CLIMATE RISKS AND THEIR IMPACT ON DEVELOPMENT OF RES IN RURAL REGIONS OF KAZAKHSTAN

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Abstract. The paper presents an overview of the climate risk impact on the development of the renewable energy facilities in the rural regions of Kazakhstan. Brief introduction in the current situation with climate changes forecasts and evaluation of the climate risks is presented in the article. Rural regions are the most sensitive areas to climate change. In addition to the actual farming, there is also an acute need to provide these areas with electrical energy. Another aspect is the necessity of considering the increasing occurrence of climate catastrophes and their impact on the facilities of power plants with renewable energy sources. Examples of such impact are also described in the article. The model of the development of the renewable energy sources in the specific region of Kazakhstan is provided. The climate risk factor has been introduced and considered in the model. Several ways of climate risk mitigation are considered in the paper: power grid backup; proper selection of the type of renewable energy sources (RES) based on climate risks; development of the energy storage facilities; regional grids interconnection and unit commitment. Nowadays a lot of renewable energy projects are realized worldwide. Kazakhstan adopted several programs of the renewable energy sources development as well, but climate risks have not been considered. We believe that without taking into account climate risks it is impossible to build sustainable long-term development of renewables, especially in the rural areas.

Keywords: climate risks, climate change, renewable energy, rural regions, grid interconnection, unit commitment, energy storage, power grid backup, sustainable development.

Introduction

According to the United Nations press release, climate change is the ‘biggest threat modern humans have ever faced’ [1]. It is a global problem which could affect all regions and countries in the world. Kazakhstan is not an exception.

Climate is a statistical concept that is related to the weather over a long period of time. A description of climate includes information on, e.g., the average temperature in different seasons, rainfall, and sunshine. Also, the risk of unusual events such as storms, disasters is covered by the ‘climate’ term [2].

Consequently, the change in the long term of such parameters as the average annual temperature, the speed and direction of movement of air masses, the number of sunny days per year are the parameters of climate change. First of all, these parameters are of interest to us from the point of view of the development of renewable energy sources.

At the same time, of course, the forecast for catastrophic climatic events, such as drought and storms, also has a great influence on the development of RES in rural areas. Above all, these events have an impact on the very possibility of developing farming in these areas. What is also important, such events like storms have direct influence on electricity production. To prevent damages of wind turbines, it is a necessity to stop their operation and the drop of electricity production could reach 70% [3].

Kazakhstan has a big potential for renewable energy facilities development [4], but in addition to other aspects the climate change risk factor should be considered and applied to the model of RES facilities selection and development forecasting. For such model creation and climate risk factor implementation with specific values and numbers, the north region of Kazakhstan was chosen.

1. Materials and methods

1.1. Global climate changes scenarios and their impact on the renewable power generation process

We will not cover here all aspects of climate change scenarios, but only what is mostly related to the renewable energy facilities, specifically wind and solar power.

In 1988 the Intergovernmental Panel on Climate Change (IPCC) was created by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) [5].

The main target of the organization is to provide governments and society with the latest information regarding climate change problems on the global level. At the same time, there are a lot of studies and institutions on the countries and regional level focused on the climate changes problem. According to the latest IPCC climate change mitigation report, there are 8 scenarios (C1-C8) which have been considered till 2100. An increase in mean annual temperature (1.5 ºC, 2 ºC, 2.5 ºC, 3 ºC, 4 ºC), combination of warming increase steps and the likelihood of this process are the basis for these scenarios (Figure 1) [6].

