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DEVELOPMENT ASSESSMENT OF SOLAR CONCENTRATING POWER SYSTEM FOR GREEN ENERGY GENERATION

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ABSTRACT

General solar power technology using photovoltaic cell to convert the sun energy directly into electric power but the efficiency is constraint by the material cost and the environmental factors. Lately, the development of the solar power move a step forward into concentrating technology where the density of the solar energy per area is multiplied from several time to few thousand time before it is convert into electric power. The breakthrough comes in many methodology based on different niche area and the concentrating solar thermal power give the most significant efficiency per unit energy cost. A detail development evaluation on solar concentrating technology has been carried out by the local university researchers to identify the future research path with lower energy cost and higher harvesting efficiency. Compared to fossil fuel based electric supply, the development of the renewable solar technology might not able to solve the current energy crisis. With the integration of hybrid system, improvement in lower production cost and compatible energy cost, the solar technology would give an alternative solution in the near future.

***Keywords**:* Renewable, Concentrating Dish, Solar Thermal, Environment Impact, Thermal Efficiency

INTRODUCTION

Current energy production from coal and oil is damaging the environment and non-sustainable. Many developing countries cannot afford these energy sources, and nuclear power stations are an unacceptable risk in most locations. Inadequate energy supplies can lead to high energy costs as well as to poverty, which commonly results in population explosion (Jorg et al., 2003). Consequently, renewable energy is the essential development for the secure future. Among various natural resources, solar energy is a radiant energy that produced by the sun. In just one hour, enough solar energy reaches the Earth's surface to supply all current human energy needs for one year (Gordon, 2009), yet this amount of energy is enormous than people have used since the beginning of time. In general, about 29 percent of the solar energy that arrives at the top of the atmosphere is reflected back to space by clouds, atmospheric particles, or bright ground surfaces like sea ice and snow. About 23 percent of incoming solar energy is absorbed in the atmosphere by water vapor, dust, and ozone, and 48 percent passes through the atmosphere and is absorbed by the surface. Thus, about 71 percent of the total incoming solar energy is absorbed by the Earth system (Rebecca, 2009).

People have harnessed solar energy for centuries. As early as the 7th century B.C., people used simple magnifying glasses to concentrate the light of the sun into beams so hot they would cause wood to catch fire. However, heating with solar energy is not an easy task. Capturing sunlight and putting it to work is difficult because the solar energy that reaches the earth is spread out over such as large area. Basically, the sun does not deliver that much energy to any one place at any one time. The amount of solar energy receives at a place depends on several conditions. These include the time of day, the season of the year, the latitude of the area, and the clearness or cloudiness of the sky. Some of the common areas that use solar power include architecture and urban planning, agriculture, solar lighting, thermal power and water heating, heating, cooling and ventilation of buildings, desalination and disinfection, cooking as well as process heat for commercial and industrial applications.

GROWTH OF SOLAR POWER TECHNOLOGY

Research on solar energy began as early as the 1860's but died down by the turn of the 20th century with increasing investments in fossil fuel. The biggest impetus to solar power research came as late as 1973, with the oil embargo. The next big push to solar power research came in 1997, with the Kyoto Protocol bringing to light the dangers of greenhouse emissions all over the world. The chronology of the solar power technology development could be summarized in Table 1 as follow:

Table 1: Development of Solar Power Technology (Commercial Solar Power Industry History, 2010)

Year	Scientist/Engineers	Achievement
1767	Horace De Saussure	Created world first solar cooker which could reach temperatures of almost 190 degrees F
1816	Robert Stirling	Patent for his solar dish system which created electricity
1866	Auguste Mouchout	Used a parabolic trough to produce steam for the first solar steam engine
1872	John Ericsson	Developed a solar thermal Stirling Dish concentrating solar-powered devices for irrigation, refrigeration, and locomotion
1878	Augustine Mouchout	First to combine the oven heat trap and burning mirrors concepts to create a solar oven.
1886	Alessandro Battaglia	First patent for a Solar Collector
1901	Aubrey Eneas, John Ericsson	Construction of the world first solar thermal dish with dual access tracking
1907	Frank Shuman	Completes construction of the "direct acting solar engine" with maximum temperature output of 202^{o}F
1913	Frank Shuman	Finished a 55HP "The No. 1 Sun Engine" parabolic solar thermal energy station
1936	Charles G. Abbot	Created solar system comprised of three parabolic troughs with tracking system
1968	Professor Giovanni Francia	Designed and built the first solar concentrated plant which entered in operation, able to produce 1MW with superheated steam at 100 bars and 500 ^{o}C.
2004	Schaich Bergermann	Design and supervises the construction of a 10kW Stirling EuroDish System
2009	Abengoe	The completion of PS20 20MW power tower

