TERMS OF REFERENCE
Identifying and Mapping Off-shore Wind and Wave Energy Potential in Turkey

1. SELECTED DEFINITIONS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>3D</td>
<td>Three-dimensions</td>
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<tr>
<td>CAPEX</td>
<td>Capital Expenditures</td>
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<tr>
<td>CDF</td>
<td>Cumulative Distribution Function</td>
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<tr>
<td>DEPA</td>
<td>Sea Energy Potential Atlas</td>
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<tr>
<td>DGFREU</td>
<td>Directorate General for Foreign Relations and EU (MoENR)</td>
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<tr>
<td>EBRD or the Bank</td>
<td>European Bank for Reconstruction and Development</td>
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<td>EC</td>
<td>European Commission</td>
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<td>EU</td>
<td>European Union</td>
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<td>GDRE</td>
<td>General Directorate of Renewable Energy (MoENR)</td>
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<tr>
<td>GIS</td>
<td>Geographic Information System</td>
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<td>ILUC</td>
<td>Indirect Land Use Change Directive</td>
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<tr>
<td>IPA</td>
<td>Instrument for Pre-Accession Assistance</td>
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<td>IRR</td>
<td>Internal Rate of Return</td>
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<tr>
<td>LCoE</td>
<td>Levelised Cost of Energy</td>
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<td>MAE</td>
<td>Mean Absolute Error</td>
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<td>MoENR</td>
<td>The Ministry of Energy and Natural Resources of the Republic of Turkey</td>
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<tr>
<td>MWh</td>
<td>Megawatt-hour</td>
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<td>NPV</td>
<td>Net Present Value</td>
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<td>NREAP</td>
<td>National Renewable Energy Action Plan</td>
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<td>NWP</td>
<td>Numerical Weather Prediction</td>
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<td>OPEX</td>
<td>Operational Expenditures</td>
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<td>OL</td>
<td>Operations Leader</td>
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<td>PDF</td>
<td>Probability Density Function</td>
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<tr>
<td>PV</td>
<td>Photovoltaic</td>
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<tr>
<td>RE</td>
<td>Renewable Energy</td>
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<tr>
<td>REPA</td>
<td>Wind Energy Potential Atlas</td>
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<tr>
<td>RMSE</td>
<td>Root Mean Square Error</td>
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<td>TA or TC</td>
<td>Technical Assistance or Technical Cooperation</td>
</tr>
<tr>
<td>TSMS</td>
<td>Turkish State Meteorological Service</td>
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<tr>
<td>WRF</td>
<td>Weather Research and Forecast Model</td>
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2. SUMMARY

The aim of this assignment is to explore the off-shore wind energy potential of Turkey, update and upgrade the existing wind energy atlas of Turkey extending to off-shore all around Turkey (Black Sea, Aegean Sea, and Mediterranean Sea Shores), and to create a wave energy atlas. Following the recent developments in the Turkish Renewable Energy sector and as a follow up to the targets set forth in the National Renewable Energy Action Plan (NREAP), it is necessary to understand the untapped potential of other renewable resources such as off-shore wind and wave energy. In addition to off-shore wind, the assignment will also review different setbacks requirements for wind turbines in
the countries that have significant experience with wind energy.

The study will also target improving the renewable energy atlases of the country which help visualize RE resources, define the potential of the country and detail the best locations for setting up RE power plants in the country guiding all relevant stakeholders. Based on the data to be provided by the public institutions, the outputs of this Technical Assistance (TA) activity will include an upgraded version of the existing wind energy atlas and the creation of the sea energy atlas.

The TA will be funded through the Instrument for Pre-Accession Assistance (IPA) Component 1 (Transition Assistance and Institution Building), as agreed between the European Commission (EC) and the Ministry of Energy and Natural Resources of Turkey (MoENR). Overall objective of this IPA sector support is to increase the capacity and better alignment in energy efficiency and renewable energy markets by promoting commercial lending facilities, providing more active donor involvement, improving the policy framework, enhancing access to information, as well as creating incentives and pilot programmes. To this end, the EC and the European Bank for Reconstruction and Development (hereinafter referred to as “EBRD” or the “Bank”) have agreed to establish the EU/EBRD Turkish Energy Efficiency and Renewable Energy Support Programme (hereinafter referred to as the “Programme” or the “Action”) within 2013 programming under the theme of “Enhancement of Turkish Energy Sector in line with EU energy strategies”. The Programme aims at providing loans, supported by TA for the purpose of promoting resource efficiency and renewable energy investments in the private sector and institutional capacity building to address specific weaknesses in the regulatory framework and other areas in Turkey, leading to a significant improvement in the investment environment for resource efficiency across the country.

