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ESMAP
Energy Sector Management Assistance Program

# 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.

It is one of several outputs from the solar resource mapping component of the activity "Renewable Energy Resource Mapping and Geospatial Planning – Pakistan" [Project ID: P146140]. This activity is funded and supported by the Energy Sector Management Assistance Program (ESMAP), a multi-donor trust fund administered by The World Bank, under a global initiative on Renewable Energy Resource Mapping. Further details on the initiative can be obtained from the ESMAP website.

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.

# ESMAP – Renewable Energy Resource Mapping Initiative

## - Solar Resource Mapping for Pakistan –

## Site evaluation report: Hyderabad Pakistan Meteorological Department


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## Contents

# 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 city 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.

One site on the office rooftop has been examined. Due to the sub-optimal shading profile and the location in the inner city centre, 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

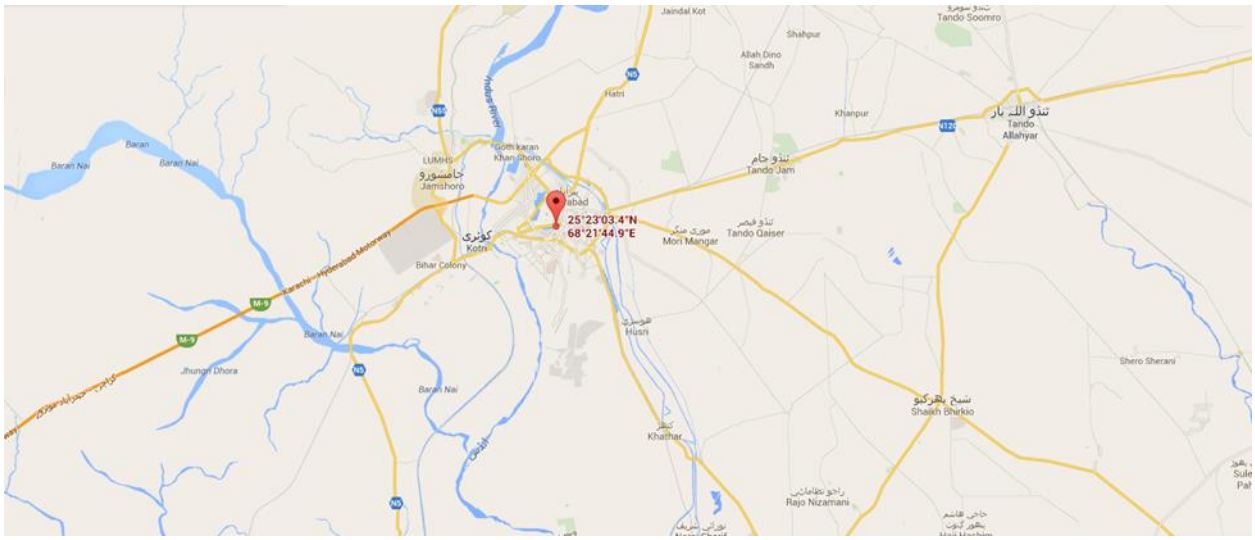


**Figure 1: Location overview (Google Maps View)**


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

The PMD office in Hyderabad airport is located directly in the heart of the city. The town of Hyderabad with dense population and settlement is located around the site. To the west, there is a small lake and further across town, the Indus river in a distance of about 5.5 km.

