A Review of Concentrating Solar Power (CSP) In Malaysian Environment

Rosnani Affandi, Mohd Ruddin Ab Ghani, Chin Kim Gan, Jano, Zanariah

***Abstract*— Malaysia has an abundance of solar energy. While the magnitude for average daily solar irradiations in Malaysia is around 4.21–5.56 kWhm−2, the sunshine duration is more than 2,200 hours per year. However, the focus on solar energy in Malaysia is mainly on the Photovoltaic (PV) panel to generate electricity. There is still lack of thorough investigation in implementing the solar thermal, such as the Concentrating Solar Power (CSP) in Malaysian environment. This paper reviews the CSP technology and the potential of developing CSP plant in the Malaysian environment by taking into account the Direct Normal Irradiance (DNI) and a few geographical aspects.**

***Index Terms*— Concentrating Solar Power (CSP), Direct Normal Irradiance (DNI), Photovoltaic (PV).**

I. INTRODUCTION

Since the beginning of the twenty first century, world has been confronted with global climate change and high oil prices. Across the world, protests and demonstrations have erupted against governments for the surge in fuel pump prices, which is also sparking general inflation affecting the price of food, electricity and other commodities.

Oil provides 40 to 43 percent of all energy used by the world. Oil and coal each accounts for 40 percent of global warming emission from fossil fuels worldwide. According to the World Bank in 2008, Malaysia was a high energy user. Each Malaysian used 2,693kg of oil. In comparison, each Indonesian used only 870kg, Filipino 455kg and Chinese, 1,598kg and in terms of electricity use, each Malaysian used an average of 3,667kWh (kilowatt hours) in 2008 [1].

By looking at the scenario, Malaysian government has started a few initiatives to tackle the problem. In April 2009, the Ministry of Energy, Green Technology and Water was established in a cabinet reshuffle to replace the Ministry of Energy, Water and Communication. Then, the National Green Technology Policy was launched by the Prime Minister of Malaysia in 24 July 2009 with the objectives to reduce the energy usage rate and at the same time increase economic growth, facilitate the growth of the green technology industry and enhance its contribution to the national economy and as well as to increase national capability and capacity for innovation in green technology development.

Manuscript received December, 2013.

Rosnani Affandi, Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka.

Mohd Ruddin Ab Ghani, Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka.

Chin Kim Gan, Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka.

Jano,Zanariah, Centre for Languages and Human Development, Universiti Teknikal Malaysia Melaka.

Concentrating Solar Power (CSP) is one of green technologies or Renewable energy technologies that is able to be the main source of electricity in the future. The technology is clean, reliable and environmental friendly. Malaysia should move a step forward to look into this technology and then consider CSP as one of the deemed capable technologies for generating electricity rather than using solar PV, Biomass, Mini Hydro and Biogas.

II. SOLAR ENERGY

Many countries all over the world including Malaysia, are now focusing more on green technology and renewable energy. According to the 2011 projection by International Energy Agency, renewable energy like solar power generators may produce most of the world's electricity within 50 years, dramatically reducing the emission of greenhouse gases that harm the environment. Of all sources of renewable energy, solar energy is by far the most abundant [2].

Under the Energy Entry Point Programme [3], Malaysia targets to build solar power capacity up to 1.25 GW by 2020. In comparison, German had the solar power capacities of 20,000 MW or 20 GW in mid 2012 which cannot be challenged by other countries until now.

Malaysia has an abundance of sunshine and solar radiation. On average, Malaysia receives about 6 hours of sunshine every day. Malaysia has an annual average of daily solar irradiations of 4.21–5.56 $kWhm^{-2}$, and the sunshine duration is more than 2,200 hours per year [4]. Hence, Malaysia has a rich supply of sunlight than German and should be aggressively tapping solar power.

It is estimated that the earth receives approximately $1000W/m^2$ amount of solar irradiation in a day [5] and by harnessing the solar energy from eight different solar power plant sites throughout the world, the energy generated from these plants has the capability to supply more than enough electricity to satisfy the present global energy utilization [6]. These sites are located in the deserts in Southwest Asia, China, Australia, Southern South America, United States and Mexico.

There are two ways to extract electricity from solar radiation; Photovoltaic and CSP. The former refers to the direct conversion of sunlight to electricity whereas the latter the use of heat to generate electricity. In contrast to photovoltaic, CSP technologies do not produce electricity directly through solar radiation, but use concentrated solar energy to indirectly generate heat and power.

