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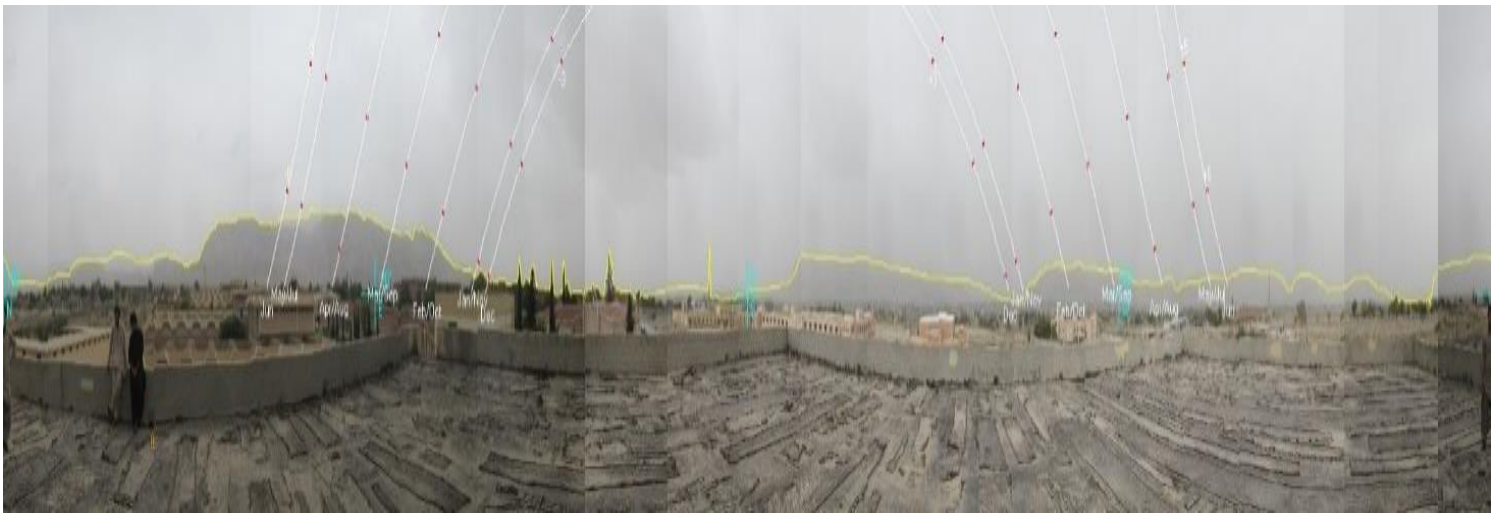
ESMAP
Energy Sector Management Assistance Program

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.

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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.

ESMAP – Renewable Energy Resource Mapping Initiative

- Solar Resource Mapping for Pakistan –

Site evaluation report: Baluchistan University of Engineering and Technology, Khuzdar

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ESMAP Energy Sector Management Assistance Program · DLR · P·I·T·C·O · ECOFYS · CSP Services Concentrating Solar Power Services

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Contents

1 Executive Summary

AEDB and the solar vendor consortium for the ESMAP Pakistan Solar Resource Mapping Project contacted the Baluchistan University of Engineering and Technology in Khuzdar with the request for support in form of hosting a solar measurement station in the framework of the project. After this support has been assured, the University provided documentation of the site that could host said measurement station. The documentation was according to the site evaluation criteria supplied by the vendor consortium with the goal of evaluating if the location is suitable for the installation of a solar ground measurement station.

A site on an office building of the university has been examined on the campus.

The site is recommended for the installation of a Tier2 meteorological station (CSP Services MDI automatic weather station). It is replacing the formerly selected site of the Pakistan Meteorological Department Office at Nokkundi, where installation of the station proved to be unfeasible.