CONCENTRATING SOLAR POWER EFFICIENCY

With few environmental impacts and a massive resource, solar power offers a comparable opportunity to the sunny countries of the world. Solar thermal power uses direct sunlight, so it must be sited in regions with high direct solar radiation. Usually, one square kilometre of land is enough to generate as much as 100 -120 GWh of electricity per year using solar thermal technology. This is equivalent to the annual production of a 50 MW conventional coal or gas-fired mid-load power plant (Concentrated Solar Power Now, 2010). In order to fully utilize the bountiful solar power readily available, it is necessary consider a wider spectrum of solar energy. Tests have proven that solar thermal concentrators can provide the high temperatures required for utility and industrial thermal applications. The demonstration in 1984 by Sandia/SES of a 25kW concentrator and Stirling engine generator system was a technical success that opened the way for further large solar concentrator development (James at el, 2009)]. Theoretically, the total amount of solar energy receives by earth surface could be calculate by using Stefan-Boltzmann law, where

$$\text{Thermal Flux, } S = \sigma \text{ x } T^4 \tag{1}$$

The calculation on the solar energy on earth surface is based on the following assumptions:

a. Sun's surface as 5800 K and the surface the sun puts out 64 x 10^6 W/m^2 [Tom C., 2010]
b. Radius of the sun as about 724,200 km and the earth is about 149.67 million km from the sun, the surface area of a sphere is $4\pi r^2$ [Davis T. N., 2010]. Therefore, the power area goes as $1/r^2$, the ratio of the two distances is (724,200/1.4967x10^9). So the power per area is down by (724,200/1.4967x$10^9)^2$.

Apparently, Power per Area from sun at earth is as follow:

$$P = (724{,}200/1.4967\text{x}10^9)^2 \text{ x } 64 \text{ x } 10^6 \text{ W/m}^2 = \sim 1500 \text{ W/m}^2 \tag{2}$$

The energy from the Sun varies from place to place and is very dependent on weather conditions. Without an atmosphere 1.4 KW/m^2 per hour is available, but with an atmosphere it can only count on 1.0 KW/m^2 per hour in the absence of clouds [John C., 2010]. In simplified form, the comprehensible relationships between the solar energy and the output power from the CSP technology can be calculated as the solar input $\dot{Q}_{solar}$ multiplied by the respective efficiencies of collector, reflector and engine(s) [Jorg S., Rudolf B. et al 2003]:

$$P = \dot{Q}_{solar}.\eta_{plant} = \dot{Q}_{solar}.\eta_{coll}\eta_{ref}\eta_{eng} \tag{2}$$

The solar energy input $\dot{Q}_{solar}$ into the system can be written as the product of global horizontal radiation $G_h$and collector area $A_{collector}$

$$\dot{Q}_{solar} = G_h.A_{collector} \tag{3}$$

Same as other thermodynamic system, transformation of energy must according to the law of energy conservation. Take the solar power direct normal irradiation (DNI) as 1000 W/m^2, the relationship between inputs, output and deficiencies could be illustrated in Figure 1.

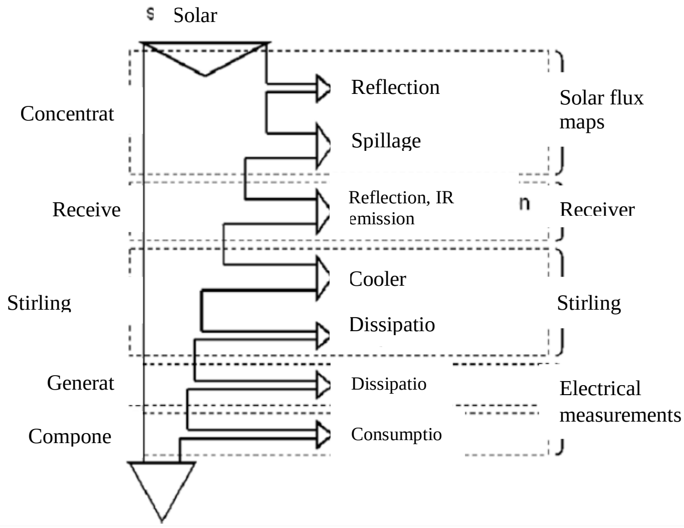


Figure 1: Solar Flux Map in the focal plane normalized to 1000W/m^2 (Francois et al, 2009)