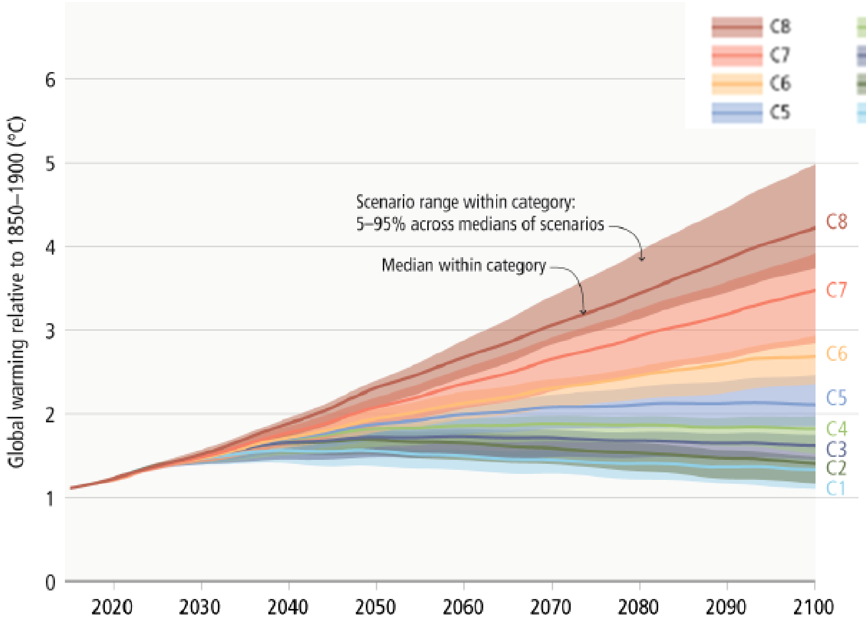

Fig. 1. **Median global warming across scenarios in categories from C1-C8 [6]**

An increase in temperature will upset the climate balance, and accordingly, air flows will change, which in theory should influence the possibility of generating wind power.

IPCC latest report states that there will be no huge impact on the possibility of using wind energy as a renewable energy source. More importantly, the statement that no major changes in the level of wind energy generation are foreseen is based on a fairly small amount of data, in most cases in Europe [6].

Other studies give certain predictive values, for example, a study that was carried out for Lithuania gives a forecast of a decrease in the possibility of near-surface wind speed (10 m) up to 8% till the end of 21st century [7]. One more example: according to the study [8], European wind farms, which are planned to be installed by 2050, will remain mostly with a stable generation (about ± 5% for different climate scenarios) during the 21st century. But in some areas, for instance, Iberian peninsula, wind power production could decrease up to 15% [8] with some climate change scenarios what is a real significant value. Wind power output changes two times higher than the wind speed change. For Mediterranean region wind power production decrease could reach 6-12%, but at the same time there are some scenarios with 4-8% power production increase [9]. Thus, there is a certain difficulty in obtaining sufficiently accurate forecasts and figures in the long term, because there are quite a lot of scenarios for the development of events and a lack of data [6; 10].

With regard to the impact of climate change on generation using solar energy, it is noted that these changes will not have a significant impact. Changes may be within < 3% until the end of the 21st century [6].

1.2. Kazakhstan's climate changes and wind forecast

To obtain information and visual data on Kazakhstan in terms of climate change and the predicted wind speed, we used the IPCC WGI Interactive Atlas. The Atlas uses the latest IPCC data and climate change scenarios [11].

For the North regions of Kazakhstan, the forecast until the end of the 21st century in terms of the wind speed shows its gradual decrease (Figure 2) [11].