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)

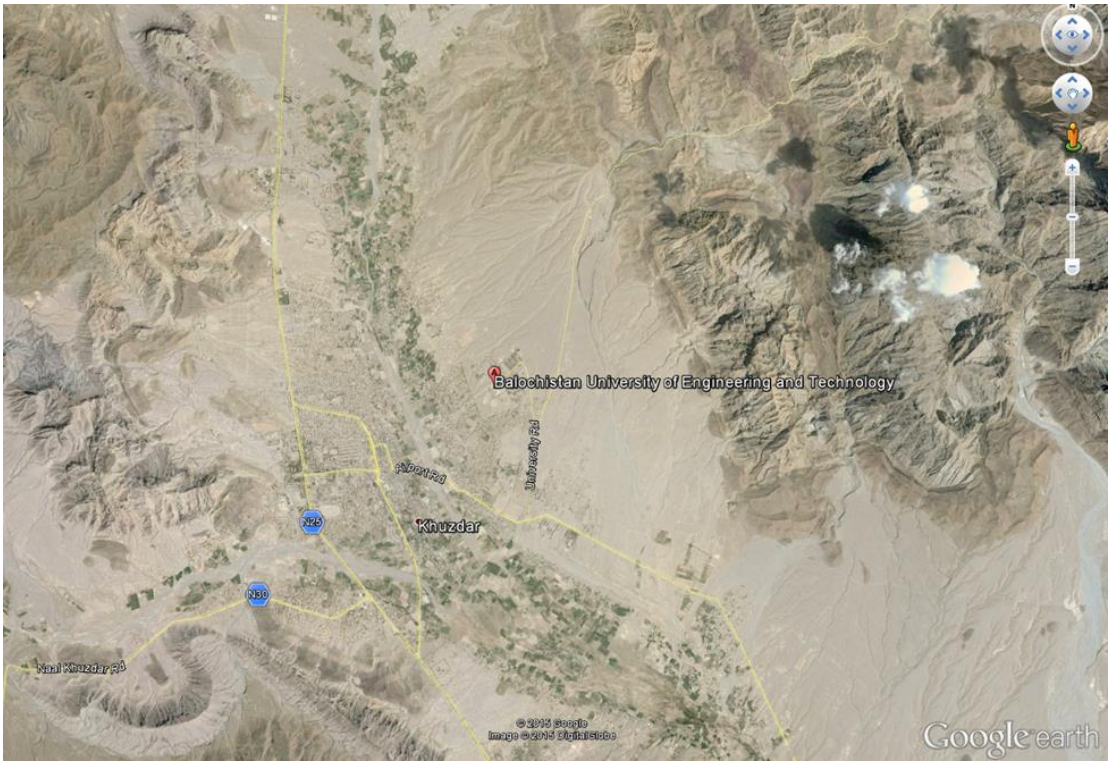

Figure 2: Aerial View (Google Earth View)

Khuzdar is located in the western part of the Khirtar mountain range which separates the province of Baluchistan from the Sindh province and the Indus valley. It is located in the river valley of the Kulachi river. The terrain around the city is mountaineous with mountain peaks exceeding 2100 m height to the east of the city. About 115 km to the Northwest, the expanse of the mostly flat Kharan desert is beginning. The national highway N25 enters the town from the south, splitting into the highway N30 continuing westwards and the N25 going north.

Khuzdars' Baluchistan University of Engineering and Technology is situated on the eastern border of town, on the gently rising slope of the mountains to the east. It consists of a large open campus with little vegetation besides some trees lining the roads and surrounding the buildings. To the south and west of the campus, the town of Khuzdar is located, consisting mainly of one- or two-storey brick buildings.

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 briefing about the required tasks and their frequency of occurrence will be given to the University representatives upon installation of the equipment. Qualification of local staff for the task is assumed to be given, since the University has dedicated engineers and technicians available for the task.

Contact Information

The local contact for the site is

Mr. Baig Muhammad
Secretary to Vice Chancellor
B-UET Khuzdar
Tel. No. +94 848 412834
Cell No. +94 333 207 8236

3.3 Site evaluation

3.3.1 Coordinates

N 27.8178° E 66.6294°, altitude 1260 m above mean sea level

The site is located on the roof of an office building of the university complex.

