

# Solar Resource Mapping in Pakistan

# SITE EVALUATION REPORT

July 2015



This report was prepared by the consultants listed on the following pages, under contract to [The World Bank](#).

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This document is an **interim output** from the above-mentioned project. Users are strongly advised to exercise caution when utilizing the information and data contained, as this has not been subject to full peer review. The final, validated, peer reviewed output from this project will be the Pakistan Solar Atlas, which will be published once the project is completed.

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**ESMAP – Renewable Energy Resource  
Mapping Initiative**

**- Solar Resource Mapping for Pakistan –**

**Site evaluation report:  
Hyderabad Airport, Pakistan Meteorological  
Department**

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**Contents**

- 1 Executive Summary..... 4**
- 2 Procedure and tasks of the site visit ..... 4**
- 3 Site visit results ..... 5**
  - 3.1 Overview, description of the site and surroundings .....5
  - 3.2 Local support, maintenance staff and future hardware use.....6
  - 3.3 Site 1 (roof top).....7
    - 3.3.1 Coordinates .....7
    - 3.3.2 Checklist for evaluation of the situation of and at the site.....8
    - 3.3.3 Shadings and Reflections ..... 10
  - 3.4 Site 2 (ground station) ..... 13
    - 3.4.1 Coordinates ..... 13
    - 3.4.2 Checklist for evaluation of the situation of and at the site..... 14
    - 3.4.3 Shadings and Reflections ..... 14
- 4 Conclusion ..... 18**



## 1 Executive Summary

A team of the solar vendor consortium for the ESMAP Pakistan Solar Resource Mapping Project visited the Pakistan Meteorological Department (PMD) office at Hyderabad airport on August 08, 2014. The goal was to evaluate if the location is suitable for the installation of a solar ground measurement station in the framework of the project.

Two different sites have been examined on the campus, one on the roof of a building of the PMD location and one on the ground. Due to the airport and especially due to industrial facilities in close proximity, the site is not recommended for installation of an ESMAP ground measurement station.

## 2 Procedure and tasks of the site visit

The following tasks have been performed for the site visit, following the procedure from the site visit manual:

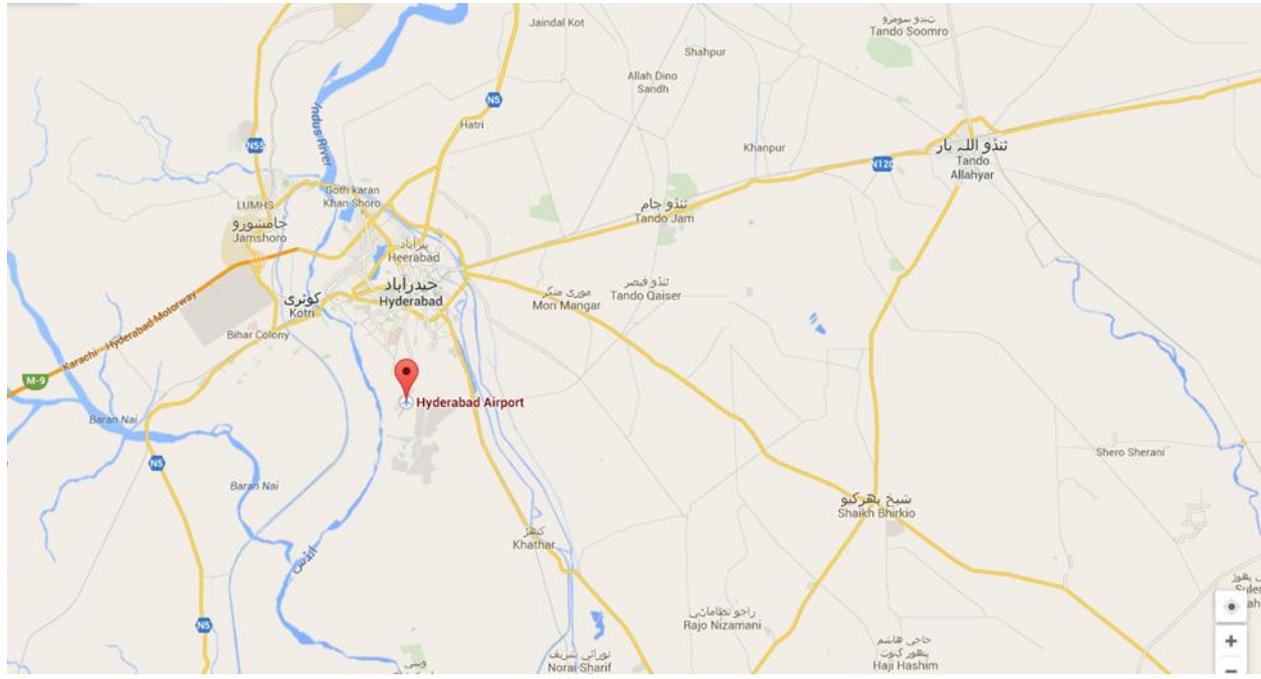
1. Recording of exact geographic coordinates of the site(s) and orientations
2. Photographic documentation of the site
  - Overview of site and location,
  - panoramic 360 degrees round view from the site for identification of potential obstacles blocking the sun path
3. Check of availability, strength and potential providers of GSM network at the site
4. Audit of local staff to clarify all relevant information (see checklist)
5. Information of local staff at the site about the project, its aim and required tasks for realization and clarification of availability and prospected quality of the required support from their side
6. In-office evaluation of results and compilation of this report



### 3 Site visit results

The results of the site visit and its evaluation is presented in the following section.