CONCENTRATING SOLAR THERMAL POWER (CST)

A legend claims that Archimedes used polished shields to concentrate sunlight on the invading Roman fleet and repel them from Syracuse. Today, the technology which known as Concentrating Solar Power (CSP) systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. The concentrated heat is then used as a heat source for a conventional power plant.

Unlike traditional power plants, concentrating solar power systems provide an environmentally benign source of energy, produce virtually no emissions, and consume no fuel other than sunlight. About the only impact concentrating solar power plants have on the environment is land use. Although the amount of land a concentrating solar power plant occupies is larger than that of a fossil fuel plant, both types of plants use about the same amount of land because fossil fuel plants use additional land for mining and exploration as well as road building to reach the mines. The advantages and disadvantages of this technology are listed as follow:

Advantages

- Fuel supply is free and renewable
- Can be integrated with fossil fuel to make it dispatchable
- Thermal storage improves capacity factor
- Proven and mature technology
- Environmentally friendly
- Creates local and domestic employment

Disadvantages

- Cost of electricity generated from CSP is higher than conventional technologies.
- Requires excellent solar conditions.
- Requires large land area for installation of solar collectors.
- Can require significant water for cooling and steam for combined cycle power plant.
- Most of the related technologies has not been demonstrated in commercial scale

A wide range of concentrating technologies exists; the most developed are divided into concentrated solar thermal (CST), concentrated photovoltaics (CPV) and concentrating photovoltaics and thermal (CPT). In general, CST is used to provide medium to high temperature renewable heat or electricity. The system use lenses or mirrors and tracking systems to focus a large area of sunlight onto a small area. The concentrated light is then used as heat or as a heat source for a conventional power plant, for example through a steam turbine or a Stirling engine. Solar heat collected during the day can also be stored in liquid or solid media like molten salts. At night, it can be extracted from the storage medium and thus, continue the power cycle operation. The technology provides the lowest cost of energy among current solar technology options and has the potential for storage to provide additional supply during increased demand. In general, four main elements are required to produce electricity from solar thermal power:

a. Concentrator
b. Receiver
c. Some form of transport or storage
d. Power conversion

Some of the CST technologies include Parabolic Trough, Concentrating linear Fresnel reflectors, Dish Stirling, Solar Chimney and Solar Power Tower.

Parabolic Trough: Parabolic trough system or solar farm, consists of long, parallel rows of identical concentrators modules and it uses the mirrored surface of a linear parabolic concentrator to focus direct solar radiation to an absorber pipe running along the focal line of the parabola. The receiver is a tube positioned directly above the middle of the parabolic mirror and is filled with a working fluid. The reflector follows the Sun during the daylight hours by tracking along a single axis (refer to Figure 2).

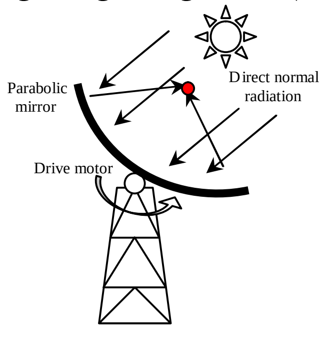


Figure 2: Parabolic Trough system

Concentrating Linear Fresnel Reflectors : use many thin mirror strips instead of parabolic mirrors to concentrate sunlight onto two tubes with working fluid. This has the advantage that flat mirrors can be used which is much cheaper than parabolic mirrors, and that more reflectors can be placed in the same amount of space, allowing more of the available sunlight to be used (refer to Figure 3).