CSP is a promising technology for power as no fossil fuel is used in this technology. Therefore, no greenhouse gases are emitted [7]. Important features of most solar thermal technologies are their capacity for bulk power generation and their viability in a wide range of plant sizes from a few kilowatts to several hundreds of megawatts [8].

III. CONCENTRATING SOLAR POWER (CSP) TECHNOLOGY

CSP is also known as concentrating solar thermal power, representing a powerful, clean, endless, and reliable source of energy. Concentrating solar power plants produce no Carbon Dioxide (CO_2), thus reducing carbon emissions from electricity generation by approximately 272.2 kg per megawatt-hour [9].

Four types of solar concentrators are commonly used; parabolic trough, parabolic dishes, central receivers and Fresnel lenses. Linear concentrator systems collect the sun's energy using long rectangular, curved (U-shaped) mirrors. The mirrors are tilted toward the sun, focusing sunlight on tubes (or receivers) that run the length of the mirrors.

There are two major types of linear concentrator systems; parabolic trough systems and linear Fresnel reflector systems.

A. Parabolic Trough Concentrator

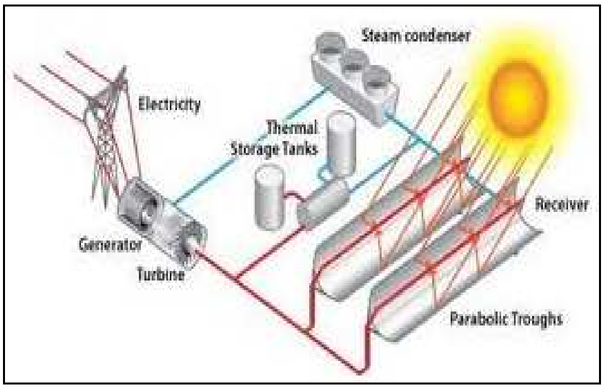

Fig 1. Parabolic trough systems [10]

A parabolic trough concentrates incoming solar radiation onto a line running the length of the trough. A tube (receiver) carrying heat transfer fluid is placed along this line, absorbing concentrated solar radiation and heating the fluid inside. The trough must be tracked about one axis, because the surface area of the receiver tube is small compared to the trough capture area and temperature up to 400^oC can be reached without major heat loss. The parabolic trough concentrator is shown in Fig. 1.

B. Fresnel reflector systems

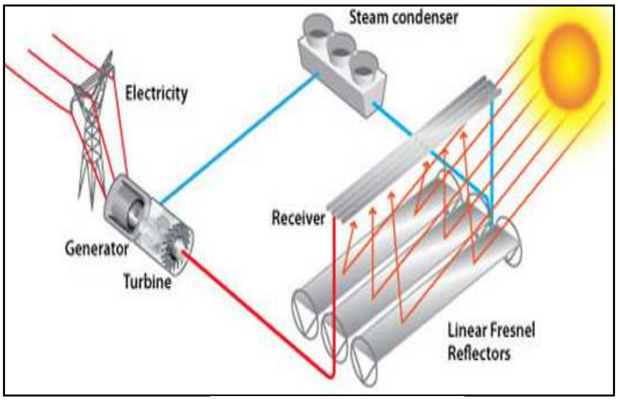

Fig 2. Fresnel reflector systems [10]

A Fresnel lens concentrator uses refraction rather than reflection to concentrate the solar energy incident on the lens surface to a point. Molded out of inexpensive plastic, these lenses are used in photovoltaic concentrators. They are not used to increase the temperature but to enable the use of smaller, higher efficiency photovoltaic cells. With regards to parabolic dishes, point focus Fresnel lenses have to track the sun about two axes [8]. The Fresnel reflector system is shown in Fig. 2.

