A Preliminary Analysis of Solar Irradiance Measurements at TNB Solar Research Centre for Optimal Orientation of Fixed Solar Panels installed in Selangor Malaysia

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Abstract. The well established rule for orienting fixed solar devices is to face south for places in the northern hemisphere and northwards for the southern hemisphere. However for regions near the equator such as in Selangor Malaysia, the position of the sun at solar noon is always near zenith both to the north and south depending on location and month of year. This paper reports an analysis of global solar radiation data taken at TNB Solar Research Centre, Malaysia. The solar radiation is measured using both shaded and exposed pyranometers together with a pyrheliometer which is mounted on a sun-tracker. The analysis on the solar measurements show that a near regular solar irradiation pattern had occurred often enough during the year to recommend an optimum azimuth orientation of installing the fixed solar panels tilted facing towards east. Even though all the solar measurements were done at a single location in TNBR Solar Research Centre at Bangi, for locations near the equator with similar weather pattern, the recommended azimuth direction of installing fixed solar panels and collectors tilted eastward will also be generally valid.

1. Introduction
The state of Selangor with the nation’s capital Kuala Lumpur in federal territory is the most populous region in Malaysia. Presently Malaysia’s largest solar farm is also located just south of Selangor at Pajam in the state of Negri Sembilan, hence it is quite important to know the local solar irradiation characteristics in order to optimize the performance of solar energy systems installed in this mid-west coastal region of peninsular Malaysia. The Solar Research Centre at TNB Research (TNBR) located near Bangi in Selangor has been monitoring solar irradiance using precise and accurate solar radiometers at the TNBR Solar House for more than a year. Taking this location to be representative for most parts of coastal Selangor state, this paper report our significant preliminary findings.

2. Factors Affecting Solar Radiation
For places above or below the Earth’s tropics, the sun at solar noon is always to the south of zenith in the northern hemisphere and always to the north in the southern hemisphere. So it is obvious that these are the recommended optimum direction to install stationary solar devices at such places.
However for regions near the equator such as Malaysia, the position of sun at solar noon is always near zenith both to the north and south depending on location and month of year. This will cause the performance of stationary solar panels installed here to be less sensitive to a north or southern oriented azimuth direction and the effect of regular weather patterns which are normally characteristic in equatorial climates becomes more significant in determining the optimal solar panel orientation that will receive the largest amount of incident solar radiation.

The general local weather pattern in this southern part of Selangor area is usually clear skies in the morning. As the ground temperature rises, it tends to produce atmospheric convection currents which push the moist air near ground to the cold air at higher altitudes. This often results in a quite rapid cloud formation that usually occurs near noon and the weather is always likely to remain cloudy in the afternoon and into the evening with frequent thunder storms by the convectional rains in late afternoon during the wet season. The air humidity is high and the often recurring convectional rains accumulate a large amount of total annual rainfall. This near regular local weather occurrences consequently results in a frequently repeated solar irradiation pattern in this area that affects the optimal orientation of fixed solar panels and collectors [1].

3. Solar Radiation Measurements

The new TNB Solar Research Centre was just established in year 2011, so we only manage to monitor and collect slightly more than one year of solar radiation data. The instruments used for measurements of horizontal global and diffuse solar radiation are two Kipp & Zonen pyranometers model CMP-11. The two new pyranometers were mounted and leveled on a Kipp & Zonen Solys-2 sun-tracker with a single shading ball. Mounted on one of the two arms of the sun-tracker is a Kipp & Zonen pyrheliometer model CHP-1 to measure direct solar radiation. These solar radiometers were connected to the Kipp & Zonen LogBox for data-logging but presently, all the solar radiation measurements are taken using a Datataker DT-80 data-logger at our solar monitoring tower. The pyranometers and sun tracker are properly levelled and all the solar radiometers are maintained according to the recommended procedures. The solar radiometers desiccants are replaced every 2-3 months upon indicator colour change and the sun tracker alignment is periodically checked and corrected when necessary. The sampling rate of the Kipp & Zonen LogBox was set to record data every one minute while the Datataker DT-80 data-logger now takes one set of readings every five seconds.

![Daily Solar Irradiation at TNBR Bangi Sept 2011-May 2012](image1)

**Figure 1.** Daily global horizontal solar irradiation (GHI) at TNBR in Bangi, Malaysia.

![Mean Solar Irradiance at TNBR Bangi- 2012](image2)

**Figure 2.** Mean hourly global horizontal solar irradiance at TNBR Bangi, Malaysia.

4. Results and discussion

The solar radiation that is incident on stationary solar panels mainly consists of both direct and diffuse solar radiation which is called the global solar irradiance. The global horizontal irradiance (GHI) is the amount of solar radiation (direct radiation + diffuse radiation) that falls on a horizontal surface [2]. Pyranometer readings that measure the solar GHI were compiled from June 2011 to May 2012 and
analyzed. First, the one minute interval GHI readings were summed up for each daylight hour in the day. Then each hourly GHI of the day was averaged for the whole month. Some results of the daily GHI are plotted in Figure 1 and a graph of the mean hourly GHI for the early months of year 2012 is shown in Figure 2. Notice the unpredictable chaotic pattern of the total daily solar irradiation with large variations between each consecutive daily measurement, and that there is hardly any sequence of days with near consistent solar radiation.

