G. Step 4: area

a. Description

At step 2, we have compared the 66 area selected at step 1 by regarding not only the economical aspects (wind speed, proximity to the network…) but also the environmental and sociological aspects as the energy balance of the area.

The criteria used are described at chapter C of the report.

The table presenting the ranking of the 66 area retained at step 1 is presented in the annex of the report.

b. Conclusion of step 2:

As the highest wind speeds in Kazakhstan are measured along the coast of the Caspian Sea, most of the locations from this region were ranked among the first after step 2 (except location too far from the network). So if we had kept only the 15 best ranked locations for step 3, we would have run a detailed calculation almost only for the region of the Caspian Sea and we would have let aside interesting area in the rest of Kazakhstan.

As our purpose is to propose locations for wind mast for future Wind parks all over Kazakhstan, then we have selected more of the best locations until we have 15 WWA areas for step 3 detailed calculations. As a matter of fact, 24 locations have been retained

c. Recommended sites for additional measurement

Ranking	Numerical quotation	Location	Coordinates (Geo WGS 84)		Oblast	average wind speed WWA and Wasp	average wind speed Kazgydromet
			East	North			
1	**5,165**	70,0 42,5_site 2 JANAMUSK	69°39'32	41°47'58	**Süd-kasachstanische**	**8,5**	_
2	**5,165**	70,0 42,5_site 1 SASTOBE	70°07'54	42°35'49	**Süd-kasachstanische**	**8,5**	_
3	**4,735**	67,5_47,5 site 1 OULITAU	66°56'14	48°39'06	**Karagandinskaja**	**8,3**	_
4	**4,480**	50_45_site 1 FORT-SCHEVCHENKO	50°17'43	44°28'15	**Mangystauskaja**	**8,2**	**8,02**
5	**4,135**	72,5_52,5 site 1 EREMENTAU-SUKUMTAU	73°14'01	51°28'39	**Akmolinskaja**	**7,7**	_
6	**3,715**	75_50 site 2 EZINDIOULAK	76°23'03	49°51'05	**Karagandinskaja**	**7,7**	_
7	**3,585**	52,5_45_site 1 CHOLTAU	53°24'06	44°14'56	**Mangystauskaja**	**7,8**	_
8	**3,512**	50_45_site 2 KACHSO	50°50'04	44°34'27	**Mangystauskaja**	**8,2**	**8,02**
9	**3,360**	75_50 site 1 KARKARALI	75°22'49	49°24'39	**Karagandinskaja**	**7,7**	_
10	**3,215**	72,5_52,5 site 2 STEPNOGORSK	71°58'24	52°24'31	**Akmolinskaja**	**7**	_
11	**3,159**	52,5_47,5_site 1 ATYRAU-Lievoberejnar	51°43'37	46°55'42	**Atyrauskaja**	**7,3**	_

12	**3,131**	52,5_45_site 2 PRORVA	53°08’37	45°55’14	**Atyrauskaja**	**7**	**8,05**
13	**2,977**	52,5_47,5_site 2 DJARLIBAS	52°43’15	46°57’57	**Atyrauskaja**	**7,7**	_
14	**2,623**	67,5_50 site 2 CHOUBARKOL	66°33’22	48°54’33	**Karagandinskaja**	**7**	_
15	**2,553**	67,5_50 site 3 ARKALYK	66°53’30	50°15’04	**Karagandinskaja**	**6,2**	**7,68**
16	**2,434**	67,5_47,5 site 2	67°27’29	47°53’42	**Karagandinskaja**	**6,8**	_
17	**2,371**	72,5/47,5_3_6,7 AGADIR	72°45’42	48°18’33	**Karagandinskaja**	**6,7**	_
18	**2,244**	72,5/47,5_2_6,7 KIIK	72°56’52	47°38’19	**Karagandinskaja**	**6,7**	_
19	**2,020**	67,5_50 site 1 between CHOUBARKOL and CHANTIKOL	68°23’46	49°17’59	**Karagandinskaja**	**7**	_
20	**1,927**	52,5_47,5_site 2 INDER	51°50’01	48°33’11	**Atyrauskaja**	**6,0**	**6,81**
21	**1,656**	72,5_50 site 1 KARAMOUROUN	75°25’30	49°25’06	**Karagandinskaja**	**6,3**	_
22	**1,656**	65_50 site 1	65°32’55	50°28’44	**Kostanaiskaja**	**6**	**6,01**
23	**1,627**	57,5/50,0_1_6,0 AKTOBE	57°19’16	50°19’17	**Aktubinskaja**	**6,0**	_
24	**1,336**	57,5/50,0_4_6,0	58°21’25	48°40’26	**Aktubinskaja**	**6,0**	_

H. Conclusion of part I report: Comments on results

The sites retained at each step are among the windiest shown by the calculation made at step 1 and 3 except sites located above 1500 that have all been let aside for obvious reasons. But it does not mean that retained site will not present difficulties due to extreme meteorological or topographical conditions. The accessibility has been approximately assessed but the slope of access roads could not be calculated with tools at our disposal and a visit of the best 12 to 15 sites seems necessary to retain only the 8 most suitable for the implementation of wind parks.

All this sites are offering exceptionally good wind potential, as a comparison, Most of wind parks built in France and even in Enfland are presenting average wind speeds at 65 m between 5,8 and 7 m/s, very rarely more. So the wind speed calculated here at 50 m are very promising and sites that are not listed here should not be let aside too for future implementations. The main difficulty that will probably occur on most of selected sites is a moderate to strong icing phenomenon that seems unavoidable in Kazakhstan.

