Solar and Wind Resource Implementation Plan

April 2017

This report was prepared by Suntrace GmbH, under contract to The World Bank.

It is one of several outputs from the solar and wind resource mapping components of the activity "Renewable Energy Resource Mapping and Geospatial Planning – Bangladesh" [Project ID: P162805]. 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, and the content is the sole responsibility of the consultant authors. Users are strongly advised to exercise caution when utilizing the information and data contained, as this may include preliminary data and/or findings, and the document has not been subject to full peer review. Final outputs from this project will be marked as such, and any improved or validated solar resource data will be incorporated into the Global Solar Atlas and the Global Wind Atlas.

SOLAR AND WIND RESOURCE MEASUREMENTS IN BANGLADESH SELECTION #: 1229311

Solar and Wind Resource

Implementation Plan

7 April 2017

World Bank Group

ESMAP Renewable Energy Mapping Initiative

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1. INTRODUCTION

Background

This report is prepared within the project Selection # 1229311/ Solar and Wind Measurements in Bangladesh. Under this project a single solar and wind measurement station funded from a World Bank executed trust fund will be commissioned. This is to be installed at a high priority site identified by the Government of Bangladesh in the district of Feni, Bangladesh. The intention is to begin measurements at this site as soon as possible, to provide validation data to inform a competitive bidding process under the Scaling-up Renewable Energy Program in Low Income Countries (SREP) investment project. The Government of Bangladesh (GOB) has plans to add renewable energy generation capacity of 2,000 MW by 2020. Solar and wind resources have been identified as the most promising renewable energy sources to be scaled up in the SREP Investment Plan.

However, Bangladesh currently has limited data on renewable energy resource potential. The World Bank team supporting the SREP project is therefore launching a parallel activity to support country level renewable energy resource assessment and mapping, focusing on solar and wind, with technical and financial support from World Bank-executed trust funds.

Objectives and approach

This assignment includes the planning, commissioning and implementation of a high quality solar and wind measurement campaign at a single site selected by the Government of Bangladesh, including regular delivery of bankable solar and wind data over a two-year period. The solar measurement equipment shall conform to Tier 1 of the standards developed by ESMAP, and the wind measurement equipment shall consist of a LIDAR unit to facilitate rapid deployment.

The measurements have to deliver bankable data to provide to provide validation data to inform a competitive bidding process under the SREP investment project. Central in this effort is a focus on reducing uncertainty of the available model estimations on solar resources and thus reducing financial and technical risk during implementation of photovoltaic solar or wind power plants at the selected site.

The station will be installed under the supervision of Suntrace in reasonable distance to the selected site in the Feni district, with GPS coordinates of 22°47'47.0"N 91°21'42.0"E.

Preceding technical consultations:

This Implementation Plan is a result based on the outcome of the Inception Mission for this project conducted from Sunday, February 19 until Thursday, February 23 2017. Suntrace supported by its partners visited stakeholders involved in this project and the selected site in the Feni district, together with its local partner.

Minutes of meetings - Inception Mission

Subject	Inception Mission – Site visit
Time & Date	12:30 PM 2017-02-13
Place	Upazila Parishad, Sonagazi, Feni
Participants present (2-3 letter acronym) *Company, Position, Role in project*	1. Muhammad Mizanur Rahman (MMR) Upazila Nirbahi Officer, Sonagazi Upazila 2. Dr. Richard Meyer (RM) Managing Director & CTO, Suntrace GmbH 3. Tauhidul Hasan (TH) Consultant, EQMS Consulting Limited 4. Najmul Hossain (NH) Asst. Consultant, EQMS Consulting Limited
Agenda	1. Introduction 2. Objectives of the Project 3. Approach and Methodology for carrying out the work 4. Clarification of site availability 5. Roles of the UNO about the project and his consent
Major decision(s)	1. Firstly Solar & wind measurements team introduced with UNO. Suntrace, EQMS presented their scope and brief methodology for installation of solar and wind measurement instrument; 2. RM explained the approach of the work and the duration of the measurement to UNO; 3. Solar and Wind Measurements team explained to MMR regarding the requirement of place for installation of the equipment; 4. Team explicated the involvement of UNO in the project

Results of the meeting

Point	Findings	Action Items (AI) with responsible persons and due dates
1	UNO was very much proactive and took the team as positive manner. After his understanding regarding the project, MMR introduced the team with Assistant Superintendent of Police, Sonagazi as well as respective Union Parishad Chairman after his understanding regarding the project. Team shared the findings with MMR from field visit which have been participated by Suntrace-EQMS personnel along with Upazila Chairman, Municipality Mayor and Surveyor from Upazila land department in the project area as well as surrounding places for two days to find out the suitable place for setting up the instrument. MMR assured all helps will be provided to team as much as possible from his end.	MMR will provide all sorts of help from his end during the installation of measuring station as well as throughout the measurement periond

Subject	Inception Mission – Site visit
Time & Date	10:40 AM 2017-02-14
Place	Char Chandia Union Parishad, Sonagazi, Feni
Participants present (2-3 letter acronym) *Company, Position, Role in project*	5. Md. Mosharaf Hossain Milon (MHM) Upazila Nirbahi Officer, Sonagazi Upazila 6. Dr. Richard Meyer (RM) Managing Director & CTO, Suntrace GmbH 7. Tauhidul Hasan (TH) Consultant, EQMS Consulting Limited 8. Najmul Hossain (NH) Asst. Consultant, EQMS Consulting Limited
Agenda	6. Introduction 7. Objectives of the Project 8. Approach and Methodology for carrying out the work 9. Clarification of site availability 10. Roles of the UP Chairman about the project and his consent
Major decision(s)	5. Firstly Solar & wind measurements team introduced with MHM. Suntrace, EQMS presented their objective of the field visit and made him understand regarding the solar and wind measuring station; 6. RM explained the approach of the work to MHM and the duration of the measurement; 7. Solar and Wind Measurements team explained to MHM regarding the suitable site selected by team; 8. Team explicated the involvement of UP Chairman

Results of the meeting

Point	Findings	Action Items (AI) with responsible persons and due dates
1	MHM express his high cooperation regarding the measurement of solar and wind as it will be national database. Though preliminary two sites are not under his jurisdiction even so he will provide support if required. MHM introduced the team with the respective UP chairman belongs to the selected sites.	Though the selected sites are not under his jurisdiction even so he express his cooperation to provide any sorts of help is needed

Subject	Inception Mission – Site visit
Time & Date	12:50 PM 2017-02-14
Place	Char Darbesh Adarsha Village Government Primary School, Sonagazi
Participants present (2-3 letter acronym) *Company, Position, Role in project*	9. Mr. Aziz Ullah (AU) Head Master, Char Darbesh Adarsha Village Government Primary School, Sonagazi 10. Dr. Richard Meyer (RM) Managing Director & CTO, Suntrace GmbH 11. Tauhidul Hasan (TH) Consultant, EQMS Consulting Limited 12. Najmul Hossain (NH) Asst. Consultant, EQMS Consulting Limited
Agenda	11. Introduction 12. Objectives of the Project 13. Understanding of the project 14. Clarification of site availability 15. Action requirement of AU for the project
Major decision(s)	9. Firstly Solar & wind measurements team introduced with AU. Suntrace, EQMS presented a brief description of the scope and objectives for installation of solar and wind measurements instrument; 10. RM explained the approach and duration of the measurement of the work to AU; 11. Solar and Wind Measurements team explained the suitability of the roof top of the primary school to AU; 12. Team explained the involvement of AU in the said activities

Results of the meeting

Point	Findings	Action Items (AI) with responsible persons and due dates
1	AU was so pleased to know the detail activities of the wind and solar measurement team and he showed the roof top of the school. He expressed his consent to set up the solar and wind measuring station on the roof top of the school. Only permission is required from UNO and Upazila education officer as the school is under the Ministry of Primary and Mass Education. He also considered that his school is safer place for installation of such type of instrument as a guard is looking after the school at night as well as police investigation center is present in the school premises. AU will also help the team to find out the local reliable person for station keeper.	AU greeted the team to install the station on the roof top of the school.

Subject	Inception Mission – Site visit
Time & Date	16:45 PM 2017-02-14
Place	Police Station, Sonagazi, Feni
Participants present (2-3 letter acronym) *Company, Position, Role in project*	13. Mr. Junayed (MJ) Assistant Superintendent of Police (ASP), Sonagazi 14. Dr. Richard Meyer (RM) Managing Director & CTO, Suntrace GmbH 15. Tauhidul Hasan (TH) Consultant, EQMS Consulting Limited 16. Najmul Hossain (NH) Asst. Consultant, EQMS Consulting Limited
Agenda	16. Introduction 17. Objectives of the Project 18. Understanding of the project 19. Clarification of site availability 20. Roles of the police department about the project 21. Consent of police department
Major decision(s)	13. Firstly Solar & wind measurements team introduced with ASP. Suntrace, EQMS presented their scope and brief methodology for installation of solar and wind measurement instrument; 14. RM explained the approach of the work and the duration of the measurement to ASP; 15. Solar and Wind Measurements team explained the suitable site selected by the team to MJ regarding the requirement of place for installation of the equipment; 16. Team explicated the involvement of Police deprtment

Results of the meeting

Point	Findings	Action Items (AI) with responsible persons and due dates
1	One site has been selected on the roof top of the Char Darbesh Adarsha Village Government Primary School where a police investigation center is present within the school premises that has been informed to MJ. Solar and Wind Measurements team was requested to the ASP to inform the in charge of police investigation center to provide a periodic patrolling during the measurement period as the police investigation center is present close to the building. MJ assured that he will to in charge of the police investigation center prior to installation of the measuring station for looking after the instrument.	MJ will cooperate by directed to the in charge of police investigation center for looking after the instrument throughout the measuring period

2. PROJECT PARTNER

Suntrace GmbH will contribute to the project with its international expertise in renewable energy project management in particular solar resource measurement expertise. It will join forces with windtest grevenbroich gmbh and EQMS Consulting Ltd. in order to provide expertise for the broad scope of the solar and wind resource measurements project.

Suntrace will subcontract both partners. While windtest grevenbroich gmbh will supporting and advise on the high-quality wind measurement campaign and for the proposed use of LIDAR equipment on this assignment. EQMS Consulting Ltd. will support the measurement campaign at the Feni site as local partner.