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
  Meteorologist – Pakistan Meteorological Department
  +92 321 3093860

- Abid Laghari
  Meteorological Assistant – Pakistan Meteorological Department
  +92 332 0303263

## 3.3 Site 1 (roof top)

### 3.3.1 Coordinates

N 25.3843° E 68.3625°, altitude 35 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[i] | Minimum area 10 × 10 m² | No | Limited space on rooftop |
| Surface | Firm natural ground[ii] | No | |
| | Ground type[iii] | Concrete | |
| | Horizontally levelled[iv] | Yes | |
| | Excavation for foundations possible[v] | Yes | Casting Blocks are preferred |
| | Fencing of the site possible[vi] | Yes | |
| | No drifting sand/snow[vii] | No | |
| | No flooding possible[viii] | No | |

| | | | |
|---|---|---|---|
| Surroundings | Obstructions<br>If yes, note direction, distance and approx. height[ix] | Yes | See Panoramic Pictures |
| | Reflections or light sources[x] | - | |
| | Industrial areas or power plants[xi] | No | |
| | Sources of smoke or vapor[xii] | No | |
| | Quarry or mine[xiii] | No | |
| | Main road, dirt road, track[xiv] | | Paved Roads |
| | Airports[xv] | Yes | 2 km distant to the South |
| | Settlements, towns, city[xvi] | Yes | Urban Area |
| | Agricultural area[xvii] | No | |
| | Swamp, lake, river, ocean[xviii] | No | |
| | Sand dunes[xix] | No | |
| | Animal populations[xx] | No | |
| | Occurrence of snowfall[xxi] | No | |
| | Temperatures below freezing point[xxii] | No | |
| | Other[xxiii] | | The building under construction to the southwest has been like that for over 10 years. Further construction is not expected. |
| Accessibility | Accessible by car[xxiv] | Yes | |
| GSM coverage | 2G network available[xxv] | Yes | All 5 providers |
| Grid power | Electricity available[xxvi] | Yes | Frequent power outages. |
| Land use rights | Permit available[xxvii] | Yes | Approval to be given by PMD |

| | | | |
|---|---|---|---|
| Operation permit | Permit available[xxviii] | Yes | Approval to be given by PMD |
| Security | No underground or overhead electrical lines, pipelines or similar [xxix] | No | |
| | Measures against theft or vandalism required?[xxx] | No | |
| 360° photographs | Take 360° photographs or panoramic photo, indicate North direction[xxxi] | Yes | Tripod bag denotes the north direction |

Regarding the aspects covered by the checklist, site 1 is 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 no industrial facilities which have a negative impact the measurement. All roads in the surroundings are paved and therefore not heavily dust-emitting; permits to install and operate the station 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.

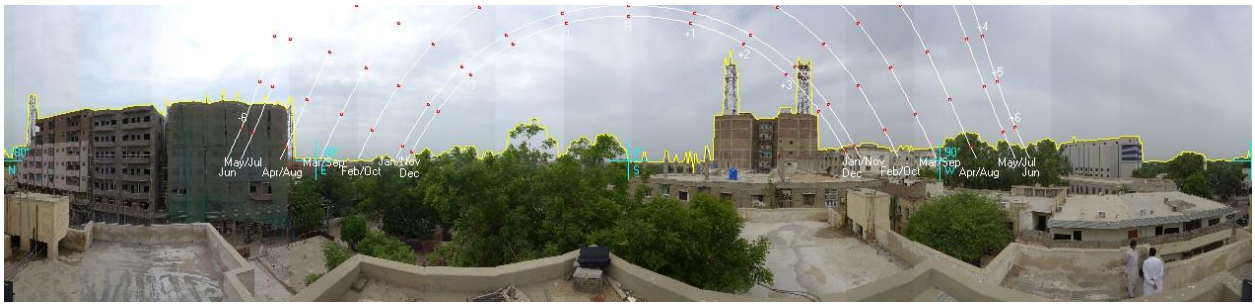


**Figure 5: Panoramic View with North, South, horizon line and monthly sun paths with the corresponding position at full hours marked**