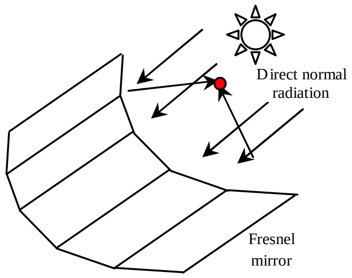


Figure 3: Concentrating Linear Fresnel Reflectors system

Dish Stirling : consists of a stand-alone parabolic reflector that concentrates light onto a receiver positioned at the reflector's focal point. The reflector tracks the Sun along two axes. The working fluid in the receiver is heated and then used by a Stirling engine to generate power. Typically, a stirling engine is used; other designs use gas (Brayton) turbines. A hybrid operation using natural gas is also possible. It provides the highest solar-to-electric efficiency among CSP technologies, and their modular nature provides scalability. The advantages of Stirling solar over photovoltaic cells are higher efficiency of converting sunlight into electricity and longer lifetime (refer to Figure 4).

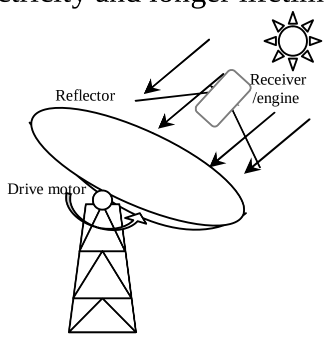


Figure 4: Dish Stirling system

Solar Chimney : consists of a transparent large room (usually completely in glass) which is sloped gently up to a central hollow tower or chimney. The sun heats the air in this greenhouse-type structure which then rises up the chimney, hereby driving an air turbine as it rises. This air turbine hereby creates electricity [refer to Figure 5].

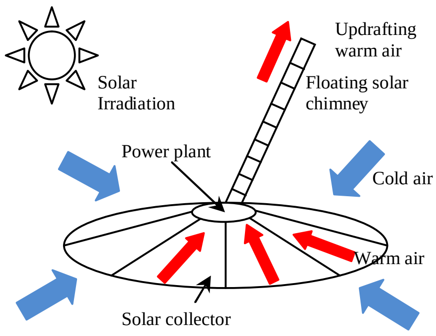


Figure 5: Solar Chimney system

Solar Power Tower : characterized by the centrally located large tower. A field of two axis tracking mirrors reflects the solar radiation onto a receiver that is mounted on the top of the tower, where the solar energy is absorbed by a working fluid, then used to generate steam to power a conventional turbine. Power tower development is less advanced than trough systems, but they offer higher efficiency and better energy storage capability [refer to Figure 6]. Table 2 lists the performance data for various CSP technologies. The function principle and the main system parameters of these power plants are described below.

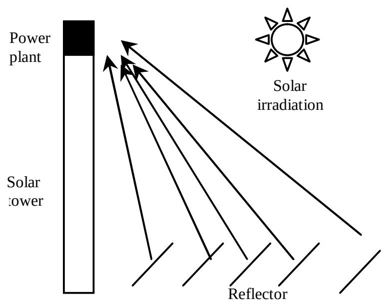


Figure 6: Solar power tower system

With capacity of 10–400kW, the dish/stirling is rather small. It does not enjoy the same economy of scale as the other two systems, so it is doubtful whether dish/stirling will ever form the backbone of multi-GW grid connected systems. However, this system could play an important role in the decentralized part of the solar economy. Parabolic trough and power tower are both centralized systems, and they are candidates for applications with grid connection. The tower is still immature and the large scale utilization of parabolic trough could be realized in near and mid-term.

Table 2: Performance data for various concentrating solar power technologies (Qu et al., 2008)

CSP systems	Parabolic Trough	Central Receiver	Parabolic Dish
Application	• **Grid-connected plants, mid to high process heat** • **(Highest single unit solar capacity to date 80MW) Total capacity built : 354 MW**	• **Grid-connected, high temperature process heat (Highest single unit solar capacity to date : 10MW)**	• **Stand-alone, small off-grid power or clustered to larger grid connected dish parks (Highest single unit solar capacity to date : 25kW)**
Capacity range (MW)	10-200	10-150	0.01-0.4
Concentration	70-80	30-1000	1000-3000
Demonstrated annual solar efficiency (%)	10-15	8-10	16-18
Thermal cycle efficiency (%)	30-40	30-40	30-40
Land use m^2/(MW ha)	6-8	8-12	8-12