#### 3.1 Overview, description of the site and surroundings



**Figure 1: Location overview (Google Maps View)**



**Figure 2: Aerial View (Google Earth View)**

The PMD office on Hyderabad airport is located directly west of the airfield. The town of Hyderabad with dense population and settlement is located to the north. To the



west, the Indus river is in close distance of about 500 m. To the south, there is barren land which apparently is being prepared for construction of new city districts and to the east there is a three-branched canal as well as a cement factory.

Hyderabad is located on the Indus river directly north of the junction of the Indus with Baran river which comes from the west, from the Khirtar mountain range which commence about 30 km west of the city. To the east lies the vast Indus valley with its large irrigated agricultural areas.

### **3.2 Local support, maintenance staff and future hardware use**

The availability of qualified staff for the regular local maintenance (cleaning of sensors and other parts, visual inspection, surveillance of equipment) and the institutional support of the involved stakeholder are directly relevant for the success of the ESMAP project measurement campaign.

Future use of the equipment after the ESMAP project termination is another issue to be considered in order to provide maximum sustainability of the project.

#### **Local support and maintenance staff**

Local staff is available and confirmed to be willing to perform maintenance tasks throughout the 24 months of the measurement campaign. A short briefing about the required tasks and their frequency of occurrence has been given to PMD representatives. Qualification of local staff for the task is assumed to be given, since PMD is the official department of meteorology with corresponding staff and there is already meteorological equipment present and operating under their control. The data from this instrumentation could potentially be an extra input for cross-check of the ground measurement data within the ESMAP campaign.

#### **Future hardware use (sustainability)**

The meteorological station from the ESMAP project would be a good complementary station to the existing PMD meteorological station. The station would likely be used actively in future for the national measurement network of PMD and the value added therefore be increased.

## Contact Information

The local contact for the site is

- Khalid Kazi  
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+92 321 3093860
  
- Abid Laghari  
Meteorological Assistant – Pakistan Meteorological Department  
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## 3.3 Site 1 (roof top)

### 3.3.1 Coordinates

N 25.3176° E 68.3627°, altitude 45 m above mean sea level

Site 1 is located on the roof of a building which is used for the existing PMD weather station.



Figure 3: View from Site 1 to the North



Figure 4: View from Site 1 to the South



### 3.3.2 Checklist for evaluation of the situation of and at the site

The following checklist has been filled at the site visit and is completed by interviewing stakeholders on site.

**Table 1: Site checklist for site 1**

Criteria/Measure		Yes / No	Notes
Dimensions <sup>i</sup>	Minimum area 10 × 10 m <sup>2</sup>	No	Rooftop.
Surface	Firm natural ground <sup>ii</sup>		No
	Ground type <sup>iii</sup>		Concrete
	Horizontally levelled <sup>iv</sup>	Yes	
	Excavation for foundations possible <sup>v</sup>	Yes	Casting Blocks are preferred on rooftop.
	Fencing of the site possible <sup>vi</sup>	Yes	
	No drifting sand/snow <sup>vii</sup>	No	
	No flooding possible <sup>viii</sup>	No	
Surroundings	Obstructions If yes, note direction, distance and approx. height <sup>ix</sup>	No	See Panoramic Pictures
	Reflections or light sources <sup>x</sup>	-	
	Industrial areas or power plants <sup>xi</sup>	Yes	Cement Factory
	Sources of smoke or vapor <sup>xii</sup>	Yes	Reduced visibility in months of December/Jan due to smoke from nearby industry.
	Quarry or mine <sup>xiii</sup>	No	
	Main road, dirt road, track <sup>xiv</sup>		Paved Roads
	Airports <sup>xv</sup>	Yes	On Airport Premises
	Settlements, towns, city <sup>xvi</sup>	Yes	Airport housing colony nearby
	Agricultural area <sup>xvii</sup>	No	3km from site



	Swamp, lake, river, ocean <sup>xviii</sup>	No	3km from site
	Sand dunes <sup>xix</sup>	No	
	Animal populations <sup>xx</sup>	No	
	Occurrence of snowfall <sup>xxi</sup>	No	
	Temperatures below freezing point <sup>xxii</sup>	No	
	Other <sup>xxiii</sup>		
Accessibility	Accessible by car <sup>xxiv</sup>	Yes	
GSM coverage	2G network available <sup>xxv</sup>	Yes	All 5 providers
Grid power	Electricity available <sup>xxvi</sup>	Yes	No Power Outage
Land use rights	Permit available <sup>xxvii</sup>	Yes	Will need to be approved by CAA (Civil Aviation Authority)
Operation permit	Permit available <sup>xxviii</sup>	Yes	Will need to be approved by CAA (Civil Aviation Authority)
Security	No underground or overhead electrical lines, pipelines or similar <sup>xxix</sup>	No	
	Measures against theft or vandalism required? <sup>xxx</sup>	No	
360° photographs	Take 360° photographs or panoramic photo, indicate North direction <sup>xxxi</sup>	Yes	Tripod bag denotes the north direction

