TERMS OF REFERENCE

SOLAR AND WIND MEASUREMENT CAMPAIGN IN XXX

PROJECT ID: XXXXX
SELECTION #: XXXXXX

JUNE 2020

NOTE for users: *This Terms of Reference (TOR) document was developed by the Energy Sector Energy Management Assistance Program (ESMAP), a global knowledge and technical assistance program administered by the World Bank (WB), under a multi-year program on Renewable Energy Resource Assessment and Mapping that ran from October 2012 to June 2020. The TOR in various different forms has been used to commission over 20 individual World Bank assignments for solar and/or wind measurements involving a number of specialist firms from many countries, and have also been used by the International Finance Corporation (IFC), which is part of the World Bank Group (WBG), and several other development partners. As a result of this they have benefited from many years of experience, feedback and technological developments. The TOR document is being made publicly available to facilitate future measurement campaigns that may be carried out by the World Bank Group, client governments, or other development partners. The World Bank and ESMAP accepts no responsibility or liability from the use of this TOR document. Further feedback on the TOR is very welcome and can be sent to ESMAP at esmap@worldbank.org. Text highlighted in yellow should be edited or deleted by the commissioning author depending on the nature of the assignment and the needs of the client agency. The comments are provided as guidance and should be deleted prior to issuance.*

1. PROJECT BACKGROUND AND OBJECTIVES

1.1. [Insert details on the client, the country/regional context, and the activity under which this procurement falls].

1.2. [Insert details on the context for requiring solar and/or wind measurements and how the data will be used].

1.3. [Insert details on the specifics for the assignment, including locations, timing and other contextual details].

1.4. The technical specifications in this Terms of Reference (TOR) document are informed by an initiative on Renewable Energy Resource Assessment and Mapping led by the Energy Sector Management Assistance Program (ESMAP), a global knowledge and technical assistance program administered by the World Bank, under a multi-year program focused on Renewable Energy Resource Assessment and Mapping that ran from October 2012 to June 2020. Under this initiative ESMAP also developed the Global Solar Atlas (GSA) and Global Wind Atlas (GWA), which provide countries with free, high quality, multi-year historical data on solar and wind resource potential that can be used for planning of renewable energy development, refinement of the need for ground-based measurement data, and identification of optimal locations where a measurement campaign is justified. Furthermore, data obtained from solar/wind measurement campaigns can help to improve future modeling and validation of the GSA and GWA, and other commercial and non-commercial solar and wind resource datasets, when such measurement data is properly commissioned, of high quality (with necessary metadata and supporting materials), and made publicly available.

2. SCOPE OF WORK

2.1. The primary objective of this assignment is to provide high quality solar and wind measurement data from multiple sites, covering two concurrent years[1], to reduce the resource risk and thereby support future development of solar and wind projects at these sites. The secondary objective of this assignment is to support global and national research efforts and improvements to solar and wind resource datasets and tools through publication of the data. The Consultant shall be responsible for the planning, commissioning, implementation and decommissioning of the solar and wind measurement campaign. The Consultant shall also provide training and capacity-building on the operation and maintenance of the equipment to their local partner(s), national utility staff, and other related stakeholders.

2.2. The measurement data shall be obtained from dedicated solar and wind measuring equipment [that is co-located (unless it is impractical to do so)], and shall be owned and operated by the Consultant or one of their appointed sub-contractors for the duration of the contract. The sites shall be selected to meet, as far as possible, both the primary and secondary objectives for the assignment, with sites prioritized according to their ability to provide data for future project development and data for global resource model improvement and validation. The contracted Consultant shall carry out the solar and wind measurement campaign in line with the technical specifications outlined in **Annex A** (solar) and **Annex B** (wind).

2.3. The Consultant shall provide, commission and operate **xx** solar measurement stations and **xx** LIDAR-based wind measurement stations under this assignment. [Insert further details on the zones/locations/sites for installation for the stations, using the table below if necessary; where this information is unknown the Consultant can be asked to identify locations using the Global Solar Atlas and/or Global Wind Atlas, and after carrying out a high-level geospatial analysis to identify zones/locations that are likely to be optimal for development]:

Table 1: Proposed locations of measurement stations

Zone/location/site	Solar	Wind
	[insert number and type of station required – refer to Annex for details on Tiers]	

2.4. For solar, the measurement equipment shall conform to Tier 1 against the existing ESMAP specifications, as outlined in Annex A, unless site conditions mandate the use of Tier 2 equipment.

