Prospects for the development of Central Asia energy-deficient regions applying renewable energy and digital technology

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Abstract. The object of research in the article is the methodology for digital design of renewable energy facilities of Central Asia energy-deficient regions. This methodology is based on the creation of multi-layer geo-information space. Each layer of this space is an information map, containing necessary data for the design and implementation of renewable energy facilities for the development of energy-deficient regions. Designing map layers takes different approaches, depending on the type of information needed. In Central Asia as well as in the global energy industry is undergoing an energy transition and a regulatory policy for renewable energy in the electricity sector is being implemented, but introduced renewable capacities are connected to centralized power supply and do not currently contribute to the development of remote areas. Taking into account the availability of sufficient renewable energy resources technical capacity, a reasonable solution is the introduction of renewables generating facilities. This allows improving energy efficiency by reducing losses during transmission and distribution of electricity due to proximity to the consumers and improving the environmental situation in energy-deficient settlements by decreasing harmful emissions. Potential analysis confirms the possibility of implementing an energy strategy with the prospect of developing renewable energy projects in Central Asian countries.

1. Introduction
The object of research is the methodology for digital design of renewable energy facilities of Central Asia energy-deficient regions.

The purpose of this study is to develop a digital space to improve energy efficiency, energy and environmental safety of energy-deficient regions of Central Asia through the introduction of renewable energy sources.

Research objectives: 1) analyze the current state of energy supply, determine development trends and the environment state in Central Asia; 2) analyze the state laws regarding renewable energy sources in Central Asia; 3) develop a methodology and basic principles for a digital space formation for the implementation of renewable energy facilities and the development of energy-deficient regions of Central Asia.

The world is currently undergoing an energy transition to the widespread use of renewable energy sources (RES) and the displacement of fossil fuels under the influence of changes in energy policy and the development of new technologies [1, 2]. This transition affects both the energy sector and the
economies of countries, the environment and the world in general, through the introduction of environmentally friendly renewable energy facilities. According to IRENA 2020 report, the share of renewable energy sources in the installed capacity (IC) of the global electric power industry at the end of 2019 reached 34.7% [3]. Renewable energy facilities installed capacity in the world is more than 2,300 GW by the end of 2018, which is 26.2% of the total. The IC of wind power plants (WPP) in 2019 amounted to 623 GW and increased by about 3.5 times since 2010. In 2018, 135 countries applied renewable energy regulatory policies (for example, preferential tariffs or utility quotas), up from 75 countries in 2010. In a number of countries, investment in research and development, as well as the industrial strategy have significantly reduced the cost of renewable energy technology and attracted private sector funding.

The countries energy policy has a significant impact on the development of world energy. Central Asia is also undergoing an energy transition, a regulatory policy for renewable energy in the electricity sector is being implemented to ensure the reduction of carbon dioxide (CO₂) emissions, increase the growth of electricity production in energy-deficient regions, and improve energy efficiency. Below are the adopted state laws regarding renewable energy in Central Asia on the example of Kazakhstan and Uzbekistan:

- The concept of the Republic of Kazakhstan transition to the “green economy” to 2050 (2013);
- Strategy “Kazakhstan-2050” (2012);
- Law of the Republic of Kazakhstan “On Supporting the Use of Renewable Energy Sources” (2009);
- Decree of the Government of the Republic of Kazakhstan dated October 5, 2009 No. 1529 “On approval of the Rules for monitoring the use of renewable sources”;
- Law “On the Use of Renewable Energy Sources” (2010, as amended in 2015);
- Law “On Electricity” (2014);
- Decree of the Republic of Uzbekistan President “On measures for the further development of alternative energy sources” (2013);
- Resolution of the Republic of Uzbekistan President on the program of measures for the further development of renewable energy, energy efficiency in the sectors of the economy and social sphere for 2017-2021 No. PP-3012. from 26.05.2017;
- Resolution of the President of the Republic of Uzbekistan on measures to ensure the rational use of energy resources No. PP-3379 dated 08.11.2017.

According to the studied regulations, Central Asia has an active policy regarding the use of renewable energy sources [4, 5, 6]. In Kazakhstan, in the first of the Central Asian countries it has developed a strategy of transition to a low carbon economy and renewable energy. In addition, Kazakhstan is the only country in Central Asia that has adopted a long-term strategy – “Kazakhstan-2050”, in which special attention is paid to the diversification of energy sources in total energy consumption. According to this strategy, it is necessary to increase the share of renewable energy sources to 50% by 2050. Thus the percentage of generating facilities will be as follows: 39% - solar and wind energy; 14% - nuclear and hydropower; 16% - gas CHP; 31% are coal CHP. To achieve these indicators in Kazakhstan decided to invest at least 1% of GDP in the development of the strategy, which is 3-4 billion dollars per year [7].

