

TOWARDS IMPLEMENTATION CSP TECHNOLOGY IN MALACCA PART. 1: DNI ASSESSMENT IN ALOR GAJAH

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Abstract—The direct irradiance received on a plane normal to the sun, called direct normal irradiance (DNI) and of course relevance to concentrated solar technologies. Therefore, the aim of this study was to analysed temperature, GHI and DNI data for the assessment of solar radiation availability in the effort of implementing CSP technology in Malacca. There are four stations was selected in Alor Gajah (Malacca). SolarGIS and Solar flux meters are a pathway to analysed radiation effect in Alor Gajah. The analysis showed that the DNI from predicted model and measurements provided adjacent data. Although continued measurements are needed to understand the interannual resource variability, the current study should have significant applications for preliminary technology selection, power plant modeling, and resource forecasting. With the fast technological improvement, decreasing costs and increasing public acceptance, solar energy will surely play a relevant share of future energy systems.

Keywords—CSP, DNI assessment, GHI, solar radiation.

I. INTRODUCTION

Today, the population growth, development programs and attempt of growth in developing countries as well as new industrial growth in the globe becomes the imperative reasons towards the substantial progression in energy demand. Inaccessibility of fossil fuel in most regions, high cost, their depletion and air pollution are the most disadvantages of fossil fuels consumption. Therefore in order to overcome these concerns, development and implementation of new energy resources like nuclear and renewable energies are undeniable [1].

Solar energy is belief to be the most manageable and reliable renewable energies to an extensive development based on the last two decades. One of the solar energy application is CSP that leads to extend in commercial scale in several countries. CSP technologies exist in four forms; Parabolic Trough, Dish Stirling, Concentrating Linear Fresnel Reflector and Solar Power Tower, among which solar power tower and parabolic trough are the two main approaches of a large-scale application of CSP systems [1].

Towards establishment a CSP plant need to conduct a pre-feasibility study that includes solar energy resource, cost and water supply analysis. CSP plants only exploit direct beam solar radiation in order to generate electricity. Enjavi-Arsanjani generally assumed that CSP systems are fiscal at the locations with DNI above 1800 kWh/m²/year (about 5 kWh/m²/day) [1]. Thus the country or location that receives abundant of solar radiation has become the key to be used for solar energy development [2]. Even so, the first solar thermal power plant in South East Asia has started operation in January 2012 in the region of Kanchanaburi, Thailand. This TSE-1 power plant has shown the proof of concept DSG technology and also operated under sub-tropical climate [3].

Observation of solar energy resources over large areas and the description of solar radiation maps can be conducted using satellite derived information. The solar radiation data information is of important for atmospheric research and solar energy technology deployment [4,5,6,7]. But then again, solar radiation readings vary with geographic latitude, season and time of day, due to the various positions of the sun under unpredictable weather conditions.

Therefore, such databases are setup to obtain most effective and precise data for long term benefits [6]. In addition, the complexity of solar radiation parameter to model is because of its dependence on complex phenomena as cloudiness, changeable weather conditions and environmental conditions [8].

II. DIRECT NORMAL IRRADIATION

Solar radiation can be transmitted, absorbed or scattered by an intervening medium in variable amounts depending on the wavelength over the approximate range of 300-3000nm. Referring to the intricate interactions of the Earth's atmosphere with received solar radiation result in three fundamental broadband components of interest to solar energy conversion technologies [7]:

DNI – Direct (beam) radiation available from a 5° field of view across the solar disk on a surface oriented normal to the sun's position in the sky. Measurements of DNI are made with a pyrheliometer mounted in an automatic solar tracker. This solar component is of importance for concentrating solar technologies such as CSP and CPV.

DHI – Scattered solar radiation from the sky dome except from the solar disk (i.e. not including DNI) on a horizontal surface. Measurement of DHI is made with a shaded pyranometer. Levels of DHI are generally lower under clear (blue) sky conditions than under partly cloudy (white) sky conditions. DHI data are helpful for estimating the POA irradiance, automating data quality assessments, and architectural daylighting design applications.

GHI – Total hemispheric or geometric sum of the DNI and DHI components available on a horizontal surface. GHI measurements are made with an unshaded pyranometer. GHI data represent the amount of solar radiation incident on horizontal flat plate solar collectors, and can be used alone or in coincidence with DNI, DHI and albedo (reflected ground irradiance) to evaluate the solar radiation on tilted flat plate collectors.

