THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP

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: Multan, MNS UET University Campus

Responsible Authors

Birk Kraas (CSP Services)
Christoph Schillings (DLR)
Qazi Sabir (PITCO)

DOC: SiteEvalReport_MultanMNS-UET_2014-06

Author Contact Information:
CSP Services GmbH
Friedrich-Ebert-Ufer 30
51143 Köln/Cologne, Germany
e-mail: b.kraas@cspservices.de

02 July 2014

CSP Services GmbH

Birk Kraas
Friedrich-Ebert-Ufer 30
51143 Cologne, Germany
Phone: +49 2203 959003 6
Mob.: +49 162 9373484
b.kraas@cspservices.de

DLR

Dr. Christoph Schillings
Pfaffenwaldring 38-40
70563 Stuttgart, Germany
Phone: +49 711 6862 784
christoph.schillings@dlr.de

PITCO:

Qazi Sabir
Phone: +92 (42) 36363751
qazi.sabir@pitcopk.com

Contents

1 Executive Summary

A team of AEDB (Alternative Energy Development Board of Pakistan), WBG (World Bank Group) and the solar vendor consortium for the ESMAP Pakistan Solar Resource Mapping Project visited the campus of M. Nawaz Sharif University of Engineering and Technology (MNS UET) in Multan on June 06, 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. The site that has been examined is on the rooftop of a campus building.

The site is recommended for the installation of a Tier 1 or 2 meteorological station (CSP Services MHP/MDI automatic weather station). Shading of sensors is negligible, physical conditions for installation are comfortable and maintenance personnel is available among MNS UET scientific staff. The local stakeholder expressed his interest and willingness to facilitate a meteorological station at his premises.

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

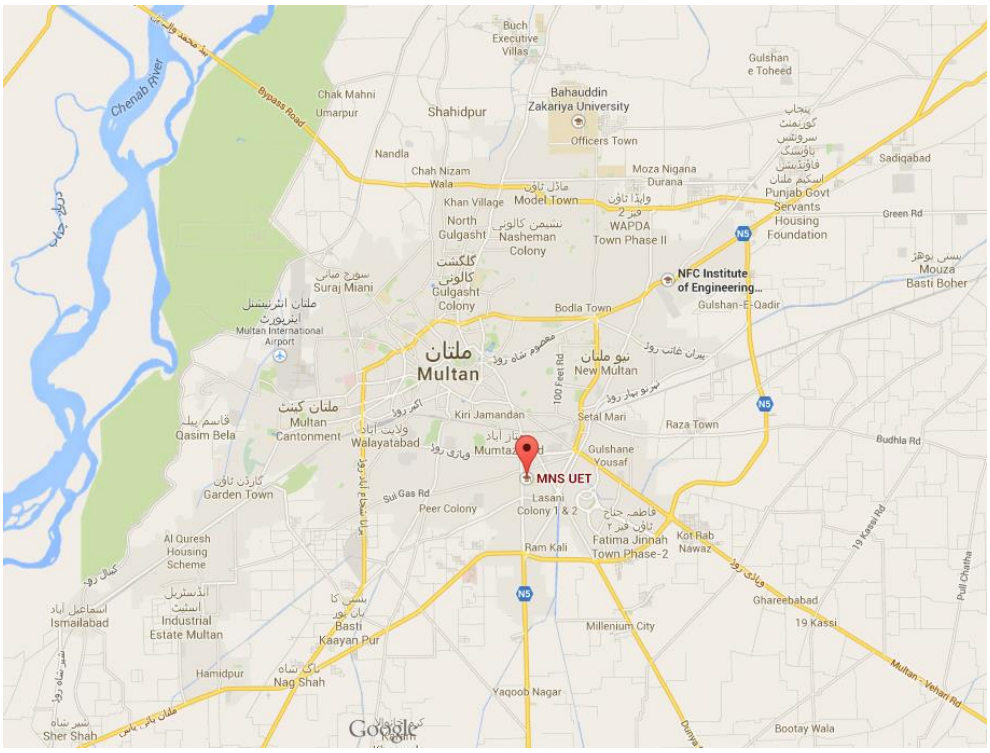

Figure 1: Location overview (Google Maps View)

Figure 2: Aerial View (Google Earth View)

Multan is located in central Punjab. The surroundings of the city are flat, agriculturally used land which is mostly irrigated. The area is crossed by the rivers Chanab and Ravi which provide the water. The climate is dry, with the majority of annual precipitation occurring in the months July and August (monsoon).