3. OBJECTIVES

The main objectives of the assignment will be:

- To identify the off-shore wind energy potential in Turkey, conduct a market assessment regarding off-shore wind technology and review challenges, risks and opportunities in construction and operation phases of off-shore wind farms.

- Assess environmental and social risks and regulatory requirements to develop off-shore energy in Turkey inclusive of protecting Key Biodiversity Areas (KBAs) and archaeological sites.

- To prepare a cost breakdown and investment analysis of potential off-shore wind farms in Turkey.

- To improve the existing renewable energy potential atlases of Turkey by using main meteorological inputs and base maps to be provided\(^1\). The atlases\(^2\) to be developed will include:

  - Wind Energy Potential Atlas (REPA) including both on-shore and off-shore potential in Turkey:

\(^1\) The data required for the maps will be provided as per Annex I. The assignment does not include any measurement activities and does not require any site visits.

\(^2\) The atlases to be developed within the study are expected to be user-friendly and delivered to the Bank in data files format (xls, xml, txt, csv and/or ASCII), digital maps (.tab and shape file) and raster map format (tiff, Geotiff, png, jpeg).
• A pilot study on the off-shore wind potential of a selected region in the country will precede the full study.
  o Wave Energy Potential Atlas (DEPA) identifying the energy potential arising from waves, current and thermal cycle in Turkey’s seas.

• To define setbacks for wind energy power plants in Turkey taking best practices in the world into account.
4. **SCOPE OF WORK**

Following the contracting of the assignment, the relevant public authority, GDRE, will provide the measurement data and base maps necessary to conduct the assignment. Annex I lists the items that will be provided to the Consultant.

**A. Off-shore Wind Potential and Wind Turbine Setbacks**

The assignment aims to exploit the off-shore\(^3\) wind energy potential in Turkey. The Consultant is expected to undertake an assessment of the existing off-shore wind farm technologies and identify the potential for the country.

The Consultant is also expected to develop a methodology to define setbacks for on-shore and off-shore wind turbines in Turkey based on EU regulations, literature, meteorological and climatic conditions of the wind power plant site. This will include taking into consideration environmental and social criteria.

The sub-tasks include but not limited to the following:

a. Description and comparative assessment of the different types of existing and commercially available off-shore wind technologies (turbines, foundations, technique and equipment for the installation) considering supply chain, environmental/social impact, archaeological and protected areas and energy conversion efficiencies;

b. Revision of off-shore wind farm siting procedures and criteria;

c. Cost breakdown and investment analysis (with LCoE, IRR and NPV) for off-shore wind farms including:
   i. CAPEX and OPEX,
   ii. Transportation and assembly,
   iii. Off-shore transformer,
   iv. Transmission lines,
   v. Operation and maintenance;

d. Identification of the key challenges, barriers and opportunities for the deployment of off-shore wind farms;

e. Market assessment of major off-shore wind technology providers;

f. Revision of potential risks for off-shore wind farm during construction and operation;

g. Environmental and social impact assessment of off-shore wind farms and preparation of an environmental and social impact assessment template for off-shore wind turbine;

h. Identification and mapping of off-shore wind energy potential all around Turkey based on the following:
   i. site selection criteria;
   ii. NWP data at 3 km resolution;
   iii. micro-scale wind flow model;
   iv. wind data at 100 m horizontal resolution;
   v. bathymetric data;

Within this sub-task (4 – A – h), the consultant is expected to prepare the offshore wind atlas for one pilot region\(^4\) selected jointly by the Bank and GDRE based on the

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\(^3\) The potential area for off-shore wind energy generation is limited to sea depths less than 50 m.