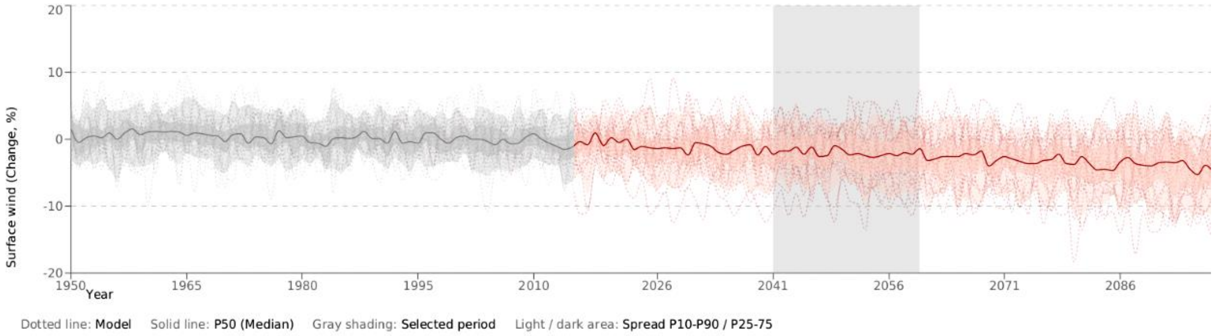

Fig. 2. **CMIP6 – Surface wind change forecast for the North Kazakhstan area, % [11]**

This tool uses all available models and scenarios. The numerical results of the simulation and the values of the change in the wind speed are presented in Figure 3, 4 [11].

Considering the worst scenario, annual wind speed decrease could reach up to 9.9% till the end of the 21st century. For the medium-term period (2041-2060) the value is 5.7%. For the short-term period (2021-2040) the value is 4.3% [11].

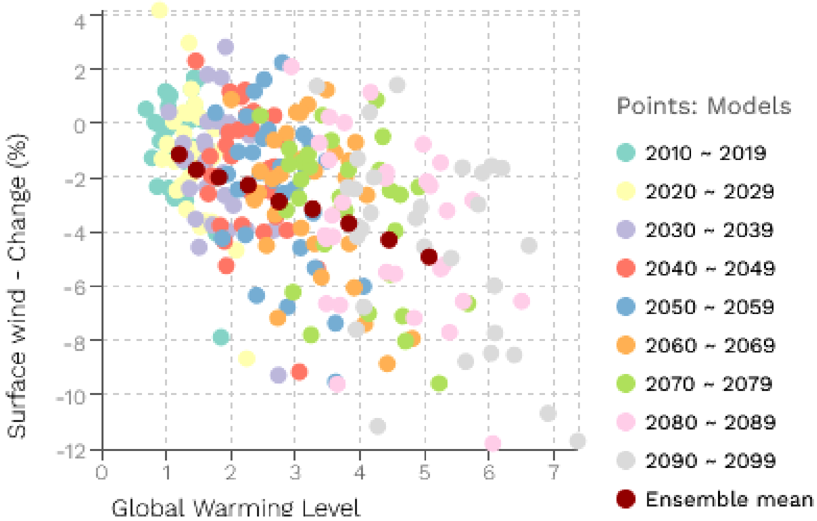

Fig. 3. **CMIP6 – Surface wind change forecast for the North Kazakhstan area, 31 models, % [11]**