2.5. For wind, to reduce the permitting, land and cost challenges associated with installing conventional wind measurement masts (lattice and tilt-up), this assignment shall utilize LIDAR devices to obtain high quality wind measurements. As a result of the reliance on LIDAR for the primary wind measurements, all solar measuring stations shall include enhanced wind measurement equipment to provide additional, non-LIDAR wind measurements at a lower level.

[1] This means that at the end of the measurement campaign that the solar and wind data from all the sites should be concurrent for two years, even if this results in a longer measurement period for some sites (because they were installed earlier than the final site).

2.6. The assumption is that sites with grid-provided power shall be selected for both solar and wind measurements, in most cases flat rooftops on low-lying buildings, with no shading issues (for solar), and located in areas with non-complex terrain and minimal other obstacles (for wind). Consultants are encouraged to exploit opportunities for cost savings through the co-location of equipment at sites where both solar and wind measurements are to be taken, and through the sharing of common infrastructure, data transmission equipment, and maintenance and security costs.

2.7. The Consultant shall be responsible for:

- Identifying the measurement sites according to the two outcome objectives outlined above, and in close consultation with the Client, the member utilities, and other key stakeholders;
- Visiting the proposed site locations and selecting the optimal location for the measurement equipment;
- Supply of high-quality measuring equipment, in line with the technical specifications, including all necessary importation arrangements;
- Arranging for site leasing, permitting, and site access;
- Carrying out national and local consultations as needed to ensure the success of the assignment, especially around the areas where the measurement equipment will be located;
- Complying with World Bank Safeguards policies[2] in the selection of the sites and the implementation of the measurement campaign;
- Commissioning of the sites and ensuring that they are fully functional;
- Providing two years of high quality, 'bankable' meteorological data on a monthly basis, including transfer to an 'open data' platform for public dissemination;
- Ensuring operations and maintenance, security, local cleaning/caretaking, mitigation against extreme weather events and corrosion, and regular calibration during the life of the contract;
- Ensuring strong local involvement and capacity building at all stage of the measurement campaign;
- Decommissioning of all sites at the end of the measurement campaign, unless separate arrangements are made with one or more host institutions to continue with measurements outside of this assignment/contract.

2.8. The Consultant shall propose an initial Site Selection Plan as part of their Technical Proposal, upon which their Financial Proposal shall be based. The contracted Consultant shall then, as their first task, carry out a more detailed analysis of potential sites and site hosts, to identify a Site Selection Shortlist for country visits, which shall be shared with the Client within four weeks following the award of contract. In preparing the Site Selection Shortlist, the Consultant shall consult with the international providers of solar and wind modeling data to obtain their input on the optimal locations for the purposes of improving resource estimates in the country and region.

2.9. Within ten weeks of the award of contract an Inception Mission shall be organized, during which the Consultant shall meet with the client and other key stakeholders, in [insert location(s)], and then carry out an initial series of site visits to the shortlisted locations. A half-day workshop shall be organized by the Consultants as part of the Inception Mission to engage with the Client and other stakeholders to seek their feedback. The Consultant shall have made prior contact with organizations/institutions that may be eligible hosts for a solar and/or wind measurement stations,

[2] https://projects.worldbank.org/en/projects-operations/environmental-and-social-policies

and shall then organize and carry out visits to potential sites and hosts to determine their suitability. The Consultant shall also meet with host country officials and counterparts to discuss siting, importation logistics, permitting, and maintenance issues. The Consultant may be accompanied by Client representatives for part or all of the mission, including the site visits. Considering the complexity of the task and associated logistics, one or more further site visit missions may be organized subsequently if needed, as proposed by the Consultant.

2.10. The Consultant shall document this process and their final site recommendations in a Project Implementation Plan, including details of each viable site visit in a common template included as part of the annexes to this report. The Project Implementation Plan shall be submitted to the Client within 12 weeks of the award of contract, with all site visits completed by this point. It shall include the precise location (with GPS coordinates), technical specifications, suitability analysis, and arrangements being proposed for each site including the measurement equipment, risk assessment, analysis of Safeguards issues (and proposed mitigation measures, if required), maintenance provisions, and the decommissioning and removal plan. The Project Implementation Plan shall be accompanied by photographs of the proposed sites and the surrounding terrain, both within the report and delivered separately as individual, high resolution image files.

2.11. Once the Project Implementation Plan is agreed the Consultant shall begin implementation of the solar and wind measurement campaign in close coordination with the Client and other stakeholders.

2.12. The Consultant shall prepare a consolidated Site Installation Report immediately following commissioning of all sites, providing details of the equipment used, and a full description of each site separated into individual chapters/sections. This shall include the site location, site characteristics, technical specifications, calibration procedures, and all other relevant information to allow data users to fully understand the site and ensure the bankability of the measurement data. The Site Installation Report shall be accompanied by photographs of each site and the surrounding terrain, both within the report and delivered separately as original photo image files (raw or jpeg, at least 6 MP and including original geographical and time EXIF information).