MNS UET campus in Multan is located in the southeast of the city center. In close vicinity, there are housing areas with mainly one and two storey buildings around the campus. To the east, there are a few small fields or gardens for about 400 m, which are limited by a large main road. About 500 m to the west the Bahawalpur road is located, passing the site from north to south.

The campus itself consists of several 3-4 storey buildings with walkways and small trees in between.

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 MNS UET representatives. Qualification of local staff is given, since MNS UET has qualified scientific personnel available.

Future hardware use (sustainability)

The station would probably be used actively in future for research projects of the university.

3.3 Site evaluation

3.3.1 Coordinates

N 30.1653° E 71.4978°, altitude 120 m above mean sea level

The site is located on the most eastern building of the campus on the flat roof top.

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 by interviewing stakeholders (MNS UET scientific personnel) on site.

Table 1: Site checklist for site 1

Criteria/Measure		Yes / No	Notes
Dimensions[i]	Minimum area 10 × 10 m²	yes	Roof-top
Surface	Firm natural ground[ii]	no	
	Ground type[iii]	cobbled	Firm-Concrete
	Horizontally levelled[iv]	yes	
	Excavation for foundations possible[v]		Not necessary, drilling/casting is possible
	Fencing of the site possible[vi]		Not necessary
	No drifting sand/snow[vii]	no	
	No flooding possible[viii]	no	
Surroundings	Obstructions If yes, note direction, distance and approx. height[ix]		See Panoramic View Figure 5
	Reflections or light sources[x]	no	
	Industrial areas or power plants[xi]	yes	Pak Arab Fertilizer Plant is 10 km away
	Sources of smoke or vapor[xii]	no	
	Quarry or mine[xiii]	no	Excavation work in the vicinity (small building construction, not expected to create any obstruction UET will confirm these details and share with us.
	Main road, dirt road, track[xiv]	yes	Paved roads only
	Airports[xv]	yes	Large distance, ~15 km

	Settlements, towns, city[xvi]	yes	Inner city site
	Agricultural area[xvii]	yes	Small fields and gardens to the east
	Swamp, lake, river, ocean[xviii]	yes	Canal
	Sand dunes[xix]	no	
	Animal populations[xx]	no	
	Occurrence of snowfall[xxi]	no	
	Temperatures below freezing point[xxii]	no	
	Other[xxiii]	-	
Accessibility	Accessible by car[xxiv]	yes	
GSM coverage	2G network available[xxv]	yes	All 5 providers
Grid power	Electricity available[xxvi]	yes	
Land use rights	Permit available[xxvii]	yes	
Operation permit	Permit available[xxviii]	yes	
Security	No underground or overhead electrical lines, pipelines or similar [xxix]	no	
	Measures against theft or vandalism required?[xxx]	No	Secured campus

Regarding the aspects covered by the checklist, the site is well suited for the installation of a ground measurement station. The installation on the rooftop is a good option due to the available free area; safety of the equipment against human or animal influences is given on the guarded campus. The surroundings lack any large industrial facility thus no negative impacts on irradiation and measurement conditions is stated. All roads in the surroundings are paved and therefore not heavily dust-emitting; large water bodies (Chenab river) are at least several kilometres distant, a small canal close to the site is not critical. Permission to use the site can be given directly by the resident stakeholder MNS UET.

The location within the city is of course not optimal since anthropogenic emissions and aerosols are likely present and the "natural conditions" of solar irradiance may be slightly disturbed, but due to considerations of site and maintenance staff availability, this has to be accepted.

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.