These basic solar components are related to the SZA by equation (1) [7,9,10,11]:

$$GHI = DNI \times \cos(\theta_z) + DHI \quad (1)$$

The DNI data is use for transposition models in estimating global irradiance on tilted planes, which is utilized by flat-plate systems. Such models convert the global irradiance on the horizontal plane to the global irradiance on the tilted plane and their use requires transposing separately the direct and diffuse radiation components. As direct radiation has a geometric behaviour, the horizontal direct irradiance comes from DNI multiplied by the cosine of the zenith angle. Hence, the assessment of DNI is vital for the study of both concentrating and flat-plate solar systems [12]. Besides, solar collectors are built to utilize the solar radiation.

The reference instrumentation for the measurement of DNI is composed of a thermopile pyrheliometer installed on a sun tracker which is quite expensive. Alternatively is to indirectly derive DNI from the measurements of global and diffuse horizontal irradiance. The diffuse irradiance is measured with a shaded pyranometer and the best way is to occult the solar disk with a ball driven by a sun tracker [12].

A cheaper and common technique uses a shadow band by screening the pyranometer along the day. By using this method, manual adjustment of the band is required each few days as the declination changes, yet the measured irradiance has to be corrected, because the band blocks also a part of diffuse radiation. Unfortunately, the tricky part of indirect evaluation of DNI is that pyranometers can be affected by several sources of uncertainty, which should be properly considered. The uncertainty of DNI defined by Padovan as (2) [12].

$$\mu_{DNI} = [\sqrt{(\mu_{GHI})^2 + (\mu_{DHI})^2}]/\cos(\theta_z) \quad (2)$$

In consequence, solar radiation data fluctuation is very significant when working with solar energy. Sky conditions too are particularly stimulating since the attenuation of solar radiation in the atmosphere is strongly dependent on the cloud variability [8]. Thus, this paper is to analyses the

collected DNI data in Mukim Alor Gajah and compared with the prediction model in the effort of bringing in the new solar application; CSP technology, in Malacca.

III. LOCATION

Izquierdo et al. [13] proposes a hierarchical approach when studying the use of a specific renewable resource such as the solar radiation, introducing gradual restrictions to define different levels of the potential. The first one is the physical potential, which is encompasses the maximum amount of solar energy that can be received in a certain area. Second is the geographic potential is calculated by gradually excluding the zones reserved for other uses, restricting the locations where solar energy can be gathered. In this study, there are four stations was selected in Mukim Alor Gajah as pointed in Figure 1 and the coordinates for all stations is shown in Table 1.