2.13. The Consultant shall regularly transfer the measurement data from each site to their central data repository, and shall then transfer the data from all sites to the Client on a monthly basis. The Client shall also be provided with access to the Consultant's data repository or monitoring platform for real-time analysis.

2.14. The Consultant shall deliver a consolidated Site Measurement Report after the first year of data collection, and again following the second year of data collection. The Site Measurement Report, and the complete, quality assured datasets and metadata for each site, shall be uploaded by the Consultant to xxx. Measurement data shall thus be made public following each 12-month period.

2.15. At the end of the contracted measurement period, the Consultant shall decommission and remove the equipment from each installed location, and shall return the sites to their previous condition. If host governments or utilities wish to continue measurements at one or more sites, or wish to take ownership of the equipment, then this shall be arranged bilaterally by the Consultant outside of this assignment.

2.16. The measurement campaign shall be deemed completed once two years of concurrent data is delivered from all contracted sites, all equipment is decommissioned and removed, and all specified outputs are delivered to, and accepted by, the Client.

3. DELIVERABLES / SPECIFIC OUTPUTS EXPECTED FROM CONSULTANT

3.1. The following deliverables, with associated timelines, are required:

Milestone	Deliverable	Due date
i) Site Selection	Site Selection Shortlist	3 weeks from award of Contract
	Inception Mission	10 weeks from award of Contract
	Project Implementation Plan	12 weeks from award of Contract
ii) Installation & Commissioning	Commissioning of Solar & Wind monitoring stations	6 months from award of contract
	Site Installation Report	1 month from commissioning of the last site
iii) Data Collection	Delivery of data at 1-month intervals	Monthly from date of commissioning of the last site
	Consolidated Site Measurement Report and one year of data for all sites	Following 12 & 24 months of data collection from commissioning of the last site
iv) Decommissioning	Complete measurement campaign	24 months after commissioning of the last site (with all sites having delivered 12 or 24 months of data)
	Decommission and remove equipment	2 months after completion of measurement campaign
	Assignment completed and all outputs delivered	1 month after decommissioning of last site

4. SPECIFIC INPUTS TO BE PROVIDED BY THE CLIENT

- Contact details of government and utility company contacts, where needed.
- Support from xxx in obtaining relevant permits and site permissions, although the process shall be led by the Consultant.

5. SPECIAL CONDITIONS

5.1. All the attached Annexes shall apply in full.

5.2. The Client shall conduct all correspondence in English, and all deliverables shall be presented in English. Any translation of materials will be organized and paid for by the Client.

5.3. All deliverables shall be presented to the Client in electronic format suitable for online publication unless otherwise specified. Should the Client decide to print any of the outputs then this will be

commissioned outside of this contract.

5.4. The Contract for this assignment shall be lump sum plus reimbursable expenses, with receipts required for all submitted expenses.

5.5. For any travel, the Consultant shall be responsible for their own in-country logistics (including getting to/from meetings and site visit locations). All travel charged by the Consultant shall be for economy class flights via the most direct route. The Consultant shall charge for expenses (meals, tips and valet) as 'actual costs' (supported by receipts) or in accordance with their internal 'per diem' rates, so long as these do not exceed the rates that apply to xxx staff for the countries visited.

5.6. All taxes, duties and permitting fees are the responsibility of the Consultant. The equipment deployed shall be owned by the Consultant, and may be new or refurbished so long as it fulfills the technical criteria and standards outlined. The equipment is therefore being 'leased' to this assignment for the duration of the contract for the purposes of data provision, and remains the full responsibility of the Consultant. This includes liability for theft, damage or natural hazard, and any related insurance costs or claims.

5.7. A contingency fund of xxx shall be included in all bids as part of the lump sum offer and included in the final issued Contract. This shall only be utilized with agreement of the Client, to cover costs that were not previously envisaged or to cope with "force majeure" events.

5.8. Consultants should assume availability of grid power for all Tier 1 stations, but provide options to protect against regular blackouts. For Tier 2 stations, off-grid operation shall be assumed, with power supply provided by the Consultant. Any additional costs relating to provision of off-grid power to Tier 1 stations shall be covered by the set contingency fund.

BIDDING INSTRUCTIONS

5.9. It is strongly recommended that any local partner(s) proposed should have a track record of working in xxx, and excellent logistical capabilities. Staff personnel and local partners do not have to correspond to those listed in the Consultant's EOI response, and Consultants may propose local partners that are also collaborating with other invited Consultants to this RFP.