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

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

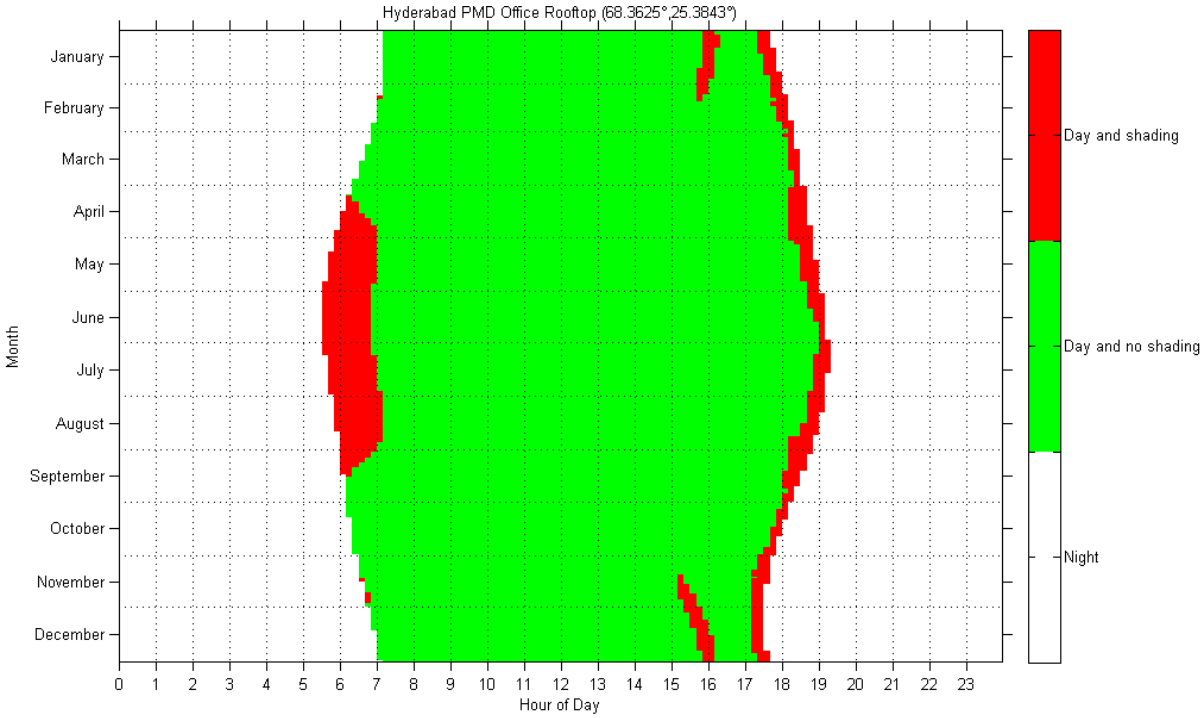


**Figure 6: Shading Table for Sun Elevations >0°**

Figure 6 shows the shading table throughout the year. The obstacles in the east are shading the sensor in the first 1-1.5 h after sunrise in the summer months and the obstacles in the west have an impact before sunset throughout the year. In winter, the mobile phone network tower on the nearby building has a shading impact in the afternoon as well.