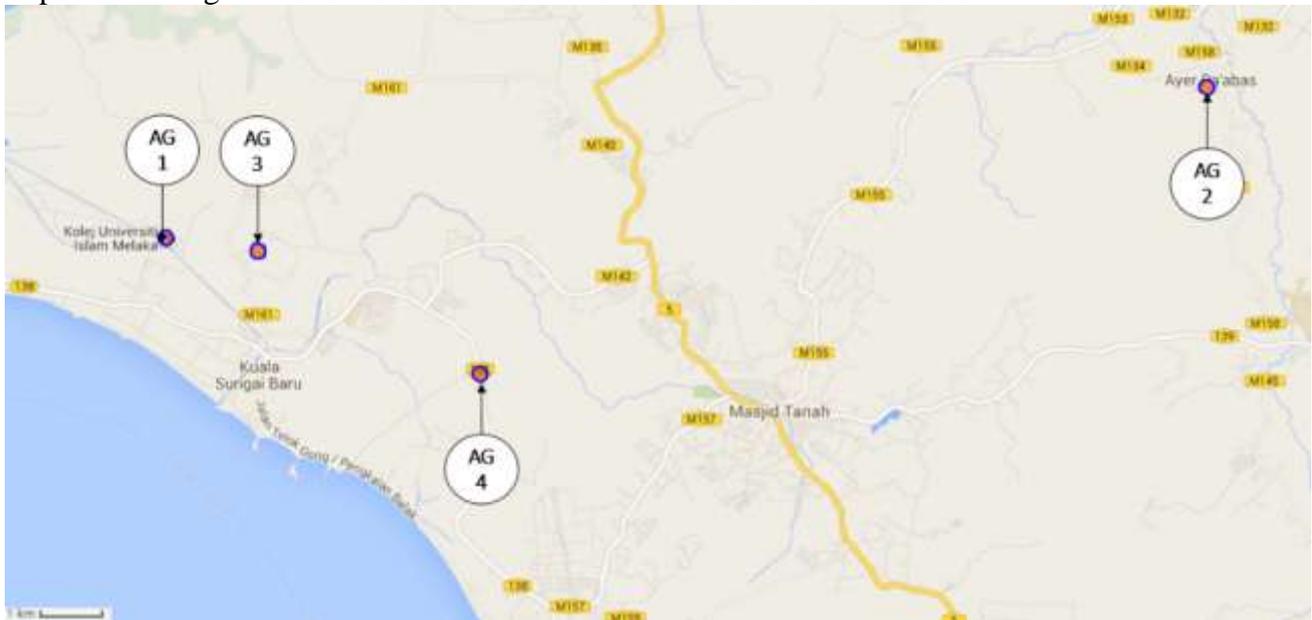


Figure 1. Solar monitoring location of AG1, AG2, AG3 and AG4 in Mukim Alor Gajah, Malacca

The evaluations of selected locations because irradiances are derived from climate model data and climate models are designed to provide reliable information about the atmosphere.

Table 1. Coordinates of solar monitoring location in Mukim Alor Gajah

Location	Coordinates
AG1	2°22'32.3"N 102°01'36.2"E
AG2	2°23'49.1"N 102°09'59.6"E
AG3	2°22'26.0"N 102°02'20.4"E
AG4	2°21'27.1"N 102°04'17.2"E

IV. METHODOLOGY

In this study, first method is based on the prediction model using SolarGIS. In order to attain identical observational data for solar radiation it acquires to forecast the data at different time horizons and from minutes to hours on a specific location. The use of geostationary satellites measurements for estimating downward solar radiation can provide the necessary time and space resolution, but the local accuracy of the products has to be specifically assessed [8].

The simulation of a CSP system is convoluted due to non-linearity of thermal systems, capacity limitations and storage. Therefore, the usage of a satellite-modelled solar resource data became standard. Specifically in CSP, prior to generation TMY, historical satellite-based time series are correlated with short-term ground measurements and they are adapted for the specific conditions of a site [14].

Multiyear time series of solar radiation and meteorological data are transformed to a simpler data representation with an aim to reduce data volume and speed-up energy simulation. TMY

condenses hourly or sub-hourly time series, typically representing more than 10 years of historical data, into one year [14]. Thus, the prediction model will project yearly data of particular location.

Above and beyond during the observation field, the team is using solar flux meter with specification shown in Table 2 to measure the DNI parameter. This solar flux meter end mount light sensor is faced upward and parallel with the sun as in Figure 2. Hence, the data collected consider hourly average of DNI data [8].footnotes sparingly (or not at all) and place them at the bottom of the column on the page on which they are referenced. Use Times new roman 8-point type, single-spaced. To help your readers, avoid using footnotes altogether and include necessary peripheral observations in the text (within parentheses, if you prefer, as in this sentence).

Table 2. Solar power meter specifications

Specification	Value
Range	2000W/m ²
Resolution	0.1 W/m ²
Operating conditions	0°C to 50°C (32°F to 122°F) below 80%RH
Angular accuracy	Cosine corrected < 60°
Accuracy	Typically within ±10 W/m ² [±3 Btu / (ft ² x h)] or ±5%, whichever is greater in sunlight ; Additional temperature induced error ±0.38 W/m ² /°C [±0.12 Btu / (ft ² x h)/°C] from 25°C

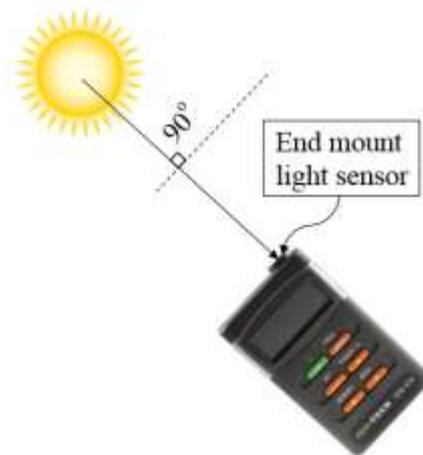


Figure 2. Measurement methods

V. RESULTS

5.1. Temperature

The temperature map data is retrieved from SolarGIS predicted model and weather forecast for all four locations [1]. The results is shown in Figure 3 and explained a good agreement of both results sources that range the temperature at all four locations is within 30 to 32°C.