5.10. Consultants are required to submit a Technical and Financial Proposal that complies with the scope and specifications outlined in this TOR document. There must be a single figure relating to the Consultant's financial bid that is based on a compliant Technical Proposal: failure to provide this, or provision of a technically non-compliant offer, will lead to disqualification.

5.11. Consultants shall include a contingency fund of xxx in their core offer, as part of the lump sum component.

5.12. Consultants may provide costs in their Financial Proposal for any optional items not included in the TOR but proposed or recommended by the Consultant for consideration by the Client. If the Consultant is proposing a technical solution that differs from the TOR specifications then they must outline this in their Technical Proposal, and include it in their Financial Proposal (clearly specified as Optional Items) outlining the impact this would have on the overall cost (positive or negative). They may also note in their Technical Proposal where such proposals would result in cost savings.

5.13. The specified number of solar and wind measurement sites is considered to be the minimum that shall be procured under this assignment. However, should the winning Consultant's bid come in below the available budget for this assignment, then the client may exercise the option to add additional solar and/or wind measurement sites into the final contract. To facilitate this process, all

Consultants are requested to provide, in a separate part of their Financial Proposal, fully inclusive costs for additional solar and/or wind measurement sites, broken down into their key cost components. These costs must be the same or less than the respective unit costs of the core solar and wind measurement sites.

5.14. It is assumed that Consultants will factor in the resale/reuse value of any provisioned equipment into their bids.

5.15. Financial offers may be in the preferred currency of the Consultant.

ANNEX A: SOLAR MEASUREMENT PROCEDURES AND SPECIFICATIONS

The Consultant may propose an alternative set of standards and/or methodology in place of these requirements, but they should provide an equivalent or better performance and reliability. Should site conditions warrant this, the Consultant may also propose additional instrumentation as optional items.

EQUIPMENT SPECIFICATIONS

TIER 1

Tier 1 stations are the preferred choice for the purpose of validating the solar resource modeling and the provision of long-term reference data, where they are a practical option. They provide the highest accuracy measurements, and use thermopile radiometers to measure all three components (GHI, DNI, and DHI). The sensors chosen for the GHI and DHI measurements must meet ISO Secondary Standards (or alternatively WMO High Quality Characteristics); the sensors chosen for the DNI measurements must meet at least ISO First Class (or alternatively WMO Good Quality) standards. The ISO and WMO Classifications are described in more detail in the Solar and Infrared Radiation Measurements[3] and Concentrating Solar Power: Best Practices Manual for the Collection and Use of Solar Resource Data[4] (see in particular Table 5.1 in the first reference and Tables 3-2 through 3-5 in the second). The research quality station shall collect and archive data according to the protocols of the Baseline Surface Radiation Network[5].

A Tier 1 station consists of a pyrheliometer mounted on an automatic tracker for the DNI measurements and a tracker with a shading ball shading a pyranometer from the direct beam for the diffuse measurements. Such a station provides the highest accuracy measurements, although a Tier 1 station requires (ideally) daily maintenance to ensure that the domes of the pyranometers and pyrheliometers are properly cleaned and the instruments are properly leveled. A Tier 1 station also includes a weather station with temperature, humidity, barometric pressure sensors at 1 to 2m above ground level[6], and wind speed and direction data at a height of 10m from the surface of the installation site (if the site is a rooftop, then the height shall be 10m from the rooftop base). The wind measurements at each solar site shall also serve as an additional reference/comparison dataset to the LIDAR measurements, in the case of co-located sites.

Tier 1 stations shall be installed at locations where trained personnel are readily available to operate the station properly, yet should also be installed in secure locations free of influence from local aerosols or urban effects. Tier 1 stations shall be designed with a goal to achieve measurement uncertainties of 2% to 3% for one-minute values, and <2% for daily GHI and <1% for daily DNI values.

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[3] Vignola, Frank, Joseph Michalsky, and Thomas Stoffel. 2012. "Solar and Infrared Radiation Measurements". CRC Press, Taylor and Francis Group, New York. 394 pp.

[4] Manajit Sengupta, Aron Habte, Christian Gueymard, Stefan Wilbert, Dave Renné, and Thomas Stoffel. 2017. "Best Practices Handbook for the Collection and Use of Solar Resource Data for Solar Energy Applications: Second Edition". Technical Report NREL/TP-5D00-68886. Available at https://www.nrel.gov/docs/fy18osti/68886.pdf

[5] http://bsrn.awi.de

[6] In cases where it is necessary to install the station on a rooftop or other raised installation then these heights shall be from the base of the station.