MAIN ISSUE WITH THE CST DESIGN AND THE POTENTIAL SOLUTION

Although the CSP is low compare to other solar technology, it will be more cost effective but it can be further reduce by innovative design of the CSP system, manufacturing cost, material utilisation. For most of the CSP technology, the principal problem with current solar concentrator dishes is their use of glass mirrors and it is identified as a key driver for the design (Lovegrove at el, 2010). Parabolic is the ideal curve line to focus solar DNI at a specific focal point. For large scale production, manufacturing of perfect 3D parabolic dish is too expensive and the single point concentrated solar power is less preferable in practical application where heat energy is distributed asymmetrically. The new technology to replace curved glass mirrors is a faceted panel of flat-plate reflective mirror elements (James et al., 2009). The proprietary connectors joining these identical reflecting elements together are adjustable so that the reflection from each element falls within the target area of a power generator.

In 2009, scientists teamed to develop large curved sheets of metal that have the potential to be 30% less expensive than today's best collectors of concentrated solar power by replacing glass-based models with a silver polymer sheet that has the same performance as the heavy glass mirrors, but at a much lower cost and much lower weight. It also is much easier to deploy and install. The glossy film uses several layers of polymers, with an inner layer of pure silver (Concentrating solar power, 2010). These faceted panels have the advantage that they are more robust, lighter, easier to construct and transport, and lower in cost compared to fragile, heavy, expensive conventional curved glass mirror panels. The solar concentrator dishes built from this mirror are the improvements in economics, durability, maintenance, weight, and transportation, ease of construction and life cycle cost that can satisfy the needs for utility power generation.

One of the local available materials would be the plastic mirror or PMMA Arcylic mirror. The light or shatter-resistant of plastic mirror is an alternative to glass, an economical alternative to polycarbonate (PC) when extreme strength is not necessary. It is often preferred because of its moderate properties, easy handling and processing, and low cost, but behaves in a brittle manner when loaded, especially under an impact force, and is prone to scratching compared to glass. In addition, it has a density of 1.150–1.190g/cm^3, less than half the density of glass, and similar to that of other plastics with excellent environmental stability compared to other plastics such as polycarbonate, and is therefore often the material of choice for outdoor applications (Acrylic, 2010).

FUTURE OF CST SYSTEM

Solar technology has made huge technological and cost improvements, but more research and development remains to be done to make it cost-competitive with fossil fuels. Some of the affirmative steps are to increase the demand of this technology worldwide, improved the component design and advanced systems. One key competitive advantage of concentrating solar energy systems is their close similarity to most power plants. Concentrating solar power technologies use many of the same technologies and equipment used by conventional power plants; they simply substitute the concentrating power of the sun for the combustion of fossil fuels to provide the energy for conversion into electricity.

For large scale electric power generation, it involves several aspects including costs, capacity, reliability, maintenance and of course the environment. The cost for providing electricity itself involves several aspects, including base load or peaking power, transmission costs, and in conventional systems, the fuel cost. A study found that concentrated solar power could account for up to 25% of the world's energy needs by 2050. Also, with this expansion of concentrated solar power, thousands of new jobs would be created and millions of tonnes of carbon dioxide would be prevented from being released (EREC, 2001). Unfortunately, the development of CSP technology will not able to achieve independence power supply at current time. The hybrid system that combine various generation methods to achieve optimum supply and cost effectiveness such as using hydro-power, gas fired turbines, diesel power stations, and so on is the intermediate steps to the solar power future.

Advancements in the technology and the use of low-cost thermal storage will allow future concentrating solar power plants to operate for more hours during the day and shift solar power generation to evening hours. Researchers are developing lower cost solar concentrators, high-efficiency engine/generators, and high-performance receivers. The goal is to further develop the technology, to increase acceptance of the systems and help the systems penetrate growing domestic and international energy markets. Significantly, urban area with low electricity requirement and plentiful of solar resource is one of the biggest and fastest growing market for the solar power producing technologies.