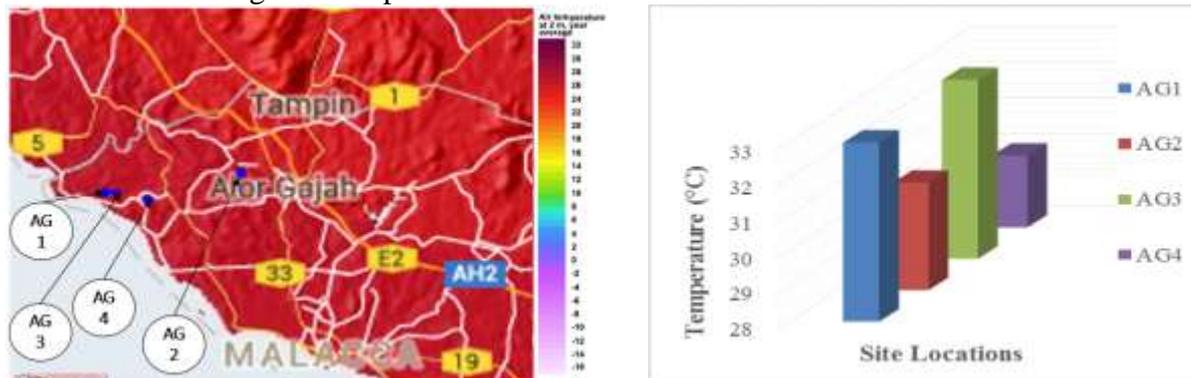


Figure 3. Temperature mapping of experimental sites in Alor Gajah based on (a)SolarGIS (b) weather forecast

5.2. Solar radiation

One decisive step towards this objective, or any solar-based energy project, is the assessment of the irradiation available at ground level throughout the country in order to select the best locations for each type of solar technology [9]. The map in Figure 4 illustrates the GHI value of all four locations observed is within 1200 to 1400 kWh/ m²/year.

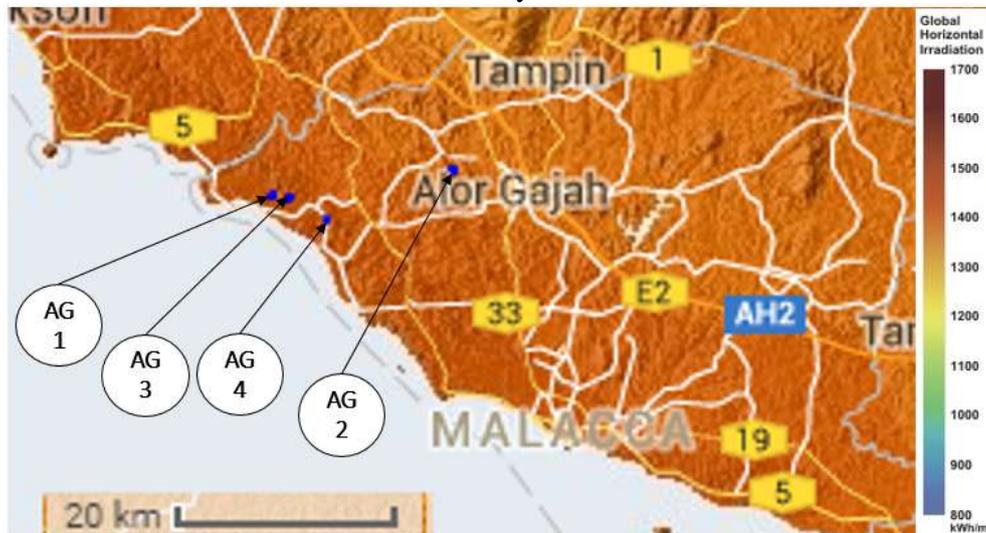


Figure 4. GHI data of experimental sites in Alor Gajah by SolarGIS

Though accurate datasets of GHI are available for many sites, still efforts are required to fully characterize the DNI resource [12]. In this study, the map in Figure 5 illustrates the geographic distribution of average yearly total DNI of the four experimented sites in Alor Gajah [15]. This result can be explained taking into mind that the contour values correspond to the location of AG1 is in the range of 1000 to 1100 kWh/ m²/year. This range corresponded to the location covering at 5 km² area nearby location AG1 whereby results in the same range of DNI data as in AG3 and AG4 [4]. Meanwhile AG2 is pointed in the range of 800 to 1000 kWh/ m²/year.