Table 1. Mean daily global horizontal solar irradiation data at TNBR in Bangi, Malaysia.

| Month     | Mean Daily GHI (Wh/m²·day) | Total       | Morning     | Afternoon    | Difference |
|-----------|-----------------------------|-------------|-------------|-------------|------------|
| January   | 4404.66                     | 2546.69     | 1857.97     | 688.71      |            |
| February  | 4646.12                     | 2697.80     | 1948.32     | 749.48      |            |
| March     | 4330.91                     | 2390.75     | 1940.15     | 450.60      |            |
| April     | 4871.61                     | 2692.19     | 2179.42     | 512.77      |            |
| May       | 4761.77                     | 2710.54     | 2051.23     | 659.31      |            |
| June      | 3953.19                     | 2108.85     | 1844.35     | 264.50      |            |
| July      | 4198.16                     | 2149.08     | 2049.07     | 100.01      |            |
| August    | 4739.48                     | 2713.69     | 2025.80     | 687.89      |            |
| September | 4272.11                     | 2404.35     | 1867.76     | 536.59      |            |
| October   | 4357.74                     | 2565.77     | 1791.98     | 773.79      |            |
| November  | 3765.48                     | 2319.28     | 1446.20     | 873.08      |            |
| December  | 3536.49                     | 2021.04     | 1515.45     | 505.59      |            |
| Average   | 4319.81                     | 2443.34     | 1876.47     | 566.86      |            |

The daily GHI measurements were then integrated from sunrise to solar noon (morning GHI) and from solar noon to sunset (afternoon GHI) for each day and the monthly average is tabulated in Table 1. During the one year monitoring period, the highest mean daily GHI at TNBR in Bangi is 4871.61 Wh/m² for the month of April 2012 and the lowest is 3536.48 Wh/m² for the month of December 2011 which is in the wet North-East monsoon season. A monthly plot of the mean daily morning GHI, mean daily afternoon GHI and mean daily total for each month is shown in Figure 3.

If there is no air or the atmosphere is perfectly clear, the amount of daily global horizontal irradiation (GHI) should be symmetrical about solar noon i.e. the morning GHI from sunrise to solar noon should be equal to the afternoon GHI from solar noon to sunset in perfectly clear air, because both the transit time taken and angular motion of the sun is almost the same (see Figure 4). However, due to atmospheric dust scattering, haze and clouds the two amounts of solar energy (morning GHI and afternoon GHI) are obviously not the same. This can be easily seen in Table 1 where the mean
monthly morning GHI is clearly higher than in the afternoon when there are more clouds in the sky, for all the months during the measurement period. The mean daily difference for the year is 566.86 Wh/m².day that is 13.16% more solar radiation falls in the morning half of the day. This adds up to a significant amount of 206,903.9 Wh/m² total for the annual period.

The mean afternoon GHI was found to be quite constant about 2000 Wh/m².day for that year with the exception of the wet months of November and December during the North-east monsoon period where the monthly solar irradiance is lowest (see Figure 3). Hence the variation of the total daily solar irradiation is mainly due to the morning GHI that follows almost the same curve pattern as the total daily GHI.

From the acquired results above it is quite obvious that during the one year period of solar radiation monitoring at TNB Solar Research Centre, the amount of solar irradiation in the morning is considerably more than in the afternoon when the sky is usually cloudy. Although these are only preliminary results for just one year, the difference is significant enough that for the proposed absorption cooling system to be implemented at TNBR Solar House [3], we had highly recommended that the flat-plate solar thermal collectors should be installed facing towards east.

5. Conclusion
This paper reports an analysis of global solar radiation data taken at TNB Solar Research Centre, Malaysia. The objective of the analysis is to determine the optimal solar panel azimuth direction that will receive the largest amount of incident solar radiation. The radiation is measured using both shaded and exposed pyranometers together with a pyrheliometer which is mounted on a sun-tracker. The analysis on the solar measurements show that a near regular solar irradiation pattern had occurred often enough during the year to recommend an optimum azimuth orientation of installing the fixed solar panels tilted facing towards east. Even though all the solar measurements were done at a single location in TNBR Solar Research Centre at Bangi which was taken to be representative for the state of Selangor, this does not mean that the results obtained could be applied to places at the immediate surrounding areas in southern Selangor only. For locations near the equator with similar weather pattern, the recommended azimuth direction of installing fixed solar panels and collectors tilted eastward will also be generally valid.

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