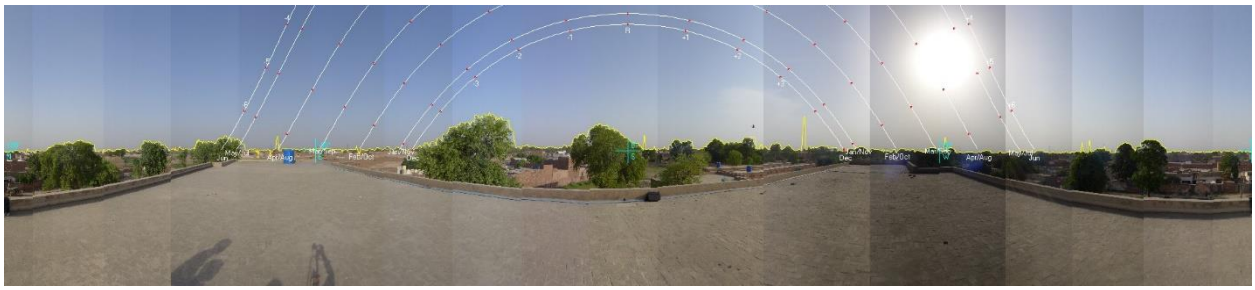

Figure 5: Panoramic View with North, South, horizon line and monthly sun paths with the corresponding position at full hours marked

From the panoramic view, it is visible that even at low sun angles around sun rise and sunset, no remarkable obstacles on the horizon are blocking the sun except for a few tree tops in the northeast.

Shading Table for Sun Elevations >0°

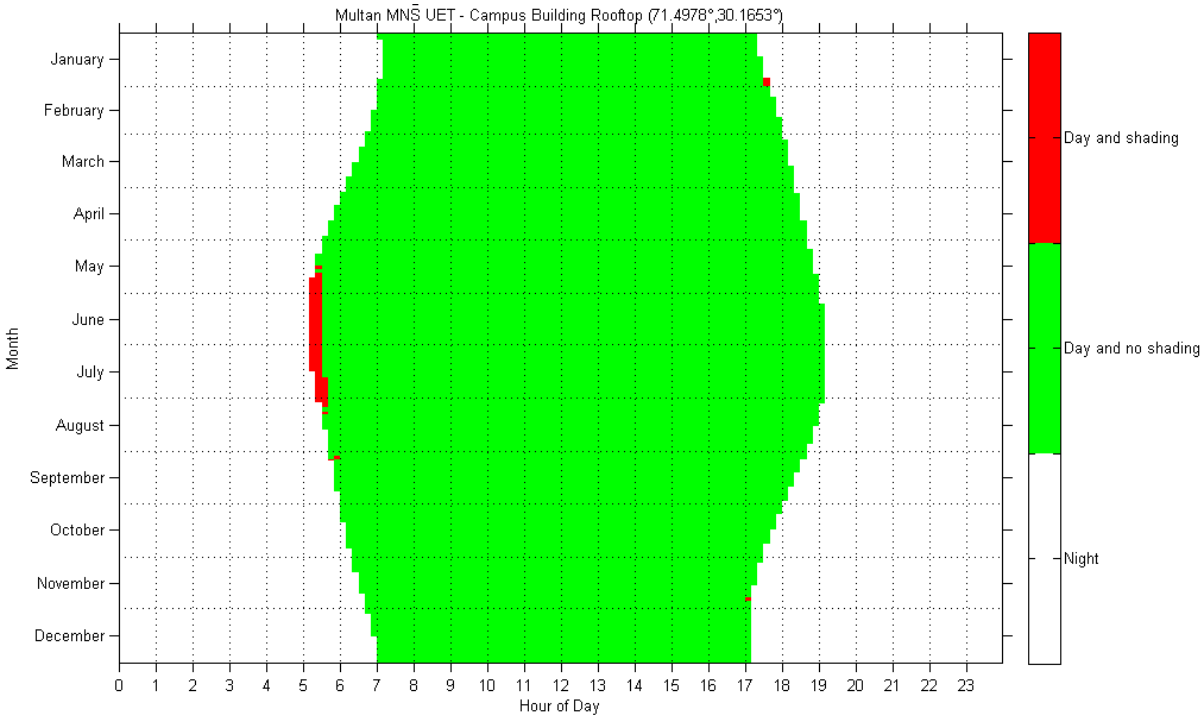

Figure 6: Shading Table for Sun Elevations >0°

Figure 6 shows the shading table throughout the year. It becomes clear that throughout the year, there is practically no shading except for a period in the summer, where the aforementioned trees are blocking the sun in the first 10-20 minutes of the day.