In the adopted state laws regarding the introduction of renewable energy sources in the energy supply of Central Asia, special attention is paid to environmental aspects. The total reduction in greenhouse gas emissions from energy sector when using renewable energy sources in Kazakhstan can range from 500 thousand tons to 2.5 million tons of CO₂ [8]. According to NREL report, the production of 1 MW of wind energy prevents about 2,600 tons of CO₂ emissions. Currently, Kazakhstan and Turkmenistan have some of the highest per capita CO₂ emissions from fuel combustion in Central Asia (Figure 1) [9].
In connection with these indicators, the role of RES in reducing greenhouse gas emissions will be essential for Kazakhstan. So, at the conference on climate change in Copenhagen, as part of the implementation of the Kyoto agreements, Kazakhstan took voluntary commitments to reduce greenhouse gases: by 2020 by 15%, by 2050 - by 25% in relation to the level 1992 year.

The total installed capacity of generating facilities in Central Asia is more than 50 thousand MW, of which about 50% belongs to Kazakhstan. Figure 2 shows the capacity of generation facilities in Central Asia and the power transmission network. According to the report, the total generation from 2000 to 2015 increased by more than 50 thousand GWh per year, and is more than 200 thousand GWh per year [9]. Electricity production by type of energy source in Central Asia is shown in Figure 3. Thus, power plants in Central Asia are located in accordance with the geographical location of energy sources, for example, the energy sector in Kyrgyzstan and Tajikistan is mainly hydropower, which is due to the significant hydro potential of these regions.

One of the energy sector problems in Central Asia is the high coefficient of losses in the transmission and distribution of electricity, which leads to relatively low energy efficiency indicators: Kazakhstan - 6%, Kyrgyzstan - 21%; Tajikistan - 16%, Turkmenistan - 14% and Uzbekistan - 9%.

Figure 2. Generating facilities installed capacity in Central Asian countries. Diagram of existing power lines.

Figure 1. CO₂ emissions from fuel combustion per capita.
Figure 3. Electricity production by energy source in Central Asia, 2015.

The share of renewable energy sources, excluding hydropower, in 2015 was only 0.2% of total electricity production. However, due to the active policy of the Central Asian states, especially Kazakhstan, by 2020 the situation has changed. According to the report [7], Kazakhstan has realized the planned 3% in the balance of energy consumption by 2020. According to the forecast data, it is expected that in 2020 3.5 billion kWh will be generated on renewable energy sources, excluding large hydropower, which will be about 3.5% of the average annual consumption. According to the Ministry of Energy, nowadays in Kazakhstan there are 19 wind farms (283.8 MW), 31 solar power plants (541.7 MW) and 3 bioelectric power plants (2.42 MW).

However, despite the active development of renewable energy sources in Kazakhstan, the introduced solar and wind energy capacities do not currently contribute to the development of remote and energy-deficient areas, since the introduced capacities are connected to centralized power supply. In energy-deficient settlements that are not connected to a centralized power supply, residents are forced to solve the problem of energy resources shortage for domestic purposes by burning coal, which has a negative impact on the environment (84% of all coal consumers in the country live in rural areas).

2. Methods
To improve energy efficiency and the environmental situation, a reasonable solution is the introduction of generating facilities based on renewable energy sources to replace existing generation facilities used in distant countryside areas, or to create energy complexes with a high traditional fuel penetration level.

In Central Asia, and particular in Kazakhstan, applying of renewable energy sources is becoming a priority area for the energy saving development, which contributes to solving the energy sector problems. Moreover, the development of renewable energy sources is conditioned by the presence of a significant potential of renewable sources. Central Asia has all the opportunities to create a sustainable energy sector: 5.5% of the world's economically efficient hydropower potential, located mainly in Tajikistan and Kyrgyzstan, the availability of an average of 3000-3600 hours of solar radiation per year in Kazakhstan, Uzbekistan and Turkmenistan. The wind potential in eastern Kazakhstan alone is more than 1.3 trillion kWh per year [7].

Energy efficiency in energy-deficient areas largely depends on the introduction of renewable energy sources due to its proximity to the energy consumer. It is worth noting that regions remote
from centralized energy supply have significant potential, which makes the use of renewable energy sources in these regions most relevant.

To ensure the balance of electricity and capacity of Central Asia energy systems in connection with the presence of energy-deficient regions and the increasing dynamics and prospects for the development of renewable energy sources, a reasonable solution is the use of digital design to optimize the process of selecting parameters of energy systems and justifying their application. The introduction of digital and intelligent systems in the power industry allows covering the entire life cycle of the project. Geographic information systems (GIS) are one of the key components of intelligent technologies in the energy sector, which help in solving problems related to energy efficiency and energy saving, in making engineering and investment decisions.