\(^4\) The pilot region is envisaged to be Thrace Region. Exact coordinates will be provided following the signing of the contract.
identified potential and/or needs, to be delivered with the inception report. The data required to build the model will be provided as per Annex I and this subtask will be in line with the following Wind Energy Potential Atlas task. The pilot atlas shall be in line with the terms presented in section 4-B1 Wind Energy Potential Atlas.

i. Review of relevant European regulations (mainly Noise-Based Setbacks) and best practices defining setbacks, minimum horizontal separation distances, between the base of wind turbines and dwellings, noise receptors, property lines, roads and railways and the methodologies behind these regulations. The analysis should take into account the following, but not limited to:
   i. Lakes and wetlands
   ii. Wildlife/Nature protection and improvement areas
   iii. Special environmental protection areas
   iv. Areas with conservation-reliant species inclusive of Key Biodiversity Areas
   v. Bird migration routes
   vi. Dwellings
   vii. Airport sites
   viii. Archaeological sites
   ix. Fishery protection
   x. Hospitals;
   xi. Radio lines and radars
   xii. Roads and Railways
   xiii. Electricity transmission/distribution lines

Wind and Wave Energy Potential Atlases

The Consultant shall develop two different renewable energy potential atlases based on the data to be provided by GDRE. Within this section, the assignment aims to improve the existing wind energy potential atlas and add a new marine energy potential atlas.


The Consultant is expected to produce the wind atlas using numerical weather prediction (3x3 km resolution) and wind flow (microscale - 100x100 m resolution) models at a level sufficient for the wind energy calculations relating to the study area covering the coordinates specified in Annex II. The area is expected to cover the land, sea and lakes of Turkey within the coordinates specified. The input of NWP Model shall be re-analysis data (NCAR, ECMWF etc.) and the outputs of NWP model are expected to verified by using real measurement data which is provided by YEGM. NWP Model results shall be downscaled by using micro-scale wind flow model for 100 m resolution by considering all micro-scale effects. The output will reveal the wind energy potential and show the usable areas for wind energy power plants through the Atlas and base maps to be provided by the Bank and GDRE as specified in Annex I. The guidelines for the wind atlas are presented in Annex III.

The final electronic deliverable (the Atlas) shall be prepared considering the following:

• Annual/seasonal/monthly/daily/hourly average of the following parameters will be generated in grids of \([100 \text{ m} \times 100 \text{ m}]\) and calculated at elevations of 30, 60, 90, 100, 120, 150 and 200 m from the earth surface of the specified work area\(^6\):
  
  o Wind speed (m/s)
  o Wind direction
  o Temperature (0C)
  o Pressure (mb)
  o Weibull k and A parameters
  o Air density (kg/m\(^3\))
  o Power density (W/m\(^2\))
  o Wind class
  o Capacity factor
  o Energy generation (MWh)

• The final electronic deliverable shall include:
  
  o Land roughness map of the specific work area
  o Topographical map and data (.tab and shape file)

• Wind rose (sectoral wind direction) and their data on sectoral basis (16 sectors), annual, seasonal, monthly wind power intensity maps along with the roughness, monthly temperature and pressure maps and their legend at an elevation of 100 m shall be electronically submitted in the form of data file, digital map and raster format.

• Daily mean wind velocities and sectoral wind direction data generated at an elevation of 100 m shall be electronically submitted in the form of data file, digital map and raster format.

• Annual/seasonal/monthly/daily/hourly mean wind velocity, wind direction, pressure, temperature values in grids of 3km x 3 km or less shall be electronically submitted in data files containing each grid point and in digital map and raster format via GIS techniques and individually shown on base maps.

• A colour-coded wind classification map on an annual/seasonal/monthly basis generated using wind data at an elevation of 100 m and with a resolution of 100 m using a capacity factor calculated with a power curve for a 3 MW wind turbine shall be electronically submitted in digital map and raster format.

The following printed documents shall support the atlas prepared under the sub-task:

• A detailed report including the model used, implementation of the model to the work area, verification statistics, wind maps and the wind maps operation manual.

• The verification results derived using the NWP model results and met mast data shall be included electronically in the report.