TIER 2

A Tier 2 station shall be used for those situations where data is required from a remote or extreme weather location, or where daily or regular maintenance is not possible, thus ruling out a Tier 1 station. A Tier 2 station must therefore consist of rugged, robust equipment that operates satisfactorily over extended time periods (a month or more) without on-site maintenance. The minimum requirement for a Tier 2 station is a Rotating Shadowband Radiometer (RSR) capable of measuring against all three components (GHI, DNI and Diffuse). A Tier 2 station shall include an ISO Secondary Standard pyranometer to allow for quality control and calibration of the RSR equipment, and shall also collect data on temperature, humidity, barometric pressure at 1-2m above ground level (agl), and wind speed measurements at a height of 3 m above ground level. A Tier 2 station shall be designed with a goal to provide measurement uncertainty of <5% for daily values.

A Tier 2 Station may also be used as a substitute for a Tier 1 station where cost savings may be required due to budget limitations. However it should be understood that replacing a Tier 1 station with a Tier 2 station in principle will result in higher measurement uncertainty.

ADDITIONAL EQUIPMENT

The following additional equipment shall be installed at all sites:

- Rain gauge;
- Corrosion test stand;
- Soiling measurement assembly;
- Surveillance camera.

EQUIPMENT INSTALLATION AND MAINTENANCE

The Consultant shall ensure that:

- The solar irradiation measurement equipment, the station containing other weather sensors, as well as any on-site data logger equipment is easily accessible for cleaning, level checks, and maintenance.
- For the wind measurement equipment:
    - The mast shall have two top anemometers measuring at the same level.
    - The top-most anemometers shall be unobstructed by booms or other instruments and therefore shall be mounted in a 'goalpost' arrangement on booms with rods extending above the main body of the measurement mast in accordance with the IEC 61400-12-1 standard.
    - Instrumentation must be first class calibrated anemometers with equivalent or better classification in complex terrain, and with a longevity suitable for later refurbishment and recalibration (e.g. RISO or THIES First Class Advanced or THIES First Class or Vector). All anemometers must be supplied with an individual calibration certificate. Calibration must have been performed by an accredited MEASNET laboratory and following the MEASNET procedure.
    - Each mast shall have one calibrated first class wind vanes type THIES First Class, RISO Aa3590, Vector W200P or equivalent, located near the top anemometer level.
    - The tower and instrument assembly shall comply with the IEC 61400-12-1 standard. Booms and instrument spacing and mounting shall be in accordance with or larger than required by the IEC 61400-12-1 standard.

- All equipment is adequately protected from storms/cyclones, wind, corrosion, rain, humidity, frost and dust to operate safely in the environment in which it is installed. Electrical devices and cubicles shall have IP 65 protection class. Dome heating shall be included in humid areas.
- All equipment is protected from lightning strikes and shielded from radio frequency interference. In general, a single point ground using a copper rod deep in the ground shall be installed. Twisted pair cables shall be used for low voltage measurements. The low voltage sensor cables shall be physically isolated from power cables (not run in parallel or in the same conduit). Masts and tripods for mounting meteorological equipment shall be well grounded to assure a path for lightning strikes. As an option, Metal Oxide varistors, or gas tubes, can be used to protect signal cables from electrical surges.
- All equipment is sited to minimize conditions that might cause shading of the sensors, such as nearby trees, buildings, or other tall objects, including the meteorological mast and boom for the wind vane. The weather sensors shall be installed at a location that does not shade the solar sensors.
- All equipment, including temperature, humidity, barometric pressure, and wind speed and direction, shall include factory calibrations.
- At the end of the first year of measurements, a field calibration using a reference pyranometer (referenced to the World Radiometric Reference established in Davos, Switzerland) shall be conducted at each solar measurement station for a period of no longer than one working day.
- The station, including the data logging equipment, is powered adequately for proper year-round operation, with appropriate protection against power surges and frequency fluctuations.
- Data is collected at minimum 1-s sampling frequency, averaged over 1-minute time intervals.
- The data recovery rate from each of the sensors shall be >95% over the course of the measurement campaign. If this rate is not achieved, then measurements will be extended until this threshold is reached. Additionally, any single incident of data loss shall not exceed 15 days. Unless the loss of data can be attributed to a force majeure event, the Consultant shall be required to collect an additional month of data for every data loss event in excess of 15 days.
- Arrangements are made for maintaining and servicing the solar and other meteorological equipment throughout the measurement campaign. These arrangements shall include daily (Tier 1) or weekly (Tier 2) inspection and proper leveling and cleaning of the thermopile solar monitoring equipment, including checking the sensor levels, and a physical maintenance visit by a qualified technician at a minimum frequency of every six months. The time settings on all data loggers shall always be set to local standard time using GPS, and shall be verified during inspections.
- Data download from each site shall be done at least daily and checked to ensure against data loss, corrupted data, calibration drift, and instrument failure. There must be adequate local data storage capacity for at least 12 months of data collection.
- Arrangements are made to ensure that data from each sensor are transmitted electronically through a GSM connection (or satellite connection if GSM coverage is inadequate) to a secure data portal managed by the Consultant to which the Client shall be given online access. The Consultant shall utilize data logging equipment that has two way-communications capabilities. There shall be a manual backup data collection procedure for each station, which can be activated within 24 hours in order to minimize data loss.
- All collected data and quality-assessed data shall be provided monthly to the Client. Data transmission (from each measurement site, and to the data repository) is the responsibility of the Consultant.