Partner for Wind-LiDAR: windtest grevenbroich gmbh

windtest grevenbroich gmbh (wtg) has more than 12 years experience in working with LiDAR measurements and 20 years experience in working with met masts in order to provide IEC compliant measurements for wind turbine prototypes or measurements for the analysis of site specific wind conditions or provide site assessments (yield prognosis) for planned wind farm projects. Moreover, wtg provides the verification station for LiDAR-units on its calibrated test site in Grevenbroich.

The role of wtg will be the following:

- Verification of the LiDAR before the start of measurement campaign and after 24-month of operation at the site
- Installation and commissioning of the LiDAR at the selected location
- Station keeper training for LiDAR maintenance
- Data quality checks with daily monitoring and monthly as well as yearly reports regarding the wind potential
- LiDAR maintenance as required after 12-month or 24-month of operation

Local partner: EQMS Consulting Limited

EQMS Consulting Limited (EQMS) is located in Dhaka, Bangladesh and to carry out the on-field and other related tasks. EQMS provides a multitude of services that range from engineering and project management to consultancy services. EQMS focuses on providing customized, innovative, renewable energy and energy efficiency solutions as well as on-going maintenance and support. Our expertise spans across various technologies including: Solar Power Plant, solar PV, solar thermal, biogas, hydro power, water or waste management, energy efficiency and industrial process optimization and also give sustainable solution for climate change adaptation and disaster management issues. EQMS can provide a highly qualified and multi disciplined team of professionals for station commissioning and operation, as well as provide capabilities for in-county storage and transportation.

The role of EQMS will be the following:

- Site preparation and civil works
- Equipment will be cleared in Bangladesh with the aid of EQMS and stored at their premises
- Customs clearance of equipment
- Site permitting
- Installation of stations at the site together with Suntrace and wtg's technical expert
- Assistance for field verification after 12 months and recalibration/verification after 24 months
- Ensuring local measurement site security
- Unscheduled site visits on ad hoc or as need basis.
- Supervision of regular measurement equipment cleaning and maintenance

SUMMARY

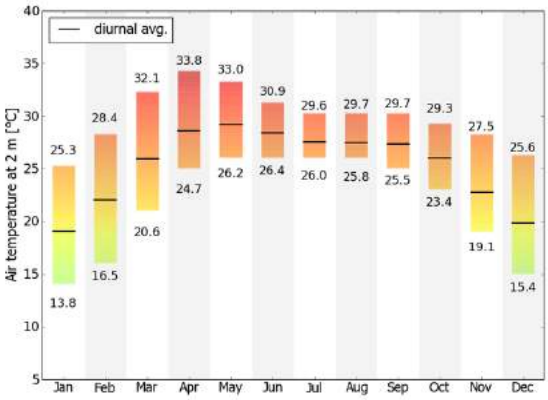
- ◇ The visits took place from 13.02.2017 to 14.02.2017
- ◇ 3 possible locations were visited and evaluated during the Inception Mission
- ◇ Location BDFE2 identified as most suitable location for equipment

3. SITE SELECTION FOR MEASUREMENT STATION

Geographic and climate conditions at the site

Bangladesh is a semi-tropical region lying in northeastern part of South Asia. Three different types of landscapes are found in Bangladesh: floodplains, terraces and hills with floodplains being the most frequent with around 80% of the total landscape. The proposed site is situated between the two rivers: Feni River and Chotto Feni River and also adjacent to the Sandwip channel of Bay of Bengal. Huge fallow land is available in this area. Initially the land was Khash (government-owned) Land. Most of the land is used for cattle grazing with some part of the land under limited cultivation once in a year.

Bangladesh is characterized by subtropical monsoon climate with wide seasonal variations in rainfall, moderately warm temperatures, and high humidity. Regional climatic differences in this flat country are minor. Three seasons are generally recognized: a hot, humid summer from March to June; a cool, rainy monsoon season from June to October; and a cool, dry winter from October to March. In general, maximum summer temperatures range between 32°C and 38°C. April is the warmest month in most parts of the country. January is the coldest month, when the average temperature for most of the country is 10°C. Heavy rainfall is characteristic of Bangladesh. Most parts of the country receive at least 200 centimeters of rainfall per year.

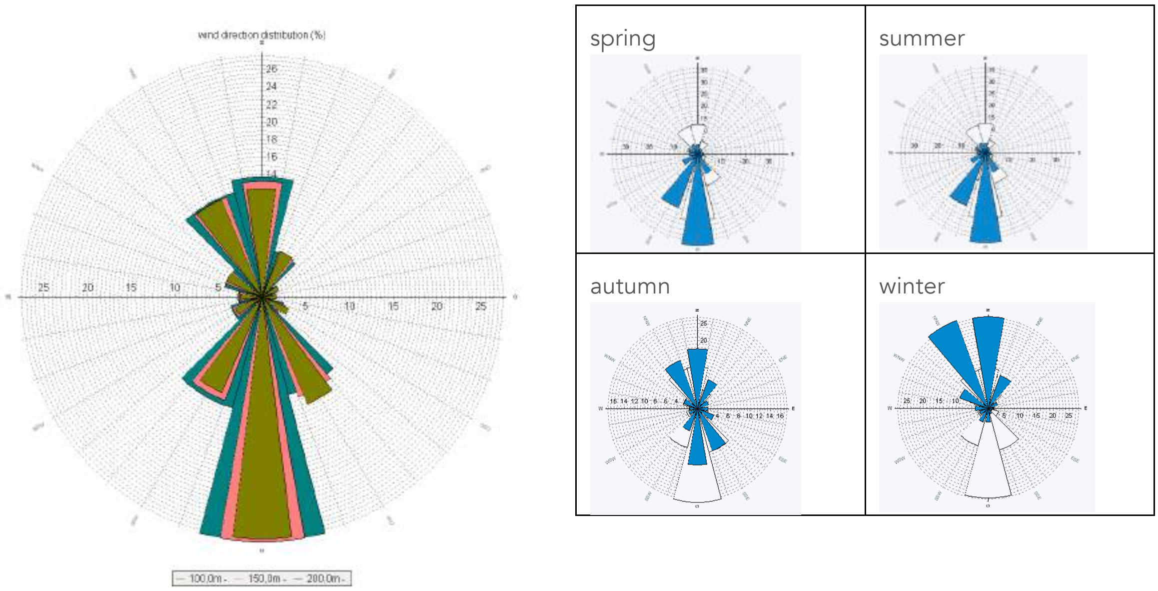


The average bright sunshine duration in Bangladesh in the dry season is about 7.6 hours a day, and that in the monsoon season is about 4.7 hours. Annual averages of solar resources in Bangladesh vary between 1550 and 1750 kWh/m² for Global Horizontal, between 850 and 950 kWh/m² for Diffuse Horizontal and between 900 and 1250 kWh/m².

Winds are mostly from the north and northwest in the winter, blowing gently at one to three kilometers per hour in northern and central areas and three to six kilometers per hour near the coast. From March to May, violent thunderstorms, called northwesters by local English speakers, produce winds of up to sixty kilometers per hour. During the intense storms of the early summer and late monsoon season, southerly winds of more than 160 kilometers per hour cause waves to crest as high as 6 meters in the Bay of Bengal, which brings disastrous flooding to coastal areas.

The following figure shows the wind direction distribution of the reanalysis dataset EMD ERA_N22.807 E91.390 which is situated around 1.4 km to the North of the limit of the planned project boundary. Reanalysis integrates a wide variety of observations (weather stations, weather observations from ships, planes, satellite etc.) simultaneously. The global reanalysis dataset is based on the ERA-Interim dataset from the European Centre for Medium-Range Weather Forecasts (ECMF). The processed dataset (EMD) is focused on parameters relevant for wind-energy use. The following figure illustrates wind direction data of the period 1987-01-01 to 2017-01-01 in 100m, 150 m, and 200 m above ground.

On the right side of the figure the seasonal pattern of the wind direction distributions is shown. In spring and summer the prevailing wind directions are from the South, in autumn and winter prevailing wind directions are the northern directions.



Source: EMD ERA_N22.807 E91.39

Figure 3-1: regional and seasonal wind direction distribution

Criteria for deployment of measurement equipment

A suitable location for proper and secure station operation should fulfill the following criteria:

- ◇ The site should well represent climate region
- ◇ Low obstructions by nearby terrain, preferably situated in flat terrain and homogeneous landscape and land use
- ◇ Sufficient distance from coastlines, water bodies, mountains, frequently used dirt roads, industrial pollution and open pit mining operations
- ◇ Availability and quality of GSM/GPRS connections
- ◇ Site should be accessible for installation and regular maintenance via roads
- ◇ Local assistance should be available
- ◇ Station should be placed where provision of secure operation is possible
- ◇ Danger of flooding should be as low as possible
- ◇ Installation of the LiDAR-system on a nominally level, adjusted as close as possible to the horizontal

Description of proposed locations for measurement equipment

The visit at the site in the Feni district located in the Southeastern part of Bangladesh took place from 13.02.2017 to 14.02.2017. The following map shows the location and extension of the selected site.

Figure 3-2: Extend of the site and evaluated locations for measurement equipment

Table 1: Coordinates of possible locations for measurement equipment

Site	Latitude	Longitude
BDFE0	22.79	91.37
BDFE1	22.819360	91.366122
BDFE2	22.80	91.3582

Location 1: On the Feni project site (BDFE0)

Description of location: The first location selected prior to the Inception Mission is located directly in the area of the Feni site marked on the above map. The conditions at the location are described as well connected by road from Feni and Mirer-Shorai. The nearby rail station Sinkiastan of Murolganj is 7 km away. According to interviews with locals the temporal flooding during monsoon is confirmed. Most of the land will be flooded during monsoon for at least 2 months every year. Depending on tide situation and position on site then water levels range 1 m above the land level. According to the utility company, during the 1991 cyclone and in 1985 the proposed area was flooded with approximately 3.0 - 4.6 meters high tidal surge from the ground level and these conditions lasted for a few days. According to local community members the site is moderately flooded for about half a year. The pictures in Figure 3-3 show the conditions as found at the Feni site during the Inception Mission.

The following pictures show the conditions as found at the Feni site during the Inception Mission.

Figure 3-3: Condition at the site during Inception from different directions and location

Figure 3-4: Picture of the frequently used dirt road near the site and strong soiling visible on plants directly apart.