\(^6\) Please see Annex II

Existing renewable energy atlases of Turkey do not include a wave energy potential atlas, and thus the assignment aims to understand the untapped energy potential arising from winds, currents and thermal cycle. Within the scope of this assignment, outputs capable of satisfying the requirements for wave energy calculations, which are representative of the conditions of wave energy potential and the characteristics for wave energy, shall be produced along with models that are calibrated and verified with current measurements or analysis models for the seas of Turkey. Wave energy potential shall be calculated using the data generated, and spatial areas shall be generated for the seas. Outputs that can provide all information required for a wave energy potential atlas shall be generated and presented over maps.

The final electronic deliverable (the Atlas) shall be prepared considering/including the following:

- The annual/seasonal/monthly areal variations (for periods of 20 years) of following parameters of waves for each grid point along with their long term averages (prepared via GIS software and indicated on the base maps) shall be provided by the Consultant in digital map and raster format and data files (xls, txt, etc.):
  - significant wave height
  - wave energy flux
  - areal variation of wave energy flux (ex: flux variation coefficient)
  - areal variation of mean wave energy flux
  - monthly and seasonal variability index of wave energy flux
  - total wave energy potential (reserve)
  - discoverable wave energy potential (reserve)
  - wave velocity;
  - wave period
  - wave energy intensity
  - temperature, salinity and density of sea surface, thermocline and deep water layers

- The following parameters shall be analysed for each grid point and delivered within the data files and on the digital and base maps in the raster format electronically:
  - Significant wave height (Hm0)
  - Table of statistical parameters of wave energy flux (P) (average, median, maximum, standard deviation, coefficient of variation, steepness coefficient, kurtosis coefficient)
  - Wave roses, wave power roses
  - Significant wave height theoretical probability density (PDF) and cumulative distribution (CDF) graphs
  - Wave energy flux theoretical probability density (PDF) and cumulative distribution (CDF) graphs

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- Table of bivariate frequency of significant wave height and energy period
- Table of bivariate frequency of significant wave height and peak wave period
- Scatter diagram of significant wave height to its energy period
- Variation graph of significant wave height and wave energy period to annual mean wave energy
- Variation graph of significant wave height and wave direction to annual mean wave energy
- Hourly variation graph of mean wave energy flux, monthly variation graph of mean wave energy flux
- Temporal variation graph of seasonal mean wave energy flux
- Temporal variation graph of annual mean wave energy flux values

- Extreme value statistics graph of extreme waves with different repetition periods shall be delivered electronically.

- Temporal variation graphs for salinity, density, temperature, current velocity and direction parameters for each grid point shall be reported.

- Areas that are suitable for installing wave power plants shall be indicated on the deliverable and base maps (electronically and in raster and data format). The Consultant is expected to assess and report the forecast annual and monthly electricity generation and the capacity factor that can be obtained from the area suitable for installing a wave power plant. The Consultant shall work with the Bank and GDRE on determining the installed power per square-kilometre and characteristics of the plants to be used for the modelling and the areas which should be excluded from the study.

The following printed documents shall support the atlas prepared under the sub-task:

- A detailed report including the model used, implementation of the model to the work area, verification statistics, maps and the operations manual for the maps.

- The final report shall include the following parameters along with their legends:
  - Average and seasonal/monthly variations of long-term mean significant wave height;
  - Average and seasonal/monthly variations of mean wave energy flux;
  - Average and seasonal/monthly variations of variation coefficient of wave energy flux;
  - Average areal variations of mean wave energy flux for periods of 10 years;
  - Monthly and seasonal variability index of wave energy flux;
  - Areal variation of total wave energy potential (reserve) and discoverable wave energy potential (reserve) maps;
  - Annual/seasontal/monthly variability index of the vertical temperature gradient;
  - Annual/seasontal/monthly wind velocities map for wind at 100 m;
  - Monthly temperature and pressure maps;
Annual/seasonal/monthly power density maps;

- The power density map for wave energy shall be delivered separately along with long-term annual (average of all years), seasonal and monthly average power density layers. The legends, scales and electric energy potentials shall be indicated on the maps.

- The energy potential for large-scale power plants shall be provided (in MW) on basis of Turkey’s seas and specific locations. Eligible sites for electricity generation shall be reported together with the forecasted generation figures.