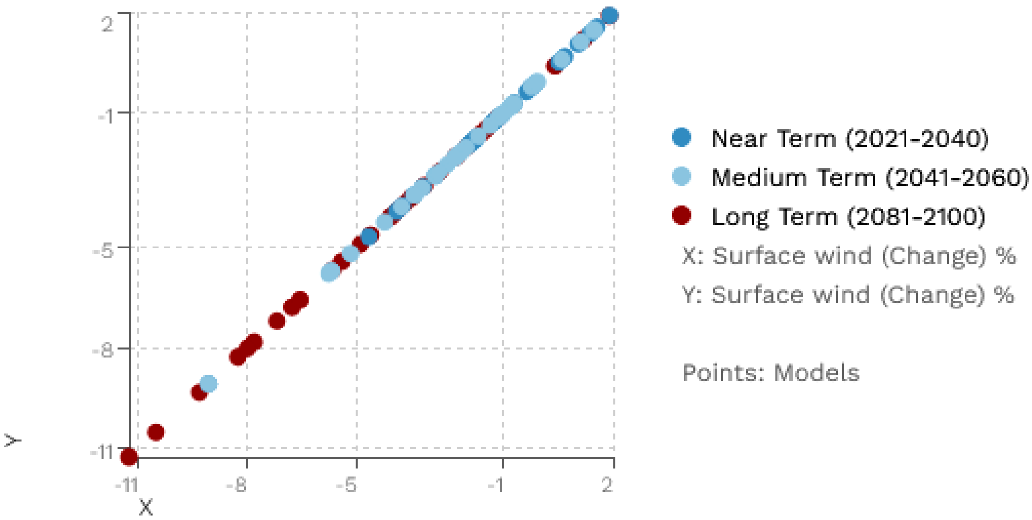

Fig. 4. **CMIP6 – Surface wind change forecast for the North Kazakhstan area, 31 models, % [11]**

Thus, for the purposes of modeling the conditions for the development of renewable energy sources, we took three values for three periods of time: 2021-2040 – 4.3%, 2041-2060 – 5.7%, 2081-2100 – 9.9%.

1.3. Climate catastrophes and their impact on the facilities of RES

A few words about wind generation and climate catastrophes (storms). What is important to know is that most wind turbines have wind speed limits for operation. Operation of a wind turbine is not starting from zero wind speed but from a certain speed value. This value is called ‘cut-in’ speed. Also, the turbine cannot operate beyond a certain speed, as too high a wind speed can damage the turbine mechanisms. This speed is called ‘cut-out’ speed. The average values of these speeds are shown in Figure 5 [12].

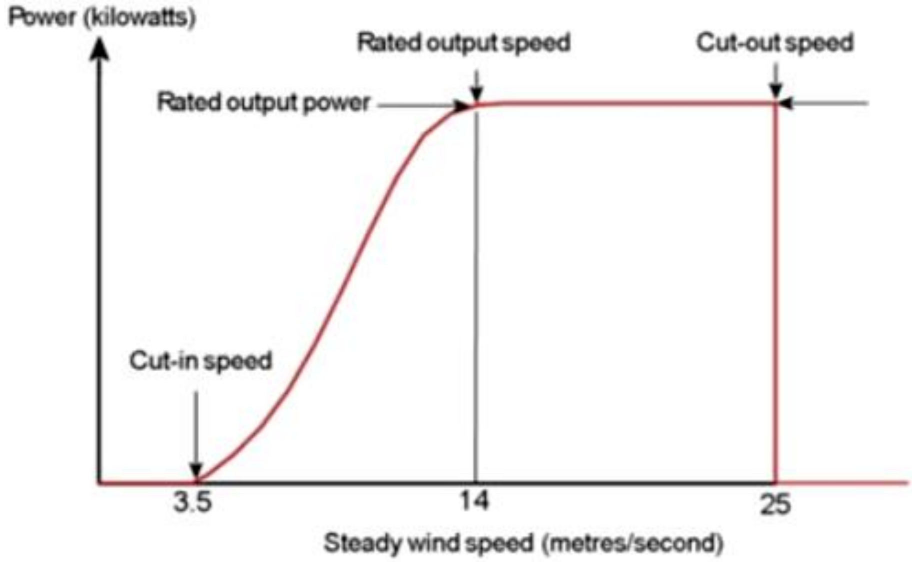

Fig. 5. **Typical wind turbine power speed with steady wind speed [12]**

Figure 6 shows an example of what can happen to a turbine if the blades are not stopped spinning at high wind speeds [13].

Fig. 6. **Effects of a storm on a wind turbine. Image: Stuart McMahon/Getty [13]**

According to the forecast [6] the probability of occurrence of such events and the geography of their distribution will increase due to climate change. Therefore, this should be taken into account when building new RES capacities and operating existing ones.

2. Results and discussion

According to the analysis, there is no doubt that the wind speed will change. To analyse the impact of the process of renewable energy source development in the rural regions of the North Kazakhstan a modelling process was performed.

