 4. Significant progress and major improvements aimed by the NGTP [24]

Sector	Progress and major improvements
Energy supply	Application of green technology in power generation and energy-supply management, including co-generation of power by industrial and commercial sectors
Energy utilisation	Application of green technology in all energy utilising sectors and demand-side management programmes
Buildings	Adoption of green technology in the construction, management, maintenance and demolition of buildings
Water and waste management	Adoption of green technology in the management and utilisation of water resources, wastewater treatment, solid waste and sanitary landfill
Transportation	Incorporation of green technology, particularly biofuels and public road transport, into transport infrastructure and vehicles

expected to reach about 2000 MW by 2020. Thus, the Malaysian government will institute a renewable energy law in 2011, including a policy focusing on a feed-in tariff (FiT) mechanism. Different forms of renewable energy are given their share in the FiT mechanism as shown in Table 5. The proposed duration for the FiT ranges between 16-21 years with an annual digression of up to 6%. Less focus seems to be given to mini-hydro power and more focus to solar energy. The policy trends towards promotion of renewable energy have shown that Malaysia is aware of the importance of renewable energy and energy efficiency in its energy development. Based on the energy trends, the national economic developments are similarly aligned in the Malaysia Plans. Table 6 shows the key emphases in energy developments from the 7th-10th Malaysia Plans.

Table 5. Proposed FiT rates [26]

Renewable energy (RE)	Duration (year)	Tariff (RM/kWh)/(USD/kWh)	Annual digression	Displaced electricity cost (RM/kWh)
Wind	21	0.23–0.35/0.071–0.108	1%	0.22
Solar PV	21	1.25–1.75/0.386–0.541	6%	0.35
Solid waste and sewage gas	21	0.3–0.46/0.093–0.142	1.5%	0.22
Biomass	16	0.24–0.35/0.074–0.108	0.2%	0.22
Biogas	16	0.28–0.35/0.087–0.108	0.2%	0.22
Geothermal	21	0.28–0.46/0.087–0.142	1%	0.22
Mini-hydro	21	0.23–0.24/0.071–0.074	0%	0.22

Table 6. Malaysia's key emphases for energy development [26]

Malaysia Plan	Key emphases
Seventh Malaysia Plan (1996–2000)	<ul style="list-style-type: none"> - Emphasis on sustainable development to compensate for depletable resources, and on diversification of energy sources. - Ensuring adequacy of generating capacity as well as expanding and upgrading transmission and distribution infrastructure. - Encouraging the use of new and alternative energy sources as well as efficient utilisation of energy.
Eighth Malaysia Plan (2001–2005)	<ul style="list-style-type: none"> - Emphasis on sustainable development of energy resources, both depletable and renewable. The energy mix includes five fuels: oil, gas, coal, hydro and renewable energy (RE). - Intensifying efforts on ensuring adequacy, quality and security of energy supply. - Greater emphasis on energy efficiency (EE): encouraging efficient utilisation of gas and RE as well as providing adequate electricity generating capacity. - Supports development of industries in production of energy-related products and services. - Highlights promotion of RE and EE. - Incentives for EE. - Incentives for use of RE resources. - Incentives to maintain quality of power supply.
Ninth Malaysia Plan (2006–2010)	<ul style="list-style-type: none"> - Emphasis on strengthening initiatives for EE, especially in transport, commercial and industrial sectors, and in government buildings. - Encouraging better utilisation of RE through diversifying fuel sources. - Intensifying efforts to further reduce dependency on petroleum and to integrate alternative fuels. - Incentives to promote RE and EE are further enhanced.
Tenth Malaysia Plan (2011–2015)	<p>Short-term goals vested in NGTP:</p> <ul style="list-style-type: none"> - Increased public awareness and commitment for adoption and application of green technology through advocacy programmes. - Widespread availability and recognition of green technology in terms of products, appliances, equipment and systems in local market through standards, rating and labelling programmes. - Increased foreign and domestic direct investments in green technology manufacturing and service sectors. - Expansion of local research institutes and institutions of higher learning to accommodate research, development and innovation activities on green technology with the aim of commercialisation through appropriate mechanisms. - New RE act and FiT mechanism to be launched.

CHALLENGES OF SOLAR ENERGY IMPLEMENTATION

Energy efficiency means using less energy to produce the same amount of services or useful output [27, 28]. The rapid growth of energy use has already raised concern over problems of supply worldwide. It is exhausting the energy resources and causing severe environmental impacts such as depletion of the ozone layer, global warming and climate change. In developed countries, especially in Malaysia, the contribution from residential and commercial buildings to energy consumption has steadily increased to between 20-40% of the total energy consumption [29]. Nowadays, energy efficiency of buildings is a prime objective for energy policies at regional, national and international levels due to population growth and increasing pressure on building services to handle the continuing upward trend in energy demand [30,31]. The current energy and socio-economic systems are clearly unsustainable and in generating electricity for commercial and domestic uses will undoubtedly

exhaust fossil fuel resources. The lifestyles of the developed nations will have a serious environmental impact and will lead to patterns of consumption with increasing energy needs and consequently to higher carbon dioxide concentrations in the atmosphere [32,33]. Energy efficiency is only one of many qualities valued in a building and some of these, such as the use of large glass surfaces, may even counteract energy efficiency [34]. The rapid growth in energy demand is expected not only in developed countries but also in developing countries as they attempt to reach a higher living standard [35,36]. Efficient use of energy will play an essential role in minimising energy usage and associated emissions released into the atmosphere [37].