UTILISATION OF SOLAR POWER TECHNOLOGY IN MALAYSIA

In Malaysia, rural electrification is currently regarded as an integral part of the government's important strategy to share the economic development benefit with the rural people. There are currently two categories of rural electricity supply: public supply, provided by the Sabah Electricity Board in Sabah, SESCO in Sarawak and TNB in Peninsular Malaysia; and private supply, which can be further subdivided into the following three categories:

- Government provided diesel generator sets
- Commercial generators owned and operated by a private business
- Private use diesel or petrol generator sets, purchases by a household or group of households

Rural household in Malaysia would need to be adequate for lighting and to run a few domestic appliances, such as ceiling fans, a TV, a radio and possibly a refrigerator. These loads could all be D.C. but this would be less popular with consumers, who would wish to have the freedom to buy cheaper standard A.C. products from the suppliers. Due to fluctuation of fossil fuel market and limited resource supply, new and renewable energy sources would certainly be preferred if available at acceptable costs and with proven reliability. In some locations, wind generators or micro hydro systems may be feasible, but in general, solar power system is preferable due to cost and maintenance consideration.

At the moment, Malaysia solar power or also known as photovoltaic (PV) system is only limited to solar water heating systems in hotels, small food and beverage industries and upper middle class urban homes. It was estimated that there are more than 10,000 units of domestic hot system using PV system at the moment in Malaysia (Mohamed, 2006). Although PV system has tremendous potential, especially for remote areas in Malaysia, PV panels are most likely imported and not suite for long lasting tropical climate utilisation. Costs of PV cells have to be viewed in a different manner since, as is now widely accepted. PV cell costs are on a falling cost curve, but not such a large fall in price to balance system costs which including batteries, controls, wiring, installation and etc. The system costs will probably not fall as fast as the module costs and eventually, this technology still too expensive for mass power generation.

REVOLUTION FROM CPV TO CST SYSTEM

Basically, CST systems require high DNI for cost-effective operation. Sites with excellent solar radiation can offer more attractive levelized electricity prices, and this single factor normally has the most significant impact on solar system costs (Qu et al., 2008). Near to the Equator line, there is little distinction between summer, winter, autumn or spring. There is abundant rainfall due to the active vertical uplift or convection of air that takes place there, and during certain periods, thunderstorms can occur every day. Temperatures are high year round (permanent "summer"), with the exception of periods during the wet season and at higher altitudes. In many tropical regions people identify two seasons: wet and dry. However, most places close to the Equator are wet throughout the year, and seasons can vary depending on a variety of factors including elevation and proximity to an ocean. The rainy and humid conditions mean that the equatorial climate is not the hottest in the world. Nevertheless, this belt still receives considerable sunshine.

At night the abundant cloud cover restricts heat loss, and minimum temperatures fall no lower than about 22°C. This high level of temperature is maintained with little variation throughout the year. The climate is distinguished not as warm and cold periods but by variation of rainfall and cloudiness. Greatest rainfall occurs when the Sun at midday is overhead. On the equator this occurs twice a year in March and September, and consequently there are two wet and two dry seasons. Further away from the equator, the two rainy seasons merge into one, and the climate becomes more monsoonal, with one wet season and one dry season. In the Northern Hemisphere, the wet season occurs from May to July, in the Southern Hemisphere from November to February.

In Malaysia, the climatic conditions are favourable for the development of solar energy due to the abundant throughout the year. With the average temperature of 27.5^{o}C, there is an average of 2228 hours of sunlight per year with an average of 6.1 hours of sunlight per day and range between 4.9 hours per day in November and 7.4 hours per day in February. Apparently, the solar radiation ranges from 6.5 kWh/m^2 in the months of January and drops lower to 6.0 kWh/m^2 in the months of August (Mohamed et al., 2006). As a result, the solar radiation in Malaysia is high by world standards. Even in Kuala Lumpur, a CPV system able to receives 30% more energy than western countries (Bakar R.A., 2010). The detail of Malaysia climate change could be referred to Figure 7.