5. IMPLEMENTATION ARRANGEMENTS AND DELIVERABLES

A. Implementation Arrangements

- The Consultant is expected to cover the following expertise:
  - Wind energy technologies with a focus on off-shore wind power;
  - Understanding of renewable energy resources mapping coupled with experience in using GIS based tools;
  - Wave energy technologies.
- Previous experience with developing renewable energy atlases will be an asset.
- The Consultant will report to the Bank and liaise with the EBRD Operation Leader (“OL”), on all aspects of the assignment. This will be done via telephone, email and through periodical face-to-face meetings where required.
- All material produced by the Consultant within the scope of this assignment will be in line with the EU and the EBRD’s visibility rules.
- The Consultant shall ensure that appropriate disclaimer is provided on all deliverables/reports that are shared with the third parties.
- The Consultant will interview stakeholders such as public officials and associations if necessary for the access of information required for the assignment.
- Ad-hoc provision of information (maximum 4): if requested by the EBRD OL, the Consultant will furnish the EBRD OL, GDRE, and DGFREU with information in the form of written information relating to the assignment.
- The duration of the assignment will be approximately 9 months. The Consultant will be responsible for all travel and logistical arrangements necessary to undertake the assignment.

B. Deliverables

Unless otherwise agreed with the Bank, the Consultant will provide the following deliverables:

<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Content</th>
<th>Timeline</th>
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<tbody>
<tr>
<td>Kick-off meeting and presentation</td>
<td>A kick off meeting with the relevant stakeholders will be held in Ankara. The consultant is expected to introduce the team and the structure of the activity they foresee with a brief introduction of the proposed methodology</td>
<td>Within 2 weeks from assignment commencement</td>
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<tr>
<td>Inception Report</td>
<td>Preliminary proposals and data in relation to all tasks in the scope of work and a detailed timetable for the work to be carried out. Inception report will include an off-shore wind energy atlas for a selected region of</td>
<td>Within 8 weeks after the kick-off meeting</td>
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<td>Interim Report</td>
<td>An initial findings report building on the inception report, stakeholder feedback and the work that has been undertaken in the first 10 weeks following the inception report.</td>
<td>Within 10 weeks after the approval of the inception report</td>
</tr>
<tr>
<td>Draft Final Report</td>
<td>Draft report to include all of Task A, B and C together with the tools, data files and maps. The consultant is expected to prepare a manual for the use of the tools/maps within the draft report.</td>
<td>Within 20 weeks after the approval of the inception report</td>
</tr>
<tr>
<td>Final Report</td>
<td>Final report presenting the outcomes of all above tasks and digital maps and data files following the feedback from the Bank and MoENR.</td>
<td>Within 2 weeks after the approval of the draft final report</td>
</tr>
<tr>
<td>Final Workshop</td>
<td>A presentation summarising the main findings of the assignment in English. The workshop will also include a training session for MoENR on the developed tools.</td>
<td>Within 2 weeks after the approval of the final report</td>
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Turkey as described under Section 4.A.h above.
ANNEX – I: Data Provision for Wind & Wave Energy Potential Atlases

The Consultant will be provided with the following data and maps, following contracting of the assignment. The consultant is expected to make use of all these material while developing the deliverables for the assignment.

1. The vector map of the world covering all of Turkey including maps of seas, continents, provinces of Turkey, districts of Turkey, settlement places of Turkey and lakes of Turkey (This map is to be used as the main base for the atlases to be developed under the assignment);

2. Datasets including district administrative borders, village centres, creeks, brooks, rivers, streams, military zones, archaeological sites, and forest areas, to be procured from the relevant public institutions following certain protocols via GDRE (to be shown on the Atlases to be developed);