The Global Wind Atlas was used for wind energy potential calculation [14]. Mean wind speed map for 50 m heights is represented below (Figure 7) [14].

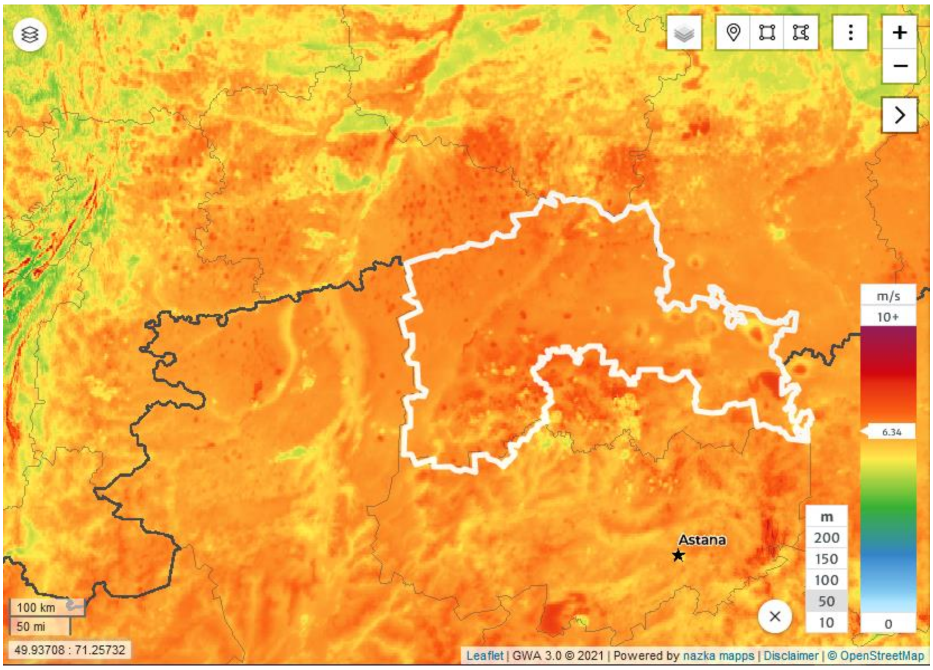

Fig. 7. **Mean wind speed map for 50 m heights [14]**

Mean wind speed was calculated as 6.93 $m \cdot s^{-1}$ and the average wind power potential is 375 $W \cdot m^{-2}$ (Figure 8) [14].