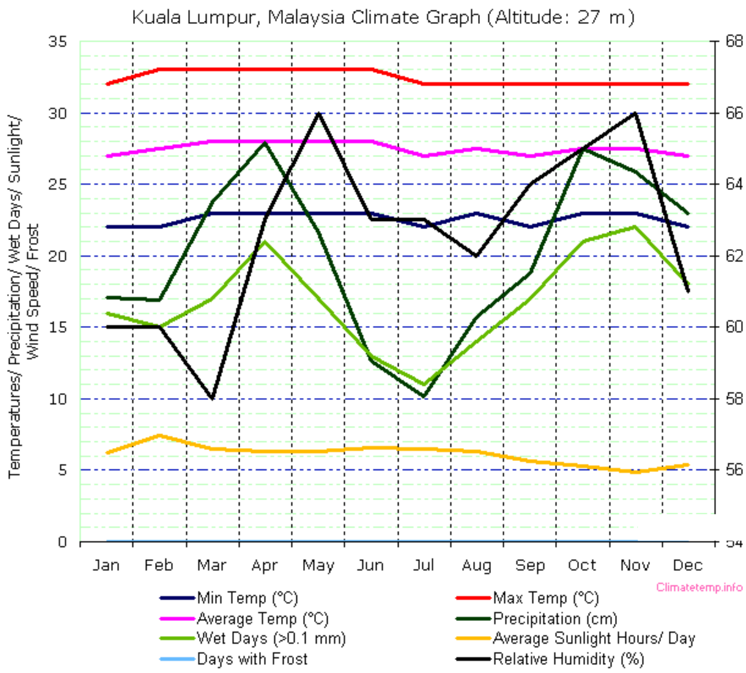
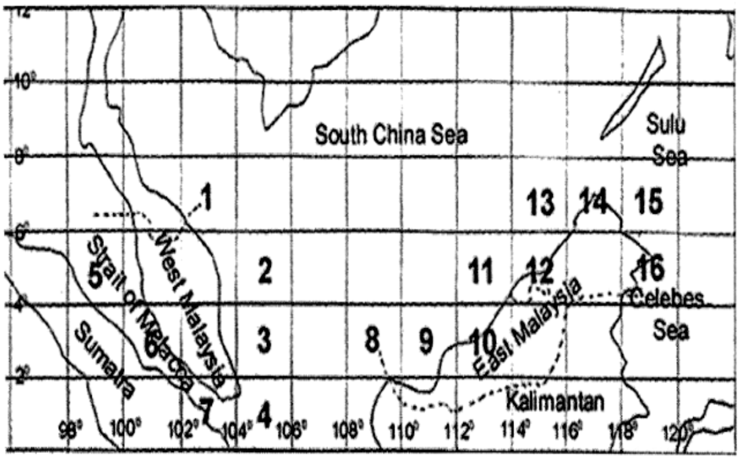


Figure **7:** Malaysia climate change graph for over the year (http://www.climatetemp.info/Malaysia, 2010)

Due to two monsoonal winds in Peninsular, Sabah and Sarawak, dynamic loads were a major driver in determining the structural design. A study had been carried out by Chiang E.P., et al from 1985 to 2000 to identify ultimate limit state wind speeds based on location, height and other factors and the result is shows in Figure 8. The main wind direction is variable and the mean surface winds over peninsular Malaysia are generally mild, with the mean speed of about 1.5 m/s, and a maximum speed of less than 8 m/s (Ismail, 2010).



a. Study location

Month	East Peninsular Malaysia				West Peninsular Malaysia			Sarawak				Sabah				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Jan	5.8	6.8	6.7	5.7	2.4	0.7	2.2	5.7	3.8	2.5	3.9	4.0	6.8	4.0	3.1	2.7
Feb	4.8	5.3	5.4	4.6	1.6	0.7	2.4	4.7	3.8	2.2	3.4	3.7	6.2	4.2	5.7	1.9
Mar	3.9	4.0	3.8	3.3	1.4	1.0	1.4	3.8	2.5	1.9	2.6	2.8	5.2	4.0	3.6	2.3
Apr	2.7	2.0	1.7	1.1	1.2	0.9	1.4	1.2	1.2	0.9	0.9	1.3	2.9	2.2	0.5	1.3
May	2.2	2.5	2.1	1.6	1.0	1.0	1.6	1.4	1.2	0.8	0.7	1.2	1.6	1.5	0.0	1.4
Jun	3.1	3.4	3.1	2.6	1.4	1.5	1.9	2.2	1.0	0.6	1.2	1.6	2.7	2.5	2.6	1.7
Jul	2.4	4.9	4.3	3.7	1.3	2.1	2.2	3.2	1.5	1.2	1.7	1.7	3.5	2.8	3.5	1.6
Aug	3.9	4.8	4.5	3.7	1.6	1.4	1.9	2.9	1.2	1.5	2.0	2.4	4.4	3.5	2.1	2.8
Sep	3.3	3.5	3.3	3.0	0.9	0.8	1.3	2.9	1.6	1.1	1.2	8.7	2.9	2.7	0.0	1.9
Oct	0.0	1.1	1.7	2.7	1.6	1.2	1.5	2.7	1.5	1.0	1.9	1.7	2.8	2.7	3.1	1.2
Nov	5.1	3.6	2.7	2.3	2.1	1.7	2.2	1.6	1.4	1.3	1.2	1.9	2.4	2.1	3.1	1.8
Dec	5.1	7.6	5.9	5.0	2.4	1.5	2.9	4.6	2.5	1.4	1.7	2.1	4.3	2.8	4.3	3.1
Mean	3.5	4.1	3.8	3.3	1.6	1.2	1.9	3.1	1.9	1.4	1.9	2.8	3.8	2.9	2.6	2.0