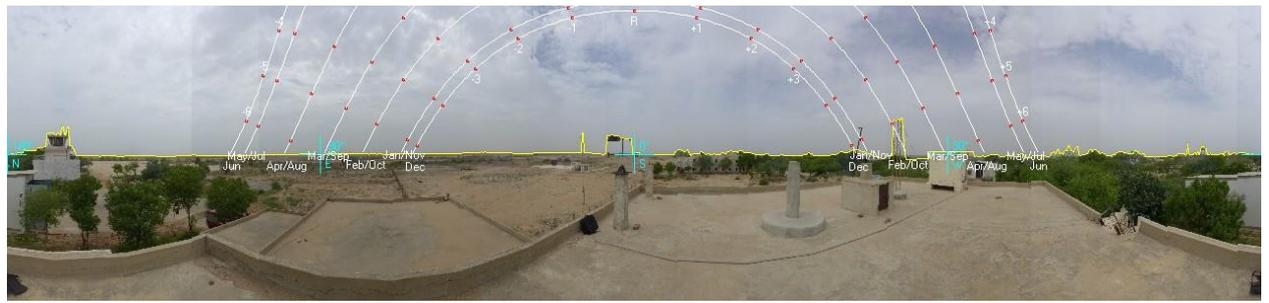
Regarding the aspects covered by the checklist, site 1 is barely suited for the installation of a ground measurement station. The installation on a roof-top is a good option since it elevates the station above many obstacles; In the direct surroundings there are industrial facilities (cement factory) which pointedly have a negative impact on visibility and presumably irradiation. The airport air traffic will also be emitting a certain amount of pollutants, although not very much since the airport is not very frequented. All roads in the surroundings are paved and therefore not heavily dust-emitting; the site is encased by water bodies (Indus river and canals), and permits to install and operate the station from the civil aviation authorities are required additionally to the permission to use the site which can be given by the PMD.



### 3.3.3 Shadings and Reflections

#### Panoramic View

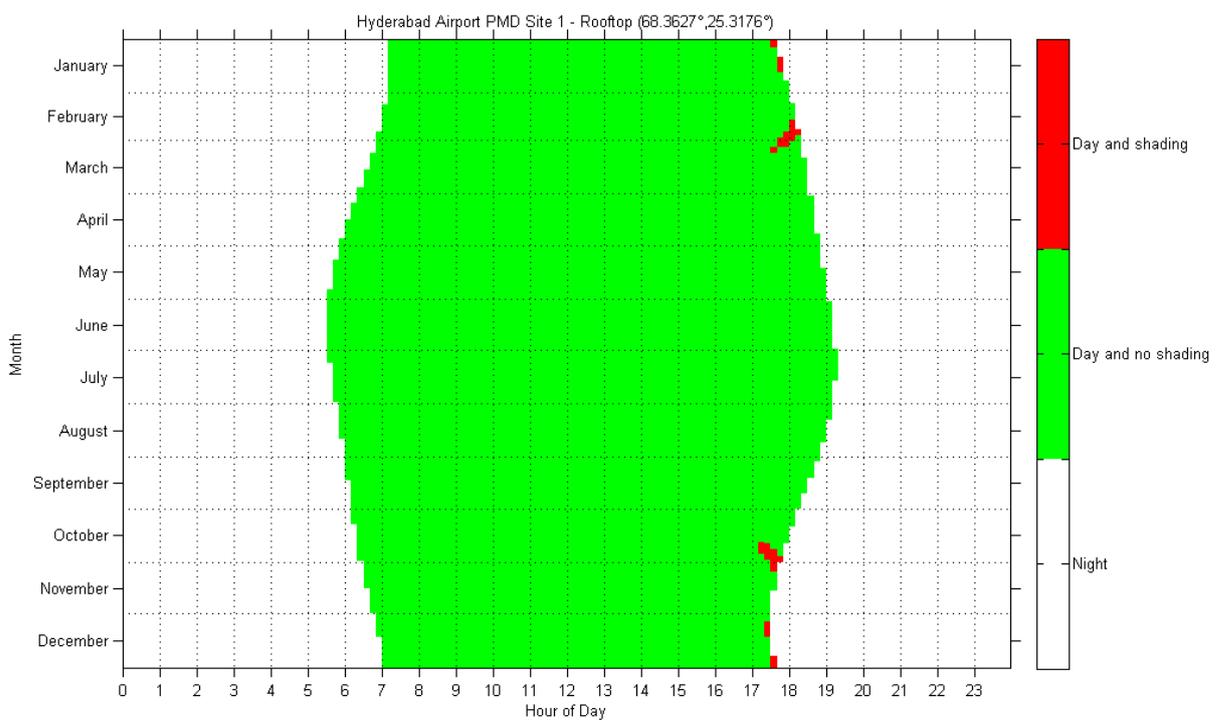
The picture in Figure 5 shows a panoramic view with a centered south view, North is on the left and right edge of the picture. Blue markers show the North, South, East and West direction as well as horizon height. The sun paths throughout the year are displayed in the picture, revealing if any objects on the horizon are imposing an obstruction to the direct solar irradiance.



**Figure 5: Panoramic View with North, South, horizon line and monthly sun paths with the corresponding position at full hours marked**

From the panoramic view, it is visible that a few obstacles on the horizon are blocking the sun especially at sunset. The impact is further analyzed in the following paragraphs.