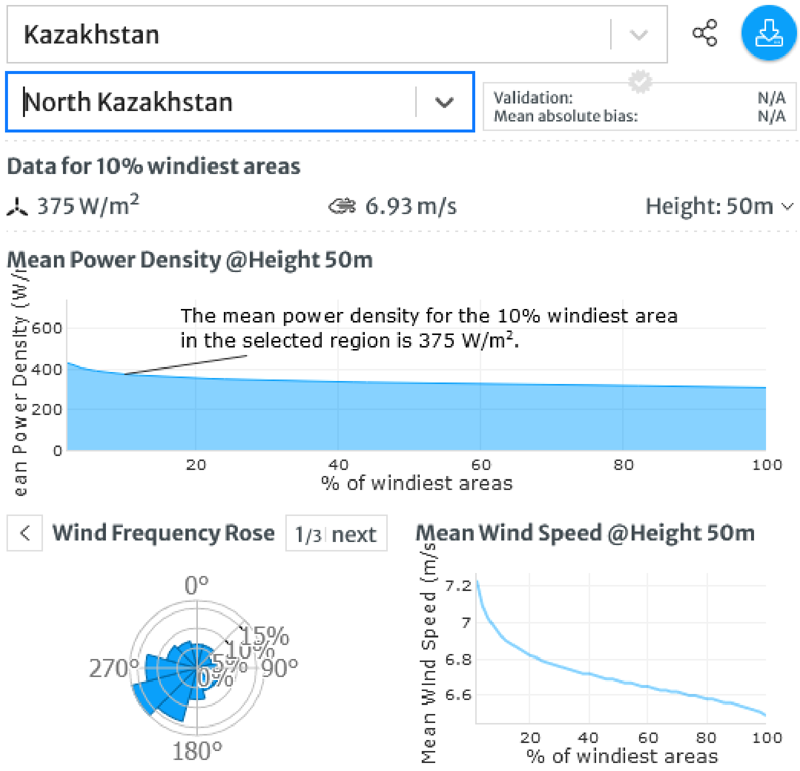

Fig. 8. **Wind calculacion data for 50 m heights [14]**

For forecasting purposes, considering climate risks, it is necessary to introduce a correction factor for each forecast period, which will be proportional to the predicted changes in the wind speed in future.

The turbine power depends on the wind speed according to the relation [15]:

$$P = \pi/2 \cdot r^2 \cdot v^3 \cdot \rho \cdot \eta, \tag{1}$$

where r – turbine radius;
v – wind speed;
ρ – air density;
η – efficiency factor.

The calculation results are presented in Table 1.

Table 1

Wind power potential calculations considering the climate change factor for the rural regions of the North Kazakhstan

Period, years	Wind speed climate factor, %	Wind speed, $m \cdot s^{-1}$	Wind power, $W \cdot m^{-2}$
Base period (2022)	0	6.93	375.06
2021-2040	-4.30%	6.63	328.73
2041-2060	-5.70%	6.53	314.51
2081-2100	-9.90%	6.24	274.33

As we can see, there is a rather significant decrease in the wind potential of the region, when the worst-case climate scenario is implemented. It is necessary to compensate for this power loss by adding solar generation to wind generation, considering, for instance, the potential of solar energy in this region as it is not affected seriously by the climate change process [6; 16].