The main objective of this project is to collect "high quality, credible and reliable ground-based measurements that can be used to evaluate the solar and wind resource at the selected site. The most important task to achieve this objective is the ability to operate and maintain stations as per the specific requirements.

Based on the five main objections against this option were identified.

1. The Tier 1 solar equipment needs daily maintenance. To allow this is really executed, the measurements must be easy to access by the station keeper. The only easy access to the site currently is from the road along the Western boundary of the site.
2. The frequently used dirt road near the Feni site is causing significant amounts of dust. Figure 3-4 shows fine dust strongly accumulates on plants nearby this road. Our impression is that at least a distance of 50 m to this road should be kept. The location for the equipment should be in sufficient distance from the road, resulting in difficulties to make the equipment accessible for local assistance and daily maintenance. The condition of the soil and ground at the site is mostly muddy and in up to 6 month of the year flooding. These considerations need to be factored into the technical solution provided and would cause noticeable adjustment on site preparations.
3. Flooding was already identified as major concern for station security at early stages of the search for a suitable location for the measurement equipment. The visit at the site has confirmed this concern to be relevant. Natural calamities, such as floods during monsoon season, and tidal bores—with destructive waves or floods caused by flood tides rushing up estuaries--ravage the country, particularly the coastal belt, almost every year. Tropical cyclones with notable effect on the site occurred twice in the past 3 decades. Then a maximum water level of 4.6 m above ground was observed. The danger of flooding during the measurement campaign might result in loss of equipment. To be safe from regular flooding the measurement equipment should be elevated at least 3 m above ground. However, cyclone induced storm surge may cause even higher water levels. Waves in such strong storms could be even higher and could damage an even much higher platform.
4. Any measurement location near the public road makes the station visible to anybody. This easily could cause unwanted attention to the expensive instruments or just the relatively many PV panels used to operate the station autonomously. Locals say survival chances are low for such fancy equipment in such unobserved location survives without being damaged by children or equipment stolen.
5. The LiDAR system should be as close as possible to horizontal in order to avoid installation with a tilt or roll-angle, since this may lead to incorrect data of the wind speed and wind direction measurements. In order to avoid gradual change of the horizontal orientation of the device a stable underground should be preferred.

To avoid strong soiling the measurement platform should be erected in at least 50 m distance from the road. Due to the temporal flooding of the site, for allowing easy daily access we would need to erect a bridge about 3 m above surface. If such a pier bridge is constructed in metal it is likely to be stolen. Alternatively, the station might be reached by boat for maintenance during monsoon season. However, this is less comfortable for the station keeper and might be avoided leading to poor maintenance performance.

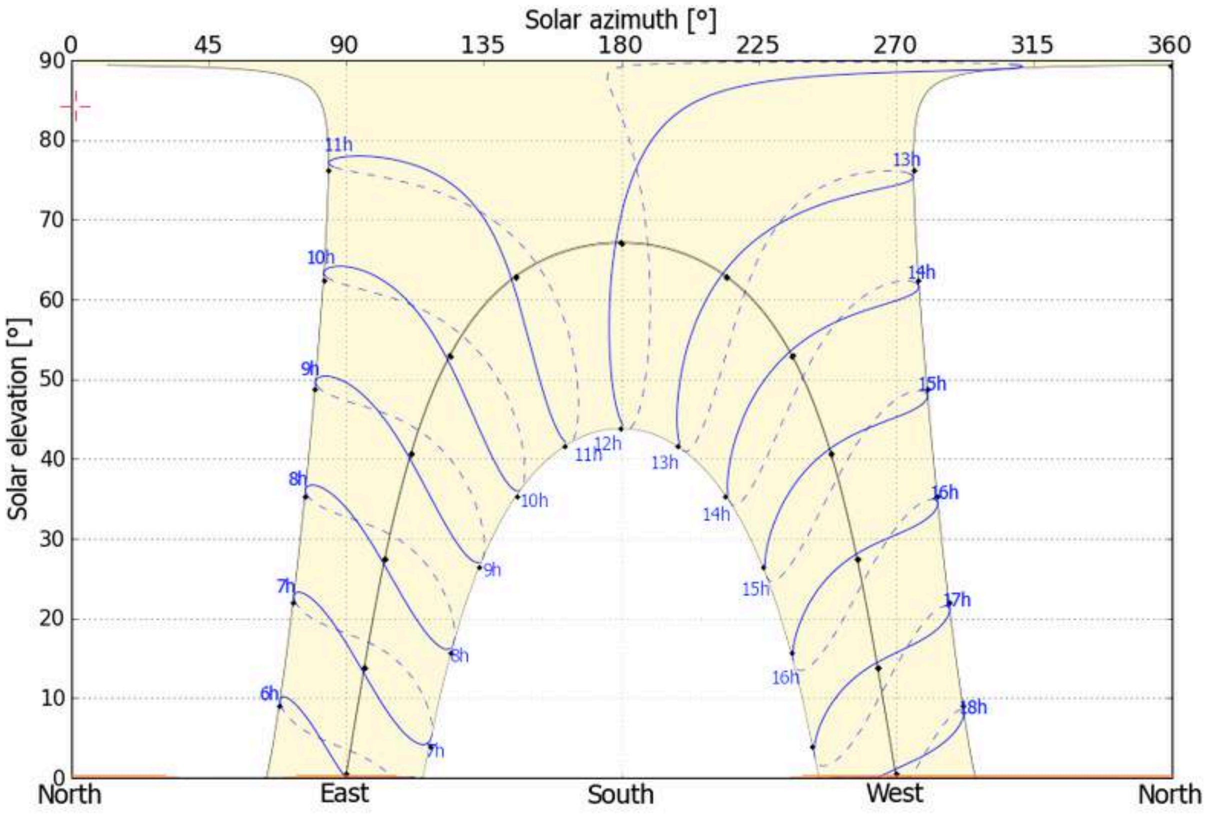


Figure 3-5: Sun horizon and sun path for BDFE0

Location 2: Rooftop of school building in nearby village (BDFE1)

As the location of the measurement station on the site seems not suitable for reasons of security and flooding, the Contractor's team searched for safe alternate locations. First, a nearby school building was found situated about 3 km North of the site.

Description of location: The second considered location for the measurement equipment is located in a nearby village. The location is located in northern direction with a distance of 2.8 km to the northwestern border and 5 km distance to the southeastern border to the Feni site.
The rooftop of the school building is surrounded by trees with approx. 7 m to maximum 12 m height all directions The distance of the vegetation to the school building is approx. 7 m in northern, 60 m in eastern, 22 m in southern and 22 to 41 m in western directions. The highest roughness is found at this site compared to the other potential sites suitable for the wind measurement. The existing development (buildings height to a maximum of two levels and trees with a maximum height of 12 m is still characterized as relatively open since the measurement is planned to be installed on the rooftop. The rooftop with its height of approx. 7 m exceeds parts of the trees. The wind sensors on the 10 m mast are going to be influenced by the surrounding vegetation. Therefore, a detailed sector by sector assessment of tree heights has to be performed during the site visit and the installation of the mast. The shadowing is taken into consideration when analyzing the data. The influence of the vegetation on the LiDAR data in the relevant heights of at least 80 m above ground is of less relevance for the energy yield calculations.

The terrain is characterized as flat and simple. The maximum distance of 5 km to the southeastern border of the Feni site would still be representative its wind conditions.

Despite the distance the collected measurements will still be representing the climate conditions at the site. Identified most suitable for locating the equipment is the rooftop of a school building shown on the following pictures.

Locating the station on top of the school seems principle in possible. The school master said he would be willing to host. However, it was found that the school is surrounded by relatively many trees even higher than the 3rd floor of the school building. Also this location is relatively distant to the site. It is about 3 km inlands from the site where wind speeds might be already little less than closer to the coast.

An important advantage compared to the BDFE0 site is the possibility of the installation of the wind measurement equipment (especially the LiDAR-system) on a stable underground without the risk of changing its orientation.

Figure 3-6: School building considered for placing equipment

◇ Figure 3-7: Panoramic view from possible location for solar equipment at location BDFE1

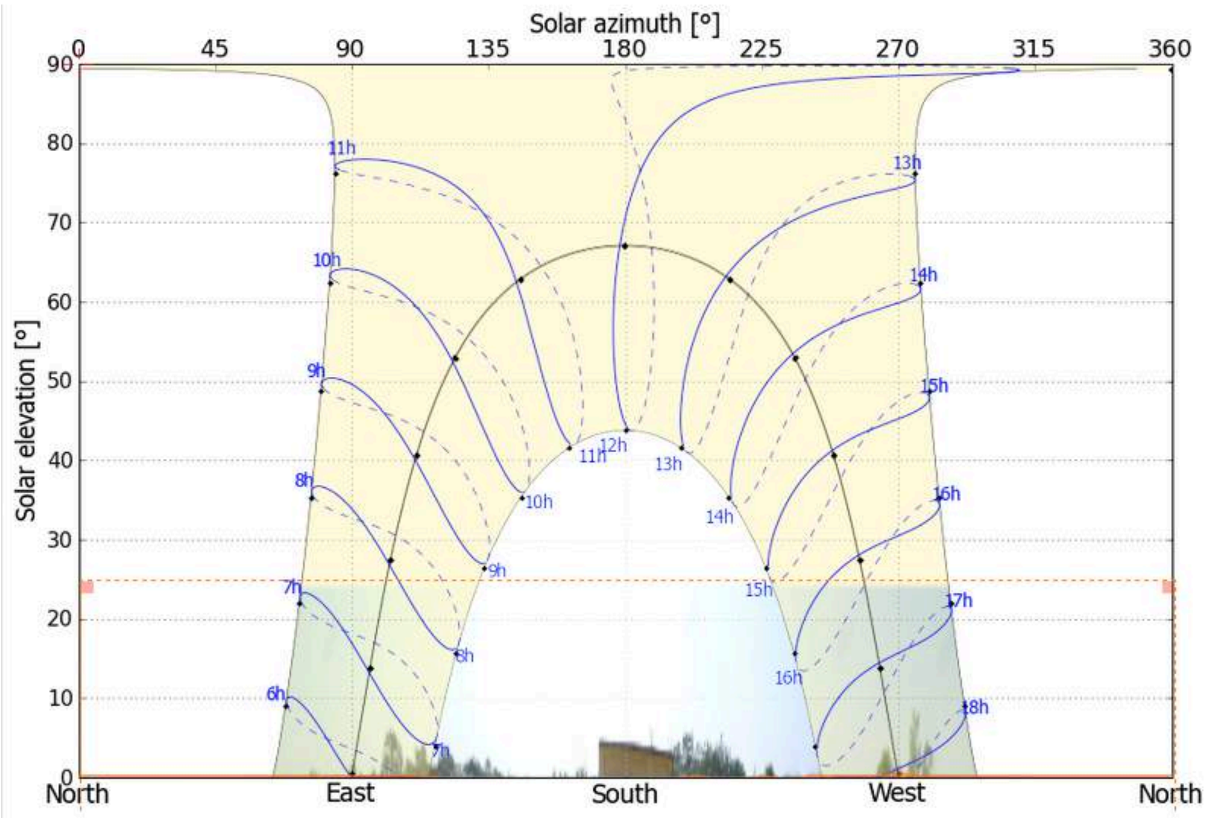


Figure 3-8: Sun horizon and sun path for BDFE1

Location 3: Rooftop of school building in nearby village (BDFE2)