#### Shading Table for Sun Elevations >0°

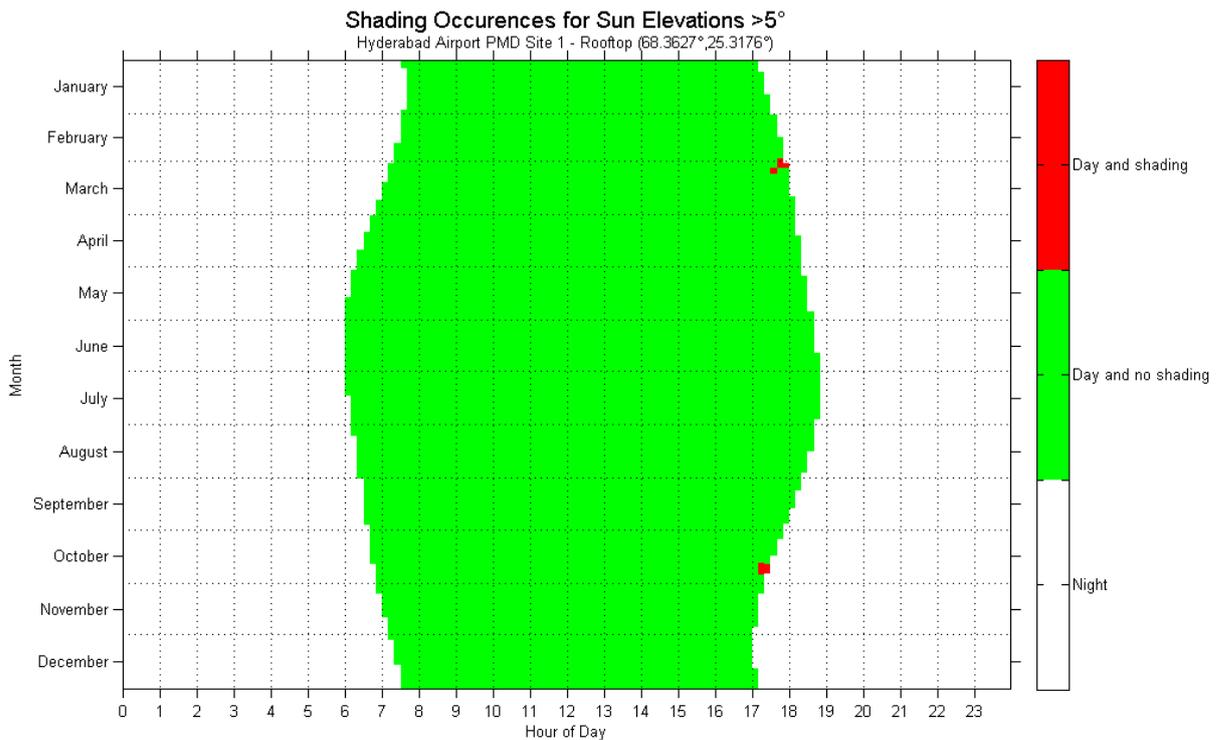


**Figure 6: Shading Table for Sun Elevations >0°**



Figure 6 shows the shading table throughout the year. The obstacles in the west which have already been mentioned above show some impact especially in February and October.

### Shading Table for Sun Elevations >5°



**Figure 7: Shading Table for Sun Elevations >5°**

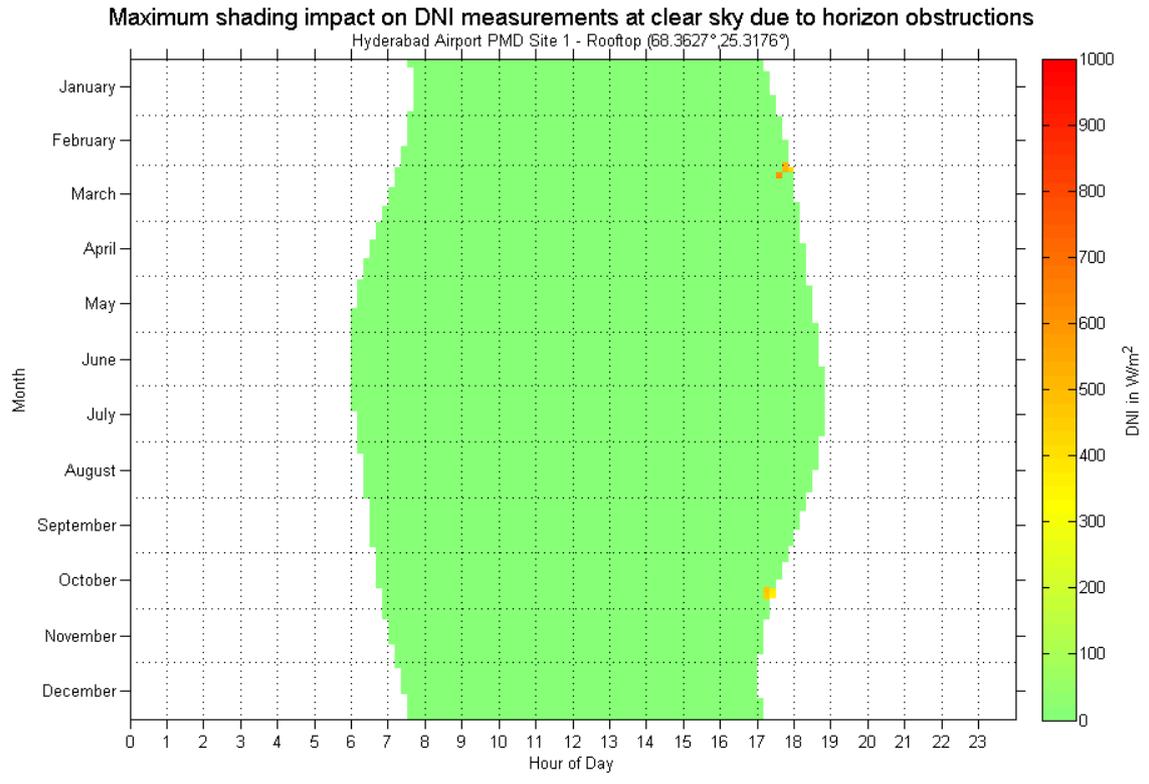
Figure 7 shows the shading table after excluding Sun Elevations smaller than 5° above horizon. At these low angles, measurement uncertainty of satellite and ground measurement is elevated due to the large cosine error, and the data from these periods is therefore excluded from the satellite data adjustment and validation. Also from the view of any solar power installation (PV or CSP), sun elevation smaller than 5° is usually not contributing to electricity or heat generation due to shading, unfavorable incidence angles and low irradiance intensity. *Subsequently, all further graphs and evaluations refer to sun elevations larger than 5°, as the main aim of the measurements on ground is the adjustment of the long-term satellite data.*

From the graph, it is visible that shading still occurs in the evenings in March and October, but only in minimal temporal extension.