3. Following vector base maps (all with relevant legends and scales) to be used to show unusable areas on the atlases:
   a. Forestlands base map classifying the forest lands;
   b. Protected areas base map defining special environmental protection areas, wild life protection areas and national parks;
   c. Power transmission lines and transformer centres base map presenting the power transmission lines (along with their voltages) and transformer centres (along with their power values);
   d. Transportation networks base map indicating sea, air and land transportation network;
   e. Base bathymetric (depth) map of Turkey’s seas;
   f. Turkey's river network, natural lakes and power generation plants base map;
   g. Base map of provinces, districts, regions and urbanization areas (along with the population data);
   h. Topographical base map of Turkey;
   i. Seismic fault zones base map of Turkey;
   j. Base map of licensed and operational wind power plants;
   k. Topographical slope base map of Turkey;
   l. Turkey's bird routes map, RAMSAR and Natura 2000 area base maps;
   m. Navigational Map of Maritime Routes of Turkey;
   n. Navigation, Hydrograph, Oceanography Maps of Turkish Seas with Warnings;
   o. Base map of protected areas defining special environmental protection areas in sea areas, wild life protection sites and any areas and sites required not to be used;
   p. Map of Turkey's power transmission lines and transformer centres defining the places where the power transmission lines (along with their voltages) and transformer centres (along with their powers);
   q. Base map of Turkey's transportation networks indicating the sea, air and land transportation network;
   r. Base bathymetric (depth) map of Turkey’s seas;
   s. Master Plan of Turkey's provinces, districts and regions (along with the population data) and Administrative Borders;
t. Water pollution map of Turkey (if available);

These maps above will not be given in full detail. The areas excluding those mentioned above shall be determined as "Usable/Available Areas" and a single map of these areas will be provided to the Consultant;

4. Measurements and radiosonde data sets which will be used to verify Numerical Weather Prediction (NWP) model outputs;

The following data/maps are expected to be procured by the Consultant:

1. Topographical data in 30m or higher resolution from data sources such as SRTM;
2. Up-to-date land-cover data in 30m or higher resolution from data sources such as GeoCover, Corine Land Cover (Corine 2016, etc.).
ANNEX – II: Coordinates for Wind and Wave Energy Potential Atlases

The coordinates for the wind energy atlas is given in the table below.

<table>
<thead>
<tr>
<th>POINTS</th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>25.646819</td>
<td>47.473825</td>
</tr>
<tr>
<td>B</td>
<td>44.844937</td>
<td>42.473825</td>
</tr>
<tr>
<td>C</td>
<td>25.646819</td>
<td>34.988342</td>
</tr>
<tr>
<td>D</td>
<td>44.844937</td>
<td>34.988342</td>
</tr>
</tbody>
</table>

The points specified in the above table correspond to the corners of the shaded rectangle in the map below.

The wind potential atlas model is expected to include/consider the following:

- Main meteorological inputs (those that will be provided to the Consultant) for Numerical Weather Prediction (NWP) model shall be reanalysis (data obtained from the meteorological stations on the surface of the earth which is completely corrected and relocated on grid points where the digital weather prediction models can be used), radiosonde (vertical atmospheric measurement data) and meteorological surface measurement data;

- Re-analysis data (those that will be procured by the Consultant) to be used in model shall be generated using one of NCAR, NCEP, ECMWF or MERRA data for a period of 20 years;

- The technical characteristics (parameterizations, state of being hydrostatic or non-hydrostatic, initial physical conditions) of the model shall be reported;

- The NWP model shall run for the entire work area (as specified in Annex II) with a grid interval of 3 km or less;

- The NWP model shall be able to reflect and consider all meteorological effects (land, vegetation, seas and lakes, radioactive cooling, solar heating and convection etc.);

- All parameters of meso-scale NWP model shall be submitted in the form of time series in data file format;

- All parameters of the micro-scale model shall be submitted in data file format;

- Wind measurement data (data from ~50 meteorological masts to be provided to the Consultant) shall be used to test the accuracy of outputs to be obtained as a result of model running;

- Standard error methods to be used for data verification and accuracy tests shall be one or more of the following: than one of Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Mean Bias Error (MBE) and correlation coefficient;

- The accuracy tests shall be applied for all met masts and the results shall be reported accordingly;

- Actual weather and wind conditions for re-analysis data set shall be simulated retroactively for a minimum of 10 years from the contract date between the Consultant and the Bank. The model outputs shall be simulated and stored by monthly, daily and hourly means at multiple levels (1000 mb, 850 mb, 700 mb and 500 mb levels) with hourly intervals on the earth surface in terms of wind velocity and direction, temperature, pressure, cloudiness and radiation values. The model shall be an enhanced model taking into account the conservation of mass, conservation of momentum, conservation of energy, water phase changes, radioactive cooling, solar heating and sub-grid scale effects (turbulence and moisture convection);