Figure 3: View from Site to the North

Figure 4: View from Site 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

Criteria/Measure		Yes / No	Notes
Dimensions[i]	Minimum area 10 × 10 m²	Yes	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]	Yes	Slight dust storms
	No flooding possible[viii]	No	
Surroundings	Obstructions If yes, note direction, distance and approx. height[ix]		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]	-	Airport is at 4 km (no regular flights)
	Settlements, towns, city[xvi]	Yes	Small city
	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]	-	
Accessibility	Accessible by car[xxiv]	Yes	
GSM coverage	2G network available[xxv]	Yes	All 5 providers
Land use rights	Permit available[xxvi]	Yes	Internal Decision
Operation permit	Permit available[xxvii]	Yes	Internal Decision
Security	No underground or overhead electrical lines, pipelines or similar [xxviii]	No	
	Measures against theft or vandalism required?[xxix]	Yes	Fence

Regarding the aspects covered by the checklist, the site is well 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. The direct surroundings lack any 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 are not present, the river is not a perennial river. No special permits are required and permission to use the site can and is already given by the University.

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 no obstacles such as trees on the horizon are blocking the sun. There are mountains on the horizon, which are part of the natural environment and can be considered in the data analysis. Also in the satellite data model, the terrain can be integrated via 3D-models of the surroundings. Their shading impact is further analyzed in the following paragraphs.

Shading Table for Sun Elevations >0°

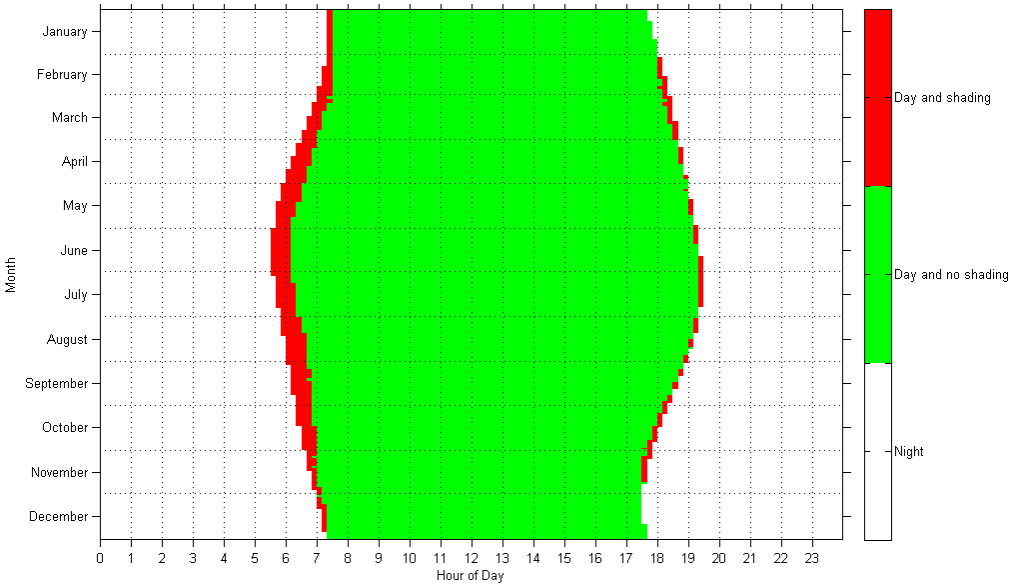

Figure 6: Shading Table for Sun Elevations >0°

Figure 6 shows the shading table throughout the year. It becomes clear that the mountains are shading the sun in the morning in the entire calendar year, and in the evening from February to November.