Description of location: The third considered location for the measurement equipment is located in the closest village to the site. The location is located in northwestern direction with a distance of 0.9 km to the northwestern border and 4.5 km distance to the southeastern border to the Feni site. Trees surround the rooftop of the school building with 5 to maximum 10 m height in the northern, southern and western direction. The distance of the vegetation to the school building is around 9 m in northern, 49 m in eastern, and 5 m in southern directions. The west side of the building is partly overgrown (trees in direct distance) and partly open (lake). The roughness of the site higher as the BDFE0 site but lower than for the BDFE1 site. Nevertheless, the existing development (buildings height to a maximum of two levels and trees with a maximum height of 8-10 m is still characterized as relatively open since the measurement is planned to be installed on the rooftop. The rooftop with its height of approx. 5 m above ground exceeds parts of the trees. The wind sensors on the 10 m mast are going to be influenced by the surrounding vegetation. Therefore, a detailed sector by sector assessment of tree heights has to be performed during the site visit and the installation of the mast. The shadowing is taken into consideration when analyzing the data. The influence of the vegetation on the LiDAR data in the relevant heights of at least 80 m above ground is of less relevance for the energy yield calculations.

The terrain is characterized as flat and simple. Despite the distance the collected measurements will still be representative for the climate conditions at the potential site Feni.

Besides nearness to the site, a strong advantage is that a police post is located directly in the neighborhood. It is a permanently manned police post, which is facing the school building.

Additionally, one important advantage of the site is that the LiDAR system can be installed on a stable underground without the risk of changing its orientation.

Figure 3-9: Building suitable for measurement equipment installation

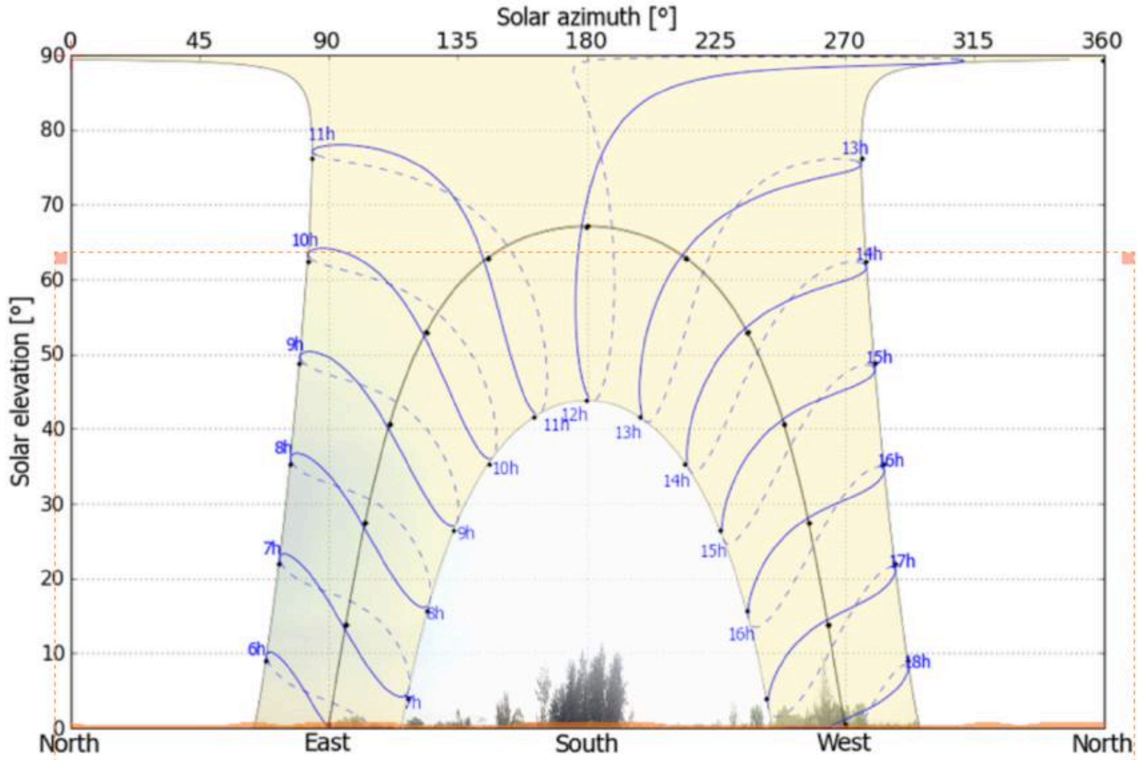


Figure 3-10: Sun horizon and sun path for BDFE2


Figure 3-11: Panoramic view from possible location for solar and wind measurement equipment

Evaluation of location options

In principal all 3 locations checked during the site visit are technically possible for setting up the measurement station. All 3 provide a relatively free horizon suitable for representative solar measurements, which requires that especially during sun rise and sun set the sun is hardly obstructed by near and far-distant obstacles.

The originally proposal of setting up the station directly on the grounds of the site turned out to be quite risky concerning security from vandalism, safety from natural hazards, and the even orientation of the LiDAR-system due to unstable underground . For this location BDFE0 was selected. The nearby dirt road would cause significant soiling, which would not be representative for the actual site unless moving at least 50 m away from this strong local source of soiling. The protection against flooding especially during a storm surge, which may be caused by tropical cyclones, which can make landfall nearby, would require severe efforts to raise the level of the measurement platform at least to 3 m above the surface. Even if elevated as high as 5 m above surface waves during such an extreme event could damage the station. The biggest concern for the location on the open field is safety against vandalism and theft as the site in the field is an unprotected area, which is not permanently observed from people living nearby.

Both alternate locations BDFE1 and BDFE2 on nearby solid rooftops of school buildings would avoid the flooding risk. Both would also be quite secure places. Additionally, one important advantage of the alternate sites is the possibility to install the LiDAR system on a stable underground without the risk of changing its horizontal orientation. If the RSD is installed with a tilt or roll angle or it changes its position gradually the probe volumes can be skewed and this may lead to a falsification of the data.

Trees surround both, BDFE1 and BDFE2. The shadowing of the wind mast data has to be assessed in detail during the installation of the measurement equipment in order to take it into consideration when analyzing the data. The influence of the vegetation on the LiDAR data in the relevant heights of at least 80 m above ground is of less relevance for the energy yield calculations. The terrain of all sites is characterized as flat and simple, therefore both sites will still be representative for the climate conditions at the potential site Feni. The site BDFE2 on top of the elementary school is significantly closer to the site as BDFE1 on top of the higher 3-story school building.

Location BDFE2 on top of an elementary school directly apart of a police post is identified as the most suitable for safely locating the equipment.

4. TECHNICAL DESCRIPTION OF MEASUREMENT EQUIPMENT

Overview of installation

In chapter 3 we come to the conclusion the best location for the measurement station is on the roof of the school building near the site. In the following we describe how the combined wind and solar measurement station best can be realized at the location BDFE2. The equipment required for continuous operation of the station is described in Table 1. Although electric grid power would be available at the school building it is known that power outages are frequent in this region. Thus, it is recommended to set up a fully independent power supply based on PV modules and sufficient battery storage capacity to independently operate the plant on the rooftop without the need to connect to the grid. This has the further advantage that no electricity must be purchased from the school and additional wires are need to be set up. Figure 4-1**Error! Reference source not found.** and Figure 4-2 show the proposed layout for the installation of the equipment on top of this building.

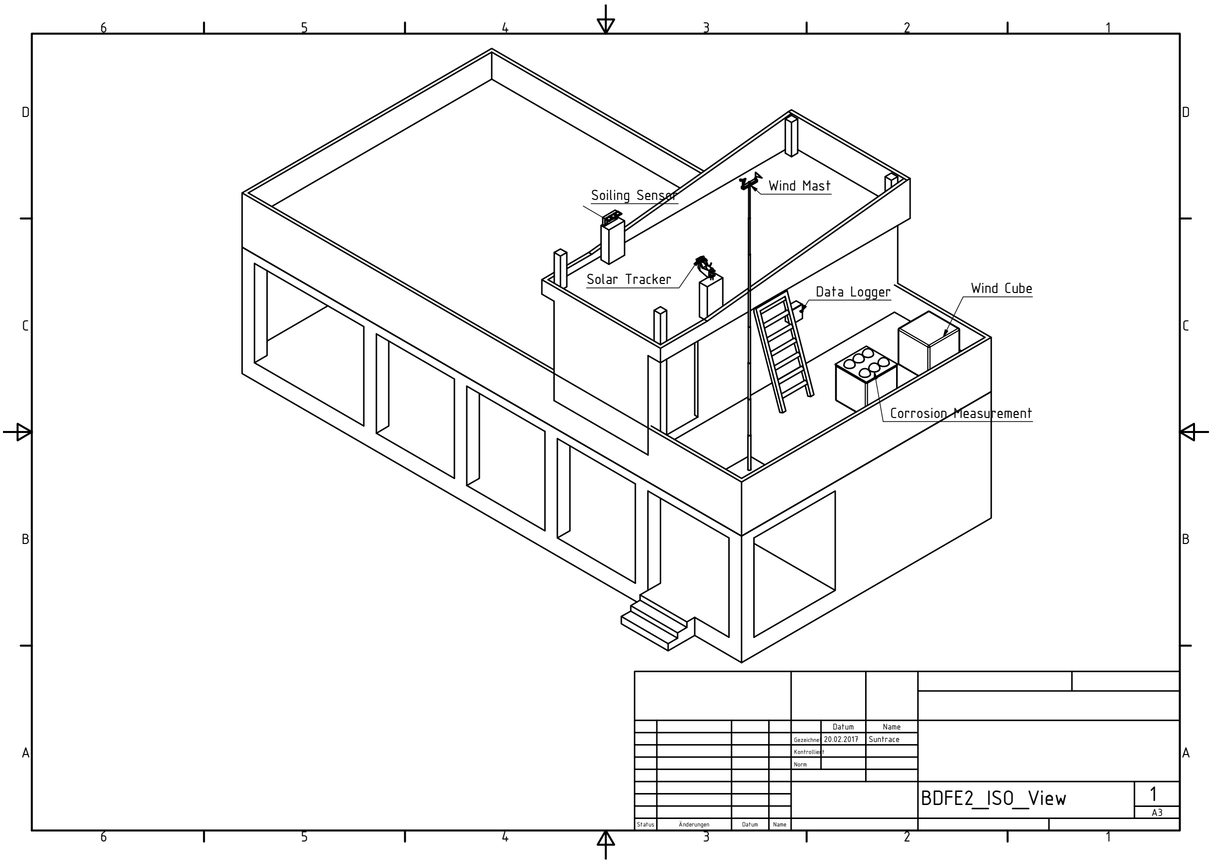


Figure 4-1: 3-dimensional view of the installation of the solar and wind measurements on top of the school building at site BDFE2.