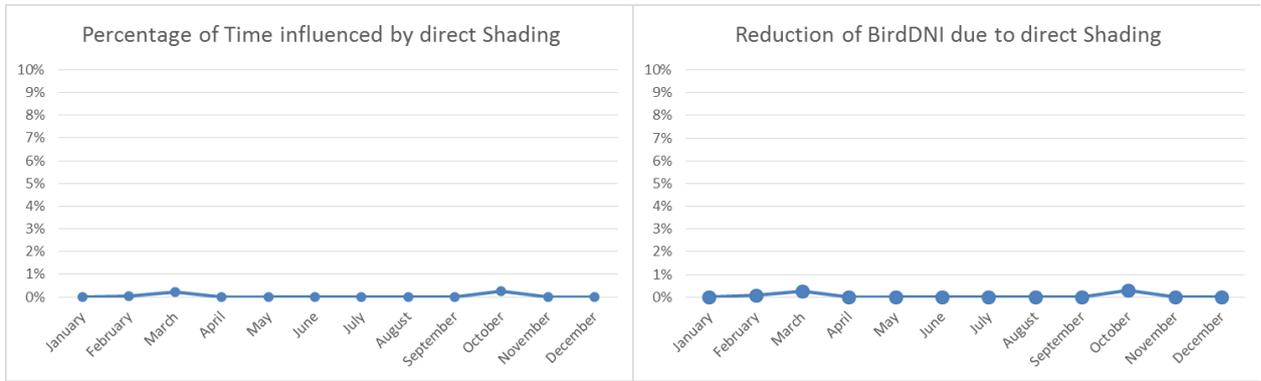
### Direct Shading Impact

Figure 8 shows the impact of shading on direct normal irradiation (DNI). DNI is modeled according to Bird (Bird et al., 1991) as a theoretical clear-sky DNI throughout the year and can be interpreted as the maximum solar resource. The impact of shading on this figure is therefore the maximum quantitative impact shading could have on solar resource.



**Figure 8: Shading Impact on BirdDNI for Sun Elevations >5°**

From Figure 8, it is clearly visible that shadings have almost no impact.



**Figure 9: Shading Impact for Sun Elevations >5°**

Figure 9 shows the impact of direct shading due to the reported obstructions. The left figure shows the percentage of time for all calendar months which is affected by direct shading. In total, 0 % of the time is affected by direct shading, with up to 0.3%



in the months of March and October. The right figure shows the quantitative impact of shading on the Bird-DNI summarized for each month. For the whole year, the reduction of the annual Bird-DNI sum due to direct shading is about 0.1 % only.

### **Diffuse Shading and Reflections**

Diffuse shading and reflections of any mentionable quantity are not to be expected since no large obstacles close to the site and no highly reflective surface above sensor height can be identified.

Artificial lighting from the airport during the night could potentially have some influence on the irradiation measurement, but could be filtered from the data.

## **3.4 Site 2 (ground station)**

### **3.4.1 Coordinates**

N 25.3170° E 68.3631°, altitude 40 m above mean sea level

Site 2 is located on the ground west of the airfield at an existing PMD station.



**Figure 10: View from Site 2 to the North**



**Figure 11: View from Site 2 to the South**

### 3.4.2 Checklist for evaluation of the situation of and at the site

The checklist is only displayed for the lines which differ from the checklist for site 1.

Criteria/Measure		Yes / No	Notes
Dimensions <sup>xxxii</sup>	Minimum area 10 × 10 m <sup>2</sup>	No	10x10m will not be available in the enclosure
Surface	Firm natural ground <sup>xxxiii</sup>		Yes
	Ground type <sup>xxxiv</sup>	Soil	Natural Ground
	Excavation for foundations possible <sup>xxxv</sup>	Yes	
	Fencing of the site possible <sup>xxxvi</sup>	Yes	

Regarding the aspects covered by the checklist, site 2 is barely suited for the installation of a ground measurement station. The installation on natural ground is recommended by WMO and there is sufficient free area around the station; installing the station would be possible even though the full 10x10 m area is not available. All other aspects are identical to site 1.