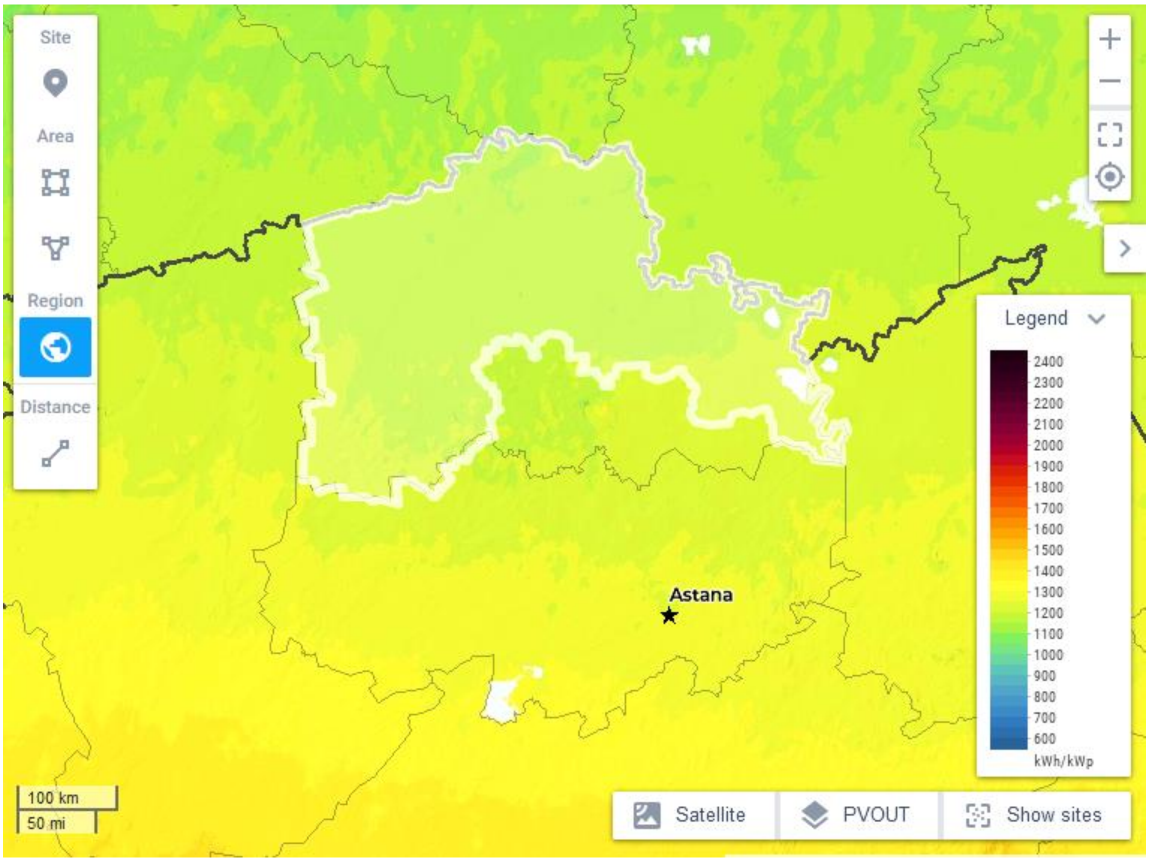

Fig. 9. **Photovoltaic power output for the North Kazakhstan [16]**

The combination of solar and wind power will make it possible to optimally use the potential of renewable resources in the region in the long term [17; 18].

Another prospective renewable energy source in the region is biofuel. Kazakhstan's rural regions have a significant biofuel energy potential. However, this type of renewable energy source is underestimated and undeveloped [4].

At the same time, it is also necessary to consider the possibility of using energy storage devices and connecting to the unified power system, considering and solving the unit commitment problem [4; 18].

As it was mentioned above, there are not so many studies on our research topic, mainly in the EU and US [19], but most of them show a negative climate change impact on the wind energy production and the necessity of having a backup with solar or biofuel power. For instance, Latin America and Caribbean research study case provides us with such scenario [20].

Conclusions

Climate change will affect all countries and aspects of our life. Renewable energy is considered as a driver to improve life and climate on the planet, but at the same time climate change can affect renewable energy development. Nowadays, there are not many studies on this topic, but every year there are more and more of them.

According to our research, at the end of the 21st century the Northern rural regions of Kazakhstan will face a problem of declining surface wind speeds. This decrease can reach up to 10%. At the moment, wind energy potential of the region is about 375 $W \cdot m^{-2}$. But in the worst-case scenario, the wind energy potential can drop down to about 274 $W \cdot m^{-2}$.

This is quite a significant amount, therefore, solutions to the problem have been proposed, such as using solar energy, electricity storage and considering the possibility of integrating renewable energy sources into the energy system.

Also, when designing renewable energy sources, the risks of storms, which will occur more often and not only in coastal areas, should be taken into account.

Kazakhstan has great potential and plans for the development of renewable energy sources, therefore, it will be necessary to consider the climate risk factor in the development and take the necessary actions to level the negative impact of the climate change process.

References

[1] Climate Change 'Biggest Threat Modern Humans Have Ever Faced', World-Renowned Naturalist Tells Security Council, Calls for Greater Global Cooperation. UN press release, SC/14445, 23 February 2021. [online] [25.02.2022] Available at: https://www.un.org/press/en/2021/sc14445.doc.htm

[2] What is climate? What is climate change? Climate Europe, Linking Science and Society, [online] [26.02.2022] Available at: https://www.climateurope.eu/what-is-climate-and-climate-change/

[3] Cutululis N.A., Litong-Palima M., Sorensen P. Offshore wind power production in critical weather conditions. European Wind Energy Conference and Exhibition 2012, EWEC, Copenhagen, Denmark, 16-19 April 2012; Proceedings, Volume 1, pp. 74-81.