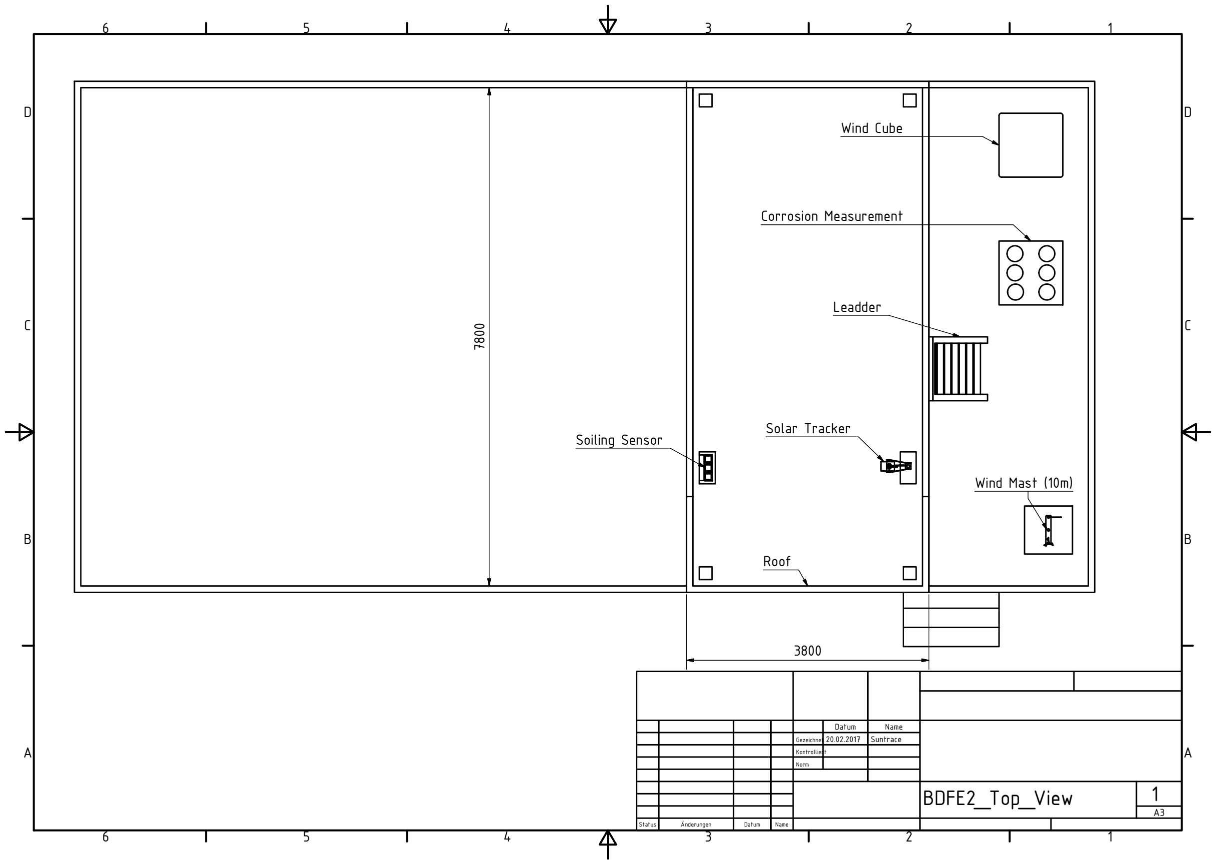


Table 1. Operation equipment for the Tier-1 station.

Equipment	Use	Characteristics
Weather proof control cabinet	Protection	IP65 protection marking
Data logging system blueberry COMPACT	Data acquisition and communications system	full built-in Linux system for signal processing and instrumentation control GPRS/GSM modem for data transmission and remote configuration charge controllers for battery use digital and analog measurement inputs Serial RS485, RS232 and Ethernet interfaces Modbus RTU and Modbus TCP SCADA connection
PV panel	Off grid Power	4 x 12 V / 60Wp
Redundant Batteries	Power back-up	2 x 12 V / 110 Ah sealed lead battery
Lightning protection kit	Protection	grounding cable for the solar station 2nd grounding cable for wind mast connected to a single point deep copper rod multi-level overvoltage protection is standard in the supplied data logger
Mounting material	Structure	mast and structure for installation of instruments 10 m telescopic wind mast secured by guy wires and erected at a height representative for 10 m wind above dround.

		10 m wind mast cabling following best practices and accessories

Figure 4-2: Layout drawing of the installation of the solar and wind measurements on top of the school building at site BDFE2.

Solar measurements

The following technical specifications are adjusted to BSRN standards. According to BSRN the recommended procedures for the measurement of global radiation require the use of a ventilated pyranometers to improve the thermal stability of pyranometer measurement by damping changes in the pyranometer body temperature due to solar loading and potentially reducing the thermal offset. In humid climates, the use of a ventilation and heating also improves the amount of recoverable data by eliminating dew. Lower frequency of dew on the dome, should also reduce the soiling of radiometers as it is observed that the most harmful crusts build when dirt is deposited on wet glas surfaces and then dries out.

Locations where a ventilated housing are recommended are:

(1) where dew, frost or snow is prevalent,

(2) where natural ventilation is infrequent or variable,

(3) where there is significant radiative cooling during portions of the year, a ventilated housing may reduce thermal-offset,

(4) where the humidity is high during portions of the year a ventilator will reduce the possibility of water damage and reduce the frequency of desiccant changes.

Suntrace will provide the heated and ventilated Pyranometer SR30 by Hukseflux to fulfill BSRN standards. High data availability of the pyranometer is attained by heating of the outer dome using internal ventilation between the inner and outer dome. This has proven as effective against dew and frost as traditional external ventilation.

For the measurement site at Feni Suntrace will provide the heated and ventilated Pyranometer SR30 by Hukseflux to fulfill BSRN standards. High data availability of the pyranometer is attained by heating of the outer dome using internal ventilation between the inner and outer dome. This has proven as more effective against dew and frost as traditional external ventilation.

Table 2: Technical specifications of instruments for the TIER-1 station

Instrument	Parameter	Technical Specification				
		Range	Resolution	Instantaneous Accuracy	Long term Accuracy	Response Time
Sun tracker including sun sensor and GPS	Tracking of the sun position at any point of time in the year	Elevation: 0 – 90 ° Azimuth: 0-180 °	0.009°	<0.01 °	-	-
Thermopile Pyrheliometer (ISO 9060 First Class)	DNI	0 to 4000 W/m^2	0.5 W/m^2	< 1.8 %	< 1.0 %	2 s
Heated Thermopile Pyranometer (ISO 9060 Secondary Standard)	GHI , DHI (using the shadowball assembly)	0 to 2000 W/m^2	1 W/m^2	<3%	<1.2 %	3 s

Technical description of the wind measurement equipment

This sub-chapter describes the wind measurement instruments to be supplied for the station.

Table 3. Technical specifications of the wind instruments to be provided by Suntrace station in Bagladesh.

Instrument type	Parameter	Technical Specification				
		Range	Resolution	Instantaneous Accuracy	Long term Accuracy	Response Time
Instruments at 10 m Wind Mast	Wind Speed 1 (at 10 m) THIES First Class Advanced	0 to 75 m/s	0.05 m wind run	2% or 0.2 m/s	IEC 61400-12-1 Class 1	-
	Wind Speed 2 (at 10 m) Vector	0 to 75 m/s	0.05 m wind run	1% or 0.4 m/s	IEC 61400-12-1 Class 1	-
	Wind Direction (at 10 m)	0...360°	0.01° @ 12 Bit data stream	1°	-	Damping ratio D > 0.25

Suntrace will provide a Windcube v2 with the following specifications. The LiDAR Windcube will be delivered with an outdoor comparison to reference sensors installed on a met mast. The procedure for tracing back the LiDAR instrument to national standards is called verification test. A verification campaign (expected duration: 5 weeks depending on the wind conditions) is carried out on the calibrated test site of windtest in Grevenbroich, Germany. The Windcube has been exposed at the verification site since Feb, 20 2017. Verification of the instrument proceeds well and it is expected to be completed at the latest by end of March 2017.

Table 4: Specifications of LiDAR wind cube v2

Specification	WINDCUBE V2
Measurement principle	Pulsed LiDAR
Measurement height range	40 to 200 m
Measurement integral height range	20 m

	Constant for all heights above ground
Number of measurement levels	12
Sampling rate	250 MHz
Measurement range	Wind speed: 0 to 60 m/s Wind direction: 0 to 360°
Accuracy	Wind speed: ±0.1 m/s Wind direction: ±2°
Operating temperature	-30 to +45 °C
Supply voltage	18 to 32 VDC
Power consumption	45 W @ -5 to +30 °C 100 W @ <-5 °C 70 W @ >30 °C
Weight	45 kg

Table 5: Details of LiDAR from verification site

Information on LiDAR system							
Type of LiDAR:	WLS7		Serial Nr.			WLS7-598	
Firmware Version:	2.1.3		Timezone:			GMT+0	
GPS Coordinate System:	-		Email setting:			validation@windtest...	
GPS easting:	-		GPS northing:			-	
Measurement heights: [m]	66	68	78	80	99	101	118
	120	132	134	160	200		
PTH Sensor connected:	☐ Yes	☒ No	Pitch: [°]	0,1	Offset: [°]	-50	
FCR activated:	☐ Yes	☒ No	Roll: [°]	-0,1			

Table 6: Details of LiDAR from verification site

According to the Terms of Reference for this project the LIDAR shall be powered adequately for proper year-round operation, with appropriate protection against power surges and frequency fluctuations. The site does have a source of power from the grid, but power outages occur frequently.