### 3.4.3 Shadings and Reflections

#### Panoramic View

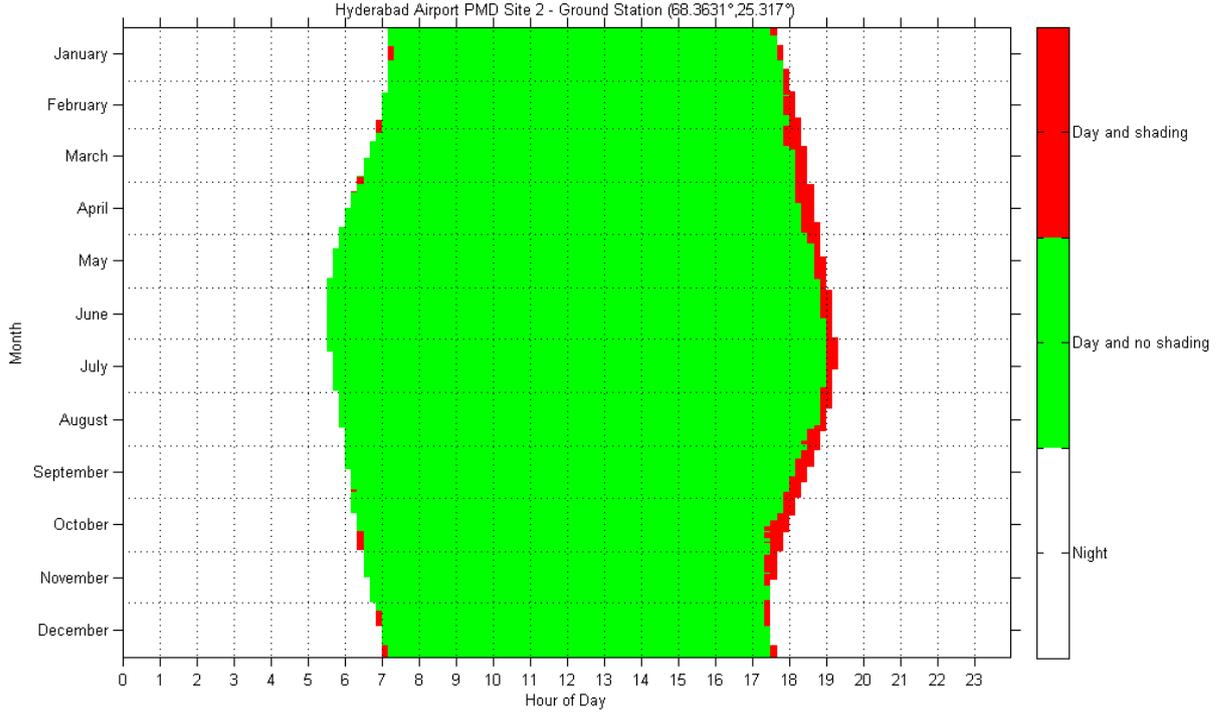


**Figure 12: Panoramic View with North, South, horizon line and monthly sun paths with the corresponding position at full hours marked**

From the panoramic view, it is visible that only few obstacles are blocking the sun and the horizon is almost clear.



**Shading Table for Sun Elevations >0°**

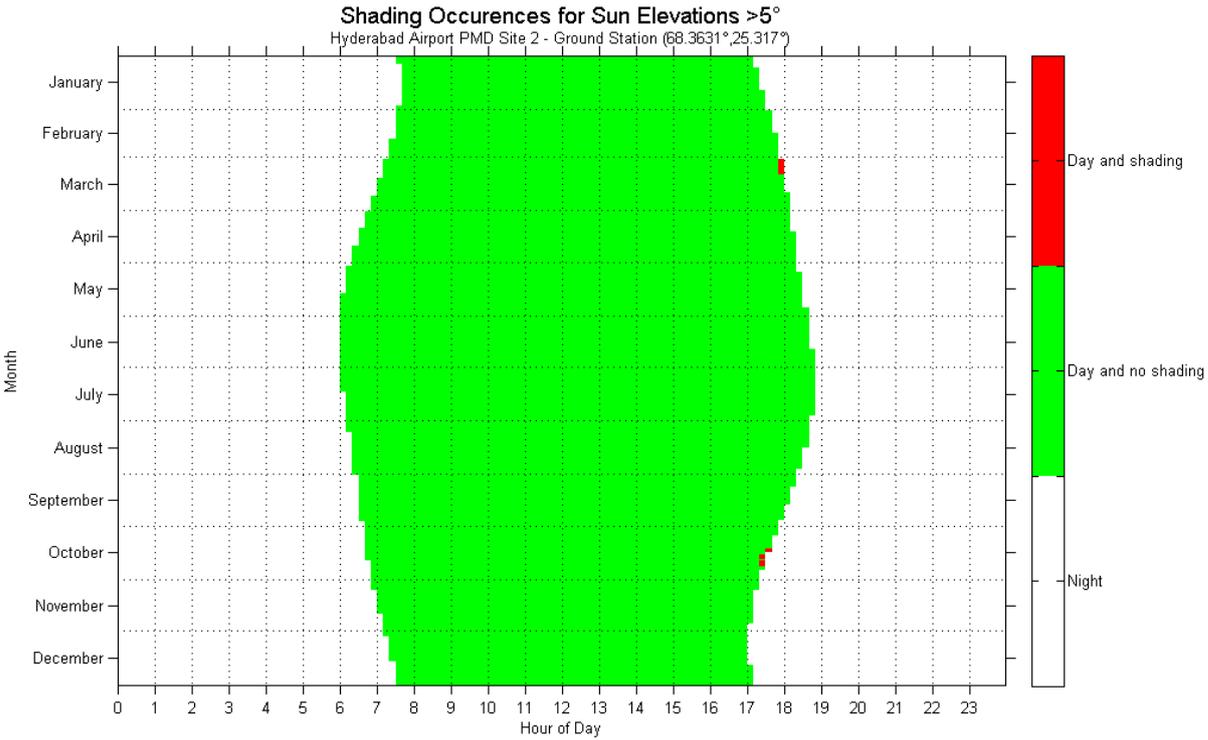


**Figure 13: Shading Table for Sun Elevations >0°**

Figure 13 shows the shading table throughout the year. It becomes clear that throughout the year, brief shadings especially at sunset are present.