C. Central Receiver Systems

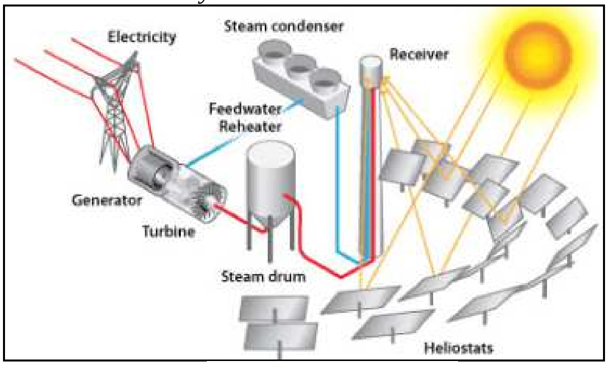

Fig 3. Central receiver systems [10]

A central receiver system consists of a large field of independently movable flat mirrors (heliostats) and a receiver located at the top of a tower. Each heliostat moves about two axes throughout the day to keep the sun's image reflected onto the receiver at the top of the tower. The receiver, typically a vertical bundle of tubes is heated by the reflected insolation, thereby heating the heat transfer fluid passing through the tubes. The central receiver system is shown is Fig. 3.

D. Parabolic Dish

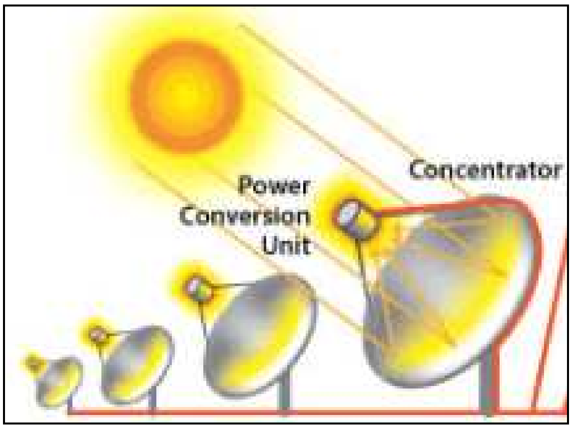

Fig 4. Parabolic trough systems [10]

Parabolic dish concentrators are made from reflecting mirrors. They have a stirling engine that is situated at the focal point of the dish reflector. The solar radiation is concentrated onto a receiver at the focal point and the heat is absorbed and then the gas is heated up to generate electricity. The parabolic dish is shown in Fig. 4.

IV. COMPARISON OF CSP TECHNOLOGY

All of the CSP technologies can generate clean energy with no fuel cost. The only drawback that concentrating solar power plants have on the environment is land use. To be able to generate high electrical energy, more land is needed for the plant. Although the amount of land a CSP plant occupies is larger than that of a fossil fuel plant, both types of plants use about the same amount of land as fossil fuel plants utilize additional land for mining and exploration as well as road building to reach the mine [11].

Each of CSP technology has its own value proposition and different deployment optima. Table 1 shows the different CSP technologies. The parabolic dish has the highest efficiency, 18-25% but its hybrid operation is still in the R&D phase. Solar tower efficiency is the second highest which is around 14-17% and has the highest operating temperature of High Temperature Fluid (HTF) 1000°c. The efficiency and the operating temperature HTF of Linear Fresnel is the lowest but the cost for linear Fresnel is cheaper than the others CSP systems. Even though Parabolic Trough efficiency is 10-15%, it has the lowest material demand; good land-use factor, modularity, thermal storage and others. Which make parabolic trough the most popular CSP option. [7]. However, among the CSP technologies, parabolic trough is the most mature. Parabolic trough has a total capacity of 354 MW and become the largest operating solar plant in the world [12].

Table 1. Different CSP Technologies [7, 13]

Technology	**Temperature**	**Hybrid operation**	**Cost ($/Kw)**	**Efficiency**
Parabolic Trough	400°C	Possible	4,156	10-15%
Solar Tower	1000°C	Possible	4,500	14-17%
Parabolic Dish	750°C	Still in R&D phase	6,000	18-25%
Linear Fresnel	270°C	Possible	2,200	9-15%

Changes in global renewable energy markets, investments, industries and policies have been so rapid in recent years. The cost for producing electricity from renewable resources is traditionally higher than producing electricity from coal or natural gas. However, as renewable technologies attain commercial viability and enter the mainstream market, their price per kilowatt hour is usually decreasing.