The report also shows the great level of reliability of the proposed list of Kazselenergo project. 5 of their sites are among the best sites selected at step 4 and the other should be considered as interesting because they are well known and located in area with quite reasonable meteorological conditions. Actually electrical lines and substations must be accessible a year long so we can assume that sites proposed by Kazselenergo Project are always accessible.

a. Icing phenomenon in Kazakhstan: Wind turbines and Frost (see documents about frost in Appendix)

According to the documents collected during the first part of the Wind monitoring program and to witnesses average temperatures in winter in Kazakhstan are between -10° C around the Caspian Sea down to – 27°C in the area of Almaty. Temperature can even reach -35°C quite frequently in Oblasts of East Kazakhstan.

Almost all sites selected in this report will have to be equipped with heating system for measurement sets and also with humidity sensor to be able afterward to estimate the frequency of icing phenomenon.

Some areas in Kazakhstan seem to suffer particularly from frost, especially the hills around Jezkagan, probably because they are the first high terrain with cold temperature when coming from the Caspian Sea. The map of temperature in January and the map of rain quantity (se appendix) show higher level of rain in the hills combined with lower temperature. So the access to sites located around Jezkagan between December and February seems more than uncertain.

I. Limits of the methodology used

The proposed methodology laid on the availability of some key documents and data, unfortunately, not all of them could be gathered before the deadline of the first part of the report. This fact increase the inaccuracy of the conclusions presented in the report

a. Projection systems for maps used:

All maps used to locate sites were in geographical coordinates with spherical projection system but there some different spherical projection and we did not always have the information about which system was a map made with.

b. Accuracy of the maps used

Some of the map used, particularly the map of the electrical network (KEGOC, see in appendix) is relatively inaccurate and shows not which system was used to make it. To measure the distance between a point located for its wind potential on a physical map and the closest sub-station or electrical line, it was always necessary to make manual corrections estimate the position of the selected site. This may cause some distances written in the report to be inaccurate. No other source of information about the position of lines and substations exists. The maximal acceptable inaccuracy is 5km. This mistake can cause an error of 5 % for the quotation of electrical network proximity and as a consequence 2% in final mark of selected sites

c. Availability of requested data

To provide more accurate calculation of the wind potential of Kazakhstan before sites selection, selected process laid on RAW data from one meteorological station per WWA area over the same period or even with longer time period for long term correlation. But, it was not possible to get these data.

J. Glossary

World Wind Atlas: The World-Wind-Atlas was developed from meteorological data of a global weather model. This model covers the whole globe. It is run by the National Center of Atmospheric Research, NCAR, Bolder USA and by the National Center for Environmental Prediction NCEP, USA. The model makes use of observations from satellites, balloons, meteorological surface stations, weather ships and several other sources which are collected and provided daily by the World Meteorological Organisation WMO. The meteorological data source of this atlas was provided by the NCAR / NCEP. For proper usage of the data received from the NCAR / NCEP they must be provided at unique heights. For that purpose the same method was applied as is commonly used to analyse radiosonde wind profiles. In the horizontal the data are equally distributed on a geographical grid of 2.5 degrees. According to WMO standards data are available each 6 hours.

The World-Wind-Atlas includes wind roses and time series only over the land masses and in the near off-shore areas. Maps do cover the whole globe – including the open seas.

Like the European Windatlas1 the new World-Wind-Atlas serves above all to determine the wind potential of large areas. In addition maps can be created and time series are available. For the detailed analysis of individual locations of wind energy systems the Atlas method does not provide a sufficient data basis. Measurements at the planned locations should always be taken. However, in combination with measurements the World-Wind-Atlas allows to assess the long-time wind potential. This can be performed with the method called “Measure Correlate Predict” MCP. In order to apply the MCP, the correlation from the time series of the World-Wind-Atlas and the measurements must be calculated. If one finds a sufficient high correlation between the measurements and the wind series from the Atlas, the long-term wind potential can be determined.

Raw data: Data from any meteorological station (real or virtual) are saved in ASCII format regularly, measurements are not rectified in anyway, that is why raw data from a meteorological station contains every single measurement (temperature, wind speed, direction…) done during studied period of time.

Meteorological station from the World Wind Atlas: Virtual station: As described in the definition of the World Wind Atlas, data from WWA are coming from many different sources (satellites, balloons…) and must be put together. the data are equally distributed on a geographical grid of 2.5 degrees, so every 2,5 degree, meteorological data are available as if collected by a meteorological station. That is why the term Virtual meteorological station from the WWA is sometime used in the report (WWA virtual station).

WWA area X: 2,5*2,5 degrees area (200*220km) centred on the location of WWA virtual station X.

Hellman model: The wind velocity changes with height as a function of the terrain roughness. It is possible to calculate the velocity at a given height, if the velocity at a specified height at the same location and the terrain roughness coefficient (called Hellman’s height coefficient, factor α, or simply α) are known. In a general way, one can write the equation for α as:

$$\alpha = \left(\frac{V(h_2)}{V(h_1)} \right) \ln \left(\frac{h_1}{h_2} \right)$$

Where V(h2) and V(h1) are the velocities at the heights h2 and h1.

Roughness length: The distance above ground level at which the wind speed should theoretically be zero, due to the roughness of the surface at this point. Roughness length is used by model as Hellman's to calculate the wind speed at any height considering the roughness of the surface where measurement is done. Kazakhstan is more than 90 % semi desertic with really few inhabitants so the roughness length is quite stable over Kazakhstan. As first approximation it is possible to consider only one roughness length for all on-shore surfaces.

WASP: WAsP Engineering is an umbrella of activities including measurements, analysis and modelling of those properties of the wind, which are relevant for the estimation of loads on wind turbines and other civil engineering structures situated in all types of terrain. The project is funded by the Danish Energy Agency (EFP). Most of the results of these activities are unified in the computer program called WAsP Engineering.

K. Annexes