Figure 5. DNI data mapping for locations experimented in Alor Gajah by SolarGIS

5.3. DNI on-site

Since measurements of global and diffuse irradiance have good accessibility and availability, the present paper aims at clarifying to the extent such data can be used for deriving DNI data hourly by observing on-site using solar flux meter [12]. DNI on site for AG1 shows in Figure 6 explained a

good agreement between the result obtained on-site and result mapping by SolarGIS that simulates the area of AG1 will give the results at the range of 1000-1100 kWh/ m²/year [4].

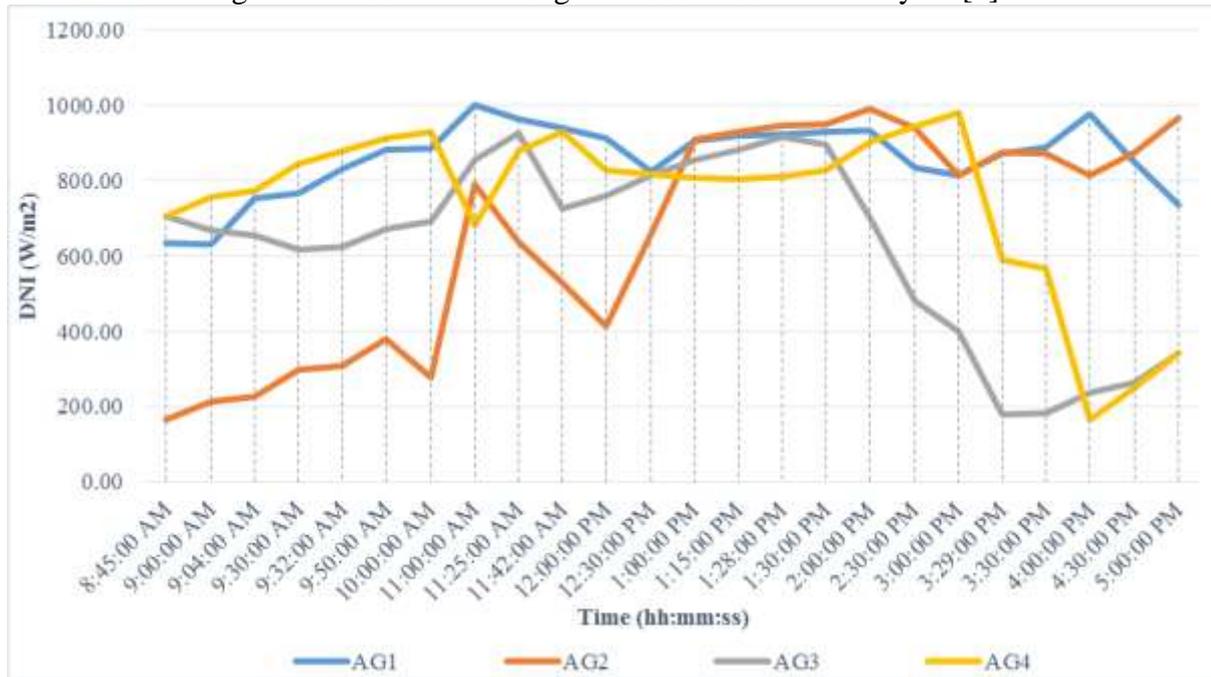


Figure 6. DNI data collected on-site

The DNI observed at the site range in 600 to 1000 kWh/ m² for all four locations in Alor Gajah. The peak DNI data appears at solar-noon started at 11.00 am until 3.00 pm that ranges between 900 to 1000 kWh/ m². The data is over than 700 kWh/ m² after 9.30 am until 4.30 pm. The data less than 400 kWh/ m² are observed at early morning and late evening after 4.30 pm. There is a slight decrement of DNI at certain hours due to the presence of cloud as shown in Table 3. The data showed differences due to clear sky and cloudy sky conditions.

Table 3. Sky condition for results reducing

Sky conditions			
(a) AG2 cloud condition during low results early in the morning.	(b) AG2 sky condition during first reading	(c) AG3 cloud condition during data dropping.	(d) AG4 cloud condition during data dropping.
			

Based on the data observed, the location that results in highest and stable data is AG1. By taking into consideration on AG1 location and compared the data obtained by three others location, it projected the DNI percentage difference as in Figure 7. The graph appears in positive value explained that AG1 value is higher than AG2, AG3 and AG4. Vice versa for the results appears in negative values.