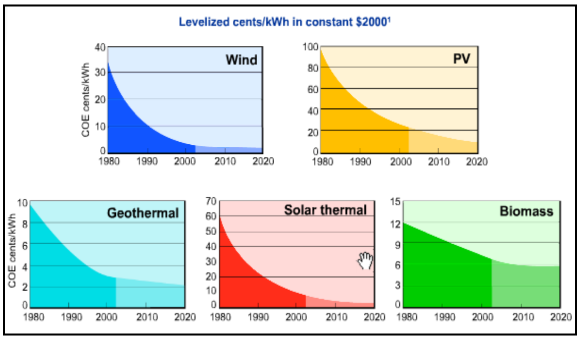

Fig 5. Renewable Energy Cost Trends.
Source: NREL Energy Analysis Office
(https://tdksc.ksc.nasa.gov/servlet/dm.web.Fetch/TEERMShahRenewableEnergyOverview.pdf?gid=102614)

PV, the renewable technology, has historically shown a large proportion of cost reductions. Cost reductions in solar PV in particular mean high growth rates in manufacturing. Cost reductions in wind turbines, Geothermal, CSP and biomass technologies also contribute to the growth. The dramatic reductions in PV costs can become a real challenge for the growing market of CSP. However, in comparison to PV, CSP technologies are economically competitive. To some extent, market size can be compared with PV technologies [14]. The Renewable energy cost trend is shown in Fig. 5. In general, in CSP, mirrors or concentrator do not require much maintenance, any greenhouse gas emissions and production of mirrors. In short, in comparison to PV cells, CSP technologies have less energy, are intensive and more environmental friendly [15].

V. CONCENTRATING SOLAR POWER AND ITS ISSUE IN MALAYSIA ENVIRONMENT

CSP technology requires Direct Normal Irradiance (DNI) of at least 1900-2000 kWh/m^2/year in order to be economically feasible. Basically, locations that have been primarily targeted as suitable for CSP solutions are those with high sun exposure and low cloud coverage, such as southern states of the United States, Mexico, Mediterranean sea region, Middle East, South Africa, parts of China, Pakistan, India, Australia and parts of South America [8].

Fig. 6 shows the geographical ranges for CSP Plant. Malaysia and other countries in tropical region are not in the high insolation zone or within the areas with excellent resource of solar radiation. The DNI for Malaysia is below than 1900 kWh/m^2/y. In most tropical regions, clouds reduce the annual production of CSP Plants to such an extent that they probably will never become viable [16]. Because of this problem, it is difficult for the countries at the tropical region including Malaysia to develop their own CSP plant.

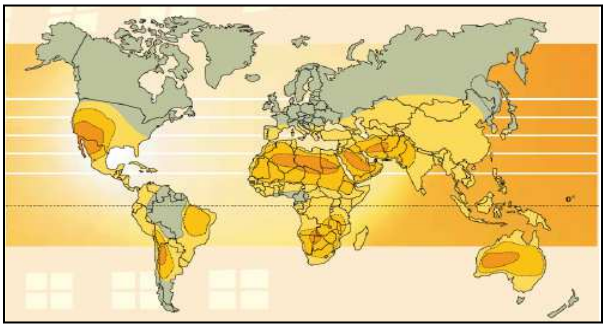

Fig 6. Geographical Ranges for CSP Plant
Source: CSP Global Market Initiative.
Key: Dark orange = excellent resource; pale yellow = adequate resource; green = insufficient resource.

Due to climate condition, it is commonly believed that the CSP systems cannot be used in the tropics with relatively high diffused fraction of global radiation. However, there is no systematic study on this issue [17]. From Fig. 6, Malaysia and other countries in the tropical region still have adequate solar resources to develop CSP plant and most world regions except Canada, Japan, Russia and South Korea have significant potential areas for CSP [18]. Hence, Malaysia still has the potential to develop its own CSP Plant.

Solar energy is available over the entire globe and only the size of the collector field needs to be increased [19], or else the new design of CSP technology should be produced to provide the same amount of heat or electricity as in the region area with excellent resource of solar energy.

Among available technologies for energy production from solar sources, CSP could give a significant contribution to develop a more sustainable energy system [20] and many calculations have shown that CSP is more cost effective than PV not only in sunbelt [21]. But in Malaysia, power generation from solar energy is monopolized by PV solar and it is proven when Malaysia FIT scheme is limited for only four sources of renewable energy namely solar PV, Biomass, Mini Hydro and Biogas.