**Shading Table for Sun Elevations >5°**



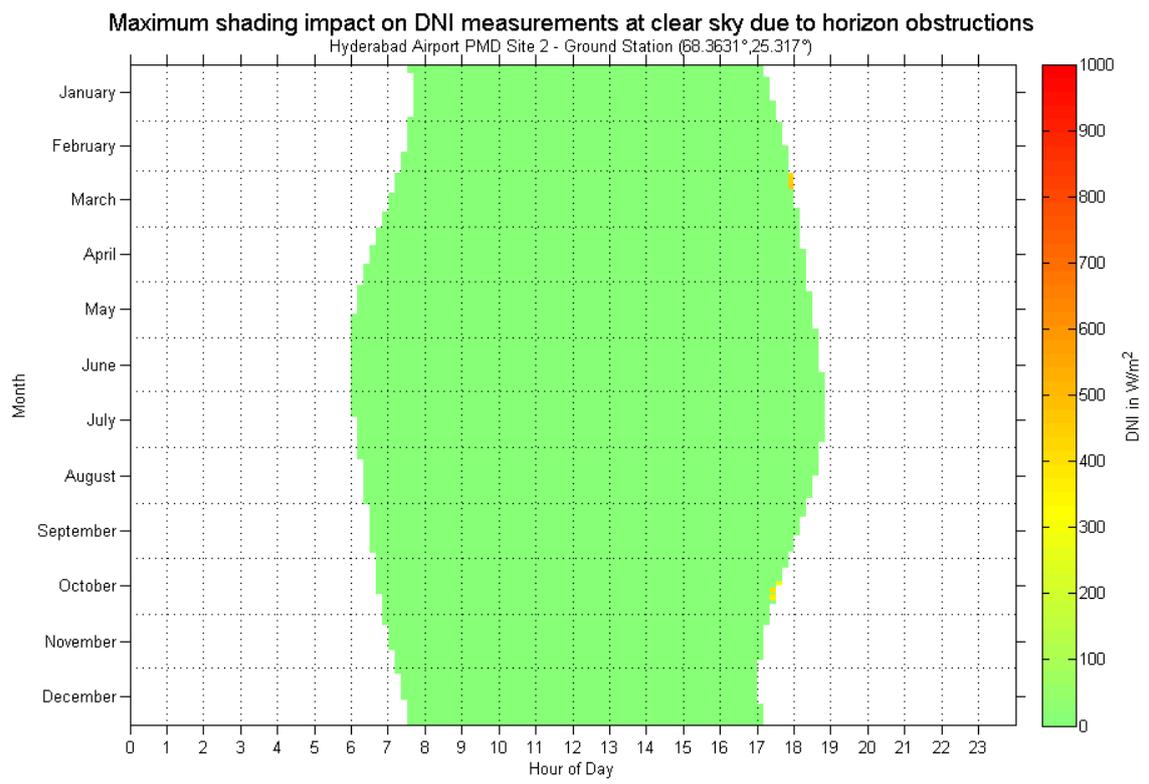
**Figure 14: Shading Table for Sun Elevations >5°**

Figure 14 shows the shading table after excluding Sun Elevations smaller than 5° above horizon. *Subsequently, all further graphs and evaluations refer to sun elevations larger than 5°, as the main aim of the measurements on ground is the adjustment of the long-term satellite data.*

From the graph, it is visible that shading above 5° sun elevation is practically not existent.

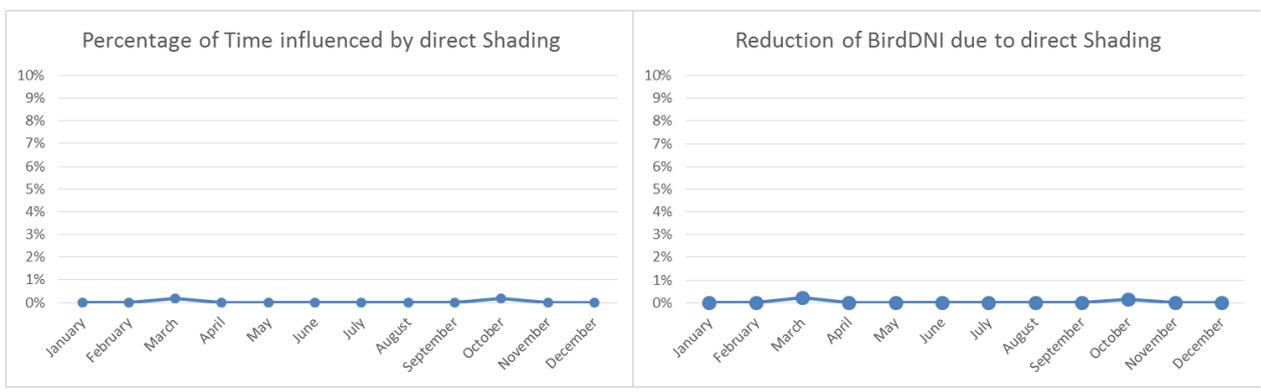


## Direct Shading Impact



**Figure 15: Shading Impact on BirdDNI for Sun Elevations >5°**

From Figure 15, it is clearly visible that shadings have no mentionable impact.



**Figure 16: Shading Impact for Sun Elevations >5°**

Figure 16 shows the impact of direct shading due to the reported obstructions. The left figure shows the percentage of time for all calendar months which is affected by direct shading. In total, about 0 % of the time is affected by direct shading with a maximum in March and October of 0.2 %, the other months show no impact at all. The right figure shows the quantitative impact of shading on the Bird-DNI summarized for each month. For the whole year, the reduction of the annual Bird-DNI sum due to direct shading is 0 % with the same characteristics as for the temporal influence.



### **Diffuse Shading and Reflections**

Artificial lighting from the airport during the night could potentially have some influence on the irradiation measurement, but could be filtered from the data.

### **4 Conclusion**

Although the site itself, especially site 2, are technically suitable for the installation of a measurement station, the surroundings of the location are not favourable. The airport and mostly the cement factory are likely to be strong emitters of pollutants that may influence the solar radiation (absorption, scattering of sun rays) and increase the sensor soiling. Also, obtaining permission from the civil aviation authorities is an additional task that could possibly involve a lengthy process.

Therefore, it is recommended to not install any measurement station at the airport office of PMD in Hyderabad.