b. Monthly vector resultant mean wind speed in m/s from 1985 to 2000

Figure 8: Malaysia Mean Wind Speed Study (Chiang et al., 2003)

The CST system design process in tropical region such as Malaysia must followed rigorous systems-design principles with the consideration of these environmental factors and carefully considered the interactions between the key subsystems of structure, mirrors, receiver, foundation, control and harvester, as each was developed in parallel. Meanwhile, the limited day time also means solar radiations are intermittent and effective energy storage is an important issue because modern energy systems usually assume continuous availability of energy. Some of the examples are:

Thermal Mass Systems: can store solar energy in the form of heat at domestically useful temperatures for daily or seasonal durations. Thermal storage systems generally use readily available materials with high specific heat capacities such as water, earth and stone. Well-designed systems can lower peak demand, shift time-of-use to off-peak hours and reduce overall heating and cooling requirements.

Molten Salts: Salts are an effective storage medium because they are low-cost, have a high specific heat capacity and can deliver heat at temperatures compatible with conventional power systems.

Rechargeable Battery : Batteries are the most common methods for storage of solar energy. There are 2 types of batteries available. They are nickel cadmium and lead acid. The lead acid batteries are cheap and preferred for solar energy storage. The nickel cadmium battery also functions in the same manner but are expensive. However the nickel cadmium batteries discharge more electricity and also last longer.

Pumped Storage Hydroelectricity: stores energy in the form of water pumped when energy is available from a lower elevation reservoir to a higher elevation one. The energy is recovered when demand is high by releasing the water to run through a hydroelectric power generator.

CONCLUSION

Detail assessment on the selected CSP technology, especially in terms of harnessing efficiency, theoretical principles and future development of CSP especially in Malaysia region is well established. The transformation of solar harvesting methodology into technological working prototype is a parallel process between the key subsystems of structure, mirrors, receiver, foundation, control and harvester unit. The innovative development of low cost CSP could be achieved by detail consideration of manufacturing cost and overall material utilisation. Due to monsoonal climate near to equator line, tropical countries like Malaysia must take extra consideration of different weather change such as windy, cloudy, rainy and etc. Due to limited day time, energy storage is another essential factor where different storing method could be considered. Based on the technological constraint, fully independent sustainable solar power plant is a long term alternative technology. Before that, hybrid system with conventional fossil fuel power plant is the most recent and dependable methodology.

FUTURE WORK

Instead of using parabolic features to concentrate solar power density, an innovative design and development plan for the new reflecting, receiver and harvester is under construction. Engineering analysis on stress, system efficiency and control algorithm is necessary to generate local and new solar technology for rural and urban utilization.

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Nomenclature

T is in degrees Kelvin.
P total power W
$\dot{Q}_{solar}$ Solar power in W
η_{plant} power plant efficiency
η_{coll} collector efficiency
η_{ref} reflector efficiency
η_{eng} engine efficiency
G_h global horizontal radiation
$A_{collector}$ collector area
S is in thermal flux W/m^2
σ is Stefan–Boltzmann constant in 5.67 x 10-8 $Wm^{-2}K^{-4}$