VI. GLOBAL DEVELOPMENT OF CSP PLANT

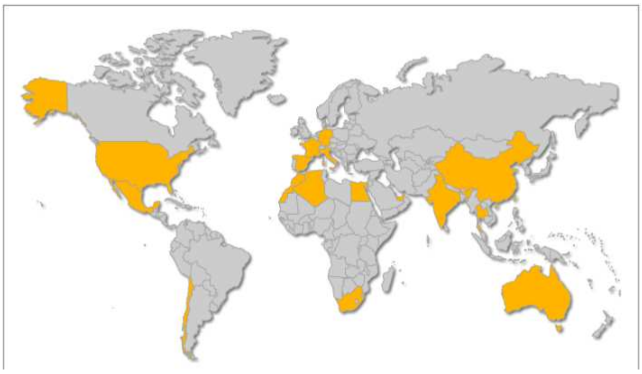

Fig 7. CSP project by country
Source: National laboratory of U.S Department of Energy

In general, most of the CSP potential studies were mainly focused on application in dry arid areas of mid-latitude zones [15]. Fig. 7 shows that most CSP plants are located in area with excellent solar resources with DNI higher than 1900 kWh/m2/year. German, a country that is located in area with DNI 902 kWh/m^2/year, has much lower DNI than Malaysia. However in December 2008, German has launched their CSP plant at Jülich, Rhineland. They are using Tower system with capacity of 1.5MW.

Meanwhile, Thailand a tropical country with Direct Normal Irradiance in ranges of 1350–1400 kWh/m^2/year becomes the first country in Southeast Asian that owns CSP plant. On January 25, 2012, Thailand's first Concentrating Solar power Plant called TSE1 supplied 5 MW of electrical power to Thailand's public power network for the first time. Therefore, this scenario proves that CSP plant can work even at regions with DNI lower than 1900 kWh/m2/year.

VII. CONCLUSION

Malaysia is located in the tropical regions with its own characteristics, such as wind speed, rapid change of clouds, rain, thunder storm and high humidity level. All of these climate conditions will affect the performance of the CSP system. Therefore, an innovative development and research of CSP should be carried out in Malaysian environment with detail considerations both on the technical and economic aspects. The research will give big impact not only for Malaysia but for other countries which aim to understand and explore CSP technology and the performance in tropical environment. Moreover, Thailand as a nearest neighboring country with Malaysia started their CSP Plant with the capacity of 5MW in 2012 and will increase the capacity to 135MW in the next five years. Malaysia should seriously consider looking into CSP technologies as one of the promising renewable energies for its future by looking at the CSP progress in Thailand.

ACKNOWLEDGMENT

The authors would like to gratefully acknowledge the funding support provided by the Ministry of Education Malaysia under the research grant No: FRGS/2/2013/TK02/FKE/01/F00167.

REFERENCES

[1] Ministry of Energy, Green Technology and Water, http://www.saveenergy.gov.my/conserve-energy-and-reduce-costs (Accessed 25 September 2012).

[2] U.S Department of Energy of Sciences, http://web.anl.gov/solar/primer/primer1.html (Accessed 25 September 2012).

[3] http://etp.pemandu.gov.my/upload/etp_handbook_chapter_6_oil_gas_and_energy.pdf (Accessed 26 September 2012).

[4] Muzathik, A. M., Wan Nik, W. B., Samo, K. B. & Ibrahim, M. Z, Hourly Global Solar radiation Estimates on The Horizontal Plane, Journal of Physical Science, Vol.21(2),51-66,2010.

[5] R. Winston, J.C. Minano and P. Benitez, "Nonimaging Optics", Elsevier Academic Press, pp. 1217, (2005).

[6] Q. Liu, G. Yu, and J.J. Liu, Solar Radiation as Large-Scale Resource for Energy, Short World Energy & Environment, 20(3): 319-329, 2009.

[7] Nafisa Noor and Sadid Muneer, Concentrating Solar Power (CSP) and Its Prospect in Bangladesh, 2009.

[8] Pawel Szczygiellski & Leonard Wagner (Mac 2009), Research Report CSP : Concentrated Solar Power Large Scale Alternatives to Traditional Solar PV, Mora Associates, Internal research

[9] http://www.brightsourceenergy.com/faq.htm (Accessed 27 September 2012).

[10] http://www.eere.energy.gov/basics/renewable_energy/linear_concentrator.html (Accessed 27 September 2012).

[11] Rosli A.Bakar, Development Assesment of Solar Concentrating Power System For Green Generation, 2010.