## Shading Table for Sun Elevations >5°

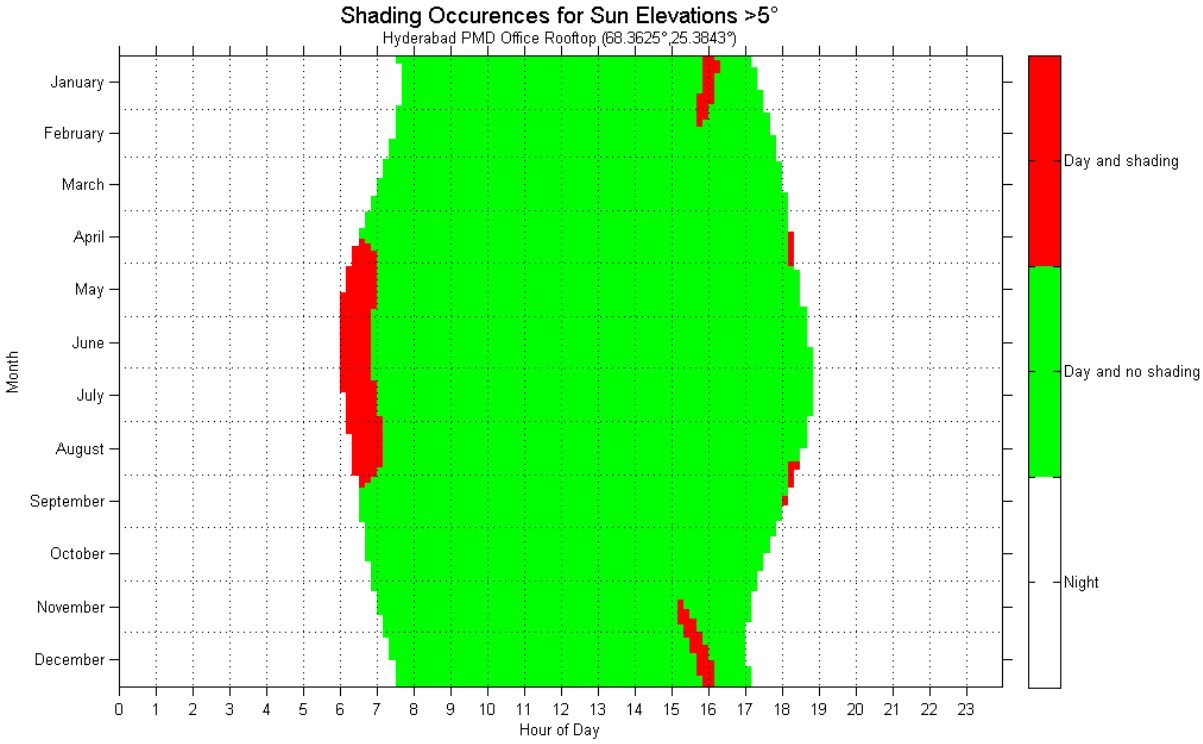


**Figure 7: Shading Table for Sun Elevations >5°**

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 for up to 1 h in the morning in the summer months, the impact of the mobile phone tower is also still present. Shading in the evening, however, is almost non-existent for sun elevations larger than 5°.