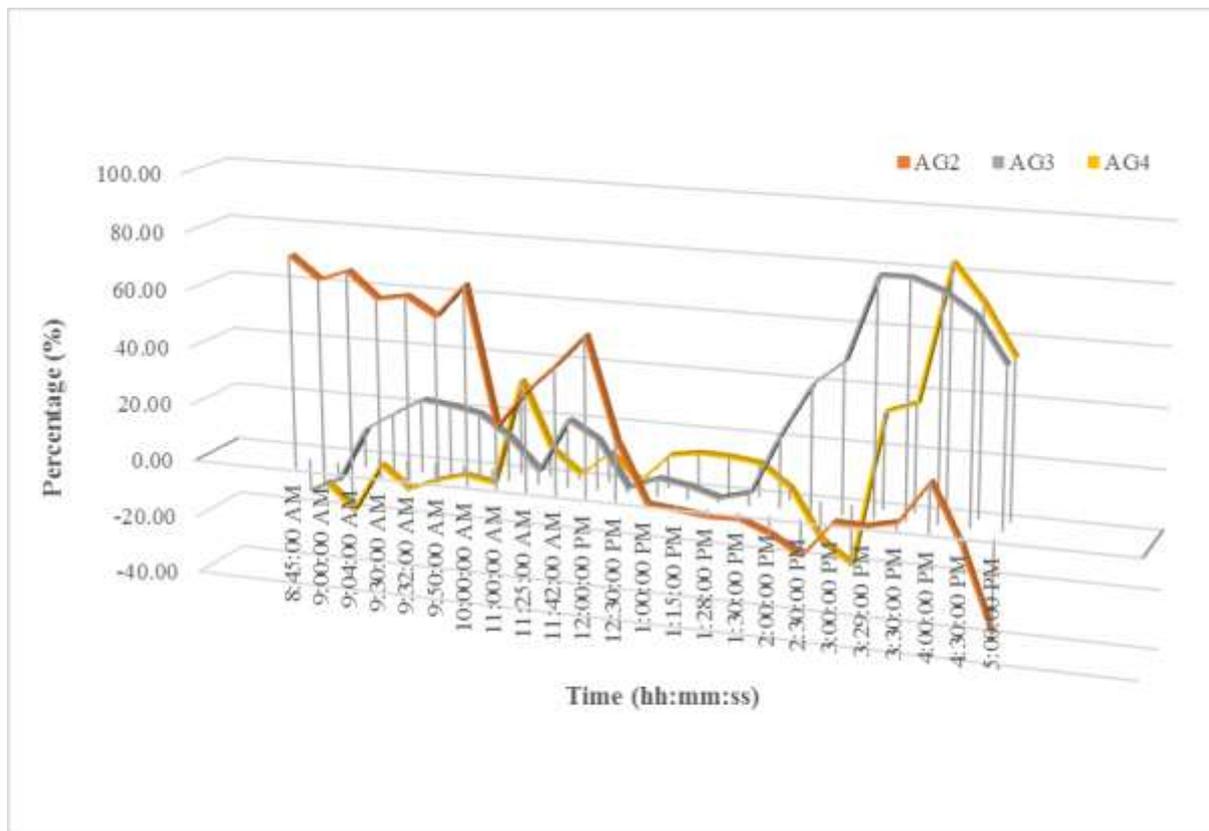


Figure 7. DNI percentage difference of AG2, AG3 and AG4 with AG1

VI. CONCLUSIONS

A review on models to represent solar potential was conducted. This study has addressed the analysis of temperature, GHI and DNI data for the assessment of solar radiation availability in the effort of implementing CSP technology in Malacca. The results have shown that the DNI from predicted model and measurements provided adjacent data. Clearly, the experimental uncertainty based on the percentage difference associated with this procedure decreases at irradiance conditions characterized by sky conditions. In conclusion, the objective of this paper is achieved and can be improve in order to make CSP development in Malacca is economic and beneficial. Therefore, this DNI data on-site measurement shall need to be continued in order to obtain the precise data by taking the prediction model as the benchmark. Moreover, advanced prediction model shall consider to simulate the cloud in prediction software such as RAMS (forecast models). Solar energy is the future energy and utilized the source will not only benefits a country but also the people by admitting the power of nature.

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