[12] N. and J. W. Kulichenko, Concentrating Solar Power in Developing Countries Regulatory and Financial Incentives for Scaling Up. Washington, DC: The World Bank, 2012, pp. 1–153.

[13] Laura Esmeralda, Garcia Moreno, Concentrated Solar Power (CSP) in DESERTEC-Analysis of Technologies to Secure and Affordable Energy Supply, IEEE International Conference on Intelligent Data Acquisitionand Advanced Computing Systems: technology and Applications, 2011.

[14] REN21, "Renewables Global Status Report: 2009 Update", Renewable Energy Policy Network for the 21 st Century (REN21), 2009: Available at http://www.ren21.net/pdf/RE_GSR_2009_Update.pdf (access on the 02/02/2010).

[15] R. Winston, J.C. Minano and P. Benitez, "Nonimaging Optics", Elsevier Academic Press, pp. 1217, (2005).

[16] Van Voorthuysen, The promising Perspective of Concentrating Solar Power (CSP), 2005.

[17] S. Janjai, J.Laksanaboonsong, T.Seesaard, Potential application Of Concentrating Solar Power Systems For The Generation Of Electricity In Thailand, Applied Energy 88 (2011) 4960-4967.

[18] Franz Trieb, Christoph Schillings, marlene O'Sulivan, Thomas pregger, carsten Hoyer-Klick, Global Potential Of Concentrating Solar Power, SolarPaces Conference, Berlin, September 2009.

[19] Pawel Szczygiellski & Leonard Wagner, Research Report CSP:Concentrated Solar Power Large Scale Alternatives to Traditional Solar PV, Mora Associates, Internal research, 2009.

[20] Q. Liu, G. Yu, and J.J. Liu, "Solar Radiation as Large-Scale Resource for Energy',Short World Energy & Environment, 20(3): 319-329, 2009.

[21] Volker Quaschning, Technical and Economical System Comparison of Photovoltaic and Concentrating Solar thermal Power Systems Depending on Annual Global irradiation, Solar Energy 77 (2004) 171-178.

Rosnani Affandi received her B.Eng in electrical engineering and the M.Edu degree from the Universiti Teknologi Malaysia (UTM). She joined the Polytechnic Department, Ministry of Education, Malaysia as a lecturer in 1999. She is currently pursuing her PhD at the Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Malaysia. Her current research interests include the renewable energy and concentrating solar energy.

Chin Kim Gan received his B.Eng and M.Sc degrees both in electrical engineering from the Universiti Teknologi Malaysia (UTM) and PhD degree from the Imperial College London, UK. He is currently a Senior Lecturer at the Universiti Teknikal Malaysia Melaka (UTeM). His research interests are distribution network design, integration of renewable energy and smart grid.

Mohd Ruddin Ab. Ghani is a professor and the Rector of the Universiti Teknikal Malaysia Melaka (UTeM). Before coming to UTeM, he was professor and the dean of the Faculty of Electrical Engineering at Universiti Teknologi Malaysia (UTM). Prof. Mohd. Ruddin Ab. Ghani obtained his Ph.D. in Systems Engineering and Control from the University of Manchester Institute of Science and Technology in 1989. His current research interests include: dynamic economic load dispatch, unit commitment, distribution automation, optimization of large scale power systems, system identification, expert system applications and advanced control techniques to power systems. He has published over 90 papers and articles in the related fields. Besides actively involved in research and publications, he is also a committee member of various distinguished boards such as: committee member of Malaysian International Electro-technical Commission (IEC), Intensification of Research in Priority Areas (IRPA) and IEEE Malaysia chapter. He is also member of Advisory Council Member of Malaysian Armed Forces Academy, and a member of Energy Technology under Economic planning unit.

Zanariah Jano is a Senior Lecturer at the Centre for Languages and Human Development, Universiti Teknikal Malaysia Melaka (UTeM). She obtained a BEd (TESL) (Hons.) from the University of Winnipeg, Canada. She also obtained an MA (Communication studies) specialising in information technology from the University of Brighton, UK. Currently, she is pursuing her PhD at Universiti Sains Malaysia in the field of ICT in communication. Her research interests relate to the area of ESP, EAP, ICT, gender studies, ICT in PBL, ICT in Management and E-commerce. She has presented her research at several international conferences, and has been involved in projects and teaching programmes at the national level.