- A historical log report is maintained by a local representative of the Consultant documenting all maintenance undertaken, date and reason for replacement of instruments, etc. The log report shall be provided to the client, and the Consultant shall update the historical log report within 15 days of a site visit.
- A suitable inventory of spare and wear parts and consumables is available for one year of operation (e.g. for instrument replacement), and that the spare parts inventory are available and can be delivered on short notice for each site.

SITE SECURITY

With regard to site security, the Consultant is required to ensure the following:

- Any security arrangements put in place by the Consultant shall be proportional and appropriate.
- The Consultant shall be guided by good international practice and applicable law in relation to the hiring of security personnel (e.g. due diligence on the past conduct of the security personnel), rules of conduct, training, and equipment provision.
- Appropriate oversight and control measures of security personnel shall be in place.
- Information will be made available at each site on appropriate contact persons in case of queries or concerns.
- Client funds cannot be used for the procurement of arms and ammunition, nor for the training of security workers in the use of arms.
- The Consultant shall install a system for remote site monitoring, such as a low-cost webcam at each site that can be viewed/activated remotely using the data connection if possible.

REPORTING

SITE INSTALLATION REPORTS

The Consultant shall prepare a Site Installation Report for each site, which shall include, but not be limited to:

- Exact location details, including coordinate system and station elevation info. There shall be GPS loggings at the location of the solar sensors to within an accuracy of 1-meter. All references shall be according to geographical North instead of Magnetic North;
- Configuration drawing of the station layout, including mounting height of the equipment above ground, its layout, and local obstructions
- Layout of the wind mast showing alignment of the wind direction boom, the North arrow and expected main wind direction;
- The alignment of the north of the 10-m wind vane and its inclusion in the data logger settings shall be documented.
- Photos and a list of instruments including brand, model and serial numbers;
- Pictures of mounting details of each instrument;
- Picture of data logger and logger cabinet;
- Documentation photos of the station installation, including the installation of the meteorological sensors;
- Directional pictures of the area looking out from the station position in 30° angles, starting from straight North (0°) and moving clockwise, to be taken after station installation;
- Drawing showing 360° horizon shade line indicating time and point of sun shade exit/entry for 4 seasons;

- Picture of the fully installed station including exact coordinates from where picture is taken;
- Calibration certificates for each instrument;
- All data logger and modem settings, and a copy of the logger's software program.

SITE MEASUREMENT REPORTS

Site Measurement Reports for each site are required outputs following each 12-month measurement period.

Consultants are required to:

- Review and quality check the measured solar data from the site using best practices quality assessment procedures that provide appropriate data flagging for all questionable or missing data. Examples of best practices can be found at http://rredc.nrel.gov/solar/pubs/seri_qc/;
- Report on the calibration procedures and results of the pyranometers and pyrheliometers, including calibrations at the start of each 12-month study period. The report shall include the traceability of the calibration procedures to the World Radiometric Reference that is established in Davos, Switzerland every five years;
- Estimate the uncertainty in the prediction of the long-term GHI and DNI at each site;
- Analyze the seasonal and diurnal characteristics of the measured GHI and DNI;
- Provide monthly summaries of any other meteorological parameters captured at the site;
- List the occurred disturbances, failures, etc. and explanation of lost or biased data which was excluded from the analysis.

ANNEX B: WIND MEASUREMENT PROCEDURES AND SPECIFICATIONS

This annex outlines the minimum requirements for conducting a high quality wind measurement campaign for the purpose of validating the wind mesoscale modeling outputs and thereby contributing to the creation of a validated Wind Atlas.

The Consultant may propose an alternative set of standards and/or methodology in place of these requirements where they can demonstrate that these provide an equivalent or better performance and 'bankability'. Should site conditions warrant it, the Consultant may propose additional instrumentation, e.g. for the measurement of vertical wind speed etc. In the case of any alternative solution, the Consultant shall provide a detailed justification and have this agreed by the Client.