## 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.

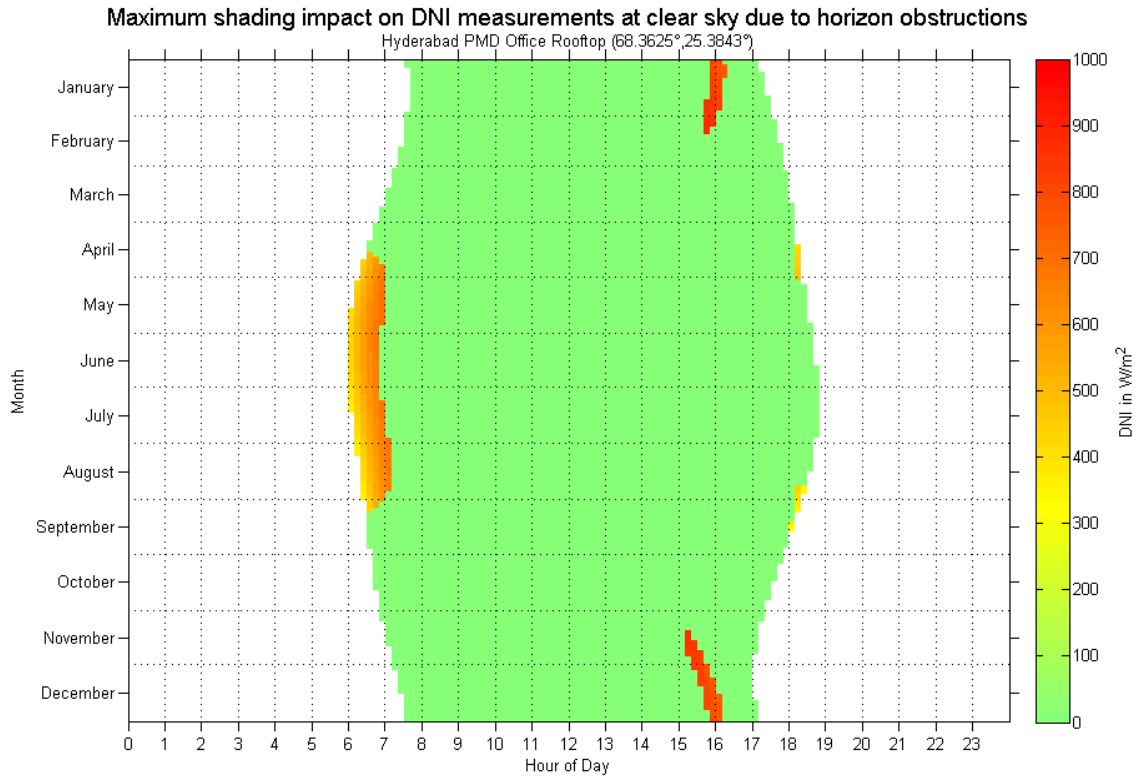


**Figure 8: Shading Impact on BirdDNI for Sun Elevations >5°**

From Figure 8, it is clearly visible that shadings in the morning in the summer as well as those from the mobile phone tower have some visible impact.

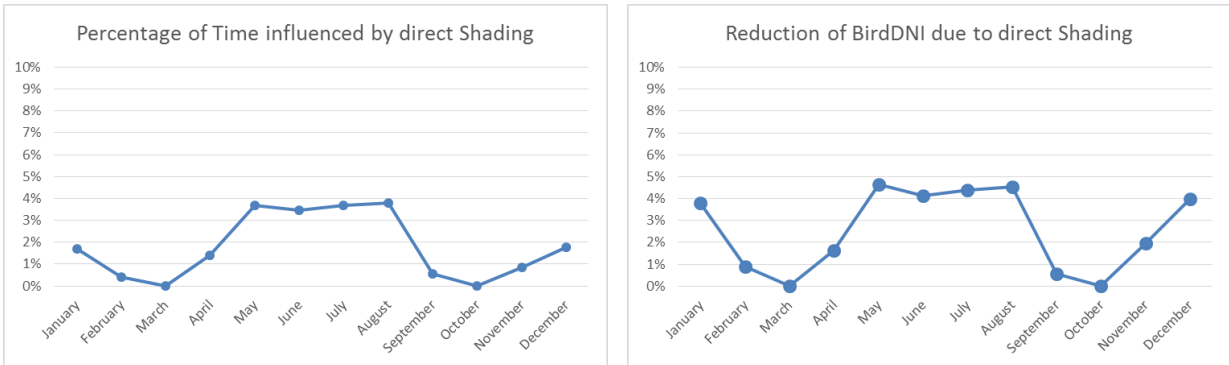


**Figure 9: Shading Impact for Sun Elevations >5°**

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, 1.8 % of the time is affected by direct shading, with up to

3.8% in the months of May to August. 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 2.6 %.

**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.

# 4 Conclusion

The surroundings of the location would be acceptable for the installation of a ground measurement station. No significant single external influence from surrounding facilities on the overall meteorological and atmospheric conditions could be stated during the site visit, however the location within the city centre might have some influence on the representativeness of the measurements for the surroundings. The shading profile of the site is not optimal with the shadow of the mobile phone network tower falling on the sensor in the afternoon for several months. The local stakeholder confirmed his support and smooth operation and proper maintenance of the station is expected with high probability. Future use of the equipment by the local stakeholder after the two years measurement campaign would be probable.

Due to the unfavourable shading profile and also the location in the center of town, the site is not recommended for the installation of a meteorological station

**Detailed description of checklist criteria:**

[i] A site with a minimum extension of 10 × 10 m² 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 × 1 m² and ~0.3 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 (~±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° 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.