[4] Zavadskiy V. Unit Commitment in a dispersed power system involving renewable energy, LAP LAMBERT Academic Publishing, ISBN-13:978-3-659-82615-3; ISBN-10:3659826154; EAN:9783659826153, 2018

[5] About the IPCC. The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change. [online] [27.02.2022] Available at: https://www.ipcc.ch/about/

[6] IPCC Sixth Assessment Report. Mitigation of Climate Change. [online] [05.04.2022] Available at: https://www.ipcc.ch/report/ar6/wg3/

[7] Jankeviciene J., Kanapickas A. Projected Near-Surface Wind Speed Trends in Lithuania. Energies 2021, 14, 5425. DOI: 10.3390/en14175425

[8] Tobin I., Jerez S., Vautard R., Thais F., van Meijgaard E., Prein A., Déqué M., Kotlarski S., Maule C.F., Nikulin G., Noël T., Teichmann C.. Climate change impacts on the power generation potential of a European mid-century wind farms scenario. Environ. Res. Lett. 11 (2016) 034013. DOI: 10.1088/1748-9326/11/3/034013

[9] Devis A., Van Lipzig N.P.M., Demuzere M. Should future wind speed changes be taken into account in wind farm development? Environ. Res. Lett. 13 (2018) 064012. DOI: 10.1088/1748-9326/aabff7

[10] Collins M., R. Knutti J. Arblaster J.-L., Dufresne T., Fichefet P., Friedlingstein X., Gao W.J., Gutowski T., Johns G., Krinner M., Shongwe C., Tebaldi A.J., Weaver M. Long-term Climate Change: Projections, Commitments and Irreversibility. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2013.

[11] IPCC WGI Interactive Atlas. https://interactive-atlas.ipcc.ch/ [08.04.2022]

[12] How Do Wind Turbines Survive Severe Storms? Office of Energy Efficiency & Renewable Energy, U.S. Department of Energy, [online] [26.03.2022] Available at: https://www.energy.gov/eere/articles/how-do-wind-turbines-survive-severe-storms

[13] Why storm winds turned wind turbine into a fireball, NewScientist, Technology, 10.07.2022, [online] [26.03.2022] Available at: https://www.newscientist.com/article/dn23848-why-storm-winds-turned-wind-turbine-into-a-fireball/

[14] DTU Wind Energy, Department of Wind Energy, Global Wind Atlas. [online] [08.04.2022] Available at: http://globalwindatlas.com/index.html

[15] Wind Turbine Power Calculator. [online] [08.04.2022] Available at: https://rechneronline.de/wind-power/

[16] The World Bank Group, Global Solar Atlas. [online] Available at: http://globalsolaratlas.info/ [08.04.2021]

[17] Zavadskiy V., Anifantis A.S., Santoro F. Solving of renewable energy sources usable potential evaluation in remote rural area on example of Basilicata region (Southern Italy) - Case study//

ENGINEERING FOR RURAL DEVELOPMENT, Jelgava, 22.-24.05.2019, DOI: 10.22616/ERDev2019.18.N138

[18] Zavadskiy V., Revalde G., Possibility of using electric power storage systems in rural regions with combination of renewable energy sources for autonomous energy supply // ENGINEERING FOR RURAL DEVELOPMENT, Jelgava, 22.-24.05.2019, DOI: 10.22616/ERDev2019.18.N481

[19] Brettman A. PNNL, Preparing for Climate's Impact on Renewables, Pacific Northwest National Laboratory, April 21, 2021, Web Feature, [online] [25.04.2022] Available at: https://www.pnnl.gov/news-media/preparing-climates-impact-renewables

[20] Santos da Silva S.R., Hejazi M.I., Iyer G. et al., Power sector investment implications of climate impacts on renewable resources in Latin America and the Caribbean, Nat Commun 12, 1276 (2021), DOI: 10.1038/s41467-021-21502-y