Auxiliary measurements

Table 7. Technical specifications of auxiliary measurements to be provided by Suntrace for the station in Banglasesh.

Instrument type	Parameter	Technical Specification				
		Range	Resolution	Instantaneous Accuracy	Long term Accuracy	Response Time
Ambient Temperature and Relative Humidity Sensor encased in radiation shield (mounted on wind mast at 8 m height above ground level)	Air Temperature	-40 to 123.8 °C	0.01 °C	< 0.3 °C	-	15 s
	Relative Humidity	0 to 100 % RH	0.05 % RH	< 3 % RH	-	8 s
Barometer Built in in Wilmers DL	Barometric Pressure	500 to 1100 hPa	0.01 hPa	0.5 hPa	-	15 ms

Rain gauge

The provided tipping bucket mechanism is a robust and effective rainfall measurement system. The bucket geometry and material are specially selected for maximum water release, thereby reducing contamination and errors.

Table 8: Technical specifications of rain gauge

Dimension	Ø 0.18 m x 0.3 m height
Resolution	0.1 mm precipitation per count
Exposing standard	1 year according to ISO 9226:2012
Accuracy	2% up to 25 mm/h 3% up to 50 mm/h
Operating temperature	–20 ℃ to +50 ℃

Soiling measurement

The Soiling measurement system allows quantifying the site-specific effects of soiling on PV cells. The system acts as a soiling sensor by comparing the power output of a naturally-soiled PV reference cell to expectations based on two cleaned PV reference cells. Different cleaning intervals (one cell shall be cleaned every three months and one once a week) allow identifying potential seasonal soiling fluctuations.

Table 9: Technical specifications of soiling measurment

Dimension	Ø 0.18 m x 0.3 m height
Resolution	0.1 mm precipitation per count
Exposing standard	1 year according to ISO 9226:2012
Accuracy	2% up to 25 mm/h 3% up to 50 mm/h
Operating temperature	–20 ℃ to +50 ℃

Atmospheric corrosion measurement kit

The design of an entire PV installation, including the array structures, should target a similar life span to the photovoltaic modules and should make them able to withstand even harshest weather conditions. Whether corrosion is a serious problem depends on the type of metal used, the atmospheric conditions and the concentration of atmospheric contaminants.

Suntrace, together with Frauhofer ISE, provides a measurement set that estimates the effects of corrosion at your location. The measurements are carried out by exposure of standard specimens for one year to the atmosphere according to international standard ISO 9226:2012. The standard specimens are flat plate of the four standard metals: aluminum (Al), copper (Cu), steel (Fe) and zinc (Zn). The sample size will be 100 x 50 x 1 mm. One corrosion set contains 12 metal samples (3 samples of each metal). The samples will be punched with an identification number. The samples will be mounted on aluminum frame with polyamide screws by complete electrical insulation.

The determination of corrosion rate of metal samples will be performed in accordance to the international standard ISO 8407/2009: Corrosion of metals and alloys - Removal of corrosion products from corrosion test specimens. The loss of weight after one year of exposure (as a difference between the original weight and the final weight in grams) will be determined.

Table 10: Technical specifications of corrosion kit

Measurement elements	12 metal samples of aluminum (Al), copper (Cu), steel (Fe) and zinc (Zn)
Dimension	0.6 m x 0.4 m
Exposing standard	1 year according to ISO 9226:2012
Maintenance	The measurement set-up is maintenance-free
Output	Rate of corrosion of the metal samples in accordance to ISO 8407/2009

Water gauge

Flooding was identified a major concern on site. Therefore it was recommended to use the originally planed measurement platform on site also to gather more information about the observed water level on site. As for reasons of much better security it was decided to erect the station on top of the nearby school building installing the water gauge does not make sense anymore.

5. TASKS AND DELIVERABLES

After approval of the Implementation Plan, the following tasks will be carried out in a sequential order:

- Task 2: Procurement of the measurement equipment
- Task 3: Installation and Commissioning of the Measurement Equipment
- Task 4: Operation and maintenance of the measurement station
- Task 5: Regular assessment of data quality and data delivery
- Task 6: Verification and re-calibration of the instruments
- Task 7: Capacity building, wrap-up meeting and handover

Procurement of the measurement equipment

Suntrace will arrange procurement of the agreed equipment.

The following are the planned activities:

- The assembly of the Tier-1 station and the factory tests in Hamburg, Germany.
- A factory acceptance test protocol will be conducted and will document the full functionality and physical integrity of the equipment before shipment.
- All measurement equipment will include factory calibrations. Calibration of solar radiometers shall be traceable to the World Radiation Reference (WRR) at the World Radiation Centre (WRC) at PMOD in Davos
- Documentation for the station will be prepared, describing the technical details and the initial calibration protocols.
- A verification campaign for the wind-LiDAR equipment will be carried out and certified on the MEASNET / IEC 17025 accredited test site of windtest in Grevenbroich, Germany.
- Packing and shipment (Incoterm DDP) of the equipment to the premises of the local partner in Dhaka, Bangladesh.
- Documentation will be prepared for successful custom clearance, which will be the responsibility of Suntrace and EQMS.

Deliverables:
D2.1 Procurement of measurement equipment
D2.2 Obtaining required permissions
D2.3 Documentation of station with calibration certificates for all sensors, including pre-commissioning test protocols

Installation and Commissioning of the Measurement Equipment

- Site preparation will be performed, including fencing and foundations for the station.
- The location will be cleaned for obstacles taking extra attention to modify as least as possible the natural environment of the station
- A local GPRS SIM card will be procured and tested for the data transmission of the station
- Commissioning tests for the meteo station will be carried out by Suntrace to certify that the station is installed properly following best practices.
- Suntrace will provide lighting protection and proper grounding of all instruments
- After the Installation, Suntrace and windtest will prepare the Site Installation Report including site location, site characteristics, technical specifications, calibration procedures, a detailed station description and photos according to specifications by WBG.

D3.1 Preparation of selected site
D3.2 Delivery of measurement equipment at the selected site
D3.3 Station keeper training certification
D3.4 Site installation report

Operation and maintenance of the measurement station

HelioScale stations operate in a fully automatic manner thanks to its integrated Blueberry data logging system and its off-grid PV based power supply.

At the end of the first year of operation, a Suntrace international expert will go to the site to perform a schedule maintenance visit. At this visit, all sensors will be checked for correct functioning, the status of the site will be checked and discussed with the station keeper.

The remote connection to the data logging system enables Suntrace to access the station at any time to check/modify the configuration and to perform troubleshoot actions if needed. To handle exceptions, EQMS will be trained on first hand troubleshoot and will have real-time remote support from Suntrace and windtest to handle eventual contingencies. EQMS will also be responsible for organizing the in-country maintenance of the equipment. This will include the following tasks:

- ◇ Security surveillance at the station site
- ◇ Daily cleaning of the sensors at the station through local station keepers
- ◇ Documentation of maintenance activities

Deliverables:
D4.1 Ensuring security of equipment and mitigation measures
D4.2 Provision of maintenance protocols according to recommendations for equipment
D4.3 Maintenance visit including field side-by-side calibration after 12-month of operation
D4.4 Maintenance visit after 24-month of operation

Regular assessment of data quality and data delivery

The measured data will be transferred daily via the internet to the servers configured by Suntrace (Tier-1 station) and windtest (LiDAR-unit). Automatic value/limit checks that send alert emails in case or errors/problems are set up directly on the data logger in the installation phase.

The solar data received will be interpreted with the following, but not limited to, typical errors:

- ◇ Missing data
- ◇ Extreme (minimum and maximum) physical value test
- ◇ Rare observation test
- ◇ Clear-sky exceedance test
- ◇ Diffuse component exceedance test
- ◇ Cleaning frequency test
- ◇ Tracking error test

The wind LiDAR-data will be interpreted with the following but not limited to typical errors:

- ◇ Missing data
- ◇ Check on plausibility (extreme values)
- ◇ Cleaning frequency test
- ◇ SNR (signal-to-noise ratio)
- ◇ Pitch, roll angle (orientation of the device)

Monthly reports will be delivered to the World Bank summarizing the situation at the station including issues encountered and irregularities in data flow.

The monthly reports will include the following information:

- ◇ Summary of available site information
- ◇ Technical status of the instrumentation and sensor calibration

- Summary of conducted maintenance works including a list of issues and irregularities encountered
- Data display through easy to understand plots
- Data coverage summary and quality statistics (following best practices)
- Data recovery rates from each sensor Suntrace and windtest will provide site measurement reports according to WBG requirements every year of station operation.

Aerosol optical depth from pyrheliometer measurements

The monitoring of aerosol optical depth (AOD) has been considered an important, but difficult, observation that is necessary if there is to be an increase in understanding of the surface radiation budget. While theopticaldepthprovidesinformationonspectralatmosphericextinction,a number of inversion algorithms have been developed to use this information to produce data on the columnar aerosol number-size distribution,volumedistributionandconcentration.Alongwithothermeasurementsofthesolaraureole and almucantar the data has also been inverted to provide information on aerosol absorptivity. Measuring, or more normally assuming, a change in aerosol concentration with height above the surface can use these optical properties used to better understand the radiative regime of the atmosphere. Over time, m ore and m ore user communities have expressed the need for this type of data. Fross (2014) in collaboration with Suntrace developed an algorithm to derive aerosol optical depth (AOD) from pyrheliometer measurements. Results will be delivered with the monthly reports.