MEASUREMENT STANDARDS

The Consultant shall ensure compliance with the following standards:

- International Energy Agency. Recommended practices for wind turbine testing and evaluation. 11. Wind speed measurement and use of cup anemometry. Ed. 1, 1999.
- Measnet. Evaluation of site-specific wind conditions. Version 1, 2009.
- Measnet. Power performance measurement procedure. Version 5.
- International Standard. IEC 61400-12-1. Latest edition. Wind turbines-Part 12.1: Power performance measurements of electricity producing wind turbines.
- The World Bank's Safeguards policies, and Environment, Health and Safety Guidelines, plus any environmental or social mitigation measures required by local regulations.

DESIGN AND IMPLEMENTATION

General requirements are as follows:

- Consultant is required to perform technical, climatic, environmental and social due diligence for each measurement site in relation to any event that may impact the proper, continuous functioning of the equipment (e.g. power outages, extreme winds, flooding, icing, dust, sand, risk of theft or vandalism) and propose appropriate mitigation measures (e.g. a UPS system, insurance), as needed.
- Data download from shall be done at least daily and checked to ensure against data loss, corrupted data, calibration drift, and instrument failure. There must be adequate local data storage capacity for at least 12 months of data collection.
- Data shall be transmitted electronically through a GSM connection (or satellite connection if GSM coverage is inadequate) from each site. The Consultant shall utilize data logging equipment that has two way-communications capabilities. There shall be a manual backup data collection procedure for each site, which can be activated within 24 hours in order to minimize data loss.
- All collected data and cleaned data shall be provided by the Consultant to the Client on a monthly basis. Data transmission (from each measurement site, and to the data repository) is the responsibility of the Consultant. Data shall be uploaded in a format compliant with the latest standards provided by the Client. Both corrected and uncorrected data be supplied from the measurements.
- During the measurement campaign a historical log report shall be maintained documenting all maintenance undertaken, date and reason for replacement of instruments, etc. The log report shall be periodically provided to the Client and/or uploaded to the Client's data repository.

- Timer settings shall always be set to local (winter) time, and shall be verified during inspections. It is preferred that the data logger synchronize its clock settings with a time server on the internet on a daily basis.
- The Consultant shall notify the Client by email before and after all maintenance visits and forward the updated historical log report within seven days of the visit.
- The safe installation and operation of any wind measurement equipment, including site maintenance and security, shall be the responsibility of the Consultant or their nominated sub-contractor for the duration of the project.
- The Consultant shall maintain a suitable inventory of spare parts, which shall be available for instrument replacement at short notice.
- The Consultant shall offer, as optional items, the replacement and MEASNET recalibration of one or more anemometers per mast.

Specific requirements relating to LIDAR are as follows:

- Measurements shall be taken at a minimum in the range of 60-100m, preferably with additional heights up to 200-300m according to the specifications of the LIDAR equipment.
- It is preferred that the LIDAR equipment automatically and reliably compensates for non-horizontal airflows (e.g. caused by complex terrain or obstacles), even if the preferred siting would be in non-complex, open terrain. This will make it simpler and less costly to deploy the equipment onto other sites at a later stage. If the equipment is of a type that requires pre-calibration for the specific site using CFD modeling, a detailed report of the site modeling and the resulting correction algorithm is required.
- The LIDAR equipment shall be calibrated prior to transportation at a certified calibration facility;
- The LIDAR shall be powered adequately for proper year-round operation, with appropriate protection against power surges and frequency fluctuations.
- The data recovery rate shall be >90% over the course of the measurement campaign (lower than the standard rate for met masts to account for the use of LIDAR). If this rate is not achieved then measurements shall be extended until this threshold is reached. Additionally, any single incident of data loss shall not exceed 15 days. Unless the loss of data can be attributed to a force majeure event, the Consultant will be required to collect an additional month of data for every data loss event in excess of 15 days. If a data loss event exceeds 16 days, it will be counted as a new data loss event.
- The Consultant shall maintain the equipment throughout the measurement campaign, and inspect it at least every three months to verify its proper functioning. Maintenance in relation to cleaning of the LIDAR shall be carried out as required by the manufacturer, at least monthly, and immediately whenever substantial missing or corrupted wind data is detected.

SITE SECURITY

With regard to site security, the Consultant is required to ensure the following:

- Any security arrangements put in place by the Consultant shall be proportional and appropriate.
- The Consultant shall be guided by good international practice and applicable law in relation to the hiring of security personnel (e.g. due diligence on the past conduct of the security personnel), rules of conduct, training, and equipment provision.
- Appropriate oversight and control measures of security personnel shall be in place.
- Information will be made available at each site on appropriate contact persons in case of queries or concerns.