Thus, in order to improve the energy efficiency of Central Asia energy-deficient regions, it is proposed to use geo-information space, which is an integration platform, for solving energy problems. Comparison of the data obtained through the graphical interface of the information system makes it possible to reliably assess the current state of the regions under consideration and make a decision on the feasibility and effectiveness of energy supply technologies based on RES application.

3. Results and Discussions
To cover most of the key factors and increase the energy efficiency of the Central Asian countries, a multi-layer geo-information space has been developed. Each layer of this space is an information map (Figure 4). Designing map layers takes different approaches, depending on the type of information needed.

For example, to obtain information about the state of the power supply, the balance of electricity and power of the energy system, prices for electricity, and the amount of fuel applied, etc. detailed analysis of regional reports, official information sites and departments is carried out. The information obtained is processed, structured and recorded in an internal database in the required format. This information allows assessing the current state of power supply and making a decision either on the need to modernize a worn out power plant by creating an energy complex based on renewable energy sources, or on the relevance of creating a new one to optimize the power supply of the region.

Particular attention should be paid to obtaining climatic information and the resource potential of the RES under consideration, since this is the most important component of the renewable energy industry development. To assess the resource potential at the first level of assessment, satellite observation data, data from meteorological masts and resource atlases are used, and a large-scale assessment is carried out. Unfortunately, with a detailed study, the problem of obtaining reliable information about natural energy resources for a specific point arises. To solve this problem, a three-level methodology for assessing resource potential is used [10, 11]. At the third level, with micro-scale modeling, applying the WindPro software, a reliable assessment of resource information is carried out with an accuracy of 95% [12, 13].

Accounting for climatic information, for example, air density, air humidity, atmospheric pressure, as well as their variability, is necessary for a reliable assessment of the long-term production and cost of the project, taking into account the organization of additional adaptation measures.

The processed climatic and resource information is also a database, which is interpreted in the information space in the form of layers with the required parameters.

For a comprehensive analysis, it is necessary to create a layer with information about the socio-economic state of the region for the project logistic component development, as well as a geological layer containing the required information about soils to determine the parameters and type of the power plant foundation.

Depending on the specifics of the project and the required results in the developed geo-information space, it is possible to create additional layers and evaluation criteria. As a result, based on the requested parameters and user-selected layers, the system visualizes and outputs the data required for further calculations.
Figure 4. Digital multilayered space, where O is the target attribute set by the user (operator) based on the information presented on the layers $a_1 \ldots a_n$ and weight coefficient $b_n$.

For example, if wind turbine energy production is used instead of the target attribute, it will be calculated according to the equation on Figure 4 and depend on information layers, where $E_{WT} -$ wind turbine energy production, $C_p -$ wind power coefficient, $\rho -$ air density, $F_{WW} -$ wind turbine swept area, $V -$ wind speed, $P -$ loss due to the climate patterns, $T -$ operation time, $K_\text{of} -$ operational factor.

Based on the analysis carried out, the location and layout of the energy complex is selected (taking into account the requirements for distance from the consumer of electrical energy, availability of the place, a sufficient amount of energy resources, relief, individual obstacles, etc.).

The creation of a geo-information space makes it possible to clearly demonstrate the presence and feasibility of applying one or another type of renewable energy source in the design of an efficient energy complex, to assess the possible level of traditional fuels penetration to improve the energy and environmental state of energy-deficient regions.

Renewable energy production technologies are rapidly improving, and the increase in the use of renewable energy sources will allow achieving high increases in energy production, reducing the harmful impact on the environment in comparison with the use of traditional generation facilities.

4. Conclusions

1. As a result of the potential analysis for the use of renewable energy sources, the possibility of implementing an energy strategy with the prospect of developing renewable energy projects in Central Asian countries was confirmed.
2. Due to the presence of energy-deficient regions and sufficient technical potential of renewable energy sources, the introduction of generating facilities based on local renewable energy resources will reduce the loss coefficients in the transmission and distribution of electricity, improve energy efficiency and environmental safety.

3. To optimize the process of selecting the energy systems parameters and justifying their application, it is proposed to use digital technologies, the introduction of which contributes to solving problems related to energy efficiency and energy saving, and in making engineering and investment decisions.

4. A methodology has been developed and basic principles have been proposed for the formation of a geo-information space capable of interpreting the obtained data into layers and structuring the information necessary for the creation of renewable energy facilities in the energy-deficient regions of Central Asia.

5. The introduction of a multilayer geo-information space will improve the reliability of the calculation results due to the detailed study and consideration of influencing factors at each stage of the design and will become a convenient visual tool for justifying renewable energy facilities.

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