One of the most cost-effective measures in reducing emissions of carbon dioxide, believed to be a major cause of global warming, is the improvement of energy efficiency in buildings [38,39]. To comply with measures to save energy and reduce environmental pollution, the Malaysian government has already built the LEO building, whose energy intensity is 114 kWh/m², only 50% of that in conventional buildings [40]. However, this model building has very few followers. In encouraging the use of renewable energy, the Malaysian government has included a target for renewable energy use of 5% in its 9th Malaysia Plan to reduce the burden on the atmosphere. In addition, University Science Malaysia's centre for education and training in renewable energy and energy efficiency is playing an active role in increasing awareness of energy efficiency and the use of renewable energy among end users [29]. The ineffective distribution of costs and benefits between actors makes the promotion of energy efficiency in the new construction particularly complicated in Malaysia [41]. For residents, energy costs are a small and well-hidden part of the total rent [42]. In relation to supply strategies, there may be a number of reasons why energy efficiency often falls short; one is the problem of imperfect information, which is typically more pronounced in the market of energy efficiency. The service of energy efficiency may consist of a series of small changes with unclear estimates of costs and benefits. Unlike energy supply issues, which are driven by major actors, energy efficiency lacks influential advocates [43]. Furthermore, householders or landlords who have made the investment in energy efficiency generally require much shorter payback time than that for investments in the extension of supply made by major specialised energy companies [33].

The issue of sustainable development and renewable energy in buildings is frequently addressed, yet only a minority of Malaysia's population are actually putting words into action. Like all new developments, solar technology in Malaysia faces several issues and challenges:

Lack of policy framework. Despite the aims of the fifth-fuel policy and green technology policy, there is a lack of comprehensive detail. These policies merely state their objectives and numerous approaches the government can use to create a greener, sustainable development in the future. MS 1525:2001 is effective, yet it does not ensure that all future constructions will be low energy consumption buildings, while MS 1837:2005 has yet to encourage confidence in the public.

Expensive solar technology and lack of expertise. Despite rapid development in solar technology, it is still in its infancy in Malaysia. Installation of solar panels is very costly even for small projects, and there are only a few specialists or consultants who truly understand and know how to effectively save energy in the long term. Because of the high capital investment required, developers in the private sector do not even consider solar technology in their projects.

Lack of public interest and awareness. Public interest at a national level can be considered as relatively low. Environmental and energy issues are generally ignored because the public take it for granted that the government will propose a solution when the problems arise. With fossil and other non-renewable fuels still available to the public, alternative technologies tend to be overlooked.

Insufficient funding. Despite government incentives, funding is still insufficient for most of the projects in Malaysia to consider energy efficient buildings. There are no specific loans from the financial sector to encourage the development of solar technology, and the private sector is always more profit-conscious in the shorter term rather than the long term.

POSSIBLE SOLUTIONS TO CHALLENGES

A future with limited amounts of non-renewable fuels is drawing nearer each day. All the issues raised should be dealt with comprehensively before it is too late:

Legislation and policy. In order to implement solar technology in buildings, acts and policies regarding incentive subsidies should be passed for all future developments. The legislation should include incentive subsidies for: 1) solar technology such as the BIPV system connected to the grid supply for large-scale developments; 2) thin-film solar panels to be incorporated in residential buildings or small projects; and 3) renewable energy as a preferred component of electricity generation for use in homes and other buildings.

Funding from the Private Sector. Private developers and financial institutions are very influential in the construction industry and can potentially affect the solar technology market. Developers should be instilled with the awareness of environmental issues and the need for energy efficiency in buildings, while self-motivation to use solar technology in their projects should be encouraged. Financial institutions could offer developers loans with special interest rates for developments incorporating solar technology. A 'national solar technology fund' could be set up in a campaign to create more awareness among the public and to encourage people to seek out solar technology for domestic purposes.

Tax relief or rebates. The government plays a key role in encouraging the public to enter the solar technology market by giving tax relief or rebates to those who implement solar energy conversion. Tax relief can appeal to the public and create an interest. Furthermore, rebates can be given on electricity bills if their daily energy generation and consumption are from a renewable energy source.

Skilled and knowledgeable manpower. Undoubtedly, skilled manpower or labour in this industry is crucial and will play an important role in the future progress of the construction projects. Malaysia seems to be lacking in specific programmes; most educational institutions regard solar technology as a part of a wider subject, and not as a programme in its own right. The scope of solar technology is wide and there is much to explore and develop, but the provision of skilled manpower is not keeping pace. One way to overcome this is to propose more programmes on the subject at a higher educational level. Technical or vocational schools and comprehensive diploma programmes in universities can produce the required expertise in this field. Workshops and courses can be organised on a weekly basis for professionals such as building surveyors, engineers and architects.

CONCLUSIONS

Solar technology as an energy efficient approach in buildings is generally considered to be beneficial and would result in a cleaner environment in the long term. Stricter legislation is vital. Rules and standards will ensure conformity in future developments. Furthermore, the cost of solar technology should be controlled and be in proportion to the project size. Funding from private organisations can be a huge influence in the country's advancement of solar technology and its use as well as the progress towards sustainable development. Tax relief and rebates will attract more public awareness and instil interest in energy-saving techniques in daily life. An opportunity exists at the educational level for knowledgeable and skilled manpower to be produced on a large scale through research programmes and other educational activities. Malaysia has so much potential for solar technology, especially in the construction industry. With environmental issues and a worldwide energy crisis looming, solar technology is surely one of the ways forward to a greener and more sustainable development in the future. Malaysia faces several issues and challenges in accepting new developments, especially solar technology, such as the lack of a policy framework, lack of expertise, lack of public interest and awareness, and insufficient funding. Appropriate policies to encourage the implementation of solar energy are recommended for future study.

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