Shading Table for Sun Elevations >5°

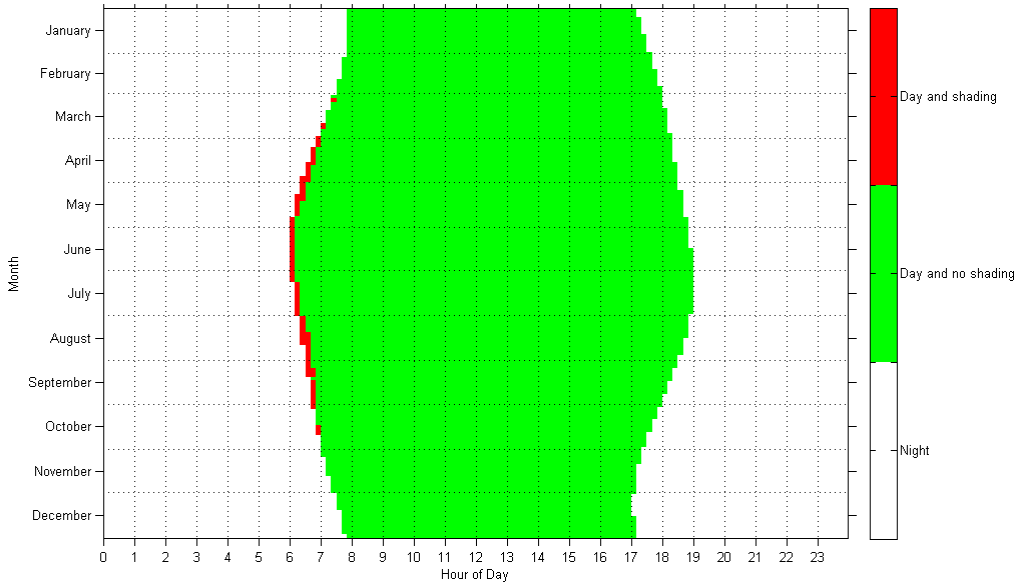

Figure 7: Shading Table for Sun Elevations >5°

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 from the mountains is only left in the morning in the months from March to October after exclusion of sun elevations smaller 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.

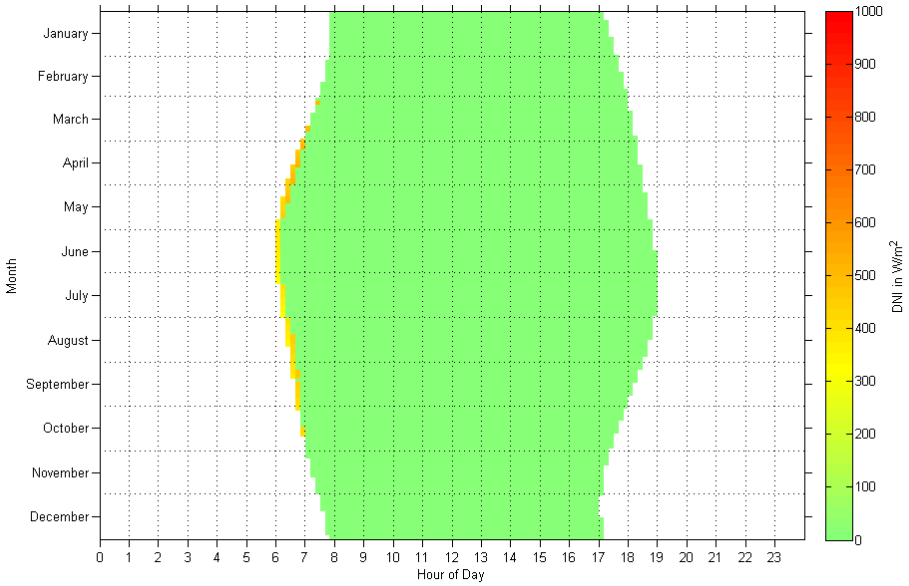

Figure 8: Shading Impact on BirdDNI for Sun Elevations >5°

From the figure, it is obvious that shadings have little impact on the total DNI measurement throughout the year. In total, 0.4 % of the time (sun elevation >5°) is affected by direct shading.

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 are well suited 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. 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 is also probable, since the University representatives expressed a keen interest in collecting solar data.

The site is recommended for the installation of a Tier 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] Verify and annotate if the land use permits are conceded or given from the land owner.

[xxvii] 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.

[xxviii] 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.

[xxix] 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.