Deliverables:
D5.1. Daily check of station operation
D5.2 Monthly provision of measurement data including report describing the quality of the data
D5.3 Site measurement report after 12 months of station operation
D5.4 Site measurement report after 24 months of station operation

Verification and re-calibration of the instruments

The agreed procedure for re-calibrating the solar sensors is the following:

For the pyranometers:

- Dismount both pyranometers (to be re-calibrated) and replace it with the spare pyranometers.
- Send the dismounted pyranometers to the factory for full re-calibration. This procedure will last between 4-8 weeks including the shipment.
- Remount the recalibrated pyranometers and log in parallel with the still operating spare pyranometers. Ideally this is done under sunny conditions so that a cross-check with the re-calibrated pyrheliometers can be done.

Pyrheliometer:

- Dismount the pyrheliometer (to be calibrated) and replace it with the spare pyrheliometer.
- Send the dismounted pyrheliometer to the factory for full re-calibration. This procedure will last between 3-6 weeks including the shipment.
- Remount the recalibrated pyrheliometer and operate the spare pyrheliometer in the 2nd mount for a short time in parallel under sunny conditions. Use data to confirm continued validity of the calibration of the spare instrument.

At the end of this procedure the radiation sensors of the station will be fully calibrated and no measurement gaps will exist in the data. The manufacturer of the applied radiometers indicates that inly during days exposed to environment instruments the radiometers experience relevant aging. Thus, the calibration certificate of instruments kept in shelf usually remains valid for more than two years unless significant deviations are observed during checks as described above.

The agreed verification campaign for the LiDAR-unit (recalibration) includes:

1. Dismount the LiDAR-unit after 24 months of measurement at the site,

2. Send the LiDAR-unit to windtest in Grevenbroich, Germany. An outdoor comparison to reference sensors installed on a met mast is undertaken in order to verify the instrument. A verification campaign (expected duration: 5 weeks depending on the wind conditions) is performed. The deviation of the horizontal wind speed component measured by the LiDAR system at all evaluated heights and other results will be summarized in a verification report. This procedure will last between 7-8 weeks including the shipment.

3. Provision of the verified LiDAR and the verification report to the designated recipient.

Deliverables:
D6.1 Provision of recalibrated pyranometers and pyrheliometer to designated institution
D6.2 Provision of the verified LiDAR (after recalibration campaign) to the designated institution

Capacity building, wrap-up meeting and handover

The training and capacity building in Bangladesh are mainly dedicated for EQMS, local authorities, interested WBG staff members and local station keepers.

The following topic will be covered in the training during the Installation Mission:

General part – summary workshop (half-day)

- ◇ Roles of participants
- ◇ Ownership and responsibilities over the duration of the project and beyond
- ◇ Importance and value of solar monitoring campaign for site qualification
- ◇ Basics of solar radiation
- ◇ Components of solar monitoring system (model data and measurements)
- ◇ Brief summary of solar measuring instruments and approaches
- ◇ How to select sites

Technical part – theoretical and hands-on training (1-day)

The training is designed to include a mixture of theory and hands on practice. The training focused on technical staff involved and will involve mock tests where the local partner company will have to solve a problem created by at a test meteo station. The main topics to be covered under these training sessions are as follows:

- ◇ Overview of measuring technologies and instruments and related uncertainties
- ◇ Data loggers and modems, data formats, data retrieval
- ◇ Installation and operation of meteo stations
- ◇ Procedures for daily cleaning and maintenance, safety and security
- ◇ Documentation, operation, servicing
- ◇ Troubleshooting, maintaining long term quality
- ◇ Hands-on exercise during the installation and demonstration phase
- ◇ Review of first measuring results

Involvement workshop for the local community (2-hours)

Suntrace has experienced that local community engagement can substantially help to build a successful measurement campaign. Often local communities do not fully understand that the implementation of measurement campaigns is supporting reliable power supply in their region. Therefore, we suggest including the local community by introducing the objective of this project in a hearing to be held in a nearby town hall or other suitable convention center.

The following topics will be covered in the presentation:

- ◇ Why is the project important for the region?
- ◇ What’s the value for the community?
- ◇ Principles of renewable energy production
- ◇ Basic ideas of solar and wind measurement

Training after 12-month of station operation

The training after 12-month of station operation is dedicated to the local partner and the station keeper with the aim to refresh their knowledge. Therefore, Suntrace will cover topics that where relevant during the first 12-month of the campaign and the following:

- ◇ Data loggers and modems, data formats, data retrieval
- ◇ Status of cleaning and calibration verification
- ◇ Status of data analysis and interpretation, data quality checks and reporting
- ◇ Lessons learned

Training after 24-month of station operation

At the end of the measurement campaign and in preparation for the passing on of the equipment to the organization identified by Client, we will provide a training to continue the measurement activities. We support the idea that meteo stations are kept operational in long-term as part of supporting infrastructure for management of country solar energy program and to further improve the reliability of solar maps for the country. Therefore the decommissioning of stations is not considered in this proposal, but can be provided upon request as additional service.

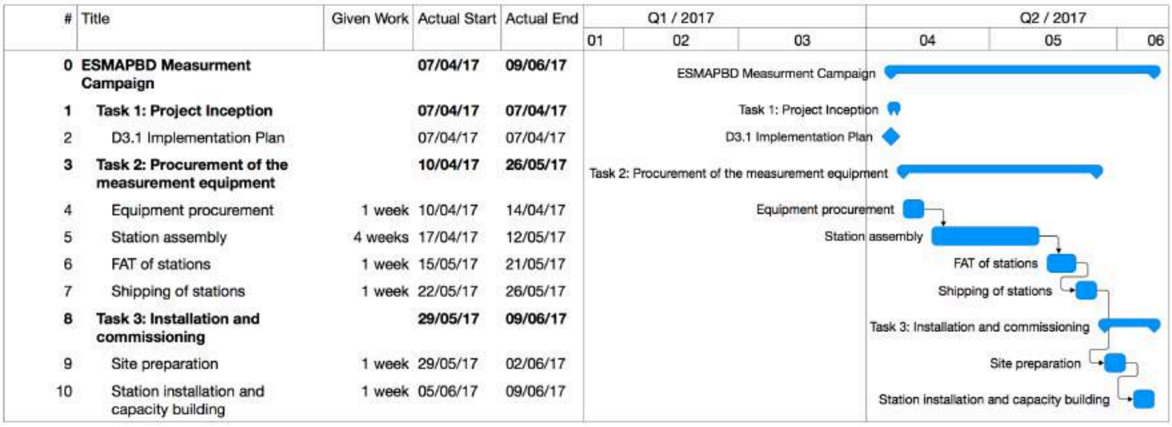
Review of the results achieved at the end the measuring campaign

- ◇ Status of meteo stations, instruments, measurement statistics
- ◇ Report on calibration
- ◇ Summary report on site resource assessment delivered on completion of 24 months of the measurement campaign with time series of locally measured and satellite-based data
- ◇ Transfer of ownership
- ◇ Demonstration of preparedness for sustainable continuation of the measurement program
- ◇ Lessons learned

Deliverables:

D7.2 Certificate for Installation Training
D7.3 Certificate for Maintenance Training
D7.4 Official transfer of ownership to designated authority

6. TIME TABLE AND DELIVERABLES



#	Title	Given Work	Actual Start	Actual End
0	**ESMAPBD Measurment Campaign**		**07/04/17**	**09/06/17**
1	**Task 1: Project Inception**		**07/04/17**	**07/04/17**
2	D3.1 Implementation Plan		07/04/17	07/04/17
3	**Task 2: Procurement of the measurement equipment**		**10/04/17**	**26/05/17**
4	Equipment procurement	1 week	10/04/17	14/04/17
5	Station assembly	4 weeks	17/04/17	12/05/17
6	FAT of stations	1 week	15/05/17	21/05/17
7	Shipping of stations	1 week	22/05/17	26/05/17
8	**Task 3: Installation and commissioning**		**29/05/17**	**09/06/17**
9	Site preparation	1 week	29/05/17	02/06/17
10	Station installation and capacity building	1 week	05/06/17	09/06/17

Figure 6-1: Time schedule for procurement and installation

Table 11: Summary of work plan and deliverables

Task	Description of task	Deliverables	
2	Procurement of the measurement equipment	D2.1	Procurement of measurement equipment
		D2.1	Obtaining required permissions
		D2.3	Documentation of station with calibration certificates for all sensors, including pre-commissioning test protocols
3	Installation and commissioning of the measurement equipment	D3.1	Preparation of selected site
		D3.2	Delivery of measurement equipment at the selected site
		D3.3	Station keeper training certification
		D3.4	Site installation report
4	Operation and maintenance of the measurement station	D4.1	Ensuring security of equipment and mitigation measures
		D4.2	Provision of maintenance protocols according to recommendations for equipment
		D4.3	Maintenance visit including field side-by-side calibration after 12-month of operation
		D4.4	Maintenance visit after 24-month of operation
5	Regular assessment of data quality and data delivery	D5.1.	Daily check of station operation
		D5.2	Monthly provision of measurement data including report describing the quality of the data
		D5.3	Site measurement report after 12 months of station operation
		D5.4	Site measurement report after 24 months of station operation
6	Verification and re-calibration of the instruments	D6.1	Provision of recalibrated pyranometers and pyrheliometer to designated institution
		D6.2	Provision of the verified LiDAR (after recalibration campaign) to the designated institution
7	Capacity building, wrap-up meeting and handover	D7.2	Certificate for Installation Training
		D7.3	Certificate for Maintenance Training
		D7.4	Official transfer of ownership to designated authority

Scheduled visits to site:

Task	Date	Suntrace	wtg	EQMS
Installation and commissioning	June 2017	x	x	X
Start of measurement campaign	July 2017			
Maintenance visit	June 2018	x		X
Maintenance visit	June 2019	x	x	x

Experts participating on the installation campaign:

1. Dr. Richard Meyer, Suntrace GmbH
2. Dr. Jorge Lezaca, Suntrace GmbH
3. Jana Müller, Suntrace GmbH
4. Marko Schwandt, Suntrace GmbH
5. Frank Albers, windtest grevenbroich gmbh
6. Florian Schmidt, windtest grevenbroich
7. Tauhidul Hasan, EQMS
8. Najmul Hossain, EQMS

7. ASSESSMENT OF RISKS

The assessment of environmental and social risks is applied for all stages of the project Solar and Wind Resource Measurements in Bangladesh (Selection #: 1229311) to minimize and prevent harm during the planning and implementation of the project. Before site selection, the assessment was started with research into existing legislation and guidance relevant to the assessment followed by a screening to identify potential risks. The identification of potential risks can help to answer hypotheses at an early stage in the assessment and was based on data important for the analysis. Results were used to determine which risks should be investigated in greater detail using techniques suitable to the nature of the risk and quality of the evidence base.