- The climate characteristics of Turkey created making use of NWP model outputs shall also be included in the final report;
Along with the outputs to be obtained from the NWP model, high-resolution elevation and roughness data shall be inserted into the micro-scale wind flow model as input, and high-resolution wind source maps (wind velocity maps, wind power density maps, wind direction information, wind velocity and direction frequency distribution parameters, energy generation, Weibull parameters) shall be produced;

The micro-scale wind flow model shall be a Computational Fluid Dynamics (CFD) - based model so as to reflect and consider all the micro-scale meteorological effects (local effects of land and surface roughness variations, turbulence etc.). In case of working with non-CFD-based models, the Consultant is expected to justify that the CFD-based models are not required;

The micro-scale wind flow model to be used shall be a non-linear flow model running based on the principle of conservation of mass, energy and momentum;

The micro-scale and NWP models to be used shall be able to simulate the atmosphere three-dimensionally;

The micro-scale wind flow model shall be capable of increasing the precision (resolution) of the outputs obtained from the NWP model;

Information such as technical characteristics of micro-scale model and turbulence density etc. shall be included in the final report;

All calculated parameters shall be mapped as color-coded.

Wave Energy Potential Atlas model is expected to include/consider the following:

- The simulation period to determine the average wave energy potential shall be 20 years minimum whereas that for the calculation of repeated design waves shall be minimum 30.

- The temporal resolution of data (model output) to be collected shall be two hours or less. In cases where this is not possible, the Consultant is expected to seek for Bank’s approval.

- "Wind Wave" shall be taken as basis to determine the wave energy.

- Vertical current regime across water column in vertical profile shall be determined in current site. In order to obtain this result, the Consultant shall choose necessary sources and conduct procedures in the necessary format.

- The vertical temperature gradient can be determined separately for the first 100 m, subsequent 80 m and deep water regions, however, in case of any failure to do so, another approach can be adopted as a result of examination of source data.

- Date of the morphological, geological and geophysical structure of the sea floor of the working marine space shall be supplied from the relevant centres by the consultant.

- In the wave model, re-analysis data to be used for retrospective predication (hindcasting) shall be supplied from ECWMF-WAM, ECMWF ERA Interim, ECWMF ERA-20, NCEP, CERA 20 or equivalent sources. The model to be used shall cover minimum of 20-year data retrospectively from the date the contract is signed. The resolution of the model shall be 0.25° x 0.25° or less.

- The bathymetric data that may be necessary for wave model to pick up shallow water effects and the fetches that may cause waves, shall be procured from data sources such as GEBCO and UTOPO 1-2, EMODnet, etc. by the Consultant.

- To obtain salinity, density data and flow profiles for the initial (first 100 m) and transition (80 m) sea surface layer and deep-water sections, the current direction and velocity components as well as sea water level data shall be procured by the Consultant.

- The prediction model for the wave energy parameters shall run for a grid interval of 2 km or less.

- One or more third generation wave prediction models such as SWAN, WAM, Wave Watch III, MIKE 21 SW (or equivalent) which can model all the wave generation and distribution processes, shall be employed to predict wave data. Suitability of outputs for 2D/3D animations, easy access to wave and current models via one interface will be preferred.

- The wave prediction model shall be able to take atmospheric, bathymetric effects and the effects of change in water level into account.

- The model(s) to be employed shall be able to simulate the atmosphere, sea and sea floor in 3D.
• The model to be employed in current energy potential works shall be able to take account of atmospheric, bathymetric, water level, discharge, salinity, density and temperature effects and changes.

• The analysis needs to include the error statistics (BIAS, RMSE, MAE, SI, R) of significant wave heights and wave periods measured by buoys and supplied to the Consultant by the Bank and/or GDRE and predicted by the model. Significant wave height and periods for this analysis shall be:
  o 0.15 m (max) wave height and 0.5 s (max) wave period for BIAS;
  o 0.45 m (max) wave height and 1.3 s (max) wave period for RMSE;
  o R value of 0.70 (min) for both;
  o SI value of 50% for wave height and 25% for wave period;

• The verification tests within this sub-assignment shall employ observation data supplied by the Bank or the GDRE. In case the data is unavailable, the Consultant shall use analysis data from ECWMF-WAM (or equivalent) and satellite measurement data from Jason (or equivalent).