- Client funds cannot be used for the procurement of arms and ammunition, nor for the training of security workers in the use of arms.
- The Consultant shall install a system for remote site monitoring, such as a low-cost webcam at each site that can be viewed/activated remotely using the data connection if possible.

SITE INSTALLATION REPORT

A consolidated Site Installation Report shall be prepared upon commissioning of all measurement sites, which shall include, but not be limited to:

- Exact location and elevation details of each mast or LIDAR in longitude-latitude and UTM, including coordinate system and Datum info. There shall be GPS loggings at each anchor point or four points taken 25 m N, E, S and W of meteorology masts. All references shall be according to geographical North instead of Magnetic North;
- Configuration drawing of the measurement equipment on masts including mounting height of each instrument above ground, length of booms, clearances etc;
- Layout of any met masts installed showing alignment of each boom, the North arrow and expected main wind direction. The alignment of the north of each wind vane and its inclusion in the data logger settings shall be documented. It is recommended that the north of the wind vane (i.e. dead band) is aligned along the boom axis, pointing inward towards the mast.
- List of instruments including brand, model and serial numbers;
- High resolution photographic pictures as follows:
    - Mounting details of each instrument;
    - The data logger and logger cabinet;
    - During uplift for met mast installations (at least two pictures);
    - Directional pictures of the area looking out from the measurement equipment position in 30° angles, starting from straight North (0°) and moving clockwise, to be taken after commissioning;
    - The fully installed measurement equipment/site including exact coordinates from where picture is taken.
    - From the bottom of any met mast installations looking upward with North at the top;
- Calibration and recalibration certificates for each instrument;
- All data logger settings;
- Elevation overview map 20x20 km for site using SRTM 3-arc-second data with 20m and 10m height contours;
- Elevation detailed site map 4 x 4 km, with 5m contours;
- Ruggedness index (RIX) for the site;
- Land cover map 20 x 20 km with surface roughness zones based remote sensed data (e.g. Google Earth, Landsat, etc.) and photos.
- The consultant shall prove the WAsP workspace used for the 12 and 24 month reporting, and notably the roughness and topography files, which may be used for the wind atlas validation procedures by the Technical University of Denmark (DTU) as the owners of the Global Wind Atlas.

The Site Installation Report shall be made publicly available by the Client.

SITE MEASUREMENT REPORT

A consolidated Site Measurement Report covering all measurement sites is required following each 12-month measurement period. The purpose of this report is to document site measurement operations for quality assessment purposes and to provide measured datasets, which can be used to compare with the modeling results. The report shall include a complete microscale analysis using the mainstream microscale modeling software, WAsP, taking account of the local topography, the surface roughness rose, obstacles, and other key variables. In complex terrain where the limits of safe use of microscale modeling tools are exceeded, a CFD model analysis (e.g. WAsP CFD) shall be used.

Consultants shall carry out the following for the preparation of the Site Resource Report:

- Review and quality checking of measured wind data from each site and appropriate nearby long-term reference masts and/or weather model reanalysis data;
- Review of calibration of anemometry (pre and post calibration for the 12/24-month study);
- Correlation with long-term reference data;
- Prediction of the long-term mean directional wind speed and frequency distribution for each mast, energy-conserving directional Weibull wind speed distributions (as defined in the European Wind Atlas), turbulence and wind rose (for use in mainstream microscale modeling software);
- Wind shear analysis at each mast taking into account atmospheric stability;
- Seasonal and diurnal variations in wind characteristics;
- Prediction of the site air density;
- Estimate of the uncertainty in the prediction of the long-term wind speed at each mast provided as a value of mean wind speed standard deviation;
- Estimates of extreme winds and turbulence according to IEC 61400-1;
- Estimates of the equivalent mean and 12-directional Weibull wind speed distributions for the relevant heights above ground level corresponding to the local as well as the standardized output assumptions of the mesoscale model (flat terrain, roughness length 0.03m);
- Provide suitable example layouts with a nominal turbine type suitable for each site's environment, preferably a mainstream IEC-61400 fully certified turbine to be agreed with the Client;
- Estimate of the sensitivity of net annual energy production (P50, P90, P95) based on the mean wind speed standard deviation, energy losses and the nominal turbine type;
- Estimate of the net hourly and 10-minute energy production for the example wind farm layout with the nominal turbine type for the period of wind measurements. The data shall be provided in Excel worksheets, including the simultaneous national load data from the associated nearby grid, if available.