Shading Table for Sun Elevations >5°

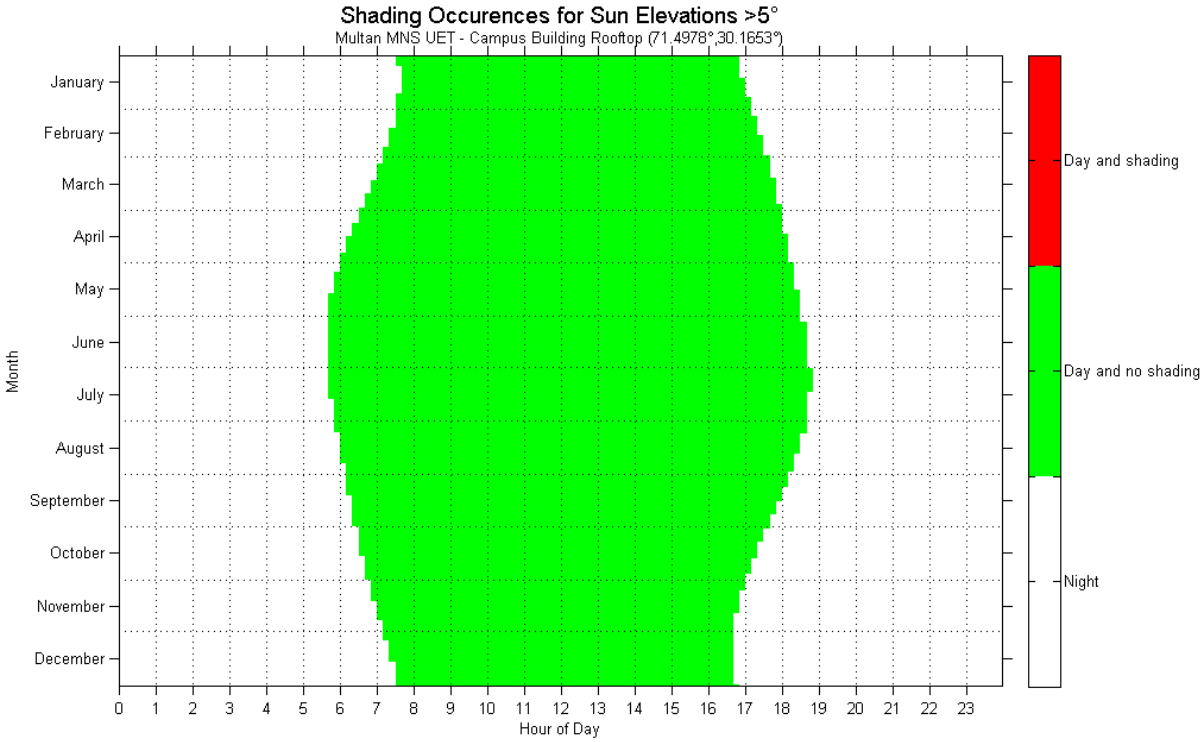

Figure 7: Shading Table for Sun Elevations >5°

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 at sun elevations above 5° is not present.

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.