### Detailed description of checklist criteria:

- i A site with a minimum extension of  $10 \times 10 \text{ m}^2$  is required for the collocation of the meteorological measurement equipment, complying with the characteristics and criteria listed in the following.
- ii The site suitable for collocation of a meteorological station needs to have a firm ground in order to enable a secure fixation of the equipment on the ground, e.g. by ground anchors and guying ropes.
- iii Annotate here if the ground consists of firm and naturally grown soil or artificially (by man) filled soil, if it consists of bedrock, firm soil, loose soil or sand.
- iv Annotate here if the site is approximately horizontally levelled and flat.
- v Annotate here if it is possible and permitted to lay small foundations (4-5 foundations each approximately  $1 \times 1 \text{ m}^2$  and  $\sim 0.3 \text{ m}$  deep).
- vi Annotate here if it is possible and permitted to fence the compound.
- vii Annotate here the terrain consists of drifting sand or snow.
- viii Annotate here if the terrain may run the risk to be flooded at heavy rain falls.
- ix Describe any object which exceeds 2 m height in the closer environment of the site and which might shade the measurement equipment on the site from direct sun at any time of the year or which obstructs parts of the sky dome. Describe in detail at least all such objects within 30 m distance as well as bigger objects up to at least 200 m distance from the site. As the sun at sun rise and sun set approaches the horizon in East and West direction ( $\sim \pm 30$  degrees depending on season), obstructions in these directions are of particular importance. Add sketches of the site environments where possible.  
Possible obstructing objects are: mountains, hills, buildings, skyscrapers, houses, industrial or commercial buildings, warehouses, churches/mosques or similar buildings (for religious or cultural activities), walls, bridges, towers, chimneys, wind energy plants, transmission masts, power poles, other poles or rods, cranes, street lights, greenhouses, trees, bushes, shrubberies, any other higher vegetation, or similar.  
Moreover, the view from the site towards the horizon should be documented by  $360^\circ$  photographs (see corresponding description) or a short movie taken from the site, starting in direction to the North over East, South, and West to North direction again.
- x Annotate if any reflecting surfaces like mirrors, glazing, shiny metal surfaces, PV panels, etc., or artificial light sources are in the environments and might cause reflections or radiation on the measurement equipment, influencing irradiation measurements.
- xi Annotate if any industrial production site or power plant is located in the environments of a few kilometers, which may cause emissions of smoke, vapor, dust or other aerosols.
- xii Annotate any source of smoke or water vapor columns located in the environments.
- xiii Annotate quarries or mines in the environments causing pollution by elevated dust.



- xiv Annotate close by roads as they frequently cause increased sensor soiling by elevated dust settling down on the sensors, or increase the risk for theft or vandalism due to increased visibility.
- xv Annotate the presence of airports in the environments as exhaust gases of planes may influence the measurements.
- xvi Annotate the presence and size of settlements in the environments in order to judge potential influences on the measurements (personally or as secondary effects like smoke or dust) by man.
- xvii Annotate type and frequency (if possible) of agricultural activities in the environments in order to judge potential impacts on the measurements (e.g. elevated dust, etc.).
- xviii Annotate their potential presence in the environments in order to judge impacts on the measurements due to increased humidity, oxidation of the equipment, instability of the ground, etc.
- xix Annotate the presence of sand dunes in the proximities of some kilometers in order to judge potential deposition of sand on the equipment.
- xx Annotate if any animal population frequents the area which might have any impact on the measurements. Also take into account birds, termites, insects (bees, wasps, etc.), etc.
- xxi Annotate the occurrence and the frequency (if possible, may be estimated) of days with snowfall or remaining snow cover in order to design the power supply and version of the irradiation sensor(s).
- xxii Annotate the occurrence and the frequency (if possible, may be estimated) of days with temperatures below freezing point temperature (zero degrees Celsius) in order to design the equipment and judge potential impacts on the measurements.
- xxiii Annotate any other observations, occurrences or presences which you may estimate them causing potential impacts on the measurements. In the case of doubt about an influence, please annotate the observation.
- xxiv Annotate if the site is easily reachable by car in order to facilitate the transport of the equipment to the site.
- xxv Verify with your mobile phone or contacting a reliable local mobile phone network provider the availability of 2G network from different providers. If only 3G network (or higher) is available, verify with the network provider if GPRS connection in 2G mode is enabled. Check with your mobile phone by switching it manually to 2G connection only and test data connectivity via GPRS or EDGE.
- xxvi Annotate if electricity grid is available at the site for power supply. If information is available, annotate the voltage level and if grid stability issues are known for the site.
- xxvii Verify and annotate if the land use permits are conceded or given from the land owner.
- xxviii Verify and annotate if the permits to use the compound for operation of a meteorological station are conceded or given by law and local authorities.
- xxix Verify and annotate if no high voltage lines (exceeding 20 V) are crossing the compound neither as overhead line nor in the ground. Verify and annotate if no gas, water, remote heat or other pipeline are crossing the compound above or in the ground.



xxx Estimate the risk of theft or vandalism on the measurement equipment. Give an estimation of a safety guard or similar is required to watch the equipment.

xxxi See section „**Fehler! Verweisquelle konnte nicht gefunden werden.**“ above.

#### **Detailed description of checklist criteria:**

xxxii A site with a minimum extension of  $10 \times 10 \text{ m}^2$  is required for the collocation of the meteorological measurement equipment, complying with the characteristics and criteria listed in the following.

xxxiii The site suitable for collocation of a meteorological station needs to have a firm ground in order to enable a secure fixation of the equipment on the ground, e.g. by ground anchors and guying ropes.

xxxiv Annotate here if the ground consists of firm and naturally grown soil or artificially (by man) filled soil, if it consists of bedrock, firm soil, loose soil or sand.

xxxv Annotate here if it is possible and permitted to lay small foundations (4-5 foundations each approximately  $1 \times 1 \text{ m}^2$  and  $\sim 0.3 \text{ m}$  deep).

xxxvi Annotate here if it is possible and permitted to fence the compound.