Screening procedure was applied to determine whether a proposed project is likely to have significant effects on the environment. Availability of land for installation of solar measuring stations without causing an impact on the environment was identified as a major issue. Areas protected under domestic and international environmental law and regulations were identified at the beginning of the project and excluded as potential sites. The same applies for military exclusion zones, urban areas and land owned by local people. Potential locations for the installation should meet requirements such as availability of personnel for maintenance and cleaning, security and sustainability of running the measurement campaign in a long term and acceptance of the present landowner. These requirements reduced the potential sites significantly after the first screening. Furthermore, solar measuring stations should be located in a flood-safe area, not close to sources of pollution and close to existing infrastructure being accessible without additional environmental impacts. Finding a synergy between mitigating environmental impacts and quality and reliability of the measurement campaign resulted in a list of three potential sites. Potential sites listed have the advantage that limited clearance of trees is required, no location of natural habitats in the region or sector is involved and other safeguards do not apply. No long-term effects on the environment are expected from installation and operation of the solar measurement stations and LiDAR system. After the initial assessment of World Bank Groups Safeguards, the likely impact of the project on the environment is expected to be Category C, having minimal or no adverse impacts.

Based on the list of selected candidate locations most suitable sites were visited by technical experts of Suntrace and EQMS with local assistance from wtg during the Inception Mission. During the visits, both environmental and social acceptability and technical suitability of the sites have been evaluated. Considering that proposed sites should have the support of the wider community while providing safe operation of measuring stations, most promising sites were identified on the property of the local elementary schools. After examination of the rooftop, it was decided to install the stations without solid foundations and only simple fencing. Furthermore, no significant quantities of emissions or effluents nor hazardous materials or processes are generated during the construction, operation, and decommissioning phase of the project. Adverse impacts are minimized, where possible, in all stages of the project phase. Emissions caused by transport means will comply with national programs of Bangladesh and the approach given in the EHS Guideline. The meteorological stations are designed to be efficient in energy at low cost, for example being independent of external power supply. Water quality will not be influenced by any direct or indirect discharge of wastewater.

The WINDCUBE LiDAR is a class 1M Laser product. The laser beam emitted by the LiDAR system lies within the infrared spectrum and is not visible to the naked eye. Optical instruments like binoculars or telescopes should not be used to stare directly into the beam to avoid harms. The beam is emitted through the laser aperture which is situated on the top of the LiDAR system within a cone at 28 ° angle off vertical (Fig. 1). The WINDCUBE LiDAR utilizes a class 4 laser. In order to avoid eye injury, it is recommended not to open the optical head nor disconnect any optical fibres. If the measurement equipment is used in a manner not specified by the manufacturer, it may result in hazardous radiation exposure. To ensure the electrical safety while handling the LiDAR, the power supply cable should always be unplugged before performing servicing of any part of the system. The power supply grounding has to be checked. A poor ground quality may result in electrical shocks and damage of electronic components.

The WINDCUBE LiDAR complies to the following standards:

EMC	IEC EN 61326-1, July 2006
Safety	IEC EN 61010-1, June 2001

LASER Radiation IEC EN 60825-1, January 2008
Class 1M
Accessible Emission Level: 7 mW
Pulse Duration: 175 ns
Wavelength: 1543 nm

Degrees of safety features of enclosure: IEC EN 60529, June 2000
IP54: enclosure
IP67: power supply and internal components

Transport: ISTA, FEDEX 6B (International Safe Transport Association)

Figure 7-15: WINDCUBE Laser aperture

The proper functionality of the LiDAR system is ensured, if the aperture is free from soil or dirt. The WINDCUBE uses a wiper to clean the aperture, if dirt is detected on the window. Therefore, the LiDAR comes with a container for cleaning fluid and an external pump. Depending on the outside temperatures, the cleaning fluid has to be mixed from water and isopropanol alcohol (isopropyl rubbing alcohol). For temperatures above 0 °C no extra isopropanol alcohol is needed to ensure a proper functionality. For outside temperatures between 0 °C and – 10 °C the water/isopropanol-mix should be 85/15 %. For outside temperatures below – 10 °C the water/isopropanol-mix should be 70/30 %. For the BD region temperatures below 0 °C scarcely are to be expected, therefore no impact on the environment due to the water/isopropanol-mix should occur.

Risks related to the installation, operation and maintenance itself could occur from the use, storage or handling of any quantity of hazardous materials, we assessed materials representing a risk to human health, property or the environment. The delivered stations are equipped with data logger batteries (12V with at least 15Ah capacity) that will be transported, stored and handled in order to facilitate the safe handling of battery packs under normal and emergency conditions. To guarantee safe handling during operation, the meteorological stations are equipped with encapsulated batteries, that are resistant to shocks and vibration, as well as against moisture, solvents, and corrosive agents. Encapsulation is also used to aid electrical insulation, flame resistance and heat dissipation. All batteries will be made safe for handling, prior to packing for shipment. The International Air Transport Association (IATA) regulates air transportation. International Maritime Organization (IMO) whose regulations are contained in the International Maritime Dangerous Goods (IMDG) Code regulates the maritime transport. Various weight limits apply to batteries, batteries with equipment, and batteries in an equipment of each passenger and cargo of an aircraft. Pursuant to 49 CFR 173.185, all shipments of hazardous materials must comply with packaging regulations based on recommendations made by the United Nations.

All waste management steps (collection, temporary storage, recycling, disposal, etc.) for spent or waste materials for disposal will be conform to the Universal Waste Management Guideline and the EHS Guidelines of the World Bank Group. In general, all processes in this project are designed and operated to restrict the quantities of generated waste. Where waste generation cannot be avoided, it will be minimized. Delivered Meteorological Stations, for example, are designed to be reliable and long lasting and we support the idea that Meteorological Stations are kept operational after implementation of the project. Therefore decommissioning and waste management for the meteorological stations is not considered in this Implementation Plan.

Preventive and protective measures are carried out to protect the health and safety of all workers during construction, decommissioning and the operational phase of the project. The staff of EQMS and wtg have high technical capabilities and experience to manage the occupational health and safety issues. In general, the construction, decommissioning and operational activities were designed to fulfill the highest possible standards of safety. All staff contributing to commissioning and operation of the meteorological stations will be trained before and periodically during the maintenance and operation of the stations by authorized personal. The highest possible safety while a fence placed around each station will guarantee station operation. The sites are based on rooftops at public premises with restricted movement of unauthorized personnel, which ensures a high level of security.

Community health and safety are related to the project operation and some aspects outside of the traditional project boundaries. At the current stage of the project it is not expected that relevant issues concerning community health and safety arise.

Suntrace, wtg and EQMS shall be obliged to assure compliance with all federal, state and local law at the worksite, including compliance with all applicable health, safety and environmental requirements relating to the presence of Contractor´s personnel at the worksite. Before commencement of Services, Suntrace will notify the subcontractor of all relevant safety regulations in force at the site.
Subcontractors shall have no obligation to follow any instruction or direction that would violate any applicable law, rule or regulation, or subontractor´s professional standard of care.
All partners concerned will ensure that the following conditions are satisfied:

- Services shall not be carried out in unhealthy or dangerous surroundings. All the necessary safety and precautionary measures shall have been taken before Services are started and shall be maintained during the time of services
- All staff shall be able to obtain suitable and convenient board and lodging in the neighborhood of the site and shall have access to canteen facilities, internationally acceptable hygiene facilities and medical services.

8. PERMITS AND IMPORT PROCEDURE

Since the location of solar and meteo stations are finalized Suntrace and EQMS will liaise with national authorities to best fulfil the requirements of the project. While making these decisions we will rely on local knowledge of EQMS, who will arrange for identifying and acquiring the necessary permits and clearances for the selected sites.

Obtaining an Environmental Impact Assessment for the selected sites is not required. It is assumed that no land leasing costs shall apply.

To obtain permission for placement of the station EQMS will makw a agreement with the school governing body and EQMS for next two years specially mentioning the following terms:

- ◇ No further vertical expansion/ construction during the monitoring period (2 years)
- ◇ Any disagreement will not allow

Headmaster of the school will also sign the agreement.

Equipment will be tested, prepared for shipping and shipped from Suntrace premises in Hamburg. Shipping from Hamburg to Dhaka Bangladesh will be done according to DDU - Delivered Duty Unpaid - means that Suntrace fulfills their obligation to deliver when the goods have been made available at EQMS premises in Bangladesh. Once the goods arrive by air freight at Dhaka international airport the goods will be stored at the airport cargo section.

Import of goods from outside Bangladesh is regulated by the Ministry of Commerce in accordance with Import & Export (Control) Act, 1950 and the notification issued thereunder. In terms of the importers, Exporters & indentors (Registration) order, 1981 no person can import goods into Bangladesh unless he is registered with the chief controller of Import & Export (CCI&E) or exempted from the provision of the said order. Before any Letter of Credit is opened or remittance made on behalf of any importer for import into Bangladesh, Authorized Dealers must verify that the importer is registered with the CCI&E or otherwise exempted from such registration. Import shall be allowed only against opening of irrevocable Letters of Credit unless otherwise authorised by CCI&E in certain exceptional cases as mentioned/ in the Import Policy order in force.

EQMS will hire a company who has authorized Import/ Export license.

Documents that are needed to be submitted to customs are the following:

- ◇ Authorized Import/ Export company will open an L/C on the name of Exporter
- ◇ Invoice from Exporter
- ◇ Packing List
- ◇ L/C copy
- ◇ Air Bill
- ◇ Specific details of goods
- ◇ Tax Exemption letter from National Board of Revenue (NBR)

Clearing & Forwarding (C&F) release the goods from custom office.

EQMS supports with the following procedure to obtain a tax exemption for the equipment:
Step 1: EQMS will hire a company who has Import/ Export Licences and that company will open a L/C for the goods
Step 2: WBG will apply to NBR
Step 3: NBR will issue a letter of tax exemption to Tax Commissioner (Airport)
Step 4: Goods will be come to Bangladesh on the name of chosen Import/ Export Licences holder company
Step 5: C&F agent will release the goods

9. LIST OF FIGURES

10. LIST OF TABLES