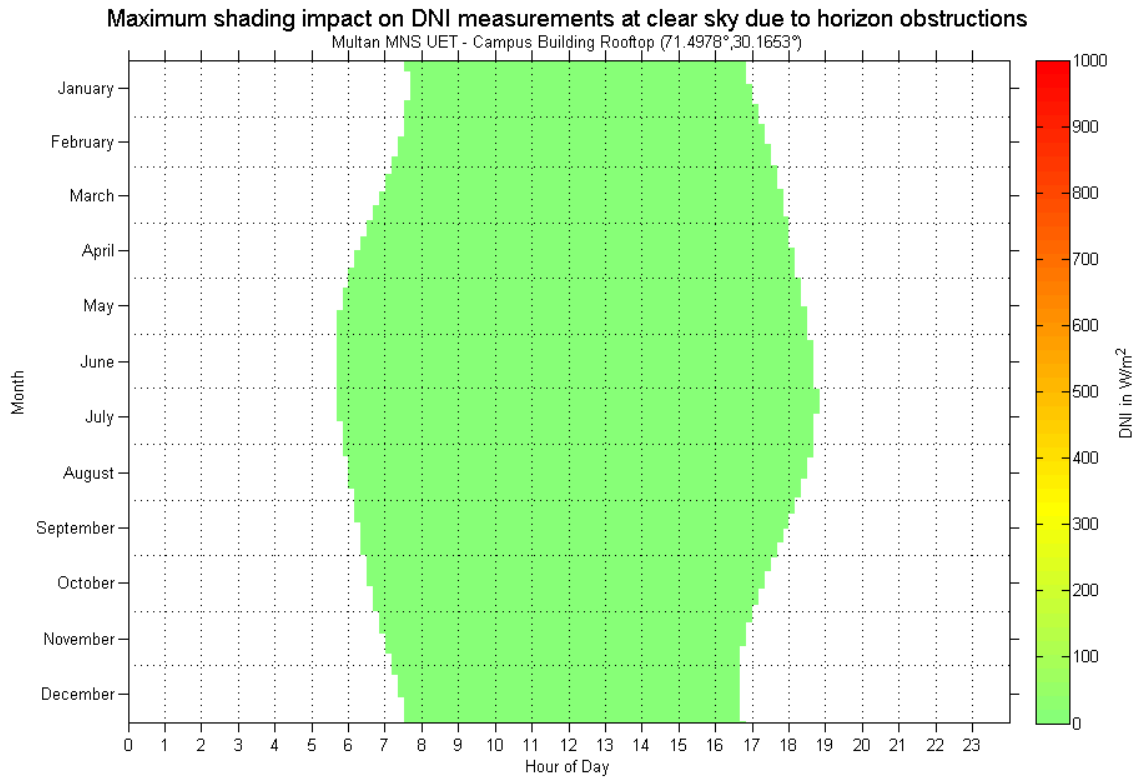

Figure 8: Shading Impact on BirdDNI for Sun Elevations >5°

Obviously, there is no impact of shading when restricting the evaluation to sun evaluations above 5° as there is no shading present.

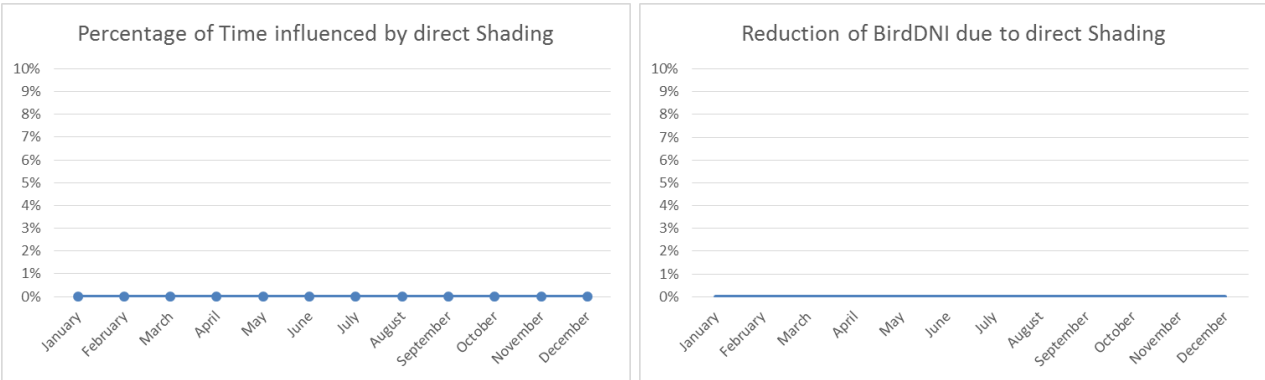

Figure 9: Shading Impact for Sun Elevations >5°

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. The right figure shows the quantitative impact of shading on the Bird-DNI summarized for each month.

Consequently, the shading-affected time and the BirdDNI reduction is zero.

Diffuse Shading and Reflections

No shading of diffuse radiation contributions and no reflections or artificial light sources are influencing the potentially installed sensors.

4 Conclusion

The surroundings of the location are acceptable for the installation of a ground measurement station. No significant external influence from surrounding facilities on the overall meteorological and atmospherical conditions could be stated during the site visit except for the fact that the site is located within a major city and not in a natural environment. 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 after the two years measurement by the local stakeholder is also possible, the sustainability of installing a meteorological station at MNS UET is expected to be high.

Shading effects are virtually negligible, since no shadings occur in the relevant sun elevations which will be used for the comparison of ground and satellite data. The roof allows for easy casting of foundations or drilling for bolts.

The site is therefore recommended for the installation of a Tier 1 or 2 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.